TEXAS A&M UNIVERSITY – KINGSVILLE

Department of Civil and Architectural Engineering.

CEEN 3244 – 001: Construction Materials

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ASPHALT

INSTRUCTOR

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INTRODUCTION

Bituminous material is a viscous material which occurs naturally or can be manufactured that consists of various mixtures of complex hydrocarbons. Bituminous material can be classified into tars and asphalts. Asphalts are cementitious materials composed largely of bitumen. Asphalts may occur naturally (natural asphalts) or as a result of petroleum processing (petrol asphalts). Tars on the other hand do not occur in nature and instead are obtained as condensates in the processing of petroleum, coal, oil shade, wood and any other organic material or by cracking of petroleum vapors. The use of tars as a construction material has reduced due to the concern of possible emission of hazardous fumes on heating. As such asphalt is the main bituminous material used in construction (Jamal, Applications of Bitumen in Civil Engineering, 2017).

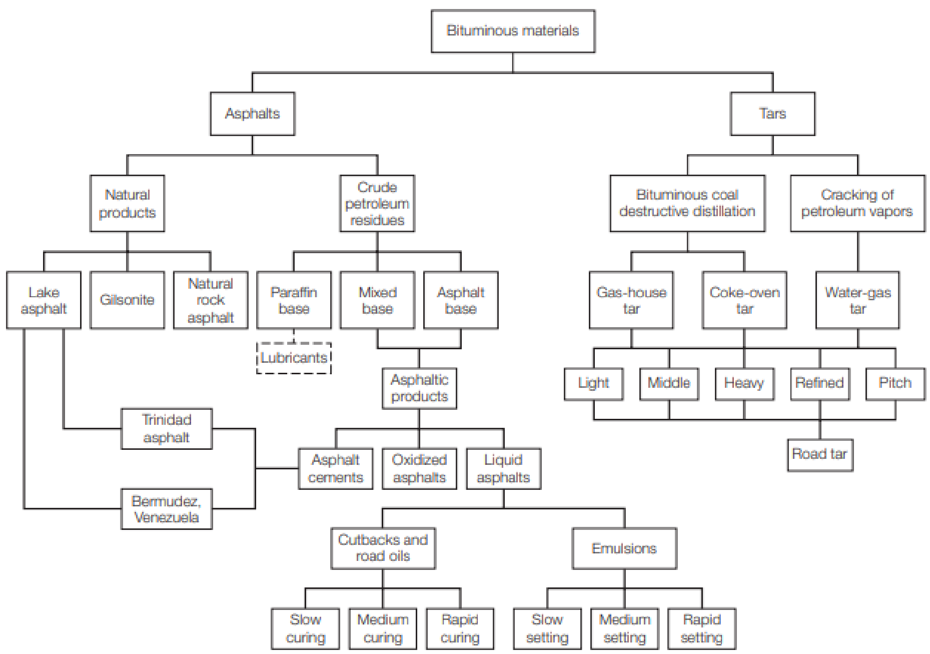

Figure 1: Classification of bituminous materials (Mamlouk & Zaniewski, 2018)

As illustrated in Figure 1, asphalt can be obtained from natural products such as natural rock asphalt, Gilsonite or Asphaltum and asphalt lakes an example being Trinidad Asphalt Lake. Asphalt can also be obtained as a residue referred to as asphalt cement from the fractional distillation of crude oil as illustrated in Figure 2.

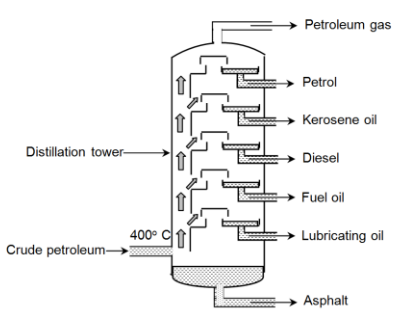

Figure 2: Fractional distillation of crude oil (Sourced from (funscience.in, 2022))

Types of Asphalt Cement

Asphalt cement is manufactured and used in the following forms: asphalt cement, asphalt cutback and asphalt emulsion. Asphalt cement is a mixture of various hydrocarbons such as maltenes and asphaltenes with different molecular weight. Asphalt cement is semi solid at room temperature and its viscosity and hardness is dependent on the molecular weight of the hydrocarbons that constitute it. The heavier the molecular weight of the hydrocarbon the harder and more viscous the asphalt cement. Asphalt cement is normally heated and mixed with selected aggregates before application. Asphalt concrete is one of the most widely used material in pavement surfacing as it has excellent adhesive characteristics. (Mamlouk & Zaniewski, 2018)

Asphalt cutback is produced by dissolving asphalt cement in a lighter molecular weight hydrocarbon solvent such as petroleum. The asphalt cutback is sprayed onto the pavement or mixed with aggregates and upon application, the petroleum solvent evaporates leaving behind the asphalt residue that acts as the binder. The advantage of using asphalt cutback is that it does not involve heating and can be applied easily on the field. The disadvantage is that it is not cost-effective due to the use of expensive solvents. Another disadvantage is that because of the volatility of the solvent, it poses significant fire risks. Lastly, asphalt cutbacks release environmentally unacceptable hydrocarbons into the atmosphere. (Mamlouk & Zaniewski, 2018)

Asphalt emulsion is produced by dispersing asphalt cement in water containing an emulsifying agent which is basically a soap material. The emulsifying agent has a head portion with an electrostatic charge (positive or negative) and a tail portion that has a high attraction to asphalt. When asphalt is introduced, the tail portion is attached onto the asphalt leaving the head part exposed. The various head parts repel one another resulting in asphalt globules suspended in water thus maintaining their separation. Asphalt emulsion consists of about 60-70% asphalt with the remaining being water. The asphalt emulsion is mixed with the well graded aggregates and placed. Once placed the water evaporates leaving the asphalt alone. Since the water is no longer suspending the asphalt globules, they combine to form the binder, a process referred to as setting or breaking. Asphalt emulsion are preferred over asphalt cutbacks as they do not involve costly solvents and are not hazardous. (Mamlouk & Zaniewski, 2018)

Uses of Asphalt.

Asphalt is used in the following methods:

- **Hot mix asphalt concrete:** It is made by carefully batching and mixing the aggregates with the asphalt cement at high temperatures.

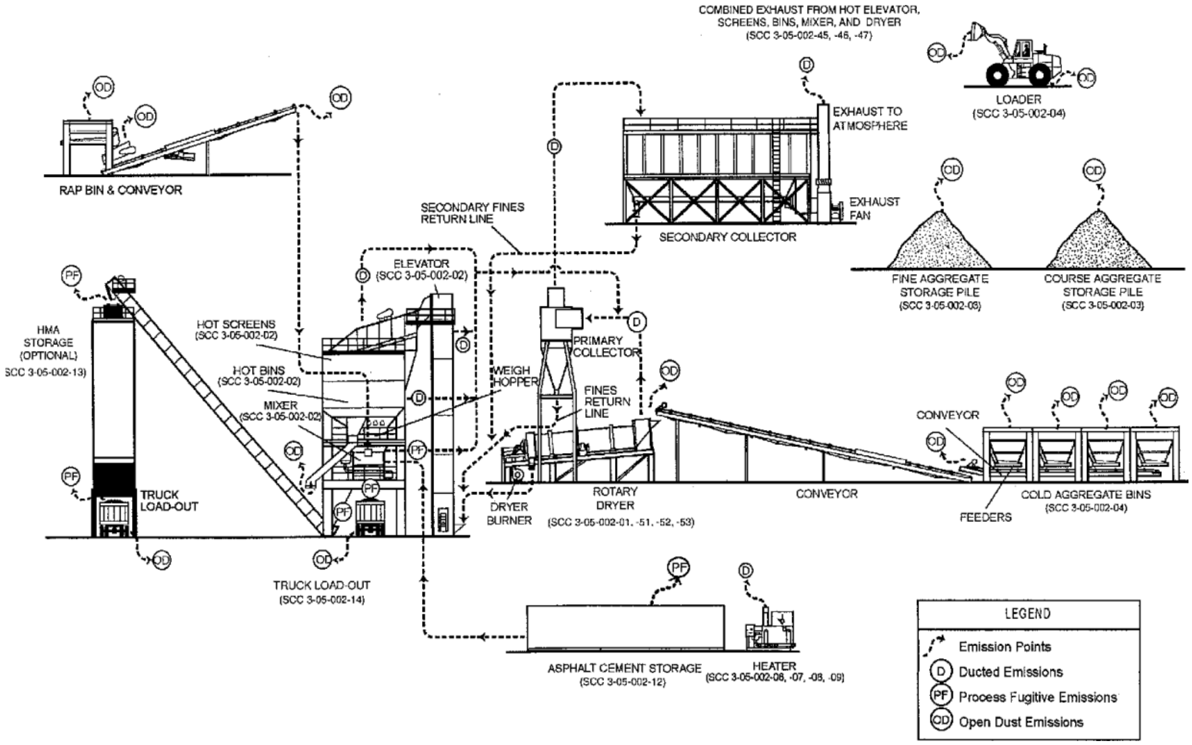

Figure 3: Hot Mix Asphalt Processing (Myers, Shrager, & Brooks, 2000)

It is used as material for the pavement surface layer and base layer as well as in patching of roads.

- **Cold Mix:** It is asphalt concrete that is made by mixing well graded aggregates with liquid asphalt It is used for patching of roads as well as material for low volume road surface and asphalt stabilized bases.
- **Fog seal:** It is a spray of asphalt emulsion that has been diluted. It is applied on existing pavement surfaces and is used to seal them in order to prevent water penetration.
- **Prime coat:** Asphalt emulsion is applied as a spray coat in order to increase the adhesion between the asphalt concrete surface and the aggregate base.
- **Tack coat:** This is asphalt emulsion applied in form of a spray coat between lifts of asphalt concrete and is used when applying an overlay on existing pavement surface or when constructing a new pavement surface.
- **Slurry seal:** This is a mixture of fine aggregates which are well graded, water and asphalt emulsion and is used to resurface low volume roads.
- **Chip seal:** This is asphalt emulsion or asphalt cement applied as a layer in the form of a spray coat and an aggregate layer added on it and is used for maintaining existing pavements or low volume road surfaces.
- **Micro-surfacing:** It is a mixture of asphalt emulsion, well graded crushed fine aggregate, polymer, mineral filler, water and additives and is used for texturing, sealing, crack filling, rut filling and minor leveling. (Mamlouk & Zaniewski, 2018)

Temperature Susceptibility of Asphalt

Viscosity is a property of asphalt that is severely affected by temperature. An increase in temperature results in a decrease in the viscosity of asphalt. At high temperatures asphalt is soft while at low temperatures asphalt is hard and brittle. Due to the temperature susceptibility, asphalt pavements may suffer from thermal cracking when hard-grade asphalt is used in cold climates or rutting when soft grade asphalt is used in hot climates. Rutting is surface depression in the wheel path (Rutting, 2022). Additives such as plastomers and elastomers can reduce the temperature susceptibility of asphalt. (National Academies of Sciences, 2017)

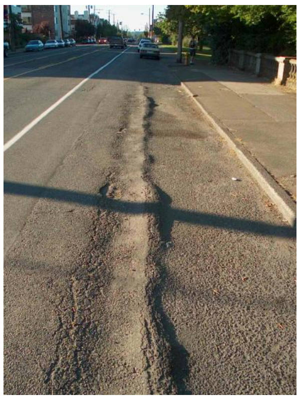

Figure 4: Rutting (Rutting, 2022)

Figure 5: Thermal cracking (Subramani, 2022)

To avoid these defects, it is important to select asphalt according to the climate (hard grade asphalt in hot climate and soft grade asphalt in cold climate) and the asphalt viscosity should remain between the optimum range as illustrated in Figure 6.

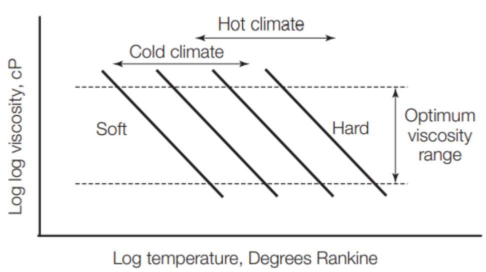

Figure 6: Log graph of viscosity against temperature (Mamlouk & Zaniewski, 2018)

ASTM STANDARDS RELATED TO ASPHALT

Below are various ASTM designations used to determine various properties of asphalt such as viscosity, shear modulus and consistency.

ASTM D4402

ASTM D4402 – Viscosity Determinations of Asphalt at Elevated Temperatures Using a Rotational Viscometer is an experiment conducted on the Asphalt binder to determine the apparent viscosity at temperatures from 38^0C to 260^0C.

The significance of the experiment is to determine the viscosity of asphalt which is needed for quality control as well as to ensure that the asphalt binder is properly handled like determining the temperature during mixing and compaction when placing the asphalt concrete. The value of viscosity obtained from the experiment is used for the Superpave performance grading of asphalt binders.

The apparatus used are:

- Rotational viscometer
- Spindles
- Thermosel system

Figure 7: Rotational Viscometer (Rotational Viscometers, 2022)

The experiment is conducted by turning on the thermosel and setting it to the desired temperature. The sample is prepared while exercising caution to avoid sample overheating or ignition which is loaded in the thermo-container of the thermosel system. The viscometer is then lowered and placed while aligned with the thermo-container. The selected spindle is inserted into the liquid-in-chamber and coupled to the viscometer. The asphalt sample is allowed to come to equilibrium temperature before starting the viscometer. The viscometer is started at a 20-rpm setting and three readings are taken 60 seconds apart at each test temperature and recorded. To obtain viscosity, the rotational viscosity readings are multiplied by the viscosity factor and the units are in centipoises. The viscosity at each temperature, the spindle number and the rotational speed are reported. (Mamlouk & Zaniewski, 2018)

ASTM D17175

ASTM D17175 – Determining the Rheological Properties of Asphalt Binder for Specification Purposes using a Dynamic Shear Rheometer (DSR) is an experiment carried out to determine the complex shear modulus (G) and the phase angle (δ) of the asphalt binders.

The complex shear modulus and phase angle are parameters of asphalt binders that is used to indicate the stiffness resistance to deformation under load while in the viscoelastic region. The test is useful in Superpave performance grading of asphalt binders.

The apparatus used are:

- Dynamic shear rheometer
- Test plates
- Temperature controller
- Loading device
- Control and data acquisition system
- Environmental chamber, specimen mold, heat trimming tool and thermal detector.

Figure 8: Dynamic Shear Rheometer (Kumar, 2022)

In the experiment, the asphalt binder is heated until the specimen can be poured with ease. The test plates are cleaned, dried and preheated to about 45^0C in the chamber before placement of the test specimen. The specimen is then placed in the Dynamic Shear Rheometer and the test pates moved using device to squeeze the asphalt sample between the plates until the gap between the two plates is equal to the test gap +0.05mm. A heat trimming tool is used to trim the excess asphalt around the perimeter of the two plates. The loading is then continued until the gap between the two plates is equal to the testing gap. The specimen is brought to the test temperature before application of the shear strain for ten cycles at a radial frequency of 10 radians/second. The data acquisition system automatically calculates the complex shear modulus and phase angle. (Mamlouk & Zaniewski, 2018)

ASTM D5

ASTM D5 – Penetration of Bituminous Materials is a test conducted in order to determine the penetration of asphalt binder. It is used to measure the consistency of asphalt. A high penetration suggests that the asphalts has a soft consistency and a low penetration suggests a hard consistency.

The apparatus used are:

- Penetration apparatus and needle.
- Sample container, thermometer, transfer dish, water bath and timing device.

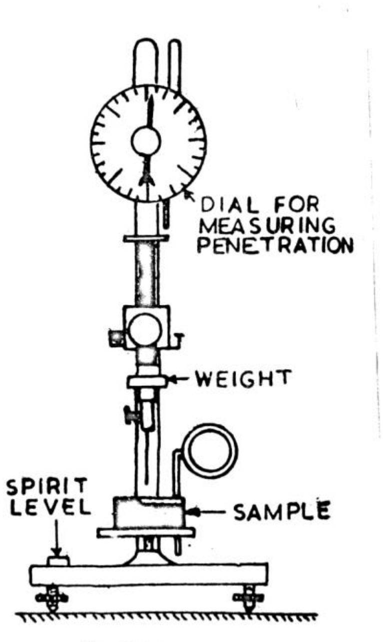

Figure 9:Penetration apparatus (CementConcrete, 2019)

In the experiment, the asphalt binder is heated until fluid enough and is poured into the sample container and allowed to cool for an hour. The sample along with the transfer dish is placed in a water bath at a temperature of 25°C for 1-2 hours. The penetration needle is cleaned and dried with a cloth, attached to the penetrometer and a 50g is placed above the needle. The sample container is placed in the transfer dish and water from the water bath added that it covers the sample container completely. The transfer dish is then placed on the stand of the penetrometer and the needle is positioned where it just touches the sample surface. The needle is released for about 5 seconds and the penetration recorded. The penetration is repeated at other points on the surface of the sample at least two more times. The average of the three penetrations is reported to the nearest millimeter. (Mamlouk & Zaniewski, 2018)

ASTM D2726

ASTM D2726 – Bulk Specific Gravity of Compacted Bituminous Mixtures is a test carried out to determine the bulk specific gravity of compacted asphalt specimen. The test results are used in analysis of voids in the compacted asphalt mix.

The apparatus needed are:

- Balance
- Water bath

The specimen tested are laboratory molded samples compacted using either the Marshall compactor or Superpave Gyratory compactor. Cores drilled from asphalt pavements can also be used as specimen.

In the test, the specimen is weighed in air and the value recorded. The specimen is immersed in water. The weight of the specimen while suspended in the water is obtained and recorded. The specimen is removed from water and the surface of the specimen dried with a towel. The surface dry sample is weighed and recorded. The bulk specific gravity can then be calculated using the formula:

$$Bulk\ specific\ Gravity = \frac{A}{(B - C)}$$

Where:

A – mass of the specimen in air, grams.

B – mass of the surface dry specimen, grams.

C – mass of the specimen in water, grams.

The value of the specific gravity is unitless and reported to three decimal places. (Mamlouk & Zaniewski, 2018)

ASTM D1559

ASTM D1559 – Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus is a test carried out to determine the Marshall stability and flow values of asphalt concrete.

Marshall stability and flow values are useful in laboratory mix design of bituminous mixtures and can be used to give characteristics to the asphalt mixes.

The apparatus used are:

- Testing machine.
- Breaking heads
- Load cell or ring dynamometer, flow meter and water bath.

The sample used for the experiment is the laboratory molded sample obtained by using the Marshall compaction method.

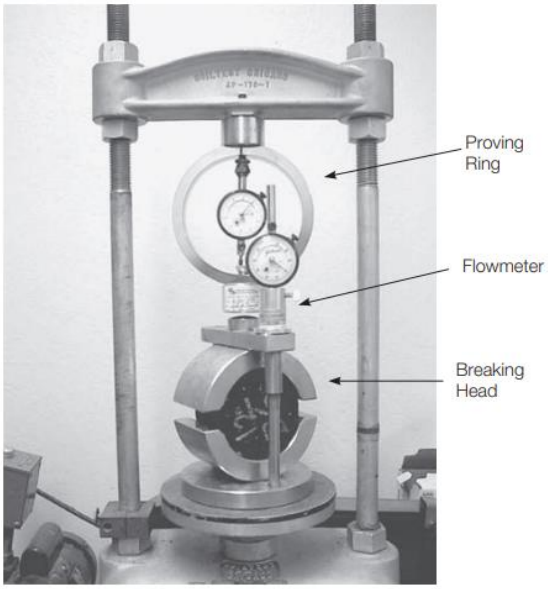

Figure 10: Marshall Stability Machine (Mamlouk & Zaniewski, 2018)

In the test, the specimen from the Marshall compaction method is heated to a temperature of 60^0C either using a water bath or using an oven, The specimen after heating is placed in the Marshall stability machine by placing it in the lower portion of the breaking head and placing the upper breaking head onto the specimen and positioning the breaking head on the testing machine as shown in Figure 10. The flow meter is placed in position over either one of the guide rods and adjusted to zero. The load is applied to the specimen by means of constant rate of movement until the maximum load is reached and the load decreases. The time from heating to maximum load determination should not exceed 30 minutes. The maximum load is recorded as the Marshall stability and the deformation is recorded as Marshall flow. The process is repeated for at least two more replicate specimen to obtain average Marshall stability and average Marshall Flow. (Mamlouk & Zaniewski, 2018)

IMPORTANCE OF ASTM STANDARDS

The ASTM standards are helpful in that they improve:

- Quality of the products that contain the referenced material grades. The products manufactured while adhering to the ASTM standards tend to be homogenous in quality which is free from defects that may prove detrimental to the product.
- Worker safety and health standards. The ASTM standards are designed to ensure the safety of both the workers and the users of the products.
- Sustainability of products developed. The ASTM standards ensures that environmentally friendly and do not bring harm to the surrounding and contains standards that encourages the recycling of materials to enhance sustainability of the products.
- Strengthening the market around all trades. By ensuring the quality and safety of the materials is maintained, it promotes more people to opt for materials developed using the ASTM standards.
- Recognition of existing and updated international cross-references between standards. There are other standards such as the British Standards. ASTM helps ensure that materials prepared using

other standards are compatible with the ASTM standards and vice-versa. (Importance of ASTM Standards For You, 2021)

References

(2022). Retrieved from funscience.in: http://www.funscience.in/study-zone/Physics/NonRenewableSourcesOfEnergy/Petroleum.php

CementConcrete. (2019). *Penetration Test of Bitumen-Procedure, Apparatus, and Uses for Road Construction*. Retrieved from cementcocnrete.org: https://cementconcrete.org/material-testing-guide/penetration-test-of-bitumen/1216/

Importance of ASTM Standards For You. (2021, April 15). Retrieved from Texas Flange: https://www.texasflange.com/blog/importance-of-astm-standards-for-you/

Jamal, H. (2017, February 18). *Applications of Bitumen in Civil Engineering*. Retrieved from aboutcivil.com: https://www.aboutcivil.org/Bituminous-Materials-and-Plastics.html#:~:text=Bitumen%20is%20defined%20as%20an%20amorphous%2C%20black%20or,applications%2C%20bituminous%20materials%20include%20primarily%20aphalts%20and%20tars.

Kumar, K. (2022). *Rheological studies of performance grade bitumens prepared by blending elastomeric SBS (styrene butadiene styrene) co-polymer in base bitumens*. Retrieved from Researchgate: https://www.researchgate.net/figure/Dynamic-shear-rheometer-DSR_fig2_307619055

Mamlouk, M. S., & Zaniewski, J. P. (2018). *Materials for Civil and Construction Engineers.* London: Pearson Education Press.

Myers, R., Shrager, B., & Brooks, G. W. (2000). *HOT MIX ASPHALT PLANTS EMISSION ASSESSMENT REPORT.*

National Academies of Sciences, E. a. (2017). *Relationship Between Chemical Makeup of Binders and Engineering Performance.* Wahington DC: The National Academic Press.

Rotational Viscometers. (2022). Retrieved from https://www.worldoftest.com/rotational-viscometers

Rutting. (2022). Retrieved from Washington Asphalt Pavement Association: https://www.asphaltwa.com/rutting/#:~:text=Pavement%20rutting%20is%20defined%20as%20surface%20depression%20in,a%20rain%20when%20they%20are%20filled%20with%20water.

Subramani, S. K. (2022). *VALIDATION OF NEW ASPHALT CEMENT SPECIFICATION TEST METHODS USING EASTERN AND NORTHEASTERN ONTARIO CONTRACTS AND TRIAL SECTIONS*. Retrieved from Researchgate: https://www.researchgate.net/figure/Typical-example-of-a-severe-thermal-crack-in-an-asphalt-pavement_fig2_241531063