

PG vs. AC – Why Change?

Asphalt cements have historically been graded by two empirical tests; penetration and viscosity. These tests were developed over time, using experiences with asphalt pavements. These tests attempt to repeat past successes, and avoid past failures. Empirical tests work well as long as all of the conditions at the time of the test development remain unchanged. Unfortunately, this is not true of our asphalt pavements today. Penetration and viscosity tests were developed in an era of less traffic and significantly lower pavement loadings. Trucks of yesteryear were limited to 72,000 lb. and rode on bias ply tires with tire pressures of 75 psi. Today, truck weights exceed 80,000 lb. and radial tires are inflated to 125 psi. A 10% increase in truck weight may not seem significant, but it results in a **40% increase in stresses applied to the pavement**. These factors, along with the dramatic increase in the numbers of trucks traveling our highway system today, subject our asphalt pavements to stresses, which result in rutting and premature failure.

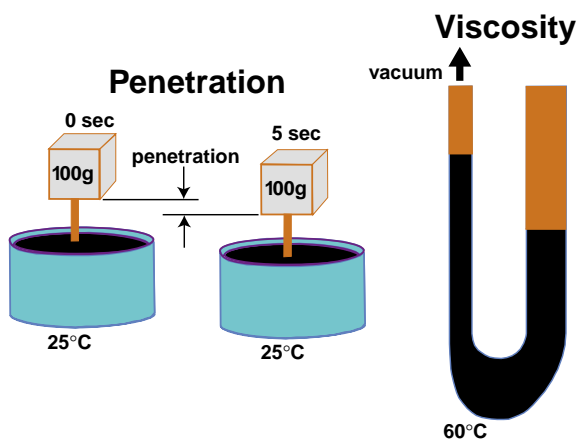


Figure 1

Figure 1 illustrates the empirically based penetration and viscosity tests. Penetration measures the depth of a sewing needle into a sample of asphalt

at 25°C. Viscosity measures the time required for asphalt to flow through a calibrated glass tube at 60°C. These tests measure the asphalt sample at only one temperature, which do not give any indication how the material will perform at the wide range of temperatures the roadway will experience.

Different crude oils produce asphalts with widely different properties. Many contractors discovered this fact during the oil crisis of the 1970's, when refiners used whatever crude was available. Asphalts produced from different crudes may meet the penetration and viscosity specifications of a given grade, but perform very differently during construction and on the road.

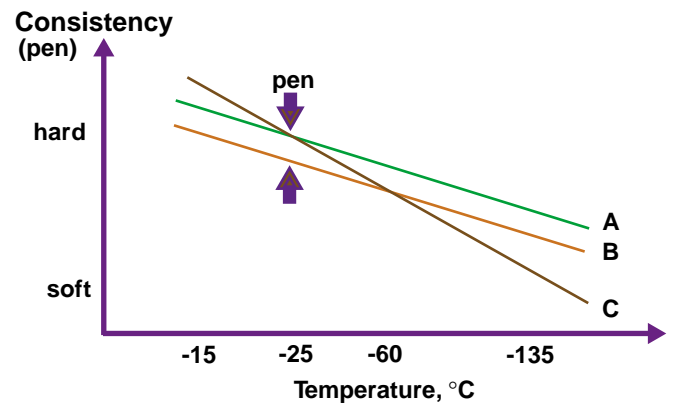


Figure 2

Figure 2 illustrates three asphalts from three crudes which meet the same asphalt grade, but perform very differently at high and low temperatures.

It is obvious our previous empirical specifications did not relate directly to asphalt binder performance in our pavements. The Strategic Highway Research Program (SHRP) sponsored \$50 million of research on asphalt binders to relate the specifications to actual pavement performance. The new Performance Grade (PG) asphalt binder specifications measure physical properties of the material throughout its temperature range.

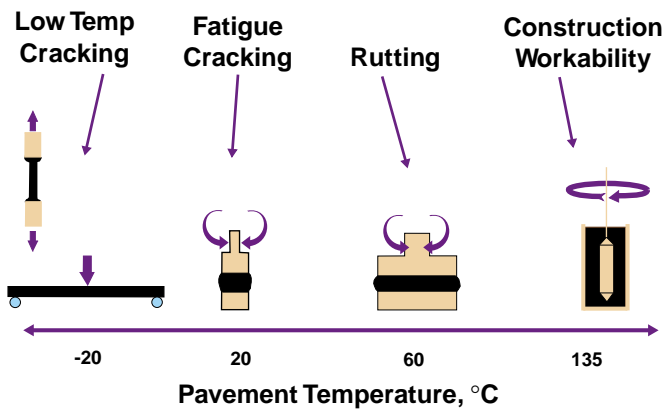


Figure 3

Figure 3 shows the new PG binder tests at the various temperatures at which they are performed. PG graded asphalt binders are graded according to the climatic conditions they will endure in the roadway. A PG 64-22 will perform from a high pavement temperature of 64°C to a low pavement temperature of -22°C. At the high pavement temperature, 64°C, a Dynamic Shear Rheometer (DSR) tests to make sure the asphalt will not become too soft and be susceptible to rutting. The DSR places a small sample of asphalt between two round plates. The lower plate is fixed, and the upper one turns back and forth (as shown in **Figure 4**). This twisting action places a stress on the asphalt being tested. The reaction of a material to stress is strain, and the ratio of stress to strain yields a stiffness value. This specification requires a minimum stiffness of 1.00 kilo-Pascal (kPa), which indicates this asphalt will not become too soft and rut at the test temperature of 64°C. The minimum stiffness value of 1.00 kPa remains constant, but the test is run at the high temperature for the PG grade being evaluated.

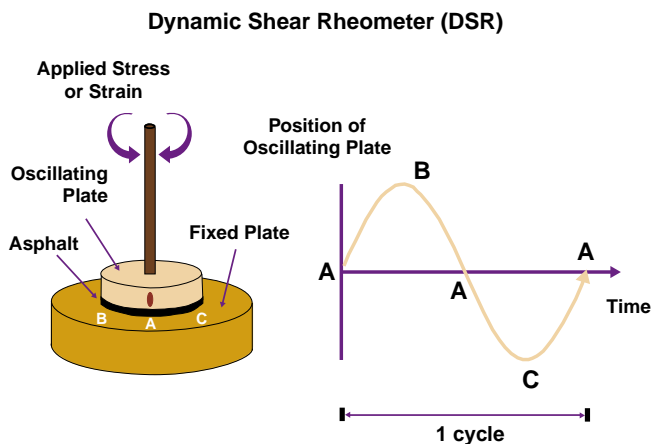


Figure 4

Materials that show an immediate strain response to an applied stress are called elastic. Materials that exhibit a delayed response are known as viscous. These responses are illustrated in **Figure 5**.

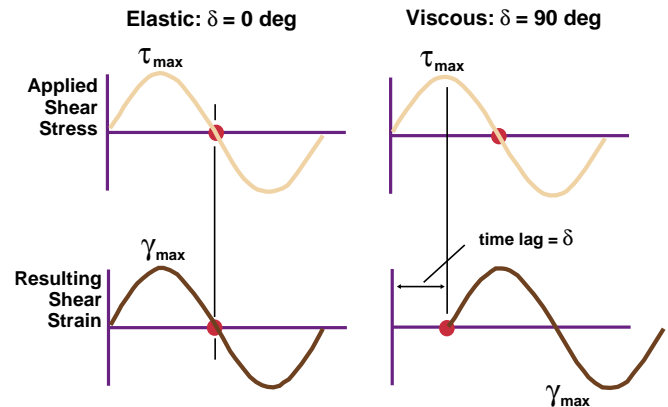


Figure 5

Asphalt exhibits both of these types of response, depending on the temperature, and is known as a visco-elastic material. The DSR is capable of measuring the phase angle, δ , and thereby helps identify the viscous and elastic components of the asphalt being tested.

As asphalt ages, it hardens due to exposure to oxygen. This oxidation also occurs in the HMA plant where the mix is produced. The asphalt binder is spread into thin film coatings on the aggregate in either a pugmill or drum in the presence of oxygen. Asphalts produced from different crude oils age differently. Under the penetration and viscosity testing systems, we did not attempt to measure the properties of the asphalt after aging. The PG grading system ages the asphalt in two separate procedures, and then tests the material to see if it will meet specifications designed to insure excellent performance during the entire life of the pavement.

The first aging procedure simulates the aging taking place during construction of the pavement. The Rolling Thin Film Oven (RTFO) procedure places the asphalt in glass bottles, rotates them in an oven, and blows air into each bottle as they rotate. This apparatus is illustrated in **Figure 6**.

Rolling Thin Film Oven

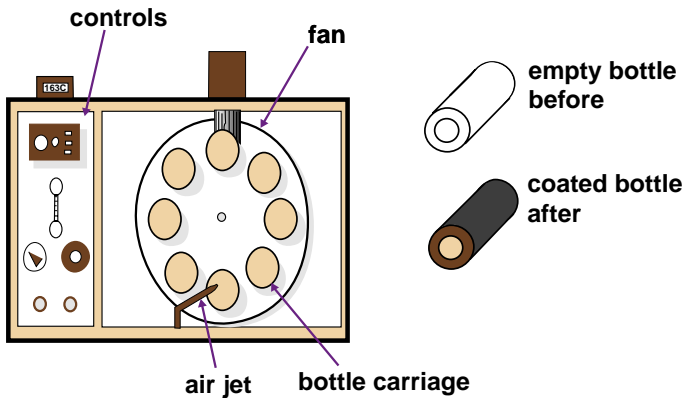


Figure 6

After the asphalt has been aged in the RTFO, it is again tested for stiffness at its high temperature value. Since the material has been aged, a higher minimum stiffness value of 2.20 kPa is required (vs. 1.00 kPa for the original material).

Following the RTFO aging procedure, the asphalt is removed from the glass bottles and placed in a Pressure Aging Vessel (PAV). The PAV subjects the asphalt to high temperature and pressure for 20 hours, which simulates 7-10 years of pavement life. **Figure 7** illustrates the PAV apparatus.

The asphalt is removed from the PAV and tested for fatigue and low temperature properties. If an asphalt binder will fail from fatigue cracking or low temperature cracking, it will most likely do so after it has aged and become brittle.

Pressure Aging Vessel

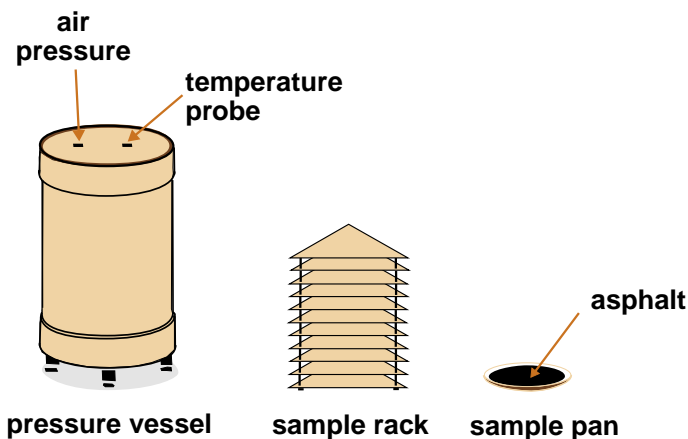


Figure 7

The DSR is run on the PAV material to test for fatigue cracking. This test is run at an intermediate temperature (25°C for PG 64-22). This test insures the asphalt is not too stiff, so that fatigue cracking will not occur. The specification value for stiffness is a maximum of 5000kPa.

The PAV material is then tested in a Bending Beam Rheometer (BBR) to measure susceptibility to cracking at the low temperature for the PG grade being tested. A small beam of asphalt is subjected to a constant load, and the deflection of the beam over time is measured. The BBR measures stiffness (S) and an m-value, which indicates the ability of the asphalt to relax the stresses induced by low temperatures. The specification calls for a maximum stiffness of 300 MPa and a minimum m-value of 0.300. The BBR is shown in **Figure 8**.

Bending Beam Rheometer

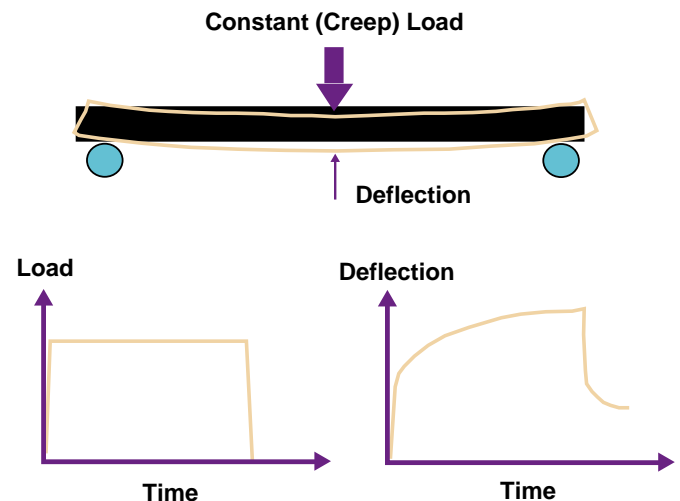


Figure 8

The Direct Tension Test (DTT) stretches a small beam of asphalt until it breaks. This test is also run at the low temperature for the PG grade being tested, and measures the susceptibility of asphalt to a second type of low temperature failure. The specification calls for a minimum strain of 1.0% at failure. **Figure 9** illustrates the DTT.

Direct Tension Test

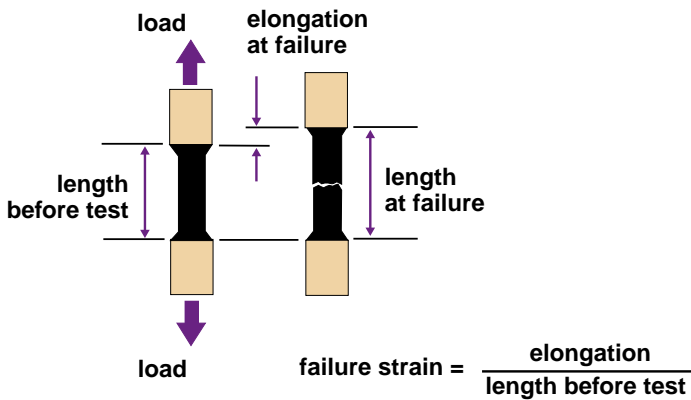


Figure 9

The viscosity of the original PG binder is measured to insure the material can be pumped and handled by HMA plants and construction equipment. Instead of the old vacuum glass tube viscometer used in the past, a Rotational Viscometer (RV) is used. This device is capable of measuring viscosity at varying temperatures and can handle highly viscous modified asphalts. The specification calls for a maximum viscosity of 0.300 Pascal-seconds. The RV is shown in **Figure 10**.

Rotational Viscometer

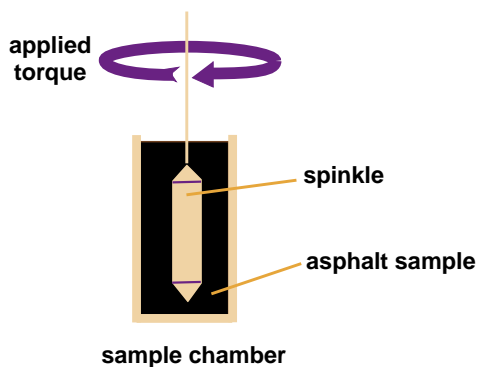


Figure 10

The PG grading system certainly improves our asphalt binder specification system, and goes a long way towards tying the specifications to actual pavement performance. So, what is the difference between PG asphalts and viscosity graded AC materials?

For some asphalts, the answer is none. Crude oil is a very complex material made up of many hydrocarbons. These many materials have different boiling points, and they can be separated by boiling them in a distillation tower. The lighter hydrocarbons are drawn off the top of the tower, and the heaviest materials are pulled from the bottom. Asphalt is truly the bottom of the barrel. Crude oil containing heavy hydrocarbon material that is rich in asphaltenes makes the best asphalt binders. Asphalts made from these crudes easily met the AC grading system and also meet PG requirements. Poor asphalt crudes could also produce viscosity graded binders because the specification was wide open, but they may not be able to meet PG binder specifications. A survey of asphalts showed the majority of AC-20's met the PG 64-22 specifications, but some did not.

In the past, refineries have treated asphalt as the bottom of the barrel, and have done little to improve production controls. Now they must produce an engineered material that meets substantial product specifications. Distillation towers must be improved to permit finer control of the cut points at which the asphalt material is drawn off. The PG binder must balance the exact amount of heavy material for the high temperature specification with the amount of lighter hydrocarbons to give the material its low temperature properties. Refiners unwilling or unable to run quality asphalt crudes and establish exacting controls on the distillation tower will have difficulty producing PG graded binders. Some refiners will abandon asphalt production altogether.

Some PG grades will require modification. Conventional asphalts made from excellent crude oil can achieve a maximum working temperature range of 92°C. A PG 70-22 has a temperature range of 92°C (70+22=92). Lower quality crudes are limited to a smaller temperature range. A PG 76-22, with a temperature range of 98°C, must be modified.

The original SHRP research was based on conventional asphalts, and the PG specs may not be able to distinguish between the performance of various modification techniques that achieve the same grade. Research is continuing in this area, but in the interim, many DOTs are specifying polymer modifiers that have a history of excellent performance.

There is nothing magical about PG graded asphalt binders. They simply represent the better quality asphalts we have used in the past specified in a new way, and there are new grades available to handle higher temperatures and heavier traffic. PG asphalts give us a new tool to insure our asphalt pavements last longer and perform better.