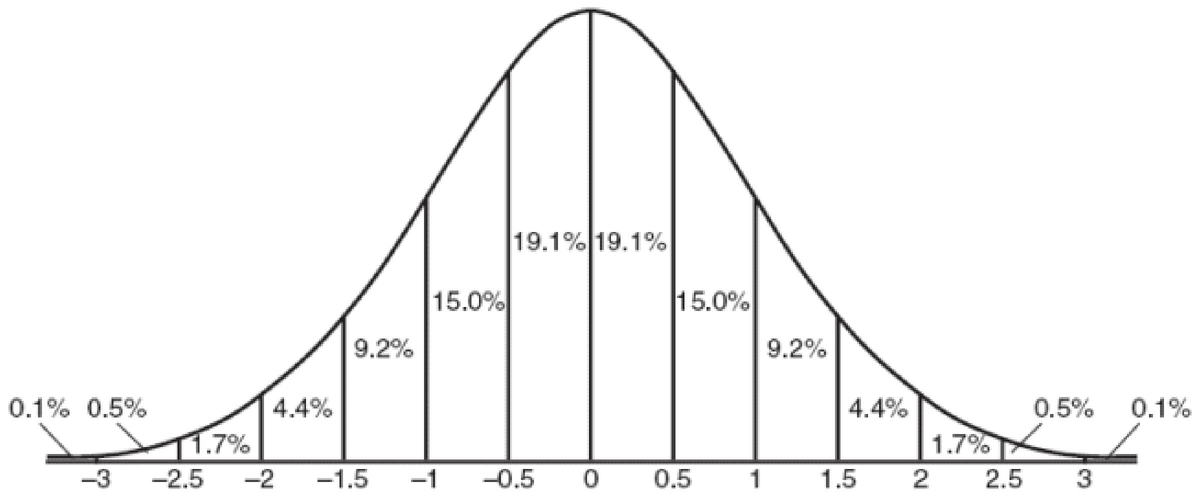
Choosing an Asphalt Grade Based on Required Reliability

Under the Superpave binder grading system, the choice of an asphalt grade is based on the lowest 1-day and highest 7-day average pavement temperature expected at the site.

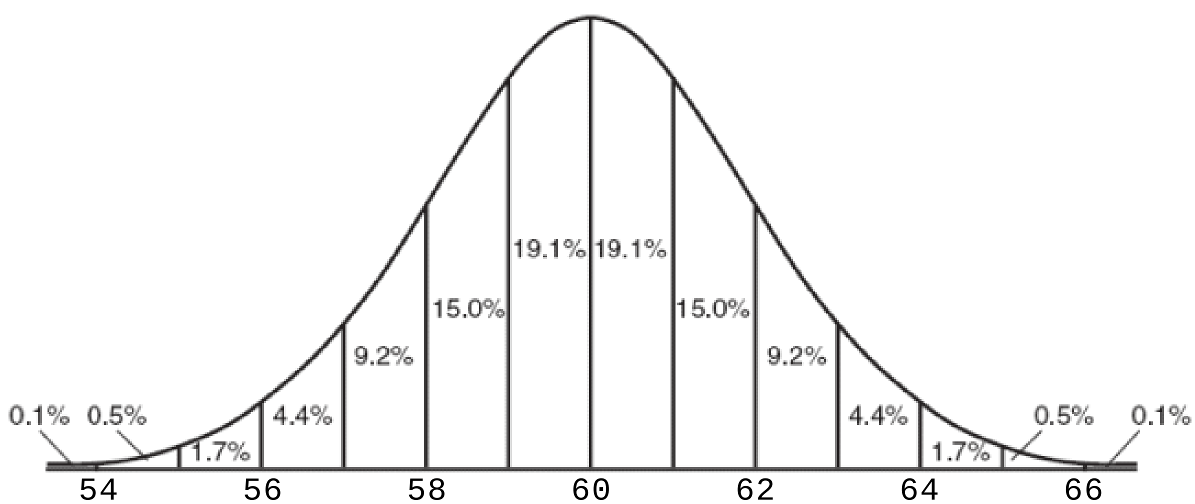
Historical temperature data such as this tends to be normally distributed, which means a histogram of temperature data is shaped like a bell curve. The temperature in the middle of the bell curve is the mean (average) of the data and the spread of the data about that mean is measured by the standard deviation. In general, 99.8% of all the temperature observations will fall within ± 3 standard deviations of the mean.



Standard Deviations

The chart above breaks the normal distribution into 14 "slices" and shows the area under the curve for each slice. These areas represent probabilities. So, according to the chart, there is 2 × 19.1% = 38.2% chance that the temperature will be within ± 0.5 standard deviations of the mean in any given year. We can use this to find the grade of asphalt cement most suitable for our project.

To illustrate, let's assume that we have 100 years' worth of data at the site of an interstate highway project. For each of those 100 years, we determine the 7-day stretch with the highest average pavement temperature. Let's further assume that the mean of those 100 values is 60^{o}C and the standard deviation is 2^{o}C. A histogram of the data would probably look something like this:



Historical 7-Day Average High Pavement Temperatures (^{o}C)

This plot shows that there is a 1.7% + 0.5% + 0.1% = 2.3% chance that the 7-day-average pavement temperature will exceed 64°C in any given year. This means there is a 100% – 2.3% = 97.7% chance that the 7-day-average high pavement temperature will not exceed 64°C. So a PG64 grade of asphalt cement would have 97.7% reliability in the summertime.

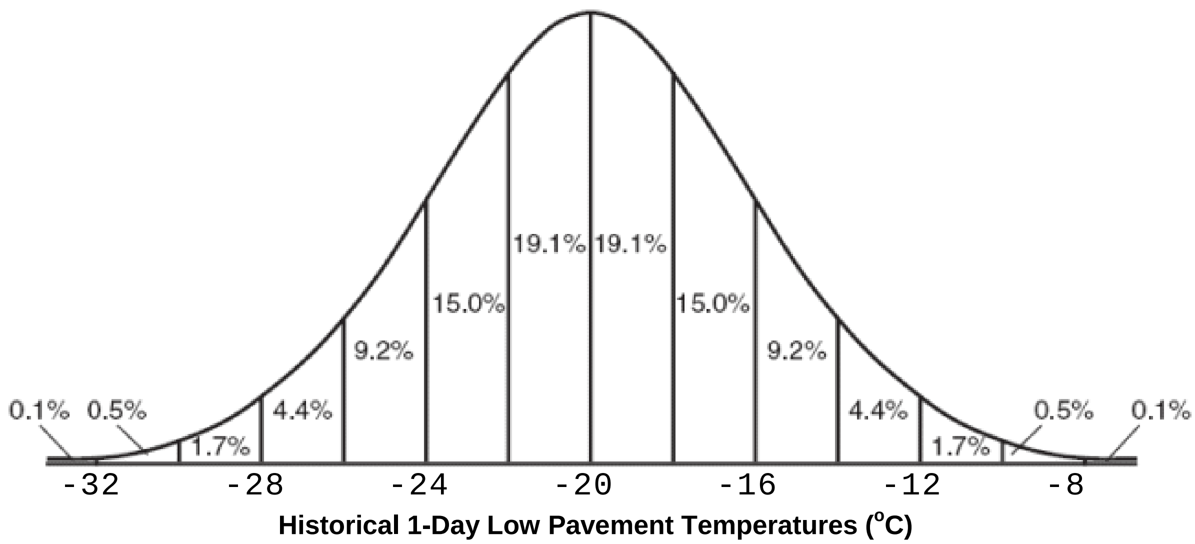
On the other hand, the probability that the pavement temperature will exceed 58°C (the next lower PG grade) is

$$15.0 + 19.1 + 19.1 + 15.0 + 9.2 + 4.4 + 1.7 + 0.5 + 0.1 = 84.1\%$$

So the probability that the temperature will not exceed 58°C is 100% – 84.1% = 15.9%. Thus, a PG56 grade of asphalt cement would only have 15.9% reliability.

So we would most likely select a PG64 binder for our pavement, unless we want to be really conservative and select a PG70 binder, for which the probability of exceedance is virtually zero.

Now assume that the lowest 1-day average temperatures have a mean of -20°C and a standard deviation of 4°C:



This plot shows that there is a 1.7 + 0.5 + 0.1 = 2.3% chance that the 1-day-average low pavement temperature will exceed -28°C and a 100% – 2.3% = 97.7% chance that the 1-day-average low temperature will not exceed -28°C. So if we choose a PGxx-28 binder grade, it will have 97.7% reliability in the wintertime.

On the other hand, the probability that the 1-day-average low pavement temperature will exceed -22°C (the next lower PG grade) is

$$15.0 + 9.2 + 4.4 + 1.7 + 0.5 + 0.1 = 30.9\%$$

So the probability that the temperature will not exceed -22°C is 100% – 30.9% = 69.1%. Thus, a PGxx-22 binder will only have 69.1% reliability in the wintertime.

We can calculate the overall reliability of a given binder grade by calculating the probability that the 7-day high temperatures will not exceed the high-temperature for that grade AND the 1-day low temperature will not exceed the low-temperature for that grade. This joint probability is calculated by multiplying the two probabilities together:

$$P(A \text{ and } B) = P(A)\,P(B)$$

So if we choose a PG64-22 binder for this project, the reliability of the binder will be

$$(0.977)(0.691) = 0.675 = 67.5\%$$

If we choose a PG64-28 binder, instead, the reliability will be

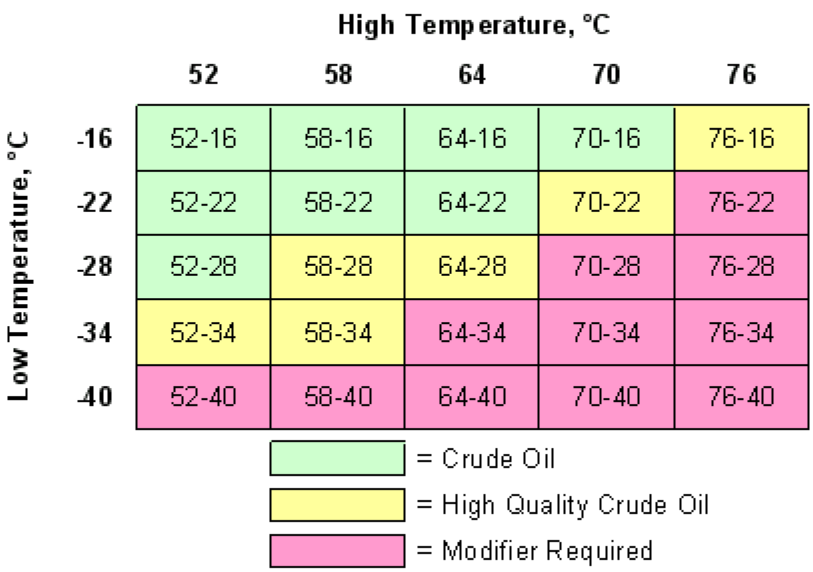
$$(0.977)(0.977) = 0.954 = 95.4\%$$

If we choose a PG70-28 binder, the reliability will be

$$(1.000)(0.977) = 0.977 = 97.7\%$$

The problem with being too conservative is that it will cost a lot more.

The chart below shows that PG 64-22 binders can be obtained from ordinary crude oil, so they are relatively inexpensive. PG 64-28 binders can only be obtained from high-quality crude oil, so they will cost 20-25% more. If we wanted to be really conservative, we might specify a PG 70-28 binder, but the only way to obtain the necessary performance properties over that wide of a temperature range is to use asphalts that have been modified by adding polymers (latex, rubber, PVC, etc.). Those binders can cost another 20-25% more than the high-quality unmodified binders.



So there is always a trade-off between the up-front cost of the binder and the long-term cost of repairs and shortened pavement life if the temperature grades are exceeded. The pavement won't fall apart if, one summer, the temperatures exceed the high-temperature grade for a week or two. But the pavement life may be shortened or future maintenance costs increased because of the extra wear-and-tear suffered by the pavement when it was in a weakened state.

For our example project, the best choice would be a PG64-28 binder because it gives us 50% better binder reliability than the PG64-22 binder in exchange for a 25% increase in binder cost. The tiny additional increase in reliability for the PG70-28 binder is very likely not worth the much higher cost of the modified binder.