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PERFORMANCE GRADED (PG) ASPHALTS IN CALIFORNIA

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Introduction

The existing Aged Residue (AR) grading system for asphalt cements currently specified by the California Department of Transportation (Caltrans) will be replaced with the Performance Graded (PG) system. The implementation date is January 1, 2006, at which time California will join the other 49 states that have adopted some version of the PG system over the past 10 to 12 years.

Historical Perspective

Prior to the early 1970s, California relied on the Penetration grading system to grade paving asphalts. This system is based on the amount of penetration into an asphalt sample achieved by a standard needle at a given temperature (25°C) with a standard weight (100 grams) for a fixed time (5 seconds). Based on Caltrans involvement with the Pacific Coast Conference on Asphalt Specifications (PCCAS), California adopted 5 penetration grades in the late 1950s: 40-50, 60-70, 85-100, 120-150, and 200-300 penetration. The primary penetration grades used in California were the 60-70 and 85-100 grades, with occasional use of the softer grades (120-150 and 200-300) in colder climates and the harder grade (40-50) in the desert environment. Other tests, such as flash point, solubility, and ductility on the original asphalt plus penetration and ductility after Thin Film Oven aging, were also used to characterize the asphalt.

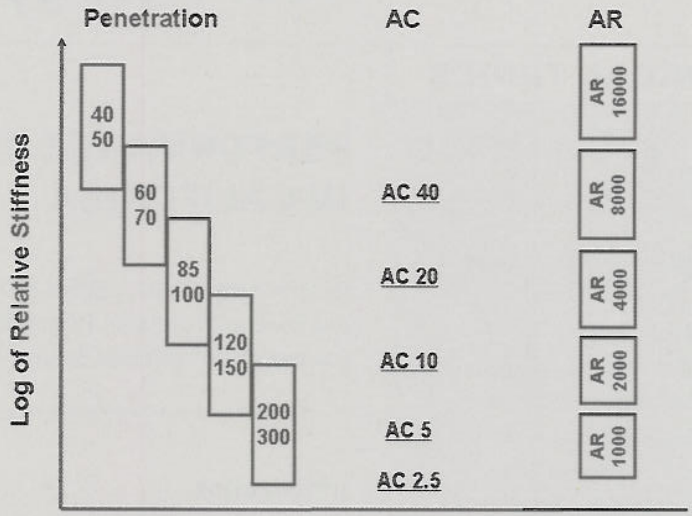
Under the Penetration grading system, the consistency of the asphalt binder at high service temperatures could vary widely, especially in asphalts produced from a wide range of crude sources. As a result of this variability, many states encountered "tender" mixes, a construction problem where the asphalt mix shoves excessively during compaction and often remains tender or soft for extended periods of time after construction. For these reasons, by the early 1970s most states had switched from the Penetration grading system to a Viscosity grading system, in an effort to control the asphalt consistency (viscosity of the binder) at higher pavement service temperatures.

Most states adopted a Viscosity grading system that focused on the measured viscosity of the original asphalt at 60°C. For example, an AC 20 asphalt has a viscosity of 2,000 poise (± 20%) at 60°C. However, Caltrans

was more interested in the consistency of the asphalt binder as it was being placed on the roadway, than the consistency when it was produced. Therefore, through the PCCAS, Caltrans proposed an AR grading system that was based on the viscosity of the asphalt binder at 60°C after it had gone through a laboratory aging process to simulate the aging of the asphalt in a hot mix batch plant. Under this AR grading system, an AR 4000 asphalt has a viscosity of 4,000 poise (± 25%) at 60°C after aging. The AR system has been in place in California since 1974. A rough comparison between penetration and viscosity (AC and AR) asphalt grades is shown in Figure 1.

FIGURE 1

Comparison of Penetration and Viscosity Asphalt Grades



In the early 1990s, Caltrans participated in a PCCAS study group that examined a new approach to asphalt specifications called Performance Based Asphalts (PBA). The study group focused on the temperature susceptibility of the asphalt binder, reasoning that climate conditions play a major role in binder selection. Both conventional and polymer modified asphalts are a part of the PBA system. Initially, conventional tests such as penetration, viscosity, and ductility were used to characterize PBA asphalts. Later, more sophisticated rheological tests were incorporated into the PBA specifications. PBA binders are still specified in California although the predominant grades have become the polymer modified asphalts identified as PBA 6a, PBA 6b, PBA 7, and PBA 6a*, which has a higher polymer loading than PBA 6a. The concepts generated from the development of the PBA grading system had a significant impact on the development of the PG grading system.

FIGURE 2

PG Asphalt Binders Suggested for California Climate Conditions

Minimum Pavement Surface Temp, °C

Average 7-day Maximum Pavement Temp, °C	-34	-28	-22	-16	-10
40					1
46			2	3	8
52		4	5	3	23
58	1	9	10	13	24
64		1	7	23	66
70				10	77
76					18

20 PG Binders!

What is PG?

The PG asphalt binder grading system was developed as part of the $150 million, 5-year Strategic Highway Research Program (SHRP) conducted from 1987 to 1992. The PG system addresses many of the limitations of the Penetration and Viscosity grading systems by focusing on the three specific pavement distress modes: permanent deformation (rutting), fatigue cracking, and low temperature cracking. The climate conditions (primarily temperature) to which pavements are exposed is a

key element of the PG system. For example, PG 64-16 asphalt is intended to provide:

- enough stiffness at 64°C pavement temperature to help the mix resist permanent deformation or rutting,
- enough elasticity at -16°C pavement temperature to prevent low temperature thermal cracking, and
- enough flexibility at intermediate temperatures to minimize fatigue-cracking.

Number of PG Asphalts in California

The big question becomes "how many PG asphalts are needed in California to cover the wide range of climate conditions existing in the state?" An analysis of temperature data gathered from 308 weather stations in California suggests 20 different PG asphalt binders would be required (see Figure 2). Obviously, this is not practical from an asphalt supplier, hot mix producer, or highway agency standpoint. Like other states faced with similar decisions, Caltrans needed to decide on a workable number of PG asphalts to cover the state's many and varied climate regions. In partnership with industry, Caltrans has selected four PG grades: 64-10, 64-16, 64-28, and 70-10. These four grades cover 279 of the 308 California weather stations analyzed (see Figure 3). The map in Figure 4 and the data in Table 1 show the PG grades of choice for the various climate regions of California.

In addition, Caltrans believes that a higher temperature PG grade (namely, PG 70-10) will be needed for certain designated routes that experience extremely heavy traffic and for special situations such as on/off ramps, intersections, or standing/slow moving load applications in the Central Coast, Inland Valley, and South Coast regions. Caltrans also believes that polymer modified PBA asphalts should be an option for designated routes and special situations throughout the state.

FIGURE 3

Four PG Binders Cover Over 90% of California Climate Conditions

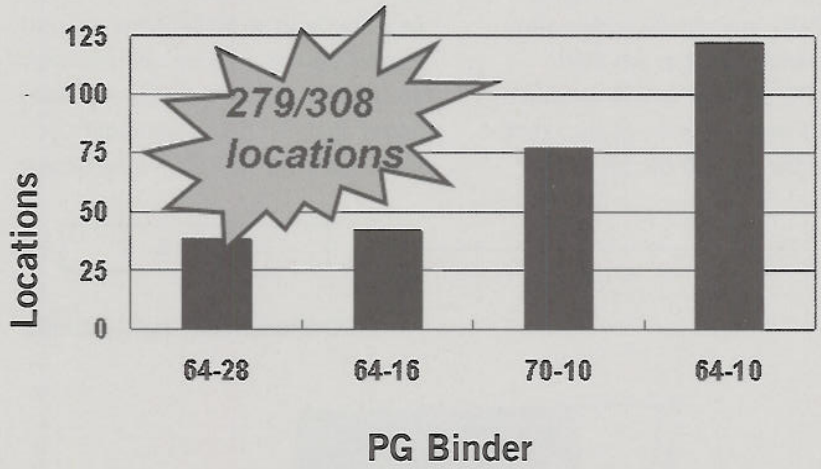


TABLE 1

PG Asphalt Grades for California

Asphalt Grade	California Climate Regions
PG 64-10	Central Coast, Inland Valley, South Coast
PG 64-16	North Coast, Low Mountain, South Mountain
PG 64-28	High Desert, High Mountain
PG 70-10	Desert

PG Tests and Specifications

Most of the tests and specifications used to characterize PG asphalts are very different from those that we were accustomed to under the Penetration and Viscosity grading systems. Since asphalt is a visco-elastic material, the SHRP binder research team drew from the polymer industry to introduce a test to measure the relative contributions of the viscous and elastic components of the asphalt binder. The Dynamic Shear Rheometer (DSR) is used to measure these properties at intermediate temperatures. The Bending Beam Rheometer (BBR) and Direct Tension Test (DTT) were developed to measure low temperature properties of the asphalt while the Rotational Viscometer (RV) was selected to measure the flow properties of the asphalt at high temperatures for mixing and compaction.

An important feature of the PG grading system is that it measures asphalt properties over a much broader range of aging conditions than previous grading systems. Short term aging to

simulate hot mix hardening in the mix plant is accomplished with the Rolling Thin Film Oven (RTFO) test, which was adopted from the AR grading system. A new aging test, the Pressure Aging Vessel (PAV), was developed to simulate long-term aging in the field.

The PG grading system specification limits are indicators of the contribution of the asphalt binder to the pavement distress conditions of permanent deformation (rutting), fatigue cracking, and low temperature cracking. Since rutting occurs early in a pavement's life, DSR measurements near the highest anticipated service temperature should be obtained from an unaged asphalt sample and compared against DSR measurements obtained from an RTFO aged sample. On the other hand, fatigue cracking and low temperature cracking generally occur later in a pavement's life. DSR measurements on an RTFO and PAV aged sample at an intermediate temperature are used to predict fatigue cracking. BBR and DTT results on an RTFO and PAV aged sample at the lowest anticipated pavement surface temperature are used to predict low

FIGURE 4

PG Binder Map for California

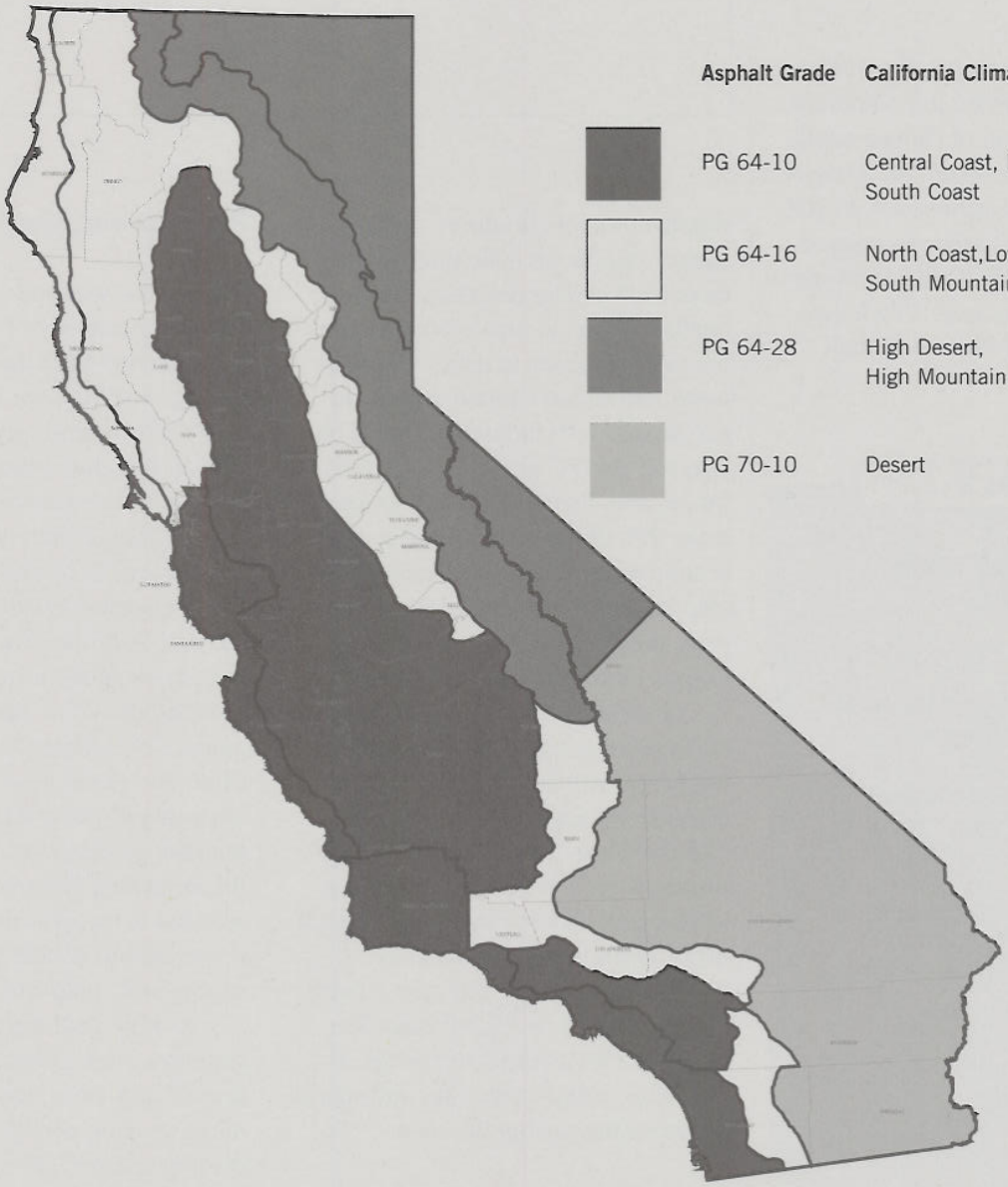


FIGURE 5

PG Graded Asphalt Performance Criteria, Required Tests, Temperatures and Aging Conditions

Performance Criteria	Low Temperature Cracking		Fatigue Cracking	Rutting	Pumpability
Test	Direct Tension Test **DDT**	Bending Beam Rheometer Test **BBR**	Dynamic Shear Rheometer Test **DSR**	Dynamic Shear Rheometer Test **DSR**	Rotational Viscometer Test
Temperature	Minimum Pavement Surface Temperature		Intermediate Pavement Temperature	Average 7-day Maximum Pavement Temperature	Mixing/Compaction Temperature
Aging Condition	Short Term Aging (RTFO) plus Long Term Aging (PAV)			No Aging and Short Term Aging (RTFO)	No Aging

temperature cracking. The relationship between PG tests, test temperatures, aging conditions, and pavement performance/ construction properties is shown in Figure 5.

Several other states have adopted the standard PG specifications contained in AASHTO M320-04. However, some of those other states have modified these requirements based on their experience with PG asphalts and/or asphalt supply considerations specific to their area. Caltrans has adopted AASHTO M320-04 with the following exceptions and options:

- The DSR maximum limit on RTFO and PAV aged asphalt may be exceeded by some major asphalt sources in California. If so, the sample may be tested at a 3°C higher temperature than the specified test temperature and will be accepted if it satisfies the specified maximum limit.
- A ductility limit of 75 cm at 25°C on the RTFO sample is included.
- The option allowed under M320-04 for a PAV aging temperature of 110°C has been selected for the PG 70-10 asphalt grade.

Polymer Modified Asphalts

The four PG grades selected by Caltrans do not require polymer modification. It is likely that most of these grades will be supplied from the same asphalt sources currently used to supply AR asphalts with some possible modifications in manufacturing procedures. One exception is the PG 64-28 asphalt required for the High Mountain and High Desert climate regions. Some suppliers may find it necessary to polymer modify their asphalt to meet the requirements for this grade.

Polymer modified asphalts are growing in popularity in California. They are often preferred in some extreme climates such as the High Mountain or Desert regions or under heavy loading conditions such as very high traffic, intersections, port installations, etc. To meet this need, Caltrans has elected to retain four PBA grades that are polymer modified, namely PBA 6a, 6a*, 6b, and 7. It is likely these PBA grades will be replaced by polymer modified PG grades by January 2007. A Caltrans-industry task force is determining which PG grades could be substituted for the polymer modified PBA grades. The polymer modified

binders will probably require a "PG Plus" specification to assure the presence of a certain level of polymer in the binder.

Asphalt Rubber Binders

There is also a great deal of interest in the use of asphalt rubber mixes in California. These are primarily used in open graded or gap graded surface mixes. A Caltrans-industry task force was formed to decide which base asphalts under the PG system would be required to satisfy the needs of these asphalt rubber mixes. The task force found that a PG 64-16 asphalt could be used as the base asphalt in most asphalt rubber applications, except in cold climate regions, where a PG 58-22 asphalt would be required. Therefore, one additional PG grade, beyond the four already identified, will be part of the asphalt supply picture.

Design Considerations

Selection of an asphalt grade under the PG/PBA system is fairly straight forward (see Table 2). First, the designer or engineer determines what climate region the project in (see Figure 4). Then, the PG grade for that region is determined. If the designer feels special circumstances, such as heavy or unusual traffic, warrant classification under the "designated route" category, a higher temperature PG grade or polymer modified asphalt might be selected. For example, a PG 64-10 is the PG grade of choice for the Inland Valley. However, in the "designated route" category, a PG 70-10 or PBA 6a* might be justified for certain applications. For the Desert region, PG 70-10 is the primary choice with a "designated route" option of PBA 6a* or PBA 7.

Data extracted from a survey by the Asphalt Institute shows how a limited number of AR asphalts used on actual projects in California would grade out under the PG system (see Table 3). In general, AR 4000 asphalts tend to grade out as PG 64-10 asphalts with a few PG 64-16 examples, while the AR 8000 asphalts tend to grade out as PG 64-16 asphalts with some PG 64-28 examples. Asphalt source will continue to play a role in the grade supplied as it did under the AR system. For orientation to the PG system, the AR viscosity at 60°C of conventional (unmodified) asphalts produced in California and neighboring states is compared to various PG graded materials in Table 4.

Mix design is not expected to be an issue with this change to PG grading. The same dense graded, open graded, and gap graded mixes used currently will continue to be used under the PG system. Caltrans is **not** changing mix types at this time. Since many of the same asphalts supplied under the AR system will be supplied under the PG system, changes in mix design are not anticipated. One possible exception may be the use of a somewhat harder binder (PG 70-10) in the Desert region. No doubt, contractors will check their mix designs during the transition to the PG system to be certain asphalt contents are not changing significantly.

TABLE 2

Asphalt Grade Selection under the PG System in California

Climate Region	PG Grade	Binder for Designated Route
Central Coast, Inland Valley, South Coast	PG 64-10	PG 70-10 or PBA 6a*
North Coast, Low Mountain, South Mountain	PG 64-16	PBA 6a*
High Desert, High Mountain	PG 64-28	PBA 6a or PBA 6b
Desert	PG 70-10	PBA 6a* or PBA 7

NOTES: PBA 6a* is a modified version of PBA 6a.

For Open Graded Asphalt Concrete (OGAC) statewide, use the PG grade for the appropriate climate region above or PBA 6a for low temperature placement conditions.

For Rubberized Asphalt, the base stock will be PG 64-16 for all climate regions except the High Desert and High Mountain regions where the base stock will be PG 58-22.

Construction Issues

With any change of this magnitude from the familiar to the unfamiliar, construction concerns are bound to surface. Will mixes made with PG 64-10 asphalt behave differently under the roller during compaction from the AR 4000 mixes used previously? Will the use of PG 70-10 asphalt change mix plant operations or laydown procedures? Will tender mix issues completely disappear once the PG grading system is in place? The answers are "probably not" to each of these questions, but there will, without a doubt, be a learning period as contractors make adjustments to the new PG system. Fortunately, 49 other states have made this transition without major disruptions and, in many of those states, mix types were also changed.

Caltrans Construction is working closely with industry to make the transition from the AR grading system to the PG system as seamless as possible. Projects that are awarded in 2005 and extend into 2006 may involve an asphalt binder change. Caltrans will allow the contractor to use the AR graded asphalt specified for the job until the project is completed, even if the project extends beyond the January 2006 implementation date. Alternatively, the contractor will be allowed to switch to the equivalent PG grade during the project if the AR asphalt is no longer available from the supplier.

TABLE 3

PG Grade Comparisons for California AC Paving Projects

Project Number	Nearest City	AR Binder Specified	Equivalent PG Binder
#22	Sunol	AR 4000	PG 64-10
#38	Placerville	AR 4000	PG 64-16
#55	Fresno	AR 4000	PG 58-28
#107	East Sacramento	AR 4000	PG 64-22
#108	East Palo Alto	AR 4000	PG 64-10
#110	Kettleman City	AR 4000	PG 64-10
#111	Magic Mountain	AR 4000	PG 64-10
#114	Oroville	AR 4000	PG 64-10
#116	Fremont	AR 4000	PG 64-16
#39	Sacramento	AR 8000	PG 64-10
#52	Mendota	AR 8000	PG 64-28
#101	Carpenteria	AR 8000	PG 64-16
#102	Paso Robles	AR 8000	PG 64-28
#103	Los Angeles	AR 8000	PG 64-16
#105	San Luis Obispo	AR 8000	PG 64-16
#113	East Barstow	AR 8000	PG 64-10

Caltrans' Implementation Plan

In summary, the Caltrans implementation plan includes the following elements:

- Replace the AR grading system with four PG grades, each associated with specific climate regions in California, by January 2006.
- Permit the use of a higher temperature PG grade and four PBA polymer modified asphalts for designated routes or special situations.
- Re-examine the PBA grades and their uses and grade polymer modified asphalt binders as "PG Plus" by January 2007.
- Define PG base asphalts for asphalt rubber mixes.
- Require AMRL certification for PG testing by asphalt laboratories by January 2007.
- Adopt AASHTO M320-04 specifications for PG asphalts with California modifications.
- Provide training to Caltrans, local agencies, and private industry at several locations throughout California in late 2005.

Local Agency Impact

This change in asphalt specifications by Caltrans will, of course, impact local agencies. AR graded asphalts will no longer be available in California shortly after the January 2006 implementation date. Engineers or consultants for local agencies will need to select appropriate PG or PBA asphalts to replace what they are currently using. The guidance provided by this article is a starting point. Pavement Associations, the Asphalt Institute, hot mix contractors, and asphalt suppliers can also provide assistance. Although the binder

selection process based on climate region described earlier is straightforward, special situations will arise for local agencies which will require good engineering judgment on the proper PG asphalt to use. For example, what PG asphalt should be used for asphalt curb construction or for container storage facilities in a climate region calling for PG 64-10 for normal paving operations? If an agency has, based on experience, adjusted the use of AR grades to meet its needs, what adjustments are necessary under the PG system? These, and other questions, will be answered as local agency pavement engineers and consultants become more familiar with the PG grading system.

Training

Both agencies and industry agree that proper training plays a critical role in a successful transition to PG grading. Caltrans and industry are jointly planning training sessions for at least 12 locations throughout California during the fall of 2005, to disseminate more detailed information on the subject. This training will be available to representatives of Caltrans, local agencies, the asphalt industry, and consulting firms.

In addition, the Technology Transfer Program of the Institute of Transportation Studies (ITS) at the University of California, Berkeley is developing a half-day Road Show on PG asphalts for local agencies. Road Shows are low-cost training courses that can be put on at a local agency's location by request. Road Shows are taught by experienced instructors retained by ITS, and are partially supported by Local Technical Assistance Program (LTAP) funds. For more information regarding this on-going training option, see *www.techtransfer.berkeley.edu/roadshows*, e-mail *roadshows@techtransfer.berkeley.edu* or call 510-665-3410.

TABLE 4

AR Viscosities for PG Production Asphalts Used in California and Neighboring States

Asphalt Used in	PG Grade	AR Viscosity @ 60°C, Poises
California (Valley Asphalt)	PG 64-10	4,889
California (Coastal Asphalt)	PG 64-16	4,110
Oregon	PG 64-28	6,676
Arizona	PG 70-16	12,302
Arizona	PG 76-16	29,765

Educational material on the PG asphalt system is also available on-line from the Asphalt Institute at *www.asphaltinstitute.org* and the National Asphalt Pavement Association at *www.hotmix.org*.

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