LONG-LIFE PAVEMENT

PT-1

5 POINTS

GOAL

Minimize life cycle costs by promoting design of long-lasting pavement structures.

CREDIT REQUIREMENTS

The first requirement AND EITHER of the following two requirements must be met to achieve points.

Requirement 1: Design at least 75% of the total new or reconstructed pavement surface area for regularly trafficked lanes of pavement to meet long-life pavement design criteria. Compute the total surface area of all trafficked lanes and show that a minimum of 75% of that area is designed for long-life. Do not include shoulders, medians, sidewalks and other paved areas in the computation. Long-life pavement is defined as a pavement structure that is designed using a minimum 40-year design life.

Requirement 2a: Meet the requirements of Figure PT-1.1.

OR

Requirement 2b: Pavement design is in accordance with a design procedure that is formally recognized, adopted and documented by the project owner.

Details

Generally, not all pavement sections on a project will be designed as long-lasting sections. Also, this credit is not applicable to roads that are not surfaced with hot mix asphalt (HMA) or portland cement concrete (PCC), such as gravel roads, dirt roads, and roads sealed with bituminous surface treatments.

Figure PT-1.1 Method. Requirements for subgrade California Bearing Ratio (CBR) and base material CBR can be taken as averages across the entire project where more than one test is done. If subgrade or base support is not measured by CBR, use the common conversion techniques in Table PT-1.1 or any local conversion that is commonly used in design and has a basis in empirical evidence. Soils testing data should support the conversion used.

Table PT-1.1: Commonly Accepted CBR Conversion Methods (AASHTO, 1993)

Conversion	Equation	Limitation
CBR - Resilient Modulus (M_R)	$CBR = \frac{M_R}{1500}$	Fine grained soils with a soaked CBR of 10 or less only
CBR - Resistance Value (R-value)	$CBR = \frac{555(R\ value) + 1155}{1500}$	Fine grained, non-expansive soils with a soaked CBR of 8 or less only

Design Procedure Method. The intention is to allow an owner agency to use its existing design procedure to design the pavement section as long as a sufficiently long design life is chosen (at least 40 years). Some common design procedures include (but are not limited to):

- **1993 AASHTO Method**. The method described in the 1993 version of the

RELATED CREDITS

- ✓ PR-2 Lifecycle Cost Analysis
- ✓ MR-2 Pavement Reuse

SUSTAINABILITY COMPONENTS

- ✓ Ecology
- ✓ Economy
- ✓ Extent
- ✓ Expectations
- ✓ Experience

BENEFITS

- ✓ Reduces Raw Materials
- ✓ Reduces Fossil Fuel Use
- ✓ Reduces Air Emissions
- ✓ Reduces Greenhouse Gases
- ✓ Reduces Solid Wastes
- ✓ Increases Service Life
- ✓ Reduces Lifecycle Costs
- ✓ Improves Accountability

AASHTO Guide for Design of Pavement Structures (1993) and computerized in DARWin, and AASHTOware product.

- **Asphalt Institute Method**. The method described in the Asphalt Institute's MS-1 Asphalt Pavements for Highways and Streets and computerized in the Asphalt Institute's publication, SW-1 Asphalt Thickness Design Software for Highways, Airports, Heavy Wheel Loads and other applications (1981).
- **Mechanistic-Empirical Pavement Design Guide (MEPDG)**. The method described in AASHTO MEPDG-1 Mechanistic-Empirical Pavement Design Guide, Interim Edition: A Manual of Practice (2008). This method is eventually intended to replace the 1993 AASHTO method.

Existing Pavements. Existing pavements that are to at least partially remain in place (in any condition) can also qualify for this credit. In these cases, evaluation for this credit shall be based on the final pavement structure, which may include (1) existing pavement remaining in place, and (2) any new pavement structure added. In this manner, a diamond grind of an existing PCC pavement or an overlay of an existing HMA pavement can qualify for this credit if the resultant pavement structure meets the criteria of this credit.

DOCUMENTATION

- A list of pavement sections to be built (or reconstructed) and their associated pavement material type, surface areas, equivalent single axle loads (ESALs), design thicknesses, subgrade CBR, and if design was intended to be long-life or not in accordance with the requirements of this credit. This may be included as part of the standard project documentation or as a separate document.
- A calculation to indicate the total percentage of trafficked lane pavement surface areas that are designed for long-life.
- A drawing or project map showing locations of pavement sections designed for long-life. These pavement sections should be highlighted on the plan, a scale should be on the plan, and the total surface area of each pavement section should be called out as a note on the plan.

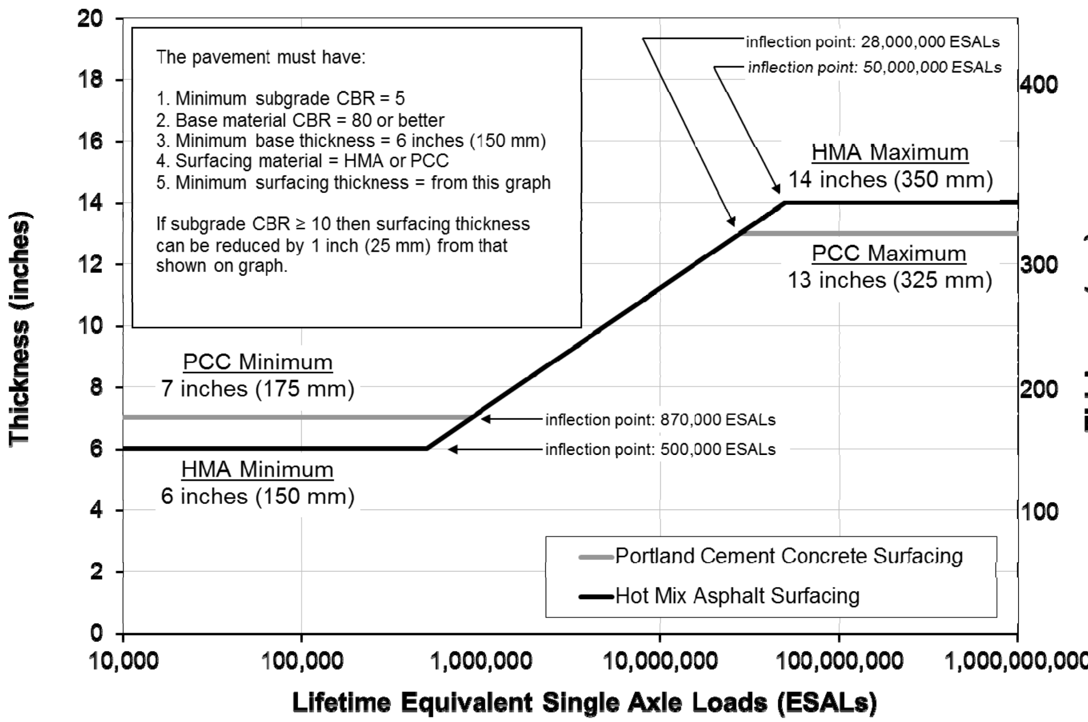

Figure PT-1.1: Long-life pavement design graph.

APPROACHES & STRATEGIES

- Consider designing long-lasting pavement that meets the requirements of this credit. Any number of pavement design methods can produce pavement sections that meet the requirements of this credit.
- Have a rehabilitation/preservation program that strives to keep existing pavements in satisfactory condition such that they may remain in place for overlays or diamond grinds. This allows simple rehabilitations such as diamond grinds and overlays to quality for this credit. Ultimately, this gives credit for a road being durable enough such that it does not need to be entirely replaced.

Example: Sample Calculation using Figure PT-1.1

A pavement is to be designed for a roadway that will have a loading of 5 million equivalent single axle loads (ESALs) over a 40-year period built on a subgrade with an average CBR of 11. ESAL calculation methods and definitions are found in the *AASHTO Guide for Design of Pavement Structures* (1993). Determine the required pavement thickness as follows:

a. Enter Figure PT-1.1 at 5 million ESALs. Note that the ESAL scale is a log scale so 5 million is more than half-way between 1 million and 10 million (Figure PT-1.2).
b. Find where 5 million ESALs intersects the plotted lines for HMA and PCC. In this case both plotted lines lie on top of one another.
c. Find where this point lies on the Thickness axis. In this case, it is 10 inches.
d. Since the average CBR is 11, the graph note allows the surfacing thickness to be reduced by 1 inch leaving a final surfacing thickness of 9 inches.
e. Note the 5 items the pavement must have as listed in the upper left corner of the graph (minimum subgrade CBR of 5, base material CBR of 80 or greater, minimum base thickness of 6 inches, surfacing material of either HMA or PCC, and a minimum surfacing thickness from the graph).
f. The final pavement should be 9 inches of HMA or PCC, placed on at least 6 inches of base course with a CBR of at least 80, placed on the subgrade.

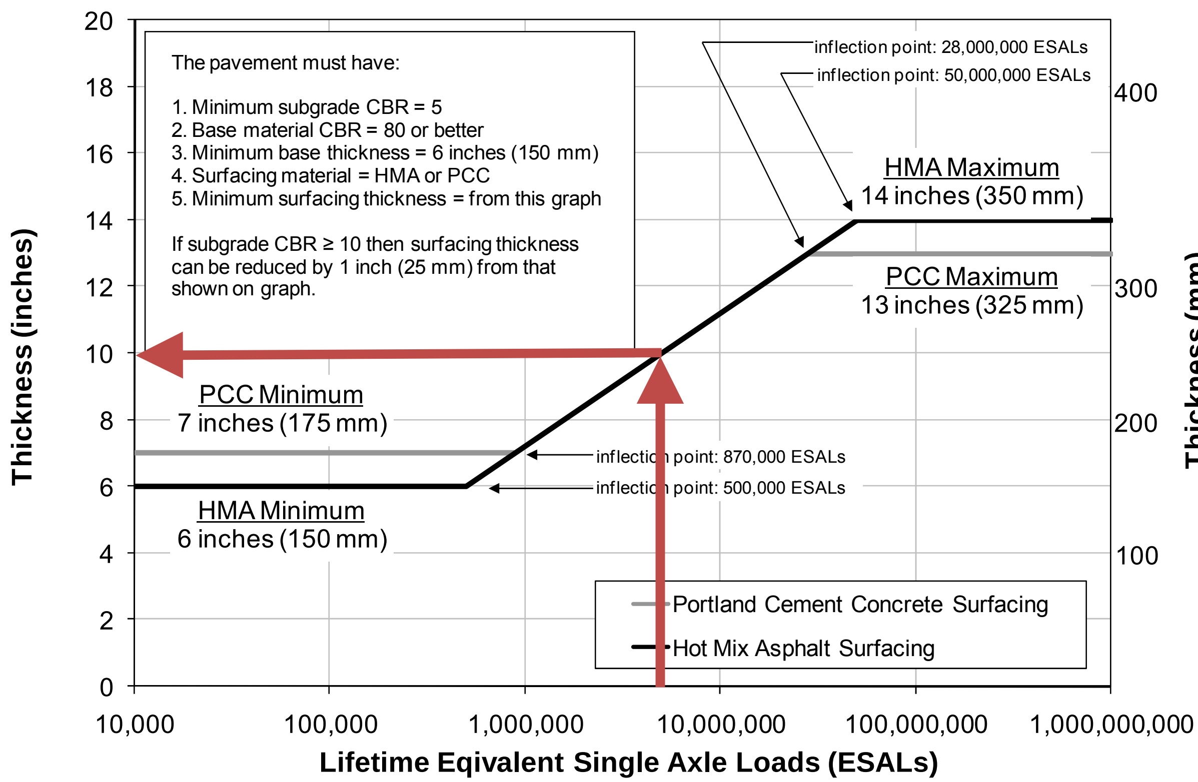

Figure PT-1.2: Example calculation.

Example: HMA Pavements

Currently, the Asphalt Pavement Alliance (APA) has a "Perpetual Pavement Award" given nearly annually to proven long lasting pavements. The APA defines a "Perpetual Pavement" as "…an asphalt pavement designed and built to last longer than 50 years without requiring major structural rehabilitation or reconstruction, and needing only periodic surface renewal in response to distresses confined to the top of the pavement." (APA, 2002). All pavements that receive the Perpetual Pavement Award are evaluated for structure, condition, maintenance and rehabilitation efforts to ensure they meet the APA requirements. Awardees for 2006, which can serve as examples of in-service long lasting pavements were:

- California Department of Transportation for a section of the San Diego Freeway (Interstate 405) between Harbor Boulevard and Beach Boulevard
- Minnesota Department of Transportation for Town Highway (TH) 61 between Wabasha and Kellogg
- Montana Department of Transportation for a 10-mile length of Interstate 90 over Homestake Pass
- Nebraska Department of Roads for a 5-mile section of State Highway 35 in Wayne County
- Tennessee Department of Transportation for a 14-mile section of State Route 14 in Tipton County
- Virginia Department of Transportation for a 6.5-mile portion of Interstate 81 in Frederick County

While these pavements are all generally higher volume, examples of a low-volume HMA long lasting pavement can be found in Muench et al. (2004). They investigated the WSDOT pavement network and found 1,339 lane-miles of low-volume pavement of which a majority (about 64%) had been in service for over 35 years without having undergone reconstruction. These pavements were also found to exist in all areas of the state and be in good condition.

Example: PCC Pavements

It may be more likely that a PCC pavement will be designed for at least 35 years. The NCHRP Report 1-32 lists 7 states in 1997 that already used PCC pavement design lives of at least 35 years. Even PCC pavements designed for shorter lives often last in excess of 35 years. For instance, most of the State-owned PCC pavements in Washington State were designed for 20 years but have lasted much longer: there are over 400 lane-miles of PCC pavement in Washington State that are already older than 35 years and are still functioning. There are many examples of this type of performance nationwide including:

- I-80 (Grundy County), I-70 (Clark County), I-290 (Cook County), I-80 (Grundy County) and I-74 (Peoria County) in Illinois (Winkelman, 2006).
- The Motorway E40 from Brussels to Leige in Belgium (Caestecker, 2006)
- US 40/ I-80 in Fairfield, CA (Rao, et al., 2006)

Additionally, many cities that surface their residential streets with PCC have experienced long-life. For example, the City of Seattle paved many urban streets with concrete before 1940 and many of those are still in service (Flynn, 2002). Some remain in their original state while others have been covered up by subsequent layers of HMA. However, in nearly all cases the original PCC pavement remains in some fashion.

POTENTIAL ISSUES

1. In many applications an adequate pavement design may not call for hot mix asphalt (HMA) or portland cement concrete (PCC) surfacing. These include gravel, dirt or bituminous surface treated (BST) roads. This credit does not apply to these roads even though these surfaces may be the most appropriate for the given project. However, the design approach is still applicable and appropriate for such projects.
2. Some commonly used pavement design methods may produce pavement thicknesses that do not meet the requirements of this graph. Such designs do not qualify for this credit even though they conform to common pavement design practice.
3. The idea that pavement design can be reduced to a single graph may be controversial among experts. However it is a necessary compromise in order to engage decision-makers who may otherwise arrive at inadequate pavement designs driven by budgetary constraints or unfamiliarity with the concepts of long-lasting design.

RESEARCH

A "long-lasting pavement" is one where the bulk of the pavement structure is designed to last for at least 35 years. The only required maintenance and rehabilitation actions are periodic surface renewals to address roughness and surface distress. This definition is taken largely from the Asphalt Pavement Alliance (APA, 2002).

This is in contrast to the historical practice of designing pavements for shorter lives (often 10 to 20 years) and then reconstructing the entire pavement structure at the end of life. Part of National Cooperative Highway Research Program (NCHRP) Project 1-32, *Systems for Design of Highway Pavements* (1997), consisted of a survey of U.S. state department of transportation (DOT) pavement design practices. This survey showed that most state DOTs use pavement design lives of 20 to 30 years (Figure PT-1.3). Based on the 35-year cutoff of this credit, most of these design lives do not qualify as "long-life." However, since 1997 the general trend has been to design pavements for longer life. For example, the Minnesota DOT has extended its PCC pavement design life standard from 35 to 60 years (Burnham et al., 2006).

Long-lasting pavements generally lead to higher initial costs (due to more material being used) but lower lifecycle costs because less rehabilitation and maintenance is needed over time. Both HMA and PCC surfaced pavements can be long lasting according to this description.

For low-volume HMA pavements Muench et al. (2004) performed a lifecycle cost comparison conforming to the guidelines of Walls and Smith (1998) between an archtype long-lasting low-volume pavement with one that was designed to be reconstructed after 25 years. They used typical Washington State Department of Transportation (WSDOT) design characteristics and found a cost savings over 50 years of about 25% for the long-lasting pavement.

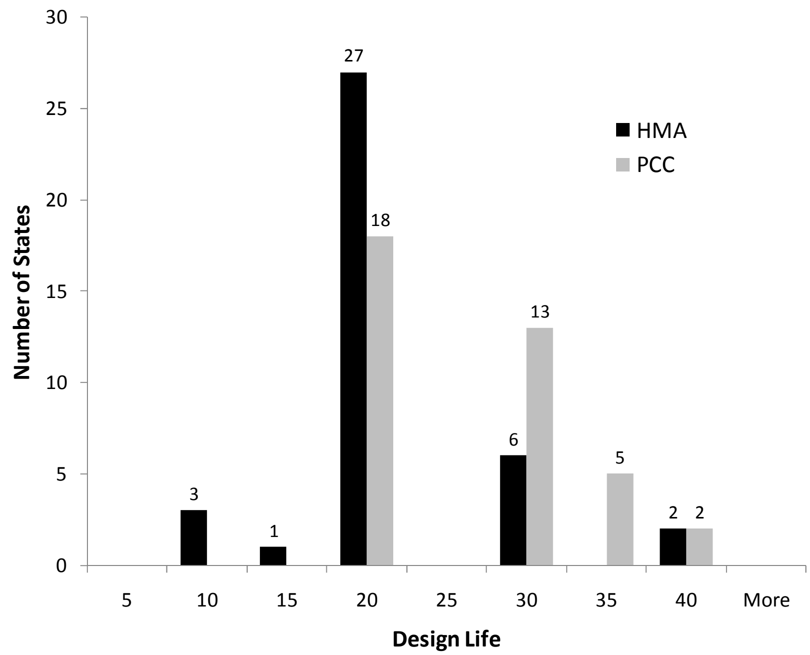

Figure PT-1.3: Pavement design lives taken from NCHRP Project 1-32 survey.

Looking at just the performance life of the pavement surface (often called the "wearing course," the Organisation for Economic Co-operation and Development (OECD) (2005) concluded that developing long-lasting surface courses that cost three times as much as traditional ones (e.g., the ones in use today) that would only require resurfacing every 30-40 years would generally be economically viable for traffic levels of at least 70,000 to 80,000 AADT in both directions. With discount rates below 6% they could be viable between 40,000 and 60,000 AADT in both directions. In general, economic savings increases as traffic levels increase and as discount rates decrease.

Development of Figure PT-1.1

Figure PT-1.1 was developed based on output from a number of generally accepted pavement design methods (AASHTO, 1993; Muench et al., 2007; Timm, 2007; Asphalt Institute, 1981; Nunn, 1998) and is an attempt to capture the basic pavement structure that is likely to result in long-life. Figure PT-1.4 shows how Figure PT-1.1 was developed using these design methods. Pavements designed according to Figure PT-1.1 are likely to be long-lasting pavements and thus result in lower lifecycle costs. Additionally, design thicknesses and subgrade requirements are straightforward.

The design assumptions that were used to develop Figure PT-1.4 are summarized here.

1993 AASHTO Rigid Design (AASHTO, 1993)

- Reliability = 75% for designs of 500,000 ESALs or less.
- Reliability = 85% for designs > 500,000 and < 20,000,000 ESALs.
- Reliability = 95% for designs of 20,000,000 ESALs or more.
- PCC modulus (E_c) = 4,000,000 psi
- PCC modulus of rupture (S'_c) = 700 psi
- Drainage coefficient (C_d) = 1.0
- Load transfer coefficient (J) = 3.2
- Modulus of subgrade reaction (k) = 200 psi/inch
- Base thickness = 6 inches of granular base material

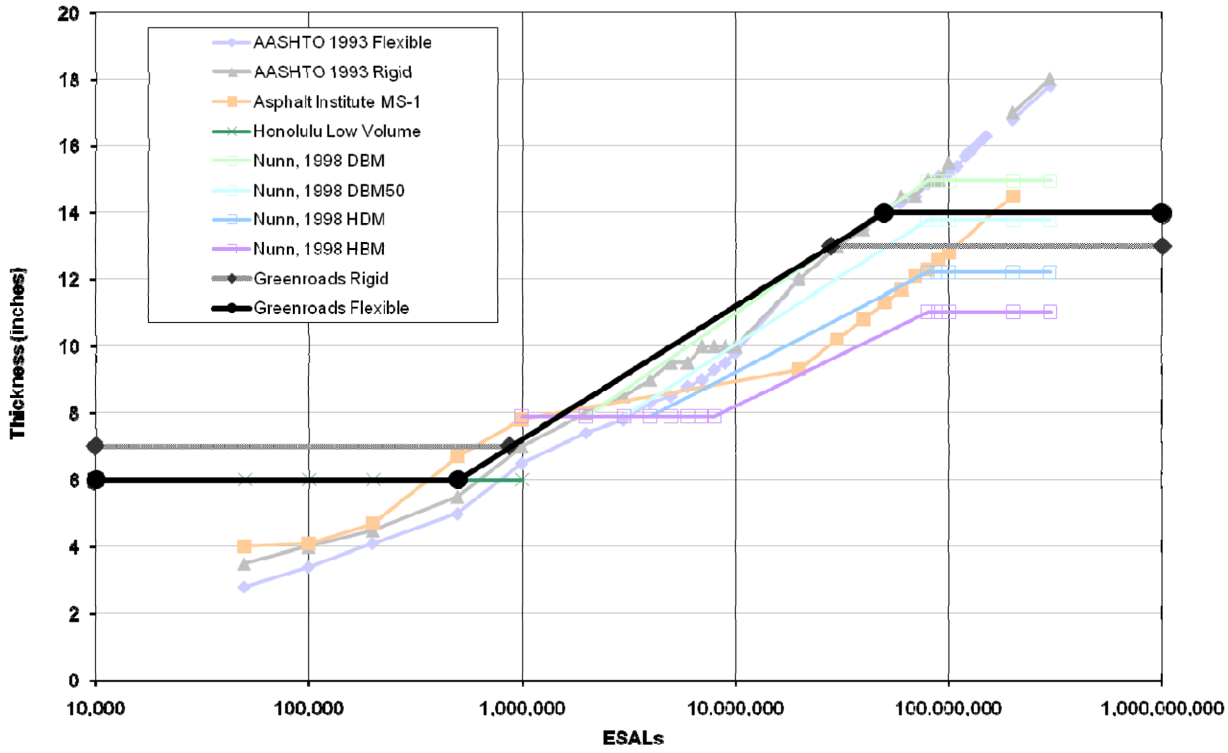

Figure PT-1.4 Development of graph using existing design methods.

1993 AASHTO Flexible Design (AASHTO, 1993)

- Reliability = 75% for designs of 500,000 ESALs or less.
- Reliability = 85% for designs > 500,000 and < 20,000,000 ESALs.
- Reliability = 95% for designs of 20,000,000 ESALs or more.
- Change in servicability over the pavement life (delta-PSI) = 1.5
- HMA structural coefficient (a-HMA) = 0.44
- Granular base material structural coefficient (a-base) = 0.13
- Granular base material resilient modulus (M_R) = 30,000 psi
- Base thickness = 6 inches of granular base material
- Subgrade CBR = 5, equivalent to a subgrade M_R = 7,500 psi

Asphalt Institute MS-1 (Asphalt Institute, 1981)

- Design table: HMA over 6 inches of untreated granular base material with MAAT = 60F
- Design Chart A-29 in MS-1

Low Volume roads (Muench et al., 2007)

- The plot for "Honolulu, low volume" comes from the City and County of Honolulu design standards that were developed as described in this paper.

TRL standards (as reported by Nunn, 1998)

The plots for the various "Nunn, 1998" come from the TRL standards.

- The full report (Report 250) can be found at: http://www.trl.co.uk/online_store/reports_publications/trl_reports/cat_highway_engineering/report_design_of_long-life_flexible_pavements_for_heavy_traffic.htm

- A version of the graph used (from Figure 8 on page 9 of 10) to get the values plotted above can be seen at: http://www.transport-links.org/transport_links/filearea/publications/1_764_PA3736_2001.pdf.

GLOSSARY

AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average daily traffic
APA	Asphalt Pavement Alliance
BST	bituminous surface treatment
CBR	California Bearing Ratio
DOT	department of transportation
ESAL	Equivalent single axle load
HMA	Hot mix asphalt
Long-life pavement	any pavement design that falls on or above the plotted line for the given pavement type and meets the criteria described in the PT-1.1 graph
M_R	Resilient modulus
NCHRP	National Cooperative Highway Research Program
PCC	Portland cement concrete
R-value	Resistance value

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