Selecting Appropriate (Cost-Effective) Pavement Treatments

Roger E. Smith, P.E., Ph.D.
Professor of Civil Engineering
Research Engineer, TTI
Texas A&M University

Outline

- Purpose
- Pavements 101
- Maintenance treatments
- Rehab/reconstruction treatments
- LCCA
- Tying this into StreetSaver network and project-selection level management

Management Levels

- Strategic (Asset) – Planning, Programming & Allocation for All Systems
- Network - Planning & Programming for Entire Set of Pavements
- Project Selection - Programming a Pavement Work for Next Funding Period
- Project - Designing a Specific Section
- StreetSaver primarily assists at middle two levels

Focus of This Presentation

- Project-level
- What treatment should be applied to a pavement with defined problems?

Purpose of Pavement

- Provide a safe and smooth surface for the traveling public
  - Safe - skid resistant
  - Smooth - transport without discomfort riders or damage to transported goods
  - Happiness is a smooth road

Safe Surface - Friction

- Function of:
  - Surface Friction
  - Tire Friction
  - Presence of Water (depth)
  - Vehicle Speed

We Control Surface Friction & Water Depth

- Surface Friction:
  - Mixture characteristics
  - Aggregate characteristics
  - Surface treatments
- Water Depth:
  - Cross slope
  - Permanent deformation (rutting)

Pavement

- Smooth, skid resistant surface that will support desired traffic loads
  - Truck loads control strength and thickness required
- Horizontal Structure
  - Distributes traffic loads to supporting soil

CALTRANS Traffic Index (TI)

$$TI = 9.0 \times \left(\frac{(ESAL \times LDF)}{10^6} \right)^{0.119}$$

- ESAL – Equivalent 18 kip Single Axle Loads
- LDF – Lane Distribution Factor

CALTRANS
Highway Design
Manual Sec. 613

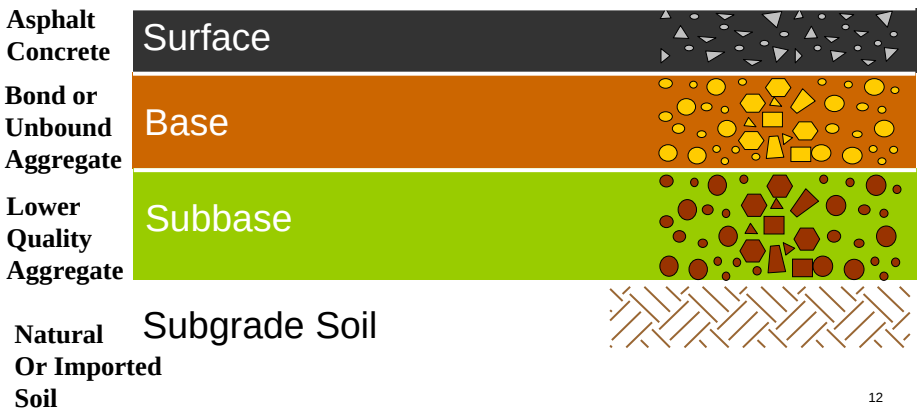
Pavement Design

- Select layer materials & thicknesses to provide desired service over life of pavement for least cost (Life-cycle cost analysis)
- Design life based on projected performance
- Structured approach to address complex problem
- Must consider major factors influencing performance

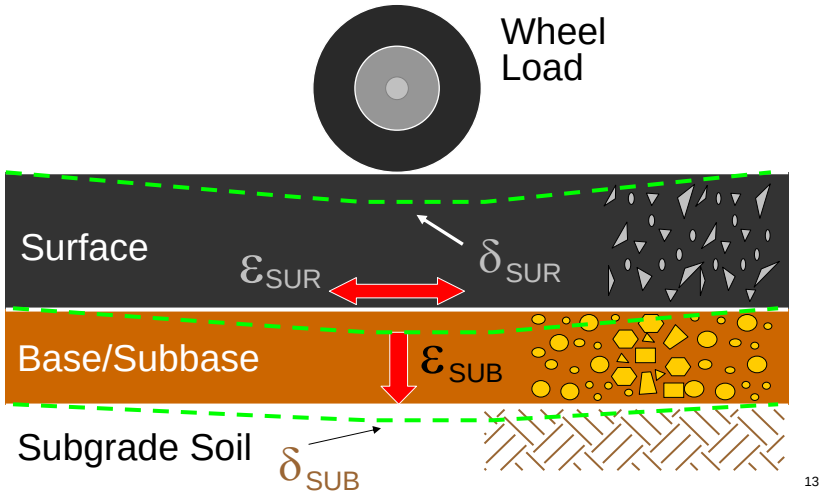
Flexible Pavement

- Base Major Structural Component
  - Surface - HMAC or ST
  - Base - Granular or Stabilized
  - Subbase - Not always used
  - Modified Subgrade - Not always used
  - Natural or imported soil (subgrade)

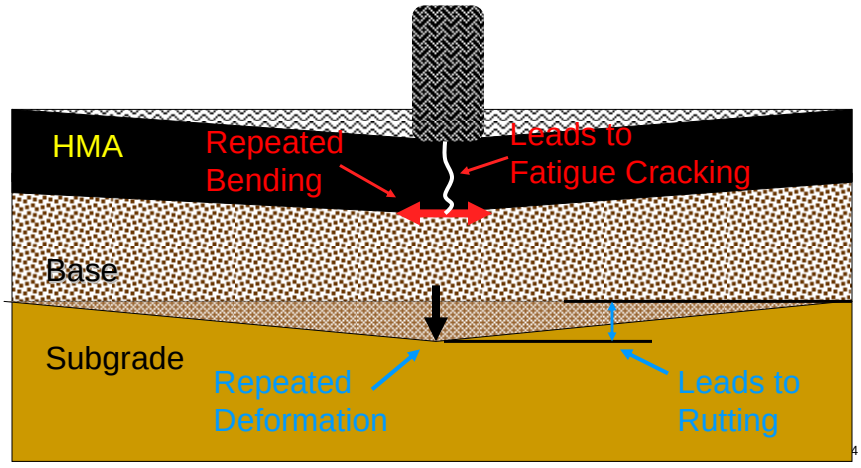
Typical Flexible Pavement Section



Pavement Responses Under Load



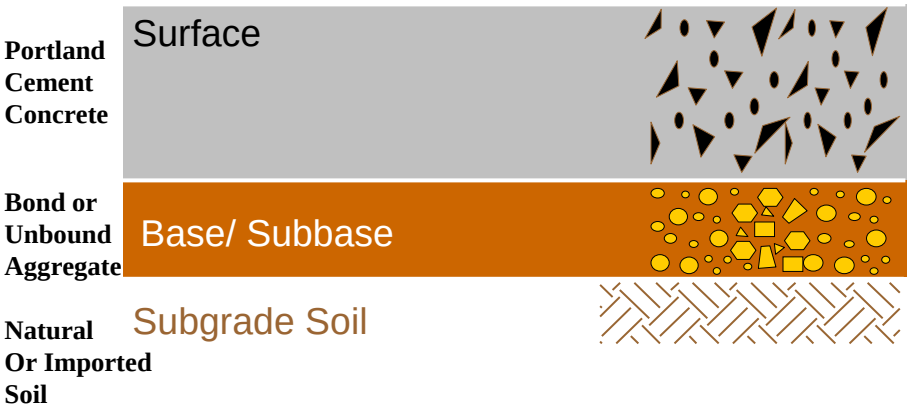
Design Goals - Control These



Rigid Pavement

- Surface Major Structural Layer
  - Surface – Portland Cement Concrete (PCC)
  - Base (subbase) - Granular or Stabilized
  - Modified Subgrade - Not always used
  - Natural or Imported Soil (Subgrade)

Typical Rigid Pavement Section



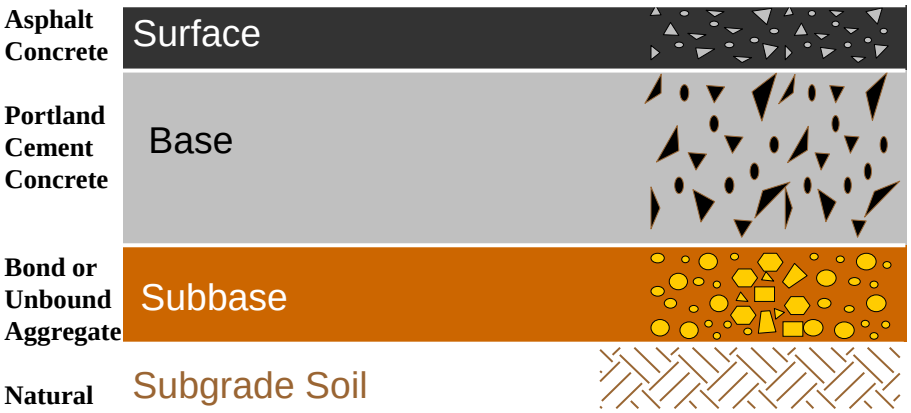
Type of Rigid Pavements

- Jointing Systems
  - Jointed Plain Concrete Pvmt (JPCP)
  - Jointed Reinforced Concrete Pvmt (JRCP)
  - Continuously Reinforced Conc Pvmt (CRCP)
  - Post-tensioned Concrete Pavement (PTCP)
  - Roller Compacted Concrete Pvmt (RCPC)

Composite

- Flexible over Rigid
- Normally Rehabilitation Overlay on Old Rigid Pavement
- Performance:
  - Structural – normally controlled by PCC
  - Surface friction – controlled by HMAC

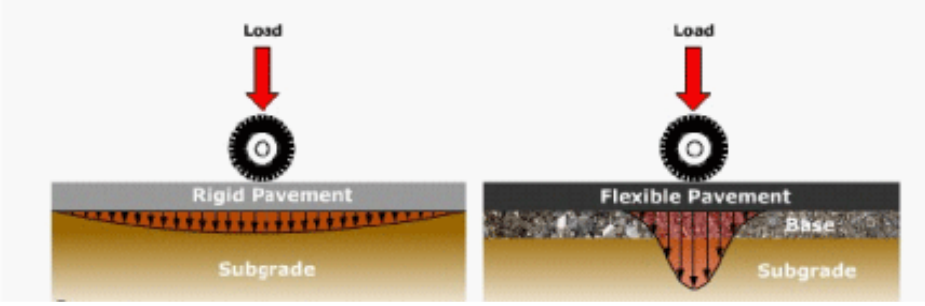
Typical Composite Pavement Section



Difference in Load Distribution

- Flexible - Conical distribution
  - Layer thickness
  - Layer stiffness
- Rigid - Slab action
  - Slab size
  - Surface thickness
  - Surface stiffness

Differences in Stress Distribution



Pavement Thickness Design Procedures (Local Agency)

- CALTRANS Highway Design Manual
- ACPA Design of Concrete Pavement for City Streets (IS 184)
- ASCE Guide for the Design and Maintenance of Paved Low-Volume Roads – 2003
- AASHTO Guide For The Design of Pavement Structures – 1993

CALTRANS

- Empirical
  - Req'd GE = 0.0032* TI*(100-R)
  - Thickness (t in ft) = $\frac{GE}{G_f}$
    - Other designs allowed with documentation

Basic Pavement Design Data

- Traffic Loads
- Supporting Soil
- Available Materials
- Material Properties
- Climate
- Cost
- Constraints

CALTRANS Factors to Consider

- Pavement design life
- Traffic considerations (ESAL's & TI)
- Soils characteristics (USCS & R-value)
- Weather (climate zones)
- Existing pavement type and condition
- Availability of materials
- Recycling
- Maintainability
- Constructability
- Cost comparisons (initial and life-cycle)

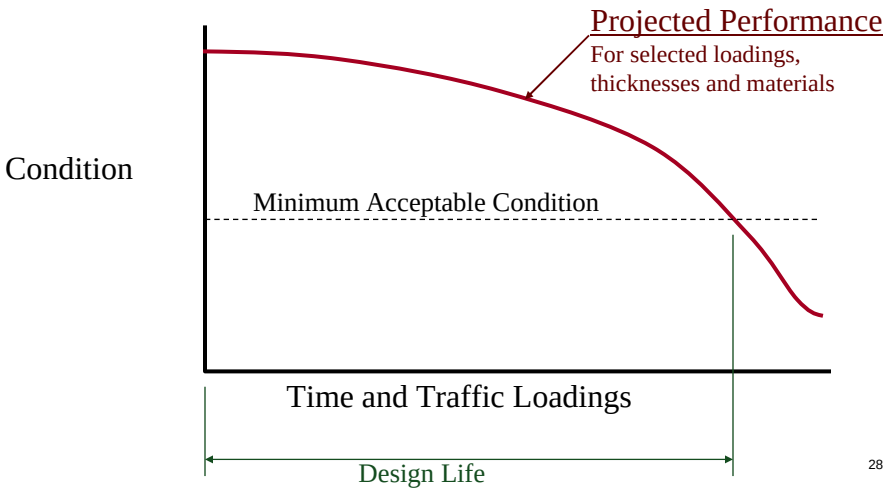
http://www.dot.ca.gov/hq/esc/Translab/ope/Climate.html

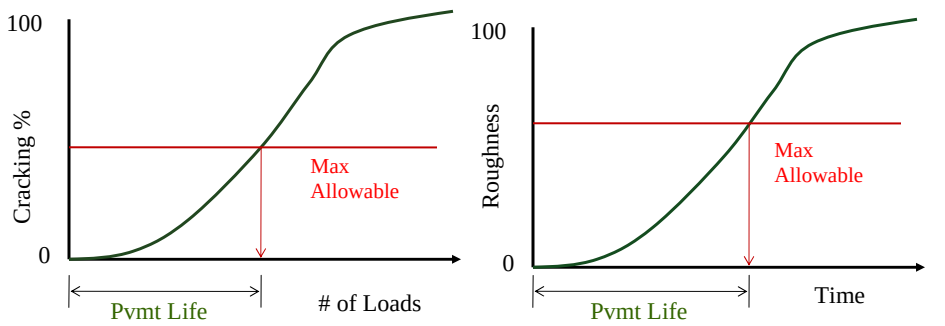
CALTRANS Pavement Climate Regions

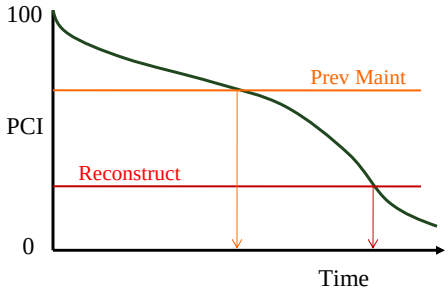
Pavement Life (Performance)

- Pavements start to deteriorate once constructed
- "Life" based on condition level set by agency
- Performance can be based on:
  - Safety
    - Generally skid
  - Functional
    - Generally roughness
  - Engineering
    - Generally distress
- Somewhat arbitrary

Pavement Design Life





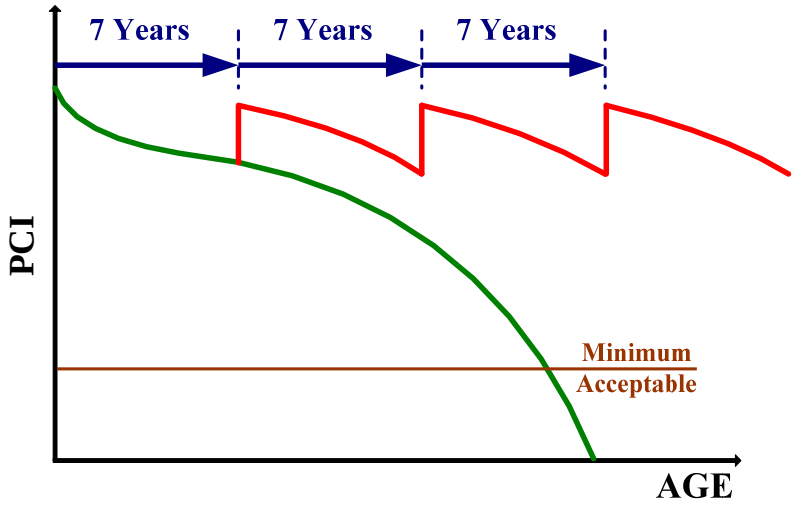


Pavement life determined on when pavement actually reaches maximum or minimum condition level

Maintenance

- Can reduce damage
- Reduce rate of deterioration
- Must be considered in design

Impacts of PM on Performance



Flexible Pavement Design Addresses

- Alligator Cracking
- Rutting in Subgrade
  - Both contribute to roughness
- Other distress types controlled by:
  - Materials selection
  - Mixture design
  - QA/QC during construction

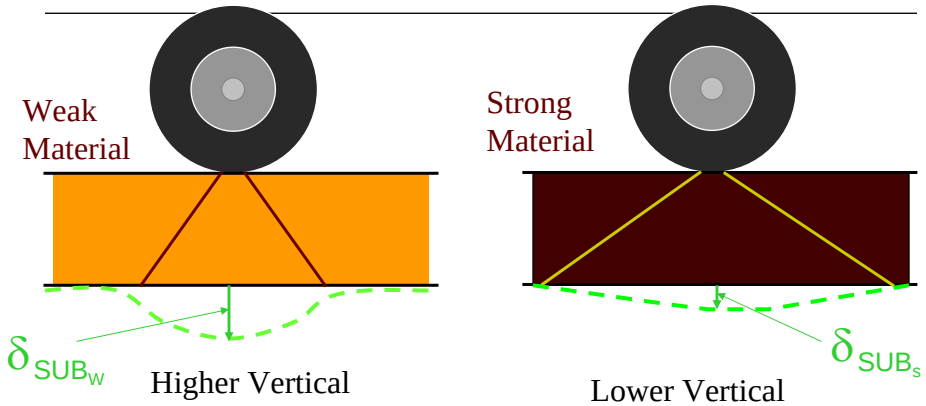
Rigid Pavement Design Addresses

- Cracking
- Corner Breaks
- Faulting & Pumping Somewhat
- Joint Design Controls Faulting Somewhat
- Other distress types controlled by:
  - Materials selection
  - Mixture design
  - QA/QC during construction

Importance of Material Properties

- Natural soil must carry load
- Pavement layers distribute load over larger area
- Stiffer materials distribute load over wider area
- Thicker layers distribute load over wider area
- Unstable or non-durable materials can lead to premature failure

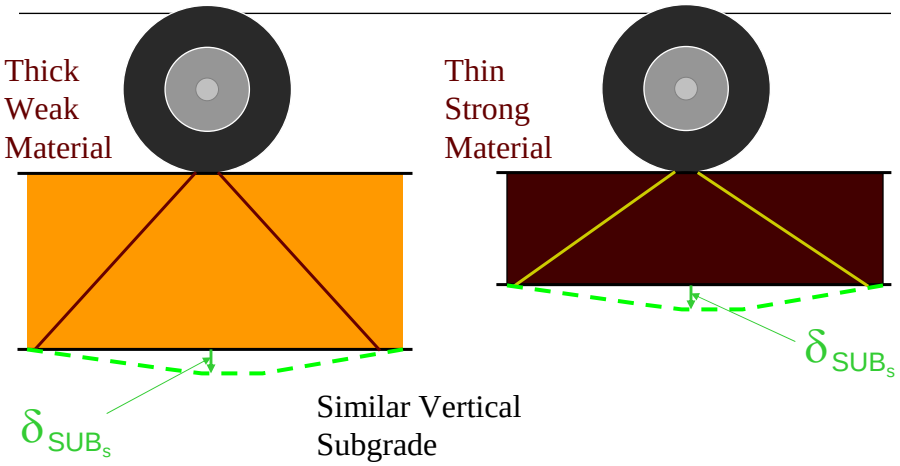
Load Distribution



Higher Vertical Subgrade Deflection & Stress

Lower Vertical Subgrade Deflection & Stress

Load Distribution



Similar Vertical Subgrade Deflection & Stress

Material Properties

- Change when moisture changes
- Change when temperature changes
- Change over time
- Change when damaged by loads
- Inadequate durability or stability can cause premature failure through development of certain distress types
- Must be “durable” as well as “strong”

Drainage

- Not generally considered directly
- Very IMPORTANT due to
  - Moisture susceptibility of most pavement layer materials and
  - Surface friction

Pavements

- Designed (we hope)
- Constructed
- Operated
- Maintained
- Rehabilitated
- Reconstructed
- Seldom ever abandoned

Maintenance, Rehabilitation & Reconstruction

- Goal:
  - Desired performance at least cost over some selected analysis period
- Approach - Apply:
  - the right treatment
  - to the right pavement
  - at the right time
- Preservation & More Extensive Treatments

Selecting the Right Treatment

- After selection for treatment at network and project-selection level
- Project-Level Evaluation
  - Identify type & extent of problem
  - Determine cause(s)
  - Identify appropriate feasible alternatives
  - Select best alternative
  - Complete design & construction

Identify Problem

- Is the road or street surface structurally adequate for future traffic?
  - Distress & deflection
- Is the road or street surface functionally adequate?
  - Ride
- Is the road or street surface skid adequate?
  - Accidents & surface texture
- Does the condition vary substantially along the section?

Distress

- Damage that can be seen on the pavement surface
  - Cracking
  - Patching
  - Rutting
  - Various other types of deterioration
- Varies with type of pavement
- Accumulation of distress reduces condition

Distress Types

- Some indicate structural issues
  - Alligator cracking & rutting in AC
  - Cracking & faulting in PCC
- Others indicate materials/construction issues
  - Weathering & raveling in AC
  - Spalling in PCC
- Distress types lead to roughness

Data/Information Collection Sequence

- Office
  - What do we know now?
- Field
  - Check of current conditions
- Determine needed information & testing
  - Full distress survey, deflection testing, cores, etc.
- Field and lab testing
  - Complete data collection &/or testing

Identify the Cause of Deterioration

- Importance of Road or Street
- More extensive investigation when
  - Functional class is high
  - Traffic levels are high
  - Impact of failure is high

Structurally Adequate?

- Distress present
- Age & traffic levels
  - Is the rate of deterioration abnormal
- Cores
- Deflection testing
  - More later

Functionally Adequate?

- Roughness
  - Drive through during field check
- Skid
  - Office check for wet weather accidents
  - Field check

Other Causes

- Are surface materials durable?
  - Premature weathering & raveling
  - Slippage cracks & double wheel ruts
- Is drainage adequate?
  - Standing water
  - Water seeps
  - Wet spots & saturated materials
- Has previous maintenance been abnormal?
  - Excessive patching & repairs

Constraints

- Does the environment/region require special consideration?
- What traffic control options are available?
- What geometric and safety factors will impact the design?
- Will the shoulders, curbs & gutters, sidewalks, bike paths or other facilities require work as well as the main travelled lanes?

Complete Project Level Analysis

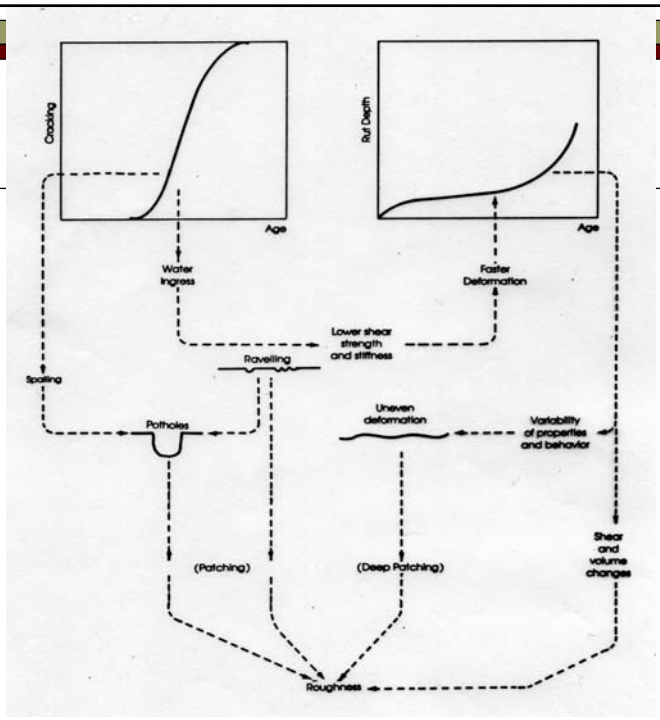
- With level and causes of damage known
- Final selection of feasible treatments (Evaluation of more complete information)
- Preliminary design
- Life cycle cost analysis
- Final design
- Construction

Structurally Adequate

- No overlay required
  - No major structural distress
  - More later
- Preservation treatments

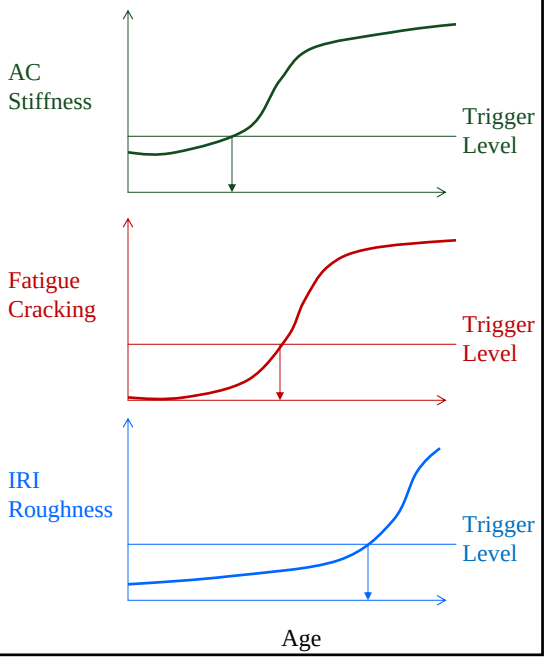
Distress to Roughness

- Distress will lead to roughness
- Better to set intervention based on distress
- Better yet to set intervention based on changes in material properties - not currently possible



Pavement Condition & Performance Measures

Provide safe & smooth pavement surface for traveling public

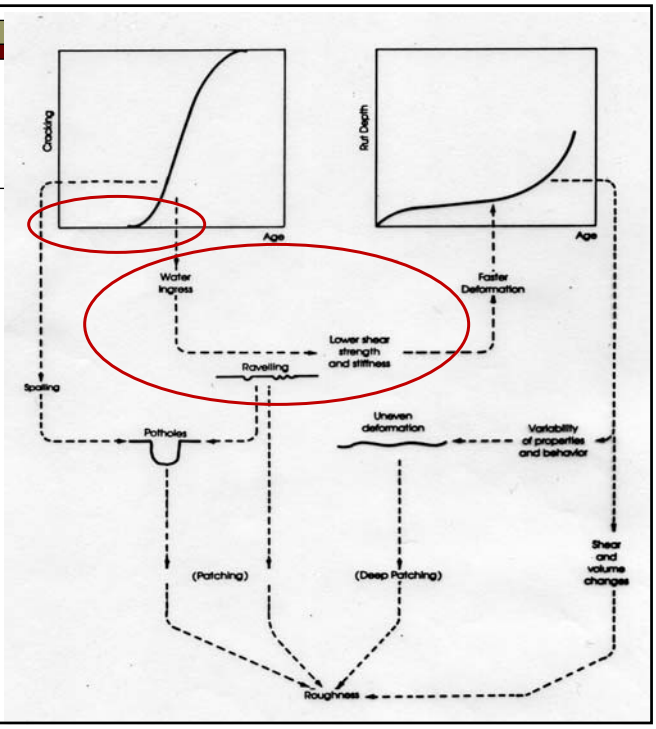


Preventive Maintenance

Prevent development of extensive distress

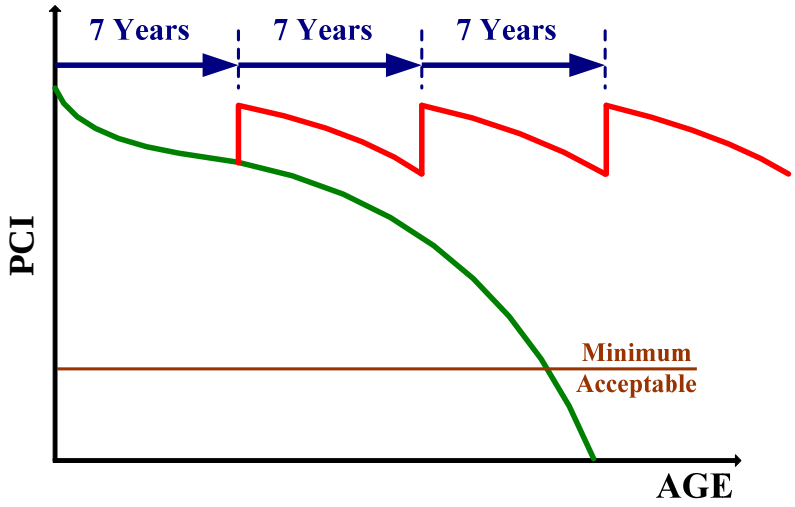
Primarily addresses environmental caused deterioration

Preserves existing structure so that it can resist traffic loadings



Preventive Maintenance

Keep cracking & other distress from developing



Preservation Treatments

- Crack sealing
- Fog/Rejuvenating Seals
- Chip seals
- Slurry seals
- Scrub seals
- Microsurfacing
- Open graded friction course
- RHMA-O, RHMA-HB
- PBA-G
- BWC
- BWC-Rubber
- Thin Overlays

Non-Structural Activities

GENERAL GUIDELINES FOR EFFECTIVE MAINTENANCE TREATMENT SELECTION

Parameters				Rutting		Climate				Traffic Volumes									Treatment Costs	Cost: $/SQ YD (Treatment Only)					Treatment Life Based On Traffic Volumes & Pavement Condition — Pavement Condition: adt < 5000			adt>5000<30,000			adt >30,000		
Preventive Treatments	Raveling	Oxidation	Bleeding	<1/2"	>1/2"	Desert	Valley	Coastal	Mountains	adt < 5000	adt>5000<30,000	adt >30,000	Night	Cold	Stop Points	urban	Rural	High Snow Plow	Cost per lane-mile (Total Project Cost includes traffic control)	Large Projects	Medium Projects	Small Projects	Addtl Premium for night work $/SQ YD	Addtl Premium for Short Work Periods or Work Zones $/SQ YD	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
Crack/Joint Seal																																	
Emulsion	N	N	N	N	N	G	G	G	G	G	G	G	N	N	G	G	G	G	8,000	0.50-0.65	0.60-0.75	.70-0.8	0.15-0.2	+0.60-1.00	2 to 8	2 to 6	1 to 4	2 to 7	2 to 5	1 to 4	2 to 6	2 to 4	1 to 4
Modified (Rubber)	N	N	N	N	N	G	G	G	G	G	G	G	G	G	G	G	G	G	8,000	0.55-0.70	0.65-0.80	.75-0.9	0.15-0.2	+0.60-1.00	5 to 9	3 to 7	N	5 to 8	3 to 6	N	3 to 7	2 to 5	N
Seal Coats																																	
Fog Seal (See note 1)	F	G	N	N	N	G	G	G	G	F	F	N	N	P	F	G	G	F	13,000	0.15-0.30	0.15-0.30	.15-0.3	+0.05	+0.10	1 to 3	N	N	1 to 2	N	N	1 to 2	N	N
Rejuvenator (See note 1)	G	G	N	N	N	G	G	G	G	G	F	N	N	N	N	G	G	F	15,000	0.20-0.50	0.20-0.50	.20-0.5	+0.10	+0.20	3 to 6	3 to 4	2 to 3	2 to 4	2 to 3	2 to 3	2 to 4	2 to 3	1 to 3
Scrub Seal (See Note 4)	G	G	N	N	N	G	G	G	G	G	F	N	N	G	N	F	G	P	17,000	2.15	2.15	2.15	N/A	N/A	4 to 7	3 to 6	3 to 4	3 to 6	2 to 4	2 to 3	2 to 3	2 to 3	2 to 3
Slurry Seals																																	
Type II (See note 1)	F	G	N	N	N	G	G	G	F	G	G	G	N	N	G	G	G	P	23,000	1.60-2.20	1.75-2.40	.90-2.6	N/A	+0.30	8 to 10	4 to 6	2 to 4	7 to 10	4 to 6	1 to 4	7 to 10	3 to 5	1 to 3
Type III	G	G	N	F	N	G	G	G	F	G	G	G	N	N	G	G	G	P	24,000	1.60-2.20	1.75-2.40	.90-2.6	N/A	+0.30	8 to 10	4 to 6	2 to 4	7 to 10	4 to 6	1 to 4	7 to 10	3 to 5	1 to 3
REAS	G	G	N	F	N	G	G	G	F	G	G	G	N	N	G	G	G	P		1.20-1.80	1.20-1.80	.20-1.8	N/A	+0.30	8 to 10	5 to7	N	7 to 10	5 to 7	N	7 to 9	5 to 7	N
Microsurfacing																																	
Type II	G	G	N	G	F	G	G	G	G	G	G	G	G	N	G	G	G	P	31,000	2.00-2.80	2.10-2.90	.25-3.0	0.10-0.2	N/A	8 to 12	5 to 8	2 to 4	7 to 12	5 to 7	2 to 4	7 to 10	3 to 6	1 to 4
Type III	G	G	N	G	G	G	G	G	G	G	G	G	G	N	G	G	G	P	31,000	2.00-2.80	2.10-2.90	.25-3.0	0.10-0.2	N/A	8 to 12	5 to 8	2 to 4	7 to 12	5 to 7	2 to 4	7 to 10	3 to 6	1 to 4
Chip Seals																																	
PME - Med. Fine (See Note 4)	G	G	N	F	N	G	G	F	F	G	G	N	N	N	P	P	G	P	27,000	1.80-2.00	2.25-2.75	.00-3.5	N/A	+0.50-1.00	8 to 12	5 to 8	2 to 4	7 to 12	5 to 7	2 to 4	7 to 10	3 to 6	1 to 4
PME - Medium (See Note 4)	G	G	N	F	N	G	G	F	F	G	N	N	N	N	P	P	G	F	27,000	1.80-2.00	2.25-2.75	.00-3.5	N/A	+0.50-1.00	8 to 12	5 to 8	2 to 4	7 to 12	5 to 7	2 to 4	7 to 10	3 to 6	1 to 4
PMA - Medium (See Note 3.)	G	G	N	F	N	G	G	G	G	G	G	N	N	G	P	P	G	F	24,000				N/A		8 to 12	6 to 9	4 to 6	7 to 12	5 to 7	4 to 6	7 to 10	4 to 6	3 to 5
PMA - Coarse (See Note 3.)	G	G	N	F	N	G	G	G	G	G	N	N	N	G	P	P	G	G	24,000				N/A		8 to 12	6 to 9	4 to 6	7 to 12	5 to 7	4 to 6	7 to 10	4 to 6	3 to 5
AR - Medium	G	G	N	F	N	G	G	G	G	G	G	N	G	G	P	P	G	F	65,000	3.75-4.55	4.00-4.75	.25-5.0	N/A	+0.50-1.00	8 to 12	6 to 9	4 to 6	7 to 12	5 to 7	4 to 6	7 to 10	4 to 6	3 to 5
AR - Coarse	G	G	N	F	N	G	G	G	G	G	N	N	G	G	P	P	G	G	65,000	3.75-4.55	4.00-4.75	.25-5.0	N/A	+0.50-1.00	8 to 12	6 to 9	4 to 6	7 to 12	5 to 7	4 to 6	7 to 10	4 to 6	3 to 5
Cape Seals																																	
Slurry	G	G	N	F	N	G	G	G	G	G	G	G	N	N	G	G	G	P							9 to 14	7 to 10	5 to 7	8 to 12	6 to 8	5 to 7	8 to 10	5 to 7	4 to 6
Micro	G	G	N	G	F	G	G	G	G	G	G	G	N	N	G	G	G	P							10 to 14	8 to 10	5 to 8	8 to 12	6 to 8	5 to 8	8 to 10	5 to 7	4 to 6
PM Alternative to a Seal Coat > 30,000 ADT																																	
PBA-O	G	G	P	F	N	G	G	G	G	G	G	G	F	F	G	G	G	P	65,000	8-12	8-14	10-16		+1.20-4.00	8 to 14	6 to 12	4 to 7	8 to 12	6 to 10	4 to 5	8 to 10	5 to 7	3 to 5
RAC-O	G	G	P	F	N	G	G	G	G	G	G	G	F	P	G	G	G	P	60,000	10-14	10-14			+1.50-3.50	8 to 14	5 to 12	4 to 7	8 to 12	5 to 10	4 to 5	8 to 10	5 to 9	3 to 5
RAC-O High Binder (HB)	G	G	P	F	N	G	G	G	G	G	G	G	F	P	G	G	G	P	65,000	10-14	10-14			+1.50-3.50	8 to 15	6 to 12	4 to 8	10 to 12	6 to 12	4 to 6	8 to 12	5 to 10	4 to 5
RAC-G	G	G	P	G	F	G	G	G	G	G	G	G	F	F	G	G	G	G	65,000	10-14	10-14			+1.50-3.50	8 to 14	6 to 10	4 to 6	8 to 12	5 to 9	4 to 5	8 to 10	5 to 7	3 to 5
PBA-G	G	G	P	P	N	G	G	G	G	G	G	G	F	F	G	G	G	G	60,000	8-12	8-14	10-16		+1.20-4.00	8 to 14	6 to 12	4 to 7	8 to 12	6 to 10	4 to 5	8 to 10	5 to 7	3 to 5
Thin Bonded Wearing Course (BWC)	G	G	P	F	N	G	G	G	G	G	G	G	F	F	G	G	G	G	85,000	10-14	10-14			+1.50-3.50	8 to 12	5 to 10	4 to 6	8 to 10	5 to 9	4 to 5	8 to 10	5 to 9	3 to 4
Thin Bonded Wearing Course Rubber (BWC-RAC O/G	G	G	P	F	N	G	G	G	G	G	G	G	F	F	G	G	G	G	85,000	10-14	10-14			+1.50-3.50	8 to 12	5 to 10	4 to 6	8 to 10	5 to 9	4 to 5	8 to 10	5 to 9	3 to 4
Maintenance Treatments																																	
Thin Lifts Overlays																																	
Conventional	G	G	P	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	45,000	8-12	8-14	10-16		+1.20-4.00	8 to 12	5 to 10	4 to 6	8 to 10	6 to 9	3 to 6	6 to 8	4 to 6	1 to 3
PBA	G	G	P	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	60,000	8-12	8-14	10-16		+1.20-4.00	8 to 14	6 to 12	4 to 7	8 to 12	6 to 10	4 to 5	8 to 10	5 to 7	3 to 5
RAC	G	G	P	G	F	G	G	G	G	G	G	G	F	F	G	G	G	G	65,000	10-14	10-14			+1.50-3.50	8 to 14	5 to 12	4 to 7	8 to 12	5 to 10	4 to 5	8 to 10	5 to 9	3 to 5
Digouts	P	P	G	N	G	G	G	G	G	G	G	G	G	G	G	G	G	G	125,000														

Estimated Life of Treatments

Treatment	Good Condition (PCI=80)	Fair Condition (PCI=60)	Poor Condition (PCI=40)
Fog Seal	3 - 5	1 - 3	1 - 2
Chip Seal	7 - 10	3 - 5	1 - 3
Slurry Seal	7 - 10	3 - 5	1 - 3
Micro-surfacing	8 - 12	5 - 7	2 - 4
Thin HMA	10 - 12	5 - 7	2 - 4

Maintenance Treatment Guidance

- CALTRANS Maintenance Technical Advisory Guide
- National Center for Pavement Preservation
  - http://www.pavementpreservation.org/fhwa/
  - Pavement Preservation Checklist Series
- California Pavement Preservation Center
  - http://www.ecst.csuchico.edu/__depts/cp2c/index.html

Crack Sealing

- Applied to both AC & PCC surfaced
- Fill & Seal(?) crack to prevent:
  - Intrusion of incompressibles to reduce deterioration of crack
  - Infiltration of water to reduce loss of strength in underlying layers
- Generally low cost

Crack Sealing Applicability

- Applicable to medium severity cracks (maybe low severity) in pavements with low & moderate amounts of cracking and little or no faulting of cracks
- Often applied prior to slurry seals & micro-surfacing as pre-treatment
- Effectiveness a function of selecting right pavement, crack preparation, crack sealing material, environment, and pavement materials

Seal Coats Address

- Weathering & Raveling
- Minor cracking
- Minor surface irregularities
- Skid problems (except fog seals)
- Reduce surface permeability

Fog Seals

- Application of dilute emulsified asphalt cement
- Seals minor micro-cracking
- Generally low cost

Fog Seal Applicability

- Asphalt surfaced pavements in good condition before significant cracking, or weathering and raveling
- Add additional binder to dry chip seal
- Generally lower volume roads
- Some concern about impact on skid resistance
- Effectiveness a function of selecting the right pavement, environment, and pavement materials

Rejuvenating Seals

- Fog seal type application of specialized material – lighter fraction of maltenes
- Supposed to soften top of HMA surface
- Maltene must be compatible with HMA
- Generally low to moderate cost

Rejuvenator Seal Applicability

- Asphalt surfaced pavements in good condition before significant cracking, with minor weathering and raveling
- Generally lower volume roads
- Some concern about impact on skid resistance
- Effectiveness a function of selecting the right pavement, environment, and pavement materials

Slurry Seals

- Application of emulsified asphalt mixed with a graded fine aggregate and special additives
- Reduces permeability of surface
- Reduces rate of weathering, raveling, and crack development
- Increases skid resistance (with appropriate aggregate)
- Generally low to moderate cost

Slurry Seal Applicability

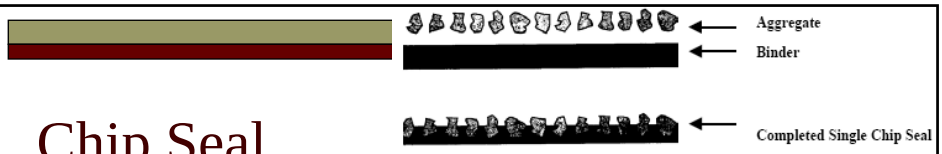
- Asphalt surfaced pavements in good condition before significant cracking but with low severity weathering & raveling
- Generally lower volume roads
- Effectiveness a function of selecting right pavement, mix & application of material, traffic levels, and weather at time of application

Micro-Surfacing

- Application of modified emulsified asphalt mixed with a graded angular wear resistant aggregate, special additives, and break accelerator
- Reduces permeability of surface
- Reduces rate of weathering, raveling, and crack development
- Increases skid resistance and hydroplaning potential
- Can fill stable ruts
- Generally moderate cost

Micro-Surfacing Applicability

- Asphalt surfaced pavements in good condition before significant cracking but with low to medium severity weathering & raveling and moderate to severe rutting
- Generally higher volume roads
- Opened to traffic loadings quickly
- Effectiveness a function of selecting right pavement, mix & application of material, and weather at time of application



Chip Seal

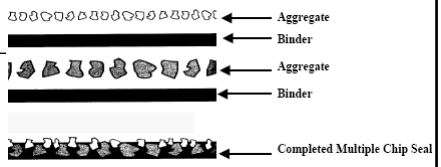
- Application of asphalt binder followed by a one-size aggregate one stone thick
- Reduces permeability of surface
- Reduces rate of weathering, raveling, and crack development
- Can seal minor cracks
- Generally moderate cost

Chip Seal Applicability

- Asphalt surfaced pavements in good condition before significant cracking but with low to medium severity weathering & raveling and rutting
- Can improve skid resistance
- Generally lower volume roads
- Aggregate loss and surface texture are issues
- Effectiveness a function of selecting right pavement, properties & application of material, and traffic at time of application

Other Chip Seals

- Multiple Chip Seal



- Stress Absorbing Membrane (SAM) Seal
  - Normally high application rate of asphalt rubber binder
- Stress Absorbing Membrane Inter-layer (SAMI)
  - Normally like SAM but applied prior to overlay

Other Chip Seal Binders

- Asphalt Emulsion: Polymer-modified emulsions (PME)
- Performance-Based Asphalt (PBA) Cements: Hot applied modified binders
- Asphalt Rubber Binder: Binders modified with high levels of crumbed tire rubber and a high natural rubber content material – applied hot and require hot chips pre-coated with asphalt
- Rejuvenating Emulsion: Emulsions modified with rejuvenating oils (and sometimes polymers) used to penetrate and soften existing asphalt pavements

CALTRANS Maintenance Technical Advisory Guide (MTAG) – Chap 5

Table 2: Binder/Chip Seal Combinations for Addressing Specific Distress Mechanisms

Binder/ Chip Seal Combination	Raveling	Aged Pavements	Bleeding/Flushing	Load Associated Cracks	Water Proofing	Climate Associated Cracks	Heavy Traffic Volumes	Stone Retention	Improve Skid Resistance
PME/Single	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes
PME/Double	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes
PME/Sand	Yes	Yes	No	No	Yes	No	No (light)	Yes	No
PBA/Single	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes
PBA/Double	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PBA/Sand	Yes	Yes	No	No	Yes	No	No	Yes	No
AR/SAM	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Rejuvenating Emulsion	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes

Cape Seals

- Chip seal followed within a few days with a slurry seal
- Gives benefits of both chip seals and slurry seals
- Chip seal may have modified binder

Cape Seal Applicability

- Asphalt surfaced pavements in good to poor condition with some cracking and low to medium severity weathering & raveling
- Where chip seal texture or chip loss are unacceptable but chip seal is right treatment
- Effectiveness a function of selecting right pavement, properties & application of material, and traffic at time of application

Cape Seal Options

- Chip seals with PBA or RA binders
  - Provides more crack sealing capability
  - Can work as flexible surfacing on low volume pavements with considerable cracking if pavement is still stable
- Micro-surfacing instead of slurry
  - When surface needs to be opened quickly
  - Rut filling
  - Skid resistance
  - Longer life

Thin Overlays Address

- Weathering & Raveling
- Minor cracking
- Minor surface irregularities
- Skid problems
- Reduce surface permeability

Thin Overlay

- Thin ~0.1 ft
  - Open graded (OGFC)
    - wet weather skid resistance, reduced hydroplaning, reduced water splash and spray, and reduced night time wet pavement glare
  - Rubberized Hot Mix Asphalt (RHMA)
    - Gap-graded (RHMA-G) - surface course or a non-structural wearing course
    - Open-graded (RHMA-O) - a non-structural wearing course
  - Dense hot mixed asphalt concrete

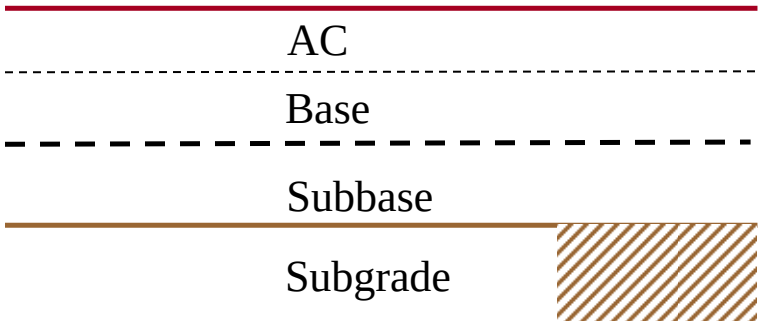
Thin Overlay Applicability

- Asphalt surfaced pavements in good to fair condition with some cracking and low to medium severity weathering & raveling
- Where seal coats are unacceptable
- Higher volume roads
- Effectiveness a function of selecting right pavement, properties & application of material, and environment

Structurally Inadequate

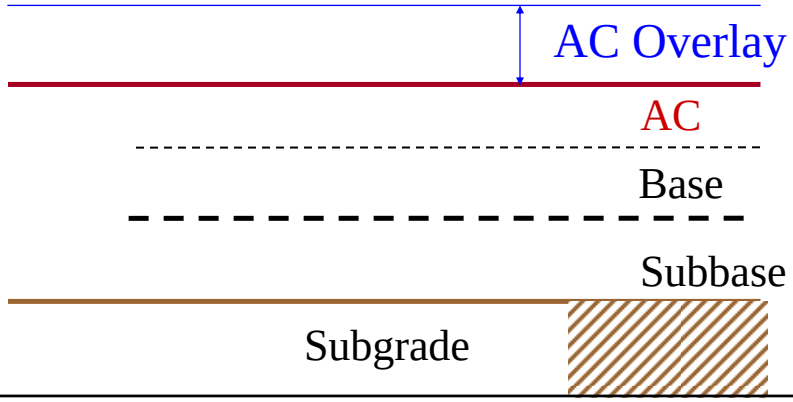
- Overlay or other strengthening approach required
  - More later
- Reconstruction - remove & replace
  - Use new design procedure
- Overlay - add additional surface layer
  - Use overlay design procedure
  - Use in-place material property values for layers left in place

Typical Flexible Pavement Layers



Overlay

Add Layer Above
Existing Pavement Layers



Properties

- Typical characteristics
  - Dense graded HMA
  - Rubberized Hot Mix Asphalt (RHMA)
  - Applied to flexible or rigid surface
  - 0.1 to 0.75 ft (25 to 225 mm) thickness
- Options
  - Mill and Fill
  - Interlayers (SAMI, Fabrics, etc.)

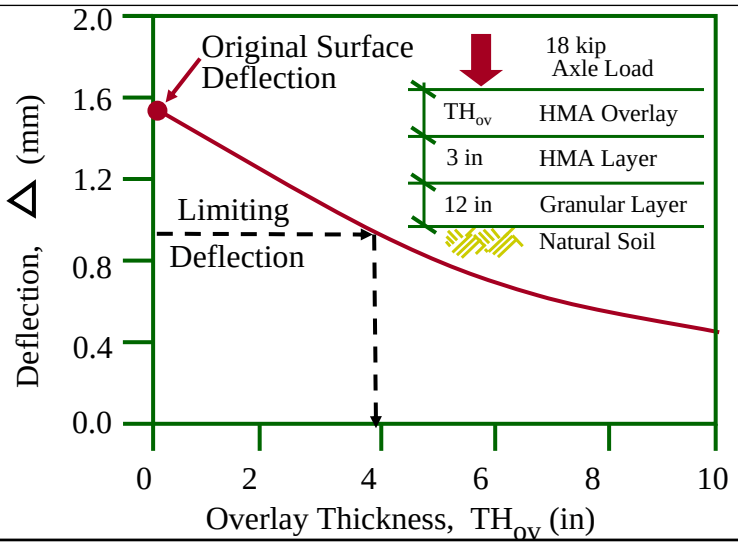
Purpose and Applications

- Improve
  - Structural capacities (structural overlay)
    - and/or
  - Functional characteristics (non-structural overlay)
- Select approach based on pavement conditions at time of overlay

Deflection Approach to Overlay Design

- Determine deflection needed to carry current and future traffic (Limiting Deflection)
- Determine current deflection
- Find added asphalt thickness required to reduce deflection to Limiting Deflection

CALTRANS Deflection Approach



CALTRANS Highway Design Man

- Empirical Method - Sec. 635
- Calculate Traffic Index (TI)
- Determine the Tolerable Deflection at Surface (TDS)
  - Tolerable Deflection" - level beyond which repeated deflections of that magnitude produce fatigue failure prior to design TI

Traffic Index (TI)

$$TI = 9.0 \times \left(\frac{(ESAL \times LDF)}{10^6} \right)^{0.119}$$

- ESAL – Equivalent 18 kip Single Axle Loads
- LDF – Lane Distribution Factor

CALTRANS
Highway Design
Manual Sec. 613

Table 635.1A
Tolerable Deflections at the Surface (TDS) in 0.001 inches

Exist. HMA thick (ft)	Traffic Index (TI)											
	5	6	7	8	9	10	11	12	13	14	15	16
0.00	66	51	41	34	29	25	22	19	17	15	14	13
0.05	61	47	38	31	27	23	20	18	16	14	13	12
0.10	57	44	35	29	25	21	19	16	15	13	12	11
0.15	53	41	33	27	23	20	17	15	14	12	11	10
0.20	49	38	31	25	21	18	16	14	13	12	10	10
0.25	46	35	28	24	20	17	15	13	12	11	10	9
0.30	43	33	27	22	19	16	14	12	11	10	9	8
0.35	40	31	25	20	17	15	13	12	10	9	8	8
0.40	37	29	23	19	16	14	12	11	10	9	8	7
0.45	35	27	21	18	15	13	11	10	9	8	7	7
0.50 (1)	32	25	20	17	14	12	11	9	8	8	7	6
TB (2)	27	21	17	14	12	10	9	8	7	6	6	5
	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5
0.00	58	45	37	31	27	23	20	18	16	15	13	12
0.05	53	42	34	29	25	21	19	17	15	14	12	11
0.10	50	39	32	27	23	20	18	16	14	13	11	11
0.15	46	36	30	25	21	19	16	14	13	12	11	10
0.20	43	34	28	23	20	17	15	14	12	11	10	9
0.25	40	32	26	22	19	16	14	13	11	10	9	8
0.30	37	29	24	20	17	15	13	12	11	9	9	8
0.35	35	27	22	19	16	14	12	11	10	9	8	7
0.40	32	26	21	18	15	13	11	10	9	8	8	7
0.45	30	24	20	16	14	12	11	9	9	8	7	6
0.50 (1)	28	22	18	15	13	11	10	9	8	7	7	6
TB (2)	24	19	15	13	11	10	8	7	7	6	5	5

Notes:

(1) For an HMA thickness greater than 0.50 ft use the 0.50 ft depth.

(2) Use the TB (treated base) line to represent treated base materials, regardless of the thickness of HMA cover.

CALTRANS Highway Design Manual Sec. 635

Deflections in Pavement Section

- Measure deflections
  - FWD or Vibratory
- Convert to California Deflectometer Equiv
  - D(CD)=1.2×D(FWDref) – in mils
- Calculate mean & standard deviation of deflections taken in pavement section
- Calculate 80th percentile deflection (D_{80})
- See CALTRANS Test Method 356

Is Section Structurally Adequate?

- If $D_{80} \leq$ TDS
  - Section structurally adequate, no overlay needed
  - Preservation treatment applied
- If $D_{80} >$ TDS
  - Section structurally inadequate, overlay needed
  - Design thickness to meet needs of future traffic
  - Use in-place material properties for existing pavement layers

Thickness of Overlay Needed

- If $D_{80} >$ TDS

$$PRD = \frac{\text{Avg } D_{80} - \text{TDS}}{\text{Avg } D_{80}} (100)$$

- PRD = Percent Reduction in Deflection
  - Table 635.1D

Table 635.1B

Gravel Equivalence Needed for Deflection Reduction

Percent Reduction In Deflection (PRD or PRM) [1]	GE (in feet) For HMA Overlay Design	Percent Reduction In Deflection (PRD or PRM) [1]	GE (in feet) For HMA Overlay Design
5	0.02	46	0.55
6	0.02	47	0.57
7	0.02	48	0.59
8	0.02	49	0.61
9	0.03	50	0.63
10	0.03	51	0.66
11	0.04	52	0.68
12	0.05	53	0.70
13	0.05	54	0.72
14	0.06	55	0.74
15	0.07	56	0.76
16	0.08	57	0.79
17	0.09	58	0.81
18	0.09	59	0.83
19	0.10	60	0.85
20	0.11	61	0.87
21	0.12	62	0.89
22	0.14	63	0.91
23	0.15	64	0.94
24	0.16	65	0.96
25	0.18	66	0.98
26	0.19	67	1.00
27	0.20	68	1.02
28	0.21	69	1.04
29	0.23	70	1.06
30	0.24	71	1.09
31	0.26	72	1.11
32	0.28	73	1.13
33	0.29	74	1.15
34	0.31	75	1.17
35	0.33	76	1.19
36	0.35	77	1.22
37	0.37	78	1.24
38	0.38	79	1.26
39	0.40	80	1.28
40	0.42	81	1.30
41	0.44	82	1.32
42	0.46	83	1.34
43	0.48	84	1.37
44	0.51	85	1.39
45	0.53	86	1.41

Note: (1) PRD is Percent Reduction in Deflection at the surface.
PRM is Percent Reduction in deflection at the Milled depth.

Table 635.1C

Commonly Used G_f for Asphaltic Materials for Flexible Pavement Rehabilitation

Material	G_f [1]
Hot Mix Asphalt Overlay	1.9
Hot Recycled Asphalt	1.9
Cold in-Place Recycled Asphalt	1.5
HMA Below the Analytical Depth [2]	1.4

Notes:

(1) For G_f of bases and subbases see Table 663.1B.

(2) Analytical depth is defined in 635.1(6)(a).

$$\text{Thickness (t)} = \frac{GE}{G_f}$$

CALTRANS Highway Design Manual Sec. 635

Reflective Crack Analysis

- Prevent cracks in existing pavement from reflecting thru overlay
- ½ thickness of existing flexible pvmt thickness up to 0.35 foot
- Adjust for:
  - Other life, PCC, other materials

Table 635.1D
Reflective Crack Retardation Equivalencies (Thickness in ft)

HMA [1]	RHMA-G	RHMA-G over SAMI-R
0.15	0.10	
0.20	0.10	
0.25	0.15	
0.30	0.15	
0.35	• 0.15 if crack width < 1/8 inch • 0.20 if crack width ≥ 1/8 inch or underlying material CTB, LCB, or rigid pavement	• N/A for crack width < 1/8 inch • 0.10 if crack width ≥ 1/8 inch and underlying material untreated • 0.15 if crack width ≥ 1/8 inch and underlying material CTB, LCB, or rigid pavement
0.45	0.15 over 0.15 HMA	0.20

Note:

(1) See Index 635.1(5)(b) for minimum and maximum HMA thicknesses recommended by the Department for reflection crack retardation on flexible pavements.

CALTRANS Highway Design Manual Sec. 635

Overlay Thickness Design Methods

- Other methods used
  - Engineering judgment
  - Structural deficiency
  - Deflection approach
  - Mechanistic-empirical approach

Structural Overlay Design Concept

- Add more surface layer thickness to increase structural capacity to handle past experienced and future expected traffic loadings

- $T_{ol} = T_{req} - T_{cur}$
  - T_{ol} = Overlay Thickness
  - T_{req} = Thickness for all traffic (past and future)
  - T_{cur} = Thickness existing (effective)

Overlays

- Most popular rehabilitation method
- Relatively fast and cost-effective means for:
  - Correcting deficiencies
  - Restoring user satisfaction
  - Adding structural capacity
- Poor performance is NOT uncommon

Why Many Overlays Fail Prematurely

- Improper treatment selection
  - Wrong type of overlay
  - Insufficient pre-overlay repair
  - Lack of consideration of reflection cracking
  - Inadequate knowledge of structural capacity of existing pavement
  - Other rehab method needed
- Inadequate design

Ways to Improve Effectiveness

- Pre-overlay testing (in-place conditions and properties)
- Better materials and practices
- Pre-overlay treatments (repairs)
- Sound engineering judgment

Pre-overlay Treatment and Repair

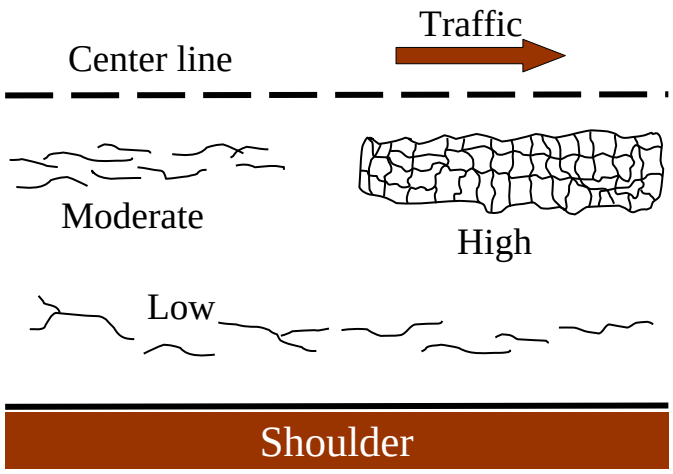
- Dependent upon:
  - Type of overlay
  - Structural adequacy of existing pavement
  - Existing types of distress
  - Future traffic
  - Physical constraints
  - Cost

To Repair or Not to Repair

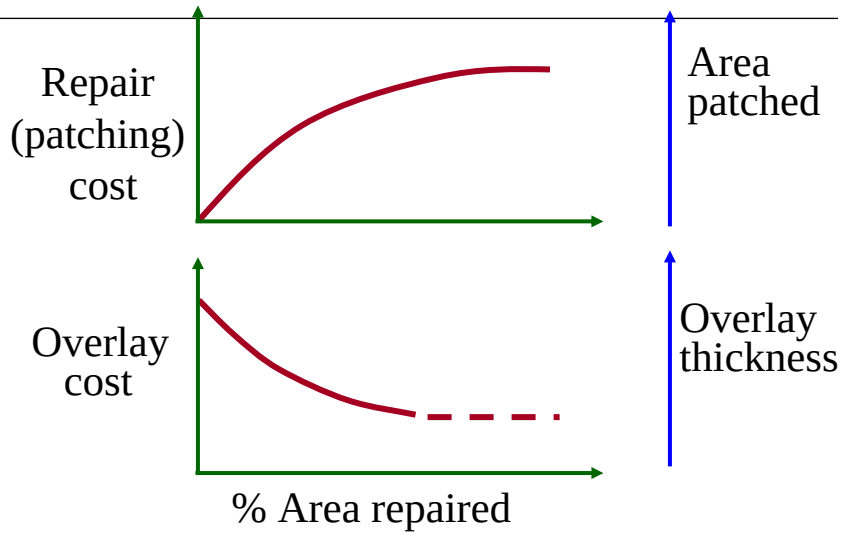
Types of Pre-overlay Treatments

- Localized repair
  - Patching
- Surface leveling
  - Milling
  - Leveling course
- Reflection cracking control
- Drainage improvements

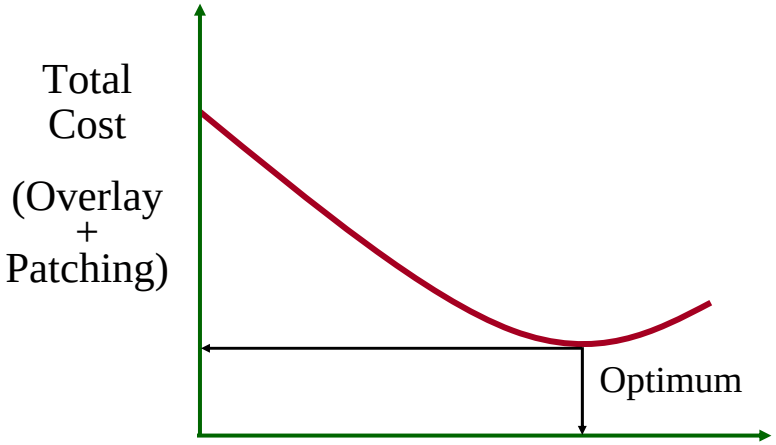
Which to Repair?



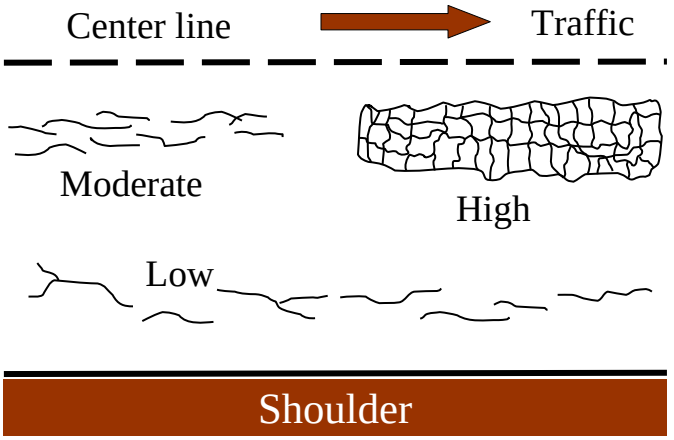
Localized Repair (Patching)



Localized Repair & Overlay



Repair Different Quantities of Fatigue Cracking



More repairs result in lower deflections for the section and resulting thinner overlay

Overlay Thickness & Costs with Pre-Overlay Patching

[redacted]

[redacted]

Patching Specifics

- CALTRANS Maintenance Technical Advisory Guide
  - CHAPTER 4: Patching

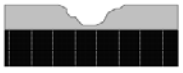


Figure 7: Dewatered and Cleaned Pothole (4)

Figure 8: Surface and Base of Pothole Prepared for Treatment (4)

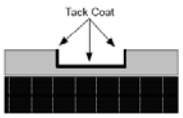


Figure 9: Tack Coat Applied to All Sides of Hole (4)

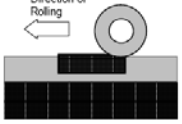


Figure 10: Patch Material Placed and Compaction in Progress (4)

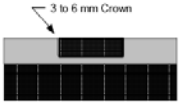


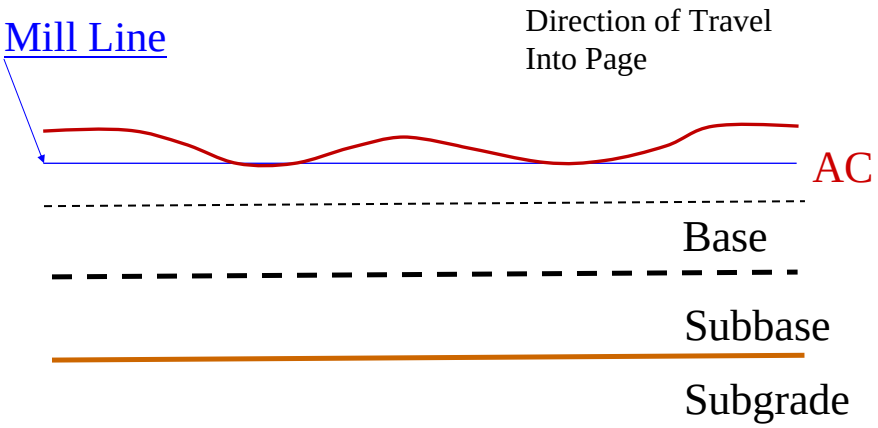
Figure 11: Finished Patch with a 3 to 6 mm Crown (4)

Surface Leveling

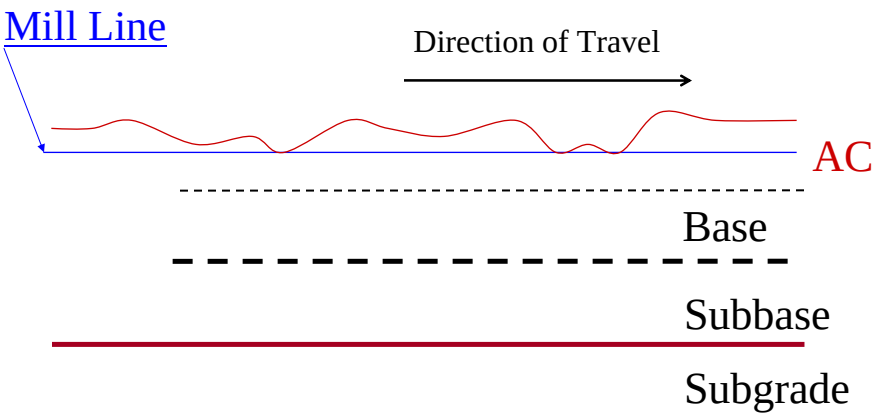
- Provide smooth surface for subsequent overlay
- Cold milling
  - Remove surface irregularities
- Leveling course
  - Fill ruts & reduce transverse surface irregularities
- Leveling course to improve longitudinal profile

Cold Milling

Cold Milling to Remove Rutting

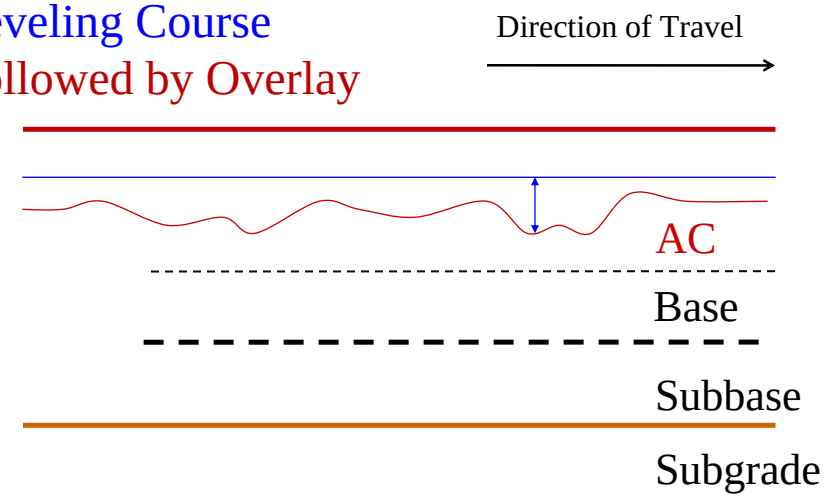


Cold Milling to Level



Leveling Course

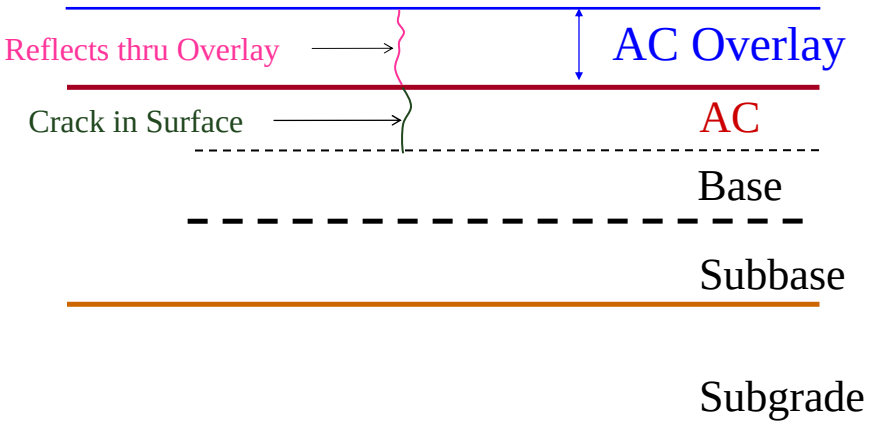
Leveling Course
Followed by Overlay



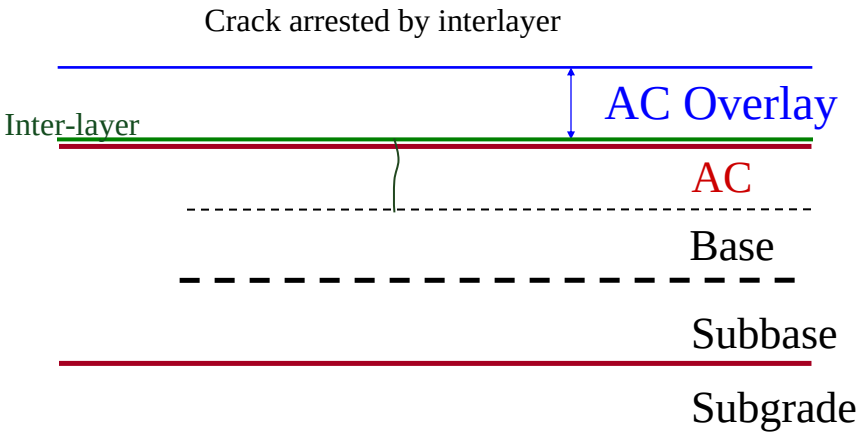
Controlling Reflection Cracking

- Increase thickness
  - CALTRANS - ½ thickness of existing flexible pvmt thickness
- Modified asphalts
- Geotextiles or fabrics
- Stress relieving or stress absorbing membrane interlayers (SAMI's)
- "Band aid" type crack sealants

Reflective Crack in Overlay

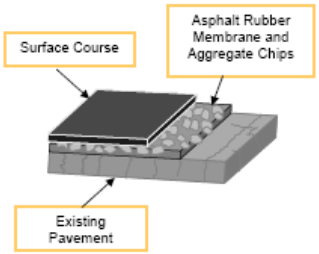


Overlay with Interlayer



Stress Absorbing Membrane Interlayer (SAMI)

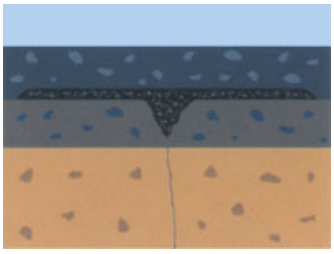
- Full area treatment
- Rubber modified asphalt to provide more flexibility
- Arrest crack prior to contact with overlay



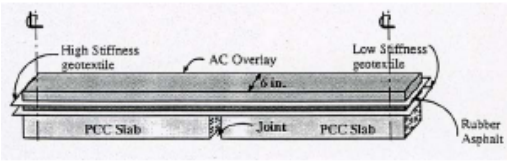
Fabric Interlayers

Band-aid Strip Treatments

- Each crack treated
- Most often used with reflection cracks in existing AC overlays over jointed PCC pavements



Composite Strip Treatment



Other Rehabilitation

- Reconstruction
  - Remove & replace
  - Surface or full depth
- Hot in-place recycling
  - Top of asphalt surface – often with thin overlay
- Cold in-place recycling
  - Asphalt surface – generally with overlay
- Full depth reclamation
  - Asphalt surface and base/subbase – with overlay

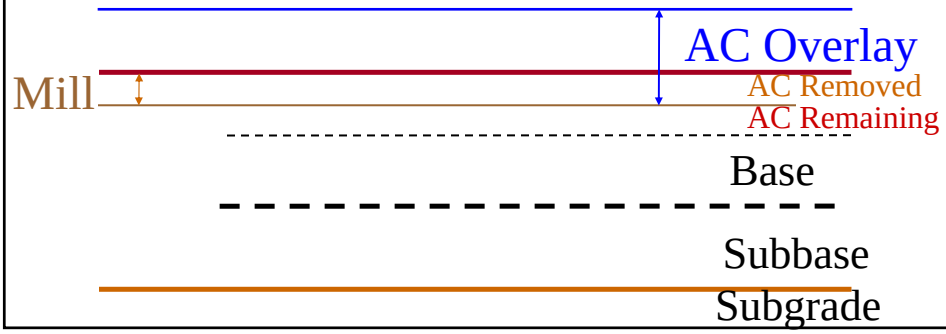
Pavement Rehabilitation Design

- Overlays – Use overlay design
- Others - Keep part of existing pavement layers & replace part of pavement layers
  - All bound layers replaced
    - Use new design procedure
  - Some bound layers remain
    - Use overlay design procedure
  - Use in-place material property values for all materials that remain in place

Overlay with Mill

Surface Preparation Often Includes Removing Some Thickness by Cold Milling

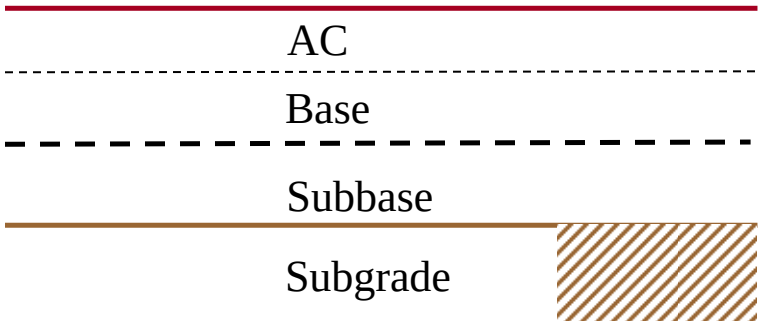
The Overlay is Placed on the Milled Surface



Remove & Replace

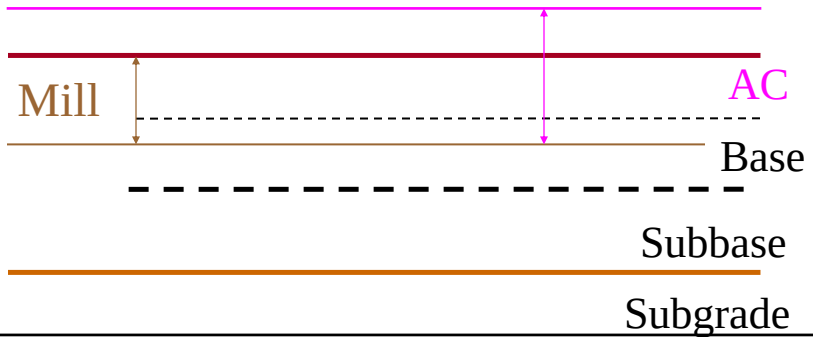
- Not possible to maintain existing profile grade using overlay (with mill?)
- Existing base and/or subbase material is failing and needs to be replaced
- Most cost effective strategy based on life cycle cost analysis

New Design with Remove & Replace



New Design when All AC Removed

If AC Thickness Removed by Cold Milling
Use New Design to Determine Thickness



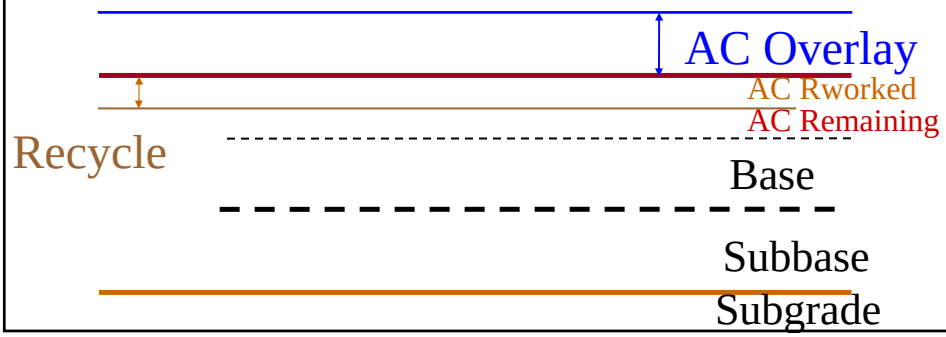
Hot in-place Recycling

- Surface cracked/raveled
  - Can be used if reworked instead of being removed and replaced
- Overlay placed to handle required structural increases
- Most cost effective strategy based on life cycle cost analysis

Hot In-Place Recycling with Overlay

A portion of surface can be reworked with hot in-place recycling

Overlay often Placed on the recycled surface



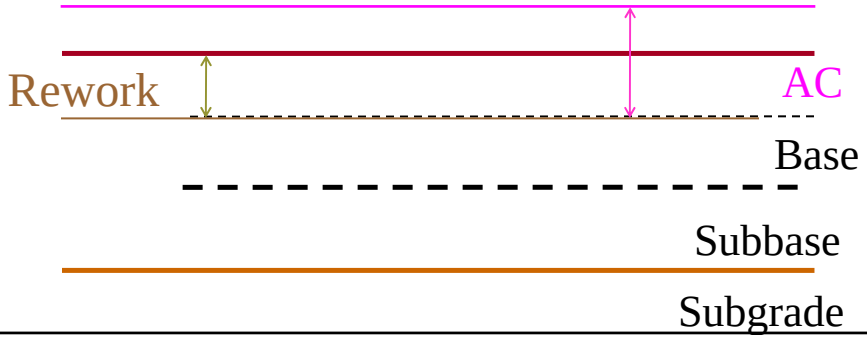
Cold in-place Recycling

- Equivalent to remove and replace existing surface
- Surface reworked in-place or in job-site pub mill
- Overlay placed to handle required structural increases
- Most cost effective strategy based on life cycle cost analysis

New Design when All AC Reworked

Cold In-place Recycling

If AC Thickness Reworked by Recycling
Use New Design to Determine Thickness



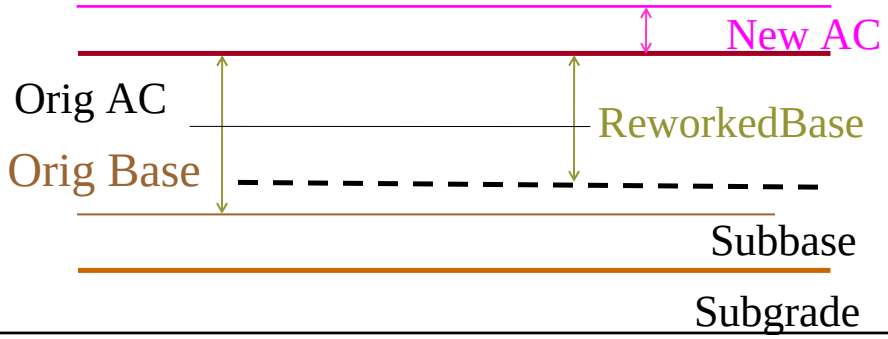
Full Depth Reclamation

- Equivalent to remove and replace
- Surface & base/subbase reworked in-place or in job-site pub mill
- Overlay placed to handle required structural increases
- Most cost effective strategy based on life cycle cost analysis

New Design when All AC Reworked

Full Depth Reclamation

If AC Thickness Reworked by Recycling
Use New Design to Determine Thickness



Select Best Treatments

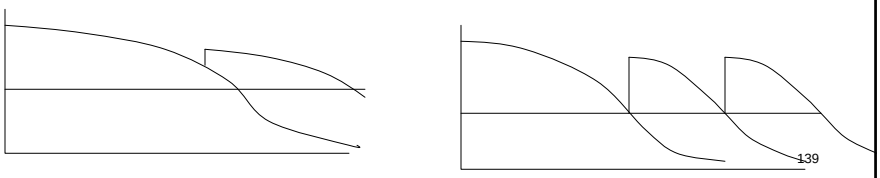
- Which treatment is best?
  - One that provides desired performance
  - Often several are appropriate
- Which provides desired performance for least cost?
  - Life cycle cost analysis

Pavement Life Cycle Cost Analysis

- Pavement LCCA is an economic evaluation technique to determine total cost of owning and operating a facility over some period of time (life)
- Purpose of LCCA:
  - Estimate overall costs of pavement alternatives and
  - Select alternative that ensures pavement will provide lowest overall cost over life (analysis period) consistent with required performance
- LCCA is a Decision Support Tool

Questions Addressed

- Select from several alternative approaches
- Build strong and preserve with preventive maintenance or design for short period and rebuild frequently



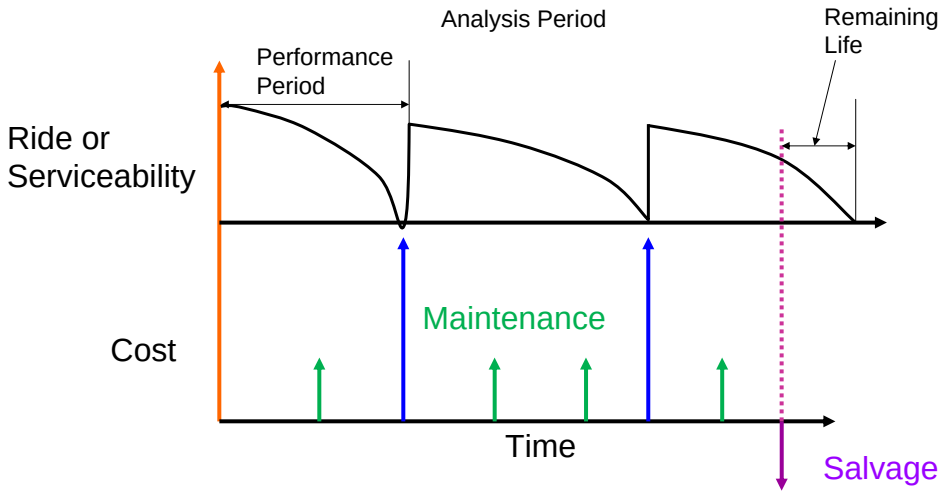
Typical Costs

- Design & engineer
- Initial construction
- Maintenance over life
- Periodic rehabilitation
- User costs

User Costs

- It costs the user x dollars to drive one mile on a pavement
- If the condition is poor, those costs will increase
- If the vehicles is delayed, those costs will increase
- FHWA has guidance in their program

Performance & Costs

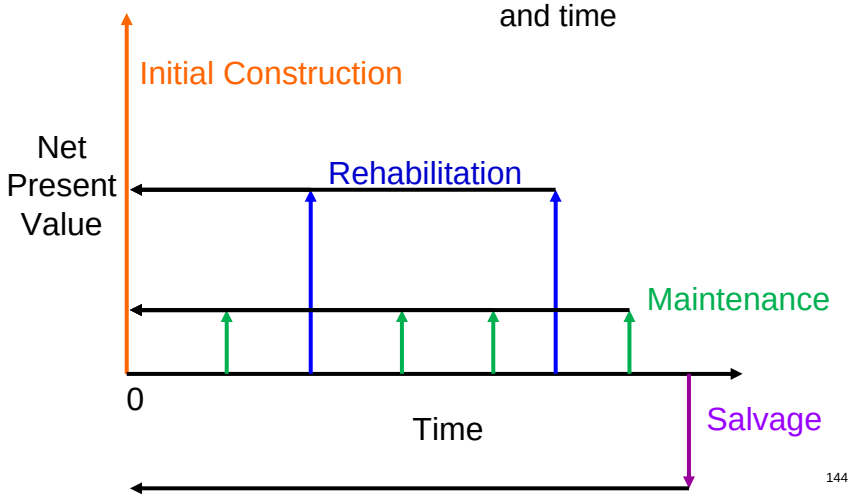


Most of Agency Cost is in:

- Initial Construction
  - 70 to 90%
- Rehabilitation
  - 10 to 25%
- Reactive Maintenance - Almost no effect
- Salvage Value - Very little effect

Net Present Value

The cost of all activities are computed at time = 0 accounting for discount rate and time



Economic Fundamentals
Discount or Interest Rate

- "Opportunity Cost" of alternative funding strategies
  - Funds are limited
  - If we spend them for one alternative, they are not available for another
- Equivalent to an investment analysis
  - What would you get for one investment strategy versus another
- Discount or Interest Rate is an annual percentage factor measuring the time value of money
  - Interest rate - $'s received if funds invested
  - Discount rate – similar but may be adjusted to reflect value to public agency

Present Value

- Value of future cost or investment in current dollars
- Also known as "Single Payment Present Worth"

$$PV = F_n \cdot [\frac{1}{(1+i)^n}]$$

$PV =$ Present Value at time zero (base yr)

$i =$ Discount Rate (Annual)

$t =$ time, yr

$F_n =$ Amount (cost) in yr n

Net Present Value

Number of Recurring Costs

$$NPV = I.C. + \sum_{k=1}^{N} R.C._k \left[\frac{1}{(1+i)^{n_k}} \right]$$

Initial Cost

Recurring Maint & Rehab Costs

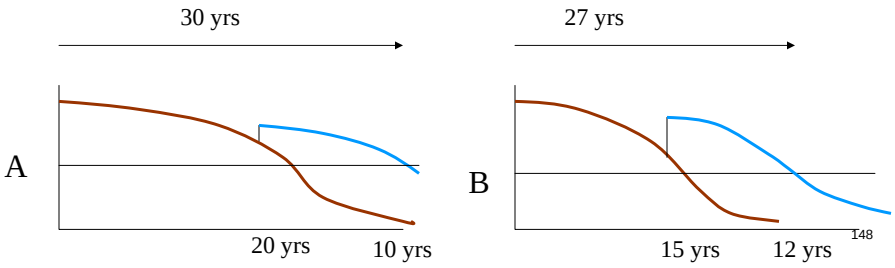
Discount (interest) Rate

Number of Years

Life Cycle Cost Analysis

Unequal Total Lifes

- NPV Considering Salvage value
- Equivalent Uniform Annual Cost



Equivalent Uniform Annual Cost

- Equivalent Uniform Annual Cost (EUAC):
  - Annualized present value
  - Cost of annual payments to pay off money borrowed now
- Also known as Capital Recovery Factor
- Must know net present value of total stream (NPV)

$$EUAC = NPV\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$

Analysis Period

- New pavement design
  - At least through the life of the first major rehabilitation treatment after initial performance period
- Rehabilitation
  - At least through the life of the subsequent major rehabilitation treatment after initial performance period

Life Information

- Agency records
- Typically in pavement management system data

Discount/Interest Rate

- Agency recommended value
- Typically from finance office
- Check before you select one

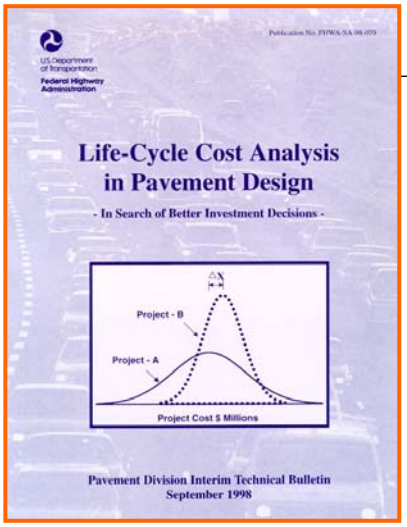
Basic Formulas

- Present Value:

$$P = F\left(1+i\right)^{-n} = F/(1+i)^{n}$$

- Equivalent Uniform Annual Cost:

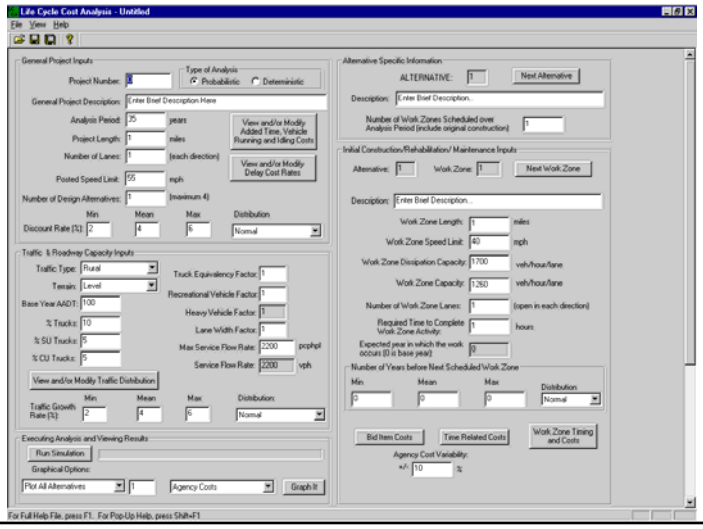
$$A = P\frac{i\left(1+i\right)^{n}}{\left(1+i\right)^{n}-1}$$



http://restructure.fhwa.dot.gov/dp115/

Good Reference!!

FHWA Has Software Available



CALTRANS

- Project Procedures Development Procedures Manual
- Appendix OO – Pavement Life Cycle Cost

FHWA

RealCost LCCA Software
http://www.fhwa.dot.gov/infrastructure/asstmgmt/rc21toc.cfm

Project-Level

- Develop Cost-effective Strategy for:
  - Original Construction
  - Maintenance (PM & Preservation)
  - Rehabilitation
  - Reconstruction
- Within Imposed Constraints
- Complete Design

Input from Project Selection-level

Project-Selection-Level

- Identify Constraints not Previously Considered
  - Physical
  - Financial
- Refine Alternative Treatments
- Improve Cost Estimates
- Select Segments for Funding & Project-Level Analysis, Design & Construction
- Show Impact of Deviation from Network-Level

Input from Network-level

Network-Level

- Related to the Budget Process
  - Identify Maintenance and Rehabilitation Needs
  - Funds Needed to Complete M&R
  - Prioritized Listings of Segments Needing Work
- Show Impact of Funding Options
  - Preservation vs New Construction
  - Funding shortfalls
- Communicate Within Agency

Input from Strategic-level

Using These Concepts with StreetSaver

- Network & Project-Selection
- Next topic
- Margot Yapp - NCE

Questions

?