

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION	1-1
1.1 PURPOSE OF PAVEMENT PRESERVATION	1-1
1.1.1 Definition.....	1-1
1.1.2 Pavement Preservation Concept	1-1
1.1.3 Benefits of Pavement Preservation.....	1-2
1.1.4 Treatment Selection and the Optimum Timing for the Treatment.....	1-2
1.2 PCC PAVEMENT DESIGN AND PERFORMANCE IN CALIFORNIA	1-3
1.2.1 Design and Performance.....	1-3
1.2.2 Causes of Rigid Pavement Deterioration	1-5
1.2.3 Faulting Mechanism and Effort on Addressing Faulting.....	1-5
1.3 COMMON PCC PAVEMENT DISTRESS TYPES.....	1-6
1.3.1 Joint Deficiencies and Cracking	1-7
1.3.2 Surface Defects.....	1-11
1.3.3 Other Miscellaneous Distresses	1-12
1.3.4 Summary.....	1-15
1.4 MATERIALS CONSIDERATIONS	1-17
1.4.1 Concrete Constituent Materials	1-18
1.4.2 Cementitious Repair Materials.....	1-20
1.4.3 Specialty Repair Materials	1-20
1.4.4 Bituminous Materials	1-20
1.4.5 Joint Sealants.....	1-20
1.4.6 Dowel Bars and Tie Bars	1-21
1.5 DESIGN CONSIDERATIONS	1-21
1.5.1 Traffic	1-21
1.5.2 Environment	1-21
1.5.3 Windows of Opportunities	1-22
1.5.4 Traffic Control.....	1-23
1.5.5 Item Codes.....	1-23
1.6 KEY REFERENCES	1-23
CHAPTER 2 SURFACE CHARACTERISTICS	2-1
2.1 IMPORTANT SURFACE CHARACTERISTICS	2-1
2.2 RIDE QUALITY.....	2-1
2.2.1 Definitions	2-2
2.2.2 Measuring Smoothness.....	2-2
2.3 TEXTURE	2-7
2.3.1 Definitions of Surface Texture.....	2-8

2.3.2 Techniques to Create Texture.....	2-10
2.3.3 Measurement of Surface Texture.....	2-12
2.3.4 Summary.....	2-15
2.4 SURFACE FRICTION.....	2-15
2.4.1 Background.....	2-15
2.4.2 Factors that Affect Pavement Friction.....	2-16
2.4.3 Measurement of Pavement Friction.....	2-18
2.4.4 Current Surface Friction Criteria and Measurement Practices.....	2-24
2.4.5 Summary.....	2-25
2.5 NOISE.....	2-26
2.6 ACHIEVING DESIRED SURFACE CHARACTERISTICS.....	2-26
2.6.1 Ride.....	2-26
2.6.2 Texture and Friction.....	2-27
2.6.3 Noise.....	2-27
2.7 KEY REFERENCES.....	2-27
CHAPTER 3 FRAMEWORK FOR TREATMENT SELECTION.....	3-1
3.1 FACTORS TO CONSIDER.....	3-1
3.1.1 Ride.....	3-1
3.1.2 Skid.....	3-1
3.1.3 Noise.....	3-1
3.1.4 Distress Type.....	3-2
3.1.5 Durability/Longevity.....	3-2
3.2 SELECTION PROCESS.....	3-2
3.3 ASSESS THE EXISTING PAVEMENT CONDITIONS.....	3-2
3.3.1 Project Information Review.....	3-3
3.3.2 Field Distress Survey.....	3-4
3.3.3 Field Sampling and Testing of Existing Pavement.....	3-4
3.3.4 Performance Requirements.....	3-5
3.4 DETERMINE THE FEASIBLE TREATMENT OPTIONS.....	3-6
3.5 COMPARE THE FEASIBLE OPTIONS.....	3-9
3.5.1 Life Cycle Costing.....	3-9
3.5.2 Compare and Select Options.....	3-10
3.6 KEY REFERENCES.....	3-11
CHAPTER 4 JOINT RESEALING AND CRACK SEALING.....	4-1
4.1 PURPOSE AND DESCRIPTION OF TREATMENT.....	4-1
4.2 MATERIALS AND SPECIFICATIONS.....	4-2

4.2.1 Sealant Properties	4-2
4.2.2 Sealant Types and Specifications	4-3
4.3 PROJECT SELECTION	4-5
4.4 DESIGN CONSIDERATIONS	4-5
4.4.1 Material Selection	4-5
4.4.2 Joint Resealing	4-6
4.4.3 Filling	4-7
4.4.4 Special Considerations.....	4-7
4.4.5 Reservoir Design for Joint Resealing.....	4-8
4.4.6 Special Considerations for Cracks.....	4-11
4.4.7 Typical Item Codes	4-12
4.5 CONSTRUCTION PROCESS	4-12
4.5.1 Traffic Control and Safety.....	4-13
4.5.2 Equipment.....	4-13
4.5.3 Remove Old Sealant	4-14
4.5.4 Shape Reservoir / Reface Joint.....	4-14
4.5.5 Clean Joint Reservoir.....	4-14
4.5.6 Install Backer Rod.....	4-15
4.5.7 Install Sealant.....	4-15
4.5.8 Crack Sealing	4-17
4.5.9 Trafficking	4-17
4.5.10 Quality.....	4-18
4.6 SUMMARY	4-20
4.7 PROJECT CHECKLIST AND TROUBLESHOOTING GUIDE	4-20
4.7.1 Project Checklist	4-20
4.7.2 Troubleshooting Guide.....	4-23
4.8 KEY REFERENCES	4-25
CHAPTER 5 DIAMOND GRINDING AND GROOVING	5-1
5.1 DESCRIPTION OF TREATMENT	5-1
5.1.1 Overview.....	5-1
5.1.2 Purpose.....	5-2
5.1.3 Advantages	5-3
5.1.4 Limitations.....	5-4
5.2 DESIGN AND SPECIFICATION.....	5-4
5.2.1 Terminology.....	5-4
5.2.2 Design Parameters	5-5
5.2.3 Specifications.....	5-5

5.2.4 Typical Item Codes	5-6
5.3 PROJECT SELECTION	5-7
5.3.1 Applications	5-7
5.3.2 Project Evaluation	5-9
5.3.3 Expected Lives of Treatments	5-11
5.4 CONSTRUCTION PROCESS	5-12
5.4.1 Traffic Control and Safety	5-12
5.4.2 Equipment	5-13
5.4.3 Productivity	5-17
5.4.4 Slurry Removal	5-17
5.4.5 Sequencing Work	5-17
5.4.6 Job Review - Quality Issues	5-18
5.5 PROJECT CHECKLIST AND TROUBLESHOOTING GUIDE	5-19
5.5.1 Project Checklist	5-19
5.5.2 Troubleshooting Guide	5-21
5.6 KEY REFERENCES	5-23
CHAPTER 6 DOWEL BAR RETROFIT	6-1
6.1 BACKGROUND.....	6-1
6.1.1 Load Transfer Efficiency	6-1
6.1.2 Measuring Load Transfer Efficiency	6-2
6.2 PURPOSE AND DESCRIPTION OF TREATMENT	6-2
6.3 PROJECT SELECTION	6-3
6.3.1 Factors to Consider	6-3
6.3.2 Expected Performance	6-4
6.4 DESIGN AND MATERIAL CONSIDERATIONS.....	6-5
6.4.1 Load Transfer Devices	6-5
6.4.2 Dowel Bar Specification	6-5
6.4.3 Dowel Bar Layout.....	6-7
6.4.4 Backfill Material.....	6-8
6.4.5 Design of Slot-Dowel-Chair System	6-9
6.4.6 Typical Item Codes	6-10
6.5 CONSTRUCTION PROCESS	6-11
6.5.1 Traffic Control and Safety	6-11
6.5.2 Dowel Bar Retrofit Process	6-11
6.5.3 Cutting Sides of Slot	6-12
6.5.4 Remove Concrete from Slot	6-14
6.5.5 Seal Joint or Crack.....	6-15

6.5.6 Placing Dowel Bars.....	6-16
6.5.7 Backfilling.....	6-17
6.5.8 Opening to Traffic	6-19
6.5.9 Diamond Grinding.....	6-19
6.5.10 Joint Sealing	6-19
6.5.11 Job Review-Quality Control.....	6-19
6.6 PROJECT CHECKLIST AND TROUBLESHOOTING GUIDE	6-22
6.6.1 Factors to Consider.....	6-22
6.6.2 Project Checklist	6-22
6.6.3 Troubleshooting Guide.....	6-25
6.7 KEY REFERENCES	6-27
CHAPTER 7 ISOLATED PARTIAL DEPTH CONCRETE REPAIR.....	7-1
7.1 PURPOSE AND DESCRIPTION OF TREATMENT	7-1
7.1.1 Partial Depth Repair	7-1
7.2 MATERIALS AND SPECIFICATIONS.....	7-1
7.2.1 Materials Selection.....	7-2
7.2.2 Cementitious Materials	7-2
7.2.3 Specialty Materials.....	7-4
7.2.4 Bituminous Materials	7-5
7.2.5 Bonding Agents.....	7-5
7.3 ENGINEERING CONSIDERATIONS.....	7-6
7.3.1 Project Selection.....	7-6
7.3.2 Concurrent Work.....	7-6
7.3.3 Repair Locations and Boundaries.....	7-6
7.3.4 Typical Item Codes	7-7
7.4 CONSTRUCTION PROCESS	7-8
7.4.1 Traffic Control and Safety	7-8
7.4.2 Equipment.....	7-8
7.4.3 Repair Locations	7-8
7.4.4 Concrete Sawing and Removal.....	7-9
7.4.5 Cleaning and Repair Area Preparation	7-11
7.4.6 Joint Preparation.....	7-12
7.4.7 Materials Placement.....	7-13
7.4.8 Finishing.....	7-13
7.4.9 Curing.....	7-13
7.4.10 Joint Sealing	7-14
7.4.11 Opening to Traffic	7-14

7.4.12 Job Review-Quality Issues.....	7-14
7.5 PROJECT CHECKLIST AND TROUBLESHOOTING GUIDE	7-15
7.5.1 Project Checklist	7-15
7.5.2 Troubleshooting Guides	7-18
7.6 KEY REFERENCES	7-18
CHAPTER 8 FULL DEPTH CONCRETE REPAIR	8-1
8.1 PURPOSE AND DESCRIPTION OF TREATMENT	8-1
8.1.1 Full Depth Repair.....	8-1
8.2 MATERIALS AND SPECIFICATIONS.....	8-1
8.2.1 Materials Selection.....	8-1
8.2.2 Cementitious Materials	8-2
8.2.3 Bituminous Materials	8-3
8.3 ENGINEERING CONSIDERATIONS.....	8-3
8.3.1 Project Selection.....	8-3
8.3.2 Concurrent Work.....	8-4
8.3.3 Repair Locations and Boundaries	8-4
8.3.4 Load Transfer Devices	8-5
8.3.5 Typical Item Codes	8-6
8.4 CONSTRUCTION PROCESS	8-7
8.4.1 Traffic Control and Safety	8-7
8.4.2 Equipment.....	8-7
8.4.3 Repair Locations	8-7
8.4.4 Concrete Sawing and Removal.....	8-8
8.4.5 Cleaning and Repair Area Preparation	8-9
8.4.6 Provision of Load Transfer	8-10
8.4.7 Joint Preparation.....	8-11
8.4.8 Bond Breaker.....	8-12
8.4.9 Materials Placement.....	8-12
8.4.10 Finishing.....	8-12
8.4.11 Curing.....	8-13
8.4.12 Joint Sealing	8-13
8.4.13 Opening to Traffic	8-13
8.4.14 Job Review-Quality Issues.....	8-14
8.5 PROJECT CHECKLIST AND TROUBLESHOOTING GUIDE	8-14
8.5.1 Project Checklist	8-14
8.5.2 Troubleshooting Guides	8-17
8.6 KEY REFERENCES	8-19

APPENDIX A – PAVEMENT PRESERVATION DEFINITIONS

APPENDIX B – GLOSSARY OF TERMS

APPENDIX C – LIST OF ACRONYMS

APPENDIX D – USEFUL WEBSITES

**APPENDIX E – CALTRANS SURFACE TREATMENT REVIEW
CHECKLIST AND EVALUATION**

LIST OF FIGURES

Figure 1-1 Typical pavement performance curve and maintenance/rehabilitation time	1-2
Figure 1-2 Concept of optimal timing for pavement preservation (Galehouse et al, 2003)	1-3
Figure 1-3 Slab drop-off caused by base erosion (Stahl, 2006)	1-6
Figure 1-4 Spalling at the joint (Caltrans, 2004a)	1-7
Figure 1-5 Faulting (FHWA, 2003)	1-8
Figure 1-6 Example of joint seal damage (FHWA, 2003)	1-8
Figure 1-7 Examples of longitudinal joint crack (FHWA, 2003).....	1-9
Figure 1-8 Transverse cracking (FHWA, 2003).....	1-9
Figure 1-9 Examples of cracks at different stages (Caltrans, 2004a).....	1-10
Figure 1-10 Corner break/cracking (Caltrans, 2004a).....	1-10
Figure 1-11 D-Cracking (Caltrans, 2004b)	1-11
Figure 1-12 Map-cracking (FHWA, 2003)	1-11
Figure 1-13 Example of scaling (FHWA, 2003)	1-11
Figure 1-14 Example of surface polish/polished aggregate (FHWA, 2003).....	1-12
Figure 1-15 Severe surface abrasion with third stage cracking (Caltrans, 2004b).....	1-12
Figure 1-16 Example of popouts (FHWA, 2003).....	1-12
Figure 1-17 Example of blow-ups (FHWA, 2003)	1-13
Figure 1-18 Examples of pumping and water bleeding (Caltrans, 2004a).....	1-13
Figure 1-19 Lane/shoulder drop-off (FHWA, 2003).....	1-14
Figure 1-20 Settlement (Caltrans, 2004b).....	1-14
Figure 2-1 Profilographs for measuring roughness (Budras, 2001)	2-3
Figure 2-2 Response-Type Road Roughness Measuring System - Mays Meter (Budras, 2001)	2-4
Figure 2-3 Road Roughness Profiling Devices (Budras, 2001)	2-5
Figure 2-4 Non-Contact Lightweight Profiling Devices (Budras, 2001)	2-6
Figure 2-5 Multi-laser Profiler Vehicle (Budras, 2001).....	2-7
Figure 2-6 ROSAN System (Budras, 2001).....	2-7
Figure 2-7 Illustration of PIARC pavement surface characteristic classifications and their impact on pavement performance measures (ACPA, 2006a)	2-8
Figure 2-8 Differences between Macrotexture and Microtexture (Shahin, 1994).....	2-9
Figure 2-9 Photo of original “sand patch” test using Ottawa sand and spreading tool	2-12
Figure 2-10 Photo of volumetric texture depth (“sand patch”) test equipment with glass beads and hockey puck (Wambold and Henry, 2002).....	2-13
Figure 2-11 Photo of Circular Texture Meter (CTMeter) (Abe et. al, 2001)	2-14
Figure 2-12 Photo of outflow meter in use (Wambold and Henry, 2002).....	2-14
Figure 2-13 Pennsylvania DOT E-274 locked-wheel friction tester (Wambold and Henry, 2002) ...	2-18
Figure 2-14 Photo of Mu Meter (Wambold and Henry, 2002)	2-20
Figure 2-15 Photo of SCRIM (Wambold and Henry, 2002).....	2-20
Figure 2-16 Photo of GRIPTESTER-towed mode (Wambold and Henry, 2002).....	2-21
Figure 2-17 Photo of SAAB Surface Friction Tester (Wambold and Henry, 2002)	2-21
Figure 2-18 Photo of Norsometer ROAR-Variable Friction Tester (Wambold and Henry, 2002)	2-22
Figure 2-19 Photo of British Pendulum Tester (Wambold and Henry, 2002)	2-23
Figure 2-20 Photo of Dynamic Friction Tester (courtesy of Nippou Sango Co, Ltd)	2-23
Figure 4-1 Illustration of sealant shape factor (FHWA, 2004).....	4-9
Figure 4-2 Joint sealant configurations (FHWA, 2004)	4-10
Figure 4-3 A typical five cell seal cross-section (ACPA, 1993)	4-11

Figure 5-1 Concrete pavement surface after diamond grinding	5-1
Figure 5-2 Concrete pavement surface after diamond grooving.	5-2
Figure 5-3 Faulting at a joint (FHWA, 2006).....	5-2
Figure 5-4 Diamond grinding and grooving terminology (FHWA, 2005).....	5-4
Figure 5-5 Faulting mechanism.....	5-8
Figure 5-6 Reliability levels for the expected survivability of California diamond ground pavements (Caltrans, 2005).....	5-12
Figure 5-7 Schematic of grinding machine (MnDOT, 2005).....	5-13
Figure 5-8 Typical grinding machine, front view (Courtesy of Caltrans).....	5-14
Figure 5-9 Grinding process (Courtesy of Caltrans).....	5-14
Figure 5-10 Diamond blades (Courtesy of Caltrans)	5-15
Figure 5-11 Typical cutting head (Courtesy of Caltrans).....	5-15
Figure 5-12 Pavement surface after diamond grinding (Courtesy of IGGA).....	5-16
Figure 5-13 Pavement surface texture behind grinding head (Courtesy of Caltrans)	5-16
Figure 5-14 Sequence of repairs in the concrete pavement restoration process (FHWA, 2005)	5-18
Figure 6-1 Load transfer (Caltrans, 2006a)	6-2
Figure 6-2 Photo of dowels with chair, end caps, and foam core insert in place (Caltrans, 2006a).....	6-6
Figure 6-3 Dowel layout figure (Caltrans, 2005)	6-7
Figure 6-4 Dowel/Slot layout (Caltrans, 2005)	6-10
Figure 6-5 Schematics of the construction process (FHWA/ACPA, 1997).....	6-12
Figure 6-6 Slot cutting machine with close-up of ganged cutter heads (Caltrans, 2006a).....	6-13
Figure 6-7 Three pairs of slots cut in a single pass by a ganged slot cutting machine.....	6-13
Figure 6-8 Details of chair-dowel system in slot.....	6-14
Figure 6-9 Jack hammering (Caltrans, 2006a)	6-14
Figure 6-10 Sandblasting (Caltrans, 2006a).....	6-15
Figure 6-11 Sealing joint/crack (Caltrans, 2006a)	6-16
Figure 6-12 Placing dowel-chair assembly (Caltrans, 2006a).....	6-17
Figure 6-13 Placing backfill (Caltrans, 2006a)	6-18
Figure 6-14 Consolidating backfill (Caltrans, 2006a).....	6-18
Figure 7-1 Marking damage area for removal (FHWA, 2006)	7-9
Figure 7-2 Concrete removal using the saw and patch methodology (FHWA, 2006)	7-10
Figure 7-3 Concrete removal using the mill and patch methodology (FHWA, 2006).....	7-11
Figure 7-4 Cleaning the repair area with sandblasting equipment (FHWA, 2006).....	7-11
Figure 7-5 Placement of bond breaker at joint (FHWA, 1999).....	7-12
Figure 8-1 Caltrans dowel bar design (Caltrans Standard Plan P8, 2006)	8-6
Figure 8-2 Concrete removal using lift out method (Caltrans, 2004)	8-9
Figure 8-3 Dowel bar anchoring in slab face (FHWA, 2001).....	8-11

LIST OF TABLES

Table 1-1 Examples of effectiveness of preventive maintenance (PM)	1-3
Table 1-2 Summary of factors affecting JPCP pavement distress.....	1-15
Table 1-3 Structural distress and possible contributing factors.....	1-16
Table 1-4 Functional distress and possible contributing factors	1-17
Table 1-5 Most commonly used types of portland cement	1-18
Table 3-1 Suggested data item needs for treatment strategies for rigid pavements (FHWA, 2001)	3-3
Table 3-2 Proposed trigger values and expected life for various PCC maintenance treatments	3-6
Table 3-3 Rigid pavement distress and related repair / preventive maintenance methods.....	3-7
Table 3-4 Trigger and limit values for jointed plain concrete pavements (ACPA, 1998).....	3-8
Table 3-5 Trigger and limit values for jointed reinforced concrete pavements (ACPA, 1998)	3-9
Table 3-6 Example worksheet of a selection process incorporating multiple selected decision factors and assigned weightings.....	3-12
Table 4-1 Sealant descriptions and related specifications	4-3
Table 4-2 Typical item codes for a joint resealing and crack sealing project	4-12
Table 5-1 Typical values for diamond grinding design in California	5-5
Table 5-2 Recommended dimensions for diamond grooving design in California (FHWA, 2004)	5-5
Table 5-3 Typical item codes for a diamond grinding project	5-6
Table 5-4 Trigger values for diamond grinding (FHWA, 2006).....	5-10
Table 5-5 Limit values for diamond grinding (FHWA, 2006).....	5-10
Table 6-1 Summary of project selection criteria	6-4
Table 6-2 Recommended backfill material properties (Jerzak, 1994).....	6-8
Table 6-3 Typical item codes for a dowel bar retrofit project.....	6-10
Table 7-1 Distresses addressed by partial depth repairs for jointed concrete pavements	7-1
Table 7-2 Properties of normal concrete mixtures used as partial depth repair materials.....	7-3
Table 7-3 Properties of specialty cement mixtures used as partial depth repair materials	7-4
Table 7-4 Properties of specialty materials used as partial depth repair materials.....	7-5
Table 7-5 Minimum dimensions of repair area for partial depth repairs.....	7-7
Table 7-6 Typical item codes for an isolated partial depth concrete repair project	7-7
Table 8-1 Distresses addressed by full depth repairs for jointed concrete pavements (FHWA, 2001)	8-2
Table 8-2. High Early-strength mix design and approximate opening times (FHWA, 2001).....	8-3
Table 8-3 Typical item codes for an isolated full depth concrete repair project	8-6
Table 8-4 Anchoring materials and dowel hole recommendations	8-10