CHAPTER 3 FRAMEWORK FOR TREATMENT SELECTION

This chapter discusses key factors to be considered during the strategy selection process for preservation and restoration treatments for jointed plain concrete pavements (JPCP). Treatments for continuous reinforced concrete pavements (CRCP) may be added to this document at a later date. Currently Caltrans does not have a formal selection matrix for preventive maintenance treatments for JPCP pavements. This chapter describes the steps involved in the treatment selection process, including typical methods for assessing existing pavement condition, determining feasible treatment options, and comparing and selecting treatment options. At present, only specific preventive maintenance treatments are included. In the future, other treatments, such as thin hot mix overlays, will be added.

3.1 FACTORS TO CONSIDER

The most important factors to consider during the strategy selection process include structural integrity, ride, skid and distress type. Noise can also be considered as a factor. Chapters 1 and 2 have provided an extensive discussion on these factors. Another important factor to consider is the durability/longevity of a treatment.

3.1.1 Ride

As indicated, the ride quality is directly related to pavement smoothness which is probably the single most important surface characteristic from the standpoint of the traveling public. A rough pavement not only adversely affects driver safety, fuel efficiency, and vehicle wear and tear, but also negatively impacts pavement durability. Therefore, the key factor for improving the ride quality is to improve pavement smoothness.

3.1.2 Skid

Skid resistance is a measure of the frictional characteristics of a pavement surface. A pavement with low skid resistance may cause vehicles to slide when the pavement surface is wet. Therefore, maintaining adequate pavement surface friction is important to public traffic safety. The key factor for improving the skid resistance is to improve pavement surface texture.

3.1.3 Noise

To many motorists, a quieter pavement provides a pleasant driving environment. A considerable number of studies have been devoted to reducing noise caused by tire-pavement interaction. Current information and findings on quieter pavement can be found at Caltrans' website:

http://www.dot.ca.gov/hq/oppd/pavement/qpavement.htm.

3.1.4 Distress Type

The type of distress on an existing pavement is probably one of the most important factors for the selection of an appropriate strategy. A specific distress may be caused by either single or multiple mechanisms. The key factor to consider during strategy selection is to identify treatments that not only mitigate distress symptoms but also resolve the mechanism(s) that caused the distress in the first place. Durability problems, such as D-cracking (although not found in California's rigid pavements) and alkali-silica reactivity (ASR), are primarily material related. Treatment selection for these types of problems depends on the rate of deterioration.

3.1.5 Durability/Longevity

The durability/longevity of a treatment is another important factor to consider. Caltrans' experience has indicated that the estimated lives of joint resealing and crack sealing may range from 4 to 7 years, while diamond grinding may provide estimated lives of 10 to 18 years before major rehabilitation or maintenance is again needed. Dowel bar retrofits, if properly carried out, can achieve estimated lives of 8 to 15 years, while partial or full depth repairs may last 8 to 10 years or longer. It must be noted that the durability/longevity of the treatment is dependent on the underlying structural condition of the pavement, traffic load, and environmental conditions as well as construction practices.

3.2 SELECTION PROCESS

There are three steps currently included in the pavement preservation and restoration treatment selection process for flexible pavements, as identified below (Caltrans, 2002; Shatnawi et al, 2006). These processes are also suitable for rigid pavements.

- Assess the existing conditions – these include the identification and cause(s) of pavement distresses and assessment of their conditions, as discussed in Chapter 1 and the desired surface characteristics as discussed in Chapter 2.
- Determine the feasible treatment options – "feasibility" is determined by a treatment's ability to address the functional and structural condition of the pavement while also meeting future needs. Feasibility is not a function of affordability. At this stage of the selection process, the purpose is to determine what treatments might work for a given pavement's structural and functional condition.
- Analyze and compare the feasible options – once feasible options are identified, they are compared in terms of cost, life expectancy, and extended pavement life resulting from the treatment. At this stage, a life cycle cost analysis or other cost effectiveness assessment should be made to evaluate the optimum time to apply the treatment to provide maximum cost effectiveness.

Each of these steps is discussed in the following sections.

3.3 ASSESS THE EXISTING PAVEMENT CONDITIONS

The first step of the treatment selection process is to perform an evaluation of the existing pavement condition. This evaluation includes the following processes:

- Review project information from a database and/or available records.
- Conduct visual site inspection of the pavement surface condition, as needed.

- Perform testing (for example, FWD joint testing) on the existing pavement as conditions require.
- Define the expected performance requirements for the treatment.

3.3.1 Project Information Review

Reviewing project information serves the following main purposes:

- Provides the qualitative information needed to determine the causes of pavement deterioration, and to develop appropriate alternatives for repairing the deterioration and inhibiting its recurrence.
- Provides the quantitative information needed to assess the rate of deterioration of the pavement and the consequences of delaying or accelerating the application of a given treatment and ,when appropriate, to identify feasible maintenance treatments, to make quantity estimates for the selected treatment (e.g., labor, materials, equipment), and to develop input for performing life-cycle cost comparisons of various treatments.

Table 3-1 provides data items typically needed or helpful for various treatment strategies considered in this document.

Table 3-1 Suggested data item needs for treatment strategies for rigid pavements (FHWA, 2001)

Data Item	Grinding	Load Transfer Restoration	Partial-Depth Repair	Full-Depth Repair
Existing Pavement Structure	X	X	X	X
Original Construction Data	*	*	*	*
Age	*		*	*
Materials Properties	X		*	*
Subgrade				
Climate				
Distress	X	X	X	X
Skid	*			
Accidents	*			
NDT	X	X		*
Destructive Testing/ Sampling	*	*	X	X
Roughness	*			
Surface Profile	X			
Surface Drainage	X			X
Previous Maintenance	*		*	*
Utilities				X
Traffic Control Options	X	X	X	X

KEY: X Definitely Needed * Desirable [*blank*] Not Normally Needed

Possible data sources are:

- Previous design reports;
- Previous construction plans/specifications (new and rehabilitation);
- Materials and soils properties from previous laboratory test programs and/or published reports;
- Past pavement condition surveys;
- Nondestructive testing and, if needed, destructive sampling investigations;
- Maintenance/repair history;
- Traffic measurements/forecasts to aid in estimating remaining service life;
- Environmental/climate studies or regional climatic data;
- Pavement management system reports.

These data may reside in each District office. Caltrans District Materials Engineers can be contacted to obtain the necessary information.

3.3.2 Field Distress Survey

A field distress survey is a very important activity in the process of pavement evaluation and strategy selection. Depending on the size and nature of the project, a field distress survey can be conducted through "windshield" observations, automated surface distress data collection equipment, and/or a detailed distress mapping survey involving lane closures. As part of this activity, information on distress type, extent, and severity, pavement roughness, surface friction, and moisture/drainage problems should be gathered (Caltrans, 2000). In addition, requirements for traffic control options for a detailed field survey and for construction may be assessed during the field visit. Caltrans Maintenance has been developing forms for flexible pavement surface treatment review checklists and pavement evaluation, as presented in Appendix E. These forms need to be modified to include checklists and pavement evaluation for concrete pavements.

3.3.3 Field Sampling and Testing

If needed, field tests on existing pavements may be conducted. The purpose of field testing is to verify and/or quantify the extent and severity of the observed distresses. The type of field testing to be conducted depends on the distresses on the existing pavement and its structural integrity. For example, roughness or profile & macrotexture tests may be required if there is concern about surface smoothness or surface texture; a skid test may be needed if there is concern with loss of skid resistance; deflection tests may be appropriate if there are concerns about the structural capacity of the pavement, the loss of support beneath the PCC slab due to voids, or the loss of load transfer efficiency of the joints.

Field sampling/testing may be required to provide additional information for detailed analysis or for laboratory testing if needed. The purposes of field sampling/testing and lab testing are to adequately characterize the structural characteristics of the existing pavement and to develop input for the selection of most appropriate strategies. Depending on the project requirements, field sampling activities may include pavement coring, augering, field testing using Dynamic Cone Penetrometer (DCP), and/or standard penetration test to measure the in-situ strength of the subgrade soils.

When required, laboratory testing may be conducted to verify, confirm, or quantify field observations from distress surveys or from non-destructive test program and to provide additional insight into the mechanism of the distress or to provide additional information needed for the development of treatment strategies. Examples of information that can be determined from laboratory testing include the following:

- California R-value of an unbound material
- Concrete flexural or tensile strength
- Petrographic testing and analysis for the concrete surface layer
- Resilient modulus of concrete or other materials

The National Highway Institute (NHI) Course No. 131062 (FHWA, 2001) provides an excellent discussion on various field sampling/testing and laboratory testing techniques. It is strongly encouraged that the reader looks into this reference when developing a plan for field sampling/testing and lab testing.

3.3.4 Performance Requirements

For rigid pavements, performance requirements vary by the type of treatment applied to the pavement. The treatments currently considered by Caltrans for maintenance include the following:

- Joint resealing and crack sealing. Caltrans makes extensive used of crack or joint sealants in jointed concrete pavements. Asphalt emulsions, fiber and asphalt, rubberized asphalt, and silicone sealants have been used. The estimated lives of these treatments vary from 4 to 7 years depending on where they are applied, existing pavement condition, structural integrity, and traffic levels.
- Diamond grinding. Diamond grinding is used extensively as a maintenance treatment to restore smoothness. Estimated lives of the grinding can be 10-20 years, with an average of about 16 years depending on traffic loads, structural integrity, environmental factors, and overall pavement surface condition.
- Partial or full depth slab repair. This treatment is used to repair performance problems such as spalling. The estimated lives of these treatments vary from 8-12 years.
- Dowel bar retrofit. Caltrans has used dowel bar retrofit as a pavement restoration strategy. This treatment is expected to be used more; however, the pool of candidates in California is considered small due to pavement age and distress levels. When dowel bar retrofits are carried out properly, the estimated lives of this treatment range from 8-16 years. The dowel bar retrofit may be considered as rehabilitation strategy if the amount of repair is extensive.
- Full slab replacement. Caltrans also replaces isolated full slabs where the slab has exhibited extensive cracking or is unstable. The estimated lives of this treatment may range from 3 to 15 years, highly dependent on overall pavement condition and the quality of the slab replacement project. Full slab replacement should be considered as a rehabilitation strategy if the amount of slabs to be replaced is extensive.

A summary of expected life for various treatments for rigid pavements is provided in Table 3-2. Trigger values for initiating various treatments based on national practices are also provided in the table. Work is currently underway by Caltrans to evaluate the effect of climate and traffic conditions and to develop specific trigger values for these conditions (Shatnawi, et al, 2006). However, proposed trigger values for use by Caltrans are currently based on national values and appropriate adjustments made for the local climate and traffic volume. Estimated costs are provided by Caltrans Maintenance for reference only and could vary from district to district and by the selected treatment for each traffic condition. District Materials Engineers and/or Resident Engineers should be consulted for costs for each treatment used on a specific project.

3.4 DETERMINE FEASIBLE TREATMENT OPTIONS

Once the pavement condition has been quantified, test results collected and analyzed to determine that the pavement's structural condition is adequate, and other available data are reviewed, feasible pavement preservation treatments can be identified. In this context, "feasibility" is determined by a treatment's ability to address the functional and non-structural condition of the pavement while also meeting any future needs. At this stage of the selection process, feasibility is not a function of affordability. The primary purpose is to determine what treatments may work.

Table 3-2 Proposed trigger values and expected life for various PCC maintenance treatments (Modified from Shatnawi et al, 2006)

Treatment	Trigger (National)	Climate Region[1]				Traffic ADT			Life of Treatment (Year)	Estimated Cost ($)[2]
		Desert	Valley	Coastal	Mountain	<5000	>5000;<30000	>30000		
Crack Resealing	>1/4 inch	>1/4	>1/4	>1/4	>1/4	>1/4	>1/4	>1/4	4 - 7	$28k - 42k/ ln mi
Diamond Grinding	Faulting >1/4 inch; Ride 95 in/mile	>1/4 >190	>1/4 >95	>1/4 >95	>1/4 >190	>1/4 >190	>1/4 >125	>1/4 >95	10 - 18	$30k - 80k/ ln mi
Partial Slab Repair	Surface distress - Patches <1.2 yd^2	<1.2	<1.2	<1.2	<2.4	<2.4	<1.2	<1.2	8 - 12	$135 - 270/$yd^3$
Isolated Slab Replacement	3rd stage cracking or unstable slabs	Same Trigger Value. For desert, mountain, or ADT<5000, District makes decision to repair.							8 - 12	$4000 - $8000/slab
Dowel Bar Retrofit	LTE <60%, Faulting >1/4 inch, Max 10% Cracking	<40 >1/4 20	<70 >1/4 10	<70 >1/4 10	<50 >1/4 20	<50 >1/4 20	<70 >1/4 10	<70 >1/4 10	8 - 17	$141k – 177k/ln mi

Notes:
[1] For locations of climate regions, see Pavement Climate Map at: http://www.dot.ca.gov/hq/oppd/pavement/guidance.htm.
[2] Estimated costs were provided by Caltrans Maintenance

A feasible alternative is one that addresses all identified distresses of the pavement (from the various evaluations performed), provides the desired future performance over the life of the treatment, and fits within identified constraints. Some of these constraints may include:

- Construction windows.
- Traffic flow conditions.
- Overhead clearances.
- Right-of-way.
- Funding.

It should be noted that the constraints should be identified, but should not be used to eliminate treatment alternatives from consideration or development unless the constraints indicate the treatment is not feasible.

The information presented in Table 3-3 may be used as a guideline for the selection of feasible treatments. This table is to target distresses commonly found in the California rigid pavement system. The information is general in nature, and is not designed to cover either every possible distress type or treatment alternative. Some of the repair techniques have not been discussed in detail here, but they are mentioned so that appropriate consideration may be given during the treatment selection process, as necessary. In Table 3-3, the restoration techniques are defined as activities that are performed in response to the development of a deficiency or deficiencies that may negatively impact the safe, efficient operation of the pavement. Preservation/preventive techniques are intended to retard future deterioration, and maintain or improve the functional condition of the pavement system (without significantly increasing the structural capacity).

Table 3-3 Rigid pavement distress and related repair/preventive maintenance methods

Distress Type	Preservation Techniques	Restoration Techniques
Structural Distresses		
Transverse Cracking	Joint and crack sealing	Full-depth repair Dowel bar retrofit
Longitudinal Cracking	Joint and crack sealing Slab stabilization	Full-depth repair Dowel bar retrofit
Corner Cracking	Joint and crack sealing Edge joint resealing Slab stabilization	Full-depth repair
2nd/3rd Stage Cracking	Joint and crack sealing Slab stabilization	Full-depth repair Dowel bar retrofit Slab replacement
Spalling	Partial-depth repair Joint and crack resealing Full-depth repair	
Pumping	Joint and crack resealing Slab stabilization	Full-depth repair Dowel bar retrofit
Blow ups	Full-depth repairs	Joint and crack resealing
D-cracking (not common in California)	Partial- or full-depth repair; Joint and crack resealing	
Functional Distresses		
Faulting		Diamond grinding Dowel bar retrofit Slab stabilization Joint and crack resealing Retrofitted edge drains
Ride Quality		Diamond grinding
Settlement		Diamond grinding
Surface Polishing	Diamond grinding Grooving	
Noise	Diamond gringing See Caltrans website for the latest information at: http://www.dot.ca.gov/hq/oppd/pavement/qpavement.htm.	
Scaling	Diamond grinding	
Popouts	Diamond grinding	

Several treatments may be feasible for a given set of conditions. Therefore, efforts should be made to identify as many feasible treatment alternatives as possible for a given project. Once the feasible treatments have been identified, the limitations of each of the options should be taken into account in relation to its suitability in comparison with the other feasible options. Treatment limitations are controlled by such factors as pavement surface deflections, pavement structural condition, roadway curvature, pavement roughness and permeability. With multiple alternatives, advantages and disadvantages of each treatment can be compared. The selection process can be used to rate alternatives against each other on all of the factors deemed important by Caltrans, such as initial cost, life-cycle costs, constructability, expected performance, expected life, and so on.

The American Concrete Pavement Association (ACPA, 1998) has also developed trigger and limit values for jointed plain concrete pavements (JPCP), for jointed reinforced concrete pavements (JRCP), and for continuously reinforced concrete pavements (CRCP). Trigger/limit values for JPCP and JRCP are presented in Tables 3-4 and 3-5 and they may be useful when developing feasible treatment options. However, most of the concrete pavements in California consist of JPCP.

Table 3-4 Trigger and limit values for jointed plain concrete pavements (ACPA, 1998)

Jointed Plain Concrete Pavements (Joint Space < 19.7 ft [6 m])*	Trigger/Limit Values**		
Traffic Volumes	High (ADT>10,000)	Medium (3000<ADT<10,000)	Low (ADT<3000)
Structural Measurements			
Low to high severity fatigue cracking (% of slabs)	1.5/5.0	2.0/10.0	2.5/15.0
Deteriorated joints (% of joints)	1.5/15.0	2.0/17.5	2.5/20.0
Corner breaks (% of joints)	1.0/8.0	1.5/10.0	2.0/12.0
Faulting (avg. - inch)	0.08/0.5	0.08/0.6	0.08/0.7
Durability distress (severity)	Medium-High		
Joint seal damage (% of joints)		>25/---	
Load transfer (%)		<50/---	
Skid resistance	Minimum local acceptable level/---		
Functional Measurements			
IRI (inch/mile)	63.4/158.4	76.0/190.1	88.7/221.8
PSR	3.8/3.0	3.6/2.5	3.4/2.0
California Profilograph	12/60	15/80	18/100

** Assumed slab length =15 feet.*

*** Values should be adjusted for local conditions. Actual percentage repaired may be higher if the pavement is restored several times.*

Table 3-5 Trigger and limit values for jointed reinforced concrete pavements (ACPA, 1998)

Jointed Reinforced Concrete Pavements (Joint Space > 19.7 ft [6 m])*	Trigger/Limit Values**		
Traffic Volumes	High (ADT>10,000)	Medium (3000<ADT<10,000)	Low (ADT<3000)
Structural Measurements			
Medium to high severity transverse cracking (% of slab)	2.0/30.0	3.0/40.0	4.0/50.0
Deteriorated joints (% of joints)	2.0/10.0	3.0/20.0	4.0/30.0
Corner breaks (% of joints)	1.0/10.0	2.0/20.0	3.0/30.0
Faulting (avg. - inch)	0.16/0.5	0.16/0.6	0.16/0.7
Durability distress (severity)	Medium-High		
Joint seal damage (% of joints)		> 25/---	
Load transfer (%)		< 50/---	
Skid resistance	Minimum local acceptable level/---		
Functional Measurements			
IRI (inch/mile)	63.4/158.4	76.0/190.1	88.7/221.8
PSR	3.8/3.0	3.6/2.5	3.4/2.0
California Profilograph	12/60	15/80	18/100

** Assumed slab length = 33 feet.*

*** Values should be adjusted for local conditions. Actual percentage repaired may be higher if the pavement is restored several times.*

3.5 COMPARE THE FEASIBLE OPTIONS

It is likely that several maintenance or repair treatments may be identified as feasible. When comparing these different treatments, thought should be given to the treatment placement cost and the life of the treatment. Additional factors to consider when analyzing and comparing treatment options include: cost effectiveness, traffic level, construction windows or limitations, and other factors, such as weather, curing times or local issues that affect a specific treatment. The most desirable treatment is the one that provides the greatest benefit (whether that benefit is measured in terms of improvement in condition, extension of pavement life, or even, more simply, the life of the treatment) for the lowest life cycle costs. At this point, a life cycle or other cost effectiveness measure should be performed.

3.5.1 Life Cycle Costing

Life-cycle cost analysis (LCCA) is an analytical technique that is built upon principles of economics to evaluate long-term alternative investment options. It is a useful tool for comparing the value of alternative treatments. In the LCCA, all costs associated with a feasible treatment or alternative could be compared based on the present value (PV) or equivalent uniform annual cost (EUAC).

The LCCA typically involves the following steps:

- Establish alternative/treatment;
- Determine analysis period;
- Determine discount rate;
- Determine maintenance/rehabilitation treatment frequencies;
- Estimate both agency and user costs;
- Calculate LCC; and
- Select treatment/alternative.

Caltrans is currently developing a pavement life-cycle cost analysis procedure based on the RealCost model developed by FHWA (FHWA, 1998). A draft user manual has been prepared (Caltrans, 2006). The user manual provides descriptions of the LCCA methodology, the use of the RealCost software, and examples of LCCA. The user manual also includes the following information:

- Typical maintenance and rehabilitation schedule for California;
- Maintenance and rehabilitation cost estimation;
- Maximum queue length estimation;
- State highway traffic hourly distribution;
- Agency construction unit costs (by district); and
- Work zone/traffic inputs determination.

It is anticipated that the development of the LCCA procedure will be completed by the end of 2007. It will then be possible to perform LCCA for various treatments for a variety of conditions.

3.5.2 Compare and Select Options

Typically, when a pavement preservation treatment/alternative is chosen, the option with the lowest LCC is generally selected. However, there are other factors that should be taken into consideration when making a final decision. These factors include the following:

- Agency policies.
- Overall pavement management of network (policies).
- Provisional (staged) construction.
- Traffic control requirements (safety and congestion).
- Available lane closure time.
- Existing geometric design problems and constraints that may prevent a treatment to be used.
- Right-of-way restrictions that may prevent a treatment to be used.
- Regulatory restrictions.
- Available materials and equipment.
- Contractor expertise and manpower for the location.
- Construction considerations (duration of construction).
- Conservation of materials and energy by using recycled materials.
- Potential climatic issues and/or constraints.
- Performance of the proposed treatment elsewhere under similar conditions.
- Availability of local materials and contractor capabilities.
- Worker safety during construction.
- Incorporation of experimental features.
- Municipal preference, local government preference, and recognition of local industry.
- Project funding and scope.

A simple ranking procedure, using the model described in the FHWA NHI Course 131062 (FHWA, 2001) http://www.nhi.fhwa.dot.gov/, may be developed to rate each feasible treatment/option. Factors to be considered in the ranking procedure should include key factors such as initial cost, life cycle cost, expected life of the treatment, user costs, and Caltrans experience with the feasible treatment option, or options. The importance of each factor can be signified by assigning a weighting to it. The weighing value represents the relative importance of a factor in all factors considered and could be on a scale of 1 to 10 or 1 to 100. The weighting can be assigned either by an individual or by groups of managers and other decision makers with a direct knowledge of the project and/or a stake in the outcome.

Each feasible treatment option is then rated independently against the key factors using a uniform scale, such as 1 to 5 or 0 to 100. The highest rating means that a treatment option best meets that criterion. The score or factor is calculated by multiplying the weights for each factor by the rating assigned. The total score for each treatment is the sum of the individual scores. The alternatives are then ranked in order, from the highest score to the lowest. The treatment option with the highest score is then selected. Table 3-6 shows an example of this process.

3.6 KEY REFERENCES

ACPA, 1998. *The Concrete Pavement Restoration Guide-Procedures for Preserving Concrete Pavements*, American Concrete Pavement Association, 1998.

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Table 3-6 Example worksheet of a selection process incorporating multiple selected decision factors and assigned weightings. (FHWA, 2001)

Decision Factor Names ⇨	DECISION FACTORS: Initial Cost	Life Cycle Costs	Expected Life	Ease of Repairing/ Maintaining	Construction Traffic Control	Proven Design in Agency	Total Score	Rank
Weightings ⇨	25	15	20	15	10	15		
Alternative 1	60 / 15	60 / 9	100 / 20	80 / 12	90 / 9	100 / 15	80	1
Alternative 2	60 / 15	60 / 9	100 / 20	80 / 12	90 / 9	100 / 15	80	1
Alternative 3	60 / 15	60 / 9	70 / 14	50 / 7.5	60 / 6	40 / 6	57.5	6
Alternative 4	60 / 15	60 / 9	70 / 14	50 / 7.5	60 / 6	40 / 6	57.5	6
Alternative 5	60 / 15	40 / 6	100 / 20	80 / 12	100 / 10	90 / 13.5	76.5	3
Alternative 6	60 / 15	80 / 12	40 / 8	20 / 3	40 / 4	20 / 3	45	9
Alternative 7	40 / 10	60 / 9	40 / 8	50 / 7.5	50 / 5	30 / 4.5	44	10
Alternative 8	70 / 17.5	80 / 12	60 / 12	50 / 7.5	80 / 8	40 / 6	63	5
Alternative 9	100 / 25	100 / 15	20 / 4	20 / 3	40 / 4	40 / 6	57	8
Alternative 10	30 / 7.5	60 / 9	100 / 20	100 / 15	100 / 10	30 / 4.5	66	4