Protection and Rehabilitation Treatments for Concrete Bridge Components: Status and Service Life Opinions of Highway Agencies

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As part of Task 1 of Strategic Highway Research Program Project C–103, "Concrete Bridge Protection and Rehabilitation: Chemical and Physical Treatments," state and provincial highway agencies in the United States and Canada were surveyed in early 1989 by mailed questionnaire on the status and service life of protective and rehabilitative treatments applied to concrete components of bridges in their jurisdictions. Responses were received from 47 states and 9 provinces. Respondents indicated that patching with rigid mortar or concrete (portland cement, quick-set, or polymer) is more widely accepted as a standard practice than any other deck treatment category (71.4 percent of agencies). Some treatments were judged by more agencies to be experimental rather than standard and were associated with generally lower acceptance frequencies. With the exception of cathodic protection, treatments for substructure and superstructure concrete were judged to be far less experimental than those for decks, and the standard acceptance frequencies more uniform. Opinions on the service life of treatments were generally widely scattered. Median responses for deck treatments varied from 1 year for asphalt concrete patching to >20 years for micro-silica overlays; and for nondeck treatments from 5 to 10 years for sealers to 20 years for cathodic protection. Questionnaire responses have been used to focus the study of service life expectancy in Task 1 on those treatments considered to be in the mainstream of current practice.

The purpose of Strategic Highway Research Program (SHRP) Project C–103 is to develop cost-effective, nonelectrical methods of protecting and rehabilitating salt-contaminated decks and other concrete bridge components subject to corrosion. The object of Task 1 of C–103 is to determine costs and service lives of those treatment methods that are in *current* use (*1*).

In connection with Task 1, a short questionnaire was mailed to each of the 50 SHRP state coordinators and to each of the 12 Canadian provincial coordinators. The questionnaire was designed to serve several purposes:

1. To provide an opportunity for the client agencies to influence the direction of the Task 1 study by indicating which of the current treatments were considered to be standard and which were experimental (Question 1);
2. To obtain an indication of which of the treatments were most important to the agency's program (Question 2); and
3. To elicit a body of informed opinions on the average service lives of the treatments (Question 3).

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For each question, respondents were asked to provide answers for each of 26 combinations of treatment methods and bridge components. The treatment methods included were those thought to represent the common current alternatives. Cathodic protection (CP) was included for information, at the request of SHRP main office staff, even though it was not within the scope of Project C–103. Respondents were invited to add new treatments to the matrix reflecting practices not otherwise included.

Bridge components were grouped in the questionnaire matrix on the basis of assumptions regarding differences in chloride exposure, i.e.,

1. Those subject directly to chloride-laden runoff such as pedestals and pier cap beams; and
2. Those subject to spray or splash such as pier columns adjacent to a roadway, and elements in a marine environment.

The introduction that accompanied the questionnaire instructed that its intent was to "identify treatments that are expressly used as long-term solution rather than an immediate reaction to an existing problem," and the SHRP coordinators were asked to direct the questionnaire to the persons in their agency best qualified to respond.

QUESTIONNAIRE RESULTS

Responses were received from 47 states and 9 Canadian provinces. One state, Mississippi, and one province, Prince Edward Island, responded but declined to complete the questionnaire. Mississippi does not use chloride deicing chemicals and Prince Edward Island, until recently, has built mostly timber bridges.

Four treatments not included in the original matrix were added voluntarily by respondents:

1. A proprietary rubber-modified asphalt concrete (AC) overlay by Pennsylvania (experimental);
2. In situ polymerization with methacrylate of high molecular weight by California (standard);
3. Bituminous chip seal by Kansas (experimental); and
4. An epoxy-coated deck seal by Wisconsin (experimental).

Of those, two (in situ polymerization as practiced by California and epoxy-coated deck seal) fall within the existing treatment category of thin polymer overlay. The other two were added to the list of treatments in the matrix.

Individual questionnaire responses were discussed by Chamberlin (*2*).

STATUS OF TREATMENTS (QUESTION 1)

In the discussion that follows, the terms "acceptance" and "frequency of acceptance" are used in referring to the number of agencies reporting a particular treatment as standard or experimental in their jurisdiction. These terms should not be confused with use or frequency of use, which are the number of applications of that treatment actually applied. For instance, a treatment may be accepted as a standard by an agency, but not widely used because of economic, logistic, or other reasons. This work deals with acceptance, not use, and reports the status of treatments as of the date the questionnaire was mailed, February 1989.

Decks

The status of deck treatments is shown in Figure 1, which is a graphical representation of the survey responses, and presented in Table 1, which correlates results of this survey with results of two similar surveys, one conducted by TRB in 1977 (*3*), and another conducted by the New Mexico State Highway Department in 1984 (*4*,p.33)

For the purpose of this discussion, treatments are divided into two groups, topical and areal. Topical treatments are those used to repair damage at specific locations on a deck (i.e., patching and crack filling). Areal treatments are those typically applied to the entire deck surface at one time. On the basis of the relative extent and nature of their acceptance as revealed by this survey, areal treatments are further divided into those that are widely enough accepted to be considered conventional and those that are still highly experimental.

Treatment	Status*	N	%
Topical			
PCC, Quick-Set or Polymer Mortar/Concrete Patching	S	40	71.4
	E	4	7.1
Epoxy Injection	S	16	28.6
	E	8	14.3
A C Patching	S	15	26.8
	E	1	1.8
Areal			
LMC Overlay	S	31	55.4
	E	4	7.1
LSDC Overlay	S	26	46.4
	E	4	7.1
Membrane + AC Overlay	S	29	51.8
	E	2	3.6
Sealers	S	24	42.9
	E	11	19.6
Thin Polymer Overlay	S	7	12.5
	E	15	26.8
Cathodic Protection	S	7	12.5
	E	26	46.4
MSC Overlay	S	2	3.6
	E	14	25.0
FRC Overlay	S	1	1.8
	E	6	10.7
Polymer Impregnated	S	1	1.8
	E	5	8.9
Rubber-Modified AC Overlay	S	0	0.0
	E	1	1.8
Bituminous Chip Seal	S	0	0.0
	E	1	1.8

Number of Agencies Responding (0–40)

* S = Standard, E = Experimental

FIGURE 1 Status of bridge deck treatments.

Topical Treatments

Of the three treatments in the topical category, the various mortar and concrete patching materials were reported as standard at a frequency more than twice that of each of the other two (Figure 1). The remaining two, epoxy injection and AC patching, are still not widely accepted as standards for deck repair, but their acceptance has grown significantly since 1977 (from 6.2 to 34.0 percent of states and from less than 10.4 to 29.8 percent of states, respectively).

Conventional Areal Treatments

Of the 11 treatments in the areal category, four latex-modified concrete (LMC) and low-slump dense concrete (LSDC) overlays (membranes and sealers) were identified as standard with a high enough frequency, and as experimental with a low enough frequency, to set them apart from the other seven (Figure 1).

Each of the three overlay systems represents a technology that has been available in its present form for at least 15 years and, with the exception of membranes, has grown substantially in acceptance during that period (Table 1). Membrane systems, being a somewhat older approach to deck rehabilitation than concrete overlays, appear to have maintained a relatively constant level of acceptance, at least since 1977 (Table 1).

Forty-nine of the 56 responding agencies accept as standard at least one of these three overlay systems, an indication of the popularity of the overlay concept. The Venn diagram of Figure 2 shows the frequency with which the responding agencies have accepted as standard treatment more than one of these options. These associations appear to be random (chi square analysis at the 0.95 significance level), that is, acceptance of one of the treatments by an agency has not predisposed it to acceptance of another.

Although sealers are included with areal treatments, they differ in that they are used on existing decks only for protection, not for rehabilitation. They also have a higher ratio of experimental to standard acceptance than the other three. This situation undoubtedly reflects the continuing introduction of new proprietary materials to the market and the difficulties in evaluating these products, as well as the shift in interest away from surface sealers such as linseed oil to so-called "penetrating" sealers such as the salines. Also, what appears in Table 1 to be aggressive growth in the acceptance of sealers between 1977 and the present (8.3 versus 44.7 percent of states, respectively) may be explained merely by the failure of either survey to distinguish clearly among surface sealers, penetrating sealers, and coatings.

The geographic distribution of acceptance of the four conventional treatments within the United States is shown in Figure 3.

TABLE 1 CHANGES IN REHABILITATION PRACTICES FOR U.S. BRIDGE DECKS AS REFLECTED IN NATIONAL SURVEYS

	Percentage of Respondents Indicating Use*					
	TRB (1977) (2)		NM (1984) (3)		SHRP (1989)	
Treatment	Std.	Exper.	Extive.	Lmtd.	Std.	Exper.
Sealers	8.3	10.4	Not Included		44.7	19.2
Silane Treatment	Not Included		4.6	7.0	Not Included	
Epoxy Injection	6.2	4.2	Not Included		34.0	12.8
Polymer Impregn.	Not Included		7.0	0.0	2.1	10.6
Patch with AC	10.4**	12.5**	Not Included		29.8	2.1
Patch with PC Mortar/Concrete			Not Included		76.6	4.2
Membrane + AC Overlay	48.8	12.5	37.2	39.5	46.8	4.2
Thin Polymer Overlay	Not Included		Not Included		12.8	29.8
Normal Slump PCC Overlay	8.3	0.0	Not Included		Not Included	
LSDC Overlay	31.2	6.2	32.6	39.5	51.1	8.5
LMC Overlay	35.4	14.6	30.2	44.2	63.8	6.4
MSC Overlay	Not Included		Not Included		2.1	29.8
FRC Overlay	Not Included		Not Included		0.0	12.8
Cathodic Protection	0.0	18.8	Not Included		10.6	53.2

* Number of Respondents:
TRB 48
New Mexico. 43
SHRP C-103. 47
** The 1977 survey did not distinguish among patching materials.

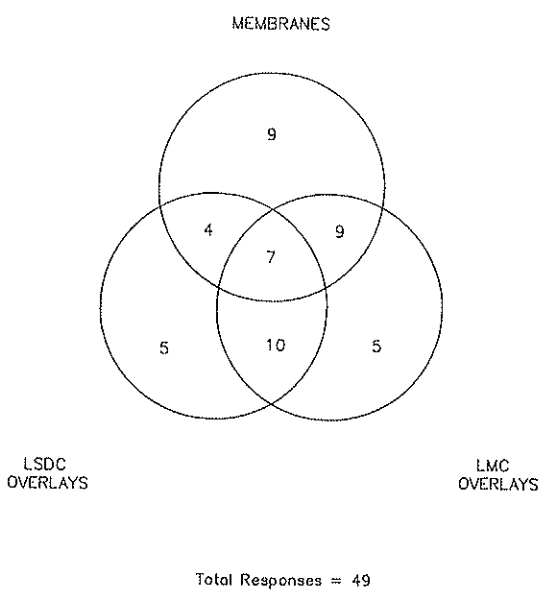


FIGURE 2 Acceptance frequency for conventional overlay treatments.

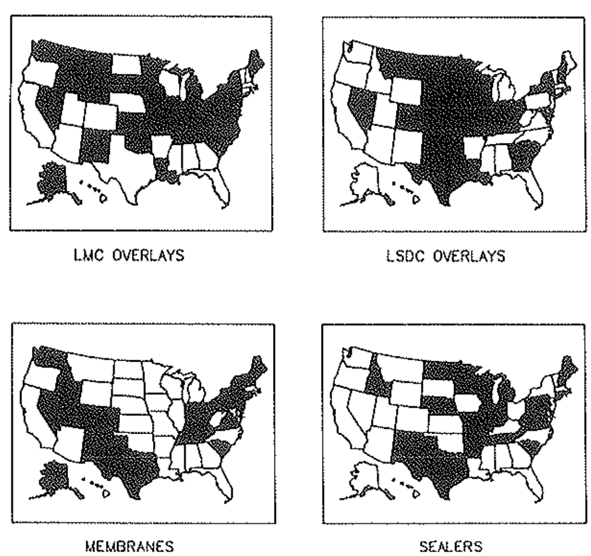


FIGURE 3 Geographic distribution of acceptance for conventional areal treatments.

Experimental Areal Treatments

The remaining seven areal treatments are each characterized by a substantially lower acceptance frequency, and, except for the two added by respondents, have an experimental to acceptance ratio that well exceeds 1. CP, micro-silica concrete (MSC) overlays, and thin polymer overlays appear to have experienced higher overall acceptance than the other four.

CP, the only widely promoted system to date that will arrest corrosion, has been an option for bridge deck application for approximately the same period of time as have LMC and LSDC overlays. Yet, its acceptance as a standard in the United States is still only a modest 10.6 percent of states compared to 63.8 and 51.1 percent for the other two, respectively (Table 1). This is in contrast to the strongest experimental interest indicated for any of the 14 deck treatments included in the survey. There are probably a variety of reasons for CP's lagging acceptance for decks and many of the reasons may be nontechnical (*5*).

In contrast to CP, MSC overlays are relatively new. The first experimental bridge deck overlay with MSC was placed in 1984 (*6*). Yet, such overlays are rapidly gaining in acceptance, in part because of their low reported permeability and their compatibility with conventional concrete overlay techniques.

Thin-polymer overlays have become particularly popular in those instances where minimizing dead load is a factor and where it is advantageous not to have to raise joints or approaches. The relatively strong experimental components to the responses for this treatment reflect the proprietary nature of many of the overlay systems that are on the market and the difficulties inherent in their evaluation.

Elements Other Than Decks

The status of treatments applied to concrete bridge elements other than decks is shown in the bar charts of Figures 4 and 5.

With the exception of CP, all of the nondeck treatments were identified as standard by a substantial number of respondents (roughly comparable to that for the conventional areal deck treatments), with the various mortar and concrete patching materials having the greatest acceptance. None had a strong experimental component.

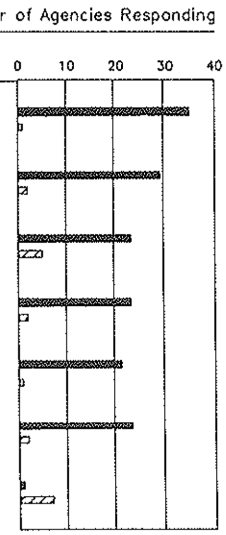
No consistent difference was indicated between treatments applied to elements subject to runoff and those subject to spray or splash. Where the same treatment was applicable both to deck and nondeck elements, a higher level of acceptance in favor of the former was indicated for mortar and concrete patching and for CP.

IMPORTANCE OF SERVICE-LIFE AWARENESS (QUESTION 2)

In Question 2, agencies were asked to identify whether a knowledge of the service life of each of the treatments they had identified in Question 1, as either standard or experimental, was of primary or secondary importance. Responses to this question were taken as a measure of respondent's interest in service life awareness. The purpose of this information was to assist in setting priority for the task of collecting service life and cost data.

Accordingly, information on the frequency of treatment acceptance from Question 1, including both standard and experimental use, was plotted against the frequency of primary interest from Question 2, expressed as a percent of the former (see Figure 6). In Figure 6, the response field has been divided into four quadrants using the mean responses as boundaries. The identities of the treatments in each of the response quadrants are presented in Table 2 in the order listed in the questionnaire.

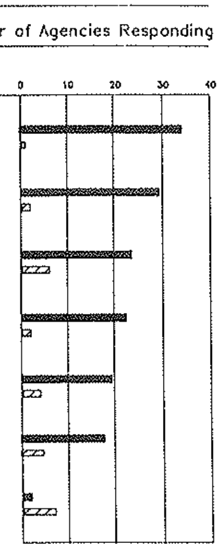
Treatment	Status*	N	%
PCC,Quick–Set or Polymer Mortar/Concrete Patching	S	35	62.5
	E	1	1.8
Patch & Encase w/PCC	S	29	51.8
	E	2	3.6
Sealers	S	23	41.1
	E	5	8.9
Shotcrete	S	23	41.4
	E	2	3.6
Coatings	S	21	37.5
	E	1	1.8
Epoxy Injection	S	23	41.1
	E	3	5.4
Cathodic Protection	S	1	1.8
	E	7	12.5



* S = Standard
E = Experimental

FIGURE 4 Status of nondeck treatments for bridge elements subject to chloride-laden compounds.

Treatment	Status*	N	%
PCC,Quick–Set or Polymer Mortar/Concrete Patching	S	34	60.7
	E	1	1.8
Patch & Encase w/PCC	S	29	51.8
	E	2	3.6
Sealers	S	24	42.9
	E	6	10.7
Shotcrete	S	23	41.1
	E	2	3.6
Coatings	S	19	33.9
	E	4	7.1
Epoxy Injection	S	18	32.1
	E	3	5.4
Cathodic Protection	S	2	3.6
	E	7	12.5



* S = Standard
E = Experimental

FIGURE 5 Status of nondeck treatments for bridge elements subject to chloride-laden spray and splash.

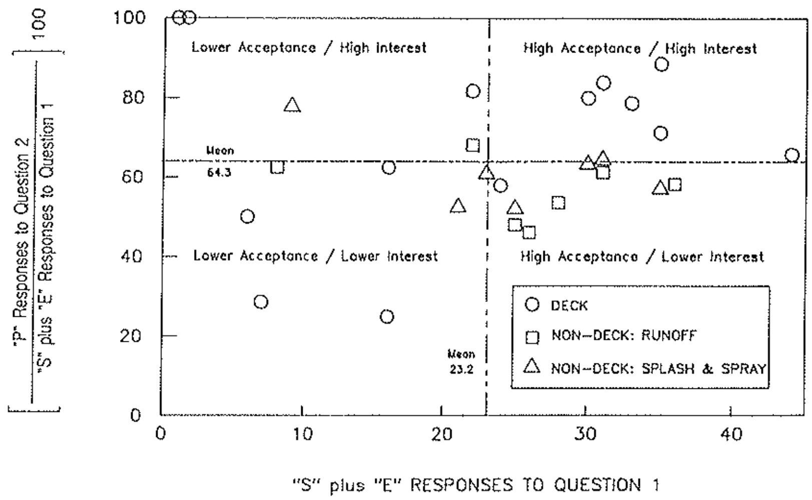


FIGURE 6 Treatment acceptance versus service life awareness interest.

Bridge deck treatments, as a group, rank high both in frequency of acceptance and frequency of primary interest. Also, most of the condition and performance data that exist relate to bridge deck treatments, in contrast to treatments for nondeck elements.

Except for bituminous concrete seal coats and rubber-modified AC overlays, for which there was only one response each, three anomalies stand out in Figure 6 in what is otherwise an approximately straight-line relation between acceptance and interest.

1. CP is associated with a high level of interest despite its relatively low acceptance. This is consistent with its high ratio of experimental to standard acceptance, noted earlier, and is taken as further evidence of the reluctance of highway agencies to make widespread use of this technology.
2. AC patching is associated with low to moderate acceptance relative to use, but there seems to be little interest in knowing its service life. The modest experimental interest in this treatment has already been noted, and it will be seen later that there is a strong respondent's perception that its service life is also modest, on the order of 1 year.
3. In contrast, thin polymer overlays, which are also associated with a moderate level of acceptance, have one of the highest levels of respondent interest measured. This is taken

TABLE 2 TREATMENTS IN EACH OF THE RESPONSE QUADRANTS

Quadrant	Treatment	Bridge Element*
High Acceptance/High Interest	Sealers	Decks
	Mortar/Concrete Patching	Decks
	Membranes + AC Overlay	Decks
	LSDC Overlay	Decks
	LMC Overlay	Decks
	Cathodic Protection	Decks
High Acceptance/Lower Interest	Sealers	Non-Deck (R)
	Sealers	Non-Deck (S/S)
	Epoxy Injection	Decks
	Epoxy Injection	Non-Deck (R)
	Mortar/Concrete Patching	Non-Deck (R)
	Mortar/Concrete Patching	Non-Deck (S/S)
	Patch & Encase	Non-Deck (R)
	Patch & Encase	Non-Deck (S/S)
	Shotcrete	Non-Deck (R)
	Shotcrete	Non-Deck (S/S)
Lower Acceptance/High Interest	Coatings	Non-Deck (R)
	Thin Polmer Overlays	Decks
	Cathodic Prtection	Non-Deck (S/S)
	Bituminous Chip Seal	Decks
	Rubber-Modified AC Overlay	Decks
Lower Acceptance/Lower Interest	Coatings	Non-Deck (S/S)
	Epoxy Injection	Non-Deck (S/S)
	Polymer Impregnation	Decks
	AC Patching	Decks
	Cathodic Protection	Non-Deck (R)
	MSC Overlay	Decks
	FRC Overlay	Decks

* R = elements subject to chloride-laden runoff
S/S = elements subject to chloride-laden splash and spray

as a reflection of the niche (noted earlier) that these materials occupy among rehabilitation options and of the potential for product development in this area.

ESTIMATED SERVICE LIFE (QUESTION 3)

Question 3 asked for the respondent's best estimate of the average useful life (service life expectancy) of each of the combinations of treatments and bridge components listed in the response matrix.

Most of the answers to Question 3 were in the form of discrete numbers. However, some were given as ranges and others as numbers followed by a plus sign. One response simply said, "indefinite." For these reasons, values of the median and mode (rather than the arithmetic mean) were reported as measures of central tendency in summarizing the responses. Minimum and maximum values, as well as interquartile ranges, were used as measures of scatter.

The responses for bridge deck treatments are presented in Table 3 where they are arranged in order of increasing median value of the service life estimate, within the categories of topical and areal. Responses for nondeck treatments are presented in Table 4, also arranged in order of increasing median value of the service life estimate, but without further categorization.

Deck Treatments

Considering the deck treatments first (Table 3), those typically considered more in the nature of repair or protection, as distinguished from major rehabilitation, are associated with the expectation of a shorter service life. The median life expectancies for both forms of patching, epoxy injection and sealers, were judged to be between 1 and 10 years. The single most consistent response for any of the treatments was that for AC patching, with a median estimated life of 1 year.

In contrast, those treatments that are of a more rehabilitative nature were associated with median service lives estimated at between 10 and 20 years. Several observations follow.

1. Apparently, most respondents perceive LSDC and LMC overlays as roughly equivalent in terms of their expected life. This has been traditional as long as these materials are placed in thicknesses that reflect the presumed difference in their inherent chloride permeability. In this regard, LSDC has usually been placed at a nominal thickness ½ to ¾ in. greater than LMC, reflecting its higher permeability. However, several recent studies have indicated that much of the LSDC in actual use is more permeable to chlorides than laboratory studies have indicated (*7–9*). Awareness of this information, which would seem to have a performance implication, does not appear to be reflected in current opinion regarding the relative service lives of these two overlays.

TABLE 3 ESTIMATED SERVICE LIVES FOR DECK TREATMENTS (IN YEARS)

		Average*		Scatter*		
Treatments	N	Median	Mode	Min.	Max.	Inter-Quartile Range
Topical						
AC Patching	30	1	1	0	25	1-2
Mortar/Concrete Patching	45	5	5	1/2	35	4-10
Epoxy Injection	28	10	10	4-5	50	10-20
Conventional Areal						
Sealers	32	4-5	5	1	25	2-10
Membranes + AC Overlay	39	15	15	5	60	10-15
LMC Overlay	40	15-20	20	0	60	10-20
LSDC Overlay	36	20	20	0	50	10-20
Experimental Areal						
Thin Polymer Overlay	29	10	10	2	25+	6-12
Polymer Impregnation	7	15	NA	1-10	30+	NA
FRC Overlay	7	15	NA	0	25	NA
Cathodic Protection	28	20	20	1	Indef.	15-30
MSC Overlay	13	20+	NA	10	60	20-25

* Where "NA" appears in the "Mode" column, it indicates either that the number of responses is too few for the mode to have meaning or that the distribution of responses is multimodal. Where it appears in the "Interquartile Range" column, it indicates that the number of responses is too few to identify a meaningful interquartile range.

TABLE 4 ESTIMATED SERVICE LIVES FOR NONDECK TREATMENTS (IN YEARS)

			Average*		Scatter*		
Treatments	Element	N	Median	Mode	Min.	Max.	Inter-Quartile Range
Sealers	R	30	5-10	10	2	25+	3-10
Sealers	S/S	29	5-10	10	2	35	3-10
Concrete Patching	R	36	10	10	2	35	5-10
Concrete Patching	S/S	37	10	10	2	35	5-10
Coatings	R	29	10	10	4	25	7-15
Coatings	S/S	31	10	10	2-3	25	5-10
PCC Patch & Encase	R	29	10	10	5	40	10-20
PCC Patch & Encase	S/S	33	10	10	2	40	10-20
Shotcrete	R	33	10+	10	0	40	10-15
Shotcrete	S/S	31	10+	10	0	40	10-15
Epoxy Injection	R	29	15	NA	4-5	50	10-25
Epoxy Injection	S/S	25	15	10	0-1	50	10-20
Cathodic Protection	R	10	15-20	NA	10	50	NA
Cathodic Protection	S/S	11	20	NA	5	50	NA

* Where "NA" appears in the "Mode" column, it indicates either that the number of responses is too few for the mode to have meaning or that the distribution of responses is multimodal. Where it appears in the "Interquartile Range" column, it indicates that the number of responses is too few to identify a meaningful interquartile range.

2. Similarly, MSC, which has been shown in laboratory studies to be inherently less permeable than either LSDC and LMC, is also rated as equivalent in respondents' perceptions of its service life in overlays.

3. All three of the concrete overlay systems (LSDC, LMC, and MSC) were associated with lower estimated service lives than expected. This may reflect the fact that individuals' perception of service life is probably influenced more by the age at which the first items in the population fail than the average age at which they fail. This is likely to be particularly true for treatments that have been in use for a period of time less than their average service life.

4. Membranes were found to have a level of acceptance roughly equivalent to LMC and LSDC overlays (Figure 1) and a greater perceived service life (15 years) (*3*) than has generally been assumed, at least as reflected by the median estimated value.

Nondeck Treatments

Among the treatments applied to elements other than decks, there was essentially no difference in respondents' opinions regarding the service life of those elements subject to direct chloride-laden runoff and those subject to chloride-laden splash or spray (Table 4). In retrospect, it may have been more informative to have categorized the nondeck treatments in terms of the nature of the surface of repair (e.g., vertical, horizontal, and irregular).

For those treatments applicable both to deck and nondeck elements, respondents' opinions favored a longer service life for the nondeck applications, except for CP (Figure 7). This undoubtedly reflects the perception that decks generally present a more severe environment for the durability of rehabilitative treatments than do other elements of the bridge.

General Comments

Considering these responses as data, they are in the realm of expert opinion collected under highly unstructured conditions. Thus, any single response taken by itself should probably be looked on more as representing the individual respondent than the agency by which that respondent is employed. This judgment is supported by the surprising divergence observed between two completed questionnaires prepared and submitted by different persons in the same agency, each apparently without knowledge of the other.

The information on service lives for both deck and nondeck treatments offers the only concensus judgment to date of the relative service lives of the different treatment options in common use. Clearly, it oversimplifies. For instance, the effectiveness of any of the treatments is dependent on a complex interaction along material characteristics, condition, and pre-

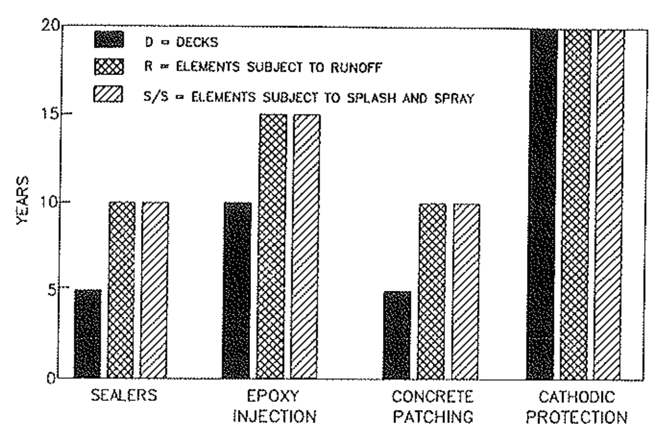


FIGURE 7 Comparison of service life estimates for deck and nondeck treatments.

treatment of the bridge element being enhanced; the techniques and skill of those actually doing the work; and the environment of service. Some of the factors contributing to this performance variance are identifiable, others are not. Notwithstanding, it is believed that there is a base of common experience that permits a general ranking of the treatments with respect to one another and that that experience is reflected in the median service life estimates reported here. Likewise, the scatter, which in the case of some treatments was surpassingly large, is believed to reveal useful information about variance in the perception and experience of the respondents.

No geographical influence was detected in the responses to Question 3, suggesting that the respondents, as a group, do not perceive a relationship between treatment service life and severity of the climate in which the agency operates.

CONCLUSIONS

The following general conclusions have been drawn from results of the questionnaire on the status and service life of protection and rehabilitation treatments for concrete bridge components.

1. Among deck treatments, rigid mortar and concrete patching; overlays (including LMC, LSDC, and membranes with AC); sealers; epoxy injection; and AC patching are considered by more highway agencies to be standard practices than experimental, and in that order of decreasing frequency.
2. Acceptance by highway agencies of cathodic protection, thin polymer overlays, MSC overlays, fiber-reinforced concrete overlays, polymer impregnation, rubber-modified AC overlays, and bituminous chip seals as experimental treatments is more common than their acceptance as standard; and in that order of decreasing frequency.
3. Among treatments for bridge elements other than decks, only CP is considered to be experimental by more agencies than consider it to be a standard treatment.
4. There is a general and positive correlation between the frequency of acceptance as standard and the frequency of interest in service life awareness (as reflected in the responses to Question 1).
5. Opinions regarding the service life of treatments are generally widely scattered and bear little relationship to the severity of the climate in the responding agency's jurisdiction.
6. No difference was found between estimates of service life for nondeck treatments applied to elements subject to direct runoff and those subject to splash or spray.
7. Where the same treatment was applicable both to decks and other bridge elements, longer service lives were estimated for the nondeck elements.

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