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Decision-Making Tool

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DECISION-MAKING TOOL

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This report is not intended for construction, bidding, or permit purposes. The researcher in charge of the project was Dr. Anol K. Mukhopadhyay.

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OBJECTIVE AND BACKGROUND

The primary objective of Task 6 was to develop guidelines, recommendations, and a decision-making tool based on extensive laboratory performance evaluation of the selected sealers and coatings (Task 3, Chapter 3 in the Research Report [R1]) under both normal and accelerated weathering (QUV and QFOG exposure) followed by developing a rating system (Task 4, Chapter 4 in the Research Report [R1]) and selective field validation (Task 5, Chapter 5 in the Research Report [R1]). The development of practice guidelines and recommendations in the form of a decision-making tool (systematic stepwise approach) is presented below. Practice guidelines and recommendations developed through this research will be used to ensure effective product selection and application for protecting substructure concrete from chloride-induced corrosion and extending the service life of bridges.

DEVELOPMENT OF GUIDELINES, RECOMMENDATIONS, AND A DECISION-MAKING TOOL

The overall guideline for the effective application of sealer/coating products and protection of field substructure concrete in the form of a decision-making tool is presented as a flowchart (Figure 1). The flowchart shows a step-by-step approach covering (a) condition assessment of field substructure concrete, (b) product selection based on condition assessment and project requirements, (c) selection of appropriate surface preparation and optimum substrate concrete surface moisture contents to maintain before application of any product, (d) product application followed by assessment (e.g., measurements of wet film thickness [WFT) and dry film thickness [DFT]) to ensure effective application, and (e) selective field performance monitoring after application. Each aspect (i.e., A1–A8) is discussed, with necessary details subsequently highlighting the areas of further recommended research. The step-by-step guideline for product evaluation in the laboratory before selecting a suitable product for a field project was presented in Chapter 3 of the research report. To select the right product for a particular project, a prior lab evaluation of the commonly used products that apply to this guideline is highly recommended. A total of eight products were evaluated in this project to develop the lab test protocol. However, it is recommended that all commonly used products along with potential new products be evaluated and a database with an in-built ranking system be created. Because lab-based product evaluation using the developed protocol takes time (~5–6 months), it may not be practical to check the suitability of a product during the planning stage for a project application. Consequently, a database with product ranking based on a one-time detailed evaluation will facilitate a rapid selection of a suitable product for a field project with no need for a long-term protocol-based product evaluation (unless any new products have not yet been added to the database through evaluation) before selection for a project application.

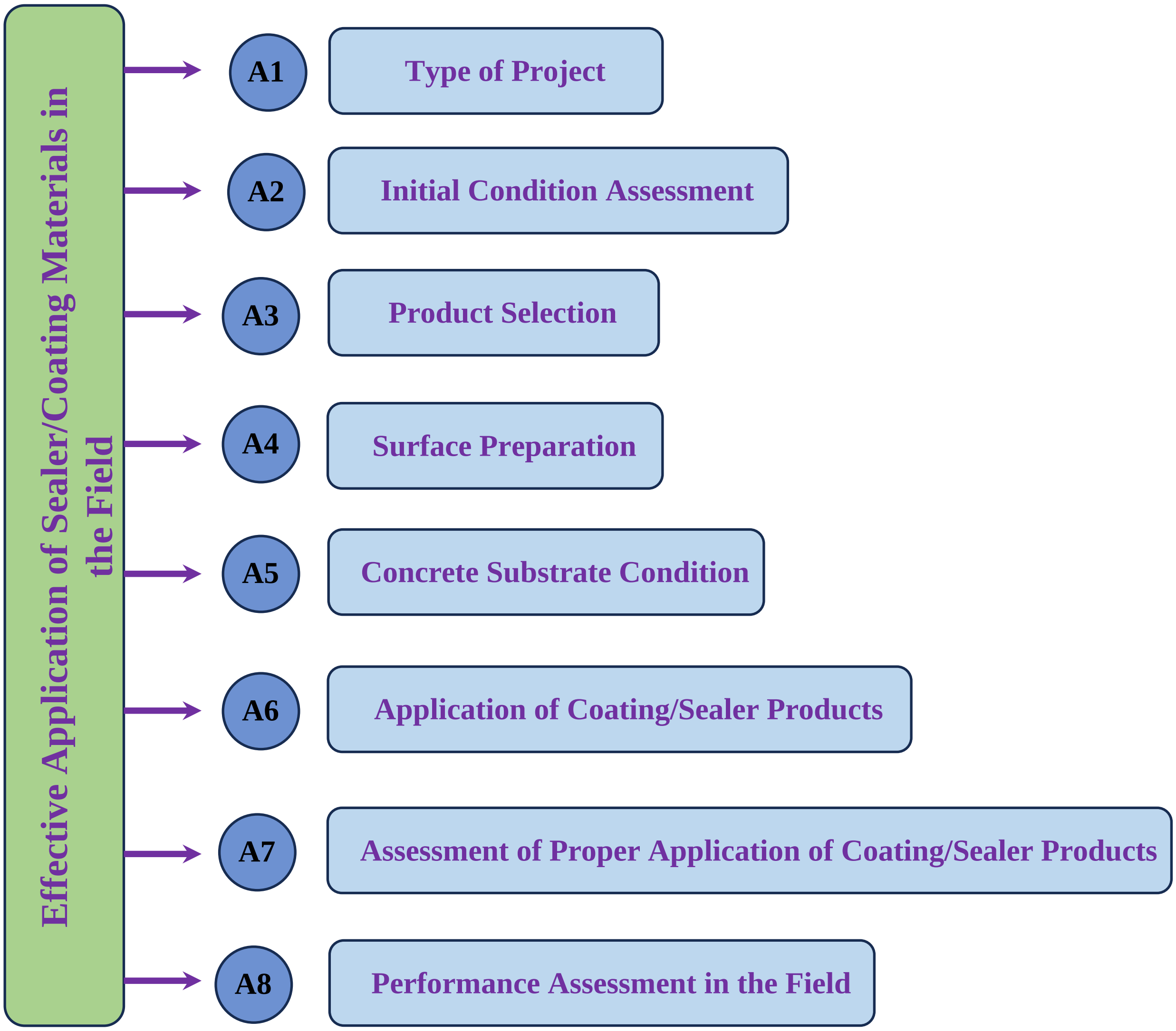

Figure 1: Flowchart for effective selection and application of sealer/coating products and performance assessment to protect field substructure concrete

A1 Type of project:

The type of project can be as follows:

- New construction.
- Old construction (without any previously applied coating/sealer products).
- Old construction (with previously applied coating/sealer products).

A2 Initial condition assessment:

The following aspects can be considered for the initial condition assessment:

- New construction: Assess concrete surface profile (CSP) and check for any visible defects.
- Old construction (no previously applied coating/sealer products): Perform concrete substrate inspection through (a) Pull-off adhesion strength (POAS) measurements of the concrete substrate, where POAS values within the acceptable range indicate sound substrate concrete; (b) assessment of CSP (Note 1); (c) determination of depth-wise chloride contents (if possible) by taking small cores from substructure concrete (Note 2); and (d) assessment by visual observation and POAS measurements of the effect of weathering caused by UV rays (sunlight) and rain on the substrate concrete-poor POAS measurements are an indication of high weathering effect on substrate concrete.
- Old construction (with previously applied coating/sealer products): Perform concrete substrate inspection through (a) POAS measurements of the old existing coating (in case of previously applied coating product) with the concrete substrate; (b) assessment of CSP (Note 1); (c) determination of depth-wise chloride contents (if possible) by taking small cores from substructure concrete (Note 2); (d) depth of penetration (DOP) measurement (in case of previously applied sealer product); and (e) assessment by POAS measurements of the effect of weathering caused by UV rays and rain on the previously applied coating products.

Note 1: The role of CSP in a concrete substrate to achieve optimum POAS is not known. The product data sheets recommend CSP 1–3 in general, which does not address the CSP of field concrete substrate. Sometimes, field CSP can be more than 3 (e.g., after abrasive blasting or other types of blasting methods), and it is important to know if a relatively higher CSP (i.e., > 3) can have any detrimental effects on achieving optimum POAS. The applicability of any suitable device to measure surface roughness directly may be more effective than the estimation of CSP (qualitative approach), which needs further testing to check if this method provides acceptable results.

Note 2: Chloride analysis at different depths should be useful for understanding the status of corrosion potential before applying any product if corrosion protection is the main purpose of product application. The available data (if maintained by TxDOT on selective projects) on depth-wise chloride contents will be very useful in selecting projects with low, medium, and high corrosion potential. If the chloride data are not available, depth-wise chloride contents can be determined using small core samples. The guidelines for product selection based on the ranking system developed by the lab protocol and the degree of field corrosion potential can be effectively developed.

A3 Product selection:

A suitable product needs to be selected for its effectiveness in the laboratory from the list of products that have already been assessed (Chapter 3). A total of eight products were evaluated using a good quality (i.e., low w/cm [0.42], low permeability with denser microstructure) substrate concrete (Type C concrete, TxDOT Item 421) in this project to develop the lab test protocol (Chapter 3). Lab evaluation using a good quality substrate concrete closely resembles newly made substructure concrete protection through the application of coatings/sealers. Higher degrees of weathering under environmental exposure conditions with high severity and/or some mix design deficiencies (e.g., relatively poor transport properties due to the use of relatively higher w/cm) can sometimes lead to the creation of a relatively poor substructure concrete. Therefore, product evaluation using freshly made good quality substrate concrete doesn't represent relatively poor substructure concrete in the field. Although the data using a good quality concrete substrate were useful to do a comparative assessment (develop ranking) of tested coating/sealer products, rapid evaluation of the corrosion protection effectiveness of the products was not satisfactory. Further work using poor concrete substrate (concrete made with a high w/c ratio) is recommended, which should be useful for rapid and comprehensive product evaluation (especially chloride protection effectiveness) and improving the ranking system of the products. It is expected that corrosion protection evaluation using this kind of poor substrate concrete can be considered standard practice in the specification.

Based on the evaluation of eight products, the ranking system using five performance indicators (e.g., POAS, sorptivity, RCPT, chloride ponding, and corrosion rate measurements by the accelerated test) compared well with the ranking system using three performance indicators (e.g., POAS, sorptivity, and RCPT).

Once the lab testing protocol using a standard substrate concrete (representative of relatively poor substructure concrete) and the ranking system are finalized through the above mentioned work, evaluating more products (all potential products that TxDOT is currently using plus new potential products) is recommended to validate the applicability of the testing protocol and ranking system and generate an extensive database. The above comprehensive evaluation using several products will be useful to validate the acceptability of the ranking system based on three performance indicators instead of five, which saves time for future evaluation. This kind of database, with an in-built ranking system based on a one-time comprehensive evaluation, can be used to select products depending on project requirements in the future. The product ranking in the extensive database will be used to choose products depending on the condition assessment results (mainly corrosion potential) for a project. An example of product selection guidelines based on product evaluation so far (a total of eight products) is provided in Table 1. Life-cycle cost analysis also needs to be considered to make the product selection robust and effective. However, for new products (new formulations or ones never used in field projects before), evaluation based on the developed lab testing protocol followed by determining ranking is mandatory. It is expected that selecting the best-performing products—by the above product selection guidelines—in a new project will extend service life, be economical (reapplication will be minimal), and offer sustainable options (less consumption of material and waste generation if reapplication is minimal).

Table 1: Example of product selection using applicable selection criteria

Potential	Coatings	Sealers	Life-cycle cost analysis
Application	Easy to apply on vertical surfaces by maintaining proper WFT/DFT and coverage	It can be effectively applied on vertical surfaces by maintaining proper coverage/DOP	Not yet attempted
High corrosion potential	Coat-M(SB), Coat-R(SB)	Sealer-40%, Sealer-100%	
Medium corrosion potential	Coat-D(SB), Coat-L(WB)	—	
Low corrosion potential	Coat-A(WB), Coat-S(WB)	—	

Note: The degree of corrosion potential (low, medium, high) can be assessed through depth-wise chloride content measurements using small cores or the application of suitable non-destructive techniques (NDT).

A4 Surface preparation:

Based on limited field studies, the following guidelines for selecting appropriate surface preparation methods are recommended:

- For a newly constructed structure, water-blasting is recommended to remove dust and laitance.
- For old construction with and without any previously applied coating, the guidelines for selecting a suitable surface preparation method in Table 2 can be used.

Table 2: Recommendation on surface preparation based on visual inspection and POAS measurements

Surface preparation	Old construction (without any previously applied coating)	Old construction (with previously applied coating)
Water-blasting should be adequate (minimizes cost, effort, and environmental impact compared to sandblasting)	If the POAS measurements directly on the concrete substrate are within the acceptable range	If the POAS measurements of the old coating are within the acceptable range
The use of abrasive blasting or any kind of suitable blasting method (for complete removal of the old coating ± topmost portion of the substrate concrete) should be recommended	If the POAS measurements directly on the concrete substrate are << the acceptable range	If the representative POAS measurements of the old coating are << the acceptable range and the concrete below the coating is weaker due to weathering

The above guidelines on surface preparation are preliminary. More field evaluation covering different products in different bridges is needed to validate the above guidelines Table 2.

A5 Concrete substrate condition:

Before the application of coating/sealer, the substrate concrete surface should be assessed for the following:

- Measure concrete surface moisture content (CSMC) by using a portable moisture meter (Note 3).
- Ensure the concrete substrate is clean and dry, as per the product datasheet.
- Estimate concrete surface roughness in terms of assigning a CSP value, as per the ICRI guidelines (Note 4).

Note 3: Concrete substrate surfaces should be free from moisture, as per the ICRI guidelines. However, guidelines on assessing CSMC and providing recommendations on optimum CSMC and the time needed in hours to achieve that CSMC do not exist. A moisture meter was found to be effective in monitoring CSMC before applying coating/sealer products. Further research is recommended to evaluate the impact of substrate moisture conditions (low to high moisture) on the performance of sealer and coating products.

Note 4: After surface preparation (sandblasting), the CSP value may change from the initial surface roughness. The final CSP value should be matched with the selected product datasheet.

Further, more field evaluation covering different products in different bridges is needed to validate the above guideline.

A6 Application of coating/sealer materials:

The guidelines for application of coating/sealer products are provided below:

- Coating (spray pump, roller, brush):
  - Hand roller (for small-scale application).
  - Spray pump (for large-scale application).
  - Other applications should be based on the product datasheet.
  - WFT and coverage need to be defined and maintained properly (Note 5).
  - Select a one-coat or two-coat application based on the project requirements.
- Sealer (small spray pump):
  - A small spray pump can be used.
  - Other applications should be based on the product datasheet.
  - Coverage or rate of application needs to be defined and maintained properly.

Note 5: A guideline on maintaining the required WFT along with the conventional practice of maintaining specified coverage (sq ft/gal) should be developed to ensure an effective application. Monitoring WFT with the corresponding specified coverage rate and linking with key performance measurements (e.g., monitoring POAS and others) in several field projects is recommended to develop WFT-based guidelines.

A7 Measure/assessment of the proper application of coating/sealer materials:

For coating materials, DFT can be measured by the NDT-based method (DFT gauge, Note 6) or direct measurement (stereo microscopic method using a small core). For sealer materials, the DOP can be checked (examining a small core under a stereo microscope, Note 7).

Note 6: Effective application of different coating materials can be assessed by measuring the DFT using a portable dry film thickness-measuring gauge. The direct measurement of coating thickness by a stereo microscope using a small cut specimen of the concrete substrate with an attached coated layer was found to be useful for validating the gauge-based DFT measurements. Monitoring DFT with the corresponding specified coverage rate and linking with key performance measurements (e.g., monitoring POAS with WFT/DFT and others) in several field projects is recommended to develop DFT-based guidelines.

Note 7: For sealer material, the DOP test using a stereo microscope was found to be effective. More lab testing is in progress to check the effectiveness of this method. Once the effectiveness is verified in the lab, monitoring DOP in several sealer projects is necessary to check the validity of this method.

Further, more field evaluation covering different products in different bridges is needed to validate the above guideline.

A8 Performance assessment in the field:

Performance assessment for coating through POAS measurements over time.

- If the reduction of POAS value over time (in years) is less, the coating should work well for a longer period, and reapplication with a longer interval (e.g., 10–15 years) can be recommended.
- If the rate of reduction in POAS is significant over time compared to the initial adhesion strength, reapplication with a shorter interval (within 5 years) can be suggested.

Other NDT-based assessments (e.g., corrosion monitoring).

Note 8: Based on the POAS measurements on both vertical and horizontal surfaces in the lab, POAS on the horizontal concrete substrate was slightly higher than on the vertical surface. This result is a limitation of the test itself and should not be considered as a reduction of POAS in the field with vertical surfaces. A certain percentage reduction (which needs to be evaluated through further testing) needs to be assigned for each product based on a one-time lab versus field POAS assessment study.

Note 9: POAS may vary based on the CSP value of the concrete substrate. After abrasive blasting, the CSP value can be 3–4, and POAS on such substrates may differ from POAS on CSP 1–2. More field evaluation coverage is needed to evaluate this aspect further by considering field conditions.