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Highway Bridges: Painting and Deck Construction

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Highway Bridges: Painting and Deck Construction

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Highway Bridge Painting

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Long life, moderate maintenance, and attractive appearance of structural steel highway bridges can all be enhanced by reference to a checklist of basic principles. Although little or no painting of structures may be required in a hot, dry, rural atmosphere, a carefully designed coating system is necessary where moisture, de-icing salts, and industrial or automotive contaminants are present in abnormal amounts. Even in these latter cases, however, economical protection can readily be obtained through use of the wider choice of materials and methods now available, including designs free of moisture-collecting crevices, pockets, or unprotected areas; more rapid and economical sandblasting and other methods for surface preparation in shop, field, or maintenance practice; chemical pretreatments where special corrosion resistance is required; primers and topcoats based on the tried and true oil-base vehicles and on field-proven newer vehicles and pigmentations, consistent with the type of surface preparation and service environment; better or cheaper methods of application, inspection, and maintenance painting at regular intervals.

The checklist of things to avoid includes painting over dirt, loose rust, grease, or loose millscale; use of short-oil quick-drying primers over rusty hand-cleaned steel; too-long interval between priming and top-coating of phenolic paint systems; designs which bring drippings from concrete or from de-icing salt into prolonged contact with inadequately protected surfaces.

For the highway engineer to make best use of continually improving materials and methods, it is first necessary that there be better dissemination of known information and the development of simpler and better specifications. In addition there should be continual impartial evaluation of new products and the study of special problems, such as painting of welded bridges, protection of hand-cleaned (or rusty) steel, comparison of field versus shop priming, evaluation of brine-resistant paints, comparison of alternate application methods, and study of application under adverse humidity-temperature conditions. This kind of program will make both structural steel and protective coatings still more versatile for highway construction and maintenance.

●FOR MANY highway engineers, the painting of steel structures represents an important but very specialized field to which they can devote only a limited amount of time and study. The purpose of this paper, therefore, is to summarize some of the more important steel painting information presently available, and to suggest where further information can be obtained.

The most important considerations in the painting of highway bridges are: 1. Recognition of the environment of the structure; 2. Influence of the bridge design upon corrosion and painting; 3. Choice of the surface preparation; 4. Application methods; 5. Choice of the coating system itself. These factors apply both to the original shop and field painting and to maintenance painting. Each of these factors will be discussed briefly, much of the material being taken from the Steel Structures Painting Manual (1, 2) which is widely used as a reference in structural steel painting problems. This Manual is organized, cross-referenced and indexed in such a way that it can be used by one who is unfamiliar with the Manual and even with painting technology. Examples will also be taken from the current research and testing programs and reports of the Steel Structures Painting Council. Many of the cases involving railroad bridges are directly applicable to highway bridges. It is hoped, however, that in our future program more highway bridges can be included.

ENVIRONMENT

The first step in considering any paint problem is recognition of whether the structure will be exposed in a rural, industrial or marine atmosphere or whether it will be exposed to a special condition, such as brine salt, fumes, abrasion, soil, moisture, blast or the like. The environment may vary radically from one part of a highway bridge to another and may therefore require more than one paint system, particularly on the prime coat. For example, the steel piling may be under the water while the understructure is splashed by waves and the superstructure is exposed to the atmosphere only. It has also been shown repeatedly that the parts of the structures subjected to frequent salt drippings ordinarily require much more careful maintenance than those which are exposed to the atmosphere only.

Most bridges are subject to high humidity or fumes. The highway bridge may present a different problem from the railroad bridge, but the similarities are greater than the differences. Appearance is more of a factor on highway bridges and the color may be selected to harmonize with topographic features, to provide a two-tone effect or to be as obvious as possible for safety reasons.

In the selection of a paint system for a specified application the Painting Manual lists 9 principal classifications. For each of these, a description is given in Volume 2 of the surface preparation covered, the recommended paints and paint system for this application, and comments on the advantages and limitations of each primer recommended. The 9 classifications are as follows:

1. Dry interiors;
2. Normally dry but exposed to the weather;
3. Frequently wet or exposed to high humidity;
4. Continuously wet or immersed in fresh water;
5. Hand-cleaned steel immersed or exposed to condensation;
6. Continuously wet or immersed in salt water;
7. Underground;
8. Rust-proofed;
9. Chemical exposure.

In addition, separate cross-referencing is shown for cases where special properties are required, such as abrasion resistance, anti-sweat properties, anti-fouling, use over galvanized metals, high surface temperature, linings, etc. The alphabetical index lists recommendations for about 400 different kinds of surfaces and structures.

Chloride salts, often used on the highways for de-icing, are also used by the railroads in most refrigerator cars. Here the continually melting ice results in spraying corrosive brine along the railroad right-of-way. A wide variety of coatings having the necessary brine resistance is now available.

In a different approach to the problem, work done by the Association of American Railroads (10) and the Armour Research Foundation has shown that it is possible to reduce greatly the corrosiveness of railroad brines (or de-icing salts) by adding small amounts of chromates or phosphates directly to the salt. The use of such inhibitors adds substantially to the cost of the salt, however, and has not been adopted by the railroads or generally by most public authorities.

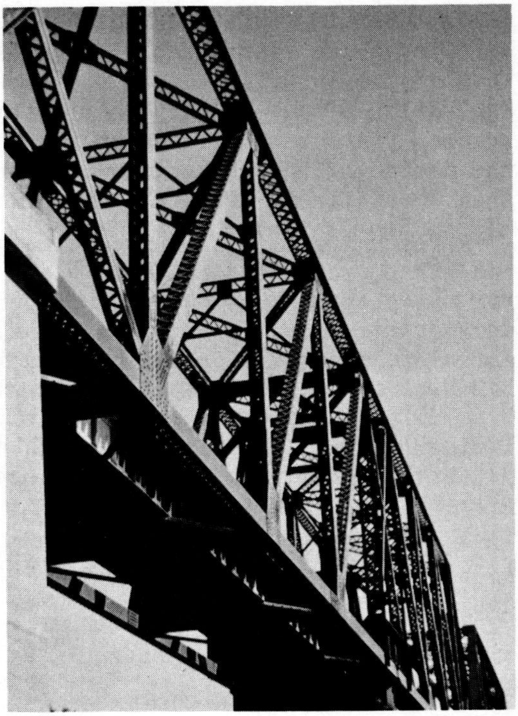

Figure 1. One of the through truss span test bridges (sand-blasted) near St. Louis for evaluation of brine-resistant paints.

Several years ago a test was undertaken on 2 bridges of the Missouri Pacific Railroad near St. Louis for the specific purpose of evaluating synthetic brine-resistant coatings which could be applied over sandblasted or over wirebrushed surfaces. Figure 1 shows one of the bridges on which many alternative paint systems were tested. Subsequent to this a similar test was undertaken on the Seaboard Airline Railway over 2 bridges in the southeastern U. S., both of which were hand-cleaned (Fig. 2). After several years' experience with these 2 tests it was concluded that a wide variety of coatings provides successful protection over sandblasted surfaces. Even over a hand-cleaned surface, good protection can be obtained if the systems are carefully retouched every few years. A report on the Missouri Pacific work is being published this month in the annual bulletin of the American Railway Engineering Association.

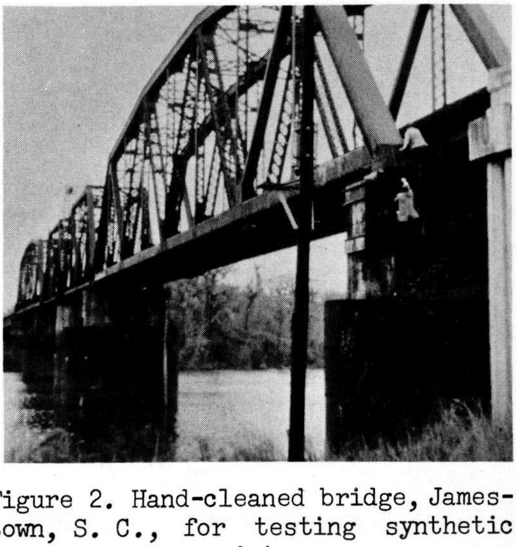

Figure 2. Hand-cleaned bridge, Jamestown, S. C., for testing synthetic paints.

Where severe environmental factors such as brine drippings are not present, many years of maintenance-free service can be obtained with less expensive materials applied over hand-cleaned surfaces. This is illustrated (Fig. 3) by the test being conducted on 3 bridges of the Santa Fe Railway near Kansas City in which several proprietary paints are being evaluated. Over the past 7 years even the less durable types of coatings have been effective. Retouching at intervals up to 10 years should be adequate on such surfaces. Evaluation of proprietary coatings is also being followed over the past several years on 2 bridges on the Southern Railway System. Depending upon the design of the bridge itself, it is possible to test from 1 to more than 30 different coating systems on a comparable basis.

Tests are also used to evaluate the performance of paint, metallizing and other protective coatings under specialized environmental conditions. For example, the top portions of bridges which support either a concrete deck or timber railway ties are sometimes subjected to a combination of abrasion, condensation and brine drippings. An expensive test was undertaken on a Chicago Great Western bridge (Fig. 4) this year, in which more than 20 protective systems were evaluated, including adhesive tapes, metallizing, vinyls, Neoprene, chlorinated rubber, epoxies and other resistant materials. To a considerable extent the results of this test should be applicable to highway bridges.

These tests also illustrate dramatically that the life of the paint system is affected by the amount of sheltering of the surface and by the details of design.

TABLE 1

YEARS TO FAILURE OF PAINT FILMS ON STEEL IN MARINE ATMOSPHERE
EFFECT OF COPPER CONTENT

Steel	Surface Condition	Primer Pigment Red Lead[a]	 Zinc Chromate[b]
High strength Low alloy[d]	Hot-rolled	6.5	c
C1020 Cu (struct. copper)	" "	5.0	5.0
C1020 (struct. carbon)	" "	4.0	4.0
High strength Low alloy[d]	Cold-reduced	c	c
C1005 Cu (copper)	" "	c	c
C1005 (carbon)	" "	c	c

[a] TTP86aI.

[b] Similar to SSPC-Paint 11-55T.

[c] Paint film unbroken after 8 years.

[d] Cor-Ten.

DESIGN

Proper protection of steel structures begins with the design of the structure. Some features which should be eliminated are crevices which can neither be protected nor sealed off; pockets on bolted joints, channels, flat surfaces and the like where moisture cannot drain properly; and steel in contact with concrete surfaces in such a way that a firm bond cannot be obtained.

An increasingly large number of modern highway bridges employ large amounts of welding in their fabrication or erection. Figure 5 shows a few typical welded highway bridge structures. In order to determine the factors necessary for good paint performance over welds, a comprehensive study was undertaken by the Council, in which more than 1,100 welded specimens were prepared with various combinations of welding rods, surface preparation, primer paints, and special pretreatment (Fig. 6). N. Morgan of the Bureau of Public Roads is chairman of the subcommittee on this study. After 2 years of exposure, the factors which lead to good paint performance over welds have been determined and are soon to become the subject of a separate report. Good painting is obtained if any one of several steps is taken. First, welds made with some electrodes require no special treatment. Second, all weld slag and other residues should be removed from the weld area by sandblasting or by power wirebrushing, if practicable. If not, any one of a number of simple surface treatments, such as washing with dilute chromic or phosphoric acids followed by a water rinse, should be used. Surprisingly, washing with plain water is very effective over welds which have not been properly cleaned. The method of paint application appears to have little effect, but there are differences in the performance of various primers. It is indicated that the occasional difficulties encountered in painting over welds are largely due to failure to remove small amounts of alkaline slag deposits caused by the electrode coating.

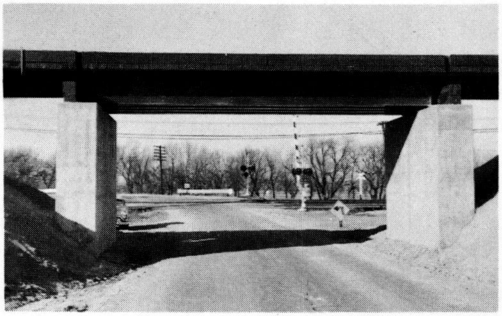

Figure 3. Proprietary paints in relatively sheltered location on rolled beam deck spans. (One of 3 test bridges near Kansas City.)

The designer should avoid placing a steel-concrete interface at an area, such as an expansion joint, where relative motion will occur between the concrete and steel, especially when moisture or condensation will be present.

To date, it has not usually been economically feasible to help solve the bridge painting problem by the use of corrosion-resistant alloys in place of the usual carbon structural steel. For some time it has been known, however, that the presence of small amounts of copper (for example, 0.2 percent) greatly reduced the corrosion rate of the bare metal. More recently it is indicated that at least in some environments, this small amount of copper in the base steel also lengthens the life of the protective coating film applied to it. Table 1 shows this effect of copper content upon the life (2 percent of film ruptured) of 2 types of structural steel primers. It also shows that both the red lead and the zinc chromate

TABLE 2

SURFACE PREPARATION SPECIFICATIONS

Specification	Subject	Contents
SSPC-SP 1-52T	Solvent cleaning	Solvent wiping, immersion, end spraying; vapor degreasing; alkaline, emulsion, and steam cleaning; paint stripping.
SSPC-SP 2-52T	Hand cleaning	Hand chipping, scraping, sanding, and wirebrushing.
SSPC-SP 3-52T	Power tool cleaning	Power tool chipping, descaling, sanding, wirebrushing, and grinding.
SSPC-SP 4-52T	Flame cleaning of new steel	Flame dehydrating and cleaning followed by wirebrushing.
SSPC-SP 5-52T	Blast cleaning to "white" metal	Nozzle (dry, wet, or vapor) or centrifugal blast cleaning using sand, synthetic abrasives, crushed iron or steel grit and shot.
SSPC-SP 6-52T	Commercial blast cleaning	Blast cleaning with removal of rust and millscale only to degree specified.
SSPC-SP 7-52T	Brush-off blast cleaning	Blast cleaning with removal of considerably less rust and millscale.
SSPC-SP 8-52T	Pickling	Sulfuric, hydrochloric, and phosphoric acid pickling; duplex pickling and electrolytic pickling.
SSPC-SP 9-52T	Weathering	Exposure to weather to remove millscale by rusting. Must be followed by other cleaning methods. Commercial blast cleaning recommended.

primers lasted considerably longer over the high-strength low-alloy steel than they did on the C1020 structural carbon steel having less copper (9).

SURFACE PREPARATION

Table 2 shows the standard surface preparation specifications. These are, of course, described in considerable detail in the Steel Structures Painting Manual (2), and in a previous paper to the Highway Research Board by Bigos (4). The first specification, solvent cleaning, removes oil, grease, dirt and soil, salts and residues of contaminants, but does not remove millscale. Hand cleaning removes rust, millscale and paint that are loose, whereas power tool cleaning removes these along with a portion of the more adherent millscale, rust and paint. Flame cleaning tends to remove some of the tight millscale and to dehydrate the surface before painting. Blast cleaning to white metal completely removes all rust, millscale and foreign matter, whereas the commercial blast cleaning may leave slight residues of tight millscale and rust. With brush-off blast cleaning, considerable residues of tight millscale and rust are tolerable. Pickling, if properly done, removes rust and millscale completely, and in some operations also passivates the surface. Council specification SSPC-SP9-52T "Weathering," is a procedure in which millscale is removed by allowing the steel to rust before being cleaned and painted. It is recommended that weathering be followed by commercial blast cleaning.

Hand cleaning is usually most economical for small areas where power is not available or where the setup time is excessive. Cleaning in most other cases with a sandblast or power tool not only does a much better job, but is also less expensive.

A number of the current SSPC field investigations are concerned with the effect of variations in surface preparation upon primer performance. One of these tests, which has just been set out for exposure (Fig. 7), is an effort to determine what paints can give the best protection to inexpensively prepared steel surfaces, even those containing some degree of rust. Each of 60 specification and proprietary paints was applied to 20 specimens including sandblasted steel, adherent millscale, descaled-and-rusty steel, and hand-cleaned specimens with degrees of rust combined with millscale.

In a related, but unusual research project recently reported by the Council before the American Chemical Society, it was shown that ordinary iron rust could be substituted for commercial iron oxide pigment in various primer formulations without injury to durability (Fig. 8).

Two other Council tests involve shipping fabricated steel unpainted, allowing the millscale to weather away partially on the structure before cléaning and priming. It has been found that the millscale can be removed more easily after weathering and that cleaning and priming can then be done just before the usual field painting. This is essentially a comparison between Surface Preparations No. 2 "Hand Cleaning" followed by shop painting in comparison with No. 9 "Weathering" followed by cleaning and field painting. The first such test (Fig. 10) is under way near Breckenridge, Minnesota in which the first 3-deck girder spans have been shop primed and the other 3 spans have been weathered, cleaned and painted. In a similar comparison near Rayland, Ohio, each of 4 different primers has been used over both hand-cleaned and blasted surfaces. Previous work (5) shows that, at least in some environments, weathering results in reduced paint life unless followed by blasting or the equivalent.

Figure 4. Some of the test areas on protection of top flanges, Chicago Great Western Rwy., Byron, Illinois.

APPLICATION METHODS AND PRETREATMENTS

Table 3 outlines the SSPC Pretreatment and Application specifications. Numerous studies have

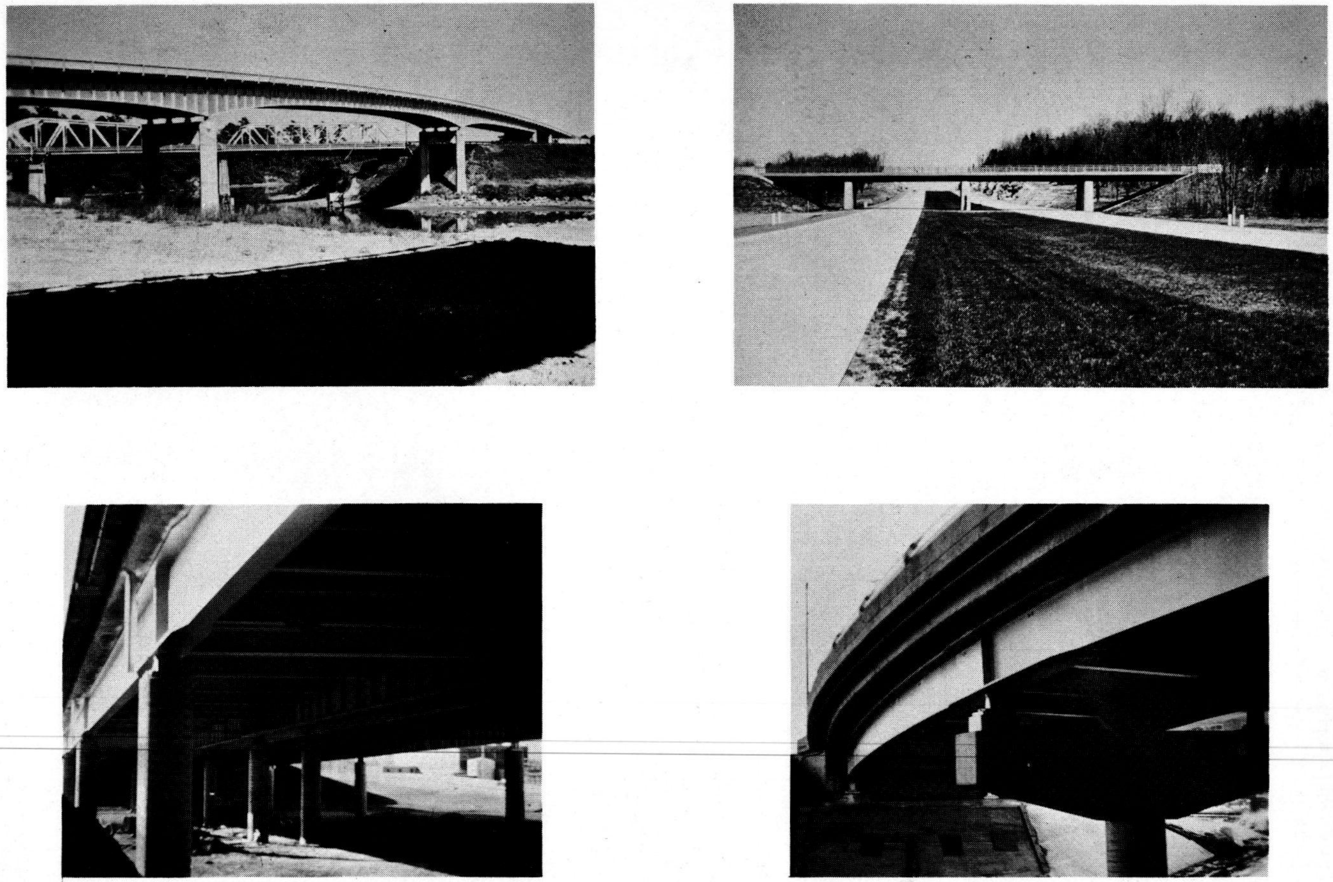

Figure 5. Upper Left: Prize-winning continuous plate girder bridge in Houston. Upper Right: One of several hundred welded bridges on N. Y. Freeway. Lower Photos: Curved plate girders on Kansas Turnpike structures (aluminum topcoat over iron oxide primer). SSPC tests give added assurance of paint performance over such welded structures.

shown that while pretreatments increase the probability of getting a good painting job, an improperly designed surface pretreatment can be worse than nothing. This was illustrated on a test conducted in cooperation with the Association of American Railroads on a New York Central Railway bridge, using a proprietary flush-off type of pretreatment. Other work, however, has shown that proper pretreatment results in more consistent results, especially in severe environments. With unweathered galvanized steel, pretreatment is very important.

TABLE 3

PRETREATMENT AND APPLICATION SPECIFICATION

Specification	Subject	Contents
SSPC-PT 1-53T	Wetting oil treatment	Covers application of wetting oils to surfaces, from which all rust and millscale have not been removed, to improve adhesion and bond of paint.
SSPC-PT 2-53T	Cold phosphate surface treatment	Covers application of phosphoric acid treatments to passivate steel surfaces which have been thoroughly cleaned.
SSPC-PT 3-53T	Basic zinc chromate vinyl butyral washcoat.	Covers application of wash primer to thoroughly cleaned steel; improves adhesion and bond of paint; reduces underfilm corrosion.
SSPC-PT 4-53T	Hot phosphate surface conversion	Covers hot conversion by zinc or iron phosphate solutions to form crystalline surface for improvement of paint bonding and reducing of underfilm corrosion.
SSPC-PA 1-53T	Shop, field, and maintenance painting	Completely covers all phases of paint storage, mixing, thinning, application by brush or spray in shop or field, permissible temperatures and humidities, drying, and protection of painted steel.

There are considerable differences of opinion on the relative merits of application by brush, spray, hot spray, airless hot spray, paint roller, cold airless spray and dip application. With properly formulated paints several spraying methods are used satisfactorily. Some structures have features which are difficult to cover properly by spraying alone, so brush striping or brushing following spraying of these areas is sometimes recommended. Labor costs are reduced by cold spraying and still further by hot spraying or airless cold spray. Hot spray also claims advantages in savings of thinner, reduced overspray and heavier films, but requires a proper formulation to avoid trapping of solvents or dry spray. The Council is undertaking a special project in which the various methods will be compared.

No matter which method of paint application is used, proper care is necessary in order to be sure that the paint is not under- or overthinned,

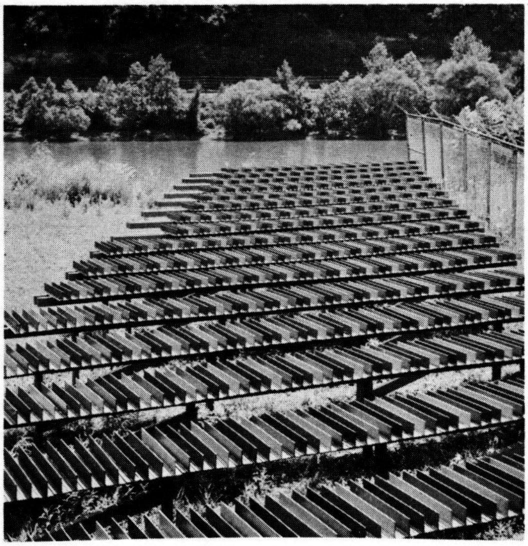

Figure 6. Test panels for determining best methods for painting of welds. (Neville Island, Pittsburgh, Pennsylvania.)

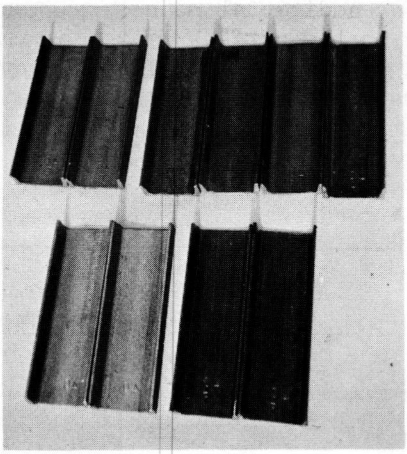

Figure 7. Hand-cleaned channel irons for testing paints on rusty steel. Two are sand-blasted; two have new adherent millscale; two are sand-blasted and rusted; four have combined rust and millscale. 120 such sets are exposed.

that no holidays or gaps are left in the film, and, most important, that the proper film thickness is applied uniformly.

Painting is preferably not applied at ambient temperatures below 40 F for several reasons: (1) possibility of condensed moisture or frost on surfaces; (2) thick viscosity requiring excessive thinning; and (3) slowness of drying. Upper application temperature limits are not set. Painting on dew-covered surfaces, particularly on the shaded side of a structure in the morning, is to be avoided. Further work is indicated to determine what upper limit, if any, should be set on humidity during painting.

Safety requirements are listed in each specification and provide a valuable checklist of precautions against toxic materials, flash fires, and the like.

PRIMERS AND PAINT SYSTEMS

A summary of the SSPC specification primers is listed in Table 4. Table 5 is a list of the SSPC paint systems, which include recommended combinations of surface preparation, pretreatment, primers, intermediate and top coats. The paint systems provide a very wide choice of primers suitable for individual requirements. In Table 5, however, only one of the alternatives is listed for each system.

Paint systems are applied to structural steel for both protection and appearance. The theory of corrosion and its prevention, described in Volume 1 of the Council's Painting Manual, will not be repeated here. Briefly, for corrosion of steel to take place, both oxygen and moisture must be present, together with minute electrical potential differences which are usually present in the surfaces themselves. Protective coatings may prevent corrosion by setting up a partial barrier to the passage of moisture and oxygen; usually, however, they also protect by one or more of the following additional means: pigmentation to set up a corrosion-inhibiting film on the metal surface; sacrificial pigments (such as zinc) which are used up electrolytically as they protect the steel; electrically insulating films; films resistant to oxidation and chemicals.

TABLE 4

SSPC PRIMERS

Primer	Pigment	Approx. Pigment (% by Wt.)	Vehicle Solids	Approximate Set to Touch (hr)	Dry through (hr)	Minimum Surface Prep. Recommended
SSPC-Paint 1-55T	Red lead 100%	77.5	Raw linseed oil	6	72	Hand cleaning
SSPC-Paint 2-55T	Red lead 75% Iron oxide 25%	75	Raw linseed oil (2 parts) Alkyd varnish (1 part)	4	24	Hand cleaning
SSPC-Paint 3-55T	Red lead 75% Iron oxide 25%	75	Fractionated linseed oil		24	Hand cleaning
SSPC-Paint 4-55T	Red lead 75% Extender 25%	63	Raw linseed & Bodied linseed oil		24	Hand cleaning
SSPC-Paint 5-55T	Zinc dust 80% Zinc oxide 20%	75	Phenolic varnish	2	6	Blast cleaning or pickling
SSPC-Paint 6-55T	Iron oxide 67% Red lead 24% Extender 9%	60	Phenolic varnish	4	12	Blast cleaning or pickling
SSPC-Paint 7-55T	Zinc dust 50% Zinc oxide 20% Iron oxide 30%	63	Phenolic varnish	2	6	Blast cleaning or pickling
SSPC-Paint 8-55T	Aluminum 100%	6.7	Vinyl	1/4	1	Blast cleaning
SSPC-Paint 9-55T	Titanium dioxide 100%	12	Vinyl	1/4	1/2	Blast cleaning
SSPC-Paint 10-55T	Zinc yellow 35% Red lead 2.5% Iron oxide 30% Extenders 32.5%	43	Phenolic varnish	4	20	Hand cleaning
SSPC-Paint 11-55T	Iron oxide 40% Zinc yellow 40% Extender 20%	50	Raw linseed oil Alkyd varnish (equal pts.)	6	24	Hand cleaning
SSPC-Paint 12-55T	Inorganic filler		Asphalts	4	72	Blast cleaning
SSPC-Paint 13-55T	Iron oxide 60% Red lead 12% Zinc yellow 3% Mg. silicate 25%	55.5	Tung oil ester gum varnish Raw & bodied linseed oil	4	8	Nominal

In each instance, however, a firm bond must be obtained between the metal and the coating. If the metal is at all rusty the paint vehicle is required to have a high degree of wetting ability, such as that obtainable by raw linseed oil. Unfortunately, many of the best wetting vehicles do not have outstanding moisture resistance or chemical durability. For this reason, various types of treated oils and oil-synthetic vehicle combinations have been used as compromises. In addition, it may also be possible to combine the wettability of oil base paints with the durability of synthetics by the use of an additive to the synthetic paint. To date, no spectacular results have been noted through the use of additives, but the Council is following the evaluation of several of these in the hopes that such a combination will be obtained. A test involving several hundred fabricated panels, with rivets, welds and crevices, has been set up (Fig. 9) specifically to evaluate the effect of additives in phenolics, alkyds, epoxies and other synthetic types of paint. These tests have not been under way long enough for conclusive results to be obtained. Another test being followed by the Council involves painting of a large Crane Runway in Pittsburgh to evaluate the effect of a wetting oil type of pretreatment. To date, no advantage is apparent as compared with the use of a prime coat in place of the pretreatment.

A fast-drying, poor-wetting synthetic paint should not be used over a poorly cleaned steel surface. Such a poor combination can easily be avoided, either by specifying thorough surface preparation (with inspection) or by specifying, as a second best, a raw linseed oil-based paint with inhibitive pigment applied over hand-cleaned steel.

Another combination to be avoided is the use of a hard-surface phenolic primer with too long an interval between the application of the first and second coats. The Manual recommends addition of cellosolve or the equivalent to the delayed coat, especially for water immersion application.

Figure 8. Exposure of 16 paints in which rust was substituted for commercial iron oxide.

REPAINTING PRACTICE

Spring is the customary time for the annual inspection of highway bridges. At this time the effect of ice, de-icing salts and other winter damage can be assessed in time for repairs and painting the following summer. Special attention should be given to points subject to dampness, condensation and drainage, and in particular to rivet heads or points adjacent to masonry.

Table 6 is a very general guide to a decision on whether to touch up, completely repaint, or otherwise repair the painted surface. This decision also depends on how the surface was originally prepared. If the primer is of a contrasting color with the topcoat, as it should be, incipient failures become more apparent. It is poor economy to let the paint deteriorate to a point where

TABLE 5

TYPICAL SSPC PAINT SYSTEM ALTERNATIVES

SSPC PS	Paint System	Minimum Surface Prep. Recommended	Pre-Trmt	Primer (Alternate)	Second Coat (Alternate)	Third Coat (Alternate)
1	Oil base	Hand Cleaning	None	SSPC-Paint 1-55T;	SSPC-Paint 1-55T;	Standard Aluminum
2	Alkyd	Blast Cleaning or Pickling	None	TT-P-86a Type III	TT-P-86a Type III	Aluminum Alkyd
3	Phenolic	Blast Cleaning or Pickling	None	TT-P-86A Type IV	TT-P-86a Type IV	Aluminum Phenolic
4	Vinyl	Blast Cleaning or Pickling	Wash Primer	MIL-P-15929 A	MIL-P-15929 A	SSPC-Paint 8-55T
5	For hand-cleaned water immersion	Hand Cleaning	None	SSPC-Paint 10-55T	SSPC-Paint 10-55T	Aluminum Phenolic
6	For vessels	Blast Cleaning or Pickling	None	USMA 52 MA-401a Type 1 Fourth Coat:	USMA 52 MA-401a Type II (USMA 52 MA-403a, Antifouling)	USMA 52 MA-401a I
7	For mild exposure	Hand Cleaning	None	SSPC-Paint 13-55T	None	None
8	Rust preventives	Unpainted surfaces requiring protection	None	USMA 52 MA-602a Type B (Rustproofing Compound)	None	None
9	Bituminous	Blast Cleaning or Pickling	None	SSPC-Paint 12-55T	None	None

TABLE 6

ROUGH GUIDE FOR REPAINTING

Degree of Rusting or Area Exposed	Cleaning and Painting Recommended
No rusting	Solvent clean if necessary. Apply 1 or 2 coats of finish paint, depending upon conditions.
Slight rusting in localized areas	Spot clean and spot prime. Apply 1 or 2 over-all coats of finish paint as necessary.
25% to 50% rusting in localized areas	Spot clean and spot prime. Apply 1 over-all coat of priming paint, and 1 or 2 coats of finish paint as necessary.
Over 50%	Remove as much old paint as is practical. Apply 2 priming coats and 1 finish coat, or 1 priming coat and 2 finish coats as necessary.
Where there is large area of sound adhering paint, which is not too thick to be detrimental	Spot clean bad areas. Apply enough coats of rust inhibitive primer over these areas to build them up to a satisfactory level, then 1 or 2 over-all finish coats.

Figure 9. Testing additives to synthetic resin paints—designed to combine wetting with durability. Fabricated panels have rivets, crevices and welds.

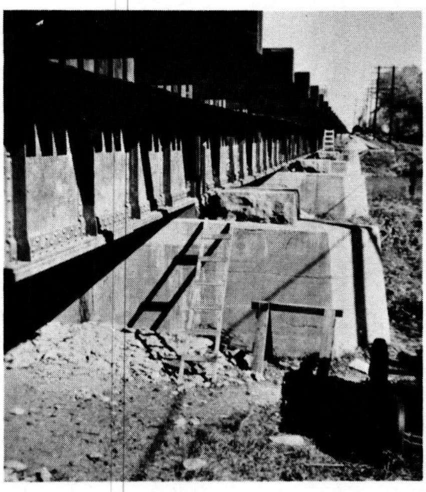

Figure 10. Three spans of this deck girder bridge were shop primed. The other three were weathered nine months before being cleaned and painted.

rust shows at all, or particularly, as shown in Figure 11, to a point where extensive surface preparation is required. Due to the high cost of surface preparation, the total cost of repainting in such a case in terms of dollars per sq ft here is invariably higher than if painting is carried out at more timely intervals.

TABLE 7

TABLE OF CONTENTS, VOL. 1
STEEL STRUCTURES PAINTING MANUAL

Chapter	Title		Author
1	Simplified Theory of Corrosion		F. N. Speller
2	Mechanical Surface Preparation		A. J. Liebman
3	Chemical Surface Preparation		F. P. Spruance, Jr.
4	Practical Aspects, Use, and Application of Paints		A. J. Eickhoff and J. Bigos
5	Inspection		F. W. Shanks and J. L. Rohwedder
6	Quality Control of Paints		J. B. Garner
7	Comparative Costs		L. Adams
8	Shop Painting of Steel in Fabricating Plants		J. Jones and J. Bigos
9	Painting of Railroad Bridges and Structures		M. A. Roose
10	Painting of Highway Bridges and Structures		E. L. Erickson and N. W. Morgan
11	The Painting of Steel Vessels for Salt Water Service		R. P. Devoluy
12	The Painting of Steel Vessels for Fresh Water Service		A. J. Liebman
13	The Painting of Steel Tanks		J. O. Jackson
14	Painting of Steel in Hydraulic Structures		R. F. Blanks and G. E. Burnett
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	Section I.	Water and Sewage Works Structures	W. T. McClenahan
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STEEL STRUCTURES PAINTING MANUAL

This Manual consists of 2 volumes, the first of which is a practical encyclopedia of economical and satisfactory painting methods. Some idea of the scope of this volume can be obtained from Table 7, which shows a condensed Table of Contents. Volume 1 contains a separate chapter on the painting of highway structures, including the factors involved in various environments, types of structures, labor considerations, paint life expectancy obtained, etc. Volume 2 has been discussed. It includes the paint systems which give good results in various applications as well as an indexed guide to the selection of suitable systems for various types of structures and exposure conditions. It contains detailed specifications which have been widely adopted throughout the world for surface preparation, pretreatment, paint application, paint formulations and paint systems. For contract purposes the individual specifications may be referred to SSPC number only, or they may be included in whole or in part in the over-all construction specifications. They are also well integrated with AASHO specifications.

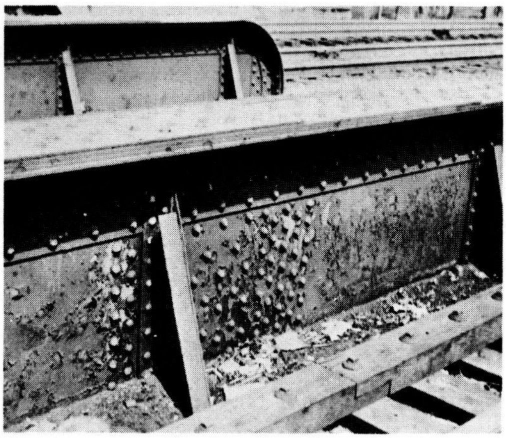

Figure 11. Painting has been deferred too long on this through girder for most economical maintenance painting.

CONCLUSION

A knowledge of the best materials and methods presently available for painting of steel structures, as presented, for example, in the Steel Structures Painting Manual, can contribute much to the appearance, life and low maintenance of highway bridges. In addition, however, it is mandatory that improved specifications and new experimental work be continued in order to take advantage of the vast amount of development work by coatings manufacturers and associated industries. Much work of this kind remains to be done.

First, new coatings, products and methods must continually be evaluated. Secondly, special applications such as painting of welds, protection of load-bearing surfaces, salt-resistant finishes, etc., must be investigated. Thirdly, further information is still needed on such basic questions as painting of hand-cleaned steel, protection of millscaled or rusty surfaces, economics of maintenance painting and durability versus application method.

Most of the structural steel painting studies carried out by the Council in cooperation with other industries are equally applicable to highway bridge painting. Continued cooperation, therefore, between highway engineers and the Council will result in both improved research and better highway structures.

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Smooth-Riding Bridge Decks

NOMER GRAY, Ammann and Whitney, Consulting Engineers

●MODERN HIGHWAYS, particularly those with limited access, encourage travel at high speeds. For safety and comfort these highways require smooth-riding surfaces, finished to small tolerances.

Why is a distinction made between the construction of a concrete bridge deck and construction of concrete pavement on grade? The answer is that the techniques for construction and the problems are very different. Some major differences are:

1. The support yields appreciably with the addition of the concrete load.
2. The methods of controlling the surface during construction are markedly different.
3. The labor situation differs, often producing profound effects.

Each of these factors is examined because the key to smooth-riding decks will lie in their proper handling.

This report is confined to a discussion of bridges with concrete decks supported on steel members because the overwhelming majority of new highway bridges is still of this type and the problems are more serious than for short structural concrete spans. Secondly, only single course pavements in which the structural slab and wearing surface are placed monolithically are considered.

What is desired in attempting to provide a smooth-riding surface? Most specifications for bridge deck finish tolerances use the same requirements as for paving on grade. These generally call for no surface deviation over 1/8 in. from a straight line 10 ft long, although some agencies say 16 ft. While such a requirement is necessary, it is not in itself sufficient.

It is possible to have long waves in a pavement surface that will meet the 1/8 in. in 10-ft criterion and yet cause a sensation of roughness at high driving speeds. For example, if a straight profile grade line approaches an 80-ft span steel bridge and a smooth sagging curve on the bridge with a 2-in. ordinate at midspan of the structure, the specified 1/8-in. deviation in 10-ft requirement is met and yet a pronounced bump results at high speeds (Fig. 1). If the shape of this smooth sag is assumed to be circular, for simplicity, its radius is 4,800 ft. The deviation from any 10-ft chord would be only 1/32 in., which would be scarcely discernible with a 10-ft straight edge.

Is it at all likely that any such sag as 2 in. can occur in an 80-ft span? It can be demonstrated that it can occur, and will, unless some simple precautions are taken, which are not uncommonly overlooked.

The supporting structural steel girders or rolled beams deflect appreciably during deck concreting with the addition of the dead load of concrete because this load is a large part of the load to be carried. In conventional rolled beam design, this deflection for an 80-ft span is of the order of 2 in. at the center of the span and tapers off parabolically to zero at each support. For longer spans, of 200 ft, for example, a corresponding deflection would be 5 to 6 in.

The controls for finishing the concrete surface, such as screed rails mounted on adjustable chairs, are set in position by survey before the concrete is placed and hence some account must be taken of the predicted steel deflection in setting them. The methods of calculating such deflections are well established and their accuracy is generally sufficient for the purpose.

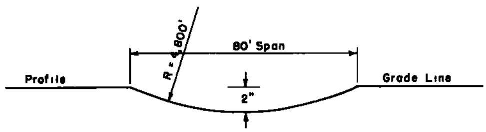

Figure 1. Sag at bridge.

At this point, it is desirable to digress to comment on the confusion occasionally encountered between camber and dead load deflection. Camber diagrams are usually given on the structural steel contract drawings. These show the total vertical curvature specified to be fabricated into the beam or girder to provide for total dead load deflection, plus, occasionally, the vertical curvature of the profile grade line. This camber is not to be confused with the dead load deflection for the concrete only, not even including the reinforcing steel. Such figures are usually obtained from the design office. It is apparent from the figures given that neglect of the concrete dead load deflection must produce an appreciable ripple in the finished riding surface for each span. As a matter of fact, the oscillation described is close to resonance for the spring systems of most passenger cars traveling at approximately 60 mph.

The method of controlling the strike-off of the fresh concrete on bridge decks differs markedly from that used for pavement on grade. At the present time, machine finish is not widely used for bridge decks and may never be warranted for single short span bridges. This means an essentially manual operation with heavy emphasis on the skill and reliability of the cement finishers.

The usual practice is to set screed rails either of tee structural sections or of $1\frac{1}{4}$-in. diameter pipes supported on adjustable metal chairs. The function of the screed rail is to support the screed which strikes off the wet concrete. The screed rails generally lie parallel to the direction of traffic and spaced about one lane width, but preferably so spaced as to place the supporting chairs over a structural member. Needless to say, the spacing of the chairs must be small enough to prevent the rail from sagging under the load of the screed when partly supported by wet concrete.

From time to time there are references to the desirability of detailing the curbs or some element of edge structural steel to serve as a screed rail for the paving. While superficially this sounds like an excellent idea, it has the fatal defect, as will be seen later, that it lacks adjustment to correct for the inevitable improper camber.

The proper setting of the screed rails is a matter of the utmost importance. They are set to calculated grades by surveying methods, and hence are entirely independent of the camber of the supporting structural steel (Fig. 4). The elevations for the screed rail are calculated from the profile grade line, taking account of the transverse roadway slope and the dead load deflection resulting from the concrete load. It must be remembered that the rails are set after the forms and reinforcing steel are in place, but before the concrete has been deposited. This means that the supporting structural steel is carrying its own weight plus that of the forms and reinforcing steel. The table below indicates the proportionate weights the steel must carry, and the corresponding deflections.

LOAD	PROPORTIONATE SHARE	DEFLECTION FOR 80-FT SPAN
Structural steel itself	20 percent	$\frac{1}{2}$ in.
Slab forms	5	1/8
Reinforcing steel	5	1/8
Concrete	70	1 3/4

At this point, attention is again called to some common defects in design and fabrication. Slabs are usually designed to be of uniform thickness (from $6\frac{1}{2}$ to $7\frac{1}{2}$ in.) in a given bridge. The top surface of the slab is shaped to fit the profile grade line. For uniform thickness, the bottom surface of the slab should be parallel to the profile grade line. Yet many designs are still seen with no haunches over the beams to take up the variation in shape of these 2 curves—the profile and the beam camber (Fig. 2).

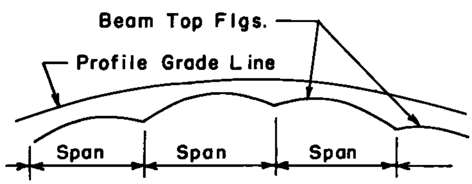

Figure 2. Variation-beam to profile.

Where the above situation is imperfectly understood in the field, some serious troubles arise. The carpenters, for simplicity, will often frame the slab forms in a fixed position relative to the top flange of the beams, ignoring the profile grade line. The top and the bottom reinforcing steel is then placed and the surveyors then set the screed rails. At this point, perhaps the night before concreting, the inspector uses a rule to measure from the screed rail to the form at several places. He may find the slab thickness varying with badly cambered beams as much as 2 in. (Fig. 3).

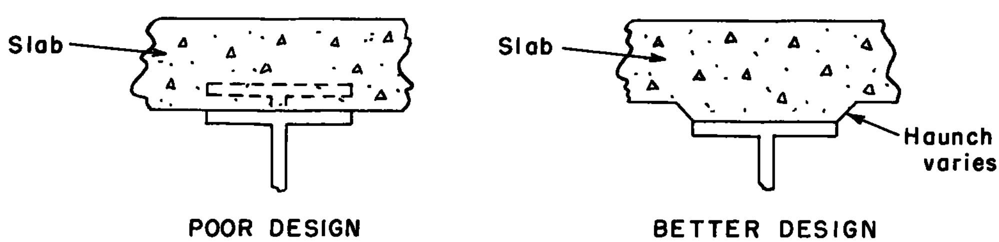

Figure 3. Slab bearing detail.

The correct procedure is to take elevations by level survey on the top flanges of every beam or girder at about 25-ft intervals and from these elevations calculate the accurate relative positions of the form top surface and the beam flange at each point. This information is given to the carpenters and they frame the slab form in the proper position. Only in this way can the slab turn out to have the precise and uniform thickness.

Pursuing this same method will correct another serious defect: namely, the incorrect positioning of the top reinforcing steel relative to the slab surface. The chairs that support this top reinforcing steel are detailed for uniform height. Where the slab varies in thickness, due to field error as described, the position of the top steel varies relative to the riding surface. There have been instances where reinforcing steel designed for $1\frac{1}{2}$-in. cover turned out to have as little as 5/8 in. to the riding surface. This fault was discovered only after 3 years of heavy traffic had caused flaking off of the concrete over each rod. Only rapid repair of such defects can save such a deck from complete deterioration. At this point it may be well to stress the importance of adequate cover over the top reinforcing steel in achieving improved durability of the wearing surface. Two inches is not excessive.

Because the structural steel and dams should lie exactly in the riding surface, it is of the utmost importance to set them carefully to the proper grade. When properly detailed, they have provisions for facilitating exact setting. Such adjustments may be by shims at the bearing surfaces or by reaming undersized rivet holes after C-clamping or tack welding the end dam to exact elevation. It is necessary, of course, not only to set them to the proper grade but also to the exact inclination so that their top surfaces will lie in the plane of the bridge and approach pavement. Similarly, because it is usually easier to adjust the approach slab paving, this is properly done after the bridge paving in the end spans has been completed.

Figure 4. Checking camber.

Everyone has experienced the disconcerting bumps frequently encountered when entering or leaving a bridge. These are usually caused by settlement of poorly compacted fill behind the abutment which has dropped the approach pavement. The best solution, albeit not inexpensive, is the use of a structurally designed concrete approach slab bearing on a concrete seat built into the back of the abutment wall. Such structural slabs are used even where the approach pavement is bituminous. Some authorities, wishing to save money, advocate the omission of the structural approach slab and set the approach pavement about 3/4 in. high. Such a practice definitely creates a bump for some indeterminate period until the approach pavement settles, and it is manifestly impossible to predict how much settlement will take place. This practice is not recommended. If a structural approach slab is omitted for economy, it is better to exercise close inspection to secure proper compaction of the fill behind the abutment and finish the approach pavement to meet the bridge pavement. Securing good support is greatly aided by limiting the excavation for the abutment to a minimum, and specifying a coarse granular backfill behind the abutment.

* * * * * * *

In regard to the actual paving operation, no matter what precautions have been taken in early preparation, the conduct of the operation itself will have a major effect on the final riding quality of the deck. The exact details and sequences of operations must be well known to both the contractors' supervisory force and the owner's inspection force. There is no time to resolve differences or improvise while the paving is in progress. For example, with the mass of reinforcing steel in the slab it is most difficult to bulkhead if it becomes desirable to stop the work before reaching an end dam. Accordingly, the exact details for such a bulkhead, including the steel dowels, should be known and any possible preparations made for its installation before the concreting starts (Fig. 5).

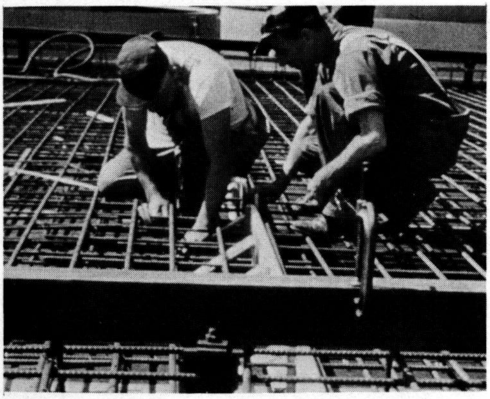

Figure 5. Placing a bulkhead.

Contrasted with the situation of paving on grade, the working space on bridge decks is severely limited. The space becomes progressively smaller, hence the sequence of moves, the placing of equipment, and even the lines of travel of the personnel should be planned in advance. Many concrete slabs have had their surfaces damaged by careless workmen walking over the wet surface at the end of the day.

Since bridge paving employs manual methods to a greater degree than paving on grade, the experience and attitude of the labor force must be considered. There are many union locals in this country which, while containing an adequate number of experienced cement finishers, have few if any who have done highway paving. The finisher usually is concerned with texture rather than accuracy of alignment, and may have a very poor appreciation of the necessity for very close tolerances in the final riding surface. Where a long stretch of pavement on grade is to be done, the contractor and owner have 2 major factors working for them:

1. The prospect of steady employment for many weeks, with large earnings from overtime pay, induces an exceptionally cooperative attitude in the finisher.
2. The operation continues long enough for even inexperienced finishers to learn the proper techniques, if given appropriate guidance.

On bridge decks, the exact opposite is true. The number of finishers required is such that the contractor usually must augment his regular finisher force greatly for the single day or two required to pave the limited area he has ready for paving. With the prospect of only 1 or 2 days' work on this relatively strange operation, the extra finishers have small incentive either to learn the new techniques or to observe the care necessary to secure the desired results.

This factor is by no means of merely academic interest. It is a basic difficulty and not readily solvable under the customary methods of contracting for work.

In the author's experience, the best results have been attained where the bridge construction was part of a large package contract for highway construction and where the bridge work was not subcontracted. In such cases it has occasionally been possible periodically to interrupt the paving on grade and to use the same experienced paving crew on the bridge deck paving.

In designing the concrete mix, in addition to the usual requirements for paving on grade, a more fluid consistency must be adopted because of the large amount of reinforcing steel in the slab. Somewhere between a 2-in. and a 4-in. slump will usually be required. Efforts to maintain a high degree of uniformity in the consistency are well worth the trouble. Variations in the consistency are believed to account for unexpected settlements in portions of surfaces which appear to have been properly struck off when the concrete was placed.

While it is unquestionably the contractor's responsibility to provide all the necessary tools and equipment, the writer has found it a good practice to have his inspection force check these off the day before the early stages of concreting. These include vibrators, screeds, scraping straight-edges, lutes, testing straight-edges, longitudinal floats, burlap and, last but not least, portable cross-bridges from which to work over screeded wet concrete.

Since the final finishing operations require good light for proper performance, the engineer should exert his influence to see that the size of deck paving and the starting hour are so chosen as to permit finishing during daylight hours. Further, he should assure himself that adequate labor, both skilled and unskilled, is available for work before starting the concreting. There is only one time to obtain a good riding surface and that is the day the concrete is placed. Corrective grinding of the surface later is of very limited effectiveness and may do more harm than good.

Proper distribution of the concrete to the deck is important. The method varies with the size of bridge and the site conditions. For small bridges a common method is by crane and bucket. This has the advantage of great flexibility, since the concrete may be deposited in any part of the deck and in any sequence. However, it has the disadvantage of placing concrete in a heap as the bucket is discharged, with the tendency to develop dense spots at the center of each heap, connected by less dense concrete shoveled into the spaces between. The author has sought to overcome this tendency by swinging the bucket like a pendulum during discharge in order to get a more uniform density. Manually, this is admittedly an awkward operation and there is no positive proof of its efficiency. The least that should be done is to spread the heaped concrete as uniformly as possible by manual shoveling, and to vibrate all areas fully.

For long bridges or viaducts, especially where all parts are not readily accessible by crane, a common method is by buggies (manual or power-driven) operating over portable platforms which are progressively removed as the concrete is placed (Fig. 6). If a second roadway or a wide dividing mall is available for concrete delivery, this method has flexibility as to sequence of placing concrete. If not, each successive move should be thought out carefully in advance to avoid possible "cold joints" in the concrete.

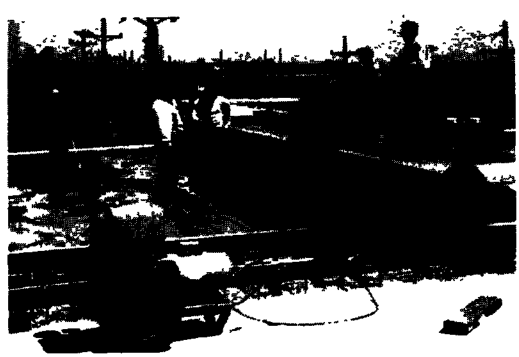

Figure 6. Distributing concrete with a power buggy.

In planning the sequence of concrete distribution in any given span, a controlling factor is the position from which the various finishers must work. It is not feasible for a finisher to manipulate a scraping straight-edge or testing straight-edge much beyond 12 ft from where he stands. This has led to the practice of placing and finishing one lane at a time. This method has the disadvantage of deflecting the supporting structural steel some hours after concrete in an adjacent lane has been placed. Unless the concrete set has been retarded, either by cold weather or by a chemical retarding agent, such movements can open cracks in the young concrete or reduce bond effectiveness through movement of the concrete and reinforcing steel relative to one another. Where at all possible, the concrete should be placed and finished across the entire width to be poured simultaneously and advanced uniformly along the roadway (Fig. 7). This procedure requires the use of cross-bridges close to the concrete surface from which the finishers can work. Such cross-bridges are substantial and must be fabricated in advance of the concreting. Also, means must be provided to move them from position to position.

Figure 7. Spreading concrete manually.

A similar problem arises where continuous steel main framing for 2 or more spans is used. If the concrete were to be placed in a single advancing movement from one end toward the other over the intermediate support, the angular deflections of the steel over the intermediate support would tend to open cracks in the partially set concrete at that point as the weight of the concrete was added to the second span. Two methods have been used to overcome this effect:

1. Require in the specifications that the contractor employ 2 concreting crews and simultaneously deposit concrete in both spans working from the ends toward the intermediate support.

2. Add a retarder to the concrete mix design and refinish over the intermediate support if necessary.

The first method meets with very strong objections from the contractors, even when specified, and is more costly. Also the question arises: what to do in a 3-span continuous bridge?

The second method has much to recommend it and the effects of its use should be studied and reported on.

Another consideration is the method of striking off the wet concrete to the proper elevation and slab thickness. The screed rails of pipe or structural tee section properly supported on adjustable metal chairs that remain in the finished slab have already been described. If the screeding is completely manual the screed may be no more than a wooden 2 x 6 about 14 ft long moved with a sawing motion by 2 finishers. This method, while primitive, is still in use and can produce good results. However, a much more common device is a metal screed which may consist of a steel beam or channel with web vertical and a bearing surface of about 6-in. width (Fig. 8). It should be of sufficient stiffness to support a vibrator mounted at its center without observable deflection. If the deflection under its own weight and that of the vibrator exceeds 1/16 in., it should be performed with sufficient camber to eliminate this deflection.

Figure 8. Vibrating screed.

The metal screed with the centrally mounted vibrator is conventionally moved forward along the screed rails by 2 laborers who pull on light lines fastened to the ends of the rail. No sawing motion is necessary, since the vertical oscillatory motion imparted by the vibrator both strikes off and consolidates the concrete. While it is true that the screed is partly supported by the wet concrete, it is the author's observation that the support provided while vibrating is small. For this reason, it is most important that the spacing of chairs and the flexural strength of the screed rails be such as to prevent sagging of the screed rail under the weight applied by the screed. Clearly, if the screed rail is too weak to support the screed properly it is of small value. It can be shown that under normal paving consistency of concrete, the conventional $1\frac{1}{4}$-in. pipe screed rail, if supported at 6- to 8-ft centers, will deflect excessively and so tend to put a ripple in the struck-off concrete. Although it is true that other later finishing operations tend to minimize these ripples, it is bad practice to strike off the concrete with a built-in ripple.

The reason larger diameter pipes are not used is the obvious one that the designed cover dimension over the reinforcing steel will not permit their use. However, since the deflection of any beam under central loading varies as the cube of the span, the deflection of the screed rail can be reduced to negligible proportions by decreasing the spacing between the supporting chairs to about 4-ft centers. The only proper way to do this is to write such a requirement, in general terms, into the specifications so that the contractor includes the cost in his bid.

For best results with the vibrating screed, several precautions are necessary:

1. A uniform roll of concrete should be maintained ahead of the screed. This is done by the laborers who spread the concrete to a reasonably uniform thickness.

2. When working with concrete of less than a 3-in. slump, it may be necessary to watch the bearing of the screed on the screed rail, to be sure that the screed is not "riding up" on the concrete and thus losing the control the screed rail should provide. In this connection, care should be taken to prevent dragging pieces of the coarse aggregate ahead of the screed rail over the top reinforcing steel. Designing for an absolute minimum cover of $1\frac{1}{2}$ in. will minimize this difficulty.

3. Whenever it is necessary to stop the screed, the vibrator should be disengaged in order to avoid the formation of a mortar pool caused by excessive vibration in one spot.

After satisfactory screeding has been done, it is necessary to remove the screed rails. This must be done from cross-bridges in order to avoid any deformation by laborers standing in the fresh concrete. The

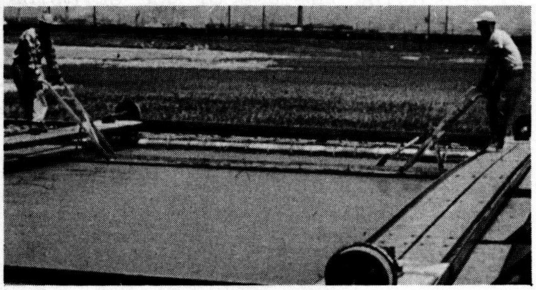

Figure 9. Longitudinal float.

timing of the removal of the screed rails is important. It should not be done so early as to permit the soft concrete alongside the screed rail to slump into the space left when the rail is removed. Neither should removal be so delayed as to break pieces out of the set concrete and prevent proper bond with the concrete added to fill in the space left by the rail.

Occasionally, screed rails are seen placed at right angles to the direction of traffic. This is usually done on wide roadways in order to give the finishers a place to stand when the concrete is being placed the full width of the roadway. This arrangement is not advisable, as it tends to produce ridges across the line of traffic that give a sensation of roughness or poor riding quality.

Following the screeding operation, a longitudinal manually operated float is used (Fig. 9). This may be a 10-in. steel channel about 15 ft long. It is placed parallel to the direction of traffic with the web on the concrete surface. The sharp corners have been slightly ground off to avoid pulling out pieces of coarse aggregate as the float is moved transversely with a longitudinal sawing motion imparted by 2 finishers, one at each end operating from cross-bridges. Wherever ripples across the roadway may have been left in the strike-off by the screed, the longitudinal float tends to diminish or remove them. The important thing is to have a plane surface parallel to the direction of traffic. The longitudinal float tends to produce this as well as to consolidate the concrete surface. It is advanced only $\frac{1}{2}$ its length at each pass in order to produce continuity of the smoothed surface.

After the longitudinal float, the scraping straight-edge is used. One common type is a piece of 1 3/4-in. oak about 10 ft long and about 6 in. wide. This is fastened at its center at right angles to a long handle. It is placed parallel to the direction of traffic and pushed across the lane with the handle about knee-high. It is then pulled back with the handle shoulder-high. In this way the sharp edges of the 1 3/4-in. surface scrape over the wet concrete surface and further reduce any ripples which may remain from the earlier operations. The scraping straight-edge is also advanced only $\frac{1}{2}$ its length after each double pass.

The scraping straight-edge is followed by the lute (Fig. 10). The lute is a smoothing tool used to smooth down any local irregularities that may have been caused by the action of the scraping straight-edge in turning up pieces of coarse aggregate. It is usually a piece of pressed aluminum about 6 in. wide and 4 ft long attached to a long handle. It is manipulated in the same direction as the scraping straight-edge.

Finally, it is a good idea to follow up the foregoing operations with a testing straight-edge 10 ft long. This is gently placed on the surface and the handle wiggled slightly to make a fine line imprint in the surface. The uniformity of the slight imprint will show clearly how true the surface is. This is commonly done 2 to 3 times in the width of each lane and every 5 ft longitudinally. It is late to discover irregularities, but these can usually still be corrected by repeating the use of the scraping straight-edge. The great value of the testing straight-edge is that it shows whether the preceding operations were done with sufficient care while it is still possible to take corrective measures. Its use is particularly important on the concrete adjacent to or crossing joints such as end dams.

For proper results all these tools are tested at least once a day for straightness and either discarded or repaired if not found to be perfectly true.

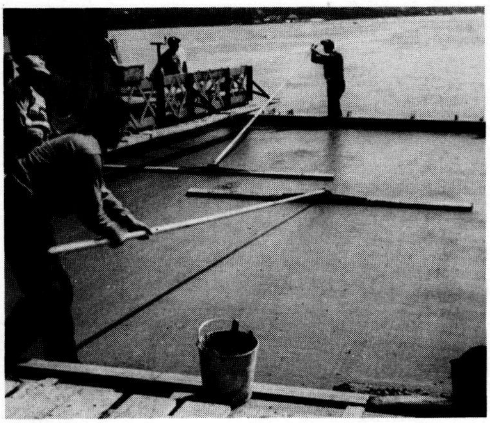

Figure 10. Smoothing floats.

Figure 11. Final surface texture.

The final step before curing is the texturing by the use of either burlap drag or the drag followed by brooming (Fig. 11). The burlap drag is a double piece of a seamless burlap about 42 in. wide and long enough to stretch across the width being paved. It is kept wet and clean by dipping frequently in a metal trough half filled with water. It is most important, for good results, that no hard spots of dried mortar be allowed to form, as these will gouge lines into the surface of the concrete. If the broom is used it is equally important to keep the bristles clean and free of hardened mortar.

Curing has little to do with early riding quality, however vital it may be to the production of a durable concrete surface. Hence no comment on curing methods will be made here.

It is apparent from the foregoing exposition that the attainment of concrete bridge decks with smooth-riding surfaces requires more than the ordinary techniques for placing concrete. Although nothing very profound has been said, it will be apparent to even the casual observer of bridge deck construction that many of the elementary requirements are being regularly ignored. This accounts for the obvious difference in riding quality as one passes from the approach pavement on grade to the bridge deck. There is plenty of justification for close supervision by experienced engineers in constructing concrete bridge decks.

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