MYTHS AND REALITIES OF SURFACE-TOLERANT COATINGS FOR BRIDGES[1]

by Karen A. Kapsanis and Bernard R. Appleman[2]

Like any component of technology, "surface-tolerant" coatings can be misused if their purposes and limits are not adequately understood. They can be mistakenly expected to do everything from eliminating the need for surface preparation to improving the adhesion of an existing coating.

This first Point-Counterpoint article reports on a panel discussion, "Myths and Realities of Surface-Tolerant Coatings," held in Pittsburgh, Pennsylvania, last June in conjunction with the International Bridge Conference and co-sponsored by SSPC (Steel Structures Painting Council) and the Engineers Society of Western Pennsylvania. The panel included Richard Hanlon, West Virginia Department of Transportation (WVDOT); Simon Boocock, SSPC; Dan Griffin, Porter International; John Montle, Carboline Co.; Stavros Semanderes, Odyssey Contracting; and Richard Winick, Witco. Steve Pinney of S. G. Pinney and Associates was moderator. Members of the audience also shared their expertise.

The panel was assembled to illuminate misunderstandings or myths about surface-tolerant coatings and to examine the realities of the materials—experiences and realistic expectations about use and performance.

This article is not a comprehensive account of the panel or of the use of surface-tolerant coatings. Rather, it organizes several issues raised at the discussion, explains their significance, and summarizes insights from the panel. The explanation of the significance of each question, including the potential for misunderstanding the technology, constitutes the "Point" in the point-counterpoint framework. The summary of panelists' insights constitutes the "Counterpoint"—nuanced answers from experts to clarify and qualify the purposes and uses of the technology.

What Are Surface-Tolerant Coatings?

An earlier name for these materials, "rust-tolerant" coatings, indicated that the coatings did not require removal of all rust (as well as millscale and paint) as specified in SSPC-SP 6 and higher degrees of surface preparation. Eventually, this term came to include surfaces containing small amounts of moisture, grease, and oil. A starting definition for surface-tolerant coatings, therefore, is coatings that are intended to be applied over a lesser degree of surface preparation than that defined in SSPC-SP 6. These coatings are thus distinguished from high-technology synthetic polymer coatings such as vinyls, conventional urethanes and epoxies, and zinc silicates, which are intended to be applied over a commercial grade (SSPC-SP 6) or better.

As Pinney pointed out, new products tend to be used initially in too many places. He thus opened the panel with an attempt to further define surface-tolerant coatings. He

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started the discussion with the following slightly different definition of surface-tolerant coatings: coatings that are designed to wet out over a surface that has not been completely cleaned. He included coal tars and oil-based coatings, which have been used for years, and newer coatings such as moisture-cured urethanes, various epoxy mastics, and calcium-sulfonate-based coatings.

Other distinctions were added. For instance, Boocock pointed out that "surface tolerance" may need to be further qualified in terms of the types of surfaces over which the coating can be applied, such as over an aged alkyd, or an oily surface, and in terms of what makes the coatings surface-tolerant.

The Hulton Bridge near Pittsburgh PA before recent removal of lead-based alkyd (commercial blast) and recoating with an epoxy mastic primer and urethane topcoat. (Picture courtesy of Pennsylvania Department of Transportation, Pittsburgh, Pennsylvania.)

Griffin suggested also identifying the amount of chlorides and the amount and types of rust (e.g., loose or stratified) that can be tolerated by specific products.

Semanderes suggested that an SSPC-SP 7, Brush-Off Blast, with tightly adherent millscale, rust, and paint on the surface, is suitable for a surface-tolerant coating. Winick agreed and suggested that SSPC-SP 2 (hand tool cleaning) and SSPC-SP 3 (power tool cleaning) be included in the definition, since like SP 7, both allow adherent millscale, rust, and paint to remain.

From the audience, William Brinton of Wasser and consultant Mal Hendry elaborated on other types of surface-tolerant coatings. Hendry described the use of moisture-tolerant coatings in the wet, salt-laden atmospheres of the North Sea area. Brinton described the use of moisture-cured urethanes in the wet, subfreezing conditions of Alaska.

Are There General Guidelines on Where and How To Apply Surface-Tolerant Coatings?

Surface-tolerant coatings represent a tradeoff between cost and performance. Steel covered with rust, millscale, moisture, oil, and grease is not an ideal substrate on which to apply coatings. A surface-tolerant coating partially overcomes these deficiencies by providing a combination of good wetting, barrier protection, and, in some cases, other means of suppressing the natural tendency of oxides to absorb moisture and expand. Thus, a surface-tolerant coating will have a greater chance of success in those situations where forces promoting corrosion are least severe. Circumstances to avoid include:

- Highly aggressive exposure environments (e.g., heavy chemical fumes, high temperature, frequent immersion); and

- Highly contaminated substrates (e.g., containing chlorides, sulfates, or high quantities of grease or other contaminants).

Millscale, poor adhesion of an existing coating, or incompatibilities between it and a surface-tolerant coating could also contribute to early failure of a surface-tolerant coating.

Winick noted that his company's tests on calcium-sulfonate-based and other surface-tolerant coatings indicated that chloride contamination has been a more important limiting factor in their use than the adhesion of the existing coatings.

Montle added that in his company's field tests, a limitation of conventional surface-tolerant epoxy mastics is rust with salt, unless high-pressure water blasting is used to remove much of the salt contamination.

Semanderes described good results with several products, including moisture-cured urethanes and aluminum epoxies, but he cautioned that some of them must be sprayed; they are too thick to be brushed or rolled.

<u>Is a Surface-Tolerant Coating Better Over a Blast-Cleaned Surface or a Hand or Power Tool-Cleaned Surface?</u>

It is an axiom of protective coatings technology that the better the surface preparation, the longer the coating lifetime. It has been reported that some surface-tolerant coatings perform better over hand or power tool-cleaned surfaces than over blast-cleaned steel. It is vital to carefully examine the evidence of these claims and to identify the specific circumstances and limits of these occurrences.

Montle qualified the claim by describing several test programs with varying results. In one program, an epoxy mastic over blast-cleaned steel gave in quickly to pinpoint rust in salt fog, while the same coating over a wire brush-cleaned surface did not show pinpoint rusting. The substrate did not have millscale or contaminants such as oil or salts, only rust from weathering. Another study indicated that one coat of an epoxy mastic over rusted steel would perform about the same as the one-coat mastic over abrasive-blasted steel, 15 years over rusted steel and 13 over blast-cleaned steel. In 13,000 hours of salt fog cabinet testing, blast-cleaned panels failed, showing four medium-dense blisters and traces of rust while the hand-cleaned steel panel performed satisfactorily. But on millscale, the surface-tolerant coatings performed poorly if the steel was hand cleaned, not blast cleaned.

Winick cited results from a study with which he was involved (*JPCL*, January 1989). Nine commercial epoxy mastics were evaluated in salt spray over surfaces ranging from an SP 2, Hand Tool Cleaning, to an SP 5, White Metal. According to Winick, most epoxy mastics delaminated at the scribe on an SP 2 surface but generally adhered well to blast-cleaned steel. On unscribed hand tool-cleaned steel, the coatings did not delaminate but adhesion strength diminished compared to the coatings over blast-cleaned steel.

Boocock cited SSPC research in which a variety of surface-tolerant coatings, including a number of epoxy mastics, have been tested over SP 2, hand tool-cleaned surfaces, and SP 10, near white surfaces. Generally, he said, deterioration is occurring earlier on SP 2 surfaces than on the SP 10. But not all formulations have been tested, he said, emphasizing that performance is critically related to formulation characteristics.

When a steel surface is intended, the specifier has a much wider selection of materials. Whether to use a surface-tolerant coating depends on the overall merits of this system and of the alternatives (e.g., application characteristics, expected performance, ease of maintenance, and costs). A surface-tolerant coating over blast-cleaned steel could provide some insurance when the specified degree of cleaning is not achieved.

Hanlon offered one user's perspective: specify surface-tolerant coatings for bridges that are very difficult to blast, not for bridges that can be blasted efficiently. Griffin suggested that epoxy mastics are suitable for use over different degrees of cleaning. He cautioned users to specify dry film thicknesses of at least 5 mils (125 microns) for surfaces with either a high blast profile or a great deal of pitting.

Are There Differences Among Surface-Tolerant Coatings?

"Surface-tolerant coating" is a very loose, non-generic description. Among the types of materials touted as having surface tolerance are one- and two-component epoxies, moisture-cured urethanes, oils and alkyds, petroleum wax, petrolatum, coal tars, and others. Thus, it is first necessary to identify the generic class. Two commonly used types are high-solids, high-build, two-component epoxy ("epoxy mastic") with good wetting ability, and one-component moisture-curing urethanes.

Even within these generic classes, variations in chemical types can be substantial. "Epoxy mastic" can use a variety of curing agents, solvents, wetting agents, and other additives. As a result, the chemical and physical properties, durability, and performance properties under different exposure conditions can vary enormously among products.

To the unsophisticated, coatings that are generically similar are expected to perform similarly. There is also a long-standing pattern in the industry of specifying coatings by generic type rather than by performance. But real world experience, as evidenced in the panel discussion, is often quite contrary to the expectations for generically similar surface-tolerant coatings.

Performance can vary widely among generically similar coatings.

Reporting again on his study, Winick noted significant differences among nine epoxy mastics in chemical and solvent resistance as well as salt spray performance.

Montle concurred, adding that there are also differences in performance within coatings from the same manufacturer because a company may market materials with different components of performance, depending on the intended use and surface preparation.

Hanlon explained why WVDOT adopted a specification for epoxy mastics that includes an approved products list. Before the specification was used, there was little control over selection of surface-tolerant coatings and no monitoring of performance. Thus, if a coating failed, no one was sure of the cause: specification, surface preparation, application, or formulation. The current specification, adapted from Virginia DOT, guides bridge engineers when selecting surface-tolerant coatings and provides a basis for monitoring performance. For the six or seven epoxy mastics on the approved list, at least as many other epoxy mastics have been turned down. (Monitoring of field performance is in the early stages, he said.)

To Encapsulate Lead-Based Paint?

The danger of assuming surface-tolerant coatings withstand any substrate condition extends to the issue of lead paint removal in bridge maintenance. Covering a deteriorating lead paint with a surface-tolerant coating may appear to be a cost-effective alternative to removal, treatment, and disposal of lead paint.

But it is important to keep in mind the types of surfaces for which surface-tolerant coatings were designed and the types of surfaces often found on bridges. Virtually every reputable coatings manufacturer requires that the surface-tolerant coating be applied to tight rust, tight millscale, and tight intact paint. Unfortunately, these conditions do not usually describe the condition of most bridges that are scheduled for repainting; thus, they require surface preparation by hand or power tool cleaning, water jetting, or other means. The generation of potentially hazardous dust and debris must be considered when examining the repaint options. Also, typically, the most badly corroded areas are those subject to salt dripping and splash. Many of the most common surface-tolerant coatings are least effective in protecting these chloride-contaminated joints and flange areas.

There is no magic number for adhesion testing before specifying encapsulation.

Moreover, as audience member Tom Calzone of Carboline Co. explained, encapsulation has often been specified without first assessing the surface and existing coating for their compatibility with the surface-tolerant coating. Incompatibilities can lead to premature failure of the encapsulant. He therefore urged prequalification of a bridge before specification and inspection during application if encapsulation is to be specified appropriately. The issue of coating compatibility was then discussed in terms of practical field tests, as described below.

How Can One Determine Compatibility of a Surface-Tolerant Coating and the Existing Coating?

As noted, surface-tolerant coatings are typically designed to be applied over a variety of surfaces, including existing intact paint. The physical condition (e.g., brittleness, thickness) and chemical type (e.g., linseed oil, alkyd, or phenolic resin and various pigment types) of old paint can vary significantly. The compatibility of the new and old paint cannot be assumed. Consequently, testing for compatibility or adhesion may be required.

Pinney cited a case illustrating the danger of applying a surface-tolerant coating that is not compatible with the existing lead-based paint. In one case, an epoxy mastic, specified as an encapsulant over a lead-based coating, became, in effect, "a red lead remover," Pinney said, because the whole system beneath the mastic delaminated. Griffin said that to prevent such catastrophic failures, test patches of the surface-tolerant system should be applied to make sure that it will in fact tolerate the existing coating (or surface).

Montle described another source of trouble when surface-tolerant coatings are specified as encapsulants on bridges that were not blasted originally. Often, the adhesion of the underlying coating is substandard.

Panelists agreed that adhesion testing was needed to determine whether the existing coating was strong enough to be encapsulated, but there is not a single criterion for adhesion testing before specifying encapsulation. Brinton and Winick added that a more flexible surface-tolerant coating may put less stress on existing coatings than a "harder" one.

From the audience, Lou Vincent of S. G. Pinney pointed to cases in which surface-tolerant coatings lifted off coatings with high adhesion rates as well as coatings with low adhesion rates. In the former case, he said, a surface-tolerant coating had been applied well above the specified dry film thickness. According to Vincent, the epoxy mastic looked intact for about 3 months, until the temperature dropped 62 °F (34 °C) and the mastic pulled the original coating off.

He suggested using several test patches over different configurations on the steel to determine whether the surface-tolerant coating will pull off the existing coating. It is important to do multiple test patches through the cycle of weather to which the bridge is subject, he added, because weather will affect various configurations of the steel differently.

Hanlon agreed with comments on the need for testing but reminded panelists that most highway departments lack funds and staff for testing. Thus, he said, the DOTS want surface-tolerant coatings that are easy to use.

Conclusions

From the panel discussion, several conclusions can be drawn.

- Surface-tolerant coatings are diverse materials designed to be applied over surfaces that receive less than a commercial blast cleaning.

- Surface-tolerant coatings have achieved a strong position in the industrial maintenance painting market. They have demonstrated a significant value in certain applications but also have severe limitations.

- There are many types of surface-tolerant coatings and major differences within a given class such as "epoxy mastic." Each product must be investigated to verify that it has the properties sought.

- Epoxy mastics are most successful over hand-cleaned rusted steel free of salt contamination. They are much less effective over millscale or chloride-contaminated surfaces. Other surface-tolerant coatings are suitable for moist and damp surfaces. Surface-tolerant coatings are generally less effective in severe exposures.

- Most protective coatings, including surface-tolerant coatings, perform better over uncontaminated blast-cleaned substrates. The value of a surface-tolerant coating is that it can often provide only slightly reduced performance at a significant cost savings. In some instances, a significant loss of performance may occur, but when blast cleaning is restricted, this may be the best alternative.

- Because of possible incompatibilities, patch tests are strongly recommended when applying a surface-tolerant coating over an existing coating. Tests should cover representative areas of the structure and should last long enough to observe several temperature fluctuations. Field adhesion tests (i.e., cross-cut tape test) may be used but are less reliable.

- Performance of surface-tolerant coatings depends on proper specification and application as well as formulation.

DEWATERING USING A FLOATING BULKHEAD PROVES FLEXIBLE, REUSABLE, AND COST EFFECTIVE[1]

by Frederick Lux III[2] and Eric P. Regner[3]

Introduction

Going beyond a traditional bulkhead dropped in place with a barge crane or crane hoist, a floating bulkhead was conceived to dewater powerplant intakes, gated spillway bays or outlet works. It is especially suited where the structure has no provision for dewatering, cranes are not available to install stoplogs or the dewatering structures are no longer serviceable. For aging hydroelectric plants, it is an effective means to dewater entire intakes or bays so that gates or the structure itself can be maintained or repaired. With the Federal Energy Regulatory Commission (FERC) requiring each spillway gate to be operated through its full range once every 5 years, a bulkhead allows gate operation without making a release or lowering the reservoir.

The floating bulkhead consists of a number of individual floating caissons that can be used separately like stoplogs, or pinned together and installed as a unit. A caisson consists of a floatation compartment and another compartment to sink or float it (see figure 1). Each caisson is lowered into the reservoir from a suitable location and towed into position by a boat. Individual caissons can be placed one at a time or pinned together, depending upon the opening or intake structure configuration. If installed as a unit, the caissons are pinned together at hinges. The bulkhead unit resembles a giant garage door as it floats on the water. A caisson is slowly submerged by filling a specific compartment in a controlled manner. If assembled as a unit, the submerged caisson pulls the remainder of the bulkhead behind it (figure 2). When the bulkhead needs to be removed, it is raised by draining water from the caisson chambers, floated to the next intake to be dewatered and reinstalled. Installation of the floating bulkhead has taken less than 2 hours. Removal has been performed in about 30 minutes.

Besides using a conventional bulkhead, other dewatering schemes include lowering the reservoir, constructing a temporary cofferdam upstream of the intakes or performing the repairs underwater. Lowering the reservoir involves a loss of generation revenue and regulatory agencies may not permit such an action. A temporary cofferdam may represent a significant portion of the cost to repair or maintain intake features, particularly for high dams or where work must be done on a frequent basis. While it may be economical to repair portions of a structure using divers, maintenance of operating components, such as painting of gates, needs to be performed under dry conditions. Thus, a bulkhead provides the most economical and practical approach for most dewatering applications.

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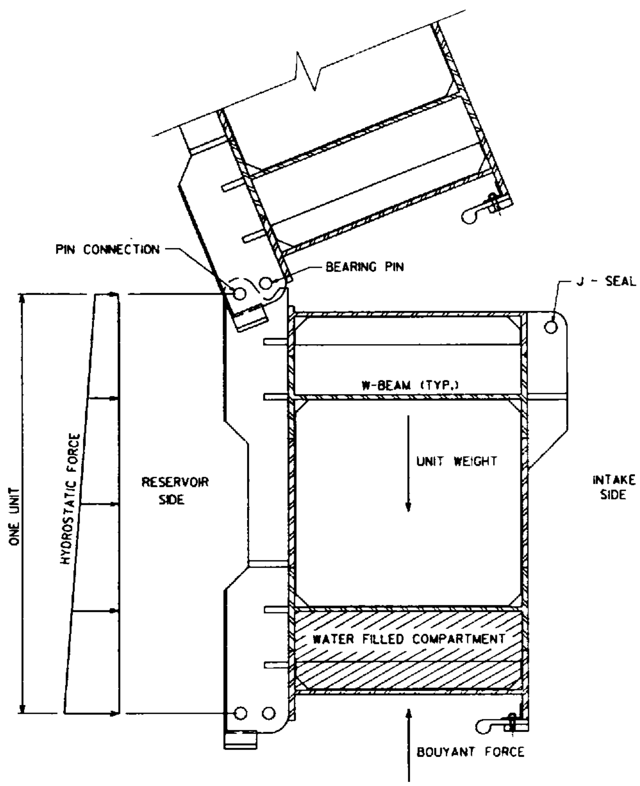

Figure 1.–Section through bulkhead caisson.

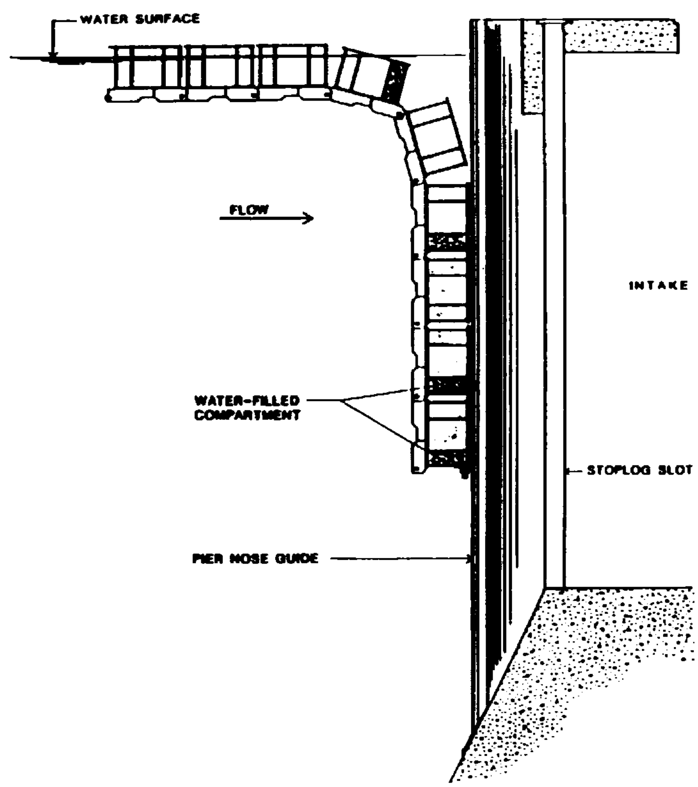

Figure 2.–Section through intake during bulkhead installation.

Advantages of the articulated floating bulkhead over conventional bulkheads or stoplogs include:

- One bulkhead can be adapted to fit various intake configurations.
- One bulkhead can be used at a number of dams rather than being a site-specific design.
- A large capacity crane is not needed at the dam to carry and position the caissons.
- Bulkhead slots are not needed since it seals against the upstream face of the structure. However, it can be used where existing bulkhead slots are present.
- The floating bulkhead may be used as a barge or work platform in the water, when it is not required for use as a bulkhead.

Design

Four general requirements were established for design of the floating bulkhead. First, each caisson must float or sink, depending on the amount of water it contains. Second, the bulkhead must be able to resist the hydrostatic pressures of the dewatering process. Third, upon removing the bulkhead, each caisson must ascend slowly to reduce the potential danger of heavy caissons ascending quickly, rising above the water, and damaging the dam and bulkhead or injuring workmen. Fourth, the bulkhead caissons must be small enough to hoist out of the water and transport to other dams by truck.

The height and number of bulkhead caissons selected for each design were based on the range of reservoir fluctuations expected, intake characteristics, site access, and transportation requirements. Structural design of each caisson was based on strength, deflections, and buoyancy. The bottom caisson is the critical unit for design. It is under the greatest water pressure, yet needs to span the entire intake bay like the caissons above it. The section, as shown in figure 1, has about 15 percent additional bending capacity than required to limit deflection. The deflection was kept low to keep the bottom seal from moving in the event of a significant change in the reservoir water level.

The steel sections used for the bulkhead are comprised of W-shapes in combinations with steel plates (figure 1). The use of steel plates throughout was not considered due to the additional cutting and difficult welding needed. The W-beams have a very low weight to area (depth x flange width) ratio to achieve the required buoyancy. The selected material was readily available to many fabricators. Lighter sections were considered for the upper caissons since less strength is required under a lower hydrostatic head. However, little cost savings would be realized in fabricating lighter upper caissons. Also, the bulkhead would be less versatile and more complex with various size and weight caissons.

The introduction of hinges between each caisson was initially intended for ease of placement when the bulkhead is installed as a unit. Other benefits were realized and some are listed below.

- By allowing only selected compartments in alternate caissons to be filled, the bulkhead remains almost weightless in the water during placement and after the bulkhead is fully installed (see figure 2). This provides easy maneuverability and requires hoists as small as 2-ton (18-kN) capacity on each side of the bulkhead. The weight of the two bulkheads described later are approximately 68 tons (605 kN) and 89 tons (794 kN) dry weight.

- Bulkhead placement and removal can occur fairly quickly. Should the bulkhead need to be installed or removed because of high runoff or emergency use in another location, only a few hours of preparation time is required. Also, diver time in the water is kept to a minimum providing additional cost savings.

- The placement process is safer, since little equipment is used and less work must actually be performed under water than with conventional bulkheads.

The hinges were designed to allow 180 degrees of movement, and the pins are stressed only when the bulkhead is being installed or removed. When the bulkhead is either totally horizontal or vertical, the caissons are in direct contact with one another, leaving the pins free to be removed or installed without shear forces on them.

Where individual caissons are to be installed, such as in a bulkhead slot, each caisson is individually set in place. For this type of installation, the caisson ends are tapered to allow one end to be placed into the slot and the other end to be rotated into alignment with the other bulkhead slot. The individual caisson is then lowered into position by filling a compartment with water. Hoists are used to control the descent and ascent of each caisson.

The design of the bulkhead buoyancy was based on a lower and upper limit. When "full" of water and descending, the bulkhead must be relatively light to allow a small hoist to set it in place. When "empty" and in the vertical position, the wall must be kept heavy to facilitate a slow ascent. This balancing act resulted in a limited amount of water to be used as the "sinking" force.

Three key locations required a seal: between caissons, at the pier nose or bulkhead slot, and at the base of the bulkhead. Wood was placed against concrete because of its ability to conform to irregular, rough surfaces and its slow cost of replacement. Rubber seals were used at steel surfaces. Small leaks through and around the bulkheads were expected; however, construction crews installing the bulkhead have sealed leaks with cinders, rubber hose, etc.

The final major design concern was the durability of the newly fabricated structure. Special attention was given to the welds to assure that faying surfaces would not come in contact with water and corrode. All of the interior surfaces were sprayed with linseed oil. The compartments that are filled with water receive applications of linseed oil at regular intervals. The exterior surfaces were painted with coal-tar epoxy.

In addition to designing the bulkhead itself, assemblies of timber, steel, and rubber were designed as a guide and seal for each pier nose. They consisted of wood, steel sections, and rubber seals, all preassembled and anchored to the concrete piers with expansion anchors. The guides were necessary to ensure that the bottom caisson was in correct location. In addition, steel pieces were placed at the bottom of the guides to pull the bulkhead tight to the pier nose and provide a stop for the bottom caisson when it reached its final position.

Fabrication

The long, longitudinal welds required special care to prevent warping the long bulkhead caissons. Many of the individual steel components had to be heat straightened prior to welding to meet specified tolerance limits. Welding was performed by certified welders, and weld testing was provided by an independent testing laboratory as the caissons were completed. Pressure testing was accomplished prior to painting to ensure that the caissons were watertight. Each caisson was numbered and the caissons above and below the unit fitted in the dry to meet specified tolerances and so caissons could be pinned together in the water. The two sets of bulkheads were fabricated within 90 days.

Wissota Hydro Project — The Hinged Concept

The Wissota Hydro project is located on the Chippewa River about 3 miles upstream from the city of Chippewa Falls, Wisconsin. The Wissota reservoir, which is known as Lake Wissota, extends upstream about 14 miles (22.5 km) and has a surface area of about 6,300 acres (2,550 ha) with a normal full reservoir volume of 56,000 acre-feet (7.9×107 m^3). The maximum height of the dam is 68 feet (20.7 m) above the streambed. The powerhouse contains six 6,000 kW, identical vertical shaft generating units with each unit having an intake bay 26 feet wide (7.9 m) by 24.5 feet high (7.5 m).

Faced with major repairs of the head gates, stoplog slots and trash racks for the Lake Wissota hydroplant's six intakes, Northern States Power Company (NSP) needed a means to seal the entire forebay of each unit or lower the reservoir to perform repairs. The existing stoplog support trusses of this 70-year structure were badly deteriorated and had questionable load-carrying capability. Any work in the headgate area necessitated a minimum 15-foot drawdown of the lake to lower pressure on the stoplogs and ensure the safety of the repair crews.

Rather than rent a barge and crane, an articulated floating bulkhead was designed and fabricated in the fall of 1986. It was installed in Lake Wissota hydroplant's intakes for the first time in 1987 (see Reference at end of article). The bulkhead is 36 feet (11.0 m) square and 27 inches (0.69 m) thick when fully assembled. The bulkhead was designed to span 30.9 feet (9.4 m) under a water head of 35 feet (10.7 m). Each of the nine caissons contains three compartments. Each caisson is comprised of four W27 × 84 steel beams and 5/8-inch-thick (16-mm) steelplate.

Aligned by using vertical guides of steel and timber installed on the pier noses, the bulkhead resembles a giant garage door as it floats in the water before installation. Selectively filling the caisson compartments creates the correct buoyancy for descent. Subsequent caisson compartments fill on their own as they settle (photo 1). The buoyancy of the 136,000-pound (12.5-kN) structure ensures that only about 2,800 pounds (12.5 kN) rests upon the concrete below the headgate. Water pressure from the lake seals the bulkhead (photo 2). When repairs were completed, the water-filled compartments are opened and drained through the headrace. Once emptied, the headrace is filled through gates installed in the bottom caisson. The bulkhead rises along the vertical guides mounted on the pier noses, ready for use on the next bay. The bulkhead has been installed in as little as 2 hours and removed within 30 minutes.

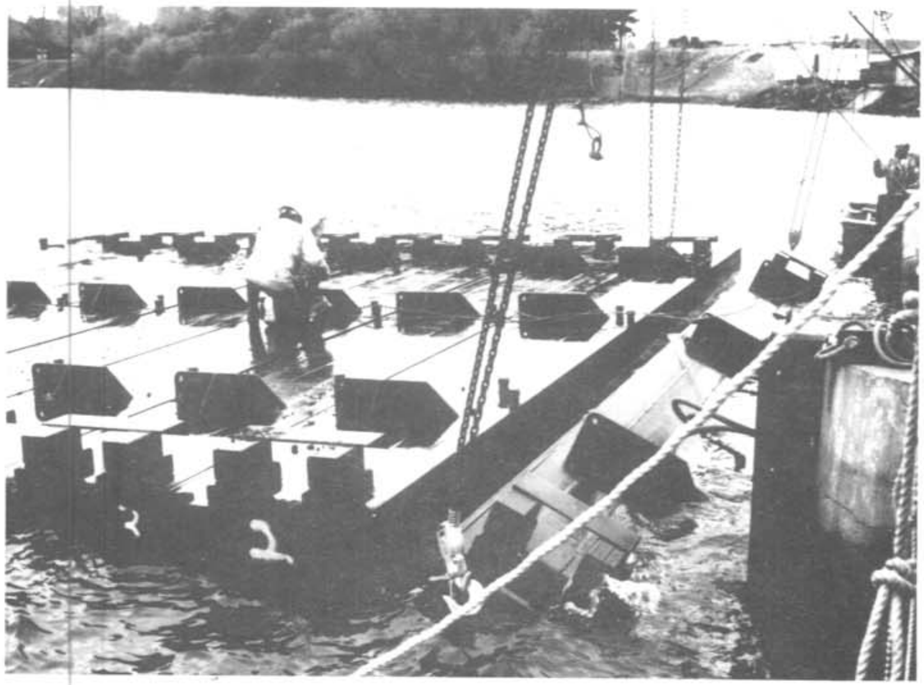

Photo 1.-Filling of caissons for sinking the bulkhead-Wissota hydroplant intake, 1987.

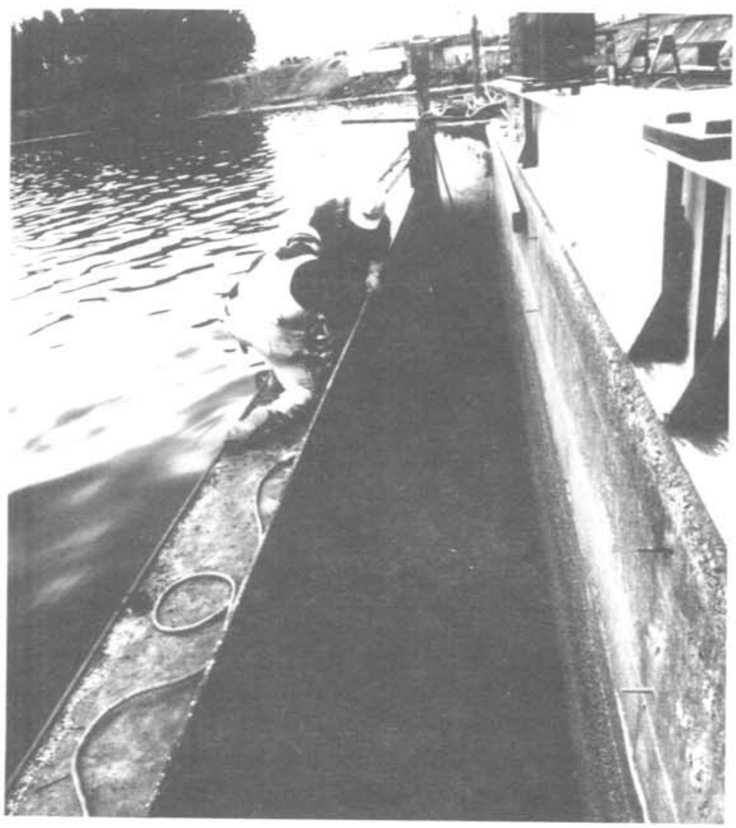

Photo 2.-Bulkhead installed and headrace dewatered-Wissota hydroplant intake, 1987.

This bulkhead was designed to be utilized at other hydroplants besides the Lake Wissota facility. NSP officials estimate a $1.4-million savings through use of the floating bulkhead including avoided loss of generation revenue because a drawdown was not needed. Fabrication cost of the bulkhead was about $130,000.

Snake River Dams — Flexibility and Multiple Use

Idaho Power Company is planning to replace the spillway radial gate seals and paint the spillway gates of the Upper Salmon, Lower Salmon, and Bliss Dams on the Snake River, Idaho. These dams do not have stoplogs or bulkheads to seal the spillway bays, which enables work to be performed on the gates in a dry environment. Except for Bliss Dam, no stoplog or bulkhead slots are provided in the spillway piers. Presently, there is no vehicular access on any of the three dams' spillways; and the spillway hoist bridges cannot carry heavy loads such as a crane or stoplogs. Idaho Power was further limited in its approach to dewatering the spillway bays. The reservoirs could not be lowered without a loss in generating revenue and possible environmental consequences.

A floating bulkhead was designed for use at all three dams to assist in facility repairs and maintenance. Table 1 contains information pertaining to the three dams used in designing the bulkhead. The bulkhead consists of eight caissons each 40 feet wide (12.2 m) and 53 inches high (1.35 m). Total height when all caissons are assembled is 36 feet. The bulkhead was designed to span 38.0 feet (11.6 m) under a water head of 36 feet (11.0 m) at Lower Salmon Dam, the most critical structure. Each of the eight caissons contains three compartments. Each caisson is comprised of four W30 × 108 beams and 3/4-inch- (16-m) thick steel plate. Fabrication cost of the 180,000-pound (800-kN) bulkhead was about $190,000. Idaho Power estimates that use of the floating bulkhead saved them more than $3 million compared to other dewatering means.

Table 1.–Pertinent Data of Idaho Power Spillways

Item	Bliss (feet)	Lower Salmon (feet)	Upper Salmon (feet)
Maximum normal pool elevation	2,654.0	2,798.6	2,880.4
Pool fluctuations	1.5	2.0	0.0
Spillway Crest elevation	2,624.0	2,783.5	2,865.4
U/S apron or sill elevation	2,623.2	2,762.0	2,861.8
Maximum design head	30.8	36.6	18.6
Spillway span at gate	39.0	30.0	30.0
Spillway span at pier	49.0	38.0	38.0
Bulkhead slots	Present	None	None

The same hinged, floating bulkhead design used for Lake Wissota Dam was used at Upper Salmon and Lower Salmon Dams. Minor changes in the side and bottom seals were made to accommodate differing site conditions. At both Upper Salmon and Lower Salmon Dams, the spillway pier noses and an upstream concrete apron will be used as the bearing surfaces for the bulkhead seals (figure 3). The bulkhead will be installed in the same manner as the bulkhead for Lake Wissota Dam.

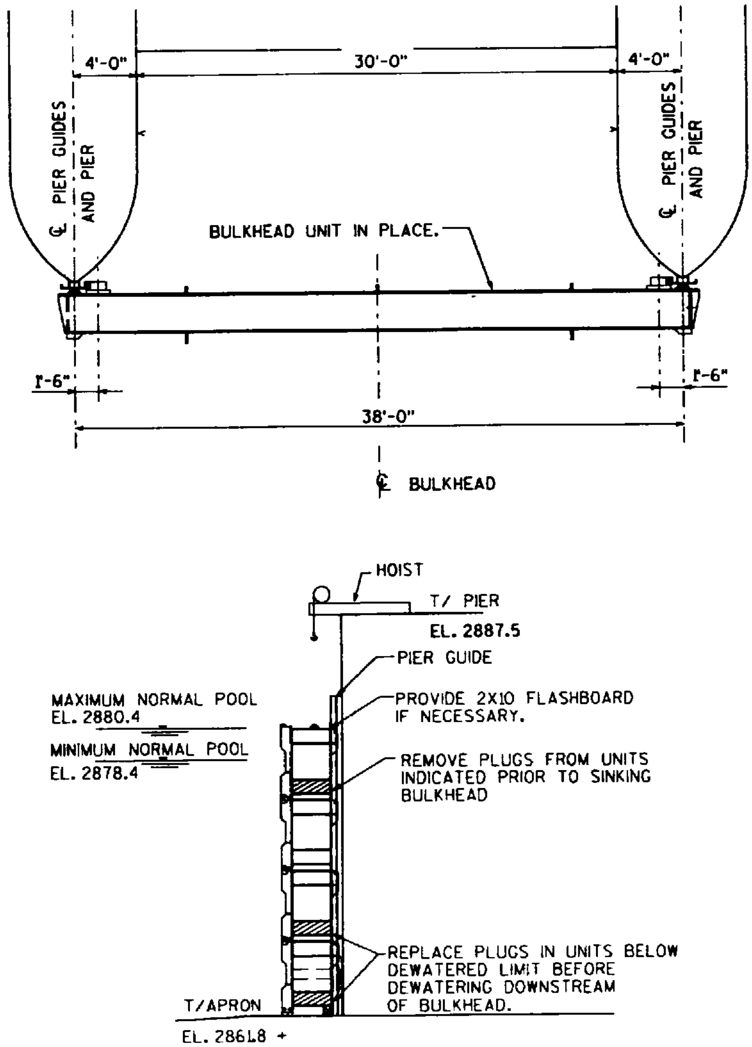

Figure 3.–Upper Salmon Dam–Typical spillway bay, plan, and section.

At Bliss Dam, the existing 13-inch- (0.33-m) wide bulkhead slots will be utilized as the sealing surfaces for the floating bulkhead. At this location, each caisson will be installed and removed individually. Each end of the caisson has a tapered end to allow the bulkhead to be fitted into the bulkhead slots (figure 4).

Summary

Two articulated floating bulkheads have been designed and fabricated for use at several dams. A 36-foot- (11.0-m) square hinged floating bulkhead was used at Wissota Hydro Plant to dewater the powerplant intakes so repairs to the intake, trash racks, and stoplog guides could be performed. Power company officials estimate a $1.4-million savings through the use of this bulkhead including avoided loss of generation revenue. A 40-foot- (12.2-m) wide by 36-foot- (11.0-m) deep bulkhead was designed for use at Bliss, Lower Salmon, and Upper Salmon dams to dewater the spillway bays for gate maintenance. This bulkhead was designed to be installed for both a spillway having bulkhead slots and two spillways with no provision for dewatering. These examples

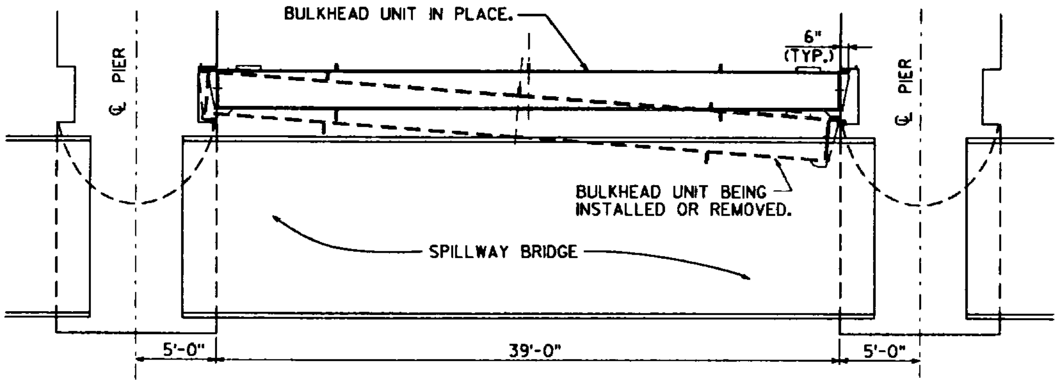

Figure 4.-Bliss Dam-Typical spillway bay plan.

demonstrate the flexibility, reuse potential, and cost effectiveness of the floating bulkhead over conventional dewatering systems.

Reference

Bakken, Jr. R. and J. S. Vonasek, "Floating Bulkhead Installed for Hydro Intake Repair," Small Hydro '88, Ministry of Energy, Toronto, Ontario, Canada, July 1988.

ICE MELTERS AND CONCRETE DAMAGE: ARE THEY RELATED?[1]

by Lawrence E. Balkin and Richard C. Schend, P.E.[2]

Once days get shorter and temperatures get cooler, people across the U.S. snowbelt begin the daily task of maneuvering themselves through ice and snow. As public works officials know, these weather hazards present immediate concerns to the public welfare, but as fewer stop to consider, the secondary concerns can prove just as ominous.

With ice and snow removal comes the use and abuse of public walkways and roadways. The use of heavy equipment and ice melters are a necessary precaution to winter weather, but they can also be directly related to concrete damage.

R. C. Schend & Associates, a consulting engineering company, was commissioned to evaluate concrete damage related to ice melter use. In the base of its findings, the firm has found that concrete damage did not usually occur when ice melter was applied as directed and used on good quality, air-entrained concrete designed for cold weather climates. Instead, concrete damage was most often traced to low-quality concrete lacking in air-entrainment or some other critical ingredient. The freeze/thaw damage that occurs is generally a result of the quality of the concrete laid—not necessarily the type of ice melter applied.

Concrete damage due to freeze/thaw cycles occurs for various reasons and in several different forms, including: scaling, the flaking or peeling away of surface mortar; dusting, the formation of a fine powder that can be rubbed off the surface easily; and popouts, the breaking away of small concrete fragments.

Scaling is the most common form of winter concrete damage. Usually caused by a buildup of excess pressures produced when water in concrete freezes and expands, the expansion forces flakes of mortar loose from the surface. As the cycle repeats, damage accelerates.

Dusting occurs when a small, thin, weak layer called "laitance" appears. It is composed of water, cement, and fine particles. When the surface freezes and thaws, this thin layer becomes dust.

Popouts are formed when a piece of porous rock absorbs more water than its surrounding areas. As the offending aggregate absorbs moisture or freezes, internal pressures are created. Consequently, the concrete ruptures, expelling the rock and leaving a shallow depression.

According to books and articles on the subject of freeze/thaw effects on concrete published by the American Concrete Institute (ACI) and the Portland Cement Association (PCA), the two leading U.S. authorities, concrete quality is measured according to its air-entrainment, strength, water/cement ratio, cement content, and concrete slump.

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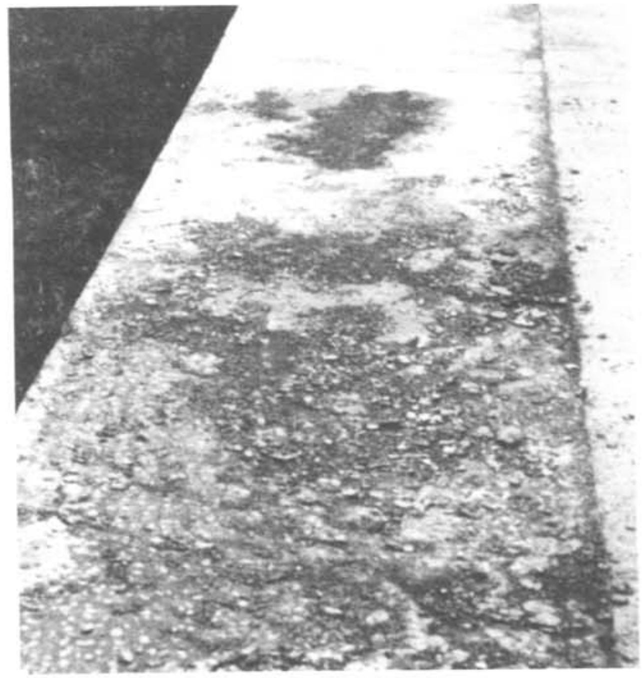
[2] Mr. Balkin is Vice President, Operations/Finance, Koos, Inc., Kenosha, Wisconsin; Mr. Schend is President, R.C. Schend and Associates, Kenosha, Wisconsin.

Flaking and peeling of surface mortar is usually caused by internal pressure created when water freezes within the concrete, not by corrosive chemical action.



To avoid concrete damage completely where freezing and thawing occur, the concrete must be air-entrained. Properly air-entrained concrete provides significantly improved surface durability that resists freezing and thawing in most conditions, even when ice melters are used.

Formulated by either using an air-entrained cement or adding an air-entrained agent, this type of concrete forms microscopic air bubbles throughout the concrete during the mixing process. These air bubbles relieve the pressures that result when absorbed water freezes and expands. In areas with severe freeze/thaw exposure, concrete should contain at least 6 percent air-entrainment.

But an adequate amount of entrained air is not the only guarantee of freeze/thaw durability. Several other conditions should be met. The ACI and PCA recommend that concrete be composed of the following when subjected to freeze/thaw conditions:

- Durable materials
- Low water-cement ratio of 45 percent or less
- Slump of 4 inches or less
- Cement content of 564 lb/yd^3 or more
- Adequate drainage with a slope of 1/8 in/lin ft or more
- Minimum compressive strength of 4,000 lb/in^2 at 28 days
- Minimum 30-day drying period after moist curing of the concrete

Also, avoid using ice melters for at least the first winter season after laying the concrete. And, it is equally important to select a reliable and respectable cement contractor.

Selecting an Ice Melter

Ice melters have many effects on concrete and the immediate environment. To decrease the possibility of damage and increase the life of public roadways, the type of ice melter used should be a careful consideration. Sodium chloride, calcium chloride, potassium chloride, potassium-chloride based with added compounds, and urea are the most frequently used ice melter products. Ammonium nitrate and ammonium sulfate are also sometimes used.

In the absence of freezing conditions, sodium chloride has little to no chemical effect on concrete, but will damage surrounding vegetation and corrode metal. Calcium chloride in weak solutions generally has little effect on concrete and vegetation, but does corrode metal. However, in concentrated solutions, it can chemically attach concrete and harm vegetation. Also, when tracked inside, calcium chloride will leave an oily residue on floors, and, when stored, will clump if exposed to moisture. Ammonium nitrate and ammonium sulfate compounds attack and disintegrate concrete, and should be strictly avoided. Urea will not chemically damage concrete, vegetation, or metal.

Potassium chloride-based ice melters, and potassium chloride-based ice melters with additives, can liquefy ice effectively, without harming plants or other vegetation when used as directed.

Another area to consider when choosing an ice melter is how the manufacturer backs the product. All ice melter manufacturers stress that customers must apply deicer products according to directions and maintain good sidewalk maintenance practices. Alter repeated applications, excess water and slush formed by ice melter products should always be removed.

However, many ice melter companies take a "buyer beware" approach, not offering any type of satisfaction guarantee or customer assistance. Several deicer packages include the following disclaimer: "Manufacturer or seller makes no warranty expressed or implied concerning the use of this product other than the purposes indicated on the label. Buyer assumes all risk in storing, handling and the use of this product." Not all companies make this disclaimer and it is always wise to find those that take the responsibility upon themselves, and offer a satisfaction guarantee.

Also as important is the reliability of the supplier. Look for a customer relations or customer service department that is regularly on hand to support your needs.

If damage occurs during the first frost season, or if the concrete is poor quality, a breathable surface treatment should be applied to the dry concrete to help protect against further damage. ACI and PCA recommend adding a penetrating sealer made with boiled linseed oil, silane, siloxane, and/or breathable methacrylate. Non-breathable formulations should be avoided as they may accelerate scaling conditions.

Roadways, walkways, and parking areas need not be replaced on a frequent basis. Careful development of the concrete at the outset as well as a prudent choice of a winter ice melter can go a long way to extending the life of your area concrete—and, in the long run, your overall maintenance budget.

MAINTENANCE WORKSHOP

(Sponsored by Pacific Northwest Region)

by Mike Pearson[1]

In December 1991, the Irrigation Operation and Maintenance Branch held a workshop for personnel responsible for the day-to-day maintenance of Reclamation facilities.

The highly successful workshop was the first of this type presented by Reclamation. In addition to PN Region personnel, other participants came from the Denver Office; Upper Colorado, Mid-Pacific, and Great Plains Regions; State of Oregon; and one irrigation district.

Onsite demonstrations were the highlight of the workshop such as welding repairs for cast iron and epoxy repairs of metal. A unique part of the workshop included a view of a mobile workshop–a special designed vehicle that can be driven directly to a site where maintenance needs are performed. Demonstrations were also made on how to determine equipment failure modes using an infrared gun and vibration testing meter. Other items of maintenance addressed were:

- Electrical and mechanical maintenance: General procedures described along with demonstrations of infrared and vibration testing
- Galvanic corrosion: Lessons learned
- Cavitation: How to recognize, repair, and prevent cavitation damage
- Favorite supplies: Supplies and where to order them
- Lubrication: How to lubricate systems such as control systems, gear boxes, wire ropes, etc.
- Hydraulic control systems: Reclamation design of control systems–how they operate and how to maintain the system
- Gates: Reclamation gate design and common problems
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- Epoxy repairs: Handout of test results done by the Corps of Engineers on tion damage
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- Gates: Reclamation gate design and common problems
- Welding repairs of cast iron
- Epoxy repairs: Handout of test results done by the Corps of Engineers on epoxy and different types of weld metal used to repair cavitation
- Concrete repairs: When and how to repair
- Sealant repairs—Correct procedures and a listing of sealants tested by Reclamation; included are manufacturers' names and telephone numbers
- Nuts, bolts, washers, and torquing procedures

[1] Mike Pearson is a mechanical engineer, Bureau of Reclamation, Pacific Northwest Regional Office, Irrigation Operation and Maintenance Branch, Boise, Idaho.

The workshop is designed to exchange knowledge and provide a forum to discuss techniques and suppliers. Each participant received a reference notebook covering all the information presented.

The PN Region is planning to have two workshops this winter, one for Reclamation employees and one for irrigation district employees within the PN Region. The workshops are listed below:

Workshop for Reclamation Employees.-This workshop is only for Reclamation employees. The workshop will be held at Grand Coulee Dam on December 8-11, 1992. On Friday morning, December 11, participants will be given a tour of the dam and maintenance facilities.

Workshop for Irrigation District Employees.-This workshop is only for irrigation district employees within the PN Region. The workshop will be held in Boise, Idaho, on January 12-14, 1993.

The PN Region would like to have personnel from all Regions participate in the workshop and share maintenance problems and practices. They have reserved a limited number of seats for those desiring to attend.

If you have any questions pertaining to these workshops or wish to attend, please contact Mike Pearson, (208) 334-1169.

This mobile workshop plays a vital part in ensuring that maintenance work can be performed quickly at various project locations.

SILICA FUME CONCRETE REPAIRS ON THE SAN JUAN-CHAMA PROJECT

by Bill Bouley, P.E. and Charles Fisher[2]

The diversion and collection system was constructed between 1964 and 1970. The system conveys San Juan River water through the Continental Divide into the Rio Chama, a tributary of the Rio Grande. Annual diversions average about 110,000 acre-feet. The system consists of three diversion dams, two siphons, and three tunnels. The names of the tunnels, starting with the uppermost, are Blanco which is 8.6 miles long; Oso which is 5 miles long; and Azotea which is 12.8 miles long. All three tunnels are concrete-lined, with inside diameters of 8-foot 7-inches for Blanco and Oso Tunnels, and 10-foot 11-inches for Azotea Tunnel. The 28-day concrete compressive strength used in the design of the system was 3,000 lb/in^2.

The system was designed with sluiceways at each diversion dam to pass the gravelly sediment load carried by the mountain streams. Personnel in the Southwest Regional Office (which office has since been abolished) ordered a halt to the sluicing operations in the late 1970's due to complaints from the Colorado Department of Water Resources and downstream irrigators as those operations were creating a maintenance burden to irrigators and affecting fisheries downstream of the diversion dams. Over several years of operation, the gravelly sediment caused severe wear to the inverts of the tunnels.

Project personnel tried various repair materials to slow the wearing of the invert. Epoxy mortars and polymer concretes were used with little success. The toxic fumes made use of these materials difficult in the closed tunnel environment. Conveyor belt material was attached to the concrete near the portals of some of the tunnels with no success in reducing the damage. It appeared that repairs with conventional concrete mixes to be the best material.

With the gravelly sediments passing through the tunnels, repair materials should be able to withstand the constant abrasion. Silica fume concrete was proposed as a repair material by personnel in the Division of Research in Denver because of its high resistance to abrasion. The 28-day compressive strength for the silica fume concrete is over 11,000 lb/in^2.

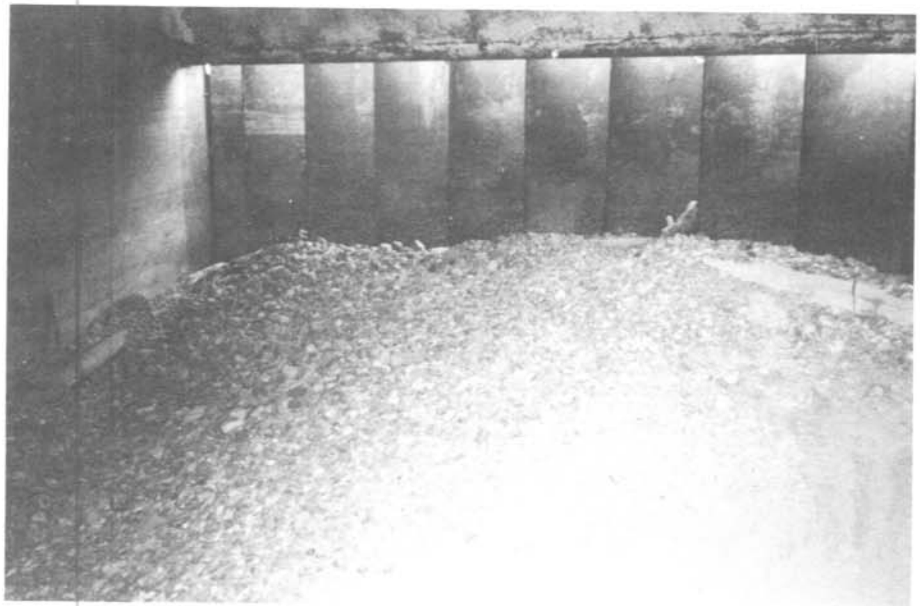
In March 1986, Dennis Arney, Division of Research, assisted in providing test sections of silica fume concrete to evaluate its effectiveness in the eroded invert of Blanco Tunnel. The test sections were partially funded through the Open and Closed Conduit Systems research program. Various methods of surface preparation were employed: sawcutting the edges, chipping out tights, and bushhammering the remainder; to sawcutting the edges, chipping out tights, and sandblasting the remainder; to merely washing down the areas and using stiff brooms to clean it out. Other sections of the invert have been repaired with standard concrete mixes using 1-1/2- and 3/4-inch aggregate.

Cores were obtained from all the different sections; i.e., which silica fume concrete mix, which standard concrete mix, or what kind of surface preparation for each concrete

[2] Bill Bouley is a Civil Engineer, Denver Office, Bureau of Reclamation; Charles Fisher is Chief, Chama Field Division, Bureau of Reclamation, Chama, New Mexico.

mix. The cores were then sent to the Denver Office for tensile tests, which indicated there was no apparent advantage in adhesion between any of the new mixes to the existing concrete, or in any of the surface preparations. Based on these results and the lesser material costs, the Chama Field Division has been using a standard concrete mix with a surface preparation consisting of washing and sweeping out the area prior to placing the repair mix.

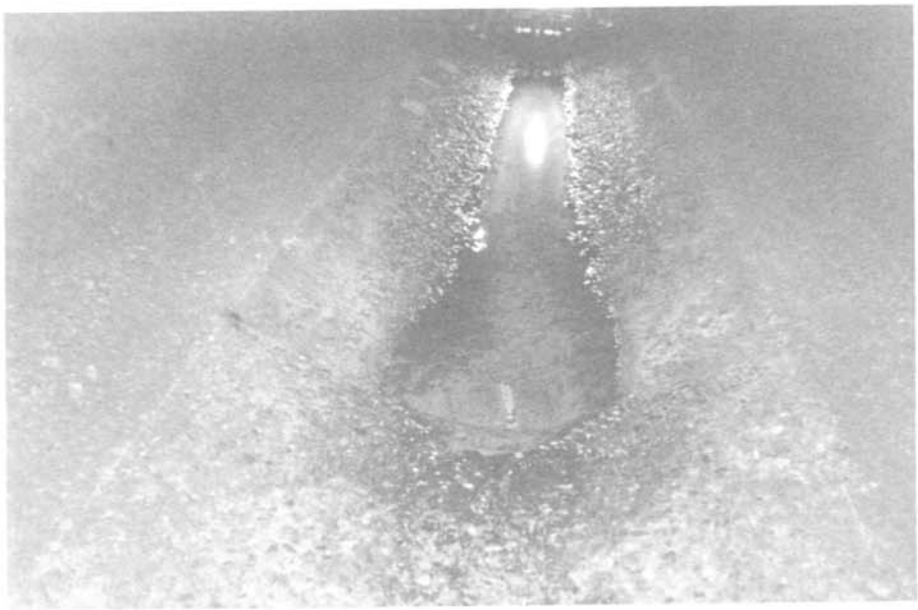
Project personnel continue to inspect the repaired areas annually to monitor the condition of the test sections and past repair work to other tunnel inverts in the system. Since



Typical sediment load–Blanco. 10/22/91

1.10-foot-deep hole in Azotea Tunnel invert. 10/22/91 silica fume mixes are more expensive, Project personnel will use such mixes at the portal areas where exposure to the high altitude weather would be more detrimental. Inside the majority of the tunnel, the air temperature remains near 50 °F, so standard concrete mixes with 1-1/2-inch aggregate should endure against the sediment load.

Personnel in the Chama Field Division plan to use a silica fume concrete mix to repair the sluiceway and a 4-foot-wide Parshall flume at Blanco Diversion Dam in the fall 1992.



0.7-foot-deep hole in Azotea Tunnel invert. 10/22/91

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Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Advertise your district's or project's resourcefulness by having an article published in the bulletin! So let us hear from you soon.

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