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News from the Repair, Evaluation, Maintenance, and Rehabilitation Research Program

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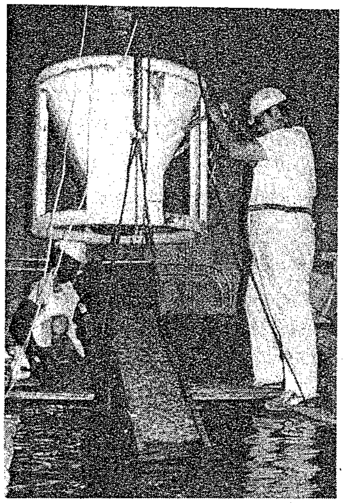

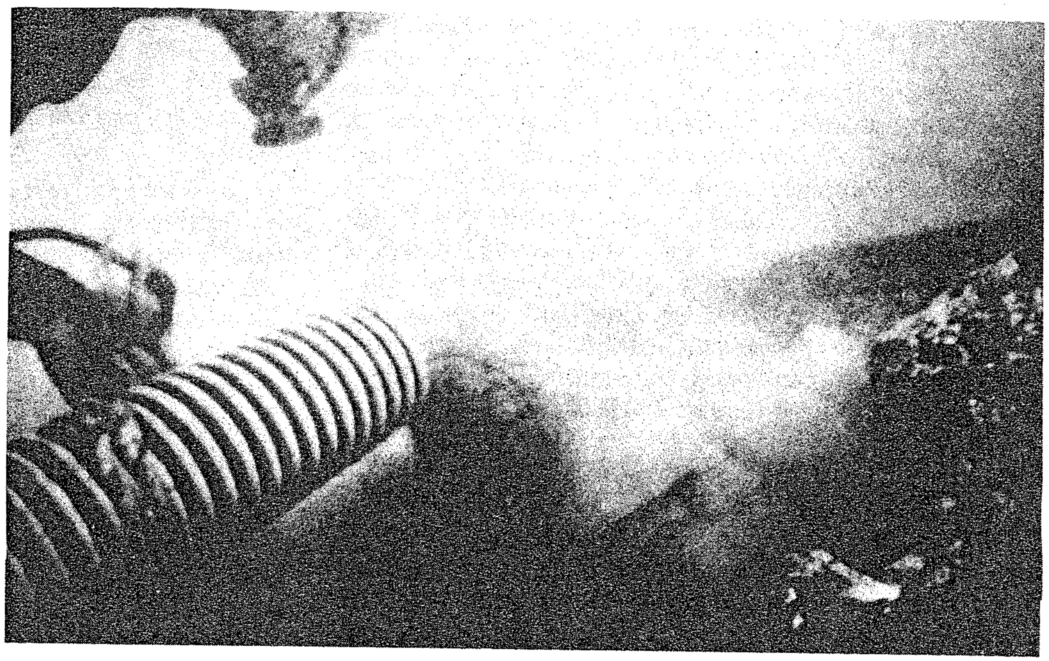

Anti-Washout Admixtures for Use in Underwater Concrete Placement

by
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Many hydraulic structures in use in the United States are suffering from serious deterioration because of environmental effects, aging, and abrasion-erosion damage to the concrete.

A recent survey by the US Army Corps of Engineers (McDonald 1980) identified 52 concrete structures that have been damaged by erosion. Depths of erosion ranged from a few inches to approximately 10 ft. In general, this erosion damage resulted from the abrasive effects of waterborne rocks and other debris circulating over the concrete surface during construction and operation of the structure.

Background

A variety of materials, including armored concrete, conventional concrete, epoxy resins, fiber-reinforced concrete, and polymer-impregnated concrete, have been used with varying degrees of success in 31 repairs reported. The degree of success generally was inversely proportional to the degree of exposure to those conditions conducive to erosion damage.

McDonald (1980) concluded that, given appropriate flow conditions in the presence of debris, all of these materials are susceptible to some degree to erosion damage. No one material demonstrated a consistently superior perfomance advantage over alternate materials. A properly placed, conventional concrete containing high-quality paste and the hardest coarse aggregate economically available is still an excellent method of repair for abrasion-prone structures.

The ability to place the repair concrete underwater would eliminate the need for dewatering and, therefore, would make the repair of hydraulic structures less expensive. Dewatering costs associated with repair of erosion damage in stilling basins can be as much as $1 million and average approximately 40 percent of the total repair cost. A state-of-the-art report on techniques for the underwater repair of concrete structures subjected to abrasion erosion suggested that pumped concrete offers excellent potential for underwater placement, particularly when used with newly developed pneumatic còntrol valves and admixtures (Gerwick 1985).

Materials

A laboratory program undertaken at the US Army Engineer Waterways Experiment Station (WES) addressed the incorporation of anti-washout admixtures in concrete to be used for underwater repair of stilling basins. The relatively new family of anti-washout admixtures is used to minimize the washing out of fines, including cement, from freshly mixed concrete and to reduce segregation of the concrete to be placed underwater. Most anti-washout admixtures contain cellulose in some form to increase the water retentivity and thixotropy of the mixture. These are important parameters for successful underwater placement, since the concrete must be cohesive yet flowable.

The first phase of the program consisted of a laboratory evaluation of five selected anti-washout admixtures (AWA). Preliminary work indicated that the AWAs did impart a significant amount of cohesiveness to typical underwater concrete mixtures. Indeed, an excessive amount of AWA rendered the concrete so cohesive as to be unworkable. The key then becomes the successful optimization of AWA in conjunction with water-reducing admixtures (WRA) used to increase slump. Previous work indicated that silica fume in concrete substantially increased resistance to abrasion-erosion effects (Holland 1983). Silica fume added to the mixtures also increased the cohesiveness of the concrete and provided another variable to the optimization process.

Tests

Two tests were used in Phase I to qualify and quantify the various mixtures incorporating AWAs, WRAs, and silica fume: the two-point workability apparatus and the washout test.

The two-point workability apparatus (Tattersall and Banfill 1983) was used to evaluate the relative workability of each concrete mixture. Use of a second point, the plastic viscosity, provides a better description of workability than the conventional one-point tests such as the slump test.

A washout test (Figure 1) was used to determine the relative amount of cement paste lost when the concrete is exposed to a large amount of water. This test consists of placing a representative sample of concrete in a wire-mesh basket, allowing it to fall through a column of

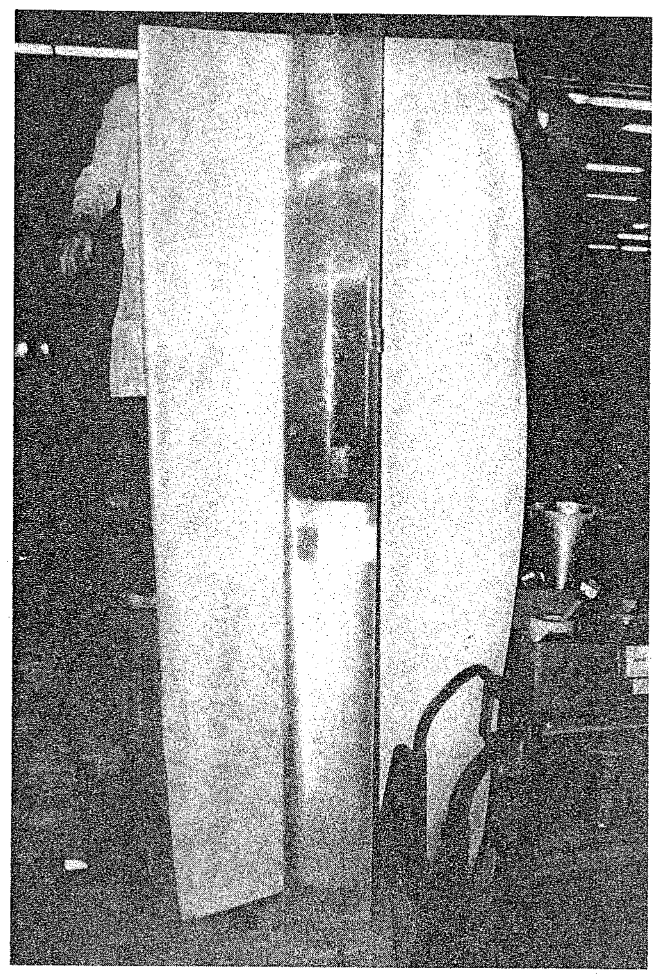


Figure 1. Washout test apparatus

water three times, and measuring the change in mass after each drop. The results are expressed as a percentage loss in mass.

The abrasion-erosion resistance was tested according to procedures in CRD-C 63-80, "Test Method for Abrasion-Erosion Resistance of Concrete (Underwater Method)" (US Army Engineer Waterways Experiment Station 1949). This method is being proposed, in revised form, as an American Society for Testing and Materials (ASTM) standard. The results were recorded as volume per unit surface area rather than mass because specimens of different mass were used.

Results

Results of several mixtures tested in Phase I are given in Table 1. Five AWAs were used; admixtures A, B, C, and D were cellulose derivatives; admixture E was polyethylene oxide. Lignosulfonate (Lig), sulfonated melamine (mel), sulfonated naphthalene (nap), and hydroxylated carboxylic acid (HCA) water-reducing admixtures were used to increase slump. Water-cement ratios (W/C) ranged from 0.32 to 0.42. Mixture 1, which contained no AWA, exhibited severe washout. The polyethylene-oxide admixture in mixture 2 did not perform as well as the other AWAs. The best combinations were either the lignosulfonate or the melamine with any of the cellulose AWAs. These combinations generally resulted in 3 percent or less loss of mass in the washout test (mixtures 3, 4, 7, 9, and 10). The naphthalene admixture imparted excellent flowability to the concrete, but when used in conjunction with the AWAs at normal dosage, the resulting concrete exhibited erratic fluctuations in flowability and cohesiveness. Consequently, to maintain proper workability, the AWA dosage was minimized, rendering the concrete more washout prone (mixtures 5 and 8). The abrasion-erosion resistance and workability of all mixtures were comparable, although there appeared to be a tendency for those mixtures without AWA to sustain more abrasion.

Phase II Work

Phase II of the study involved three different methods for the underwater placement of selected mixtures. Method 1 consisted of the free fall of concrete through 3 ft of water (no protection from dilution). Method 2 consisted of pumping the

Table 1
Phase I Mixtures

Mixture	Cement lb	Silica fume lb	Fly Ash lb	AWA	WRA	W/C	Percent Washout @ 3 drops	Abrasion Erosion Loss cm^3/cm^2	Workability
1	353	--	353	None	HCA	0.40	12.64	0.392	Good
2	590	89	--	E	Lig	0.40	7.46	0.343	Average
3	700	105	105	A	Lig	0.32	1.05	0.351	Average
4	590	89	--	B	Mel	0.36	2.39	0.379	Average
5	590	89	--	C	Nap	0.36	8.09	0.330	Good
6	549	61	61	None	Lig	0.42	3.48	0.453	Good
7	590	89	--	A	Lig	0.36	2.25	0.369	Average
8	590	89	--	D	Nap	0.36	6.81	0.368	Good
9	590	89	--	C	Mel	0.36	2.83	0.382	Average
10	700	105	105	B	Lig	0.32	1.59	0.404	Good

concrete to the point of underwater placement (complete protection, but no tremie seal maintained). Method 3 involved the use of an inclined chute which supported the concrete to the point of final disposition (partial protection, known as the inclined tremie). The results of six trials are given in Table 2.

The basic mixture for a cubic yard of concrete used in all trials contained 590 lb of portland cement, 89 lb of silica fume, and 1-in. nominal maximum size gravel and had a W/C of 0.36 and a ratio of fine to total aggregate of 0.40 by solid volume.

Abrasion-erosion specimens from Phase I were placed abraded side up in the bottom of tanks containing 4 ft of water to determine bond strength of the fresh concrete to old abraded concrete. Trial 1, in which concrete without anti-washout admixture was allowed to free fall through 3 ft of water, resulted in complete disaggregation of the fresh concrete (Figure 2). Figure 3 shows the porous, friable concrete after hardening. Free fall with AWA added to the mixture in trial 2 also resulted in some loss of fines, but good cohesion of the mixture did permit bond to the hardened concrete specimens. In trial 3 the concrete was pumped underwater into a form with no free fall. The tremie seal was not maintained, but only a small loss of fines was observed in the water (Figure 4). The mixture was very stiff and had to be moved underwater by hand. Bond was excellent. The top surface was hand finished underwater as shown in Figure 5.

Table 2
Trial Placements (Phase II)

Trial No.	Admixtures: WRA* oz/cwt	Admixtures: AWA Type	Admixtures: AWA %/cwt	Slump in.	Percent Washout	Placement Method	Remarks
1	25	None	--	8-1/2	6.0	Free fall for 3 to 4 ft in water.	Water very cloudy. Heavy loss of fines. Concrete disintegrated. No bond to old concrete.
2	25	A	0.15	8-3/4	2.1	Free fall for 3 to 4 ft in water.	Some loss of fines. Good cohesion. Good bond to old concrete.
3	25	A	0.20	5-1/2	0.8	Pumped underwater 4 ft deep. Discharge on bottom. Stiff concrete moved underwater by hand.	Excellent cohesion, very little loss of fines. Good bond. Finished concrete underwater.
4	19	D	1.2	8	2.7	Pumped underwater 4 ft deep. Discharge on bottom. Pump hose moved about to fill form.	Good cohesion, bond. Small loss of fines. Concrete moved well underwater.
5	25	A	0.15	8	2.9	Inclined tremie to bottom of form. Concrete flowed underwater laterally 3 ft. Tremie underwater length = 7 ft.	Good cohesion, some clouding of water. Underwater slope after placement, approx. 15 deg. Finished underwater.
6	48	B	0.5	9	1.6	Inclined tremie to bottom of form. Concrete moved, but not as well as trial 5.	Good cohesion, some clouding. Required more manual manipulation than trial 5.

* Lignin type.

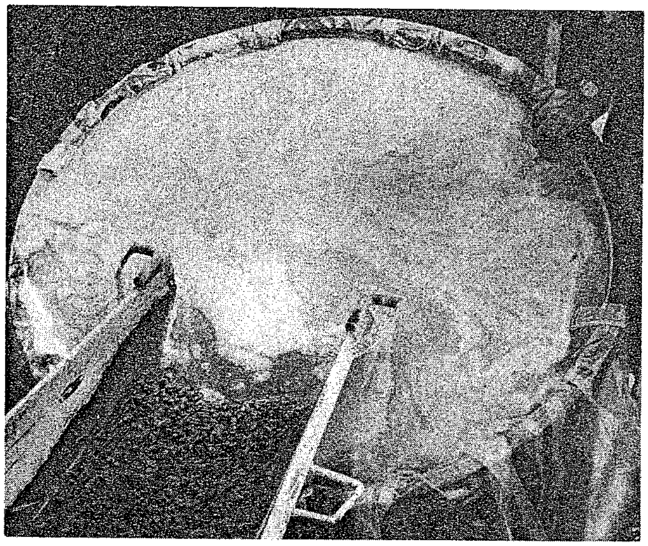


Figure 2. Trial 1, free fall through water

Figure 3. Trial 1, concrete after stripping

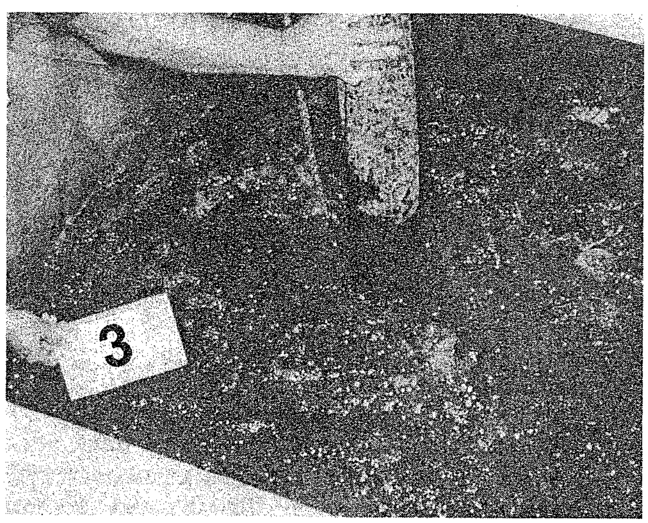


Figure 4. Trial 3, concrete pumped underwater

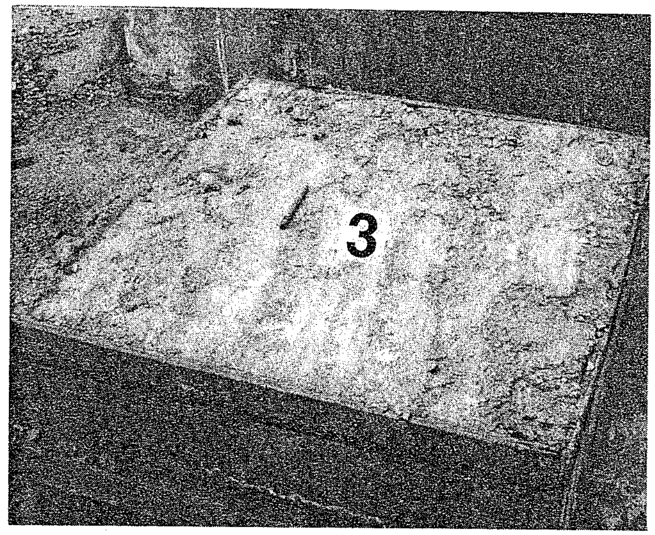


Figure 5. Concrete finished underwater

In trial 4 the concrete was again pumped into a form. This time, however, the concrete was much more fluid and moved underwater very well. The discharge hose was moved around in the form with only a small loss of fines. The concrete had good cohesion and bonded well to the old concrete. Trials 5 and 6 were conducted with an inclined tremie, as shown in Figure 6. The open top of the

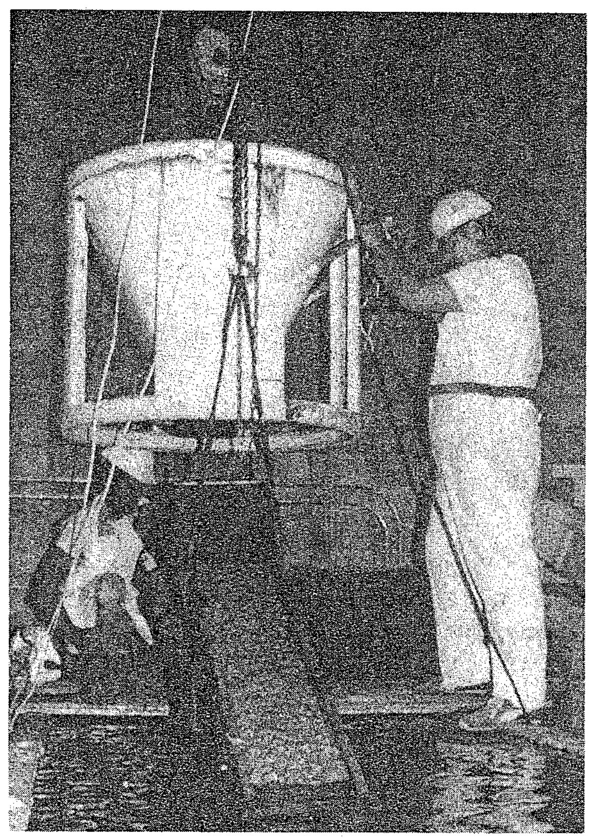
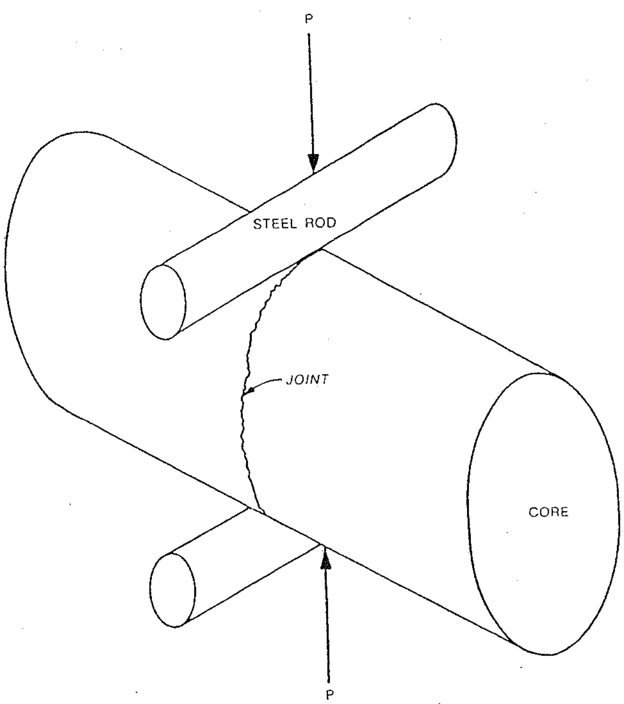


Figure 6. Inclined tremie

chute allowed exposure to the water on the top surface as the concrete moved down the slope. Concrete with a slump of 8 to 10 in. was required to secure steady movement down the chute, but little loss of fines was noted. The concrete flowed underwater approximately 3 ft to the limit of the form. Hand finishing was necessary to level the approximately 15-deg slope of the completed placement. Cohesion and bond to old concrete were excellent.

Tests of Hardened Concrete

After the concrete had hardened in the trial placements, the forms were stripped and cores were taken through the fresh concrete into the hardened abrasion specimens. The cores were tested for bond strength of the joint and for tensile strength of the old and new concrete by use of a point-load tensile test, as shown in Figure 7. The excellent bond obtained on one set of specimens is shown in Figure 8.



Note: Test of parent concrete conducted with identical configuration

$$T = P/D^2$$

where:

T = Tensile strength, psi
P = Failure load, lb
D = Core diameter, in.

Figure 7. Point-load tensile test

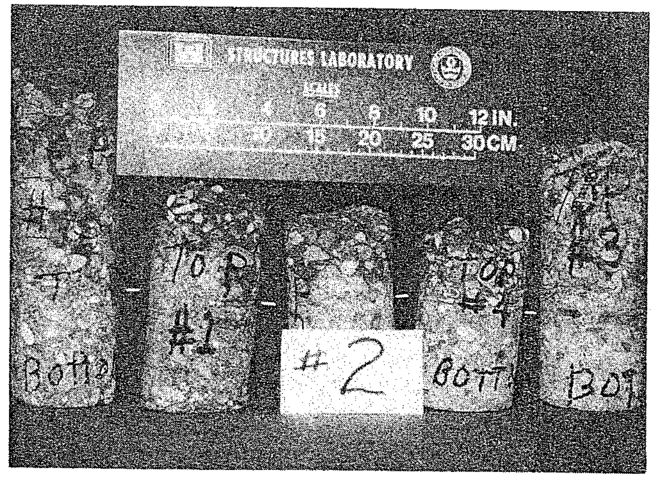


Figure 8. Cores of new concrete placed on old (joints are marked)

Results are given in Table 3. No tests were conducted on trial 1 since the concrete became highly diluted during the free fall through water. The concrete in trial 2 fell through 3 ft of water and developed bond and tensile strength equivalent to approximately half the strength of the old concrete. Significantly, those trials in which the fresh concrete was placed directly on the old concrete (trials 3, 4, 5, and 6) developed bond strengths approximately half the tensile strength of the new concrete which in turn yielded tensile strengths equal to or greater than that of the old concrete.

Table 3
Bond, Tensile, and Abrasion Test Results, Phase II

Trial No.	Bond Strength psi	Tensile Strength, psi Old Concrete	New Concrete	Abrasion-Erosion Loss, cm^3/cm^2, at 72 hr Screeded	Cut
1	--	--	--	--	--
2	185	410	250	0.481	0.321
3	240	445	470	--	0.383
4	300	450	525	--	0.232
5	265	435	540	0.357	0.205
6	--	--	--	0.398	--

Note: All specimens cast underwater; results are the average of a minimum of two tests.

Abrasion-erosion specimens were cast underwater from several of the trial mixtures and tested for underwater abrasion. Results are given in Table 3. The surfaces that were cut prior to installation in the abrasion apparatus compared favorably to the results of the mixtures in Phase I, which were cast in air. Those specimens which were simply screeded off underwater and then tested sustained additional abrasion loss. This loss was to be expected as the screeded surface had some laitance which formed as the concrete hardened underwater. Once this layer of laitance was abraded, the rate of loss was comparable to that of the cut specimens.

Discussion

The results of these tests indicate that cohesive, flowable, abrasion-resistant concrete can be placed underwater by available methods without the use of the tremie seal and with minimal loss of fines if proper materials are used and precautions taken. Anti-washout admixtures and silica fume may be used to reduce segregation and dilution with the water. Fresh concrete containing AWA will reduce washout of fines in concrete allowed to free fall through 3 ft of water; however, dilution will occur. Thus, this technique is not recommended for repair of underwater concrete.

Concrete containing AWA and WRA (for increased fluidity) and placed at the point of use will bond well to hardened concrete and sustain only relatively small loss of fines. Very fluid concrete with good cohesion will move laterally for short distances, again with only minimal dilution.

Concrete so placed can be worked underwater to a rough finish. As with any underwater concrete work, agitation and movement should be kept to a minimum. Indications are that abrasion resistance of concrete placed and finished underwater is the equal of concrete placed in air once the laitance is abraded from the surface.

New valves and control devices reportedly under development in Europe and Japan, used in conjunction with washout-resistant concrete, will likely advance the field of underwater concrete work. When the water is clear and an underwater operation can proceed on visual control, divers could conceivably man an underwater paving train similar to a slipform paving job in the dry. Underwater video monitoring could even replace divers in a very sophisticated application. Where vision is severely restricted, sensors would be required to monitor the underwater placement and guide the movements of equipment.

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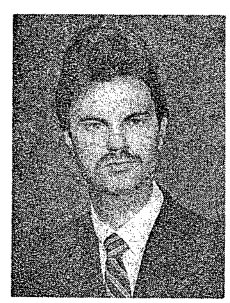

Use of Fiber-Reinforced Acrylic Polymer Modified Concrete as Repair Material at Lock 2

by
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During the winter of 1986-87 the St. Paul District used fiber-reinforced acrylic polymer modified concrete (FRAPMC) to repair Lock 2 located on the upper Mississippi River near Hasting, Minnesota. Twenty-eight vertical monolith joints in the lock chamber and selected sections of the lock wall were repaired with this material. This project is the first known application of FRAPMC on such an extensive basis.

The deterioration of the nonair-entrained concrete in the lock wall monoliths was caused by a combination of barge abrasion and cycles of freezing and thawing. The deterioration at the monolith joints extended from the top of the lock wall to an elevation approximately 2 ft below lower pool for a total height of approximately 25 ft. The width of the joint deterioration ranged from 6 to 12 in. on either side of the 1/2-in. expansion joint. The depth of the deterioration averaged approximately 3 to 8 in. The deteriorated wall areas were located almost exclusively between the upper and lower pool elevations on the wall with southern exposure.

The Material

The St. Paul District contracted with Harza Engineering Company to evaluate the condition of the concrete and recommend repair procedures. Harza considered several criteria before making recommendations:

- Apparent causes of original deterioration
- Compatibility with existing materials
- Bonding properties
- Strength
- Vapor transmission
- Durability
- Cost

FRAPMC was chosen over conventional concrete because of its reported high performance compared to the above criteria and its low shrinkage potential relative to portland-cement concrete. Also, the addition of polypropylene fibers reduced the possibility of shrinkage cracks and crack propagation. Acrylic polymer modified concrete (APMC) is a two-component product consisting of a modified cement and a liquid polymer. The components come in prepackaged units that make proportioning very simple and result in good quality control. The APMC used was Sikatop 111 extended with 3/8-in. granite aggregate with polypropylene fibers 2-1/4 in. in length added at the jobsite. The use of aggregate and fibers reduced the workability of the mixture so that 25 to 30 percent extra polymer was required to obtain the desired consistency. The resulting mixture was capable of being poured into forms and vibrated internally. The effect of using additional polymer may be detrimental to the properties of the material; therefore, its use is not recommended. The reason extra polymer was required will be investigated, and the practice will be eliminated on future projects.

Design Detail

In addition to selecting a material, Harza had to consider three other factors in the design of the repair details:

- How to anchor the repair material to the existing concrete
- How to prevent direct barge impact on the monolith joints
- Whether to fill the 1/2-in. expansion joints between monoliths

Although FRAPMC has significant bonding capabilities, the patches were also secured to the existing concrete with 1/2-in.-diam mechanical anchors at 9-in. spacings. A stud-type anchor was chosen because once set it cannot be displaced and, therefore, would not be loosened if hit by the vibrator.

Additionally, the edges of the patches were saw-cut at a 15-deg angle to form a keyway, except those at the top of the wall patches, which were cut perpendicular to the face of the concrete so no void would remain after concrete placement. Recessing the expansion joints 1/2 in. protected them from impact. The recess was created by a 3-1/2 in. by 1/2 in. bevel in conjunction with a chamfer strip in the forms on either side of the expansion joint (Figure 1).

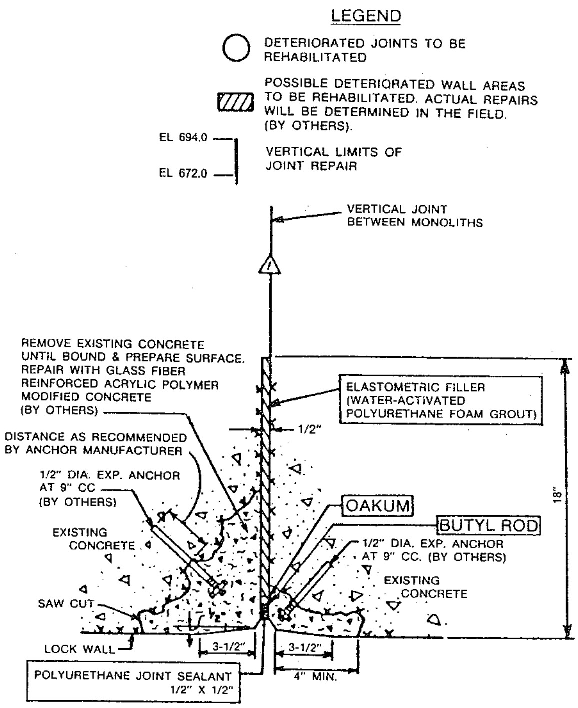


Figure 1. Repair of deteriorated joint

Whether to fill the expansion joints between monoliths was one of the most difficult decisions. The alternatives were to leave the joints open to drain freely and thereby to reduce the effects of freezing and thawing or to fill them with a water-activated foam grout in an attempt to preclude the presence of water altogether. At first it was decided to fill some joints and to leave some open in an experiment to determine which method was better. The final decision, made just as construction was beginning, was to fill all of the joints for safety reasons. Because a large number of pleasure craft use Lock 2, there was concern that people might catch their fingers in an open joint and suffer serious injury.

Construction Sequence

The first step in the construction sequence was to identify and remove the deteriorated concrete. The exact delineation of removal areas could not be done until dewatering was completed. Removal areas were identified by visual examination and sounding hammers. Removal depth at all repair areas extended to sound concrete.

Workers first saw-cut the perimeter of the patch area (Figure 2) and then used handheld jackhammers to remove the deteriorated concrete. The jackhammers were successful because of the small size of the patch areas (about 1,100 sq ft), and they allowed the workers to "feel" sound concrete when they reached it. The only problem with the jackhammers was that the air lines tended to freeze when the temperature was near freezing. Adding antifreeze solution to the air line eliminated this problem.

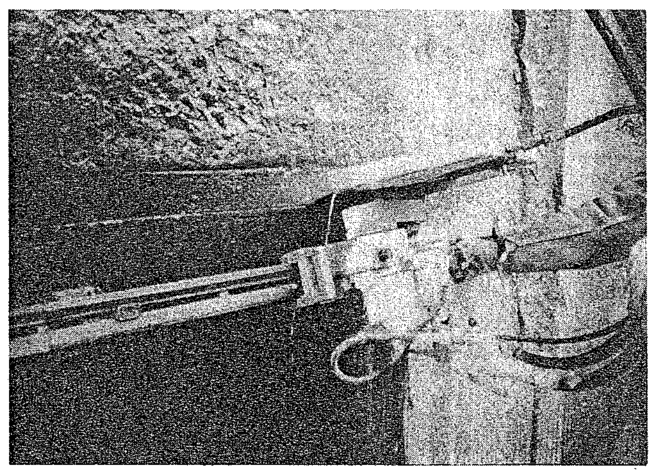


Figure 2. Angled saw cut at bottom of wall repair area

Removing the existing joint filler, an asphalt-impregnated foam rubber which was cast with the concrete and fastened with nails, was the most troublesome step in the removal process (Figure 3). The most effective way to remove this material was to use an electric chainsaw to reach into the joint to cut the nails and shred the rubber.

After the deteriorated concrete was removed, the surfaces to receive new concrete were cleaned of any loose concrete scale and dust with brushes and air (Figure 4). Sandblasting, which would have caused problems with the polishing of the surface, and waterblasting, which would have resulted in ice formation, were ruled out as cleaning methods. Because of these limitations on surface preparation, the superior bonding property of FRAPMC was even more important.

Some special considerations specific to APMC had to be observed. The forms were lined with 6-mil polyethylene sheets because the FRAPMC would adhere to wood forms coated with form oil. In one lift in which a form release agent specially formulated for APMC was tried, the outer layer of plywood peeled off, bonded to the concrete, and had to be removed manually. A high-density overlay plywood with form release agent was used for a wall patch. This trial was successful except that more "bug holes" resulted, probably because of the increased friction between the mortar and the wood as compared to the friction between the mortar and the polyethylene. After these trials, forms lined with polyethylene sheeting were used throughout the project.

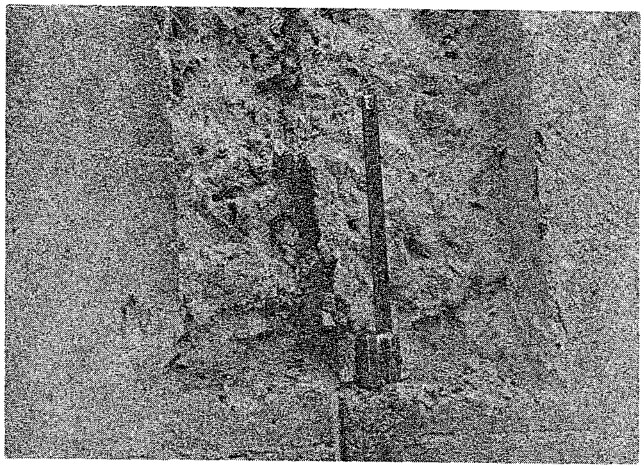


Figure 3. Close-up of removal at monolith joint. Note rubber expansion joint filler

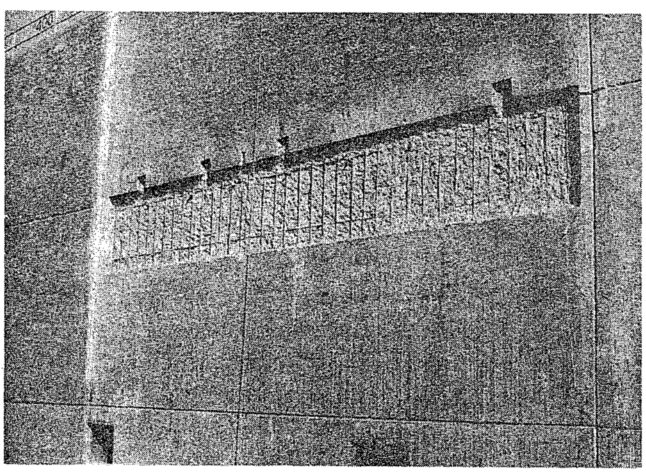


Figure 4. Removal at wall repair area

The most troublesome aspect of forming was finding a suitable method of maintaining the 1/2-in. expansion joint during concrete placement. Several methods were tried before a successful one was found. Because FRAPMC is nonshrink, the only way to remove the joint form made of plywood wrapped in polyethylene sheeting was to jackhammer out one side of the patch. A three-layer, Formica-faced Masonite system produced the same results. A two-layer, steel system was successful, but the safety hazards involved with handling the large steel plates and the potential bond disturbance because of the hammering required to remove the steel made this system unacceptable Styrofoam was ruled out because it was not locally available in the required thickness and was not thought to be durable enough to withstand vibration. Finally, two 4 by 8 ft sheets of 1/2-in. Gatorboard were obtained from the District drafting office. Gatorboard consists of a soft Styrofoam core with thin plastic sheets on each face. The hard plastic sheets (Figure 5) added strength and also released easily from the FRAPMC when they were coated with form oil. The relatively soft core was easily removed with chainsaws or hooks. Using this type of form saved approximately 8 man-hours of labor per pour; was safe; and produced a clean, uniform joint.

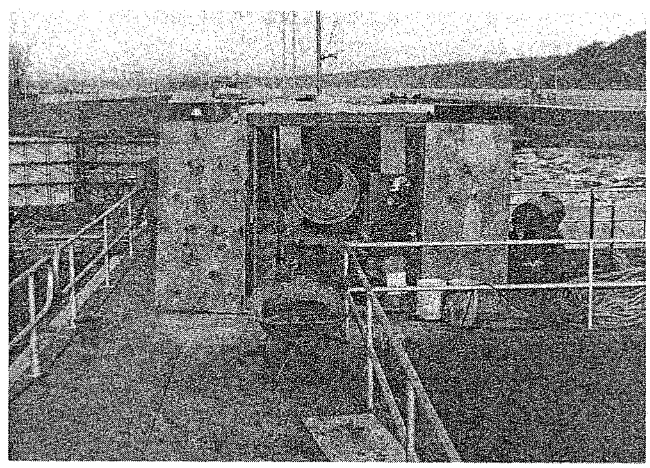


Figure 5. Pouring FRAPMC at top of joint repair

The forms for monolith joint repairs were reused many times, and the rapid turnaround time for FRAPMC allowed several lifts of a single joint to be completed in one day.

Weather Protection

Construction was underway during the winter, so provisions had to be made to continue work during periods of subzero temperatures. FRAPMC cannot be placed when air, substrate, or component material temperatures are below 45° F. To assure compliance with the temperature requirements, the two components of the concrete were stored indoors and the aggregate was stored in a heated, covered stockpile. Mixing was done in heated mixing shelters (Figure 6). In addition, enclosed scaffolding was erected at each

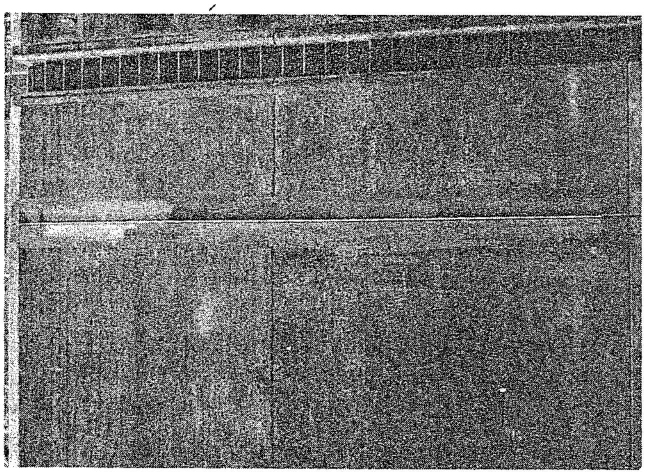


Figure 6. Heated concrete mixing shelter

repair area and heated with portable heaters (Figure 7). To verify that temperatures were acceptable, thermocouples were embedded in most pours and thermometers were placed in the shelters. The temperature of the placed concrete averaged about 60° F, even during subzero temperatures. The use of FRAPMC requires two important precautions: the material must be kept

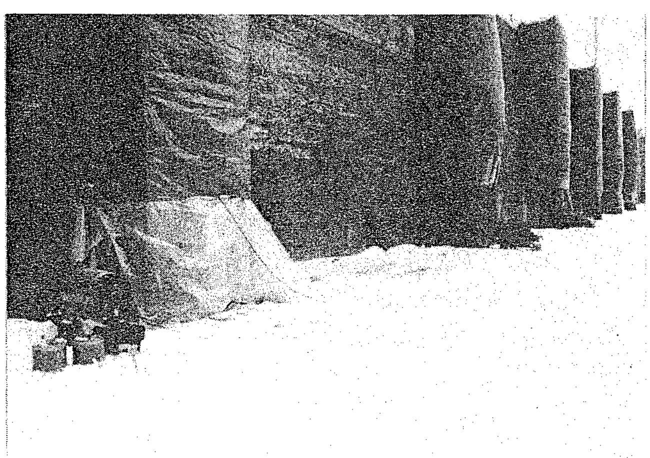


Figure 7. Heated scaffold towers at monolith joints

from freezing and it must not have exceeded its shelf life. One questionable incident during the use of FRAPMC was the formation of a moldlike "fuzz" on certain areas of some pours. Because the outline of the "fuzz" seemed to follow the form lines, engineers hypothesized that the growth came from the forms and was activated by the concrete. Technical representatives at SIKA have been contacted to determine the cause and effect of this growth.

Even though the concrete work at Lock 2 was successfully completed (Figure 8), it will be several years before the long-term performance can be determined. It is highly recommended that trial programs be conducted before FRAPMC is used because local conditions and material availability can affect the performance of the repairs.

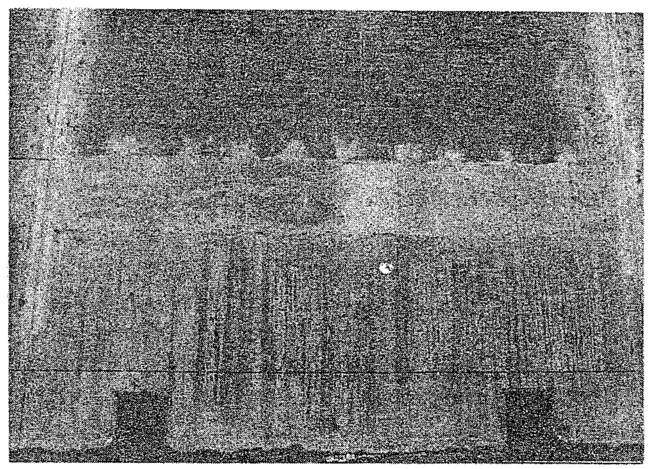


Figure 8. Completed patches at monolith joints and wall repair area

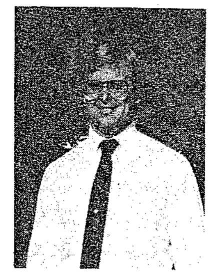
Future Applications

The repair at Lock 2 will serve as a model for the repair of Locks 3 through 10 in the St. Paul District. These structures are at or near their design life of 50 years and are in need of rehabilitation and modernization to extend their safe and efficient operation an additional 50 years.

A concrete repair system similar to that used at Lock 2 will be used at Lock 3 during the winter of 1987-88. The only anticipated change is the use of portland-cement concrete or other type of concrete on wall patches that require large volumes of concrete; the cost of APMC (approximately $30.00 per half cu ft) makes the use of a less expensive substitute desirable for large volume requirements. However, the St. Paul District plans to continue its rehabilitation program with the use of FRAPMC for small volume patches because of its superior properties. Also, the high material cost may be partially offset by the reduced amount of concrete removal required with the use of FRAPMC due to its ability to be applied in thin sections.

For more information contact Michael S. Dahlquist at the St. Paul District at (612) 725-7628 or 725-7628 (FTS).

Michael Dahlquist is a civil engineer in the Structural Design Section of the St. Paul District. On the Lock 2 project, he served as an assistant to the design project engineer, Gerald Cohen, and as construction engineer for the work done by the Corps' hired labor crew. He received his B.S. in civil engineering from the University of Minnesota, where he has also taken advanced course work.



REMR Bulletin News

Bobby Baylot has been selected to succeed Tim Ables as the Technology Transfer Specialist for the REMR Research Program. Bobby has been an Editor in the Information Products Division, Information Technology Laboratory (ITL), WES, since March 1980.

Special thanks are due Tim for his efforts in the development of a technology transfer plan for REMR and for establishing the foundation and format for REMR products: *The REMR Bulletin, The REMR Notebook,* and the technical report series. Tim worked with John Scanlon, former Chief of the Concrete Technology Division, to develop the report which led to the beginning of the REMR Research Program in 1983. Tim was promoted to Information Systems Management Specialist in the Information Planning and Resources Division, ITL, in February 1987.

Appreciation is extended to Katherine M. Kennedy for her capable and tireless assistance in the REMR office during the interim period. Katherine is a Librarian (Engr) in the Technical Information Division, ITL. She is presently assigned to the Hydraulic Engineering Information Analysis Center, Hydraulics Laboratory. She has worked at the Waterways Experiment Station for 30 years.

A revised list of REMR key personnel is presented on page 13 of this issue.

Request for Articles

If you have experience in any of the areas being addressed by the REMR Research Program, *The REMR Bulletin* is actively soliciting articles. Articles by individuals outside the Corps will be considered if relevant to REMR activities of the Corps.

To submit an article, write to: Commander and Director, US Army Engineer Waterways Experiment Station, ATTN: CEWES-SC-A, PO Box 631, Vicksburg, MS 39180-0631.

When submitting photographs with articles, please provide glossy prints rather than screened negatives.

REMR Research Program

KEY PERSONNEL

	Office	*Office Symbol*	*Commercial No.*	*FTS No.*
DRD Coordinator, HQUSACE				
Jesse A. Pfeiffer, Jr.	Civil Works Programs	CERD-C	202-272-0257	272-0257
Overview Committee, HQUSACE				
James E. Crews (Chairman)	Operations Branch	CECW-OO	202-272-0242	272-0242
Tony C. Liu	Structures Branch	CEEC-ED	202-272-8672	272-8672
Program Management				
William F. McCleese (Program Manager)	Structures Laboratory, WES	CEWES-SC-A	601-634-2512	542-2512
CPT Greg May (Deputy Program Manager)	Structures Laboratory, WES	CEWES-SC-A	601-634-3243	542-3243
Robert A. Baylot, Jr. (Technology Transfer Specialist)	Structures Laboratory, WES	CEWES-SC-A	601-634-2587	542-2587
Problem Area Leaders				
James E. McDonald (Concrete and Steel Structures)	Structures Laboratory, WES	CEWES-SC-R	601-634-3230	542-3230
G. Britt Mitchell (Geotechnical—Soils)	Geotechnical Laboratory, WES	CEWES-GE-E	601-634-2640	542-2640
Jerry S. Huie (Geotechnical—Rock)	Geotechnical Laboratory, WES	CEWES-GR-M	601-634-2613	542-2613
Glenn A. Pickering (Hydraulics)	Hydraulics Laboratory, WES	CEWES-HS-L	601-634-3344	542-3344
D. D. Davidson (Coastal)	Coastal Engineering Research Center, WES	CEWES-CW-R	601-634-2722	542-2722
Ashok Kumar (Electrical and Mechanical)	Construction Engineering Research Laboratory	CECEL-EM	217-373-7235	958-7235
Jerome L. Mahloch (Environmental Impacts)	Environmental Laboratory, WES	CEWES-EP-W	601-634-3635	542-3635
Anthony M. Kao (Operations Management)	Construction Engineering Research Laboratory	CECEL-EM	217-373-7238	958-7238
Field Review Group				
OPERATIONS MEMBERS:				
Thomas Pfeffer	Missouri River Division	CEMRD-CO-O	402-221-7289	864-7289
James C. Wong	New England Division	CENED-OD-P	617-647-8411	839-7411
Robert Neal	North Central Division	CENCD-CO	312-353-6378	353-6378
John J. Sirak, Jr.	Ohio River Division	CEORD-CO-M	513-684-3418	684-3418
Carl F. Kress	South Pacific Division	CESPD-CO-O	415-556-8549	556-8549
Jerry Smith	Southwest Division	CESWD-CO-O	214-767-2433	729-2433
ENGINEERING MEMBERS:				
Victor M. Agostinelli	Lower Mississippi Valley Division	CELMV-ED-TS	601-634-5932	542-5932
Eugene Brickman	North Atlantic Division	CENAD-EN-MG	212-264-7141	264-7141
John G. Oliver	North Pacific Division	CENPD-EN-T	503-221-3859	423-3859
Karl V. Keller	Pacific Ocean Division	CEPOD-EN-T	808-438-1635	–
James W. Erwin	South Atlantic Division	CESAD-EN-F	404-221-4256	242-4256

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COVER PHOTOS

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Placement of fiber reinforced acrylic polymer modified concrete

The REMR *Bulletin*

The REMR Bulletin is published in accordance with AR 310-2 as one of the information exchange functions of the Corps of Engineers. It is primarily intended to be a forum whereby information on repair, evaluation, maintenance, and rehabilitation work done or managed by Corps field offices can be rapidly and widely disseminated to other Corps offices, other US Government agencies, and the engineering community in general. Contributions of articles, news, reviews, notices, and other pertinent types of information are solicited from all sources and will be considered for publication so long as they are relevant to REMR activities. Special consideration will be given to reports of Corps field experience in repair and maintenance of civil works projects. In considering the application of technology described herein, the reader should note that the purpose of *The REMR Bulletin* is information exchange and not the promulgation of Corps policy; thus, guidance on recommended practice in any given area should be sought through appropriate channels or in other documents. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. *The REMR Bulletin* will be issued on an irregular basis as dictated by the quantity and importance of information available for dissemination. Communications are welcomed and should be made by writing the Commander and Director, US Army Engineer Waterways Experiment Station, ATTN: Bobby Baylot (CEWES-SC-A), PO Box 631, Vicksburg, MS 39180-0631, or calling 601-634-2587 (FTS 542-2587).

DWAYNE G. LEE
Colonel, Corps of Engineers
Commander and Director

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