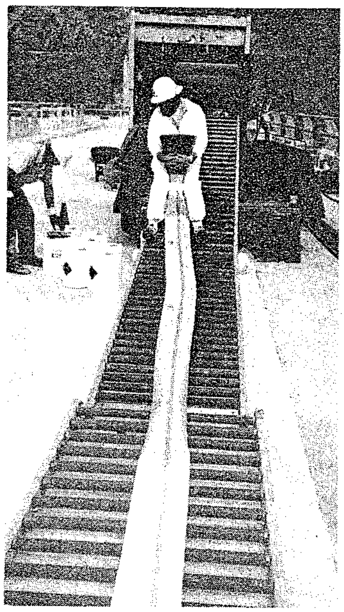
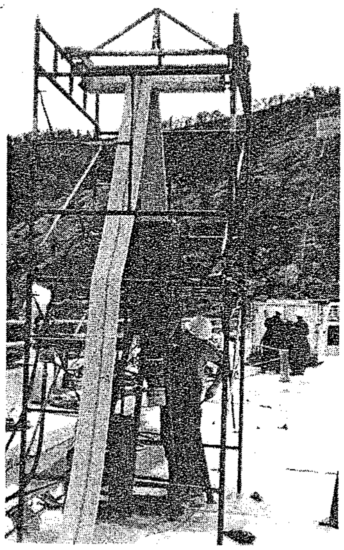
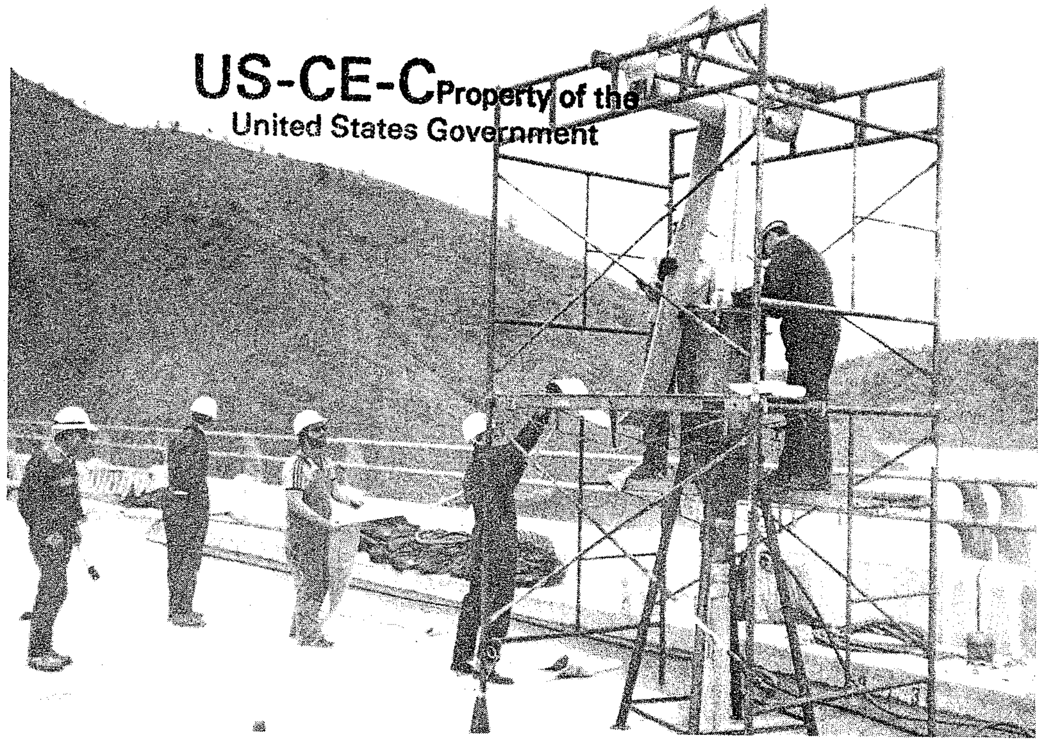




The REMR Bulletin

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

VOL 2, NO. 3 INFORMATION EXCHANGE BULLETIN SEP 1985



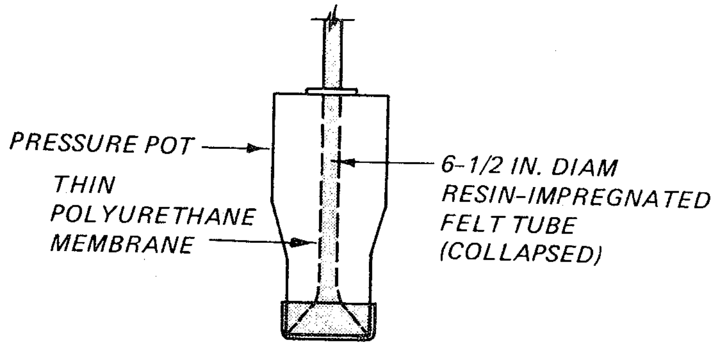
New Technique for Waterstop Replacement Used at Pine Flat Dam

by Debra Tanis
US Army Engineer District, Sacramento

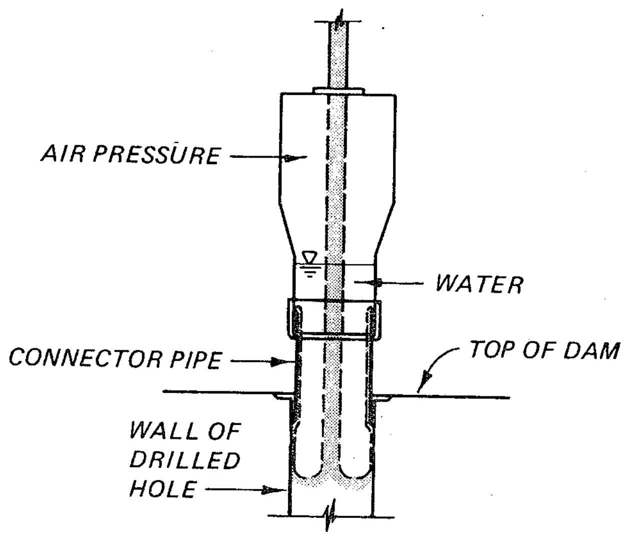
At Pine Flat Dam, California, failed waterstops between monoliths have been successfully replaced using a new type of resin-encased grout plug. Pine Flat, on the Kings River in the central Sierra Nevada Mountains, is a 429-foot-high gravity dam constructed from 37 concrete monoliths meeting at 36 vertical joints and ranging in height to 425 feet.

Six years ago, three leaking joints in the dam were repaired using vertical grout plugs. At monolith joints 28/29, 29/30, and 30/31, a 6-1/2-inch-diameter hole was drilled and was then filled with elastic chemical grout AV-100 acrylamide Initially, the grout appeared to hav worked, but movement between neigh boring monoliths and heavy leakag during application ended the repai efforts. As the reservoir elevation reache 890, flow through the joints returned t levels recorded prior to the repair.

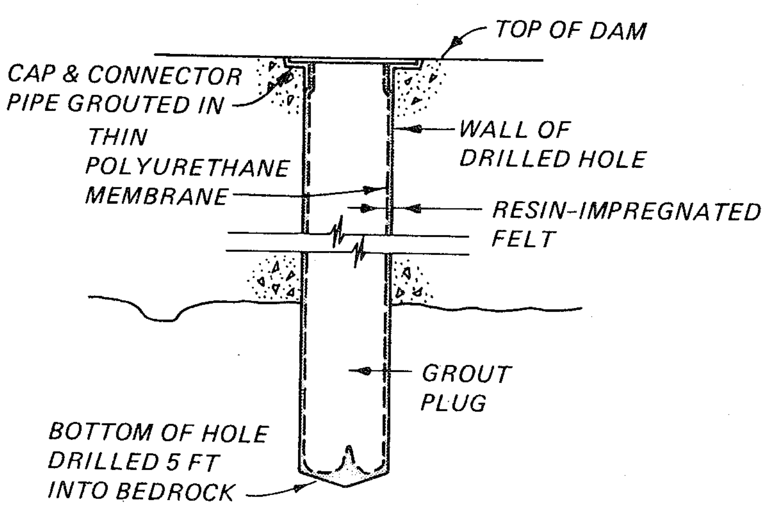
In 1983, Sacramento District forme an evaluation team and issued a Reques for Proposals in search of a reliabl long-term seal to act as a secondar waterstop for the failed copper-stri waterstops between monoliths. The tear consited of concrete experts from th Waterways Experiment Station as we



a. CONNECTION TO PRESSURE POT



b. PRESSURE FORCES FELT TUBE TO INVERT



c. COMPLETED WATER STOP

Construction of replacement waterstop by inversion process

as from Walla Walla and Sacramento Districts. Two proposals were deemed acceptable, and bids were solicited from the proposers.

Gelco Grouting Service of Salem, Oregon, was the lower bidder and began work on the project in February 1985. Gelco used a patented system based on techniques used for in-situ relining of pipelines. First, grout from the old repair was removed by drilling with a tri-cone drill bit. The resulting 6-1/2-inch-diameter hole was then filled with a liner bonded to the surfaces of the drill hole.

The liner was essentially a tube consisting of a thin polyurethane membrane with an underlayer of felt approximately 1/4 inch thick. Prior to installation, water-activated polyurethane resin was poured into the tube to saturate the felt lining. To ensure that the resin was distributed evenly throughout, the tube was passed through a set of pinch rollers.

The tube was then inserted into the drill hole using water pressure to turn the tube inside-out as it was being forced down the hole. Internal air and water pressure pressed the resin-impregnated felt tightly against the concrete surface, and water inside the drill hole activated the resin creating a bond between the liner and the drill hole. After the resin had cured, the center of the tube was filled with grout to form a strong yet flexible core.

The liner was successfully inserted into joint hole 30/31 (191 feet deep), and the seepage was reduced from 24 gal/min to an immeasureable amount. However, the liner for joint hole 29/30 (238 feet deep) broke after being inserted 145 feet deep due to excessive water pressure. Repairs were halted temporarily, and a truck had to be used to pull the liner out of the hole. The polyurethane-resin bond was so strong that pieces of concrete were pulled out with the liner. The hole was cleaned of resin, and the following week a new liner was inserted into the hole using air and water pressure. The leakage of 37 gal/min through the joint was reduced to 5 gal/min. When Gelco's liner was inserted in joint hole 28/29 (257 feet deep), the leakage of 75 gal/min was immediately reduced to 14 gal/min. By the next day, this amount was reduced to 7 gal/min.

Use of videotape during installation was specified in the contract for this repair. Video inspection of the holes before, during, and after liner insertion greatly aided Gelco and Sacramento District in discovering the exact locations of foundation rock, crevices in the concrete, and points of seepage.

For more information on the repair efforts at Pine Flat Dam, contact Bill Heyenbruch, Sacramento District, at FTS 460-2072 or 916-551-2072. For more details on the waterstop system, contact Steve Waring, Gelco division manager, at 206-872-2550.

Debra Tanis, a technical writer with the Civil Design Section of the Sacramento District, has been with the Corps of Engineers since 1981. She holds a B.A. degree in English from California State University in Sacramento. Prior to her employment with the Corps, she worked in Washington, DC, as a political researcher for the Hearst Newspaper Corporation.

Performance of Repairs to Stop Leakage in Intake Structures

by

James P. McKenzie, US Army Engineer District, Philadelphia
Roy L. Campbell, US Army Engineer Waterways Experiment Station

One of the most common deficiencies in concrete structures at Corps of Engineers' dams is leakage. Dam intake structures, since they are surrounded by water, are especially vulnerable to leakage. In fact, they are the second most frequently reported location of deficiencies in Corps concrete hydraulic structures.

In the past, repairs to stop leakage in intake structures have generally performed poorly—so poorly that several different types of repairs are often attempted at a project before a satisfactory (if any) reduction in leakage is achieved. Poor performance usually results from an improper remedy being employed, from improper or inadequate application techniques, or from failure of the repair material itself due to adverse effects of the environment in which the repair was made on the physical characteristics and behavior of the material.

REPAIR HISTORY AT BELTZVILLE DAM

A typical example of repair performance can be seen in the history of repairs to the intake tower of Beltzville Dam in Philadelphia District. Water seepage in the intake tower at Beltzville was first noted during the third periodic inspection of the project in September 1972. Water was observed in electrical conduits and boxes, and minor leakage was seen at the joints and form tie locations below pool level. This condition worsened over the next few years, being manifested by numerous instances of minor leakage, extensive calcite formation, and corrosion of imbedded connection plates that support interior framing.

Starting in 1977, a series of repairs was performed in various areas of the intake tower using a variety of techniques and materials. It should be noted that each of the products used in these repairs had been evaluated (including laboratory analysis) by its manufacturer and in some instances by third parties to determine its suitability for use as a repair material in this type of application. Documentation of these evaluations was available and, where appropriate, was considered in planning the repairs. However, the evaluations generally did not take into account the full influence of the repair environment, and therefore would not give a true indication of product performance in the hostile intake tower environment.

September 1977 Repair

In September 1977, the first of five repairs was undertaken. A surface treatment manufactured by VANDEX (USA), Inc., Stamford, Connecticut, was applied to the negative side (interior face) of a test section of the tower wall. During the repair, calcite formations were removed using a chipping hammer, and cracks were routed out approximately 1 to 2 inches to sound concrete, producing a dovetail groove where possible. Four treatment layers were applied to the routed surfaces in the following order: a slurry coat of Vandex Super®, a layer of dry mix containing Vandex Special® or Pure®, a layer of wet mix containing Vandex Super and Premix®, and a layer of wet mix containing Vandex Premix. Application began at the highest points of the cracks and continued downward to the lowest points where drainage ports were installed. The drainage ports were later plugged using a wet mix of Vandex Super and Premix. All adjacent areas were coated with a slurry of Vandex Super followed by a slurry of Vandex Premix.

The Vandex representative recommended that a second coat be applied within a year. However, the performance of the repair was not considered effective enough in stopping the seepage and deterring the formation of calcite to warrant further use. (A 1984 core sample analysis showed that penetration of the Vandex into the concrete was less than 1 mm).

September 1980 Repair

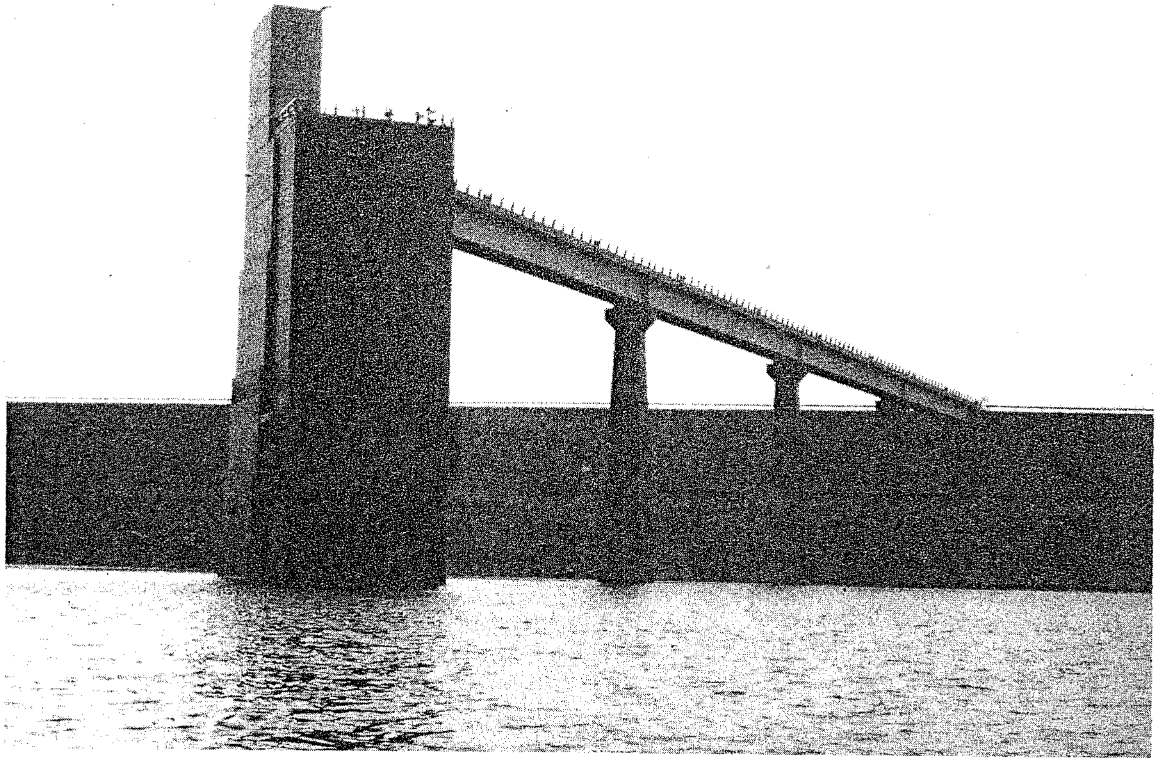
The second repair attempt, in September 1980, involved a test section in which cracks were injected with a two-component, low-viscosity liquid adhesive called Concresive® 1380. This material was manufactured by Adhesive Engineering Co., San Carlos, California. After surfaces bordering the cracks were cleaned and sealed, injection ports were installed. The cracks were then injected under 100 psi of pressure. Like the repair with the Vandex treatment, that with Concresive 1380 was not considered effective enough in stopping the intake tower leakage and deterring the formation of calcite to warrant further use.

December 1982-March 1983 Repair

In the third repair, a two-component polyurethane membrane called Vibraspray S-80® (manufactured by Uniroyal, Inc.) was applied to the positive side (exterior face) of the upper third of the normally submerged portion of the tower. The work was performed during a 4-month period beginning in December 1982 when the lake had been partially drawn down. The repair required sandblasting the surface to be treated, erecting scaffolding and a temporary enclosure over the area to be repaired (necessary because of the cold weather), patching cracks and spalled concrete, heating the area inside the temporary enclosure, applying a bonding agent, applying two successive 40-mm coats of Vibraspray S-80, patching bug holes, applying a final 30-mm coat of Vibraspray S-80, and maintaining sufficient temperature to ensure proper curing. Inspection of the interior of the tower in June 1983 revealed that the leakage had lessened in the area of application.

June 1984 Repair

In June 1984, a fourth repair was made during a two-day contract operation. A two-component grout labeled TACSS-020 NF® and manufactured by DeNeef America, Inc., St. Louis, Michigan, was used to repair a test section of leaking cracks. Holes 1/2 inch in diameter and 6 inches deep were drilled into the cracks at intervals of 6 to 36 inches. An injection port was placed into each hole, and fluorescein dye was pumped into the port through a brass valve. The dye was used to flush the crack clean and determine the extent of crack opening.



Intake tower of Beltzville Dam (completed 1972), located on Pohopoco Creek near Parryville, Pennsylvania

The amount of accelerator needed to achieve the desired reaction time was then determined, based on the extent of crack opening. The TACSS-020 NF and accelerator were mixed in a 5-gallon pail and hand-pumped through a hose to the injection valve and port. Injection began at 100 psi and increased to 400 psi. This pressure was maintained until refusal occurred, at which time the valve was closed until the reaction was completed. The injection process was continued at the next port located adjacent to or above the previously injected port.

The cracks being repaired were very fine and required the use of a low-viscosity injection material to allow for adequate penetration and sealing of the crack. TACSS-020 NF is a low-viscosity grout that reacts with water to form a polyurethane foam. It appears, however, that during the injection process the grout forced water needed for the reaction out of the cracks and thereby slowed reaction time. Also, it is suspected that the temperature in the cracks was low enough to further retard the reaction. At any rate, the injection process was time-consuming and judged economically unacceptable for the remaining crack repair work in the intake tower.

September 1984 Repair

The fifth repair was undertaken in September 1984, when 750 linear feet of cracks was injected with two-component, low-viscosity, epoxy-resin system called Sikadur 52® Injection Resin, manufactured by Sika Corporation, Lynhurst, New Jersey.

Chipping hammers and wire brushes were used to clean the surfaces and remove loose materials bordering the cracks. Holes 3/4 inch in diameter and 6 inches deep were drilled into each crack, and injection ports were installed. Sika High Mod Gel® was used to seal the crack surface between ports. The Sikadur 52 Injection Resin was then injected at 100 psi into the injection port.

Inspection of the interior of the tower in July 1985 showed that leakage and calcite formation had recurred in some of the injected areas. Overall performace of the injection repair was judged to be not fully successful.

Summary of Repairs

Leakage was reduced to some degree after each of these repairs. However, the repairs made using Vibraspray S-80 membrane and Sikadur 52 Injection Resin were the most successful. Though neither of these repairs proved to be 100-percent effective, they did reduce the amount of leakage in treated areas to an acceptable level. As a result of the repairs and a modification to the heating and ventilation system in the tower, moisture levels in the intake tower have been reduced, with some seasonal variations.

Repair costs for the efforts described above were as follows:

Repair	*Material*	*Unit Cost*	*Total Cost*
1	Vandex treatment	$0.75/sq ft $20/lin ft	$ 0*
2	Concresive 1380	$700/day	9,800
3	Vibraspray S-80	$22.76/sq ft	227,560**
4	TACSS-020 NF	$1225/day	2,450
5	Sikadur 52 Injection Resin	$50/lin ft	37,500†

* This was a demonstration effort performed by the manufacturer's representatives at no cost to the government.

** Erecting and heating the enclosure (necessitated by cold weather) approximately doubled the cost of this repair.

† This does not include the cost of scaffolding used to inject areas 90 feet above the floor.

CAUSE OF CRACKING AT BELTZVILLE DAM

Based on observations made during the ninth periodic inspection of Beltzville Dam in 1983, it was recommended that concrete cores be taken and examined to determine the cause of cracking. Philadelphia District forwarded the cores to the Waterways Experiment Station for testing and petrographic examination, and a June 1984 report of the results of the testing concluded that the cores showed "abundant evidence of alkali-silica reaction which is believed to be largely or wholly responsible for cracking of the concrete." The report also stated that the potential for further expansion and cracking of the concrete due to alkali-silica reaction still exists.

As a part of any concrete investigation involving alkali-aggregate reaction, it is important to determine if the reaction is complete. If complete, surface treatment and crack injection may prove effective in reducing leakage through concrete. If the reaction is not complete, it may continue as long as reactive aggregate, alkali, and moisture are available. In the case of an intake structure, it is unlikely that the structure could be sealed sufficiently to prevent the intrusion of moisture necessary for alkali-aggregate reaction to continue if alkali and reactive aggregate remain combined in the concrete. Any repair of cracks resulting from alkali-aggregate reaction may not result in a lasting repair unless the reaction has ceased.

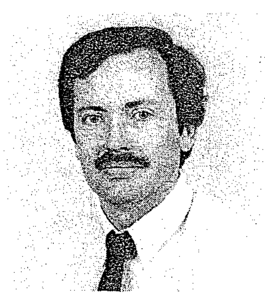
RESEARCH UNDER WAY ON CRACK REPAIR PROBLEMS

Crack repair problems associated with intake structures are being addressed in the REMR Research Program. A new test apparatus and test method for evaluating crack repair methods and materials to stop leakage are currently being designed as part of the work under Work Unit 32304, "Maintenance and Repair of Intake Structures and Conduits."

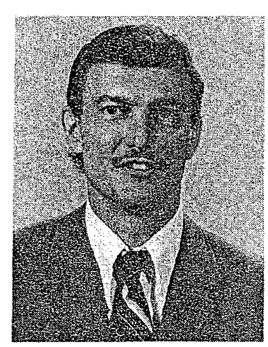
The test apparatus will simulate actual field conditions and provide a realistic environment for testing and evaluating methods and materials for crack repair. The apparatus will allow cracks to be repaired while a concrete test specimen is in the test apparatus and up to 100-psi hydrostatic water pressure is being applied to the specimen face opposite the repair. It will be possible to vary the temperature of water flowing through the crack from 40° to 85°F. Designs of the apparatus and development of the test method are scheduled for completion in January 1986, and construction is scheduled for completion late in FY 87.

ADDITIONAL INFORMATION

For more information on the crack repairs at Beltzville Dam, contact James McKenzie at FTS 597-4820 or 215-597-4820. For details on maintenance and repair of intake structures and on the new test apparatus and test method for evaluating crack repair methods and materials, contact Roy Campbell at FTS 542-2814 or 601-634-2814.



James McKenzie is a civil engineer in the Geotechnical Section of Philadelphia District. He holds both B.S. and M.S. degrees in civil engineering from Villanova University.



Roy Campbell is a research civil engineer in the Concrete Technology Division, Structures Laboratory, WES, and is currently principal investigator for REMR Work Unit 32304, "Maintenance and Repair of Intake Structures and Conduits." He received his B.S. in civil engineering in 1972 from Mississippi State University.

News in Brief

The 6th Field Review Group meeting for REMR was held August 19-21 at the Waterways Experiment Station. Principal investigators for proposed FY 86 work units briefed the FRG members and management officials from Corps headquarters on research accomplishments in FY 85 and plans for the coming year. The next FRG meeting will be hosted by Rock Island District in the spring, and all but the last session of the meeting will be open to the public. Watch for further details in future issues of *The REMR Bulletin*.

The American Concrete Institute has announced its 1985-86 seminar series to be presented at cities in both the US and Canada. The program covers "Structural Concrete Repair—Corrosion Damage and Control" and is to be presented by ACI and local ACI chapters in cooperation with ACI's Committee on Repair. Presentations will be made on the actual "how-to's" of repairing structural concrete. The seminar will be offered in the following locations: Kansas City (October 31), Atlanta (November 14), Baltimore (November 21), Detroit (December 5), Toronto (February 20), and Cincinnati (April 16). More information is available from the Education Department, American Concrete Institute, PO Box 19150, Detroit, MI 48219 or by calling 313-532-2600, ext. 77.

A REMR-sponsored workshop on drainage system and relief well problems was held April 16 and 17 in Denver. Thirty representatives from 13 Corps Districts met with REMR problem area monitors and principal investigators for Work Units 32312, "Restoration of Drainage Systems," and 32313, "Restoration of Relief Wells," to further define problems and develop research priorities. For assistance with these types of problems, contact Buck Taylor (drainage systems) at FTS 542-3454 or 601-634-3454, or Roy Leach (relief wells) at FTS 542-2727 or 601-634-2727.

The Mid-South Chapter of ACI, recently reorganized and serving only the State of Mississippi, has announced plans to meet on a quarterly basis in either Jackson or Vicksburg. The chapter currently has 52 members and is in the process of electing officers. For more information, contact the interim president, Ed O'Neil, at 601-634-3268.

Recent Publications

The condition of Corps of Engineers civil works concrete structures. J. E. McDonald, R. L. Campbell, Sr. US Army Engineer Waterways Experiment Station, Vicksburg, MS, April 1985. Technical Report REMR-CS-2.

This report presents quantitative information on the present condition of concrete portions of Corps of Engineers civil works structures based on an analysis of two computerized data bases. The structure-description data base contains basic information (location, structure type, age, purpose, etc.) on 766 projects. The damage and repair data base contains information on deficiency types, causes (where reported), location, and degree of damage as well as available information on repair materials, techniques, and performance. Included are appendicies giving details of computer programs used in analyzing the two data bases, definitions of deficiencies, and photographs of typical deficiencies classified according to degree of damage.

Improvement of liquefiable foundation conditions beneath existing structures. R. H. Ledbetter. US Army Engineer Waterways Experiment Station, Vicksburg, MS, August 1985. Technical Report REMR-GT-2.

This report presents and briefly discusses methodologies that are deemed potentially applicable for remedial treatment of liquefiable soils beneath existing structures. A comprehensive bibliography is included on the feasible methods.

The Repair, Evaluation, Maintenance, and Rehabilitation Research Program. US Army Engineer Waterways Experiment Station, Vicksburg, MS, June 1985.

This full-color, 12-page pamphlet briefly describes the purpose and scope of the REMR Research Program and lists key personnel involved in managing and reviewing the program.

Request for Articles

If you have experience in any of the areas being addressed by the REMR Research Program which might be of interest to our readers, we would appreciate your drafting an article describing your work or contacting us for assistance in doing so. Articles by persons outside the Corps are welcome and will be considered for publication so long as they are relevant to REMR activities of the Corps.

Write to: Director, US Army Engineer Waterways Experiment Station, ATTN: WESSC-A, PO Box 631, Vicksburg, MS 39180-0631. Or call Tim Ables at 601-634-2587 (FTS 542-2587).

COVER PHOTOS

Felt-lined tube used by Sacramento District in its waterstop replacement project at Pine Flat Dam, Kings River, California, has been stretched out along the top of the dam and is being filled with water-activated polyurethane resin.

Workers prepare to couple the resin-impregnated tube to a pipe connected to a drill hole running the length of one of Pine Flat's leaking joints.

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 Director, US Army Engineer Waterways Experiment Station, ATTN: T. D. Ables (WESSC-A), PO Box 631, Vicksburg, MS 39180-0631, or calling 601-634-2587 (FTS 542-2587).

Allen F Grum

ALLEN F. GRUM
Colonel, USA
Director

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
PO BOX 631
VICKSBURG, MISSISSIPPI 39180-0631

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

WESSC-A

BI
POSTAC
DEPARTME
PERMIT NO.