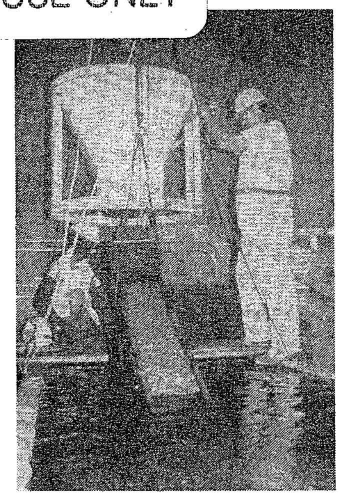
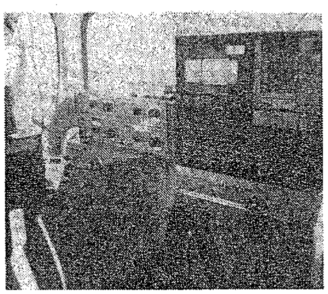
The REMR *Bulletin*

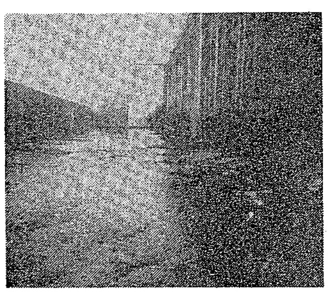
News from the Repair, Evaluation, Maintenance, and Rehabilitation Research Program

VOL 8, NO. 4 — INFORMATION EXCHANGE BULLETIN — DEC 1991

...ny Corps
...ineers







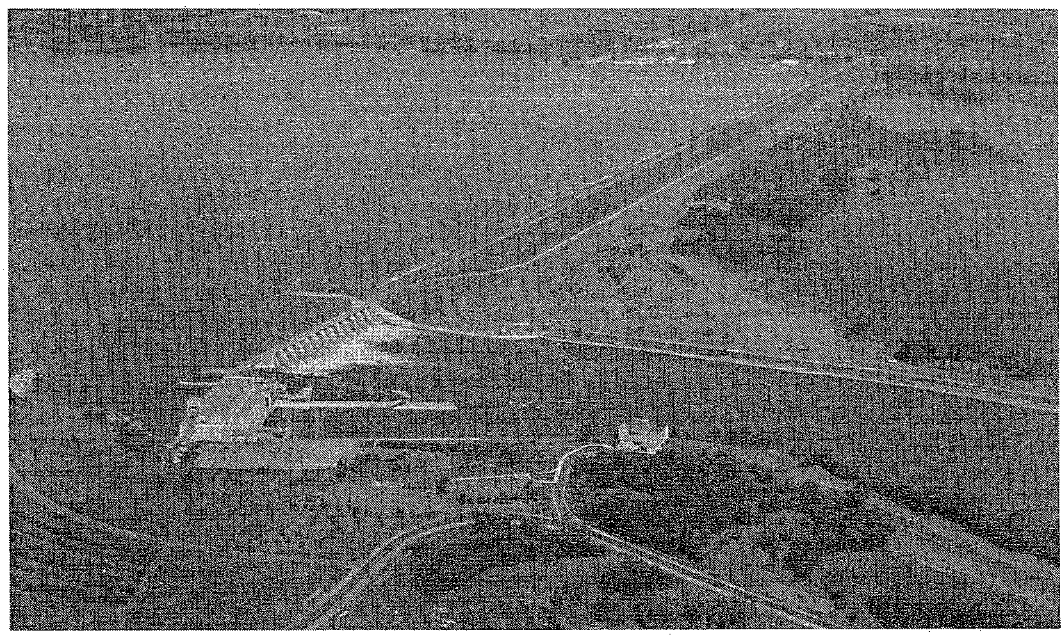


Figure 1. Gavins Point Dam, Yankton, South Dakota

Underwater Repair of Concrete Based on REMR Technical Information

by

Bruce N. Harris, James F. Palma, and Donald F. Miller
US Army Engineer District, Omaha

Technology published by the REMR Research Program was used in developing plans for spall repairs at Gavins Point Dam. REMR information on underwater concrete placement techniques, installation of anchors, and stay-in-place forms enabled engineers to provide a durable and cost-effective repair.

Background

Gavins Point Dam, located on the Missouri River near Yankton, South Dakota (Figure 1), is the smallest of the six Missouri River main stem dams. The powerhouse contains three Kaplan turbines with a generator rating of 33,333 kw each and a plant capacity of 100,000 kw. The average gross head is 45 ft. The power facilities were built in the late 1950s.

Diving inspections identified concrete spalling at the top of the powerhouse foundation, at the downstream edge of the draft tube portals, at the interface with the tailrace slab (Figure 2). The inspection also identified

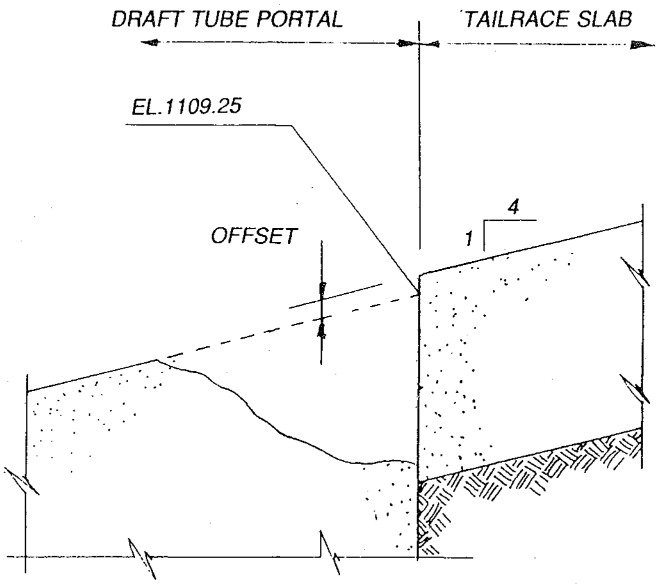


Figure 2. Spall at draft tube portal

concrete spalling of the south retaining wall foundation downstream of the powerhouse at its interface with the tailrace slab (Figure 3). There were several void areas where water had eroded the shale under the tailrace slab along the length of the retaining wall.

It was decided to fund a concrete repair of the spalled areas when inspections indicated the spalling damage was increasing in area and depth. Another concern was that the tailrace slab along the south retaining wall was being undermined.

Plans and specifications would have to address concrete repair complicated by the fact that the repair would be done underwater at a depth of approximately 50 ft.

Cause of Spalling

The following description is the authors' best scenario for the cause of the spalling. Figure 2 shows the interface between the draft tube portal and the tailrace slab. The powerhouse and tailrace slab are supported on excavated Niobrara chalk and Carlisle shale. The draft tube portal is part of a massive monolithic concrete placement that is part of the powerhouse foundation. The tailrace slab is a 1-ft-thick free-floating slab. The chalk and shale have rebounded over the years since the excavation for the powerhouse. The draft tube portal, being part of the heavy powerhouse foundation, has not rebounded at the same rate as the tailrace slab. The offset between the draft tube portal and slab varies from 1/2- to 1-1/2 in. (Figure 2). It is interesting to note that the thinner tailrace slab did not crack and spall; however, it is fully supported by the rebounding shale. In time, water entered the cracks of the concrete causing the top reinforcement to rust, and the abrasive effects of rocks and debris caused spalling of the concrete (Figure 3). Over time the spalled areas have increased in depth because of the continuing abrasive effects of rocks and debris over the concrete surfaces during plant operation. The cause of the spalling along the south retaining wall is similar.

Need for Repair

For those who participate in annual or periodic inspections, seeing spalled concrete is not always that much of a concern. However, in this case, the spalled areas had been monitored over the years by diving and/or underwater camera inspections and had recently accelerated in depth and width. The major concern was the undermining of the tailrace slab since the depth of spalling was nearly the same as the slab thickness. The tailrace slab along the south retaining wall had several areas where the chalk and shale had been eroded by the water discharged through the draft tube portals, causing a void under the slab.

Repair Technique

The US Army Engineer District, Omaha, Foundation and Materials Section contacted the US Army Engineer Waterways Experiment Station (WES) to discuss the spalling problem and methods of repair. *The REMR Bulletin* articles and technical reports referenced in this paper were helpful in preparing the construction documents of the selected repair method.

The main goals of repairing the concrete spalled areas and filling the void areas were obvious. However, the selection of construction techniques and materials required further study. The two basic construction techniques applicable to this repair were in-the-dry and underwater.

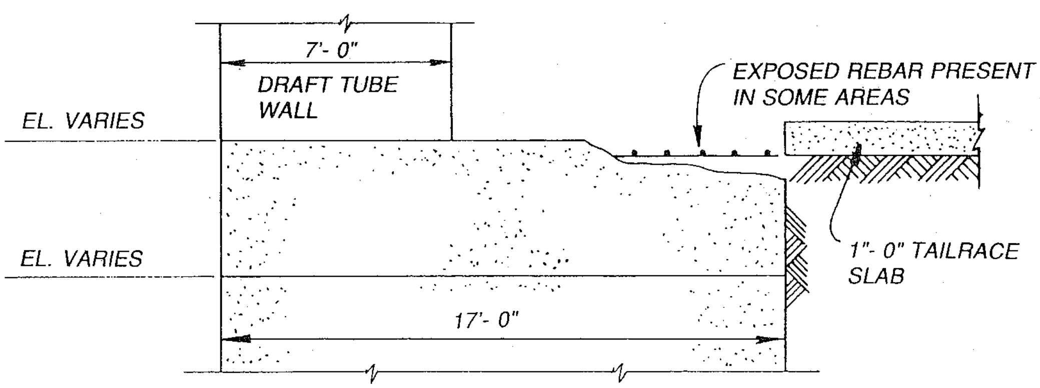


Figure 3. Spall at south retaining wall

A dry repair would have necessitated construction of a cofferdam between the powerhouse wall and south retaining wall. The cofferdam would have had to be approximately 55 ft high since the water in the tailrace area was around 50 ft deep. The cost of the cofferdam and power plant outage for this construction technique were too great; therefore, underwater repair was selected.

The underwater repair consisted of cleaning drummy rock and loose, semidetached or unsound fragments from the spalled concrete, positioning preplaced aggregate covered by anchored steel or precast concrete units, and filling voids in the aggregate by injecting grout through pipes in the steel plates or precast concrete units (Figures 4 and 5). The same method was used to fill voids under the tailrace slab. All work was done by divers.

The steel plate was used as the form for the top surface of the preplaced aggregate concrete repair. The plate was anchored to the sound concrete around and below the spalled area to act as a rigid form, since the grout was placed under pressure to displace the water in the aggregate voids. It was felt that the concrete repair would bond well with the cleaned existing concrete and would be durable in the abrasive environment without any metal armoring. However, since a form was needed and had to be anchored for the grouting, it was decided to keep the steel plates as an added assurance to prevent future abrasion of the draft tube portal concrete repair.

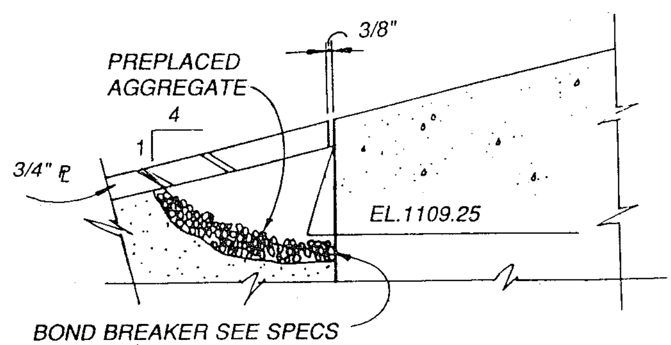


Figure 4. Repaired spall of draft tube portal

The precast concrete units were used as a form similar to the steel plates along the south retaining wall (Berger/Abam Engineers 1989). The reason for the precast units instead of the steel plates was that the offset between the retaining wall foundation and the tailrace slab was nearly 1 ft. To make up for the large offset and allow for some future tailrace slab rebound, 15-in.-thick precast concrete units were used (Figure 5). The tailrace slab downstream of the powerhouse was rebounding over 10 times more than the area adjacent to the draft tube portal. This difference could be attributed to the weight of the powerhouse causing a reduction in the tailrace slab rebound near the draft tube portal and permitting more rebound downstream of the powerhouse where its weight has less downward effect.

Another special feature of this repair for which the REMR information gave good insight was in the anchoring of the steel plates and precast concrete units. The selection of anchors was important if the plates were going to stay in place when the power plant was placed back in operation. Expansion anchors were not used since the hydrodynamic forces on the plates would be vibratory in nature; therefore, adhesive anchors were selected for use.

REMR information stated that adhesive anchors installed under submerged conditions had an average tensile capacity 75 percent less than anchors installed in the dry (Best and McDonald 1990). The reason for the reduced tensile strength for submerged conditions is the mixing of the resin and water in the drill hole (McDonald 1988). The contractor on this project worked with Hilti, Inc., who in turn had worked with WES to develop a procedure to solve the problem of the water mixing with the resin. The procedure basically uses a doweling adhesive called C-100 in bulk that fills the hole approximately half full. A vinylester resin capsule is inserted into the hole allowing the C-100 to displace the water. Now the two-part capsule can be broken by the threaded anchor rod and mixed without water being present (McDonald 1990). Tensile strength tests on anchors installed with this procedure have yielded nearly the same capacities as those on anchors installed in dry conditions.

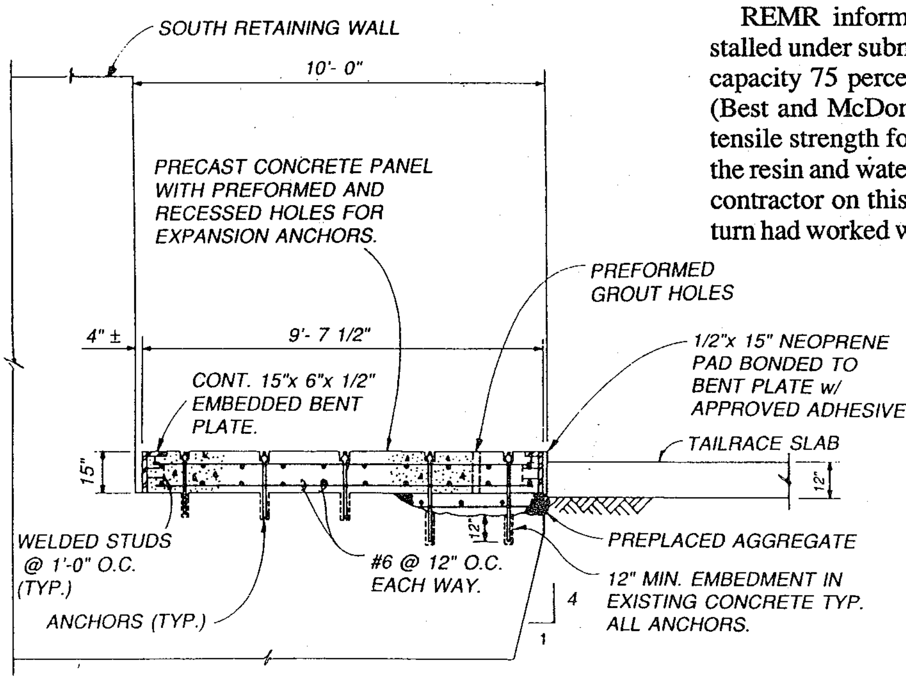


Figure 5. Repaired spall at south retaining wall

Completion of Work

Repair work of the type discussed requires close coordination with regulatory, environmental, and power administrations. These groups are normally affected by the total shutdown of all power units.

In this repair, the power units were shut down for a period of 14 consecutive days, during which time the contractor was to schedule and accomplish all of the underwater construction activities. No time extensions to the shutdown period were to be granted because of adverse weather conditions.

If the contractor failed to complete the underwater construction activities within the 14-day power unit shutdown, resulting in an extension of the shutdown period, the contractor would have to pay the government $36,000 for each additional day as liquidated damages. Conversely, the contractor was given an incentive for completing the underwater construction activities in a satisfactory manner in fewer than 14 days. The contractor could receive $18,000 per day (1/4-day increments) up to a maximum of 4 days for completing the project earlier than the 14 days.

The contractor completed the project 3-1/2 days early. To meet this schedule, the contractor went through every procedural step with his crews on land so that the only variable would be the underwater aspects. Cement grout was prepackaged to assure proper proportioning. The contractor had several diving crews that allowed him to work 24 hr a day. The Corps monitored the material quantities to assure all spalls and voids were being filled. An independent diving company was used to assure work was completed satisfactorily.

Conclusion

Materials and procedures have been developed to repair concrete underwater with good results. Repair of concrete underwater is very attractive given the cost of cofferdams that allow the repair to be done in-the-dry. The installation of adhesive anchors under submerged conditions must follow a procedure in which water is removed from the hole so that mixing of water and resin will not occur.

For further information, contact Bruce N. Harris at (402) 221-4521, Donald F. Miller at (402) 221-4431, or James F. Palma (402) 221-4433.

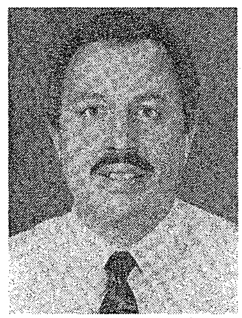
References

Berger/Abam Engineers. 1989 (Dec). "Concepts for Installation of the Precast Concrete Stay-in-Place Forming System for Lock Wall Rehabilitation in an Operational Lock," Technical Report REMR-CS-28, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

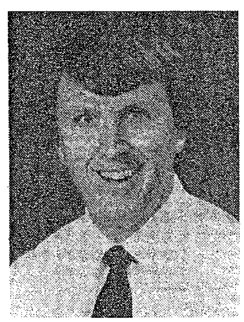
Best, J. Floyd, and McDonald, James E. 1990 (Jan). "Evaluation of Polyester Resin Epoxy and Cement Grouts for Embedding Reinforcing Steel Bars in Hardened Concrete," Technical Report REMR-CS-23, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

McDonald, James E. 1988 (Jul). "Evaluation of Vinylester Resin for Anchor Embedment in Concrete," *The REMR Bulletin*, Vol 5, No. 2, pp 1-5.

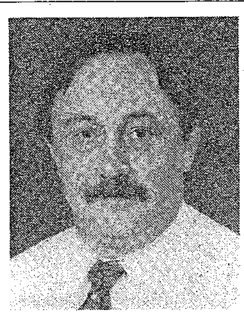
____. 1990 (Oct). "Anchor Embedment in Hardened Concrete under Submerged Conditions," Technical Report REMR-CS-33, US Army Engineer Waterways Experiment Station, Vicksburg, MS.



Bruce N. Harris has been a structural engineer with the Omaha District for 18 years. As Assistant Chief of the Design Branch, he is responsible for the day-to-day Civil Works operations of the branch. Bruce has a Bachelor of Science degree in Civil Engineering and a Master of Science degree in Structural Engineering from the University of Nebraska - Omaha. He is a registered professional engineer in the State of Nebraska, a member of the American Society of Civil Engineers (ASCE), a member of the Society of American Military Engineers, past president of the Nebraska Section of the ASCE, and present chairman of the High School and Engineer's Week for the Nebraska Section of the ASCE.



James F. Palma is a structural engineering technician with the Omaha District. He has been affiliated with the Omaha District for 18 years. He has an Associate Degree from the University of Nebraska - Omaha. Currently, Jim is working on flood control projects and the development of structural expertise in Computer-Aided Design and Drafting (CADD).



Don Miller has been a structural engineer with the Omaha District for 7 years and has 10 years' experience in the private sector. He has a Bachelor of Science degree from the University of Nebraska - Omaha. Don is currently involved in the structural design of both flood control and military projects.

Acoustic Emissions Survey to Map Seepage Patterns Under a Navigation Lock

by

James Warriner

A single-channel acoustic emission (AE) counting system was used at Lock 3 at Seneca Falls, New York, to make a gridded survey of the lock floor. The survey resulted in a systematic pattern of variations in acoustic activity intensity that could be rationalized with AE generation by subfloor turbulent water flow. This AE technique, currently being developed under the REMR Research Program, has potential for providing a means of delineating naturally occurring AE.

Cayuga-Seneca Locks 2 and 3 on the New York State Barge Canal were constructed in 1915. Substantial leakages, soft and porous rock, and large solution cavities have been observed from the initial construction to the present time. Remedial measures undertaken have included cutoff walls and cementitious grout injection. Major grouting efforts in 1986 and 1987 were directed at subsidence in the backfill and water flows through the core wall, earth embankment, and lock monolith joints.

NYDOT Inspection

A New York State Department of Transportation (NYDOT) inspection while the lock was empty showed that a section of the concrete floor slab about 60 ft long and more than half the width of the lock had subsided into a cavity approximately 40 ft east of the upstream gates of Lock 3. At the point of deepest subsidence, approximately 3 ft, water flowed freely and at high velocity into passages below the floor slab. There was an active boil of water in the canal alongside the river-side wall of Lock 2, 400 ft downstream from the subsided slab section. The boil became more violent and turbid when Lock 3 was filled, though it also appeared to flow continuously when the lock contained only leakage water.

NYDOT personnel drilled small diameter holes through the floor slab of Lock 3 to take soundings with rods. They found below-slab cavities that ranged from 0.5 to 16 ft in depth. Some of the drill holes emitted air when the lock was filled. At least one larger diameter boring (DNX 32) exhibited powerful suction caused by the flow of water into it. Also, NYDOT reported that floats with continuous lengths of rope were sent from the subsided slab through the flow path(s), but they became lodged before emerging from the boil. A truck tire used in an attempt to seal the floor crack was passed through to the boil.

Plans to rehabilitate the locks included plugging the downstream boil and subsequent grouting of the flow channels connecting it with the subsided slab. The broken slab was to be removed and replaced. A necessary step in performing the rehabilitation was delineating the flow channels in the subsurface.

AE Survey

A commercially available, portable, single-channel AE monitoring system (Figure 1) was used to identify areas of the lock structure most appropriate for use of a bore-hole mounted acoustic monitoring system. The portable system uses a piezoelectric crystal transducer resonating at 30 kHz. A 40-db, low-noise preamplifier in the circuit approximately 6 ft up the cable from the transducer boosts the signal prior to transmission along the main cable to the control unit. The primary electronic system includes selectable-

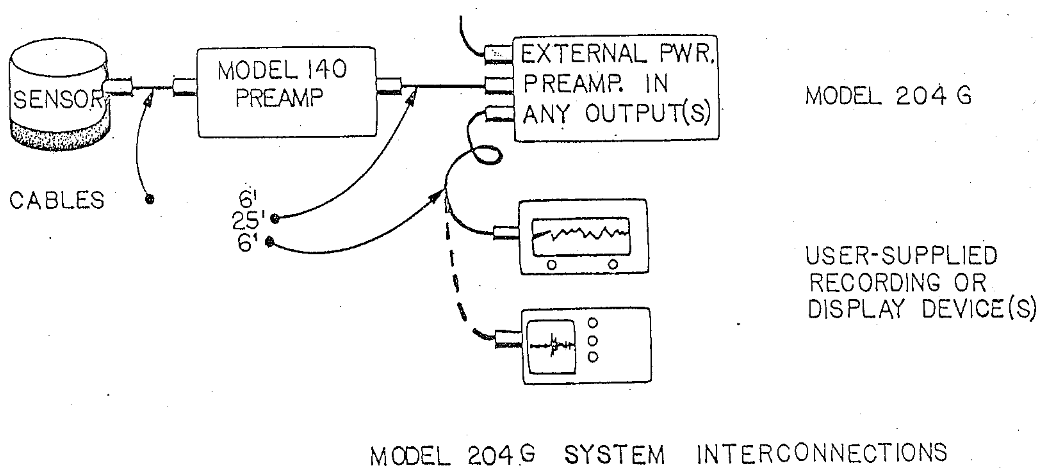
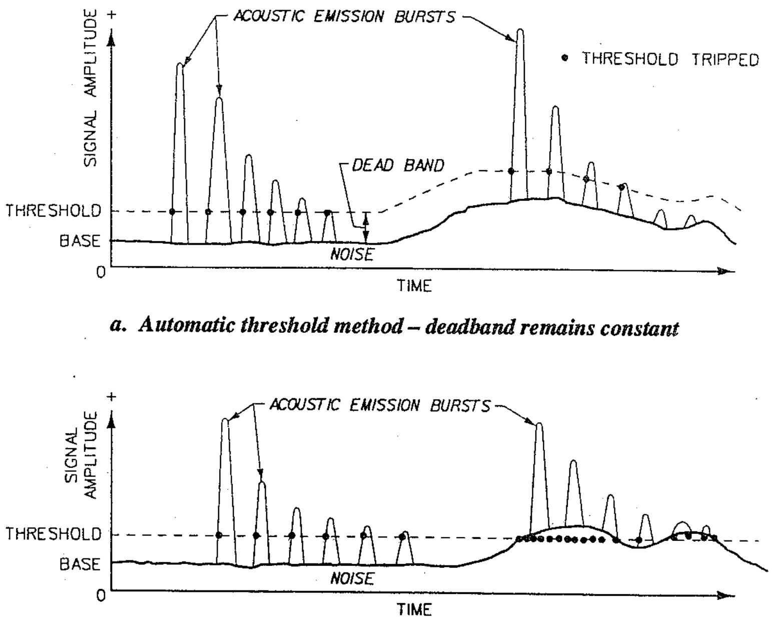


Figure 1. Diagram of portable AE monitoring system



a. Automatic threshold method – deadband remains constant

b. Fixed threshold method – threshold remains constant

Figure 2. Comparison of automatic and fixed threshold modes of AE signal/noise discrimination

gain amplification to a maximum total of 98 db, a mainframe bandwidth of 100 Hz to 175 kHz, an automatic signal discrimination circuit that selects only signals with amplitudes above the continuous level of background electrical noise (Figure 2) and a pulse-counting circuit and display. The portable system operates as a counter of AE rather than as a recorder of the received and conditioned electrical signal. The system produces data in the form of repetition rates of AE or AE activity; it does not allow capture of signal wave forms.

The portable system was used on top of the lock near each of the borings intended to be accessed by the down-hole arrays. The measured AE repetitions showed highest rates above the large failed slab and decreasing repetition with distance from it. The system was carried down to the lock floor, and a reconnaissance was performed in random locations. There appeared to be systematic variations in the AE repetition rates measured. The highest were nearest the entry hole where the greatest leakage occurred, but there were semicontinuous loci of high rates as well as a pattern of minimum AE repetitions.

The portable, single-channel system was used to make a gridded survey of the floor of Lock 3 in order to systematically measure the AE repetition rate or intensity of AE activity. The floor was flooded with leakage water, ice, and debris. Near the entry hole where the greatest leakage occurred, the water was too deep and swift for safe access. As an expedient, the 14 pairs of ports into the fill-empty culverts were used for alignment of traverses across the floor. As an expedient, the measurement points along each traverse were located by heel-to-toe pacing of the man carrying the transducer. The roughness of the weathered concrete, moss, and debris coupled with the manual handling of the transducer underwater made exact measurement point location such a variable that the expedients were satisfactory.

The survey grid consisted of 14 cross-lock traverses at 20-ft intervals. Measurement points were spaced at 5 ft along each traverse between the wall-footing joints. Only locations in the most turbulent flow into the major leak and under an iceberg were missed in the survey grid.

The AE system was set to particular control parameters and left unchanged throughout the survey. "EVENTS" were counted rather than cumulative peaks of cyclical events. The AE signal discriminator was set to "AUTO" to automatically vary the minimum amplitude of a signal required to define it as an AE event. The "GAIN" was set at a total (including preamplification) of 92 db after observation of the lowest gain detecting AE (60 db) and the highest gain that discriminated against ambient noise. The transducer was manually pressed against the concrete surface. An arbitrary counting period of 10 sec was selected for accumulation of detected AE events in each reading. Ten separate readings were taken at each grid location. The uniformity of reading magnitudes at each particular point

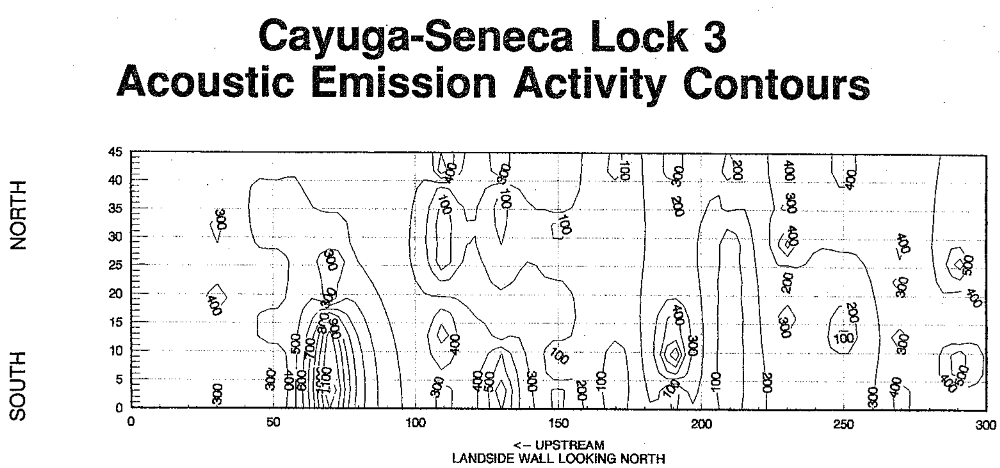


Figure 3. Acoustic emission activity levels taken from AE measurements

was one of the criteria used to judge acceptable coupling of transducer to concrete. The separate readings were later averaged and standard deviations computed. A probability of inappropriate data less than 0.1 percent was applied to determine the need for rejection of a reading. No more than one reading was rejected from any measurement, and many points needed no rejection.

Figure 3 shows AE activity levels taken from AE measurements. There is no known report of acoustic reconnaissance for water flow under a lock floor or wall. Interpretation of the patterns of acoustic activity obtained through the lock floor must, then, consider both acoustical phenomena and water flow. Not enough is known of the frequencies generated by flowing water to use a wave parameter for interpretation. To be detected and recorded, an acoustic wave must have sufficient amplitude. There must have been sufficient energy imparted originally in the wave, the distance of travel must not be excessive, and the material intervening must allow transmission of the energy with minimal loss between the point of origin and reception.

The accelerometer used for the survey was directional with its sensitive axis vertical as used on the floor. Therefore, most detected acoustic events propagated more or less vertically as compressive waves to arrive at the transducer; that is, they came from below the point of measurement after propagating through either solid or water.

Conclusions

The above considerations lend credibility to the idea that regions of the lock floor exhibiting high acoustic activity directly overlie conduits in which water flow is turbulent. The conduits producing noise are believed to be nearly full but still have some gas/vapor volumes that allow splashing or "popping" of bubbles. Those regions showing activity of a lower intensity are believed to encompass deeper flow channels or channels where there is less freedom for sound generation. Regions showing little or no acoustic activity are either overlying completely intact rock material or overlie some material that attenuates acoustic energy. The gridded survey (Figure 3) indicates regions of high acoustic activity closest to the large leakage entry hole, in discontinuous regions downstream that are located near the wall footings, and along two linear regions approaching the sill structure and subparallel to the lock. These are interpreted presently as turbulent flow paths where much water energy is expended near the bottom of the floor slab. Very quiet regions are seen across the middle third of the lock floor and gradually narrowing as the sill structure is approached. A high activity region of potential interest is linear and narrow and extends from the large leakage entrance towards the center of the upstream gate structure. If the assumptions of the nature of subfloor conditions causing the rest of the patterns in AE activity are correct, then there is a possibility of a flow channel approaching the foundation of the upstream gate structure of Lock 3.

Recommendations

The degree of success experienced in this use of the single-channel AE counting system leads to a recommendation that the technique be developed. The means of coupling the transducer to the body being surveyed needs to be improved. Manual pressure is too variable, especially under rigorous conditions. Future use of the AE activity counting system should include use of earphones connected to the signal conditioning system. Operator discrimination could then estimate the quality of received signals or possible recognition of the AE origin. The statistical treatment of the AE activity intensity data manipulation method should be examined and enhanced. The AE intensity survey should be considered as a valid form in and of itself, rather than as a "back up." At least its application should be included as a preliminary to more extensive (expensive) types of AE survey.

For further information, contact James Warriner at (601) 634-3610.

Jim Warriner is a geophysicist in the Rock Mechanics Branch of the Soil and Rock Mechanics Division, Geotechnical Laboratory, US Army Engineer Waterways Experiment Station. He has a Bachelor of Science degree from Iowa State University.

Performance of Microprocessor-Based Reinforcing Steel Detector for Concrete Structures

by

A. Michel Alexander and Willie E. McDonald
US Army Engineer Waterways Experiment Station

A device capable of detecting embedded reinforcing steel in a concrete structure can provide information necessary for quality assurance testing during new construction and aid in the in-situ condition assessment of an existing structure in need of repairs.

Since reinforcing steel performs a specific function in concrete structures, proper positioning of reinforcement is essential. Quality assurance parameters include depth of embedment, size, location, and spacing. Devices that detect embedded steel can be used to verify compliance with design specifications throughout construction.

Before rehabilitation of an existing structure is begun, the structure must be evaluated to determine the scope of the rehabilitation for the estimation of repair costs. The evaluation and rehabilitation may require coring, grinding, resurfacing, and anchor installation. Such work requires the identification of areas free of embedded steel. If as-built construction drawings detailing information on the location of the embedded reinforcement are not available, a detection device capable of providing the information would be a valuable tool.

Background

Researchers at Picatinny Arsenal, sponsors of a military test program that involved building reinforced concrete structures, had concerns about the actual position of reinforcing steel in several of the structures. Knowledge of the position of the reinforcing steel within approximately +/- 1/8 in. was one of the critical requirements in the test program. A second aspect of the program was to verify the capability of a high-resolution detection device being developed by a private contractor under a government contract. Picatinny needed an independent, qualified person to conduct a nondestructive testing (NDT) evaluation of the structures and the detection device. (Military confidentiality requires that limited information be given about the contract device and the purpose of the structures.)

Improving the efficiency of NDT of concrete structures is one of the research efforts within the Concrete Technology Division (CTD), US Army Engineer Waterways Experiment Station (WES). Consequently, Picatinny Arsenal researchers requested assistance from WES in (1) constructing physical models with known positions of reinforcing steel for laboratory testing of the steel-detection device, (2) conducting field demonstrations with the device, (3) using destructive methods for onsite verification against the device-predicted location of steel in the actual structures, and (4) providing staff knowledgeable about NDT devices to serve as follow-up consultants on the project.

Detection Devices

A variety of steel-reinforcing detection devices are available commercially. All can be separated into two classes: the less expensive non-microprocessor-based systems and the microprocessor-based systems. The various devices and their sources have been reported (REMR Technical Note CS-ES-1.9). Generically, such devices are known as cover meters or pachometers. Present microprocessor-based models have such features as state-of-the-art integrated circuits, recorders, digital readouts, and audible beeps. They are lighter, faster, and easier to interpret than the earlier non-microprocessor-based devices.

Most detection devices operate according to the same general principle. The device transmits magnetic flux lines into the concrete through a probe. When the magnetic flux lines encounter steel, an increased number of lines traverse the steel rather than the concrete because the steel provides a lower resistance path. A sensing circuit in the detection device detects this increase in field strength. The transmitted signal is received, processed, and displayed or recorded by a digital readout, beep, meter pointer, or chart recorder. The strength of the signal is affected by the size and depth of placement of the reinforcement.

No extensive effort was given to choosing the particular microprocessor-based detector used in this investigation since the time constraints on the project did not permit an evaluation. The device was chosen simply on the basis of the information contained in a brochure received in the mail presenting the capabilities of the microprocessor-based device. There is no reason to believe that the other microprocessor-based systems on the market are not just as capable as this one.

Additional probes that determine depth, diameter, and position of the reinforcing steel can be attached to the device. Also, this device can quickly ascertain general locations of the steel and can compensate for false signals created by magnetic aggregates. It has audible or digitized visual indicators and a toggle switch for easy alternation between operating modes; it is compact, lightweight, and easy to operate.

Laboratory Evaluation

Two laboratory specimens were fabricated to simulate the parameters of the field concrete structures, particularly the depth, spacing, and diameter of the embedded reinforcing bars (Figure 1). In addition, smaller pieces of metal were incorporated into the physical models to simulate snap form ties and tie wire used to secure reinforcing bars at intersections as there was concern that the presence of these materials could adversely affect the accuracy of the detector.

Laboratory Results

Initially, detection devices with and without microprocessor-based systems were used. The device without a microprocessor-based system included coil movement, a needle, and a scale for reading. In most situations, it performed satisfactorily; however, it was not capable of resolving the position of the center axis of the reinforcing steel within the specified tolerances for this application. Although the data from the measurements were not critically analyzed, a rough estimate of the accuracy of the locations was +/- 1/2 in. Evaluations conducted with the microprocessor-based system yielded satisfactory results; therefore, it was used throughout the remainder of the laboratory evaluation process.

To evaluate the accuracy and repeatability of the microprocessor-based detector, 30 measurements were taken. Results are reported in Table 1. The mean offset from the actual centerline in this evaluation was determined to be +/- 0.081 in. The standard deviation was determined to be +/- 0.047 in. Even though there was a 67-percent probability that each reading would fall below the sum of the mean and the standard deviation, the degree of accuracy was within the required specified accuracy limit of +/- 0.125 in.

Table 1
Measurement Data on Accuracy and Repeatability

Measurement Observation	Deviation from CenterLine, In.
1	0.03
2	0.02
3	0.09
4	0.07
5	0.05
6	0.08
7	0.06
8	0.06
9	0.05
10	0.11
11	0.17
12	0.01
13	0.09
14	0.06
15	0.05
16	0.06
17	0.08
18	0.08
19	0.08
20	0.12
21	0.09
22	0.05
23	0.11
24	0.17
25	0.06
26	0.23
27	0.00
28	0.11
29	0.08
30	0.11

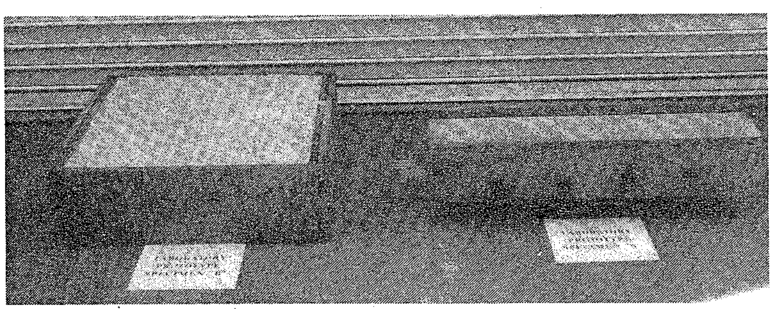


Figure 1. Laboratory prototype specimens

Field Demonstrations

In all instances of the field demonstrations, the detection device proved its capability for consistently locating the center axes of the reinforcing steel measured. Visible verification was possible in some structures because of the extent of their deterioration. For other structures, construction drawings were available.

Field Structural Evaluation

The field evaluations involved locating the position of embedded reinforcing steel in the structures and verifying the performance of the detection device developed under contract. To determine the accuracy of the microprocessor-based detection device, the concrete cover was destructively removed from a section of a structure to reveal the reinforcing steel. The microprocessor-based detection device indicated the correct positions of the center axis of the embedded reinforcing steel with few deviations, all of which were within the acceptable limits of accuracy. Upon review of the performance of the device, Picatinny staff decided that the microprocessor-based system satisfied the desired requirements for an independent quality assurance device.

Follow-up Structural Evaluation

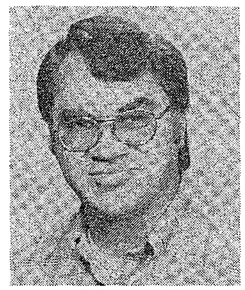
The follow-up phase of this investigation involved sending a consultant who was knowledgeable about NDT instrumentation and concrete materials from CTD to the field. The role of the consultant was to satisfy the contract representative that the microprocessor-based system would serve as a proper standard for evaluating the prototype device being developed. In addition, he was to evaluate the contract device and advise the Picatinny staff of its performance.

Conclusion

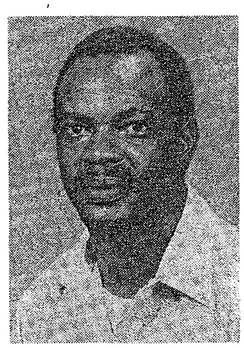
In the construction industry, there is an increased emphasis on improving NDT techniques to provide quality assurance and to evaluate structures in need of repair. The new microprocessor-based steel detection systems are a step in the right direction. The detection device satisfied the specified requirements for serving as an independent calibration source for locating embedded steel precisely and for permitting a proper evaluation of a high-resolution detection device being developed under contract for the Army.

The capability of high accuracy, versatility, battery power, portability, reliability, and ease of operation should promote routine usage of the device for evaluating concrete structures in the field. A disadvantage is that the microprocessor-based systems are about three times the price of non-microprocessor-based systems. However, the various features noted will increase the benefit-to-cost ratio of the device.

For further information, contact A. Michel Alexander at (601) 634-3237 or Willie E. McDonald at (601) 634-3893.



Mitch Alexander is a research physicist in the Concrete Technology Division, Structures Laboratory, US Army Engineer Waterways Experiment Station. He received a Bachelor of Science degree in Physics from Western Kentucky State University and a Master of Science degree in Electrical Engineering from Mississippi State University. He is a recipient of the Army Research and Development Achievement Award for technical achievements in nondestructive testing of concrete.



Willie McDonald is a civil engineer in the Concrete Technology Division, Structures Laboratory, US Army Engineer Waterways Experiment Station, and has been with the Corps since 1979. He has a Bachelor of Science degree in Technical Education from Alcorn State University and a Bachelor of Science degree in Civil Engineering from Tennessee State University and is currently pursuing a Master of Science degree in Civil Engineering from Mississippi State University. Willie has recently returned from a 3-month assignment in Kuwait, where he was involved in structural design, analysis and rehabilitation, and concrete construction and renovations for public schools as a member of the Kuwait Emergency Recovery Office (KERO).

News in Brief

Appreciation is extended to Ms. Elke Briuer for her contributions to the REMR Research Program from November 1988 to October 1991. Elke has accepted the position of Technology Transfer Specialist for the Wetlands Research Program, WES. During her affiliation with REMR, Elke was instrumental in expanding public awareness of REMR-related activities and in providing a smooth transition from REMR I to REMR II technology transfer.

Ms. Lee Byrne has been selected to succeed Ms. Elke Briuer as the REMR Technology Transfer Specialist. Lee has been an editor for the Information Technology

Laboratory since 1986. If you have any questions about REMR technology transfer, please call her at (601) 634-2587.

A workshop on levee rehabilitation has been tentatively scheduled for 17-18 March 1992 at the Waterways Experiment Station, Vicksburg, MS. More information will be provided in the next REMR Bulletin, or call Dr. Edward B. Perry at (601) 634-2670.

REMR II Field Review Group Meeting

The management structure of REMR II is much the same as that of the original REMR Program. A key component is the Field Review Group (FRG), which consists of members from Corps Civil Works Divisions. This group meets twice each year to provide a broad technical review of REMR problems being addressed, provide continuous field input, recommend R&D priorities, and assist in technology transfer. At the Fall FRG Meeting (11-12 September 1991 at the Waterways Experiment Station), the progress of ongoing work units was reviewed, and priorities were established for new starts. Seventeen work units were approved for new starts in Fiscal Year 1992.

The Rock Island District was selected as the location for the Spring FRG Meeting. This meeting will be open to the public as well as to all Corps personnel interested in the research being conducted under the REMR Research Program. Details on the exact location and date for the meeting will be published later.

Request for REMR Bulletin Articles

The REMR Bulletin provides a means for readers to share information about REMR technology. Please send us your manuscripts along with any photographs or other illustrations that may apply. Articles may be submitted by persons outside the Corps as long as they are relevant to REMR activities. For more information, write to: Commander and Director, U.S. Army Engineer Waterways Experiment Station, ATTN: CEWES-SC-A (Lee Byrne), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call Lee Byrne at (601) 634-2587.

REMR Technical Reports Published in 1991

REMR-CS-31 "Evaluation of Civil Works Metal Structures," by Frederick H. Kisters and Frank W. Kearney. AD A232 865

Engineering personnel who oversee inspections at Civil Works projects can use the theory, applications, advantages, and disadvantages of each nondestructive testing (NDT) method discussed in this report to guide the selection of an appropriate test method. The elements of an NDT method that should be specified in an NDT contract are discussed. Also included is a process for corrosion detection and the equipment needed for the process. Case histories describe how NDT procedures can enhance inspection routines.

REMR-CS-32 "Properties of Silica-Fume Concrete," by James E. McDonald. AD A235 369

This study was conducted to determine those properties of silica-fume concrete that might affect cracking and to develop guidance for minimizing cracking problems associated with the use of such concrete in future repair projects. Tests included compressive and tensile splitting strengths, modulus of elasticity, Poisson's ratio, ultimate strain capacity, uniaxial creep, shrinkage, coefficient of thermal expansion, adiabatic temperature rise, and abrasion erosion.

REMR-CS-35 "Predicting Concrete Service Life in Cases of Deterioration due to Freezing and Thawing," by Larry M. Bryant and Paul F. Mlakar. AD A235 616

A probabilistic procedure was developed for prediction of the service life of concrete structures subject to damage due to freezing and thawing and was applied to two typical Corps of Engineers' Civil Works structures. Hindcast applications demonstrate the procedure. The sensitivity of the results to key material and environmental variables is discussed. Current testing procedures relevant to service life prediction are provided along with recommendations for improvements in these areas.

REMR-CS-36 "Evaluation and Repair of Concrete Structures: Annotated Bibliography, 1978-1988," Vols. I and II, by James E. McDonald and Willie E. McDonald.

This bibliography covers the period from 1978 through 1988 and contains 2,062 annotated references on evaluation and repair of concrete structures. The bibliography includes four sections relating to (1) concrete durability and causes of deterioration, (2) procedures for evaluating the condition of existing structures, (3) maintenance and repair materials, and (4) maintenance and repair techniques. Subject and author indexes are also included.

REMR-GT-15 "Plastic Concrete Cutoff Walls for Earth Dams," by Thomas W. Kahl, Joseph L. Kauschinger, and Edward B. Perry. AD A234 566

This research was conducted to quantify the stress-strain-strength behavior and permeability of plastic concrete and to develop design data for specifying plastic concrete for use in a diaphragm cutoff wall for an earth dam. The results of this research indicate that the addition of bentonite clay to conventional concrete significantly increases the ductility and plastic deformation of the concrete while simultaneously reducing its shear strength. The permeability of plastic concrete was found to be the same or less than that of conventional concrete, and it decreased significantly with consolidation. A design method is given for determining the mixture proportion of a plastic concrete cutoff wall based upon the unconfined compressive strength and/or modulus of the embankment soil.

REMR-HY-8 "Shallow-Draft Training Structure Current Repair Practices and Repair Guidelines," by David L. Derrick. AD A239 045

This report documents past dike repair work and current repair methods and includes a set of guidelines for training structure inspection, record keeping, evaluation, and repair. New technology on dike repair applicable to the field is also included.

REMR-OM-11 "REMR Management Systems – Coastal/-Shore Protection structures: Condition Rating Procedures for Rubble Breakwaters and Jetties; Initial Report," by Donald E. Plotkin. AD A237 042

This is an initial report on the development of a basic system for uniformly evaluating the condition of breakwaters and jetties of all or primarily rubble construction with either rock or concrete armor. This system is based on visual inspection and uses numbers on a scale from 0 (worst) to 100 (best) to represent the relative condition of the structures. The condition rating system considers both structural and functional aspects of each structure. The intent of this system is to provide a consistent evaluation method that supplies numerical condition descriptors easily handled on a microcomputer. This numerical system aids in the maintenance planning process by permitting the condition to be monitored over time and by allowing a relative condition comparison between structures.

REMR-EI-5 "The Effects of Vegetation on the Structural Integrity of Sandy Levees," by Donald H. Gray, Anne MacDonald, Thomas Thomann, Imogene Blatz, and F. Douglas Shields, Jr. AD A240 267

The purpose of this study was to investigate the relationship between vegetation and the structural integrity of river levees. A specific objective was to determine the distribution of roots within levee embankments and how these roots alter soil properties of levee embankments and affect their resistance to mass wasting, surficial erosion, piping, etc. With this information, engineering criteria can be developed that may allow additional (particularly woody) vegetation to remain on levee embankments where sufficient effort can be made for levee inspection.

Unnumbered "Proceedings of REMR Workshop on Repair and Maintenance of Shallow-Draft Training Structures, 24-25 February 1987," by David L. Derrick. AD A235 666

These proceedings provide summaries of the following: the presentations by the Districts, discussion periods, and conclusions. The discussion periods focused on unusual repair techniques used and future research needs in the field of dike repair.

Cover Photos:

Laboratory investigation of underwater concrete mixtures.

Acoustic emissions monitoring device.

Cayuga-Seneca Lock 3.

The REMR Bulletin is published in accordance with AR 25-30 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. Contribution 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, or promotional purposes, nor are they to be published without proper credits. Any copyright material released to and used in *The REMR Bulletin* retains its copyright protection, and cannot be reproduced without permission of copyright holder. Citation of trade names does not constitute an official endorsement or aproval 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: Lee Byrne (CEWES-SC-A), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or calling 601-634-2587.

LARRY B. FULTON
Colonel, Corps of Engineers
Commander and Director

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
3909 HALLS FERRY ROAD
VICKSBURG, MISSISSIPPI 39180-6199

OFFICIAL BUSINESS
CEWES-SC-A