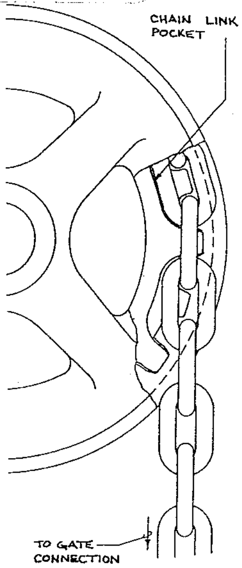
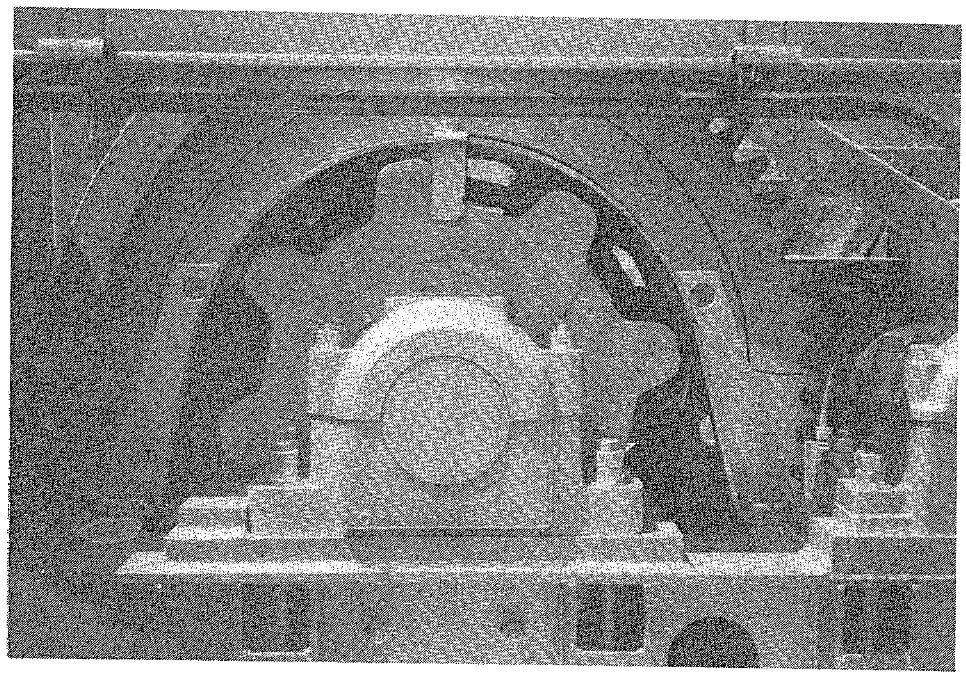
The REMR Bulletin

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

US Army Corps of Engineers

VOL 7, NO. 3 INFORMATION EXCHANGE BULLETIN SEP 1990





Pocket wheel at Lock and Dam No. 20, Mississippi River

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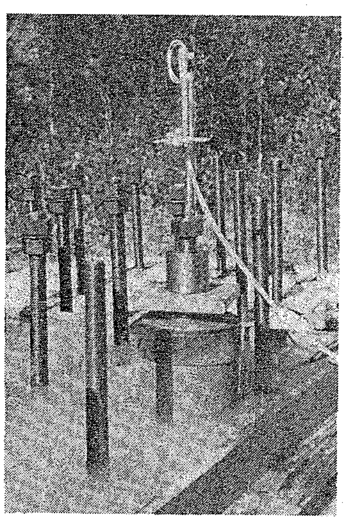


REMR RESEARCH PROGRAM

Tainter Gate Hoist Chain Replacement to Improve Operations and Maintenance of Lock and Dam No. 20

by
James W. Bartek, P.E.
US Army Engineer District, Rock Island, Illinois

Lock and Dam No. 20 is located at Mississippi River Mile 343.2, near Canton, Mo. Original construction on the lock was completed in 1933. Construction of the dam was completed in 1935. The dam has a total length of 2,294 feet consisting of forty 20- by 40-ft tainter gates and three 20- by 60-ft roller gates. All of the roller gates, but only two of the tainter gates, are currently mechanized. The remaining 38 tainter gates are raised and lowered by traveling hoist cars which roll along the service bridge on crane rails. A single gate adjustment requires a three-man operation and is hazardous and time consuming. The original hoist chains for these gates were of the round link type and were severely corroded and pitted. Chains have broken four or five times since the original construction. A better system for raising and lowering the tainter gates needed to be found.

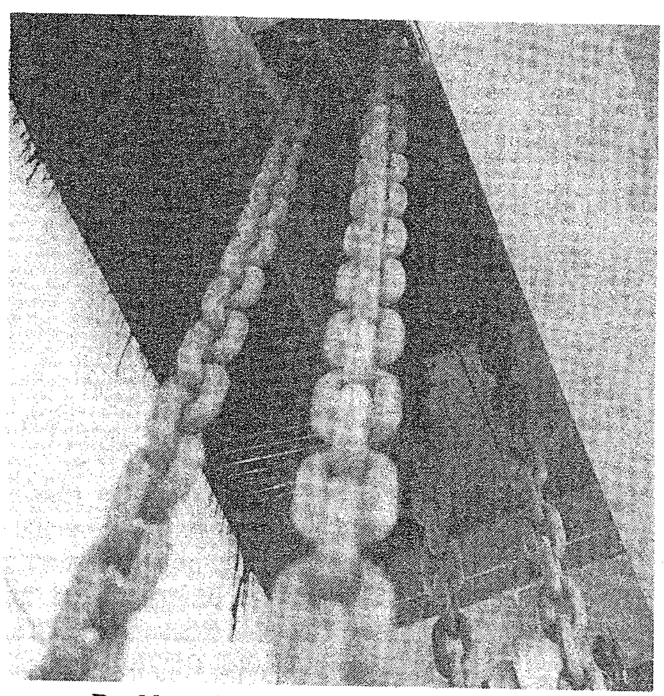
REHABILITATION EFFORT

Major rehabilitation of Dam No. 20, which is currently under way, includes mechanizing the 38 unpowered gates and retrofitting the two powered gates. The machinery designer stayed with the round link chain concept but incorporated the use of pocket wheels for hoisting

CHAIN UPGRADED

The round link chain selected for the rehabilitation project is required to be made of a high alloy steel (SAE 8620) and heat treated to approximately 300 BHN. The higher hardness of this material improves wear quality. High-alloy chain is also designed to be very abrasion resistant, an important factor since chain used for dam-gate lifting will have silt trapped in submerged links.

The chain is calibrated, meaning each link is manufactured to close dimensional tolerances in accordance with Deutsche Indutrie-Norm (DIN) 22252 High Tensile Round Link Steel Chains for Mining, Testing. Minimum breaking strengths range from 43 kips for 14-mm chain to 326 kips for 34-mm chain. Specifications for this rehabilitation project called for a corrosion-resistant immersion coating to be applied after the chain had been visually inspected and proof tested. Breaking strength was to exceed 326 kips.



Double pocket wheel and chain at Peoria, viewed from below

POCKET WHEEL SELECTION

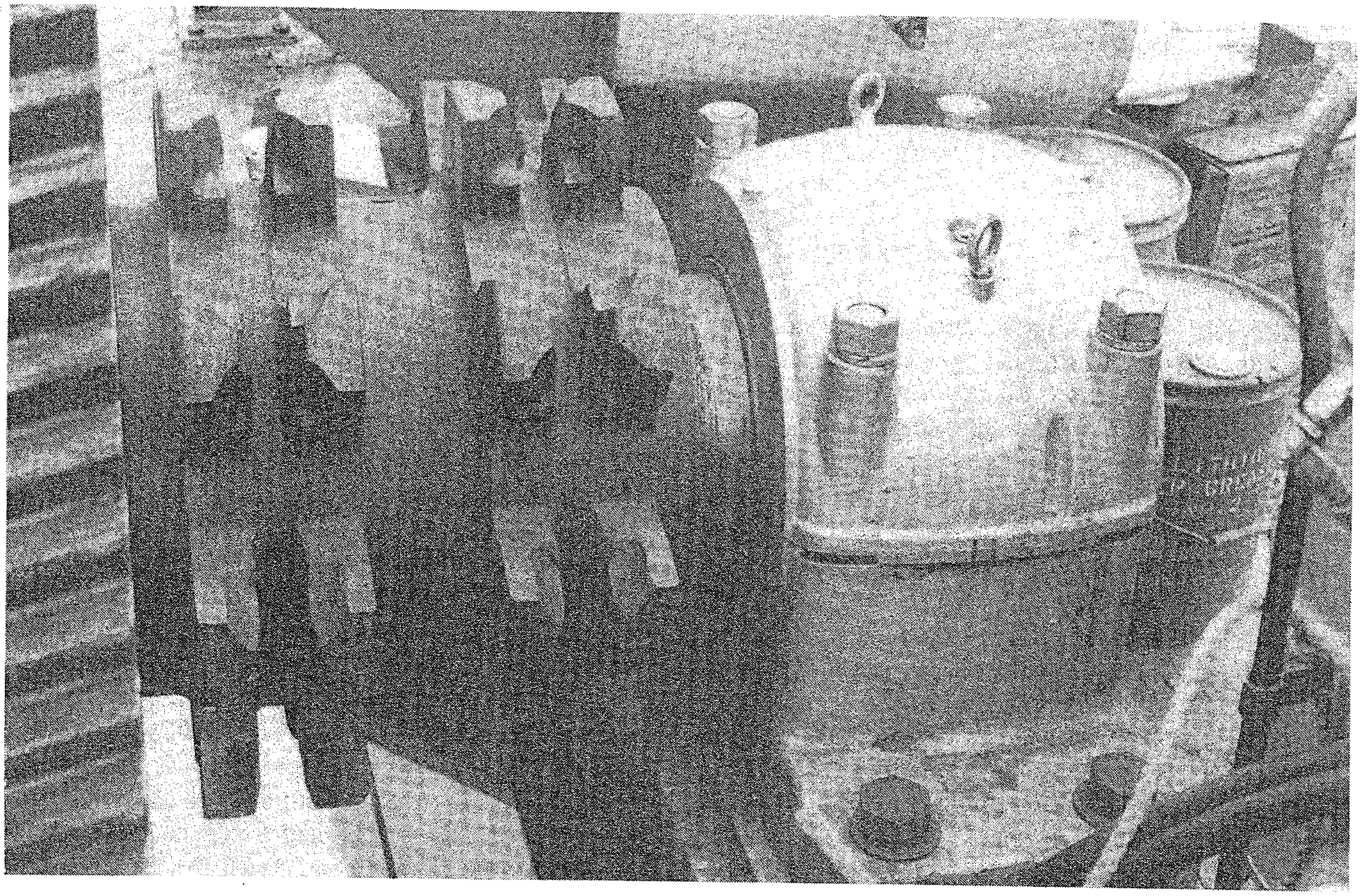
Pocket wheels are usually used on high and low speed hoists such as overhead cranes and on long conveyors in the mining industry. Pocket wheels are designed using ISO Standard 110 drive sprocket assemblies for armored flexible conveyors. As the name implies, every other link of the chain rides in a pocket as it passes over the wheel which loads the chain in tension and bearing. Pocket wheels are designed with sufficient accuracy to handle and hold a chain to its breaking strength.

A pocket wheel effectively transfers the load to each link of chain as it turns. The chain passes over the pocket wheel and is deposited in a chain storage bin or locker. The locker may be cylindrical or box shaped, and the volume must be carefully calculated in consideration of the length and diameter of chain that will need to be stored.

BENEFITS OF SYSTEM USED

The main advantage of the pocket wheel and round link chain combination is that no maintenance will be needed after this upgrade. The chain does not need lubrication as is the case with roller chain or wire rope. The chain does not stiffen in corrosive environments, in contrast to roller chain, and it is more durable. Durability will exceed that of wire rope. Other than installation of structural supports for the new machinery and chain lockers to contain the slack chain, no major modification of the dam's service bridge will be required.

A prototype set of pocket wheels and 34-mm chain was installed on one of the existing mechanized gates at Dam No. 20 in 1987. It was operated to simulate roughly 25 years of gate adjustment. No appreciable wear or significant operational problems were noted, resulting in the decision for rehabilitating the remaining gates using this system.



Double pocket wheel used at Peoria Lock and Dam

FUTURE APPLICATION

The pocket wheel and round link chain offer an excellent alternative for hoisting large tainter gates.

The design has become so well accepted within the Rock Island District that it has been incorporated into the machinery design of new additions at two other dams consisting of one tainter gate each at Peoria and LaGrange, Ill. Major rehabilitation at Lock and Dam No. 18 on the Mississippi River has included replacing all of the existing roller chain and sprockets on the 14 tainter gates at the dam. Pocket wheel and round link chains may eventually replace all of the existing tainter gate roller chains and sprockets at dams on the Mississippi River within the Rock Island District.

Additional information is available from Jim Bartek at (309) 788-6361, extension 599.

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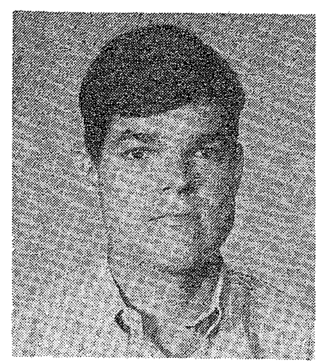


Anchor Embedment in Hardened Concrete under Submerged Conditions

by
James E. McDonald
US Army Engineer Waterways Experiment Station

Rehabilitation of hydraulic structures usually requires removal of deteriorated concrete and replacement with new concrete. Steel dowels are normally used to anchor the replacement material to the existing concrete. Typically, anchors are installed by (a) drilling a small-diameter hole into the remaining sound concrete, (b) cleaning the hole, (c) inserting a capsule containing either polyester resin or vinylester resin, and (d) spinning the anchor into the hole. Early-age field pullout tests on anchors installed in this manner under *dry* conditions indicate this to be a satisfactory procedure. However, a number of failures of anchors embedded in polyester resin grout under *wet* conditions have been reported (McDonald 1980 and Krysa 1982). Consequently, a study was initiated as part of the Repair, Evaluation, Maintenance and Rehabilitation (REMR) research program to evaluate the effectiveness of selected materials for embedment of anchors in concrete.

MATERIAL EVALUATION

The effectiveness of neat portland-cement grout, epoxy resin, and prepackaged polyester resin and vinylester resin in embedding anchors in hardened concrete was evaluated under a variety of wet and dry installation and curing conditions (McDonald 1989, Best and McDonald 1990). Pullout tests on anchors with 12- and 15-in. embedment lengths were conducted at several different ages ranging from 1 day to 32 months. Beyond 1 day, all pullout strengths were approximately equal to the strength of the anchor when the anchors were installed under dry conditions, regardless of the type of embedment material or curing conditions. With the exception of the anchors embedded in polyester resin and vinylester resin under submerged conditions, pullout strengths were essentially equal to the strength of the anchor when the anchors were installed under wet or submerged conditions. The overall average pullout strength of anchors embedded in polyester resin and vinylester resin under submerged conditions ranged from about 35 to 65 percent less than the strength of similar anchors installed and cured under dry conditions. Although the epoxy resin performed well in these tests when placed in wet holes, it should be noted that the manufacturer does not recommend placement under submerged conditions.

Long-term durability of the embedment materials was evaluated by periodic compressive strength tests on 2-in. cubes stored both submerged and in laboratory air. After 32 months, the average compressive strength of polyester-resin and epoxy-resin specimens stored in water was 37 and 26 percent less, respectively, than that of companion specimens stored in air. The strength of portland-cement grout cubes stored in water averaged 5 percent higher than that of companion specimens stored in air during the same period (Best and McDonald 1990).

The reduced tensile capacity of anchors embedded in concrete under submerged conditions with prepackaged polyester resin and vinylester resin cartridges is primarily attributed to the anchor installation procedure. Resin extruded from dry holes during anchor installation was black and very cohesive, and a significant effort was required to obtain the full embedment depth. In comparison, the resin extruded during submerged installations was cream colored and more fluid, and less effort was required for anchor installation. These factors indicated that the water in the drill hole was mixing with the resin when the cartridges were ruptured by insertion of the anchor. Although insertion of the adhesive capsule or cartridge into the drill hole displaces the majority of the water in the hole, water does remain between the walls of the adhesive container and the drill hole. When the anchor is inserted, this water is trapped in the drill hole and mixes with the adhesive, resulting in an anchor with reduced tensile capacity.

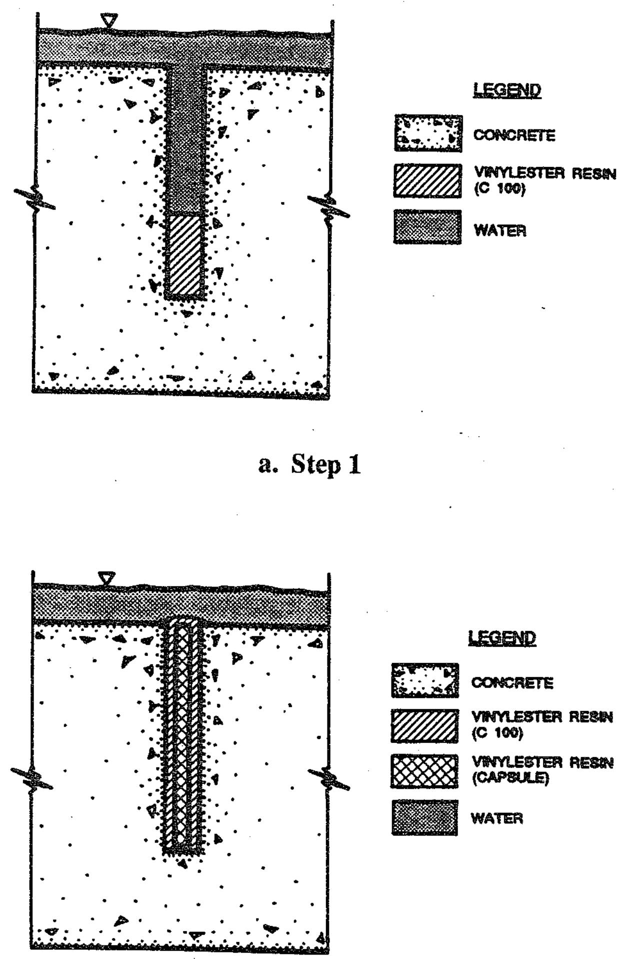
These findings generated concern in the geotechnical community regarding the ultimate performance of rock bolts previously installed under similar conditions. Because of this concern, the Geotechnical

Laboratory at WES contracted with the Bureau of Mines Denver Research Center to determine what effect water present during installation would have on longer anchors installed with polyester resin. As a result of these tests, Avery (1989) concluded that in a submerged borehole, water appears to affect the resin by mixing with the top 12 to 14 in. to form an emulsion which may be too diluted to catalyze effectively. He also concluded that water is detrimental to the successful curing of polyester resins only in situations involving very short anchors (less than 2 ft). To solve this problem, Avery recommended drilling the anchor hole 1 ft deeper than desired and adding an additional cartridge of resin.

Subsequent tests on anchors embedded in vinylester under submerged conditions (McDonald 1990) indicated that increasing the embedment length from 12 to 24 in. resulted in a 60 percent increase in tensile capacity at 0.1-in. displacement. However, this increased tensile capacity of anchors installed under submerged conditions was still only about one-half the load capacity of anchors with 12-in. embedment lengths installed in dry holes. While it may be possible to improve anchor performance under submerged conditions by further increasing embedment lengths, additional material and labor costs will be significant. Therefore, the development of improved anchor installation procedures which do not require excessive embedment lengths was necessary.

REVISED ANCHOR INSTALLATION PROCEDURE

An anchor installation procedure that eliminates the problem of resin and water mixing in the drill hole was developed (Fig. 1). In the revised installation procedure, a small volume of adhesive was injected into the bottom of the drill hole in bulk form prior to insertion of the adhesive capsule. According to the material supplier, Hilti, Inc., the injection resin was a modified vinlyester resin with essentially the same composition as the resin in the prepackaged HEA capsules. The injection was easily accomplished with paired plastic cartridges which contained the vinylester resin and a hardener (Fig. 2). The cartridges were inserted into a tool similar to a caulking gun (Fig. 3) which automatically dispensed the proper material proportions through a static mixing tube directly into the drill hole. Once the injection was completed, a prepackaged vinylester resin capsule inserted in the drill hole prior to anchor insertion and spinning displaced the remainder of the water.



a. Step 1

b. Step 2

Figure 1. Revised anchor installation procedure

Anchors with 15-in. embedment lengths installed with the revised procedure exhibited essentially the same tensile capacity under dry or submerged conditions (McDonald 1990). At 0.1-in. displacement, the tensile capacity of vertical anchors installed with the revised procedure under submerged conditions averaged more than three times that of similar anchors installed with the original procedure (Fig. 4). Also, the ultimate tensile capacity of anchors installed under submerged conditions with the revised procedure averaged more than 130 kips compared to an average ultimate capacity of less than 50 kips for similar anchors installed with the original procedure.

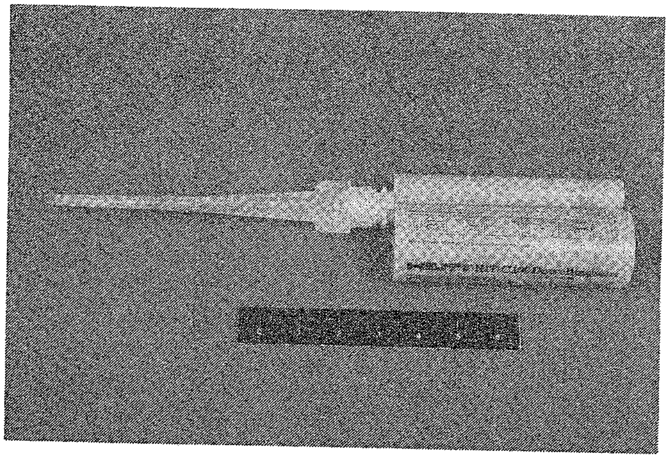


Figure 2. Paired plastic cartridges and static mixing tube

Horizontal anchors installed with the revised procedure under both dry and submerged conditions also exhibited excellent tensile load capacities. Overall, the difference in tensile capacity between horizontal anchors installed under dry and submerged conditions was less than 2 percent at 0.1-in. displacement. Similarly, the average difference in tensile capacity between horizontal and vertical anchors was only 3 and 5 percent for anchors installed under submerged and dry conditions, respectively.

Figure 3. Injecting the adhesive into a drill hole

RECOMMENDATIONS

The two-step anchor installation procedure described herein should be followed when prepackaged polyester resin or vinylester resin is to be used as an embedment material for short (less than 15-in. embedment length) steel anchors in hardened concrete under submerged conditions. The two-step installation procedure may not be necessary for rock anchors which normally have longer embedment lengths.

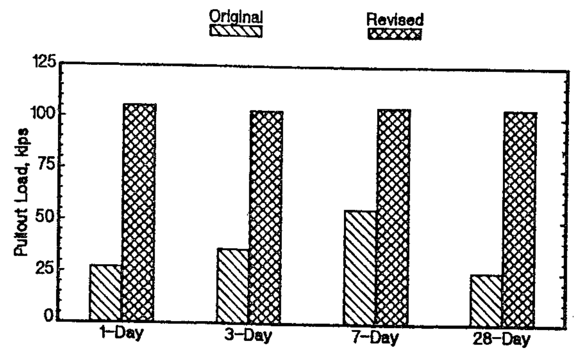


Figure 4. Average tensile capacity at 0.1-in. displacement of anchors installed under submerged conditions with the original and revised procedures

Tests, to date, on anchors installed with the revised procedure have been limited to short duration loadings at relatively early ages. Additional testing should be conducted to determine the long-term performance of vinylester resin under wet, alkaline conditions. Also, creep tests should be conducted to evaluate the effect of sustained loads on anchors installed with the revised procedure.

For further information, contact James E. McDonald at (601) 634-3230.

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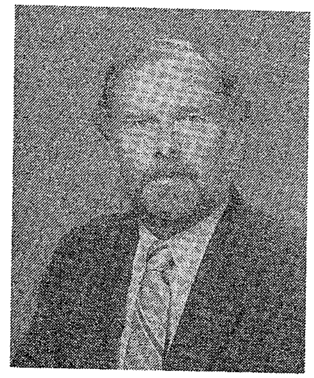
James E. McDonald is a research civil engineer in the Concrete Technology Division, Structures Laboratory, Waterways Experiment Station. He is the problem area leader for the Concrete and Steel Structures portion of REMR and was also principal investigator for four REMR work units, including 32303, "Application of New Technology to Maintenance and Minor Repair." He has been involved with various aspects of concrete research for more than 29 years. McDonald received his B.S. and M.S. degrees in civil engineering from Mississippi State University.



Use of Plastic Concrete to Construct Cutoff Walls for Earth Dams

by
Edward B. Perry
US Army Engineer Waterways Experiment Station

Seepage control is critical to the safe operation of earth dams. While remedial seepage control can be achieved with a rigid concrete cutoff wall, deformations of the earth embankment (for example, caused by an increase in reservoir level or seismic loading) can cause the concrete wall to rupture. Therefore, the designer must select materials for construction of cutoff walls that are not only strong and watertight, but also possess stiffness comparable to the surrounding embankment soil. Satisfying strain-compatibility between the wall and surrounding soil will lessen the likelihood of over stressing the wall and will allow the wall and soil to deform without separating. Plastic concrete shows great promise for satisfying the strength, stiffness, and permeability requirements for remedial cutoff wall construction. Plastic concrete consists of aggregate, cement, water, and bentonite clay mixed at a high water-cement ratio to produce a ductile material. However, literature provides little guidance for proportioning constituents to arrive at the desired properties. This article describes a design procedure, developed from a laboratory testing program, which can be used to select mixtures for plastic concrete walls which meet the requirements described above.

LABORATORY TEST PROGRAM

A comprehensive laboratory test program was conducted under the REMR Research Program to examine ranges of plastic concrete properties. Unconfined compressive stress-strain-strength data were recorded from tests on 250 standard concrete cylinders (water-cement ratio* was chosen to produce an 8-in. slump as required for tremie placement in a slurry trench) which were cast with the bentonite content, cement factor,** and curing time varied. Specifically:

- the weight of bentonite (i.e., bentonite content) was varied from 0 to 60 percent of the weight of cement
- the cement factor was varied from 230 to 450 lb/yd^3
- curing time was varied from 3 to 660 days

In addition to the unconfined compression test, 45 splitting tensile, six beam flexure, and two high velocity pinhole erosion tests were also conducted.

The unconfined compression test data base was used to develop a batching procedure that will allow a designer to select a plastic concrete mixture that satisfies the strength and stiffness requirements for a cutoff wall. The mixture design can be related to short term (3 days) and long term (90 to 660 days) stress-strain behavior.

Many remedial seepage cutoff walls are deep; i.e., Mud Mountain Dam (425 ft) and Navajo Dam (400 ft). Following initial set, the wet, high-slump plastic concrete tends to consolidate because of its self-weight. The amount of consolidation is a function of many variables (e.g., concrete mixture, drainage path, embankment soil type, height of tremie pour, etc.). The consolidation effect was examined by the use of triaxial tests which simulated field placement and curing conditions of plastic concrete. Twenty isotropically consolidated, undrained compression tests (CIUC) were performed on 6-in.-diam by 12-in.-high plastic concrete samples having a cement factor of 300 lb/yd^3 and bentonite contents of 0, 20, and 40 percent. Wet, 8-in. slump concrete was poured inside a mold; a vacuum was applied; the triaxial chamber was assembled; and consolidation pressure was applied. The effective confining pressures on the plastic concrete varied from 50 to 300 psi. Curing times varied from 3 to 14 days, with permeability measured on most test specimens. At the end of curing, the undrained strengths (CIUC) were measured. Twenty unconsolidated, undrained tests (Q) were conducted as companion tests to the CIUC tests. The Q tests produced data comparable to tremie concrete being placed without self-weight consolidation.

*Water-cement ratio equals ratio of water to cement plus bentonite, by weight.

**Cement factor equals weight of cement plus bentonite per cubic yard of plastic concrete.

TEST RESULTS

Some triaxial test results (CICU) indicated that self-weight consolidation of the plastic concrete may increase the undrained strength 10 fold over unconfined samples. At the same time, the strain at failure (CIUC) can be as much as five times greater than that measured during unconfined compression. The coefficient of permeability measured on samples with 0, 20, and 40 percent bentonite content, did not vary greatly and was typically between 10^{-8} and 10^{-9} cm/sec. Although the 40-percent bentonite sample was richer in bentonite, the permeability was not greatly lowered because more water was required in the mixture to maintain an 8-in. slump. The increased water tended to counterbalance the increased bentonite.

DESIGN PROCEDURE

Based upon the test results, a design procedure for plastic concrete cutoff walls was developed. Particular emphasis was placed on quantifying the relationship between mixture composition and stress-strain-strength behavior to minimize or eliminate the trial and error approach to mixture design commonly used today.

The guiding philosophy behind the analyses was to correlate complex and time consuming (expensive) triaxial tests to simple and quick (less expensive) unconfined compression tests. This change will allow designers to estimate triaxial stress-strain-strength parameters from unconfined stress-strain-strength data. In addition, unconfined behavior was examined at ages up to 660 days, a much longer time frame than typical project test programs allow.

Figures 1 through 3 are companion plots for selecting a plastic concrete mixture proportion (bentonite content, cement factor, and water-cement ratio) which will produce a certain unconfined compressive strength and ultimate tensile strength at a particular age. In addition, Figure 2 can be used in conjunction with Figure 4 to specify unconfined (Young's) elastic modulus.

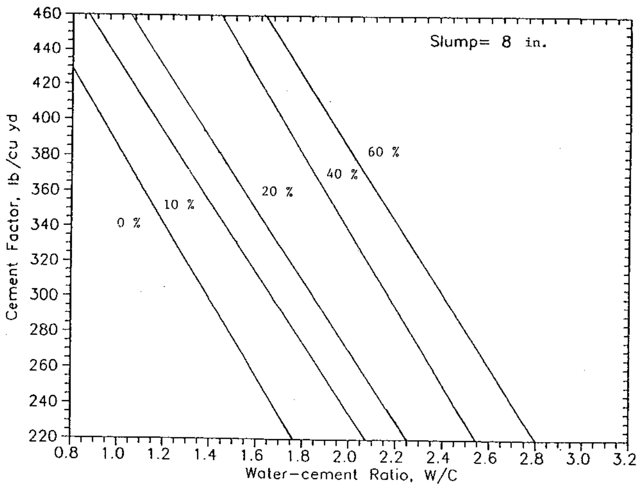
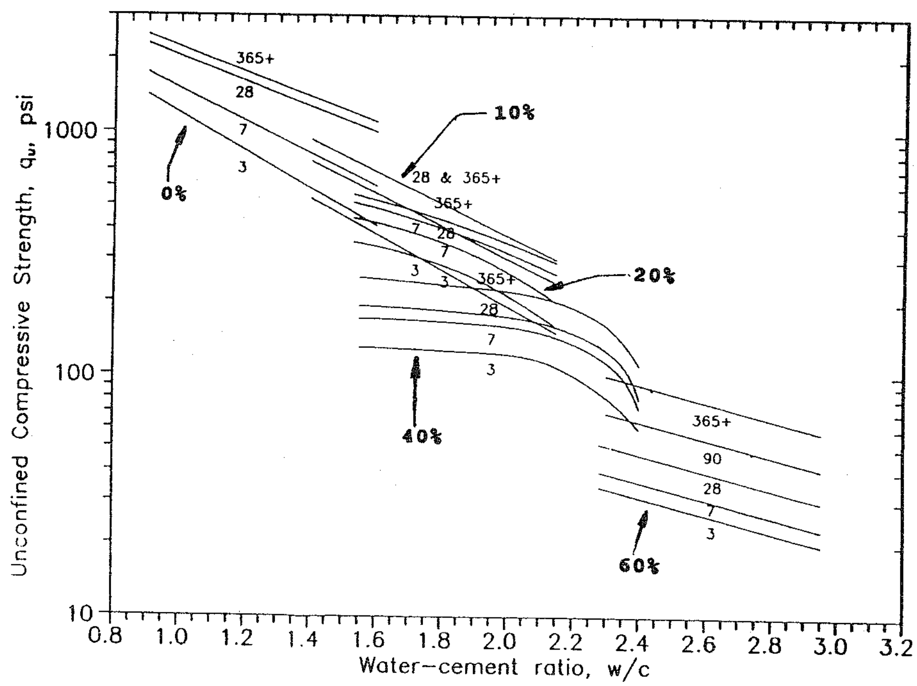


Figure 1. Cement factor versus water-cement ratio and bentonite content

The unconfined compressive strength as a function of water-cement ratio, bentonite content and age, shown in Figure 2, are presented in more detail in Figures 5 through 9. Data shown in Figure 3 (ultimate tensile strength as a function of water-cement ratio, bentonite content and age) are incomplete because of the limited number of tensile batch designs and curing ages.

A designer who needs plastic concrete of a certain unconfined compressive strength and/or modulus at a certain age can enter Figures 2 through 9, obtain a corresponding water-cement ratio and bentonite content, and then enter Figure 1 to obtain the corresponding cement factor. For example, a designer has measured the unconfined elastic modulus of a proposed compacted embankment soil as 200 ksi (using a compressometer to measure deflection) and wants to specify a plastic concrete cutoff wall of matching long-term stiffness. Figure 4 yields a corresponding unconfined compressive strength of 210 psi. Figure 2 then shows a choice exists at 210 psi, between 10 and 20 percent bentonite content at curing ages of 3 days and a 40 percent bentonite content at a curing age of 365+ days. Since the criterion is long-term stiffness, the designer chooses the 40-percent bentonite mixture. The designer then moves to Figure 8 (a blow-up of the 40-percent bentonite content relation) to more precisely estimate the corresponding water-cement ratio, 2.05. The designer then moves to Figure 1 and reads a cement factor of 325 lb/yd^3, corresponding to 40-percent bentonite content and 2.05 water-cement ratio. The designer thus has all the information necessary to proportion a batch. An identical procedure can be used to specify mixture proportions based on ultimate tensile strength by using Figure 3.

Figure 2. Unconfined compressive strength vesus water-cement ratio for all bentonite contents with lines being isobars of curing age



For more information contact Ed Perry at (601) 634-2670.

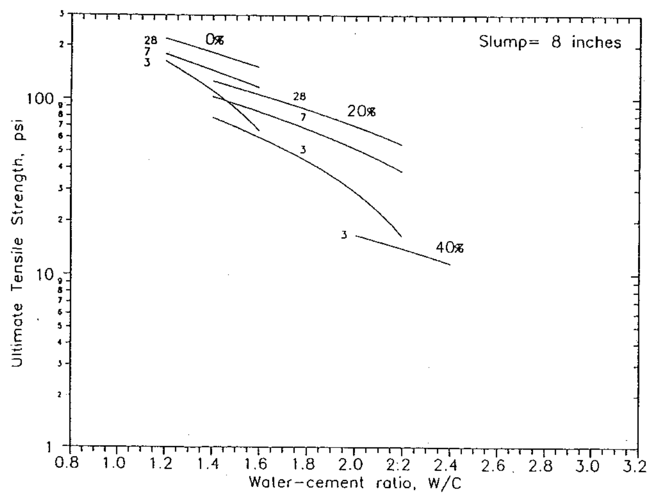


Figure 3. Ultimate tensile strength versus water-cement ratio and bentonite content with lines being isobars of curing age

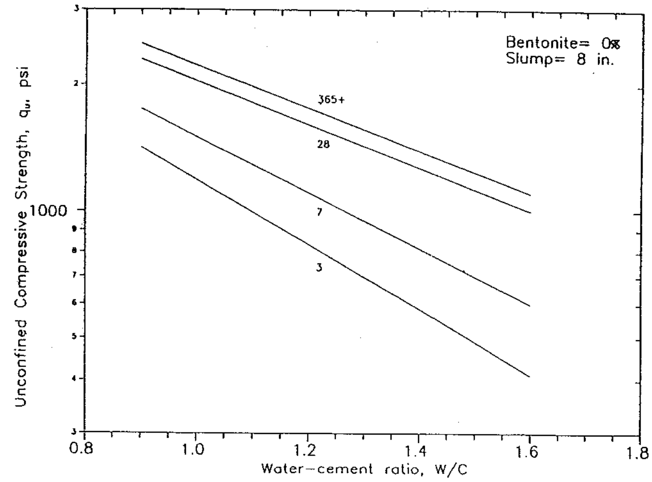


Figure 5. Unconfined compressive strength versus water-cement ratio for 0 percent bentonite content with lines being isobars of curing age

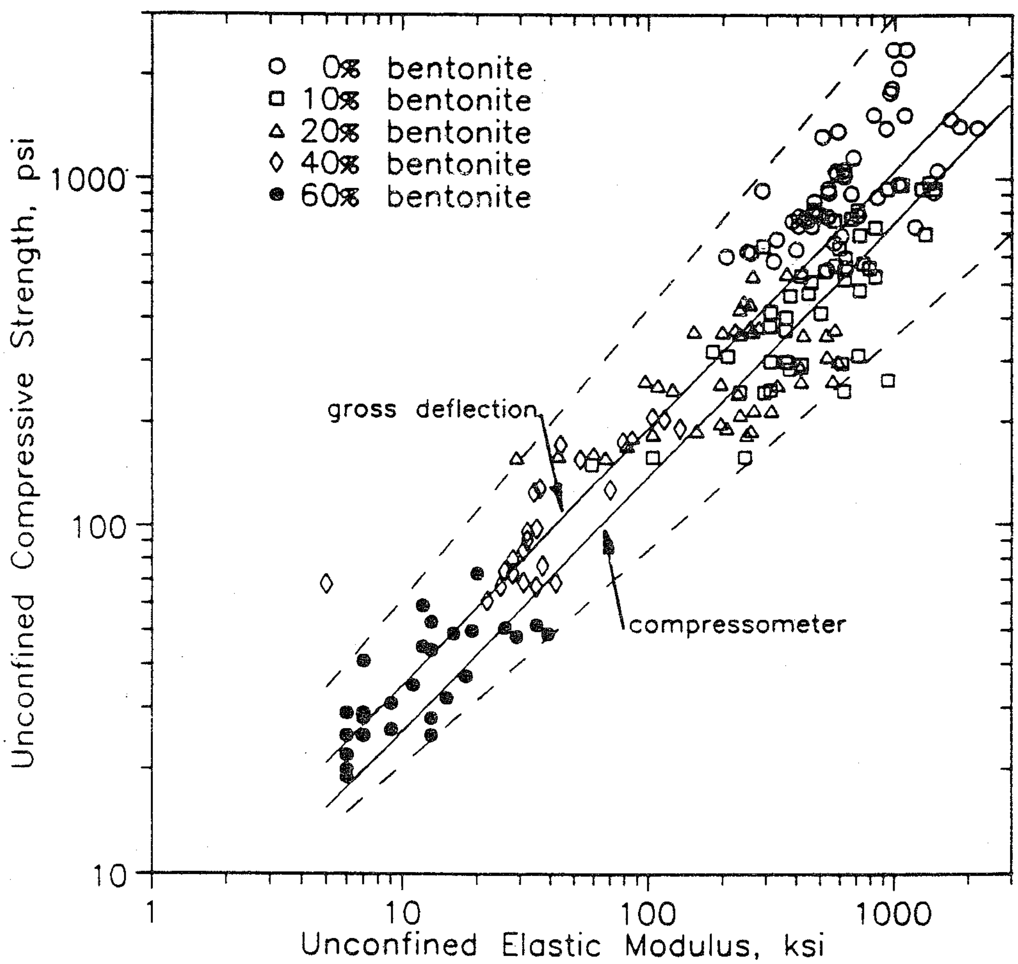


Figure 4. Unconfined compressive strength versus unconfined elastic modulus for all ages and bentonite contents

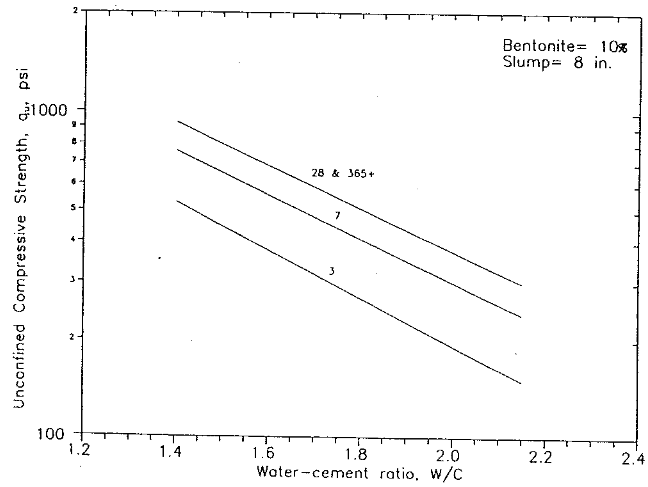


Figure 6. Unconfined compressive strength versus water-cement ratio for 10 percent bentonite content with lines being isobars of curing age

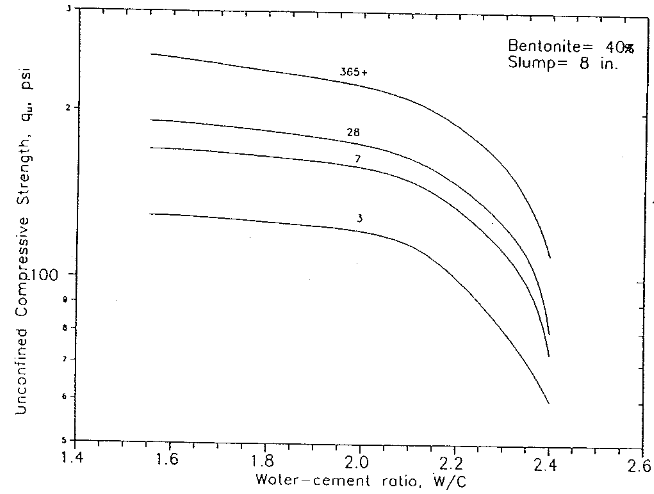


Figure 8. Unconfined compressive strength versus water-cement ratio for 40 percent bentonite content with lines being isobars of curing age

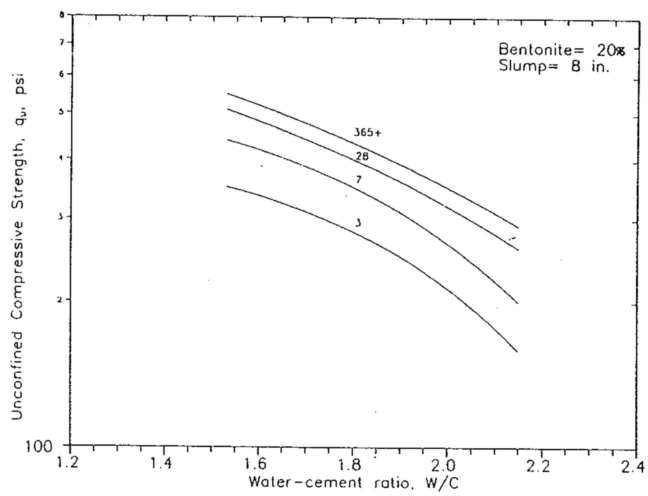


Figure 7. Unconfined compressive strength versus water-cement ratio for 20 percent bentonite content with lines being isobars of curing age

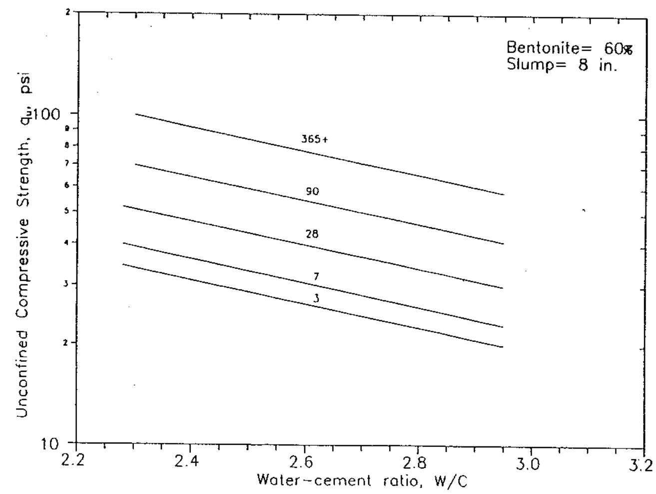


Figure 9. Unconfined compressive strength versus water-cement ratio for 60 percent bentonite content with lines being isobars of curing age

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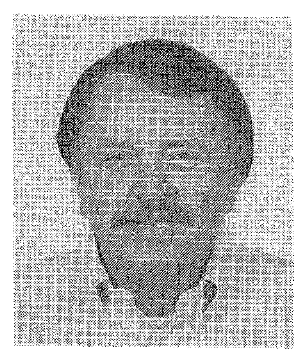

COVER PHOTOS:

Schematic of chain link pockets

Pull-out test on anchor installed under submerged conditions

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