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Fabric revetment protects 174,000 square feet[17] of the slope of the discharge canal of the fossil-fueled Anclote plant in Tarpon Springs, Florida owned by Florida Power Corporation.

Fabric forms for erosion control and pile jacketing

Innovative uses of fabric forms where soil meets water and for repair of existing coastal structures

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The merits of fabric as a material for containing fluid mortar or concrete until it hardens were recognized in the United States at least as early as 1906, shortly after the introduction of portland cement into this country. In that year, a patent was granted to Robert Cummings of Beaver, Pennsylvania describing the use of a fabric sleeve which was inserted into a driven pipe pile, filled with concrete and the pipe withdrawn. Other interesting patents describe the use of canvas bags placed under water and filled with concrete to form dikes, groins, breakwaters or structural supports.

The late Karl Billner appears to have been first to use water-permeable fabric forms as a means for beneficiating rather than simply containing concrete. His well-known vacuum process used a metal grillage faced with lightweight water-permeable fabric such as cheese cloth or muslin placed on top of fresh concrete. Excess mixing water is then pulled out of the concrete by application of a vacuum.

However, it wasn't until the development of modern high strength synthetic fibers such as nylon and polyester that large fabric assemblies could be used effectively and economically as forms for casting concrete. Fabric forming offers exceptional advantages for underwater work where conventional rigid forms are very expensive and concrete placement by the tremie method further adds to the cost. Normally a sand-cement mortar, occasionally with pea gravel added, is simply pumped into a bag tailored to whatever shape is required. The fabric acts as a separator between sur-

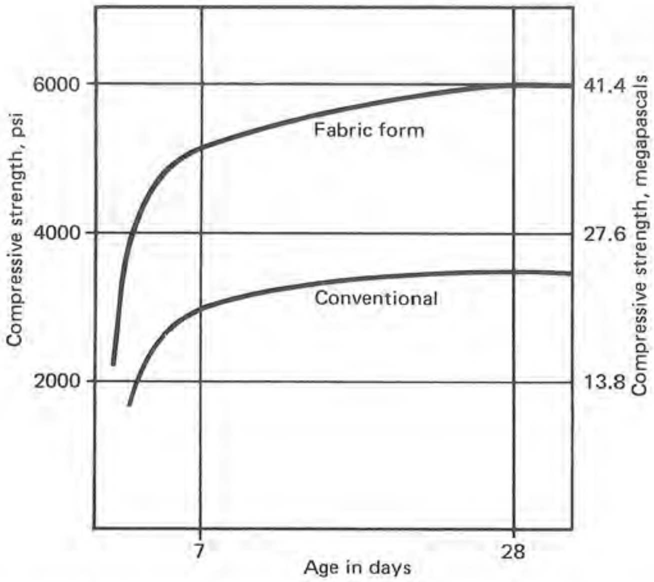

Figure 1. *A comparison of strength of concrete cast in conventional watertight molds and in fabric forms of nylon fiber. The fabric forms increase strength by permitting a lower water-cement ratio as excess mix water is squeezed through the fabric.*

rounding water and the concrete as it flows into the fabric container, preventing segregation of the concrete.

Improvement of water-cement ratio

Any fabric of suitable strength may be used. A refinement of the fabric forming technique uses a highly water permeable fabric which is designed to serve as a filter as well as a form. This fabric is woven of high-strength industrial nylon which has been textured to provide improved filtering as well as adhesion to the mortar. The mortar is pumped into the form and pressure is maintained on the mortar after the form is full. Excess mixing water is squeezed through the fabric causing a pronounced reduction in the water-cement ratio for a distance up to 6 inches[1]* or more from the surface of the fabric. The curve in Figure 1 shows actual test values from ten typical jobs compared with tests on companion specimens cast with identical mortar in conventional watertight molds.

Pile restoration

A unique use of fabric forming is in the structural restoration of bearing piles under waterfront structures. A fabric sleeve with a zipper closure is suspended around the pile to be repaired and mortar is pumped into the sleeve to form a concrete jacket. Fabric sleeves are individually tailored to required length and diameter. This repair process has proven to be equally applicable to piles of wood, concrete or steel. After cleaning the pile of rotten wood, loose rust scale or deteriorated concrete, as the case may be, reinforcing steel is placed if required and the fabric sleeve hung by a suspender ring inserted in a hem in the top of the sleeve. The zipper is then closed and the lower end of the sleeve banded to the pile. The fabric sleeve is then tensioned by pulling upward on the suspender ring with turnbuckles or similar means. Mortar is then injected simultaneously through two flexible hoses extending to the bottom of the sleeve. The hoses are usually positioned at opposite ends of a diameter to ensure that the mortar rises uniformly around the pile and concentricity is maintained. Use of water-permeable fabric produces a dense abrasion-resistant surface.

If piles are battered or if there is light wave action, standoffs are required to space the fabric from the pile or from the reinforcing steel. Fabric-formed pile jackets of 10-foot[2] diameter have been used to enlarge piers while jacket lengths have ranged up to 50 feet[3] (see photo). Light steel strapping, acting much like the hoops on a barrel, is used to reinforce the fabric sleeve on unusually long or large-diameter jackets.

Three men are applying jacket to a pile. In the foreground is a jacketed pile that has been concreted.

Erosion control revetments

The most important application of fabric forming is in the construction of erosion-control revetments. Here two layers of fabric are woven together forming an envelope-like configuration into which structural mortar is injected to form nylon encased concrete armoring to protect the shorelines of waterways, lakes or reservoirs or as drainage channel lining to prevent erosion.

In one type the two layers of fabric are woven together at circular tie points 8 inches[4] on centers. A special open weave is used in the middle of the tie point so that tie points not only serve to hold the two layers of fabric together but also act as weep holes to permit escape of ground water through the revetment to relieve uplifting hydrostatic pressure. Figure 2 illustrates a so-called 8-inch filter-point revetment. The deeply cob-

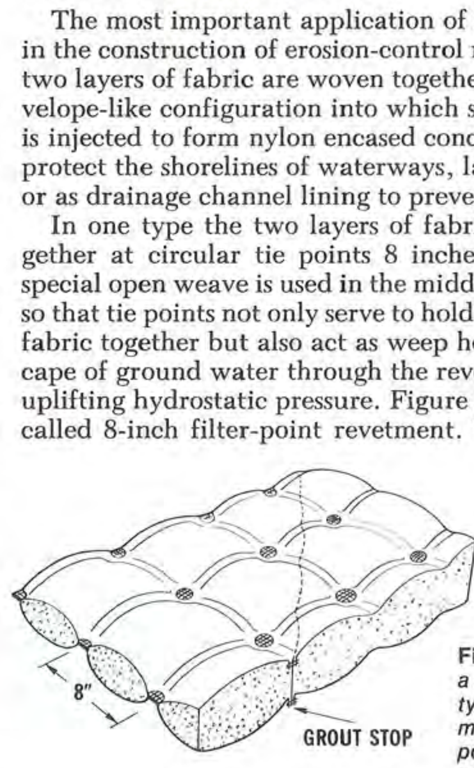

Figure 2. *Sketch of a segment of quilted type revetment mattress with filter points 8-inches[4] on centers.*

* Superscript numbers refer to metric equivalents listed with this article.

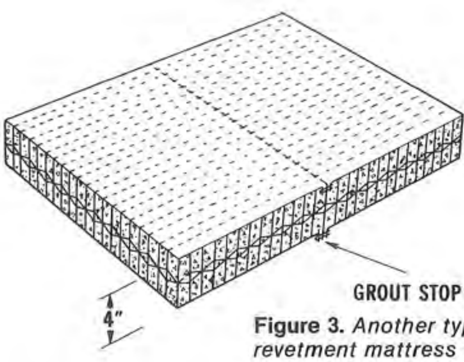

Figure 3. *Another type of revetment mattress with uniform cross section.*

bled surface has a coefficient of hydraulic friction, n, of about 0.025 when used in the Manning formula and so is effective in attenuating the hydraulic energy characteristic of most erosion control projects. Filter points may also be woven 5 inches[5] on centers for light duty application or a maximum of 10 inches[6] on centers where a heavy revetment is required.

For the situation where a smooth lining is required, as in some rechannelization work or in lining a holding basin where an impermeable lining is required, the two layers of fabric may be tied together with drop stitches running back and forth between the two surface layers. The thickness of this fabric-cast paving is normally on the order of 4 inches.[7] A typical cross section appears in Figure 3.

Boulders, stumps and brush should be removed from the site before installing the fabric. Installation of these nylon encased concrete revetments is a relatively simple task for any contractor familiar with concrete pumping equipment. Normally the upper edge of the fabric is draped into an anchor trench running along the crown of the slope beginning upstream. Seams are usually run perpendicular to the shoreline and kept straight. Sometimes guide ropes are run to small boats or the opposite shore to help place the fabric.

Mortar is first injected into the fabric in the anchor trench where it serves to prevent the rest of the fabric from sliding down the slope while it is being filled with mortar in the second stage of the pumping operation. Typically, a five man crew will install on an average of about 5000 square feet[8] of finished revetment per day. Mortar and fabric together represent about 80 percent of total finished cost with the remaining 20 percent covering labor, equipment and other out-of-pocket field costs.

These revetments are gravity-stable and require no anchoring to the earth slope. Since they add relatively little weight, they should be used only on slopes which are stable in the absence of erosive forces. They are typically installed on slopes in the 1.5:1 to 2.5:1 range, although they have been installed on slopes as steep as 50 degrees.[9] The crown of the mat is always carried to an elevation well above run-up from anticipated wave action and well below low pool to avoid underscour along the toe of the revetment.

The oldest significant job in the United States was installed along the shoreline of the Allegheny Reservoir above Kinzua Dam in southwestern New York state where 130,000 square feet[10] of 8-inch[4] filter-point revetment prevent erosion of the slope beneath a state highway. The revetment was installed on a 53-foot[11] embankment, much of it at high pool under 20 feet[12] or more of water. The installation is subject to wave action estimated at 3 feet[13] as well as ice up to 24 inches[14] thick. Although ice has abraded the fabric on the crowns of the nodules, the installation has remained fully effective and maintenance free.

The fabric itself is an important structural element in any fabric-formed revetment system. While the upper layer of fabric is subject to strength degradation as a result of ultraviolet radiation and may be abraded by erosion, the lower layer of fabric, which is bonded tightly to the mortar, acts not only as a filter cloth but provides highly flexible tensile reinforcement, the strength of which is approximately equivalent to that of ¼-inch[15] steel bars 17 inches[16] on centers. On residential installations, where appearance is an important factor, the finished revetment may be spray coated with acrylic emulsion, suitably colored to blend with the landscape, which acts as an effective shield against ultraviolet radiation.

Conclusions

Increasing acceptance of fabric forming may be attributed to at least four factors:

- availability of synthetic fibers at favorable strength-to-cost ratios
- the wide availability of economical concrete pumping equipment
- the rapidly rising cost of construction labor
- our growing recognition of the value of the land-water interface

Within the bounds of these parameters, fabric forming will soon become simply another accepted construction tool in the service of the construction industry and the engineering profession. CC

Revetment on shoreline of Allegheny Reservoir in southwestern New York state.

Metric equivalents

(1) 150 millimeters
(2) 3-meter
(3) 15 meters
(4) 200 millimeters
(5) 125 millimeters
(6) 250 millimeters
(7) 100 millimeters
(8) 450 square meters
(9) 0.87 radian
(10) 12,000 square meters
(11) 16-meter
(12) 6 meters
(13) 0.9 meter
(14) 600 millimeters
(15) 6-millimeter
(16) 430 millimeters
(17) 16,000 square meters