IS126

Portland Cement Association

CONCRETE INFORMATION

Soil-Cement for Facing Slopes, and Lining Reservoirs, Channels, and Lagoons

For more than 50 years, engineers and contractors have been using soil-cement in the paving of roads, streets, airports, and parking areas. Its performance has been outstanding. Particularly during the last three decades, developments in technology have led to the use of exposed soil-cement for water control applications. More than 400 water resources projects utilizing in excess of 14 million cubic yards ($10.7 \times 10^6 m^3$) of soil-cement have been constructed to provide slope protection for earth dams and other embankments, seepage control for water storage reservoirs, and linings of spillways, channels, and lagoons. Soil-cement's low cost, ease of construction, and convenient utilization of local or in-place soil make such applications economical, practical, and environmentally attractive.

Easily pulverized soils containing at least 5% but no more than 35% fines (material passing a No. 200 [0.075 mm] sieve) generally are the most practical and economical to use for producing soil-cement. For channels, ditches, and other applications exposed to debris carrying, rapid flowing water (velocities greater than 8 ft./sec [2 m/sec]) a study by the Portland Cement Association[1] showed superior performance with soil-cement where the soil contained at least 20% gravel (material retained on a No. 4 [4.75 mm] sieve). Fine textured soils such as clays are usually difficult to pulverize and require more cement for satisfactory hardening, as do poorly graded granular soils, which have no material passing the No. 200 (0.075 mm) sieve. Cement contents for typical soil-cement mixtures are generally in the range of 7 to 12% by weight of dry soil.

Soil-cement may either be mixed in a central mixing plant (Fig. 1) or mixed in place using traveling mixing machines. The central plant method of mixing is recommended, especially for stairstep and multiple-layer construction, because it provides more accurate and uniform mixing than the mixed-in-place technique. Except for very small projects, the central plant method is also more economical and generally results in faster production of soil-cement.

Fig. 1. Continuous flow central mixing plant. Note vibrating screen for removing oversized material.

The mixed soil-cement is then placed, compacted, finished and cured. The resulting soil-cement hardens into a strong, durable, erosion-resistant material with low permeability.

For slopes exposed to moderate to severe wave action or debris carrying, rapid flowing water, the soil-cement is usually placed in successive horizontal layers adjacent to the slope. This is referred to as stairstep slope protection. For less severe applications, such as small reservoirs, ditches, and lagoons, the slope protection may consist of one or more layers of soil-cement placed parallel to the slope face. This method is often referred to as "plating".

This publication primarily provides information on design and construction of single layer linings and plating of slopes. Throughout this publication, the reader will be referred to Portland Cement Association (PCA) publications to obtain more detailed information on specific aspects of soil-cement. Publications are available on soil-cement planning, laboratory testing, design, specifications, construction, and field inspection and control.

Facing Slopes

The use of soil-cement plating to provide slope protection for small dams was developed primarily by the Texas state office of the Soil Conservation Service (SCS). Either two 6-in.-thick (150-mm) layers or one 8-in. layer (200-mm) was placed directly on the upstream slope of 15 dams in the McClellan Creek and Lakeview Creek watersheds in northwest Texas constructed between 1980 and 1985 (Fig. 2).

When the Texas SCS first proposed the plating concept instead of the more widely used and thicker stair-stepped method, it was only approved by their regional engineering staff on the basis that it be considered somewhat experimental and be inspected and evaluated annually. After three annual inspections, and based on the good performance of the soil-cement plating, it was recommended the inspections be conducted every two years. Then following a thorough inspection of the 15 sites in 1985, a five-year inspection interval was adopted. It is now an accepted method by the SCS for providing upstream slope protection for small dams.

Fig. 2. Completed soil-cement facing at McClellan Site No. 10 Dam, Texas.

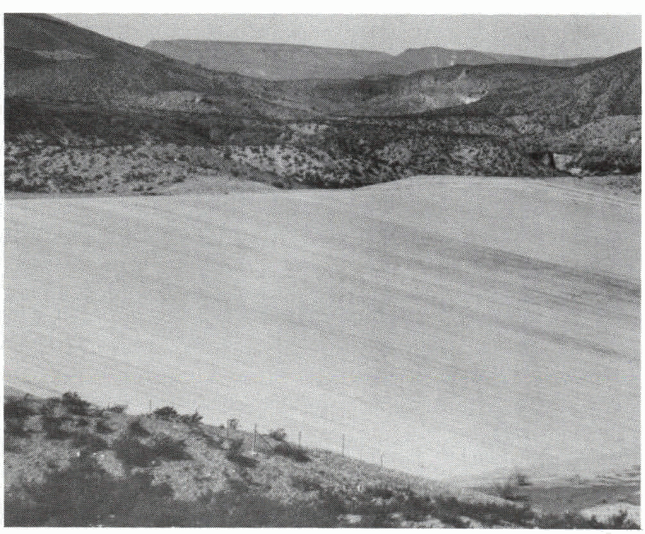

Fig. 3. Soil-cement emergency spillway at Broad Canyon Dam, near Radium Springs, N.M.

For the plating method of construction, the slope should be 3H:1V or flatter in order to properly spread and compact the soil-cement. For best results, the soil-cement should be plant mixed rather than mixed in place and placement of the soil-cement should be up and down the slope rather than cross slope. While the plating method of design and construction allows for thinner facings and eliminates layer joints exposed to the water, greater wave runup will occur due to the smooth compacted face.

Spillways, Channels, and Drainageways

In 1969, the Soil Conservation Service in New Mexico designed a soil-cement emergency spillway for the 740,000 yd^3 (566,000 m^3) earthfill Broad Canyon Dam near Radium Springs, N.M. (Fig. 3). At the time, it was the largest SCS project designed in the state.

The soil-cement was prepared in a central mixing plant and placed on the 4:1 downstream slope, 8 in. thick (200 mm). Compaction was by smooth vibratory roller working across the slope rather than up and down. The crest elevation of the wide soil-cement spillway is at the 100-year storm level and extends to the valley's bottom. The lining was designed to control erosion during this overflow condition.

A study[2] was conducted in 1986 to evaluate the effectiveness of various types of erosion protection methods in preventing overflow erosion of earth embankments. The methods ranged from grass-lined embankments to geotextile systems, gabions, riprap, cellular concrete blocks and soil-cement. The study concluded the performance of soil-cement was excellent with no evidence of erosion to the soil-cement or embankment material below.

Lining channels and drainageways with soil-cement provides erosion protection and minimizes water loss due to seepage. Soil-cement linings have been used for flumes carrying cooling water to and from several power plants. Figure 4 illustrates such a flume constructed in

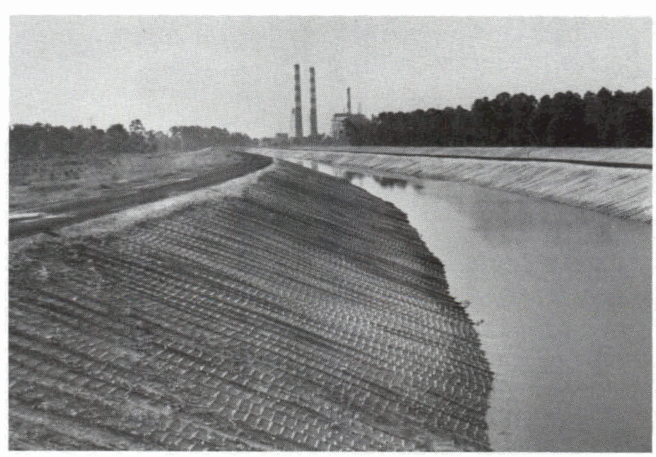

Fig. 4. Cooling water flume at Sanford, Fla., power plant.

1971 at the Florida Power & Light Company plant in Sanford, Fla. The soil-cement was central plant mixed, placed on 3:1 side slopes and compacted by a bulldozer equipped with street pads operating up and down the slope.

Reservoir Linings

Prior to the development of stairstepped soil-cement slope protection, engineers were experimenting with soil-cement for lining water storage reservoirs. In 1945, soil-cement was used to line the bottom of a 12-mg (45-ML) reservoir in Port Isabel, Texas. This reservoir had been constructed initially with concrete faced side slopes but no bottom lining. The soil-cement was mixed in place, using 12% cement by volume, and compacted to a thickness of 4 in. (100 mm).

In 1951, the U.S. Army Corps of Engineers used 6-in.-thick (150-mm) mixed-in-place soil-cement to line the bottom of the 8-acre (3.2-ha) Georgetown Distributing Reservoir in northwest Washington, D.C. The primary purposes of this lining were to prevent weed growth and facilitate cleaning with heavy equipment, but over the years water conserved by prevention of seepage has also been important.

In 1955, engineers of the Soil Conservation Service started lining small farm irrigation reservoirs with 4- to 6-in.-thick (100- to 150-mm) soil-cement (Fig. 5). These reservoirs in the southern California desert are 1 to 2 acres (0.4 to 0.8 ha) in area. By 1972, 17 such reservoirs had been lined with soil-cement. The reservoirs permit irrigators to accept deliveries of irrigation water 24 hours a day, storing the flow in the lined reservoir during the night hours and irrigating from the reservoir during the day. A study by the Soil Conservation Service[3] in 1970 determined the average seepage loss for these soil-cement lined farm reservoirs was 0.060 ft/day (2×10^{-5}cm/sec), which was considerably less than similarly lined clay reservoirs. The study also concluded that seepage through soil-cement linings typically reduce with time due to siltation and calcification of seepage paths.

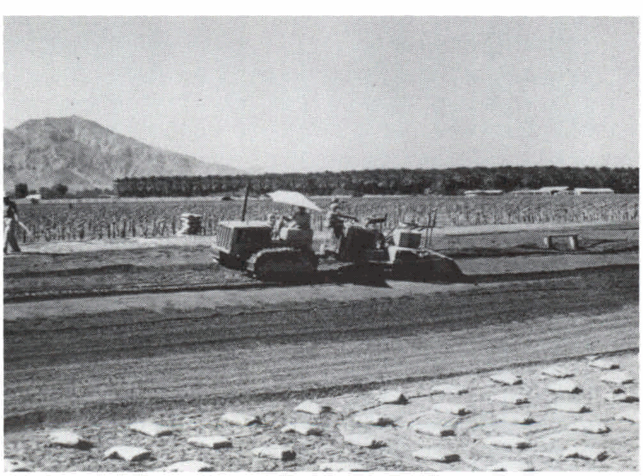

Fig. 5. Mixing soil-cement on 4:1 slope of irrigation reservoir, Riverside County, Calif., about 1955.

Lake Cahuilla, a terminal regulating reservoir for the Coachella Valley County Water District irrigation system in the Mojave Desert of southern California, was completely lined with soil-cement in 1967. Designed by the U.S. Bureau of Reclamation, the 135-acre (55-ha) bottom of the reservoir has a 6-in.-thick (150-mm) soil-cement lining while the sand embankments forming the reservoir are faced with 2 ft (0.6 m) of soil-cement, measured normal to the slope (Fig. 6). This water could not be preserved for subsequent use were the reservoir not lined to prevent seepage into and through the very permeable sandy foundation. Also in this very dry, hot desert area the lake is a welcome recreational asset.

Fig. 6. Lake Cahuilla, Coachella County Water District, Calif. Two-ft-thick (0.6-m) soil-cement, constructed in stairstep fashion, protects embankment.

Wastewater Treatment Lagoons and Impoundments

Soil-cement linings are being used to line lagoons for the storage and treatment of wastewater, both municipal and industrial. Outstanding examples are the seven-basin wastewater treatment system of Muskegon County, Mich., and a similar system at Taft, Calif. The Muskegon facility is designed to treat an average flow of 42 mgd (159 ML/d) of municipal and industrial wastewater. It consists of three 8-acre (3.2-ha) aerated lagoons, completely lined with soil-cement; a similar sized, fully lined settling lagoon; two 840-acre (340-ha) storage basins with soil-cement-faced banks; and a 10-acre (4-ha) outlet lagoon, also with soil-cement faced banks.

In 1973, soil-cement was used as erosion and seepage control for the wastewater treatment lagoons owned and operated by the Taft Heights and Ford City Sanitary District in southern California. The facility is designed to treat an average flow of 1.2 mgd (4.5 ML/d). It consists of two aerated lagoons each about 2 acres (0.81 ha) in area (Fig. 7). There are also two settling lagoons. A holding lagoon, 230 ft wide (70 m), 400 ft long (122 m), and 10 ft deep (3 m), was added in 1978. The final effluent is chlorinated and used for irrigation purposes.

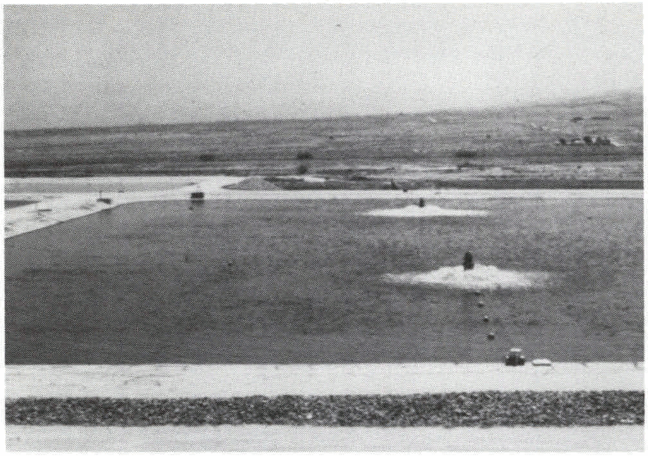

Fig. 7. Aerated lagoons at Taft Heights-Ford City Sanitary District, Taft, Calif.

Approximately 14, 500 yd^3 (11,000 m^3) of soil-cement was placed on the bottom and 3:1 side slopes of these lagoons. The bottom was lined with 6 in. (150 mm) while the side slopes received a 12 in. (300 mm) facing of soil-cement. The bermed and access roadways were also constructed with 6 in. (150 mm) of soil-cement.

At Denver's Stapleton Field, soil-cement was used to line and provide slope protection for two ponds. The ponds, which were built in 1988, are used to store ethylene glycol runoff from aircraft deicing operations. A 12-in.-thick (300-mm) soil-cement lining was used for the bottoms of both the 9 mgd (34 ML/d) capacity pond to serve regular airline operations and a 1 mgd (3.8 ML/d) pond for air cargo carriers. Soil-cement was placed in 8-ft-wide (2.4-m) stepped layers on steep 1:1 side slopes in order to minimize the area required for the collection ponds and to provide the required erosion protection for the slopes (Fig. 8).

A major factor in considering a soil-cement liner for wastewater lagoons or any type of waste impoundment is its compatibility with stored wastes. The U.S. Environmental Protection Agency (EPA) sponsored laboratory tests to evaluate the suitability of a number of lining materials, including soil-cement, exposed to various wastes.[4]

Fig. 8. Soil-cement lined pond for storing ethlene glycol runoff at Stapleton Field, Denver, Co.

The tests indicated that after one year of exposure to leachate from municipal solid wastes, the soil-cement had hardened considerably and cored like portland cement concrete. In addition, it became less permeable during the exposure period.

The soil-cement was also exposed to various hazardous wastes including toxic pesticide formulations, oil refinery sludges, toxic pharmaceutical wastes, and rubber and plastic wastes. Results showed that for certain hazardous wastes no seepage had occurred through soil-cement following a 2-1/2 year exposure. After 625 days of exposure to these wastes, the compressive strength of the soil-cement exceeded the compressive strength of similar soil-cement that had not been exposed to the wastes. Soil-cement's compatibility with toxic pesticide formulations, oily refinery sludge, toxic pharmaceutical waste, rubber and plastic received the highest rating of "good." Soil-cement was rated only "fair" in containing caustic petroleum sludges, indicating that the specific combination of soil-cement and waste should be tested. As expected, the compatibility of soil-cement with acidic steel-pickling waste was rated "poor." Other aggressive wastes being considered for containment should be tested for compatibility with soil-cement prior to its use.

Soil-Cement/Geomembrane Linings

A composite liner consisting of a synthetic membrane used in conjunction with one or more layers of compacted soil-cement has been developed to combine the impermeability of the membrane with the ability of soil-cement to withstand wave action or protect the membrane from equipment or other objects coming in contact with its surface.

The construction feasibility of a composite liner with 6-in.-thick (150-mm) layers of soil-cement both below and above the geomembrane was demonstrated in 1983 at a test section built at Apalachin, N.Y. To simulate a portion of a waste impoundment, the composite liner was constructed along the base and up a 40-ft-long 3:1 side slope. Both a 30-mil and 40-mil high density polyethylene (HDPE) membrane were placed adjacent to each other over a 6-in. (150-mm) compacted layer of soil-cement and field welded. A premixed 6-in. (150-mm) layer of soil-cement was then placed over the HDPE membrane with a small bulldozer (Fig. 9). Compaction was accomplished using a smooth, steel drum, 10 ton vibratory roller. After compaction, the membrane was inspected for signs of damage. Observations showed that there was no damage to either membrane or seam, and both were found to be puncture resistant to the placement and compaction of soil-cement even with 3/4 in. (19 mm) aggregate intentionally placed under the membrane. The test proved the ease and reliability of constructing a composite liner.

Actual applications to date have utilized a single layer of soil-cement or roller compacted concrete (RCC) placed either below or above the membrane. The use of

Fig. 9. Spreading soil-cement on membrane at 3:1 slope, Apalachin, N.Y.

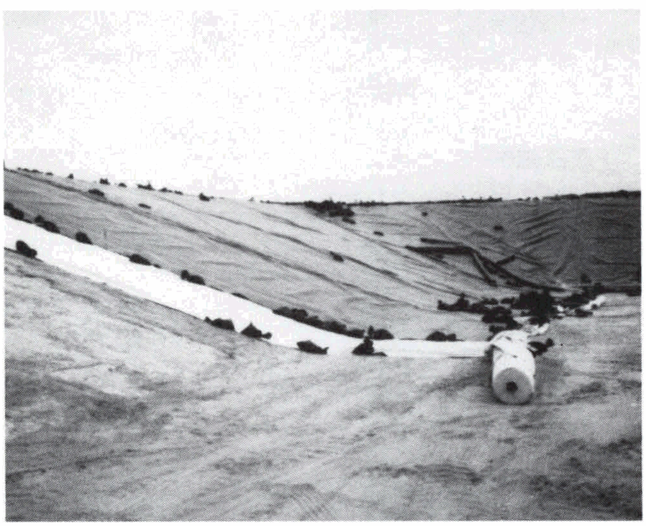

Fig. 10. Placing geomembrane over geotextile and 12-in.-thick (300-mm) soil-cement slope at Midland Terminal Reservoir, Texas.

soil-cement as a rigid backing for a membrane lining was used at two open municipal water storage reservoirs completed in 1991 at Lubbock, and Midland, Texas. The Lubbock terminal storage reservoir was designed to store 619 mg (2340 ML) of water, while the reservoir at Midland, has a 94 mg (356 ML) capacity.

Experience with geomembranes placed directly on the slope indicate they do not perform well when subjected to significant wave action. The horizontal force of wind-generated waves compresses the embankment behind the lining causing an extension of the membrane resulting at times in a rupture at the seams of the lining. The ruptured seams allow water to get in behind the lining causing additional seepage and erosion problems.

To provide an incompressible backing for the 60 mil HDPE lining, a 12-in.-thick (300-mm) layer of compacted soil-cement was placed on the 3:1 embankment side slopes at both Lubbock and Midland (Fig. 10). In the low end of the reservoir at Midland, soil-cement covers the membrane to provide a working pad for equipment used to remove silt when the reservoir is empty.

By placing the membrane atop the soil-cement, it can be visually inspected and repaired if required. The membrane is however continually exposed to sunlight, waves, and any water borne objects at the water line. If the membrane needs to be protected or will be required to support cleaning equipment in addition to being watertight, the cement stabilized layer may be placed on top of the geomembrane.

The latter design incorporating roller compacted concrete (RCC), which is very similar to soil-cement, was used to reline an existing leachate basin at an ash disposal site in south central New York in 1989. In order to comply with updated environmental regulations, the owner was required to replace the existing single geomembrane liner for the basin with a double geomembrane liner having a leak detection system placed between the two membranes. To protect the top geomembrane from direct sunlight, vandals, burrowing animals, and possible damage during cleaning operations, RCC was chosen as the cover material. A 6-in. (150-mm) thickness of RCC was placed over the 50 mil PVC geomembrane.

Design and Testing

Established test methods from the American Society for Testing and Materials (ASTM) and the Portland Cement Association (PCA) are used to determine the required amounts of cement, optimum moisture content, and density to which the mixture should be compacted.

The optimum moisture content and maximum density are determined by ASTM D558. The required cement content for durability is then established by wet-dry and freeze-thaw tests, ASTM D559 and D560, on representative specimens molded at optimum moisture and compacted to maximum density. Additional details on laboratory test procedures can be found in PCA publication *Soil-Cement for Water Control: Laboratory Tests*, IS166W.

For reservoirs and lagoons where moderate to severe wave action is anticipated the soil-cement should be placed in horizontal layers 7 to 9 ft wide (2.1 to 2.7 m) and 6 to 9 in. thick (150 to 230 mm) adjacent to the slope. This stairstepped type of design should also be used for channels and ditches exposed to debris carrying, rapid flowing water. Details on designing stairstep slope protection may be found in PCA publication *Soil-Cement Slope Protection for Embankments: Planning and Design*, IS173W.

For less severe applications such as smaller reservoirs, ditches, or lagoons the slope protection may consist of one or more 6- to 9-in.-thick (150- to 230-mm) layers of soil-cement placed parallel to the slope face.

Numerous laboratory tests have been conducted to determine the permeability of soil-cement. Permeabilities less than 1 ft/yr ($10 cm^{-6}$/sec) can generally be achieved with the proper cement content. Data on permeability of cement-treated soils can be found in the PCA publication *Soil-Cement Slope Protection for Embankments: Planning and Design*, IS173W. In addition, PCA conducted permeability tests in which 2% lime and varying percentages of fly ash were added to soil-cement mixtures. Test results indicated that permeabilities could be reduced with optimum mixtures of lime and fly ash, and in a number of cases permeabilities less than 10^{-7} cm/sec were recorded.[5]

Shrinkage cracks often develop in soil-cement liners; however, field studies have indicated that the vast majority of the crack openings are no larger than hairline width and spaced for granular soils between 10 to 20 ft (3 to 6 m)[6]. In addition, sediment along the bottom of reservoirs and lagoons will usually fill the cracks.

This was demonstrated in 1972 when Lake Cahuilla in the southern California desert was drained to remove sediment that built up during its initial three years of service. Inspections indicated shrinkage cracks in the soil-cement bottom were filled with sediment.

For applications where shrinkage cracking is a concern, the following methods have been used.

1. Keeping the soil-cement surface moist. Filling a soil-cement-lined reservoir or lagoon with water immediately after completion will reduce the likelihood of shrinkage cracking.
2. Applying a bituminous or other type of sealing material over the soil-cement approximately one month after completion. The one-month delay allows sufficient time for most of the shrinkage cracks to occur. This method was used for the 56,000 yd^2 (47,000 m^2) of soil-cement-paved coal pile storage pads at the McIntosh Power Plant in Lakeland, Fla. Two coats of liquid asphalt were applied over the completed soil-cement. The first coat was applied at 0.4 gal/yd^2 (1.7 L/m^2) immediately after final compaction and served as a cure coat. In an attempt to seal any a hairline shrinkage cracks that may have developed, a second coat at 0.2 gal/yd^2 (0.8 L/m^2) was applied 30 days later.[7]
3. Minimizing the initial moisture content of the soil-cement. The quantity of water lost influences the amount of shrinkage. Since only a small quantity of water is needed for cement hydration, the higher the initial water content, the more shrinkage will occur. To minimize shrinkage the soil-cement should be at or slightly below optimum moisture content during compaction.

Construction

Procedures for constructing soil-cement in stairstep fashion (successive horizontal layers adjacent to slope) are thoroughly described in the PCA publication *Soil-Cement Slope Protection for Embankments: Construction*, IS167W, and will not be repeated in this publication. Placing soil-cement along the bottom of a reservoir and parallel to the slope, requires further discussion.

Soil-cement may either be mixed in place using a traveling mixing machine or central plant mixed. The mixed-in-place method may be used for single-layer bottom lining or plating of flat slopes (4H:1V or less). The central plant method of mixing is recommended for multiple-layer and steeper slope construction because it provides more accurate and uniform mixing than the mixed-in-place technique. Also, mixing equipment is difficult to operate on steep slopes.

Soil-cement may also be mixed in place on a horizontal surface known as a "working table." The mixed soil-cement is then hauled and placed on the slope as would be done if the soil-cement were central plant mixed. Often, the working table is located near the slope to minimize haul distance.

Proper compaction is one of the fundamental requirements of soil-cement construction. If the subgrade is soft and cannot properly support the compaction equipment, adequate density will not be obtained. Therefore, soft areas should be located and corrected before processing begins. On horizontal surfaces, soft areas can generally be detected by observing a depression or "pumping action" under the wheels of the motor grader as it shapes the area prior to soil-cement processing.

Shallow, soft, wet subgrade areas can usually be stabilized by aerating and recompacting the soil. When deep unstable areas are encountered, it is usually necessary to remove the underlying wet or unsuitable soil and replace it with stable material.

Slopes that are to receive soil-cement should be firm moist and shaped to the required lines and grades prior to soil-cement placement. Proper preparation of the subgrade will ensure the soil-cement is uniform and specified thickness and adequate density can be achieved with minimal compactive effort.

A number of methods have been used for placing soil-cement. Aggregate spreaders, often attached to bulldozers, can place premixed soil-cement uniformly to specified widths and thicknesses (Fig. 11).

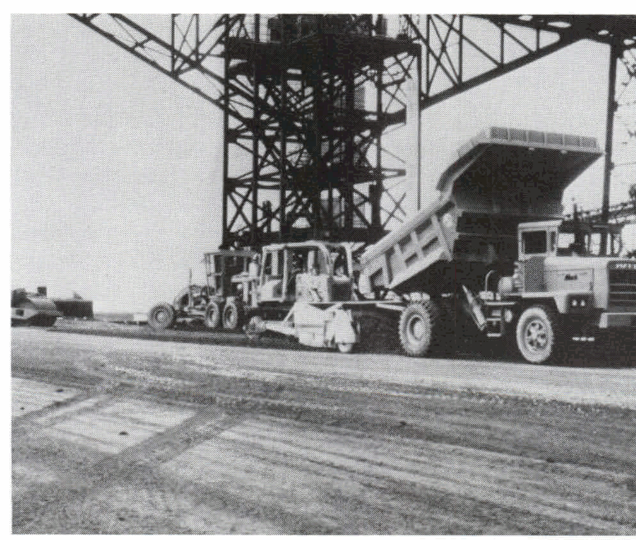

Fig. 11. Aggregate spreader being used to place central plant mixed soil cement for coal storage area at Independence Power Plant, near Newark, Ark.

Fig. 12. Bulldozer used to place soil-cement on slope at Riverside wastewater lagoons, California.

Fig. 13. Spreader running down the 3:1 slope places 12-in.-thick (300-mm) layer of soil-cement for spillway inlet channel at Palmetto Bend Dam, near Edna, Texas. Bulldozer at left is compacting soil-cement.

On relatively low embankments, soil-cement may be placed on the slope using a bulldozer that pushes the soil-cement up from the toe of the slope (Fig. 12). Where there is water or insufficient room at the bottom of the slope, the bulldozer may have to place the soil-cement by working cross-slope. It is important to have a reliable and accurate method for controlling layer thickness to ensure uniformity.

On a 27-ft-high (8.2-m) embankment for the spillway inlet channel at Palmetto Bend Dam in Texas, soil-cement was placed using an spreader working from the top of slope down. Central plant mixed soil-cement was hauled and dumped into a storage bin at the bottom of the embankment. A front end loader then fed the spreader as it traveled down the 3:1 slope (Fig. 13). Much less effort was required to place the 12-in.-thick (300-mm) layer of soil-cement from top to bottom than if the soil-cement had to be pushed up the slope.

Compaction of soil-cement may be achieved by any equipment that will satisfy minimum density requirements and provide uniform compaction throughout. Tamping, pneumatic tire, or vibratory steel wheel rollers, may be used depending on soil type and job conditions. Generally, vibratory steel wheel rollers are recommended for soil-cement made of granular materials (Fig. 14). On slopes steeper than 4:1, a traveling "deadman" on top of the embankment can support or assist compaction equipment operating up and down (Fig. 15) or cross-slope .

Adequate compaction has also been achieved using bulldozers. Multiple, overlapping passes are generally necessary to obtain the required density. To minimize the surface tearing, cut grousers or street pads should be used.

Regardless of the construction method used, the completed soil-cement must be protected from drying out for a 7-day hydration period. Moist earth, plastic sheeting, application of water by fog spray, or bituminous or other sealing material can be used for curing. Because soil-cement has a low initial moisture content,

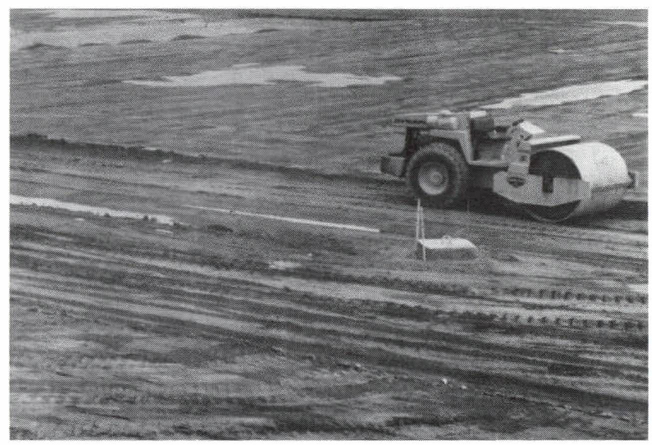

Fig. 14. Vibratory steel roller compacts bottom layer of soil-cement for one of the three 8-acre (3.2-ha.) aerated lagoons, Muskegon, Mich.

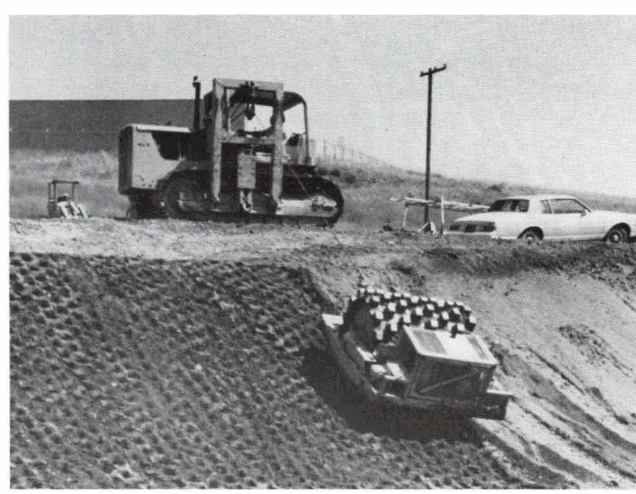

Fig. 15. "Deadman" pulling vibratory sheepsfoot roller up the slope.

water curing is preferred over other types of curing methods. No bituminous or other membrane curing material should be applied to surfaces that will be in contact with succeeding layers of soil-cement.

Suggested specifications for constructing single-layer linings or facings are presented in PCA publication *Suggested Specifications for Soil-Cement Linings for Lakes, Reservoirs, Lagoons*, IS186W. Other publications from PCA not previously mentioned that may be of assistance include *Soil-Cement Inspector's Manual*, PA050S, and the American Concrete Institute's (ACI) *State-of-the-Art Report on Soil-Cement*, LT120W.

References

1. Nussbaum, P.J., and Colley, B.E., "Dam Construction and Facing with Soil-Cement," RD010W, Portland Cement Association, Skokie, Ill., 1971.
2. Clopper, P.E., and Chen, Y.H., "Minimizing Embankment Damage During Overtopping Flow," *Final Report*, by Simons, Li & Associates, Inc., for Federal Highway Administration, Washington, D.C., and Bureau of Reclamation, Contract Number DTFH61-85-C-001341, Denver, Colo., 1988.
3. Koluvek, P.K., "Seepage Losses from Soil-Cement Lined Irrigation Reservoirs," American Society of Agricultural Engineerings, Paper No. 72-760, Chicago, Ill., December 11-15, 1972.
4. "Lining of Waste Impoundment and Disposal Facilities," SW-870, Office of Solid Waste and Emergency Resources, Washington, D.C., March 1983.
5. Nussbaum, P.J., "Permeability of Soil-Cement, Lime and Fly Ash Mixes," Portland Cement Association, Skokie, Ill., 1979.
6. *Soil Stabilization with Portland Cement*, Highway Research Board Bulletin 292, 1961.
7. *Coal-Handling and Storage Facilities*, PL152W, Portland Cement Association, Skokie, Ill., 1983.

CAUTION: Contact with wet (unhardened) concrete, mortar, cement, or cement mixtures can cause SKIN IRRITATION, SEVERE CHEMICAL BURNS, or SERIOUS EYE DAMAGE. Wear waterproof gloves, a long-sleeved shirt, full-length trousers, and proper eye protection when working with these materials. If you have to stand in wet concrete, use waterproof boots that are high enough to keep concrete from flowing into them. Wash wet concrete, mortar, cement, or cement mixtures from your skin immediately. Flush eyes with clean water immediately after contact. Indirect contact through clothing can be as serious as direct contact, so promptly rinse out wet concrete, mortar, cement, or cement mixtures from clothing. Seek immediate medical attention if you have persistent or severe discomfort.

Portland Cement Association *5420 Old Orchard Road, Skokie, Illinois 60077-1083*

An organization of cement manufacturers to improve and extend the uses of portland cement and concrete through market development, engineering, research, education, and public affairs work.

Printed in U.S.A.

IS126.01W