CANAL AND RESERVOIR LINING

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Lining of irrigation canals and reservoirs offers one of the best opportunities to extend limited water supplies. Not only is lining effective in controlling seepage losses, but it provides insurance against breaks, reduces maintenance costs, and constitutes a good weed-control measure.

Many materials have been used successfully for linings. In the United States, earth, asphalt, and concrete are the materials most commonly used. Recently a number of new materials have been investigated; among these are butyl rubber, plastic film, and soil stabilizers. The material best adapted for a given lining will depend upon site conditions and the choice determined by the labor involved and the relative cost of material, equipment, and labor.

Earth linings

Earth linings are not new, but in recent years the use of earth for controlling seepage is being investigated with renewed interest. Several types of earth linings are being investigated and utilized to some extent. A lining which has attracted considerable attention is the thick, rolled, earth lining. This lining is about 8 feet thick in the horizontal plane and 3 feet thick normal to the side slope. The U.S. Bureau of Reclamation reports[2] seepage in the order of 0.07 cubic foot per square foot of wetted area per 24 hours from properly constructed heavy compacted earth-lined canals. This is comparable to seepage losses from good concrete-lined canals. There are indications that these thick earth linings will become more permeable with use. Some investigations to determine the increase in permeability which accompanies use are in progress currently by the U.S. Bureau of Reclamation.

The earth linings at our River Laboratory, with one exception, have all tended to deteriorate with time. This includes natural earth materials and soil bentonite mixes. However, none of these

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1/ Soil Scientist, Western Soil and Water Management Section, Soil and Water Conservation Research Branch, Agricultural Research Service, U.S. Department of Agriculture.

2/ Canal Linings and Methods of Reducing Costs. Bulletin U.S. Bureau of Reclamation.

linings are of the thick, rolled type, but are composed of relatively thin earth blankets covered with gravel. The thin blanket-type linings, if compacted when installed, gradually decrease in apparent specific weight. Likewise, uncompacted earth linings have tended to increase in apparent specific weight until both the compacted and the uncompacted linings have about the same apparent specific weight and exhibit similar seepage losses. It has been concluded from our studies, therefore, that thin-blanket-type linings, to be effective, must be constructed of earth material having a low permeability independent of compaction. Apparently, material such as gravelly and sandy clay in which the clay does not exhibit extreme volume change upon wetting and drying is better adapted to the thick compacted earth lining. While frequently employed without a cover, the life of the thick compacted earth lining will be extended appreciably by the addition of an erosion-resistant topping such as gravel.

Treatment of canals and reservoirs with fine sediment has long been employed to control seepage. The cost is extremely low, but the benefits of this type of lining were generally of short duration and limited effectiveness depending upon the penetration of the sediment into the porous structure of the subgrade. An extensive study on the development and use of sediment linings is in progress at present under the direction of R. D. Dirmeyer.[3/] It has been reasoned that, if by some method the sediment can be held in suspension until penetration can be accomplished, the amount of material deposited in the canal subsurface will be proportional to the extent of the seepage--since the most water will be moving through the bed material at these locations. Various dispersing agents have been used and the results obtained to date are encouraging. Because of the cheapness of the method, it has great possibilities even if the treatment must be repeated at fairly frequent intervals.

The use of dispersing agents, such as polyphosphates, to reduce the permeability of soil, and thereby control seepage, is another promising cheap method which may be effective under certain conditions. Good seepage control from polyphosphate treatment in eastern United States has been reported by Lambe.[4/] Only small quantities of the chemical are required and the treatment is cheap by comparison with other materials. The effectiveness of the treatment, however, is limited by the character of the earth to be treated,

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3/ Dirmeyer, R. D. Colorado Agricultural and Mechanical College, Fort Collins, Colorado.

4/ Lambe, T. William. Impermeabilization of the Lagoon at the International Paper Co., Technical Association of the Pulp and Paper Industry, January 1955, Vol. 38, No. 1.

and therefore, the use of polyphosphates should be preceded by an investigation of site conditions and materials.

Asphalt linings

The water-repellent and adhesive properties of asphalt early attracted attention to it for canal and reservoir lining. Its resistance to biological deterioration and the action of acids, bases, and salts is another property of asphalt which is favorable to its use as a lining material. These properties and the availability of asphalt in this country led to numerous attempts to employ it in irrigation canals and reservoirs for seepage control and channel stabilization. Linings for these purposes have varied widely and many types of asphalt products have been used.

While numerous variations of asphaltic linings have been tested, the types most studied or successful fall into six categories; asphaltic-concrete linings, prime-membrane linings, buried-membrane linings, prefabricated liners, built-up linings, asphalt-emulsion linings and underseals. The general characteristics of the lining in the first four categories are outlined in a publication of the Asphalt Institute5/ and a series of publications by Benson.6/, 7/

The renewed interest and development work in the use of asphalt for controlling seepage losses in irrigation canals and reservoirs has been due to greater awareness of the need for water conservation and recognition that cost of the lining is a governing factor in its choice. Both the asphalt industry and public agencies have contributed to these studies. The search for lower-cost linings and linings adapted to varying site conditions goes on; nevertheless, some progress has been made. The cost of standard linings, such as concrete and earth, has been reduced through improved design and mechanization to less than it was 10 years ago, despite the general rise in construction costs during this period. The acceptance and wide usage of asphalt in this period was largely the result of the development of the buried-asphalt membrane (BAM) lining by the U.S. Bureau of Reclamation under the direction of J. R. Benson.

The BAM lining is the product of early failures, failures of exposed asphaltic linings, and adjustments to overcome these difficulties. The cracking and hardening of the asphalt from

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5/ The Asphalt Institute, 801 2nd Ave., New York 17, New York Asphaltic Canal Linings, Construction Series No. 86, February 1949.

6/ Benson, J. R. Buried Asphalt Membrane Lining Developed to Give Canal Seepage Control at Low Cost. Western Construction News, Sept. 15, 1949.

7/ --------------. Test of Prefabricated Canal Lining. Western Construction News, April 15, 1950.

exposure and mechanical damage was found to be sufficient to destroy the effectiveness of prime-membrane linings in about one year's time. In an attempt to improve the durability of these exposed membranes, fillers such as diatamaceous earth were added to the asphalt which extended their life but did little to improve the resistance to mechanical damage. Development work on prime-membrane linings has been largely discontinued or redirected.

The most common of the BAM linings is the sprayed type. Since the asphalt used in this type of lining has a high-softening point, special equipment and experienced contractors are required. This and practical difficulties led to the prefabrication of asphaltic liners for canals and reservoirs. These liners look and are handled much like roofing felts. The first were nothing more than a layer of asphalt on a paper backing to facilitate handling. Since then, a number of types have been produced, all containing supporting structures or fillers, such as fiberglass, asbestos felt, and aluminum foil. These liners are about 1/8 inch in thickness, and because of the weakness of the structure and susceptibility to deterioration upon exposure, are intended and employed primarily as buried membranes. Recently, prefabricated asphalt liners about 1/2 inch in thickness have become available commercially. These liners have a high percentage of filler and are semi-rigid and supplied in plank form. They are sufficiently flexible, however, that they can be fitted to the shape of a canal and can be employed as exposed linings. They are moderately resistant to mechanical damage but time alone will determine how long this type of lining will last.

The built-up lining is an exposed lining which consists of alternate layers of asphalt and a supporting fabric, such as jute, cotton, or fiberglass. Such linings have considerable resistance to mechanical damage and the supporting fabrics reduce the deterioration resulting from exposure. Toppings of gravel or other material imbedded or bonded to the surface may be employed to provide further protection from the elements and thereby materially reduce the deterioration of the asphalt.

The possibilities of this type of lining have not been fully explored, and further tests using such materials as fiberglass and jute are being made at the Utah Station. This work is new, and consequently no conclusion can be drawn concerning the effective life of these linings. It does appear, however, that they can be constructed somewhat cheaper than the heavy prefabricated type and should exhibit equal or better durability.

Another lining which has received considerable attention is asphaltic concrete. It consists of sand and gravel aggregate, stabilized with asphaltic cement. Linings of this type have performed reasonably well, and at one time, were being promoted rather extensively. The hot mixes have proven most satisfactory. The cost of this lining is about the same as portland cement concrete lining but appears to be considerably less durable under most conditions.

The use of emulsions for surface applications and as underseals is currently being investigated, but this work has not progressed far enough to draw any general conclusions.

The development of the catalytically-blown asphalt by the Lion Oil Company of El Dorado, Arkansas, likely can be considered largely responsible for the success of the BAM lining. Catalytically-blown asphalt is flexible over a wide range of temperatures without becoming liquid. It is tough and retains these properties over a considerable period of time, if protected from the sun's radiation. Experience with this liner indicates it will give reasonably good service, if properly installed, but unless certain minimum requirements are met, BAM linings will not be effective and will be more costly than other types of lining.8/ The subgrade should be smooth, firm, and fine-textured and the cover material should consist first of a fine-textured layer topped with material sufficiently coarse to be stable at the velocities for which the canal is designed. Although it has been demonstrated that these BAM linings effectively control seepage where properly constructed and maintained, they have serious disadvantages as do all buried linings. In the first place, if they are damaged, it is very difficult to make repairs. Where cleaning is necessary, it is a problem to carry out the operation without damaging the lining. There is more of a cleaning and weed problem, and a much larger ditch is required to provide the same capacity, because of the less favorable hydraulic properties associated with these liners. Because of these unfavorable properties, we are continually searching for some means to avoid covering. The use of asphaltic concrete accomplishes this, and the thick prefabricated and built-up linings are attempts to do the same thing. The most serious difficulty encountered with these linings is the deterioration inherently associated with asphalt when exposed. Much progress would be made, if an asphalt could be developed which had better weathering properties. Some attempts have been made to accomplish this. Probably the poor stability upon exposure is associated with the unsaturated condition of the constituent hydrocarbons and saturation or partial saturation would improve the aging properties upon exposure. Some work has been done along this line with evidence of some success. Shielding the asphalt provides another approach.

Concrete linings

Mention canal lining to a water user in the United States and the chances are good he will think in terms of portland cement concrete. Portland cement concrete has long been used, and under conditions favorable to its use, it is hard to beat. The only reason other

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8/ Lauritzen, C. W. Site Conditions Increase Cost and Problems of Canal Lining Maintenance in Utah. Western Construction News, May 1953.

of lining are considered by many people is the high cost of concrete lining. Concrete linings have good hydraulic properties, they resist damage, and minimize cleaning and weed problems. Considering the durability and limited maintenance required for concrete linings, there is considerable doubt about the annual cost of concrete linings being greater than some other so-called lower-cost linings. Advances during the past 10 years have made it necessary to revaluate relative cost. As previously mentioned, although construction costs have more than doubled during this period, the cost of lining with concrete is lower now than it was 10 years ago. Costs as low as $2.20 per square yard for 3 1/2 inch concrete are reported by the USBR for the Friant-Kern Canal in California, a canal with a capacity of 2,500 to 5,000 cfs. A small canal in the vicinity of Ogden, Utah, was lined at a cost of $2.62 per square yard with 3-inch unreinforced concrete and $2.25 with 2-inch. The cost of the concrete for 1 square yard delivered to the site of the job ready for use was $1.02 and $0.62, respectively. Not only have construction costs been reduced, but new developments such as the use of air entraining agents have resulted in better concrete.

Butly rubber and plastic film linings

Plastic is becoming a universal material. Among some of the newer uses is its use for conveying water and controlling seepage losses. Butyl[9] has been found to be highly resistant to aging and appears to be well adapted to use as buried lining in the form of unsupported sheeting and to tubing in the form of coated fabrics. Plastic film of certain types also looks promising for buried linings, and plastic tubing offers possibilities for use in farm distribution systems. Information on long-time tests is not available, but short-term tests and artificial-aging studies indicate that film linings[10] of polyethylene, and polyvinyl chloride will effectively control seepage when employed as buried liners. When these films are employed as barriers to seepage, it is necessary to take special precautions against damage to the film during installation. If this is done, it appears that these materials will provide effective seepage control over a considerable period of time. Because of the weakness of the film and the ease with which it is punctured, it is necessary to use a cushion course of fine-textured material, both above and below the film. To protect the cover from erosion, a

9/ Lauritzen, C. W. and Peterson, W. H. Butyl Fabrics as Canal Lining Materials, Utah Agricultural Experiment Station Bulletin No. 363.

10/ Lauritzen, C. W., Haws, Frank W., and Humpherys, Allan S. Plastic Film for Controlling Seepage Losses in Farm Reservoirs. Utah Agricultural Experiment Station Bulletin No. 391

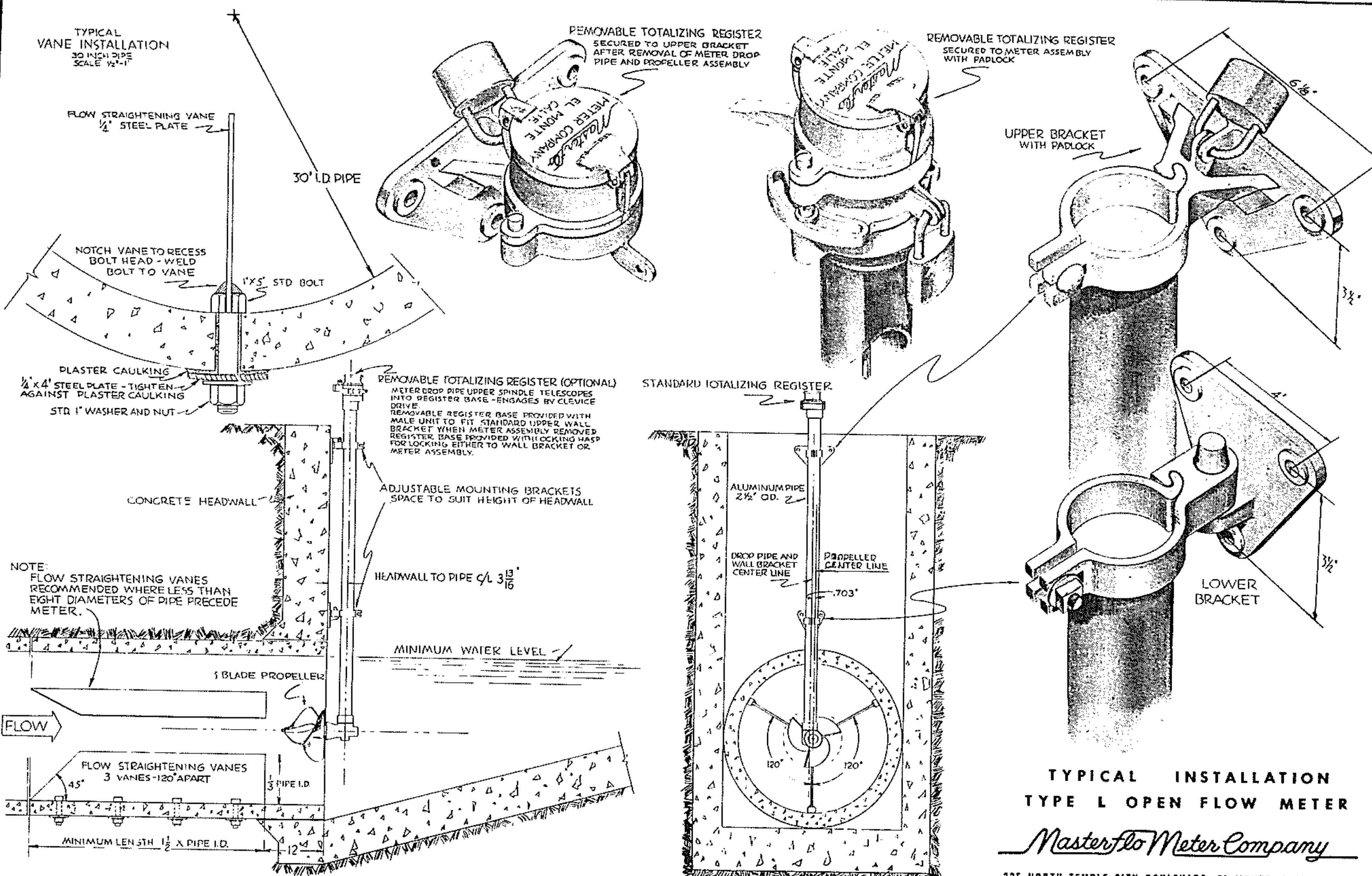
topping of gravel or other erosion resistant material will be required. Buried plastic films, like other buried liners, have certain disadvantages particularly for canal linings as previosuly mentioned. When employed for reservoir lining, the reduced capacity factor vanishes. Because of this, buried liners compete more favorably for reservoir lining than canal linings.

Plastic film for buried linings has one important advantage over other types. Because of its light weight, it can be fabricated in large units, minimizing field joints. It also eliminates the necessity for careful trimming of the canal prism in an effort to avoid fish mouths along the joints. Since the material is extremely flexible, if a little slack is allowed, it will adjust to subgrade irregularities without difficulties or impairment to the effectiveness of the material as a liner. The same advantage applies to butyl rubber to a lesser degree.

Stabilized earth linings

Concrete is not always the answer. In some areas, suitable concrete aggregate is not available locally, and because of this, other types of lining must be resorted to, if lining is to be economically feasible. In certain areas, buried membranes might be used, but since some type of gravel will be required to stabilize the cover, there are areas where something else must be used. Soil cement is a promising possibility in sandy areas. Soil cement consists of a mixture of portland cement and soil, the soil replacing the sand and gravel used in concrete. There are two types of soil cement--the plastic and standard. The plastic is mixed and placed similar to concrete. The standard, on the other hand, is mixed at optimum moisture for maximum compaction as determined by the Proctor method. Compaction is necessary to obtain the desired density. One of the problems encountered in the use of standard soil cement in canals has been the problem of compaction on the side slopes. Where good compaction can be obtained, the standard soil cement is more durable than the plastic type. Many methods have been employed to secure compaction on the side slope but a successful method has yet to be developed. The use of a traveling vibrator is being investigated, and the results obtained are promising, particularly for small canals. There seems to be no reason why the method cannot be adapted to larger canals.

The use of soil chemical stabilizers is another possibility for controlling seepage in canals and reservoirs. The one with which we have done the most work is water soluble, and when a catalyst system is added to a monomer solution, it polymerizes. When mixed with the soil, the gel forms around the solid particles and in this way binds the soil particles together and effects stabilization. The resulting mass is tough, yet slightly flexible when wet. The stabilized soil becomes hard when dry, but upon rewetting, assumes its original semiflexible characteristics. The character of the gel formed can be varied by varying the concentration of the monomer--a stiffer gel being produced with more concentrated solutions. The



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time required for polymerization or gelling is governed by several factors, among which are the concentration of the catalyst and activator in the catalyst system and the temperature. Preliminary studies indicate that better stabilization is obtained when the soil contains some fines. The use of the stabilizer, therefore, might well be used in areas where the silt and clay content of the soil is too great for good soil cement. While encouraging results have been obtained, additional work will be required before the use of this stabilizer to line canals and reservoirs is practical. In the laboratory, we have been able to secure stabilization with both plastic mixes and mixes with the moisture content optimum for maximum compaction. Although several field tests have been conducted, we have yet to install a successful lining employing the dry mix.

Summary

Frequently the question is asked, "What is the best lining?" The answer to such a question obviously cannot be a generalization. Site conditions, relative cost, and availability of materials are governing factors. A canal located on a hillside presents a different problem than one through a broad valley, for at least one important reason. It is costly, if not next to impossible, to construct a canal on a steep sidehill with flat side slopes. Because of this, generally linings requiring flat slopes are not adapted to these locations. It is inviting trouble to use earth and membrane linings in canals and reservoirs where the material is subject to piping unless special precautions are taken to limit the hazard. It would be folly, on the other hand, to employ concrete linings in areas subject to high groundwater tables during periods of freezing weather. Frequently, in the design of a canal, there is a choice of reducing the gradient through drops to provide low stream velocity, or employing a lining material which will tolerate higher velocities. The most satisfactory and least costly method will depend upon the situation. The sediment content of water, the cleaning problem, and the importance of weed control are other factors which bear on the choice and effectiveness of a lining. Other factors might be enumerated.

We have made progress in the past in improving and adapting materials and methods employed for lining, and I feel sure the future holds promise of further progress. An encouraging development of our time has been the joining of industry with research organizations to solve problems and adapt materials to new uses. Such a combination should speed progress.