SEEPAGE REDUCTION WITH COLORADO CLAYS

By

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and

M. M. Skinner

Prepared for

SEEPAGE SYMPOSIUM

AT

U.S. Water Conservation Laboratory
Tempe, Arizona

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CER63RDD-MMS8

Rough Draft

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INTRODUCTION

A new program was started by the CSU Sediment-Sealing Research Group in 1960 with guide principals as listed below:

1. The sediment-sealing material would be locally available Colorado clays, evaluated by direct measurements of sealing potential with laboratory test procedures to be developed.
2. The trial installation would be concentrated in test sections of Colorado canals where (a) seepage losses are high--in excess of 50% where possible and, (b) the pervious bed materials are coarse--gravelly to rocky where possible.

These investigations are now nearing completion. Two reports are being readied for publication:

1. Dirmeyer, R. D., Jr., Clay As a Canal Sealant, a literature review, prepared for Review, Vol II, Div. of Engrg. Geol. Soc. of Amer. (In preparation)
2. Dirmeyer, R. D., Jr., Skinner, M. M., Lutz, G. A, and White, L. G., Evaluation of Colorado Clays for Sealing Purposes (Part I--Laboratory Testing and Part II--Field Trial Evaluation) Expt. Sta. Bull., Colorado State University. (In preparation)

The information outlined in this paper is restricted to summary statements developed from the reports above. It is felt that this will suffice for most readers, however, should more detailed information be desired, please do not hesitate in requesting it from the authors of this paper.

This Symposium, in itself, emphasizes that the canal lining needs of many irrigation systems are well recognized. It is also well recognized that large-scaled efforts of seepage control are, in many instances, blocked or scaled-down by this all important factor of cost. Thus it may be seen that the idea of lowering the costs by using flowing canal water for placing an impermeable clay (or other sealant) in the leaky zones is an extremely attractive one. Judging from the widely variable results of such work, it may also be seen that many troublesome problems can be encountered in using these short-cut methods.

It will be recognized that there are many clay materials and methods for applying these clays in sealing irrigation canals, but the summary statements that follow our restricted to general items that it is believed apply equally as well that all silting and clay-sealing methods and they may be of some help from the standpoint of design and control of construction.

CHARACTERISTICS OF ACCEPTABLE SEALING CLAYS

Water-tight--Whether the material is called silt, clay or bentonite, it must have one feature above all others--it must be water-tight or in other words, capable of holding water when used as a sealing agent in canals. This may seem like an over obvious statement but during the course of our research activities, we have encountered many jobs (especially the silting examples) where the material used for silting or clay-sealing apparently was not tested to see if it was impermeable--at least no record of the testing can be found.

Testing methods--The various clay testing methods used in our research work are discussed in detail in the second report listed in the Introductions paper, they are not in this paper. In general, for uses where the clay is to be washed into place in the canal bed and banks, two of the tests seem more pertinent than the others: (1) the filter permeability, and (2) mixibility index. The mixibility index gives a measure of the ease of mixing which is especially important if the clay is to be washed into suspension from dams spaced in the canal. The filter permeability gives a measure of the water-tightness after the clay is in place in the leaky zones of the canal bottom and banks.

Chemical and mineralogical--In general, those clays of most favorable characteristics for sealing purposes are (1) high in content of colloidally-sized particles, (2) montmorillonitic or bentoniticin nature, and (3) 10% or more sodium-saturated. Thus, they usually exhibit some degree of swelling upon wetting with water. This also means that the silting or clay-sealing methods have a limited used in hard-water areas, since a sodium clay when mixed or dispersed into hard water (high in calcium and magnesium) will exchange almost immediately to a calcium clay. When deposited as a filter cake, the calcium clay will usually be much more permeable than its sodium counterpart. This action can be counter-acted by placing the clay as a compacted layer rather than as a sedimented material. It is difficult for the permeable structure to develop after the clay is compacted.

CONDITION OF CANAL CHANNEL

Preparatory work--Since the silting and clay-sealing methods are, as implied, sealing methods only, they have no other significant benefits, such as the erosion and weed control benefits exhibited by hard-surfaced canal linings. Thus, before going ahead with the clay-sealing work, the channel should be clean, eroding areas repaired and rip-rapped, and any other needed maintenance work completed.

Stable channel--Another factor, as vitally important as the clay characteristics and the channel preparation, is that the canal channel must be stable. If it is not, the life of the sealing is cut short. Conditions that will shorten the service life include:

(1) erosion or undercutting of canal banks.

(2) movement of bed materials (as dunes, etc.) along bottom.

(3) burrowing or rooting of animals, such as crayfish, earthworms, muskrats, pigs, coons, etc.

(4) growing or rotting of plant roots.

(5) loosening of canal soil by frost heave or drying cracks.

Generally, the channels in fine-grained materials, such as sandy to clayey soils will be much more disturbed by the above conditions than those in coarse materials, such as coarse sand, gravel, cobble, or talus.

SEALING OF COARSE MATERIALS

From the above, it follows logically that the best results with silting and clay-sealing commonly are produced in canals traversing (or rip-rapped with) rocky to gravelly materials. This relates not only to the longer life of the sealing in stable materials, but also to the level of seepage loss, which is usually much higher in the coarse materials than it is in the fine-grained ones. Thus, the immediate benefits of clay sealing in the coarse materials usually are of a much higher magnitude and they last longer than those for treatments in fine-grained soils.

Penetration and sealing--Under ideal conditions, the coarse channel plating is underlain by a finer material in depth (say 6-12 inches deep). With this condition, the sealing takes place on the finer-grained materials and is protected by the coarse-grained cover material. This ideal condition is not unusual. It is common in canals in mountainous areas where coarse materials are prevalent and where, with time, the flowing canal water removes the fines, leaving the coarse fragments as a gravel, cobble or rock plating. The sealing-in-depth produced under these conditions is protected from erosion and resists, fairly well, disturbing actions such as frost and drying.

Penetration without sealing--If the coarse material is very open and lacks the necessary fines-in-depth, the sealing clay may penetrate very well but not seal. In this case, such as in canals traversing talus slopes, the intermediate particle sizes in the silt and sand range are needed as bridging agents and must, therefore, be furnished along with the sealing clay in order to produce an adequate sealing action. Wet saw-dust has also been used as the bridging or void-plugging agent alon with the clay for sealing coarse talus materials in remote alpine areas where sand and silt-size materials are not readily available.

Costs to benefits--The most favorable relationship of construction cost to benefits of clay-sealing is found in mountainous areas, such as in some parts of Colorado, where it is not uncommon to encounter canals that have from 50 to 100 percent loss late in the summer--at a time when the water is most needed. In these areas, conditions may be unfavorable for conventional canal linings because of higher than normal construction costs compared with relatively low crop income. In these same areas, however, conditions are commonly very favorable for clay-sealing. Rocky to gravelly materials with high seepage losses are common in such areas, with the result that the benefits of clay-sealing may be strikingly visible--such as in the case where water is delivered where it could not be delivered before the clay treatment.

SEALING OF FINE MATERIALS

In contrast to the generally good results produced in coarse materials, the least satisfactory results of clay-sealing or silting have been produced in silty to sandy materials. This results from a combination of several factors:

1. <u>Surface sealing</u>--The silting or clay-sealing materials will not readily penetrate many of the fine-grained soils. Thus, a surface coating of clay on the canal materials is a common result. This coating is vulnerable to puncturing by animals and plants, cracking by drying or freezing, or removal by water or wind erosion.
2. <u>Unstable channel</u>--In addition to the problems of a surface coating, many of the canals in the fine-grained materials have an unstable section. Waves and flowing water cut the banks. Animals work the soil of the canal section. Sand dunes move along the canal bottom, and the soils crack upon drying or freezing and thawing.

In addition to the above problems, it is difficult to measure accurately the seepage losses in fine-grained soils. While seep-damage below canals in fine-grained soils may be very obvious, the amounts of water actually lost from the canals in these soils may be fairly low--compared to the losses from channels in coarse materials. In attempting to measure seepage losses of a low level of intensity, it is found that few water measuring methods have an accuracy of $\pm$ 2.0% and most methods probably are in the accuracy range of $\pm$ 5.0% to $\pm$ 10.0%. Since the seepage losses from fine-grained soils are often of the same magnitude for short lengths of canal (say less than 2 miles long), one is never quite certain whether the measured seepage loss is fact or fantasy.

<u>Costs to benefits</u> are, therefore, difficult to determine for clay-sealing work in fine-grained soils. It may be assumed, however, that in general it will take a special set of conditions to produce favorable results in fine-grained soils. For example, in an irrigation system where short supplies of water may require intermittent operation of the canals late in the summer, clay-sealing with the first water into the dry canal can, under some circumstances, save sufficient water in one or two days of operation to pay for the clay used.

MAINTENANCE OF CLAY-SEALED CHANNELS

The needs and cost of maintenance of canal linings are frequently overlooked, but the completion of such work on a periodic basis is, nevertheless, important. This is especially so far clay-sealing installations, since in several ways they are more susceptible to damage than conventional canal linings. The clay-sealed channels in rocky to gravelly materials generally will require less maintenance than those in the fine-grained soils, but in both cases repeat treatments are recommended. The best time for the repeat treatments is in the spring with the first water into the dry canal. The amount of re-treatment will vary with the conditions, but the usual recommendation is for a 10% treatment--if 200 tons used initially, 20 tons used in re-treatment each spring. In gravelly or rocky channels re-treatment may not be needed every year--perhaps every other year or every third year will be sufficient.

In some instances, special clay mixtures have been used to seal leaky pipelines or canal linings.

RESEARCH NEEDS

In reviewing the various examples of silting and clay-sealing, a variety of research needs were encountered--some directly related to the subject of canal sealing and some only indirectly related.

Of direct importance is the need for basic research into the various factors influencing canal seepage. The variability of canal conditions relates not only to the basic differences in permeable materials, but also to the modifying influences of the canal environment. The flowing canal water erodes bank or bed material in one area and deposits it in another. Animal life of many forms and activities, inhabits and modifies the canal bed and bank materials. With changing conditions of water, such as temperature, sediment content, hardness, etc., the seepage rate will change--but how much and why? In regard to the measurement of seepage loss, how much of the highly variable result is due to changes in actual seepage and how much is due to the inaccuracy of the measuring method?

Clays are extremely varied in composition and in their impermeability characteristics. Thus, there is a great need at the present time not only for fundamental studies of clays and their sealing characteristics but also for studies of the mechanics involved when all of the conditions of the canal site and clay sediment are interacting.