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FINAL REPORT
of
CLAY SEALING INVESTIGATIONS

FOOTHILLS WATER BOARD

For the Period
of
February 1, 1960 to January 31, 1961

by
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Prepared for the
Southeastern Colorado Water Conservancy District
and the
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¹Includes bentonite.

INTRODUCTION

Loss of irrigation water, as result of seepage from canals and reservoirs, is a widespread problem in the irrigated areas of the South-eastern Colorado Water Conservancy District and other Irrigation Districts in Colorado. In some instances, these losses can be tolerated because a part of the seepage water normally returns to the main river. In many cases, however, the seepage water damages valuable land. In addition, in areas or times of extreme water shortage, saving the seepage water becomes important. One direct way of saving the seepage water--for use by those that divert the water--consists of sealing the leaky canals and reservoirs.

From a long-range standpoint, the best answers to the seepage loss problem are, in many instances, hard surface linings, such as concrete and asphaltic cement. These linings not only can control seepage but also add advantages related to the control of water weeds and bank erosion. It is emphasized, therefore, that the clay linings being investigated by the CSU Clay Sealing Research Project do not, in a normal sense, compete with or replace the conventional linings.

In other words, a planned program of installing relatively permanent linings, such as concrete, may be very desirable for an irrigation district--even if the program includes only a short section each year. Low-cost linings with locally-available clays can fit profitably into such a program--either as a companion development or as a temporary cost-imposed limitation. In some instances the objective of the clay linings may be one of providing an immediate method for salvaging seepage water while the future goal is seepage control with conventional linings.

This report is concerned with (1) the clay deposits existing in the District area, and (2) the initial results of installations made with local clay materials in canals and reservoirs.

Since the evaluation and development work is not complete, this report also includes future plans for continuation of the work. The activities are now being carried out as part of a state-wide clay (including bentonite) inventory and sealing research program of the CSU Agricultural Experiment Station with funding as provided by the Colorado Legislature directly and through the Colorado Water Conservation Board.

CLAY SAMPLING

A comprehensive sampling of all clay deposits in the District area has not been completed. It is believed, however, that a satisfactory representation of the clays available within the District area has been obtained. Information concerning each of the deposits sampled to date is briefly outlined in Table 1, starting at the upstream end of the District.

TABLE 1
CLAY DEPOSIT INFORMATION

Sample No. ¹	Name	Nearest Town	Nature of Deposit	Description of Mining
S48	Mumma	Poncha Springs	Altered volcanic ash	Not developed--may be too spotty in quality
S49	Lamberg	Howard	Altered volcanic ash in fissures	Good operation--mat'l air-dried in place--then stock-piled
S34	Kessler	Howard	Altered volcanic ash and tuff	Several openings started--product extremely variable
S64	Harvey	Parkdale	Altered Shale	Not developed for open pit operation
S28	Fox-Dilley	Canon City	Altered volcanic ash in Morrison formation	Good operation--could improve air-drying and stock-piling operations
S44	Butterfield Stough	Las Animas	Altered volcanic ash in Morrison formation	Several different pits ranging from poor to good pit operation
S73	Mahan	?	?	?
S60	Welte	Colorado Springs	Altered Pierre Shale	From brick clay pit
S78	Vahldick	West-cliffe	?	Not developed

¹ See Map I of 3rd Quarterly Progress Report for locations.

CLAY TESTING

The results of the laboratory testing of clay samples collected thus far in the Colorado State University program are outlined in Table II. In examining the results, please keep in mind that they are based upon sampling of an exploratory nature. A complete sampling program at any one deposit--especially if concentrated on only the best clay layers--could produce results appreciably different than those found in Table II.

The results of the clay testing are discussed in more detail later in this report under DISCUSSION OF INITIAL RESULTS, but because of the sampling limitations, conclusions regarding acceptability of specific clays for sealing work are only tentative at the present time. This is a question that involves not only the laboratory testing results but also the results of evaluations of field trial installations. In other words, before flatly stating what constitutes a good clay, it is necessary to also consider where and how the clay is to be used.

FIELD INSTALLATIONS

A total of 21 installations of local clays in ditches and ponds within the District area have been evaluated. With the exception of one near Colorado Springs, all of the installations evaluated were in the District area above Pueblo. All but five of the installations were made with the S49 clay from near Howard.

The installation evaluations are tabulated in Table III and Map 2 of the 3rd Quarterly Progress Report to the District. The results of the evaluations are incorporated in the DISCUSSION OF INITIAL RESULTS section of this report.

In general, installations of two types were evaluated:

1. Ditch installations -- Since most of the installations were made in steep rocky ditches, a multiple-dam method of washing the clay into place in the ditch banks and bottom was generally adopted.
2. Pond installations -- Most of the pond installations were of the mixed surface membrane type, where the clay is spread on the ground surface in the pond and mixed into the sub-soil. In some instances, the water-line area was blanketed as a protection against wave erosion.

OTHER ACTIVITIES

While most of the Colorado State University clay project activities have, to date, been concentrated on (1) exploratory sampling of potential deposits, (2) laboratory evaluation of the clay samples, and (3) evaluation

TABLE II.

CLAY SAMPLE EVALUATIONS¹

Sample No.	Name	Nearest Town	Particle Size		Permeability		Mixability Index	Swelling Index
			Grit	Colloidal Yield	Layer	Filter		
			%	%	ft/day 10 ⁻³	ml/min	%	%
S28-1	Fox-Dilley	Canon City	8.3	39.5	0.58	5:1	77.5	98
-2	"	"	7.9	39.6	2.29	4.8	34.9	88
-3	"	"	9.1	37.0	0.58	10.3	48.5	90
-4	"	"	2.0	49.3	2.60	7.7	----	30
-5	"	"	5.8	30.2	6.80	8.3	----	60
-6	"	"	6.0	43.8	0.0	8.0	----	100
S34-1	Kessler	Howard	0.9	26.1	0.0	26.7	93.5	60
-2	"	"	0.8	22.9	15.0	19.1	----	60
-5	"	"	2.6	27.7	1.14	10.1	97.5	50
-6	"	"	1.4	22.5	32.20	36.2	93.9	68
S44-1	Rodgers	Las Animas	5.7	55.3	0.0	0.9	12.6	230
-2	"	"	4.1	63.0	0.0	0.9	11.5	312
-3	Stough	"	7.8	55.0	1.16	4.7	31.5	111
-4	Butterfield	"	1.9	66.1	0.74	1.2	8.5	253
-5	School	"	3.9	58.1	0.0	1.0	16.9	150
S45-1	Wagner	"	7.9	55.6	0.48	16.8	38.2	130
S48-1	Mumma	Poncha Sprgs.	2.4	30.6	0.26	4.3	89.7	110
S49-3	Lamberg	Howard	6.7	35.6	0.30	2.6	100.	77.7
-4	"	"	22.1	49.8	2.88	1.9	75.	54.3
S60-1	Welte	Colo. Sprgs.	9.4	26.3	57.12	48.8	38.1	20
-2	"	"	5.0	32.2	38.90	35.6	42.6	25
-3	"	"	6.5	31.3	32.80	38.0	63.6	50
-4	"	"	3.5	37.3	29.84	57.0	62.1	30
S64-1	Harvey	Parkdale	18.9	44.4	73.92	130.0	38.1	40
-3	"	"	8.4	23.9	3.20	8.5	11.0	-10
S73-2	Mahan	Pueblo	3.2	31.7	33.90	17.0	82.4	50
S78-2	Vahldick	Westcliffe	15.5	42.2	67.46	36.5	91.5	25
S00-1	Am. Colloid	Wyoming	2.8	86.8	0.0	0.9	----	627
S00-6	G & W Base	S. Africa	1.4	86.8	0.0	0.9	----	594

¹For additional details as to test procedure, see TABLE I, page 3, of 3rd Quarterly Progress Report.

of actual installations in ditches and ponds, several additional activities-- that will assume increasing importance as the development and research work progresses--are listed below:

1. Assistance to contractors -- During the past year, project work was accomplished with three clay contractors (S49, S28, S44). This assistance consisted of: (1) help in planning development of clay deposits so as to obtain advantages of air-drying and proper sizing and uniformity of produced clay material, and (2) help in planning and installing clay materials in leaky ditches and ponds.

2. Specifications -- Cooperative activities--pointed toward the eventual development of clay sealing specifications--have been initiated with the State Agricultural Stabilization and Conservation Office and with the ASC Committees in Chaffee and Fremont Counties where cost-sharing for bentonite or clay sealing work has been allowed.

DISCUSSION OF INITIAL RESULTS

To produce satisfactory sealing results with clays in canals and reservoirs, both the procedure and the clay material must "fit" the conditions of the site.

Site Conditions

A comprehensive evaluation of canal and reservoir conditions in the District area is not within the scope of the CSU program, but for development purposes, several generalizations seem pertinent.

Area West of Pueblo -- In this area of the District, the canals are relatively steep and fast, the soils commonly rocky or gravelly, and the seepage losses from both canals and ponds, in many instances, are high. As a result of this situation, and also because of the availability of both clays and clay sealing services, a considerable amount of ditch and pond sealing work has been accomplished in this area--especially in the Salida-Buena Vista area.

Area east of Pueblo -- In this area of the District, the canals are relatively flat and slow, the soils commonly clayey to sandy, and the seepage losses for both canals and ponds, variable from low to high. To date, very little CSU project work has been devoted to this area--mainly because the irrigation waters in many parts of this area intermittently carry a clay sediment which does have some effects. The need for clay sealing on a planned basis, however, does exist in some areas--especially in clear-water canals below large reservoirs. (~~See attached article--Lets Muddy the Ditch Water~~).

Procedure

Two general methods have been used in the initial clay sealing activities in the District Area: (1) The float-in methods, and (2) the

membrane or blanket methods. Since most of the work, to date, has been pointed at sealing rocky to gravelly soils, the discussion that follows reflects this emphasis. Sealing finer-grained soils involves problems different from those presented by the rocky soils, but the idea of fitting the clay and the procedure to the site conditions applies equally well in either case.

Float-in methods -- These methods--where the clay sealing material is carried into place by flowing water--have been used almost exclusively in canals. The actual procedures have varied with the accessibility and steepness of canal. In instances where the canals are very steep and inaccessible to trucks, the sealing procedure has been accomplished by washing the clay into the flowing canal water at the upper end of the canal section being sealed. On flatter, more accessible canals, the multiple-dam method of installation has been used. It consists of the following steps:

1. Dams of the sealing clay or bentonite are placed in the dry canal--close enough together for adequate ponding of the entire canal section.

2. A small head of water is run into the dry canal so that the following procedure takes place slowly:

- a. Water ponds behind first upstream dam of clay.

- b. As water tops first dam, the break-out process is assisted by shovelling clay into the water rushing through the break.

- c. The muddy water formed in this manner is ponded behind the second dam.

- d. The process of ponding, over-topping and wash-out of clay dams is repeated through successive downstream dams.

3. As spring maintenance procedure for at least two years following the initial treatment a small amount of clay is washed into the treated reach. (Usually about 10 percent of initial amount.)

In all installations an effort has been made to plan the installations (including follow-up maintenance treatments) for a time when the seepage losses are at the highest level. Some canals gain water during some parts of the irrigation season and lose water from the same sections at other times. It will be realized that in those areas of the canal bed or banks where an inflow of ground water is occurring, clay usually will not be deposited.

The amount of clay used in the installations has been in the range of 1 to 5 lbs/sq. ft. of wetted surface area in the treated reach--open rocky materials requiring the larger amounts and fine sandy materials the smaller amounts. The frequency and amount of clay used in the repeat maintenance treatments depends mainly on the stability of the canal bed and banks.

Membrane methods -- The blanketing methods of sealing have been used to a limited extent in controlling seepage from short sections of canal above troublesome seepage areas, but the major use of the methods has been in ponds. The common procedure has consisted of: (1) spreading from 1/4 to 3-inches of clay, (1 to 25 lbs/sq. ft.) over the leaky area, and (2) harrowing the clay into the sub-soil and then compacting the mixture. The main problems have been: (1) non-uniform distribution of or insufficient clay used and (2) erosion at water line in pond. To combat the latter problem, in some instances the clay membrane in the water-line area has been protected with a cover of soil or rock.

Clay Testing

Since the clay sampling as represented in TABLE II is of an exploratory nature, interpretations at this time in regard to the quality of the various clays may be misleading. Comprehensive sampling of deposits that have been developed commercially already is planned for this coming summer. Even though detailed interpretations cannot be made at this time, the testing represented by TABLE II can be discussed in a general way.

Particle size -- The particle size testing of grit (sand) content and colloidal yield (silt-free clay) gives an idea of the particle size range in the clay sample. Contrary to popular belief, a high colloidal yield alone does not insure good sealing results. For example, in sealing coarse rocky soils a high colloidal yield clay alone, such as a Wyoming high-swell bentonite, in many cases will not hold or stay in place. In rocky materials, the grit content is important because of its ability to bridge over and plug large voids or holes. On the other hand, for sealing fine sandy soils it is not good economy to haul, for example, 4 tons of sand for every 6 tons of clay. In other words, the sand in this latter case is sheer waste whereas in the case of rocky soils it is most essential.

Permeability -- The sealing ability of the clay samples has been tested in two ways.

1. The layer permeability test measures the ability of a layer of clay to hold water. This test is pointed at the uses of clay blankets in sealing ponds and short sections of canal. From the layer permeability test and with site information, such as water depth, soil, etc., it is possible to calculate the approximate thickness of clay or bentonite needed.

2. The filter permeability test is pointed at the float-in or wash-in applications of clay. It tests the ability of a thin cake of clay, deposited from a muddy water dispersion, to hold water. The test results are in volume (milliliters) per minute. A small value of loss is desired but how small is yet to be determined by additional laboratory and field trial work.

Mixability -- The mixability index test measures the relative speed with which a clay-sealing material will soften and wash away when subjected to flowing water in a canal. This procedure is pointed at the wash-in or float-in methods of clay application in canals. A low percentage of loss figure means that the clay is hard to mix, whereas a high figure means easy

mixing. Some clays may indicate very favorable low layer and filter loss permeability results, while at the same time show extreme resistance to dispersing in water. The Fuller's earth type of bentonite displays this characteristic that seemingly limits its use in the float-in methods of canal sealing. However, a promising way of overcoming this problem is being investigated.

Swelling index -- This test measures the amount of swelling that takes place when a clay sample is dropped into water. A slight amount of swelling is helpful because of its hole-closing effect on newly-placed clay layers when wetted for the first time. A large amount of swelling, however, can introduce troublesome problems--especially in areas where the irrigation waters are hard or where severe frost or drying occur during the winter time.

Other tests -- In addition to the characteristics that can be determined in the test procedures already described, several other characteristics of clay are important from a canal and pond sealing standpoint. Clays are commonly referred to as inert materials formed by the chemical decomposition of rock materials. The decomposition part is true in a general sense, but many clays are far from inert. They have certain chemical characteristics that profoundly affect their sealing characteristics. For example, a so-called "black-alkali" soil can in some instances be changed from a gummy tight unmanageable soil to a loose crumbly open soil by the application of gypsum. This, of course, is to be avoided in canal and pond sealing work. Thus, it is important, especially from a service or sealing endurance standpoint, that the major chemical and mineralogical traits of a sealing clay be known. Detailed evaluations of this type are planned for samples from those deposits now being commercially developed.

Development Problems

With the increasing use of clays for sealing purposes in the District area, several development problems are being encountered. Control of clay quality probably is the most serious one at the present time. Materials have been mistakenly sold as bentonite that actually are mostly rock with only a small percentage of clay content. Even the materials of substantial clay content, in many instances, have varied widely from one truck load to the next. The water content in some clay materials has run as high as 50 percent. These problems emphasize the need for (1) a flexible set of clay specifications to fit various installation conditions, and (perhaps of most critical importance now) (2) adequate mining and air-drying operations, sufficient to insure satisfactory quality and uniformity of production of any desired type of clay.

It is for the reasons outlined above, that in the planning of CSU clay project activities, increasing emphasis is being placed on filling requests for the following services: (1) assistance to ASC County Committees, in setting up specifications that fit the locally-available clays to the local canal and pond conditions, and (2) assistance to clay producers in setting up pit operation procedures necessary to produce an acceptable and uniform clay material for canal and pond sealing purposes.

It will be realized, however, that while the quality and uniformity of clay material is extremely important, more than this alone is required to produce good sealing results in canals and reservoirs. Installation experience is of utmost importance. The mining of the clay and the installation are being handled separately in some areas, but in our opinion, the solution with the best potential for keeping the costs low and the sealing results high is a combined operation where the contractor or irrigation district do both the mining and the installation. Many local earth-moving and ditch-cleaning contractors can handle this combined operation with no additional equipment being required.

CONCLUSIONS AND RECOMMENDATIONS

1. Where does clay sealing fit in? -- The uses of local clays in sealing canals and ponds offer important low-cost, stop-gap methods for controlling loss of water. In many instances, however, the best long-range approach will be one of salvaging seepage water now by using a clay sealing method while working toward a future goal of eventually controlling the seepage with hard-surface linings.

2. Is the sampling complete? -- A complete inventory of all potential deposits of clay for sealing purposes in the District area has not been completed. It is believed, however, that the best deposits have been sampled; therefore, no additional sampling of new deposits is planned. If sampling of new deposits is requested, it will be accomplished--within limits of available project funding.

3. What is an acceptable clay? -- It is a basic premise that local clays, if properly handled, can be used to seal local canals and ponds. Thus, the emphasis of the CSU development work is concerned more with how to use the local clay to obtain satisfactory results rather than with developing a rigid specification or preconceived notion of what is acceptable and what is not acceptable. Specifications are needed, but not on a hasty premature basis.

4. What are the recommended installation methods? -- The initial evaluations of clay installations in canals and ponds have revealed several dominant methods:

a. For canals in rocky soils -- The wash-in or multiple-dam methods seem best. Follow-up maintenance treatment is recommended for inclusion with first water into ditch for at least the next two irrigation seasons following the original treatment (usually 10% of original amount).

b. For canals in sandy soils -- Extensive experience with local clays in these materials is lacking, but trials on a wash-in or float-in basis are planned.

c. For ponds in leaky soils -- The mixing of not less than 1 inch of bentonite into the top 3 inches of sub-soil following by compaction seems best. Extra bentonite or cover protection is advisable for the water-line area.

5. Is more specific information in installation methods available? -- Not at the present time. How-to-do circulars for each of the important methods are planned as sufficient information becomes available. Limited cost information is available in TABLE III of the 3rd Quarterly Progress Report to the District. Additional cost information is being obtained.

6. Where is additional work needed? -- Additional research and development work is needed and is planned (contingent upon funding) in the following categories:

- a. Trial installations in clear-water canals below reservoirs in the area east of Pueblo.
- b. Controlled trial work in determining how much clay is required in float-in installations--especially in rocky soils and including follow-up maintenance treatments in succeeding years after initial installation.
- c. Comprehensive sampling and laboratory testing of clays from those deposits now being worked on a beginning commercial basis.
- d. Development of recommended application rate tables by leaky soil types for each major clay deposits now being worked on a commercial basis.
- e. Assistance to clay producers in setting up pit operation procedures necessary to produce acceptable and uniform clay materials for canal and pond work in their area.
- f. Assistance to ASC County committees in setting up specifications that fit the locally-available clays to the local canal pond conditions.
- g. Encouragement, to the maximum extent possible, of combined operations where the contractor or irrigation district accomplishes both the mining and installation of clay.