EARTH DAMS AND ROADS IN THE NATIONAL FORESTS

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SYNOPSIS

The Forest Service has made practical use of recent developments in the intelligent handling of soils in two very important types of structure—dams and roads Most of the dams are comparatively small and do not justify large expenditures for laboratory equipment The problem has been one of getting satisfactory results at a reasonable expense, and has included the training of the engineers responsible for field supervision The paper describes the control exercised over the selection of embankment material and also the control measures followed during construction operations

The work in road construction has been for the most part confined to experimental sections with different kinds and amounts of admixtures, and with various combinations of aggregate and binder soil Installation and maintenance costs are being carefully determined, as they will be most important factors in the determination of the suitability of the method and the extent of use on the system of low standard Forest roads usually known as truck trails Progress is being made, but it is believed that the final answer must await the development of improved technique, particularly for localities where natural materials are not well suited to present methods

The National Forests are 157 in number and with the Purchase Units are located in 40 states, Alaska and Puerto Rico The gross acreage exceeds 220 million acres This is roughly 10 per cent of the total area of the United States Naturally within such a large area and located in so many portions of the United States, the resources included are great in number and of many kinds A transportation system of roads, truck trails and trails is essential for the protection of the National Forest property against fire and disease and, further, for the development and utilization of such resources as timber, grazing, recreation, mining, water power, irrigation, fishing and hunting Beyond all this, there is a need for public travel—interstate, state, county or community The planned road system includes about 22,000 miles of Forest Highways which are of primary importance to public travel and more than 100,000 miles of development truck-trails which are of primary importance for the administration, protection and utilization of the Forest resources Roughly less than one-half of this system is now of satisfactory standard design but the trail system for the planned length of about 154,000 miles is about 78 per cent completed

The Forest Highways carry a relatively large volume of travel and therefore justify a considerable investment per mile The roads are of high standard and are usually surfaced with crushed rock treated with oil On the truck trails the justifiable investment in construction and maintenance must be restricted to less than the value rendered to the Forest property The values per acre are relatively low This means that instead of an expenditure exceeding $30,000 per mile as is made for Forest Highways, the general objective is to keep the average construction cost of the truck trails to roughly 10 per cent of that amount Accordingly the standard of the truck trails is low. they are safe to travel, but at relatively low speeds

Restriction on the total allowable expenditure requires utilization of the natural soils for the road surface wherever such soil is at all suitable since a surface treatment will ordinarily increase the cost beyond the expenditure justifiable from an economic standpoint It is fortunate that to a very large extent the natural soil is of a satisfactory character. But for a very considerable portion of the total mileage, something must be done to secure a surface which will assure the truck trail being in suitable condition for travel at required speeds during the entire period of the year when travel is necessary Besides soils too light or otherwise not adapted for road purposes, dust is a source of discomfort, danger and loss of investment

In addition to the mileage on the planned truck trail system, there are also many thousand miles of trails and short lengths of road in the recreation areas On these the travel is highly concentrated and while the speed is low, the dust nuisance and wear on the roads is great

The Forest Service accordingly has been very much interested in finding some inexpensive method of treating the natural soils that would make them suitable for travel, and on which the annual cost would be materially less than for crushed rock surfacing It has therefore followed with great interest the laboratory and field experimentation relating to stabilized roads It has also constructed two experimental roads

Many millions of people now use the National Forests annually for recreation and the number is rapidly increasing For this use it has become necessary to construct dams to create lakes for boating, swimming and fishing Also dams have been needed in connection with small water supplies, irrigation, water conservation, wild fowl and fish propagation and for stock watering These dams are usually located on the headwaters of streams in mountainous areas and since they are constructed very largely by the Civilian Conservation Corps, possibly 70 per cent are of the earth type While the dams are relatively large in number, the height runs from only a few feet up to about 65 feet and the storage capacity averages less than 100 acre feet But even though the height is small and the storage capacity little, it is of great importance to make these dams safe

The indications are that the public will demand the construction of many more such dams It is therefore necessary for the Forest Service to keep fully abreast of the latest developments in earth dam construction as well as to contribute its part in these developments The Forest Service has adapted the modern technique for the construction and maintenance of earth dams to its own work

The earth dams are widely distributed and include a great variety of foundation conditions and soil types To know how a soil will act when subjected to water pressure has compelled an investigation of each project The usual laboratory tests have been conducted for determining the permeability and susceptibility of the soils to settlement under the weight of embankment Selection of suitable soils for embankment use has been guided by the laboratory tests of grading, density, plasticity, stability, and permeability under known densities The tests include the determination under standard laboratory conditions of the Proctor relation of moisture content to density for use as a guide in the construction operations These tests have been made by regularly organized laboratories such as the Bureau of Public Roads

The control of the construction operations along the lines indicated by the laboratory tests has necessitated training field engineers and developing practicable methods at reasonable expense As a rule men with adequate experience have not been available and it has been necessary to develop them by instruction and training on the Forest Service work Obviously the cost of such control work has to be kept in proper relationship to the total cost of the structures and as few of the earth dams exceed 25 ft in height or 40,000 cu yd in volume, the difficulty of getting adequate control over the construction operations has not been small

Simple field laboratories have been set up and equipped for mechanical analyses, density, and moisture content determination as established through use of the Proctor control methods Responsibility for proper use of designated borrow pit material is placed on the field engineer, who also regulates the moisture control and rolling operations The uniformity of borrow pit material is checked in the field laboratory and compared with the original laboratory results Control of spreading, application of moisture, and the amount of rolling, are guided by frequent tests of samples from the completed fill Two or three samples are taken each day, giving an average of about one test for each hundred cubic yards of fill on the smaller projects In practically all cases it has been possible to keep the average moisture content within $1\frac{1}{2}$ per cent above or below the optimum The density measurements indicate that the results are fully satisfactory for these low embankments

The use of the Proctor needle is now confined almost entirely to the laboratory where screened material can be used Use of the needle on the fill gave many erratic measurements which served only to undermine confidence in the entire procedure Most of this trouble could be traced to the presence of gravel or stone chips in the soil

On one project the field engineer was faced with what might be called a reverse problem of moisture control About 90 per cent of the impervious fill was below ground water level in the borrow pits and had to be dried out on the fill before compacting operations could be started The control problem here was to determine when the moisture content had been reduced to the maximum permissible value

In construction, material has been dumped, spread with bulldozers and rolled with sheepsfoot rollers The layers are limited to an average compacted thickness of 6 in Generally the addition of moisture has been necessary Where the material is of a pervious sandy nature, such as would be suitable for the downstream pervious portions of some design sections, water has been added in the borrow pits If done a day in advance of the time of moving the material, the moisture distribution has been satisfactory This method however is unsatisfactory for impervious materials because the moisture will not penetrate to a sufficient depth in a reasonable time Water added after the layer has been spread but before rolling, causes difficulty through clogging the roller feet and otherwise impeding the equipment operation With the first rolling done with deficient moisture in the top layer, it has been practicable to add the required water just before the next layer is dumped Subsequent rolling gives the necessary compaction with perhaps one or two extra trips of the roller and without danger of interruption to progress from bogged down equipment

The increased cost of moisture and compaction control work has come mainly from additional supervision and investment in rolling equipment, both of which are relatively small portions of the total costs For the most part the results have been negative, that is, a lack of trouble with the dams when in service Materials have been used and sites have been developed which a few years ago would not have been considered good risks There is room for improvement and standardization of certain tests, such as the measurement of percolation and for the development of a scale of mensuration of the suitability of soils for use in dams Many engineers and technicians are at work on the problem and progress can be expected

In one case the soil compaction practice was used in the preparation of the foundation for a warehouse at Asheville, North

Carolina Two buildings, 32 x 96 ft and 32 x 72 ft , each two stories high, were erected on an earth fill two feet deep on one side and eleven feet deep on the other After compacting the fill with a sheepsfoot roller under moisture control, the buildings were immediately erected They are now complete and occupied and in four months time have shown no indications of settlement

The two experimental road stabilization projects are located in Northern Georgia

The project known as the Chimney Mountain Road is on the Cherokee National Forest It is 7 miles long, and is subdivided into 36 sections each of which was given a different treatment The combinations included variation of the size and proportions of coarse aggregate and binder soil, different admixtures and sections without admixture There are 12 sections on which sodium chloride was used, 11 with calcium chloride and 5 sections with a mixture of the two salts Two more sections have a stabilized surface mix without admixture and the remaining six were built to Forest Service specifications for class B gravel roads

The binder soils were obtained from the subgrade or from borrow pits along the right-of-way The coarse aggregate was a graded crushed stone Insofar as possible and to facilitate visual comparison, adjacent sections were built of the same aggregate and proportions, but with different admixture conditions Wherever sodium chloride was used, it was added integrally, calcium chloride was applied by both integral and surface treatment methods

One-half of this project was built in September and October 1935 and the rest between March and June of 1936 The 1935 sections have been through a cycle of fall rains, winter snows, spring rains and a dry summer The only maintenance has been light blading with a motor patrol, no chemicals have been added, nor has there been any patching It is too soon to expect conclusive results but certain weaknesses seem to be developing, some of which will undoubtedly be traced to the aggregate and binder materials

The Lake Rabun Road presented a somewhat different problem because it is a heavily traveled road and serves a very popular recreational area in the summer The grades are steep and there are many curves The original surface showed poor grading and the presence of a high percentage of micaceous material A suitable clay binder was located with difficulty and used with the surface aggregate already on the road Compacting by loaded trucks was tried out first but proved so expensive that a rubber tired "packing truck" was improvised It did an excellent job at a greatly reduced cost This project is about 4 miles long, and has both calcium chloride and sodium chloride treatments The aggregate proportions have been kept uniform

After a dry summer this road was entirely free from dust, but in places showed small amounts of free stone that had been torn loose, principally on the curves Some of the curves were corrugated slightly as a result of cross drainage

The Forest Service is very hopeful that these two experimental roads and stabilized roads constructed by the states and others will show that the stabilization method with the application of sodium chloride or calcium chloride will provide a road of satisfactory quality and with a cost for construction and maintenance materially less than would be required for other methods and within the amount justified for expenditure from an economic standpoint The period of observation and experience is as yet insufficient to permit drawing any final conclusions as to the practicability, value and cost of the method However even if found satisfactory under certain conditions, there would also be a large mileage where it is probable that this method will not meet the need It is the hope of the Forest Service that the scientists may find means, through the use of other materials, chemicals, waste liquors or otherwise, to secure a surface of satisfactory quality and of low cost Thorough experimentation and extensive research along these lines is urged

DISCUSSION

MR C N CONNER, *U S Bureau of Public Roads* Were core walls used in the construction of these earth dams and if so, what type? In the compaction of the layers of earth in the dams were rollers used? Did you use the specially designed roller made up of truck wheels?

MR NORCROSS We did not use the specially designed roller, which was intended only for the compaction of road surfaces Much heavier rolling equipment is required for dam construction For this, we have used the so-called sheeps-foot roller almost exclusively

As to core-walls or cut-off walls, the practice varies and depends entirely on the material and sub-surface conditions In most cases the cut-off consisted only of a wide trench excavated to relatively impervious sub-soil, and backfilled with compacted impervious soil

MR CONNER Are the cut-off walls of masonry or other material?

MR NORCROSS· In general, where the foundation is a smooth rock surface, concrete core walls about 5 ft high are used to stop leakage between the rock surface and the fill Otherwise, compacted soil core walls serve the purpose Masonry walls are seldom used for this purpose