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EARTH-FILL OVERFLOW DAMS IN FLOOD CONTROL

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SUMMARY.

In connection with its Flood Control system in the mountains and foothills the Los Angeles County Flood Control District has, under the writer's general direction, developed an overflow type earth-fill dam of moderate height which is believed to be unique. The purpose of such dams generally is to act as debris barriers at the mouth of canyons draining a watershed of the order of one square mile in surface area. While six such structures have so far been built there will eventually be over a hundred required. In view of this number, economy was necessarily of particular interest besides safety requirements.

As practically without exception, a debris cone has formed below such canyons, the barriers in question are generally located in the upper part of such debris cones, or, in other words, on coarse, granular, porous but stable alluvial fills. As the depth to bedrock is usually such as to make it impracticable to excavate thereto and to construct these dams thereon, they are with few exceptions floating dams. The height of the spillway crest of such dams above the original stream bed is of the order of 25 feet.

As relatively coarse alluvial fills are subject to little yield under moderate load, it is possible to construct upon it a compacted embankment of high density which will serve as a foundation for the upstream slab and the spillway structure without the danger of critical deformation due to settlement, provided such construction is suitably articulated as well as reinforced. Suitable subdrainage must likewise be provided under the spillway structure.

In order to facilitate construction, vertical cutoff walls are not used in connection with these dams but the inclined face slab is extended below the ground surface on its regular slope so as to penetrate to a depth which is equal to or greater than the depth to which a vertical cutoff wall could be economically carried. This aids in the spreading of the load on the foundation and the lengthening of the base.

Due to the low height, the length of the base of such a dam and the temporary nature of storage, percolation is normally not a serious problem particularly in view of the free-draining characteristics and the relative coarseness of the alluvial fill on which the dam rests.

It is of course essential to avoid overload on the spillway. This means that the spillways must be over designed so as to have a capacity over the entire length in contact with the dam and for some distance downstream from it, which must be in excess of the largest probable flood peak originating from the watershed above the dam. The computed flood peaks for spillway design are based on the assumption that the watershed had been denuded by fire immediately before the flood and that the clear water flow were bulked 100 per cent by eroded debris.

EXPLORATION

Little if any foundation exploration is normally required in view of the familiarity with the characteristics of cone deposits and the moderate height of the barrier. Thorough exploration of a borrow pit for suitable materials for the compacted fill as near to the dam site as possible is, however, indispensable. In general, the fill material is old, decomposed, granitic alluvium. Samples are tested for compaction characteristics, shearing strength and permeability.

DESIGN

Figure 1 shows the plan and details of the typical earth-fill overflow dam recently constructed at the mouth of one of the canyons in Los Angeles County draining a watershed of roughly two-thirds of a square mile. An interesting appurtenance to the dam is the outlet works as shown in Figure 2 consisting of a tower constructed of precast concrete tile, a rock mound which acts as a filter, and a pipe conduit discharging into the spillway downstream from the dam. The pipe, not less than 3 feet in diameter, is encased in reinforced concrete provided with cutoff collars to avoid "creepage" of water and the latter is in turn encased in compacted earth of similar characteristics as the material in the dam. It has proven desirable to provide a reasonable camber for the conduit so as to avoid sag due to settlement under surcharge below the theoretical grade line. This camber also serves to avoid undesirable tension in the conduit structure due to such sag.

In order to provide uniform support for the facing slab it has been found desirable to extend the compacted fill below the ground surface into the cutoff part of the slab as indicated in Fig. 1 (b). A mat of compacted earth of suitable thickness is advisable under the entire face slab so as the distribute the bearing pressure and avoid abrupt changes in settlement.

The spillway structure proper may have vertical or inclined walls to suit the type of materials used, that is, either reinforced, plain or asphaltic concrete. Reinforced concrete with continuous steel bars across the joints is the normal, permanent type of construction. The spillway crest is treated as a broad crested wier and the downstream slope of

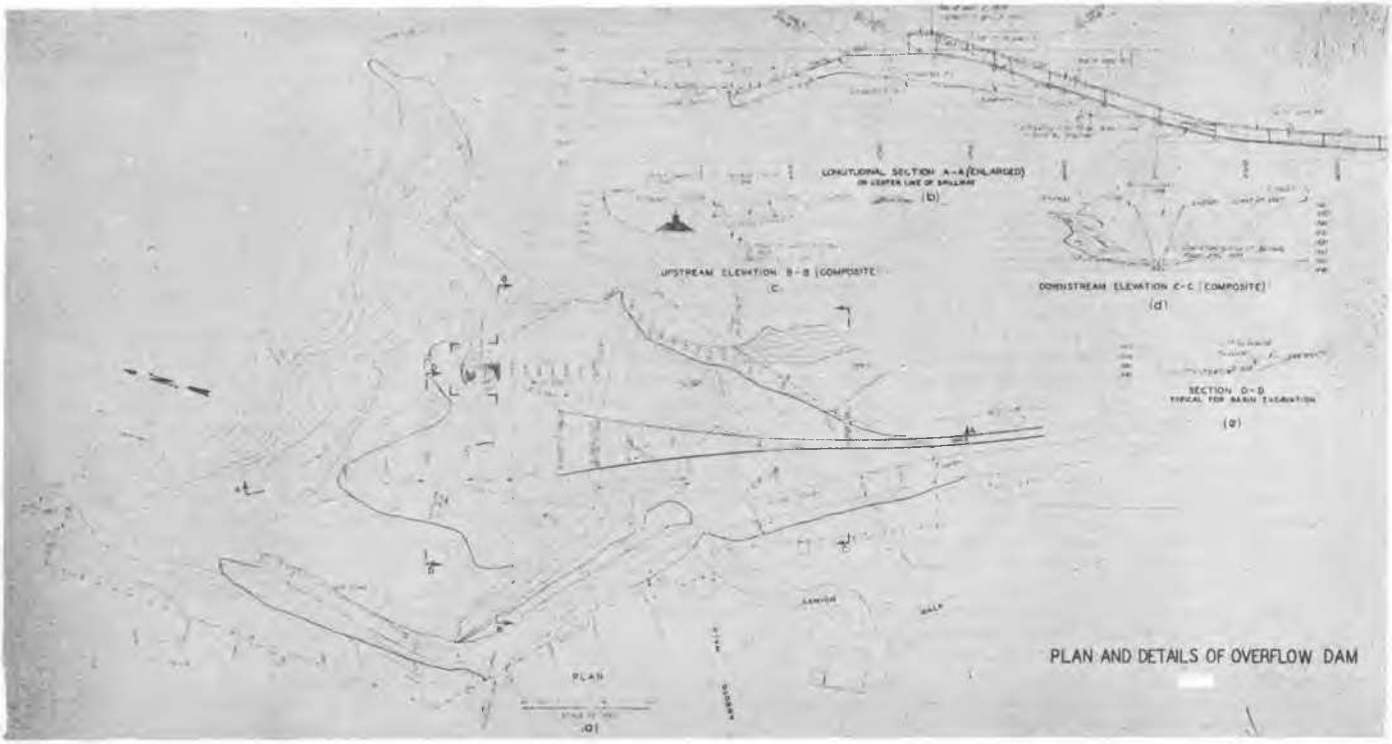

FIG.1

the compacted zone of the dam on which the structure rests is generally not steeper than 3 : 1.

For subdrainage, a system of concrete pipe of adequate size consisting of a collector along the center line and laterals at right angle thereto is provided underneath the spillway floor encased in gravel, and the main collector penetrates the floor of the spillway channel downstream from the toe of the dam. Weep holes are never provided in connection with these spillway structures because of the danger of "suction" causing migration of soil particles from the subbase and the fill behind the walls of the spillway on the one hand, and the feeding of water from the channel to the subgrade on the other.

The spillway structure is generally located near the middle of the dam and the crest of the dam slopes upward from the spillway wall to correspond to the maximum anticipated debris slope.

The dry density of the compacted fill varies between 110 and 120 pounds per cubic foot for all particles smaller than one-quarter inch, all according to the height of the dam and the character of the alluvial foundation. Particles one-quarter inch in size or smaller are defined as "fines" while particles larger than one-quarter inch are defined as "rock". To ascertain the dry density of the fines of a field sample whose gross weight and volume have been ascertained by conventional methods - the latter for example by filling the hole from which it was taken with dry beach sand of known density - the rock is separated from the fines by means of a No. 4 screen and is then air dried and its volume determined by means of immersion. Deducting this volume and corresponding weight from the gross volume and weight results in the wet density of the fines and after determining the moisture content, the dry density thereof. The reason for the use of one-quarter inch as the dividing line is due to experience in that it has been found that the fines so defined govern the critical properties of the fill, namely, shearing strength and permeability. Ordinarily the dry density of the fines is specified at minimum 115 pounds per cubic foot.

It is entirely feasible to incorporate in the soil for such a compacted fill a certain percentage of rock ranging up to 5 or 6 inches in size provided the rolling equipment is designed to handle materials of such coarseness. The incorporation of rock of such size naturally improves the density and stability of the fill. It was been found however, that particles larger than one-quarter inch in size should not materially exceed 50 per cent of the total volume lest compaction and therefore stability as well as impermeability of the fill fall below the requirements.

A zone of coarse, free-draining material is provided on the downstream side of the dam. The material therefor ordinarily originates from stream bed or basin excavation. The top of this fill coincides with the top of the spillway walls as shown in Fig. 1(b). A reasonable balance between excavation and loose fill is in the interest of economy and is therefore striven for.

CONSTRUCTION

In constructing the outlet works a trench of adequate width and depth is first excavated (usually by dragline) below the stripped ground surface. Compacted material is placed in this trench so as to fill it completely. A trench is then cut into the compacted fill which has the neat width of the concrete encasement of the pipe and a depth which is in excess of its height. The density and moisture content of the compacted fill must be such as to permit the cutting and precise trimming of vertical walls. After placing the reinforcing steel and the bulkheads at joints and after laying the pipe in this trench the concrete in the encase-

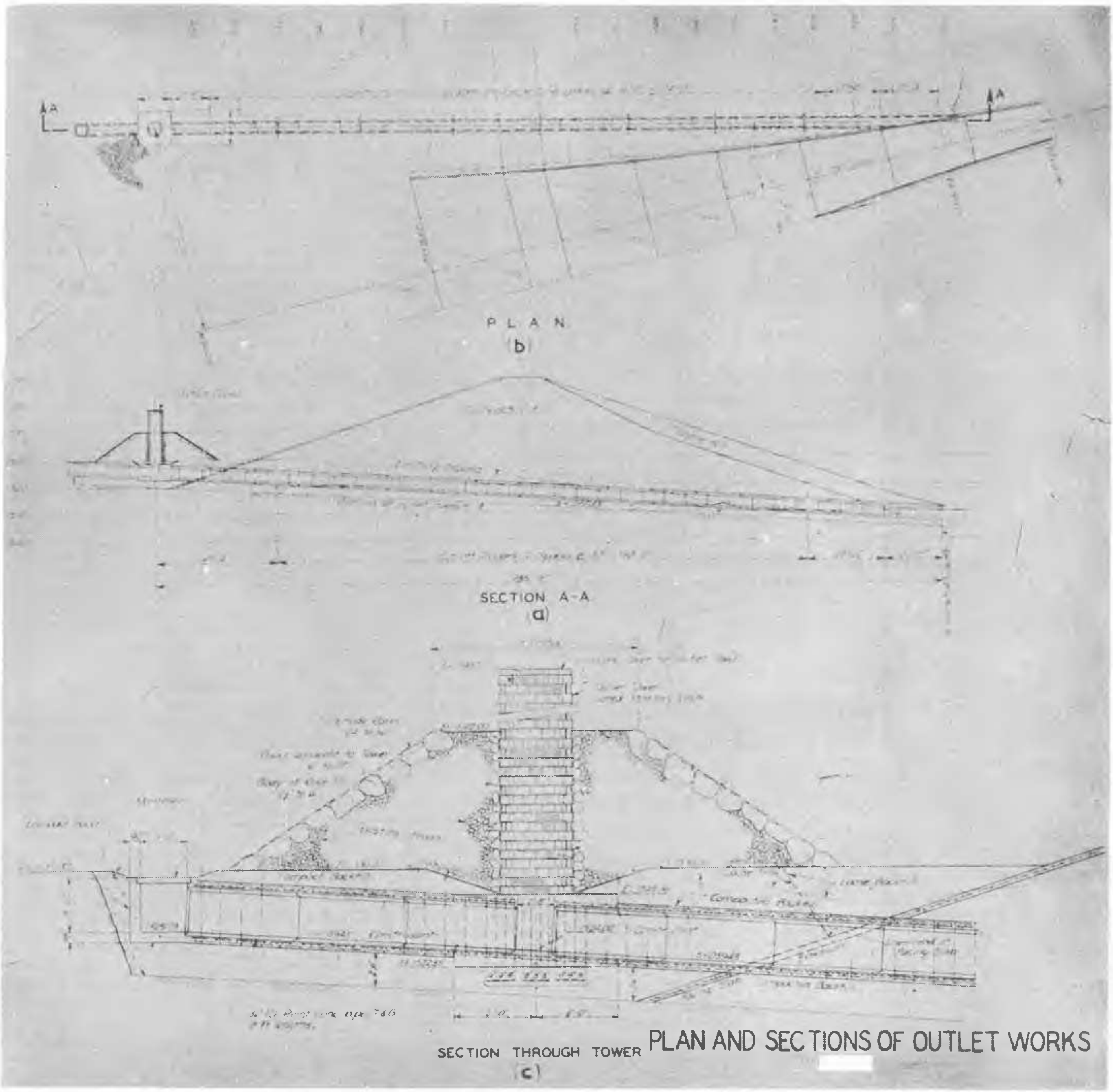

FIG. 2

ment block is then poured in alternate sections without forms. The steel reinforcing is continuous across the joints. After sufficient hardening of the concrete the trench is then filled completely with hand compacted materials which will protect the concrete from damage due to the impact of equipment used in the rolling of the main embankment fill.

The construction of the spillway is usually arranged in a similar manner as the construction of the outlet conduit in that the fill near the crest is first compacted to the full height of the embankment and the channel then cut through it to the neat lines if the section is trapezoidal. For rectangular sections, such as the one shown in Fig. 1, the compacted fill is excavated to the neat subgrade and to a width which will permit sufficient space for the placing of outside wall forms. Compacted backfill is subsequently placed against the spillway walls within the respective zone of the dam. Fig. 3 shows the completed structure.

CONCLUSIONS

The use of earth embankments in connection with overflow structures enhances the usefulness of compacted earth as a construction material and lends itself advantageously in particular to dam sites where the foundations would not be suitable for immediate support of concrete structures. In the latter case the excavation of basins below natural ground of equi-

Upstream view of completed structure.

FIG.3

valent capacity as the surface basin formed by the overflow dam would have to be provided. This would entail much higher cost, particularly in view of the inlet structure which would become necessary at the upstream end of the excavated basin. This inlet structure serves to stabilize the stream bed upstream from the basin to prevent retrogression for an indefinite distance upstream. The economic picture is thereby affected not only because of the high initial cost but also because of the high cost of maintenance as a result of wear and tear of this structure due to debris bed load discharging over it.

ACKNOWLEDGMENT

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SUB-SECTION IVc

EXCAVATION AND SLOPES

IVc8

CALIFORNIA EXPERIENCE IN STABILIZING EARTH SLOPES THROUGH THE INSTALLATION OF HORIZONTAL DRAINS BY THE HYDRAUGER METHOD

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INTRODUCTION.

Construction and maintenance of highways in hilly and mountainous regions is frequently complicated by the activity of old landslides and by the development of new mass ground movements in unstable material during and following construction.

The presence of ground water is the most important factor influencing the development of slides and embankment slipouts. Subsurface water reduces the stability of cut slopes and foundations under embankments through saturation of the soil, thereby diminishing the shear resistance, and thus reducing the stability. The weight of the ground mass constitutes a driving force tending to induce slide movements, particularly where hydrostatic pressures are induced in impounded ground water, thereby adding to the dricing force. The earth masses often contains strata of plastic material with an unfavorable dip. Lubrication of this plastic material by subsurface water may result in sliding along such a zone. The stratum or zone along which the sliding occurs is described as a "slip-plane".

When unstable areas cannot be avoided the structural design of the highway embodies the necessary corrective treatment. Embankment foundations may be stabilized by drainage trenches, vertical sand drains, or pervious blankets, and cut slopes may be stabilized by benching, slope flattening or unloading. However, where slipouts of previously constructed embankments or cut slopes occur sub-drainage of the slide mass is more difficult. Excavation of drainage trenches through slipouts is usually very costly and experience shows that deep cut-off trenches above the slipout are often not effective. Slides in roadway cuts are also frequently costly to correct by the usual method of unloading and slope flattening.

In recognition of the need for some more economical and effective method of stabilizing landslides through sub-drainage the California Division of Highways in 1939 undertook to correct such conditions through the installation of perforated metal pipe drains in horizontal or slightly inclined holes. "Hydrauger" equipment was adopted for drilling the holes and is still being used, although numerous improvements have been developed in both the procedure and equipment. In general, the tentative locations, lengths, and required number of drains are determined by a preliminary investigation consisting of vertical test borings and a geological survey. The final locations and lengths of drains are determined by conditions encountered during the installation.