Case histories of dams in Alaska

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Presentation Outline

• Mission Statement
• Case histories of dams in Alaska
  – My introduction to dams in Alaska
    • Humpback Creek Dam
    • Shotgun Diversion Dam
  – Dams in permafrost
    • Hess Creek Dam
    • Kotzebue Water Supply Dam
    • Nixon Fork Tailings Dam
    • Red Dog Tailings Dams
Alaska Dam Safety Program

Presentation Outline

– **Water in winter at dams**
  • Icy Creek Dam
  • Lower Fire Lake Dam

– **A tribute to Bruce Tschantz**
  • Itasigrook Dam

– **Other Alaska challenges**
  • Upper Seldovia Dam
  • Mahoona Dam
  • Rock Creek Tailings Dam
The mission of the Alaska Dam Safety Program is to protect life and property in Alaska through the effective collection, evaluation, understanding and sharing of the information necessary to identify, estimate and mitigate the risks created by dams.
Area = 665,384 sq. mi. (1,723,337 sq. km)
1,480 mi. (2,382 km) east to west
810 mi. (1,304 km) north to south
M9.2 Good Friday Earthquake of 1964
Humpback Creek Dam near Cordova, Alaska

Skyhook used to sling logs into canyon
Area = 665,384 sq. mi. (1,723,337 sq. km)
1,480 mi. (2,382 km) east to west
810 mi. (1,304 km) north to south
M9.2 Good Friday Earthquake of 1964
Shotgun Diversion Dam on Kodiak Island, Alaska

June, 1999
Shotgun Diversion Dam concrete faced upstream slope
Shotgun Diversion Dam right abutment after repair
Shotgun Diversion Dam downstream slope after repair
Shotgun Diversion Dam outlet structure after repair
Shotgun Diversion Dam emergency spillway
Alaska Dam Safety Program

Presentation Outline

– Dams in permafrost
  • Hess Creek Dam
  • Vortac Lake Dam
  • Nixon Fork Dam
  • Red Dog Tailings Dams
Area = 665,384 sq. mi. (1,723,337 sq. km)
1,480 mi. (2,382 km) east to west
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M9.2 Good Friday Earthquake of 1964
Hess Creek Dam near Livengood, Alaska

AN EARTH FILL DAM ON PERMAFROST
HESS CREEK DAM, LIVENGOOD, ALASKA

F.F. Kitze and O.W. Simoni

March 1972

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APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED JUL 1 1972
AN EARTH FILL DAM ON PERMAFROST:
HESS CREEK DAM, LIVENGOOD, ALASKA

by
F.F. Kitze and O.W. Simoni

INTRODUCTION

The construction of dams in arctic and subarctic regions of the Northern Hemisphere has been rare. The Hess Creek Dam, located near Livengood, Alaska (Fig. 1), is one of the few known large earth fill dams constructed to date in the permafrost regions of North America.

The effect of dams on underlying permafrost is generally unknown. Equally unknown are settlement and stability characteristics, and effects of a wide range of ambient temperatures on the permeability of earth fill embankments.

Construction of dams in arctic and subarctic regions will be stimulated by future development of northern regions. This report on design, construction, performance and later investigations of a large earth fill dam in an arctic environment will be of value in developing engineering criteria for similar dams on permafrost.

BACKGROUND

The Hess Creek Dam was designed and constructed for Livengood Placers, Inc., San Francisco, California, a subsidiary of Callahan Mining Corporation of New York. It was built to impound water from the Hess Creek watershed for diversion through a tunnel and ditches to hydraulic mining operations in the vicinity of Livengood, Alaska, south of the reservoir. Figures 2, 3 and 4 show the dam and reservoir.

The structure was designed in 1939 by Mr. W.A. Kraner, Goldfields Consolidated Mines Company, San Francisco, California. Special hydraulic and soils tests and design assistance were provided by Mr. Charles H. Lee, Consulting Engineer, San Francisco.

Construction of the dam was started by Livengood Placers, Inc. in April 1940 and continued through the construction season of 1941. Mr. Charles Lewis was Resident Manager for the corporation. All work was suspended between 1942 and 1946 due to World War II. Construction was resumed in April 1946 under a contract with C.F. Lytle and Green Construction Co., Des Moines, Iowa, and the structure was completed in August 1946.
Hess Creek Dam near Livengood, Alaska

Design concepts

The general plan of the structure is shown in Figure 8. Figure 9 is a profile along the axis of the dam and Figure 10 is a typical embankment section. Following are structural and operational concepts upon which the design was based:

a. No part of the structure was to be founded on existing bedrock. The embankment fill was to be placed on the frozen subsurface sands and gravels and bonded to this material by freezing.

b. The embankment design included an impervious central core, conical in section, averaging about 15% of the thickness of the dam measured at any particular section and at any elevation (Fig. 10). Fill material from adjacent hillside borrow pits could be sluiced to the embankment area through pipes and discharged at the outer limits of the foundation. Subsequent flow of the discharged material toward the center of the dam would cause a soil gradation in which the finer material would settle near the center of the dam to form the impervious core. The coarser material deposited at the outer limits of the foundation could be spread and compacted by bulldozers.

c. A steel sheet pile cut-off wall was included along the centerline of the dam to augment the impervious core and bind the embankment to the foundation. The cut-off wall would ensure imperviousness at the interface of the foundation and the embankment and restrict seepage through the foundation in case of thaw.

d. The outer face of a hydraulic fill type dam is more pervious than the outer face of a rolled earth fill type dam and thus is less affected by frost action.

e. The design included artificial refrigeration to assure positive freeze-back and bonding at the interface between the frozen foundation gravel and the central core of the hydraulic fill. The refrigeration also ensured positive freeze-back of the sheet pile cut-off wall installation trench.

f. Operational procedure for the dam included annual draining of the reservoir just prior to freeze-up to promote refreezing of summer thaw at the upstream and downstream toes and at the upstream embankment face.
Hess Creek Dam near Livengood, Alaska

Foundation soils

Soils explorations at the site in 1939 revealed frozen black silt and ice overburden to approximately 20-ft depth. The material between 20- and about 40-ft depth consisted of a variable mixture of frozen clay, silt, sand, gravel and hard angular fragments of chert rock ranging up to 9 in. in size. The remaining subsurface material above bedrock consisted of frozen coarse sands and gravels containing considerable ice. Fractured chert bedrock was encountered at 60-ft depth and greater.
Hess Creek Dam near Livengood, Alaska

Figure 10. Typical embankment section (Section D-D).
Figure 21. Detail of outlet works pipe (Section B-B).

Artificial freezing was accomplished by circulating "Stoddard Solvent," a proprietary petroleum product, through the system by means of centrifugal pumps. Heat was removed from the system by passing the solution through a 300 ft long radiator at both toes exposed to the atmosphere (Fig. 20). Artificial freezeback at the center of the dam was performed during the winter of 1941–1942. Effectiveness of the refrigeration was checked by thermometer readings taken at various locations in the system and in the soil between and below the freezing pipes.

Outlet works

An outlet consisting of a 48 in. diam steel pipe was installed through the embankment at the west end (Fig. 8, 21). A hydraulic lift type control gate (Fig. 22) was installed on the upstream
Hess Creek Dam near Livengood, Alaska
Kotzebue Water Supply Dam (Vortac Lake)
Kotzebue Water Supply Dam (Vortac Lake)
Kotzebue Water Supply Dam (Vortac Lake)
From application for Certificate of Approval to Modify a Dam

New buried siphon water intake line
Boring Log
in left abutment

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<th>Ground Temp. (F)</th>
<th>* Ground Temp. (F)</th>
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*Ground temperatures measured August 27, 1997
**Ground temperatures measured August 19, 1976 by CRREL

LOG OF BORING C3

Equipment: 16-inch Bucket Auger
Elevation: ----
Date Drilled: 3-27-97

Gray Sandy Gravel with Silt (GP-GM)
Brown Sandy Silt (ML) bonded Nf
becomes Nbn at 8 feet
Ice-rich between 15 and 25 feet
Ice crystals to 1/2 inch thick
Whiplash curves in left abutment
Left abutment of Kotzebue Water Supply Dam
Upstream slope of Kotzebue Water Supply Dam
CERTIFICATE OF APPROVAL TO MODIFY A DAM
Kotzebue Water Supply Dam

Attachment A – Special Conditions

1. This certificate approves modifying the Kotzebue Water Supply Dam to include an intake structure as described in the issued for construction drawings and specifications prepared by Lantech, Inc. titled: “Vortac Lake Intake, Kotzebue, Alaska ITB # 14-15” dated on 4/3/15.

2. During the modification and after construction is complete, the Kotzebue Water Supply Dam must be operated as a Class III (low) hazard potential classification dam as defined in 11 AAC 93.157.

3. Within 7 days of mobilizing construction resources to the project site, submit a current construction schedule to the Department. Submit a revised construction schedule for any substantial deviations from the schedule previously submitted to the Department.

4. Within 7 days of mobilizing construction resources to the project site submit the detailed work plan to protect permafrost approved by the city and its engineering representative. This work plan will include time of year and allowable ambient temperature conditions during construction; work components, sequencing, and schedule; constraints on amount of time and conditions whereby trench or other excavation may remain open; temporary insulation, coverings, or other measures to be used, if needed; and top soil, fertilizer, and seeding plans.
Siphon system on Kotzebue Water Supply Dam

New buried design never constructed
Nixon Fork Tailings Dam in winter

Area of interest
Nixon Fork overtopping incident in 2011

Point of overtopping

Staff Gauge
Snow erosion

Nixon Fork overtopping incident in 2011
Nixon Fork Tailings Dam in May 2011
Excerpt from 2015 Periodic Safety Inspection for Nixon Fork Tailings Dam

PERIMETER ROAD WITH ADJACENT DIVERSION DITCHES

LOW POINT OF CREST

ESTIMATED PERMAFROST LIMITS

TAILINGS INSIDE IMPOUNDMENT

DAM CREST SURVEY ALIGNMENT WITH 25-FOOT STATIONS

SCALE

FEET

NOTE: THE ABOVE INFORMATION IS INCLUDED FOR INFORMATIONAL PURPOSES ONLY AND SHOULD NOT BE CONSIDERED AS A SUBSTITUTE FOR PROFESSIONAL ENGINEERING INSPECTION.
Excerpt from 2015 Periodic Safety Inspection for Nixon Fork Tailings Dam

NOTES
1. DEPTHS SHOWN ARE RELATIVE TO NATURAL GROUND SURFACE. VALUES NEGATIVE Ref. TO NATIVE MATERIALS AND POSITIVE VALUES REFER TO FILL MATERIALS.
Excerpt from 2015 Periodic Safety Inspection for Nixon Fork Tailings Dam
Minimum impoundment is now current requirement for operation of Nixon Fork Tailings Dam in temporary mine closure.
Area = 665,384 sq. mi. (1,723,337 sq. km)
1,480 mi. (2,382 km) east to west
810 mi. (1,304 km) north to south
M9.2 Good Friday Earthquake of 1964
Red Dog Tailings Dam

Large Thermal Mass

Seepage Collection System
Red Dog Tailings Dam

Wide beach for seepage control
Presentation Outline

– Water in winter at dams
  • Icy Creek Dam
  • Lower Fire Lake Dam
Icy Creek Dam in Unalaska, Alaska
Icy Creek Dam in Unalaska, Alaska

WINTER

Ice load on braces