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4. Debris Torrent Control Facilities (Vancouver, BC, Canada)

Owner: *Ministry of Transportation and Highways, Province of British Columbia*

Consulting Engineers: *Thurber Consultants*
Ker, Priestman & Assoc. Ltd.

Construction Period: *1984 to 1987*

General

The British Columbia Railway mainline and Highway 99 follow the coastline of Howe Sound north from Vancouver. The steep mountain slopes above these corridors experience a mean annual runoff in excess of 3000 mm. Since the B.C.R. was opened in 1956, six bridges and a number of residences have been destroyed by natural phenomena known as debris torrents. In the vicinity of Howe Sound a debris torrent is a rapid mass movement of water-charged inorganic and organic material down steep, confined creek channels. The material in a torrent ranges from gravel to very boulders entrained with forest debris from mulch to intact trees. The torrent can be initiated during periods of high runoff by a small slide that temporarily dams a creek. When the dam breaks the resulting flow is very erosive and the torrent grows by mining substantial volumes of material from the channel bed. The torrent moves at about 7 to 10 m/s in teardrop-shapes pulses with a steep-fronted accumulation of the larger fragments at the leading edge. The after-flow behind the accumulation is both finer and more dilute. Yields of 20,000 m^3 have been recorded in the most recent events on these creeks.

Control Facilities

In 1983 design work commenced on measures to mitigate the effects of the torrents. Design discharges are typically in the order of 350 to 500 m^3/s with flow depths of about 4.5 m in lined channels with truncated V shapes.

For creeks without housing or other development on their banks it was only necessary to provide new bridges with properly proportioned openings which safety permit passage of the torrent flows. A 3-m air draft is provided above the calculated flow depth to prevent blockage at the upstream edge of bridge openings.

For three high hazard creeks with development on the deposition fan, barriers have been constructed above Highway 99. The function of the barriers is to impound a design debris flow and to decant the accompanying water flow. Debris storage requirements ranged from 33,000 to 60,000 m^3 depending on the creek. The capital cost of a barrier divided by the design storage capacity varies from $ 30 to $ 65/m^3 (CDN.) depending on the amount stored and the difficulty of the site. The barriers are typically 12 to 15 m high to the crest of the spillway with another 8 or 9 m provided for run-up freeboard. Permanent access roads were constructed into all basins to facilitate their cleanout.

At one location, a barrier was not feasible and a 800-m long channel with an average grade of 31 % was designed to convey the torrent through the residential community to the sea. The 5.6 m by 13 m concrete channel cost approximately $ 3,500/m (CDN.) and the integral earthworks, secondary retaining walls, and eight

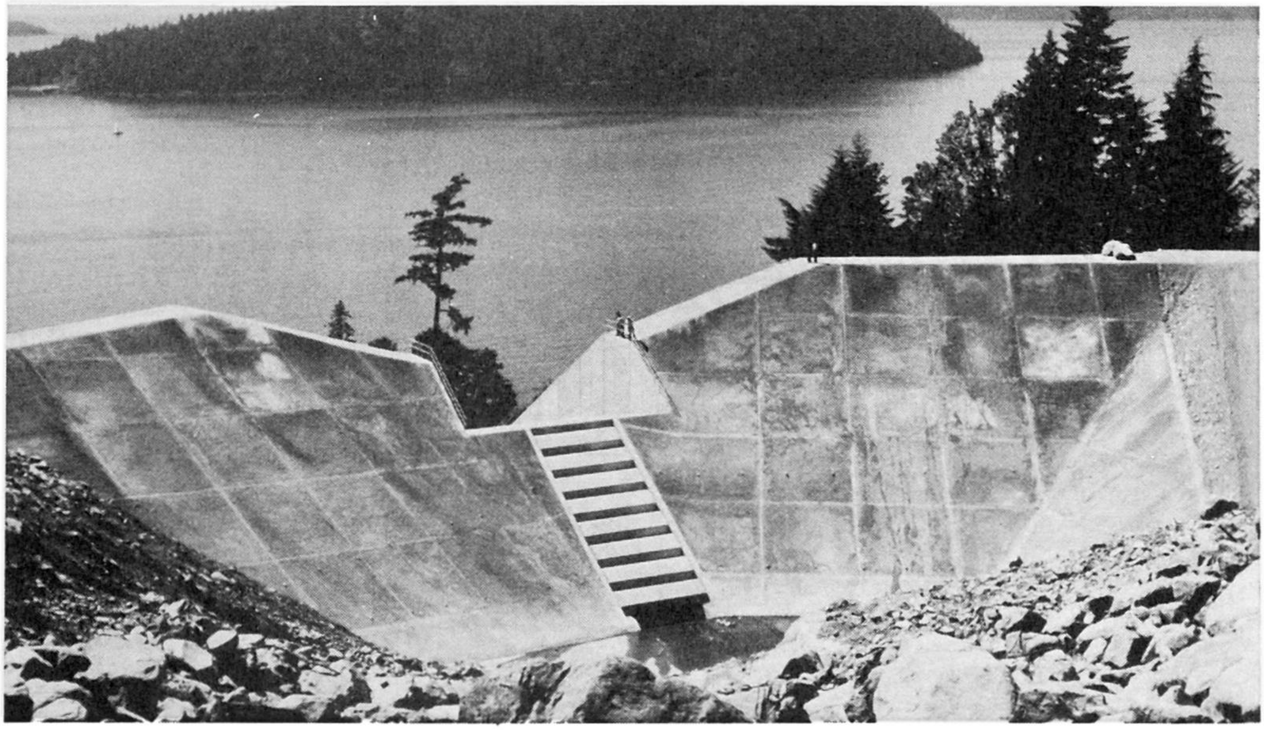

Fig. 1 Fill type debris barrier

bridge crossings increased the cost by a factor of two. The concrete in the channel invert area is a 60 MPa silica fume mix with a 200 mm wear allowance.

Barriers

Two types of barrier were developed. The simplest is a 15 to 25 meter deep hole excavated in bedrock with a decant structure at the outled. The grillage beams for the basin decant are supported by a central buttress and abutments post-tensioned into the rock. The 15 m high decant tapers from 20 m wide at the top to 6 m at the bottom to reduce the total hydrostatic sliding force acting on the buttress. The design case for the buttress was hydrodynamic impact of a wave of debris transiting a partially full basin at 10 m/s. The front of the decant is sloped to reduce the force of the impact and to generate a stabilizing vertical reaction at the toe of the buttress. A small concrete faced wing dam is provided on one side of the decant to provide the necessary run up freeboard to redirect the overtopping debris flow.

At the two other sites where rock was not available, sliding on the steep original ground governed the barrier design resulting in the selection of concrete-faced, zoned fill, structures. The material in the fill barriers was typically obtained by mining the creek above the barrier site to help form storage basin. Each fill barrier features a service spillway for the basin full situation and a decant structure to prevent significant accumulations of water behind the barrier when the basin is only partially full. To control seepage in the zoned fills, a network of relief wells was drilled prior to constructing each barrier and a shotcrete facing and apron was applied to the front of the barrier.

The most important design criteria for the barriers was that the new structures must not exacerbate conditions which prevailed prior to barrier construction. If the estimates of required storage were incorrect or if the barriers could not be emptied in a timely manner, the barriers had to be capable of withstanding repeated overtoppings without failing and thereby adding material to the debris aleady being carried by the torrent. In one case a 400-m long channel was built downstream of the barrier to conduct a flood flow of over 100 m^3 safely past three downstream bridges. The channel gradient is in excess of 20% and the formation of shock waves was a concern, so a rough bed was produced by setting 1000 mm diameter boulders in a steel fibre reinforced concrete bed.

With the basin full, a subsequent flow entering the storage basin would not necessarily spread out and decelerate on the plane of the previously stored debris. Material at the edges of the flow comes to rest and may form levies which have the ability to contain the flow. If the subsequent flow transits the basin without losing much energy, the shape of the barriers above the spillway will direct the overtopping flow into the creek channel below the barrier.

The decant structure which conveys normal (non-overtopping) flood flows is composed of two parts, the grillage beams and their supporting works, and the outlet conduit. The face of the decant is sloped to deflect the impact of the torrent's boulder front. The reinforced concrete grillage beams are proportioned to

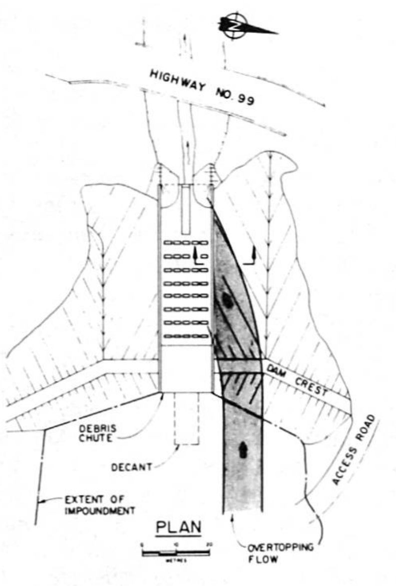

Fig. 2

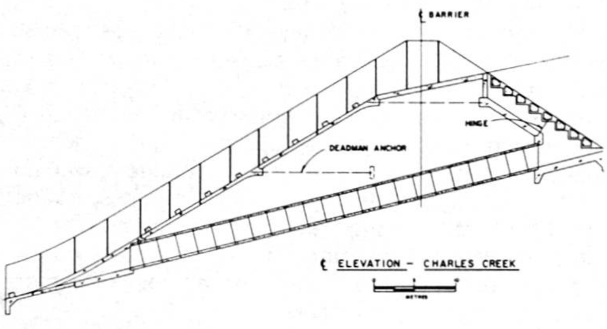

Fig. 3

dissipate the kinetic energy of a 2000 mm diameter boulder by plastic hinging and compression of unreinforced rubber bearing pads. The beams must survive the boulder impact and continue to span under hydrostatic loads generated during basin infilling and barrier overtopping. The pressures on the beams can be equivalent to a head of water in excess of 30 m.

The possibility of structural failure of the outlet conduit which passes through the fill barriers was unacceptable. The reinforced concrete box sections were designed to withstand the full weight of the column of soil supported by them with no arcching and no side wall support.

The spillways constructed on the downstream faces of the fill barriers have slopes of approximately 60%. The tendency for sections of the spillways, when full of debris, to slide downhill is resisted by deadmen anchors with a combined capacity of over 6000 kN per spillway segment. The walls of the spillway are proportioned to withstand a 4-m deep redirected overtopping flow at it plunges into the spillway. The floor of the spillway is inclined and only receives glancing blows from the redirected overtopping flow. The floor is also proportioned to resist punching shears while holding the spillway walls apart.

(John Price)