Risk of the trees and the stumps to the embankment dam safety. Experimental study

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Summary

The clearance of the trees and the bushes on the embankment dam slopes has to be carried out after couple of years. New growth is powerful especially at truncated deciduous trees and willows. By allowing trees to grow bigger it will reduce new growth of the bushes and the maintenance cost. Sparse vegetation does not hinder maintenance inspections.

Finnish dam safety legislation allows the trees and the bushes in the embankment dam, if they will not cause damages to the structures or harm to the maintenance or monitoring of the dam (Government Decree on dam Safety 309/2010).

Fortum Power & Heat Oy carried out experimental studies by removing stumps in the embankment dam slopes in spring and summer 2010 in order to estimate the risk of the larger vegetation. Removed stumps were more than 20 years old. Two sites were selected: one in South Finland having deciduous trees and one in Northern Finland having mainly conifer trees. The stumps were removed by pulling them.

The roots were mainly on the surface parallel to dam slope and only few stump had a main root. 20 years old pine roots were in good condition, whereas the roots of deciduous trees were decomposed. Therefore the roots of deciduous trees shall be removed, when the tree is cut.

“Asta”-storm in the Eastern part of Finland in July 2010 had a gust wind speeds of 29 m/s and several million m^3 of trees fell down. The mechanism of the tree fall by the wind force was studied by observing the consequences. Big spruce is a potential risk to dam safety, because falling tree may withdraw couple m^3 of soil.

The decision allowing vegetation in the embankment dam slope is a case-specific.

Introduction

Finnish dam safety legislation has been renewed. Dam Safety Act (494/2009) entered into force on October 1, 2009 and Government Decree on Dam Safety (319/2010) on May 5, 2010. The Section 4.3 specifies the vegetation at the dam "…There may be no vegetation or other substances or objects which do not belong to the dam and which may cause damage to the structure of the dam or harm to the maintenance or monitoring of the dam". The Section in the Government Decree does not prohibit or allow bigger vegetation (bushes, trees) on the embankment dam slope. The risk of the vegetation shall be evaluated.

The trees or willows on the embankment slopes have to cut at two-three year intervals, if the larger vegetation is not allowed. New growth after the cutting of the deciduous trees runs wild and the need for cutting increases. It has been a practice to allow trees grow bigger at the embankment dams in Fortum Finland. It has been noticed that larger trees decreases new growth of sprout forest and bushes. The need for cutting and also the maintenance costs are decreasing. A sparse tree stand does not prohibit dam surveillance.

Fortum Power & Heat Oy carried out experimental studies by removing stumps in the embankment dam slopes in order to estimate the risk of larger vegetation. Two sites were selected: Peltokoski embankment dam in Southern Finland and Nuojua embankment dam at River Oulujoki in Northern Finland. The low end part of Peltokoski left embankment dam has trees even at the upstream slope. The hazard of the trees to the dam safety at Peltokoski was studied in spring 2010. The stumps at the right embankment dam at Nuojua were pulled in summer 2010. The trees were cut and the stumps were left in the dam slope in 1990's. The stumps were about 20 years old. The tree type is different at the dam sites: deciduous trees at Peltokoski and conifer trees at Nuojua.

The objectives of the study were to determine, if the trees and bushes can be allowed in the embankment dam slope. The paper presents the stump pulling studies and its findings. The risk of the falling tree in the embankment dam slope is also discussed based on the observations of the "Asta"-storm in the Eastern part of the Finland in July 2010.

The impact of the trees and vegetation to the dam safety based on the legislation

Old Dam Safety Act (1.6.1984/413) did not have regulations on the trees or vegetation. However the Section 4.2. of the Act specified "The owner of a dam shall be obliged to keep the dam in a condition such that it is safe and it will not cause a hazard or have damaging or harmful effects on public or private interest". Finnish dam safety guidelines (1999) determined further:

- The vegetation shall not danger the structures nor harm the dam maintenance.
- In principal the trees are not allowed at the upstream slope or at the embankment dam crest.
- The trees may be at the downstream slope under the reservoir water level, if they are not causing danger to the structure. The trees and bushes shall be sparse that the dam surveillance can be carried out.
- The drainage system shall be kept free from the trees and the bushes at least in the distance of 5 meters.
- The trees downstream of the embankment dam shall not hinder the maintenance nor the dam surveillance.
- The trees and bushes were allowed even in the upstream slope of the flood embankments.
- In addition the trees and the bushes shall be coppiced and the branches of the trees shall be cut to resist the wind gusts.

The findings of the stump pull tests at Peltokoski left embankment dam in May 2010

Peltokoski dam is situated in River Mustionjoki in Sothern Finland, about 70 km west from Helsinki. The hydropower plant was constructed in 1950-51. The embankment dams are homogeneous earth fill dams of glacial till. The wooden sheet piling is constructed in the higher part of the dam. The embankment dams don't have any drainage system. The dams are classified as consequence class 2-dams.

Figure 1: The willow stumps at the embankment slope.

The stump pulling tests were carried out at the left embankment at two places: at the downstream slope of the embankment dam with the sheet piling (first part) and at the upstream slope of the lower end part.

The trees of the first part were goat willows, willows and alders. The trees were cut during autumn 2009. The stumps of the willows were in 2-4 tree groups and having a diameter of 100-200 mm, max. 300 mm (Figure 1). The black alder and rotten alder were removed at the lower end part. The stumps were removed with backhoe excavator. The bucket was lifted and twisted (Figure 2).

Figure 2: The stump pull test at Peltokoski embankment dam.

Figure 3: The root system was parallel to the surface.

There is a considerable leakage through the bedrock under the left embankment dam at Peltokoski [1]. Therefore it was made some preparations for the emergency situation. The pulling test was discussed with the dispatch center that the lowering of the reservoir could be started by reducing the river inflow upstream and increasing outflow by opening the spillway gates. Finnish dam safety authorities were informed of the test and its arrangements. In addition soil material (sand, rockfill) and geotextiles were reserved at the site to start the closing possible emergency leakage.

The shape and diameters of the root system were mapped and measured. Biggest roots had a diameter of 80 mm. Total lengths of the individual roots were not measured. However some roots had a diameter of 45 mm at 1.5 meter distance from the center of the stump. The root system was parallel to the surface profile, not going deeper in the soil (Figure 3). The stump and the root system of the rotten alder were almost totally decomposed.

The findings of the stump pull test at Nuojua embankment dam in June 2010

Nuojua dam is situated in River Oulujoki in Northern Finland. The hydropower plant was commissioned in 1954. The right embankment dam is zoned earth fill dam with steel sheet piling in the center. The dam shoulder are made of rockfill and the upper part of the slope has 10-15 cm soil layer. The dams are classified as consequence class 2-dams.

Eleven (11) stumps were removed from the embankment dam slope. The trees were cut in 1990's. Ten stumps were identified as pine trees and one birch tree. Average diameter of the pine stumps was 260 mm. The age of trees was not determined.

The pull test was carried out with backhoe excavator at the dam crest. A steel rod was pushed under the stump and the stump was lifted. Some of the stumps were removed with the help of a wire rod.

Figure 4: 20-year old pine stump was removed with wire rod at Nuojua.

Excavated root system was measured. Only one stump and its root system was opened and studied in more detail. At Nuojua only couple pine stumps had a vertical primary root (tap). Generally the roots were spreading parallel the slope and they were at the upper soil layer only. None of the roots was intruded in the rockfill shoulder. The diameter of individual root varied from 80 to 200 mm. The roots were in good condition although they have stayed 20 years in the ground. There were hardly any signs of rot. The stumps were tightly connected to the slope, which indicates good resistance against winds (Figure 4).

Observations and discussion of fallen trees after "Asta"-storm in July 30, 2010

"Asta"-storm followed a long hot season in July 30, 2010. Previous day the temperature raised to +37.2 °C at Joensuu airport. The storm crossed Finland from southeast to northwest. The wind speed of 29 m/s were measured and it was estimated that 8.1 million m^3 of forest were fallen and damaged.

Figure 5: The top of the pine tree has snapped.

The fallen mechanism of pine, spruce and birch trees was observed and photographed after the storm at Sulkava commune, southeastern part of Finland.

The **pine** trees have fallen totally with the root system or the top was snapped leaving the trunk in its place (Figure 5) or the trees remained bended (lodged tree). It was observed that the primary root (tap) of the fallen trees was broken.

The **spruce** trees have fallen totally with the root system or the top was snapped leaving the trunk in its place.
The **birch** trees have fallen totally with the root system (Figure 6) or the trees remained bended (lodged tree).

Figure 6: Fallen birch tree.

The root system on the bedrock or on the marsh was quite small located at the surface. Therefore the tree had fell easily.

Figure 7: Fallen spruce tree with thick soil layer.

The soil density together with the extent of the root system has an influence in cohesive or granular soil. The root system of some fallen spruce took a thick soil layer of couple m^3 of silt/sand ground (Figure 7).

Discussion of the trees to the risk of the embankment dam breach

Possible hazards of the trees at the embankment dams may be:

- The roots can block the drainage system.
- The roots can penetrate to the core and the roots may increase the risk of internal erosion (piping).
- The rotten tree stumps (mainly deciduous trees) changes the soil properties of the embankment dam (organic decomposed soil, loosen, form caverns etc.).
- The trees and the bushes complicate to find the changes in the seepage e.g. bigger trees are collecting seepage water. Note! The changes in the vegetation are also helpful to find the changes in the seepage.
- The falling tree may grab large amount of soil, which may lead to the emergency situation.

At Nuojua only couple pine stumps had a vertical primary root (tap). Generally the roots were spreading parallel the slope and they were situated in the upper soil layer. None of the roots was entered in the rockfill shoulder. The stumps of the pine trees were in good condition after 20 years, whereas the older stumps of deciduous trees (birch, alder) were partly or totally decomposed.
The loose soil helps the development of the primary root (tap) of the pine trees. The earth fill dams are compacted and the development of the primary root may be limited and the whole root system may grow parallel to the surface.
The root system of the conifer trees (pine, spruce) remain unchanged in the embankment slope, but the root system of the deciduous trees (birch) are decomposed. Therefore it is recommended that the stumps of the deciduous trees are removed and filled with dam material, when they are cut. The stumps of the conifer trees may be left, if they are situated in the upper part of the slope.
Following properties can be considered to have influence to the resistance of individual falling tree:

- the wind speed (intensity of the storm),
- the cross-sectional area of the tree at the wind direction,
- the bending capacity of the trunk of the tree and
- the soil properties and the size and strength of the root system including the primary root (tap).

The wind is bending the tree. The strength at the tree base (e.g. the extent of the root system, type of the soil) and the turning forces are determining the stability of a tree.

If the strength at the tree base is sufficient, the snapping of the top could be determined by the bending strength of the trunk.

The strength of the trees at the embankment dam against the storms is difficult to estimate based on this experimental study. Therefore more research is required.

It may be concluded that the size of the tree at the embankment dam shall be limited based on the observation that big falling spruce in the embankment dam slope may grab thick soil layer together with the root system.

It is not likely that the falling of big spruce at the embankment dam slope may not necessary lead to the dam breach, but together with a dam deficiency e.g. wetted slope or increased leakage can be a thread to the dam safety. Therefore to allow the trees and larger vegetation at the embankment dams should be studied case by case.

References

[1] Laasonen, J. 2010. Internal Erosion and Duration of Grouting Works. Case History of a small embankment dam. Proceedings of the 8th ICOLD European Club Symposium. Dam Safety - Sustainability in a Changing Environment. 22nd - 23rd September 2010. Innsbruck, Austria. Edited by ATCOLD. pp. 409-413.