dam world 2018 Third International Dam World Conference
BRAZIL • Foz do Iguaçu • September 17-21, 2018

THE IMPORTANCE OF VEGETATION PROTECTION MAINTENANCE OF SLOPES IN EARTH DAMS FOR SURFACE EROSION PREVENTION

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Keywords: Maintenance, protection vegetation, surface erosion.

Abstract. *The systematic and effective routine maintenance of the protection vegetation of an earth dam is fundamental to prevent the structure from surface erosion processes. Regions where brachiaria is present, maintenance is even more relevant, since its proliferation can make the structure more susceptible to superficial erosion processes.*

In the case of the Retiro Baixo HPP Dam, located in Curvelo/MG, brachiaria proliferated along the downstream slope of the earth dam. Its fast growth, combined with the absence of systemic maintenance, eliminated the protection grass existing in the structure and was responsible for the evolution of the surface erosion on the downstream slope of the earth dam.

The return of effective and systemic routine maintenance of slope protection vegetation was decisive for the reversal of the condition. This study is an example of how the vegetation of slope protection on earth dams can contribute to dam safety.

1 INTRODUCTION

The upstream and downstream slope stability of an embankment is directly related to dam safety. During the early stages of planning and design, the embankment slopes have to be calculated under all conditions of construction and reservoir operation[1]. On the other hand, during the dam lifetime, the structure systemic routine maintenance will ensure the prevention of surface erosion processes that can lead to disruptions.

Finished embankment surfaces should be properly graded and protected from wave and surface erosion to prevent beaching or serious maintenance problems, considering surface flows concentrate there[2]. For downstream slopes, the speed of rainwater running the distance from the top of the slope to the foot of the dam can cause rill erosions and, over time, gullying erosions. Thus, externally, the downstream slope must be protected using vegetation, gravel, riprap, as well as external drainage system, such as gutters, to properly collect and direct rainwater.

One of vegetation protections that are used is Brachiaria, which is a grass that can be used for erosion control, as has a fast development and can cover a terrain quickly[3]. Despite its high nutritional value, Brachiaria grass can be considered an invading plant of the most frequent in the soils of annual crops, due to its unusual competitive aggressiveness, totally dominating the environment that invades[4].

Retiro Baixo Hydroelectric Power Plant has an earth dam with a rockfill closure on the left abutment, totaling an extension of 1075.9 m and a maximum height of 44 m. The vegetation protection of the slope downstream of the dam was performed using brachiaria that proliferated disorderly, causing high vegetation in some places and unprotected soil in others, mainly due to the brachiaria's shape, with branches coming off a central axis. Although this vegetation cover minimizes the energy of the water of direct incidence, its irregularity allowed the superficial water flow, causing the development of erosion process in the embankment of the dam, evolving in some cases to appearances of rill erosions. Thus, the present article aims to analyze how the routine maintenance of the vegetation cover of the downstream slope influenced the erosion formation in the Retiro Baixo Dam.

2 DOWNSTREAM SLOPE PROTECTION

Placement of downstream slope protection may be accomplished after the embankment is completed, due to possibility of surface erosion. According to the Bureau of Reclamation[5], it is possible to secure the downstream slope using grass turf, riprap, gravel, cobbles or spalls and surface drainage as explained below.

Riprap placed on the lower downstream slope to protect against wave action caused by tailwater should be controlled in the same manner as that discussed above for the upstream riprap.

Gravel, Cobbles, or Spalls can be used when the outer downstream shell contains random granular materials. It is often specified that cobbles and rocks be raked to the outer edge of the embankment and used in the slope protection. The gravel, cobbles, or spalls are usually dumped and spread in horizontal lifts along the outer slope to thicknesses of at least 1 foot measured normal to the embankment surface. If the downstream embankment is erodible, bedding may be required to prevent erosion.

Surface drainage, both during construction and for future operations, can be important and should be considered during design of slope protection. Lateral drains across the

embankment face are sometimes useful to break up sheet flow caused by runoff on the slope and collect the flow in a more controlled manner.

Grass turf protection consists of clearing the slope of any roots and stones, tilling to a depth of at least 4 inches, fertilizing, seeding or sprigging, compacting, watering, and maintaining as required to establish the turf. It is usually used for humid climates and the slope should be flat enough to enable reasonably easy mowing and maintenance.

2.2 Brachiaria

A type of vegetation of protection that can be used to control erosion incidence in downstream slopes is the the grassy Brachiaria (B. ruziziensis), originated from Africa.It is one of the most used species for pasture development, being distributed around tropical countries, being introduced in Brazil in the 1960s[6]. The brachiaria ruziziensis is allied through its elliptic oblong spikelet shape, has a few to several racemes, scattered along a central axis, ascending or spreading, broad or narrow rachis, ribbon-like or crescentic, one-sided; spikelets solitary, on short pedicels, forming one or two distinct rows, dense, spreading[7]. Moreover, this type of brachhiaria provides palatable forage of high nutritive quality[8].

In a general way, brachiaria provides good soil cover, facilitating water infiltration and preventing erosion[9], however, the brachiaria ruiziensis is shaped with tufts scattered from a central axis, implies a false protection for sloping terrain against superficial erosion. The regions of the terrain that do not have vegetation cover in roots are unprotected from the action of water rain and wind. The quality of the brachiaria to spread easily through the tropical terrains can become a problem, due to its dominant characteristic over other species, besides requiring routine maintenance.

3 CASE STUDY

The Retiro Baixo HPP is located in the Paraopeba River, between the counties of Pompéu and Curvelo in the state of Minas Gerais, Brazil. The dam is constituted by an earth dam with a closure of rockfill dam at the closing of the left abutment, totalizing an extension of 1075.9 m and a maximum height of 44,0 m. The low ogive spillway, with three segment gates, is located on the left abutment, being constituted by an approach channel excavated in soil and rock. The adduction channel begins within the reservoir, in a straight stretch to the water outlet, and is dimensioned for the maximum turbinable flow of 248 m^3/s.

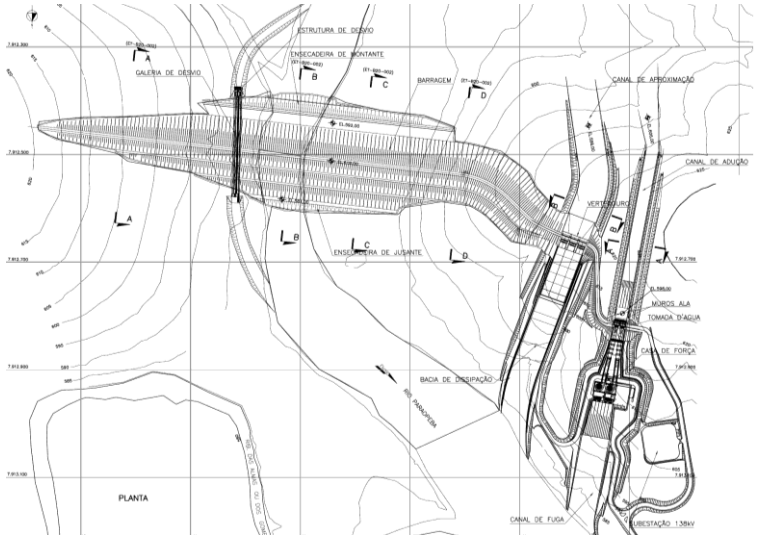

Figure 1: Layout of Retiro Baixo Hydropower Plant.

The Retiro Baixo earth dam becomes the focus of this study because of the brachiaria definition as the downstream slope protection vegetation of the structure. Although brachiaria minimized the energy of the direct incidence water (rainfall), its irregularity along the downstream slopes allowed the superficial water flow, which, together with the absence of a systemic and effective maintenance over the years, caused the development of surface erosion in the downstream slopes, evolving in some cases to rill erosions.

3.1 Historical process of the deterioration

Vegetation protection by hydro-seeding of brachiaria was adopted for protection along the entire downstream slope. In 2012, inspection records, carried out by a multidisciplinary team, reported that the protection has not developed, in a generalized way, promoting good vegetation cover, by minimizing the energy of the water of direct incidence. However, there was already a caveat about the possibility of surface erosion development in the slopes of the dam due to the superficial drainage of the water, and in some cases the rill erosions could evolve.

In 2013, the effects of choosing brachiaria as vegetation for downstream slope protection were observed during the inspection. At some points the slope had localized erosions and development of rills due to vegetation failure and lack of maintenance with systematic treatments of the sites.

For the observed deteriorations it was recommended the recovery of the points with manual compaction of soil and planting of vegetation, in order to cease the evolution of the erosive processes. In places where there was a lack of protection, vegetation replanting was recommended in order to avoid the emergence of new erosive process.


Figures 2 and 3: Failure of protective vegetation on downstream slope (left). Erosive process identified during inspection in 2013 (right).

In 2014, the dam maintenance team performed weeding of downstream slope vegetation and began testing with a regional grass type for a possible replacement of brachiaria.

With low vegetation, it was possible to visually evaluate the evolution of surface erosions during the inspection, so that the observed erosions were comprised in sheet and rills erosions of greater expression. Despite an erosive evolution compared to the previous year, recovery recommendations remained the same in relation to 2013.


Figures 4 and 5: Sheet erosions observed along the slopes (left). Rill erosion observed along the downstream slope (right).

As early as 2015, the absence of systemic maintenance culminated in the vegetation growth along the slope, which made it difficult to identify deteriorations. Still, in some parts, points of rill erosion and slippage were visible. This situation made it necessary, as a more effective recommendation, the substitution of all vegetation protection by species of grass with regular surface growth.

In addition, the importance of the continuity of the preventive maintenance program was reinforced with the dam maintenance team, optimizing it so that the vegetation is kept low and homogeneous for the longest possible intervals, allowing the correct visual monitoring of the structure.


Figures 6 and 7: High vegetation on downstream slopes (left). View of erosive process observed during the 2015 inspection (right).

Attention to the maintenance of downstream slopes protection vegetation was reiterated in 2016. The protection was completely irregular, alternating stretches of very high vegetation with areas without any protection, which should have generated the evolution of the serious erosion picture previously observed.

Throughout the extent of the downstream slopes, erosions with considerable depths were perceptible along the entire structure. It is estimated that there were more than 300 points of sheet and rill erosions. Notably, the lack of maintenance of the slope surface and the use of brachiaria as surface protection were the agents of the problem.

The evidences of a visual assessing of the evolution of erosion processes had made it crucial to carry out corrective measures to recover the slopes. In addition to the previously recommended maintenance, erosion points needed to be recovered with soil filling and compacting within the erosions. Some more expressive areas might even require other recovery techniques.

The replacement of the protective vegetation with brachiaria was indispensable so that, after the erosion recovery, the deterioration would be definitively solved.


Figures 8 and 9: View and detail of the erosive processes in advanced stages in the downstream slope.

3.2 Maintenance and recovery of the downstream slopes

In 2017, the maintenance team's efforts to combat brachiaria and recovery of the downstream slopes from erosion are being decisive for the reversal of the deterioration and for the safety of the dam. The erosions observed in downstream slope in the last years were all recovered through the recomposition and compactation of soil in the erosions. The work was performed manually and it comprised the entire structure length.

Figure 10: Recovery of the downstream slopes' erosions.

The adequacy of the downstream slope protection vegetation consisted in the complete manual removal of the existing vegetation, with a predominance of brachiaria, and the planting of the creeping ground grass specie, which is currently in progress. The grass is being planted by sowing and irrigated by sprinklers in the dry season. Due to the resistance of the species and the easy proliferation of its seeds, the battle against the growth of brachiaria is carried out constantly by the maintenance team.

Figure 11: Region being irrigated after the sowing process.

There is concern about the exposure of the slope, especially in rain season, as there will not be enough time for the vegetation to re-establish itself. Thus, the monitoring of the behavior of the structure is constantly being carried out by the maintenance team of the dam, through routine inspections.

The actions were not limited to the recovery of the slopes. A process of study and investigation of the region has been established to understand if there is any other

mechanism that contributed to the evolution of the deterioration, to allow creating barriers to the appearance of new problems or, at least, to know how to recover from the occurrences.

12 CONCLUSIONS

Brachiaria has been commonly used in dams as an alternative vegetation to protect the slopes in Brazil. This can be linked to the ease of proliferation and resistance of the specie, which reduces the costs of implantation and maintenance. However, their use can trigger an erosive processes that, eventually, can create risks to the dam safety.

Despite the significant evolution of erosions in the downstream slopes of Retiro Baixo Dam, recovery and corrective maintenance began in time to avoid major damage to the structure's safety. This historical process of Retiro Baixo Dam's deterioration reinforces the importance of having systemic and effective preventive maintenance to reduce risks to the security of the structure and greater operational costs.

ACKNOWLEGEMENTS

The authors wish to thank to Retiro Baixo Energética S.A. for the permission to publish data on dam operated by the company.

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