Albania Dam Safety Monitoring

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Abstract

This article deals with the implementation of geotechnical and geodetic monitoring systems for five hydropower dams in Albania. The dams were equipped with different automatic and manual sensor systems to improve the safety of the dams by monitoring the behaviour of the structures and their surroundings. The topography and accessibility in this wild and beautiful country presented a very special challenge.

Figure 1. Geodetic Monitoring at Fierza HPP.

1. Introduction

As a mountainous country with a large amount of precipitation during the winter months, Albania has a huge potential for hydro power which has been used for a long time. Spread across the country there are numerous dams, big and small. Most of these dams are used for irrigation during the dry summer months. A number of dams are also used to produce electric power. The dams are mostly embankment dams with heights of up to 160 m. The three largest dams are under the control of KESH (Korporata Elektroenergjitike Shqiptar), a joint-stock company which is 100% state-owned. Hence KESH is responsible for the maintenance and the safety of these dams.

2. The Dam Safety Project

A survey of the present state of the safety of the three hydropower plants of the Drin River Cascade (Fierze, Koman, Vau I Dejes) and the two hydropower plants of the Mat River Cascade (Ulza, Shkopeti) in the north-eastern part of Albania (see *Table 1*) financed by SECO (Swiss Federal Department of Economic Affairs) was carried out.

				
Fierza HPP (1978) 1. Level of the Drin-cascade	**Koman HPP (1988)** 2. Level of the Drin-cascade	**Vau i Dejes (1971)** 3. Level of the Drin-cascade	**Ulza (1957)** 1. Level of the Mat-cascade	**Shkopet(1963)** 2. Level of the Mat-cascade
Embankment dam with 160m height Capacity of the reservoir: 2700 Mio. m^3 Max. capacity: 500 MW	Embankment dam with 115m height Capacity of the reservoir: 250 Mio. m^3 Max. capacity: 600 MW	2 Embankment dams and one Gravity dam Capacity of the reservoir: 319 Mio. m^3 Max. capacity: 250 MW	Gravity dam with 64 m height Capacity of the reservoir: 124 Mio. m^3 Max. capacity: 25 MW	Buttress dam with 52 m height, Capacity of the reservoir: 15 Mio. m^3 Max. capacity: 24 MW

Table 1. List of Hydropower Dams.

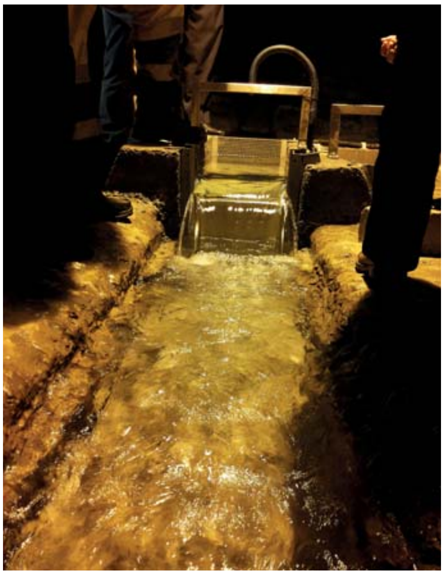

Figure 2. Automated rectangular weir measuring seepage flow inside Komani dam.

Figure 3. Drilling works for inclinometers with sub-contractors Altea Geostudio2000 at Porava.

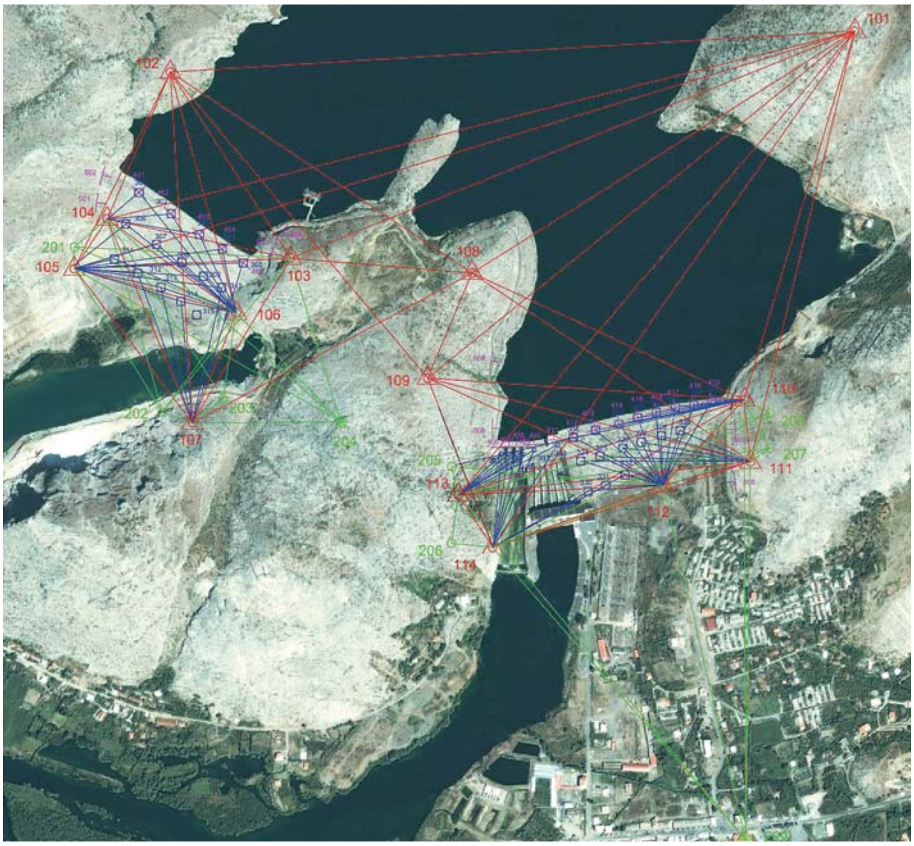

Figure 4. Geodetic Network for Vau I Dejes HPP (with Zadeje and Qyraq dams), reference points and lines of sight in red and green, object points and lines of sight in blue, levelling points and lines in purple.

In this context, the dams and appurtenant structures were inspected to identify the main hazards and the present conditions of the civil structures.

Dam safety is a fundamental precondition for sustainability of hydropower generation. Without adequate safety, not only are there large numbers of people at risk, but the power production will be jeopardized. Since the Drin and Mat River Cascades represent about 85% of the total electricity production in Albania, any loss of power production will have a significant negative impact on the economy and the regional energy market as well.

Dam safety as an integral concept includes the following items:

- Structural safety of dam and technical information and documentation;
- Dam safety monitoring (visual and instrumental observations, periodic dam safety evaluations, etc.);
- Operational safety and dam maintenance (reservoir rule curves, qualified staff, etc.); and
- Emergency planning such as emergency action plans, alarm system, etc.

The status of the structural safety of the dams built along the Drin and Mat rivers several decades ago was uncertain. Therefore, in the first step, the safety of these dams was assessed, and remedial actions were proposed, where necessary, to reduce the most urgent risks. As far as Dam safety monitoring is concerned, investments such as successful finalisation of the implementation of geotechnical and geodetic monitoring systems for five hydropower dams in Albania are discussed in this paper.

3. Geotechnical Monitoring

Geotechnical monitoring included the design, specification, manufacturing/procurement and installation of sensors and the data acquisition systems. This included all cabling, drilling and injection grouting works and the setup of monitoring stations. Data handling and analysis software and measurement devices were provided and local and personnel at headquarters were trained in using the measurement equipment and the data acquisition and analysis software, respectively. Measurement intervals and equipment maintenance schedules were suggested based on both local conditions and the experience with the systems in use.

4. Instrumentation

To monitor the structural integrity of the dams a three-pronged approach is used. Seepage through the dam body is monitored using automated piezometers behind the grout curtain and by collecting and measuring seepage run-off via automated V-notch weirs (see *figure 2*). Standpipe piezometers are used on the downstream dam face and the abutments to monitor water levels. And lastly, an automated seismic network records vibrations in a background mode and seismic events.

Other measurement points include inclinometers installed in landslide areas near the dams (Fierza HPP and Koman HPP). An example is shown in *figure 3* regarding the Porava landslide area near HPP Fierza. Furthermore, jointmeters and pendulums are used inside Ulza dam to monitor its deformations depending on the reservoir level.

Figure 5. The construction steps of a double-wall pillar, foundation, concrete, finish.

Figure 6. Transport of construction material, Mules, improvised cable cars.

Figure 7. Powerhouse in Koman with land slide area in the background.

5. Monitoring

Measurements are taken automatically and also manually at specified intervals. Automatic data acquisition is achieved through a network of automated sensors, interfaces at the nodes and the Geomonitor software installed on a dedicated industrial PC inside the command centre where all the raw data streams come together at each hydropower plant. The Geomonitor software is very versatile in that it not only collects data, but also allows supervisors to monitor sensors in real-time, plot, view and interpret recorded data. Furthermore, alarms can be set and, when triggered, send event-specific information to supervisors via email, SMS or other pre-defined methods.

Manual records and data downloaded from the Geomonitor system is then transferred to the Dam Department at KESH, Tirana. Trained staff there uses the WebDAVIS web-based data management and visualisation software to interpret, store, plot, manage and share the information. A periodical report is issued based on the visualised data.

The installed systems provide both an early warning system for structural failure as well as long term monitoring capability to ensure correct maintenance procedures and enhance longevity of the dams. Thus, the future of Albanian energy production is secured and the safety of its people living downstream of the dams guaranteed.

Figure 8. Improvised ferry service downstream of Shkopet HPP, Installation of object points at Ulza HPP.

6. Geodetic Monitoring

The geodetic monitoring encompasses the design, building, measurement and adjustment of a geodetic network of points on and around the hydropower dams as well as in land slide areas in the sphere of influence of the reservoirs. Furthermore, it involves the commissioning and delivery of all the specific equipment required to take the geodetic readings such as total stations, digital levels, adjustment software and accessories as well as the training of the personnel of the dam operator.

The goal of a geodetic monitoring is to study the behaviour of the dam structure and its surroundings and to derive the structural health thereof.

7. Instrumentation

In every geodetic monitoring the reference points are of greatest importance, since all future readings will be based on the coordinates of the 0-reading of these points. The reference points are properly and durably secured in stable ground outside the expected deformation area.

In spring 2012 a first site visit of all the dams and land slide areas took place. Meanwhile the locations for the object points (on different levels of the downstream faces of the dams, on the intakes, on the spillways, on rocks in landslide area etc.) were set and stable locations for the construction of reference points were evaluated with the support of a geologist.

The reference points were mainly built as doublewall survey pillars with centring plate and protective cover. The foundation of the pillars reaches up to 1.5 m into the soil and is whereever possible sounded in proper rock (see *figure 5*). Additional reference points have been mounted in the vicinity of the pillars as a back-up. Every network consists of approx. 10 pillars and 5 to 7 additional reference points (see *figure 4*).

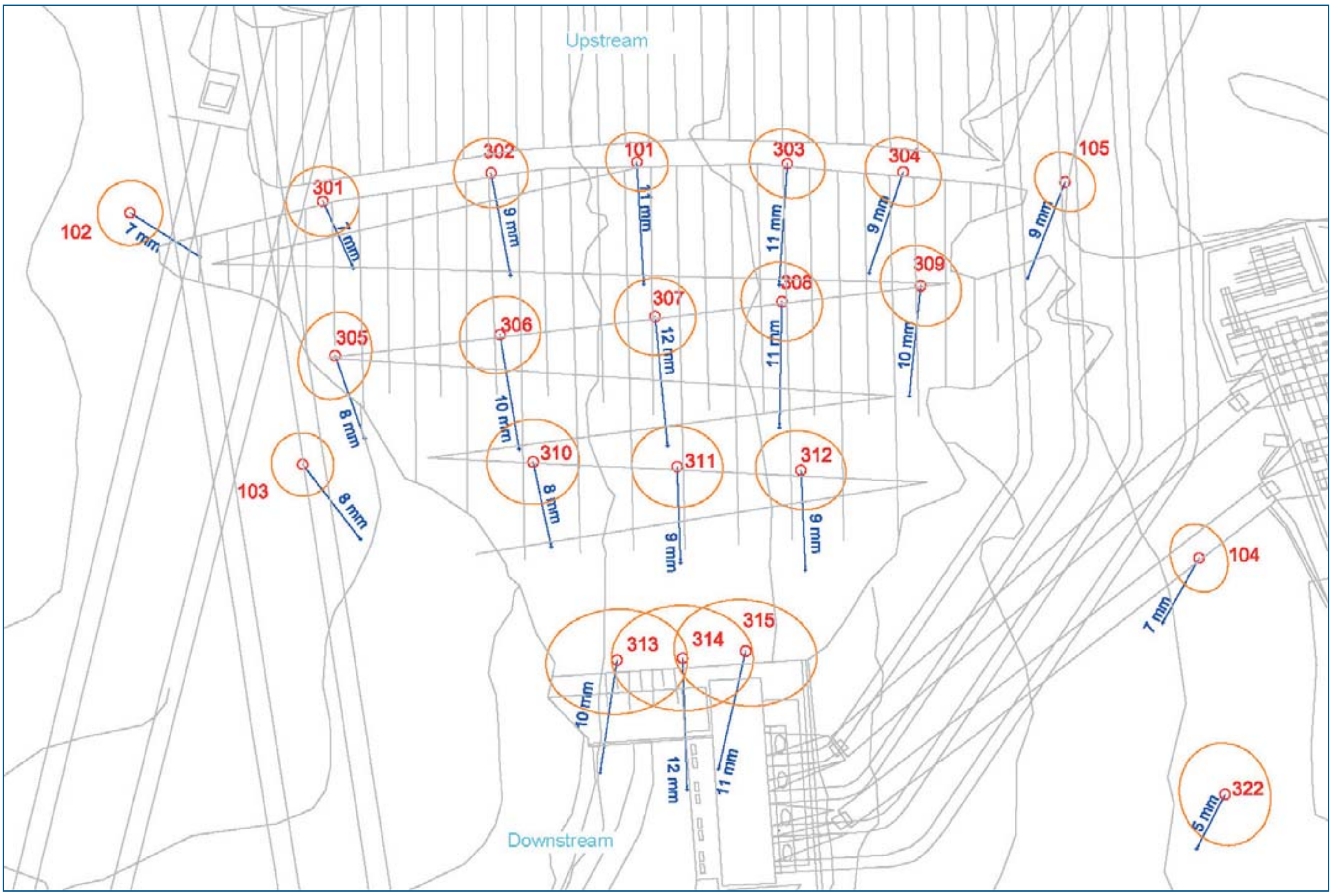

Figure 9. Fierza HPP with horizontal displacement vectors and confidence ellipses 95%.

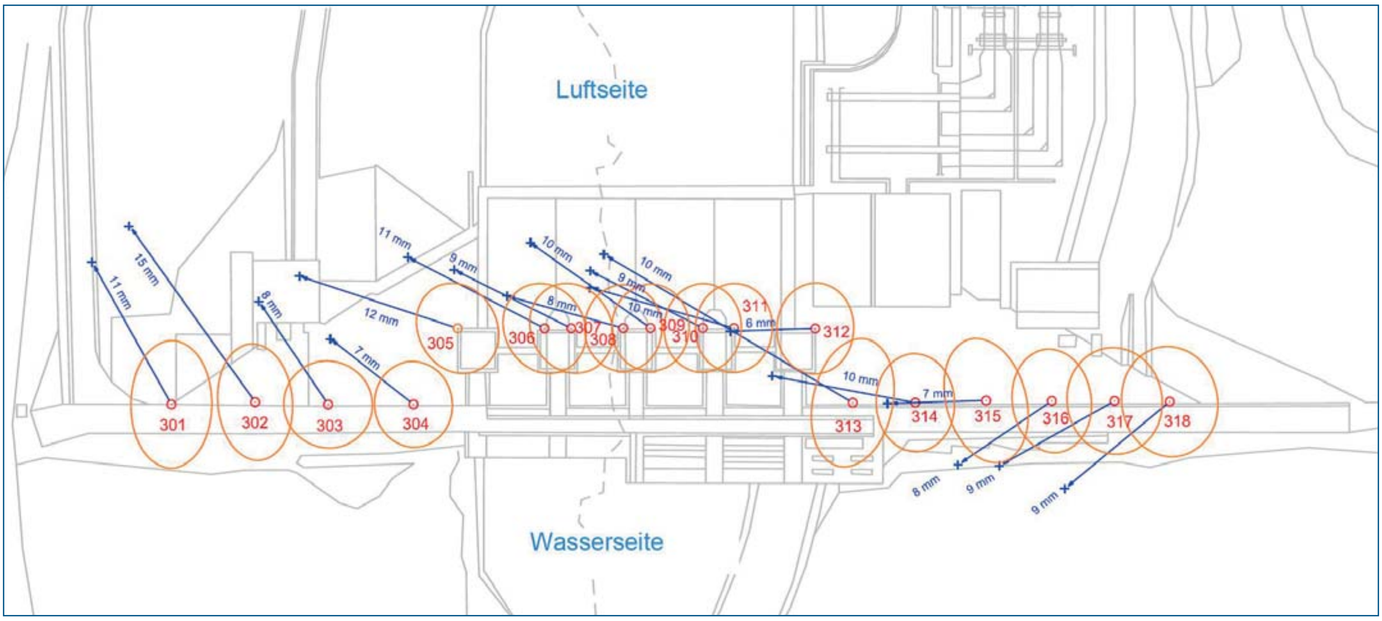

Figure 10. Ulza HPP with horizontal displacement vectors and confidence ellipses 95%.

The civil work for the reference points was carried out in the summer months May to September 2012 and proved to be difficult due to the topography and accessibility. Most of the locations are in steep and rocky terrain and cannot be reached by car. The construction material such as cement, gravel, water, etc. had to be transported by mules or by pretty adventurous self-made cable cars. There we were happy to have the support of a local subcontractor who had the experience and creativity to make it happen. All the excavations were done manually (see *figure* 6).

The object points on the dams were either built as concrete foundations or secured directly into the rock or concrete of existing structures. Some of the points were mounted directly onto the inclinometer pipes to connect the geotechnical measurement systems with the geodetic network. Additionally to the 3d-deformation measurements a number of levelling points were installed on the dam crests.

In Koman the rock mass above the intake and the slope above the power house proved to be very unstable and represents a serious hazard to the infrastructure (see *figure 7*). To monitor the move-

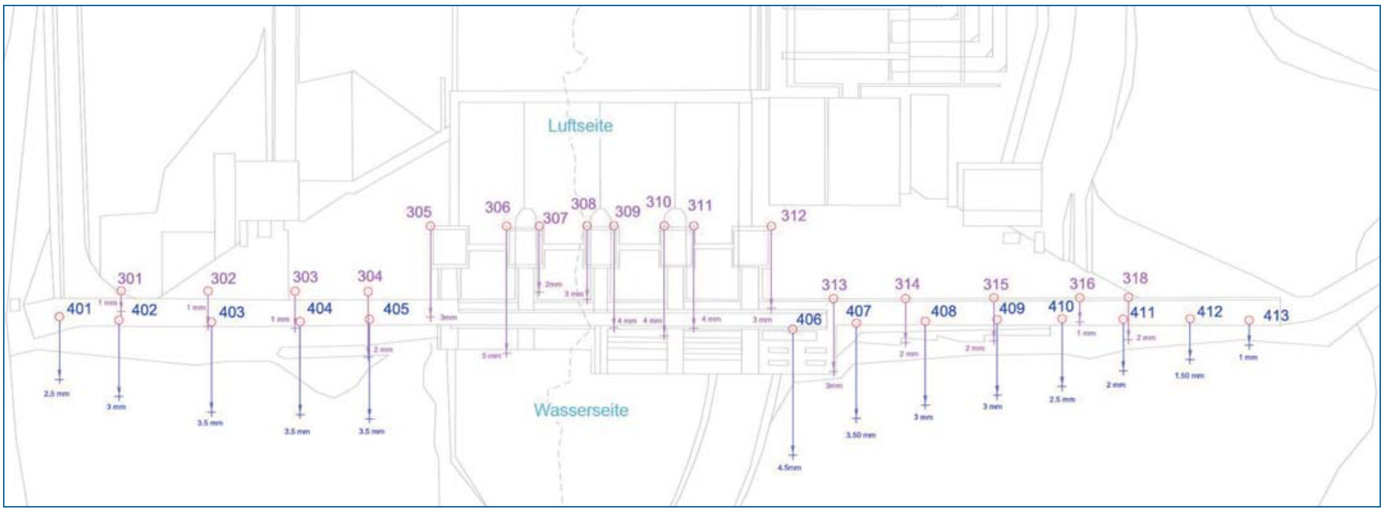

Figure 11. Ulza HPP with vertical displacement vecotrs.

ments and their velocity a number of object points were installed.

In total 45 pillars, 70 concrete foundations, 147 bolts, 27 target plates and 5 permanent reflectors were installed.

8. Measurement concept

All points (reference and object points) are measured and adjusted in one highly overdetermined network. Thus every point within the network receives a coordinate for its 0-reading position. The measurements are repeated in a slightly slimmed-down version at regular intervals. The network will be adjusted after every measurement and is referenced to the 0-reading coordinates of the stable reference points. With every measurement the stability of the reference points is checked again. Only in this way the comparability of results can be guaranteed over a long time.

9. 0-Readings

The 0-readings for all dams took place in October 2012. Autumn holds the best conditions for geodetic measurements: the reservoirs are almost empty after the long and dry summer; the weather is usually still dry but not as hot as in summer anymore and the vegetation is getting lighter.

The measurements were taken by a team consisting of specialists from BSF Swissphoto and KESH. Meanwhile on the job training was given. The measurements were completed within two days at each dam. Due to the difficult access and long distances between the points we were happy to have additional personnel of the hydropower plants at our disposal (see *figure 8*).

On every pillar at least two to three sets of angles were measured. Every point within the network was observed from at least three positions.

The analysis of the measurements was done in the following week at the offices of the dam operator. All the measurements of each dam were evaluated and adjusted coordinates were calculated. In a first step the data was verified in a free network adjustment. The networks were measured highly over-determined whereby single erroneous measurements can be detected and eliminated. The reference frame for the adjustment was chosen locally so that the Y-axis is aligned with the dam crest and the X-axis points into the direction of the largest expected deformations.

10. First Sequence Readings

The first sequence readings took place in early spring 2013 in the same constellation as in autumn the year before. After the long precipitation period in winter and the snow melting in spring the reservoirs were filled to their maximum level. All dams had to open their spillways to release water which caused flooding in the downstream areas. The metrological conditions for the geodetic measurements were excellent and the survey points had survived their first winter well. Only one pillar had been destroyed by «human rock-fall». Once again the measurements were also used to train the personnel of the dam operator in the handling of the equipment, the challenging logistic and the evaluation and interpretation of the data.

11. Results

The analysis of the first Sequence reading data set allowed for a first interpretation of the deformation of the dams and the velocity of the land slides. The differences of the waterlevels of the reservoirs between the two measurements can be regarded as maximal for the first Levels of the Drin- (Fierza 40 m) and Mat-cascade (Ulza 12 m). The lower levels of the Drin- (Koman, Vau I Dejes) and Mat-cascade (Shkopet) can adjust their water levels only marginally. The results show that the embankment dams in Koman, Vau I Dejes and the buttress dam in Shkopet are stable and hardly show measurable deformations. The situation is different in Fierza and Ulza.

In Fierza significant horizontal shifts towards the downstream side are recognisable. However, the displacements include a transversal component, which indicates an opening and closing of the valley cross section and a resulting influence on the dam (see *figure 9*).

The valley cross section narrows in spring by about 8 mm at a distance of about 420 m, but the uncertainty with only one measurement is high. In the meantime, the dam operator carried out a second sequence reading which confirmed this effect. The «breathing of the valleys» was already observed in Switzerland during the permanent monitoring related to AlpTransit Gotthard [1], [2]. There a continious series of measurements over several years is available and the validity of the results is much higher. It is interesting that in Albania,this effect is evident only in Fierza, which is probably related to the geology and natural fluctuation in ground water level in this area. Unfortunately the geotechnic lot had not yet been completed and therefore no data from geotechnical sensors such as piezometers were available for the period of the geodetic measurements.

On the gravity dam in Ulza, significant deformations that resemble the shape of a folding motion, occur (see *figure 10*). The settlements along the dam crest are significant with up to 5 mm over the entire crest (see *figure 11*). Again, the uncertainty with only one measurement is high and the behavior of the dam can not be conclusively determined. However, it is conceivable that the additional applied load due to the higher water level (+12 m) causes a settlement and vertical tilting. Although the settlements are at their maximum in the middle of the dam, the largest horizontal displacement or tilting can be found towards the left abutment. This might be caused by either topography/geologie or structural unstabilities. The downstream tilting/displacement seems to effect the whole structure by pulling the right abutment towards the left abutment.

Basically, the deformations in Fierza and Ulza are large. The dams are already 35 respectively 56 years old. Unfortunately no previous measurements are available. Before a series of at least four measurements over two years is present, it can not be determined whether the deformations only represent a special event or a normal behavior and how these movements influence the stability of the dams.

12. Conclusions

Within the Dam Safety Project a geodetic and geotechnical network has successfully been implemented for the five largest hydropwer dams in Albania. The local staff was trained thoroughly and is now able to carry out the measurements independently which they have already demonstrated. The project was a success from the perspective of the entrepreneurs involved.

The dam operator must collect further data through periodical measurements within the next two years, to re-evaluate the stability of the dams. After completion of the geotechnical part more data from inclinometers, piezometers, pendulums, etc. will be available with which a more detailed assessment of the behavior of the dams will be possible.

The maintenance of the measuring equipment and devices will constitute a further challenge. Due to the large deformations in Fierza and Ulza a permanent automatic monitoring would be desirable.

Bibliografie

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