AN OVERVIEW ON SEEPAGE INVESTIGATION DURING IMPOUNDING BY INSTRUMENTATION DATA – A CASE STUDY

A. HAFEZQURAN
Site Supervisor Engineer, Canisib Dam, Mahabghodss Consulting Engineers, Iran

GH. DERAVI
Head of Site Supervision of Drilling and Grouting, Canisib Dam, Mahabghodss Consulting Engineers, Iran

A. MOSHIRPANAHI
Chief Supervisor engineer, Cheragh_vays Dam, Mahabghodss Consulting Engineers, Iran

ABSTRACT

The first filling of dam reservoir is a very vital step in dam life, and the future success of dam operation greatly depends on the technically monitor and management of this phase. Many of the unfortunate events of dam failures have happened due to mismanagement at first filling phase, regardless, the construction phase was appropriate.

The Cheragh-vays dam is located in the north-western of Iran at Kurdistan province, and is rock-fill dam with 62 m in height, 30 m curtain final depth. The first filling phase of the reservoir started on 2017 May. In This paper, detailed attitude on grouted curtain data in terms of performance has analyzed with respect to instrumentation data which is including dam foundation piezometer, observation wells, and V-notch, during impounding. Besides, conditions of the dam foundation geoengineering, relationship of any probable seepage media by the cement injected data on curtain grout holes in the course of construction is analyzed briefly.

1. INSTRUCTION

Dam monitoring in the first filling phase and during first five years of its operation is very important step in dam life. Almost half of dam failures occurred during the first five years of dam's life and Two-thirds of these events happened in the first impounding. Therefore, the first stage of dam impounding requires technical planning and monitoring system. Actually, the first filling of reservoir is first practically dam body structure test under hydraulic loading and, any implementation or design weaknesses at this stage are likely to appearance (Foster et al 1999).

Seepage generally is defined as a water flow through the upstream dam body and foundation toward downstream. Depending on the classification of the dam size and foundation geological conditions, a certain amount of seepage is assumed as normal values. Excess water seepage can increase dam failure risk due to embankment and/or foundation erosion damage.

Internal erosion and foundation piping are two main causes of dam failure related to seepage that accounts for about 33% and 16% of dam failure events, respectively. The most cases of internal erosion failure occurred at the highest reservoir water level, however, the reservoir water level was not effective factor for foundation piping failure type (Foster, et al 2000).

The most important instruments used to estimate direct and indirect seepage through dam structures are: V-notch weir system, drainage curtain boreholes, observation wells, rock foundation piezometer and rock stand-pipe piezometer. In addition, visual observations of downstream dam areas are one of the most important and preliminary method for determination and monitoring of abnormal seepage points in dam sites. (Fell et al, 2014).

2. HERGH-VAYS DAM SPECIFICATIONS AND GEOLOGICAL SETTING

2.1 Dam specification

The Cheragh-vays dam is located in the northwestern Iran at Kurdistan province. The dam is clay core rock-fill dam type with a height of 67 meters, 980000 cubic meters' embankment volume and 270 meters' crest length. The dam is designed for drinking water supply of Saqqez city and irrigation purposes (MGCE, 2016).

2.2 Geological setting

The Cheragh-vays dam is located in Sanandaj-Sirjan tectonic zone of Iran. The dam foundation consists of diorite to quartz-diorite rocks with sub-vertical rhyolite dikes, and alternative seams of schist in left abutment as affected of tectonic force (figure1). Hydrothermal fluid zones were extended from the upstream of the dam reservoir to the left abutment due to hydrothermal quartz injection into the structural joints especially in schist formations. Hydrothermal phenomenon effected zone on the dam foundation was much less than the reservoir. Clay in-filled joints are extended in dam foundation up to 8 meters in depth (MGCE. 2016).

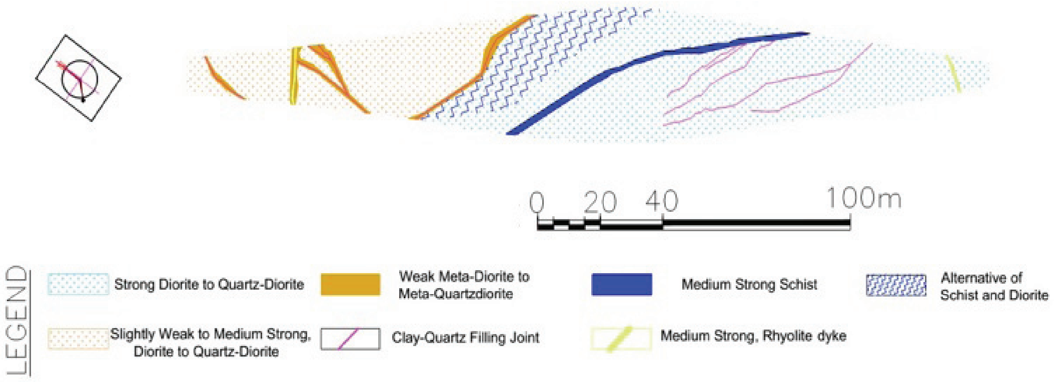

Figure 1 : Geological plan view of clay core foundation (MGCE, 2016).

Water pressure test results during implementation phase decelerated that clay in-filled joints are capable to wash-out potential. Special (pressure) washing is used before cement injection for wash out of weak clay infilling which there were in the rock foundation joints aligned dam curtain (see Fig.2), (Hafezqurn, 2017).

Figure 2 : Wash-out of clay filling joints by pressure washing (MGCE, 2016).

3. GROUTING PROGRAMS

3.1 Consolidation grouting

Consolidation grouting has been done to improve geotechnical parameters and thereby increase the bearing capacity of a part of the rock mass that is damaged by blasting operation and weak shallow rock mass. Consolidated grouting of Cherag-vays dam is designed as a triangular grid with 2 * 2 m borehole spacing and a final depth of 10 m. Type II micro-fine Portland cement (Blaine number > 5000 gr/cm^2) was used for consolidation grouting. Consolidated grouting started with a water-to-cement ratio of 1:1 by weight and finally continued in highly grout-able stages to a ratio of 0.5. Superplasticizer has been added to the grout mix to increase the mobility and penetrability of the slurry at a rate of 0.4 to 0.6 percentage of cement weight. Figure 3 shows the results of consolidation grouting in primary and secondary boreholes for the dam banks.

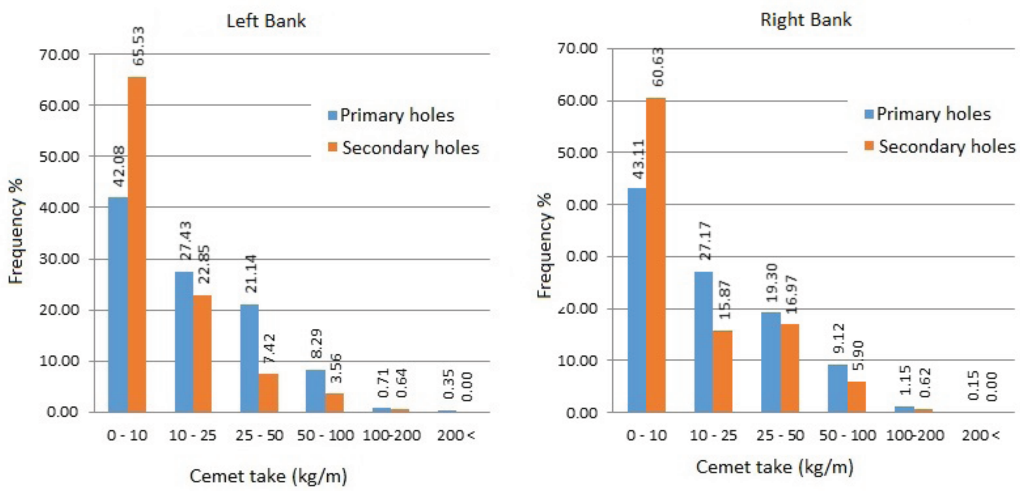

Figure 3 : Consolidation grouting results for primary and secondary boreholes (MGCE, 2016).

3.2 Curtain grouting

Curtain grout is generally installed to reduce seepage through dam foundation, decrease uplift pressure and control the foundation. Due to the presence of clay-filling joints, the curtain grouting of the dam carried out with high degree of control and monitoring in order to prevent long-term erosion of the foundation. According to Houlsby's (1990) criterion, the sealing level of the dam should be below three Lugeons. Figure 4 shows the permeability distribution in study and implementation phases for curtain holes.

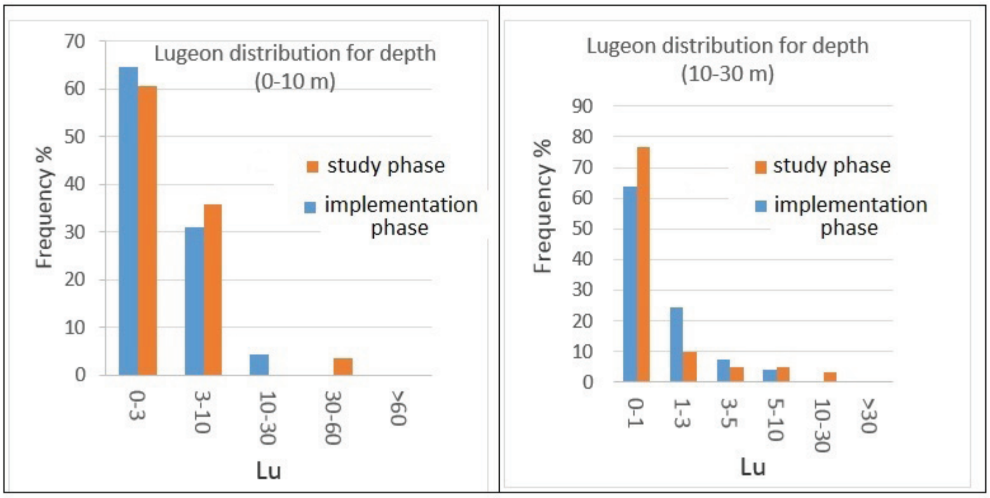

Figure 4 : Lugeon distribution in study and implementation phases for curtain grouting (MGCE, 2016).

Type II micro-fine Portland cement (Blaine number > 5000 gr/cm^2) was used for curtain grouting. Curtain grouting with water: cement ratio of 2:1 by weight started, and if necessary w: c decrease as 0.5 by weight.

The curtain of the Cheragh-vays dam is installed in the central row of the consolidation grout holes. Due to the low permeability of the site, a final depth of the grout holes was 15-30 m from quaternary to primary holes. The spacing of the first series of curtain holes (Series A) is 16 m. curtain grouting done by "split-spacing" method because it has shown its effectiveness in practice. One of the main reasons for using this method is the inability of grouting science to estimate the slurry penetration radius. The split-spacing method is actually an inverse method for estimating the injection radius Figure 5 shows the relationship between permeability and cement take for consolidation and curtain grouting. As can be seen, the permeability in the grout curtain is generally below 10 Lugeon. This is due to the effect of consolidation grouting on permeability reduction for depths less than 10 m as well as permeability reduction with depth along grout curtain Fig. 2 shows the permeability and cement take results of curtain control boreholes. According to the figure, more than 93% of the permeability values are below 3 Lu and more than 98% of cement take values are below 25 kg / m.

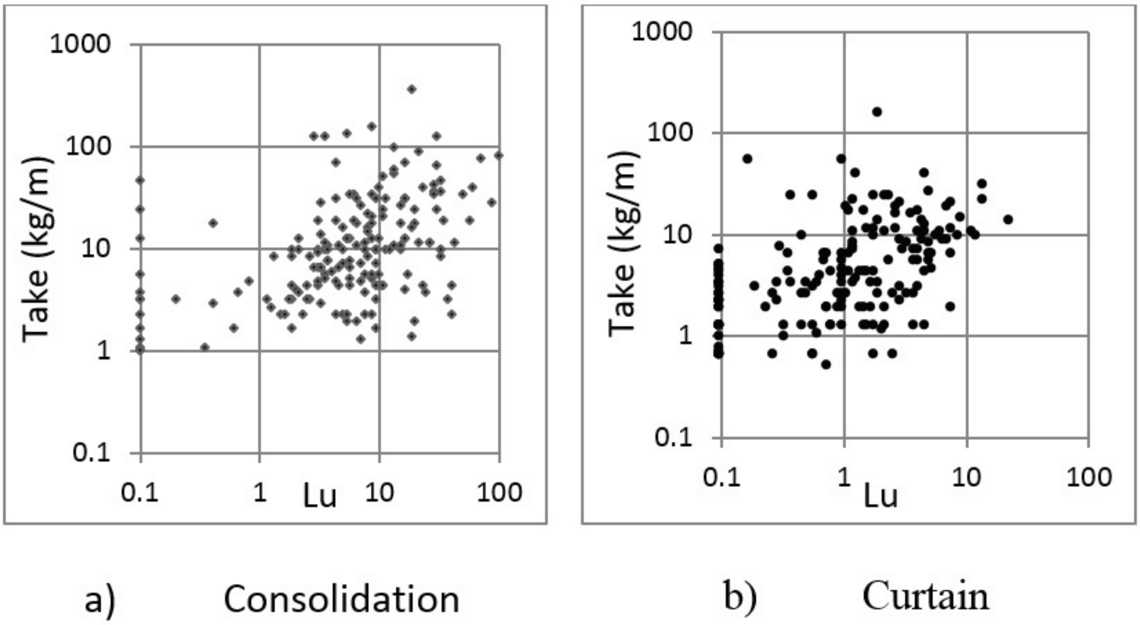

Figure 5 : The relation between permeability and cement take in consolidation and curtain grouting (MGCE, 2016).

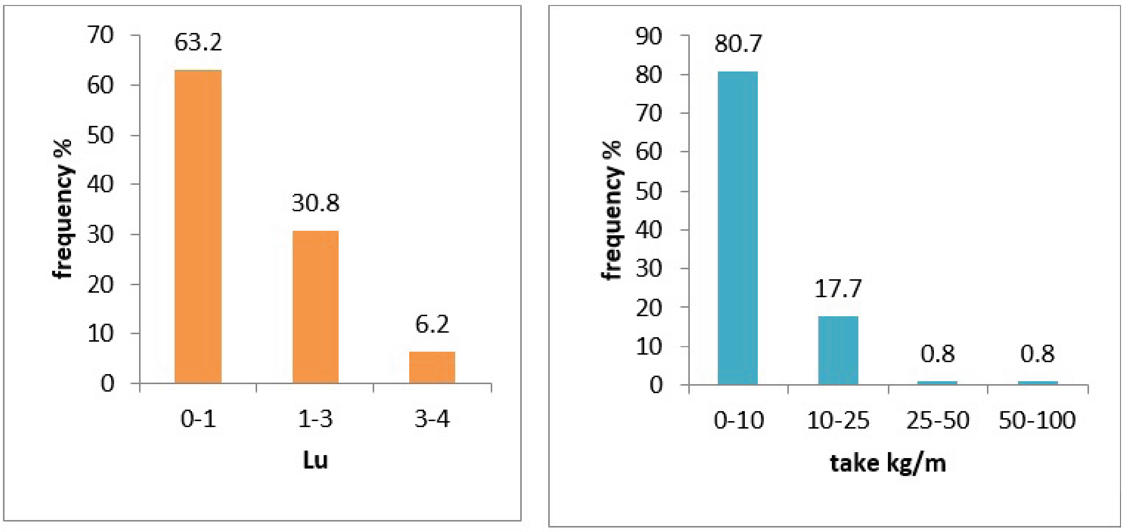

Figure 6 : The results of permeability and cement take in control holes of curtain grouting (MGCE, 2016).

4. FIRST FILLING AND SEEPAGE MONITORING

The first filling phase of the cheragh-vays dam reservoir started on 2017 May. After the water level rising to the elevation of 1580 m, equivalent to about 3/4 of the dam height, the dam impounding was stopped for relocating of a village in reservoir area. In this paper, the performance of the grouted curtain has analyzed with respect to instrumentation data including dam foundation piezometer, observation wells, and V-notch, during impounding.

Figure 7 shows the plan view of the cheragh-vays instrumentation section. In this figure, only the rock foundation piezometer, rock stand-pipe, observation wells, and V-notch, which are related to the estimation of dam seepage, are shown. For each section, two rock piezometers are installed 5 m upstream and downstream of the grout curtain respectively, at a depth of 10 m beneath the foundation surface. These piezometers are used to evaluate the grout curtain performance. Adjacent to the downstream piezometer, a twin stand-pipe is installed in two different levels to evaluate the accuracy of rock piezometers. Other standpipes are installed downstream of the clay core along these sections. Observation wells are installed for recording groundwater changes. These tools actually complement the rock piezometers and standpipes.

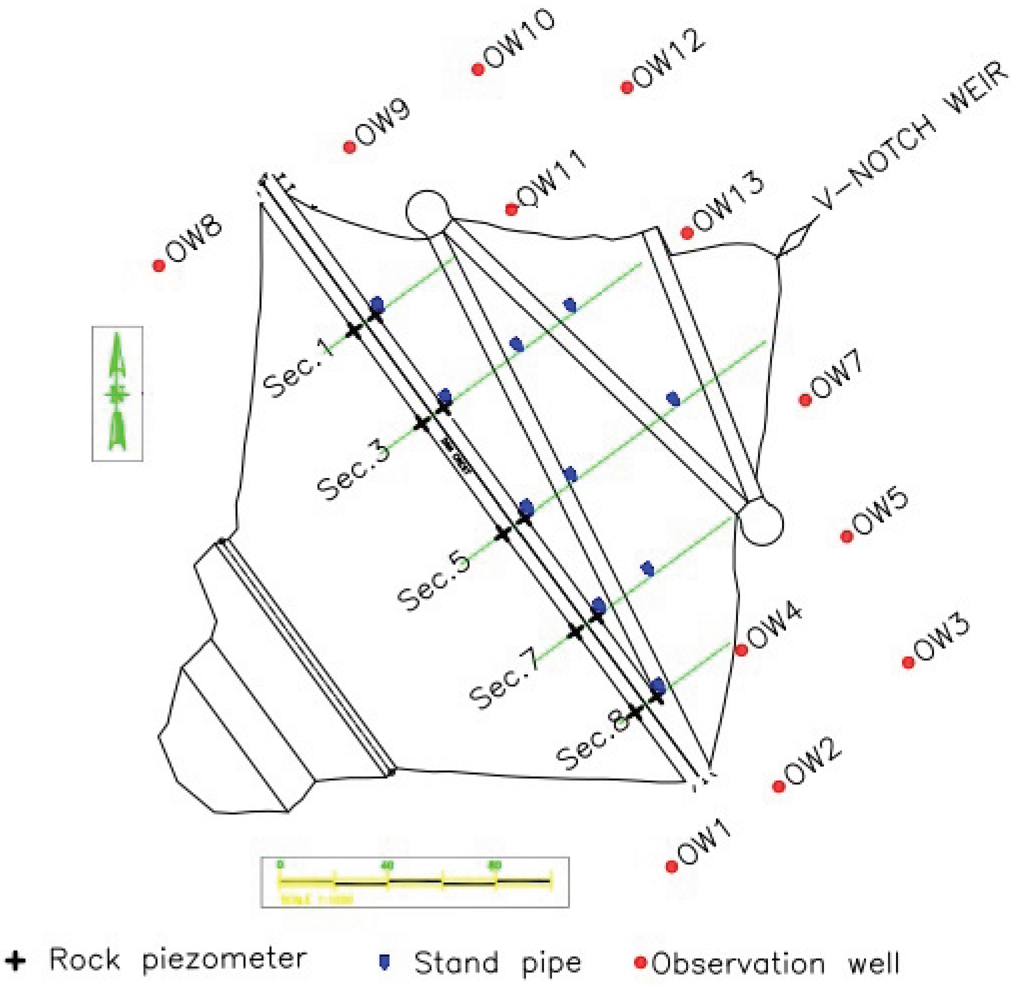

Figure 7 : General plan view of dam instrumentation sections.

Figure 8 shows the results of rock foundation piezometer for sections 3, 5 and 7. According to this figure, there is a significant difference between the upstream and downstream piezometric levels for section 3 and 7, which indicates the good performance of the curtain at these sections. But for section 5, the downstream piezometer shows higher piezometric level than the upstream piezometer level and also the reservoir water level, which indicates an abnormal case in the piezometers behavior or curtain performance. Downstream standpipes and V-notch weir system are used for interpretation of this rock piezometer.

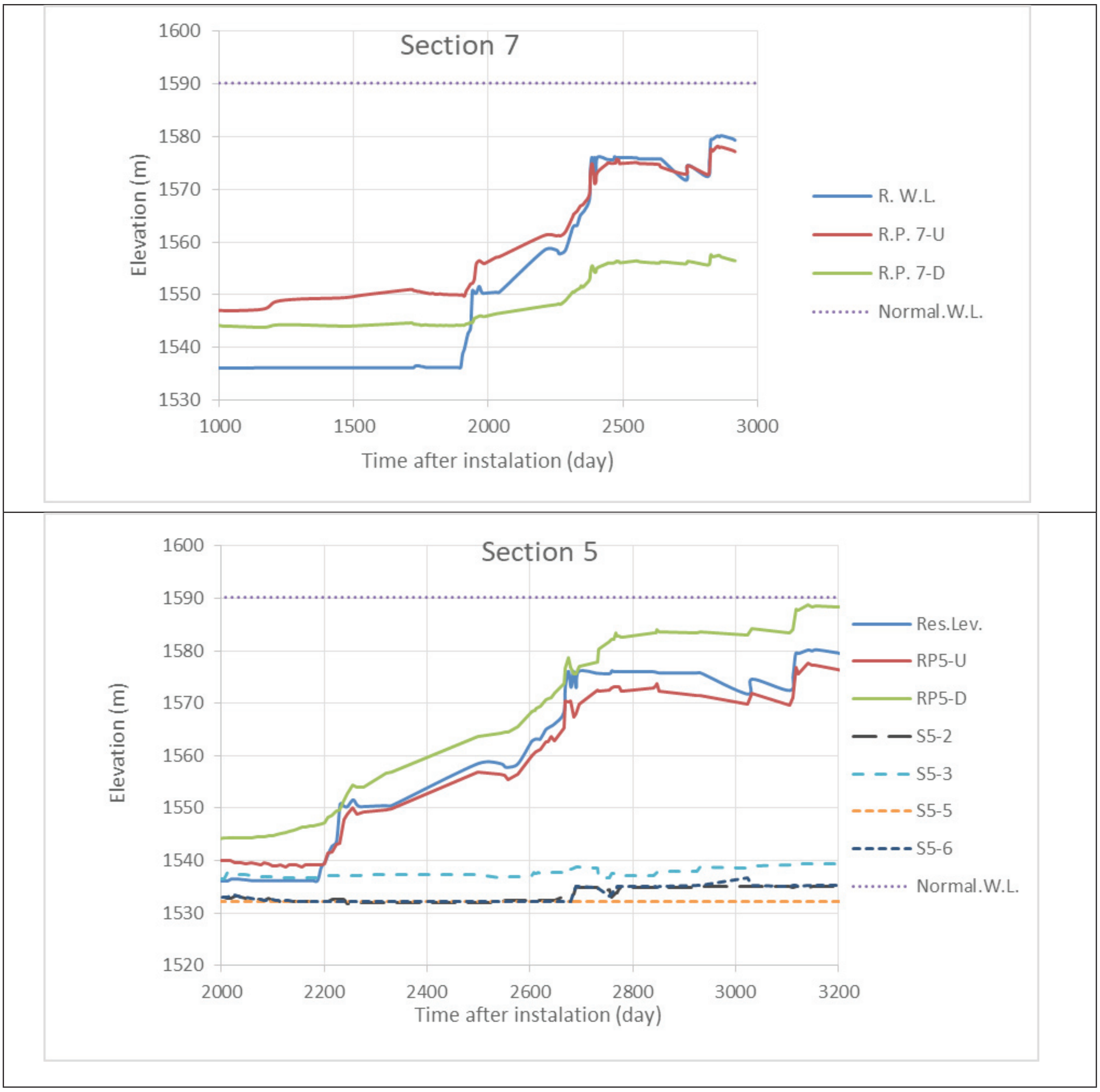

Figure 8 : The results of rock foundation piezometer for sections 3, 5 and 7.

Figure 9 shows the position of the rock foundation piezometers and standpipes for section5. Unfortunately, standpipe S51 that installed near this rock piezometer was destroyed during dam construction. Piezometers S52 and S53 that located downstream the clay core show little fluctuation with water level increasing (see figure 8). Currently, the supervisor team's recommendation is careful monitoring of this section, because unusual behavior not seen in other related instruments.

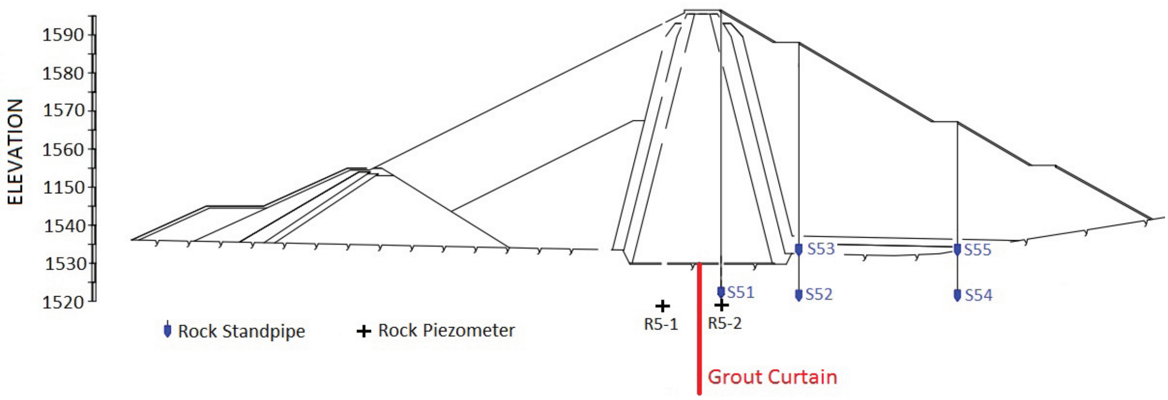

Figure 9 : Position of the rock foundation piezometers and standpipes for section No.5

5. OBSERVATION WELLS

Figure 10 shows the results of observation wells of the Cheragh-vays Dam before and during first impounding (see figure 7 for well positions). Water level fluctuations in the observation wells before and during impounding are approximately the same behavior. This indicates that the dam abutments have normal conditions in terms of seepage status. The sawdust peak points in these diagrams are generally due to the increase in the water level of the wells due to rainfall, which has returned to normal level after rainfall time.

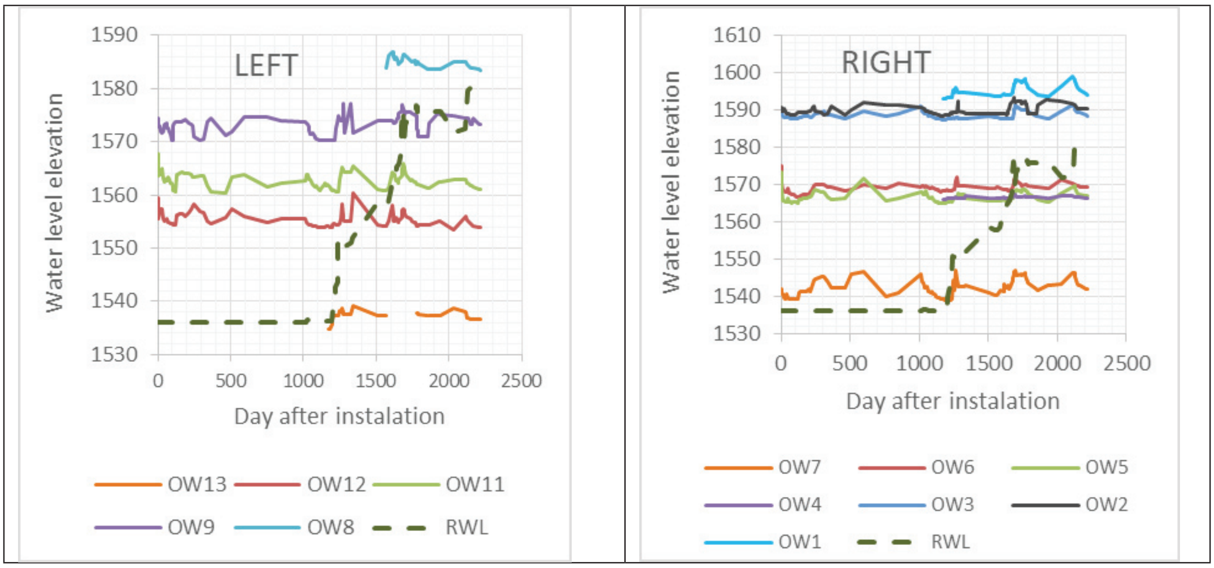

Figure 10 : The results of observation wells of the Cheragh-vays Dam before and during first impounding

6. V-NOTCH SYSTEM

The Cheragh-vays V-notch system is not installed yet. The extent of dam seepage has been measured approximately by graduated plastic containers. Due to the low river width downstream the dam and the low seepage amount, the seepage water is collected to a small ditch and measured approximately by graduated plastic containers.

Figure 11 shows the diagram of dam seepage values in accordance with reservoir water level. Seepage values are corrected according to the method proposed by (Lee, 2015), and the effect of rainfall water on seepage values is eliminated.

Visual observations are one of the basic tasks of dam monitoring during first filling. During the impounding time, downstream areas of the dam have been continuously monitored to identify abnormal springs and seepage points. So far, abnormal springs or seepage points have not been observed downstream of the dam.

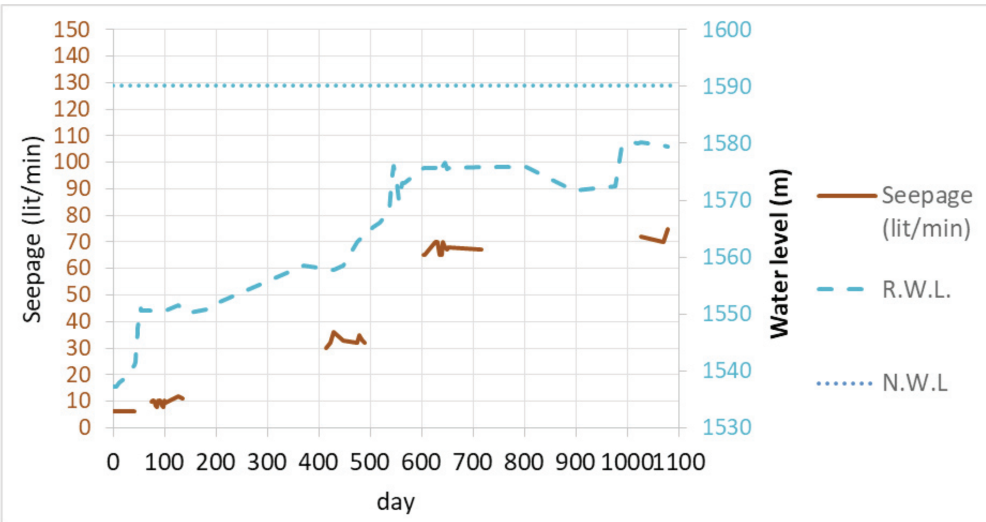

Figure 11 : The diagram of dam seepage values in accordance with reservoir water level

7. CONCLUSEIONS

In the present paper, the behavior of seepage-related instruments in Cheragh-Vays dam has been investigated.

- For instrumentation section No. 3 & 7, there is a significant difference between the upstream and downstream rock piezometer levels, which indicates the good performance of the curtain at these sections

- For instrumentation section No. 5, the downstream piezometer shows higher piezometric level than the upstream piezometer level and also the reservoir water level, which indicates an abnormal case in the piezometers behavior or curtain performance. Downstream standpipes and V-notch weir system are used for interpretation of this rock piezometer. Currently, the supervisor team's recommendation is careful monitoring of this section, because unusual behavior not seen in other related instruments.
- Water level fluctuations in the observation wells before and during impounding are approximately the same behavior. This indicates that the dam abutments have normal conditions in terms of seepage status.
- Seepage values in downstream of the dam is normal. Unusual springs or seepage points have not been observed downstream of the dam.

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