# Effect of Drainage Blanket on Reducing Uplift Pressure Under Chute Spillway: A Case Study on Megech and Ribb Dam Projects

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**Abstract.** Ribb and Megech dams have been designed by same designer, both dams have similar foundation, capacity and profile. However, Ribb dam spillway was designed and constructed with drainage blanket beneath the spillway channel slab. Whereas, the design and construction of Megech Dam Spillway was without this material. This study investigates the distribution of uplift pressure and seepage at control, chute and terminal section of the spillway's foundation of the two projects with and without drainage blanket using SEEP/W software and measured data. The result showed that on Ribb dam spillway up to 14% reduction of uplift pressure around control section and an average of 5% uplift pressure reduction at chute section of the spillway was found by using drainage blanket beneath the structure. However, providing drainage blanket beneath the stilling basin slab couldn't reduce the uplift pressure rather it allows the tail water to enter and surcharge the under-slab drainage system. If this drainage sand has been used on Megech dam spillway up to 12% uplift reduction around control section and an average of 3% reduction can be achieved at chute section of the spillway. Therefore, the provided drainage blanket beneath the spillway channel slab at control and chute section of Ribb dam spillway is necessary and good design. But this drainage system is not essential at the stilling basin of the spillway. Whereas, the control and chute section of Megech dam spillway without drainage blanket beneath channel slab is not safe against uplift pressure.

**Keywords:** Ribb · Megech · Spillway · Uplift pressure · Seepage · Numerical model

## 1 Introduction

Water resources are nowadays important to be controlled in the view of limited available water in accordance with the increasing demand for water. Hydraulic structures such as dams, reservoirs, barrages, weirs are those structures used for controlling water resources.

Ribb and Megech Dam Projects are located in Lake Tana sub Basin, in the upper Blue Nile Basin, Ethiopia. Ribb and Megech rivers in which these two dam projects


M. A. Delele et al. (Eds.): ICAST 2020, LNICST 385, pp. 17–35, 2021.
https://doi.org/10.1007/978-3-030-80618-7_2

are being developed are two of the main streams flowing in to Lake Tana. Both these Dam Projects are being constructed through the Ethiopian Government and they are multi-purpose by providing controlled discharge to irrigate 37,000 ha of land in Fogera and Denbia floodplains, expected to harvest fish, to control flood and Megech will also supply drinking water for Gondar Town [1, 2]. These show that the projects have crucial role for alleviating problems particularly in the study area and for the country at large. The design and supervision work of these two projects are conducted by Ethiopian Construction Design & Supervision Works Corporation, Water & Energy Design and Supervision Works Sector in association with TAHAL Consulting Engineers, while the construction is carried out by the Ethiopian Construction Works Corporation, Water Infrastructure Construction Sector.

For hydraulic structures constructed on permeable foundations, seepage occurs under the foundation of the structures due to the difference of water levels between upstream and downstream sides of the structures [3]. The effects of seepage on the foundation of hydraulic structures can be classified into three parts: uplift force, seepage discharge and exit gradient. Uplift force reduces the shear resistance between structure and its foundation, causes a reduction in stability of the structure against sliding or overturning. Increasing the seepage velocity at the downstream end of hydraulic structures, may cause the movement of soil particles and accordingly accelerates piping and soil erosion. The exit gradient is the main design criterion in determining the safety of hydraulic structures against the piping phenomenon [4].

The hydraulic engineer should carefully design the hydraulic structures such that it can perform its function safely. The most critical aspect of the design of such structures is the design concerning its foundation. The water seeping underneath the hydraulic structures endanger the safety of the structure and may cause failure. Therefore, the seepage under hydraulic structures can be considered one of the most important problems in the hydraulic structures safety [5]. Due to water under the spillway many catastrophic failures of the spillway which leads to the whole dam failure has been occurred in the world; for instance, Mt. Carmel Dam located in North Dakota, Big Sandy Dam Spillway: June 1983, and Hyrum Dam Spillway [6].

Ribb and Megech dam projects have appurtenance structures such as spillway, Intake tower and conduit which are very vital for the whole dam operation and safety. To achieve the projects final target, the necessary defensive design measures for the appurtenance structures should be taken into considerations which basically ensure safety and economy [7, 8]. The foundation, capacity and profile of Megech and Ribb dam spillways are almost the same. But beneath the chute, a drainage blanket typically consisting of drainage gravel (50 cm thick) and filter sand (30 cm) is provided at Ribb dam project to control seepage and relieve any hydrostatic pressures. Whereas, in Megech dam project, there is no any drainage and filter material provided beneath the chute slab except bedding sand placed for protection of the perforated transversal pipes which are located within 20 m interval parallel to the cutoff wall. The objective of this study was to analyze the effect of drainage blanket on reducing uplift pressure and seepage through the foundation of side channel chute spillway. This can be complemented through specific objectives; by analyzing the uplift pressure and seepage condition with and without drainage blanket beneath the spillway channel slab and by evaluating drainage system of the chute spillway. Hence, in this study the distribution of uplift pressure and the seepage condition through the spillways chute foundation of Megech and Ribb dam projects with and without drainage blanket was analyzed by using the numerical model, SEEP/W software (program) which is a sub-program of the Geo-Studio software. The measured uplift data were used for validation purpose. The study will have a good outcome in the future to take necessary defensive design measures under consideration for similar projects which will be conducted.

## 2 Materials and Methods

### 2.1 Study Area

The study was conducted on Megech and Ribb Dam which are located in Lake Tana Sub Basin, as shown in Fig. 1.

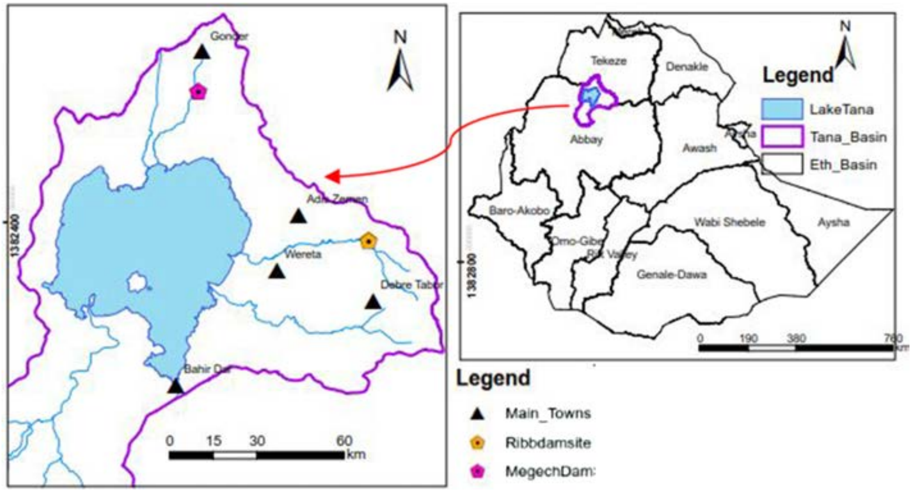


**Fig. 1.** Study area map

The mean annual rainfall at Megech and Ribb dam site is 1100 mm and 1400 mm respectively. The catchment area of Ribb is 685 $km^2$ and the dam maximum reservoir area is 10.02 $km^2$. Whereas, Megech has 424 $km^2$ catchment area and the maximum reservoir area is 8.7 $km^2$ [7, 8].

### 2.2 Materials

**Design Documents.** Laboratory test result certificates, as-built drawings, design documents, and technical specifications were used. Moreover, the engineering drawings for the spillway plan and section was considered.

**Digital Elevation Model.** A 30 m by 30 m resolution ASTER Global Digital Elevation Model which can be download from EOSDIS website (http://reverb.echo.nasa.gov/reverb) was used for topographic explanations of the study area by using ArcGIS.

**Geo-Studio (SEEP/W) Software.** The SEEP/W software (program) which is a sub-program of the Geo-Studio software was used to develop a numerical model that enables to simulate the distribution of uplift pressure and the seepage condition through the spillways chute foundation of Megech and Ribb dam projects with and without filter and drainage blanket. SEEP/W is a finite element package that can be used to model the fluid flow and pore-water pressure distribution within materials such as soil and rock [9]. Its comprehensive formulation makes it possible to analyze both simple and highly complex seepage problems [10].

## 2.3 Methods

Technical procedures that were formulated after problem identification in a way that answer research questions and address research objectives were outlined as of Fig. 2.

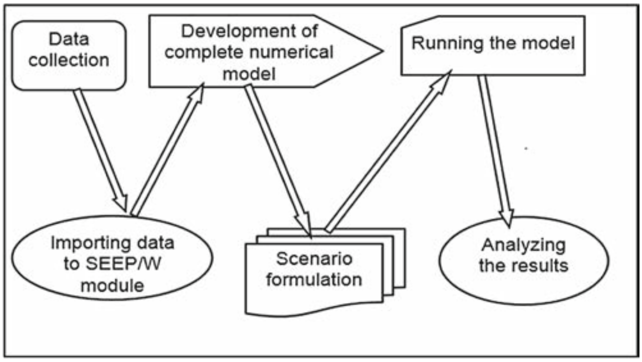


**Fig. 2.** Methods by schematic

**Numerical Model Setup.** After viewing the theoretical engineering basis, features and benefits for the SEEP/W program, the work procedures for the numerical model on the SEEP/W programs were done as follows:

*Construct the Model.* The first step to develop a numerical model in SEEP/W was defining the working area size, choosing the engineering units and setting the used scale. Sketching axes to define an evenly-spaced region for the axes, the number of increments along each axis was calculated by SEEP/W when the axes were generated. Then sketch model dimensions for drawing the problem region has been prepared.

*Analysis Parameters.* The first analysis parameter was the analysis type, the analysis type was selected as steady-state solution. Because under steady state conditions, the difference between input flux and output flux is zero at all times and solution to steady state, laminar-flow seepage problems can be obtained with the Laplace and Darcy equations. The analysis control was chosen as two-dimensional analysis. The coefficient of permeability of the foundation under the spillway chute had determined by Falling head and Packer test for both Megech and Ribb dam projects. Accordingly, the average hydraulic conductivity value has been fixed for Megech 4.71 * $10^{-6}$ m/s and for Ribb 4.74 * $10^{-6}$ m/s as per the tests result [11, 12]. Regions and finite elements were generated, the region boundary was drawn and number of elements in X and Y directions for region was chosen. The region was divided automatically by SEEP/W to number of elements.

*Boundary Conditions.* Boundary conditions in the study problem means the total head acting on upstream and downstream soil free surfaces. The total head acting on upstream side in this study problem is the normal pool level, and the total head acting on the downstream side is equal to zero since there is no stagnant tail water.

*Drawing Flux Section.* A flux section was required for the aim of studying problem to compute total seepage flow through floor of hydraulic structure model, flux section was drawn completely across elements which located under the hydraulic model floor in order to include flux through elements.

*Verification of the Studying Problem Data.* Before solution start, the problem data should be verified by SEEP/W to ensure that the data has been defined correctly, SEEP/W was performed a number of checks on the nodes and elements data, including filling any missing data, any missing node number, element overlap, initial water table, and appear these checks in the dialog box.

*Modelling Scenarios.* To analyze the distribution, impact of uplift pressure and pattern of the flow condition through the foundation of side channel chute spillway, model simulation with and without drainage sand beneath the chute slab were done for both Ribb and Megech Dam Spillways. During the model simulation the perforated transversal pipes which are located within 20 m interval parallel to each of the cutoff wall and the cutoff wall itself was considered. The effect and advantage of these drain pipes and cutoff walls was evaluated.

**Output and Results.** After the previous steps were done the output results can earn by seep/w as generating contour plot, displaying velocity vectors that represent the flow direction, displaying the computed flux across the specified section, displaying the numerical information for individual nodes and elements, and plotting graphs of the computed results.

**Validation of Model Results.** The simulated results obtained from SEEP/W software for different scenarios was compared as per the objectives and literatures stated on literature review portion of this study. Moreover, model results were validated with recorded data from installed Piezometer on the actual site.

# 3 Results and Discussion

## 3.1 Spillway Modelling and Model Result with and Without Drainage Sand

Figure 3 shows model simulation for Ribb Spillway cross-section with drainage blanket as designed and constructed and Fig. 4 displays model simulation of this Spillway cross-section without drainage blanket beneath the channel slab. In the same way the model is simulated for Megech Dam Spillway for the original design without drainage blanket beneath the chute slab and with sand blanket in place as of Fig. 9 and 10 respectively.

**Model Simulation for Ribb Dam Spillway as Designed**

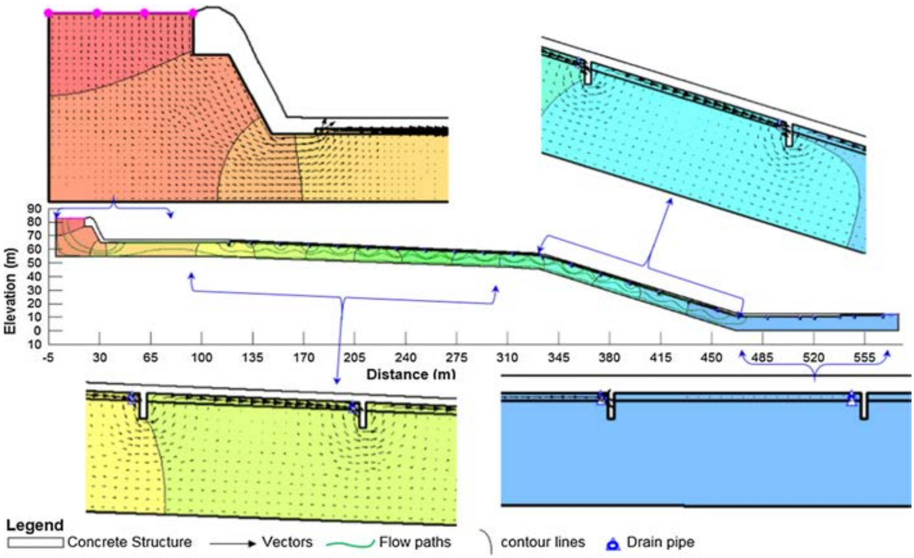


**Fig. 3.** Ribb spillway cross-section with drainage sand as designed and constructed

### Model Simulation for Ribb Dam Spillway without Drainage Sand

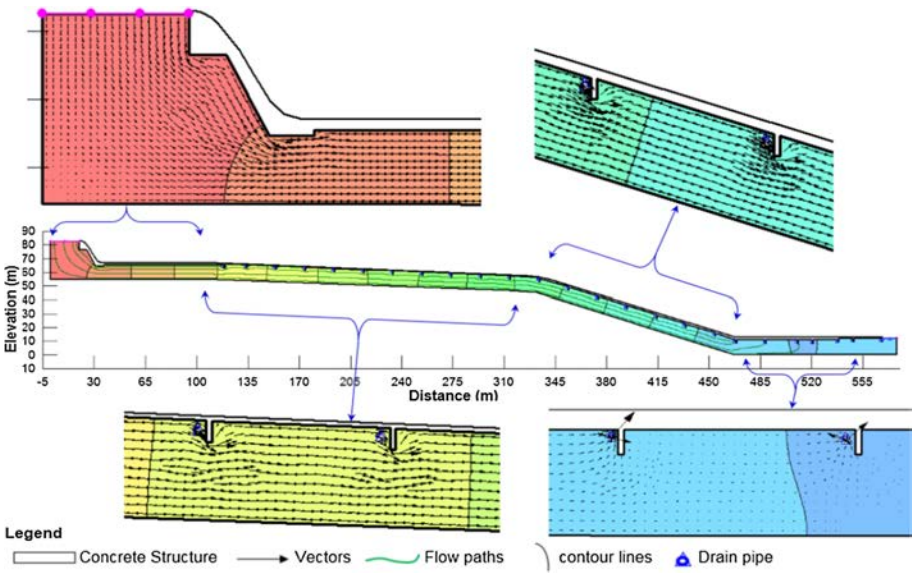


**Fig. 4.** Ribb spillway cross-section without drainage sand beneath channel chute slab

### Model Results Head Comparison of Ribb Spillway at Each Section

(See Table 1).

**Table 1.** Total uplift pressure head comparison of Ribb spillway with and without drainage sand blanket

| Chainage of selected nodes | Total uplift pressure head (m) | | Head reduction (m) | Head reduction (%) | Remark |
|---|---|---|---|---|---|
| | without sand | with sand | | | |
| (a) | (b) | (c) | d = (b − c) | e = (d * 100)/b | |
| 44.967 | 76.761 | 65.976 | 10.785 | 14.050 | Section 1 (From Chainage 0 + 000 up to 0 + 333) Chute with gentle slope (0.45%) |
| 64.968 | 73.355 | 65.623 | 7.732 | 10.540 | |
| 84.969 | 69.939 | 65.250 | 4.689 | 6.704 | |
| 104.970 | 66.518 | 64.879 | 1.638 | 2.463 | |
| 124.714 | 63.203 | 61.639 | 1.564 | 2.475 | |
| 144.782 | 60.451 | 58.914 | 1.536 | 2.542 | |

(*continued*)

**Table 1.** (*continued*)

| Chainage of selected nodes | Total uplift pressure head (m) | | Head reduction (m) | Head reduction (%) | Remark |
|---|---|---|---|---|---|
| | without sand | with sand | | | |
| (a) | (b) | (c) | d = (b − c) | e = (d * 100)/b | |
| 164.782 | 57.612 | 55.992 | 1.620 | 2.812 | |
| 184.782 | 54.748 | 53.052 | 1.696 | 3.098 | |
| 204.782 | 51.855 | 50.094 | 1.761 | 3.396 | |
| 224.782 | 48.934 | 47.118 | 1.816 | 3.712 | |
| 244.782 | 45.986 | 44.124 | 1.862 | 4.048 | |
| 264.782 | 43.007 | 41.110 | 1.897 | 4.411 | |
| 284.782 | 40.000 | 38.079 | 1.921 | 4.803 | |
| 304.782 | 36.963 | 35.027 | 1.936 | 5.238 | |
| 324.782 | 33.928 | 31.983 | 1.945 | 5.733 | |
| 344.271 | 30.971 | 28.981 | 1.989 | 6.423 | Section 2 (From Chainage 0 + 333 up to 0 + 468) Chute with steep slope (33.31%) |
| 364.271 | 27.723 | 25.925 | 1.798 | 6.484 | |
| 384.271 | 24.491 | 22.875 | 1.616 | 6.599 | |
| 404.271 | 21.286 | 19.841 | 1.444 | 6.785 | |
| 424.271 | 18.024 | 16.698 | 1.326 | 7.357 | |
| 445.241 | 14.626 | 13.625 | 1.001 | 6.845 | |
| 461.453 | 11.943 | 10.795 | 1.148 | 9.612 | |
| 479.145 | 10.574 | 10.165 | 0.409 | 3.868 | Section 3 (From Chainage 0 + 468 up to 0 + 568) stilling basin with 0% slope |
| 499.795 | 10.077 | 10.102 | −0.026 | −0.253 | |
| 516.477 | 9.899 | 10.100 | −0.201 | −2.033 | |
| 530.297 | 10.069 | 10.152 | −0.083 | −0.826 | |
| 544.157 | 10.320 | 10.422 | −0.102 | −0.987 | |
| 558.829 | 10.657 | 10.715 | −0.058 | −0.540 | |

The negative value at stilling basin section of the spillway indicates that the total head becomes greater when there is drainage blanket and perforated drain pipe beneath the stilling basin slab. The elevation head at this section is below the downstream river water level. The permeability of the drainage sand placed beneath the stilling basin slab is higher than the permeability of the downstream foundation. Due to this elevation head and permeability variation there is back water flow from downstream to stilling basin as shown on Fig. 9 which develops pore water pressure under the slab structure. The bedding slope of both transversal and longitudinal perforated pipe is horizontal which keeps the accumulated water to be stagnant rather than easily drain. That is why the total head becomes higher when there is drainage sand blanket beneath the stilling basin slab (Fig. 5).

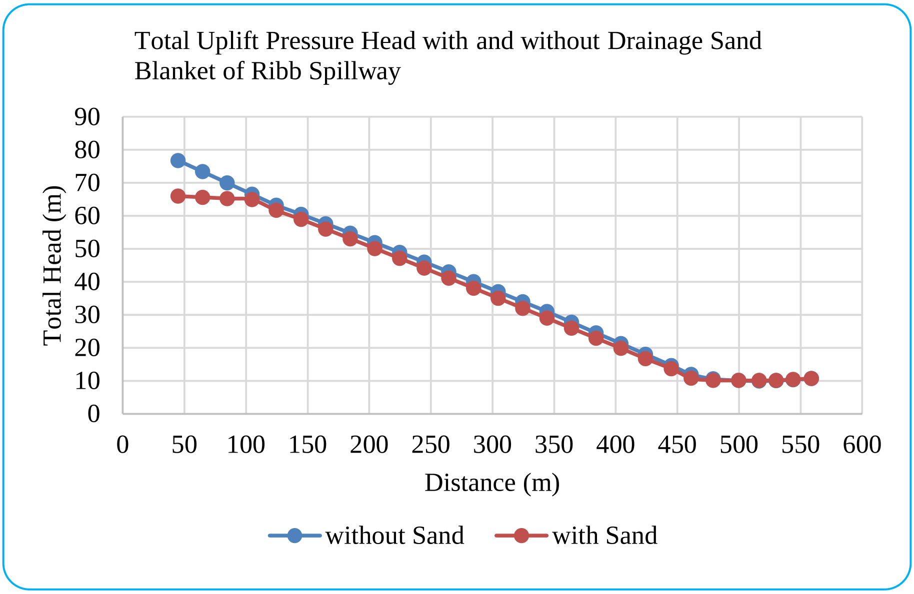


**Fig. 5.** Total uplift head comparison of Ribb spillway with and without drainage blanket

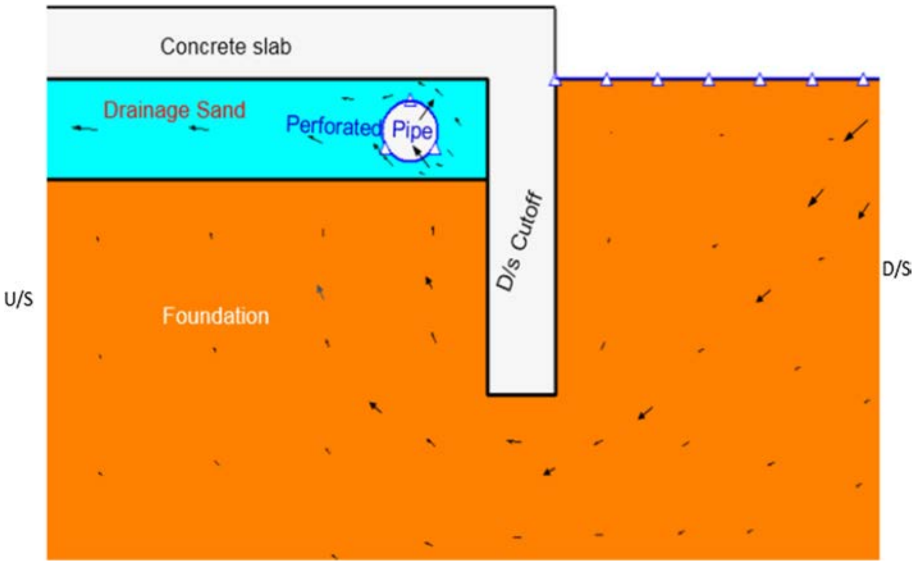


**Fig. 6.** Entering and surcharging of d/s tail water to the under-slab drainage system of stilling basin

**Comparison of Measured Head and Model Result of Ribb Spillway**

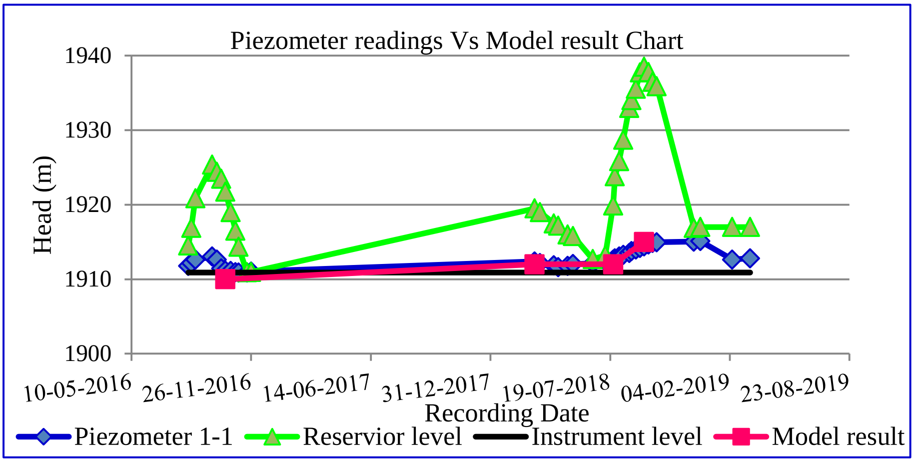


**Fig. 7.** Comparison of measured head and model result of Ribb spillway

There are many instruments installed on Ribb Dam at different locations to monitor the dam and its appurtenant structures. Piezometer 1-1 is one of a vibrating wire piezometer which was installed in the abutment foundation near to the spillway to measure ground water elevations and pore water pressures around spillway foundations. Data was recorded every week from this piezometer. More than three years data from piezometer 1-1 was taken for validation purpose of the numerical model.

The model was simulated for different reservoir levels (1920, 1925, and 1938) m amsl which are the peak reservoir level at different season as shown in Fig. 7. The model result taken from similar location of piezometer 1-1 at each stated reservoir level model output was compared with the measured values taken at the same reservoir level. The relationship of measured head and model result is direct as shown on Fig. 8.

**Pressure Head Validation for Ribb Dam Spillway**

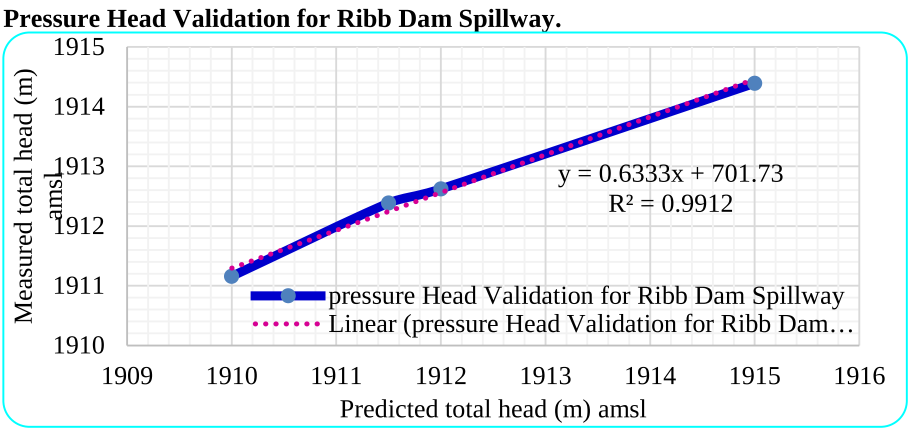


**Fig. 8.** Pressure head validation for Ribb dam spillway

## Model Simulation for Megech Dam Spillway as Designed

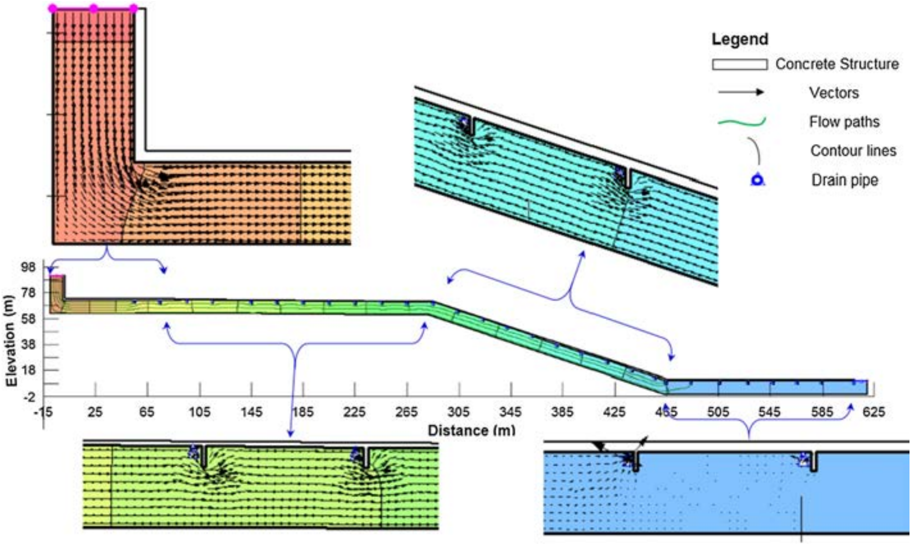


**Fig. 9.** Megech spillway cross-section without drainage sand as designed and constructed

## Model Simulation for Megech Dam Spillway with Drainage Sand

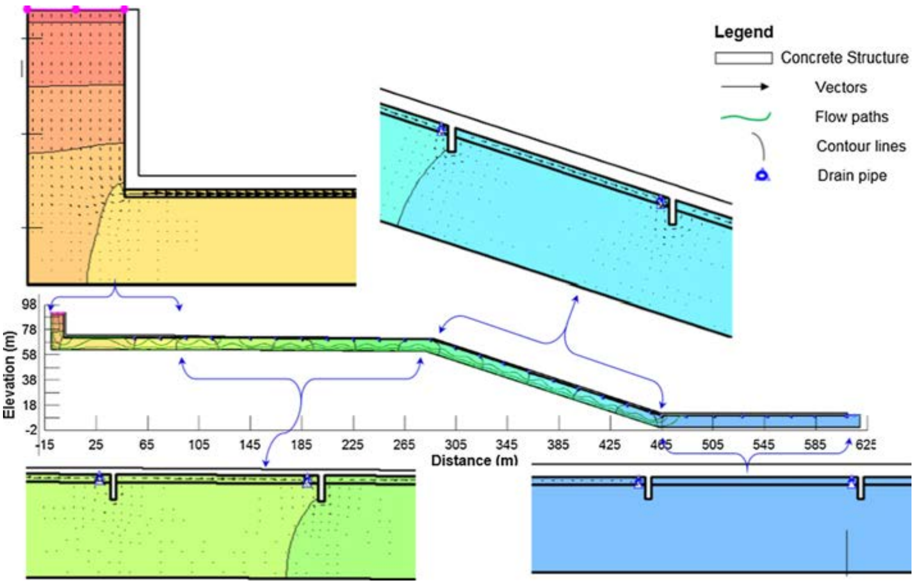


**Fig. 10.** Megech spillway cross-section with drainage sand beneath channel slab

(See Table 2).

**Table 2.** Total uplift pressure head comparison of Megech spillway with and without drainage sand

| Chainage of selected nodes | Total uplift head (m) | | Measured Total uplift head (m) | Head reduction (m) | Head reduction (%) | Remark |
|---|---|---|---|---|---|---|
| | without sand | with sand | | | | |
| (a) | (b) | (c) | (d) | e = (b − c) | f = (e * 100)/b | |
| 9.911 | 82.597 | 72.301 | 72.023 | 10.296 | 12.465 | First Chute with gentle slope (1%) (From Chainage 0 + 000 up to 0 + 284) |
| 29.732 | 77.729 | 71.830 | 71.220 | 5.900 | 7.590 | |
| 49.554 | 72.811 | 71.364 | 70.491 | 1.448 | 1.988 | |
| 66.311 | 69.928 | 68.215 | 69.018 | 1.713 | 2.450 | |
| 85.500 | 66.999 | 65.143 | 66.796 | 1.856 | 2.771 | |
| 106.187 | 64.067 | 62.204 | 66.460 | 1.863 | 2.909 | |
| 130.478 | 60.535 | 59.099 | 62.873 | 1.437 | 2.373 | |
| 296.232 | 35.875 | 34.815 | 40.812 | 1.060 | 2.955 | 2nd steep Chute (33.42% slope) (Chainage 0 + 284 up to 0 + 464) |
| 411.046 | 18.519 | 18.156 | 23.624 | 0.363 | 1.959 | |
| 429.690 | 15.582 | 15.277 | 18.838 | 0.306 | 1.962 | |
| 448.551 | 12.618 | 12.413 | 13.621 | 0.205 | 1.624 | |
| 461.600 | 10.328 | 9.521 | 10.222 | 0.807 | 7.815 | |
| 476.125 | 9.536 | 9.261 | 10.000 | 0.275 | 2.888 | Stilling basin with 0% slope (Chainage 0 + 464 up to 0 + 610) |
| 495.988 | 9.168 | 9.251 | 10.000 | −0.083 | −0.905 | |
| 517.888 | 9.057 | 9.250 | 10.000 | −0.193 | −2.126 | |
| 539.544 | 9.057 | 9.250 | 10.000 | −0.193 | −2.129 | |
| 557.131 | 9.079 | 9.250 | 10.000 | −0.171 | −1.885 | |
| 576.625 | 9.098 | 9.250 | 10.000 | −0.152 | −1.670 | |
| 599.085 | 9.282 | 9.252 | 10.000 | 0.030 | 0.319 | |

The total head with drainage sand beneath the stilling basin slab is higher than the total head under the slab without the sand. The justification for this scenario is the same as explained above for Ribb Dam spillway.

The ground water level at Megech spillway foundation was directly measured by using an apparatus called deep meter during borehole drilling for anchor bar installation throughout the length of the spillway at 20 m interval. The model result was taken from the selected location for ground water measurement. The measured head and model result were compared and the relationship is direct (Figs. 11 and 12).

**Pressure Head Validation for Megech Dam Spillway**

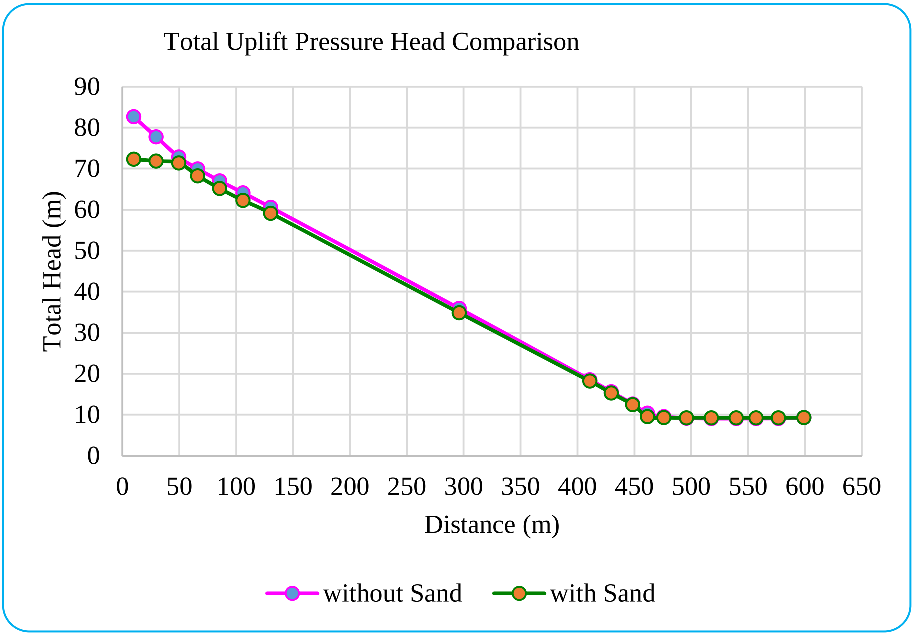


**Fig. 11.** Residual head comparison of Megech spillway with and without drainage blanket

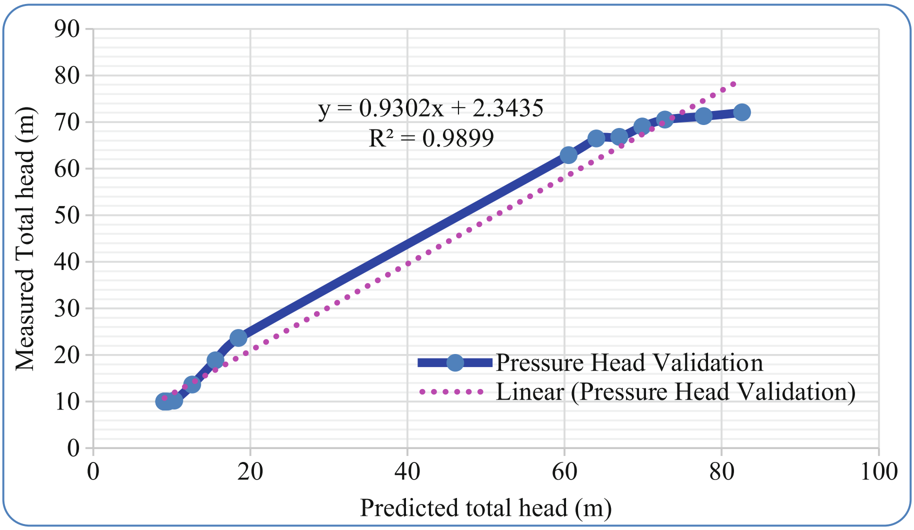


**Fig. 12.** Pressure head validation for Megech dam spillway

### 3.2 Uplift Pressure with and Without Drainage Sand

The simulated model results of both Ribb and Megech Dam Spillways with and without drainage sand beneath the spillway chute are compared as per the objective of this study.

The drainage sand provided beneath the structure chute slab reduces the uplift force acting on the structure slab as shown in Fig. 13 throughout the spillway Chainage.

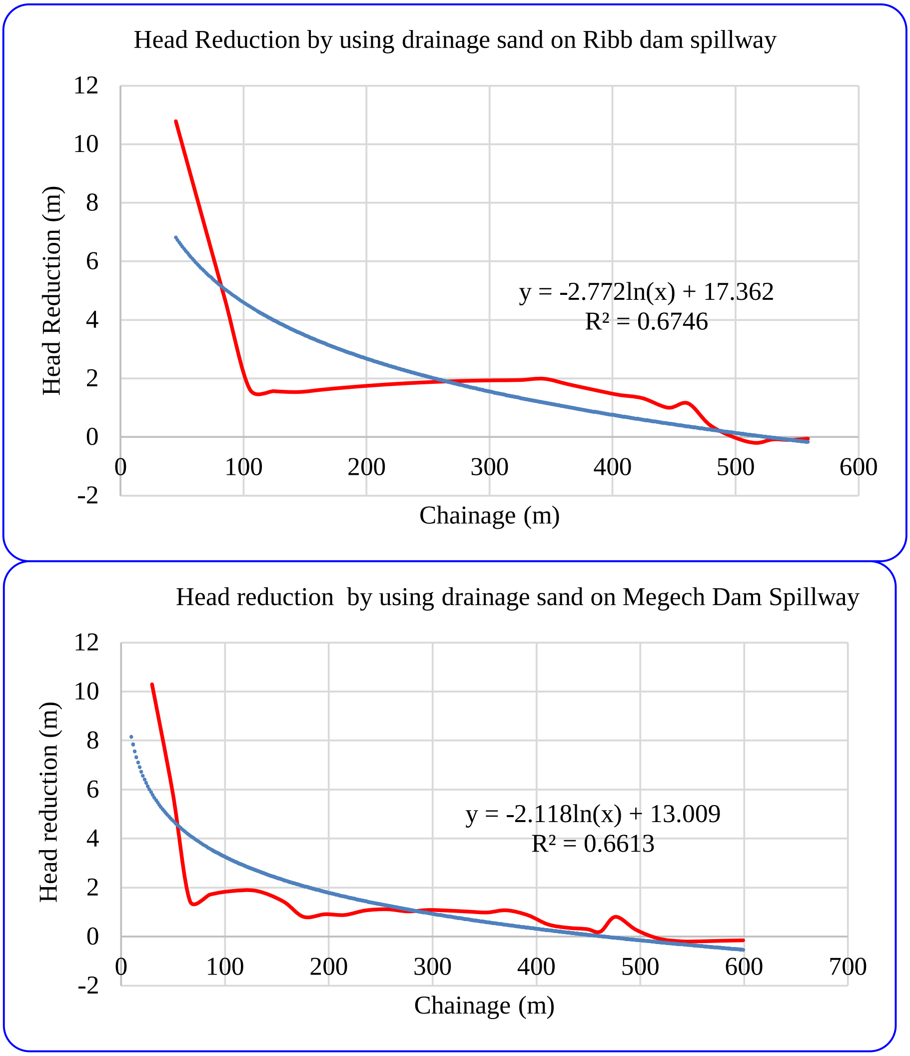


**Fig. 13.** Reduction of uplift pressure throughout the spillway Chainage by using drainage sand

Drainage blankets, drain pipes and cutoff walls are considered as effective measures to reduce seepage, uplift pressure and exit gradient under the foundation of hydraulic structures [4].

Cutoff walls were designed and constructed within 20 m interval throughout the spillway reach and perforated transversal drain pipes were installed parallel to each cutoff wall on both Ribb and Megech spillways. This arrangement causes the uplift reduction by providing drainage sand beneath the structure not same throughout the chute and ups and downs as shown in Fig. 13.

### 3.3 Distribution of Seepage and Uplift Pressure at Spillway Sections

**Seepage and Uplift Pressure at Control and Chute Sections.** The main seepage reduction zone for a chute spillway is typically located at the control section area [13]. The Control Section at Ribb Dam Spillway includes an impervious blanket constructed within the cross section of the approach channel, an impervious embankment constructed behind the abutment walls, a cutoff wall and a grout curtain which extends beneath control structure that makes the spillway safe against uplift pressure as shown in Fig. 14.


**Fig. 14.** Approach and control section of Ribb dam spillway

Whereas, the topographic condition of Megech dam spillway requires an impervious embankment which should be constructed behind the abutment walls or any other barrier to block the reservoir water entering to the back of the approach wall that may increase the uplift pressure under the near chute slab as shown on Fig. 15.

The seepage coming from reservoir under approach slab seeps to the foundation of spillway channel slab and intercepted by transverse perforated drain pipes that typically provided at 20 m intervals to intercept and convey seepage flows into a collection manhole located at either end of each of the drain pipes. From the coming seepage 42.24% of the seepage removes by the first transverse perforated pipe. In this case the first transverse perforated pipe in the chute section serves as pressure relief drains as shown in Fig. 16. The diameter of this first transverse perforated pipe is 25 cm which is more than enough to accommodate the coming seepage, 1.74E−05 $m^3$/s. As it is stated on US Army Corps of Engineers Manual the perforated transverse drainpipes should not be less than 20 cm in diameter in order to minimize the chance of plugging and to facilitate inspection and

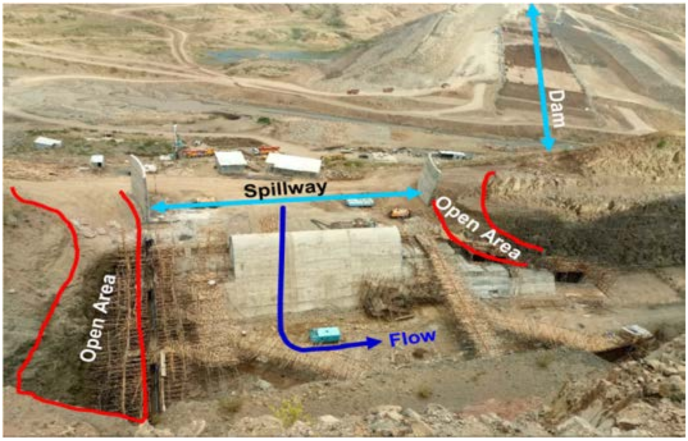


**Fig. 15.** Approach and control section of Megech dam spillway

maintenance. Therefore, the size of this pipe installed on Megech and Ribb dam spillway is acceptable.

A longitudinal pipe is used to connect the manholes and convey seepage water into the outlet channel. This drainage system reduces the seepage and uplift pressure from upstream to downstream gradually. Figure 16 shows the interception of the coming seepage by transverse perforated drainpipes and reduction of uplift pressure towards downstream.

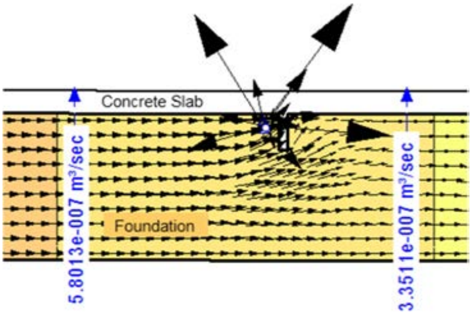


**Fig. 16.** Interception of Seepage flow under foundation of Megech dam spillway

**Seepage and Uplift Pressure at Terminal Section of the Spillway.** The first preference is to provide a narrow basin, where feasible, that can be designed to resist the entire uplift pressure that occurs due to the hydraulic jump by weight rather than relying on drains. Because drains may plug easily, difficult for maintenance and increase risk when they may not be fully functional [14]. However, for wide basins where it is determined that the drainage system is viable and cost effective, a separate (i.e. isolated from the chute under slab drainage system in order to prevent surcharging) under slab drainage system consisting of a drainage blanket (filter sand and/or drainage gravel) and perforated drainpipes may be incorporated. Water collected by the transverse drainpipes would normally be conveyed into manholes that would also permit access for inspection and maintenance. Although the under-slab drainage system will ordinarily be below the bed of the outlet channel, it may be possible in some cases to discharge some of the water by gravity from the manholes back into the stilling basin near the start of the jump. In other instances, pumping may be required. Careful attention to backfill provisions and cutoff requirements particularly along the sides and downstream end of the basin slab is required to prevent tail water from entering and surcharging the under slab drainage system (i.e. becomes a pump) [13].

Megech and Ribb Dam Spillway Stilling Basins are wide which leads the drainage system to be under slab drainage system consisting of a drainage blanket and perforated drainpipes that is viable and cost effective rather than providing a narrow basin that can be designed to resist the entire uplift pressure due to the hydraulic jump by weight. Although, the Stilling Basin at Ribb Dam Spillway is designed and constructed with a drainage blanket and perforated drainpipes as stated above, the drainage system is not isolated from the chute under slab drainage system in order to prevent surcharging that increases the uplift pressure under the stilling basin. Whereas, in the Megech dam spillway, there is no any drainage blanket provided beneath the stilling basin slab except the bedding sand placed for protection of the perforated transversal pipes which are located within 20 m interval parallel to the cutoff wall.

The model simulation result of both Megech dam spillway and Ribb Dam Spillway shows no reduction of uplift pressure in the stilling basin by using drainage blanket beneath the stilling basin slab rather it allows the tail water to enter and surcharge the under-slab drainage system as shown in Fig. 6. The slope of the stilling basin is 0% towards downstream and the ground level of the abutment behind the wall on each side (left and right) of the basin as well as the level of tail water is above the foundation of the stilling basin floor on both Megech dam spillway and Ribb Dam Spillway. Due to this elevation difference the drainage sand provided beneath stilling basin slab can’t drain the develop water. This situation enforces the water developed under the stilling basin slab to be stagnant that increases the uplift pressure.

## 4 Conclusion and Recommendations

In this study, uplift pressure and seepage condition under side channel chute spillway was studied with and without drainage sand blanket beneath the chute slab considering the case of Megech and Ribb Dam Spillways. From the analysis, conclusion and recommendations were made.

### 4.1 Conclusion

The effect of drainage blanket on reducing uplift force varies on the different sections (control section, chute and stilling basin) of the spillway.

On Ribb dam spillway up to 14% reduction of uplift pressure around control section and an average of 5% uplift pressure reduction at chute section of the spillway was detected by using drainage sand beneath the structure. But no reduction of uplift pressure in the stilling basin by using drainage sand blanket beneath the stilling basin slab rather it allows the tail water to enter and surcharge the under-slab drainage system. Because the slope of the stilling basin is 0% towards downstream and the ground level of the abutment behind the wall on each side (left and right) of the basin as well as the level of tail water is above the foundation of the stilling basin floor. Moreover, the permeability of the drainage sand placed beneath the stilling basin slab is higher than the permeability of the downstream foundation. Due to this elevation and permeability difference the drainage sand provided beneath stilling basin slab can't drain the develop water. This situation en-forces the water developed under the stilling basin slab to be stagnant that increases the uplift pressure. Therefore, the provided drainage sand blanket beneath the spillway channel slab at control and chute section of Ribb dam spillway is necessary and good design. But this drainage system is not essential at the stilling basin of the spillway.

If this drainage sand has been used on Megech dam spillway up to 12% uplift reduction around control section and an average of 3% reduction can be achieved at chute section of the spillway. Therefore, the design and construction of control and chute section of Megech dam spillway without drainage sand blanket beneath channel slab is not safe against uplift pressure.

### 4.2 Recommendations

The stilling basin drainage system of Ribb dam spillway should be isolated from the chute under slab drainage system in order to prevent surcharging that increases the uplift pressure under the stilling basin. In addition to this careful attention to backfill requirements and the extent of cutoff walls is required to ensure that tail water is prevented from entering and surcharging the under-slab drainage system at the stilling basin.

The topographic condition of Megech dam spillway around control section requires an impervious embankment which should be constructed behind the abutment walls or any other barrier to block the reservoir water entering to the back of the approach wall that may increase the uplift pressure under the near chute slab.

Piezometers should be installed in the drainage blanket and deeper strata to monitor the performance of the drainage systems. If the drains become plugged or otherwise non effective, uplift pressures will increase which could adversely affect the stability of the structure.

If there will be an improved method to know the amount of water flowing into cracks and joints during spillway releases, the water can be considered in addition to ground water and the seepage from reservoir for better estimation of uplift force.

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