Study of the Sarough Dam Fusegates

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Abstract

Dam construction industry has concerned specific attention to engineering economy, over the past years; so in this direction the topic of emergency fusegates has considered as a new technology since 1989, in all over the world. Fusegate is a simple, safe, and robust structure in increasing live storage or spillway capacity and a mechanical equivalent of a fuse plug. Although the installation of gates with different types and heights might practically be difficult, but its lower annual cost, flexibility in operation and smaller wasted water resulting from gates tipping justifies their selection as a more desirable solution. In this paper, the fusegates of Sarough storage dam (Googerdchi) in West-Azerbaijan province is studied an analyzed. The fusegates are installed for the first time in Iran, on Sarough dam spillway instead of radial gates. By installing these gates, the storage capacity of the reservoir increased up to gates overhead level for about 10 mcm. Flood hydrograph in six different return periods (from 2 to 1000 years) of the dam, shows that dam capacity has increased by equipping with fusegates. In addition, a comparison discharge-time-reservoir level chart between 1st to 6th individual fusegate overthrow periods is done.

Keywords: Fusegates, Sarough Dam, Spillway Capacity, Flood.

1. INTRODUCTION

Increasing the storage capacity of existing reservoirs might be considered an economical and effective alternative for their alleviation. Fusegates installation is a comparatively new alternative, which has increased in popularity during recent years due to its numerous advantages. Since their first real-world application in the Lussas Dam in 1991, they have been widely used in over 50 dams all over the world and have gained considerable recognition as a safe and economical tool for providing extra water supply (Chevalier, 2004). Fusegates are essentially a technical method to increase the maximum water level without structural dam heightening. Fusegates may be efficiently implemented to increase spillway capacity without sacrificing existing reservoir storage. In fusegates system, gates are placed side-by-side to fill in the original spillway width. (Afshar and Takbiri, 2012). The fusegated spillway is favored to pass the design flood with maximum water level not exceeding that of original free spillway. Different gates combinations, their setting aprons, and varying routing characteristics of the fusegated spillway should be employed to fulfill this requirement. The principal advantage of fusegates over fuse plugs lies in their operational schedule. Fuse plugs completely fail when they overtop whereas a number of tipping fusegates depends on flooding conditions and design tipping head of the individual gates.

Fusegates were invented in 1989 by Francois Lemperiere as a simple, robust, and safe system to increase live storage or spillway capacity. The system has been patented by Hydroplus International in the United States, Europe, and most other countries. It is implemented in more than 40 dams in 14 different countries across 5 continents (Falvey and Treille, 1995). This system can be a good alternative for radial gates without any need to mechanical and electrical equipment and continuous maintenance; such a structure can be placed on running or even constructed dams separately. By installing this gate, the capacity of reservoir can be increased by maintaining safety factor and without any need to increase dam height. In some special cases this structure can be used to increase the capacity of overflow drain (discharge) without increasing the length of overflow threshold.

The fusegates will increase the capacity of the spillway without exceeding the flood pool level. Fusegates have the shape of a labyrinth weir and thus pass more flow than an equivalent straight crest. Among different type of spillways, the labyrinth one is a useful structure for the reservoirs having narrow floodways in which, by increasing the crest length in a constant width, the spillway enhances its conveyance capacity by maintaining upstream water level (Hosseini et al., 2015). A labyrinth weir (Fig. 1) is a type of polygonal overflow structure that has a distinct geometric shape (triangular, trapezoidal, or rectangular cycles in plan-view) and advantageous hydraulic characteristics.Labyrinth weirs are used as primary orauxiliary spillways (new and rehabilitated structures) to increase discharge capacity, regulate water levels (e.g., intake ponds, residential areas, rivers with high max/min flow ratios), or as a cost-effective, passive-control alternative to gated control structures. (Crookston and Tullis, 2013). The most hydraulically efficient design of the labyrinth spillway is not always possible because of limited construction costs and/or implementation issues in construction procedure must be considered for the overall effectiveness of the project (Paxson et al., 2011). A labyrinth spillway is an overflow weir folded in plan view to provide a longer total effective length for a given overall spillway width a labyrinth spillway has advantages compared to the straight overflow weir and the standard ogee crest. The total length of the labyrinth weir is typically three to five times the spillway width. Its capacity varies with head and is typically about twice that of a standard weir or overflow crest of the same width. (Tullis et al., 1995). The capacity of a labyrinth spillway is a function of the total head, the effective crest length, and the crest coefficient. The crest coefficient depends on the total head, weir height, thickness, crest shape, apex configuration, and the angle of the side legs. Another important variable that influences the general layout and economy of a labyrinth is the number of cycles, *N*. Ultimately, the design engineer should seek an economical layout with good hydraulic performance (Ghare et al., 2008).

Figure 1: Example of a labyrinth weir (after Crookston and Tullis, 2013)

The Fusegate System is based on the following concept:

- Fusegates are free-standing units installed side-by-side on a spillway sill to form a watertight barrier.
- They bear against small abutment blocks set in the sill to prevent them from sliding before they are required to rotate (under extreme flood conditions).
- There is a chamber in the base of each Fusegate, with drain holes to discharge incidental inflow (due to leaking seals for example).
- An inlet well on the upstream side of the Fusegate crest discharges water into the chamber when the headwater reaches a predetermined level (see figure 2).

In normal operating conditions, the Fusegates act as a watertight barrier. Medium to moderate floods are simply discharged above the Fusegate crest as they would do over a free weir (see figure 3).

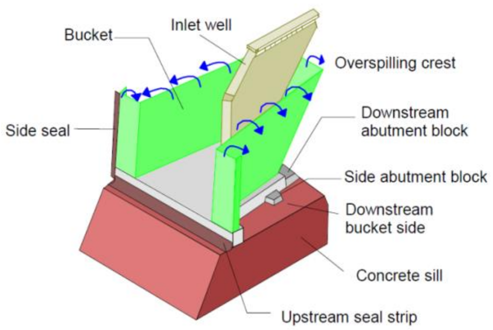

Figure 2: Typical 3D view of a Fusegate

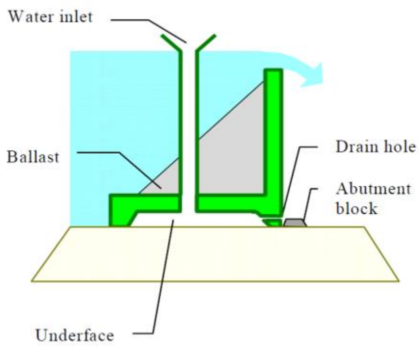

Figure 3: water spills over the Fusegate

If the reservoir level exceeds a predetermined value, water will flow into the inlet well and cause an uplift pressure to develop in the chamber (see figure 4). The uplift pressure, combined with the hydrostatic pressure (acting from left to right on the adjacent diagram) is sufficient to overcome the restraining forces and the imbalance causes rotation of the unit off the spillway. The Fusegate is then washed away clear of the spillway by the flood (see figure 5).

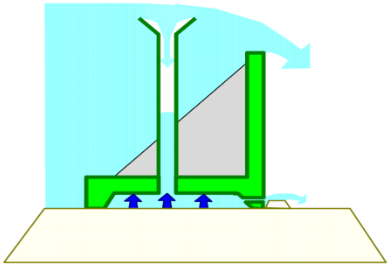

Figure 4: well-being fed

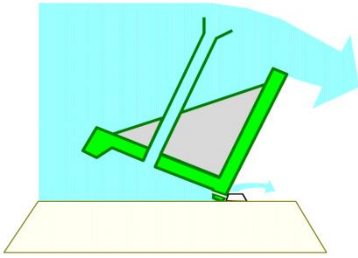

Figure 5: Fusegate tipping

2. MATHERIALS AND METHODS

2.1. STUDY AREA

Sarough Reservoir Dam (Gugerdchi) is located in about 17 km north of the Takab city, in the West-Azerbaijan province, Iran, between 36˚30'54" N latitude and 47˚06'40" E longitude; Figure 6 shows its satellite picture and its position in the country. Its capacity is about 40 mcm (million cubic meters); It is a clay core rockfill dam and construction of the dam is conducted in order to meet the following objectives: - To supply 10.3 mcm drinking and industrial water. - Development of 40 mcm of water to irrigate 5500 hectares of ground area. Dam's spillway is showed in figure 7.

2.2. EQUATION

Hydraulic features of fusegates have obtained by hydraulic models in Europe and America laboratories and has

Figure 6: Study Area

conducted equal to special weather conditions for Sarough dam reservoir project. Adapted data from laboratory model roughly correspond with current standards. Flood discharge flow from crown to length is computed by following equation:

$$Q = \sqrt{2g}\,\mu\, h^{3/2} \qquad if\ \ h < 0.27\ m \qquad (1)$$

$$Q = (A.h + B).k \qquad if\ \ h > 0.27\ m$$

Where h = Flow elevation upper than crown gate that make to pure; K, B, A and μ are constant values; S is determined due to physical parameters and physical conditions of flow. Constant values have implemented by experimental model in laboratories and has simulated for Sarough dam which is A = 4.99 and B = -0.7.

3. Results and Discussion

3.1. Hydrograph

The peak flood discharge of the Sarough dam reservoir for 2, 10, 20, 50, 100, 1000, and 10000 return period (years) is 78, 150, 187, 237, 270, 427, and 614 (m^3/s), respectively; Design flood is 10000 years. The dam inflow hydrographs are displayed in the figure 7.

3.2. Geometric features of fusegates

Geometric features of Sarough dam fusegates are briefly presented in Table 1.

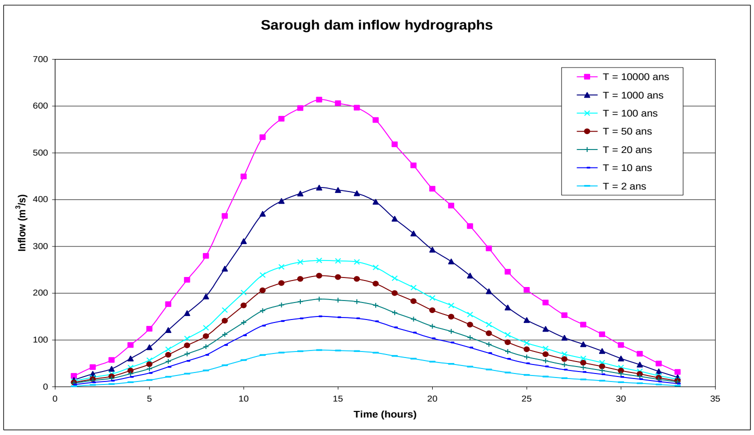

Figure 7: Hydro graphs flood with different return period in Sarough Dam

Table 1: Geometric features of fusegates

Gate Type	Snails with Average Height
Number of Gates	6
Gate Height	3.5 m
Gate Length	3.47 m
Real Gate Length	3.50 m
Crown Length of Spillway Gates	21 m
Gate Width	3.52 m
Base Elevation of Gate	1837.80 m
Crown Elevation of Gate	1841.30 m

Table 2: Determined reversal elevation for each gate

Reversal Order	Gate	Reversal Elevation (m)	Elevation difference with crown gate (m)	Height difference with spillway crown elevation (m)
1	F1	1843.30	2	5.50
2	F2	1843.34	2.04	5.54
3	F3	1843.38	2.08	5.58
4	F4	1843.41	2.11	5.61
5	F5	1843.44	2.14	5.64
6	F6	1843.46	2.16	5.66

Figure 8: Laboratory Model

Figure 9: A view of gates swamp

3.3. REVERSAL SCHEME

Reversal elevation is increased level of dam's water area that lead to gate reversal. This elevation will be in the upstream of spillway; and in this step, velocity of inflow current is very low and specified reversal elevation to each gate is according to table 2.

Figure 8 displays a view of establishment of fusegate model at the threshold spillway, which is a part of implementation on an experimental model in the laboratory; Figures 9 shows a view of every six gates swamp.

A comparison discharge-time-reservoir level chart between first and 6th individual reversing fusegate are displayed in figure 10 and 11, respectively. The hydrograph of Sarough dam equipped with fusegates for 10 and 10000 years flood are shown in figure 12 and 13, respectively which 10000 years flood is design flood. The effect of fusegate installation are well illustrated, in these resent four figures.

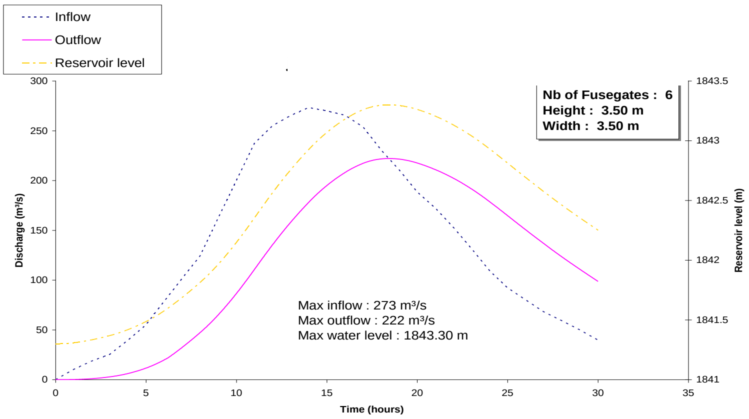

Figure 10: Dam equipped with fusegates just before 1st reversing

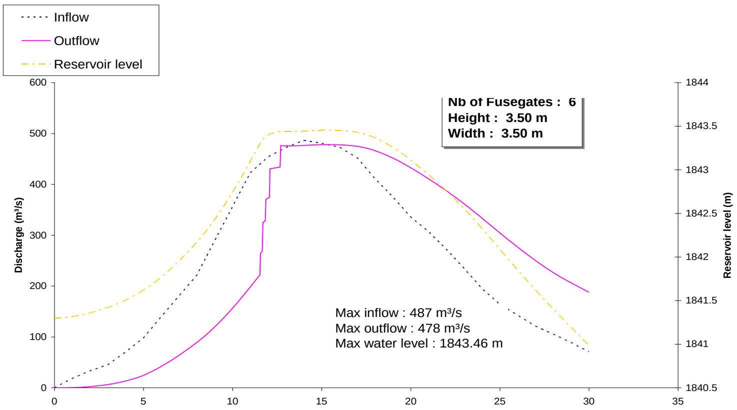

Figure 11: Dam equipped with fusegates just before 6th reversing

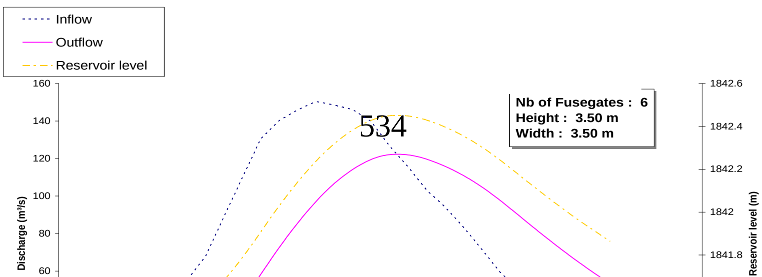

Figure 12: Dam equipped with fusegates for 10 years flood

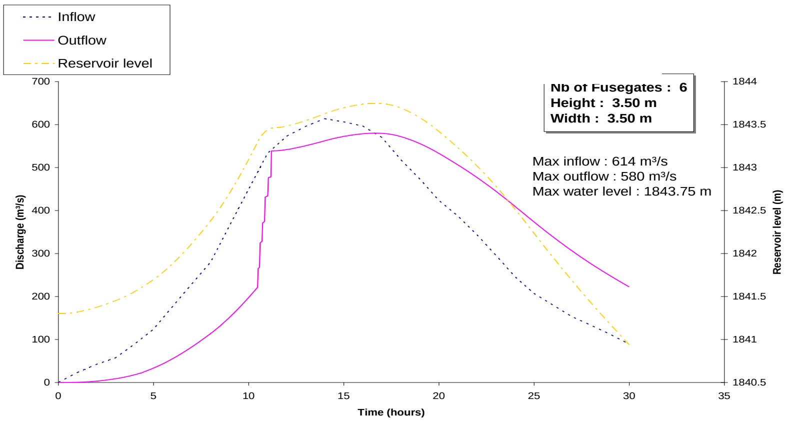

Figure 13: Dam equipped with fusegates for 10000 years flood (design flood)

4. CONCLUSIONS

Gates reversal are performed continuously one after the other and gates with average opening height will be able to overturn and empty by floods with return period of 100 years and less, easily. Without any additional operation, fusegates in comparison with mechanical errors or lack of access to electricity and other mechanical gates, can act as the simplest structure in safety and stability of dams and spillways against occurrence of large floods. With installing the mentioned gates, the reservoir storage capacity of dam has increased about 10 mcm until the align of gates crown.

By installing these gates, the storage capacity of the reservoir increased up to gates overhead level for about 10 mcm. Flood hydrograph in six different return periods (from 2 to 1000 years) of the dam, shows that dam capacity has increased by equipping with fusegates. In addition, a comparison discharge-time-reservoir level chart between 1st to 6th individual fusegate overthrow periods is done that illustrate the effect of these gates well.

5. ACKNOWLEDGMENT

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