

8-1-2014

Pressure Fluctuations On The Slabs Of Stilling Basins Under Hydraulic Jump

Abdollah Sobani

Follow this and additional works at: http://academicworks.cuny.edu/cc_conf_hic



Part of the [Water Resource Management Commons](#)

Recommended Citation

Sobani, Abdollah, "Pressure Fluctuations On The Slabs Of Stilling Basins Under Hydraulic Jump" (2014). *CUNY Academic Works*.
http://academicworks.cuny.edu/cc_conf_hic/379

This Presentation is brought to you for free and open access by CUNY Academic Works. It has been accepted for inclusion in International Conference on Hydroinformatics by an authorized administrator of CUNY Academic Works. For more information, please contact AcademicWorks@cuny.edu.

PRESSURE FLUCTUATIONS ON THE SLABS OF STILLING BASINS UNDER HYDRAULIC JUMP

ABDOLLAH SOBANI (1), SHAHIN HASANI MEHR (2)

(1): Department of Civil Engineering, K.N.T University of Technology, No.5, Moosavi Aley, Ohadi Ave., P.code:5513913176, Maraghe, East Azarbayjan, Iran

(2): Department of Civil Engineering, Tabriz University, Address No.9, ZiaAzar Ave. Pastore Gadim, P.code:5138966473, Tabriz, East Azarbayjan, Iran

Although in the design of hydraulic structures generally the average characteristics is considered, but according to studies, use of this approach for the design of structures such as spillways and the stilling basins which are under the influence of turbulent flows and in other hand, the difference between the moment values of the parameters of the medium values, are impressive, is not recommended. Due to the enormous and costly construction and operating costs of such buildings, the study of fluctuation characteristics of the turbulent flow and their role in estimating the maximum tensile force is necessary and inevitable.

Keywords: pressure fluctuations, hydraulic structures, stilling basin, hydraulic jump, cavitation

1-INTRODUCTION

The phenomenon of pressure fluctuations in hydraulic structures, in recent decades have been considered of a large number of hydraulic engineers and researchers.

Along with the rapid developments in science of applied hydraulic and building thousands of large and small hydraulic structures around the world, the need to identify and measure the pressure exerted by the water on the components of structures on the structural design is more and more. Particular attention to safety issues in the design of hydraulic structures and the need to avoid economic losses, is needed a true understanding of the size and the characteristics of the stresses applied to surface of hydraulic structures which are under the effect of turbulence.

In energy dissipaters hydraulic structures like stilling basins which dissipates energy in outlet of dams by mixing water and air and turbulence creation, especially by hydraulic jump, this pressure fluctuations are so important. In these structures, respect of average particulars of flow for designing are not enough and can't explain effective forces on this type of structures, because the moment pressure fluctuations may be serious risk to the structure, therefore, it is necessary to examine and interpret the characteristics of pressure fluctuations.

2-RECORDS

Most of the engineering design of hydraulic structures are based on the average particulars of flow and experience has shown that usually hydraulic structures that have been designed with consideration of this average specification, have been shown acceptable performance and has a good operation.

In the case of hydraulic structures which are under effect of turbulent flows, considering the average properties of the flow was not sufficient for their design and is not properly represent effective forces on this type of structures. Therefore, these structures requires a careful design and by attention to the fundamentals of fluid dynamics.[1]stilling basins (hydraulic jumps) are the most obvious examples of these structures. High speed flow after passing through the spillway and chute if with the same speed enter the downstream of the river will make bed scour in downstream, there are many ways to prevent and control this phenomenon. [2]Including the creation of a hydraulic jump in a certain location immediately downstream of the weir, turn supercritical flow to a sub-critical flow with low speed. [3] stilling basin is a short section of a floored channel in bottom portion of the dams spillway or any other place that is exposed to supercritical flow, which the purpose of making it; is controlled formation of hydraulic jump inside it.In this case supercritical flow with high kinetic energy, before reaching other parts of the river which are unfloored is converted to subcritical flow with potential energy.In recent years, especially after the destruction the chute of the Karnafuli dam in Bangladesh (Figure 1) in 1961 due ignoring the phenomenon of pressure fluctuations on the project was announced more attention to this issue and a lot of research on aspects of it have been.The base of pressure fluctuations in this structures is vibrational features of hydraulic jump phenomenon which are caused by vortexes and mixing air with the water and it used for additional energy dissipation of the water flow [4]

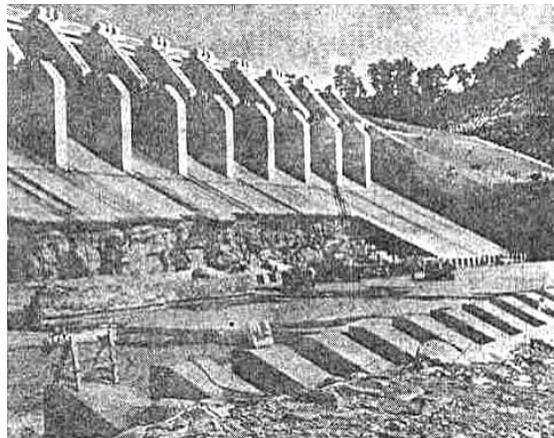


Figure 1. The chute of the Karnafuli dam in Bangladesh after destruction

Energy dissipation and turbulent flow in stilling basins is associated with intensive pressure fluctuations. [5]This intensive volatility may cause the take-off power (Uplift Force) under structures and causes a significant rise dislodge stilling basin floor slabs or Tiredness (Fatigue) of materials used in intermittent loading and unloading, or destruction floor and to create cavitation.

If there is discontinuities at the boundaries of flow, detachment of the flow from structure because of these discontinuities can increase the intensity of pressure fluctuations and local demolishing of structure. [6]

Also, due to the concentration of energy in the dominant frequency range of fluctuations, the risk of structural vibration also increases the risk of cavitation. Stilling basins, where is formed hydraulic jump by extreme water turbulence, and the resulting pressure fluctuations in the bed and the wall flow surface as they occur. These fluctuations may sometimes be more than structural bearing capacity and have been partially or totally destroyed, it will be held. Several cases of severe injury stilling basins of the pressure fluctuations is reported that most of them is for stilling basins of Karnafuli Dam in Bangladesh and the Malpas dam in Mexico.



Figure 2. Spillway and chute of the Karnafuli dam in Bangladesh

Serious study on the effects of pressure fluctuations on stilling basins began in 1961. [7] In this year chute of Karnafuli dam spillway (Figure 2) was severely damaged. While the current flow through it during the demolition was only 20% of designed discharge of it. Extensive studies were carried out following the incident confirmed that the phenomenon of pressure fluctuations was the main cause of the damage. The project includes a dam to a height of 41.5 meters and 227 meters in width spillway (with a design flow of 18,000 cubic meters per second) and a hydroelectric power plant which construction work of it ended in June 1961.

In August 1961, because of the flood passing 3480 cubic meters per second, which is about 20% of the spillway design flood is, a large damage and destruction on the chute slab and bottom slab of stilling basin in an area with a length of 23 meters and a width of 180 was observed.

[8]Reviewer commission presented various reasons for failure such as Uplift pressure in the structure because of water seepage from the reservoir, chance encounter brought pieces of wood and pieces of trees which are brought together with floods to the bottom of stilling basin and the uplift pressure because of the water level in the coastal. But after making the model and more accurate studies, the main reason of the damage, intense pressure fluctuations created by hydraulic jump mentioned.

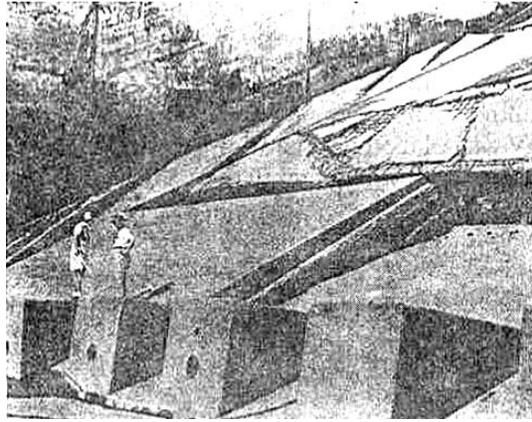


Figure 3. Fracture of chute slabs in Karnafuli dam because of intense pressure fluctuations

So many observations and experiences breakdowns in stilling basins and chute of spillways when passing floods, drew attention of designers to the influence of hydrodynamic forces exerted on the structure and role in the design of stilling basins and suitable cover for chute of spillways.[9] One of the most valuable experiences is about the Malpaso dam located in the country of Mexico. In 1970, parts of the basin floor slab of this dam by dimensions of 12 m × 12 m and a thickness of 2 m and weighing 720 tons which each sewn into the bedrock by 12 steel hook, in terms of flood passing with water head of 100 meters (on the basins), was blown away and major damage was to the bedrock.

The dam stilling basin slabs were cast in situ and expansion joints between slab pieces fully paid and were flatted by mortar filler of concrete and materials for sealing. Interestingly, the flood passing through the spillway of the dam in peak have a flow rate equal to one-third designed flow of spillway.

In both cases (Karnafuli and Malpaso) after studies on model, showed that the design principles of hydraulic structures (chute and stilling basin) are correctly applied and the destruction and damage will not come off due to a uniform uplift pressure on beneath of stilling basin floor slabs and not due to poor coverage and Improper arranging and orientation of stilling basin floor slabs, but in both cases the intense fluctuations of pressure in the hydraulic jump is the main cause of failures in chute and stilling basin slabs. Figure (3) show chute slabs of Karnafuli dam after destroyed.

Examine the possibility of cavitation

Research and studies ever has been done and conducted on phenomenon of pressure fluctuations by various researchers and investigators have confirmed that damage and cavitation in stilling basins and the chute blocks, will happen even if the average pressure far exceeds than the atmospheric pressure. [10] In other words, cavitation occurs when the negative peak pressures of the moment, for a short time reach to the boundary of the water vapor pressure. Accordingly, if in the hydraulic structures sectional the absolute pressure below the vapor pressure of water at ambient temperature, the vapor bubbles generated and in good condition cavitation phenomena and the subsequent damage due to that has occurred, then we will:

$$P_a + P - KP' = P_v \quad (1)$$

P_a is the atmospheric pressure, P the average pressure, P' equivalent RMS of pressure fluctuations, P_v is the vapor pressure of water, K coefficient next to P' fluctuations, lead to localized pressure approaching the vapor pressure of the fluid and cavitation will occur.

3-SUMMARY AND CONCLUSIONS

One of the causes of major losses in the large dams spillway is phenomenon of pressure fluctuations. Stilling basins are used for distribution and energy dissipation of water that overflowed the chute of spillways. In this basins water energy will depreciate by excessive turbulence and clash of particles with each other. This interaction results production of low-frequency pressure fluctuations, which unfortunately in conventional design methods of stilling basins, due to the lack of sufficient information in hand, this phenomenon is not exactly considered. Energy distribution in hydraulic jump as a direct result of the formation of the severe turbulence and conversion of this swinging energy, is always accompanied by intense pressure fluctuations which is on the basins floor and walls. This volatility and intense pressure fluctuations may cause significant drifted Force (Uplift Force) and rose floor slab or Fatigue of materials, or occurrence of cavitation and finally lead to the damage of floor slab of chutes and basins. Being discontinuities at the boundaries of flow and detachment of the flow from structure because of these discontinuities increase the intensity of pressure fluctuations and leads to the local demolishing and destruction of structure.

Also, due to the concentration of energy in the dominant frequency range of fluctuations, the risk of structure vibration also increases the risk of cavitation. Significance of this phenomenon when Baffle Piers or Chute Blocks is used in the stilling basin for more energy dissipation, it is noteworthy and important to note.

Observed numerous stilling basins failures in various projects around the world, the need to consider this phenomenon as a design parameter in estimating the forces acting on stilling basin will tell.

REFERENCES

- [1] Naudascher E., “*Hydrodynamic Forces*”, IAHR Hydraulic Structures Design Manual, (1991).
- [2] Hager W.H., “*Energy Dissipators and Hydraulic Jump*”, 1st edition, Kluwer, (1992).
- [3] Peterka, “*Hydraulic Design of Stilling Basins and Energy Dissipators*”, U.S.B.R, (1983).
- [4] Bowers C.E., Toso J., “Karnafuli project, model studies of spillway damage”, *Hydr.Engrg.*, Vol. 114, No. 8, (1988).
- [5] Fiorotto V., Rinaldo A., “Fluctuating uplift and lining design in spillway stilling basins”, *Hydr.Engrg.*, Vol. 118, No. 4, (1992), pp 578-596.
- [6] Pirooz B., Kavianpour M.R. Spectral Analysis of Pressure Fluctuations under Hydraulic Jump, Proceeding of the 13th APD-IAHR Congress, Singapore, (2002).
- [7] Bowers C.E. & Toso J. “Closure to Karnafuli project model studies of spillway damage” *J.of Hydr.Engrg.*, ASCE, 116 (6), (1990).
- [8] Fiorotto V & Rinaldo A. “Discussion on Karnafuli project, model studies of spillway damage” *J.Hydraulics Division*, ASCE, Vol. 116(Hy6), (1990).
- [9] Toso J.W. The Magnitude and Extent of Pressure Fluctuations in the Hydraulic Jump PhD. Thesis, Submitted to the faculty of graduate school of the university of Minnesota, (1986).
- [10] Sobani A. Hydrodynamic Forces Caused by Pressure Fluctuations on the slabs of Stilling Basins MSc. Thesis, Submitted to the faculty of Civil Engineering, K.N.T University of Technology, (2005).