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Review of The Energy Dissipation Over Stepped Weir

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1. Abstract

This thesis aims to investigate the end sills in stepped spillways and to assess their effect on energy dissipation. For this purpose, physical models of four steps were built on stepped spillways. End sills were installed at the end of each step of the spillway. The energy dissipation could be increased by different behaviors, depending on the characteristics of the end sills (height, shape, and V notch angle). The dimensional analysis was used to link the various parameters influencing the studied phenomena. All end sills used enhanced energy dissipation, reduced the relative scour depth, reduced the relative scour length and reduced the relative scour volume. Increasing the relative height of solid and rectangular partially hollow end sills, enhanced energy dissipation. Minimizing the V notch angle of V notch end sills enhanced energy dissipation.

Keywords: Stepped Spillways, Energy Dissipation, Efficiency, Scour Depth, Scour Length, Scour Volume

2. Introduction

Hydraulic structures are used for many purposes. Major hydraulic structures, such as dams, barrages, weirs and others are used to store water and control water level. Dams are built for irrigation purpose, flood management, power generation, recreation and a lot of other purposes. The velocity of water just downstream major hydraulic structures is supercritical. Supercritical flow results in scouring in downstream river or channel bed and side. Energy dissipation structure should be presented downstream to force the flow to be subcritical. Hydraulic engineers and researchers have dedicated much of their effort to enhance the energy dissipation downstream hydraulic structures. The main function of energy dissipaters is to disperse the excess kinetic energy. This dispersion is executed through hydraulic jump formation.

3. Spillways

A spillway is a structure used to control releases of water from a dam into a downstream area, in some cases the river itself (Savage and Johnson, 2001). Spillways are used to ensure that the flood water won’t overflow destroy the dam. Gates may be built into spillways to control water flow to downstream and consequently the reservoir level (Sehgal, 1996). Normally, Water flows over a spillway during periods of flood only, when the water in reservoir expand beyond the level of emergency. There are many types of spillways already in use worldwide. Some of the most common types are discussed breifly in the following sub-headings. **Free Over-Fall Spillway** As the spillway name tells, the flow drops freely from the spillway crest. Such a spillway is used for an arch dam with almost vertical downstream face (Samadi et al., 2015, Ghodsian et al., 2012**).Ogee (Overflow) Spillway** An ogee spillway has a downstream profile matches closely to the profile of water falling freely from a sharp-crested weir. Generally, Ogee spillway is better suited for masonry and concrete dams (Chen et al., 2002). **Chute Spillway** In a chute spillway, the spillway discharge flows in an open channel from the dam reservoir to the downstream (Kramer et al., 2006). **Siphon Spillway** A siphon spillway is a closed conduit system taking the shape of an inverted unequal legs U with its inlet end at dam emergency reservoir level (Babaeyan-Koopaei et al., 2002). **Cascade Spillway** In very high dams, the kinetic energy at the toe of the dam will be very high and the downstream river water depth may not be capable of handling a single-fall hydraulic jump (Vittal and Porey, 1987). **Tunnel Spillway** Tunnel spillway discharges water by tunnels in the form of a vertical or inclined shaft (Falvey, 1982). **Stepped Spillway** Stepped spillways are the general form of cascade spillway. Stepped spillways are used mainly to dissipate excess kinetic energy. There are many devices used with it to enhance energy dissipation and consequently minimize stilling basin construction cost (Chamani and Rajaratnam, 1994)

3. Energy Dissipation types

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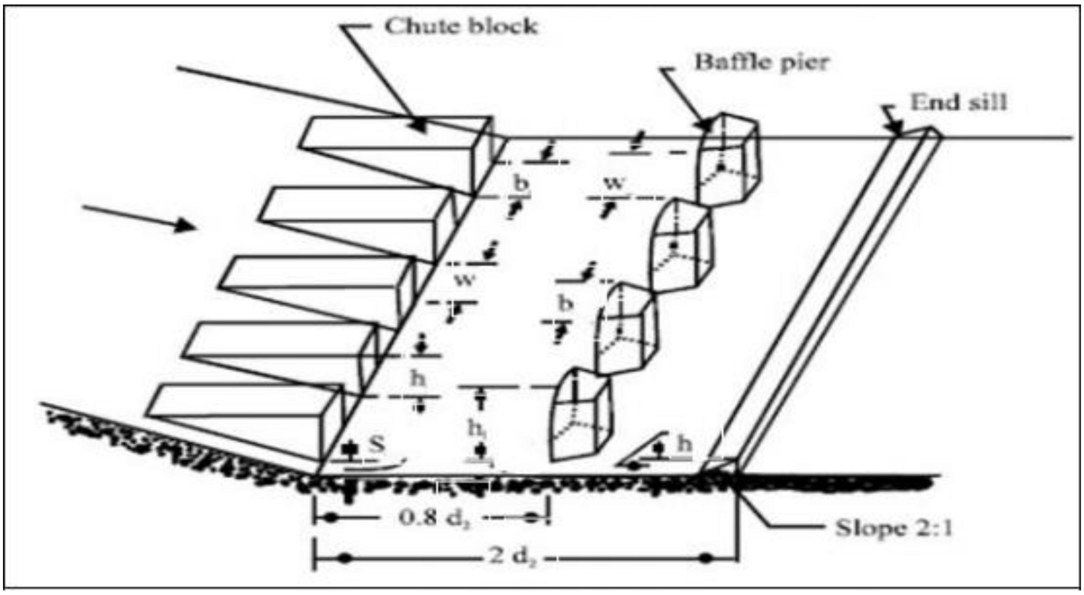

Fig. (2.1): Large Control Structures.

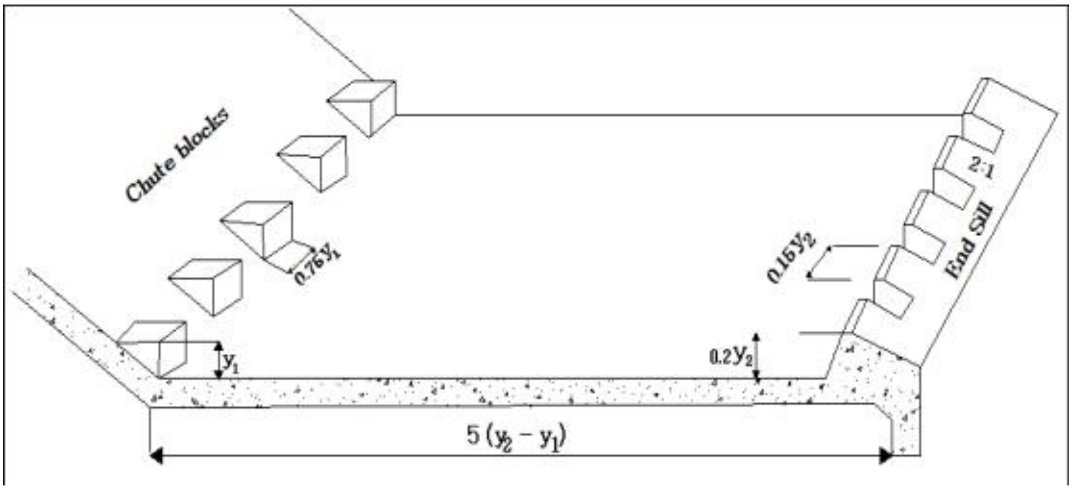

Fig. (2.2): New stilling Basins.

hs= height of sill;
Ls= distance of maximum scour from the end sill;
Sb= distance of baffle piers from side wall;
Sc= distance of chute blocks from side wall;
Sd= depth of maximum scour;
wc= clear spacing of baffle piers;
wb= clear spacing of chute block

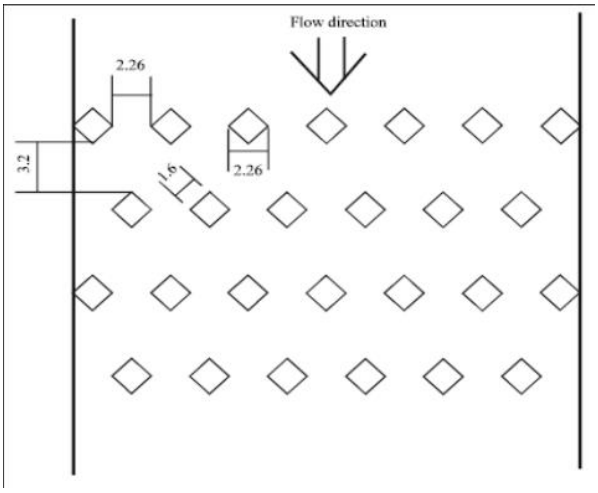

Fig. (2.3): Arrangement of Roughness Elements.

4. Applications Studies

A lot of researchers examined energy dissipation techniques. Here are the major findings of some researchers.

(Ahmed, 2004) studied the efficiency of utilizing parabolic sill as an energy dissipation measure downstream hydraulic structure. It is found that parabolic sill reduced the velocity in the downstream. Parabolic sill caused specific energy dissipation about 8% to 13% compared with the circular sill. Hundred and ninety-two experiments were done, including different flow conditions applied over four positions of the parabolic sill. Parabolic sill reduces the length of apron up to 31.5 %. It dissipated the specific energy about 17.0 % higher than the straight sill.

(Mohamed, 2012) undergone theoretical and experimental investigation on perforated walls as a mean to dissipate excess energy and to reduce jump length. Three models of different holes area are tested in a rectangular channel to find the best hole area in terms of energy dissipation. Another three models tested to find the perforation best angle. It is proved that all the perforated models are better than solid model. Also, all perforated wall decreased the conjugate depth. It is found that A 30° inclination angle and 8% perforation area is able to decrease the conjugate depth by 17% and decrease scour downstream by 46% better than solid type. Energy dissipation by perforated wall is about 75% from the total hydraulic jump energy in average.

(Darder, 2015) tried to find an innovative device that could dissipate as much of the energy entrapped in the hydraulic jumps as possible. One hundred and forty-four (144) runs were performed in an open channel in the Laboratory. Nine models with four different discharges were examined. Relative floor length “Lb/Lf” (where Lb is the distance from the control structure to the first sill and Lf is the length of the floor) was varied to be 1.00, 0.875, 0.75, 0.625, 0.50, 0.375, 0.25, 0.1875 and 0.125. The ratio between the diameter of the sill and its height d/h0 was ranged from 1.00, 0.85 and 0.67. Also, different angels “Ɵ” from center were 0.00, 10.00 and 20.00 was tested. the main findings of the study were as follows: Sitting the sill closer to the gate enhances the energy dissipation. The sill relative position of 0.25 is best. In the relative floor length Lb/Lf= 0.25, a jump length reduction about 47% occurs, scour depth reduction reaches 43% and scour length reduction approaches 51%. For jump length reduction, the optimum ratio d/h0 = 1.00 and the optimum inclination angle is 20°.the minimum scour depth and length occurs at 20° inclination angle and 0.85 d/ho ratio. The inclination of the upper sill increases the hydraulic jump energy dissipation. For all arrangements of sills and relative floor length (Lb/Lf), the scour hole dimensions increase with the Froude number Fr increment. Both the straight and semicircular sills minimize the length of the hydraulic jump, the scour depth and scour length.

(Felder, 2013) focused on two objectives: the investigation of energy dissipation and aeration on alternative stepped spillway designs and the improved understanding of the macroscopic and microscopic two-phase flow properties. Twelve different stepped spillway arrangements were tested in different experimental facilities with slopes of 8.9° and 26.6° include flat uniform steps, non-uniform steps, pooled steps, porous pooled steps and combination of flat and pooled steps. The air-water flow properties on the flat stepped configurations matched well with the corresponding non-uniform stepped configurations, but with small instabilities and larger aeration for the non-uniform steps. Some instabilities were observed for small discharges including pulsations in the first step cavity on the pooled stepped spillways. For the pooled stepped spillway with a slope 8.9° the instabilities affected upon the air water flows including propagation of jump waves downstream and irregular ejection and recirculation processes of cavity.

(Nesreen et al., 2014) An experimental study was carried out to investigate effect of using stepped spillways of different arrangements instead of a sloped one on the scour characteristics D.S a convergent stilling basin. The results of the experimental study are presented. The discussion and analysis of the results highlighted the following conclusions:

1. The maximum scour depth increased with increasing of upstream Froude number (F0) for all spillways (sloped and of different numbers of steps) as shown in Fig.3.

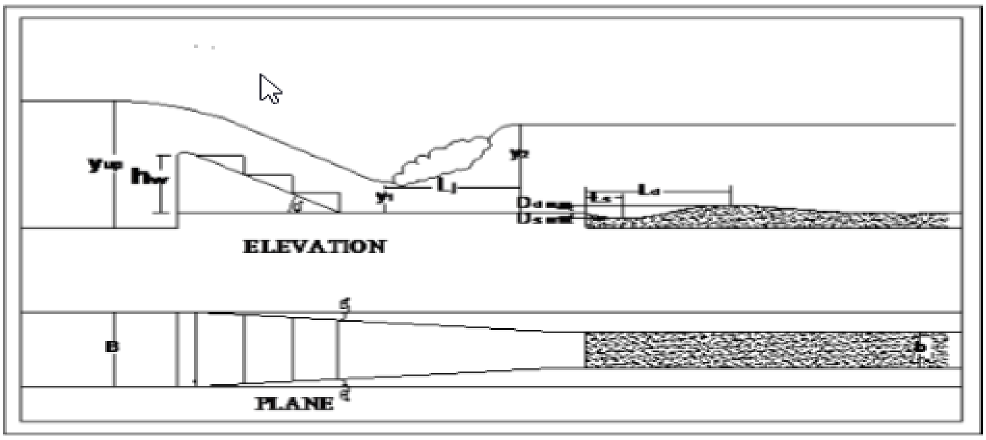

Fig. 3 Definition sketch of the flow over a stepped weir in a convergent stilling basin.

2. At the same upstream Froude number (F0), the relative maximum scour depth decreased with increasing numbers of steps.

3. The spillway with three steps gave the smallest value of scour depth while the greatest value of maximum scour depth occurred at the sloped spillway as shown in Fig.4.

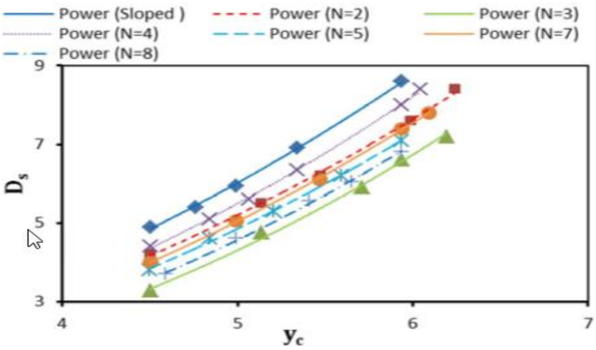

Fig. 4 The relationship between (Ds) and (yc) for different number of spillway steps.

5. for the same upstream Froude number (F0) the spillway with N=3 produced the maximum relative energy loss while the sloped spillway produced minimum energy dispersion.

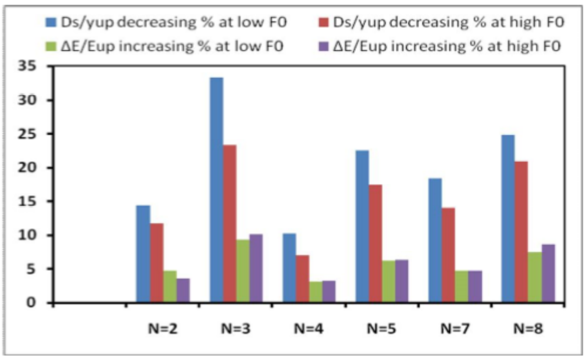

Fig. 8 Percentages of decreasing and increasing in (Ds/yup) and (ΔE/Eup).

5. The relative critical scour depth (Ds/yc) decreased with increasing number of steps. The spillway with N=3 produced the minimum relative critical scour depth and the maximum value was at sloped spillway.

(Elashry, 2011) investigated the characteristics of the free jump controlled by curved sills, both theoretically and practically. the hydraulic characteristics of a free hydraulic jump on rough rectangular channel beds were investigated for Froude's number values from 4 to 7.5. The experiments made using four sill positions and five gate openings. The results study of the jump water surface profiles shows that: the initial water depth Y1 increases when the hydraulic jump shifts towards the beginning of the sill while the tail water depth Y2 decreases, also when the curved sill approaches the gate opening, there is a rise in water depth at the beginning of the sill then drops downstream the sill taking the shape of the curved sill, both the tail water depth and the jump length decrease with sill movement towards the opening gate, empirical formulae was obtained in dimensionless forms for constant gate opening and constant sill positions, general formulae for the relative jump length, the relative depth and the relative energy losses, were mathematically derived relating them to the relative sill positions.

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(Tabari and Tavakoli, 2016) studied the effect of different parameters such as number of steps (Ns), step length (L), step height (h), and discharge in unit width (q) on energy dissipation in the simple stepped spillway. Flow-3D model was used and the relationship between critical flow depth and energy dissipation in the stepped spillway was studied. The results declared that energy dissipation decreases as the flow discharge increases, and energy dissipation decreases as the steps height decreases and their number increases. It is found that increasing the discharge, the number of steps and the roughness Froude number in the simple stepped spillways does not only decrease the rate of energy dissipation but also reduce the step effects. In addition to that, it is proved that the height of step and the step length (while the step height is constant) of the stepped spillway has a direct straight relationship to the rate of energy dissipation. For the same total spillway height, higher step heights (with the same slope) results in a reduction of the number of steps and increase the rate of energy dissipation. It is declared that flow discharge impact on the rate of energy dissipation is higher than the steps number.

(Aal et al., 2017) evaluated the effect breakers in stepped spillways energy dissipation in the three cases of flow; over-flow, through-flow, and under-flow. A physical stepped spillway model of four steps was introduced and breakers were installed over the steps of spillway. The used breakers were varied in width, height, arrangement of breaker heights and perforated holes allocation). the study concluded that; constructing breakers on stepped spillway enhances energy dissipation, the maximum energy dissipation occurred using the breaker with relative height 0.8, the breakers with 5% relative holes area were the best for energy dissipation. High discharges made all the results approximately identical, breakers with holes are better than solid breakers or classical stepped spillway in energy dissipation.

(Tajabadi et al., 2018) studied the effect of an end sill angle on the hydrodynamic parameters of a stilling basin. Simulations using RNG for turbulence and VOF and free water surface models are performed. Four different end sill angles; 30◦, 45◦, 60◦ and 90◦, were simulated. Results showed that the stilling basin having triangle end sill with angle of 60◦ is the best in terms of energy dissipation by 62%.

5. Conclusion and Recommendation

Open channels are mostly designed to carry uniform flow from upstream to downstream to avoid turbulence and scouring of the channels. To protect dams body and downstream area, spillways should be built. Spillways are structures built upstream dams to divert excess water to either the dam downstream or to another depression. Because the difference in water level upstream and downstream spillways is usually very big, energy dissipation facilities should be introduced.

Stilling basins where used for many years for the purpose of energy dissipation. But the big length of stilling basins used with very high construction costs drove the researcher and hydraulic engineers to find a helping tool to enhance energy dissipation. The idea of energy dissipaters is built upon converting the kinetic energy into turbulence. Stepped spillways are found to be a great discovery in the area of enhancing energy dissipation. A lot of researches was made on stepped spillways to optimize the energy dissipation. Some of researches focused on the impact of surface roughness on hydraulic jumps formation and thus on scaling down the velocity and kinetic energy. Others focused on the existence of end sills, and another's studied the effect of steps slope We will take several forms and see the impact of those changes in the geometric characteristics of the tourist attraction on the efficiency of energy dissipation and after it forms in different discharge Using Steeped Weir with solid sills Steeped Weir with Rectangular sills And Steeped Weir with regular sills

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Seismic Design Effect on the Progressive Collapse Potential of R.C. Frames

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Abstract
Progressive collapse potential studies are performed on two-dimensional R.C frames with different reinforcement details under the effect of interior column removal. This study aims to determine the effect of seismic detailing on the structural resistance and behavior of RC frames during progressive collapse event. The R.C frames and reinforcement details would be designed according to Egyptian Code ECP-203 [1]. In this study, two prototype frames were executed from concrete structure and were designed. The first frames F1 is designed with non-seismic reinforcement detail. The second frame F2 is designed with seismic rebar detail. Nonlinear software, used for modeling R.C frames, is extreme loading for structures (ELS). The numerical technique is based on the applied element method with suitable stress-strain relations for concrete and steel. It is found that frame with seismic detail improve the frame resistance against progressive collapse event by 40-45% more than the non-seismic detail in all response stages. The load-steel strain curves and the cracking patterns are also compared for the two frames.

Keywords: Reinforced concrete frames; Progressive collapse; Load-deflection curves; Crack patterns; Applied element method; ELS.

1. Introduction

Several structural progressive collapses accidentally took place in the last few decades. For example, in 1968, the collapse of the 22-story Ronan building [2], East London took place due to gas explosion in 18th floor. In 1995, the Murrah Federal Office Building in Oklahoma City was collapsed due to a terrorist bomb explosion at the ground floor [3]. In 2001, the World Trade Center [4], New York, was totally collapsed due to planes impact at the tower upper levels. Recently, design guidelines such as General Services Administration (GSA) [5] and the Unified Facilities Criteria (UFC) [6] addressed progressive collapse due to sudden loss of a main vertical support. Progressive collapse is a critical event that happened due to failure of load carrying element. For this event, it is important to study the different detailing of frames to withstand progressive collapse event. Much attention has been given to the behavior of beams that bridge over removed column areas, which are under amplified gravity loads in beam-column substructures or planar frames (Sadek et al. [7]; Mehrdad et al. [8]; Yi et al. [9]; Hou and Yang [10]; Kim and Choi [11]). It was concluded that a generous reserve capacity of the catenary action in beams that carry the gravity loads in a tension mode is necessary for mitigating progressive collapse.

In this paper, the alternative path method is used to evaluate the resistance of the frames subjected to progressive collapse. It occurs by removing the one or several bearing element and analysis the remaining structures to determine if this initial damage propagates from element to another. Reinforcement details for frames are conducted to investigate the different structural resistance mechanisms during progressive collapse occurrence. Also, the aim of this study is to determine the reinforcement details effect on the response of frames after column removal event.

2. The Applied Element Modelling (AEM) of R.C Frames

AEM is a modeling method adopting the concept of discrete cracking. As shown in Fig. 1(a), the structure in the AEM is modeled as an assembly of elements connected together along their surfaces through a set of normal and shear springs. The two elements shown in Fig. 1(b) are assumed to be connected by normal and shear springs located at the contact points, which are distributed on the element faces [12]. These connecting springs represent the state of stresses, strains and connectivity between elements. They can represent both concrete and steel reinforcing bars. Each single element has six degrees of freedom: three for translations and three for rotations. Relative translational or rotational displacement between two neighboring elements cause stresses in the springs located at their common face as shown in Fig. 2. Two neighboring elements can be