EVALUATION OF ENERGY DISSIPATION DOWNSTREAM SLUICE GATE

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ABSTRACT

Energy dissipation downstream of hydraulic structures is a problem facing engineers working in the field of hydraulic irrigation design. In this paper, the Authors experimented a new technique by using hanged pendulum sill to dissipate the residual portion of energy of the hydraulic jump downstream hydraulic structures consist of one vent with vertical gate and compare the experimental results with other different researchers output. An experimental study has been conducted in glassed wall flume with a vertical gate and rectangular cross section of (50 cm x 90 cm) and length of 12.00 m. The experimental work has been carried out in hydraulic laboratory flume in 10th of Ramadan higher technological institute. The new technique shows an increase of energy dissipation and reduces the floor length compared with the previous technique by using sills with different shapes and location.
The new technique is applied by using a hanged pendulum sill downstream of the sluice gate of the hydraulic structure. A hollow cylindrical steel sill with a constant diameter of 5.0 cm is used. The weight of the pendulum sill is changing by filling it partially with sand material. The experimental work carried out one with empty pendulum sill with weight 500 gm then the test is repeated after filling the pendulum sill with sand and its weight is 1500 gm. The flow discharge and the gate opening were changed during the experimental work. The discharge capacity ranged between 2 and 6 L/sec. The experimental results showed that using the pendulum sill increased the energy dissipation downstream hydraulic structures.

Keywords: Water structures, Energy dissipation, Hydraulic jump, Pendulum sill

1 INTRODUCTION

Dissipating the energy of water is essential especially downstream hydraulic structures where the energy and velocity are high in order to reduce the cost of the floor. Several investigators work in the increasing of floor friction by using sill with different location, height, and shape. All these variables affecting the stream layer which is just above the floor. As the velocity distribution (as shown by previous authors) show that the maximum velocity in an open channel is not near the bed, for this reason, it is expected that if the obstruction to the flow is located at the zone of maximum velocities, then the dissipating energy will be also reaching the maximum energy dissipation. In the same time as the used bed sill is fixed in its position and height by its construction original design then the sill cannot be modified due to flow characteristic changes. In terms of the importance of dissipating the generated energy behind the vertical gates which is one of the major challenges that face the hydraulic designers, this research was initiated with the objective of dissipating a major part of water energy behind the vertical gate by using more effective tools.

In this study, hanged hollow cylindrical sill was examined as a non-traditional sill behind the vertical gate of hydraulic structures. The pendulum sill is examined once with its original weight and after partially filling with sand to increase the weight.

A theoretical study was conducted using a numerical analysis technique to detect the relationships between the various parameters and variables. An intensive experimental study has been conducted in glassed wall flume for pendulum sill physical Model. Several records of flow characteristics and head losses are analyzed and discussed.

2 LITERATURE REVIEW

Many researchers investigated the required length to ensure the safety of the foundation of the hydraulic structures. For example:

Pillai and Unny (1964) studied experimentally using various shaped blocks by changing the vertex angle from 60° to 120°. the effect of baffle blocks on the energy of the jump was examined. The blocks were fixed at a distance of 6 y_1 from the beginning of the jump. They made a comparison between the different types, and they found that the blocks with an angle of 120° gave the least energy at the end of the jump. Hager (1985) studied the hydraulic jump in non-prismatic rectangular channels. He introduced the following equation for the efficiency of the hydraulic jump.

$$\frac{\Delta E}{E_1}=1-\sqrt{\frac{2\sqrt{2}}{1+F_1}} \tag{1}$$

Abdel Azim M. (1992)investigate the effect of bed roughness on the energy dissipation, he examined different sill shapes as rectangular strip roughness, hexagonal strip roughness, and cylindrical strip roughness. For staggered roughness, he examined cylindrical staggered roughness and hexagonal staggered roughness. From his study, he concluded that: For the best intensity of rectangular shape rough sill is 12%. He used five different intensity (31.37%, 15.68%, 12%, 9.8%, and 6%). For Hexagonal sill Abdel Azim recommended intensity of 14%, and for the cylindrical shape, he recommended intensity 18%. Comparing the three different types of roughness element Abdel Azim M. recommended the rectangular roughness with an intensity of 12%.

Aziz F. E. et. al. (1999) carry out experimental work to study the effect of curved sill blocks having different sizes curvatures and arrangements in energy dissipation. They concluded that curved blocks when comparing with regular straight blocks have indicated that and for all flow conditions, the curved blocks are more effective in dissipating the excessive kinetic energy of the flow. In addition, the curved blocks provided better stability to the hydraulic jump. El- Masry (2001) experimentally studded using baffle blocks to dissipate the energy of water flowing under a sluice gate. Two arrangements were considered. Baffles height, flow discharge, and downstream water depth were the considered variables. The results were compared with other investigators' results for a single and double line of angle baffles.

Çagdas S. (2006) through his experimental work in rectangular section with a horizontal bed laboratory flume with non-protruding strip- and staggered-roughness arrangements conclude that: the non-protruding roughness results in 3 to 7% more energy reduction than that obtained on smooth beds, staggered roughness dissipates more energy compared to strip roughness and energy dissipation is basically a function of incoming Froude number. And the length and pitch ratios of roughness do not have a significant effect on energy dissipation.

Sanjeev (2010) conduct an experimental investigation for the relative energy losses in sloping channels and produce empirical relationship between initial Froude number and the relative energy losses for different channel bed slopes. Sanjeev et al (2013). study the hydraulic jump in horizontal prismatic channel considering the effect of approach Froude number. Empirical models for relative energy loss of free hydraulic jump based on experimental data using Buckingham– theorem and regression analysis have been developed. The developed empirical computational model is validated using Bhutto (1987) data. He developed an empirical equation for the relative energy losses and concluded that relative energy loss of the free jump increases with increase in approach Froude number. Youngkyu (2015) through experimental work using a channel with a fixed weir and sluice gate-type movable weir installation in order to examine the resulting hydraulic jump and differences of each weir type. Concluded that the energy dissipators for energy reduction at the sluice gate were found to dissipate energy by more than 50% per unit length compared with the non-dissipator installation status if installed at a 10% height of the average river water depth in a location as far as approximately

70% of the average river water depth. El Toky (2016) conducted laboratory experiments to investigate the hydraulic jump characteristics for different rectangular open channel with different bed slopes. El Toky produces an equation to calculated the relative energy losses and the sill height to dissipate the jump energy. Khairy et. al (2018) conduct experimental work to investigate the effect of pendulum sill with fixed weight on the energy dissipation downstream siluse gate. She concluded that pendulum sill shows better results in energy dissipations in some cases. But when the staggered sill is used with certain shapes and arrangement gives dissipation results better than pendulum sill.

3 EXPERIMENTAL SET UP

The experiments were carried out in the hydraulic lap of The Higher Technological Institute (HTI), 10th of Ramadan City. The flume used for the experiments is 12.0 m long, 0.50 m wide and 0.90 m deep. The flume is supported on a steel truss that is pivoted at the end of the flume. The other support is near the upstream side of the flume. The downstream support can be adjusted to have the required slope by the help of a lifting arm. In all experiments, the flume slope was adjusted to have a horizontal slope. The bed slope is constant for all experiments. To reduce the turbulence at the entrance of the flume and to ensure a uniform flow, a coarse gravel screen was placed at the flume entrance.

A tailgate is used to control the water level in the flume. It is inclined and pivoted at its lower end to the flume bed, and the upper end is maintained to a screwed rod attached to gears system to adjust the gate height by rotating an arm.

A sharp-edged calibrated weir is located at the end of the lower flume to measure the discharge. The water height above the crest of the weir is measured by a scaled observation well mounted at the side of the lower flume. A point gauge is used to measure the water depth and the scour depth at the bridge site. The point gauge has a scale accuracy of 0.1 mm. the fume is shown in photos from 1 through 3.

The modeled pendulum sill is placed at the positions relative to the inlet gate with relative floor length (L_p/L_f) equal to 0.50, 0.65 and 0.75 respectively and relative sill height(y_p/d) equal to 0.20, 0.30, and 0.50. four values of average discharges are used.

The model is fitted with a certain position, the point gauge is used to measure the levels and depths. Determination of discharge was measured by measuring weir. The weir was calibrated in laboratory and head –discharge curve was plotted. The used discharge equation is:

$$Q = \frac{2}{3} * Cd * b * \sqrt{2g} * h^{1.5} \qquad (2)$$

More than 120 runs are installed, during the run, the normal water depth is measured and the hydraulic jump is formed under condithe tion of free flow downstream the gate and the formation of a stabilized jump. Depths and Lengths are measured as, the sequent depth y_2 and Jump length L_j from the leading edge of the jump to a point just downstream from the top roller of the jump.

The weight of the pendulum sill is changing by filling it with sand material in the first case the cylinder was empty and its weight is 500 gm and in the second case it filled partially and its weight is 1500 gm. The flow discharge and the gate opening were changed during the experimental work.

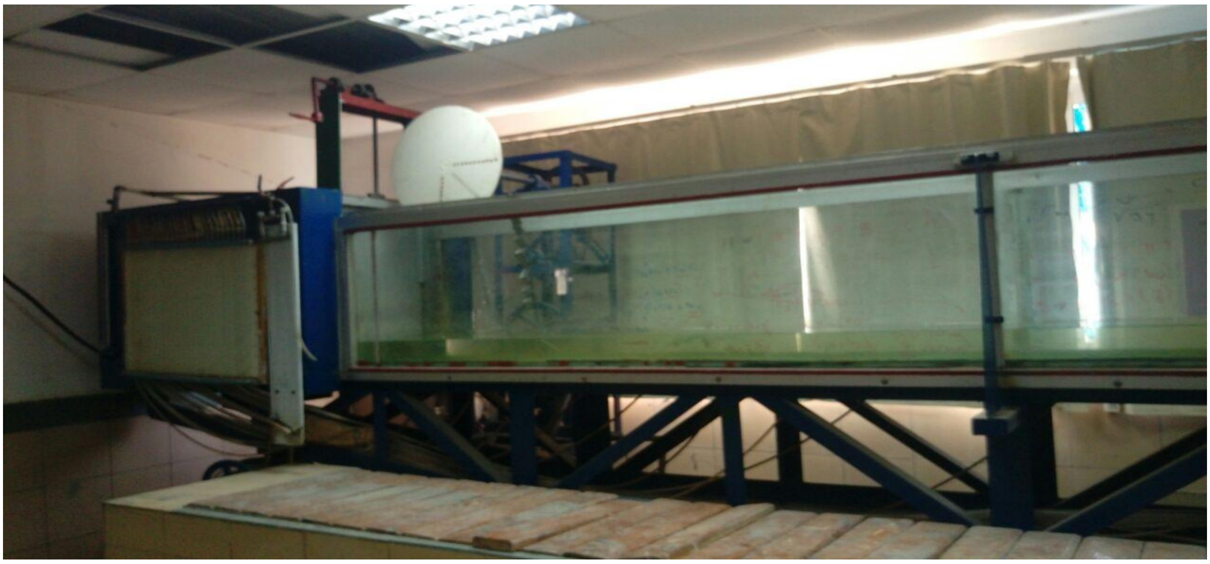

Photo 1. Longitudinal section of the flume

Photo 2. Hanged pendulum sill

Photo 3. Used celebrated weir

4 THEORETICAL INVESTIGATION

A theoretical investigation was conducted using a numerical analysis method to detect the relationships between the various parameters and variables for interaction between pendulum sill downstream of the sluice gate and hydraulic jump behind the vertical gate. All parameter and geometry are defined in figure (1).

The head loss through the jump is a function of the following:

$$H_L = F\,(\rho,\ \mu,\ y_1,\ y_2,\ L_j,\ V_1,\ V_2,\ g,\ B,\ G,\ L_{b.},\ d,\ y_b,\ P) \tag{3}$$

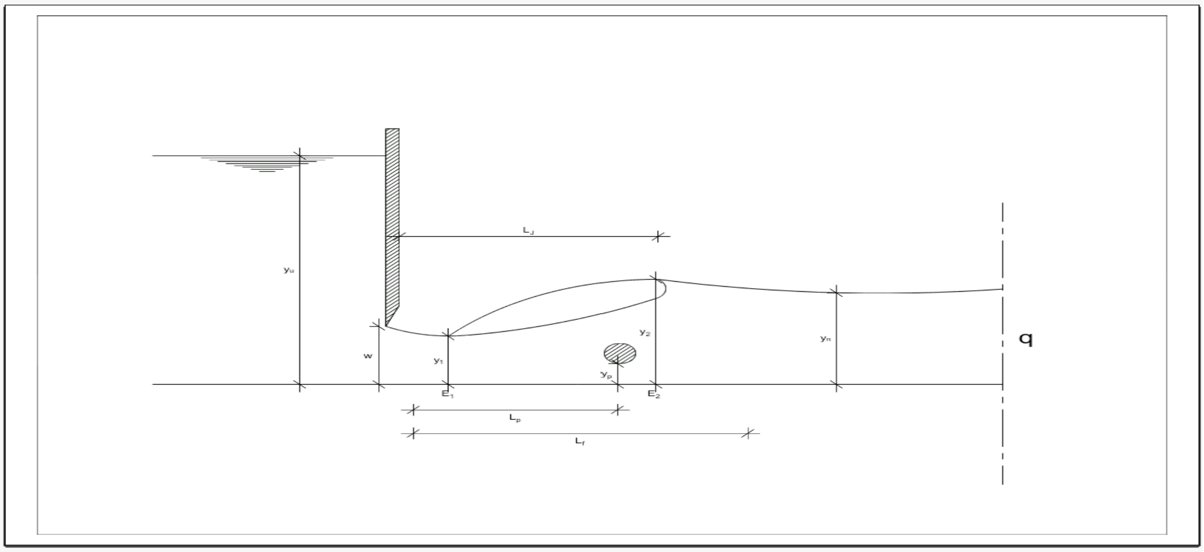

Figure1. Parameters affecting losses downstream the hydraulic jump

According to Buckingham Pi-theorem, the general form of relationship between these variables may be written as follows:

$$\frac{H_L}{G} = f\left(\frac{y_1}{B}, \frac{y_2}{B}, \frac{d}{B}, \frac{L_j}{B}, \frac{G}{B}, \frac{Lb}{B}, \frac{yb}{B}, \frac{V_2}{V_1}, R_n, F_r^2, \frac{P}{B^2 V_1^2 \rho}\right) \tag{4}$$

Taking the properties of Pi-terms into account, the following relationship can be obtained after removing the unnecessary terms:

$$\varphi_1 = \left(\frac{E_1}{E_2}, \frac{y_p}{d}, \frac{L_p}{L_f}, F_r, \frac{\mathrm{P}}{\mathrm{B}^2 \mathrm{V}_1^2 \rho}\right) \quad (5)$$

Where:

d	is the diameter of the pendulum sill.	(L)
E_1	is the energy at the initial jump depth	(L)
E_2	is the energy downstream the jump with	(L)
L_f	is the length of the floor	(L)
L_p	is distance of pendulum sill measured from the gate	(L)
L_f	is distance of floor length measured from the gate	(L)
y_b	is height of pendulum sill above the floor	(L)
p	is the weight of the pendulum sill	(MLT^{-2})
y_1, y_2	is the water depths upstream and downstream the jump	(L)
E_1/E_2	is the relative specific energy.	-
L_j / y_1	is the performance of hydraulic jump.	-
y_p/d	is the relative sill height.	-
y_n / y_u	is the relative height.	-
L_b / Lf	is the relative floor length.	-
h_L/B	is the relative head losses.	-
F_r	is Froude number.	-
R_n	is Reynolds number.	-
	is the Mass density	(ML^{-3})
	is Dynamic viscosity	(ML^{-1} T^{-1})

5 RESULTS AND ANALYSIS

Case 1 when the pendulum sill is empty. A- Sill at relative height 0.20

For the three pendulum sill location, it is found that and as shown in Figure 1 it is found that the best location for the pendulum sill is at 0.20 the floor length. The same conclusion is observed for relative pendulum sill height 0.30 as shown in Figure 2.

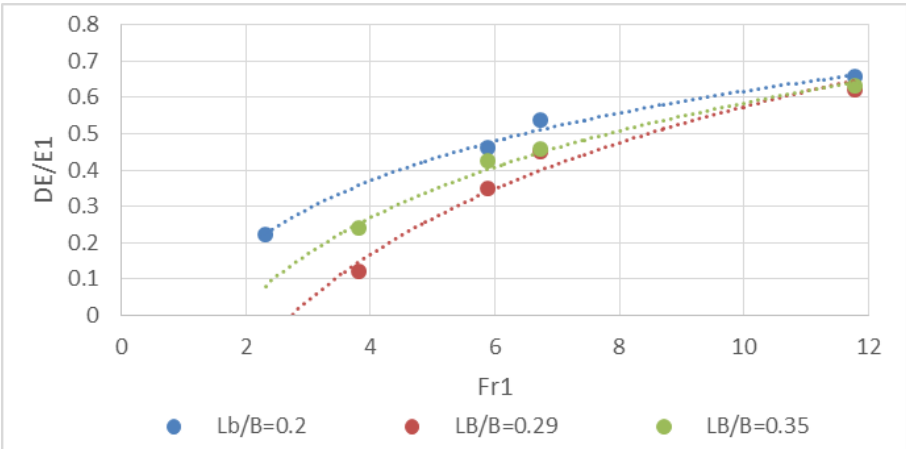

Figure 1. relative energy losses for empty pendulum sill at relative height 0.20

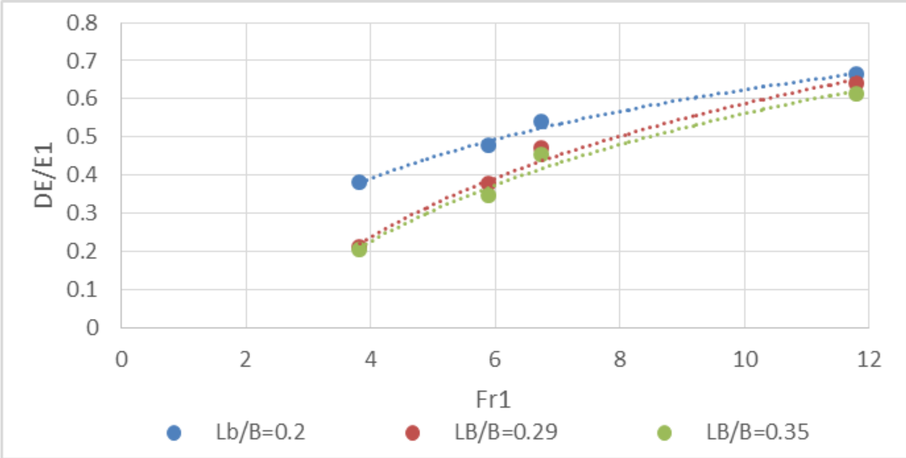

Figure 2. relative energy losses for empty pendulum sill at relative height 0.30

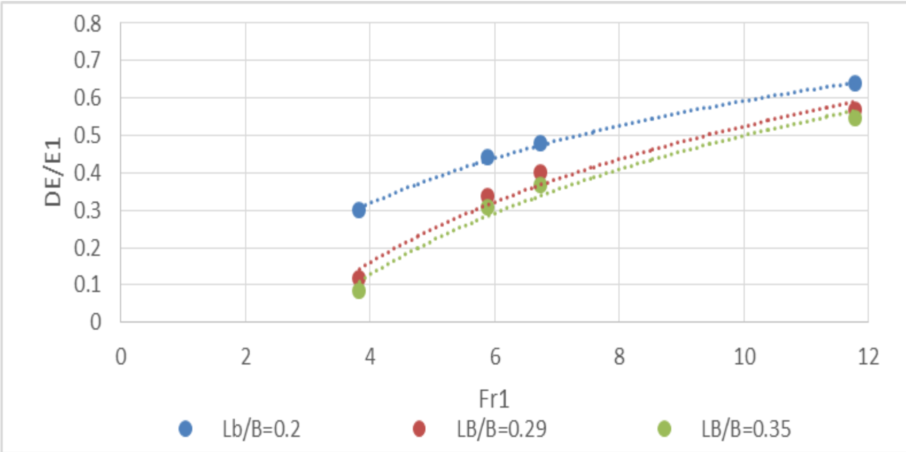

Figure 3. relative energy losses for empty pendulum sill at relative height 0.30

Changing the weight of the pendulum sill. A- Sill at relative height 0.20

The results of the experiments show that after filling the pendulum sill with sand and change its weight from 500 gm to 1500 gm that, the best relative location of the pendulum sill is 0.2 as shown in figs from

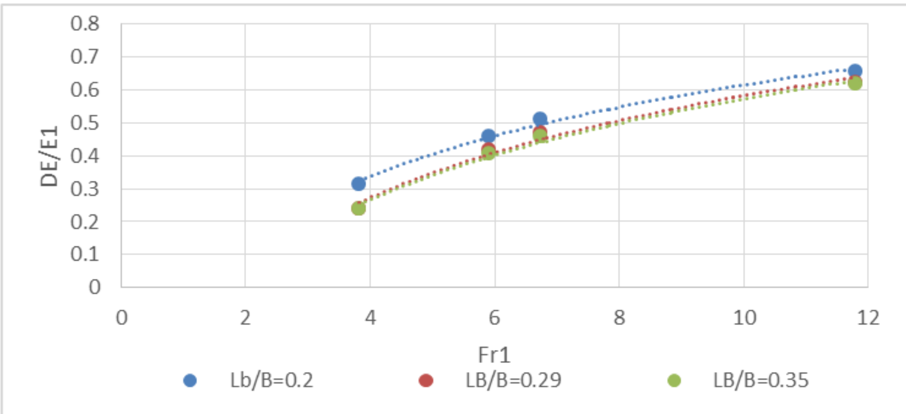

Figure 4. relative energy losses for weighted pendulum sill at relative height 0.20

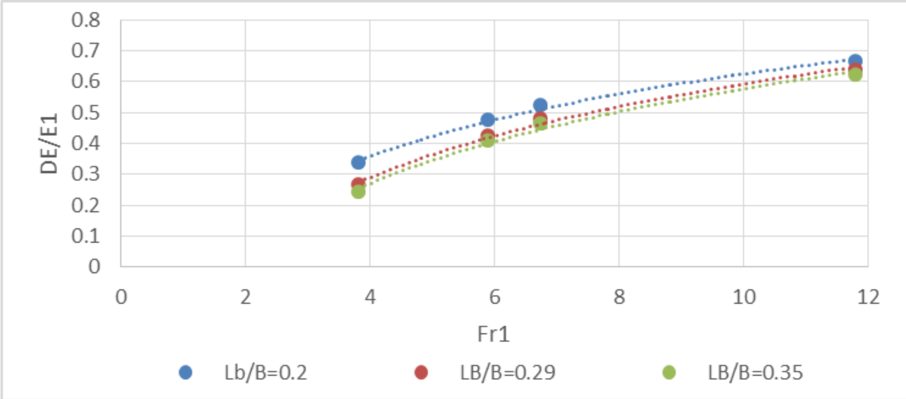

Figure 5. relative energy losses for weighted pendulum sill at relative height 0.30

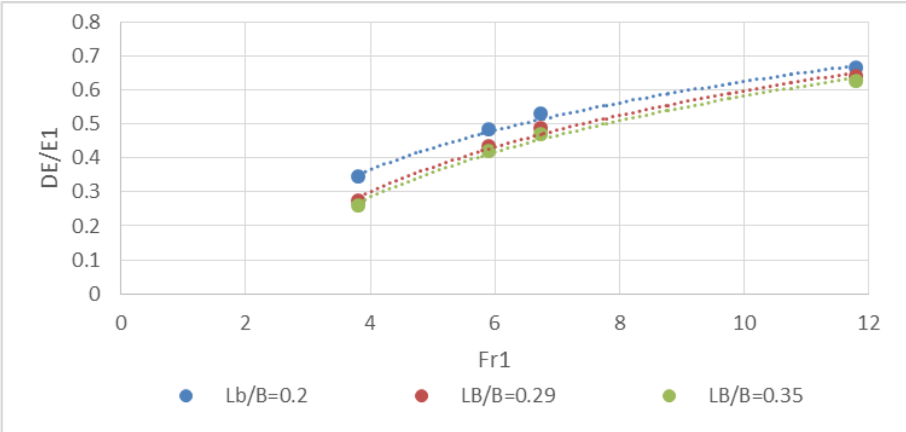

Figure 6. relative energy losses for weighted pendulum sill at relative height 0.50

For all cases with and without weight were the pendulum relative location is 0.20 and as shown in

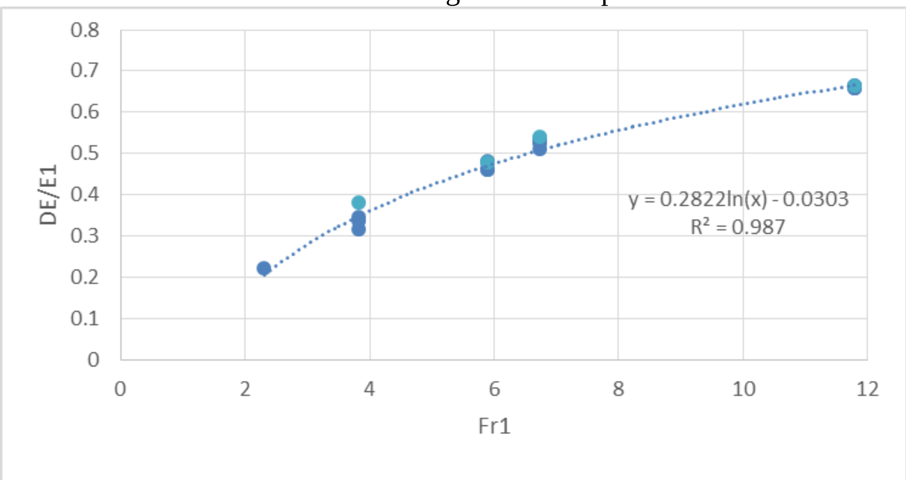

Figure 7 one can generalizing the relative losses equation.

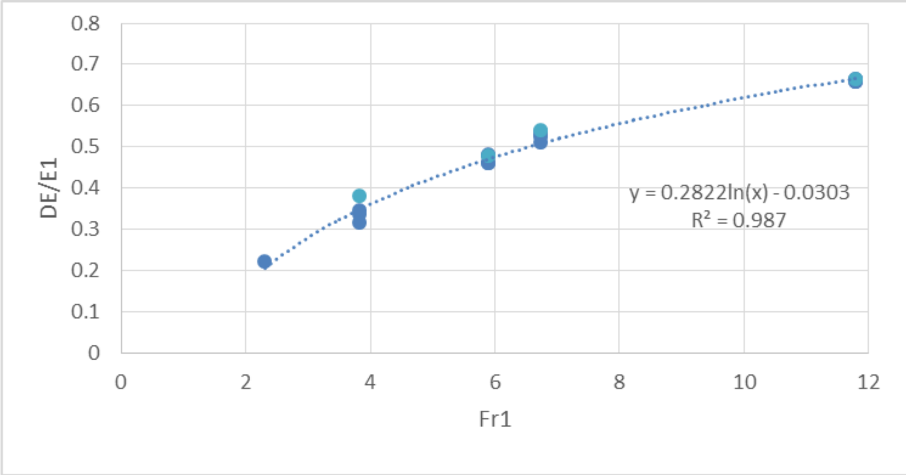

Figure 7. relative energy losses for all cases at relative location 0.20

6 COMPARISON WITH OTHER AUTHORS

Comparison between the existing experimental work and that published by Hager 1985, Negm 1992, Mostafa A. A. (2004) and khairy 2018 are shown in

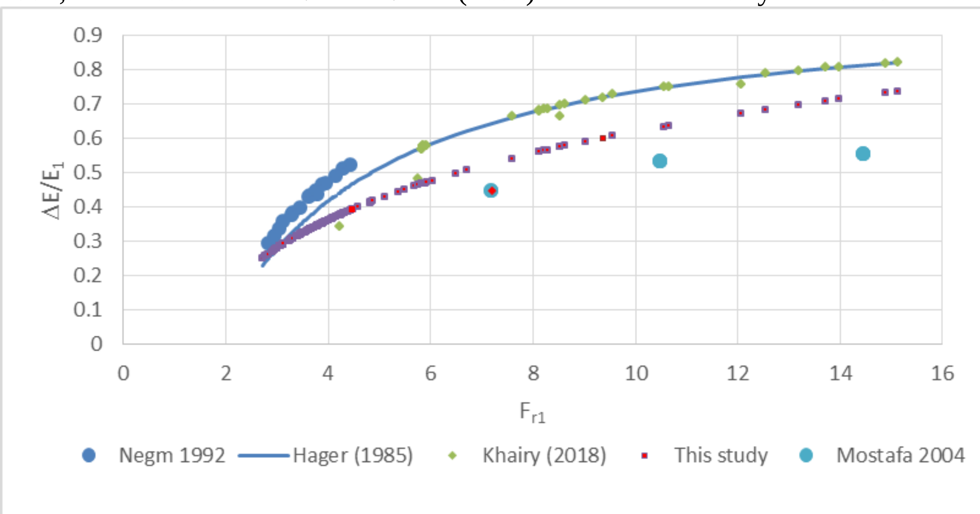

Figure 8. The figure shows that staggered block with certain arrangement used by Negm is still most effective that pendulum sill. But pendulum sill is still better than aprons of formed surfaces used by Mostaff A. A. (2004) and also pendulum sill has flexibility to move its position according to the flow characteristics.

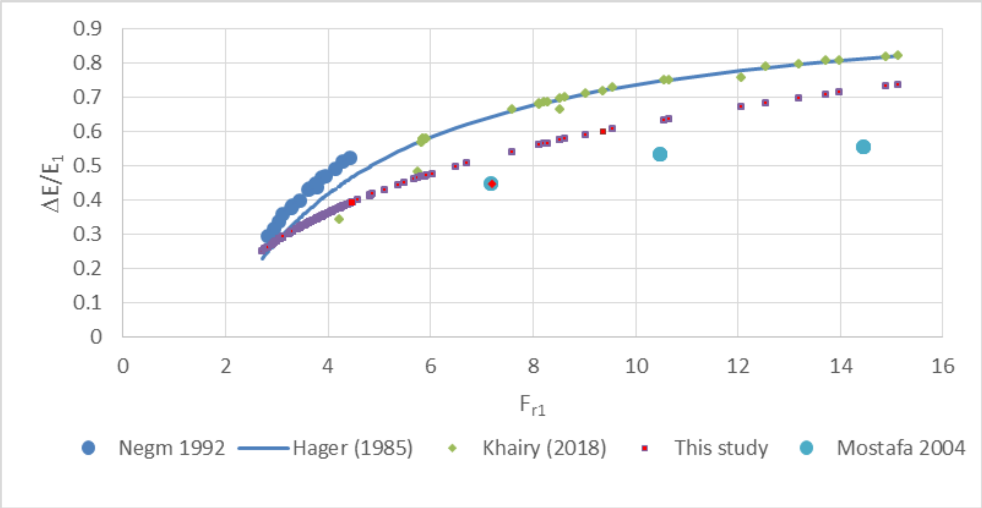

Figure 8. relative energy losses comparison

7 CONCLUSION AND RECOMMENDATIONS

Pendulum sill with different relative height and different location is examined experimentally. The Pendulum sill has the advantage of being fixable method for energy dissipation as it is possible to change its position and height. But after the experimental work for different sill weight, height and location it is found that staggered blocks with certain intensity is still better than hanged sill.

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