International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.3 Issue No.4, pp : 400-402 1April 2014

Hydraulic Energy Dissipators – A Review

Avinash Panwar, H.L.Tiwari
Civil Engg. Deptt. MANIT, Bhopal
email – avinash551991@gmail.com , hltiwari@rediffmail.com

Abstract:* Hydraulic Energy dissipators are devices to protect downstream areas of basin from erosion by reducing the velocity of flow up to an acceptable limit. The stilling basins are transition structures fabricated to dissipate excess energy confined by flow with high velocity at the outlet of conduit or tunnel so that the flow beyond the basin does not threaten the firmness of bed and banks of downstream channel in structures like culvert spillways, canal, etc. from scouring. Henceforth proper attention needed by hydraulic engineers for the design of energy dissipators so as to obtain optimum energy dissipation at outlet. The type of stilling basin most suitable at a particular location mainly depends upon initial velocity of flow and initial Froude Number. This paper describe about the different type of energy dessipators with different appurtanances used in hydraulic structures for protection work.

Keywords – Energy Dissipation, Stilling basin, Froude number, Outlet work, scouring.

1. Introduction

Water flowing over a spillway has a very high kinetic energy because of the conversion of entire potential energy into kinetic energy.If the water flowing with such a high velocity discharged directly into the downstream channel by spillway or pipe outlet, serious scour of channel bed may occur.The scour is not properly controlled, it may extend backward and may endanger to the dam and spillway. Energy dissipator are any device design to protect downstream areas from erosion by reducing the velocity of flow an acceptable limit. An outlet works is a combination of structures and equipment required for the safe operation and control of water released from a reservoir to serve various purposes (i.e., regulating stream flow and quality; releasing floodwater, providing irrigation, municipal, and/or industrial water).

The outlet works typically resides of an intake structure, conduit, control house, gate chamber, regulating valve(s) or gates(s), and an energy dissipation structure [5]. Flowing water emerging from an outlet works can be in one of two states: subcritical or supercritical. With subcritical flow, waves travel upstream. With supercritical flow, all waves migrate downstream. The transition between these two states is called "critical flow" .When water at high velocity (supercritical) discharges into a zone of lower velocity (subcritical), a rather abrupt rise (a step or standing wave) occurs on the liquid surface. This Abrupt rise is called a "hydraulic jump" [5]. The hydraulic jump is a commonly used method of energy dissipation. The cross-sectional flow area of the rapidly flowing water increases (which, in an open channel, appears as an increase in elevation), converting some of the initial kinetic energy of flow into a lower kinetic energy, an increased potential energy, and the remainder to irreversible losses (turbulence, which ultimately converts the energy to heat) [5].

The phenomenon depends upon the initial velocity of the flow. If the initial velocity is below the critical velocity, no jump is possible. For relatively low initial flow velocities, above the critical velocity, an undulating wave appears. As the flow velocity increases, the transition grows more abrupt, and at high enough velocities the front breaks and curls back upon itself. This rise can be convoyed by eddying, violent turbulence, air entrainment, and surface undulations [5].

Stilling basins are used to reduce the high velocity of flow of water from the jet as quickly as possible in order to minimize the scour of downstream river bed. A number of stilling basins like hydraulic jump type, hump type, jet diffusion type, free jet type, impact type and a combination of two or more are employed in most of the hydraulic structures . The energy dissipators for culvert outlets that are designed to operate at the streambed level and re-establish natural flow conditions downstream from the culvert outlet. They are also intended to drain by gravity when not in operation. Some of the example of are: Contra Costa basin, U.S. Bureau of Reclamation (USBR) Type VI impact basin ,manifold stilling basin, USU stilling basin.

2. Literature Review

In this part of report deals with a review of past research work in the field has been compiled to enable better understanding of the research in various region methods of analysis on the experiment subject:

Bradley and Peterka (1957) developed impact type stilling basins.In this study it is found that the energy dissipation is not dependent on tail water depth, but the performance of stilling basin can be improved with a moderate depth of tail water. This study resulted with the development of a new stilling basin which carries higher discharge through constructing the multiple units. Authors also advocated that new stilling basin has restraint up to discharge of $10 m^3/s$ and velocity up to 9m/s.

Garde and Saraf (1986) designed the energy dissipator centred on the principle that the jet is made to spread over the width of stilling basin and then made to fragmented into number of smaller jets which further diffuse thereby dissipation of energy takes place in the shortest possible length. The energy dissipator evolved has been acclaimed for circular outlets whose invert level is proximate the river bed into which it is discharging.

O.S Rageh (1999) studied effect of baffle block on a radial hydraulic jump (R.H.J.), with the aim to derive the limiting design parameters for this type of jump in expanding channels. The restraining design circumstances state the radial hydraulic jump, when it occurs entirely on the horizontal bed, with a sill liable to move in both vertical and horizontal directions. To obtain non-dimensional relationships between the design parameter of radial hydraulic jump for different height of local baffle blocks this study was carried out in the laboratory for Froude number ranged from 2 to 6.5.

Goel and Verma (1999) studied on the development of efficient energy dissipators as compared to Garde's energy dissipator for pipe outlets. The recommended designs were laboratory tested on scale models with pipe outlet diameter of 10 cm and 7.5 cm for Froude number ranging from 1.70 to 5.50. The performance of the new dissipator improved tremendously by using new shapes, sizes and locations of the appurtenances for the same length of stilling basin. This was possible due to better spreading of efflux jet by using a proper splitter block. The formation of a strong vortex in front of the solid impact wall, in place of a grid, and an additional horizontal shear at the bottom produced more fine grained eddies and turbulence, which finally reduced the energy of the outgoing flow. The low bottom velocities at the end of the basin resulted in reduction of the scour. The performance of various models has been compared by estimating the scour index based on maximum depth of scour and its location at the end of run time.

Goel and Verma (2000) experienced that splitter block has very effective performance in spreading the jet of water over the width of the stilling basin within a shorter length. In this study investigators used the wedge shaped splitter blocks having a vertex angle of 150^0 in the stilling basin for pipe outlets for effective performance of basin.

Goel and Verma (2001) used grid type of baffle with solid one and a curved splitter with wedge shape block toreduce the length of the stilling basin. The experiment resulted with a significant improvement in the performance of the stilling basin.

Verma and Goel (2003) conducted experiments for two pipe diameters with Froude numbers ranging from 1.70 to 5.50 to develop an efficient stilling basin with the floor at the invert elevation of the pipe outlet. Experiments were conducted with the use of different appurtenances such as splitter block, impact wall, baffle block and end sills with the specific dimensions. The performance of the stilling basin were analysed by performance number which is the function of constant experimental running time and erodible material used in experiment The experiment resulted with the comparison between the new developed stilling basin and USBR impact type VI for the pipe outlet for the defined Froude number .In this study it is also found that for the better performance the length of basin was reduced up to 25% As compared to impact type VI stilling basin.

Negm *et al* (2003) investigated scour characteristics downstream of abruptly enlarged stilling basin by using lateral central sill of limited width. The study resulted with that the effect of sill position and the sill height are comparatively sufficient for the energy dissipation. The study emphasized the fact that downstream the sudden expanded stilling basins scour are asymmetric and thus protection of side slopes, both bed, and banks are imperative when using such basins. The key features of the scour patterns are tested in presence and absence of the central sill. The prime location of the central sill that recovers the flow behaviour, diminishes the magnitude of scour process is found to be function of the flow regime and the height of the sill.

Verma *et al* (2003) studied about the development of new designs of stilling basins for deep and narrow openings used as outlets. Appurtenances such as wedge shaped blocks, grid, stepped wall ,Impact wall, wedge shaped blocks, weir wall, sloping end sill are used to study their impact on the hydraulic performance of the stilling basins with a purpose to propose efficient stilling basin models. All the models were tested at inflow Froude number F_r = 4.89 keeping a constant run time and same erodible bed material for each stilling basin model for comparison of the performance. By observing the maximum depth of scour and its location after the end sill the performance of each model was evaluated. A non-dimensional number named as Scour Index has been evolved for comparing the performance of the different stilling basin models. The use of wedge shaped blocks as a splitter block and baffle blocks reduced the depth of scour indicating a significant dissipation of energy and good flow conditions, downstream of the stilling basin.

Sameh *et al* (2010) investigated that in certain condition, the flow pattern is asymmetric although the geometry of a rectangular basin is symmetric. The experiment shows that the basin geometry influences the structures of large turbulence behaviour and the flow is rather delicate to the geometry shape. When the addition of suspended sediment is done to the turbulent flow over a plane bed the following was observed: (a) compared to clear water flow the large coherent structures disappear with similar flow properties and (b) under certain condition with reduced width of the reservoir flow pattern is asymmetric and when reducing the length of the reservoir it disappears.

Tiwari *et al* (2010) experienced that the stilling basins are transition structures assembled to dissipate excess energy limited by high velocity flow at the outlet of conduit or tunnel so that the flow beyond the basin does not threaten the stability of bed and banks of downstream channel. This study shows that ,in a stilling basin kinetic energy causes turbulences and it is ultimately lost as heat and sound energy, there are several types of stilling basins which are used in various hydraulic structures like dam, canal, culvert etc. The type of stilling basin most suitable at a particular location mainly depends upon initial Froude Number and initial velocity of flow. This study results with design principles and features of various stilling basins used for outlet works.

Tiwari *et al* (2013) studied about scour pattern downstream of stilling basin for non-circular pipe outlet using end sill of different geometry. The study was conducted by designing new stilling basin models in a rectangular shaped pipe outlet with three inflow Froude numbers namely,Fr=1.85, 2.85 and 3.85 to study the scour pattern downstream of stilling basin. The study indicates that a significant effect of the shape of the end sill geometry on the reduction of scour depth downstream of end sill for the pipe outlet stilling basin.

Flammer *et al* (2012) studied the relation between tail water depth, outlet flume floor elevation, the height of boils in the stilling basin, width of stilling basin and amount of free board as a criteria for designing a stilling basin to work as transaction from closed conduit flow to open channel conduit. This stilling basin was limited to use for a fully submerged pipe outlet. The effectiveness of structure has evaluated by the relative boil height and unsteadiness of water surface .The study resulted with a new stilling basin as a short pipe energy dissipator which is located and designed to providing a maximum energy dissipation for the specific basin .In this study the length of stilling basin was established by the use of shear drag, pressure drag and diffusion action of a submerged jet. The study shows that for the maximum energy dissipation the optimum dissipator pipe ratio was recommended $W/D_1=0.5$, $D_2/D_1=2$ and $L/D_1=1$.

Tiwari (2013) inspected the energy dissipation by varying the gap of baffle wall in the stilling basin to protect the downstream structures from immense scouring. Experiments have been carried out for Froude number 3.85, 2.85, 1.85 with keeping the baffle wall at same location. Experiments resulted with much effect on the performance of the stilling basin by changing the gap underneath the wall from the basin floor due to change in floor pattern. During the study it was found that the flow condition as well as the scouring pattern in downstream of the stilling basin affected by the gap of impact wall in the basin.

3. Conclusions

During the literature view it was reported that much work has been carried out by past researchers related to design of stilling basin model for pipe outlet .It is observed that in so many cases normal depth is not always available downstream of a stilling basin .Hence there is a need to design the stilling basin other than normal depth and also height of the exit of pipe outlet over floor of the stilling basin should be change for designing a new stilling basin model for different Froude number

References

i. *Bradley, J.N. and Peterka A.J. (1957)." Hydraulic Design of Stilling Basins", Journal of Hydraulic Engeneering. A.S.C.E, 83(5), 1401-1406*

ii. *Garde R.J., Saraf P.D. and Dahigaonkar D.J., Evolution of Design of Energy Dissipator for Pipe Outlets, J. of Irrigation and Power, 41(3), 145-154 (1986)*

iii. *Goel, A. &Verma, D.V.S.1999. "Improved design of energy dissipators for pipe outlets",Journal of Irrigation and Drainage Systems, Kluwer Academic Publishers, The Netherlands, pp. 313–320, Vol. 13, No. 4.*

iv. *Goel,A&Verma, D.V.S. 2001. "Model studies on stilling basins for pipe outlets". Journal. of Irrigation and Drainage Systems, Kluwer Academic Publishers, the Netherlands, pp. 81–91, Vol. 15, No. 1.*

v. *FEMA (2010) "Outlet Works Energy Dissipators" Technical Manual FEMA P-679*

vi. *Negm A.M , Saleh O.K, Abdel-Aal G.M and Sauida M.F (2003) " INVESTIGATING MAXIMUM SCOUR DEPTH DOWNSTREAM OF ABRUPTLY ENLARGED STILLING BASINS WITH LIMITED LATERAL SILLS" AEJ, Faculty of Eng., Alex. University, Alex., Egypt, Vol.42, No.1, 2003, pp77-87.*

vii. *Rageh, O.S (1999) "EFFECT OF BAFFLE BLOCKS ON THE PERFORMANCE OF RADIAL HYDRAULIC JUMP" Irrigation & Hydraulics Dept., Faculty of Engg. El-Mansoura University, El-Mansoura, Egypt.*

viii. *Sameh A. KANTOUSH, Tetsuya SUMI and Anton J. SCHLEISS (2010) " GEOMETRY EFFECT ON FLOW AND SEDIMENT DEPOSITION PATTERNS IN SHALLOW BASINS" Journal of HydraulicEngg A.S.C.E, vol.5*

ix. *Tiwari,Gahlot,Verma (2010) "STILLING BASINS BELOW OUTLET WORKS – AN OVERVIEW" International Journal of Engeneering Science and Technology Vol. 2(11), 6380-6385*

x. *Tiwari H.L, Goel A. and Gahlot V.K. (2011), "Experimental Study of Sill Controlled Stilling Basins for Pipe Outlet", International Journal of Civil Engg. Research, 2(2), 107-117*

xi. *Tiwari H.L (2013) "ANALYSIS OF BAFFLE WALL GAP IN THE DESIGN OF STILLING BASIN MODEL" International Journal of Civil Engineering and Technology Volume 4, Issue 4, pp. 66-71*

xii. *Tiwari H.L. (2013) "Design of Stilling Basin Model with Impact Wall and end Sill" Res. J. Recent Sci. Vol. 2(3), 59-63*

xiii. *Verma, D.V.S. and GoelA (2000) ."Stilling Basins for Outlets Using Wedge Shaped Splitter Blocks", Journal of Irrigation and Drainage Engg., ASCE 126(3), 179-183*

xiv. *Verma D.V.S, Goel Arun and Rai Vipin(2003), "NEW STILLING BASINS DESIGNS FOR DEEP RECTANGULAR OUTLETS" International journal of civil engineering Vol. 17, No 1*

xv. *Verma, D.V.S. and Goel, A. (2003), "Development of Efficient stilling basins for pipe outlets", Journal of Irrigation and Drainage Engg. ASCE, 129(3), 194-200*