EXPERIMENTAL AND NUMERICAL STUDY OF FLOW AROUND PIANO KEY WEIR.

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Doctor of Philosophy

By

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CHAPTER 7 SUMMARY, CONCLUSIONS AND FUTURE SCOPE OF STUDY

7.1 Summary and Conclusions

Experimental and Numerical results have been analyzed to examine the hydraulic characteristics of different planforms of Piano Key Weir. Two different types of flume have been utilized for the experimental study. The first flume was of relatively smaller width (0.4 m) and has been utilized for head reduction study, evaluate head discharge relationship and study the sediment profile upstream of PKW of different plan forms. The rest of the experimentation has been carried out on the second flume under a partially closed tailgate for a relative submergence study of PKW outlets of different plan forms. The following key inferences have been drawn from the overall study:

1. Piano Key Weirs are structurally stable, economical, have higher hydraulic advantages over their counterparts, and offer broad field applicability. Piano Key Weir offers an excellent alternative for Dam rehabilitation in comparison to its counterparts.
2. The numerical CFD study compared the heads for different values of discharges with the experimental values from the experiment and the Literature. The numerical CFD model can reproduce flow depths near PKW with good agreement with the experimental model. The nature of flow around PKW for h/P ratio less than 0.9 is clinging in nature, where h is the average head over the crest of PKW, which is supported by the Literature. Streamlines have been plotted for flow over PKW. It suggests that the water level remains flat along the entire crest length of PKW as the flow enters the lateral crest length with no buildup of negative pressure at the inlet and outlet portion within the range of experimental discharge. The longitudinal velocity profile shows that the velocity increases as we move away from PKW.
3. As many geometrical parameters influence the flow, constructing different physical

models for PKW for estimating the optimal geometric parameters required for any project design can be tedious. Present Numerical studies suggest that CFD can be used as a guiding and analysis tool for investigating the hydraulic need of the various PKW projects, thus drastically lowering the time required to plan a project.

4. Analytical study in the different sections indicates that by using Piano Key Weir, up to 80% of head reduction can be achieved compared to a rectangular weir of the same width. The reduction may be attributed to an increase in total crest length due to its nonlinear shape.
5. The study presents the head discharge relationship among PKWs of different plan geometries to find the hydraulically superior plan-form of PKW in Flume 1 of 0.4 m width. The study was conducted both experimentally and by CFD. The experimental study of the head discharge relationship was carried out for three plan geometries (RPKW, TPKW6 & TPKW13) at eighteen discharges, while the numerical study was conducted on five of these experimental discharges. With the same no. of cycles in a fixed-width W of any channel, aligning the lateral crest from the longitudinal direction decreases the developed length (L) of the PKW. As we have observed, the developed length (L) reduced from 4.22 to 3.88 from RPKW to TPKW 6 and further reduced to 3.56 for TPKW13. The RPKW shows a higher discharge coefficient than TPKWs owing to greater crest length for the same no. of cycles of PKW in a fixed channel width (W). As the h/P ratio increases, we can see that the discharge coefficient decreases for all geometries.
6. The sedimentation study was also conducted on the same flume F1 to find which plan form offers the better self-cleaning ability. The sediment passage over PKW with a rigid bed with three different discharges has been carried out for two plan geometries (RPKW & TPKW6) for accessing which plan geometry is showing more significant

sediment passage downstream. Turbulence generated near the upstream of these weirs provides self-cleaning characteristics to these weirs. Comparing the three PKW plan geometries, it has been observed that sediment transport is higher for RPKW at the same discharges compared to the TPKWs.

7. The vertical velocity component 'v' in sediment passage at nine critical locations for the three experimental discharges has been studied using CFD for two plan forms of PKW. Vertical velocity component (v) has been studied at the start of the inlet key, under the outlet key just below the lateral crest and at the upstream overhang of the outlet key. The values here are relatively higher, suggesting the scouring and sediment transport happens primarily from these locations. The study shows the self-cleaning ability of RPKW to be higher than TPKW for a constant channel width (W) and the same number of cycles (N).

   Vertical velocity (v) is utilized for deposition or suspension of sediment particles in open channel flow, and results show that the vertical velocity attains a higher value as the distance from the bed increases. Another interesting observation is that the vertical velocity close to PKW and nearer to bed level (l3) is small but higher than the vertical velocity near the bed level but farther from PKW (l6 & l9) for both the pan forms of PKW. This observation helps to understand why PKWs are self-cleaning, i.e., PKWs help in sediment passage over them through the inlet, unlike other weirs. Vertical velocities were observed to be higher at the middle portion of keys compared with in front of the sidewall.

   Vertical velocity component 'v' plays a vital role in lifting the sediments and helping them pass downstream. The study will contribute to studying the correlation between 'v' and the sediment uplift upstream of the PKW.

8. An experimental study was carried out on two different plan forms of PKW, i.e., RPKW

and TPKW9, in a second flume (F2) of 0.984 m width to determine their hydraulic efficiency under relative submergence of the outlets of PKW. The graph of discharge vs. head was plotted for each weir geometry. A numerical study was also done on four of these experimental discharges using ANSYS-FLUENT. The experimental study showed RPKW to be more hydraulically efficient than TPKW for the same number of cycles and upstream-downstream length in fixed channel width. The interference wedge was more prominent in the TPKW plan. The study showed that partial to full outlet submergence had a negligible effect on the head measured at the crest of PKW within the experimental limits of the discharge range and h/P ratio. Head over the crest of PKW increased only after full submergence of outlets of PKW and downstream water level being higher than the height of PKW (P).

9. The study using CFD tools like ANSYS-FLUENT suggests that numerical studies can be carried out further to predict the flow around PKWs accurately and within permissible error limits, thereby saving cost, time and economy.

7.2 Future Scope of the Study

The prime thrust of the present research work is to compare the hydraulic superiority of PKWs of different plan shapes and the use of CFD as a guiding tool to reduce project cost and time. The present study hopes to contribute to the literature on developing and refining discharge-head empirical equations for RPKW & TPKWs. The sediment profile upstream of PKW has also been studied and will contribute to the correlation studies between vertical velocity component 'v' and the sediment uplift upstream of the PKW. Numerical study of the experimentation model using CFD tools has been studied mainly for the upstream of Piano Key Weir may be the potential area of research. Sediment passage in the upstream and scour formation in the downstream need to be studied for different plan geometries of PKW.

The dissipation of energy downstream is another issue concerning PKWs. Various energy dissipators and their combination can be further studied for effective energy dissipation with minimum cost.

The methods of construction need further study as prefabricated reinforced concrete can be an exciting solution. Cost and delays are the main issues affecting a project. Methods for rapid construction of PKWs based on hydrologic data and a minimum number of parameters and local conditions could be further taken up for study.

Structural aspects, along with material selection used for PKW construction like composites, can be an area of further research.

In addition, associating PKWs to other spillway types with minimum cost is an area of further inspection.

Few authors have addressed the risk of floating debris, which warrants further investigation. Experiments have been conducted with trunk roots; however, more research is needed if these schemes are located near catchment areas covered with forest or in inhabited areas.

The use of numerical modeling can be extended further to study or even replace the physical models, which are often more time-consuming and costly, can be exciting. A combination of experimental and numerical studies will lead to a better understanding of these grey areas in the future.

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