Section A-Research paper

Bank Protection By Submerged Vanes

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Abstract- To create artificial circulations downstream, submerged vanes, or airfoils, are frequently positioned in a canal at an angle to the flow direction. These artificial circulations allowed for the employment of submerged vanes to control river shifting and bank erosion, prevent sediment building from obstructing lateral intake, etc. In an experimental study, Odgaard and his associates identified the appropriate vane sizes and recommended applying them to vane design. This paper makes an effort to evaluate and validate the results of Odgaard and his colleagues using computational fluid dynamics and experiments as a tool. In order to achieve perfect vane settings, the vorticity created by the vane in the downstream was maximized.

Keywords—*Submerged vanes; vorticity; optimization; circulations; computational fluid dynamics.*

I. INTRODUCTION

River engineers face significant challenges in managing sediment, including controlling its movement, preventing scour and deposition. Bed scour along the outer bank of river curves often leads to bank undermining and loss of soil and infrastructure. Sediment deposition can reduce a river's flood-conveyance capacity and disrupt navigation. It is also a recurring issue at water intakes and diversions. The main difficulty in addressing these problems lies in the lack of effective and affordable measures to control sediment movement.

Building revetments, dikes, wing dams, weirs and using dredging have historically been the main methods used for sediment control and river training. These methods modify variables such bed topography, flow patterns, bank resistance, and bank erodibility. Their ideas and standards have been well-documented in the literature for many years, and this includes research by Biedenham et al. (1997), Petersen (1986), Jansen et al. (1979), and others, as well as numerous publications from the U.S. Army Corps of Engineers.

A comparatively recent and less well-documented method that is gaining popularity is the submerged-vane technique. Its wide range of uses is demonstrated by laboratory and field studies carried out by Odgaard and Kennedy (1983), Odgaard and Spoljaric (1986), Odgaard and Mosconi (1987), Wang (1990), Fukuoka (1989), and Fukuoka and Watanabe (1989). The Nile River in Egypt, the Waikato River in New Zealand, the Kosi River in Nepal, the Kuro River in Japan, the Feng-Shan Creek in Taiwan, the Missouri River in the United States, and other smaller rivers in the Midwest region of the U.S. have all already had vane installations. The operation and design principles of vanes have been better understood as a result of the information gathered from these installations and other locations.

Comparing installing vanes to building comparable traditional river training facilities, the cost of installing vanes is often lower. The cost per metre of the vane installation along the East Nishnabotna River installation was around half that of a rock riprap embankment built concurrently over a comparable section of the neighbouring Raccoon River.

II. LITERATURE WORK

A. Optimising the parameters of a tapered submerged vane

The dimensions for the experiment were 10 m long, 0.910 m wide, and 0.152 m depth was made in order to start modelling a submerged vane. A cuboidal volume with dimensions of 0.152 m in length and 0.001 m in thickness was built at a distance of 2 m from the channel's intake. This volume's height ranged from 0.038 to 0.114 m. After that, the smaller cuboidal volume was cut to accommodate various sweep angles of 10 to 35 degrees and an attack angle of 10 to 45 degrees. After the geometry was finished, the 3D blocking option was used to start the blocking process.

Blocking is a technique for capturing flow characteristics at the microscopic level by constructing a partition or block around the region of interest. In this instance, the block was designed to fit the geometry of the tapered vane. Splitting edges of the vane helped develop vertices on the surface, which were then associated with projected points on the channel geometry to ensure proper meshing. The resulting block surface around the tapered vane was assigned as a 'SOLID' boundary to prevent flow from passing through it. A global mesh size of 10 mm was assigned, and mesh quality was checked to ensure its workability, which was found to be within the acceptable range. After saving the geometry and importing it into ANSYS CFX, various surfaces of the geometry were assigned appropriate boundaries based ontheir intended role in the analysis.

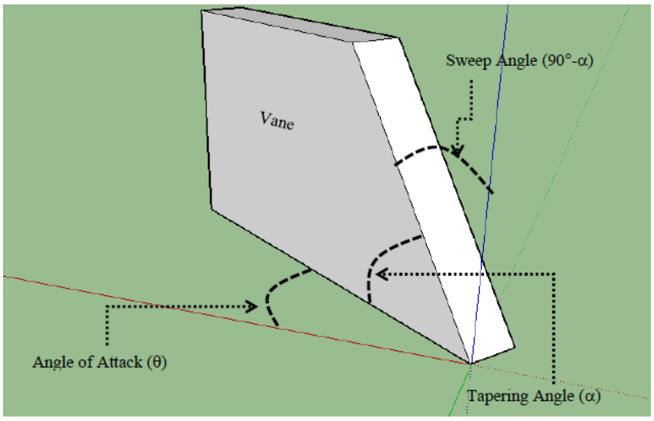


Fig.1 Different Parameters of tapered Vanes

i. Intake Boundary Parameters:

A uniform flow without any lateral or perpendicular components to the longitudinal velocity is assumed to exist in the inlet boundary conditions. At the inlet boundary, an initial speed of 0.24 m/s is specified as the average.

ii. Release Boundary Parameters:

It is assumed that there is no streamwise diffusion of velocity at the exit boundary plane in order to ensure that the resultant velocity field maintains the continuity of the model. A specified average velocity of 0.24 m/s is supplied at the outflow.

iii. Rigid Parameters:

All RigidParameters were given "WALL" marginparameters, signifying that the flow could not travel through these surfaces.

iv. Water Top layer:

The assumption that the water surface is a stiff lid with no potential of crosswise flow was used to model the water surface. Additionally, it is assumed that the water is flowing at the same speed on the stiff lid's surface as it is at the inlet border.

Discussion:

a) Support of CFD model:

The ICEM-CFD platform was used to create and mesh the channel flume model, and ANSYS-CFX was used for simulation. An investigation performed by Wang and Odgaard (1993) served as the foundation for the geometric features of the channel segment and flow conditions. The computed transverse velocities were compared to the empirically determined transverse velocities from Wang and Odgaard's study in order to evaluate the created model's accuracy. The comparison showed that the modelled and experimental transverse velocities were in good agreement, proving that ANSYS-CFX can faithfully predict the flow upstream and downflow of a submerged vane. This highlights the potential of using ANSYS-CFX effectively for optimizing parameter of taper turn vanes and capturing flow characteristics around and downflow of the vane.

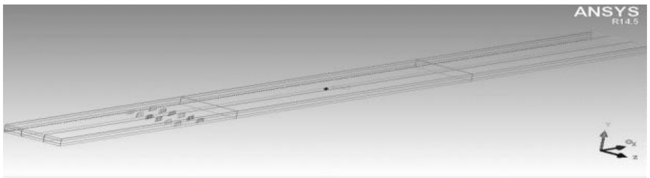


Fig.2 Prototype of Submerged vane generated by ICM-CFD

b) Sweep angle of taper turn vanes:

In a tapered vane, the leading edge's inclination with respect to the horizontal axis is determined by the tapering angle, whereas the leading edge's inclination with respect to the vertical axis is determined by the sweep angle. A vane with dimensions of 0.076 m in height, 0.152 m in length, and changing sweep angles between 10 and 35 degrees was employed in this study. The sweep angle was optimized, and the findings revealed that the largest amount of vorticity was produced by the tapered vane at anangle of sweep at 10 degrees. The vorticity produced by the vane linearly dropped as the increased in sweep angle.

The decrease in lift force per unit length produced by the vane can be blamed for the decrease in vorticity with increasing sweep angle. The fluid density, the fluid's velocity as it approaches the vane, and the circulation the vane creates are what define the lift force acting on the vane, according to the Kutta-Joukowski theorem. Lift force per unit length reduced with increasing sweep angle and decreasing circulation. Because to the decrease in circulation brought on by the drop in lift force per unit length, the flow separating from the trailing edge experiences less induced vorticity.

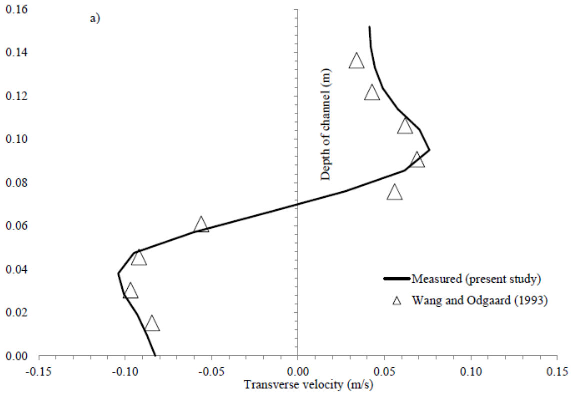


Fig.3 Validation of model x=2H

Therefore, it can be concluded that among the studied sweep angles of 10º, 20º, 30º, and 35º, angle of sweep at 10º induced the flow's strongest vortex passing by the trailing edge.

c) Angle of attack of taper turned vanes:

The flow that interacts with the hydrofoil is created by secondary currents, which are greatly influenced by the attack angle. The best angle required to attack for rectangular submerged vanes to produce the strongest secondary currents is between 2 and 40 degrees, according to previous study by a variety of scientists. While other studies have adopted 20 degrees as the ideal angle of attack based on the findings of Odgaard and his colleagues According to (Odgaard and Spoljaric, 1986; Odgaard and Mosconi, 1987; Odgaard and Wang, 1991a), a 45-degree optimal angle of attack for tapered vanes was proposed by Gupta et al. (2006).

As seen in Figure, the tapered vane produces the most vorticity at an attack angle of 17 degrees, and the vorticity values drop as the angle of attack increases. The thin plate stall effect is to blame for this pattern. At tiny angles of attack, the fluid easily separates from the trailing edge to meet the Kutta condition, following a perfect potential flow pattern. The trailing edge's velocity gradient, on the other hand, becomes more pronounced as the angle of attack rises. Higher vorticity is produced for the flow passing through the vane's trailing edge as a result of the greater velocity gradient. In the current investigation, it was found that the vorticity reaches its peak at a 17-degree angle of attack.

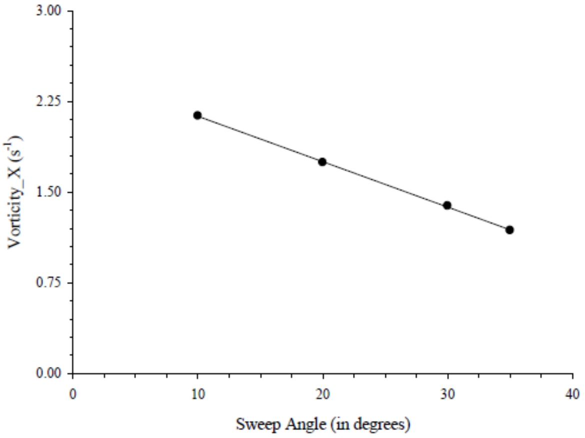


Fig.4 Variation in vorticity with the sweep angle

Beyond this angle, the significant velocity gradients close to the trailing edge begin to commence separation from the trailing edge, which causes the skin drag on the vane surface to increase and the lift component to decrease. Thin-plate stalling is the term used by Anderson (2007) to characterize this occurrence. In the current investigation, this angle of attack was determined to be roughly 17 degrees, which closely matches Anderson's (2007) estimate that thin plate stall starts at a 15-degree angle of attack.

d) Height of vanes:

The height of the vane determines the submergence or depth of flow above it. According to Sharma et al. (2016) and Odgaard (2007), the ratio of vane height to depth of flow (H/h) is a key factor in creating vorticity in the flow passing past the vanes. According to Sharma et al. (2016), The development of vorticity requires an optimal value of H/h.

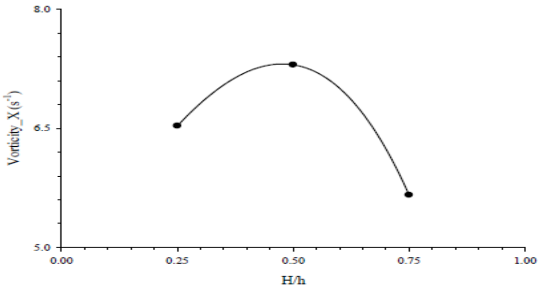


Fig.5 Variation in vorticity with respect to height of vane

In the present investigation, three different H/h values—0.25, 0.5, and 0.75—were taken into consideration, which caused the flow to become vortexed. The tapered vane produces the most vorticity when H/h = 0.48, which is similar to the value of H/h = 0.4 suggested by Sharma et al. (2016). According to Sharma et al. (2016), the vane's height influences the core flow region's deflection towards the vane, enhancing the stability of the vortices it generates.

Lower vane heights (H/h 0.2) are ineffective for sediment control because they are too small to draw flow from the core flow zone. In order to create a vortex, the flow may be restricted rather than deflected by higher vane heights (H/h > 0.48). Therefore, for effective sediment control, the optimal vane height—determined in the current study to be H/h = 0.48—is required.

e) Transverse velocity downflow of the vane:

According to idea of Sharma et al. (2016), the transverse velocity is a key factor in influencing the strength of flow diversion in the secondary currents' lateral course and strength.The degree of bed erosion in a river bend is shown by the transverse slope in a curve, which is caused by the transverse velocity of the flow, according to studies by Zimmerman and Kennedy (1978), Odgaard (1981), Odgaard (1982), and others. Odgaard and Kennedy (1983) and Odgaard and Mosconi (1987) both shown how submerged vanes may generate secondary currents that spin in the opposite direction to that of bends. As a result, erosion is significantly decreased since the secondary currents created by the vane and the bend balance one another out. As a result, it is important to investigate how the tapering angle affects the transverse velocity for tapered vanes since it has a substantial influence on the production of secondary currents.

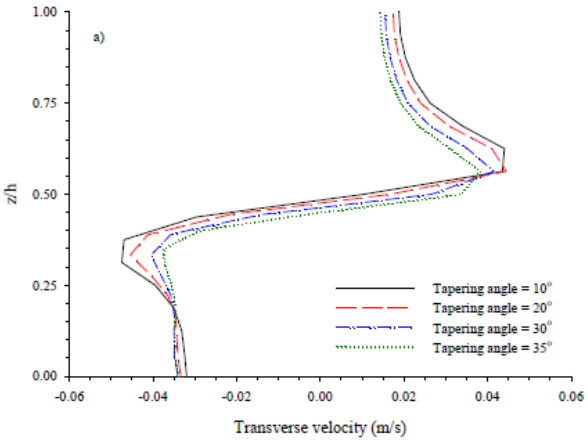


Fig.6 Change of transverse velocity with tapered angle

According to the figures, the transverse velocity increases linearly from the bed to a height equal to 0.2 times the flow depth (h), at which point the transverse velocity reaches its maximum. The transverse velocity declines to zero and then increases once more to reach the water's surface at the profile's mid-depth region, which is further away. It was found that sweep angles of 10o produced the highest transverse velocity magnitude. This demonstrates that a sweep angle of 10 degrees produced secondary currents of the largest magnitude.

Observed:

1) The strongest secondary currents are produced by tapered vane for sweep angles of 10 degrees or less because the bound vortex is stronger than at other tapering angles.
2) The highest strength of the secondary currents produced is corresponding to the attack angle of 17 degrees. This figure is near to the critical angle of 15 degrees, above which thin plate stalling takes place and any hydrofoil's ability to provide lift is reduced.
3) The strongest and most vertically active secondary currents were created at a relative vane height (H/h) of 0.48.

B. Research on the Protection of River Banks Affected by Submerged Vane Shapes

In the discipline of river engineering, sediment management is crucial for tackling problems such river bank scour and sediment deposition. These worries may result in rivers' ability to transport floodwaters being reduced. Gabions and groynes have both been used as protective measures for river banks against these problems. Submerged vanes are another strategy that can be used to manage scour and deposition zones and alter the sediment transport regime along river banks.

These submerged vanes may be made and placed in numerous rows with different angles of attack relative to the flow direction, typically ranging from 10 to 30 degrees. They achieve this by generating secondary currents that alter the local velocity distribution and sediment transport patterns.
Researchers like Odgaard and Kennedy (1983) have examined the construction of submerged vane systems to stop or minimise bank erosion at river bends. They found that the vanes may effectively reduce velocity and scour along the bank without altering the energy slope of the channel. Similar studies have investigated the circulation, transverse velocity, bed shear stresses, and variations in depth distribution of submerged vanes. Among these are investigations by Odgaard and Wang (1991), Marelius and Sinha (1998), and Voisin and Townsend (2002).

In the studies, several submerged vanes, including flat plates constructed of diverse materials, were used. Three different shapes of vane—flat, angled, and curved—were used in the current study's laboratory tests along a straight channel to examine their effects on scour and sediment control. In the trials, flow and sediment depth hydraulic parameters were measured.

In conclusion, submerged vanes are a practical way to manage sediment-related difficulties in rivers, and the area of river engineering has done substantial research on their design, installation, and performance.

Experiments:
At Shahid Bahonar University in Kerman, Iran, the experiments were performed in the hydraulic laboratory of the Civil Engineering Department. The system included a 20-meter-long, 70-centimeter-wide, and 60-centimeter-deep rectangular cemented canal with a longitudinal slope of 0.005. At the canal's upstream and downstream ends, two storage tanks were placed.

The size of the first tank was 4x3x2, while the capacity of the second tank was 4x4x4. The second tank had a centrifugal pump that was linked to the upstream tank by two 20-centimeter lines. To regulate the discharge, gate valves were put on the pipes.

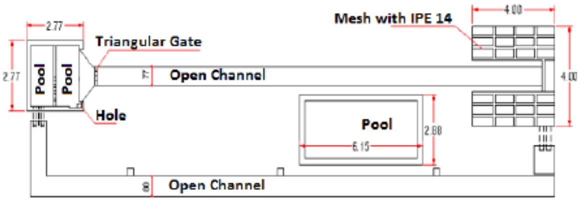


Fig. 7 Laboratory of Shahid Bahonar University

The canal bed was composed of a 6-centimeter-thick layer of sand with median widths varying from 1 to 4 millimetres. For the trials, 40 galvanised plates were put in place along the canal's side. These plates had the following measurements: 15 cm long, 13 cm high, and 1 cm thick. They were arranged in double and triple rows, 20 degrees off-centre from the river. The vanes were elevated 7 centimetres above the sand. The streamwise distance between the arrays was 30 cm, whereas the lateral spacing and distance from the bank were 12 cm and 8 cm, respectively.

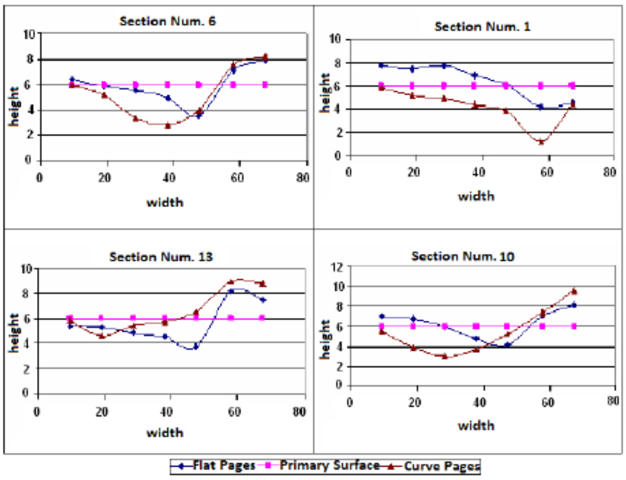


Fig.8 Vanes are arranged in two zigzag rows, with bed variations in various channel cross sections.

The experiments used three different types of identical-sized vanes. The first type was made up of flat vanes that were mounted at a 20-degree angle of attack with regard to the flow direction. The second type of vanes had an angle of 20 degrees in the middle, with a 10° angle of attack on the first half and a 30° angle on the second. The third form included two pieces: a curved and a flat piece. The flat section of this type was installed with a 20° angle of attack with the flow direction. There were two different arrangements for the vanes: parallel to one another and in a zigzag pattern. Four experiments were conducted for each type of vane, considering double and triple arrays with parallel and zigzag.It took three hours for each experiment to stabilise the canal bed morphology. After that, the pump was turned off, and the sand surface metre equipment was used to measure the heights of the bed sediment and the flow velocity(WH-406) manufactured by KENEK, Japan, with an accuracy of 0.5 mm for the depth meter and 1 mm/sec for the velocity meter.

Observed:

Coastal erosion poses a significant challenge in river engineering, and submerged vanes have emerged as a potential solution. These vanes are installed at an angle between 10 to 30 degrees relative to the water flow, aiming to induce rotational currents that can influence sedimentation patterns in rivers. In this study, experiments were conducted on a channel to compare the performance of vanes with new curved and angled shapes. The findings revealed that curved vanes were approximately 15% more effective in stabilizing the riverbanks compared to angled vanes.

C. *In channel bend of 180^o, the effects of a submerged vane positioned at the optimal angle on bank erosion and protection were experimentally studied.*

Prior to scour, the normalised time-averaged tangential velocity component's azimuthal distribution (u=u/U). The velocity magnitude across the inner bank is a little bit greater than the approach velocity in the 0° section upstream, however the velocity profiles at other locations are similar to the approach velocity. At the 30° segment, the velocity increases on the outside slope close to the bed while decreasing on the inner side of the channel. The velocity increases across the outer bank of the 90° section throughout the channel's depth. The 110° portion has a gradual rise in velocity from the inner bank toe to the outside wall. The outside zone of the velocity profile at the 130° segment shows nonuniform distribution. The velocity near the bed is a tiny bit greater downstream at the 150° segment than in another section. With greater velocities at the curve exit and on the outer side, the maximum tangential velocity seen at the bend is around 1.10 times the approach velocity.

At various azimuthal sections, the vertical distributions of the normalized time-averaged radial velocity component (v=v/U) are shown. The amplitude of v is quite tiny at the 0° segment upstream, indicating primarily unidirectional flow. However, closer inspection indicates mild radial flow in the top half in the direction of the inner bank and in the Centre area in the direction of the inner bank away from the bed. The development of circulation may be seen in the flow patterns between the 30° and 110° portions, which typically occur from the outer to inner bank near the bottom and from the inner to outer bank in the higher half. Near the bed of the inner toe. There was also some flow from the inner to outer bank. Nearly two-thirds of the flow depth is covered by the radial components for the 130° segment, but there is no radial flow in the top zone. The amount of cross-flow is diminished and mostly contained along the bed and the outer bank at the 150° segment.

The downstream portion of the bend is where velocity achieves its highest value, according to the velocity distribution diagrams on the unprotected, unscoured bed. Near the outside bank, the tangential velocity magnitude increases, while near the inner bank, it drops. The transition is seamless and does not result in the creation of a vortex at the beginning of the curve (0° section). Centrifugal force causes a vortex flow to develop as the flow flows downstream (between the 30° and 110° portions), spanning nearly the whole cross section. Additionally, little regional vortices can be seen close to the inner and outer banks' toes. The measured flow pattern may be used to explain the scour occurrence at the curve.

A super-elevated water surface with a greater level at the outer bank results from the centrifugal force, which is proportional to the square of the velocity. Due to the increased gravitational pull caused by the raised water surface, a downhill flow has developed along the outer bank. Along with causing erosion and sediment transfer downstream, the faster flow along the outer bank and downward flow along the outer slope also contribute to some sediment deposition on the inner sloping bank. Submerged vanes were used in the current trials along the outer bank at various angles to lower the tangential flow component and intercept cross-flow operating on the bed near the outer bank's toe zone.

Conclusion:

The flow behaviors and the efficiency of submerged vanes in decreasing scour at a angle of 180° curve in a parabolic shaped channel are the subject of the experimental findings in this study. There are two key sections to the study. To start, the causes of bank erosion at bends were determined by measuring the three-dimensional flow components. Second, submerged vanes were tested at various angles with respect to the tangential flow component to determine the best angle for minimizing scour along the outer bank.

According to the flow study, the erosion at the curve is mostly caused by cross-flow development and quicker flow along the outer bank as a result of centrifugal force. The main stream flow could not be diverted from the outer bank's toe by installing vanes with very tiny angles in relation to the tangential component. However, vanes positioned at sharp angles hindered and divided the flow, causing the creation of nearby scour holes and escalating erosion at the bend.

Main Findings are:

- The maximum magnitude of the tangential component was approximately 1.1V(velocity) of the approaching flow.
- The most significant scouring at the outer side of bank at 180° bend was observed between bend angles of 120° and 140°.
- Among the tested vane angles, the 15° angle showed the most effective results in reducing the depth of scour.

D. *It was investigated how different vanes' angles and the distance between them and the intake may affect how much sediment was allowed to reach the intake through a 90° convergent curve.*

The effect of the distance between submerged vanes and the intake on the volume of silt entering the intake in a convergent channel is investigated in this study. The study focuses on two independent parameters, namely the deflected sediment ratio and the efficiency of sediment control by submerged vanes, which are analysed through dimensional analysis. Additionally, the impact of a dimensionless parameter, defined as the ratio of the distance between the vanes and the intake to the vanes' height, is investigated across various angles and intake ratios. The study involves plotting graphs to analyse changes in sediment volume entering the intake and the effectiveness of vanes in sediment control, while maintaining a constant distance from the intake and varying the vane angles.

Graphs 1 and 2 depict the variations in the ratio of deflected sediment and the efficiency of vanes in controlling sediments at different distances $\alpha = 15°$ and $\frac{\delta_s}{H_V} = 6$ in a convergent channel. The results differ depending on the intake ratio. As $\frac{\delta_b}{H_V}$ the distance between the vanes and the intake increases, there is a decreasing trend in the volume of sediment entering the intake, leading to an increase in efficiency. However, at an intake ratio of 15%, $\frac{\delta_b}{H_V} = 2.5 - 3$ increasing the distance results in an increase in sediment volume and a decrease in efficiency. Minimal changes are observed in both sediment volume and efficiency at $\frac{\delta_b}{H_V} = 3 - 4$ At higher intake ratios, there is a reduction in sediment volume entering the intake, coupled with an increase in efficiency. These changes are more severe for $\frac{\delta_b}{H_V} \geq 4$ Laboratory observations indicate that atthe inflow to the intake and the effect induced by submerged vanes interact, causing an increase in sediment volume entering the intake. In this scenario, the maximum efficiency is observed at an intake ratio of 15%, and efficiency decreases as the ratio increases.

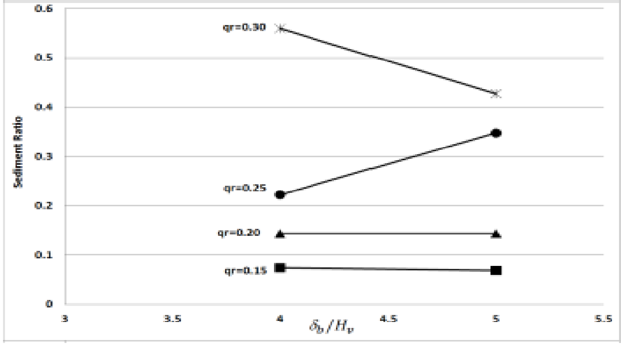


Fig.9 The ratio of deflected sediment

In this study's trials, varying angular locations of the submerged vanes were taken into account as they investigated the effects of changing the distance between the intake and submerged vanes on the amount of silt deflected into the intake at 90° convergent bends. According to the results, there is a decrease in the amount of sediment entering the intake when the distance between the vanes and the intake is increased. As a result, the vanes' effectiveness at controlling silt is increased.

E. The numerical simulation used in this work evaluates the employment of submerged vanes in various configurations within a river system while modelling channel flow.

This study involved the numerical modelling of open channel flow using submerged vanes. The obtained results were compared to laboratory measurements, and a high level of compatibility was observed. The mathematical model used in the study was found to be accurate, allowing for the determination of flow characteristics and associated effects throughout the channel. The data obtained from this research can be utilized in assessing changes in open channel flow characteristics and studying the impact of submerged vanes on flow velocities. Before making any physical modifications, the impacts of submerged vanes in different parts of a river system may be foreseen using a mathematical model simulation. Additionally, using computational fluid dynamics (CFD), flow parameters including water pressure, flow velocity, and turbulence, which are typically challenging and costly to measure in rivers, can be accurately determined. Positive results were obtained in advance of implementing the submerged vane structure.

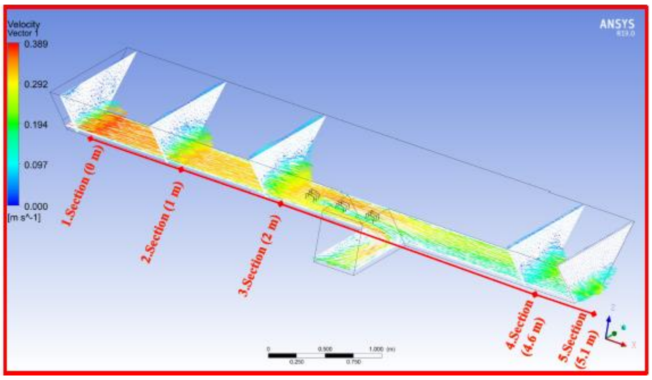


Fig. 10 Variation of 5 cross-sectional velocity distributions using CFD

F. Underwater vane matrix systems designed to support a river intake

Regional water authorities and local government organizations could save money on water treatment by using submerged vanes to direct sediment away from intake screens. This study looked at the advantages and viability of using submerged vanes in a river system, taking different configurations into account to find the best design strategy.

A mirrored pair of matrices with three vane arrays each make up the final design. When viewed from above, these matrices are symmetrically organized around the longitudinal axis of the river. Based on a thorough analysis of the available literature and taking into account a wide variety of factors and design goals, the dimensions of the vanes and matrices were established. Vane dimensions of 0.25 m in height, 1 m in length, and 10 mm in width were chosen. Each arm of the vanes is positioned at a 30° angle to the river's centerline and is arranged in two diverging matrices. Three vane arrays are installed on each arm, with lateral and longitudinal spacing of 0.5 m by 4.0 m and an attack angle of 30°.

Implementing this design can play a substantial role in reducing sediment clogging of council infrastructure at the study site. It directly contributes to improved efficiency in water treatment plants, leading to reduced energy consumption and expenditure. Furthermore, it has a positive environmental impact by helping to decrease the carbon dioxide footprint that contributes to climate change.

G. Submerged vane technology Used in Colombia:

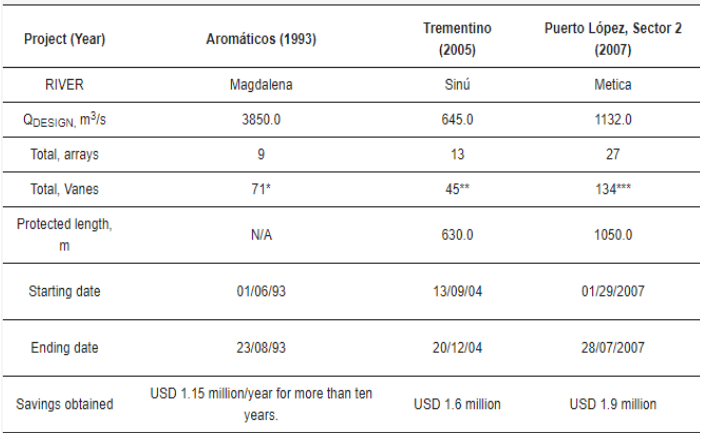
The five exemplary projects included in this paper demonstrate the efficacy of submerged vane technology in Colombia. These projects have diligently followed the design recommendations and technical articles, making necessary adaptations to suit local conditions.

The models used in Colombia were specifically tailored to suit the medium flow conditions of Colombian rivers, which exceed the flows encountered in similar projects worldwide. Continuous improvements were made in the manufacturing and installation procedures of the vanes, considering factors such as project-specific conditions, location, hydraulic variations, and the availability of materials and equipment in the area. In Colombia, the vanes are often made of thin plates, prefabricated solid or lightened concrete, or metal lattice covered in sheets of high-density polypropylene.

These initiatives, along with ones in Colombia, show how models created by the University of Iowa's Institute of Hydraulic Research may be successfully used. These models have proven effective in formulating solutions for river evolution, erosion, and undermining processes through the use of submerged vanes. These projects validate the technology's effectiveness and highlight the significant economic and environmental benefits it offers compared to traditional solutions.

Through more than 25 years of sustained effort, Colombia has made more efficient use of public resources to address erosion, undermining, sedimentation, and navigation improvement issues. This has provided a valuable service to the country and resulted in substantial cost savings for each project. Importantly, the implementation of this technology in Colombia has been carried out using local engineering expertise, materials, and labour.

Results of using submerged vane technology in Colombia for riverbank protection and sediment control, as demonstrated by the five projects included in this article, have demonstrated positive effects on the environment and have led to cost reductions in both the initial solution and ongoing maintenance.



Project (Year)	Aromáticos (1993)	Trementino (2005)	Puerto López, Sector 2 (2007)
RIVER	Magdalena	Sinú	Metica
Q_{DESIGN}, m^3/s	3850.0	645.0	1132.0
Total, arrays	9	13	27
Total, Vanes	71*	45**	134***
Protected length, m	N/A	630.0	1050.0
Starting date	01/06/93	13/09/04	01/29/2007
Ending date	23/08/93	20/12/04	28/07/2007
Savings obtained	USD 1.15 million/year for more than ten years.	USD 1.6 million	USD 1.9 million

Fig.11 Overview of Project

Environmental impact: Submerged vane systems require significantly less material compared to other types of solutions, resulting in minimal demand for mineral resources and a reduced environmental footprint. Since the panels are typically submerged and not visible from the surface, they have no visual impact on the landscape or interference with nearby navigation. While there haven't been specific studies on the potential impacts on the aquatic environment's natural conditions, there have been no reported complaints from residents regarding qualitative or quantitative changes to fauna and flora following the installation of the panels.

Economic impact: The cost of submerged vane solutions has proven to be much lower than alternative approaches considered for the sites where this technology was implemented. Table provides information on the economic benefits obtained from the five projects included in the study.

Costs of maintenance: Since the projects were built, none have needed maintenance in order to function well or be preserved., distinguishing them from other solutions that aim to achieve the same goals. The vanes, operating at the depth of the riverbed, allow floating material to pass over without trapping. Even in cases where panels are located near the shores and operate at shallower depths or protrude from the surface, there has been no accumulation of material that could lead to channel narrowing and subsequent flooding.

The enhanced maintenance, economic, and environmental results emphasise the promising potential of using submerged vane technology on significant rivers, such as those in Colombia. To further knowledge and encourage wider acceptance, it is rational to do further study and disseminate the findings as they are provided here.

H. Increasing the Usefulness of Vanes with a Collar and Submerged:

The study's experimental setup consisted of an 11-meter-long tilting flume with a 50-cm-deep and 50-cm-wide channel. The flume's side walls were made of translucent Perspex. The utilized vanes were composed of plastic sheets that were 4 mm thick and 6 cm tall. The vanes were positioned 12 cm down. Two kinds of sands with various particle sizes were used in the studies. On top of the flume, a point gauge that could be moved along rails was used to measure the flow depth and scour pattern. The flume was modified to the proper slope, and the discharge was managed with a tail gate to create a consistent flow without sediment motion. The sediment bed was levelled before to the submerged vanes installation, then following installation, the substrate was levelled once again around the vanes.

To prevent scouring around the submerged vanes at starting, flow was progressively added to the flume. Around 90% of the threshold velocity for bed sediment movement was maintained for the flow velocity. The scour pattern was measured after the experiment using a point gauge, and it took approximately 20 hours for the scour to reach equilibrium. The measurement of vortex strength was carried out using grids placed 15 cm downstream from the center of the vanes. Velocity components were measured using an acoustic Doppler velocimeter.

In order to eliminate the velocity near the flume wall and limit the wall's impact on secondary flow generation, a total of 44 measurement locations were acquired. The Centre of the vortex was visible at a distance of 0.9H from the starting bed level, with the origin taken at the halfway point of the averagesubmerged vane length and dimensions.

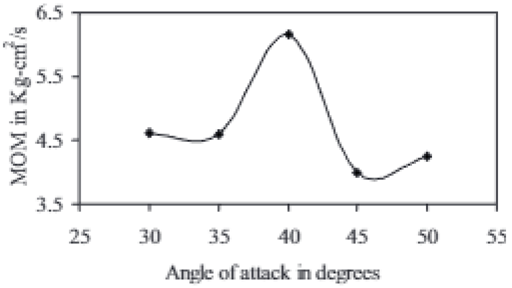


Fig.11 Variation of MOM with angle of attack

The moment of momentum (MOM) was calculated for each measurement point using the mass and velocity vectors. The MOM values were summed across all measurement points to obtain the total MOM. Further details of the MOM computations can be found in Gupta et al. (2006b).

Conclusion:

Local scour was greatly influenced by the presence of a collar on the leading edge of a submerged vane. The scour depth around the vane without a collar was less at a lower Froude number of 0.13 than it was at a more than last Froude number of 0.25, and the vane was not moved. At Froude number 0.13, the dimensionless scour depth at the leading edge of the vane was 0.294 for sediments with a size of 0.225 mm and 0.260 for sediments with a size of 0.405 mm. At Froude number 0.25, the dimensionless scour depth was 0.670 for sediments with a diameter of 0.225 mm and 0.443 for sediments with a diameter of 0.405 mm.

For both Froude numbers 0.13 and 0.25, independent of the quantity of the sediment, the scour depth at the leading edge of the submerged vane could be decreased to zero by adding a collar. According to the analysis, a rectangular vane would work better with a circular collar design. While Collar Size R-2 was most effective for rectangular vanes at Froude number 0.25 with both sediment sizes, Collar R-1 worked well at Froude number 0.13 with both sediment sizes.

The leading edge of the vane, which is 0.05H below bed level, was judged to be the best location for the collar. A rectangular vane with a collar was found to have an optimal angle of attack of about 40°.

The study highlighted the advantages of using collars in submerged vanes, although further investigations are needed to determine the appropriate collar dimensions considering the bed material and fluvial parameters in detail.

I. Material used in manufacturing of submerged vanes:

Submerged vanes can be constructed using a variety of materials, each with its own advantages and considerations. Some commonly used materials for submerged vanes include concrete, steel, plastic, and composite materials.

Concrete: Reinforced concrete is often chosen for submerged vanes due to its strength and durability. It can be moulded into different shapes and sizes to meet specific design requirements and offers excellent resistance against water flow forces.

Steel: Steel is a popular choice, especially for larger-scale projects, due to its high structural strength. It can withstand the forces exerted by water flow and provides long-term durability. Steel submerged vanes are commonly fabricated using welded or bolted connections.

Plastic: Certain types of plastic, such as high-density polyethylene (HDPE), are suitable for submerged vane construction. Plastic vanes are lightweight, corrosion-resistant, and relatively easy to install. They can be manufactured in various shapes and sizes, providing flexibility in design.

Composite materials: Composite materials, such as fibre-reinforced polymers (FRP), are being increasingly used for submerged vane construction. These materials offer a combination of strength, corrosion resistance, and flexibility in design. Composite submerged vanes can be fabricated using layers of fiberglass or carbon fibre reinforced with polymers.

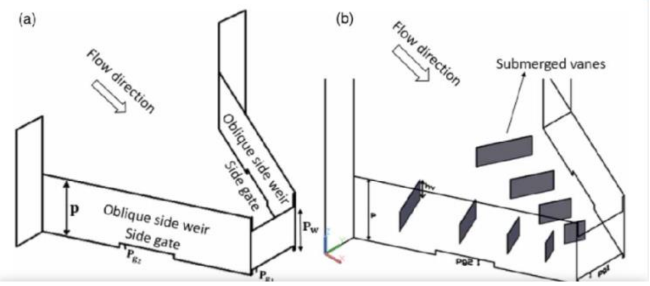


Fig.12 Submerged Vane Installed

The selection of material for submerged vanes depends on several factors, including cost, structural requirements, availability, and the anticipated hydraulic and environmental conditions at the project site. Consulting with engineers or experts familiar with the specific application can help determine the most suitable material for submerged vanes in a given project.

III. Proposed Work

The suggested strategy for the project is to enhance the current system, select the most appropriate material to decrease the cost of submerged vanes and increase the efficiency of vanes with respect to channel flow. Now a days fly ash isgood source for strength in less expense, so we can introduce fly ash as a manufacturing material of submerged vanes as it will decrease the use of cements material and also it will decrease the original cost of manufacturing. Fly ash is already in use on construction sites as a compressive member, let’s try to add fly ash in construction of submerged vanes that make the vanes more economic and affordable.

Fly ash, a by-product of coal combustion in power plants, is commonly utilized as a supplementary cementitious material in concrete production. Its incorporation in concrete offers several advantages and applications:

1. Cement substitution: Fly ash can partially replace cement in concrete mixes, resulting in reduced cement consumption. This substitution conserves natural resources and decreases the carbon footprint associated with cement production, as fly ash is a waste product.

2. Enhanced workability: Fly ash improves the workability of concrete, making it easier to handle, place, and finish. It enhances the cohesiveness of the mixture, leading to improved flow and reduced water requirements. This is particularly beneficial for large-scale concrete placements and situations that require enhanced workability.

3. Strengthening: Fly ash helps concrete's concrete build its long-term strength. As a result of its reaction with calcium hydroxide, a by-product of cement hydration, more cementitious compounds are produced over time, increasing compressive strength..

4. Reduced heat of hydration: By incorporating fly ash, the heat generated during concrete hydration can be reduced. This is especially advantageous for massive concrete structures like dams or large foundations, where excessive heat can lead to thermal cracking. The reduced heat is good for the performance of the concrete.

5. Improved toughness: Fly ash makes concrete tougher by lessening permeability and boosting chemical resistance. It increases concrete's resistance to sulphate attack, alkali-silica reaction, and chloride penetration, enhancing durability and reducing the likelihood of deterioration..

6. Benefits for the environment: Using fly ash in concrete has a positive impact on the environment. Utilising this waste material in the creation of concrete lowers the need for cement, which lowers greenhouse gas emissions and energy use. Additionally, it aids in protecting natural resources.

Fig.13 Aligned Submerged Vanes

When incorporating fly ash into concrete, it is essential to consider factors such as fly ash quality, local regulations, and proper mix design and testing. These considerations ensure that the desired performance of the concrete incorporating fly ash is achieved.

IV. DISCUSSIONS

A. Making submerged vanes using fly ash:

The approximate cost of submerged vanes can vary widely depending on the factors mentioned earlier. However, as a rough estimate, the cost of submerged vanes can range from several thousand dollars to tens of thousands of dollars per vane, considering materials, design, manufacturing, installation, and other associated costs.

It is important to note that this estimate is general and may not reflect the actual cost for a specific project. The cost will depend on the project size, complexity, site conditions, and local market rates for materials and labor.

To obtain a more accurate cost estimate for a particular submerged vane project, it is recommended to consult with engineers, contractors, or specialized firms who can evaluate the project requirements and provide a detailed cost analysis based on specific design considerations and local factors.

The use of fly ash as a construction material offers several advantages, including reduced environmental impact, waste utilization, improved engineering properties, and cost-effectiveness. However, it is essential to consider the quality and characteristics of the fly ash, adhere to local regulations and specifications, and conduct proper testing to ensure its suitability for specific construction applications.

B. Idea of using weep hole in vane design:

Till now vane design does not consist any type of hole that will help to pass the fluid without making hydraulic pressure.
Continuous flow of water generates hydraulic pressure that can crush the object coming in the path of flow. To prevent or reduce that energy we are introducing weep hole inside the vane design. If water pressure continuous hit the vane then fluid can cause vane failure but if we use weep holes then fluid can pass through weep holes that will decrease the instant hit pressure of water. Due to which durability of vanes gets automatically increased, also it will reduce the cost of maintenance which led to the economic project.

Still, it is not a practically tested idea, this idea is on theoretical base and concept weep hole occurs from the construction of weep hole dams.

Weep holes are small openings or drains that are designed to facilitate controlled drainage of water from enclosed or confined spaces. They are commonly used in construction applications such as masonry walls, retaining walls, window and door frames, and foundation walls. Here are some important points about weep holes:

1. Purpose: Weep holes serve the primary purpose of preventing the accumulation of water within a structure or cavity. Their function is to allow water to drain out, thereby reducing the risks associated with moisture, such as water damage, mold growth, and structural deterioration.

2. Location and Design: Weep holes are typically positioned at the lowest point of a structure or cavity to ensure effective water drainage. They are usually located near the base or bottom of the wall or frame. Weep holes can take the form of small round openings, slots, or gaps in the construction material, enabling water to escape.

3. Mechanism: Weep holes operate based on the principles of gravity and capillary action. As water accumulates within the enclosed space, it naturally flows towards the lowest point and exits through the weep holes due to gravity. Capillary action also aids in drawing water out of the structure, as water is naturally attracted to porous materials.

4. Protection: Weep holes are typically equipped with protective features to prevent the entry of debris, insects, or rodents. These protective measures can include screens, meshes, or specially designed covers that allow water to pass through while keeping unwanted elements out.

5. Importance of Proper Installation: Proper installation and regular maintenance of weep holes are crucial for their optimal performance. Weep holes need to be appropriately sized to allow efficient drainage without compromising the structural integrity of the construction. Regular inspection and cleaning of weep holes are essential to prevent blockages and ensure uninterrupted water drainage.

By incorporating weep holes into construction projects, the risk of water accumulation and associated problems can be significantly mitigated. Well-designed and well-maintained weep holes contribute to the overall durability, longevity, and performance of various structures.

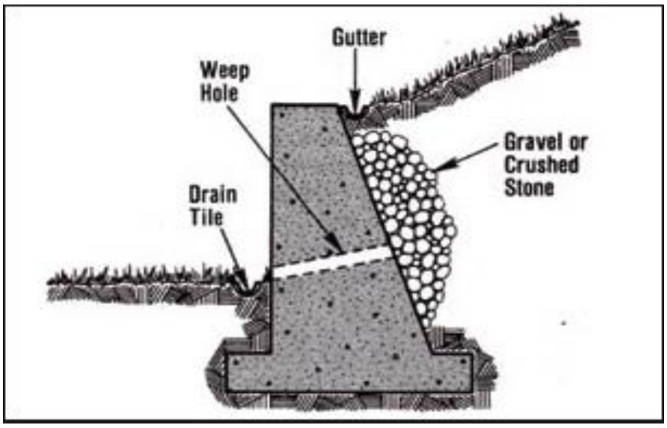


Fig.14 Weep hole in retaining wall

C. Design of vane using pre stressed concrete

Prestressed concrete is a construction method that utilizes internal forces applied before external loads to enhance the strength and durability of concrete structures. By introducing compressive stresses, it counteracts the tensile stresses that concrete typically experiences, resulting in improved performance.

Here are the main points about prestressed concrete:

1. Principle: Prestressed concrete applies pre-compression to counteract tensile stresses. Internal forces are introduced through pre-tensioning or post-tensioning, resulting in enhanced resistance to bending, cracking, and deflection.

2. Pre-Tensioning: Pre-tensioning involves tensioning steel strands or wires, called tendons, before pouring the concrete. Once the concrete gains strength, the tension is released, transferring compressive forces to the concrete.

3. Post-Tensioning: Post-tensioning involves placing ducts or tubes within the concrete, inserting tensioned steel strands or bars, and anchoring them. The tensioning forces are transferred to the concrete, achieving the desired prestressed condition.

4. Benefits: Prestressed concrete offers advantages such as increased load-carrying capacity, reduced cracking and deflection, improved durability, and the ability to create longer spans and thinner elements. It is ideal for large-scale infrastructure projects like bridges, parking structures, high-rise buildings, and industrial facilities.

5. Design Considerations: Designing with prestressed concrete requires careful consideration of prestressing force, tendon layout, concrete strength, and construction sequence. Specialized design codes and analysis methods ensure efficient and safe use.

6. Construction Process: The construction process involves fabricating precast elements, tensioning tendons, placing concrete, and curing. Skilled labor, specialized equipment, and stringent quality control measures are necessary for maintaining the integrity of prestressed elements.

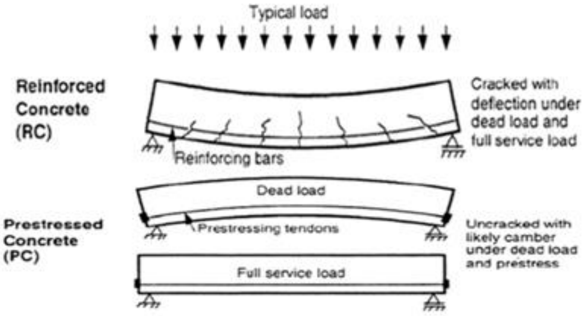


Fig.15 Prestressed Structure Diagram

Prestressed concrete has revolutionized construction, offering more efficient and durable structures. Its ability to withstand larger loads, reduce material usage, and enhance structural performance makes it a valuable choice for various engineering applications.

It will increase the properties of submerged vanes and chances of maintenance, if maintenance cost will decrease then overall budget of project will also decrease. Pre-Stressed concrete will increase compression bearing strength of submerged vanes.

But it has some disadvantages also like:

1) Costly Material, Fabrication, and delivery
2) Require large machines for heavy members
3) Flexibility in Design
4) No chance of Error
5) Design will be more complicated.

V. CONCLUSION

The purpose of this study was to present an alternative to the submerged vanes design and material used in making of vanes. And, to present previous studies on submerged vanes as reference on one paper.

To summarize, submerged vanes play a significant role in river engineering by enhancing flow characteristics, managing sediment transport, and stabilizing riverbeds. They can be made from various materials to suit specific project requirements and environmental factors.

The advantages of submerged vanes include minimizing local scour, optimizing flow patterns, and improving hydraulic efficiency. They facilitate flow redirection, create beneficial eddies for sediment deposition, and mitigate erosion along riverbanks.

Innovations like collar designs and other modifications have proven effective in enhancing the performance and efficiency of submerged vanes. These advancements offer greater control over flow patterns and sediment movement, resulting in improved hydraulic and geomorphic conditions.

However, further research is necessary to determine the ideal design parameters for submerged vanes, such as collar dimensions and shapes, and their interaction with different sediment sizes and fluvial conditions.

Overall, submerged vanes provide a promising solution for river engineering, promoting river stability, reducing sedimentation, and enhancing hydraulic performance. Continued progress in their design and implementation will contribute to the advancement of more efficient and effective approaches to river management and flood control.

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