



The Effects of submerged vanes inclination angle on sediment transport into sub-channel

Mnaf Adel Mhsen¹ and Ali N. Hilo²

Affiliations

1College of Engineering, Wasit University, Wasit, Iraq

2College of Engineering, Wasit University, Wasit, Iraq

Correspondence

Mnaf Adel Mhsen
College of Engineering, Wasit University, Wasit, Iraq

Email: mnafadel7@Gmail.com

Received

28-December-2022

Revised

31-January-2023

Accepted

2-February-2023

Doi 10.31185/ejuow.Vol11.Iss1.414

Abstract

The sub-channels that branch from the larger rivers may be manmade or natural. From the major channels, these sub-channels transfer sediments and water. The deposition of sediments at the entrance, sub-channel is a significant research challenge because it threatens the sub-facilities channel's and reduces the sub-carrying channel's capacity. Therefore, submerged vanes were used to reduce the amount of sediment entering the sub-channel. The goal of the vanes is to reduce the amount of sediment entering the sub-channel, hence redistributing sediment at the sub-entry channel's. They are vertically aligned with the flow direction and tilted at a certain angle. A physical model of the main channel, a sub-channel at a right angle, and a sediment feeder mechanism were developed. 51 tests were undertaken, 3 with submerged vanes and 48 without, with a varying number of submerged vanes (7, 5, 3 and 1). And angling it at various angles (10°, 20°, 30°, and 40°) in the discharge direction and with three sub-discharges of (19.1, 27 and 30.5 l/s), the sediment concentration flow was (6 kg/h). The weights of the sediments in sub-channel were calculated, and it was found that there is an effective use of these vanes and that the least amount of sediments is achieved when the angle is (20°). It was observed that the performance of the submerged vanes was significantly improved when there was a decrease in the discharge of the sub-channel.

Keywords: Submerged Vanes, Sub-Channel, Angle of Inclination, sediments feeding, separation zone

الخلاصة: يمكن أن تكون القنوات الفرعية التي تتفرع من الأنهار الرئيسية إما اصطناعية أو طبيعية. تنقل هذه القنوات الفرعية الرواسب والمياه من القنوات الرئيسية. يمثل تراكم الرواسب في مدخل القناة الفرعية تحديًا بحثيًا مهمًا لأنه قد يضر بالمرافق المتصلة بالقناة الفرعية، كما أنه يقلل من سعة القناة الفرعية. تم استخدام الألواح المغمورة لتقليل دخول الرواسب إلى القناة الفرعية، والغرض من الريش هو تقليل كمية الرواسب التي تدخل القناة الفرعية، والتي تعمل على إعادة توزيع الرواسب عند مدخل القناة الفرعية. يتم وضعهم عموديًا مع اتجاه التدفق وبزاوية ميل محددة. تم إنشاء نموذج فيزيائي يتكون من قناة رئيسية وقناة جانبية ذات زاوية قائمة، وجهاز تغذية الرواسب. أجريت 51 تجربة، 3 مع و 48 بدون ريش مغمورة، مع عدد متغير من الريشات (7، 5، 3، 1). وبزاوية مختلفة (10°، 20°، 30°، 40°) في اتجاه التدفق وبثلاثة تصريفات فرعية (19.1، 27، 30.5 لتر / ثانية)، كان تدفق تركيز الرواسب (6 كجم / ساعة). تم حساب أوزان الرواسب في القناة الفرعية، ووجد أن هناك استخدامًا فعالاً لهذه الريش وأن أقل كمية من الرواسب تتحقق عندما تكون الزاوية (20 درجة)، و لوحظ أيضًا أنه كلما قل تصريف القناة الفرعية من الرواسب كان أداء الريش المغمورة أفضل.

1. INTRODUCTION

M. S. Bejestan and R. Azizi [1] noted that all rivers in nature split into smaller rivers at some point in their course (naturally or artificially by human intervention). Accordingly [2] suggested that it should be noted that these sub-channels branch off at a variety of angles. The sub-channels in natural rivers or rivers that have been produced are affected by what takes place at the junction, as well as by the division of water and sediments. On another side [3] stated that rivers transport sediments, which are then deposited. Such as at the entrances of the power plants. Moreover, degrading its mechanical components and raising maintenance costs while diminishing the gained benefits. In addition, sedimentation creates conditions that allow vegetation to take root and damage the watercourse[4]. The multitude of dredging that is done to mitigate sediment deposition is not a permanent or

economical solution, by limiting the cross-section of the channel, the deposit of these sediments in the sub-channel decreases the capacity of these rivers to transport water[5]. In the case of the diversion channel, the greatest challenge faced is channel blockage and restricted capacity caused by the sedimentation at its entry point. It is the vortex region (separation zone) that determines the practical width for the passage of the flow because the sediments are accumulated in this vortex region at the entry point of the lateral channel. Therefore, identification of the vortex region or flow separation zone, as it is also termed, becomes imperative as shown in figure 1.

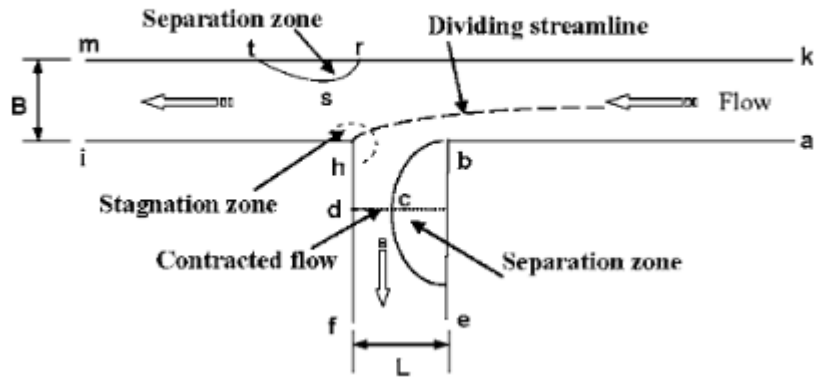


Figure 1 Flow Characteristics of a dividing flow in open channels [6].

This can decrease the entry's effectiveness and effective width while increasing sediment deposition at the entrance [7]. As mentioned in [8] for erosion and sedimentation to occur, a comprehensive understanding of the sediment deposition characteristics at the intersection of the main channel and the sub-channel is required. [9] argued that these intersections' flow is quite complicated and has been extensively researched. [9] confirmed that focuses the design engineer's attention on the division of water at the junction and the provision of measurement tools that determine the quantity of water flow in each channel. However, what will become of the sediments carried by the primary channel? And how it will divide at the junction, as well as whether or not it is possible to quantify or estimate the quantity of sediments that will enter the sub-channel. And consequently knowing the amount of damage that will be caused by the accumulation of sediments in the sub-channel. Priority must be given to understanding how to prevent or limit sub-channel entry. The primary sediment transport mechanism governs the shape and growth of the bifurcation, which controls the distribution of sediment discharge into two branches.

As can be seen in Figure 2, submerged vanes, which are often represented by regular geometric shapes and serve the purpose of controlling the submerged vanes, are positioned in the main channel and front of the sub-channel.

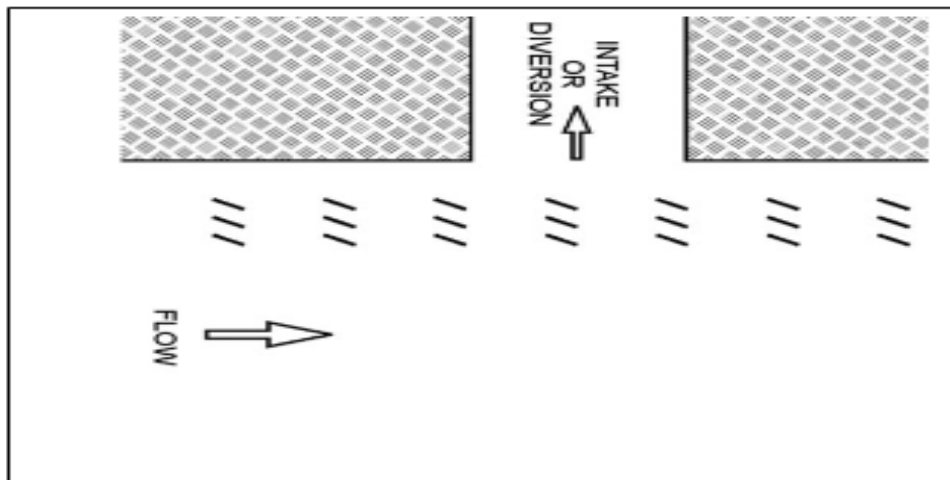


Figure 2 The design of the vanes system layout [12].

The submerged vane can be fully submerged or partially submerged, but the last one is more common [10]. [11] noted that because they are less expensive than conventional river training structures, these submerged vanes have been employed for engineering purposes within rivers, such as altering the flow pattern or reducing erosion around river bends. For sediment management in alluvial rivers, a submerged vane is a vortex-generating device that can influence the evolution of the river bed. In both laboratory trials and field operations, it has proven to be effective. Many of the elements affecting the performance of the submerged vane are hydraulic parameters, such as the main and sub-channel discharge. The velocity of the water, the breadth of the primary and secondary channels, as well as the quantity and kind of sediment. In addition to the nature of the channel's bottom (whether it contains sediments or not, the angle of the sub-channel connection, the straightness of the main channel, etc.), some other factors must be considered. In addition, several variables influence the geometrical properties of the submerged vanes, such as their number, size, shape, and arrangement, as well as their distance from the sub-entrance channels, In order to first compare them and then show which elements have a significant impact, the researcher fixes some aspects while altering others

The study of [17][18] shows altering one or more of these variables has a direct effect on the amount of sediment that will enter the sub-channel. The researcher is fixing some factors and varying others to first examine the difference between them and then provide a picture of the variables that have a substantial and influential effect on the dependent variable. Secondly, sub-channels must be taken into account when designing or managing them. Therefore, sediment entry is the vane angle relative to the flow direction, which is regarded as one of the most critical characteristics influencing the strength of the secondary flow. Numerous submerged vanes row sedimentation plans have been evaluated for their effectiveness in preventing the transfer of sediments into the sub-channel and the formation of the sedimentation zone q_r (the ratio of the sub-channel discharge to the main channel discharge) Therefore, sediments enter the sub-channel numerous scholars have studied and produced numerous types of submerged vanes concerning their size, angle of connection with the direction of flow, and effect on the amount of sediments [18][19]. After seeing that a two-row vane field prevented sediments from entering the diversion for q_r values of less than 20%. The researchers determined that adding a third row would not increase desilting performance. For q_r levels greater than 20%, the vane field proved less effective. The construction of vortices that resuspend sediments likely to be conveyed did not prevent sediments from entering the diversion [20].

None of the investigations on submerged vanes involved sediment entering the main river. In this study, the outcomes of tests with and without submerged vanes in front of a 90-degree diversion channel under sediment feeding (6 kg/hour) are compared. Many variables affect the performance of vanes in descaling, so this research showed the effect of one row of submerged vanes in treating the amount of sediment entering the outlet channel at an angle of (10°, 20°, 30°, and 40°) with three side discharge (19.1, 27 and 30.5 l/s) and with different numbers of submerged vanes (3, 5, 7 and 1).

2. EXPERIMENTAL PROCEDURE

Figure 3 shows the dimensions of a recirculating sediment channel developed for practical experiments at the College of Engineering/Wassit University.

1. The primary channel (10 m in length, 0.3 m in width, and 0.45 m in height) is built of steel, at the end of the channel, there is a tank below ground level (4 m x 3 m x 2.5 m) with a submersible pump. With a 4-inch plastic pipe, the pump is connected to the channel. Hence, the end of the channel is poured with a perforated steel tank (tank-2) (60 cm x 60 cm x 60 cm). This then feeds water into the tank, where it circulates throughout the system.
2. The sub-channel branch off from it at a distance of (8.73 m) from its beginning. It pours into a perforated tank (tank-1), which later pours into the main tank. At the end of it, a gate is manually controlled.

The main and sub-channels are carried on steel arms 80 centimeters above the ground for convenience of usage, viewing, and measurement. A rectangular weir was constructed, 10 cm high, 30 cm wide, and 35 cm from the end of the main channel.

A two-pipe that is four inches in diameter and has two open ends are as follows:

1. The first one is to drain water from the collection basin to the main tank (by gravity) having a mechanical valve to regulate how much water to manually eject from the basin.
2. The other pipe is attached to the submersible pump, and the other end is connected to the collection basin.

Top Veiw

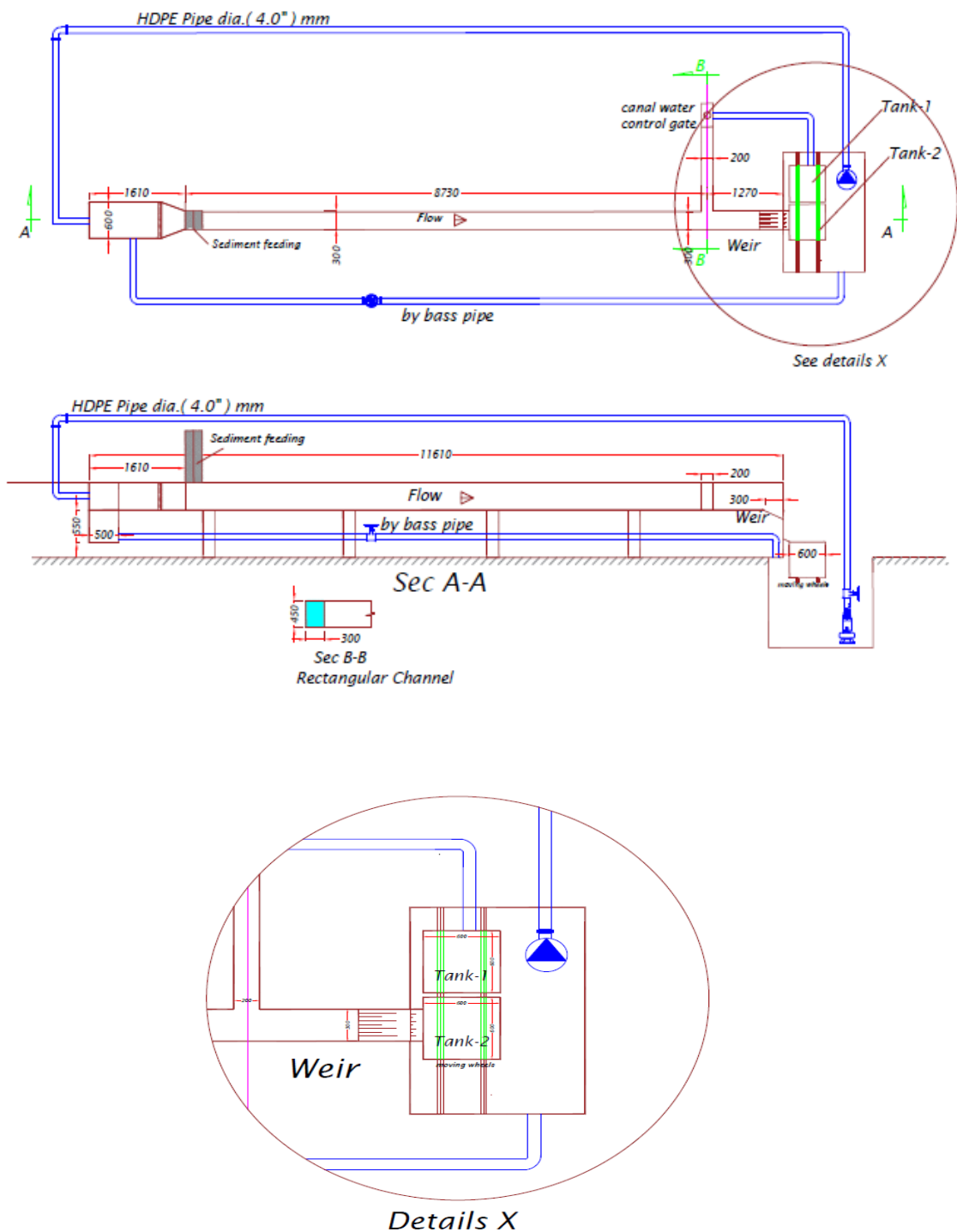


Figure 3 Illustration of The Manufactured Channel.

The calibration was carried out in the following manner:

1. Close the sub-channel completely during the calibration process.
2. Operation of the main pump at full capacity throughout the calibration period.

3. The valve in the pipe exiting the collection basin will initially be closed, causing the whole flow of water from the pump to be directed into the main channel. More to add, placing a certain amount of water in a tank with defined dimensions and measuring the discharge going through the line coming from the main pump using (60 cm ×60cm×60cm)(Tank-2). As a result, we now have a specific volume of water at a known time (using a stopwatch), as this tank moves on a rail for easy emptying of water from it every time
4. Once a simple opening is formed in the external mechanical valve, part of the collected water will come out of the collection basin, thus the amount of water entering the main channel will decrease, and step (3) will be re-worked, where a new discharge will be obtained, but with a time greater than the previous time.
5. Repeating the previous work (4) by making a larger opening in the valve each time to reduce the amount of water that enters the main channel, step (3) which will be repeated to obtain a new volume of water will require more time to complete.
6. The procedure in (3,4,5) was repeated ten times. And every time we have a set amount of water with time.
7. Establishing a relationship between the volume of water obtained manually with time (Q) and the head of water in the weir (H) shown in Figure 4, the discharge equation is deduced which is:

$$Q = 0.741H^{1.5} \tag{1}$$

Where:

Q=discharge (m^3/s).

H=head of water(cm).

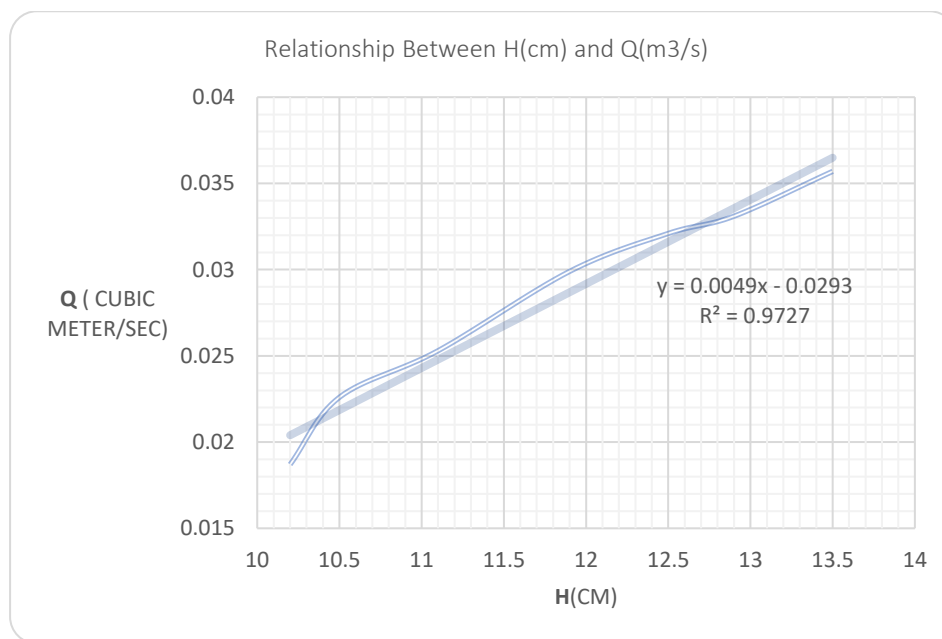


Figure 4 The Relationship Between H (cm) and Q (m3/s).

Figure 5 illustrates a sand feeder, which is a machine made of moisture-resistant cast iron and is put on top of a cone-shaped main channel trough.



Figure 5. The Sand Feeder.

The sand that was to be fed into the main channel was done so with the assistance of this equipment. It contains a shaft that is attached to an electric motor that has variable speeds, a specific weight of 1100 kg/m³, and a d_{50} value of 0.4 millimeters, it allows sediment to enter main channel regularly over time.as shown in Figure 6.

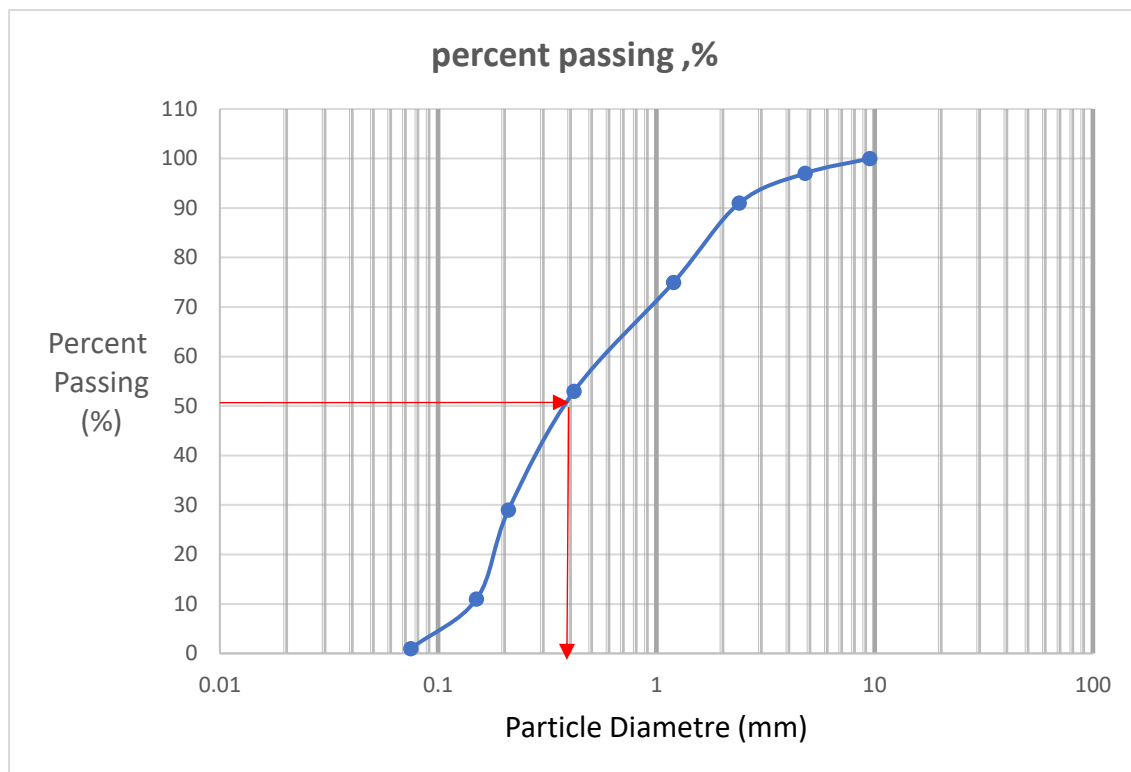


Figure 6. Sieve Analysis Curve.

It was determined that the discharge of the submersible pump was equal to 26 liters per second, and there were found to be three sub-discharges in the side channel (qr). These sub-discharges made up 19.1%, 27%, and 30.5% of the total discharge. Three experiments were conducted without the use of submerged vanes, where (7) submerged vanes were placed in front of the entrance to the sub-channel as shown in Figure 7 and the number of these submerged vanes decreased in each experiment to become (5,3 and 1), and the slope of the submerged vanes is variable (40°, 30°, 20°, 10°), The dimensions of the submerged vanes made of transparent glass were as follows

(height 3.5 cm, length 10 cm, and thickness 0.4 cm), 10 cm apart from each other and 7 cm from the channel wall, noting that the height of the water in the channel was 17 cm, as shown in Table 1.



Figure 7 Sub-Channel Created Section.

Sediment was gathered for a period of two hours. Two hours corresponded to approximately the amount of time needed for a dune to move beyond the face of the diversion[21].

Table 1 Standard limits for the design and layout of submerged vanes parameters*

Parameters					
Reference[23]	H	L	δ_b	δ_n	δ_s
	(0.2-0.5) d_o	(2-3) H_v	$< 4H_v$	(2-3) H_v	(8-10) H_v

*Where; d_o = flow depth; δ_b =vane to bank distance; δ_n = vane spacing; H_v = vane height; L = vane length and, δ_s =distance between two rows.

3. RESULTS

The main objective of this research is to know the effect of using submerged vanes on the amount of sediments, entering the sub-channel, when feeding sediments by (6 kg/h) in the presence and absence of submerged vanes, using main discharge, and three sub-discharges with a variable number of submerged vanes (7, 5, 3 and 1). Figures 6,7,8, show the relationship between the proportion of incoming sediments (S_r =weight in kg of sediments taken in sub-channel /Total sediment feeding (6 kg/h)) and the number of vanes, to obtain the least amount of sediments:

3.1. Experiments without submerged vanes

Three experiments were conducted, without submerged vanes shown in table (2), where, at the beginning of the experiments, the three sub-discharge were used with the sediments injection process, the results were fixed, and the amount of sediments that entered into these experiments was the largest.

Table 2 Relationship between the Discharge of Sub-Channel & %Sr
(without vanes cases).

qr	30.5	27	19.1
%Sr	44,1	26,8	9,76

3.2. Experiments with submerged vanes

1. When the sub-channel discharge is 30.5 l/s, the percentage of isolated sediments is approximately between 40% and 50%, as using one piece of submerged vanes, this percentage of isolation gradually improves when increasing the number of submerged vanes, where the percentage of sediments insulation is confined approximately between 12% and 26%, at the use of 7 submerged vanes, with different inclination angles for the rows of submerged vanes, as shown in Figure 8.

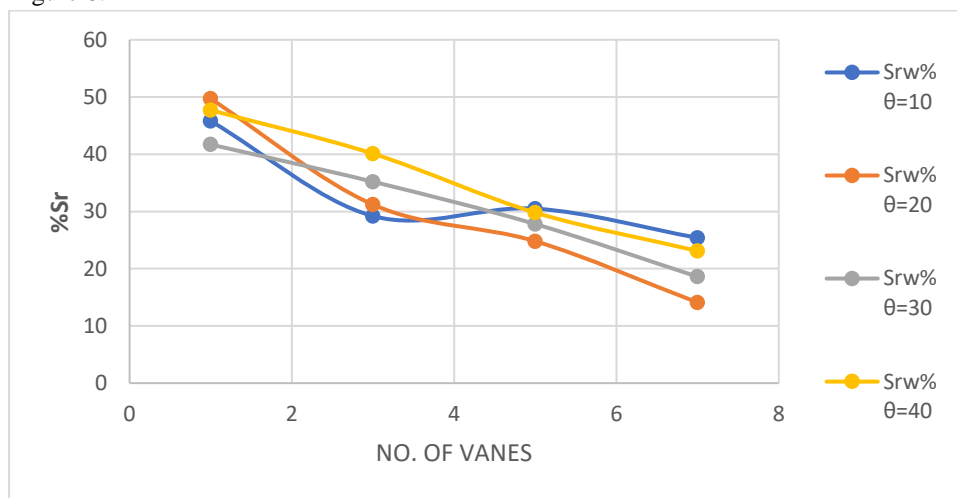


Figure 8 Shows That the Sub-Channel Discharge is 30.5 l/s With Different Angles of Inclination.

2. When the sub-channel discharge is 27 l/s, the percentage of isolated sediments is approximately between 24% and 33%, as using one piece of submerged vanes, this percentage of isolation gradually improves when increasing the number of submerged vanes, where the percentage of sediments insulation is confined between approximately 15% and 24%, at the use of 7 submerged vanes, with different inclination angles for the row of submerged vanes, as shown in Figure 9.

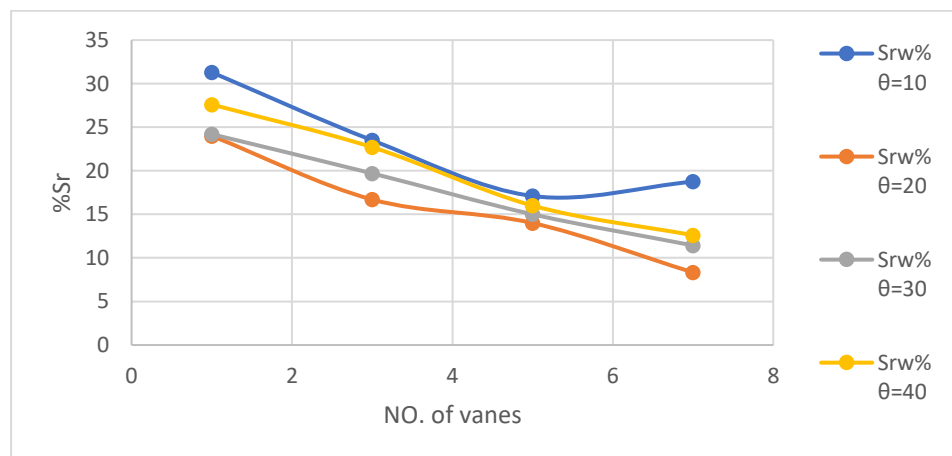


Figure 9 Shows That the Sub-Channel discharge is 27 l/s With Different Angles of Inclination.

3. When the sub-channel discharge is 19.1 l/s, the percentage of isolated sediments is approximately between 24% and 33%, as using one piece of submerged vanes, this percentage of isolation gradually improves when increasing the number of submerged vanes, where the percentage of sediments insulation is confined between approximately 15% and 24%, at the use of 7 submerged vanes, with different inclination angles for the row of submerged vanes, as shown in Figure 10.

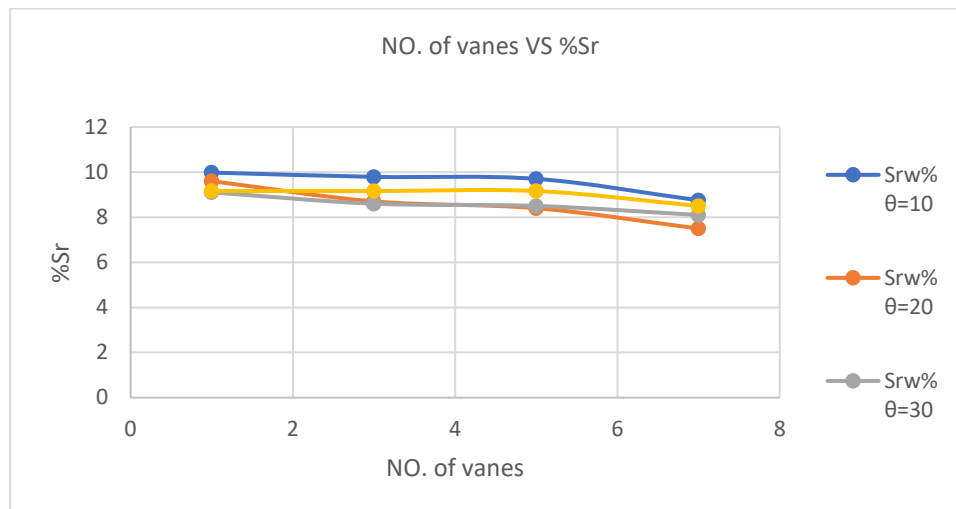


Figure 10 Shows That the Sub-Channel Discharge is 19.1 l/s With Different Angles of Inclination.

4. CONCLUSION AND RECOMMENDATION

After examining the curves depicted in the preceding illustrations for three distinct discharges (30.5, 27 and 19.1 l/s). And inclination angles for the submerged panels and the number of four angles (10°, 20°, 30°, and 40°) where the number of submerged vanes was altered to (1, 3, 5, and 7) the following was observed:

1. There is a relationship between the discharge used in the sub-channel and the percentage of isolated sediments (Sr), as it was noted that the less the discharge of the sub-channel, the better the performance of the submerged vanes, and therefore it is better to use this technique in the sub-channels with few discharges, which reduces the percentage of discharge of sediments the private sub-channel to less than 20%.
2. The percentage of isolated sand increases when the number of submerged vanes increases, but this feature is evident for high drainages, and its effect is almost limited for low drainages.
3. The performance of the 20 degree angle outperforms all other angles for all discharges that have been used. This result is consistent with the research [15], in which the researcher regarded angle 20 as the ideal angle and utilized intake ratios ranging from 0.16 to 0.4. There is a priority given to angle 20°.
4. For all used discharges, the performance of the angle of 20 degrees is better than the performance of the rest of the angles. The decision to use this angle as per the findings of one of the studies [15], in which the researcher regarded angle 20 as the ideal angle and utilized intake ratios ranging from 0.16 to 0.4. There is a priority given to angle 20°.

The outcomes of the study allow for the following experimental tests to be suggested for additional research to improve the performance of the vane:

- 1- Determine how the impact is affected by a variety of lengths and slopes of the intake channel.
- 2- When using this alignment, use two or three rows of submerged vanes in front of the intake.

REFERENCES

- [1] M. S. Bejestan and R. Azizi, "Experimental investigation of scour depth at the edge of different submerged vanes shapes," *World Environ. Water Resour. Congr. 2012 Crossing Boundaries, Proc. 2012 Congr.*, pp. 1376–1385, 2012, doi: 10.1061/9780784412312.138.
- [2] F. Ahmed and N. Rajaratnam, "Flow around Bridge Piers," *J. Hydraul. Eng.*, vol. 124, no. 3, pp.

- 288–300, 1998, doi: 10.1061/(asce)0733-9429(1998)124:3(288).
- [3] T. K. Sruthi, K. B. Ranjith, and V. Chandra, “Control of sediment entry into an intake canal by using submerged vanes,” *AIP Conf. Proc.*, vol. 1875, 2017, doi: 10.1063/1.4998378.
- [4] “No Title Morphological description of river bifurcations in gravel-bed braided networks,” *River Flow*, pp. 1311–1318, 2006.
- [5] M. B. Bishwakarma and H. Støle, “Real-time sediment monitoring in hydropower plants,” *J. Hydraul. Res.*, vol. 46, no. 2, pp. 282–288, 2008, doi: 10.1080/00221686.2008.9521862.
- [6] B. A. Murray and C. Paola, “Modelling the effect of vegetation on channel pattern in bedload rivers,” *Earth Surf. Process. Landforms*, vol. 28, no. 2, pp. 131–143, 2003, doi: 10.1002/esp.428.
- [7] Y. Wang, A. J. Odgaard, B. W. Melville, and S. C. Jain, “Sediment Control at Water Intakes,” *J. Hydraul. Eng.*, vol. 122, no. 6, pp. 353–356, 1996, doi: 10.1061/(asce)0733-9429(1996)122:6(353).
- [8] A. S. Ramamurthy, J. Qu, and D. Vo, “Numerical and Experimental Study of Dividing Open-Channel Flows,” *J. Hydraul. Eng.*, vol. 133, no. 10, pp. 1135–1144, 2007, doi: 10.1061/(asce)0733-9429(2007)133:10(1135).
- [9] J. Aberle, V. Nikora, and R. Walters, “Data Interpretation for In Situ Measurements of Cohesive Sediment Erosion,” *J. Hydraul. Eng.*, vol. 132, no. 6, pp. 581–588, 2006, doi: 10.1061/(asce)0733-9429(2006)132:6(581).
- [10] A. H. Sajedipoor, N. Hedayat, A. Rohani, and Z. Yazdi, “Analytical study of sedimentation formation in lined canals using the SHARC software- a case study of the Sabilli canal in Dezful, Iran,” *World Acad. Sci. Eng. Technol.*, vol. 71, pp. 106–108, 2010.
- [11] A. Vincent S. Neary, Student Member, ASCE; and A. Jacob Odgaard, Member, “Three-dimensional flow structure at open channel diversions,” *J. Hydraul. Eng.*, vol. 119, no. 11, 1993.
- [12] J. Aberle, *River training and sediment management with submerged vanes*, vol. 48, no. 4. 2010. doi: 10.1080/00221686.2010.491700.
- [13] M. (1992);, “Local Scour Around Cylindrical Piers,” *J. Hydraul. Res.*, vol. 1, no. 2, pp. 59–71, 2012.
- [14] A. J. Odgaard and Y. Wang, “Sediment management with submerged vanes,” *Hydraul. Eng. - Proc. 1990 Natl. Conf.*, vol. 117, no. 3, pp. 963–968, 1990.
- [15] B. D. Barkdoll, R. Ettema, and A. J. Odgaard, “Sediment Control at Lateral Diversions: Limits and Enhancements to Vane Use,” *J. Hydraul. Eng.*, vol. 125, no. 8, pp. 862–870, 1999, doi: 10.1061/(asce)0733-9429(1999)125:8(862).
- [16] H.-T. O.-S. L.-H. L. Yu, “DIMENSION AND SHAPE OF A SUBMERGED VANE FOR FLOW AND SEDIMENT CONTROL,” *9th Int. Symp. Fluid Control Meas. Vis. 2007, FLUCOME 2007*, vol. 1, pp. 190–199, 2017.
- [17] J. Baltazar, E. Alves, G. Bombar, and A. H. Cardoso, “Effect of a submerged vane-field on the flow pattern of a movable bed channel with a 90° lateral diversion,” *Water (Switzerland)*, vol. 13, no. 6, pp. 1–22, 2021, doi: 10.3390/w13060828.
- [18] A. Bor Türkben, “Experimental Study of Submerged Vanes in Intakes under Sediment Feeding Conditions,” *E3S Web Conf.*, vol. 40, pp. 1–8, 2018, doi: 10.1051/e3sconf/20184003016.
- [19] F. Abdel Haleem, Y. Helal, S. Ibrahim, and M. Sobeih, “Sediment control at river intakes using a single row of vanes,” *Ain Shams J. Civ. Eng.*, vol. 2, no. April 2015, pp. 395–401, 2008.

- [20] G. Beygipoor, M. Shafaei Bajestan, H. A. Kaskuli, and S. Nazari, "The effects of submerged vane angle on sediment entry to an intake from a 90 degree converged bend," *Adv. Environ. Biol.*, vol. 7, no. 9, pp. 2283–2292, 2013.
- [21] S. Emamgholizadeh and H. Torabi, "Experimental investigation of the effects of submerged vanes for sediment diversion in the Veis (Ahwaz) pump station," *J. Appl. Sci.*, vol. 8, no. 13, pp. 2396–2403, 2008, doi: 10.3923/jas.2008.2396.2403.
- [22] M. Rahmani Firozjaei, S. A. A. Salehi Neyshabouri, S. Amini Sola, and S. H. Mohajeri, "Numerical Simulation on the Performance Improvement of a Lateral Intake Using Submerged Vanes," *Iran. J. Sci. Technol. - Trans. Civ. Eng.*, vol. 43, no. 2, pp. 167–177, 2019, doi: 10.1007/s40996-018-0126-z.
- [23] J. Aberle, "River training and sediment management with submerged vanes," *J. Hydraul. Res.*, vol. 48, no. 4, pp. 553–554, 2010, doi: 10.1080/00221686.2010.491700.