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THE INFLUENCE OF THE CHANNEL BED RECTANGULAR CONFIGURATION ON SEDIMENT TRANSPORTATION

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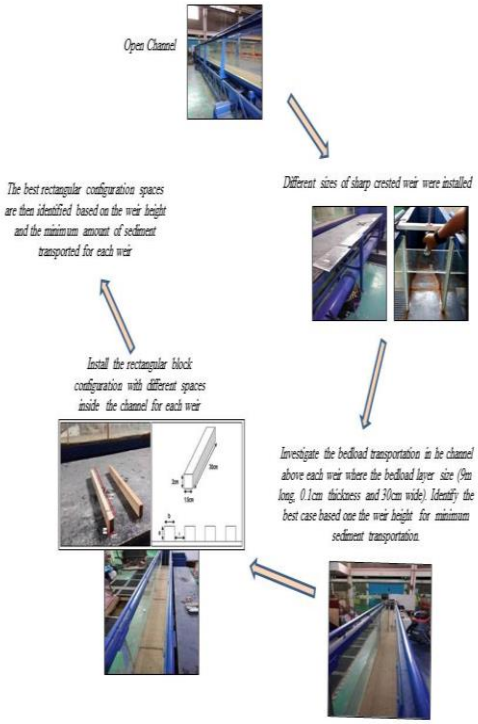
Graphical abstract



Abstract

Sediment transport is the movement of organic and inorganic particles caused by gravity, a moving fluid's force, the wind, and ice motion. Sediment deposition degrades dams' safety, leading to environmental pollution and channel area reduction. This study describes the effect of the weir height and spacing of used and non-used rectangular configuration structures on sediment transport rates in an open channel. This project was created using a rectangular open channel (30 cm wide and 60 cm deep). A sharp-crested weir was installed in the channel, and the rectangular wooden configurations were fixed in specific locations on each weir to reduce the bedload transportation rate and sediment motion. The weir heights were different (0.25B, 0.35B, 0.45B, and 0.55B, where B is the channel width). Also, the spacing between the baffle blocks (S) was set to 4Y, 8Y, 12Y, and 16Y, where Y was the maximum water depth without installing blocks and weirs. The results showed that the maximum transported bedload for the lowest weir was 1.4 kg/min, but only 4.4 × 10-3 kg/min was transported for the weir 16.5-cm high with baffle blocks. Using long baffle blocks yielded a worse result than using no blocks. The sediment-transport rate increased to 1.66 kg/min for the 7.5-cm weir due to block configurations. In conclusion, the obtained result contradicts the predicted result, as using baffle blocks increased the sediment transportation rate.

Keywords: Open channel flow, Bedload transportation, rectangular configuration structure, weir structure, sediment motion

Abstrak

Pengangkutan sedimen ialah pergerakan zarah organik dan bukan organik yang disebabkan oleh graviti, daya bendalir yang bergerak, angin, dan gerakan ais. Pemendapan sedimen merendahkan keselamatan empangan, membawa kepada pencemaran alam sekitar dan pengurangan kawasan saluran. Kajian ini menerangkan kesan ketinggian empangan dan jarak struktur konfigurasi segi empat tepat terpakai dan tidak digunakan terhadap kadar pengangkutan sedimen dalam saluran terbuka. Projek ini dicipta menggunakan saluran terbuka segi empat tepat (30 cm lebar dan 60 cm dalam). Empangan berjambul tajam telah dipasang di saluran, dan konfigurasi kayu segi empat tepat telah ditetapkan di lokasi tertentu pada setiap empangan untuk mengurangkan kadar pengangkutan muatan katil dan pergerakan sedimen. Ketinggian bendung adalah berbeza (0.25B, 0.35B, 0.45B dan

0.55B, dengan B ialah lebar saluran). Juga, jarak antara blok penyekat (S) ditetapkan kepada 4Y, 8Y, 12Y, dan 16Y, di mana Y ialah kedalaman air maksimum tanpa memasang blok dan bendung. Keputusan menunjukkan bahawa muatan katil yang diangkut maksimum untuk empangan terendah ialah 1.4 kg/min, tetapi hanya 4.4 × 10-3 kg/min yang diangkut untuk bendung setinggi 16.5-cm dengan blok penyekat. Menggunakan blok penyekat panjang menghasilkan hasil yang lebih buruk daripada menggunakan tanpa blok. Kadar pengangkutan sedimen meningkat kepada 1.66 kg/min untuk bendung 7.5 cm disebabkan konfigurasi blok. Kesimpulannya, keputusan yang diperolehi bercanggah dengan keputusan yang diramalkan, kerana menggunakan blok penyekat meningkatkan kadar pengangkutan sedimen.

Kata kunci: Aliran saluran terbuka, pengangkutan muatan katil, segi empat tepatstruktur konfigurasi, struktur empangan, gerakan sedimen

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1.0 INTRODUCTION

Hydraulic structures are structures that are submerged or partially submerged in water—for example, dams, spillways, channels, and culverts [1]. Such structures usually face problems such as seepage water, erosion, and maximum unwanted load. Sediment transportation is one of the main problems associated with reservoirs and open channel structures as the channel bed level and water velocity variations due to sediment overloading, particularly during floods transportation is one of the main problems Furthermore, slope and water velocity increase the sediment transportation rate [2]. Sediment transportation is the hydrological process of particle transportation along waterways such as channels and rivers and occurs when the stabilizing resistance force is weaker than the shear resistance.

For Sediment transportation can manifest as bedload transportation for coarse particles or in a suspended mode at different water levels. During this process, sediment particles accumulate in the river, along a channel, or close to barriers [3]. Sedimentation includes the deltaic deposition of coarse particles. Fine particles settle through the homogenous water flow, and stratified flow usually transports and settles fine sediment particles. When a stream flows into upstream reservoirs, the deltaic deposit of sediments occurs. Delta current deposit currents are divided into two parts: a top-set bed and a foreset bed. A plunge point is produced, and sediments settle along the length of the channel if the sediment current flows toward the end. Still, fine particles may become suspended at different levels and be transported kilometers away. Generally, sediment transportation causes riverbed levels to rise, sometimes leading to floods as water accumulates and the river overflows. Furthermore, sedimentation decreases the space between the bridge body and river bed and reduces water quality [4]. The surface texture of the bed channel changes due to variations in sedimentation ratio. Several methods have been used to solve this issue and maintain reservoir water quality [5]. One method involves releasing turbid water before it reaches the reservoir pool area, performing hydraulic flushing so that the deposited layer flows out of the reservoir.

The primary aim of flushing the hydraulic system is to remove sludge, varnish, debris, contaminated or degraded fluids, and system dead spots from conductor walls and other internal surfaces. There are two types of flushing processes. The first type is free-flow flushing, by which upstream water is emptied and sediments are flushed downstream. The second (less effective) type is called pressure drawdown, by which the reservoir is emptied to a lower level wang & hu[6] . Open channels provide water for irrigation systems. When particles' diameters exceed 0.1 mm, they are moved via the bed transportation mode. The channel shape also affects the sediment delivery ratio, and particles' travel velocity is always less than the channel's water velocity. The flow through the river and channel moves particles into different layers; heavier particles are transported onto the bed surface, while the lighter ones are suspended [7]. Small blocks have been used as stilling basins to dissipate energy in the hydraulic jump phenomenon. The structure of these blocks can change the jump's characteristics and reduce near-bed velocity [8]. Simple long block structures with a rectangular shape have been used for this purpose. A rectangular configuration is used in the current project as an assistant structure to investigate bedload transportation problems, with a weir used to consider the best situation. Rectangular blocks are installed in different spaces.

An analysis is then carried out to determine which trial yielded the best outcome. Figure 1 shows the sediment transport in the river and reservoir. As can be seen, heavy particles are moved and deposited near the reservoir entrance in the delta formation, while the suspended particles are transported further distance toward the reservoir barrier, thus creating a muddy pool [4].

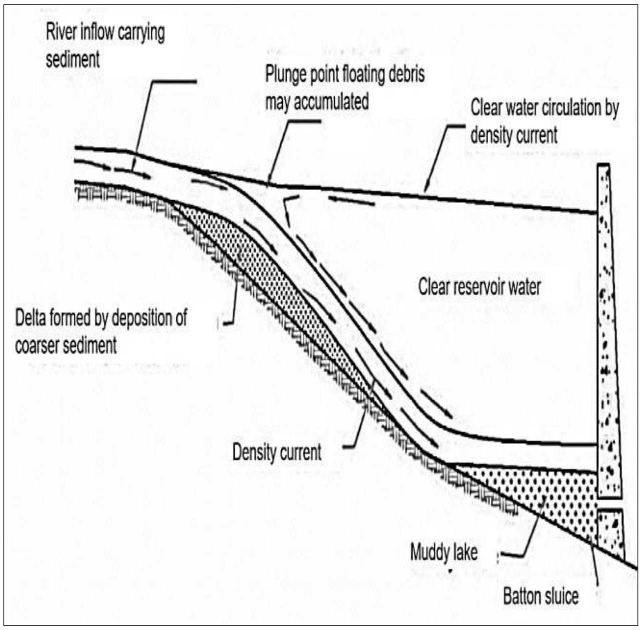

Figure 1 Sediment transportation in the reservoir [9]

This project has three broad objectives. The first is to investigate the optimum weir height (i.e., the height at which sediment transportation and sediment accumulation at upstream structures are minimized without baffling blocks). The second is to explain how the relationship between weir height and rectangular configuration distance can reduce sedimentation problems by installing rectangular configuration structures in the best positions via plotting a profile for sediment motion. The third objective is to design the most efficient and rectangular configuration structure for sediment transportation reduction

2.0 METHODOLOGY

2.1 Material

In The equipment utilized to carry out this project is made from wood and simple transparent plates. The rectangular open channel is the primary piece of equipment utilized. Its height (H) is two times its width (B) (i.e., 2B) or larger. The total length of the flume is 10 m, its width is 0.3 m, and its depth is 0.6 m. important elements of the flume include its depth gauge, weir, control valve, slump, pump stilling tank, and working station. Non-cohesive material is used for this study. The bed slope of the channel is 0.01. The weirs can be produced from a simple transparent plate. They can be mobilized, and their heights are different relative to the flume width (i.e., 0.25, 0.35B, 0.45B, and 0.55B). The maximum average discharge of a flume is 0.025 m^3/s. The rectangular configurations are produced from simple rectangular wood. Their lengths are equal to the channel width, but their height is 0.2Y, with Y representing the maximum water depth without using weirs and blocks. The overall study flow chart sreps has been shown in Figure 2.

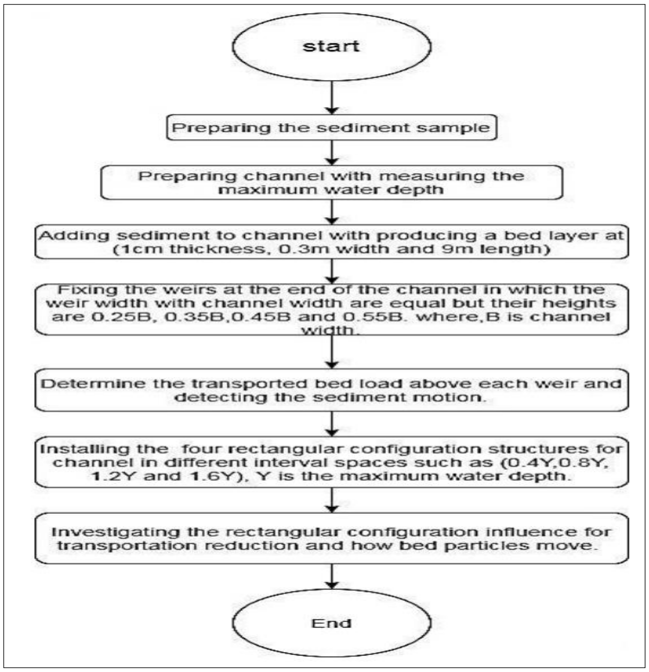

Figure 2 Flowchart

2.2 Methods

2.2.1 *Discharge Measurement*

The channel's water velocity was measured using conventional and current flow meters. The velocities associated with these two types of meters are similar. A water pump was used to move water through the channel. At the maximum discharge flow, the maximum water depth in the channel was found. An ultrasonic flow meter and valve rotation were used to calculate a maximum expected uniform discharge rate of 25 L/s.

2.2.2 *Flume Setup*

A transparent channel has been used to monitor sediment transportation. The spaces between the rectangular configurations are measured to detect sediment motion during the process. As mentioned above, the height (H) of the channel is equal to twice its width (B) (i.e., H = 2B) or greater. After the channel had been prepared, the valve was opened to measure the water flow with a fixed discharge rate of 0.025 m^3/s (or 25 L/s). Figure 3 shows the top and side views of the main experimental channel.

2.2.3 *Rectangular Configuration Structure*

Four blocks of rectangular configurations (baffle blocks) were used in this project. Their heights were different according to the maximum water depth. Specifically, if the water depth was 10 cm, the width of each rectangular configuration (b) = 1.5 cm. The height of each rectangular configuration object (a) = 2 cm. Finally, the length of each rectangular configuration was equal to the width of the channel. All configurations could be produced using simple wood, as shown in Figure 4 The weir structure was built from a transparent plate and installed at the downstream end of the channel as shown in Figure 5.

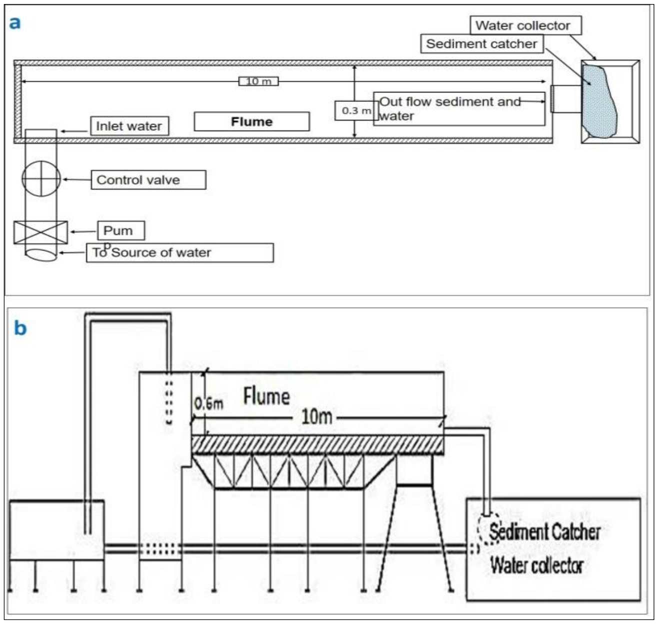

Figure 3 (a) Top view and (b) side view of the straight

The weir heights were different according to the channel width. (B) is the channel width and weir heights fixed with the different ranges (i.e., 0.25, 0.35B, 0.45B, and 0.55B). The maximum average discharge of a flume is 0.025 m^3/s. The rectangular configurations are produced from simple rectangular wood. Their lengths are equal to the channel width, but their height is 0.2Y, with Y representing the maximum water depth without using weirs and blocks.

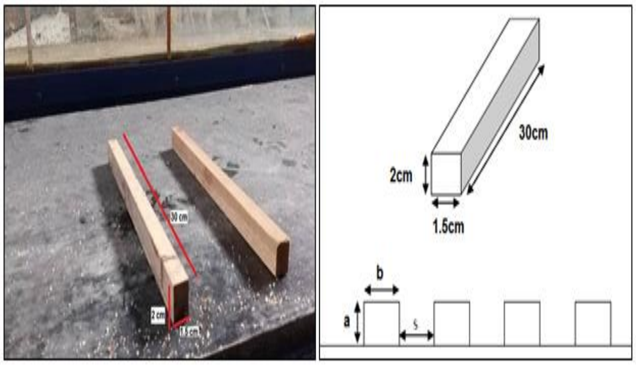

Figure 4 Model of the rectangular configuration structure

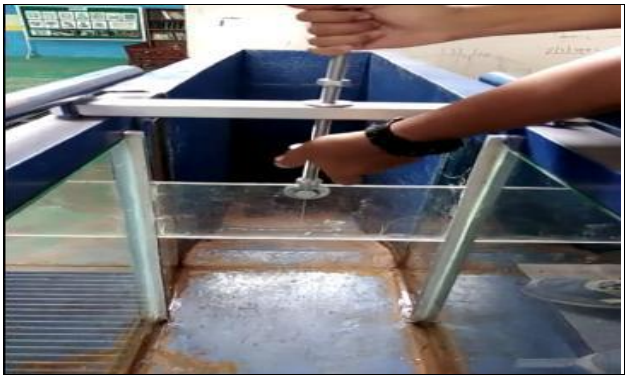

Figure 5 Adjustable weir

2.2.4 *Sediment Trap*

A sand trap is also fixed downstream to collect sediment particles transported from the main channel. For small flumes, the transported particles are collected every 15 minutes at each situation. After being weighed, the sediment is returned to the main channel. The mass ad concentration of the transported sediment can be determined according to equations (1) and (2), respectively:

$$Q_{Sr} = \frac{Qb}{t} \tag{1}$$

Where Qb = mass of transported sediment (g), t = time (s) and Q_{Sr} = rate of transported sediment (g/s), and

$$Cv = \frac{Qsr \times 10^6}{Qmc.\rho} \tag{2}$$

Where Cv is the rate of sediment concentration (ppm), Q_{mc} is the channel discharge (m^3/s), and ρ is the water density (kg/m^3) [10].The sediment trap has been fixed at the end of the channel to collect the sediment transported from upstream.

2.2.5 *Experimental Procedure*

The water valve of the prepared channel is opened to measure the maximum water flow. The full discharge of the flume is carried out at 25 L/s without adding any sediment to the channel and while fixing the weirs. Then, the maximum water depth (Y) is measured. Afterward, a sediment sample (1 cm thick, 9 m long, and 0.30 m wide) is added to the channel. The weir structure, which is 0.55B (16.5 cm) tall, is fixed at the weir location without using baffle blocks to determine the bedload transportation rate. The water valve is then opened to allow water and sediment particles to flow through the channel, and the amount of carried sediment above the weir is measured. Thereafter, the water flow, sediment transportation, and bed motion are determined and considered to calculate the maximum sediment transportation at the sediment catcher.

The abovementioned steps are repeated at the weir height positions of 0.45B, 0.35B, and 0.25B. The optimal weir height is found in the smallest amount of sediment movement without using rectangular blocks. The procedures are then repeated once again while using the rectangle configuration structure. Rectangular configurations (baffle blocks) are arranged according to different interval spaces (S) (i.e., S = 4Y, 8Y, 12Y, and 16Y), where (Y) is the maximum water depth for full discharge without using blocks (see Figure 6) and (S1 = S2 = S3 = S4). The best rectangular configuration spaces are then identified based on the weir height and the minimum amount of sediment transported for each weir. After that, the graphs of the bedload transportation ratio and weir heights are plotted. A different velocity is measured every minute. The total time interval for each trial is 15 minutes.

Figure 6 Installing rectangular configuration blocks and a bed layer

3.0 RESULTS AND DISCUSSION

3.1 Running Model and Data Collection

The flume was run to detect sediment motion and transportation with various water velocities. The time interval for each step was 15 minutes. The maximum discharge for all cases was maintained at 25 L/s. The water temperature was recorded at 20 °C for all cases, and the kinematic viscosity was 1×10^{-6} m^2/s. The total average bed layer was measured using a simple device (Vernier). The entire procedure can be divided into two cases: installing a weir with and without a rectangular block configuration. The results for these cases are described in detail in the following sections.

3.1.1 Installing a Weir without a Rectangular Configuration.

In the first case, sediment transportation was tested, and the sediment morphologies associated with different weir heights have been plotted in Figure 7. The results show that the retained sediment layer decreased as the barrier height was lowered. Moreover, a bed profile related to different velocities was found. In this step, sediment motion depended on the flow characteristics of the channel. The cross-section area changed according to the levels of sediment accumulation and scouring at particular points. Bedload deformation in debris transportation exceeded bedload sediment. While the water was flowing, the scouring and accumulation of sediment compensated for each other. This phenomenon has been explained in detail by *Theule et al.* [11]. As shown in Table 1, the water velocity varied according to the weir height. Alterations in bedload transportation changed the roughness and decreased the near-bed velocity due to bedload thickness variations [12].

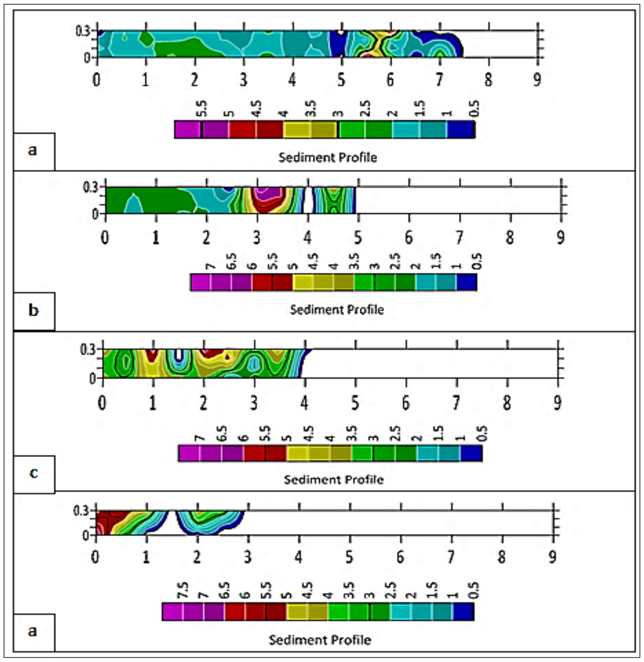

Figure 7 Sediment morphology in the channel for a (a) 16.5 cm, (b) 13.5 cm, (c) 10.5 cm, (d) and 7.5 cm weir

Table 1 Bedload shear velocities (u*) for different weir heights

W (cm)	V (m/s)	Qb (kg)	Hs (cm)	Qsr (g/s)	Hydraulic radius, R (m)	u* (m/s)
16.5	0.425	0.06	25.5	0.066	0.094	0.096
13.5	0.528	0.08	22.5	0.088	0.090	0.093
10.5	0.628	0.3	19.5	0.333	0.085	0.091
7.5	0.775	21	16.5	23.33	0.079	0.088

Beadload shear velocity was obtained as:

$$u^* = (R\times g\times s)^{0.5} \tag{3}$$

Where R is hydraulic radius for each weir (m), g is acceleration gravity and s is channel slope (0.01). In the case in which the configuration is not used, the maximum sediment transportation quantity (21 kg) is associated with the lowest weir height. When the weir height was increased, the sediment-transported ratio decreased. In total, 21.44 kg of the sediment was transported when the lowest weir height of 7.5 cm was applied. This transported rate was nearly 98% of the total particle quantity transported for all weir heights. Furthermore, the bedload profile varied from one weir height to the next. For the weir height of 16.5 cm, no more than 2 cm of the sediment accumulated in the channel center in front of the weir. It was higher than both sides. As mentioned by Chiu and Tung [13], the water velocity is highest at the channel center.

The maximum velocity was noted near the water's surface. The retained bed layer length was 7.5 m (upstream); there was no more bed material behind this point. As shown in Figure 8 the continuous bedload layer for the weir height of 16.5 cm was three times greater than that for the weir height of 7.5 cm. The sheet flow varied as velocity increased. The largest amount of bed accumulation (over 7 cm) occurred when the weir height was at its lowest. Also, the greatest amount of dead load formed in front of the small weir. In all cases, the total bedload moved as a mobile bedload. Transported sediment particles above the weir indicated the movement of the particles as sheet flow and saltation caused by the increased size of the sediment layer due to accumulation in front of the weir.

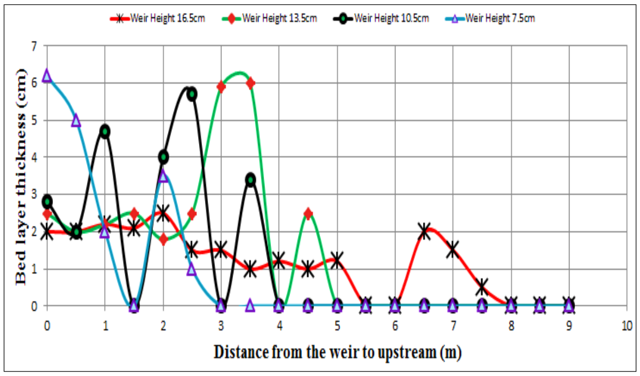

Figure 8 The bed layer thickness at the channel centerline for different weir heights

The maximum sediment length for the highest weir was 7.5 m, and its length reduced gradually according to velocity. Small scouring holes were created at some points due to changes in water depth and flow velocity. The depths of these scouring holes depended on the angle of attack of flow and the sediment's characteristics. Less sediment was transported through the channel when no block configuration was used than when a block configuration was used; this effect has been described previously by Engelund & Fredsoe [14]. During the bedload motion, the streamwise momentum was reduced due to friction. This reduction in streamwise momentum decreased the flow velocity, which, in turn, increased flow resistance (referred to as bedload transport resistance) as expressed in previous research by Gao and Abrahams [15]. For the first highest weir (16.5 cm), the bedload moved somewhat more uniformly than other weir heights, indicating the significant role of velocity in this process.

3.1.2 Installing a Weir with Rectangular Block Configurations

Figure 9 shows the sediment concentrations at various weir heights and interval distances of block structures**.** The sediment concentration ratio for each step was evaluated, and the modeling of rectangular blocks created vortex forces. Four simple rectangular structures made of wood were installed. As shown in Figure 3, all structures were of the same size (length = 30 cm, width = 1.5 cm, height = 2 cm). This procedure was carried out to increase the bed's roughness. Changing the spacing between the structures affected bedload transportation [16]. According to Shvidchenko & Pender [17], turbulent flow is produced eddy forces, and vortices forces move upwelling and downwelling in free surfaces. Thus, turbidity current flow can transport sediment particles across long distances due to the quasi-flow effect. Also, this phenomenon has already been concluded by Nomura *et al*. [18]. In the first trial, the rectangular structures were placed near the weir face to improve the resistance bed and minimize sediment movement toward the barrier face, as well as decrease the level of dead load. In the various steps, the lowest weir was associated with the highest sediment concentration. The worst case occurred when the blocks were installed at 8Y. The flow characteristics near the block changed according to the block configuration used, even though all blocks were rectangular. These blocks disturbed the shear layer above the bed and produced a separation zone streamline through the near-bed wave (bubble). The presence of separation bubbles and flow constrictions changed the flow conditions and scour depth; such effects have been reported previously in the literature [19]. Baffle blocks make the jump and increase the turbulent flow properties, thus causing the local scouring phenomenon. Altering the interval distance caused the sediment profile to change.

The rate of sediment transportation (Qb) increased during this procedure depending on which block structure was utilized. The channel's mean velocity was nearly constant and unaffected by obstacles. The Pitot tube was not used during this test to determine the near bed velocity. The most undesirable situation was observed at the minimum weir height of 7.5 cm. The rate of sediment concentration increased after the baffles were installed. The bedload-transported weights were 0.66 kg and 3.8 kg for spacings of 0.4 m and 0.8 m, respectively, with a weir height of 10.5 cm. The uniform straight layer is created by minimal distance intervals, which transports lower sediments.

Meanwhile, increasing the distance interval led to more scouring and hydraulic jumps. The bedload layer length was different for each weir height. The result of this procedure is shown Figure 9 for the retained layer. Some flow properties, like turbulent velocities, were enhanced significantly. As previously mentioned by Gajusingh *et al*. [20] , the turbulence enhancement was increased when the distance between the baffles was increased, and scouring and erosion were detected in various positions. As the distance between the blocks increased, so did bedload transportation; however, when the distance between blocks increased past a certain point, bedload transportation began to decrease again. There were serial hydraulic jumps and a subsequent turbulent vertex for a distance of 0.8 m to transport more particles. This phenomenon was less noticeable for very wide distance intervals because the bed also acted as a uniform bed, which allowed particles to move easily. No strong local jumps were produced. When the blocks were installed very far apart from each other (i.e., at distances exceeding 1.2Y), the effect was the same as when no blocks were used.

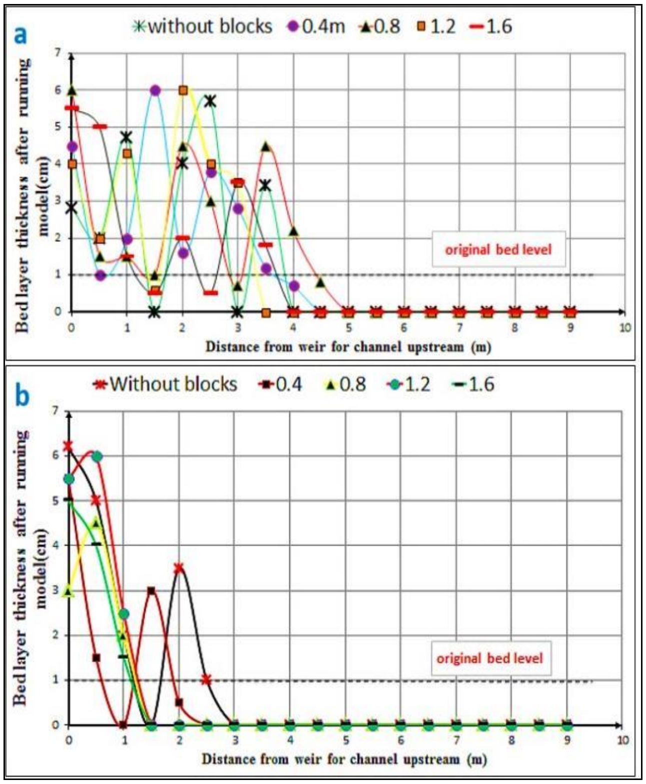

Figure 9 Sediment profiles for weir heights of (a) 16.5 cm, (b) 13.5 cm, (c) 10.5 cm, and (d) 7.5 cm, with interval spaces of (L) 0.8 m and (R) 0.4 m

Table 2 Sediment concentrations for different weir heights and interval distances

Weir height (m)	Number and spacing of configurations (m)	V (m/s)	Qb (kg)	Hs (cm)	Qsr (g/s)	Sediment concentration, Cv (ppm)
16.5	4x0.4	0.448	0.06	25.5	0. 07	2.67
13.5		0.514	0.12	22.5	0. 13	5.33
10.5		0.647	0.66	19.5	0. 73	29.33
7.5		0.739	27.5	16.5	30.56	1222.22
16.5	4x0.8	0.475	0.1	25.5	0. 11	4.44
13.5		0.595	0.14	22.5	0. 16	6.22
10.5		0.682	3.8	19.5	4.22	168.89
7.5		0.729	29.2	16.5	32.44	1297.78
16.5	4x1.2	0.498	0.1	25.5	0. 11	4.44
13.5		0.571	0.12	22.5	0. 13	5.33
10.5		0.67	4.62	19.5	5.13	205.33
7.5		0.95	20	16.5	22.22	888.89
16.5	4x1.6	0.464	0.12	25.5	0.13	5.33
13.5		0.591	0.08	22.5	0.09	3.56
10.5		0.682	4.67	19.5	5.19	207.56
7.5		1.056	25	16.5	27.78	1111.11

Sediment Morphology Variations

Figure 10 shows the total surface area for spreading bedload after running the model for the different situations according to the Surfer-Webinar program. The flow velocity affected the morphology of the sediment, whereas the channel velocity remained nearly constant since the baffle heights were low and, thus, had no effect on the flow parameters. As a result, spacing baffle blocks by 0.8 to 1.2 times the water depth in relation to bedload transportation was the optimum condition for collecting sediment in the smallest area inside the channel during the sediment removal procedure. The smallest weir yielded the worst results, as this condition generated the most sediment transportation. The sediment thicknesses in front of the weirs without and with blocks were 5 cm, 5.5 cm, and 5.8 cm (except when the distance interval was 0.8 m and the weir height was 13.5 cm or 10.5).

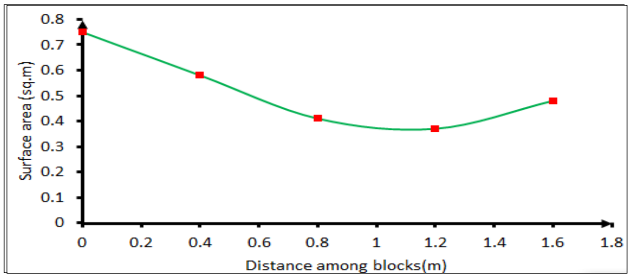

Figure 10 Surface area of bedload after running models with different distances between weirs.

The roughness coefficients of beds changed from concrete (n = 0.011) or metal to gravelly or sandy (n = 0.025) after the sediment was spread inside the channel and the bedload surface area was increased. According to Groom and Friedrich[21], the rate of roughness increases as the turbulence intensity and turbulent production increase. Also, the maximum bedload thickness was recorded along the channel's centerline. The worst-case scenario (eight times the maximum water depth) occurred when the obstacle and blocks were separated by a distance of 8Y. The thickness of the bedload layer in front of the barrier varied depending on the interval distance between the baffle blocks at zero distance. As shown in Figure 11, the depth of the layer changed consistently for various distances between the maximum and minimum distances.

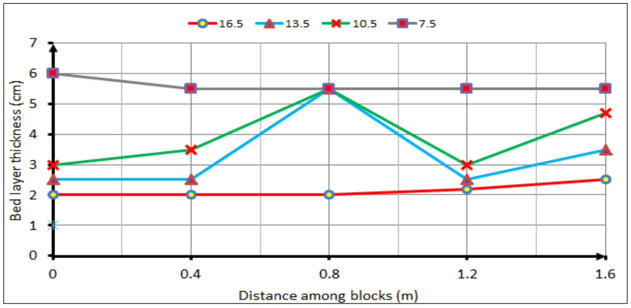

Figure 11 Dead load thicknesses in front of weir faces for different weir heights

Types of Bed Forms

Variety was observed among bed forms after models were run for each stage. Also, the Froude number was estimated for various conditions depending on the weir size and block installation (Table 3) The degree of roughness and flow velocity usually determine the bed form type. A strong relationship was observed between resistance to flow, bed configuration structure, and sediment transport rate. The spacing between blocks and their height need to be considered when exploring the variation of resistance to flow under different flow conditions and sediment characteristics.

The geometric bed structure had a significant role in identifying the flow regime types near the bed. Such effects of height and interval space ratio between blocks on a/s has been the focus of previous research [22].The shear velocity along the bed surface and the average velocity for all trials were similar. Also, critical shear stress values were equal for all conditions (as seen in Table 3 4. All the space ratios between blocks were less than 0.3. The conditions created an isolated roughness regime because a = 0.02 m (the minimum space is 0.4 m), thus a/s < 0.3, based on the work of [23]. This procedure is based on Engelund and Hansen's method for determining bed form types. Also, Table 4 shows the stream power and hydraulic radius for all conditions.

Table 3 Types of bed forms related to Froude numbers

Weir height (m)	Cases	V (m/s)	R (m)	u* (m/s)	V / u*	Fr	Type of bed form
16.5	*Block and non-block	0.462	0.094	0.096	4.811	0.287	Dunes-Plane bed
13.5		0.567	0.09	0.094	6.034	0.373	Dunes-Plane bed
10.5		0.662	0.085	0.091	7.250	0.467	Dunes
7.5		0.850	0.079	0.088	9.655	0.650	Dunes-Antidunes

Table 4 Shear stresses for all cases

Weir height (m)	Both cases, using blocks and Non-used blocks, with interval distance (m)	τc (N/m2)	R (m)	τo (N/m2)	Stream power (lb/ft.s)
16.5	All Cases	0.45	0.094	9.0	0.255
13.5			0.09	9.4	0.296
10.5			0.085	8.5	0.326
7.5			0.079	7.9	0.389

Baffle Blocks' Effect on the Rate of Transported Sediment

Many-scoured holes were produced due to local acceleration-deceleration around the obstacles. Figure 12 illustrates the lifting of particles due to boundary layer distribution. As explained by Christodoulou[24], the obstacle structures can produce significant energy dissipation and make the hydraulic jump by releasing eddy forces. The horseshoe vortex was generated due to the strong friction between the water flow and the block body, which lifted particles toward the water surface.

Figure 12 Scouring and lifting of particles near the Scouring and lifting of particles near the rectangular blocks

The water velocity was highest near the water's surface. The lifted particles mixed with higher flow movement at higher water level. According to Roy *et al*. [25], vertical tracers contain many lifted bedload particles, and traces of the storm expand behind the structure and downstream. It was assumed that the velocity of the particles was equal to the mean channel velocity. Therefore, the highest water velocity and level of scouring were produced at the channel's centerline. The length of the retained bedload for a weir with a height of 7.5 cm and no blocks was two times greater than the length of the retained bed for the same weir height but with a spacing of 1.6 times the water depth. The bedload layer was 3 m long in the case without blocks but only 1.5 m long for the 1.6 m distance interval. The bedload profiles for different intervals of baffle block spaces and different weir heights (after running the model upstream inside the channel) are shown in Figure 13 and Figure 14 The surfer program was used between the X,Y and Z direction of sand layer. While Z direction is the thickness of the layer. There are two parts for each figure below. Each part depends on the block spaces distance.

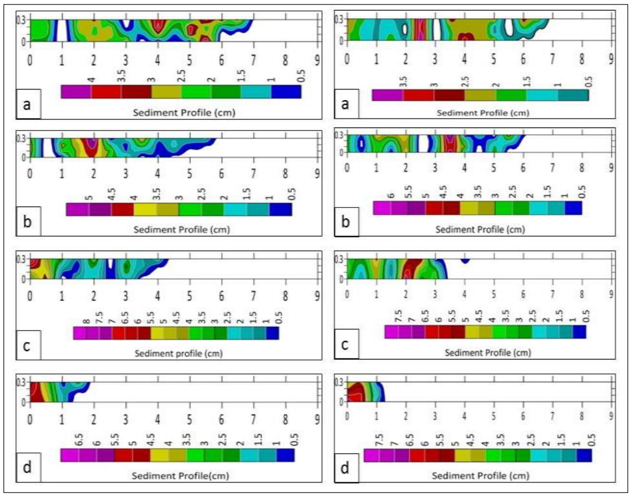

Figure 13 Sediment profiles for weir heights of (a) 16.5 cm, (b) 13.5 cm, (c) 10.5 cm, (d) 7.5 cm, with interval spaces of (L) 1.6 m and (R) 1.2 m

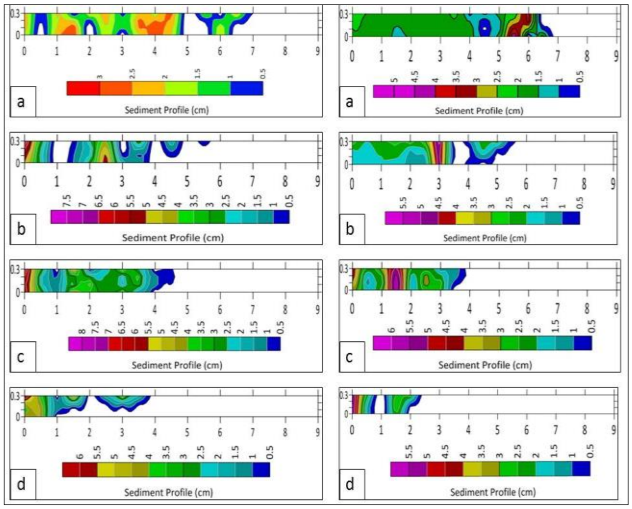

Figure 14 Sediment profiles for weir heights of (a) 16.5 cm, (b) 13.5 cm, (c) 10.5 cm, and (d) 7.5 cm, with interval spaces of (L) 0.8 m and (R) 0.4 m

4.0 CONCLUSION

Sediment transportation is one of the main problems associated with reservoirs, water channels, and streams. In this experimental work, the upstream and downstream bed sediment transportation rates of the weir structure were measured. The results showed that bed particles can be transported above small obstacles such as weirs and dams due to accumulation and cross-area reduction, depending on duration and mean velocity. The number of the particles transported is mainly governed by barrier height. The most particles were transported in the case utilizing the smallest weir (7.5 cm); meanwhile, only 0.066 kg of bed particles passed over a 16.5-cm-tall weir. Also, it was found that the length of the retained bed layer upstream in the channel is directly correlated with weir height.

Long, rectangular baffle block structures were the main structures used in this study to investigate their effect on reducing sediment movement. The project's outcome was opposite to the expected outcome, as using baffle blocks increased the rate of sediment transport across the barrier. When baffle blocks were spaced 0.8 m apart, the maximum level of sediment particle transport occurred. The data are nearly identical for all cases in which blocks were used. The use of block structures did not affect sediment reduction, even though the bedload transportation rate improved.

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