Amirkabir Journal of Civil Engineering

Amirkabir J. Civil. Eng., 51(2) (2019) 99-101
DOI: 10.22060/ceej.2018.13490.5420

Experimental study on suspended sediment deposition process in Karkheh dam reservoir

M. Khastar-Boroujeni[1], H. Samadi- Boroujeni[2]*, R. Fattahi- Naftchi[2], M. Ghasemi[2], A. Naghshbandi[2], M. Heydari[3]

[1]Water Engineering Department, Ferdowsi University of Mashhad, Mashhad, Iran.
[2]Water Engineering Department, Water Resources Research Center, Shahrekord University, Shahrekord, Iran.
[3] Khuzestan Water and Power Authority, Khuzestan, Iran..

ABSTRACT: One of the most essential works for sediment management in dam reservoirs is to identify the characteristics and effective parameters of deposition of sediments in the dam reservoir. In this research, the sedimentation process of fine sediments deposited into Karkheh dam reservoir was investigated in order to determine the required hydraulic conditions for desilting of the reservoir. Experiments were carried out in an annular flume located in Hydraulic Laboratory of Shahrekord University and sediment samples were taken from reservoir of Karkheh dam. Experiments were done at initial concentrations of 5, 10 and 20 g/l, and various shear stresses to determine the threshold shear stress for partial deposition and full deposition of suspended sediments. The obtained results showed that the shear stress of the initiation of sediment deposition was 0.1 N/m^2. It was also found that when the flow velocity to be exceed up to 0.61 m/s, the sediments would be completely remained in term of suspension. Under these conditions, the shear stress and Froude number were obtained as 2.55 N/m^2 and 0.43, respectively. Also, the results showed that in higher sediment concentrations, increasing of shear stress is more effective in the sediment deposition rate.

Review History:

Received: 29 September 2017
Revised: 18 April 2018
Accepted: 13 May 2018
Available Online: 11 June 2018

Keywords:
Critical shear stress
sediment deposition rate
Sedimentation
Karkheh dam

1- Introduction

The problems of sedimentation in reservoirs can listed as: reduce the storage capacity of the reservoirs, damage to hydro-mechanical plant and equipment's, reduce energy capacity, reduce water quality and its effects on downstream [1]. Cohesive sediment, or mud, is ubiquitously found in most aqueous environments. In nature, mud usually exists as a mixture of clay (< 4 μm), silt (< 63 μm), water, organic matters and inorganic matters. Opposite non-cohesive sediments, cohesive sediment is controlled by the competition between the attractive and repulsive force acting on its surface and within its mass. When the attractive force exceeds the repulsive one, the particles stick together to form flocs [2].

Deposition occurs when the bottom shear stress is less than the critical shear stress. Only aggregates with sufficient shear strengths to withstand the highly disruptive shear stresses near the bed region will deposit and adhere to the bed. Laboratory studies on the depositional behavior of cohesive sediment showed that deposition is controlled by the bed shear stress, turbulence processes near the bed zone, settling velocity, type of sediment, depth of flow, suspension concentration and ionic constitution of the suspending fluid [2].

Awareness of the characteristics of the sediment and the circumstances in which the sediments in the river environment settled down or eroded, is very important for the recognition and management of sedimentation in rivers and reservoirs. Construction of the dam causes connection of river upstream and downstream disrupted and the balance of sediment transfer and the trapped sediments in dam reservoir are also tailored more disruption. Due to the complexity of the behavior of fine-grained sediments, so far a coherent and sufficient information regarding the hydraulic transmission of this kind of sediment don't exist. Because the physical and chemical properties of the fluid and sediment and adhesion and aggregation properties, of cohesive sediments cause difference in the results of different research. Hence the investigation about the process of deposition of the fine grain sediments input to reservoirs, in order to assess the flow of sediment transfer, hydraulic of viscous sediments, reservoirs sediment washing, design and operation of downstream irrigation network and so on have importance. On the same basis in this research the process of deposition of fine-grained sediments within Karkheh dam reservoir, has been investigated using a circular flume.

Corresponding Author, Email: Hossein.Samadi-Boroujeni@uts.edu.au

2- Methodology

2.1. The study region

Karkheh dam with a height of 127 meters in 22 km north-west of city Andimeshk in Khuzestan province, and on the Karkheh River is constructed. The dam crest level with 234 meters above sea level and a crest length of body size 3030 m, is the largest dam on Iran with reservoir volume of 13.7 billion and 300 million cubic meters, is the largest artificial lake in Iran with a length of 60 km.

2.2. Sediments

Sediment samples were taken from the four-point located in the dam reservoir, downstream of the wire, output of bottom gates and the back of the sediment withdrawal gate of regulatory dam by using grab sampler. The sediment samples were combined and their size analyzing was tested using sieving and hydrometer method. Results showed that the sediment samples comprised 63.2% silt and 36.8% clay with mean diameter of 0.075 mm.

2.3. Annular Flume

The deposition characteristics of fine sediments were studied in an annular flume located at the Hydraulics Laboratory of Shahrekord University, Iran. The flume has a mean diameter of 1.6 m, is 0.30 m wide and 0.47 m deep, and rests on a rotating platform which is 1.9 m in diameter. A circular rotating ring was fitted inside the flume in order to regulate the flow velocity just at water surface of the flume. Bed shear stresses can be controlled by changing the rotational speeds of the flume and its rotating ring in inverse direction. In order to measure concentration of suspended solids in the water column, sixteen sampling valves were installed in four different positions of the flume at heights 5.3, 10.5, 18.3 and 25 cm from the bottom. The flume has two separate electromotor. They rotate the flume and the ring in any desired directions.

In order to determine the appropriate ratio of rotational speed of the ring to the flume, velocity and shear stress profiles were measured in the annular flume, using Acoustic Doppler Velocimeter (ADV) for different values of the ratio. The results showed that secondary flow are minimized and shear stress is uniform across the flume width when ratio of rotational speed of ring to flume is chosen at 1.1 (Nr/Nf=1.1). In this case, based on the obtained results, velocity profiles in the rotating flume were similar to flow pattern in a straight channels [1].

2.4. Experimental procedure

The tests were carried out for five bed-shear stress conditions and three different initial sediment concentrations. The shear stresses were chosen between a minimum and maximum shear stresses which caused deposition of eighty and twenty percent of suspended sediments, respectively. First, Acoustic Doppler Velocimeter (ADV) was used to measure vertical velocity and shear stress distributions, and based on these measurements, the relationship between hydraulic parameters and the flume rotational speed was obtained. Then, sediment and water mixture with a given initial concentration was prepared by weighting method and was transferred to the flume. In order to mix water and sediment completely, the flume and its ring were rotated in opposite directions at their maximum speeds, i.e. 14.8 and 16.2 rpm, respectively, which had shear stress of 11.2 N/m2, for thirty minutes. Then, the speed of the flume and its ring was lowered to reach a rotation speed providing the desired bed shear stress. All experiments were done for a period of 300 minutes, and in the meanwhile, the test samples were collected in a sampling interval of 15 min during the first hour, and 30 minutes thereafter. The samples were taken from depths 5.5, 10.3 and 18.3 cm from the bottom and then, sample concentrations were measured by the drying and weighting method (ASTM Standard Test Method D 3977-97).

3- Results and Discussion

The results showed that during the first 15 minutes, the sediment concentration drops suddenly, and then it decreases gradually to reach its equilibrium concentration. The equilibrium concentration had a good relationship with the initial sediments concentration and the bed shear stress. The results showed that, in a constant shear stress the ratio of equilibrium sediment concentration to initial sediment concentration is almost constant. In addition, the equilibrium concentration was strongly dependent to the initial concentration. Table 1 showed value of equilibrium sediment concentration to initial sediment concentration for different of initial concentration and shear stress.

Table 1. Ratio of equilibrium sediment concentration to initial sediment concentration for different of initial concentration and shear stress

initial sediment	Shear Stress (N/m^2)				
	0.12	0.25	0.57	0.94	1.29
5	0.108	0.220	0.410	0.475	0.543
10	0.113	0.240	0.410	0.475	0.543
20	0.110	0.200	0.430	0.520	0.620

Based on the obtained results from all experiments critical shear stress for threshold deposition and the critical shear stress for full deposition for sediments of Karkheh dam obtained 0.91 and 0.1 Pa, respectively. It should be noted that equilibrium concentration was considered when the ratio of the equilibrium concentration to the initial concentration reached to unit and partial deposition was determined when it approached to zero. The critical shear stress for full deposition was detected when all suspended sediment particles was deposited. Other parameters for threshold deposition condition can be found in Table 2.

Table 1. Ratio of equilibrium sediment concentration to initial sediment concentration for different of initial concentration and shear stress

Parameter	Threshold of Full Deposition	Non-Settling Condition
Shear Stress (N/m$^{2)}$	0.1	2.55
Velocity (m/s)	0.1	0.61
Froude No.	0.07	0.43

4- Conclusions

According to the results of deposition rates, it can be stated that the rate of deposition in each flow shear stress depends entirely on the initial concentration of sediments. It was also found that increasing the shear stress of the flow, decreasing the deposition rate of the Karkheh dam sediments, and this decrease is more pronounced in larger concentrations.

The results showed that the critical shear stress for full deposition of Karkheh Dam sediments is equal to 0.1 N/m2 and non-settling shear stress is 2.55 N/m2. Also, the flow velocity for full deposition of sediments is 0.1 m/s and the non-settling velocity is equal to 0.61 m/s. For these values, the simultaneous Froude numbers would be equal 0.07 and 0.43, respectively.

References

Khastar-Boroujeni, M., Esmaili, K., Samadi-Boroujeni, H,. Ziaei, A.N., 2018. "Wastewater Effect on the Deposition of Cohesive Sediment", Journal of Environmental Engineering, ASCE.

Huang, J., Hilldate, R.C., Greiman, B.P., 2006. "Erosion and sedimentation manual", in, U.S. Department of the interior. United States Bureau of Reclamation.

Please cite this article using:

M. Khastar-Boroujeni, H. Samadi- Boroujeni , R. Fattahi- Naftchi, M. Ghasemi, A. Naghshbandi, M. Heydari, Experimental study on suspended sediment deposition process in Karkheh dam reservoir ,*Amirkabir J. Civil Eng*., 51(2)(2019)327-339.

DOI:10.22060/ceej.2018.13490.5420