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The relation of bed and suspended loads in central Alborz Rivers, Iran

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ABSTRACT

Lack of appropriate technology, difficulty of measuring bed load and unclear boundary between bed load and suspended load induce experts to determine a part of suspended load as bed load. This ratio in many rivers with different conditions has the same coefficient and sometimes in a river, different experts estimate various ratios. In this study, two reach of Taleghan and Jajroud rivers was selected to determine the ratio, while stream flow was simulated by HEC-RAS software in both reaches. Bed load was calculated by Meyer-Peter-Muller, Casey, Schoklitch and Van Rijn equations, and Einstein, Chang-Simons-Richardsin, Begnold and Toffalati equations were used to estimate suspended load. After validation of equations, results showed that in both rivers, Schoklitch equation provides the best estimation for bed load. For suspended load, the Einstein and the Bagnold equations provided the best estimation for Jajroud and Taleghan rivers, respectively. R and Re tests and selecting of best equations for estimation of bed and suspended loads showed that bed load to suspended load ratio was about 3.76 and 0.14 in Jajroud and Taleghan rivers, respectively.

Introduction

Generally, sediment in rivers are transported as bed load and suspended load. The bed load in rivers moves in sliding, rolling or jumping modes along the bed and will not affect the turbidity of water. The suspended loads which moves as suspension and occupies the entire flow depth, control the concentration of sediments in rivers. Sheppard (1965) consider that amount of bed load can be 0 to 100% of suspended load. Comparison of annual yields of bed load and suspended load fluctuates largely depends on many natural factors. Soviets authors (Karaushev, 1977) showed that this ratio can be 50 to 300% for Mountain Rivers with more than 0.02 m/m slope and from 1 to 5% for foothill or Plain Rivers with less than 0.002 slope [13]. Hadley in UNESCO's report (1985) about more than 12 rivers in different regions of the world, with drainage area between 4 to 100000 km^2, showed that bed load to suspended load ratio was between 0.3 to 1600 [6]. From field investigation on an experimental river reach, Georgive (1990) estimated the ratio of bed to suspended load as 16% for a river with a mild slope and considered that the relation varies from year to year and greatly it depends on the annual variation of runoff, river turbidity, etc[5]. Bahadori (1995) by study of Iran rivers showed that in plain rivers (low slope), bed load is 2.5-45% of suspended load and in mountain rivers (high slope), this ratio increased to 100% or even more than 400% [3]. Yang (1993) declared that in most natural rivers, sediments mainly transport as suspended load, and generally, the bed load to suspension load ratio is about 5-25%. However, for coarse materials, higher percentage of sediment maybe transported as bed load [16]. Lenzi and Marchi (2000) in Rio Cordon River located in northeast Italy concluded that bed load was changing between 0 to 84% of total load [8]. Arab Khedri (2001) believes that the Iranian experts, for simplifying of their studies, determine a part of suspended load (15 to 20 percent) as bed load [2]. Mahdavi (2005) declared that bed load is related to suspended load and can be between 10 to more than 50% of suspended load. He determined the bed load by concentration of suspended materials, their material composition and texture of bed materials [10]. Chun *et al* (2005) estimate the suspended and bed loads using numerical models in Taiwan Rivers. NETSTARS Model was used to evaluate the bed load. Results showed that bed load was about 12 to 24 and 14 to 72% of total and suspended loads, respectively [4]. Lenzi (2005) analyzed the recorded flow discharge data, suspended load and bed load ratio in Rio Cordon River basin of Italy in two decades and showed that amount of suspended load was about 61% of total load [9]. Pratt-Sitaula *et al* (2007) in Himalaya concluded that in mountain rivers (high slope) bed load is approximately 35% of total load while based on Lane and Borland (1951) studies it was about 12-2% [11]. Warno and Warno (2008) based on discharge, suspended and bed load data of 6 hydrometric stations in Wonogiri reservoir in Central Java estimated that, bed load was about 10-30% of suspended load [15]. Abdolahzade *et al* (2010) in Lake of Mako Dam by comparison of suspended loads and bed loads, showed that the bed loads in Mako Dam Lake is 1380% of suspended loads [1]. Hassanzadeh *et al* (2011) in a study in Karkheh River by use of sediment transport formulas tried to estimate the sediment transport rate. Results showed that the bed load was 2% to 6% of suspended load [7].

The difficulty of direct measuring of bed load, technical problems and other practical and scientific limitation induced researchers to determine bed load as a part of suspended load.

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Sediment transport in natural rivers has been widely studied in the past few decades and there are many theoretical or empirical formulas that can be used with reasonable accuracy to predict the transport rate for sand bed rivers. In this paper, the applicability and performance of the commonly used sediment transport formulas in calculating the sediment transport capacity in Taleghan and Jajroud Rivers are evaluated. This study try to estimate the bed load to suspended load ratio through sediment transport equations, reservoir sedimentogarphy data (reservoir bathymetry) and recorded data in hydrometric stations of the Jajroud and Taleghan rivers.

Materials and Methods

Study area

Jajroud and Taleghan Rivers are very important rivers in Central Alborz of Iran, and Latyan and Taleghan Dams "which supply drinking water and electric power for Tehran metropolitan" are located on the Jajroud and Taleghan Rivers. Therefore these rivers were selected for estimation of bed load to suspended load ratio by appropriate sediment and hydrometric data.

Talghan River

Taleghan sub basin is located in 90 km northwest of Tehran and is one of the main sub basins of Sefid-Rood basin. Taleghan River is the main river in this sub basin, it originates from Asalak Mountain and enter to Sefid-Rood Dam. To study transported sediment in this River, a reach from Veshte Bridge to Glinak Bridge with length of 7.2 Km was selected. The mean slope of this reach is about 0.52% and is classified as a fine grain river. Glinak hydrometric station is located in down stream of this reach (Fig. 1).

Jajroud River

Jajroud River sub basin (Latyan basin) is located in north east of Tehran. It is the main river in this basin. It initiates from Central Alborz Mountain and enters to Daryacheh-e-Namak basin. To study transported sediment in Jajroud River, a reach from Oshan region to Lashkarak Bridge with length of 11.3 km was selected. The mean slope in this reach is about 0.82% and it is classified as a coarse gravel-bedded river. Rudak hydrometric station is located in within of this reach (Fig. 1).

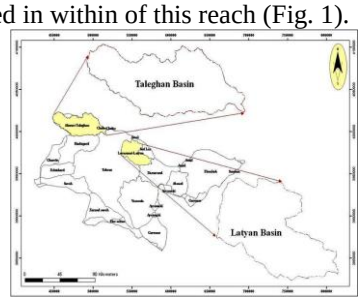

Fig. 1: Location of Taleghan and Latyan Basins, Iran.

In this study, first, Topography Maps of Jajroud and Taleghan Rivers were obtained with scale of 1:500 for Taleghan River from Tehran Regional Water Organization and with scale of 1:2000 for Jajroud River from the National Cartographic Center of Iran. Then discharge and sediment load data (suspended and bed load) related to Glinak and Rudak stations (consider to long term data of these stations) were provided from Water Resource Management Company and Tehran Regional Water Organization.

Next step was field studies, survey of cross sections, estimation and recording of main river characteristics. Manning Roughness Coefficient was determined using COWN or United States Soil Conservation Service (SCS) method in each cross section (for main channel, right and left floodplains). According to river morphology, changes of 25 cross sections and other conditions were surveyed for Taleghan River and 17 cross sections for Jajroud River. Also in each cross section, to determine the grain size curve, bed river material was sampled and grain size curve was determined in soil and sediment laboratory by Sieve Analysis.

After field studies, Triangle Irregular Network (TIN) map of river reaches was provided using ARC GIS 9.2, then required layers for HEC-RAS by using HEC-GEO RAS extension in ARC GIS 9.2 added to TIN map and output layer of GIS interred to HEC-RAS. After entering the river geometry profile in HEC-RAS, the mean annual discharge, Manning Roughness Coefficient and boundary conditions were defined for the flow simulation in HEC-RAS. Finally, HEC-RAS output including water surface profile, flow velocity, shear stress and etc. used for calculation of sediment transport equations in Excel.

Sediment transport equations

Measuring of bed and suspended loads require special equipments, expert manpower, spending much money and also it has many scientific and practical limitations. Therefore in recent decades, many equations are presented for calculation of sediment transport.

Many of these equations estimate only bed load, some only suspended load and others estimate sum of bed load and suspended load that called sediment load. Most of these methods are based on laboratory operations and always their accuracy has been questioned.

In this study, Meyer-Peter-Muller, Casey, Schoklitch and Van Rijn equations used for estimation of bed load and Einstein, Chang-Simons-Richardsin, Begnold and Toffalati equations used for estimation of suspended load [12 &14].

Rating curves of Glinak and Rodak stations used for validation of suspended load equations in Taleghan and Jajroud rivers, respectively. Also, sedimentation data of Latyan dam used for validation of bed load equations in Jajroud River but because of lack of sedimentation data in Taleghan dam, after simulation of bed load data in Glinak station and comparison of observed and estimated data, the best equation of bed load determined. In this study for selecting of best equation, R (ratio between estimated and observed sediment loads) and Re (Re=1-R) tests was done. When R and Re near to 1 and 0 respectively, it show the better estimation of sediment load by empirical equations (Tables 1 to 3).

Results

Empirical equations results

After analysis of obtained data from the hydrometric stations and determining different parameters for every bed load and suspended load equations, sediment load estimated through the above mentioned equations in Excel (table 4).

Then, the best bed load equation was selected according to bathymetric data of Latyan reservoir Dam, and simulation of discharge–bed load in Glinak station. Also, using suspended load data from Glinak and Rudak stations, the mean annual suspended load transition was determined in Jajroud and Taleghan rivers, and these values compared with the results of suspended load equations, then the best equation was selected.

Results of the best sediment transport equations compared with measured sediment load data in hydrometric stations and bathymetric data of reservoir dam showed that for both rivers, Schoklitch equation provides the best estimation for bed load (fig. 2). Also, for suspended load, Einstein and Begnold equations provide the closest estimation in Jajroud and Taleghan rivers, respectively.

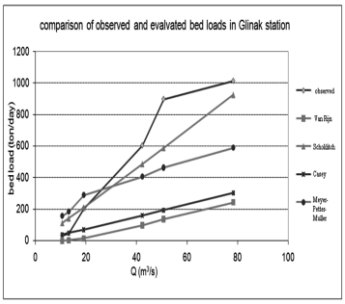

Fig. 2: Selection of best equation of bed load calculation in Taleghan River

Estimating the bed load to suspended load ratio

According to the best results from sediment transport equations in these rivers, bed load to suspended load ratio was obtained 376% and 14.7% in Jajroud and Taleghan rivers, respectively (table 5).

Conclusion

Considering the results of different equations and comparing them with measured values in the Rudak and Glinak stations and Latyan Reservoir dam showed that Schoklitch equation for estimation of bed load in both rivers provides the best answer, also for estimation of suspended load, Einstein and Begnold equations had the best answer for Jajroud and Taleghan Rivers, respectively. The bed load to suspended load ratio using the result of best equations in these rivers showed that this ratio is 376% and 14.7% in Jajroud and Taleghan Rivers, respectively.

According to previous studies, infer that, because the mean slope of Jajroud River is more than Taleghan River, the majority of sediment load in Jajroud River transports as bed load. Because the geological formations of Taleghan River sub basin is more sensitive to erosion than Latyan basin, the suspended load in Taleghan river is more than bed load, while this is reverse in Jajroud River. Results of this study is in harmony with Bahadori (1995), Karaushev (1977), Hadley (1985), also for Taleghan river conforms with Sheppard (1965), Lenzi and Marchi (2000), Chun *et al* (2005), Warno and Warno (2008) and Abdolahzade *et al* (2010) studies.

Results represent the fact that, amount of bed load can be more than suspended load, thus determining of a constant percentage of suspended load as bed load in all rivers will result to error in hydrological designs, inappropriate water resources management and etc. Therefore, suggest that for determining of bed load to suspended load ratio, the effective factors in sediment load transport such as, slope of river, river morphology, drainage area, river geology, flow discharge must be considered.

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Table 1: Calculation of bed load in Jajroud River by various equations

equation	estimated bed load (T/yr)	observed bed load (T/yr)	R	R%	Re	Re%
Casey	338319	774941	0.44	43.66	0.56	56.34
Meyer Peter Muller	1171907020	774941	1512.25	151225.3	-1511.25	-151125
Schoklitch	561966	774941	0.73	72.52	0.27	27.48
Van Rijn	12482052	774941	16.11	1610.71	-15.11	-1510.71

Table 2: Calculation of suspended load in Jajroud River by various equations

equation	estimated suspended load (T/yr)	observed suspended load (T/yr)	R	R%	Re	Re%
Begnold	2301899	170227	13.52	1352.25	-12.52	-1252.25
Toffalat	17724	170227	0.1	10.41	0.9	89.59
Chang et al	857451766	170227	5037.11	503711.1	-5036.11	-503611
Einstein	149632	170227	0.88	87.9	0.12	12.1

Table 3: Calculation of suspended load in Taleghan River by various equations

equation	estimated suspended load (T/yr)	observed suspended load (T/yr)	R	R%	Re	Re%
Begnold	14567515	16441290	0.89	88.6	0.11	11.4
Toffalat	20718	16441290	0.0013	0.13	0.9987	99.87
Chang et al	944777634	16441290	57.46	5746.37	-56.46	-5646.37
Einstein	5173217	16441290	0.31	31.65	0.69	68.53

Table 4: Estimation of bed load and suspended load using various equations in Jajroud and Taleghan rivers

River	Bed load (T/yr)				Suspended load (T/yr)			
	Meyer Peter Muller	Schoklitch	Casey	Van Rijn	Einstein	Begnold	Toffalat	Chang et al.
Jajroud	171907020	561966	338319.30	12482052	149632	2301899	17724	857451766
Taleghan	6992297	2144943	1381036	365306	5173217	14567515	20718	944777634

Table 5: Bed load to suspended load ratio in Jajroud and Taleghan rivers

River	Estimated suspended load (T/yr) K_1	Estimated bed load (T/yr) K_2	(K_2/ K_1)	(K_2/ K_1) %
Jajroud	149632	561966	3.76	376
Taleghan	14567515	2144943	0.15	14.72