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Velocity structure in interflow density currents

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ABSTRACT: Gravity currents, also known as density currents, or turbidity currents, are happened by the density difference between the flow and its ambient fluid. The density difference can be due to suspended particles, chemicals, soluble materials, and temperature differences. In dams reservoir ambient fluid, usually has a vertical stratification. When the gravity current arrived to ambient fluid, in the position that density of both gravity current and ambient fluid is equal the gravity current abandon the bed and flows in ambient fluid horizontally. Therefore the density current into this reservoir maybe intrude such as interflow density current.

This study investigates the inter flow density current in a stratification ambient. For achieve to the objectives of this study, experiments were carried out at a flumes with 9 meters long by 4 discharge 1, 1.5, 2 and 2.5 l/s, and 4 concentration 5, 10, 15 and 20 mg/l, that created density 1003.2, 1006.3, 1009.4 and 1012.5 respectively. Stratification was made by mixture water and salt with vertical gradient.

The investigation of velocity profiles showed that the flow is self-similar and velocity fluctuations Continues maximum up to 2.5 times greater than current thickness in the lower layer. The front velocity of currents in stratified environments increases at first then sizeable decreases. It shows that stratified can limited the flow movement. In each three slope, increasing of discharge and concentration increase velocity head of density current in stratified environment. As the slope increases, the current velocity increases at the underflow stage, and in the interflow stage, the slope does not have much effect on the current velocity. Interflow Travel Time decrease in increasing of discharge and concentration. Density current in weaker stratified can travel more distance in the slope and separate latter from the bed.

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1. INTRODUCTION

Gravity currents, also known as density currents, or buoyancy currents, are happened by the density difference between the flow and its ambient fluid. Gravity currents are one of the most active atmospheric and oceanic currents that are a subset of stratified currents. Those currents which two fluids are in contact with each other trough an intersection are named stratified currents. In such flows the intersection can be considered a surface whose fluid characters such as density are different on other sides. Due to the difference in interflow density with the reservoir, the current can move below, above, or through the ambiance fluid, which is called the underflow, overflow and interflow, respectively.

The complex dynamics of density currents have attracted many researchers for many years. Imberger et al. (1976), Lowe et al. (2002), Ahlfeld et al. (2003), Sutherland et al. (2004) are the researchers who have investigated the interflow in their experiments.

The deformation of underflow to interflow may cause initial mixing and entrainment. Therefore, the density of interflow and underflow may be the same. Wells and Nadarajah (2009) and Sangdo and Julien (2014) examined the entrainment of density current.

Zhang et al. (2015) investigated the effect of thermal stratification of the reservoir on the transient time of interflow.

He et al. (2016) investigated the effect of linear stratification of the ambience flow and bed slope on the hydrodynamics of interflow.

2. METHODOLOGY

The experiments are performed in a 9 meter long flume, 66 cm high and 35 cm wide. At different levels and in the floor at the end of the flume, the pipes were installed for discharge. A gate was installed at 80 cm from the beginning of the flume. To provide ambient fluid, first, the salt water tank was filled up of water and then salt added to the reservoir. Its density was measured after complete mixing. Flume was filled of ambient fluid in several times. After measure the density of ambient fluid gravity current was flow to ambient fluid. In this station the concentration and velocity profile was measured.

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For record the velocity profile was used a DOP2000 velocity meter.

3. PARAMETERS

To investigate velocity profiles, because the intersection between the density flow and ambient flow is not easily recognizable, average velocity ($\overline{U}$) and height ($\overline{H}$) values have been used [8]. Using of the momentum equation in the condensed flow:

$$\overline{U} = \frac{\int_0^\infty u(z)^2 dz}{\int_0^\infty u(z) dz} \quad (1)$$

$$\overline{H} = \frac{(\int_0^\infty u(z) dz)^2}{\int_0^\infty u(z)^2 dz} \quad (2)$$

Where velocity profile *u(z)* record by velocity meter and *dz* is height difference between points which *u(z)* is been recorded at them.

The distance of probe from inlet gate has been shown in Table 1.

Table 1. Probe's distance from inlet gate (cm)

Probe number	1	2	3	4	5	6	7
Distance	95	185	275	385	480	550	620

Table 2. Comparison between maximum and average value

Experimental condition	Case		h_{max}/h	u_{max}/U
Unstratified environment under flow	Altinakar et al. (1996)[9]		0.3	1.3
	Garsia (1994)[10]		0.3	1.3
	Hosseini et al. (2006)[11]		0.384	1.3
	Khavasi (2012)[12]		0.268	1.28
Stratified environment under flow	The present study	Probe1	0.33	1.31
Stratified environment interflow		Probe4	0.94	1.29
		Probe7	1.45	1.32

4. RESULTS AND DISCUSSION

Dimensionless velocity profile are compared with each other. The relationship between maximum value and average one in comparison with other researchers has been bring in Table 2. Moreover relationships for dimensionless velocity profile are fund through these experiments. The formation of equation is same as Altinakar equation for jet and wall region in underflow density current.

In addition, the head velocity of flow in the layered ambiance and interflow differs from head velocity in the uniform flow and underflow mode. In underflow, density current moves much faster and the head velocity reaches its peak then decreases slowly. In the layered fluid, the head velocity first increases and then decreases substantially, meaning that the layering can limit the movement of the flow.

Since the passing time of density flow in the layered ambient is especially important in predicting the process of contamination or turbulent flow into the reservoir, using SPSS software and the dimensionless parameters for time prediction of flow passing is developed.

5. CONCLUSIONS

In this study, the velocity structure of the density current with 48 experiments was investigated. Examination of the dimensional profiles velocity showed that these profiles overlapped, so it can be concluded that the flow is self-similar.

Also, the maximum velocity value in the dimensionless velocity profiles at each cross section showed that this value is about 1.3 times the average velocity in all currents. Comparing this value with the work of other researchers shows considerable similarity

The shape of the dimensionless velocity profiles showed that for the underflow in the layered ambient, the equation of velocity profile in the wall region is the same as the underflow flow in the uniform ambiance with n = 5.

As the discharge increases and the concentration increases, the passing time decreases. Increasing the concentration also reduces the layering parameter (R). Density flow at a weaker stratification (smaller R) can slip further and separate later from the bed.

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