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Physical Simulation of Discharge Flow from Deep Conduit in Dense Reservoir (In Terms of Use in the Gotvand Dam Deep Pipe)

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ABSTRACT: The stratified reservoirs are forming due to natural phenomena such as sediment current or a significant change in water quality parameters in terms of salinity, dissolved oxygen, heavy metals, etc. Today, research of the dense reservoir in different conditions is needed for better management. Understanding the outflow pattern and its interactions in stratified reservoir according to different discharges from the deep conduit and application for the operation of its system in Gotvand Dam using by a physical model is the main goals of this research. An undistorted physical model with a 1:40 scale from the deep duct structure with the details was established. This scale is calculated based on the Richardson number and the same density conditions in the model and prototype. Laboratory scenarios of the physical model were designed and implemented in two sections to allow changes water level in the reservoir and maintain it. These two categories were designed for simulating short and long term effects of saline layer evacuation in the reservoir. The results of experiments with different outflow rates (maximum up to 800 liter per second) revealed that salinity of the layer in front of the deep conduit plays an important role in the salinity of the depleted stream, and other layers in different level of the reservoir have not affect in changing this amount. Also, the pattern of the streamline formed towards the output is under very stable conditions without expanding to other layers. The experimental results revealed that the fluid below the offtake remaining unaffected by the outflow and the fluid above the outlet vertically to make up the volume lost through the outflow but preserving the horizontal isopycnals. This issue was clearly recorded in addition to measuring by imaging from the model. To ensure the necessary turbulence and increase Reynolds number in the physical model, outflow was reached more than twice (up to 1677.5 liter per second) but flow pattern towards offtake still was in very stable condition and streamlines did not expand to above and below of outlet layer. Any significant amount of vertical diffusion among dense layers was not observed.

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1. INTRODUCTION

The term "density model" is defined here as a model of fluid motions in a gravitational field in which the variations of density within the field originate or influence the flow field. Strictly speaking, this applies to all free surface fluid motions, but in this case the emphasis is on motions involving fluid masses of the same state, and with relatively small density differences, ($\Delta\rho/\rho \ll 1$). Initially the models were used to solve engineering problems, such as selective withdrawal for power plant intakes, sediment current in reservoirs, salinity intrusion studies and evacuate saline water through Deep conduit in stratified dam reservoirs. In recent years, the use of these types of models has expanded further into accident analyses (e.g. gas and oil spills, avalanches) and heat transfer studies in which buoyancy-driven convection plays a significant role.

A physical model constructed for investigating density current in Chicago River system. The model was designed based upon the Densimetric Froude number similarity. It had a horizontal scale of 1.to 250 and a vertical scale of 1 to 20. This distortion was needed to have measurable flow depths in the laboratory. In the model the excess fractional density between the North Branch and the Chicago River was exaggerated 100 times, using a saline solution as a surrogate for the heavier inflow from the North Branch The model was tested for a constant inflow discharge from the North Branch and varying boundary conditions, such as the surface water elevation at Columbus Drive, and the density gradient between both branches. The experimental results demonstrated that a bi-directional flow could develop in the Chicago River originated by density currents [1].

A research is concerned with a study of the establishment of the selective withdrawal of a linearly stratified fluid through a line sink at the base of a reservoir with bottom topography in the form of a sill of arbitrary height. The nonlinear problem is investigated numerically in two dimensions. Development of the flow towards the steady state is studied, and the effect of the sill on the withdrawal-layer thickness upstream of the sill is examined. In general, the presence of a sill causes the withdrawal layer to be thicker and to shift upward with

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respect to the flat-bed case. The proposed equation for withdrawal-layer thickness was verified experimentally [2]. In the following, another research was established in same environment but this time with a side contraction of arbitrary dimension. The research is based on physical and numerical model. In general, the presence of a contraction causes the withdrawal layer to be thicker with respect to the flatbed case, but thinner than that for a sill of the same flow cross-sectional area at the constriction [3].

A physical study was stablished to find the angle and velocity of discharge of brine sewage into the marine ambient, in order to prevent the environmental hazards of the brine sewage discharge into the sea the results showed that angle variations, in spite of changes in velocity affect the concentration distribution profile pattern at the highest elevation of the center line and also increases the width of the current plume and the most evolution and dilution occurs at the 60 ° angle [4].

Many other research studies were carried out in the field of sediment density current in reservoirs by physical simulation in order to more understanding about sedimentation and optimized the operation of sluice gates during flood with occurrence sediment current in reservoir [5, 6, 7, and 8].

So far, various studies have been carried out on the issue of salinity in the Gotvand dam [9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21]. Those research studies are mainly related to the environmental parameters of the Karun River, the factors affecting the quality of reservoirs, the quality of groundwater in the Gotvand region, the solubility rate of Gachsaran salt formations, and the numerical and physical modeling of dissolution in salt formations and Gachsaran Formation. Simulation of the quality conditions of the Gotvand reservoir water was done by interaction with salt formations over time using 3D numerical modeling [18]. One of the solutions proposed for the Gotvand Dam reservoir is water quality management decision to the depletion of saline water from the bottom layers through a deep duct and its transmission by the pipe for industrial and commercial use. Understanding the process of evacuation of saline water and its interactions in reservoir layering with regard to the amount of outlet flow and the continuity of salinity in the outlet for the industry are main goals of this research. In this study, by using a physical model tool, this issue and the role of different salinity layers in drainage through the deep conduit are discussed.

2. PRINCIPLES OF PHYSICAL SIMULATION

The term "stratified flow" is often used to designate the flow. Most of the cases of interest involve density differences $\Delta\rho/\rho$ of the order of 10^{-2} or less, although some cases, such as tailings plumes, oil slicks, and gas releases can involve $\Delta\rho/\rho > 10^{-1}$ [22].

In physical modeling, if dynamic similitude is satisfied, kinematic similitude automatically follows. Dynamic similitude of flows in which buoyancy effects are important usually requires the Densimetric Froude number to be equal in model and prototype; that is, $(Fr_D)_r = 1$. It should be noted that equality of Froude number, Eq. (1), does not require the density differences to be the same in model and prototype [23].

Fig. 1. Physical Model Components

$$Fr_D = \frac{V}{\sqrt{g\frac{\Delta\rho}{\rho}L}} \quad (1)$$

In dense models, the Richardson number (Ri) is also used. Richardson's number is the ratio of stabilizing gradient to disturbing (shear) gradient and is a formation of Densimetric Froude number as follows:

$$Ri = \frac{g\frac{\Delta\rho}{\rho}h}{U^2} = \frac{1}{{Fr_D}^2} \quad (2)$$

In general, it is not possible to satisfy equality of Reynolds number simultaneously with equality of Froude number. Reynolds number in the model usually is much smaller than in the prototype. The Reynolds numbers should, however, be in the same range of flow behavior. In most cases, prototype flows are turbulent, so model flows must also be turbulent. For a free shear flow such as a jet or plume, the flow properties are practically independent of Reynolds number when it is above about 10,000 although even smaller values do not cause significant effects suggest a limit of 4,000 [1].

An undistorted physical model with a 1:40 scale from the deep duct structure with the details was established. This scale is calculated based on the Richardson number and consider limitations in physical simulation for gates (orifices) [24, 25 and 26]. The same density conditions in the model and prototype was used in order to decrease scale effect.

3. PHYSICAL MODEL COMPONENTS

Fig. 1 shows details of the physical model. The model comprises a test tank, three tanks for saving water and a water circulation closed system. Mixer system was installed on the head of two save tanks for preparing salt water.

4. LAB SCENARIOS AND RESULTS OF PHYSICAL MODEL

The optimization of the outlet of GRP (Glass fiber Reinforced Plastic Pipe) so that the maximum amount of salinity can be discharged is an important goal of this research. For this purpose, the scenarios are designed as follows:

- Dynamic water level in the reservoir and regulated outlet from GRP
- Stable water level in reservoir and regulated outlet from GRP
- Measuring EC in front of tunnel
- Measuring EC in the inner boundary (between dense layers)

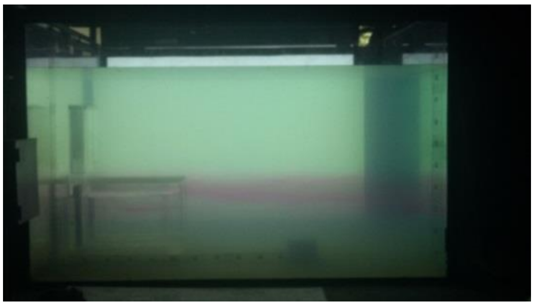

Fig. 2. Streamline toward to the outlet (GRP)

- Measuring EC on the top of stoplog
- Measuring EC from the outlet (GRP)

Also, color injection from different location in the reservoir would be run and reveal stream lines toward the outlet (Fig.2).

The measuring results for EC and imaging from the model revealed that salinity of the layer in front of the deep conduit plays an important role in the salinity of the depleted stream, and other layers in different level of the reservoir have not affect in changing this amount. Also, the pattern of the streamline formed towards the outlet (GRP) is under very stable conditions without expanding to other layers (Fig. 2).

5. CONCLUSIONS

An undistorted physical model with a 1:40 scale from the deep duct structure with the details was constructed for investigating the role of operation of GRP in stratified Gotvand dam reservoir. The main findings of this research are summarized below:

– The salinity of the depleted stream from GRP is depend only on the salinity of the layer in front of the deep outlet, and other layers in different level of the reservoir have not affect in changing this amount.
– In the range of discharge variations from 100 to more than 800 liters per second, the flow pattern was formed near the entrance of the outlet is a very stable condition. In other words, the only layer in front of the offtake is being evacuated.
– Any vertical diffusion among dense layers is not observed in the model.
– The fluid above the outlet vertically to be replaced the volume lost through the outflow but preserving the horizontal isopycnals

REFERENCES

[1] C.P. Manriquez, C.M. Garcia, P.R. Jackson, M.H. Garcia, Hydraulic Model Study of Chicago River Density Currents, Civil Engineering Studies Hydraulic Engineering Series No. 77, (2005).

[2] M. Jamali, B. Seymour, R. Kasaiian, Numerical and experimental study of flow of a stratified fluid over a sill towards a sink, Physics of Fluids, 17(057106) (2005).

[3] M. Jamali, P. Aghsaee, Effect of a contraction on selective withdrawal of a linearly stratified fluid from a line sink, Physics of Fluids, 19 (106602) (2007).

[4] H. Ardalan, V. F., M. Azizi, D. Gohary Kamel, A. Kalateh Arabi, Investigation of the Velocity and Angle Effects on the Behavior of Brine Discharge by Inclined Jet into the Stationary and Homogenize Ambient, Journal of Oceanography, 9(33) (2018) 51-58.

[5] B. Mohammadnejad, Investigation of 3D Particle Laden Density Currents with Supercritical Inflow, Sharif University of Technology, 2008.

[6] W.S. Yu, H.Y. Lee, S.M. Hsu, Experiments on the deposition behavior of fine sediment in a reservoir, Journal of Hydraulic Engineering, 126(12) (2000) 912-920.

[7] W.S. Yu, S.M. Hsu, K.L. Fan, Experiments on selective withdrawal of a codirectional two-layer flow through a line sink, Journal of Hydraulic Engineering, 130(12) (2004) 1156-1166.

[8] S. Chamoun, G. De Cesare, A.J. Schleiss, Managing reservoir sedimentation by venting turbidity currents: A review, International Journal of Sediment Research, 31 (2016) 195-204.

[9] S. Hassanian, P. Moobed, N. Hosseini zare, H. Akhourdzadeh, Y. Hamid, N. Saadati, H. Kamaei, Classification of Karoon and Deze river in limit of Gutvand to Khoramshahr and Dezful to Bamdeje with use of water quality index (WQI) and study of enterobacteriaceaes that separation of this sites, in: 7th International River Engineering Conference, Shahid Chamran University, Ahwaz,Iran, 2007. (In Persian)

[10] A. Zarei, A.M. Akhoundali, Investigation of temporal and spatial variations of Karun River water quality in Gotvand-Shushtar and the effect of Saline River on its quality, in: The first regional conference on optimal utilization of water resources in Karoon and Zayandeh Rood basins, Shahrekord University, Sharekord, Iran, 2007. (In Persian)

[11] H. Zarei, A. Azhdari, Chemical quality of water resources of Abol-Fars dam and effect of formation Gachsaran on it, in: Tenth Congress of Iranian Geological Society, Tarbiat Modares University, Tehran, Iran, 2007. (In Persian)

[12] J. Mozaffarizadeh, M. Chitsazan, Investigating the Effect of Geological Formations on the Quality of Groundwater Resources in Gotvand Plain, in: First Conference on Environmental and Medical Geology, Shahid Beheshti Univerity, Tehran, Iran, 2008. (In Persian)

[13] S.M. Haeri, F. Rezaeiyeh, Investigating and laboratory analysis of dissolution and scouring of salt karsts in dams reservoirs, in: Third National Congress of Civil Engineering, Tehran, Iran, 2007. (In Persian)

[14] N. Damugh, H. Zarei, Extending thick saline layers Gachsaran in the Gotvand Aliya dam and its effect on the quality of water, in: First national conference on water resources research in Iran, Kermanshah, Iran, 2010. (In Persian)

[15] B. Baghadashtaki, M. Khamehchian, M.H. Nazari, Determination of solubility of salt mass Anbil located at Gotvand dam and its effect on the quality of the reservoir water, in: First national conference on water resources research in Iran, Kermanshah, Iran, 2010. (In Persian)

[16] M. Hassanvand, B. Dahrazma, N. Hafezi Moghadas, Assessment formations area in reservoir of Gotvand Dam and quality variations of water in levels several, in: Seventh Conference on Geology of Engineering and Environment of Iran, Shahrood University of Technology, Shahrood, Iran, 2011. (In Persian)

[17] S.M. Hashemi Heydari, M.R. Jalili Ghazizadeh, D. Mahjub, Numerical study of the effect of salt dissolution coefficient on salinity distribution in reservoir salt formation, in: Ninth international Congress of Civil Engineering, Isfahan University

of Technology, Isfahan Iran, 2012. (In Persian)
[18] V. Naderkhanloo, M. Mazaheri, J. Samani, Investigating and Modeling of Gotvand-Olya Dam Challenge and Management Solutions, Journal of Environmental Studies, 43(2) (2017) 251-265. (In Persian)
[19] M. Mansournejad, B. Kalantari, M. Mahdavi, The Investigation of Negative Effects of Salt Dome on the Quality of Water in Gotvand Olya Dam and the Use of Cut-off Wall as Treatment, American Journal of Civil Engineering, 3(2-2) (2015) 53-56.
[20] D. Mahjoob, A. Sadatifard, H. Hassani, A. Zia, Upper Gotvand Dam and Hydro Power Plant Dealing With Salinity in Reservoir, Challenges, Remedies and Evaluations , in: International Symposium on Dams in a Global Environmental Challenges, Bali, Indonesia, 2014.
[21] M. Ajaml, M.R. Sabour, G.A. Dezvareh, The Examination of Effect of Salt Water on Mechanical Properties Clay Soil Around the Dam Gotvand Using Response Surface Method (RSM), Journal of Applied Environmental and Biological Sciences, 5(7S) (2015) 203-211.
[22] R. Martins, Recent Advances in Hydraulic Physical Modelling, Kluwer Academic Publishers and Published in Cooperation with NATO Scientific Affairs Division, 1988.
[23] R. Ettema, R. Arndt, P. Roberts, T. Wahl, Hydraulic Modeling Concepts and Practice, U.S.A, 2000.
[24] P. Novak, A. Jefrrey, G. V., D.E. Revee, Hydraulic Modelling-an Introduction Principles, methods and. Applications, Spon Press, U.S.A, 2010.
[25] P. Novak, J. Cábelka, Models in Hydraulic Engineering – Physical Principles and Design Applications, Pitman, London, 1981.
[26] H. Kobus, Fundamentals. In Hydraulic Modelling, Verlag Paul Parey/Pitman, Hamburg/London, 1980.

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