Journal of Civil Engineering and Urbanism
Volume 4, Issue 3: 287-292 (2014)
ISSN-2252-0430

Numerical Simulations of Distribution and Sediment Transmission in Pre Settled Pools Using Finite Volume Method and Comparison with Experimental Results

Mohammad Reza Borna[1], Human Janfeshan Araqi[2], Edris Merufinia[3*], Adel Asnaashari[4]

[1] *MSc Student in Civil-Water Sewage Engineering, Lamei University of Gorgan, Iran*
[2] *Assistant Professor, Department of Civil-Water Sewage Engineering, Lamei University, Gorgan, Iran*
[3] *Department of Civil Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran*
[4] *PhD Candidate, Department of Civil-Hydraulic Structure Engineering, Razi University of Kermanshah, Iran*

*Corresponding author's E-mail: edris.marufynia@yahoo.com

ABSTRACT: Pre settled pools were most important elements in water purification process. Because of enormous cost of making these pools which have been allocated about 30% of the total cost to water purification process Modeling and optimal performance of Pre settled pools is very important. In pre settled tools due to different gradients of, secondary flow and rotational have been changed. These phenomena are caused to create short paths, increasing resident zones and dead flows and changes in the levels of flow which preventing laminar flow conditions in order to reduce efficiency of pools. The first step is to optimize Pre settled pools, correct calculation of the velocity and volume of the rotating parts. In this study, the numerical simulation of flow in a rectangular pool is studied and continuity and Stokes equations were solved using finite volume method. Flow simulations in three dimensional model using of turbulence k-ε standard and velocity profiles at different sections of the pool have been compared and there was good agreement. Afterwards, in order to evaluate style of sedimentation in pre settled pool, diffusion and transfer of sediment concentration was solved simultaneously by hydraulic flow equations and finally results of vertical distribution of sediment profiles have been compared by laboratory result of other researcher which shows good adaptation of numerical results and laboratory results as well as capacity of this model to predict distribution of sediment profiles in pre settled pools.
Keywords: Pre Settled Pools, Profile of Flow Velocity, Distribution of Sediment Concentration

ORIGINAL ARTICLE
Received 04 May. 2014
Accepted 09 May. 2014

INTRODUCTION

Given the importance of drinking water quality and purification with high efficiency purification water process, performance of pre settled pool has been addressed. Pre settled pools plays important role at separating Aerosols of fluids, so that in purification department, before pre settled pool, Coagulant have been added and, so particles size have been increased and time of sediment have been decreased. Sediment particles moves to floor of pre settled pools by Gaining weight of particles and are settled as Sludge. Due to high expense of making or maintain pools, performance of pools are so important. Despite importance of these pools, designing are related to simple experimental formula and Hydrodynamic systems details are not attended. Performance of pre settled pools are influenced by Hydraulic and physical effects like current density, gravity force and sedimentation coagulation. In this regard, a chemical aspect is not important in pools, but Hydraulic flow plays most important role. In order to optimize performance of such pools, entering fluid flow should be done slowly in the pools and turbulence should be minimized. Secondary flows and rotational regions always are in the pools. These regions cause to develop dead areas in suitable sediment. Settle of independent particles in same size in a turbulent flow has been studied. He explained developed turbulence as a constant situation against velocity of Contiguous points. Shiba et al. (1975) have developed an approach to estimate dynamic parameter using laboratory tests. Larsen (1977) has started initial laboratory studies and used results on mathematical models on pre settled pools. Imam and McCorquodale (1983) have studied sediment pools. Laboratory model was a simple pool without any barriers. Rodi 1984 has developed comprehensive model to estimate flow and used transmission equation in kinetic energy. Mc. Corquodale et al. (1988) have studied experiment by Doppler laser. Their empirical experiments have been attended by many researchers. Due to importance of this model in hydrodynamic tanks, so researches have tried to design different kind of these models. Lyn and Rodi (1990) have examined sediment pools and pools inputs. Results included vertical and horizontal velocity profile and turbulence profiles. This study has been implemented by placing leading Blade in front of the input. Ueberal and Hager (1997) have examined velocity and concentration on sediment pools. Four pools have been used simultaneously for measurement. One of pools has been selected as reference and has been done in different stages and results have been shown.

Measuring profiles for different shape and situation have been done by different velocities and concentration.

To cite this paper: Borna MR, Janfeshan Araqi H, Merufinia E, Asnaashari A. 2014. Numerical Simulations of Distribution and Sediment Transmission in Pre Settled Pools Using Finite Volume Method and Comparison with Experimental Results. *J. Civil Eng. Urban.*, 4 (2): 287-292.
Journal homepage: http://www.ojceu.ir/main/

Jayanti et al. (2004) have simulated dynamic particles in pre settled pools. Findings showed that flow field could be estimated by CFD. Tamayol and FirozAbadi (2004) have simulated pools by fluent software and results of turbulence k-ε and RNG.

Naser et al. (2005) have developed a model in dynamic pools in turbulence situation. In order to formulate equation of flow, integral method has been used. Goula et al. (2007) have simulated pools and have studied flow. In this simulation, fluent software has been used .This software explains fluid flow by differential equation. Stamou (2008) proceeded to simulate. He used corrupter walls to simplify flow in order to decrease short pathway. Liu et al. (2008) used k-ε model in order to evaluate pre settled pools and HFAM method have been used in simulating pools. Current study consists of hydraulic simulation and flow sediment in pre-settled pools. Modeling according to laboratory studies was done by Shahrokhi et al. (2011) and velocity profile and vertical distribution of sediment concentration have been compared in three dimension state.

MATERIAL AND METHODS

Dominated equation on flow

In this study, continuity equations of and Navier - Stokes method are dissolved by Finite-Volume Method. Finite volume method is based on direct Discrete in the physical space. Flow analysis was done Steady by the SIMPLE algorithm for velocity and pressure coupling. Discrete method of continuity equations, momentum, turbulent kinetic energy and Reynolds stress drop and leading the way once and ¬ discretion of pressure equation are standard. According to the differential $\frac{\partial U}{\partial t}+\vec{\nabla}\cdot\vec{F}=Q$ most important step is a finite volume the method and integral equations governing the volume control:

$$\int_{\Omega_J}\frac{\partial U}{\partial t}d\Omega+\int_{\Omega_J}\vec{\nabla}\cdot\vec{F}d\Omega=\int_{\Omega_J}Qd\Omega \quad (1)$$

According to the divergence theorem of Gauss, we get:

$$\int_{\Omega_J}\vec{\nabla}\cdot\vec{F}d\Omega=\int_S\vec{F}\cdot d\vec{S} \quad (2)$$

The integral form of survival for each control volume to the point is as below:

$$\frac{\partial}{\partial t}\int_{\Omega_J}Ud\Omega+\int_{S_J}\vec{F}\cdot d\vec{S}=\int_{\Omega_J}Qd\Omega \quad (3)$$

Above equation is replaced by Discrete form and integral value is expressed in desired size on cell and integral:

$$\frac{\partial}{\partial t}\left(U_J\Omega_J\right)+\sum_{faces}\vec{F}\cdot\Delta\vec{S}=Q_J\Omega_J \quad (4)$$

The governing equations on fluid movement include continuity equation of fluid and momentum equation for turbulent flow of the fluid in a three-dimensional geometry relations are (5) and (6). Different turbulence models, the turbulent kinetic energy are defined as:

$$\frac{\partial\overline{U}_i}{\partial x_i}=0 \quad (5)$$

$$\frac{\partial\overline{U}_i}{\partial t}+(\overline{U}_j)\frac{\partial\overline{U}_i}{\partial x_j}=-\frac{1}{\rho}\frac{\partial\overline{p}}{\partial x_i}+g_{xi}+\frac{\partial}{\partial x_j}[\nu\frac{\partial\overline{U}_i}{\partial x_j}-\overline{U'_iU'_j}] \quad (6)$$

$$K=\frac{1}{2}\overline{U_iU_i} \quad (7)$$

In this relationship, ρūiūj is Reynolds stresses, Ui and Uj, respectively, the flow velocity in the x,y, t is time, ע is molecular viscosity, p the pressure, k turbulent kinetic energy, ρ the fluid density and gxiis gravitational acceleration in xi direction. Given that the k-ε turbulence model is used in study, so in turbulence model k-ε, turbulent kinetic energy (k) is as follows:

$$\frac{\partial k}{\partial t}+U_j\frac{\partial k}{\partial x_i}=\frac{\partial}{\partial x_j}(\frac{V_T\partial k}{\sigma k\partial x_j})+p_k-\varepsilon \quad (8)$$

P_k is defined as below:

$$P_k=\nu_T\frac{\partial U_j}{\partial x_i}(\frac{\partial U_j}{\partial x_i}+\frac{\partial U_i}{\partial x_j}) \quad (9)$$

$$\nu_T=c_\mu\frac{K}{\varepsilon^2} \quad (10)$$

$$\frac{\partial\varepsilon}{\partial t}+U_j\frac{\partial\varepsilon}{\partial x_j}=\frac{\partial}{\partial x_j}(\frac{\nu_T\partial\varepsilon}{\sigma_k\partial x_j})+C_{\varepsilon1}\frac{\varepsilon}{k}P_k+C_{\varepsilon2}\frac{\varepsilon^2}{k} \quad (11)$$

In the above equation, P_k is turbulence production and constants experimental values areas follow (Olsen, 2009).

$$C_\mu=0.09,\ C_{1\varepsilon}=1.43,\ C_{2\varepsilon}=1.92,\ \sigma_\varepsilon=1.3,\ \sigma_k=1 \quad (12)$$

In relation (13), c: concentration, ω deposition,: fall velocity, U: flow rate, X: the distance and Γ is the diffusion coefficient .For ground load, Van Ryan in 1987 developed an equation to equilibrium concentration of sediment in the vicinity of platform (Van Rijn, 1987).

$$c_{bed}=0.015\frac{d^{0.3}}{a}\frac{\left[\frac{\tau-\tau_c}{\tau_c}\right]^{1.5}}{\left[\frac{(\rho_s-\rho_w)g}{\rho_w v^2}\right]^{0.1}} \quad (13)$$

In the equation (14), d the diameter of sediment particles, a level in g base for roughness height, τ shear stress, c τ critical shear stress, ρ_w and ρ_s is the density of water and sediment and water and ν is the viscosity .The relationship between sediment concentrations obtained from the nearest cell is attached to the substrate. For time-dependent calculations, it is possible to use algorithm that converts sediment concentration to deposition rates. Reducing sediment particles based on critical shear stress gradient Brooks in 1963, was described by the following equation(Brooks, 1963).The coefficient K is calculated and the critical shear stress is multiplied.

$$k=-\frac{\sin\phi\sin\alpha}{\tan\theta}+\sqrt{(\frac{\sin\phi\sin\alpha}{\tan\theta})-\cos^2\phi[1-(\frac{\tan\phi}{\tan\theta})^2]} \quad (14)$$

In this regard, α is the angle between the flow direction and the vertical line matrix screen, Ø slope angle and θ are slope parameters. Van Ryan equation is used to calculate ground load (q_b)(Van Rijn, 1987).

$$\frac{q_b}{D_{50}^{1.5}\sqrt{\frac{(\rho-\rho)g}{\rho}}} = 0.053\frac{\left[\frac{t-t_c}{t_c}\right]^{1.5}}{D_{50}^{0.3}\left[\frac{(\rho-\rho)g}{\rho v^2}\right]^{0.1}} \qquad (15)$$

Substrate thickness is calculated by the equation of Van Ryan (Van Rijn, 1987).

$$\frac{\Delta}{d} = 0.11\left(\frac{D_{50}}{d}\right)^{0.3}\left(1-e^{\left[\frac{t-t_c}{2t_c}\right]}\right)\left(25-\left[\frac{t-t_c}{t_c}\right]\right) \qquad (16)$$

Effective roughness is calculated from the following equation:

$$k_s = 3D_{90} + 1.1\Delta\left(1-e^{\frac{25\Delta}{\lambda}}\right) \qquad (17)$$

In equations 17and18, d is water depth, Δ form of substrate thickness, Ks effective roughness and λ is length of ground form (Olsen, 2009).

RESULTS AND DISCUSSION

Characteristics of laboratory model

In vitro study Shahrokhi et al. (2011), long rectangular pool is (L) 2 m , width (W) 0.5 m and a length of pond water depth ratio 0.155 (H / L). Height of Input to the pool (H_{in}) is 10 cm and outlet weir height (H_W) is 30 cm. Inflow to the pool (Q) is 0.002 cubic meters per second, flow depth (H) 0.31 m, the inlet Reynolds number (Re) 3972, sediment particle density (ρ_S) is 1.049 gram per cubic centimeter diameter, half sediment particles (d) is between 75-106 mm and 106-150 mm half the duration of the experiment (t) 15 min , inlet sediment concentration (c0) is 100 mg and inflow Froude number (Fr) 0.04. Schematic view of a rectangular pool in is shown Figure 1 (Shahrokhi et al., 2011).

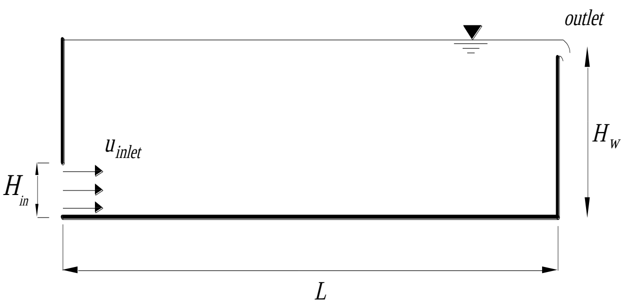


Figure 1. Geometric feature of laboratory flume

Reticulation and boundary conditions

In this study, pool inlet is 0.04 meter per second and output lines use of boundary condition. Due to small changes in water level, the symmetry boundary condition is applied to the surface of the water. The wall boundary condition for rigid boundaries is applied and walls are considered flat in terms of hydraulic. Also an important parameter in the velocity model is appropriate reticulation. In Figure 2a plan view and three-dimensional rectangular basin is shown. Number and size of cells in different areas in the directions x, y and z are given in Table 1.

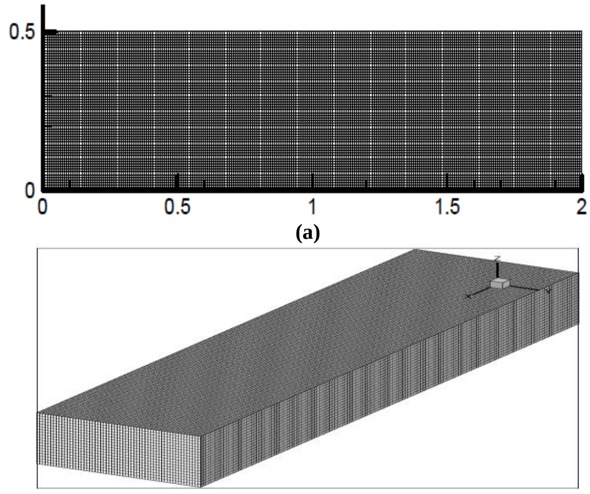


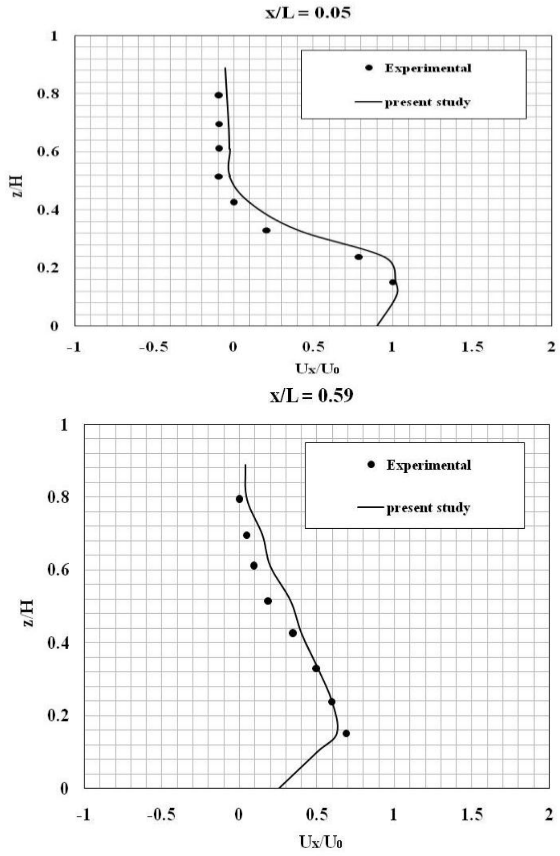
Figure 2. Reticulation range of solutions pre settling pool cases the (a) Plan (b) three-dimensional view

Table 1. Number and size of grid cells in areas of the computing field in different directions

Region	Cell dimensionsx	Cell dimensionsy	Cell dimensionsz	Cell dimensionsx (mm)	Cell (mm)dimensionsy	Cell dimension (mm)s z
Zone	250	60	19	8	8.33	16.31

Numerical simulation of the flow rate

In Figure 3, according to a laboratory study not dimensioned velocity profiles (U_x/U_0) are lack of dimension in different depths (z / H), for different times(x / L) 0.05, 0.23, 0.41, 0.59, 0.75 and 0.95 for a constant flow rateinput0.002cubic meters per second, the inflow Froude number (F_r) is shown 0.04. Respectively, x, z shows the distance along the axis x and z of pool. U_0 is the input rate whose value is equal to 0.04 m/s.



To cite this paper: Borna MR, Janfeshan Araqi H, Merufinia E, Asnaashari A. 2014. Numerical Simulations of Distribution and Sediment Transmission in Pre Settled Pools Using Finite Volume Method and Comparison with Experimental Results. *J. Civil Eng. Urban.*, 4 (2): 164-168.
Journal homepage: http://www.ojceu.ir/main/

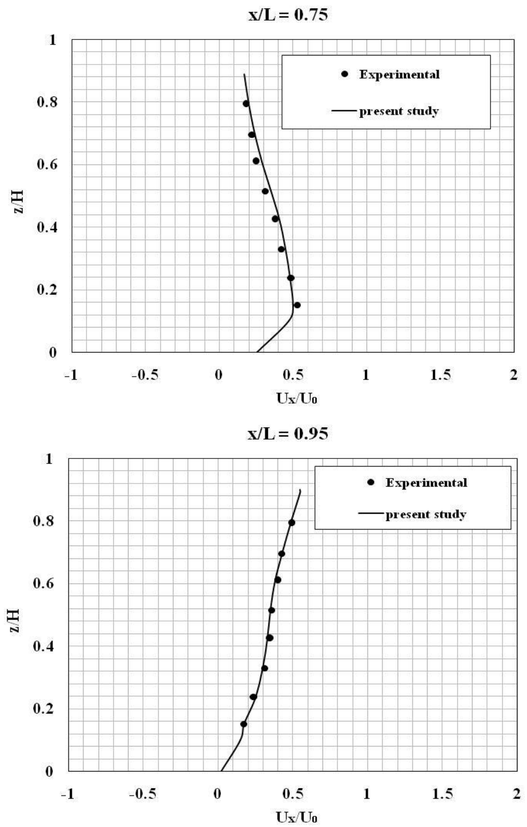
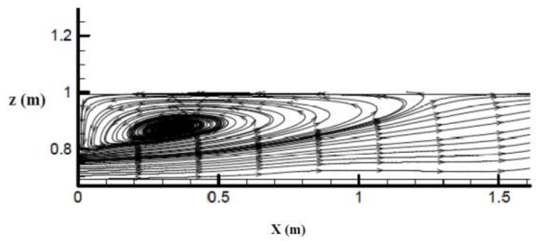
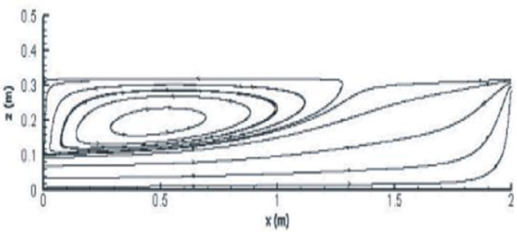


Figure 3. Comparison of numerical simulations at different speeds in different sections of pre settled pool with lab results



(a)



(b)

Figure 4. Flow lines have been drawn in pre settling pool in the present case (a) (Shahrokhi et al., 2011)

Numerical Simulation of distribute and transmit of sediment concentration at various points in pre settled pool

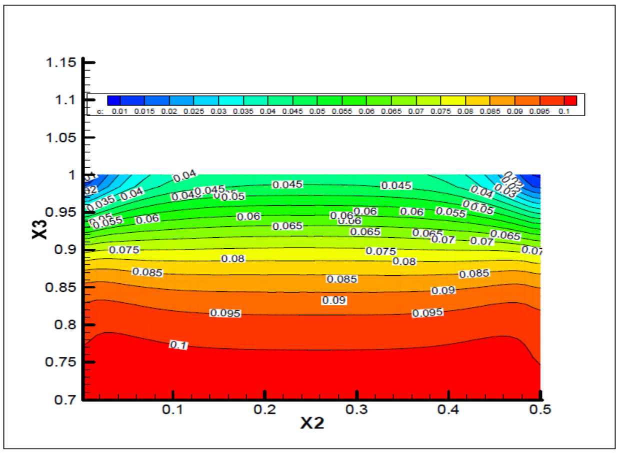
In Figure 5, according to a laboratory study, the vertical distribution of sediment concentration obtained from numerical modeling results graphically pool at different depths(z), for different times84 (x), 121, 158and 195cm from the start of deposition per discharge constant pool input 0.002 cubic meters per second, the inflow Froude number 0.04 and sediment input (c_{in}) 100mgis shown. In this Figure, the sediment concentration unit is kilograms per cubic meter. According to Figure 3, as you can see, the velocity profile at the beginning of the pool is regular and is transmitted at the end of pools t x / l = 0.05 to x / l = 0.75 . Also according to this figure, the numerical values are compared with experimental results in the context of errors , especially in areas near the pool entrance is visible The difference between the results of model calculations and experimental results may be due to differences in flow patterns in the cross entrance . In Table 2 Comparison of average percent error values obtained in the present study and laboratory values at different levels is shown.

Table 2. Comparison of mean percentage error values of velocity profiles at different sections of pool with the experimental values

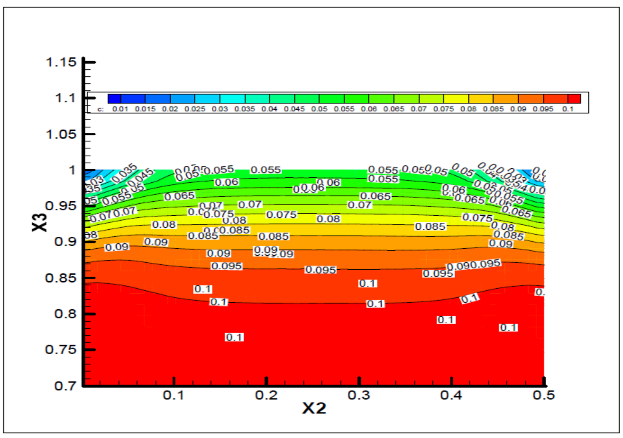
Section	x/L					
	0.05	0.23	0.41	0.59	0.75	0.95
Average of error in current study	9.58	9.12	8.18	8.03	2.92	1.25

Comparison of average percent error values of velocity profiles at different sections pool with serum obtained from Table (2) shows the numerical results with experimental results in fairly good indicator of compliance. Because the height of the lower third input is located in a pool, a large circular area above the pool entrance leads (4-a) Numerical results of flow is shown by (Shahrokhi et al., 2011).

Figure (4-b) shows the flow lines of the numerical model /District of rotation above the inlet pool created by the length and width of the present is 2.231 and 0.215 (Shahrokhi et al., 2011) were about 1.25 and 0.020 meters with a mean error equal to 1.52 and 6.97%.

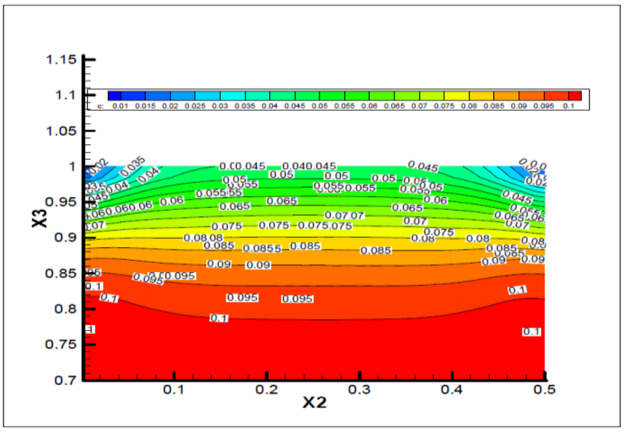


X=84 cm

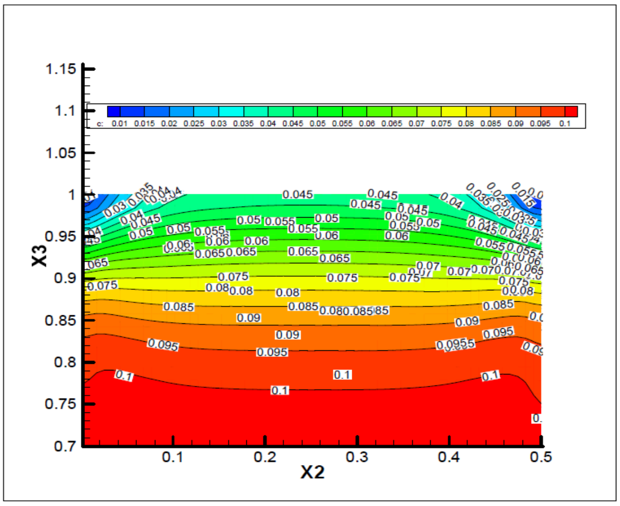


X=121 cm

To cite this paper: Borna MR, Janfeshan Araqi H, Merufinia E, Asnaashari A. 2014. Numerical Simulations of Distribution and Sediment Transmission in Pre Settled Pools Using Finite Volume Method and Comparison with Experimental Results. *J. Civil Eng. Urban.*, 4 (2): 164-168.
Journal homepage http://www.ojceu.ir/main/



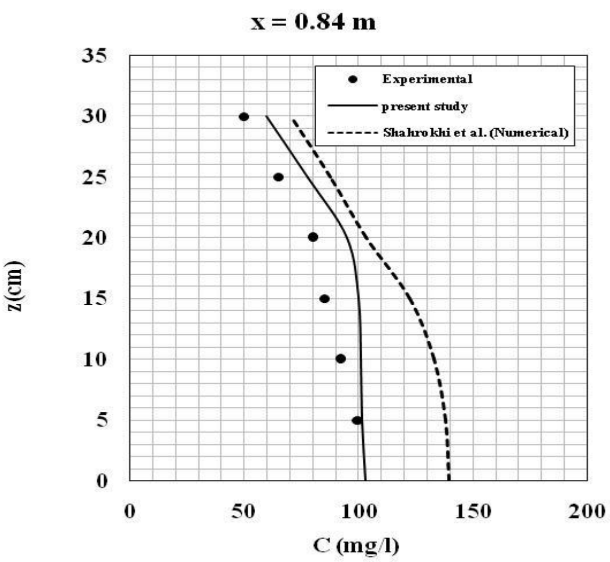
X=158 cm

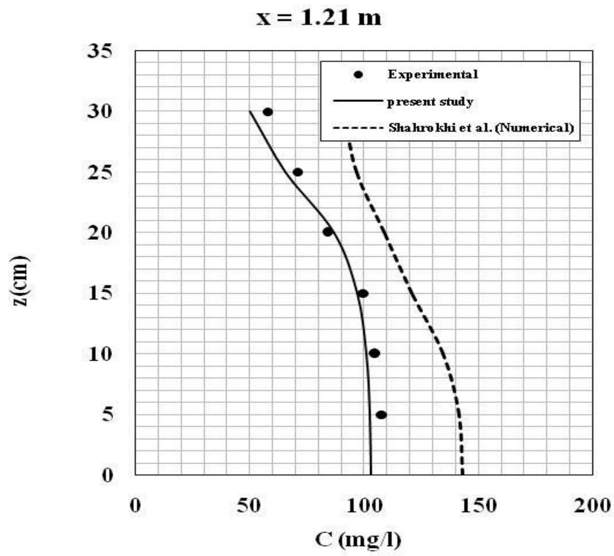


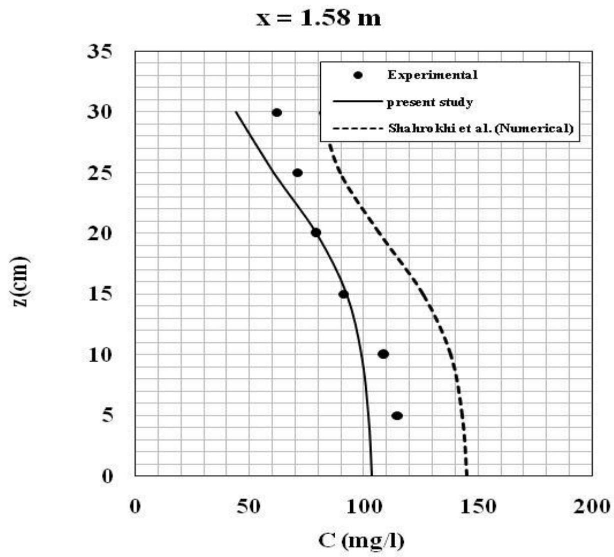
X=195 cm

Figure 5. Graphical Evaluation of the vertical distribution of sediment concentration achieved at different pools

According to the graphically results of distribution of sediment obtained from Figure 5, close to bottom of the pool concentration level of the input concentration at a distance is less than the floor. According to Figures 5 and 6 profiles of sediment concentration (constant flow per basin precipitation input 0.002 cubic meters per second and sediment input demonstrates is 100 mg/L. Results obtained from the numerical study Shahrokhi et al. (2011) is used flow 3D to investigate the distribution of sediment concentration profiles.







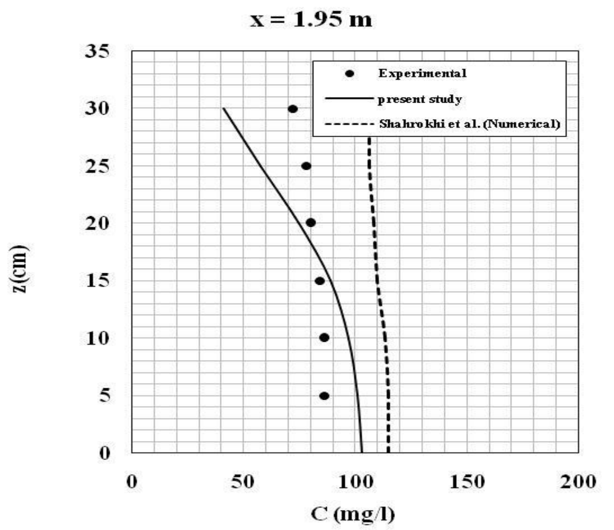


Figure 6. Distribution of sediment concentration in different points in pre settled pools

As shown in figure 6, increasing depth caused to decrease sediment concentration and near to surface, there is intensive decrease, so that in x=1.58 m, sediment concentration is 44 mg/l and portion of sediment concentration in floor is decreased to 57.48%.

Table 3 shows average percent of error obtained by study and flow 3D software and laboratory amount in different sections of pre settled pools (Shahrokhi et al., 2011).

Table 3. Percent of average of error between simulated results of sediment concentration in different section in pre settled pool and laboratory amount

Section	**(X) meter**			
	0.84	1.21	1.58	1.95
Current study	12.41	6.03	10.93	17.78
Simulation by flow 3Dsoftware (Shahrokhi et al. (2011)	26.54	24.25	22.43	25.96

In pre settled pools there is secondary and rotation flows due to different velocity gradients. This phenomenon caused to create short path, increasing residential region and changing flow which prevent of slow situation of sediment and reduce efficiency of pre settled pools. First step to optimize pre settled pools is appropriate estimation of velocity field. Physical models could not able to understand effects caused by scale due to complexity of flow. In order to understand this physic, it is required to evaluate laboratory and desert studies. In this study, numerical simulation of flow hydraulic and style of distribution and sediment transmission in a Rectangular pool have been investigated by finite volume method. Flow analysis has been done in consistency stage and SIMPLE algorithm was used to couple velocity and pressure. Discrete method of continuity equation, momentum, loss and kinetic energy and Reynolds tension are kind of standard methods. First, flow hydraulic is studied in pre settled pools, velocity profiles had been lack of dimension and different depth has been evaluated by k-ε turbulence model. Numerical amount of laboratory results have been compared and there was good corresponding. Velocity profile had regular process and x/l=0.0 to ׀x/l=0.75section, velocity have been maximized. There is some error in inlets region of pools according to numerical simulation results and this difference is due to flow pattern in input. In order to evaluate flow pattern and style of distribution and sediment transmission in pre-settled pools, distribution profile sediment concentration in different depth of pools are investigated and compared to laboratory and numerical results. Close to free level of flow, sediment concentration is decreased, so that in section of x = 1.58 m, sediment concentration is near 44 mg / l which have been decreased to 57.48 percent. Average of error among simulated amount of sediment concentration in different section shows that numerical value is corresponding to laboratory result and better results by flow 3d software and this signifies high capacity of this model to simulate sediment concentration in different section of pre-settled pools.

REFERENCES

Brooks. H.N. (1963). Discussion of Boundary Shear Stresses in Curved Trapezoidal Channels. By A.T.Ippen and P.A.Drinker, ASCE Journal of Hydraulic Engineering, Vol. 89, No. HY3.

Goula, A. M. Thodoris, M. K. Karapantsios D. Zouboulis. A. I. (2007). A CFD Methodology for the Design of Sedimentation Tanks in Potable Water Treatment, Case Study: The Influence of a Feed Flow Control Baffle. Chemical engineering journal.

Imam, E. Mc Corquodale. J.A. (1983). Numerical Modeling of Sedimentation Tanks. Proc. ASCE 109.

Jayanti.S. Narayanan. S. (2004). Computational Study of Particle-Eddy Interaction in Sedimentation Tanks. J. of environmental engineering, vol 130, ASCE. No.10.

Larsen, P. (1977). on the Hydraulics of Rectangular Settling Basins. Dept of Water Res. Engrg. Lind Institute of Technology, Lund, Sweden, No. 1001.

Liu, B. Ma, J. Huang, S. Chen D, Chen. W. (2008). Two-Dimensional Numerical Simulation of Primary Settling Tanks by Hybrid Finite Analytic Method. Journal of Environmental Engineering, Vol. 134, No. 4, ASCE.

Liu, B., J. Ma, L. Luo, Y. Bai, S. Wang and J. Zhang. (2010). Two-Dimensional LDV Measurement, Modeling and Optimal Design of Rectangular Primary Settling Tanks. J. Environmental Engineering, ASCE, 136(5): 501-507.

Lyn, D.A. Rodi. W. (1990). Turbulence Measurement in Model Settling Tank. Journal of Hydraulic Engineering, Vol. 116, No.1.

Mc.Corquodale, J. A.Moursi, A.M. El-Sebakhy. I. S. (1988). Experimental Study of Flow in Settling Tanks. Journal of Environmental Engineering, Vol. 114, No. 5, ASCE.

Naser, Gh. Karney, B. W. Salehi. A. A. (2005). Two-Dimensional Simulation Model of Sediment Removal and Flow in Rectangular Sedimentation Basin. 10.1061 /ASCE.

Olsen, N. B. R. (2009). A Three dimensional Numerical Model for Simulation of Sediment Movements in Water Intakes with Moltiblock Option. Department of Hydraulic and Environmental Engineering, the Norwegian University of Science and Technology. 177p.1

Rodi. W. (1984). Turbulence Model and Their Application in Hydraulics, a State of the Art Review. Second edition, University of Karlsruhe, west Germany.

Shahrokhi, M.Rostami, . F.Azlin,Syafalni. M.d.(2011). Numerical Modeling of the Effect of the Baffle Location on the Flow Field, Sediment Concentration and Efficiency of the Rectangular Primary Sedimentation Tanks. World Applied Sciences Journal, pp.1296-1309, ISSN 1818-4952.

Shahrokhi, M., F. Rostami and M.A.M. Said Syafalni. (2011). The Computational Modeling of Baffle Configuration in the Primary Sedimentation Tanks. 2th ICEST, pp. 392-396.

Shiba, S.ASCE, A.M . Inoue. Y. (1975). Dynamic Response of Settling Basin. ASCE, Vol.101.

Stamou. A. I. (2008). Improving the Hydraulic Efficiency of Water Process Tanks Using CFD Models. Chemical Engineering and Processing, Science Direct.

Tamayol, A. Nazari, M. Firoozabadi, B. Nabovati. A. (2004). Effects of turbulent models and baffle position on hydrodynamics of settling tanks. Int. Mech. Eng. Con, Kuwait.

Ueberl, J. Hager. W.H.(1997). Improved Design of Final Settling Tanks.Journal of environmental engineering, March., ASCE, Vol. 123, No. 3.

Van Rijn. L.C. (1987). Mathematical Modeling of Morphological Processes in the Case of Suspended Sediment Transport. Ph.D Thesis, Delft University of Technology.