THREE-DIMENSIONAL NUMERICAL STUDY OF STACKED DROP MANHOLES

By

Eng. Heba Tarek Ahmed Essawy

A Thesis Submitted to the

Faculty of Engineering at Cairo University

In Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

In

Irrigation and Hydraulics Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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DISCLAIMER

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.
I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Heba Tarek Ahmed Essawy		Date: 1/11/2018

Signature:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

(A_x, A_y, A_z): Area fraction open to flow in (x, y, and z) directions.

Diff : Diffusion

f_x, f_y, f_z: The viscous acceleration in (x, y, and z) directions.

G_x, G_y, G_z: The acceleration in (x, y, and z) directions.

i, j, k : Unit vector in x, y, and z directions.

k: Kinetic energy of turbulent fluctuation per unit mass.

l: Turbulence length scale; a characteristic of eddy size.

P: The pressure.

P_t: The turbulence kinetic energy production

t: Time.

U_i: Mean velocity in tensor notation.

U, V, W: Instantaneous velocity components in x, y, and z directions.

U', V', W': Fluctuating velocity components in x, y, and z directions.

V_f: The opened fraction volume to flow.

wsx, wsy, wsz: The wall shear stress in (x, y, and z) directions.

x_i: Position tensor in tensor notation.

x, y, z: Rectangular Cartesian coordinates.

ϵ: Dissipation per unit mass.

ω: Specific dissipation rate.

μ: The dynamic viscosity.

S_{ij}: Mean strain rate tensor.

δ_{ij}: Kronecker delta tensor.

δ_t: Time Step.

Ω_{ij}: Mean rotation tensor.

β, σ, C_ϵ: Closure Coefficient.

υ: Kinematic molecular viscosity.

υ_t: Kinematic eddy viscosity.

υ_k: Kinetic energy diffusion coefficient.

$\upsilon_\in$: $\in$ diffusion coefficient.

υ_ω: ω diffusion coefficient.

τ_{ij}: Specific Reynolds stress tensor, $-\overline{U_i' U_j'}$

λ: Taylor microscale in RNG K-e model.

ρ : The fluid density.

H_o: Inlet Hydraulic head of the experimental setup.

D: Diameter of the inlet and outlet pipes.

h: Total drop height of the experimental setup.

h_1: Height of the first chamber of the experimental setup.

h_2: Height of the second chamber of the experimental setup.

h_w: Height of the internal opening of the experimental setup.

y_o: Water depth at the inlet pipe of the experimental setup.

y_1: Water depth in the first chamber of the experimental setup.

y_w: Water depth at the internal opening of the experimental setup.

y_p: Water depth behind the water jet in the second chamber of the experimental setup.

y_2: Water depth in the second chamber of the experimental setup.

y_3: Water depth in the outlet pipe of the experimental setup.

E: Hydraulic Energy Head.

Z: Invert elevation above the datum.

V: Mean water velocity.

g: Gravity acceleration.

P: Pressure.

γ: Specific weight.

E_{in}: Hydraulic energy head at the inlet pipe.

E_{out}: Hydraulic energy head at the outlet pipe.

Q*: Dimensionless discharge parameter.

η: Energy dissipation efficiency.

H: Total drop height.

H_1: Height of first chamber.

ABSTRACT

Drop shaft manholes are usually used in steep slope urban areas in order to reduce the slope of outlet pipes when one or more of the inlet pipes have an invert elevation significantly higher than that of the outlet pipe. Usually the invert elevation of the inlet pipe is designed to be equal to the invert elevation of the manhole but in case of using drop manhole the inlet pipe invert elevation is set to be significantly higher than that of the manhole. Despite the wide usage of drop manholes structures there are no systematical studies that restrict the height of the drop manholes except for the concern of excessive aeration and corrosion in the drainage system as this may lead to poor hydraulic conditions if the manhole energy dissipation rate is inadequate. The dominant hydraulic features of the drop manholes depend on the manhole geometry, the tail water feature and the flow regimes. Depending on the flow regimes, the energy dissipation can vary within large limits, affecting thereby the downstream flow features.

This research will present a three dimensional numerical study of square stacked drop manhole (SDM). The objectives of this numerical simulation are: (I) to study the hydraulic performance of stacked drop manhole under several flow regimes with different drops combinations, (II) to conduct a comparative analysis between stacked drop manhole and single drop shaft manhole to assess the performance of both structures in terms of energy dissipation efficiency, (III) to define the criteria of choosing stacked drop manhole over single drop shaft, and (IV) to recommend the optimum stacked drop manhole geometric combinations that give the best energy dissipation efficiency.

In order to achieve the above mentioned objectives, a three dimensional numerical simulation for the stacked drop manhole structure will be carried out using a three dimensional CFD software (FLOW 3D). The model will be calibrated using available laboratory results in previously published experimental studies. Guidelines and recommendations will be developed for the design of square stacked drop manhole under different approach of flow regime.

Numerical models are constructed using the CFD- FLOW 3D program to solve the three-dimensional Reynolds-averaged Navier-Stokes equations with realizable K-epsilon turbulent model. The Numerical models are calibrated by the calculated energy losses efficiency with the efficiency results of the pervious experimental physical model done at the University of Alberta.

The results of the numerical simulations include energy head variation, velocity variation and manhole water depths. The present study finding suggests that stacked drop manhole structure is recommended for total drop height <10D where D is the diameter of the inlet pipe. Based on the flow regime, the best energy dissipation efficiency of this structure is achieved when the first chamber drop height (H_1) ranges between 60-75% of the total manhole drop height (H) (i.e. $H_1/H=0.6-075$). The optimum manhole geometry used in this study is (3DX3D), and it is recommended to add 2D free board above the inlet pipe to accommodate for the jetting splashes that occur in supercritical inflow. Exceeding these limits didn't add any significant benefits to the energy dissipation rates. The energy dissipation efficiency was calculated based on the overall energy losses inside the stacked drop manhole relative to the total drop height.