NIGERIAN INSTITUTION OF CIVIL ENGINEERS

(A division of the Nigerian Society of Engineers)

...Sus... World's Infrastructure

Proceedings of the

18th INTERNATIONAL CONFERENCE & ANNUAL GENERAL MEETING

2020

www.nicenigeria.org

Design by:
IBN Intergreted Printing
0806 578 0018, 07058143948

List of Contributors

OLUMOH SHARAFADEEN.
PRINCIPAL PARTNER, PURETECH ENGINEERING CONSULTANTS LTD, ABUJA.
osharafdn@gmail.com

Manko Ayesha and Dr. Busari A. Olumide
Department of Civil Engineering
Federal University of Technology, Minna
e-mail; ayeshamanko@yahoo.com, busari.a@futminna.com

T. N. Gbayan[*], T.W.E. Adejumo[1] and A. A. Amadi[2]
Department of Civil Engineering, Federal University of Technology, Minna.
Niger State, Nigeria.
Corresponding author email: tess[illegible].com +2437039681035; *1*-
adejumo.taiye@futminna.edu.ng +2349033795541; *2*-
agapitus.amadi@futminna.edu.ng +2348034516603

Engr. Tasiu Yusuf Idi, *PhD*
Federal College of Education, Yola
Email: Tasiu.idi@fceyola.edu.ng

R. M. Ibrahim[*], T.W.E. Adejumo and M. Alhassan
Department of Civil Engineering, Federal University of Technology, Minna. Niger State, Nig
* Corresponding author email: rahmatisah662@gmail.com +2438051239127; *1*-
adejumo.taiye@futminna.edu.ng +2349033795541; *2*- alhassankuta@futminna.edu.ng
+2347039061199

Ubi, S. E.[1*], Okafor, F. O.[2], Mama, B. O.[2], Adah, E. I.[3], Egbe J. G.[3]
[1]*Department of Civil Engineering, Faculty of Engineering, Cross River University of Technolo Calabar, Nigeria*
[2]*Dept. of Civil Engineering, Faculty of Engineering, University of Nigeria, Nsukka*
[3]*Dept. of Civil & Environmental Engineering, Faculty of Engineering, University of Calabar*
[*]Corresponding Author
E-mail: emmaubi2015@yahoo.com

***E.W. Gadzama[1], K. J. Osinubi[2], A. O. Eberemu[2], and T. S. Ijimdiya.[2]**
[1]Department of Civil Engineering, Modibbo Adama University of Technology, Yola, Nigeria
[2]Department of Civil Engineering, Ahmadu Bello University, Zaria, Nigeria
*Corresponding author email: gadzymo@yahoo.com +2348054358847

TABLE OF CONTENT CONTD.

TABLE OF CONTENT

List of Contributors Contd.

*U. T. Igba[1], A. A Adekunle[1], O. S Abiola[1], S. O. Oyebisi[2], M. O Osaghale[1]
[1] Department of Civil Engineering, Federal University of Agriculture Abeokuta, Ogun State, Nigeria
[2] Department of Civil Engineering, Covenant University, Ota, Ogun State, Nigeria.
*Corresponding Author Email: igbaut@funaab.edu.ng

*U. T. Igba[1], J.O Akinyele[1], S. O. Oyebisi[2], I. Amadi[3]
[1] Department of Civil Engineering, Federal University of Agriculture Abeokuta, Ogun State, Nigeria.
[2] Department of Civil Engineering, Covenant University, Ota, Ogun State, Nigeria.
[3] Department of Civil Engineering, River State University of Science and Technology, Rivers State, Nigeria.
*Corresponding Author Email: igbaut@funaab.edu.ng

Mohammed Suleiman*, Musa Alhassan and Mustapha Mohammed Alhaji
Civil Engineering Department, Federal University of Technology, Minna, Nigeria
*Corresponding author: mohdsuleiman2016@gmail.com

SONY EMEKA ALI
International Centre for Environmental Sustainability Email: sonyali2010@ymail.com,
sonyali.ices@gmail.com

Amina Ebimari Saidu*, Musa Alhassan and Mustapha Mohammed Alhaji
Civil Engineering Department, Federal University of Technology, Minna, Nigeria
*Corresponding Author, engramina55@gmail.com

Engr. Aliyu Ibrahim, FNICE
Corresponding email: aliyubineez12@yahoo.com

Shuaibu Suleiman*, Mustapha Mohammed Alhaji and Musa Alhassan
Civil Engineering Department, Federal University of Technology, Minna
Corresponding Author Email: suleimans608@gmail.com

Begmyrat Kulmedov and Abdulhameed Danjuma Mambo
Department of Civil Engineering, Nile University of Nigeria, Abuja

PAPER NUMBER 02

Estimation of Vegetative Hydraulic Resistance in an Open Channel Flow

Manko Ayesha and Dr. Busari A. Olumide
Department of Civil Engineering
Federal University of Technology, Minna
e-mail; ayeshamanko@yahoo.com
busari.a@futminna.com

ABSTRACT: The Hydraulics of flow in an open channel/waterway with flexible vegetation is studied. Vegetation along waterway has an ecological advantage; it enhances biodiversity, reduces erosion, and traps sediment. However, it has a hydraulic impact on flow. This study reviews hydrodynamics of vegetation along waterways (a concept to promote a sustainable green environment). It applies a modified one-dimensional (1-D) hydraulic model to repljcate the vegetative velocity profile and Reynolds stresses using several laboratories experimental and field dataset found in the literature as well as laboratory investigation from the authors. Using this concept, a synthetic velocity profile is generated under varying hydraulic conditions. Using the concept of dimensional similarity, the vegetative parameters and flow resistance equation which relates these vegetation parameters, flow depth, and the zero-displacement parameter is proposed. The findings gave clear and comprehensive deduction, that mathematical model could replace the rigorous experiments, as evaluations were parallel to the estimated laboratory values.

Keywords: Hydraulic Resistance; Mathematical Model; Vegetation parameters; Velocity profile; Hydrodynamics.

1.0. Introduction

The effect of Natural occurrences in waterways especially Vegetation is adequately beneficial to their Environmental use. The presence of vegetation significantly has an impact on flow conditions, while increasing flow resistance by (highly reducing erosion and stabilizing the earth through the plant root system), thereby improving the general purity of water.

Turbulent flows in such channels with submerged vegetation have their structures depending on the nature of vegetation, its density, and how it is arranged. An assessment of latest experimental studies presents three various research structures, thus (Defina & Bixio, 2005): flume experiments performed with natural vegetation (Meijer & Van Velzen, 1999; Nepf & Koch, 1999; Järvelä, 2002; Stephan & Gutknecht, 2002); flume experiments performed with simple elements such as strips or cylinders (Pasche, 1984; Tsujimoto & Kitamura, 1990; Shimizu & Tsujimoto, 1994; Nepf, 1999; Nepf & Vivoni, 2000; Ghisalberti & Nepf, 2004; Baptist, 2005); and field measurements (Ackerman & Okubo, 1993; Leonard & Luther, 1995; Koch & Gust, 1999; Leonard & Reed, 2002; Sukhodolov A. & Sukhodolov T., 2006), [Elzbeita Kubrak, et al, August 2008]. The hydrodynamic conditions of afore listed observations prevent any form of generalization of findings made, this is a result of the significant difference in the types of vegetation considered for each case.

With the recent intensity of discussions on flooding as a result of climate chang common acceptance that Vegetation is a cause of hindrance to flow or a cause of resistance is in high contrast to the findings by research and studies. This has f influenced the possibility that vegetation along a flow path or path line does not only environmental benefits but might also be a means of regulating excesses as a res certain flow conditions.

The Mathematical Model shall further elaborate on the significance of the need for results and shreds of evidence to reinforce this theory.

The 3-D models can give relatively accurate results, but these models are complex large computation quantities. So, simpler, valid mathematical models are needed. An method is to derive the momentum equations regarding the flow with vegetation Dimension. By adopting the mixing length expression, the model can give the ver distributions of the stream-wise velocity and the Reynolds stress, though these mo always involve some unknown parameters which are difficult to estimate.

The objectives of this research are but not limited to, understanding the basic hydra parameters of vegetated flow, develop a mathematical model for vegetated flow pa simulate mean velocity profile for various hydraulic conditions, and to also point out significance of lining/vegetation in floe channels.

1.0. Research materials and methods

To attain significant outcomes, one or two major procedures/stages are likely to be take for a high degree of accuracy. The approach that was used in achieving this research resul and documentation are stated explicitly.

This study is expected to be conducted through the following stages,

1 Theory of Vegetated flow path
2 Derive the analytic relationship between velocity, flow, and vegetation parameters
3 Application of numerical methods to the equations that relate these parameters
4 Obtain a velocity profile and Model.

1.1. **Theory of vegetated flow path:** In most cases, a flow path is subjected to the growth of lining/vegetation in its route as a result natural habitats and the ecosystem in the flow path are enhanced.

1.2. **Experimental set-up**: The tests was conducted in a circulated flume, situated at the Laboratory the flume is 20 m long with a width of 0.5 m and 0.5 m high. The bed slope of the flume is observed to be 0.0004. To ensure a steady flow state, a trunk for stabilizing the flow was mounted at the top of the flume. To manage the flow rate, an electric valve was used. A tailgate was mounted at the terminal of the flume, to regulate the depth of water

This has given rise to the focus on mathematical models by researchers, to bring out flow-vegetation relationship and velocity fields, as an alternative to experimen investigations. Some of the methods applied in developing these models as propose research vary between simplified one-dimensional (1-D) models 2-D, or even the hi complex 3-D models of the original flow conditions and turbulence phenomena a from vegetative cover in a flow path. The main aims of the present study are to devel simple, useful mathematical model for the prediction of vertical distributions of m velocity in vegetated channels. Therefore, only 1-D models have been considered, su those by Burke & Stolzenbach (1983), Shimizu & Tsujimoto (1994), Klopstra et al. (19 Nepf & Vivoni (2000), Lopez & Garcia (2001), Erduran & Kutia (2003), Ghisalberti & Ne (2004), Khublaryan et al. (2004), Baptist (2005) and Defina & Bixio (2005).

A review of models dealing with 1-D flows through flexible vegetation reveals a fe different approaches to calculating velocity profiles of such path (Elizbeita Kubrak, et 2008). They all pertain to the construction and solution of momentum conservat equations. The most popular is a two-layer approach, in which the flow within t vegetation layer is treated separately from that in the upper layer (Klopstra et al., 19 Meijer & VanVelzen, 1999; Righetti & Armanini, 2002; Ghisalberti & Nepf, 2004). One m also note the use of the modified turbulence k - model, in which the drag due to vegetati is taken into account not only in the momentum but also in the equations for kinetic ene k and dissipation rate (Burke & Stolzenbach, 1983; Shimizu & Tsujimoto, 1994, Lope Garcia, 2001).

An interesting study was presented recently by Hsieh & Shiu (2006), who modeled the fl by applying the theory of turbulent flow and biot's theory of poroelasticity after divid the flow field into three layers: homogenous water, vegetation, and pervious soil. Th present study is, in principle, an extension of the investigations presented by the autho concerning stiff, emergent vegetation (Rowinski Kubrak, 2002a,b) and it introduc modifications allowing the modeling of flow-through and above flexible vegetation. Th applied model was verified based on the data obtained by the authors in a laboratory flu containing rod-like vegetation without foliage.

1.1. Mathematical Model; in simple terms, a Mathematical Model is a descriptio of a system using mathematical concepts and language. The process o developing a mathematical model is termed mathematical modeling.

1.2. Numerical Methods; are techniques by which mathematic simulations/models are formulated to obtain their solutions using arithme operations. They usually comprise of a large number of tedious calculatio Numerical solutions are often approximate values which may be the ex solutions, thus, are generally acceptable and valid. They can be determin either experimentally or analytically, the analytical method is applied in the co of this study as experimental methods have become more cumbersome and le economical, whose results are easily prone to error due to environmen conditions and human factors. A simple principle of th discretization, which is dependent on time and space of flow considered which gives an approximate result. It is also important to note, that the smaller the time interval, the more accurate the approximate result obtained.

In Hydraulics and the likes, we have what is referred to as Computational Fluid Dynamics, which is the use of computer-aided design to determine, suggest, and analyze fluid flow. It is the study of complex fluid flow, by solving the equations of flow velocity and motion, known a Navier-Stokes equations (also referred to as Momentum equation, is used for the complete set of equations solved by computation fluid dynamics, which also includes the energy and continuity equations.), in a certain geometry and physical environment. Such flow environments could be considered waters channels with free surfaces, porous packed beds, or porous concrete/metallic structures.

Application of Computation Fluid Dynamics is of high significance as compared to physical experiment, due to its operation within the evolving computer-aided design/ Information Technology structure in conjunction with drawing and manufacturing tools, making it more accessible than experimental methods.

For a Vegetated Region, there are four major zones apparent in its Model.

1. Clear-view Zone
2. Top Vegetated Zone
3. Transition Zone and Finally
4. The Viscous Zone. These shall all be considered in the cause of this Research.

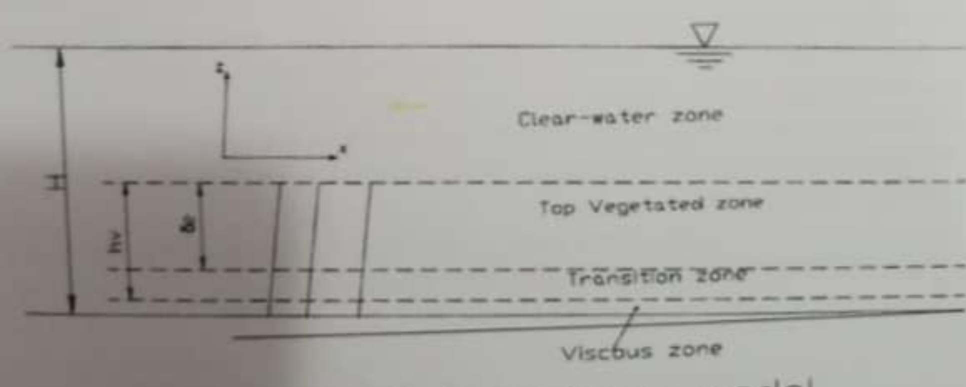

Fig.1 Sketch of Four-layer model

For a highly flexible blade or under high discharge, the vegetation along the river channel can be submerged partially or completely depending on the flow magnitude. The flow can be analyzed as a uni-directional fully developed uniform turbulent flow (Figure 1).

With the recent intensity of discussions on flooding as a result of c common acceptance that Vegetation is a cause of hindrance to flow resistance is in high contrast to the findings by research and studie influenced the possibility that vegetation along a flow path or path line environmental benefits but might also be a means of regulating exce certain flow conditions.

The Mathematical Model shall further elaborate on the significance of t results and shreds of evidence to reinforce this theory.

The 3-D models can give relatively accurate results, but these models a large computation quantities. So, simpler, valid mathematical models are method is to derive the momentum equations regarding the flow with v Dimension. By adopting the mixing length expression, the model can distributions of the stream-wise velocity and the Reynolds stress, thoug always involve some unknown parameters which are difficult to estimate.

The objectives of this research are but not limited to, understanding the parameters of vegetated flow, develop a mathematical model for vegeta simulate mean velocity profile for various hydraulic conditions, and to als significance of lining/vegetation in floe channels.

1.0. Research materials and methods

To attain significant outcomes, one or two major procedures/stages are likel for a high degree of accuracy. The approach that was used in achieving this re and documentation are stated explicitly.

This study is expected to be conducted through the following stages,

1 Theory of Vegetated flow path
2 Derive the analytic relationship between velocity, flow, and vegetation p
3 Application of numerical methods to the equations that relate these par
4 Obtain a velocity profile and Model.

1.1. Theory of vegetated flow path:

Theory of vegetated flow path: In most cases, a flow path is subj growth of lining/vegetation in its route as a result natural habita ecosystem in the flow path are enhanced.

1.2. Experimental set-up:

Experimental set-up: The tests was conducted in a circulated flum at the Laboratory the flume is 20 m long with a width of 0.5 m and 0.5 m bed slope of the flume is observed to be 0.0004. To ensure a steady flo trunk for stabilizing the flow was mounted at the top of flow rate, an electric valve was used the flume, to regulate

At the flume's bed, a mobile plate with metal rods was employed, as the rods are applied to simulate any rigid vegetation, having diameter D = 0.006m, with height h_v = 0.19m. The rods were placed in parallel on four plastic flats, each of which was 0.1mm thick, 2.0m long, and 0.5m wide, and the relative interval between the two adjacent rods is $a_x = a_y = 0.1m$ as in Figure. 2. In the experiments, the submerged readings was tabulated.
After the experiment, the mean velocity and its instabilities as measured by 3-D Micro Acoustic Doppler Velocimetry (Micro ADV). The sampling frequency was taken as 50 Hz and the time of testing was the 30s, so one measurement could collect 1500 samples. Past research had indicated that more than 700 samples data could obtain a constant velocity and guarantee the accuracy of the measurement. We selected two typical locations for the measurements. One (Point B) situated behind the blade and the other (Point A) was on the centre-line between two blades.

For a highly flexible blade or under high discharge, the vegetation along the river channel can be submerged partially or completely depending on the flow magnitude. The flow can be analyzed as a uni-directional fully developed uniform turbulent flow (Figure 1). By considering a control volume in vegetated flow, an equation based on the balance of active forces can be derived as follows:

$$\frac{\partial \tau}{\partial z} + \rho g S_o - F_d = 0 \qquad (1)$$

As the stress τ is made up of the Reynold's stress τ_{xz} and the viscous stress τ', the density of water ρ, the bottom slope i, which serves as an alternative to energy slope due to the uniform nature of the flow, and f_{cd} is termed drag as a result of vegetation which is obtained using:

$$f_{cd} = \frac{1}{2}\rho N C_D b_v u^2$$

Where N governed by

$N = \frac{1}{S_x S_y}$ S_x, S_y, in the vegetation spacing in the x-y directions,

b_v = blade width (m)
N = No. of vegetation
u = mean flow velocity
C_D = the drag coefficient of the stem stated by Schlichting.

For this study, 1.0 was considered to be C_D value. To adequately solve the equation (1) in the drag zones, we are required to proportion the entire flow area into just two zones of external and vegetated zones, as in Figure (1), since there is no case of drag in any zone above the vegetation. The Reynolds stress at the subordinate part of the vegetated zone is so little and significantly negligible, considering the outcome of the experiments hence, we may further partition the vegetated zone into to further make a total of four zones namely:

a) *Clear-water zone*, where $h_d \leq z \leq H$, as h_v is deflected height of the vegetation with the depth of water as H. Here, drag due to vegetation is not seen and the shear stress due to viscosity is too small to be considered, there the gravity and the turbulent shear stress balance:

$$\frac{\partial \tau_{xz}}{\partial z} + \rho g i = 0 \qquad (2)$$

b) Top vegetated zone, the zone governed by $h_v - \delta_e < z \leq h_d$ with δ_e signifying the extent of penetration or downward reach, Figure 1, representing the effect of instability close to the upper part of the vegetation. In this zone, there is consideration of drag force, as such, the gravity, Reynolds stress, and the drag are balanced, as illustrated in the proceeding equation:

$$\frac{\partial \tau_{xz}}{\partial z} + \rho g i - \frac{1}{2}\rho N C_D b_v u^2 = 0 \qquad (3)$$

c) The transition zone, it states here that $\delta_0 < z \leq h_v - \delta_e$, where δ_0 is the thickness of the zone of viscosity. This zone shows that the whirlpool prompted by the stems is little, hence the Reynolds stress can be ignored as well the viscous stress since the zone is a bit far from the bed:

$$\rho g i - \frac{1}{2}\rho N C_D b_v u^2 = 0 \qquad (4)$$

d) *Viscous zone*, in this zone, here $0 < z \leq \delta_0$ and is ruled by the viscous stress.

$$\frac{\partial \tau'}{\partial z}\rho g i - \frac{1}{2}\rho N C_D b_v u^2 = 0 \qquad (5)$$

The viscous stress here is determined by the Newton internal friction law, stated as

$$\tau' = \mu\frac{\partial u}{\partial z} \qquad (6)$$

3.0. Theoretical Analysis

3.1. Entire Flow Analysis

3.1.1. Mix Length

The study applies Prandtl's mixing length theory to calculate Reynold's stress as shown in Equations. (4), (5):

$$\tau_{xz} = \rho l^2 \left|\frac{\partial u}{\partial z}\right| \frac{\partial u}{\partial z} \qquad (7)$$

With *l* representing the mixing length, from the Karman similarity theory I *Nazarenko S, (2000)* it is known that the mixing length can be determined by the actual velocity distribution, that is,

$$l = k \frac{\left|\frac{\partial u}{\partial z}\right|}{\frac{\partial^2 u}{\partial z^2}} \quad (8)$$

Where k is the Karman constant, K = 0.41. Therefore, based on the velocity distribution, we can qualitatively analyze the mixing length in the clear water zone and the top vegetated zone. While we have no past knowledge of the theoretical expression of velocity, this article uses the polynomial fitting method to understand the variation trend of velocity. According to Equation (10) and the polynomial (Figure.3), we obtain the variation of mixing length with water depth (see Fig.4). Figure 4 shows that the mixing length in the vegetated zone is approximately a constant, and in the clear-water zone is proportional to the water depth. Huai[*Huai Wen Xin et al, 2009*] pointed out that the flow in the entire area can be regarded as the compressed flow on the new riverbed which is made up of vegetation, and presented a river compression coefficient to express the compression. With the results in Fig.4 and the conception of the compressed channel, we give the mixing length as:

$$l = \eta kz,\ h_v < z \leq H \quad (9a)$$

$$l = l_0,\ h_v - \delta_e \leq z \leq h_v \quad (9b)$$

Where η is the compression coefficient of the watercourse, which is = $(H - hv)/H$, l_0 is the constant determined by the continuity of mixing length at $z = hv$, hence $l_0 = \eta khv$, δ_e is the thickness of the clear water zone, *hv* is the height of the blade.

3.1.2. The thickness of each zone

It has been stated that the array of the Clearwater zone varies from *hv* to *H*, while that of the proceeding zones has not been specified yet. This is because the viscous zone is constantly thin, hence we adopt that its thickness δ_v = 0.005m. Making the distance of blade penetration, δ_e , the only problem left, which gives the boundary between the top vegetated zone and the transition zone.

The top vegetated zone is also known as the vegetation shear layer, [*Finnigan J., 2000*] suggested that numerous continuous vortices, induced by the K-H instability in the flow field, control the exchange of momentum and have a significant effect on the turbulence features, the vortices in the clear water zone grow repeatedly downstream, while that in the vegetated zone only enter through a fixed depth (δ_e in Fig.1) from the top of vegetation. The distance of the entrance δ_e splits the vegetation zone into the top layer having heavy turbulence and the lower layer with fragile turbulence [*Winant C. and Brown F.*, 1974 with *Nepf H. M. & Vivoni E. R, 2000*], which are respectively named as the top vegetated zone, the transition zone. [Nepf H. M, 2004] gave a calculated result for δ_e in vegetation by experimental study,

$$\frac{\delta_e}{h_v} = \frac{0.23 \pm 0.06}{C_D a h_v} \quad (10)$$

Where $a = b_v N$. Conferring to the data gotten from the experiment, δ_e is obtained

$$\delta_e = \frac{0.17}{\left(1.0 \times \frac{0.006}{0.05 \times 0.1}\right)} = 0.142\text{m}$$

Hence, the zone of transition thickness is, $h_v - \delta_e - \delta_0$

3.1.3. *Velocity*

For the *Clearwater zone*, we combine equations (9), (11) and then write the governing equation (4) as

$$\frac{\partial}{\partial z}\left(z\frac{\partial u}{\partial z}\right)^2 + \frac{gi}{(\eta k)^2} = 0 \quad (11)$$

The effects of surface tension and wind at z = H is negligible, so one boundary condition is fixed in the calculation as

$$\left(\frac{\partial u}{\partial z}\right)_{z=H} = 0 \quad (12)$$

Applying the boundary condition (14) to equation (13), we find the analytical solution to the stream-wise velocity in the clear water zone:

$$u = 2\sqrt{\frac{gi}{(\eta k)^2}}H\left\{\cos\left(\arcsin\sqrt{\frac{z}{H}}\right) + \ln\left[\tan\left(\frac{\arcsin\frac{z}{H}}{2}\right)\right]\right\} + C \quad (13)$$

C stands for the integral constant that is equal to the velocity at the boundary of the water surface.

For the *Top Vegetated zone*, we put together equations (9) and (11) and rewrite the governing equation (5) as,

$$\frac{\partial}{\partial z}\left(\frac{\partial u}{\partial z}\right)^2 + \frac{gi}{l_0{}^2} - \frac{C_D N b_v u^2}{2l_0{}^2} = 0 \quad (14)$$

It is challenging to obtain an analytical solution of Equation (16), so the finite difference methods are adopted for this purpose,

$$2\frac{u_i - u_{i-1}}{\Delta z}\,\frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta_z{}^2} + \frac{gi}{l_0{}^2} - \frac{C_D N b_v u^2}{2l_0{}^2} = 0 \quad (15)$$

Where Δz is the spatial step and here $\Delta z = 0.0001$m, u_1 is the instantaneous velocity at the *i*th node, the boundary condition of the variation in the pattern, (17) is the velocity at $z = h_v - \delta_e$, which can be determined from equation (6) as shown below:

$$u_z = h_v - \delta_e, = u = \sqrt{\frac{2gi}{C_D N b_v}} \quad (15)$$

The velocity in the transition zone is said to be constant, according to equation (6), which is also obtainable by equation (18).

In the case of the *viscous zone*, the governing equation (7) can be interpreted into the finite difference scheme as,

$$\tau' = \mu \frac{u_{i+1} - 2u_i + u_{i-1}}{\Delta_z^2} + \rho g i - \frac{1}{2}\rho C_D N b_v u_i^2 = 0 \quad (16)$$

Also, the scheme needs two different boundary conditions z = 0 and at z = δ_e respectively:

$$u_{z=0} = 0 \quad (17)$$

$$u_{z=\delta_0} = \sqrt{\frac{2gi}{C_D N b_v}} \quad (18)$$

4.0. Results and discussion

The output of this model as illustrated in a test analysis is shown below.

Table1.0. Available Dataset from Laboratory Using El = 4.65x10^{-5}, Frk = 75 and Fv = 11.3

Run	Bv (m)	N (m -²)	Hv (m)	Cd	h (m)	u (m/s)	gSo	h/Hv	Umean
1.	0.005	5000	0.1	3	0.151	0.03	0.0051	1.51	3.41
2.	0.005	5000	0.1	3	0.253	0.11	0.0100	2.53	6.91
3.	0.005	5000	0.085	3	0.382	0.367	0.0300	4.49	10.850.
4.	0.005	5000	0.1	3	0.152	0.098	0.0500	1.52	3.55
5.	0.005	5000	0.1	3	0.151	0.143	0.1001	1.51	3.68
6.	0.005	5000	0.05	3	0.242	0.560	0.0939	4.84	11.64
7.	0.005	5000	0.1	3	0.350	0.205	0.0100	3.5	10.93

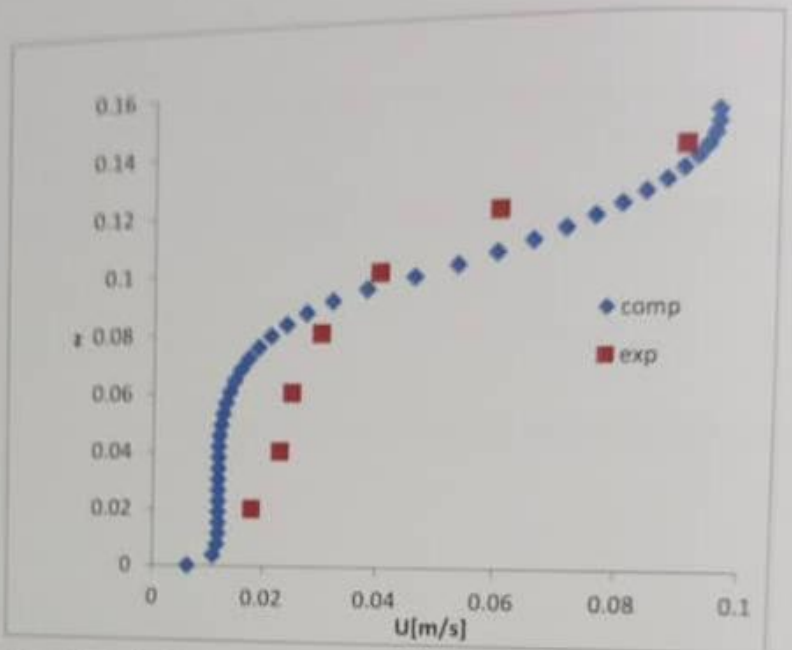

Figure 2; Graph of output for first-run Zo = 0.0869 and Zo/Hv = 0.8694

The mean Velocity obtained from the model as compared to the experimental data by Koumer...
shows reasonable agreement in flexible vegetation profile and hence justifies the use of computa...
dynamics in place of the experimental procedure. Although this research is still ...
estimated/computed outcome (mean velocity) will be expected to eventually conform to the ...
values from previous works.

5.0. Conclusion

By and large, this research outlines the numerical analyses of the flow through an aquatic canopy ...
channel. A prior Laboratory analysis shows that, where there are vegetation or the likes in a path, ...
conditions depend on the bed slope, bed roughness, flow depth, as well as the density, length, diam...
modulus of elasticity of the stems. The effect of the pattern of the stem layout was not considered ...
and should be of some concern in future investigations. The assumption of linear dependence betw...
mixing length and the distance from the bed is acceptable it only requires the introduction of two ...
proportionality factors in the vegetated zones. Vertical velocity profiles were calculated by employing ...
explicit finite difference scheme. The numerical model was computationally inexpensive and provide...
reasonably accurate estimates of the deflection and velocity profiles of the flexible stems. The analys...
calculations and the experimental results show that the predicted mixing length in the layer with flexible ...
is a linear function of the depth of water, the density of elements, bottom slope, and roughness height ...
the layer above the flexible stems, the predicted mixing length is independent of the bottom slope. ...
agreement between the calculated velocities and their measured values is acceptable within both lay...
Vegetation is observed to cause the problem of flood control in a channel, which has further reinforced ...
lapses of vegetative cover in a flow channel.

6.0. REFERENCES

[1] KOUWEN N., UNNY T. E. Flexible roughness in open channels [J]. Journal of Hydraulics Division, 1973, 99 (5): 713-728.

[2] NAOT D., NEZU I. and NAKAGAWA H, Hydrodynamic behavior of partly vegetated open channels [J]. Journal of Hydraulic Engineering, ASCE, 1996, 122(11): 625-633.

[3] LOPEZ F., GARCIA M. H. Mean flow and turbulence structure of open-channel flow through non-emergent vegetation [J]. Journal of Hydraulic Engineering, 2001, 127(5): 392-402.

[4] STOESSER T., LIANG C. and RODI W. et al. Large eddy simulation of fully-developed turbulent flow through submerged vegetation[C], International Conference on Fluvial Hydraulics, SEP06-08. Lisbon, Portugal, 2006, 1: 227-234.

[5] SU Xiao-hui, LI C. W. and CHEN Bi-hong, Three- dimensional large eddy simulation of free surface turbulent flow in open channel within submerged vegetation domain [J]. Journal of Hydrodynamics, Ser. B, 2003, 15(3): 35-43.

[6] HUANG Ben-sheng, LAI Guan-wen and QIU Jing et al. Hydraulics of compound channel with vegetated flood-plains [J], Journal of Hydrodynamics, Ser. A, 2002, 14(1): 23-28(in Chinese).

[7] HUAI W. X., ZENG Y. H. and XU Z. G. Three-layer model for vertical velocity distribution in open channel flow with submerged rigid vegetation [J]. Advances in Water Resources, 2009, 32(4): 487-492.

[8] WANG Chao, YU Ji-yu and WANG Pei-fang et al. Flow structure of partly vegetated open-channel flows with eelagrass[J]. Journal of Hydrodynamics, 2009, 21(3): 301-307.

[9] KUBRAK E., KUBRAK J. and ROWIėSKI P. M. Vertical velocity distributions through and above submerged, flexible vegetation [J]. Hydrological Sciences Journal, 2008, 53(4): 905-920.

[10] HSIEH Ping-Cheng, SHIU Yu-sheng. Analytical solutions for water flow passing over a vegetal area [J]. Advances in Water Resources, 2006, 29(9): 1257-1266.

[11] GHISALBERTI M., NEPF H. M. The limited growth of vegetated shear layers [J]. Water Resources Research, 2004, 40(7): 1-12.

[12] NEPF H., GHISALBERTI M. Flow and transport in channels with submerged vegetation [J]. Acta Geophysica, 2008, 56(3): 753-777.

[13] NEPF H. M. Drag, turbulence and diffusion in flow through emergent vegetation [J]. Water Resources Research, 1999, 35(2): 479-489.

[14] ROWIėSKI P. M., KUBRAK J. A mixing-length model for predicting vertical velocity distribution in flows through emergent vegetation [J], Hydrological Sciences Journal, 2002, 47(6): 893-904.

[15] WU Fu-sheng. Characteristics of flow resistance in open channels with non-submerged rigid vegetation [J], Journal of Hydrodynamics, 2008, 20(2): 239-245.

[16] SCHLICHTING H., KESTIN J. Boundary layer theory [M]. 7th Edition, New York: McGraw-Hill, 1979.

[17] VELASCO D., BATEMAN A. and MEDINA V... A new integrated, hydro-mechanical model applied to flexible vegetation in riverbeds [J]. Journal of Hydraulic Research, 2008, 46(5): 579-597.

[18] CAROLLO F. G., FERRO V. and TERMINI D. Flow velocity measurements in vegetated channels [J]. Journal of Hydraulic Engineering, 2002, 128(7): 664-673.

[19] NAZARENKO S. Exact solutions for near-wall turbulence theory [J]. Physics Letters A, 2000, 264: 444-448.

[20] HUAI Wen-xin, HAN Jie and ZENG Yu-hong et al. velocity distribution of flow with submerged flexible vegetation based on mixing-length approach [J]. Applied Mathematics and Mechanics (English Edition), 2009, 30(3): 343-351.

[21] FINNIGAN J. Turbulence in plant canopies [J]. Annual Review of Fluid Mechanics, 2000, 32(1): 519-571.

[22] WINANT C., BROWAND F. Vortex pairing: The mechanism of turbulent mixing-layer growth, at moderate Reynolds number [J]. Journal of Fluid Mechanics, 1974, 63(2): 237-255.

[23] NEPF H. M., VIVONI E. R. Flow structure in depth- limited, vegetated flow [J]. Journal of Geophysical Research, 2000, 105(C12): 28547-28557.

NEZU I., RODI W. Open-channel flow measurements with a laser Doppler anemometer [J]