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RESEARCH ARTICLE

MODELLING OF DEPOSITION AND EROSION PROCESSES ALONG A 180° OPEN CANAL BEND BY NAYS2DH IN IRIC

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ARTICLE DETAILS

ABSTRACT

Article History:

Received 03 August 2019 Accepted 10 September 2019 Available online 04 October 2019 This paper presents experiments and computer simulation for the erosion and deposition processes along a 180° open canal bend. The computer simulation is conducted by Nays2DH model in iRIC software. The models are conducted with the curvature's radius ratio (\emptyset /L) varies within 3.0 to 8.5. Experiments produced that the erosion and deposition actions decrease as \emptyset /L increases. The minimal erosion and deposition are detected at (\emptyset /L =8.5). The optimum place of a bridge circular support along the bend is defined. The results of Nays2DH Model are compared with tests. RSQ for the modelled statuses is 88.329% and the correlation factor between simulations and the gauged depths is 93.98%.

KEYWORDS

Flow, bend, deposition, erosion and iRICsoftware.

1. INTRODUCTION

Curved open canal are subjected to complicated erosion and deposition processes. Many researches made an effort to solve erosion problem in open canals [1-5]. A study presented CFD model to predicterosion process in three different S-bends [6]. The tests were conducted for S-bends of the curvature's radius ratio (\emptyset /L=1.5). The results showed areas of the maximum erosion along the S-bend. Based on a recent study specified that narrow rivers were subjected to stabilized meanders [7]. A research pointed to that the 135° bend can be treated as a typical regular meander [8]. Studied the lateral movement of alluvial in the Rio Grande [9]. Previous study recommended an empirical formula for the prediction of scouring in bends, see Eq. (1) [10].

$$(S_{max}/W) = 207 - 0.19 \text{ Ln } (\emptyset/L)$$
 (1)

Studied the consequence of flow discharge on the capacity of the sediment transport [11]. A study examined the different constraints affect the computations of CCHE2D model [12]. The roughness coefficient of the bed is the mainly factor affecting the flow in open canals. Others provided results of investigations of the bends' scour in Warta River [13]. The scour at bends was calculate by a numerical model. A maximum scour equation along the bend was introduced. Recent research built a 2-D numerical model to detect the transporting of the sediment through open canals [14]. Then other study used two numerical models to detect the scouring problems at Nile River upstream of the new intake of Esmaeilia canal [15]. Two-dimensional horizontal numerical model to detect the morphological changes in rivers of bends [16]. Two experiments were used to calibrate the model. Previous study applied one of the available solvers in iRIC software to simulate velocity field around piers under contraction effect [17]. Results showed, piles of 4.812 comparative extension yielded minimal velocity. In fact, no available researches studied erosion processes around the supports along curved reachs. This paper presents experiments for the erosion and deposition processes along 180° bend through open canal. Experiments are managed with the curvature's radius ratio (Ø/L) varies between 3.0 to 8.5. The optimum location of bridge supports along the bend are defined. Nays2DH Model is applied to simulate the flow and erosion processes. The numerical results are compared with the tests for open canal.

2. TESTING PROCESS

2.1 Description of the model and soil

Investigations examined experimentally through open canal flume of a width 22 = 40cm, length = 400cm and depth = 20cm. The flume is existed in the hydraulic lab of engineering collage in Zagazig University. The photos express the parameters of the phenomenon are given as shown in figure (1). Tests are conducted to analysis the erosion and deposition processes along 180° bend through open canal of solid boundaries, see figure (1a). The model boundaries are built from steel sheets fixed to the bed. The natural soil is used along the model. Some gravel boulders are putted at the inlet to stabilize the soil. Thesoil examination was done. The medium diameter of sand soil $P_{50} = 1900$ micron. The sand soil can be treated as a uniform specimen.

2.2 Time effect on the testing process

Eight tests are conducted to examine effects of the time on the erosion and deposition processes. The time of the test are (10, 20, 30, 60, 90, 120, 180 and 300 minutes). The relation between the rates of the maximum erosion depth related to the erosion of 300 minutes $(S_{max}/S_{max} s_{hours})$ is plotted against the time as illustrated in figure (2). It can be realized that about 83% of the erosion can be attained by the ending of the first hour. The applied time for the experimental tests is fixed as one hour.

2.3 The location effect of the support (ω)

The location effect of the support on the erosion process was detected by 32-tests. It was conducted to examine effects of the locating a support of diameter 3.2cm in the centerline of the open canal at different positions. The details of the model are presented in figure (1). The tests are conducted for the centerline's radius \emptyset = 50cm, F_{roude} (i.e., Froude number) \cong 0.3:0.65 and ω (i.e., the angle of location) = 41°, 53°, 70°, 90°, 110°, 127°, 139° and 180°, respectively.

2.4 The effect of the Curvature (Ø)

Effects of the centerline's radius \emptyset are detected by 16- tests. It was conducted to examine effects of the altering \emptyset on the deposition and

erosion processes. The support's diameter = 3.2cm was fixed in the centerline of the open canal (i.e. ω =90°). The tests are conducted for centerline's radius = 50cm,66cm,100cm,and160cm.

3. DESCRIPTIONS OF RESULTS

3.1 Optimum location of the Support

The results of the deposition and erosion phenomenon through open canal with bends at different ω and Ø/L =3.0 are analyzed in the following section.

Figure (3a and 3b) presents the examined erosion and deposition at the support itself. It was looked out that, SP_{max}/W_{down} (i.e., the relative erosion depth at support) is the minimum for the status of ω =41°. In contrast, DEP_{max}/W_{down} (i.e., the relative deposition depth at support) is the maximum for the status of ω =41°.

Figure (4a and 4b) presents the examined erosion and deposition at the outer bend. It was looked out that, the rate of the depth of erosion S_{max}/W_{down} is the minimum for the statuses of ω =90° and 180°. The rate of the maximum deposition DE_{max}/W_{down} is the minimum for the statuses of ω =90° and 180°.

Figure (4c and 4d) presents the examined phenomenon at the inner bend. It was looked out that, S_{max}/W_{down} is the minimum for the statuses of ω =90° and 180°. Moreover, DE_{max}/W_{down} is the minimum for the statuses of ω =70° and 180°.

3.2 The Optimum Curvature

The results of the deposition and scour phenomenon in bends of different curvatures are analyzed in the following section. The status of $\emptyset/L=8.5$ gives minimum values of S_{max}/W_{down} and DE_{max}/W_{down} at the outer boundary, see figure (5a, and 5b), respectively. Moreover, $\emptyset/L=8.5$ gives the minimum values of DE_{max}/W_{down} at the inner boundary, see figure (5d). It was looked out that, S_{max}/W_{down} is the minimum for the status of $\emptyset/L=3$ and 8.5, see figure (5c).

Figure (6a and 6b) presents the examined erosion and deposition at the support itself for different \emptyset/L and $\omega=90^{\circ}$. It was looked out that, SP_{max}/W_{down} and DEP_{max}/W_{down} are the minimum for the status of $\emptyset/L=8.5$.

4. OVERVIEW OF NAYS2DH MODEL

The numerical two dimensional in plan Nays2DH model was built by Dr. Yasuyuki Shimizu [18]. It is a powerful model used to detect the flow and sediments behavior through open canals. Nays2DH model is a solver imbedded in iRIC software [19]. A research also presented basic equations of the sediment transport and flow used in Nays2DH model [18]. The main formulas of the flow include the continuity and the momentum equations.

Few papers were presented for applications of Nays2DH model. Based on a study discussed 6- solvers embedded in iRIC software [20]. Environmentally assessed water conditions and the sediment action in the reservoir of Ogaki Dam for different operation statuses using Nays2D model [21]. A recent study applied Nays2D model for open canal subjected to water surface fluctuations [22]. The model was compared with observatories of gauged water surface levels.

5. DESCRIPTION OF THE GENERATED NUMERICAL MODELS

The generation of the Nays2DH Model passes through few steps. At the first, the mesh is generated as illustrated in figure (7a). The mesh is schematized into 10- cells in lateral direction and 70- cells in longitudinal direction. The dimensions of a single cell are $0.02 \times 0.02m$. The total number of cells is 700. The topographic bed of the model is given as figure (7b).

5.1 The open canal bends without supports

Nays2DH Model was built for the status of open canal bends without any supports existed in the canal. The model characteristics include $\emptyset = 50 \, \text{cm}$ and $F_{roude} \cong 0.23:0.73$. The flow conditions include different water surface slopes (the slope 24 = 0.001, 0.002, 0.003, 0.004, 0.0045 and 0.005), the same flow discharge (Q=0.24m³/sec) and the same time for the test (Time = $600 \, \text{second}$). The bed material was defined ($P_{50} = 1900 \, \text{cm}$)

5.2 The case of locating a support

micron).

Nays2DH Model was built for the statuses of proposed open canal with a support existed in different locations. The flow properties include followings: the discharge = $0.0024\,\mathrm{m}^3$ /sec, the flow surface is uniform slope of 0.0045. The supports' locations include 4- positions (i.e. ω =41°, ω =53°,

6. CALIBRATION OF THE NUMERICAL MODEL

The results of Nays2DH Model are compared with tests. Figure (8) presents the maximum P_{max}/W_{down} through the examined reach and for both the measurements and the calculated ones by Nays2DH model against F_{roude} . It was looked out that, there is an acceptance between the measurements and Nays2DH for $F_{roude} < 0.5$. On the other hand, the gap is noticeable between measurements and the calculations for the range $F_{roude} > 0.5$. General speaking, Nays2DH model gives more scoured depths than the detected in the lab. RSQ for the modeled cases are 88.329% and the correlation factor between the numerical modeling and the gauged = 93.98%.

7. NUMERICAL RESULTS

 ω =70°, and ω = 90°).

The results of Nays2DH Model are presented for the statuses of proposed open canal without supports, see figure (9). Figures (9a, 9b, 9c, 9d, 9e and 9f) display the numerical outcomes of the scour and deposition progression along the studied reaches for the several flow conditions. It is obvious that, the scour depth increases as F_{roude} increases.

The results of Nays2DH Model are presented for the statuses of different positions of support, see figure (10). The figure illustrates that, scouring areas around the support is minimized for the status of $\omega = 41^\circ$. In the opposite way, the status of $\omega = 70^\circ$ gives minimum scouring processes in the studied reach.

Figures (11a, 11b, 11c and 11d) display the numerical generation maps for the streamline's distribution for different positions of the support. It is easily seen that, the flow lines become in an equal distribution across the section in the cases $18 \omega = 70^{\circ}$, and 90° .

Figures (12a, 12b, 12c and 12d) display the numerical generation maps for the velocity vectors distribution for different positions of the support. The figure illustrates that, the velocity vectors become in an equal distribution across the section in the cases ω =70° and 90°.

Figure (13) displays the scoured bed profile at the support for cases of different positions of the support. It can be realized that, the scour is minimum for the status of ω =41°. Moreover, the deepness of scouring is the maximum for the case 26 of ω =90°.

8. CONCLUSIONS

This paper presents experiments and numerical modelling for the erosion and deposition processes along 180° bend through open canal for the several cases of localizing bridge support at the center line of the canal. The main conclusions include the following:

- (1) The experimental results showthat,
- The status of ω =41° gives the minimum relative erosion depth at support, SP_{max}/W_{down} in contrast it gives the maximum relative deposition depth at support DEP_{max}/W_{down} .
- For the outer bend, statuses of ω =90° and 180° give the minimum rate of the erosion S_{max}/W_{down} and the maximum deposition DE_{max}/W_{down} .
- For the inner bend, statuses of ω =90° and 180° give the minimum rate of the erosion S_{max}/W_{down} . Statuses of ω =70° and 180° give the maximum deposition DE_{max}/W_{down} .
- The status of Ø/L=8.5 gives minimum values of S_{max}/W_{down} and DE_{max}/W_{down} at both outer and inner boundaries.
- The status of Ø/L=8.5 gives minimum values of SP_{max}/W_{down} and DEP_{max}/W_{down} at the support itself.
- (2) Results of Nays2DH Model are comparing with measurements for the status of open canal without any supports. RSQ for the modeled cases are 88.329% and the correlation factor between the numerical modeling and the gauged=93.98%.
- (3) The numerical outcomes of Nays2DH Model show that scouring areas around the support is minimized for the status of $\omega{=}41^{\circ}$. The status of $\omega{=}70^{\circ}$ gives minimum scouring processes in the studied reach.

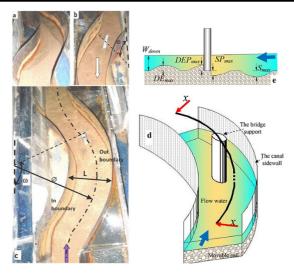


Figure 1: [a] the scour and deposition locations along the bend [b] the support [c] the model parameters [d] Isomeric along the bend [e]

Section x-x

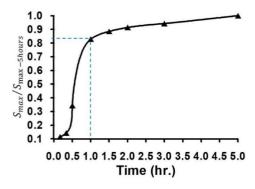


Figure 2: The rates of maximum scour versus time

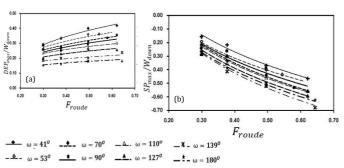


Figure 3: The deposition and scour at the support for $\emptyset/L=3.0$ and different ω (a) DEP_{max}/W_{down} versus F_{roude} (b) SP_{max}/W_{down} versus F_{roude}

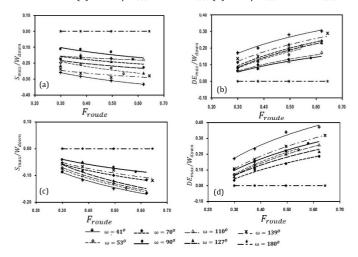


Figure 4: The deposition and scour for $\emptyset/L=3.0$ and different ω (a) S_{max}/W_{down} versus F_{roude} at the outer bend (b) DE_{max}/W_{down} versus F_{roude} at the outer bend (c) S_{max}/W_{down} versus F_{roude} at the inner bend (d) DE_{max}/W_{down} versus F_{roude} at the inner bend

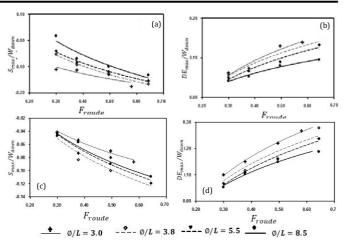


Figure 5: The deposition and scour conditions for different \emptyset/L and $\omega=90^{\circ}$ (a) S_{max}/W_{down} versus F_{roude} at the outer bend (b) DE_{max}/W_{down} versus F_{roude} at the outer bend (c) S_{max}/W_{down} versus F_{roude} at the inner bend (d) DE_{max}/W_{down} versus F_{roude} at the inner bend

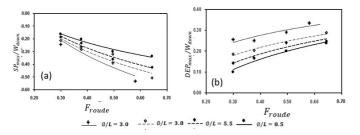


Figure 6: The deposition and scour conditions of different Ø/L and ω =90° at the support (a) SP_{max}/W_{down} versus F_{roude} (b) DEP_{max}/W_{down} versus F_{roude}

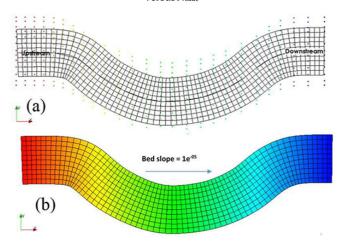


Figure 7: (a) the generated mesh of the Nays2DH model (b) the bed topography of the generated mesh

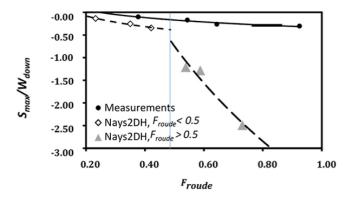


Figure 8: S_{max}/W_{down} versus F_{roude} for measurements and Nays2DH

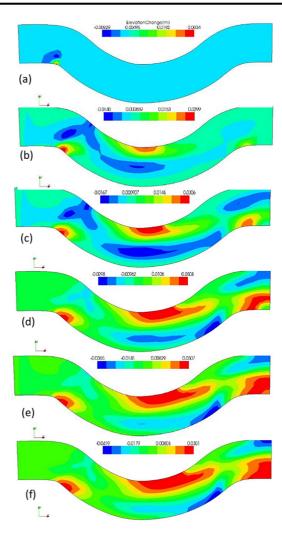


Figure 9: the scoured bed for different flow conditions (a) $F_{roude} = 0.232$ & slope=0.001 (b) $F_{roude} = 0.349$ & slope=0.002 (c) $F_{roude} = 0.421$ & slope=0.003 (d) $F_{roude} = 0.538$ & slope=0.004 (e) $F_{roude} = 0.587$ & slope=0.0045 (f) $F_{roude} = 0.73$ & slope=0.005

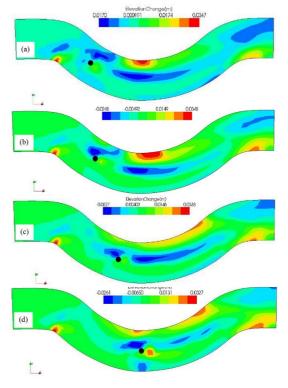


Figure 10: the scoured bed for different locations of the support (a) ω =41° (b) ω =53° (c) ω =70° (d) ω = 90°

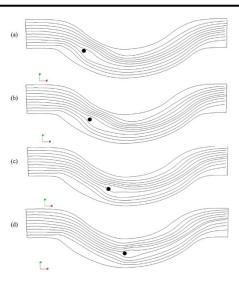


Figure 11: streamlines for different support's locations (a) ω =41° (b) ω =53° (c) ω =70° (d) ω =90°

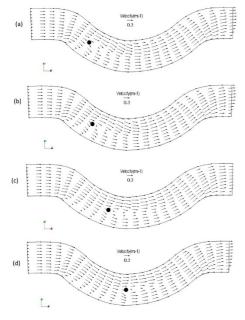


Figure 12: velocity vectors for different locations of the support (a) ω =41° (b) ω =53° (c) ω =70° (d) ω = 90°

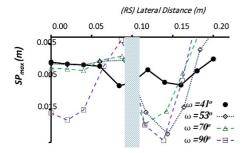


Figure 13: the bed profile before the support

REFERENCES

- [1] Nassar, M. 2010. One-dimensional hydrodynamic model simulating water stage in open channels (ws-1). International Journal of Modeling, Simulation, and Scientific Computing, 1(02), 303-316.
- [2] Nassar, M.A., Ibrahim, A.A., Negm, A.M. 2009, Modeling of Local Scour Down Stream of Hydraulic Structures Using Support Vector Machines (SVMS), In Proc. Of 6th Int. Conf. on Environmental Hydrology, Cairo, Egynt.
- [3] Negm A.M, Nassar M.A., Elnikhely, E.A. 2014, Minimization of scour and deposition downstream pipe culvert with a limited floor protection International Water Technology Journal, IWTJ, 4(3), 208–221.

- [4] Negm, A.M., Elfiky, M.M., Owais, T.M., Nassar, M.H. 2003. Prediction of suspended sediment concentration in river flow using artificial neural networks. In Proceedings of 6th International Conference on River Engineering, Ahvaz, Iran.
- [5] Negm, A.M., Elfiky, M.M., Owais, T.M., Nassar, M.H. 2007. Modelling of Suspended Sediment-In Nile River Using ANN. In ICSOFT (ISDM/EHST/DC), 209-214.
- [6] Mazumder, Q.H., Zhao, S., Ahmed, K. 2015. Effect of bend radius on magnitude and location of erosion in s-bend. Modelling and Simulation in Engineering, 1.
- [7] Blanckaert, K. 2011. Hydrodynamic processes in sharp meander bends and their morphological implications, Journal of Geophysical Research: Earth Surface, 116(F1).
- [8] Constantinescu, G., Kashyap, S., Tokyay, T., Rennie, C.D., Townsend, R.D. 2013. Hydrodynamic processes and sediment erosion mechanisms in an open channel bend of strong curvature with deformed bathymetry. Journal of Geophysical Research: Earth Surface, 118(2), 480-496.
- [9] Richard, G.A., Julien, P.Y., Baird, D.C. 2005. Case study: modeling the lateral mobility of the Rio Grande below Cochiti Dam, New Mexico. Journal of Hydraulic Engineering, 131(11), 931-941.
- [10] Thorne, C.R., Abt, S.R. 1993. Velocity and scour prediction in river bends (No. WES/CR/HL-93-1). Army engineer waterways experiment station Vicksburg MS hydraulics lab.
- [11] Prosser, I.P., Rustomji, P. 2000. Sediment transport capacity relations for overland flow. Progress in Physical Geography, 24(2), 179-193.
- [12] Nassar, M.A. 2011. Multi-parametric sensitivity analysis of CCHE2D for channel flow simulations in Nile River. Journal of hydro-environment research, 5(3), 187-195.
- [13] Przedwojski, B. 1995. Bed topography and local scour in rivers with banks protected by groynes. Journal of Hydraulic Research, 33(2), 257-

273.

- [14] Elfiky, M.M., Negm, A.M., Owais, T.M., Nassar, M. 2002. A 2-D Model Simulating Sediment Transport In Shallow-Wide Streams (SED-2). In Proc. Of 5th Int. Conf on Hydro-Science and Engineering, 16-21.
- [15] Elfiky, M.M., Negm, A.M., Owais, T.M., Nassar, M.A. 2010. Computational models for analyzing scouring problems at Nile River. In Proceedings of the 9th International Conference on Hydrodynamics, 11-15
- [16] Darby, S.E., Alabyan, A.M., Van de Wiel, M.J. 2002. Numerical simulation of bank erosion and channel migration in meandering rivers. Water Resources Research. 38(9).
- [17] Maha, R. Fahmy, Mohamed, A., Nassar. 2017, Contraction effect upstream abutments on velocity and scour: experimental and theoretical study using IRIC software, Journal of Engineering Sciences, Assiut University, Faculty of Engineering, 45(1), 17 27.
- [18] Shimizu, Y., Takebayashi, H., Inoue, T., Hamaki, M., Iwasaki, T., Nabi, M. 2014, Nays2D H Solver Manual, iRIC Software, http://i-ric.or.
- [19] iRIC Software, iRIC version2.3 (32bit), http://iric.org/en/downloads.
- [20] Nelson, J.M., Shimizu, Y., Abe, T., Asahi, K., Gamou, M., Inoue, T., Kyuka, T. 2015. The international river interface cooperative: Public domain flow and morphodynamics software for education and applications. Advances in Water Resources, Journal. 93, 62–74.
- [21] Yamada, S., Kitamura, A., Kurikami, H., Yamaguchi, M., Malins, A., Machida, M. 2015. Sediment and 137Cs transport and accumulation in the Ogaki Dam of eastern Fukushima. Environmental Research Letters, 10(1), 014013.
- [22] Ku, Y.H., Song, C.G., Park, Y.S., Kim, Y.D. 2015. A Study on the Field Application of Nays2D Model for Evaluation of Riverfront Facility Flood Risk. Journal of The Korean Society of Civil Engineers, 35(3), 579-588.

