RESEARCH ARTICLE

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

Amany A. Habib* and Mohamed A. Nassar‡

1Water Engineering and Water Structures Department, Faculty of Engineering, Zagazig University, Egypt, Zagazig, 44519, EG
2Department of Construction Engineering, College of Engineering in Al-Qunfudhah, Umm Al-Qura University, KSA, on leave from Water Engineering and Water Structures Department, Faculty of Engineering, Zagazig University, Egypt, 44519, EG
*Corresponding Author Email: nassar@zu.edu.eg

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ARTICLE DETAILS

ABSTRACT

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 IRI software. The models are conducted with the curvature’s radius ratio (Ø/L) varies within 3.0 to 8.5. Experiments produced that the erosion and deposition actions decrease as Ø/L increases. The minimal erosion and deposition are detected at (Ø/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 IRI software.

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 predict erosion process in three different S-bends [6]. The tests were conducted for S-bends of the curvature’s radius ratio (Ø/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 curvature (Ø/L) increases as Ø/L increases. The minimal erosion and deposition are detected at (Ø/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%.

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 experiments are conducted to analysis the erosion and deposition processes along 180° bend through open canal of solid boundaries, see 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. The soil examination was done. The medium diameter of sand soil P90 = 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 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. The soil examination was done. The medium diameter of sand soil P90 = 1900 micron. The sand soil can be treated as a uniform specimen.

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) (i.e., Froude number) is 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 Ø are detected by 16-tests. It was conducted to examine effects of the altering Ø on the deposition and erosion processes along the curvature’s radius ratio (Ø/L) varies within 3.0 to 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%.

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eroded processes. The support’s diameter = 3.2cm was fixed in the centerline of the open canal (i.e. $\omega=90^\circ$). The tests are conducted for centerline’s radius of 50cm, 66cm, 100cm, and 160cm.

3. DESCRIPTIONS OF RESULTS

3.1 Optimum location of the Support

The results of the deposition and erosion phenomenon through open canal with beds at different $\omega$ and $\Omega/L=3.0$ 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 $\omega=41^\circ$. In contrast, $DE_{max}/W_{down}$ (i.e., the relative deposition depth at support) is the maximum for the status of $\omega=41^\circ$.

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

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

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 $\Omega/L=8.5$ gives minimum values of $S_{max}/W_{down}$ and $DE_{max}/W_{down}$ at the outer boundary, see figure (5a, and 5b), respectively. Moreover, $\Omega/L=8.5$ 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 $\Omega/L=3$ and $8.5$, see figure (5c).

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

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 embedded 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 Nays2DH model [21]. A recent study applied Nays2D model for open canal subjected to water surface fluctuations [22]. The model was compared with observations 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 statuses of open canal bends without any supports existed in the canal. The model characteristics include $\Omega = 50cm$ and $F_{roude} = 0.226:0.72$. The flow conditions include different water surface slopes (the slope $24 = 0.001$, $0.002$, $0.003$, $0.004$, $0.005$, and $0.006$), the same flow discharge ($Q=0.24m^3/sec$) and the same time for the test (Time = 600 second). The bed material was defined ($F_{B} = 1900$ micron).

5.2 The case of locating a support

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 $=0.0024m^3/sec$, the flow surfaces is uniform slope of 0.0045. The supports’ locations include 4- positions (i.e. $\omega=41^\circ$, $\omega=53^\circ$, $\omega=70^\circ$, and $\omega=90^\circ$).

6. CALIBRATION OF THE NUMERICAL MODEL

The results of Nays2DH Model are compared with tests. Figure (8) presents the maximum $F_{max}/W_{down}$ 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 calculators 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

The results of Nays2DH Model are presented for the statuses of proposed open canal without support, see figure (9). Figures (9a, 9b, 9c, 9d) 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 18 $\omega=70^\circ$, 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 $\omega=41^\circ$. Moreover, the deepness of scouring is the maximum for the case 26 of $\omega=90^\circ$.

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 showed that:
- The status of $\omega=41^\circ$ gives the minimum relative erosion depth at support, $SP_{max}/W_{down}$ in contrast it gives the maximum relative deposition depth at support $DE_{max}/W_{down}$
- For the outer bend, statuses of $\omega=90^\circ$ 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 $\omega=90^\circ$ and 180° give the minimum rate of the erosion $S_{max}/W_{down}$. Statuses of $\omega=70^\circ$ and 180° give the maximum deposition $DE_{max}/W_{down}$.
- The status of $\Omega/L=8.5$ gives minimum values of $S_{max}/W_{down}$ and $DE_{max}/W_{down}$ at both outer and inner boundaries.
- The status of $\Omega/L=8.5$ gives minimum values of $SP_{max}/W_{down}$ and $DE_{max}/W_{down}$ 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.

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

Figure 10: the scoured bed for different locations of the support (a) \( \omega = 41^\circ \) (b) \( \omega = 53^\circ \) (c) \( \omega = 70^\circ \) (d) \( \omega = 90^\circ \)

Figure 11: streamlines for different support’s locations (a) \( \omega = 41^\circ \) (b) \( \omega = 53^\circ \) (c) \( \omega = 70^\circ \) (d) \( \omega = 90^\circ \)

Figure 12: velocity vectors for different locations of the support (a) \( \omega = 41^\circ \) (b) \( \omega = 53^\circ \) (c) \( \omega = 70^\circ \) (d) \( \omega = 90^\circ \)

Figure 13: the bed profile before the support

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