Analysis of causes of Landslide and Proposal of solution to Embankment Structure Preventing the Erosion of Tamxa Bank of the Red River

Quang Hung Nguyen, Kien Quyet Nguyen, Van Quan Tran, Huu Nam Nguyen

Abstract**:** ***TamXa bank of Red River is a curved segment of the river flowing deep on the large bank, the high flow velocity in flood season rushing and pressing close to the bank is the main cause of riverbank damage.***

Based on the analysis of real data measured and studied the hydraulic section of the river section on the physical model, the author has shown the essential nature and causes of river bank erosion in this section due to the interaction. between the river shape, the movement of the middle beach and the flow causes erosion and changes the river bed. Deep creeks and dynamic shafts close to the river banks with relatively close distance at the water level. Large coastal velocity, in the area of landslide from 1.0 ÷ 1.5 m/s corresponding to creating water level, locally has a place larger than 2m / s and tends to push to the left bank. On the other hand, due to the characteristics of TamXa beach, which are quite large over 3km, when floods rise and floods recede with a large flow, the spillway velocity is also the impact on river banks

Keywords**:** ***Red River, TamXa, Landside of the bank, Stability of the riverbank.***

I. INTRODUCTION

In 1010, along the Red River, Ly Thai To moved the capital from Hoa Lu to the land of "flying dragon" - the capital of Thang Long - Hanoi. Since Hanoi has been historically important, the Red River is always the facade of city, the main artery of all urban activities. This area which is gathered by road vehicles and waterway means, the water supply and drainage area, provides the landscape for relaxing, etc. At the same time, the Red River also has many incalculable potential dangers.

In the current situation, the river has not been planned, the interventions of people in the river with many different purposes such as bridges, ports, water works, spontaneous residential areas, making Red River flowing through Hanoi has many unfavorable developments, the severely broken urban landscape, the environment affected heavily, leading to failure of forming a civilized, modern downtown, exploiting all strengths of the river. This is also the urgent problem in managing the river bed, riverbank and urban area today.

TamXa bank located in downstream segment of Red River in Thang Long bridge to Duong river gate is a curved segment of the river, which is divided into the creeks, flows complexibly. However, the complication also due to the unintended impact of human to the river bed, making the river not fully maneuverable according to natural law, affected by the factors of force.

The training works system of the left bank (TamXa bank) in area of NhatTan bridge, the training works structure of the reinforced concrete pile combined pile foot poured stone and the shields are seriously degraded and not effective as expected because the construction works has been built and exploited for over 20 years without maintenance.

Research on this river segment has been carried out for a long time, but due to the complexity of the problem, and the different need for each stage of socio-economic development, so the research of this segment is still continuous. In the training problems, stabilities of this river segment are the mechanical rules of the factors forming the river and the interaction between them. These problems should be clarified in order to create a scientific basis for Tam Xa bank protection solutions for objectives such as ensuring flood drainage, preventing the landslide and stabilizing waterway traffic creeks, embellishing the urban landscape.

a) Upstream of welding torches | b) Space between 2 welding torches | c) Original welding torches

Fig 1. Image of beach erosion Tam Xa on Red River (2012)

II. METHOD OF RESEARCH

The content of the study deals with the interaction between flow - conductivity and river correction, which is a complex and sensitive issue in river rectification science, because it integrates 3 fields of mechanics: substance liquid (water), solid (construction) and bulk (riverbed). Solving such problems cannot simply use a research method to solve all problems, each method, due to its accessibility, only considers the object at a certain angle. Therefore, it is necessary to combine many research methods such as: measuring material analysis method, mathematical model method and physical modeling method to clarify each research content.

A. Method of measured data analysis

The measured data analysis is applied in the analysis of the Red River segment movement flowing through Hanoi, the movement changes occurred on the plan section and cross section of the erosion area of Tam Xa bank - Red

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Quang Hung Nguyen, Thuy Loi University, Hanoi, Vietnam.
Kien Quyet Nguyen, University of Transport Technology, Hanoi, Vietnam.
Van Quan Tran, Hydraulic Construction Institute, Hanoi, Vietnam.
Huu Nam Nguyen, Institute for Hydropower and Renewable Energy

river. Databases have been collected over many years (terrain, geology, hydrography, sediment) from a variety of sources edited and processed to ensure the required reliability. [2-3, 5-7]

B. Method of research on physical model

To solve the goals, use the MIKE 21 Flow Model FM model (MIKE21 FM for short) to study. This is a hydraulic model with unstructured computational mesh (Flexible Mesh, abbreviated as FM) is a complete mathematical modeling system for new 2-way (2D) and 3-dimensional (3D) hydraulic problems DHI recently developed. [1-3, 8-10]

1) The basic equations:

** Continuous equation*

$$\frac{\partial h}{\partial t}+\frac{\partial h\bar{u}}{\partial x}+\frac{\partial h\bar{v}}{\partial y}=hS \qquad (1)$$

** Momentum equation is in the x and y directions, respectively*

$$\frac{\partial h\bar{u}}{\partial t}+\frac{\partial h\bar{u}^2}{\partial x}+\frac{\partial h\overline{uv}}{\partial y}= f\bar{v}h-gh\frac{\partial \eta}{\partial x}-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial x}+\frac{\tau_{sx}}{\rho_0}-\frac{\tau_{bx}}{\rho_0}+\frac{\partial}{\partial x}(hT_{xx})+\frac{\partial}{\partial y}(hT_{xy})+hu_sS \qquad (2)$$

$$\frac{\partial h\bar{v}}{\partial t}+\frac{\partial h\overline{uv}}{\partial x}+\frac{\partial h\bar{v}^2}{\partial y}= f\bar{u}h-gh\frac{\partial \eta}{\partial y}-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial y}+\frac{\tau_{sy}}{\rho_0}-\frac{\tau_{by}}{\rho_0}+\frac{\partial}{\partial x}(hT_{xy})+\frac{\partial}{\partial y}(hT_{yy})+hv_sS \qquad (3)$$

where t is time; *x, y* are Cartesian coordinates; η is water level fluctuation; *d* là độ sâu; $h=\eta+d$ is the total depth; *u, v* is the velocity component in the *x, y*; $f=2\Omega\sin\phi$ is Coriolis parameter; *g* is the gravitational acceleration; ρ is the water density; p_a is atmospheric pressure; ρ_o is the standard density; *S* is the magnitude of the flow due to the source points and (u_s,v_s) isthe velocity of the flow into the calculated domain. The dash index above indicates the average values:

$$h\bar{u}=\int_{-d}^{\eta}u\,dz,\quad h\bar{v}=\int_{-d}^{\eta}v\,dz \qquad (4)$$

T_{ij} side stresses include viscous friction, tangled friction and differential diffusion, which are evaluated by using eddy turbulence formula based on the average velocity difference by depth:

$$T_{xx}=2A\frac{\partial \bar{u}}{\partial x},\quad T_{xy}=A\left(\frac{\partial \bar{u}}{\partial y}+\frac{\partial \bar{v}}{\partial x}\right),\quad T_{yy}=2A\frac{\partial \bar{v}}{\partial y} \qquad (5)$$

2) Numerical methods and algorithm

\+ Implement domain discrete method using finite volume method. The spatial domain is discrete into continuous smaller domains in the form of grid cells / non-overlapping elements.

\+ In the two-way case, the elements are shaped as arbitrary polygons, but here only consider triangular elements. The system's dependent variables are described as constants in each element.

\+ The full formula for two-dimensional shallow water equations can be written as follows:

$$\frac{\partial U}{\partial t}+\nabla\cdot F(U)=S(U) \qquad (6)$$

Where *U* is the vector of the component variables, $F=F^I-F^V$ is the flux vector function and S is the vector of the source term, written as follows:

$$U=\begin{bmatrix} h\\ h\bar{u}\\ h\bar{v}\end{bmatrix}$$

$$F_x^I=\begin{bmatrix} h\bar{u}\\ h\bar{u}^2+\frac{1}{2}g\left(h^2-d^2\right)\\ h\bar{u}\bar{v}\end{bmatrix},\quad F_x^V=\begin{bmatrix} 0\\ hA\left(2\frac{\partial \bar{u}}{\partial x}\right)\\ hA\left(\frac{\partial \bar{u}}{\partial y}+\frac{\partial \bar{v}}{\partial x}\right)\end{bmatrix} \qquad (7)$$

$$F_y^I=\begin{bmatrix} h\bar{v}\\ h\bar{u}\bar{v}\\ h\bar{v}^2+\frac{1}{2}g\left(h^2-d^2\right)\end{bmatrix},\quad F_y^V=\begin{bmatrix} 0\\ hA\left(\frac{\partial \bar{u}}{\partial y}+\frac{\partial \bar{v}}{\partial x}\right)\\ hA\left(2\frac{\partial \bar{v}}{\partial x}\right)\end{bmatrix} \qquad (8)$$

$$S=\begin{bmatrix} 0\\ g\eta\frac{\partial d}{\partial x}+f\bar{v}h-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial x}+\frac{\tau_{sx}}{\rho_0}-\frac{\tau_{bx}}{\rho_0}+hu_s\\ g\eta\frac{\partial d}{\partial y}-f\bar{u}h-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial y}+\frac{\tau_{sy}}{\rho_0}-\frac{\tau_{by}}{\rho_0}+hv_s\end{bmatrix} \qquad (9)$$

\+ Indicators I and V are correspondingly expressed as non-viscous flux (convection) and viscous.

Where A_i is the area of the element; Ω is the integral variable defined on A_i; Γ_i is the circumference of the ith element and *i* and *ds* is the integral variable along the circumference; *n* là is the unit vector.

\+ Horizontal convection throughput is calculated using Roe's approximation method of Roem (Roe 1981). The first diagram is used for spatial integration.

\+ Euler diagram is currently used for two-dimensional calculations.

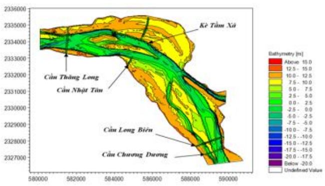

Fig. 2. Topography of the study area

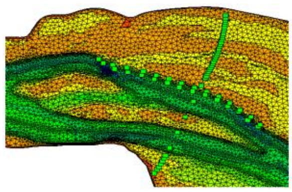

Fig. 3. Grid calculated TamXa area

C. Method of research on physical models

The physical model is designed with a ground ratio of 1/400 and a standing ratio of 1/100, satisfying the same standards of froude, Reynolds and resistance. [3-4, 8, 11-12]

D. Calibration and verification of models

The model is calibrated and tested: similar in geometry, similar to water level and roughened with flow levels. The results of model testing showed that the same conditions were satisfied, ensuring the reliability of the research results.

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E. Boundary conditions and research scenarios

- *Hard compaction:* Using the 1/1000 scale scale measuring instrument of the Company - TEDI WECCO.[4]

- *Loose boundary:* Flood boundary is taken based on calculation results on MIKE11 river network model, in case of 500 year flood (frequency 0.2%), 1996 flood form, regulated 4 lakes The boundary is created from Cua Duong to Thuong Cat Q = 11,000 m3 / s; from Cua Duong xoi to Van Phuc, Q = 7500 m3 / s. The water level at the hydrological station in Hanoi is + 9.5m. [2,3]

- *Hydrological database for model adjustment:* Real measured data of TEDI-WECCO company implemented [2,4].

- *Studying the hydraulic regime of river sections in the current conditions, the main physical phenomena need to be studied:* changes in water level, flow direction, velocity distribution field.

III. CAUSES OF LANDSLIDE TAMXA

A. The law of river bed evolution in history

The river section of the study often fluctuates strongly in areas of large bulges such as Phu Gia, Tu Lien and Thach Cau. This is clearly reflected in the changes of the beaches of Phu Gia, Tu Lien, Thach Cau, Bac Bien and Dong Nhan beaches. The unified transformation between the two big beaches Tu Lien and Thach Cau, the two small side yards are Bac Bien beach and Dong Nhan beach; an inverse relationship between two large, small opposite beaches: Tu Lien - Bac Bien and Thach Cau - Dong Nhan. Through the correlations between these beaches, we can find signs of river-bed development trends.

The river A is a river that is favorable for Irrigation, for Transport and urban development and planning. According to the A river, in Chet master, it is forced to close to the right bank and then to the left bank of Tam Xa beach. After that, the owner goes along Tam Xa beach and goes to Duong door. Passing through Duong's gate, the direction towards Gia Lam creek is directed. Leaving the Gia Lam rivulet in the direction towards Hanoi port and heading to the left bank at Xuan Quan. The representative for the river A was the period of 1959 - 1964 and in recent years 1995 - 2012. [2-4]

The rivers B and C are the long-term unstable rivers, creating creek cliffs such as Quyt creek, which are disadvantageous for irrigation, transportation, planning and city development. unwanted river. [2-4]

Nearly 20 years ago, the Red River is returning to the A River posture after people spend much effort, wisdom and time to correct it. However, there are now signs of the return of the C river.

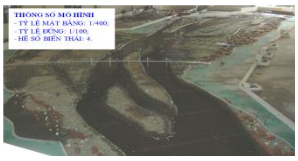
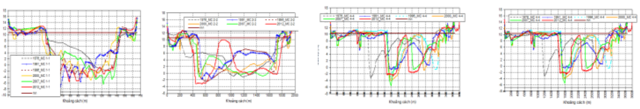


Fig. 4 Yard plan of physical model

Fig. 5. The basic trends of segments of Red River – Hanoi

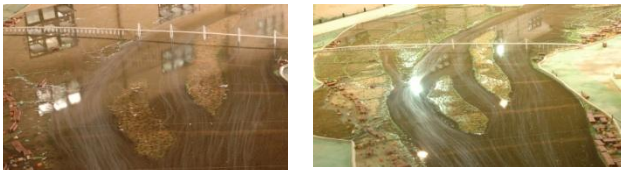


Movements on MCN Thuong Thang Long bridge saved | Movements on the MCN between Phu Gia beach | Evolution on the MCN at the end of Phu Gia-Nhat Tan | Movements on the MCN upstream of Duong road

Fig 6. Evolutions on the cross-section of the Red River - Hanoi

B. Kinetic axis of the flow along the river section

Research on the hydraulic regime of the river segment is carried out on the physical model corresponding to the flow levels (flood, bed building and low water flood), the picture of the kinetic axis of the seasons is different, but there is a common trend, which presses close to Tam Xa bank.



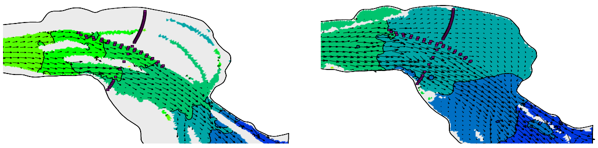
a) Level of flood flow b) Flow level of bed building

Fig. 7. Flow direction in the area of TamXa beach

C. Coastal velocity

Coastal velocity, components directly impact the river bank. Therefore, in the hydraulic modeling experiment, velocity points were measured and constructed on the waterways close to the shore (water edge). From there, analyze and assess their impact and direction with the tangent line to the shore.

Based on the measured results, in the case of research with the flow rate creating the center and supplying the flood flow, the average velocity of the shore line averages from 1.5 ÷ 2.0 m/s, with the value This number is greater than the velocity of the coastal geological mud, which is the main cause of bank erosion



a) Flow generated heart *b) Flood flow*

Fig. 8. Velocity field in the area of TamXa beach corresponds to different flows

D. Geology and slope forming the banks of river banks

Geology is one of the important factors affecting the stability of the river bank. To assess the geology of the river bank in the study area, 12 soil samples were taken to form the river bank in this area. The following is a summary of the test results.

Good soil layer is 6 (light gray clay, blue gray). This soil layer is distributed in deep so it has little effect on stabilizing the shore.

The soft soil layers are layer 2 (silty clay mixed with clay), layer 4 (clay mud mixed with plant residues). High permeability and poorly bound soil layers are mixed sand (layer 3) and medium sand (grade 4). These soils are often distributed in agriculture so it is easy to cause landslides. Especially the middle grain layer (layer 5) is distributed right at the foot of the shore so in the rainy season when the river water rises, the water penetrates deep into the beach. When floodwaters recede, groundwater seeps

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out and drags sand grains at the foot of the shore and causes landslides

E. General comment

Using the method of measured data analysis of over 100 years of the Red River passing through Hanoi, combining the study of the hydraulic regime of the river segment on the physical model, it can be seen that the Red River bed from Thang Long bridge to Duong gate are complex.

The development of Phu Thuong middle bank in recent years makes the mainstream after crossing the Thang Long bridge press close to the left bank of the Tam Xa bank area (downstream of Thang Long bridge 200m), causing the strong landslide in this area, creating a erect bankline, many sliding areas are active, especially the T14 Tam Xa embankment has landslide breaking off body and foot of embankment, so it makes the flow along the old Dau river creek.

The training works system of the left bank (Tam Xa bank) has been built and exploited for over 20 years without maintenance, the system has been seriously degraded and not effective as expected.

With the middle river bed level in the flood and water season, water transportation means mainly follow the trend A, with the river bed level in the low water flood, the flow and creeks are unstable, the mudflats along the navigation channel due to the impact of flood season and bed building water level make water transportation means after crossing Thang Long Bridge have to move along the Phu Gia creek.

Tam Xa bank is a curving segment with the mainstream of upstream of Thang Long bridge Chem peak area has nose protruding like a welding torch towards the mainstream to Tam Xa bank. In this location, it encounters TX14 solid welding torch and resistant of 14 welding torches from Tam Xa bank, horizontally turns and rushes the bank at the upstream of TX14 welding torch not reinforced, causing the serious landslide. According to the measured data analysis combined with the study of hydrological regime, the velocity of the area close to Tam Xa bank is high, the flow direction presses close the bank in all water seasons. When the flow velocity is greater than the starting velocity of the sediment, it will be the main cause of bank erosion; moreover, this is the curved segment of the river, so the effects of the surface circulation flow towards the concave bank, and the bottom flow brings the sediment to the opposite side and moves to the downstream, making the Phu Thuong - Nhat Tan bank more developed and the Tam Xa bank tends to be curving further.

Tam Xa welding torches (14 welding torches by reinforced concrete piles with bamboo shield) preventing the landslide, protect the banks and stabilize the water transportation in Tam Xa was built in 1994 ÷ 1996. In the early period, the anti-erosion effect on Tam Xa bank was quite clear. At present, the shields are lost, some of the tips of the welding torch are tilted, broken, poured; In the downstream area of most of the foots of welding torches, there are large puddles, deep into the bank, and the depth of the erosion hole is -17 elevation. The banklines of Tam Xa bank have jagged edges, creating many vertical whirlpools. When the river bed is deeply eroded, the pile will be collapsed or skewed.

The causes of the abnormal large erosion holes occurrences after reinforced concrete pile welding torch in Tam Xa can be analyzed as follows: After the damaged bamboo shields, the works operate as cross-flow welding torch, which is only suitable with two-dimensional flow. In Tam Xa, the river bed and flow are clearly 3-dimensional, the row of piles can not push the mainstream away from the bank, conversely, the mainstream is pressured to flow into the narrow pile space, the velocity increases, which makes the local erosion hole increased. At the same time, due to the elevation of peak of welding torch is lower (+7) than the flood water level (+12 ÷ +13), the flood flow recedes from the bank through the un-reinforced sloping bank, forming a new river bed erosion of horizontal circulation after the welding torch. Combining two types of horizontal erosion and vertical erosion makes the hole wide and deep.

IV. CONCLUSIONS

The bank of Tam Xa river bank causes a lot of losses in land, houses and crops, directly affecting the political welfare life for riverine inhabitants. On the other hand, Tam Xa beach erosion causes sedimentation of the channel to directly affect the water transport, the variation of the horizontal channel of the Red River through Hanoi and the tendency is returning to the river. C is detrimental to the economic sectors concerned with integrated exploitation of river sections.

Based on the analysis of real data measured and studied the hydraulic section of the river section on the physical model, the author has shown the essential nature and causes of river bank erosion in this section due to the interaction. between the river shape, the movement of the middle beach and the flow causes erosion and changes the river bed. Deep creeks and dynamic shafts close to the river banks with relatively close distance at the water level. Large coastal velocity, in the area of landslide from 1.0 ÷ 1.5 m / s corresponding to creating water level, locally has a place larger than 2m / s and tends to push to the left bank. On the other hand, due to the characteristics of Tam Xa beach, which are quite large over 3km, when floods rise and floods recede with a large flow, the spillway velocity is also the impact on river banks.

River bank erosion due to a combination of many different causes, each river section has causes and mechanisms to cause different landslides, in the new research content only refers to a fundamental problem in dynamics. The river is the flow affecting the lumen and the intermediate product is the sediment transport at a specific river section, not considering the mechanism of soil imbalance, the chemical impact on the Mineral composition of shore soil.

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AUTHORS PROFILE

Quang Hung Nguyen was born in 1975 in Hanoi, Viet Nam. I received the Engineering's degree and M.S. degrees in hydraulic construction from the Thuyloi University of Vietnam, in 1997 and 2000 and the PhD. degree in hydraulic structure from Wuhan University, China. Since 1998, he is a lecture in Faculty of Civil Engineering, Thuyloi University and becomes Associate Professor since 2009. From 2007 to 2013, he was Deputy Director of the Institute of Civil Engineering, designed and built many key projects of Vietnam. He is also principal investigator and member of many national science projects as well as Vietnam Ministry of Agriculture and Rural Development. Since 2013, he has been a senior expert in hydraulic construction of Vietnam Ministry of Construction. He is the Advisor of more than 200 bachelors, 40 masters, 2 PhD specialized in hydraulic construction.

Kien Quyet Nguyen, born in 1973 in Hung Yen, graduated from the University of Civil Engineering and received a doctorate in engineering in Construction of Waterworks at the University of Civil Engineering; Associate Professor of University of Transport Technology. Mainly teach and participate in scientific research projects at all levels of river, estuary and coast hydrodynamics. Main areas of research: application of mathematical models and physical models to analyze hydrodynamic regimes in natural conditions and when building river corrections, adjusting river mouths, embellishment and protection works coastline, thereby proposing solutions to layout space and structure for different types of works, to ensure safety to achieve economic efficiency - technical

Van Quan Tran is a researcher of durability of geomaterials at Institute for hydraulic construction-Vietnam academy for water resources. Dr. Tran holds a Ph.D degree from Ecole Centrale de Nantes-France on 2016. During Apr. 2016 due to Mar. 2017, he is the postdoctoral on Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement (Cerema), France. His researches focused on Durability of geomaterials clay, treated soil, concrete, Modelling of hydro-thermo-chemo-mechanical, Hydration mechanisms of cementitious materials, Thermodynamic modeling, Geochemical model of concrete: corrosion

Huu Nam Nguyen is a researcher of hydraulic construction at Institute for Hydropower and Renewable Energy. Now, he is a PhD student. His research focus on hydraulic power and renewable energy.

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