

# **Dynamic Effect of Variation of River Water Level on Riverbank Erosion**

Synopsis submitted by

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# SYNOPSIS

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Riverbank erosion has long had a significant impact on civilization, particularly with regard to agriculture, human settlement, and flood defence. Man-made facilities are also destroyed by land loss resulting from local riverbank collapse. The researchers are therefore very keen to learn more about the riverbank's stability. The result of bank erosion is riverbank failure. Alluvial terraces and productive floodplains were created over time as a result of riverbank erosion, a natural process. In actuality, some of the banks of even stable river systems are eroding. However, compared to unstable systems, erosion often happens at a considerably slower rate and smaller scale in stable systems. Rivers and streams can undergo abrupt, dramatic alterations due to natural disasters like flooding. Moreover, stream management and land usage might set off erosion reactions. The reactions can be complicated, sometimes impairing stability for decades and frequently leading to faster rates of disintegration. Bank erosion is hastened by management practices such as improper catchment use and deforestation, ill-managed extraction of sand and gravel, and projects affecting the natural course of flow of the stream.

Bank scour and mass failure are the two broad categories into which the different mechanisms of stream bank erosion can be divided. Both will frequently be present in cases of bank instability, with either scour or mass failure predominating. The erosive strength of flowing water rises with flow speed, and scour may occur. A clear indication of scour processes is undercutting of the bank toe. The main goals of effective scour management techniques are to reduce flow velocity through strategically placed vegetation and, in certain situations, bank stabilisation engineering.

The term “mass failure” refers to the several bank erosion mechanisms that cause portions of the bank to slide or topple into the stream. Collapse or slumping are common terms used to describe mass failure. The most visible indications of these processes are sections of slumping bank materials or bare, nearly vertical banks. Although the causes of these kinds of failures are frequently unclear, human and/or natural factors may be involved.

The majority of studies conducted in the subject of riverbank stability are based on experimental findings, which are essentially various case studies connected to a specific river system. For the other river systems, the conclusions pertaining to a particular river have very little physical significance. Also, these kinds of experiments require large investments and consume time. So, it is quite obvious to find out general expressions for riverbank stability with less time and less investigation cost which are applicable for any kind of river system. So, the necessity of the analytical approach is very important. Many researchers have tried to find out an analytical solution in microscopic level. But macroscopic approach to find out the riverbank stability is yet to be investigated. The volumetric rate of erosion has been determined through microscopic study in relation to escape velocity, which is thought to be the most important parameter for determining the stability of bank surfaces. The rate of bank material deterioration is measured by particle escape velocity. Reduced escape velocity translates into a larger volumetric erosion rate, which denotes reduced riverbank stability.

Studying the stability analysis of the riverbank in a dynamic flow scenario with fluctuating water levels is the primary goal of this work. The two categories into which this study has been divided are micro-analysis of the riverbank system and macro-analysis of the riverbank system. Firstly, taking into account the

microscopic forces, a micro-analysis of the particle has been conducted considering well established “Truncated-Pyramid Model” developed by Mukherjee and Mazumdar (2010) meant for microscopic arrangement of particles. Particle escape velocity has been calculated to assess how various microscopic forces affect the stability of the riverbank system. In order to provide visual representations of the stability under various circumstances, the escape velocity change with various parameters, including the water-bridge volume, grain (particle) diameter, and inter-grain distance, has been plotted. To investigate the dynamic behaviour under various water level circumstances both the situations of water level rising and falling have been investigated.

Secondly, a right-angled trapezoidal tension crack failure block has been investigated in order to examine macro-analysis. The common bank angle considered here is of  $60^\circ$  which is in line with Darby and Thorne (1996). Here, in this section transformation of well-established microscopic force analysis into macroscopic force analysis has been implemented which are more practical and comparable with the field data analysis. Using a newly developed method, the microscopic forces in this instance have been converted into a macroscopic force system as a function of number of particles for tends to infinite number of particles using Newton’s forward interpolation series calculation, and the various macroscopic forces have also been taken into consideration while analysing the stability in terms of escape velocity, as the escape velocity is considered to be the most significant parameter to measure the stability of the bank surfaces. Lower escape velocity implies higher the value of volumetric erosion rate which indicates less stability of the riverbank. It has been studied how the escape velocity changes as the number of particles in the tension fracture varies. To evaluate the dynamic behaviour of the riverbank system, here,

changing water level situations were investigated as well for both the circumstance of increasing and dropping water level.

In the microscopic analysis, two different studies have been made. Firstly, varying particle sizes with a fixed value of liquid-bridge volume and secondly, varying liquid-bridge volume with a fixed value of particle size. The escape velocity variations have been plotted against the inter-particle distance for both conditions pertaining to water level rising and falling, for three different degrees of exposure ( $e$ ) of the particle, Fully exposed [ $e=1.0$ ], Half exposed [ $e=0.5$ ] and Fully submerged [ $e=0.0$ ]. The results of adverse effect of inter-particle distances, particle size and the positive influence of liquid-bridge volume on escape velocity have been observed and discussed. From the analyses, it can also be concluded that increasing degrees of exposure reduce the particle escape velocity. Again, this velocity is less in case of water level falling compared to that of water level rising when the other parameters remain constant.

In the macroscopic analysis, a right-angled trapezoidal failure block with infinite number of particles has been investigated while it is subjected to different varying conditions. Three different analyses have been made by varying one parameter, keeping other two parameters fixed. These are liquid-bridge volume, inter-particle distance and number of particle. The results have been plotted with both number of base particles and number of total particles in the failure block, for rise and fall of water level. All three cases show a positive influence on the escape velocity of the block. This is because though the microscopic forces reduce the effect of macroscopic forces (hydrostatic force and pore water pressure force), the macroscopic forces increase at a higher rate. So, by and large, the system escape velocity rises

giving the bank greater stability. It can also be observed that the increasing number of particles increases the escape velocity. This is a testimony of the fact that a bigger size chunk requires more forces to dislodge from the bank surface. Lastly, the graphs of escape velocity are plotted for different free surface heights for different number of total particles in the block to study the dynamic behaviour and its effect on the stability of the riverbank. With an increase in the free surface height from 0 to riverbank height (H), the escape velocity and, hence the stability increases steadily.

Therefore, the newly devised macroscopic analysis has enough potential to play a significant role in the present scenario in terms of suggesting more generalised expressions for escape velocity to predict the stability of the riverbanks. This approach has the capability to incorporate variabilities associated with different riverbank systems of different nature. It can successfully complement the field studies and experimental investigations, being a reasonably robust theoretical approach. In a nut-shell, the present work analyzes the behaviour of a particle or a block subjected to changing circumstances. This may estimate the future scenario based on the present.

## List of publications:

### *Journal Publications*

1. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., (2020) “Effect of Cohesive and Seepage Force on A Bank Sediment Particle.” Indian Science Cruiser, Volume 34, No 1, Pages- 21-26. ISSN: 0970-4256. DOI:[10.24906/isc/2020/v34/i1/195949](https://doi.org/10.24906/isc/2020/v34/i1/195949)
2. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., (2024). “A New Approach to Transformation of Micro Analysis into Macro Analysis of Forces to Study the Dynamic Behaviour of Riverbank Morphology.” ISH Journal of Hydraulic Engineering (Print ISSN 0971-5010 Online ISSN 2164-3040), Taylor and Francis, (Available online) (DOI: <https://doi.org/10.1080/09715010.2024.2317884>)

### *International Conference Publications*

1. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., (March, 2020) “A Dynamic Analysis of Riverbank Erosion.” In: Dawn S., Balas V., Esposito A., Gope S. (eds) Intelligent Techniques and Applications in Science and Technology. ICIMSAT 2019. Learning and Analytics in Intelligent Systems, vol 12. Springer, Cham. pp 337-345. Print ISBN: 978-3-030-42362-9. Online ISBN: 978-3-030-42363-6. Print ISSN: 2662-3447. Online ISSN: 2662-3455. DOI:[10.1007/978-3-030-42363-6\\_40](https://doi.org/10.1007/978-3-030-42363-6_40).
2. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., (January, 2020) “Computational Analysis of Effect of Water Impurity on a Riverbank Particle.” Contemporary Issues in Computing. DOI: [10.26480/cic.01.2020.64.66](https://doi.org/10.26480/cic.01.2020.64.66).
3. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., (February 2021) “Micro Analysis of Riverbank Sediment Stability under Different Wetted Surface Conditions.” IOP Conference Series Materials Science and Engineering 1080(1):012042. DOI: [10.1088/1757-899X/1080/1/012042](https://doi.org/10.1088/1757-899X/1080/1/012042).
4. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., (April, 2021) “Stability Analysis of a Riverbank for Different Microstructural Arrangements of the Particles.” In: Roy P.K., Roy M.B., Pal S. (eds) Advances in Water Resources Management for Sustainable Use. Lecture Notes in Civil Engineering, vol 131. ISBN 978-981-33-6411-0, ISSN 2366-2557, ISSN 2366-2565 (electronic), Springer, Singapore. DOI:[10.1007/978-981-33-6412-7\\_2](https://doi.org/10.1007/978-981-33-6412-7_2).
5. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., (July, 2021) “Effect of Liquid Bridge Volume on Cohesive Sediment Motion.” In: Ghosh S.K., Ghosh K., Das S., Dan P.K., Kundu A. (eds) Advances in Thermal Engineering, Manufacturing, and Production Management. ICTEMA 2020. Lecture Notes in Mechanical Engineering. ISBN 978-981-16-2346-2, ISSN

- 2195-4356, ISSN 2195-4364 (electronic), Springer, Singapore. DOI:[10.1007/978-981-16-2347-9\\_2](https://doi.org/10.1007/978-981-16-2347-9_2).
6. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., (January 2022) “Riverbank Erosion for Different Levels of Impurity of Water—A Micro-analysis.” Advanced Modelling and Innovations in Water Resources Engineering (pp.719-728). Select Proceedings of AMIWRE 2021. Lecture Notes in Civil Engineering (LNCE, volume 176). ISBN: 978-981-16-4629-4. ISSN:2366-2557. E-ISSN: 2366-2565. Springer, Singapore. DOI:[10.1007/978-981-16-4629-4\\_50](https://doi.org/10.1007/978-981-16-4629-4_50).

### **List of Presentations in National / International Conferences:**

1. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., “Determination of Escape Velocity of a Particle on Riverbank under Cohesive and Seepage Force.” National Conference on Trends and Advances in Mechanical Engineering (TAME-2019), February 15-16, 2019.
2. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., “A dynamic Analysis of Riverbank Erosion.” 1<sup>st</sup> International Conference on Innovation in Modern Science and Technology (ICIMSAT-2019), September 20-21, 2019.
3. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., “Stability Analysis of a Riverbank for Different Microstructural Arrangements of the Particles.” International Conference on Sustainable Water Resources Management under Changed Climate, March 13-15, 2020.
4. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., “Comparative Study of Effect of Water Impurity on a Sediment Particle in Riverbank Stability Computation.” 1st International Conference on Contemporary Issues in Computing, ICCIC 2020, 25th - 26th July 2020. (Received Best Paper Award).
5. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., “Effect of Liquid Bridge Volume on Cohesive Sediment Motion.” International Conference on Thermal Engineering and Management Advances, ICTEMA-2020, December 19-20, 2020.
6. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., “Micro Analysis of Riverbank Sediment Stability under Different Wetted Surface Conditions.” 3rd International Conference on Advances in Mechanical Engineering and its Interdisciplinary Areas (ICAMEI-2021), January 6, 2021.
7. Biswas, D., Dutta, A., Mukherjee, S. and Mazumdar, A., “Riverbank Erosion for Different Levels of Impurity of Water – A Micro Analysis.” National Conference on Advanced Modelling and Innovations in Water Resources Engineering (AMIWRE-2020), NIT Jamshedpur, February 20-21, 2021.

