

Sedimentation Optimization on River Dam Flow by Using COMSOL Multiphysics

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Abstract. This paper is a study of the application of material sedimentation on a river water dam that does not need to be streamed again. The problem will be shown in three forms of occurrence that is, while the water is flat, curved and steep down. The finite element method is used to solve the problem in the form of Darcy equation in two dimensional case. The solution is performed by using the COMSOL Multiphysics 5.2 for the flow phenomenon. The results obtained will be more of the material sedimented in flat water conditions, but for the water conditions curved and steep to the bottom water that has not yet experienced more sedimentation is discarded.

1. Introduction

Sedimentation sourced from human activities along the river provides many positive effects such as agricultural land clearing, agricultural irrigation, industrial waste, vegetation clearance on the banks of the river and so on. While its negative impact can be seen along the river body and river estuary. These impacts are as follows: death of marine organisms, decreased biodiversity, shipping line resistance due to silting, disturbance or loss of habitat, decline in natural seafood stocks, sediment size change change, turbidity increase and depth change. Pattern of sediment deployment along rivers and River mouths can be readily known quantitatively over time through sediment model simulations.

The results of the sediment distribution survey can be analyzed by suspicion of potential sediment sources with modeling using initial conditions scenario. The physical, chemical and biological processes of sedimentation effects in rivers and estuaries can be identified using certain scenarios. Some simulations for sedimentation phenomena have been studied by some authors for some case of considerations, i.e mass fraction in the basin [1, 2], flows in the water treatment [3].

Fluids that move through pore spaces in an aquifer or reservoir can shield the porous medium from stress because they bear part of the load from, for instance, overlying rocks, sediments, fluids, and buildings. Withdrawing fluids from the pore space increases the stress the solids bear, sometimes to the degree that the reservoir measurably compacts. The reduction in the pore space loops back and alters the fluid pressures. The feedback brings about more fluid movement, and the cycle continues. Terzaghi Compaction describes a conventional flow model and uses the results in postprocessing to calculate vertical compaction following Terzaghi theory.



Based on the research by Sucipto [9], erosion and sedimentation is the process of removing the grains of land from its mother in a place and the transport of the material by the movement of water or wind and then followed by the deposition of material found elsewhere [8]. The occurrence of erosion and sedimentation according to [8] depends on several factors such as rainfall characteristics, slope inclination, cover plant and soil ability to absorb and release water into shallow soil layers, the impact of soil erosion can cause sedimentation in the river so as to reduce the capacity river. A number of erosion materials that can be fully exposed from the source until they reach the control point are called sediment yields. The sediment yield is expressed in units of weight (ton) or unit volume (m^3) and is also a function of the area of the drainage region. It can also be said that the sediment yield is the amount of sediment derived from the erosion occurring in the catchment area measured over a certain time period and place [4].

This paper will discuss how the sedimentation process in the channel in two dimensional case. The problem is solved by using of the finite element method. The input data come from the physical properties of river water that contain some sediment. What will be done in this simulation is to see how sedimentation occurs in river water purification. And it will be simulated in the three drawings which are in the first drawing in the absence of the lifting of the river flow cover, the second time when the river flow cover opens, and the third when the cover is fully opened.

2. Finite Element Method with COMSOL 5.2

The basic idea in the finite element method is to find the solution of a complicated problem by replacing it by a simpler one. Since the actual problem is replaced by a simpler one in finding the solution, we will be able to find only an approximate solution rather than the exact solution. The existing mathematical tools will not be sufficient to find the exact solution (and sometimes, even an approximate solution) of most of the practical problems. Thus, in the absence of any other convenient method to find even the approximate solution of a given problem, we have to prefer the finite element method. Moreover, in the finite element method, it will often be possible to improve or refine the approximate solution by spending more computational effort.

In 1943 Courant considerably increased possibilities of the Ritz method by introduction of the special linear functions defined over triangular regions and applied the method for the solution of torsion problems [5]. As unknowns, the values of functions in the node points of triangular regions were chosen. Thus, the main restriction of the Ritz functions a satisfaction to the boundary conditions was eliminated. Some problems of chemical mixture can also be computed by using Comsol [6]. The Ritz method together with the Courant modification is similar with FEM proposed independently by Clough many years later introducing for the first time in 1960 the term finite element in the paper of finite element method in plane stress analysis [7]. The main reason of wide spreading of FEM in 1960 is the possibility to use computers for the big volume of computations required by FEM. However, Courant did not have such possibility in 1943. Although the method has been extensively used previously in the field of structural mechanics, it has been successfully applied now for the solution of several other types of engineering problems like heat conduction, fluid dynamics, electric and magnetic fields, and others.

COMSOL Multiphysics software is a powerful finite element (FEM), partial differential equation (PDE) solution engine. The basic COMSOL Multiphysics software has eight add-on modules that expand the capabilities of the basic software into the following application areas: AC/DC, Acoustics, Chemical Engineering, Earth Science, Heat Transfer, MEMS, RF, and Structural Mechanics. The COMSOL Multiphysics software also has other supporting software, such as the CAD Import Module and the Material Library. Therefore for this simulation we use COMSOL program can simulate water flow and its sedimentation using Finite Element Method.

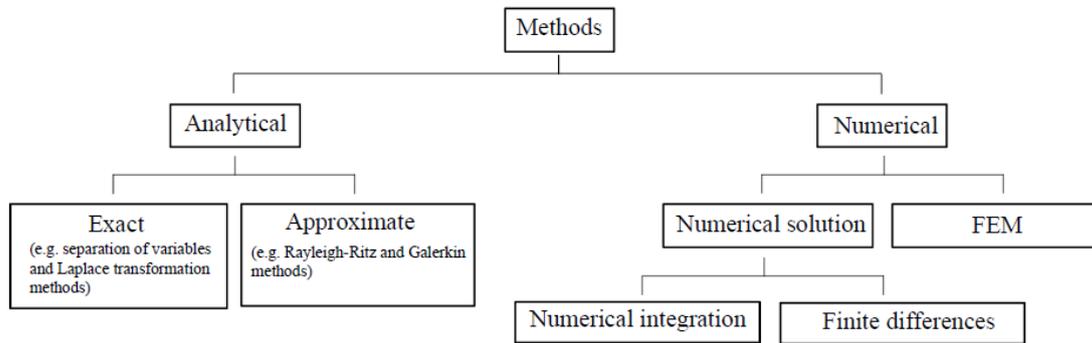


Figure 1. Classification of common Methods

3. Simulation in two dimension

The flow field is fully described using the Darcy velocity in an equation of continuity

$$S_h \frac{\partial H}{\partial t} + \nabla \cdot (-K \nabla H) = 0$$

where S_h is the storage coefficient (m^{-1}), K equals hydraulic conductivity (m/s), and H represents hydraulic head (m). In most conventional flow models, S_h represents small changes in fluid volume and pore space in that it combines terms describing the fluids compressibility, the solids compressibility, and the reservoirs porosity.

Instead of solving Darcy's law in the hydraulic head formulation, we solve in the pressure formulation.

$$\rho S \frac{\partial p}{\partial t} + \nabla \cdot \rho \left[-\frac{\kappa}{\mu} (\nabla p + \rho g \nabla D) \right] = 0 \quad (1)$$

Here, the storage coefficient $S(1/Pa)$ is related to the fluid density, acceleration of gravity and the storage coefficient given in Darcy velocity equation by the relation $S = \frac{S_h}{\rho g}$. Also, the hydraulic head is related to the fluid pressure and elevation $H = \frac{p}{\rho g} + D$ and the hydraulic conductivity is related to the permeability and dynamic viscosity of the fluid $K = \frac{\kappa \rho g}{\mu}$. In this simulation obtained three images for element volume and Darcy velocity in sedimentation.

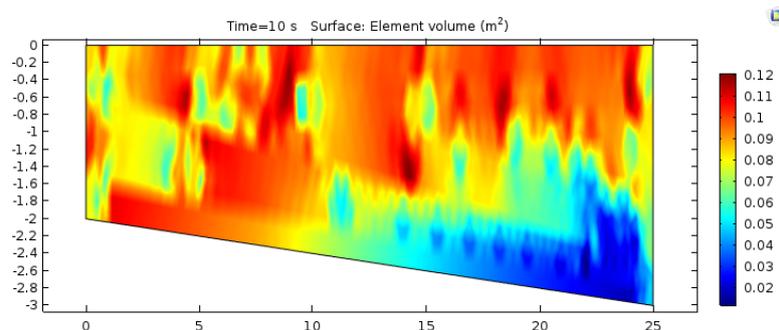


Figure 2. Simulation 1. Element Volume when Closed River Cover

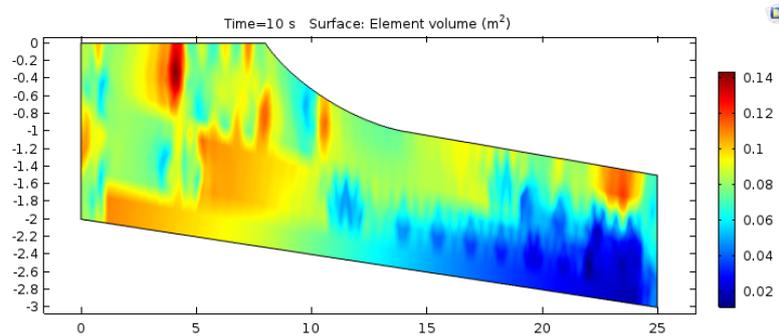


Figure 3. Simulation 2. . Element Volume at Half Open River Flow Covers

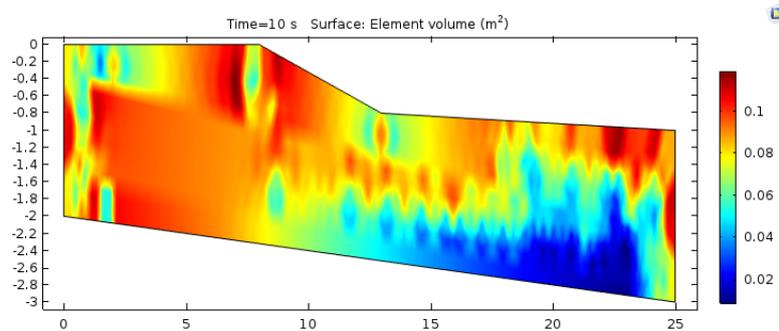


Figure 4. Simulation 3. . Element Volume on Open River Flow

From the simulation we can see how the elemental volume changes (at this time the element in question is water) in the first and second simulations, where the volume of the element decreases shown the less red color and the blue color in the image due to the change in flow shape where the dam cover In half open. While the time is fully open, the volumes of the element tend to be stable and the sedimentation formed (blue color) tends to be less, so for this condition, we can see to optimize the sedimentation process, it is necessary to open the lid of the river dam.

In figure 2, the volume on the sedimentation is stable and looks a bit mixing between water and other solid materials. While the cover will be opened, Figure 3, there is a sudden increase in the volume of solid material in the middle of the section. And when the cover is all open, the solid material is there, almost missing everything, figure 4. It shows the sedimentation process on the water purification where through the three processes we can say, the first process for the collection of solid materials with laminar currents, the second process occurs turbulence So that the solids are unified, and the third process of disposal of solid materials present in the first process

In the three simulations for Darcy Velocity, we can see how the velocity in the second simulation changed drastically because of turbulence when the cover of the dam was opened in half, but the switch was normal after it was fully opened.

4. Conclusion

A 2D numerical computation based on darcy's equation is presented to search the sedimentation phenomenon in the channel of irrigation. Three types of consideration are computed and it is concluded that there are differences between the position for the velocities.

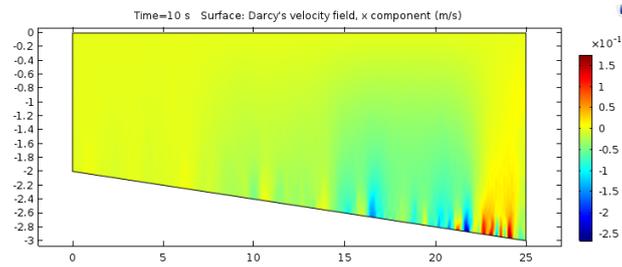


Figure 5. Simulation 1. Darcy Velocity field x when Closed River Cover

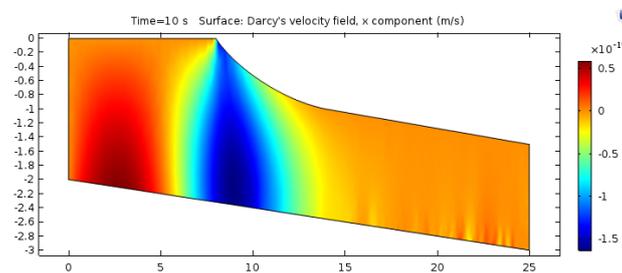


Figure 6. Simulation 2. Darcy Velocity field x at Half Open River Flow Covers

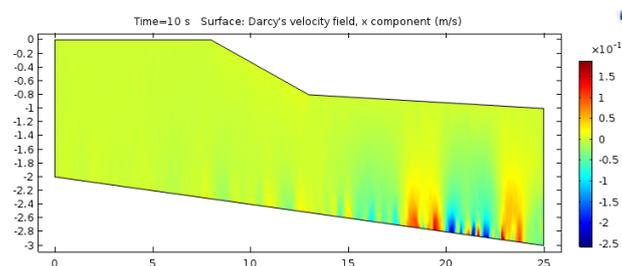


Figure 7. Simulation 3. Darcy Velocity field x on Open River Flow

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