Teaching the Drainage: Experimental Model for Understanding and for Comparison of Different Systems

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Abstract
Water is the most erosive agent that exists on the linear works, yet the abrasion that occurs in civil engineering is still very difficult to calculate.
It is needed assuming some variables like the slope and the design before calculate theoretically the erosion of a drainage system.
However, it is not possible to take into account the enormous variability of factors that affect a natural drainage system in the theoretical calculation. These factors are mainly the spatial and temporal variability of the rainfall, the soil and the vegetation cover. A miscalculation is found when the theoretical calculation is compared with the measured experimental value.
Moreover, the measures under natural conditions mean that the data collection campaign is extended in time, due to the slow process of attrition, which produces it takes long to see the first effects.
Therefore, it would be necessary to wait long time and a lot of financial resources to verify and correct the difference between the theoretical measure and the experimental one.
In order to develop a method that allows engineering students to comprehend the theoretical calculations for designed drainage it has raised the construction of a model. This model of drainage allows us for experimenting using different substrates (PVC, clay, rocks aquarium) but with the advantage of maintaining test conditions constant (same flow rate, same vegetation and the same substrate).
Other difficulty associated with the study of drainage occurs when trying to compare objectively two drainage systems. The proposed model solves this problem, since it has two drains to compare in the model, and keeps the same conditions of sampling in both of them, so an objective comparison of the two systems is achieved.
The model also has another advantage, as it allows a continuous and controlled flow of water in both sampling systems, and speeding up processes and allowing the comparison of both channels in less time.
The use of this model will allow students to:

- *Design new drainage networks.*
- *Evaluate the erosion in different forms experimentally.*
- *Evaluate the performance of drainage systems in different soil types.*

1. Introduction
One of the most frequent difficulties in the subject of Fluid Mechanics Engineer is the complexity of the used concepts, since their definition and explanation in the classroom are not assimilated entirely by students. This produces much frustration for almost all the students, because they feel unable to follow the explanations shown in class. For that and due to every time there is less time available to make students comprehend the whole of the subject, innovation in teaching is a need for helping students to assimilate these concepts more quickly and easily.
As it is expressed in Dale´s Cone of experience [1], reading is the least effective for learning activity, followed closely by the technique of listening the lesson. However, when the sight and hearing are combined within a demonstration or a video, the learning is reinforced. And this improvement is much greater when students participate in scheduled activities, for example with the performance of an experiment and the subsequent common set of obtained results. Apart from increase the motivation and verify the usefulness of learned, students will reinforce the concepts more quickly and the classes may be more interactive [2, 3 & 4].
In addition, at the university, the use of any e-learning platform is increasing (for example Moodle or similar), which is an ideal complement to this new proposal in teaching methodology [5, 6 & 7].

In 1968 Rosenthal and Jacobson made an experiment to analyze the influence of motivation and created expectations for obtaining the final acquired achievements by students [8 & 9]. The demonstrated result was that a teacher with a strong motivation was able to inject and convey enthusiasm to their students, and that produced higher motivation in both students and teacher. Therefore, bearing in mind that highly motivated students are more able to learn for themselves, it is proposed an alternative to the traditional design of laboratory practices, so that they reinforce the significant learning.

Aware of the importance of practices and within a teaching innovation project, a group of teachers of Fluid Mechanics for Engineers have designed a model that simulates a real drainage slope of a linear work, for making different laboratory experiences and thus increase the interest and motivation of the students.

2. Objectives

The main objectives to be achieved are:

- To design experimental material that allows doing different practices that promote student in the learning of Fluid-mechanical engineering.
- This material must also keep different requirements:
  - It should be easy to build, so that any interested teacher can use it in class.
  - It must be economical, as It also seeks to ensure the widespread use of this model by any interested institution.
  - It must be modular, which should allow doing many different practices throughout an academic year.
  - It must have upgradable conditions, to motivate students to contribute with their ideas for improving the model.
  - It should have suitable dimensions for being able to work in a laboratory so that we can thereby work with controlled climatic conditions.
  - It must represent the reality as accurate as possible.

3. Material and methods

The materials used in the construction of the model were:

- Custom furniture made of pine wood, acrylic panels, wheel support, screws, hinges, tools, etc...
- The sides were made with a riprap made with gravel and selected soil.
- Front were made with artificial grass carpets and topsoil.
- It has been used properly sized electrical raceway to model the longitudinal drainage road traditionally known as ditch. It has also simulated the transversal drainage road through pipes that connect upstream to downstream ditch.
- It has been used electrical raceway to simulate the drainage channels at the slope.
- It has been used an appropriate power pump for the closed hydraulic cycle in the pumping zone, plus a water tank, drain pipes, clamps, activated carbon filters, pressure joints, sleeves, dual output stopcock, etc ...
- Some ornaments, which consist on a gravel wall, trees and various shrubs, etc...

The model was built at scale 1:100, with slope 2H: 1V and it is composed of two exactly same sides. Where we can represent the layers of a generic mountain of Spain; taking riprap in the lower layer (15 meters), gravel in the middle (15 meters) and land on the top layer (10 meters). The sub-base is composed of selected soil (1.5 meters) and the base of artificial small gravel (50 centimeters) and a hot bituminous mixture as pavement (S-12 and D-12, 20 centimeters). In this case It has been chosen a reversible cycle of water, water is pumped from the water tank to the upstream ditch of the road, so that through the transversal drainage installed can move to the other ditch and then supplying the two drainage channels of the experiment. It is not necessary to use additional water consumption, which should suppose a bigger economic investment in the performance of the tests.

Two drainage systems with different geometric design have been built (Fig. 1), so that the students can observe the different paths that water lines take, assessing in turn the phenomena that occur when you change the design. In order that the results of the tests on both drainage systems are objectively comparable, the section of both channels have to be the same, also maintaining constant flow and substrate. In addition the test conditions must be reproducible to guarantee the replicability. Three laboratory practices are described below to be performed by students.

3.1 Test of basic hydraulic behaviour

Students, working in teams of 3 people, must predict which of the two drainage systems is more effective. They must also locate areas where greater erosion occurs, to protect them adequately. In these areas it will generate a greater flow velocity and this will erode a very weak substrate. In the Moodle platform will be available to the scripts of the practice with the problem description.

Previously theoretical calculation is made using the formulas explained in the theory class. After that, each students pour four dye drops into water (Fig. 2, blue and yellow) with different colour in each design. The time that takes a drop of water to travel each drainage channels is measured with a chronometer. The timer starts when the first dye drop touches the water and it stops when the last drop has reached the end of the channel. The length of the channels is known, so with the measurement of elapsed time, it is possible to calculate the medium speed, fluid specific energy and drag force.Students should compare the theoretical results with those measured experimentally. They should also check if they have been right in their initial prediction and carry out a brief discussion of the obtained results for each of the drainage systems. This experiment also allows students to observe in the model the path of the water line (Fig. 2), facilitating a faster assimilation of complex concepts such as surface tension or vorticity.

Files recorded videos of the whole experiment will rise to Moodle, so students can see the tests before its performance in the laboratory, and it will be also possible to consult the doubts through forums with peers and through virtual tutorials with the teacher. It promotes student autonomy.

3.2 Test of hydraulic behavior on different substrates

The model allows to experiment over different type of soil and therefore, the tests can perform on the model itself (PVC) or any other type of terrain, such as clay or aquarium rocks. The aim is that students compare the different obtained results for each drainage system and for each soil type.

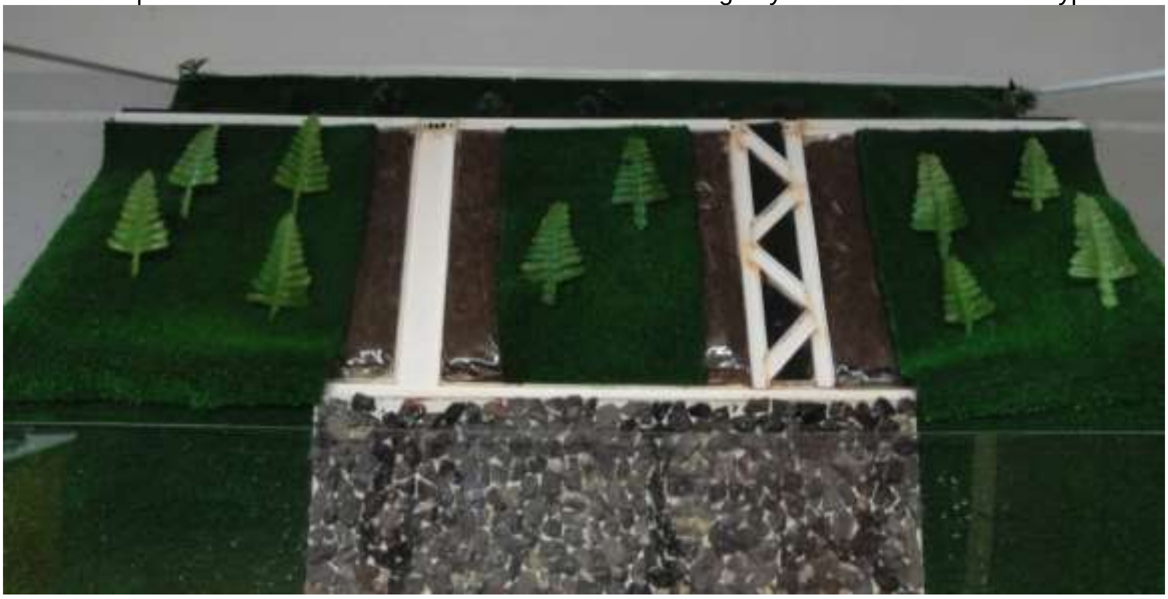

Fig. 1. Front of the model with two drainage system simulating the slope of a road.

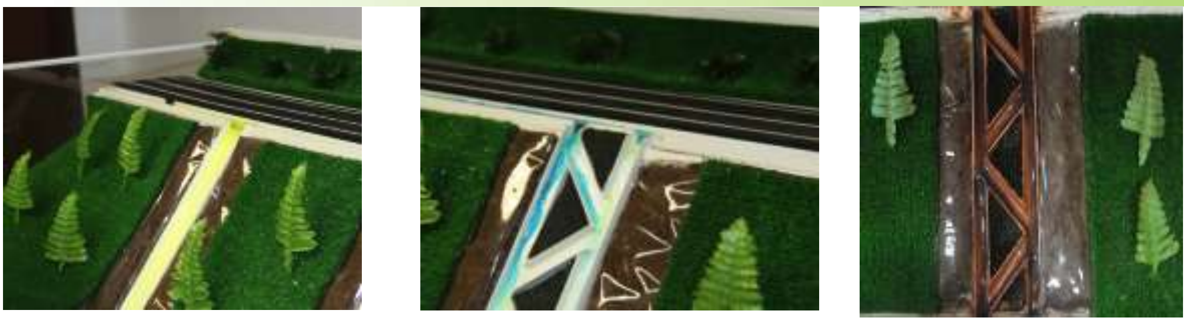

Fig. 2. Path of the water line produced during the tests on PVC and on clay soil.

3.3 Test of erosive analysis

In this practice, students must collect mobilized soil by the movement of water in both channels, in order to compare erosion and sedimentation when clay or aquarium rocks are used (Fig .3).In this test the water that runs through the channels is collected and filtered with coffee filter type conical #2 for observing the ground that is retained in the filter. Whenever you work with different soil of PVC, it is demanded to work with an open water cycle, because the sediment could seal off the pump. To avoid this, it is incorporated a new tank to collect the water with impurities, avoiding falling back into the drainage system again. The filter that retains particles of soil and sediment is placed before the second tank (Fig. 3).

The filters must be dried in a laboratory oven for 24 hours at 105 °C and then they are weighed on a precision balance. Later, the students perform the tests, and the filters with collected sediments are dried in an oven again and weighed on precision balance after stabilizing in a desiccator. Students can compare the weight of the sediments that water erodes each drainage systems in different substrates and they should get their own conclusions.

Every collected filter are photographed, and later the images are treated with Adobe Photoshop software CC 2015, to extract colorimetric histograms of each filter, so you can compare the color intensity and the dispersion. Analyzing these data, you can obtain the evolution of the erosion in the channels over time. Students are requested to contribute their personal opinion about what is happening over time in both channels

4. Results

Students, who initially entered with apathy into the laboratory, improved their attention and academic performance after the realization of laboratory experiments and It increases the rate of students who present to the exam, as other researchers found that this activities reinforced its system of laboratory practices [10, 11 & 12].

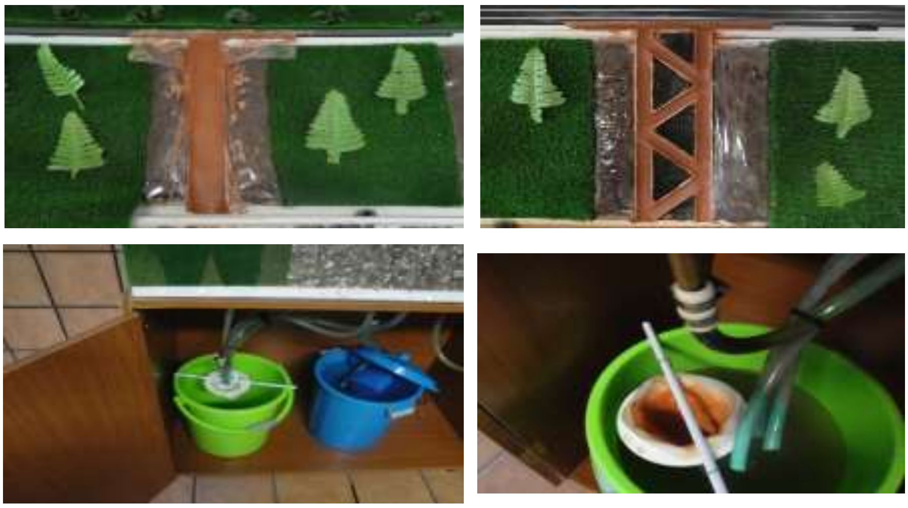

Fig. 3. Molded channels made in clay, water with sediments tank and collection filters.

The designed model has managed to adapt to the conditions requested, since its construction is simple, using cheap and ready available materials. Moreover, as it has explained, it is potentially a

very modular instrument, because it is possible to make very different experiences, calculating the attrition with different substrates, different flow rates and using different test methods.
It also allows working with it under controlled climatic conditions, as it works in laboratory. Another added advantage is that you can move it to different laboratories through the wheels that are set up. And it has been found that the model represents accurately the reality, although in a simplified manner, allowing us to study separately each factor that modify the ground.

5. Conclusions

With the use of the model in the laboratory practices, it is been observed the following improvements in student learning:

- The motivation of the students has increased with a new way of performing laboratory tests, creating a scale model that simulates the process of drainage roads.
- The interest of the students in this subject has enhanced and they can evaluate different designs drainage with the scale model.
- The students are trained in the searching of advantages, disadvantages and weaknesses of the model, preparing them to look for possible future research lines and improvement.
- The model is used as an erosion prediction model to evaluate the usefulness of different drainage systems and erosion over different surfaces.

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