CONCRETE DOSAGE: FROM TRIAL-AND-ERROR TO THE USE OF PERSONAL COMPUTERS, WHICH METHOD IS BETTER FOR UNIVERSITY STUDENTS?

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Abstract

Computer tools have been evolving at an incredible speed in education, especially at the university level. Twenty-five years ago, in university education, there were just beginning to be computer practices based mainly on tools such as Excel in experimental university careers. Today, thanks to the advance in technology, the radiography of universities are very different. Most students come to school daily with their laptops and tablets to college. They are part of the generations called "digital natives." As higher education teachers, we cannot be oblivious to this reality, and we must rethink how to adapt teachings to the daily use of computer technologies. It also means being closer to the procedure these students will follow later when they are professionals in their field. This paper deals with the work done by the Construction Materials unit of the Civil Engineering School to adapt the dosage of concrete to the use of Excel, which was carried out with manual calculations using a calculator until this academic year.

Expressly, the use of the Excel spreadsheet was limited to obtaining aggregate granulometric curves from the mixture of several of them so that they were as similar as possible to a series of theoretical curves through the use of equitable adjustments based on the use of a spreadsheet.

The teacher's challenge in the classroom is twofold. On the one hand, he has the task of making the students understand the factors and limitations to be considered when carrying out concrete batching. On the other hand, it is to explain the use of a specific tool of the Microsoft "Excel" software to know how a least squares adjustment can be carried out.

The present work explains in detail the challenges faced by the teachers, as well as the advantages and disadvantages of moving from a manual procedure (slower, more laborious, and with more room for thought) to a computerized process (more automatic and faster). The latter is how future civil engineers will carry out their work.

The advantages of using this type of tool and the main problems detected in the students related to understanding the procedure they are carrying out will be indicated.

Keywords: Digital native, digital tools, concrete dosage.

1 INTRODUCTION

The debate often arises in the media as to whether using new technologies in the classrooms of primary, secondary, and even university students is beneficial or detrimental to their teaching process [1]. It is undeniable that their use has become widespread, and in the current scenario, their presence cannot be ignored, and we must take advantage of their full potential.

For this reason, during the 2021-22 academic year, within the framework of the subject "Construction Materials and their applications to civil engineering" taught in the second year of the Civil Engineering Degree at the School of Civil Engineering of the Universitat Politècnica de València (UPV), it was decided to start using a calculation program whose use is prevalent. The aim was to use a mathematical tool that would simplify how students carried out an adjustment to a given problem.

1.1 The Context

The subject in which this innovation has been introduced is located in the second year of the civil engineering degree. Table 1 shows the issues taken by students in the first and second years of the bachelor's degree. It can be seen that in the first year, there is an abundance of subjects considered to be essential and that there is a heavy load of mathematics.

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Although we reviewed the contents of the teaching guides for the subjects available to the entire university community [2], we do not know whether the students use any type of software as a tool when taking these subjects.

Table 1. First and second-year Civil Engineering Bachelor Degree subjects.

First Year	Second Year
Basic Knowledge of Programming and Numerical Methods	Engineering Geology
Basic Statistics	Construction Procedures I
Chemistry for Civil Engineering	Construction Procedures II
Drawing	Electrical Engineering
Economics, Legislation and Business Management	Construction Materials and their application to Civil Engineering
Fundamentals of Physics in Civil Engineering	Mathematics Extension Course
Mathematical Foundations of Civil Engineering	Mechanics of Deformable Solids
Mathematical Methods of Civil Engineering	Physics Extension Course
Mechanics	Science and Environmental Impact of CE
Representation systems	Structural Analysis
	Topography

On the other hand, in the 2021-2022 academic year, the course had a total of 72 students, unevenly distributed, with 50 students in the morning group and 22 in the afternoon group. Class attendance is not compulsory and is usually between 60-70% of students.

1.2 The Innovation

The content of the subject "Construction Materials and their applications to CI" is mainly theoretical. An essential part of the course is to introduce students to all the regulations on which the use of materials in different infrastructures and works is based, taking into account their properties and limitations.

The world's most widely used construction material is concrete [3]. A significant part of the course is devoted to explaining it in depth: its components, its properties, how to manufacture it, and its uses.

The act of establishing the proportions in which the components of concrete (cement, water, additives, sand, and gravel) should be mixed to obtain the material with the desired properties is called "concrete batching." Each component must be determined in what quantities are mixed in this process.

In selecting the quantity of cement and water, the variables that must be considered and included in the regulations are resistance and durability.

The type and content of the additives are selected according to the properties to be improved, which are not possible with the range of conventional materials.

Finally, selecting the optimum quantities of sand and gravel will be directly related to the particle size distribution of these materials. The content of each aggregate (sands and gravels) selected to manufacture the concrete will be connected to the compactness we are looking for in the concrete.

For many years, studies have been conducted on obtaining the optimum aggregate granulometry. A series of theoretical granulometric curves have been drawn up, with optimum results achieved in the material. Several theoretical granulometric curves have verified their effectiveness, and two of the best known are the Fuller curves, more effective in the formulation of special concretes (high strength, self-compacting, with fibers, etc.), and the Bolomey theoretical curve with great effectiveness in the case of conventional concrete dosages.

So finally, the exercise of selecting the most suitable aggregates to make concrete is reduced to a mathematical problem in which we have to find out in what proportion we mix the available aggregates (those provided by the quarry to make the concrete) so that it is as similar as possible to the theoretical Bolomey curve. This is a curve-fitting problem. The methodology for doing so will be discussed in the previous section.

2 METHODOLOGY

Concrete batching consists, as mentioned above, of choosing the right amount of cement, water, and additives and selecting the proportion and quantity of aggregates to achieve the material we are looking for.

To carry out the first part, i.e., the quantity and type of cement and the amount of water must be done according to the regulations (in Spain, it is the Structural Code [4]) so that the resulting material has a specific strength and durability.

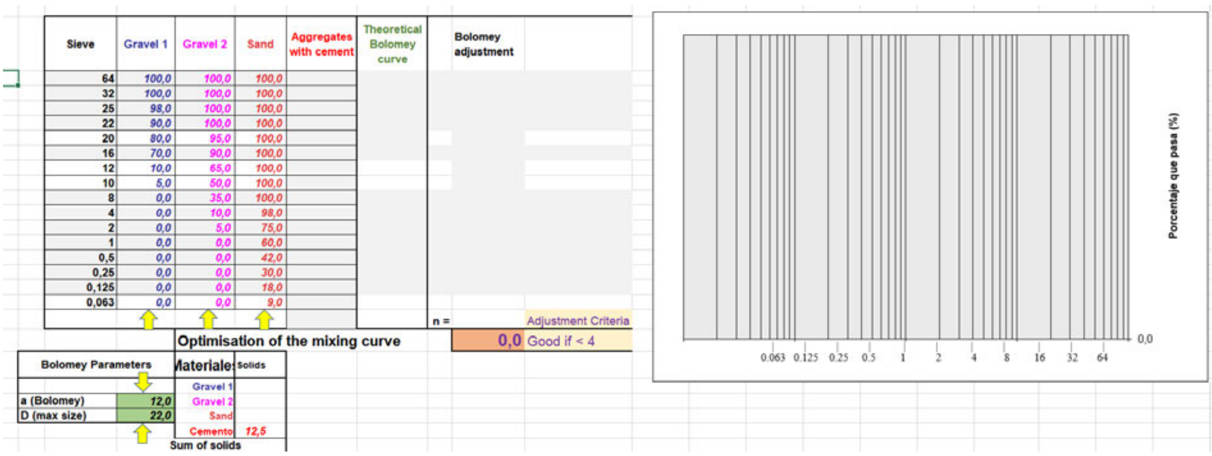
Different methods can select the correct quantity and aggregates to get closer to a theoretical ideal curve. Until the 2021-2022 academic year, the method used for its mathematical simplicity was the method of the granulometric modulus. The problem is that when applying this method (simple but laborious), the best adjustments to the ideal theoretical curve were not achieved.

The positive part is that, being a manual procedure, students have time to think about what they are doing and can identify errors while solving the problem. For example, if at the time of solving a system of three equations with three mathematical unknowns one of the solutions is negative, there must be an error. A negative number can be a solution for this type of mathematical system, but when the value of the result is going to provide us with the percentage by which an aggregate must be incorporated into the mixture, it makes no sense for it to be a negative number. That is to say, students think and go deeper into the problem (let's not forget that it is "in what proportion should I mix the aggregates to have the best possible concrete"), being aware at all times of the stage of the problem they are in.

But realistically, no professional perform this type of calculation manually; for this reason, and given that most students attend class with laptops, it was decided to carry out this part of the problem using the Microsoft Office Excel spreadsheet.

To do this, the students had to include the SOLVER add-in to make the optimal curve fit.

The course teachers provided the students with a spreadsheet template (Figure 1). On this sheet, the students had to enter the granulometric curves of the aggregates with which the concrete was to be made, and the quantity of water and cement per cubic meter of concrete (calculated according to the limitations of the existing regulations).



Sieve	Gravel 1	Gravel 2	Sand
64	100,0	100,0	100,0
32	100,0	100,0	100,0
25	98,0	100,0	100,0
22	90,0	100,0	100,0
20	80,0	95,0	100,0
16	70,0	90,0	100,0
12	10,0	65,0	100,0
10	5,0	50,0	100,0
8	0,0	35,0	100,0
4	0,0	10,0	98,0
2	0,0	5,0	75,0
1	0,0	0,0	60,0
0,5	0,0	0,0	42,0
0,25	0,0	0,0	30,0
0,125	0,0	0,0	18,0
0,063	0,0	0,0	9,0

Figure 1. Template prepared for students

Once the spreadsheet was completed, the SOLVER sentence was executed, and in a few seconds it indicated the quantity of aggregates to be mixed so that the granulometric mixing curve was as close as possible to the optimum theoretical curve.

This procedure is speedy and precise, but the big drawback is that the students only want to know how to fill in the Excel sheet without understanding what they are doing (Figure 2). This undermines the teaching-learning procedure and turns students into mere "fillers" of gaps in a form, which is unacceptable.

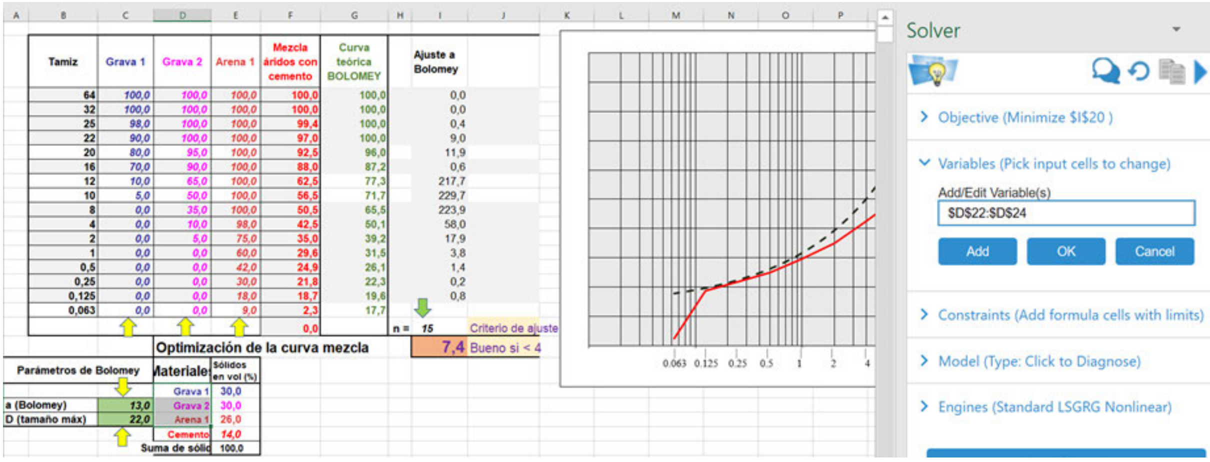


Figure 2. Explanation of the parameters to enter with the SOLVER command

Once the percentage at which the aggregates should be mixed has been calculated, the concrete dosing procedure will be completed (Figure 3).

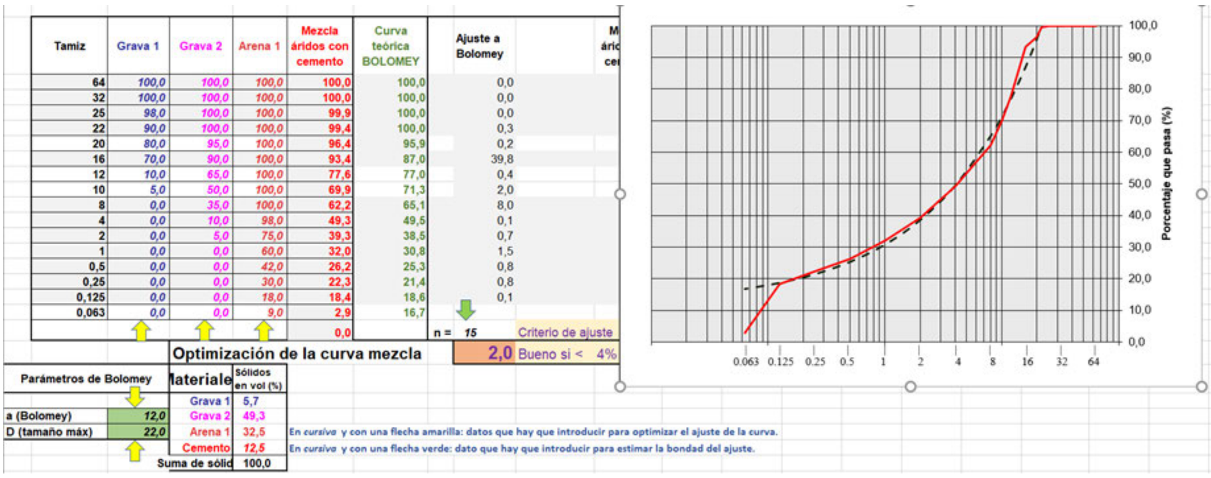


Figure 3. Result of the adjustment of aggregates to the theoretical curve.

It can be directly extracted from the result provided by the spreadsheet, in what proportion the aggregates and cement should be mixed to obtain the mixing curve most similar to the theoretical reference curve.

3 RESULTS

The results obtained when applying the change in the procedure for selecting the number of aggregates to be introduced into the mix were not as expected.

It is true that some of the students, used to working with the Excel spreadsheet, understood the procedure and the reason for using the mathematical tool. However, a very high percentage of students did not understand the purpose of the change in the system for adjusting.

Despite being digital natives and having studied subjects with high mathematical content, many did not know how an advanced spreadsheet function such as the Solver works. Therefore, their efforts were focused on "learning" (not "understanding") how to enter the data in the spreadsheet to arrive at a possible result and not on "understanding" what this procedure was used for.

On the other hand, obtaining the result with the spreadsheet is immediate, as opposed to the manual calculation procedure, which, although simple, is laborious and takes a few minutes. This speed is counterproductive to learning, as students do not have a minute for reflection. Furthermore, we suspect that while some arrive at a workable solution, many do not know precisely what they are doing.

In the traditional (we could say manual) calculation procedure, without the spreadsheet, the students developed a lengthy process in which they had to think about what they were doing while doing the exercise. This led to deeper learning aligned with the learning objective.

Changing how students solve concrete batching problems has meant that in the written tests in which they have to demonstrate the knowledge they have acquired, errors and mistakes appear that clearly show that the problem has not been understood.

It was more common than in previous years to find impossible results, which showed that the students did not know what they were doing. Among these failures, it is worth mentioning the appearance of concrete dosages without using cement (currently not possible for conventional concrete) or sand or "stuck" problems because a negative solution has been given for the percentage of an aggregate, and this does not make any sense.

This has given us as teachers pause for thought, and next year we will approach the teaching of this part of the subject differently. We will begin by explaining how to carry out concrete batching traditionally, and only when the students have internalized this learning process will we introduce the use of the spreadsheet.

We think that in this way, the student will see this process as a tool and not as the end of the learning process.

4 CONCLUSIONS

The main conclusion of the work developed in the 2021-2022 course is that it is necessary to update how the contents are taught in engineering schools to be closer to reality. However, it is crucial to reflect on how these changes are introduced.

The tools provided by the expansion of computer science are tools. This means that the learning objective must not be lost, and thought must be given to how to use them in a way that does not "distract" the student.

Moreover, although our students are digital natives, they have not yet internalized using tools such as spreadsheets to solve mathematical problems.

Any complex mathematical process can be simplified with the use of mathematical tools, but this simplification must be carried out after the internalisation of the problem we are trying to solve. Students will only make good use of these tools when they do not need them to solve the problem (although by using them they will reach the final solution more quickly and accurately).

For this reason, manual problem-solving processes should not be abandoned, but the benefits of the programs developed to facilitate the path to the solution should be presented.

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