Experimental Modules Construction: an Important Methodology to Prepare Future Engineers

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Abstract - **The present work is concerned with a global practice known as Final Undergraduate Project (FUP), adopted at FMPFM College for students attending the last year of a regular environmental engineering graduation course. In general, most of the programs in Brazil permit that the students choose a topic, review the literature and plan an engineering project even making use of existing laboratory equipments or commercially acquired experimental modules. Considering the financial resources sometimes are limited and the necessity of providing the students equipped and upgraded laboratories, an innovation was incorporated to the standard FUP. The students have to construct by themselves an experimental module, besides elaborating an operation manual and implement it for the next group of students, as a regular practice. To accomplish these tasks, the students are encouraged to use their creativity and search for alternative materials for the construction, preferentially the recyclable ones. To overcome the difficulties found during the tasks, the students count with a professor supervisor from the project concentration area. To illustrate this methodology, it was built a module composed by a channel equipped with spillways and a Parshall flume for flow studies, connected with a flocculator-decanter system. The module was validated and adopted for practical studies in laboratory, to permit the students to better understand the phenomena regarding the water flowing in this system and its treatment.**

Index Terms – Decanter, Engineering Education, Flocculator, Parsahll Flume, Spillways, Water Treatment.

INTRODUCTION

The engineering teaching has been a topic of discussions and reformulations in a scale without precedents. The reason for that are multiple and varied. It is important to emphasize that the updated and dynamic technological knowledge impact must be a core point in the engineering education, and can influence the competitiveness among enterprises and organizations [1]. The changes caused by the technological development on the teaching-learning process are very significant. New technologies and tools should be incorporated to the traditional education system of engineering courses as fast as the way they are developed [2].

A good education system has the intention of preparing good engineers for the market. This system can be described as a transformation process, in which the students are transformed in real engineers [3]. Taking in consideration the undergraduate students at the last year of the course, before getting their first job, they should have a clear notion about what be an engineer means and the tasks involved in this profession. So, new technologies and methodologies should be always incorporated by the engineering courses.

Practical activities should be stimulated as an effective way to show the students the kind of tasks the most part of environmental engineers will face after the graduation. Considering these arguments, this is work was based on a project developed by students attending the last year of a regular environmental engineering graduation course. As a matter of fact, this project represents a mandatory discipline known as FUP.

It has specific requisites that must be accomplished along the year. Besides developing the regular steps of a project as searching, planning and dimensioning among other tasks, the main FUP targets are focused in encouraging the students to construct, test, validate, implement and evaluate their own projects. The FUP to be developed by students must include a theme that should be chosen among a list of different themes of interest supplied by a commission of professors, related to environmental engineering practice.

During the whole project, the students count with a professor supervisor with restricted attributions to support their doubts and communicate the commission of professors about any set back, so they can take the necessary actions.

Once the final report is finished, it is lead to the commission of professors. At this moment, two other professors are indicated together the professor supervisor to form a board of examiners, responsible to evaluate and approve the project in two parts: one of them referring to the written report and the other to a verbal presentation. The final evaluation occurs during a verbal defense by means of a formal presentation to the examiners.

THEME CHOICE

The FUP is offered to students attending the last year of environmental engineering as a regular discipline but with some specific regulations. It starts with the choice of a theme by the students from a list of several topics from different areas of study and research. After selecting a theme, the students are oriented to look for a professor supervisor, according to the area of study and research related to the chosen theme.

Once all the students have defined their themes and their personal professor supervisor, the project tasks start following the chronogram prepared by the commission of professors for the main project activities.

THE PROJECT PLANNING

The first task that the students should perform is elaborating a preparatory project including the following items:

1. Introduction
2. Justification for the theme choice
3. Main and secondary objectives
4. A short Literature review
5. Material and methods including prices quotation
6. Chronogram including dates and activities
7. References

This written preparatory project should be formally presented to the commission of professors, which is responsible for evaluating its consistency and feasibility. From the moment a project is approved, the activities start being performed immediately according to the chronogram.

In case of reprobation due to high costs involved, operational unfeasibly, high required time for the construction or even technical deficiency or poor quality related to the written project, the students are encouraged to reformulate it, inside a pre-determined period of time for a new submission to the commission of professors. Otherwise, the FUP should be attended for the students only in the next year.

EXPERIMENTAL MODULE CONSTRUCTION

An experimental module construction was chosen to exemplify the application of FUP, focusing its construction and implementation by own students. This module is formed by a hydraulic channel, removable spillways, a Parshall flume, a hydraulic flocculator and a conventional decanter.

As a first step, based on a real water treatment station, the calculations were realized by students to promote a reduction for a laboratory scale. In order to dimension, built and guarantee the module longevity, the students took some prerequisites in consideration, as the place for installation, the maximum theoretical operation outflow, the material roughness coefficient and resistance for the construction. Besides, a specific care was taken to the channel characteristics such its inclination, its throat width, the upstream and downstream heads, the volumetric flow and the head ratio.

Additionally, a triangular and a rectangular configuration for the spillway were chosen. All welding tasks were performed by the own students. Firstly, the plates were precisely cut and then welded to assure a perfect fitting of the module peaces. For the decanter construction, the sedimentation velocity was calculated through the graphic method of Talmadge and Fitch [4], and then, it was determined the superficial area and the height. For a better visualization of the physical and chemical phenomena that occur during the flocculation and sedimentation processes, the module was equipped on the external side by a glass plate from 10 mm of thickness.

In the flocculator it was adapted a sequence of two vertical baffle plates to increase the residence time of raw water mixed with the flocculant agent, and aid the flocs formation. Between the flocculator and the conventional decanter, it was mounted a distribution curtain, with the purpose of keeping uniform the water flow in treatment. It is hope that the flow passing through all the orifices stays constant.

A very important condition is assuring that gradient of velocity in the flocculator passage way is lower or equal than the gradient of velocity inside the flocculation chamber to avoid the flocs fragmentation. All the unities mentioned above were connected upon a wood basis to compose the module (Figure 1) and after the final adjustments, it was painted by own students.

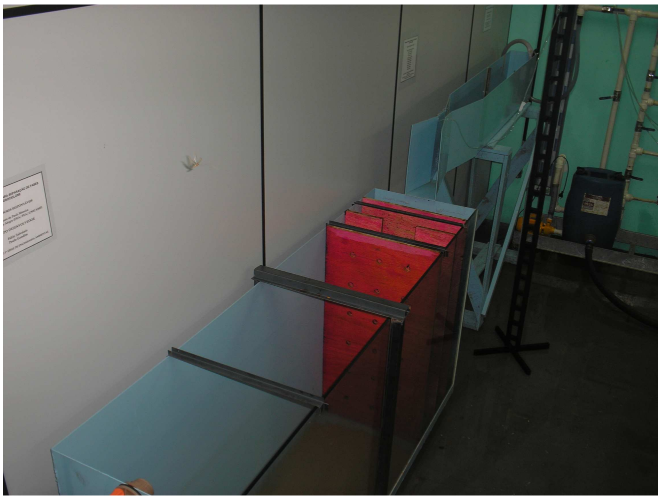

FIGURE 1
EXPERIMENTAL MODULE AFTER CONSTRUCTION

MODULE VALIDATION

After finishing the module mounting, its validation was performed in two stages, one related to the channel linked with the Parshall flume, and the other to the flocculator-decanter system. The experimental results obtained from the runs were compared with the estimated results from the theoretical equations presented in the sequence of this work.

The channel maximum volumetric flow was determined by the use of Chezzy's formula [5], described as:

$$Q = \frac{1}{n}.A.Rh^{2/3}.I^{1/2} \qquad (1)$$

The rectangular spillway volumetric flow was calculated through Francis' [6] and Neves' [7] formulas:

$$Q = 1{,}838 \, .L.H^{3/2} \quad (2)$$

$$Q = \left(1{,}816 + \frac{1{,}816}{(H.1000 + 1{,}6)}\right) \cdot \left[1 + 0{,}5 \cdot \left(\frac{H}{H + p}\right)^2\right] . LH^{3/2} \quad (3)$$

The triangular spillway volumetric flow was found through Francisco's [8] and Delmée's [9] formulas:

$$Q = \left(Cd \, . \frac{8}{15} .tg\,(\theta / 2). \sqrt{2.g} \, .H^{\frac{5}{2}} \right) \quad (4)$$

$$Q = \frac{8}{15} .C'.tg\,(\theta / 2). \sqrt{2\,g\,.h^5} \quad (5)$$

The discharge coefficient for (4) is estimated as:

$$C_d = \frac{15 \, .Q_{real}}{8 \, .tg\,(\theta / 2). \sqrt{2\,gH^5}} \quad (6)$$

The Parshall flume volumetric flow was obtained through Delmée's [9] and CPRH's [10] formulas, respectively described as:

$$Q = a * hc^n \quad (7)$$

$$Q = 2{,}2 * w * H^{3/2} \quad (8)$$

For the volumetric flow measurements during the trials on the channel connected with the Parshall flume (Figure 2), it was used a tank with the capacity of 20 L, doted by an external scale to verify the level variation, which indicates the volumetric flow. The level measures only could be taken after the system reaches the steady state.

FIGURE 2
MEASUREMENTS DURING THE TRIALS

For the second stage, the flocculator-decanter system dimensioning was based on the *HRT* (hydraulic retention time) (9). Firstly, it was determined the system volumetric flow and the tank volume. So, the *HRT* could be calculated, as shown [11]:

$$HRT = \frac{V}{Q} \quad (9)$$

Through the *HRT* information, the number of baffle plates to be installed on the system was obtained. To dimension the distribution curtain, a sequence of estimations was effectuated as follow [12]:

- Superficial flowing rate:

$$SFR = \frac{Q}{A_s} \quad (10)$$

- Sedimentation velocity [11]:

The sedimentation velocity is chosen based on the *SFR* application limit and the treatment water station capacity Q, according to Table I.

TABLE I
FLOWING LIMIT RATE AND SEDIMENTATION VELOCITY

Q (m^3/day)	V_s (cm/min)	*SFR* Application Limit (m^3/m^2.day)
Until 1000	1,74	25
From 1000 to 10000 (a)	2,43	35
From 1000 to 10000 (b)	1,74	25
Up to 10000	2,80	40

(a) Suitable operational level (b) Unsuitable operational level

- Maximum horizontal sedimentation velocity:

$$v_{max} = 18 \cdot v_s \quad (11)$$

- Gradient of velocity in the flocculation chamber:

$$G = 3162 \sqrt{\frac{Q \cdot hf}{V}} \quad (12)$$

- Baffle plates hydraulic diameter [11]:

$$Dh = 4 \cdot \left(\frac{A_w}{P_w}\right) \quad (13)$$

- Gradient of velocity in the decanter passage way [11]:

$$G = \frac{1027 \cdot D}{S} \cdot \sqrt{\frac{v^3}{x}} \quad (14)$$

Based on the calculations it was possible to determine that the distribution curtain should be doted by 6 orifices of 20 mm diameter vertically aligned, and 3 horizontally aligned, to form 10 square meshes of 0.15m.

The experimental module was built based on the above calculations. To validate the module dimensions and its performance regarding its effectiveness in promoting the flocculation and the settling, several trials were realized.

According to the aluminum sulfate reaction stoichiometry with water, some trials were effectuated by the use of a jar- test equipment doted with 6 vessels of 2 L each, to obtain the optimal dosage for the coagulator. The dosage varied from 20 to 120 mL with a concentration of 2% m/v. To keep the pH equilibrium around 7.0, NaOH was added in the range of 5 to 30 mL with a concentration of 2% m/v.

The raw water for the trials was collected directly from Mogi Guaçu River. The best values of flocculant dosage to reduce the turbidity and color parameters were achieved in jar-test. The next step was performing several runs by the use of the experimental module, trying to reproduce the results obtained from the jar-test trials and validate the system.

RESULTS AND DISCUSSION

Once finished the experimental module mounting and all the preliminary tests to guarantee a reliable operation, several runs were taken as mentioned to generate a database. The water height measured in the Parshall flume was used to calculate the volumetric flow as in (7) and (8), which was compared with the real volumetric flow measured through a small tank and a chronometer (Figure 3).

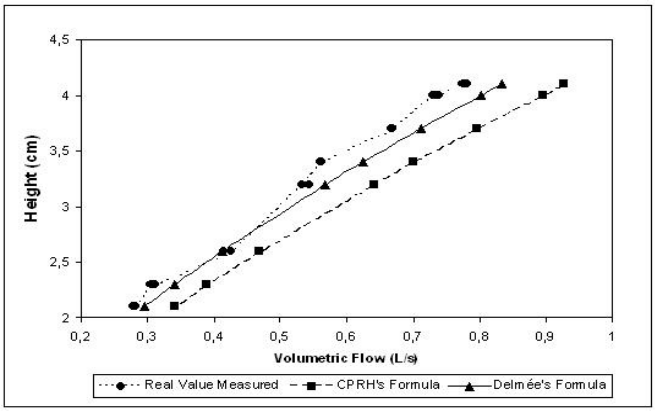

FIGURE 3
VOLUMETRIC FLOW IN THE PARSHALL FLUME

Figure 4 shows that the volumetric flow of the rectangular spillway calculated as in (2) and (3), presented a very well fitting in comparison with the real volumetric flow measured during the experimental runs.

According to Figure 5, the volumetric flow values estimated as in (5) were not satisfactory, due to this formula be limited for water leafs lower than 60 mm. By using (4), the volumetric flow values showed an excellent approach in comparison with the real measurements realized during the runs. It is well explained by the fact that the discharge coefficient as in (6), takes in consideration the real volumetric flow.

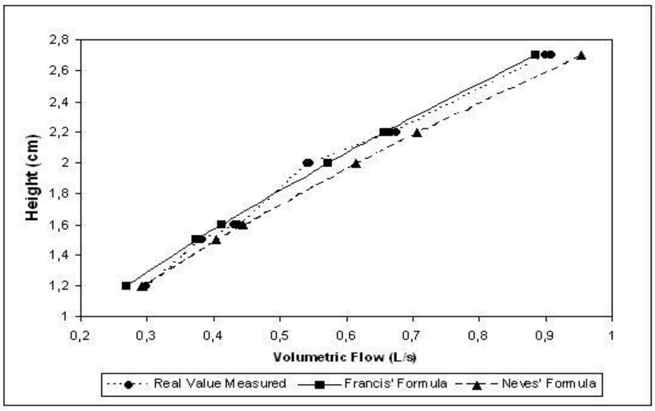

FIGURE 4
VOLUMETRIC FLOW IN THE RECTANGULAR SPILLWAY

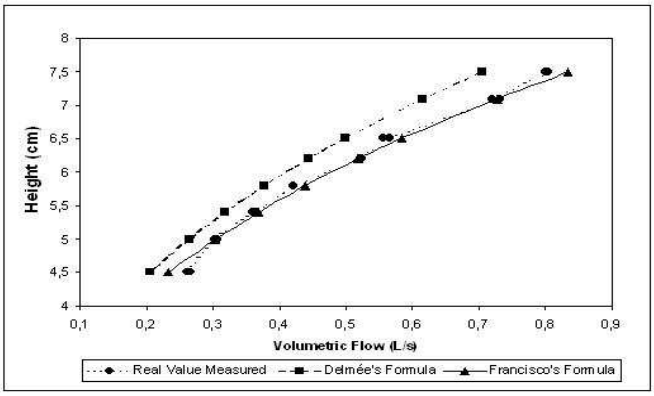

FIGURE 5
VOLUMETRIC FLOW IN THE TRIANGULAR SPILLWAY

A fast coagulant mixture with the raw water was effectuated with an agitation speed of 151 rpm during 15 seconds. The slow mixture to avoid the breaking of the formed flocs occurred with an agitation of 15 rpm during 20 minutes. After several trials with different dosages of coagulant $Al_2(SO_4)_3$ and alkali NaOH, the optimum conditions to promote the flocculation and settling were achieved showed in Table II.

TABLE II
RAW WATER CHARACTERISTICS, DOSAGES AND JAR-TEST RESULTS

Raw Water		Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
Turbidity (NTU)	20	1,43	0,33	0,31	0,30	0,24	0,17
Color (Pt/Co)	206	9,8	1,7	4,3	3,0	8,3	3,4
pH	6,7	5,2	4,5	4,45	4,46	4,42	4,44
T (ºC)	26	27	26,6	26,6	26,6	26,6	26,5
$Al_2(SO_4)_3$ (mL)		20	40	60	80	100	120
NaOH (mL)		5	10	15	20	25	30

The first chemical product to be added was the alkali followed by the coagulant. It was noticed that the flocculation occurred as expected; the bigger flocs started settling by passing through the vertical baffle plates and the distribution curtain, accumulating down along the decanter. At the decanter inlet and outlet, samples of water were colleted for the laboratory tests.

Table III demonstrates the average values after 10 experiments for the principal water characteristics.

TABLE III
EXPERIMENTAL RESULTS FOR THE SYSTEM FLOCCULATOR-DECANTER

Characteristics	Raw Water	Settled Water	Reference Values *
pH	6,5	6,4	From 6,0 to 9,5
Color (Pt/Co)	300	42,6	15
Turbidity (NTU)	30	12,7	5
T(ºC)	26	27,5	-

* Local Regulation for the Maximum Permissible Values for Treated Water

The pH and water temperature presented a very light variation. The turbidity reduction was around 58% while the color reached about 86%, when compared with the maximum permissible values established by the local regulations for treated water. These percentages can be considered very representative once the water was not leaded to a filtration process.

It is very important to register that after the construction finalization and the experimental runs, a module operating manual was elaborated by the students and adopted by the Basic Sanitation and Hydraulic disciplines for practical studies in laboratory, to permit the students to better understand the principal phenomena regarding the water flowing in an open channel, Parshall flume, spillways, besides its treatment.

CONCLUSIONS

The present work is concerned with a complementary learning methodology adopted for students attending the last year of a regular environmental engineering graduation course. The project elaborated for an experimental module construction as required by the FUP was successfully implemented, by own students. The FUP focus in constructing, testing and implementing an experimental module adopted by FMPFM College, in comparison with traditional Brazilian programs, can be consider an innovation.

As an important result, it was possible to identify that the students were very dedicated during the whole project execution, showing a high interest in applying all the theoretical knowledge acquired along the course. All of this culminated in a solid practical background, permitting that the students recognize the relevance of executing an engineering project in its totality instead of only planning.

This successful implementation evidences about how important was the adoption of this new focus for the FUP. Besides all the skills developed and demonstrated by students along the project, it was clear to see their growing by observing their ability to improvise and innovate in order to overcome a range of difficulties. It is notable that they really fell as real engineers after this process and certainly they will be more prepared for the real work market competitiveness.

Another significant contribution is regarding to the use of low cost recyclable materials for the module construction. It enables the laboratories be improved in despite of the limited resources.

NOMENCLATURE

a	Parshall flume tabled dimension
A_s, A_w	decanter area, m^2, and wet area, m^2
C', C_d	discharge coefficient
D	orifices diameter of curtain distribution, m
D_h	hydraulic diameter, m
g	acceleration of gravity, m/s^2
G	gradient of velocity, s^{-1}
H, h_c	water leaf height, m
h_f	pressure drop in the orifice, m
I	channel inclination, mm/mm
L	water crest width, m
n	Manning coefficient
p	spillway height, m
P_w	wet perimeter, m
Q, Q_{real}	volumetric flow calculated and measured, m^3/s
R_h	hydraulic radius, m
S	distance between the center of two orifices, m
V	floculator volume, m^3
x	distance reached by water jet distance from the distribution curtain, m
w	throat width of Parshall flume, m
θ	spillway angle
ν	cinematic viscosity, m^2/s

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