

Sustainable Practices in Civil Engineering Laboratories

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ABSTRACT: All over the world, Civil Engineering labs have incorporated sustainability into planning, procurement, management of the labs and the experiments given to the students. The Civil Engineering Department, the youngest department at Mohandas College of Engineering and Technology, Trivandrum, all the labs were recently erected. A unique method of approach is adopted in the setting of each lab - in procuring, installation and maintaining of machinery, thereby all the machines and equipments are giving perfect performance and result. There are seven labs in the Civil engineering department at the undergraduate level - namely, Strength of material lab, Survey lab, concrete lab, Geotechnical engineering Lab, Transportation engineering Lab, Environmental Engineering Lab and Civil Engineering Drafting lab. The labs have been set up to enable students to use the techniques, skills and modern engineering tools necessary for engineering practice. Sustainability practices are followed by caring and maintaining the equipments properly and reusing the specimen possible.

KEYWORDS: sustainability; civil engineering laboratory; green labs; procurement

I. INTRODUCTION

Watch and Tolaton [1] have listed the key aspects of sustainable laboratory design as:

- Increased energy and water conservation and efficiency
- Reduction or elimination of harmful substances and waste
- Improvements to the interior and exterior environments, leading to increased productivity
- Efficient use of materials and resources
- Recycling and increased use of products with recycled content

The design of the building envelope (overhangs, glazing, insulation and use of photovoltaic panels) plays a large role in facility's energy efficiency [1]. Vigil [2] stresses that an understanding of sustainability is important for all engineering students, but especially for Environmental Engineers who will be taking leadership roles on sustainability issues. It discusses the development of a graduate and senior level course which provides the knowledge, computational, and experimental skills in sustainability for these future engineering leaders. The Department of Civil and Environmental Engineering at Rice University stresses on enhancing the sustainability of infrastructure systems and supporting natural resources. From the research laboratories to the classrooms and beyond, the new generation of civil and environmental engineering leaders will be trained with the knowledge of current best practices and the creative agility to advance into the future [3].

The Harvard Office for Sustainability's Green Labs Program works with researchers, staff, faculty, and building managers to envision and implement sustainable practices and technologies that increase efficiency, reduce energy use, and conserve resources in lab buildings across the campus. Their goal is to expand the concept of the campus as a "living lab" by utilizing the passion of laboratory community to operate greener, more sustainable labs that serve as a model for others inside and outside the University. Because of the resource intensity of research in labs and the unique conditions in each individual lab, sustainability is approached at the lab-specific level in addition to a building-wide perspective [4,5].

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The University of Washington Department of Environmental & Occupational Health Sciences Continuing Education Programs offers a one day professional development course on best “green” practices for laboratories. This included information on designing laboratory activities to prevent chemical exposures, strategies for communicating safe chemical use, chemical waste management, and chemical selection. The purpose of the course is to share best practices and to improve the selection, evaluation, and use of chemicals in the laboratory [6].

The UC Berkeley Green Laboratory Certification Program recognizes Laboratories that implement sustainability practices and continually aim to reduce their carbon footprint. The Chancellor’s Advisory Committee on Sustainability has identified a list of sustainable actions that can be implemented by labs in order to satisfy the requirements for Green Certified Laboratory [7].

The greenNDiscovery program of the University of Notre Dame is designed to reduce the university’s carbon footprint by promoting energy efficiency in research laboratories, the most energy intensive areas on campus [8].

The Cornell University has identified 3 sustainability issues in Modern laboratories namely: (1) Carbon footprint of labs, (2) Developing Green Labs, and (3) Right sizing through risk assessment [9]. Ventilation and cold storage of samples are the two largest use of energy.

Sustainability concepts were introduced into the Civil Engineering Materials course at Manhattan College by requiring students to design their own “Greencrete” using recycled materials for their term project [10]. Students were allowed considerable freedom in choosing the recycled materials, and were challenged to predict the strength of the “Greencrete” they developed. In addition to introducing students to sustainability concepts, the project developed their creativity and critical thinking skills, enabled them to learn concrete design concepts more thoroughly, and provided a challenging yet fun learning environment that they enjoyed. Civil engineers are being increasingly expected to develop sustainable solutions to infrastructure and technology problems, yet they may find themselves inadequately prepared to provide answers [11]. In a 2006 study, the rating of new graduates’ knowledge of sustainable principles was only 2.8 out of 10, department support for teaching and research in sustainability was 4.7 out of 10, and the university leadership’s support of sustainability was 3.0 out of 10 [12]. A paradigm shift is thus necessary to educate students to recognize sustainability as a changing constraint in engineering.

Female civil engineering students with thinking type personalities showed an increase in interest in civil engineering after an introductory civil engineering course with sustainability related topics, whereas other personality types maintained “considerable” interest in civil engineering at the end of the course. Framing an introductory civil engineering course around sustainability may hold promise to increase female student interest in civil engineering. It is important to continue this study and increase the sample size to determine if this trend continues. Male civil engineering students in this study with feeling type personalities showed a larger increase in interest in sustainability at the end of an introductory civil engineering course with sustainability related topics. This result indicates that sustainability may be a viable way to attract atypical male engineering types into civil engineering [13]. References [14-19] indicate the need to incorporate sustainability aspects into curriculum.

All over the world, different Universities have adopted practices in the laboratories for sustainability and to train and instill sustainability concepts in young engineers. This paper discusses the sustainability aspects in MCET labs under different sections: procurement, installation of the laboratories, phasing of procurement, management of labs, preparation of manuals, and engagement of classes.

II. SETTING UP OF CIVIL ENGINEERING LABORATORIES

In this section, the details of procurement and setting up the labs are presented. Much importance has been given to follow the space requirements and sustainability.

A. FLOOR AREA

The floor area of every lab was decided considering mainly two factors namely the student strength and the AICTE norms regarding this. The volume of equipments to be installed has also been considered. On an average of 30-35 students are expected to attend per session.

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TABLE I. LAB FLOOR AREAS AND AICTE REQUIREMENTS

Sl. No.	Name of lab	Available floor area in m ²	Floor area requirement as per AICTE Norms (m ²)
1	SM Lab	89.7	66
2	Survey Lab	70.0	66
3	Geotechnical engg. Lab	93.7	66
4	Concrete Lab	117.0	66
5	Transportation engg. Lab	79.8	66
6	Environmental engg. Lab	72.0	66
7	Civil Engineering Drafting Lab	118	66

B. PLANNING OF LAB FLOOR AREA

All the machines are aligned in single row pattern with sufficient space in between, thereby a group of five or six students can be attended at a time and thereafter individually, and each one could be monitored from the faculty seat easily. Machines are mounted on separate foundations of sufficient height and a board carrying the name of machine with loading capacity is fixed on the wall behind. Maximizing the availability of natural day light is an important principle of sustainable design; not only does it reduce energy consumption, but it also increases comfort and enhances productivity.

C. PROCURING OF LABORATORY MACHINES AND EQUIPMENTS

All lab items have been procured by competitive Tenders. A well established purchase procedure had been followed. A schedule of items for each of the lab with cost anticipation was prepared first, after referring the syllabi; Got approved from the management. Paper notification was given by the Management for sealed tenders. The Signed and sealed tenders so obtained were scrutinized and evaluated by an expert committee; and a detailed tender evaluation report with purchase recommendation have been submitted to the management. As per the purchase order issued by the management, supply and installation of items have been made by different firms.

D. INSTALLATION OF LAB MACHINES AND EQUIPMENTS

Prior to installation, appropriate machine foundation is made as per the technical drawing and specification provided by the supplier. Electrical wiring and power supply of sufficient wattage is also arranged by the college. Placing the machine in position and installing has to be done by the supplier. After installation, trial run and demonstration is done by the supplier. All the machines are aligned in single row pattern with sufficient space in between, permitting a group of five or six students to comfortably observe and carry out the experiment.

E. PHASING OF THE PROCUREMENT OF THE LABORATORIES

The phasing of the procurement is shown in Fig.1. The procurement, supply and installation of equipments of the different labs have been made by different firms over a period of 2 ½ years. The phasing has enabled the spreading of the cashflow.

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LAB	Jun-04	Jan-05	Jun-06	July'14	Jan'15	July'15	Jan'16	July'16
SURVEY LAB								
STRENGTH OF MATERIALS LAB								
CONCRETE LAB								
CAD LAB								
TRANSPORTATION LAB								
GEOTECH LAB								
ENVIRONMENTAL LAB								

Fig. 1. Phasing of procurement

III. MANAGEMENT OF THE LABS

The management of laboratories involves several aspects for each of which acceptable practices are followed. Some of the aspects are described below.

A. STOCK MAINTENANCE

On satisfactory supply, installation and demonstration of the lab machines, each item have been registered in a Central Stock Register, maintained by the supervisory lab instructor, who has over all charge of the laboratories. These items are again taken into stock in the concerned stock registers maintained by the lab in charge of each lab.

B. PROCUREMENT AND DISTRIBUTION OF CONSUMABLES

Consumables like lab specimen/Lubricant/cotton waste/ hand wash etc are procured centrally and distributed to different labs on demand. Separate stock register is maintaining for consumable items in each lab.

C. MAINTENANCE AND CALIBRATION OF EQUIPMENTS

Daily dusting /cleaning/up keeping of equipments and weekly maintenance are done by the laboratory in charge themselves. A separate register is being maintained and updated by them to record the weekly maintenance. If any malfunctioning /fault in working are detected, it is duly informed to the supervisor for rectification. Annual maintenance and calibration of equipments are carried out annually by external experts. Calibration of all important items should be done by approved Independent agency. All valid calibration certificates are maintained as quality documents for future reference.

Log slip showing calibration date and next due date for calibration is pasted on every machine.

D. SAFETY OF STUDENTS

All students should wear tight dress with laboratory coat while working in the lab. Each student is provided with manual of experiments which provides the theory and stepwise procedure for conducting the experiments. Before students can independently work in the laboratories and operate any equipment, they must read and understand this document. It is desired that number of experiment set up be so arranged that maximum four students shall work on one set. While operating ovens or handling chemicals, hand gloves and safety goggles should be worn. First Aid Kit is provided in every lab. Fire extinguisher is located in the hallway leading to the laboratory and everyone is provided training for operating it in an emergency. Each laboratory has sufficient openings to provide enough natural light and ventilation.

Clean Up - All students using the lab must clean up the tools, the equipment and the work areas when finished with a task or at the end of work day, whichever comes first. All tested material shall be properly handled and disposed. They are always required to maintain a clear egress and walking path – remove potential fall, slips and trip hazards before leaving the laboratory.

In each laboratory, the safety precautions to be followed by the students have been prominently displayed.

E. EQUIPMENT LOGBOOK

Equipment logbooks are maintained in each lab which counts the usage of all the equipments. Every batch of students has to collect the equipments and tools from the lab Instructor in charge, after entering details of equipment issued to them and signing in the log book, prior to start of the day's work. After completion of the experiment the items has to be returned without damage, which will also be indicated in the log book.

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F. CLOSE CO-OPERATION WITH THE CAMPUS PROJECTS DEPARTMENT EQUIPMENTS.

The sustainability practices are also followed in sharing the expertise / technical know-how and tools and equipments to the general use of the college. For example the capacity of survey lab and CADD lab is used to prepare the campus map / concrete lab facility is used to examine the quality of cement, concrete and aggregate used in the different construction activities going on in the campus. Environmental lab facility is used to check periodically the quality of drinking water supplied to the campus etc. So many community linked programmes are arranged by the college NSS unit, with the active participation of students. The above shown examples are relevant and useful to the common man too. By sharing these experiences to the public, off course, with the consent of college authorities, they are getting an off syllabus experience to share their campus life with the community.

G. CO-OPERATION WITH THE BIOTECHNOLOGY LABORATORIES EQUIPMENTS.

Sharing of interlab facilities and experiences is another area of sustainability practice. For example large quantities of distilled water is required in many a labs like Environmental engineering lab, Geotechnical Engineering lab, Transportation engineering lab in civil engineering department;and purchasing distilled water is not viable compared to producing in the lab itself. But installing a distillation plant in the lab is also a costly affair. So the idea of sharing the distillation facility available in another department in the campus was thought of. Co-operation of Biotechnology Engineering department to supply distilled water from their lab to Civil Engineering labs, give rise to a best sustainability practice.

H. TRAINING OF FACULTY AND LABORATORY STAFF

Training the lab staff in proper use of the available facilities is another area of sustainability. Short term training modules arranged by the Department and the intercollegiate training programmes are also so helpful in this regard. "National Institute of Technical Teachers Training and Research" (NITTTR), Chandigarh under Ministry of Human Resource Development (MHRD), Government of India, is a well-known establishment in Training and Research. Civil engineering lab demos prepared by them are available in the internet By observing these programmes, lab staffs can train themselves and improve/ update their skill. At the beginning of each semester, teachers update on the instructions to be given to the students.

IV. LOOK AT THE INDIVIDUAL LABORATORIES

The sustainability aspects in space planning, managing of the laboratory and lab classes for each laboratory is briefly discussed below.

A. ENVIRONMENTAL ENGINEERING LABORATORY

The EE lab has two permanent work tables with ceramic tiled top (Fig. 2). These are large enough to carry out twelve titrations at a time. Each table has three test booths on either side with side wash and independent storage shelves. At a time up to forty students can do practical here. The Lab hall is well ventilated and has large windows to attract day light. A side work bench is there with enough storage space. This lab is equipped with "Nephelo Turbidity meter", "Visible Spectrophotometer", "Hot air oven", "pHmeter", "magnetic stirrer with hot plate" and very precise measuring balances. All these equipments are provided with hassle free power supply from UPS.



Fig. 2. Design of Environmental Engineering laboratory providing full monitoring of student at all times ensuring their safety

B. CIVIL ENGINEERING DRAFTING LABORATORY

It is arranged in a large hall with enough light and ventilation, meant to accommodate up to thirty five to forty students at a time, provided with that much number of systems for individual practice (Fig. 3). Systems are beautifully arranged

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on large computer tables specially made to accommodate many a students on either side of the oblong tables aligned in rows.



Fig. 3. Civil Engineering Drafting laboratory

C. GEOTECHNICAL ENGINEERING LABORATORY

The GT Lab is arranged in a spacious hall large enough to accommodate thirty five to forty students in a single session (Fig. 4). Machines are arranged in a single row having enough space in between. The Lab hall is well ventilated and has large windows providing ample day light. A large permanent work bench is provided to carry out table top experiments and a working platform is arranged to carry out experiment like the CBR test. The machines are so aligned that every work station is easily observed from the faculty seat. This lab is equipped with various soil testing equipments like “Direct shear test apparatus”, “soil consolidation test apparatus”, “Proctor compaction test apparatus”, “Unconfined compression testing machine”, Soil permeability testing machine” “Hot air oven” etc.



Fig. 4. Geotechnical Engineering laboratory

D. TRANSPORTATION ENGINEERING LABORATORY

The T.E. lab is arranged in a spacious hall large enough to accommodate thirty to forty students in a single session. The Lab hall is well ventilated and has large windows to attract day light. Two large permanent work benches are provided to carry out table top experiments and a working platform is arranged to carry out experiment like CBR test. Every work station is easily observed from the faculty seat. This lab is equipped with different metal and bitumen testing devices like “ Los Angeles abrasion testing machine”, “Metal crushing value test apparatus”, “Compression testing machine” of loading capacity 40 tonnes, “Impact value testing machine”, “CBR testing machine”, “Ductility testing machine”, “Ring and ball apparatus”, “Pensky-Martenes closed tester” etc.



Fig. 5. Transportation Engineering laboratory

E. STRENGTH OF MATERIALS LABORATORY

Arranged in a spacious hall with facility to get enough day light and ventilation. Machines are arranged in L shaped alignment with sufficient space in between. This lab is capable to accommodate up to forty students during training hours and seven experiments are possible at a time. Mechanical engineering students are also using this lab. This lab is equipped with Universal Testing machine of loading capacity 400 KN, Impact testing machine (having “charpy” mod and “izod” mod), Shear Testing Machine, spring testing machine, Hardness testing machines etc.

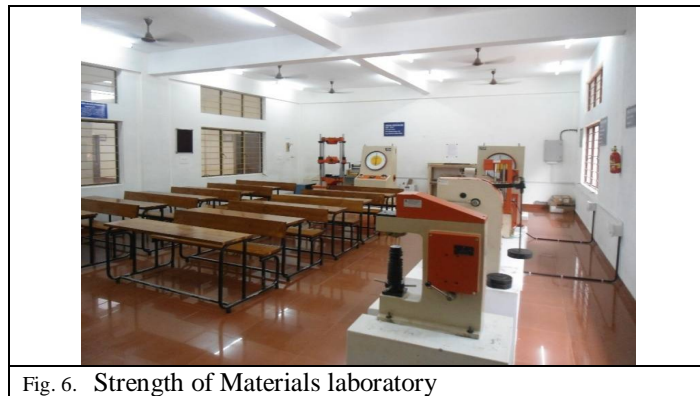


Fig. 6. Strength of Materials laboratory

F. CONCRETE LABORATORY

Arranged in very large hall, It is one of the flagship lab of civil engineering department. It has an external working plat form, curing tank and storage facilities for different aggregates. All the Machines are so arranged that every student can be monitored from the faculty station. It is provided with “compression testing machine” of capacity 3000 KN, “Vicatsapparatus”, “Blane’s air permeability apparatus”, “ Slump test apparatus”, “ Compaction factor apparatus”, “sieve shaker”, “Flow table apparatus”, “Re-bound hammer”, “ Platform vibrator” “Electric oven” and other equipments used to conduct various tests in cement, aggregates and concrete.



Fig. 7. Concrete laboratory

G. SURVEY LABORATORY

The survey laboratory is well maintained with periodic maintenance. The equipments that are exposed to moisture when survey practical are conducted during wet conditions are subjected to immediate maintenance to avoid fogging of the lenses. As a part of 7th semester subject “Survey Camp, Seminar”, students prepared a map of the college campus including elevations. This will also enable a rainwater harvesting scheme to be prepared for the campus. This lab is provided with modern survey equipments like Total station, Digital Theodolite, hand held GPS, digital leveling Instrument etc.



Fig. 8. Survey laboratory

H. CIVIL ENGINEERING WORKSHOP

This workshop was introduced as a first year engineering subject under A.P.J. Kalam Technological University (KTU) in the year 2015. The concept of energy efficient building is one of the assignments given to students which require a building model to be prepared with given plinth area and site constrained by a boundary wall. Another assignment requires collection of building materials and comparing their market rates.

V. LAB MANUALS

All labs must have a written procedure manual for the performance of all tests performed in the lab. The manual must be readily available and followed by laboratory personnel and students. It should be prepared and edited by the concerned faculty together and approved by HOD and Principal. It is in printed form which include an index page shows the list of experiments. Every experiment will be explained in a specific format – Objective – Equipments – Related theory and principles - Procedure – Observations and calculations- results/ inferences– review questions.

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VI. CONCLUSIONS

A review of literature shows the importance given internationally to incorporate sustainability as part of Civil Engineering Laboratories. This paper has discussed the efforts taken in setting up laboratories keeping sustainability aspect.

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