Design and Implementation of the Proposed Four-Storey High School Building in Lyceum of the Philippines – Laguna Using Leadership in Energy and Environmental Design (LEED)

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***Abstract*—Availability of classrooms is one of the major problems arising in schools today because of the implementation of the K-12 that resulted to the rapid growth of student populations in schools. In this project, the group of Civil Engineering students were given the opportunity by the administration of Lyceum of the Philippines – Laguna to provide the design of the four-storey high school building. The project will decongest the classrooms of the main private school building and will provide a convenient learning facility for the high school students and teachers. As an innovation, the group used the requirements of the Leadership in Energy and Environmental Design (LEED) 2009 for Schools' New Construction and Major Renovations to be eco-friendly and to have a better market among the competitors in the region as well. The special functions of the building are a podium, roof deck, and a mezzanine. The building is wind and earthquake resistant. The design will be utilized in computer softwares such as STAAD v8i and STAAD RCDC. The total cost of the project is said to be roughly around Php 150, 945, 345.97.**

***Keywords*—Computer software design, building, K-12, decongest, LEED**

INTRODUCTION

Building construction became one of the largest industries today because of the growth of the economy linked to the rapid urbanization of the world. Since the 20th century, building construction has greatly evolved and still continues to innovate.

School building construction may face various problems in different aspects that need a wide range of construction knowledge, skills, and techniques. Different schools from different countries differ in design and construction approach depending on its climate, culture, and beliefs. These kinds of problems are the same with some schools in the Philippines. Since frequent earthquakes also occur, restoration of structures that are damaged is another dilemma.

The biggest problem of schools in the Philippines today, according to one of the articles of Sunstar Bacolod, are the overcrowded classrooms because of the implementation of K-12 [34]. This problem arises most especially in public schools where some have classes in places like gymnasiums, fields, and even under a tree. Some schools also instigated night shift classes in order to accommodate their students.

Due to the implementation of K–12, colleges and universities, specifically LPU–Laguna, does not have much enrollees for the 1st and 2nd year levels during this school year. In 2022, Grade 12 students will reach their 5th year in college, if they enrolled in the Engineering program, then the five years of college will be complete with enrollees. The LPU–Laguna Marketing Committee expects to accommodate 4,000 students during this time.

This is the anticipated number of enrollees for the High School Department in the five-year study of the LPU–Laguna Marketing

Committee. In 2022, Junior High School will have 814 enrollees and Senior High School will have 1,629 enrollees for a total of 2,443 enrollees.

Since the existing buildings of LPU–Laguna is intended to cater college students only, the anticipated 2,443 students might pose a severe problem in classroom accommodation.

Before this big problem of insufficiency of classrooms occurs, LPU-Laguna planned to construct a four-storey high school building in the campus in 2020 that will be designed by the researchers. This initiative will not only help the researchers for their requirements in course on building, but will also help the institution economically by providing LEED certified plans that will be used in future implementations. This will also strengthen the student-administration relationship in the campus by applying the core values of LPU-Laguna, efforts of administration, and knowledge of the researchers.

Conceptual framework

The design project will be gathering data from LPU-Laguna through the Administration Office. Other data such as soil conditions and functional requirements will be based on past building constructions in LPU-Laguna.

After all the data needed were collected, they served as input in the structural analysis and design computer program called STAAD.Pro. This analyzed the design and provided details that completed the structural and architectural plan. From these designs, the researchers drafted the bill of materials and Gantt chart.

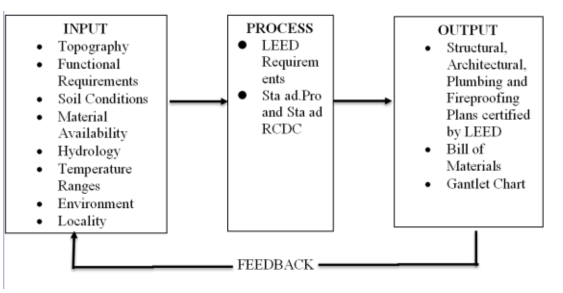

Figure 1. Research paradigm

Objectives of the study

The main objective of this study is to propose a structural, architectural, plumbing, and fireproofing design for a four-storey high school building in LPU-Laguna using Leadership in Energy and Environmental Design (LEED) 2009 for Schools' New Constructions and Major Renovations Requirements. Specifically, the study aims to:

1. Plan the complete structural design of a four-storey building with emphasis on the design of the following parameters: footings, columns, beams, floor slabs, and roofing;

2. Design the structural integrity of the building design based on the aforementioned parameters; and

3. Estimate the materials, labor, and other costs to be incurred in the completion of the design project.

METHODOLOGY

To provide the structural, architectural, fireproofing, and plumbing of the proposed four-storey high school building, the researchers applied developmental type of study. Developmental research is used to measure the variations in a period of time [26]. From when the buildings that are being constructed do not follow a set of standards up to now, where the buildings that are being constructed are aiming to be accredited by different prestige organizations such as LEED. These show that the study described the appropriate actions in response to the proposed design stated with the aid of engineering processes.

First, a visit with one of the administrators of LPU–Laguna was conducted so as to gain permission for the precedence of the study. More specifically, the researchers asked about the existence of the architectural plan of the proposed building. Then, the researchers consulted their Course Adviser about the plan of preceding the study.

As the researchers came up with the idea of designing the structure in accordance with the requirements of LEED 2009 for Schools' New Constructions and Major Renovations, the researchers sought advice from an engineer in a construction company who applies the requirements of LEED. Here, guidelines and references for the consideration of LEED 2009 for Schools' New Constructions and Major Renovations were gathered and applied during the design process of the said proposed building.

Next, based on the architectural plan of the proposed building and its physical characteristics such as topography, functional requirements, soil conditions, hydrology, temperature ranges, environment, and locality, the loads have been identified. All these data were analyzed by the Staad.Pro and Staad RCDC.

From these data, general construction notes and schedule of foundations, girders, beams, columns, and shear walls were formulated. Then, fireproofing plans and plumbing plans have been designed. After completing all the plumbing, fireproofing, architectural, and structural members' details, the researchers came up with the estimate of the construction cost and conceptualized a Gantt Chart of activities.

The perceptive approach on designing the structure was conditioned during the meeting with the Technical Adviser of the researchers.

The designing of the whole structure has been based on the National Building Code of the Philippines, National Structural Code of the Philippines 2015, and LEED 2009 for Schools' New Constructions and Major Renovations to provide minimum requirements for the design of the building. Guidelines in order to secure the stability of the building were collected including the design of construction and quality of materials.

In this project, the researchers used LEED as their innovative approach. They proposed the projected cost and benefit of applying LEED in a conventional building construction.

Table 1. Cost-benefit analysis of applying LEED in the project

Conventional	Proposed	Cost	Benefit
Use of flush for restrooms	Installation of non-flushing urinals in male restrooms	₱55,922.40	Less consumption of water up to 20%-40%
Use of refrigerants	Install the chlorofluorocarbon emitting refrigerants	Will depend on the appliances that will be installed in the future.	Prevents the reaction of CFC with the ozone gas in our atmosphere which leaves us vulnerable to the harmful effect of ultraviolet rays
Assumption of electricity from a supplier	Installation of solar panel	₱764,287.3	Decrease of electric expenditure up to 35% of the overall consumption

The project was limited by some constraints. These limitations were founded through the assigned site to the proponents and the resources available.

In the design procedure, the researchers used only the following computer aid engineering softwares: STAAD.Pro, STAAD RCDC, AutoCAD, and MS Excel. This limits the structural integrity of the building and its sustainability as a structure.

The study commenced in the first week of the month of August and finished in the third week of the of December during the 1st Semester of Academic Year 2017-2018. This limits the time to gather quotations from different hard wares and compare it to choose the most economical construction supplies to be used for the project.

RESULTS AND DISCUSSION

LEED

Table 2. Summary of LEED achievements

Achieved LEED Requirements	Considered Parameters	Equivalent Point/s	Cost
SS Prerequisite 1: Construction Activity Pollution Prevention Required	Provision of gravel bedding and silt fence polyethylene and often watering of ground	0	₱16,042.42
SS Prerequisite 2: Environmental Site Assessment Required	No past land use	0	₱0.00
SS Credit 1: Site Selection	30m away from a wetland and is not a habitat for endangered species	1	₱0.00
SS Credit 4.1: Alternative Transportation–Public Transportation Access	61.69m away from the road	4	₱0.00
SS Credit 4.4: Alternative Transportation – Parking Capacity	Sharing og parking facility of LPU-Laguna	2	₱0.00
SS Credit 5.1: Site Development – Protect or Restore Habitat	Planting of bermuda grass that will cover 20% of the total area	1	₱166,666.67
SS Credit 5.2: Site Development – Maximize Open Space	Provision of soccer field	1	₱0.00
SS Credit 10: Joint Use of Facilities	Inviting St.Frances Cabrini Medical Center and food stalls to be used for non-school events	1	₱0.00
WE Prerequisite 1: Water Use Reduction	Installation of non-flushing urinals that can save up to 40% of water consumption	0	₱55,922.40
WE Credit 1: Water Efficient Landscaping	Use of 100 pots snake plant for landscaping	4	₱25,870.00
WE Credit 3: Water Use Reduction	Installation of non-flushing urinals that can save up to 40% of water consumption	4	(already included in WE Prerequisite 1)
EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems	Making sure that the general contractor is accredited by the PCAB	0	₱0.00
EA Prerequisite 2: Minimum Energy Performance	Installation of 25 Solar Panels with 325 Watts/Hr each	0	₱389,925.00

EA Prerequisite 3: Fundamental Refrigerant Management	Installation of non-cholorofluorocarb on emitting refrigerants in the proposed building	0	Will depend on the appliances that will be installed in the future.
EA Credit 2: On-site Renewable Energy	Installation of 25 Solar Panels with 325 Watts/Hr each	7	(already included in the EA Prerequisite 2)
EA Credit 3: Enhanced Commissioning	Making sure that the general contractor is accredited by the PCAB	2	₱0.00
EA Credit 6: Green Power	Installation of 49 Solar Panels with 15,750 Watts each	2	(already included in EA Credit 2)
MR Prerequisite 1: Storage and Collection of Recyclables	Provision of trash bins	0	₱71,361.00
MR Credit 2: Construction Waste Management	Storing of 75% of the construction wastes for future use	2	₱0.00
MR Credit 5: Regional Materials	Getting the Redi Mix Concrete, Inc. to be the supplier of ready-mix concrete	2	₱0.00
MR Credit 6: Rapidly Renewable Materials	Using of armchairs with wheatboard and installation of sound absorption cotton wool in the podium.	1	₱7,434,372.8
ID Credit 2: LEED Accredited Professional	Hiring of 1 LEED professional	1	Labor Cost
ID Credit 3: The School as a Teaching Tool	Add a topic in one of the subject of high school that talks about LEED	1	₱0.00
RP Credit 1: Regional Priority	*WE Prerequisite*	4	*WE Prerequisite*
TOTAL		40 Points	₱8,534,522.69

NBCP

Table 3. Summary of NBCP met requirements

Code	Considered Parameters
Section 104: General Building Requirements	The contractor must ensure the safety and requirements that will meet the functional requirements of the building.
Section 301: Building Permits	It is the responsibility of the contractor to secure the necessary permits.
Section 401: Types of Construction	Type V: Fire Resistive Building
Section 701: Occupancy Classified	Group C: Education and Recreation
Section 704: Location of Property	The site has a direct access to a public space yard.
Section 805: Ceiling Heights	Minimum floor height is 2.9m
Section 806: Size and Dimensions of Rooms	The least dimension of kitchen is 7.95 while the bathroom has 6.8
Section 807: Air Space Requirements in Determining the Size of Rooms	The minimum air space per student is 3.886 cu.m.
Section 1207: Stairs, Exits, and Occupant Loads	There are three exits per floor and two exits for the Mezzanine.
Section 1212: Fire Extinguishing System	There is a fire-extinguishing system installed in the proposed building.
Section 1214: Motion Picture Projection Rooms	The distance of the two exits in the Mezzanine is 29.58m from each other.
Section 1901: General Rule	The STAAD results are properly documented by the researchers.

NSCP

Dead loads

In accordance with Section 204 of the National Structural Code of the Philippines 2015, dead load consists of all the material's weight and fixed equipment in the building. The dead loads are computed based on the values listed (Minimum Design Dead Loads) in NSCP 2015. These loads were utilized as inputs in STAAD v8i.

Table 4. Dead loads considered

Dead Load		
1. Slab Weight	Thickness of Slab = 200mm	4.8 kPa
2. Wall	A. Thickness of CHB for external walls = 8"	4.07 kN/m
	B. Thickness of CHB for internal walls = 6"	3.11 kN/m
	C. Interior partitions = 4"	1 kPa
3. Floor Finish	Ceramic finish on stone-concrete fill	1.53 kPa

Live loads

In accordance with Section 205 of the National Structural Code of the Philippines 2015, live load depends on the intended use or occupancy of the building. In this chapter, the live loads are computed based on the values listed (Minimum Design Dead Loads) in NSCP 2015. These loads were utilized as inputs in STAAD v8i.

Table 5. Live loads considered

Live Load		
1. Schools	A. Classrooms	1.9 kPa
	B. Corridors above the ground	3.8 kPa
	C. Ground Floor Corridors	4.8 kPa
2. Assembly Areas	Stage Areas	7.2 kPa

Wind loads

In accordance with the Section 207 of the National Structural Code of the Philippines 2015, wind load depends on the location of the site. These loads were utilized as inputs in STAAD v8i.

Table 6. Wind loads parameters

Wind Load	
1.Category	IV
2. Wind Speed	250 mph (Figure 28)

Seismic loads

In accordance with the Section 208 of the National Structural Code of the Philippines 2015, seismic load depends on the location of the site. These loads were utilized as inputs in STAAD v8i.

Table 7. Seismic loads parameters

Seismic Load	
Z	0.4 (Figure 31)
I	1
RWx	8.5
RWz	8.5
STYP	4
NA	1.2
NV	1.2
CT	1.2 (Figure 32)

Factored loads

As defined in NSCP 2015 Section 203.3.1, where the load and resistance factor are used, structures and all portions thereof shall resist the most critical effects from the following combinations of factored loads:

1. U = 1.2D + 1.6L Where:
2. U = 1.2D + 0.5L + 1.6Wx D=Dead Load
3. U = 1.2D + 0.5L + 1.6Wz L=Live Load
4. U = 1.2D + 0.5L + 1.6Ex W=Wind Load
5. U = 1.2D + 0.5L + 1.6Ez E=Earthquake Load

Structural design

STAAD framing plan

Frames that were designed in AutoCAD were transferred to STAAD v8i for analysis. These frames were then given properties and applied by loads.

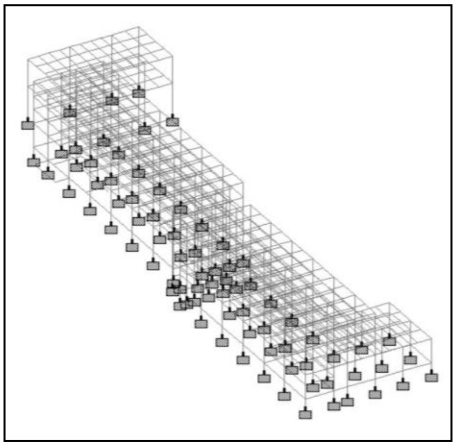

Figure 2. STAAD Framing Plan

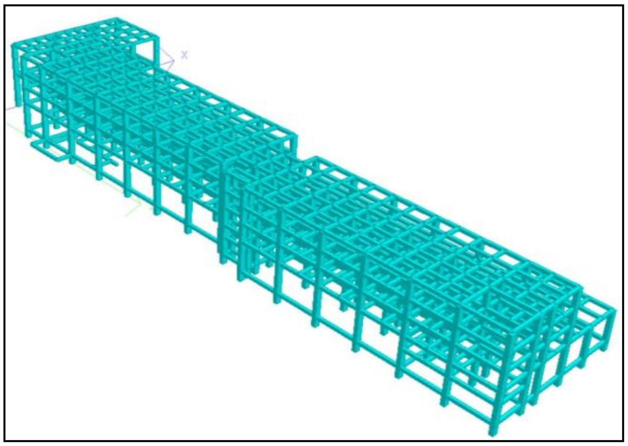

Figure 3. STAAD 3D Framing Plan

Footing design

Since the site is LPU-Laguna, 120kPa for the soil bearing capacity and 20mm for the settlement was used. These values were based on the study of Marlou Malabuyoc [17]. Just like what Braja Das said, footings are spread footing since foundations are shallow. [3]

Column design

Since longitudinal bars are braced with a series of closed ties, tied columns are used in this project based on Guillesania.[22]

Beam and girder design

Using the STAAD v8i and STAAD RCDC, the design and analysis of beams and girders were computed.

Slab and stair design

To be more conservative with the design of stairs, the stairs were treated as slabs just like in the design project of Balinay, et al. in LPU-Cavite.[9]

CONCLUSION

The aim of the design project is to be able to design a structure for the proposed four-storey high school building with a roof deck located at Lyceum of the Philippines – Laguna in Brgy. Makiling, Calamba, Laguna. The researchers were able to come up with the design using STAAD v8i and STAAD RCDC for the structural members such as footings, columns, beams, girders, and slabs. For Gantt Chart and estimates, MS Excel was used.

The design of the project comprises the minimum requirements of the National Building Code of the Philippines and the National Structural Code of the Philippines 2015. The building is designed to be structurally safe and eco-friendly but at a low cost.

In addition, the building is not just structurally safe but energy and environment innovative as well by meeting the requirements of Leadership in Energy and Environmental Design for Schools' New Construction and Major Renovations 2009. The building is qualified for LEED Accreditation for reaching 40 points in their point system.

Following LEED requirements, the building will conserve water consumption up to 40 percent, prevent the reaction of chlorofluorocarbon in the atmosphere, and decrease electricity expenditure up to 35 percent.

The total cost of the project is said to be roughly around Php 168,387,582.64 with a total estimated number of 160 construction days.

RECOMMENDATION

Based on the design project, the recommendations are hereby forwarded by the researchers:

For future researchers, design the electrical plan of the building. Also, make a manual calculation for the footing design to come up with a better, uniform footings.

For the LPU-Laguna administration, the beneficiary of the design project, the researchers recommend to conduct a traffic impact assessment in addressing transportation concerns.

For the future general contractor of the building, use shear wall for stairs for better strength and stability.

Finally, further studies should also be done to improve the function of the structure and to improve its overall potential for providing good service not only for humans, but nature as well.

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