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RESEARCH ARTICLE OPEN ACCESS

# A Proposed Structural Design of 3-Story Academic Building in DHVSU Apalit Campus by Utilizing Used Shipping Containers

Janneil T. Bagang[1], Arjay L. Baluyut[2],
Neivin R. Lapuz[3], John Paul Bryan M. Macatuno[4],
Angelo B. Tolentino[5], Raul O. Duya[6], and John Robert D. Gabriel[7]

[1-5]Student, Department of Civil Engineering, Don Honorio Ventura State University/College of Engineering and Architecture, Cabambangan, Bacolor, Pampanga, 2001

Email: 2018008523@dhvsu.edu.ph[1], 2018005926@dhvsu.edu.ph[2], 2019989672@dhvsu.edu.ph[3], 2018008603@dhvsu.edu.ph[4], 2019989756@dhvsu.edu.ph[5]

[6-7]Student, Department of Civil Engineering, Don Honorio Ventura State University/College of Engineering and Architecture, Cabambangan, Bacolor, Pampanga, 2001

Email: roduya@dhvsu.edu.ph[6], jrdgabriel@dhvsu.edu.ph[7]

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## Abstract:

This study proposed the use of abandoned shipping container to construct a three-story academic building in Don Honorio Ventura State University (DHVSU) Apalit Campus, Pampanga. The aim of the study was to address the increasing number of students enrolling at the campus while recycling old container vans and promoting environmental sustainability. Using STAAD v8i, a safe and sustainable building was designed to withstand calamities. The main findings showed the feasibility of shipping containers as an academic building and the advantages of shipping containers and steel structures in terms of durability. The proposed building's solar panels would generate sustainable electric power, and made it a reliable source of electricity during emergencies. This study's significance provided future researchers with unique ideas for sustainable and smart building construction that could withstand calamities. It demonstrated that container vans could be used as a construction material and that smart building design was feasible.

*Keywords* **—Shipping Container, Sustainable, Structural Design.**

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## I. INTRODUCTION

As urbanization continues to grow and the demand for buildings rises, the construction industry has become one of the huge contributors to environmental degradation. Traditional construction methods generate a large quantity of waste, consume significant energy volume, and release a substantial scale of carbon emissions. As a potential solution, innovative sustainable structures have emerged to address the issue. Sustainable structures aim to reduce waste by incorporating sustainable materials and designing proven practices. These structures promote the use of renewable resources, energy-efficient systems, and renewable energy sources. Sustainable buildings improve energy efficiency, reduce greenhouse gas emissions, and promote a more sustainable future. This article discusses the importance of innovative sustainable construction materials and their impact on the environment, emphasizing the need for sustainable structures and materials in the construction industry. It also provides insights into the challenges and opportunities concerning developing and implementing sustainable construction materials and practices, highlighting the importance

of continued innovation to promote a more sustainable future. (Maimunah, S., Samsudin, S. A., & Wan Omar, W. Z., 2021)

Several forms of infrastructure reconstructing and redesigning were applied as part of the attempts to control waste materials. One of these is turning a standard building into a more sustainable building, which is better for the environment since it incorporates many ideas that emphasize preserving the ecosystem 's natural state, recycling leftover materials, and controlling and conserving power and water.

Considering the ongoing movement to protect the environment, several nations are now inclined to design their structures using the green building approach. The Philippines is one of the mentioned nations, and because of its rapidly expanding industrial sector, several infrastructures have been designed to accommodate the
evolving culture and way of life. By adopting measures that encourage resource management effectiveness and site sustainability, the Philippine Green Building Code (P.D 1096) aims to increase the performance of the building while reducing the detrimental effects of structures on both human health and the environment. The Code suggests guidelines for resource management, site selection, planning, design, construction, usage, occupancy, operation, and maintenance (climatelaws.org, 2015)Shipping containers have been widely utilized for transporting various items including heavy equipment, bulk items, and other products across the globe. Currently, there are about 17 million shipping containers around the world, out of which only six million are being utilized for transportation or other practical purposes. This leaves approximately 11 million shipping containers unused and stationery in various locations. (IES, Integrated Equipment Sale, 2022) By offering a proper structural design incorporating architectural touches that will become an icon to the public spectator, this eyesore will become aesthetically pleasing to look over.

Shipping container offices were frequently found on a building site or school campus decades ago. Shipping container structures are being employed more often for commercial and public works projects. Developers found the potential container van has, thanks to better quality, quick manufacture, and superior personalization (Vesta Modular, 2023).

Increasingly more shipping containers are transfiguring into residential and commercial buildings. Global trade increased significantly in the second half of the 20th century thanks to the development of standardized shipping containers. Since 1956, the steel shipping container has served as the primary global transportation module. It has significantly lowered the price of long-distance trade and created a significant role in intercontinental commerce. But thousands of containers are sitting idle in yards all around the world. Upgrading a shipping container requires about 400 kWh while melting shipping containers need about 8000 kWh of energy to dissolve. Containers are modified and transformed into residences rather than melted down, which makes them more environmentally friendly. The shipping industry makes considerable use of shipping containers to convey freight. It is a functional piece of equipment that was known to be recycled and used in several creative ways outside the industry as well as Emergency Hospitals, Theaters and Bistros, Restaurants, Swimming Pools, Portable Toilets, Storage, and Academic Structure, just as viable as they are in their area of operation.

### *A. Background of the Study*

Pampanga cover a land area of 2,001.22 square kilometers or 772.68 square miles. In census 2020 the population was 2,437,709, this represented 19.62% of the total population of the Central Luzon region, 3.92% of the overall population of the Luzon Island group, or 2.24% of the entire population of the Philippines. (PhilAtlas, 2020)

Apalit was the landlocked municipality of Pampanga's coastal province. It has a land area of 61.47 square kilometers or 23.73 square miles which constitutes 3.07% of Pampanga's total area. In census 2020 Apalit has a total population of

117,160 represented 4.81% of the total population of Pampanga province, or 0.94% of the overall population of the Central Luzon region. The municipality covers 12 barangays including Balucuc, Calantipe, Cansinala, Capalangan, Colgante, Paligui, Sampaloc, San Juan, San Vicente, Sucad, Sulipan, Tabuyuc. In the census Sampaloc recorded as the second highest population percentage, 11.4% of the total population, 13,408 over 117,160. (Philatlas,2020).

Upon the memorandum of agreement signed to institute the creation of a satellite campus in Apalit, Pampanga, Don Honorio Ventura State University Mandate, as reflected in RA 11169 Section 3, includes the offering of technical-vocational, undergraduate and graduate courses in order to meet the needs of the Provinces of Pampanga and Region III. RA 10931 or The Universal Access to Quality Education Act intends to give underprivileged Filipino Students a chance to earn a college degree. Through Mayor Oscar Tetangco Jr., Vice Mayor Peter Nucom and the Sangguniang Bayan ng Apalit and the Local Government of Apalit the satellite campus was then approved via the DHVSU's Brand of Regents' Resolution Number 81 Series of 2019 signed last August 23, 2019. A parcel of land about 12,704 square meters in Barangay Sampaloc, Apalit, Pampanga to be the site of the Apalit Campus donated by Mayor JDT. DHVSU Apalit has 4 programs: Bachelor of Science in Business Administration Major in Marketing, Bachelor in Elementary Education, Bachelor of Science in Information Technology and Bachelor of Science in Hospitality Management. In Academic year 2020-2021 the initial batch of students enrolled has a total of 480 (DHVSU-MIS Web Development Team, 2022). As of academic year 2022-2023, the total number of students was 1,299 (DHVSU Apalit - MIS). Due to the increasing of student's population DHVSU Apalit Campus badly in-need an academic extension building.

Hence, to handle the increasing number of students enrolling at the campus, the researchers hope to develop a three-story academic building using abandoned container trucks. The goal of the proposed idea is to recycle the old container vans while also enhancing the environment. Also, by demonstrating aesthetic attractiveness, and a quick construction procedure, this research will prove to the general public, students, and professionals that container van is a good construction material.

1) ***Study Area:*** Don Honorio State University Apalit Campus is one of the satellite schools of DHVSU. The Campus is found at Sitio Tagulod, Sampaloc, Apalit, Pampanga, and has a parcel of land of about 12,704 square meters.

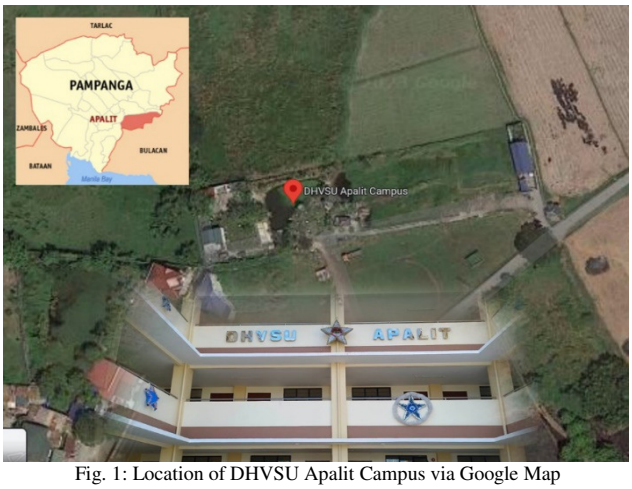


Fig. 1: Location of DHVSU Apalit Campus via Google Map

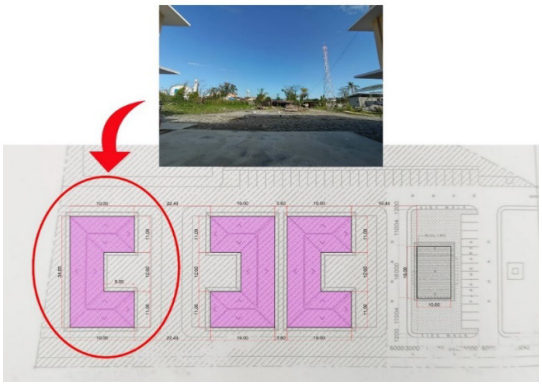


Fig. 2: Site Development Plan

***B. Review Related Literature***

**STRUCTURES CONSTRUCTED USING CONTAINER VANS**

Converting container vans into all kinds of structures has been a worldwide trend nowadays that leads to a debate over whether container vans can be a good prefabricated material. Others point out those old and dented containers can be unsafe, structurally unstable, and coated with harmful chemicals like lead-based paint. However, this trend was unexpectedly accelerating for the reason that some advocates say structures made of container vans are cost-efficient, eco-friendly, and can be built quickly. Here are some examples in which shipping containers have been creatively re-purposed.

Fig. 3: Bristol & Avon Group in the United Kingdom

Bristol and Avon Group's new head office in Bristol, United Kingdom is made of prefabricated containers which is a Chinese box puzzle with interrelated modules designed and built by Container City. This prefabricated structure was installed over five days with careful preparation in April 2016 and presents an arresting-colored facade that emphasizes the B&A brand. (Container City, 2022)

Fig. 4: Caterpillar House in Santiago

The Caterpillar house is a prefabricated house made for an art collector and his family and was built on the outskirts of Santiago in a new suburban residential area. Second-hand shipping containers were used during their construction to shorten the project's construction period and lower its costs. They used six 20 feet standard containers, five 40 "standard containers, and one 40"open-top container for the swimming pool. In constructing this structure, they started by placing the retaining walls to create a horizontal plane to place the public areas of the house. Then in mounting the containers and ensemble them on top to place the private areas. Also, Wrap the containers in a unitarian material that unifies the components, also produces a ventilated facade that regulates the inside temperatures. (ArchDaily, 2013)

Fig. 5: Vessel Hostel in San Juan, La Union

A four-level hostel composed of repurposed shipping containers stacked on top of each other, named Vessel Hostel. It is located in the heart of La Union's Surf Town and was designed by surfer architects Buji Libarnes and Nikki Dela Paz-Libarnes. This is designed as an extension of their home, as a reflection of their love for classic surfing and the nostalgic lifestyle of its golden era. This hotel is a cozy and restful place to stay in La Union because of its simplicity and efficient space planning, perfect for traveling groups or even for single backpackers. (Gutierrez, 2017)

Fig. 6: Citihub Dormitory in Mandaluyong

Citihub Mandaluyong is a dormitory constructed using scrap container vans built for low-income workers and students located at Mandaluyong, Sta. Mesa, Manila, Cainta, Rizal, and Balintawak, Quezon City. In 2011, Mr. Panya Boonsirithum was convinced by his employer to lead the corporate social responsibility of their

construction and developmental company. Did much research on what materials will be used to build the dormitory at an affordable price and ended up using scrap container vans which are more sustainable and cost-effective. Started with four container vans with a capacity of sixty-six beds. (AIM2Flourish 2023)

Fig. 7: Bayan- Bayanan Elementary School in Dinalupihan, Bataan

In the upland village at Dinalupihan, Bataan, air-conditioned container vans served as classrooms of the Bayan-Bayanan Elementary School, since they lost their old school when it was hit by a landslide during the onslaught of *habagat* in 2012 according to their principal. Having a total floor area of 22.5 meters by 9 meters donated by the Aeta Tribal Council in Bayan-Bayanan, they produce 7 container vans classrooms and each classroom has an area of 7 meters by 9 meters. (Esconde, 2018)

## FEATURES OF A SUSTAINABLE BUILDING


Fig. 8: Features of Sustainable Building

Global warming and air pollution are some environmental problems that we face and cannot deny. If buildings are made to be eco-friendlier, they don't consume a lot of electricity and water and release greenhouse gases into the atmosphere, unlike conventional buildings that contribute to such environmental problems. The Department of Public Works and Highways crafts ecologically-sound standards that require all the new buildings in the country to follow using a conceptualized Green Building Code. Last February, a Green Building ordinance in Mandaluyong City that enumerates a feature of a green building passed. These features were explained to a Rappler by the Philippine Green Building Initiative, architect Emelito Punsalan.

A Green Building could reduce electricity costs. Considering it can be naturally cooler if the walls can block moisture and humidity from the outside. Since the facility won't need as much air-conditioning system, it can lower the solar heat gain coefficient of glass that releases heat inside the building. Furthermore, the design, construction, and operation practices for this kind of building should have a minimal impact on ecosystems and water resources. In addition, the building's unpaved space should be used primarily for plants that reduce the heat urban island effect. (Ranada,2014)

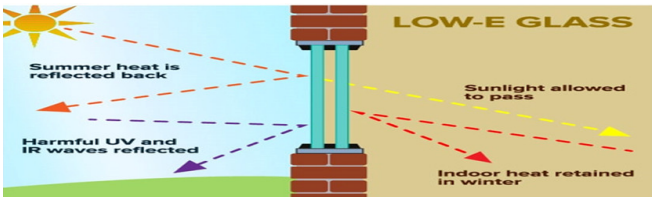



Fig. 9: Low-E Glass Coating

Low-E or the low-emissivity glass was made to lessen the amount of ultraviolet light and infrared that comes through your glass, without affecting the amount of light that enters the room. It has a microscopically transparent thin coating that is thinner than human hair and reflects heat. This coating makes the temperature of the room consistent by reflecting the temperature of its interior back inside. It may be a passive or solar control low-emissivity coating manufactured using a pyrolytic process or Magnetron Sputtering Vapor Deposition (MSVD) process. (StanekWindows,2017)

Fig. 10: Solar Panel System

Solar electricity can be a great source of power where the power requirements are simple, just a good amount of sunshine. Creating energy with solar is not only environmentally friendly; it can also be good for your bank account too. Whether you are considering solar as a way of offsetting your electricity bill in your home or business, or if you are considering a solar installation to avoid the high cost of connection to the electricity grid, solar can often save money. (Boxwell,2016)

Solar panel systems contribute to environmental sustainability in our region, but the cost savings will also contribute to the financial stability of the school or other infrastructure in the years ahead. (Ingersoll, 2010)

Many cells are linked together to make up a solar panel. According to the University of Minnesota Duluth, it works by allowing particles of light or also known as photons, to knock electrons free from atoms, and each photovoltaic cell is basically made up of two slices of semi-conducting material then generate an electricity supply. Basically, solar panels are made up of several, smaller components called photovoltaic cells, which turn sunlight into electricity. (Dhar&Harvey, 2022)

## RESEARCH GAP

The practice of transforming container vans into various structures is currently trending throughout the world. Therefore, the researchers come up with a unique idea and propose a sustainable academic three-story building using a used container van with futuristic and undeniably unique features, especially here in the Philippines. The research strives to uncover the economic and environmental benefits of building a sustainable structure and how these benefits be optimized. Inserting features that make it more sustainable like converting the windows into Low-E glass will help to maintain a good temperature, unlike a standard glass window. Also adding solar panels to reduce the carbon footprint and energy costs of the building. Considering that this building will be more beneficial to the students, teachers, and the community because it will also serve as an evacuation center.

### *C. Objective of the Study*

***1) General Objective:*** Utilizing the Load and Resistance Factor Design (LRFD), a type of method used in designing and the Ultimate Strength Design (USD), which focuses on the structure member. To use shipping container as core component in designing the proposed structure.

***2) Specific Objective:***

- To determine the suitable size of the shipping container that has an enough loading capacity and strength that will fit in the structure.
- To determine the most economical and safest structural steel members and steel and reinforced concrete member using Load and Resistance Factor Design and Ultimate Strength Design methods respectively.
- To determine the total cost of the proposed structure using shipping container as a main component.

### *D. Significance of the Study*

The proposed study will offer the data required to conduct a detailed examination of the use of steel design in building sustainable structures employing container vans as their main structural component. The function of engineering as a tool in this project's proposed solution for the structural makeup of the building will undoubtedly produce techniques and strategies that will be helpful to the building's users.

- **To the Campus**
  The proposed project will provide laboratories for the student of the campus and ensure that it will provide enough space to accommodate students and faculties when it comes to activities.
- **To the Civil Engineering Students**

The proposed project will promote awareness of the significance of understanding multiple design methodologies, including LRFD and USD, when creating sustainable green buildings.

- **To Engineering Field**
  By emphasizing the significance of utilizing diverse design methods, such as LRFD and USD, for developing sustainable green buildings, the proposed project will aid in promoting awareness about their importance.
- **To Environment**
  Through this research, the researchers can apply all the theories, concepts, and real-world practices for designing steel structures that will pick up throughout their academic and practical activities. The study also provides the chance to learn more about engineering procedures and other environmental consciousness-related elements, particularly when utilizing an underused container van.
- **To the Future Researchers**
  This research study aims to shed light on the evolution of sustainable structures, offering future researchers a valuable resource to build upon. Through furnishing robust and credible data on sustainable building innovations, this research paper will aid in resolving any uncertainties that may arise during future research endeavors.

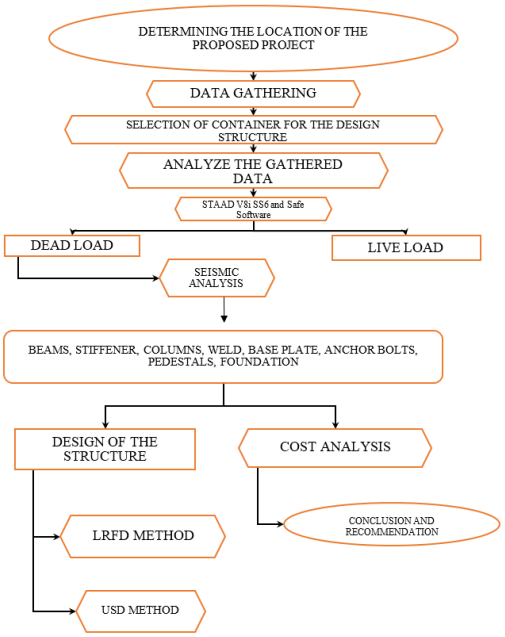
### *E. Scope and Limitations*

1) ***Scope of the Study:*** The research suggested would involve relevant studies that provide answers to environmental issues and technologies that will aid in managing energy use. The Load Resistance Factor Design and Ultimate Strength Design will be the analysis techniques used. The classification of shipping container is the main subject of the study, which come up to utilize LRFD and USD. The study includes a cost analysis**.**

2) ***Limitation of the Study:*** The proposed thesis will be limited to the provided architectural design and a structural design of the building. The soil capacity and classification of the location will be based on the geotechnical investigation report provided by the MIS of the Campus.

### *F. Conceptual Framework of the Study*

This idea increases the morale of the site by valuing the natural components present there. Recognizing nature is appreciating its inherent processes. The surrounding vegetation is one of the natural components there.




### *G. Definition of Terms*

- **BOQ- Bill of Quantity**- a document created by a quantity surveyor or cost consultant that specifies the quality and amount of work a contractor must perform to finish a project.
- **Buckling**- is the phenomenon when part of a member displaces laterally or out of its plane due to compressive forces or stresses. The displacements are associated with flexural stresses whose magnitude depends on the slenderness of the member.
- **Estimate**- to roughly judge or express an opinion regarding the value, quantity, size, or weight.
- **High Cube Container**- are a 9'6" taller relative of the 20' and 40' regular shipping containers.

Because of their increased height, shipping containers like this are in high demand. High cubes, or HC for short, resemble normal containers structurally. The height rises one foot while the length and width stay the same. They can now fulfill more freight requests as a result.

- **HISG**- Heat Insulation Solar Glass, a variety of PV modules with multiple uses. The U-value and shading coefficient of HISG are remarkably low. HISG can lower a building's energy use for heating and cooling.
- **I Beam** -also known as H, W, wide, universal beam, or rolled joist, a shape of structural steel used in buildings. They are designed to play a key role as a support member in structures, and these beams have the capacity to withstand various types of loads.
- **Smart Building -** refer to cyber-physical solutions that can assist in optimizing building management and supporting the daily routines of users. These solutions include various models that cover domains such as energy, health, and security.
- **Steel Girder Beam**- is a construction support beam. It is a structure's main horizontal support that supports smaller beams. Girders typically have an I-beam cross section, although they can also have a box, Z, or other shape. Bridge beams, channels, railings, beams, ladders, and angled components are all examples of steel beam applications. Steel is most typically utilized to construct a bridge's bearing pile foundation. There are types of girders. A girt is a shear load resisting vertically aligned girder. Plate girders, welded or bolted together from different pieces of steel plate, are used for larger girders (1 m/3 foot deep or more).
- **Sustainable Buildings-** also known as green or eco-friendly construction, encompasses the design, construction, and operation of structures that minimize their environmental impact while enhancing their functionality and comfort. It involves a range of principles and practices that prioritize efficient resource use, waste and pollution reduction, renewable energy adoption, healthy indoor environments, and occupant well-being. In the construction approach, sustainable building strives to balance environmental, social, and economic considerations to create resilient, durable, and low-impact structures throughout their entire lifecycle. The ultimate objective is to meet current needs without compromising the ability of future generations to meet their own.

## II. METHODOLOGY

This chapter discusses how the group came up with the concept for a steel multipurpose academic extension building in DHVSU Apalit Campus that incorporates container vans as a core component and complies with all applicable regulations and specifications. The researcher employed an experimental quantitative research design in their research, allowing them to manipulate variables, collect numerical data, and use computational tools to analyze and provides all calculations and evaluations comparing actual values with allowable values to ensure that the structure's design is safe.

The processes and specifications utilized in the various structural members, notably the beam, column, pedestal, connection, and foundation, are included in this chapter. These processes act as a manual for determining the cost analysis and safe and practical structural member sizes.

### 1. *Determining the Site Location for the Project*

The researchers consider the DHVSU Apalit Campus as the location to build the structure because of the nature of the issue. The intended structure for the building is at the rear of the academic building 2.

### 2. *Data Gathering*

The Management Information Office and Director Normando C. Simon of DHVSU Apalit Campus provided valuable information and carefully selected papers to complement and enhance the data collection process. The gathered information from the engineers was analyzed,

interpreted, and evaluated to develop recommendations and solutions.

## 3. *Analysis of Data Gathered*

The researchers verified the gathered documents to determine what was relevant to the study and what wasn't. The criteria for the container vans that the researchers will select are as follows:

1) ***Container Vans:*** The design requirements listed in the preceding section can be satisfied by different types of container design. However, it's important to note that every design offers an advantage of its own. Each of them partially satisfies the various design requirements, but they also each have advantages and disadvantages. Following are a few ways to summarize the different types of container vans available:

Fig. 11 Container Van: Alconet Containers

2) ***Different Types of Containers:*** **Dry Container:High Cube Container:** According to Kelly Hart, the container is energy-efficient. When the appropriate coating is applied, the envelope reflects roughly 95% of external radiation, resists heat loss within, offers a great air infiltration barrier, and prevents water from migrating.

According to KPFF Consulting, a structural engineering firm in St. Louis with extensive experience working with shipping containers, the units are stronger than conventional house framing because of their resistance to "lateral loads" - those seen in hurricanes and earthquakes- and because steel is welded to steel. The roof is strong enough to support the extra weight on roof.

Steel, a sustainable material that resists the elements, is used to construct shipping containers. They can endure the worst weather and last you for decades (depending on the condition at the time of purchase). You will be able to continue using the classroom in a shipping container for years to come.

There are many benefits to choosing a shipping container classroom over a conventionally constructed school or classroom. The advantages of using shipping containers for classrooms include their affordability, portability, durability, weather resistance, stack-ability, customizability, eco-friendliness, and speed of construction.

3) ***Requirements of the Model Container:*** To sustain a condition of zero-lateral strain (K0 condition), the model container needs to be sufficiently stiff on the sides. During the spin-up stage of centrifuge testing, this is particularly obvious.

The frictional end walls must have an identical vertical settlement to the soil layer to keep the soil from undergoing additional stresses. During the swing-up phase of centrifuge testing, this effect is very crucial. Any unwanted vertical motion should not, however, cause extra soil stress at the boundaries during 1-g testing. Brennan (2003) provides additional information regarding the circumstances surrounding centrifuge testing.

The ideal steel containers for building structures are high-cube ones, which have a net interior ceiling height of 8' 11", while the ceiling height of a conventional container is one foot lower at 7' 11". A lot of individuals seek insulated refrigerator containers. It already contains polyester insulation inside the inner walls, making it impossible to run wiring or plumbing inside the walls or weld anything for fear of setting the insulation on fire. Theoretically, to prevent welding, electrical wiring may be installed via metal pipes or steel conduit located on the exterior of such inside walls. Yet, how unsightly would that look? The reefer unit takes up a lot of room and needs to be removed; the aluminum container is significantly weaker and more expensive than steel; etc. Steel containers are simple to handle, and the easy-to-apply ceramic outer coating provides excellent heat insulation by reflecting heat before it warms up the exterior steel surfaces.

4) ***Capacity of the Model Container***

TABLE I
Dry Container External Dimension: CONTAINER CONTAINER – Part of The Parsons Container Group

| **DRY CONTAINER** | |
|---|---|
| LENGTH | 6,090 mm |
| WIDTH | 2,440 mm |
| HEIGHT | 2,590 mm |
| MAX PAYLOAD | 31.34 Tons |

TABLE II
High Cube Container External Dimension: CONTAINER CONTAINER – Part of The Parsons Container Group

| **HIGH CUBE CONTAINER** | |
|---|---|
| LENGTH | 6,058 mm |
| WIDTH | 2,438 mm |
| HEIGHT | 2,900 mm |
| MAX PAYLOAD | 31.14 Tons |

4. ***Design of the Structure***

1) ***Architectural Plan:***The process starts with architectural plans and details from the architects. AutoCAD and SketchUp are two computer graphics programs for producing 3D models and images. It can exhibit models and prototypes of the constructions thanks to its modeling skills and adaptable plugin architectural designs. The type of permanent loads that will be applied to the structure and the number of occupants it can hold will be described in the plans.

2) ***Structural Analysis:***The structural framework of the building must be developed from architectural plans. The team must identify potential places for the columns before connecting these vertical components to the footing below using horizontal members like beams and girders.

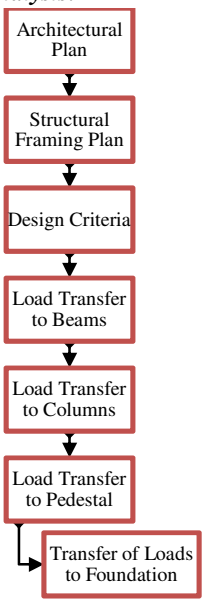
To create a structural design for the building that is both secure and cost-effective, important and distinctive analytical and design methods must be used. STAAD will be used for some calculations and analysis while handwritten calculations for others will be offered. The National Structural Code of the Philippines (NSCP - 2015) and the American Institute for Steel Construction (AISC) served as the foundation and references for all the standard specifications and computations for structural design and analysis.

The building design requirements will be compromised by information on loading load combinations, materials and their strengths, and the employed codes. The necessary dead load and live load that the building must carry were determined using NSCP.

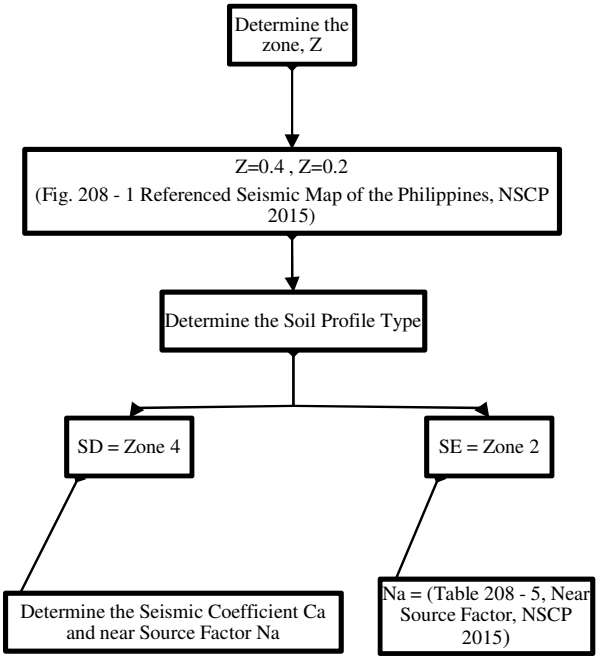
The crew experimented with several steel sections to find the best cost-effective section, using the Steel Handbook of the Association of Structural Engineers of the Philippines (ASEP).

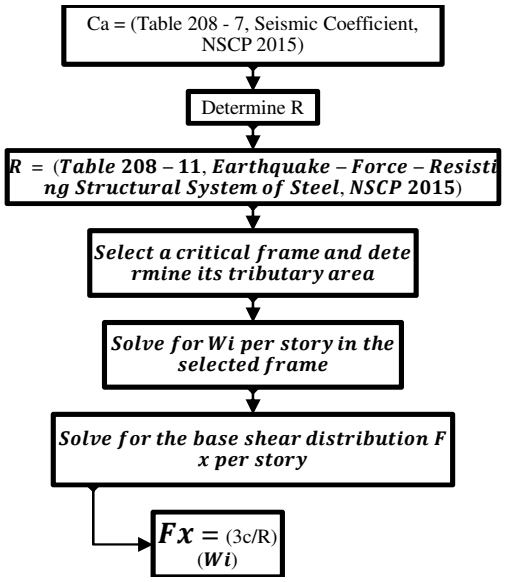
  

3) ***Flow of Analysis:***

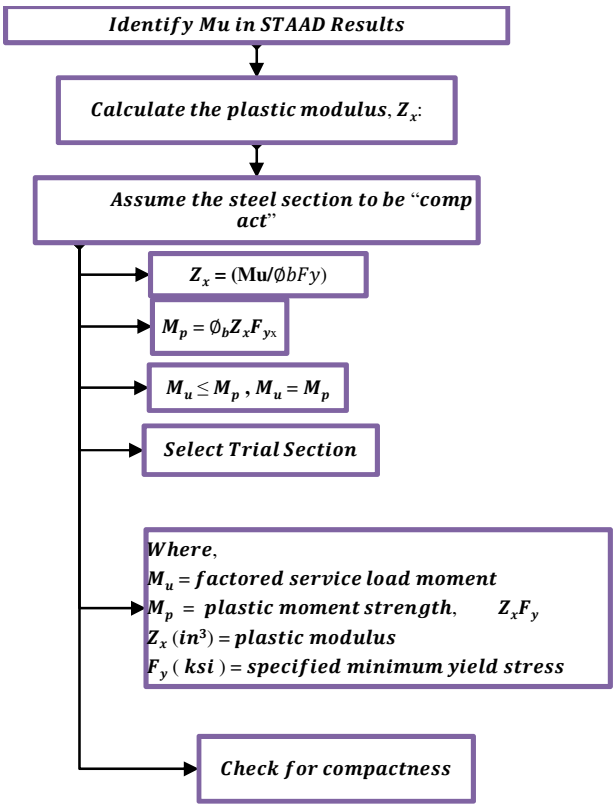



4) ***Structural Design Procedures***

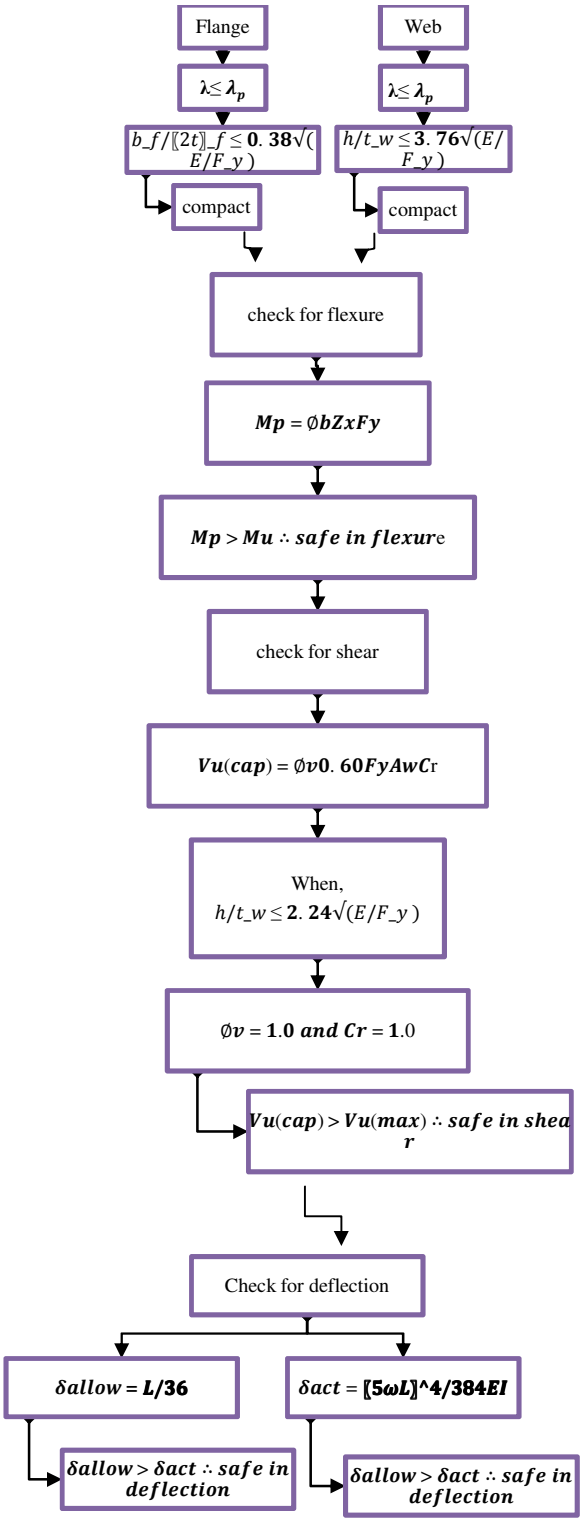


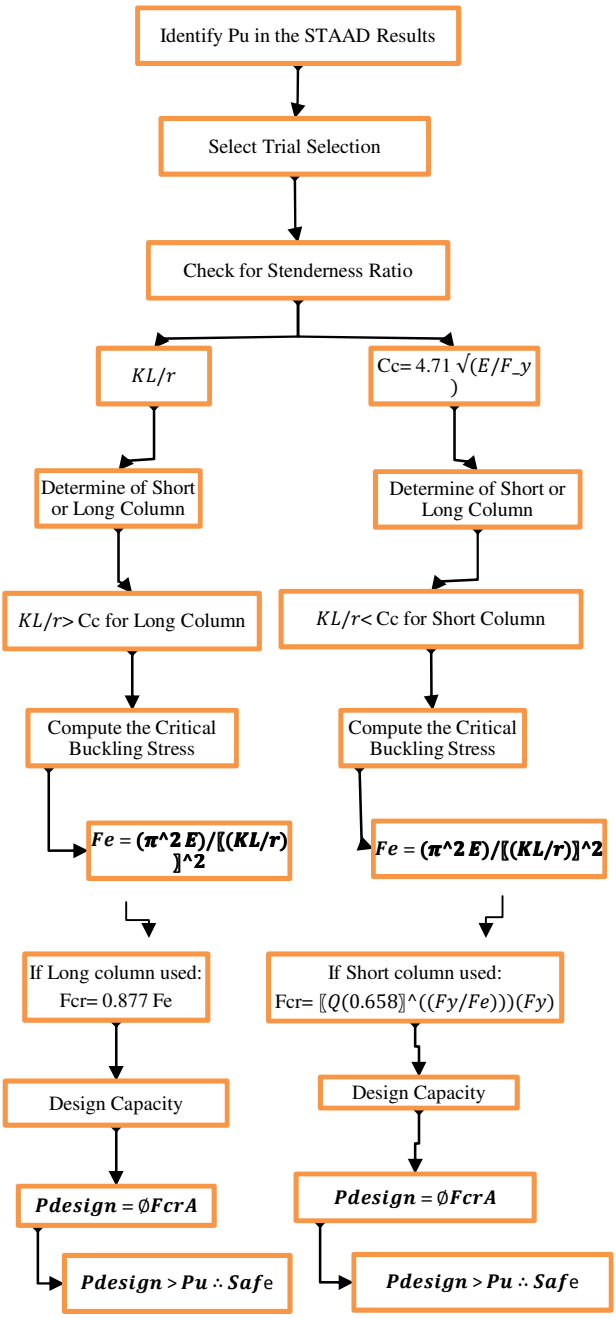

5) ***Design of Laterally Supported Steel Beams***



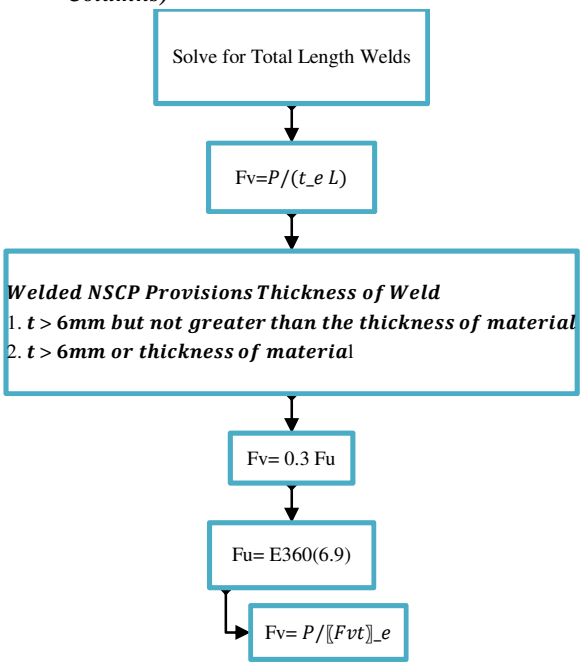

  



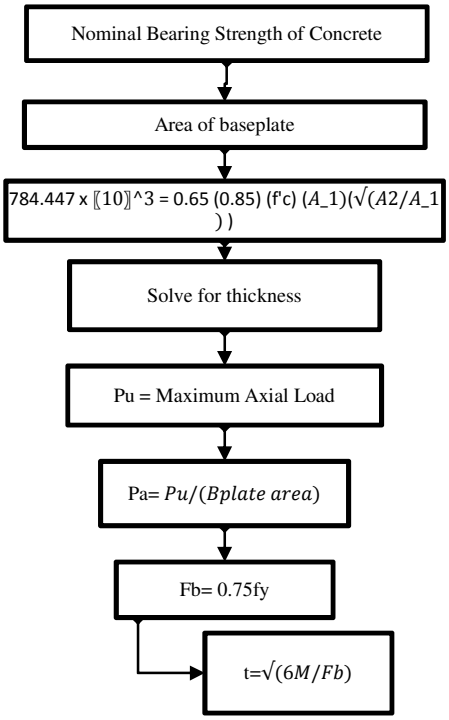

6) ***Design of Steel Columns***



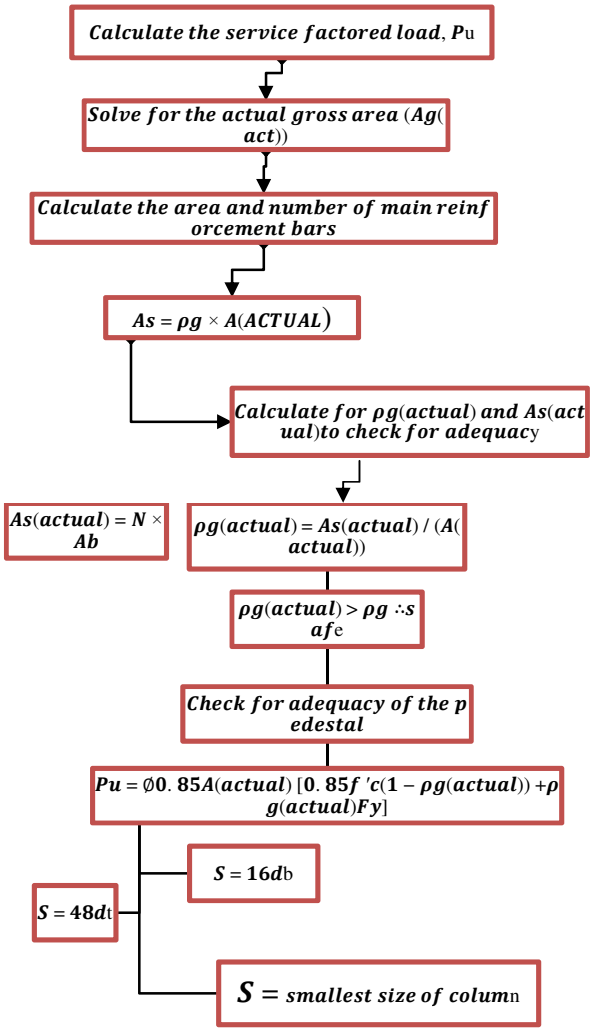
7) ***Welded Connection-Direct Shear (Beams to Columns)***



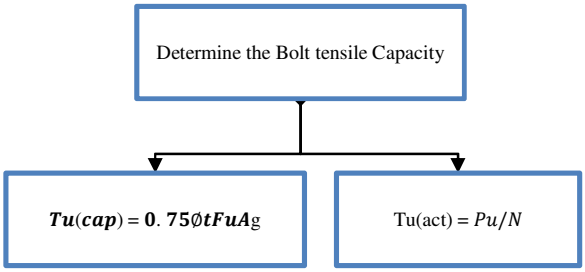

8) ***Design of Base Plate***

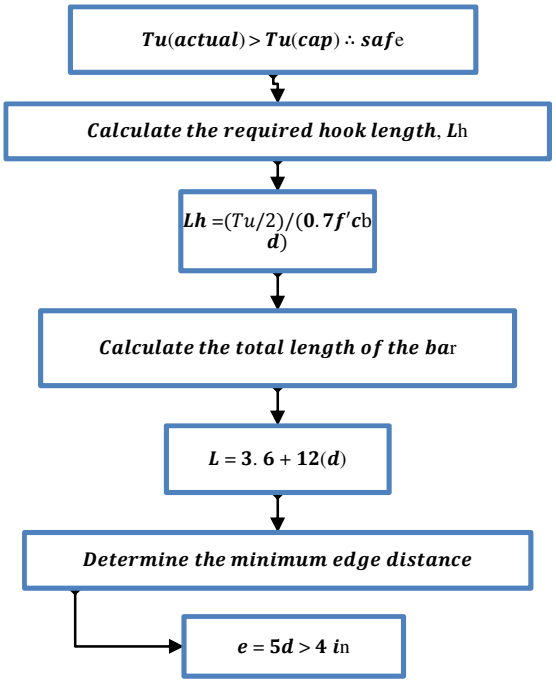



9) ***Design Pedestals***

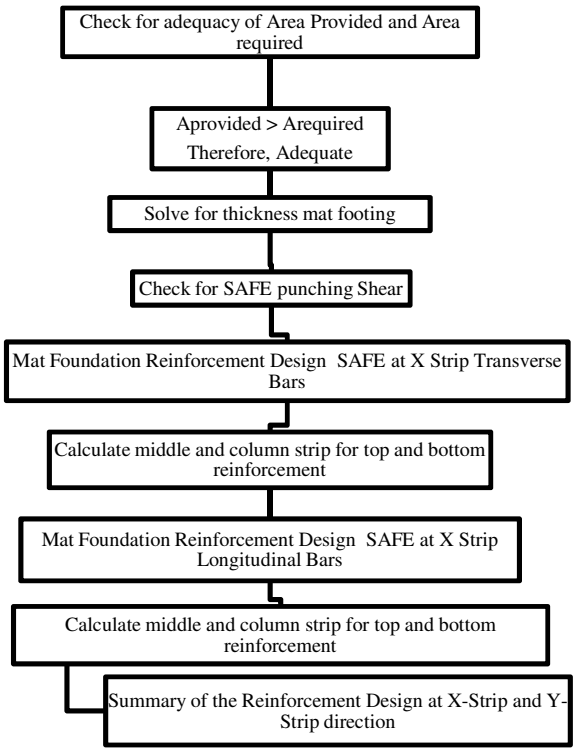



10) ***Anchor Bolts***






11) ***Design for Mat Foundation***




5. ***Cost Analysis***

1) ***Estimates:*** The group was able to estimate the structure and determine the anticipated cost needed to finish the project. One approach contractor uses to arrive at the final estimate is the analytical estimate, which is taken into consideration by people to determine their ability to pay.
2) ***Bill of the Structure:*** A BOM is simply a production schedule for a given product. It includes all the ingredients, parts, and procedures needed to make the thing. Most BOM's have a hierarchical structure. The finished product is at the top, followed by the subassemblies and the parts and supplies used to make the product. These contain information such as part names, numbers, descriptions, and required quantity. Although the idea behind a BOM is simple, it can be challenging to create and manage, especially for items with hundreds or even thousands of pieces. For instance, if a supplier's inability to meet delivery schedules necessitates a change to one component, this change must be reproduced across the BOM wherever that component was employed.
3) ***Bill of Quantities:*** A bill of quantities, also known as a BOQ or BQ, is a document created by a quantity surveyor or cost consultant that specifies the quality and amount of work a contractor must perform to finish a project.

## III. RESULT AND DISCUSSION

This chapter presents the results and data gathered from the design activities and computations, which are systematically analyzed and evaluated to uncover significant findings. The study's outcomes are presented in this section, providing valuable insights into the research topic.

1. ***CONTAINER SPECIFICATION***

The researchers have determined the requirements for the structure and developed a set of specifications for a container to be used based on the architectural plan. A 20ft high cube container fits the proposed academic building. It has an external height of 9'6", which is 1 foot taller than the standard 20ft shipping container. It meets the ISO standards and the CSC requirements since they constructed from high-quality corten steel. In addition, this container has some advantages that make it more reliable and trusty. It is wind and

waterproof, has a wooden floor that ensures minimal moisture content, and is suitable for storage and transportation.

These specifications detail the specific features and characteristics the container must possess to support the structure. The container was available on Containergurus purchasing a container located in Metro Manila, one of which will utilize in this proposed project:

TABLE III
High Cube Container External Dimension

| HIGH CUBE CONTAINER | |
|---|---|
| LENGTH | 6,058 mm |
| WIDTH | 2,438 mm |
| HEIGHT | 2,900 mm |
| MAX PAYLOAD | 31.14 Tons |

## 2. *DESIGN CRITERIA*

1) ***GENERAL:*** This document shall be considered the Design Basis for the Civil/Structural Engineering Works of the proposed 3-story academic structure of DHVSU Apalit Campus.
2) ***APPLIED CODES, STANDARDS AND REFERENCES:*** Engineering design work are performed using the latest editions of the following Codes and Standards.
   - National Structural Code of the Philippines 2015 Volume 1, 7th Edition, Association of Structural Engineers of the Philippines, ASEP, (2010)
   - ASCE/SEI 7-10, American Society of
   - Civil Engineers, Minimum Design Loads for Buildings and Other Structures
   - American Concrete Institute (ACI), ACI 318-05, ACI 318-95 (PCACOL)
   - American Institute of Steel Construction Allowable Stress Design 9th Edition
   - PCA Seismic Detailing Manual of Concrete Buildings (2007)

## 3. *DESIGN METHODOLOGY*

1) ***Structural Design:*** The design of concrete structures and foundations shall be governed by the following codes NSCP 2015, AISC and ACI.
2) ***Design Dead Loads:*** The following basic loads and forces shall be considered in the design including various combinations of loads shall be used in design calculations provided by NSCP 2015 table 204-1 Minimum Densities for Design Loads from Materials in $\boldsymbol{kN/m^3}$, Table 204-2 Minimum Design Loads in kPa, and Table 205-1 Minimum Uniform and Concentrated Live Loads.
   - 50 mm Floor Fill (Lightweight Concrete per mm= 0.015 kPa) = **0.75 kPA**
   - 20mm Floor Finish (concrete fill finish per mm thk= 0.023 kPa) = **0.46 kPA**
   - MEPFPS (Mechanical Electrical Planning Fire Protection System) = **0.1 kPA**
   - Slab (125mm thk) = **2.95 kPA**
3) ***Additional Dead Loads:***
   - Roof (purlins, rafter, and roofting sheet) = **0.3 kPa**
   - 20 feet High Cube Shipping Container = **1.63 kPa**
4) ***Design Live Loads:*** As per the relevant specifications, "live loads" refer to the total weight of all objects that can be moved, such as equipment, tools, and staff office, among others. The applied live loads are the following:
   - Classroom = **1.9 kPa**
   - Corridors Above Ground Floor = **3.8 kPa**
   - Auditorium:
     - Fixed Seats = **2.9 kPa**
     - Stage Areas = **7.2 kPa**
5) ***Seismic Load:*** Seismic load is the dynamic force that a structure experiences during an earthquake due to the shaking of the ground, and its intensity depends on factors such as earthquake magnitude, duration, soil or rock type, and building construction.

   Building and non-building structures shall be designed for seismic loads in accordance with NSCP 2015 section 208. According to NSCP 2015 Figure 208-1 "Seismic Zone Map of the Philippines" Pampanga falls under Zone 4, hence (peak ground acceleration = 0.4g) located between west valley fault.

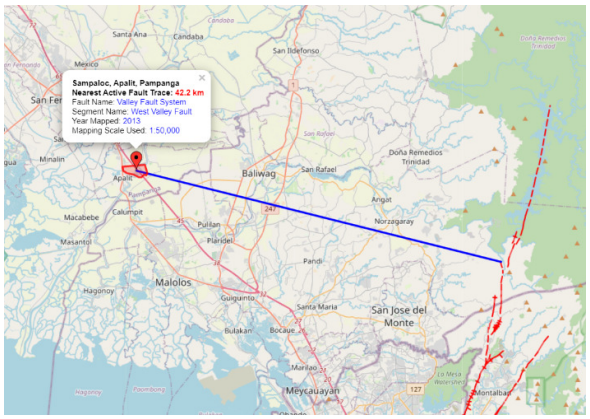


Fig. 12: Valley Fault System using Fault Finder

The fault's seismic source type is classified as type A due to its potential to generate high-magnitude earthquakes with a significant frequency of seismic activity. As per PHIVOLCS, the West Valley fault, which is capable of producing earthquakes greater than 7.0 in magnitude, has the potential to trigger a major earthquake of 7.2 magnitudes on the Richter Scale.

- Z = 0.40 Seismic Zone Factor
- I = 1.00 Occupancy Category III – Special Occupancy Structures

**Numerical Coefficient:**

Base shear coefficient shall be derived using the following formula stipulated in NSCP.
Earthquake Load Provisions for Building Structure:

- W = 5923.23 kN – result is given from STAAD v8i

Soil Profile Type: E – given from geotechnical investigation report from DHVSU Apaplit Campus

- Nv = 1.0 Table 208-5 Near-Source Factor
- Na = 1.0 Table 208-4 Near-Source Factor
- Ca = 0.44 Table 208-8 Seismic Coefficient
- Cv = 0.96 Table 208-7 Seismic Coefficient
- I = 1.0 Importance Factor
- R = 8.0
- T= 0.4605173

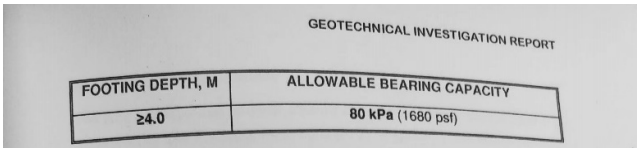
6) ***Load Combination:***

1. DL + LL
2. 1.2DL + 1.6LL
3. 1.2DL + 1.0EX + 0.5LL
4. 1.2DL + 1.0EZ + 0.5LL

7) ***Materials Strength***

- Concrete:
  - f'c = 4000 psi
- Reinforcing Steel:
  - 25 mm Ø & fy = 414 MPa
- Structural Steel:
  - Yield strength Fy = 248 MPa
  - Tensile strength Fu = 400 MPa
- Welds: E60

8) ***Soil Properties***


GEOTECHNICAL INVESTIGATION REPORT

| FOOTING DEPTH, M | ALLOWABLE BEARING CAPACITY |
|---|---|
| ≥4.0 | 80 kPa (1680 psf) |

Fig. 13: Soil Allowable Bearing Stress = 80 kPA – given in the Geotechnical Investigation Report in DHVSU Apalit Campus

## 4. *PLANS AND MODELING*

1) ***Architectural Plan:***

➢ **Perspective View**

Fig. 14: Front View

Fig. 15: Top View

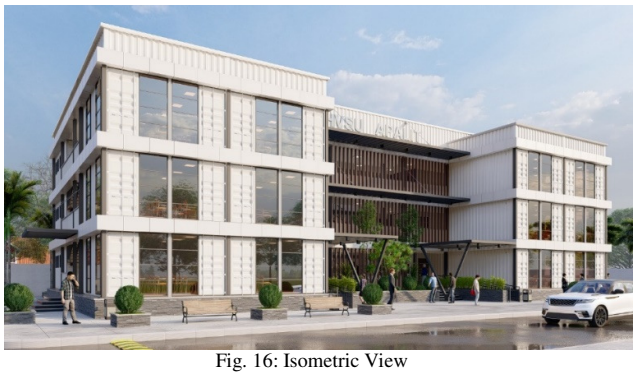


Fig. 16: Isometric View

2) ***Site Development Plan:***

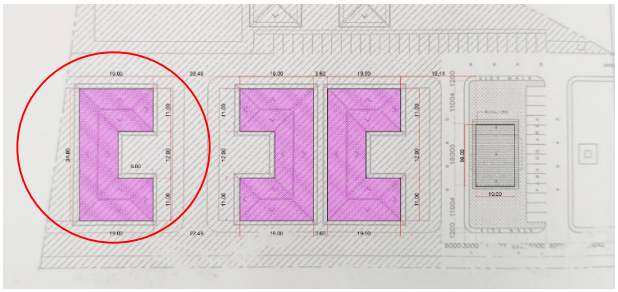
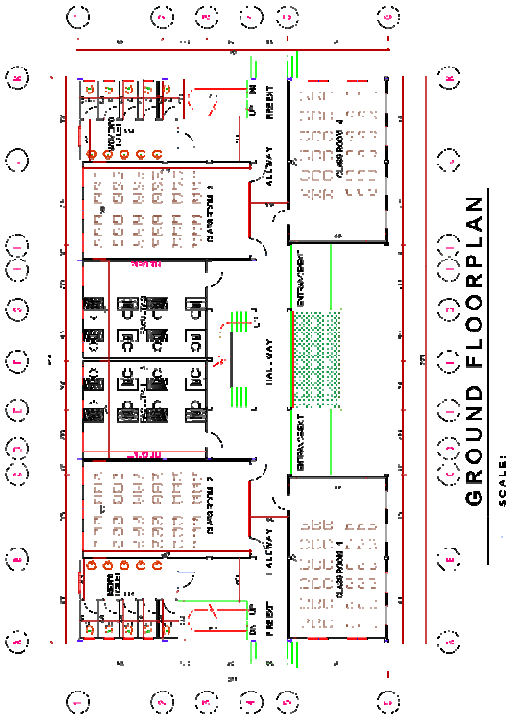
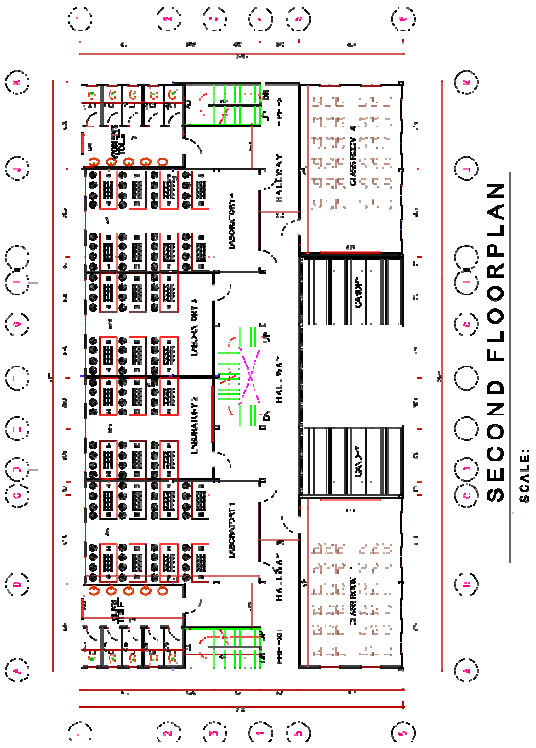
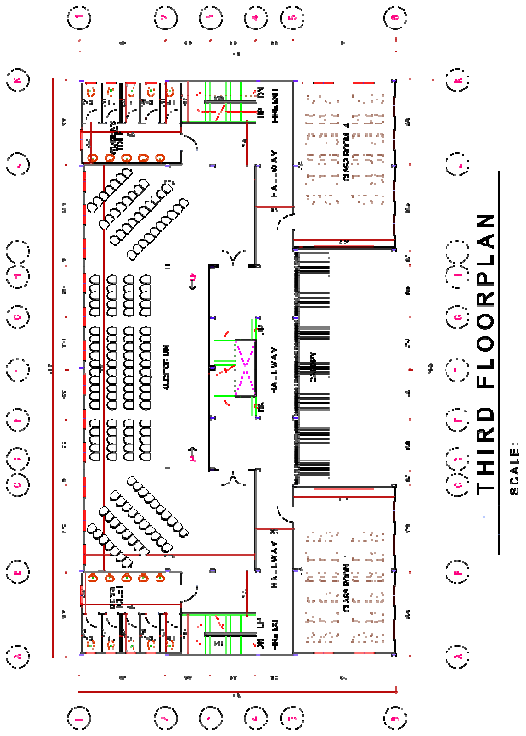


Fig. 17: Location of the Proposed Structure

3) ***Floor Plans:***



4) ***Elevation:***

*Fig. 18: Front Elevation*

Fig. 19: Left Side Elevation

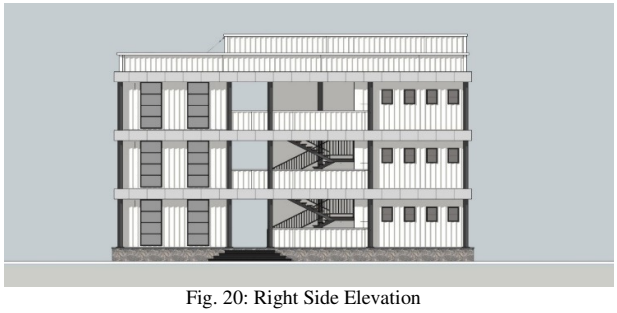
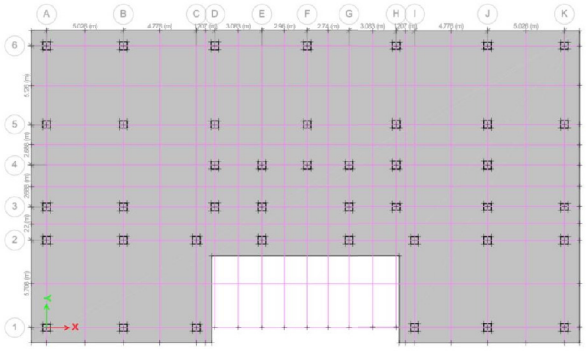


Fig. 20: Right Side Elevation

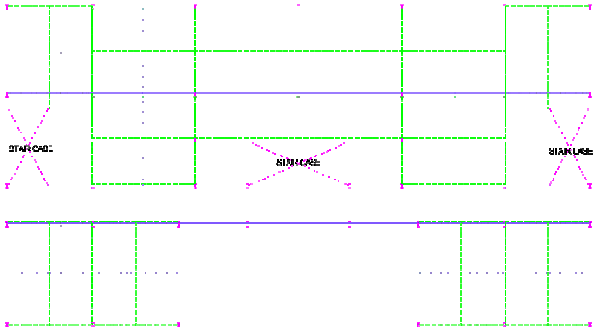
Fig. 21: Rear Elevation

5) ***Structural Framing Plan:***

- **Foundation Plan**



6) ***Steel Framing Plan***



STEEL FRAMING

7) ***Structural Modeling***

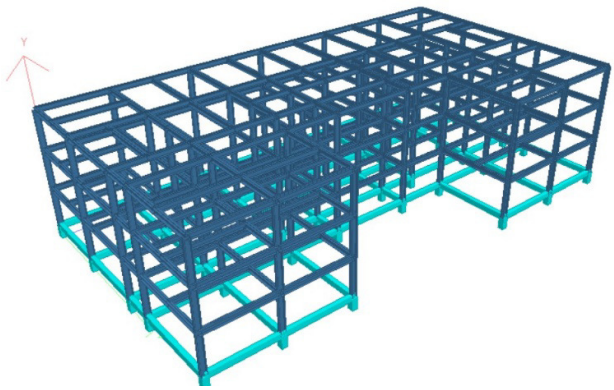


Fig. 22: Structural Framing, Isometric View using STAAD v8i

8) ***Structural Skeleton Model***

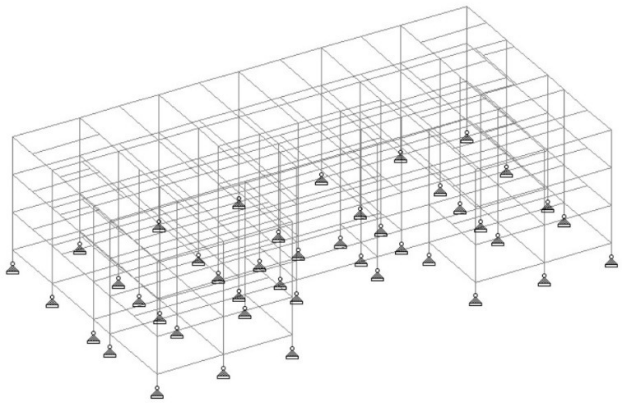


Fig. 23: Skeleton Model using STAAD v8i

E.***SRUCTURAL REPORT***

1) ***General:*** To analyze the structure STAAD Pro v8i was utilized, which is capable of conducting a range of analyses, from conventional static analysis to more contemporary techniques such as p-delta analysis, geometric non-linear analysis, Pushover analysis (Static-Non Linear Analysis), and buckling analysis. Additionally, it can employ a variety of dynamic analysis approaches, such as time history analysis and response spectrum analysis, which supports both user-defined spectra and several international code-specified spectra.

2) ***Base Shear Result/Earthquake Load***

➢ **Base Shear at X- Direction**

- X DIRECTION: Ta = 0.461 Tb = 0.281 Tuser = 0.000
- T = 0.281, LOAD FACTOR = 1.000
- UBC TYPE = 97
- UBC FACTOR V = 0.1000 x 5996.18 = 599.62 KN

## ➢ Base Shear at Z- Direction

- Z DIRECTION: Ta = 0.461 Tb = 0.399 Tuser = 0.000
- T = 0.399, LOAD FACTOR = 1.000
- UBC TYPE = 97
- UBC FACTOR V = 0.1000 x 5996.18 = 599.62 KN

3) ***Beam Displacement Summary:***

➢ ***Critical Nodal Displacement Location***

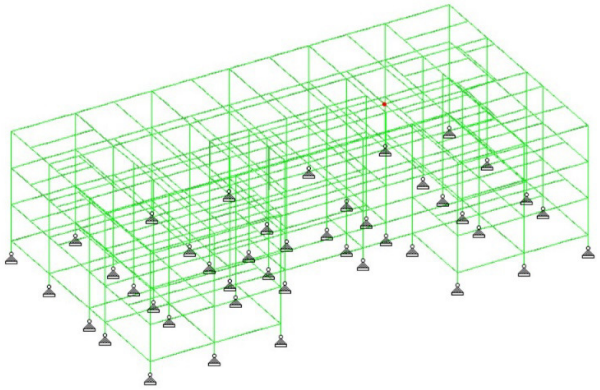


Fig. 24: Critical Nodal Displacement

➢ ***Summary of Nodal Displacement Results:***

All / Summary /

| | Node | L/C | Horizontal X mm | Vertical Y mm | Horizontal Z mm | Resultant mm | Rotational rX rad | rY rad | rZ rad |
|---|---|---|---|---|---|---|---|---|---|
| Max X | 359 | 1 EX | **3.618** | 0.028 | 0.286 | 3.630 | 0.000 | 0.000 | -0.000 |
| Min X | 335 | 8 1.2DL + 0.5 | **-0.565** | -0.127 | 7.801 | 7.823 | 0.000 | 0.000 | -0.000 |
| Max Y | 317 | 4 LL | 0.000 | **0.317** | -0.103 | 0.334 | 0.000 | 0.000 | -0.000 |
| Min Y | 310 | 6 1.2DL + 1.6 | -0.003 | **-13.253** | -0.269 | 13.256 | 0.001 | 0.000 | -0.000 |
| Max Z | 335 | 2 EZ | -0.556 | 0.027 | **7.998** | 8.017 | 0.000 | 0.000 | 0.000 |
| Min Z | 341 | 7 1.2DL + 0.5 | 3.296 | -0.182 | **-0.497** | 3.338 | 0.000 | 0.000 | -0.000 |
| Max rX | 311 | 6 1.2DL + 1.6 | -0.005 | -5.478 | -0.267 | 5.484 | **0.005** | 0.000 | 0.000 |
| Min rX | 314 | 6 1.2DL + 1.6 | -0.001 | -6.615 | -0.269 | 6.620 | **-0.006** | 0.000 | -0.000 |
| Max rY | 335 | 8 1.2DL + 0.5 | -0.565 | -0.127 | 7.801 | 7.823 | 0.000 | **0.000** | -0.000 |
| Min rY | 1 | 4 LL | 0.000 | 0.000 | 0.000 | 0.000 | -0.000 | **-0.000** | 0.000 |
| Max rZ | 327 | 6 1.2DL + 1.6 | 0.000 | -2.926 | -0.264 | 2.938 | -0.000 | 0.000 | **0.002** |
| Min rZ | 328 | 6 1.2DL + 1.6 | 0.000 | -2.926 | -0.268 | 2.938 | -0.000 | 0.000 | **-0.002** |
| Max Rsl | 310 | 6 1.2DL + 1.6 | -0.003 | -13.253 | -0.269 | **13.256** | 0.001 | 0.000 | -0.000 |

*Fig. 25: Summary of Nodal Displacement Results*

In the figure above it highlighted the LRFD load combination used EX for Max X. The horizontal X, has a nodal displacement result of 3.618mm, the vertical Y has a 0.028mm nodal displacement result, the horizontal Z has a

0.286mm nodal displacement result, and the resultant has 3.630mm nodal displacement result.

4) ***Maximum Moment Summary:***

➢ **Horizontal Member with Maximum Moment**

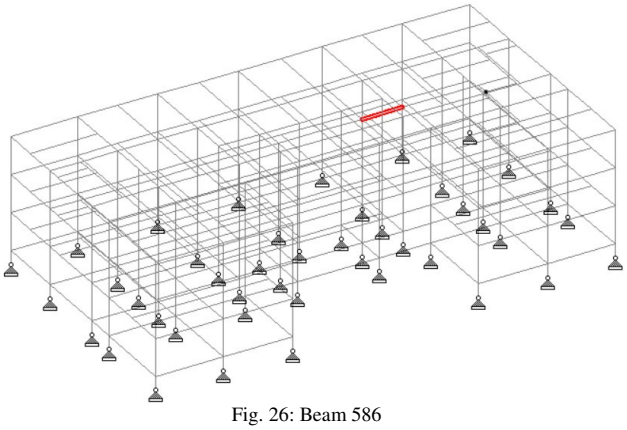


Fig. 26: Beam 586

➢ ***Maximum Moment Summary***

| Beam | L/C | Node | Axial Force kN | Shear-Y kN | Shear-Z kN | Torsion kNm | Moment-Y kNm | Moment-Z kNm |
|---|---|---|---|---|---|---|---|---|
| 586 | 6 | 271 | 0.000 | 250.516 | -0.000 | -0.054 | -0.000 | 325.038 |
| 586 | 6 | 310 | 0.000 | -159.237 | 0.000 | 0.054 | -0.000 | 287.850 |
| 584 | 6 | 268 | 0.000 | 233.216 | -0.000 | -0.037 | 0.000 | 283.048 |
| 584 | 6 | 308 | 0.000 | -141.936 | 0.000 | 0.037 | 0.000 | 278.086 |
| 683 | 6 | 269 | 0.000 | 164.752 | -0.000 | 0.054 | -0.000 | 220.314 |
| 586 | 5 | 271 | 0.000 | 166.411 | -0.000 | -0.035 | -0.000 | 215.819 |
| 585 | 6 | 270 | 0.000 | 160.184 | 0.000 | 0.054 | -0.000 | 202.432 |
| 584 | 5 | 268 | 0.000 | 157.070 | -0.000 | -0.027 | 0.000 | 190.987 |
| 586 | 5 | 310 | 0.000 | -105.409 | 0.000 | 0.035 | -0.000 | 190.756 |
| 584 | 5 | 308 | 0.000 | -96.068 | 0.000 | 0.027 | 0.000 | 187.644 |
| 586 | 4 | 271 | 0.000 | 127.058 | -0.000 | -0.029 | -0.000 | 165.138 |

Fig. 27: Maximum Moment Summary

In the figure above it highlighted the LRFD load combination used 1.2DL+1.0EQX+0.5LL for Max Moment. The Beam number 586, node 271 has a total of 325.038 kN-m.

5) ***Maximum Axial Force:***

➢ ***Vertical Member with Maximum Axial Force***

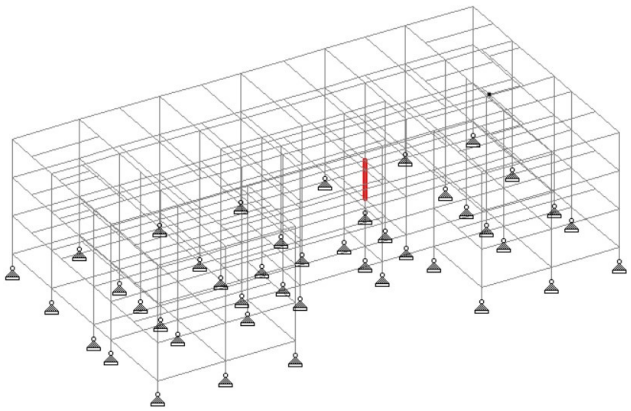


Fig. 28: Column 145

➢ ***Maximum Axial Force Summary:***

| Beam | L/C | Node | Axial Force kN | Shear-Y kN | Shear-Z kN | Torsion kNm | Moment-Y kNm | Moment-Z kNm |
|---|---|---|---|---|---|---|---|---|
| 145 | 6 | 26 | 784.447 | -2.666 | -2.815 | -0.000 | 2.751 | -1.443 |
| 143 | 6 | 24 | 771.948 | 3.352 | -2.797 | -0.000 | 2.735 | 2.097 |
| 144 | 6 | 25 | 667.963 | -0.362 | -2.602 | -0.000 | 2.549 | -0.474 |
| 518 | 6 | 112 | 592.963 | -26.046 | -11.275 | -0.000 | 13.090 | -25.031 |
| 146 | 6 | 27 | 584.617 | 6.205 | -2.329 | -0.000 | 2.260 | 5.259 |
| 142 | 6 | 23 | 582.531 | -6.583 | -2.337 | -0.000 | 2.273 | -5.534 |
| 516 | 6 | 110 | 581.748 | 26.805 | -11.231 | -0.000 | 13.036 | 26.381 |
| 145 | 5 | 26 | 544.119 | -2.233 | -2.145 | -0.000 | 2.133 | -1.216 |
| 143 | 5 | 24 | 537.557 | 2.685 | -2.136 | -0.000 | 2.125 | 1.688 |
| 517 | 6 | 111 | 499.182 | -2.321 | -12.273 | -0.000 | 13.822 | -2.147 |
| 144 | 5 | 25 | 460.405 | -0.289 | -1.992 | -0.000 | 1.985 | -0.385 |
| 137 | 6 | 11 | 457.914 | -0.425 | 4.678 | -0.000 | -5.104 | -0.525 |
| 155 | 6 | 51 | 448.474 | -0.384 | 8.783 | -0.000 | -8.905 | -0.427 |

Fig. 29: Maximum Axial Force Summary

In the figure above it highlighted the LRFD load combination used 1.2DL+1.0EQX+0.5LL for Max Moment. The Beam number 145, node 26 has a total Axial Force of 784.447 kN.

6) ***Maximum Axial Force up to Pedestal:***

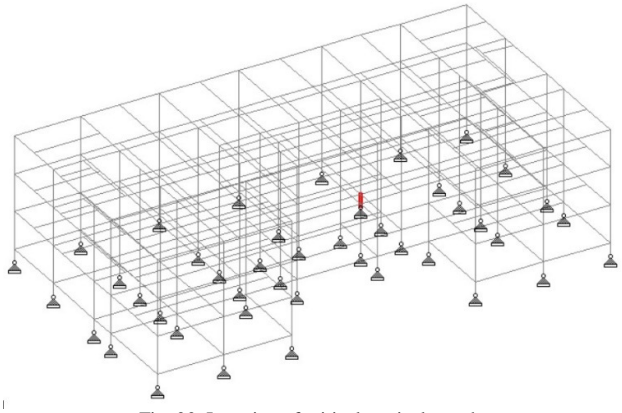


Fig. 30: Location of critical vertical member

➢ ***Maximum Axial Force summary up to Pedestal***

| Beam | L/C | Node | Axial Force kN | Shear-Y kN | Shear-Z kN | Torsion kNm | Moment-Y kNm | Moment-Z kNm |
|---|---|---|---|---|---|---|---|---|
| 24 | 6 | 19 | 847.678 | 2.293 | -7.019 | 0.000 | -0.000 | 0.000 |
| 22 | 6 | 17 | 834.627 | -1.879 | -6.983 | 0.000 | -0.000 | -0.000 |
| 145 | 6 | 26 | 784.447 | -2.666 | -2.815 | -0.000 | 2.751 | -1.443 |
| 143 | 6 | 24 | 771.948 | 3.352 | -2.797 | -0.000 | 2.735 | 2.097 |
| 23 | 6 | 18 | 732.854 | -0.534 | -6.936 | 0.000 | -0.000 | -0.000 |
| 144 | 6 | 25 | 667.963 | -0.362 | -2.602 | -0.000 | 2.549 | -0.474 |
| 25 | 6 | 20 | 645.177 | 0.862 | -6.362 | 0.000 | -0.000 | -0.000 |
| 21 | 6 | 16 | 643.124 | -0.674 | -6.365 | 0.000 | 0.000 | -0.000 |
| 24 | 5 | 19 | 597.321 | 1.893 | -5.707 | 0.000 | -0.000 | 0.000 |
| 518 | 6 | 112 | 592.963 | -26.046 | -11.275 | -0.000 | 13.090 | -25.031 |
| 22 | 5 | 17 | 590.279 | -1.483 | -5.687 | 0.000 | -0.000 | -0.000 |
| 146 | 6 | 27 | 584.617 | 6.205 | -2.329 | -0.000 | 2.260 | 5.259 |
| 142 | 6 | 23 | 582.531 | -6.583 | -2.337 | -0.000 | 2.273 | -5.534 |

Fig. 31: Maximum Axial Force

## 6. *DESIGN FOUNDATION*

### 1) *Mat Foundation:*

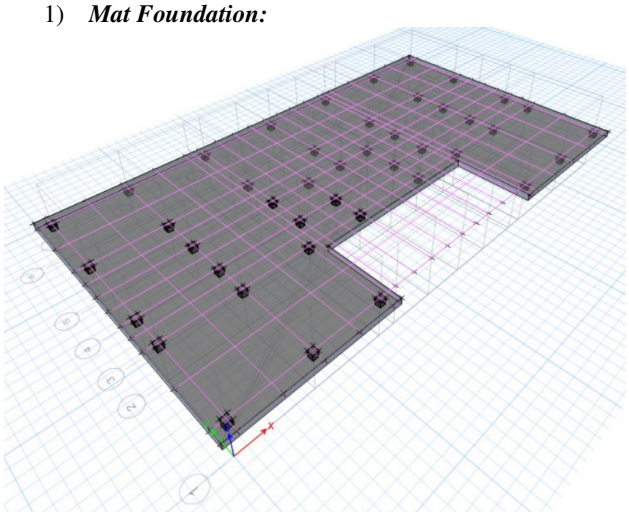


Fig. 32: Mat Foundation using SAFE Software

The calculated thickness based on the maximum axial force seen in Fig. 3.5.5.4 for the design mat foundation is 400mm given using SAFE software with 689.5854 $m^2$ total area provided.

### 2) *SAFE Punching Shear Check:*

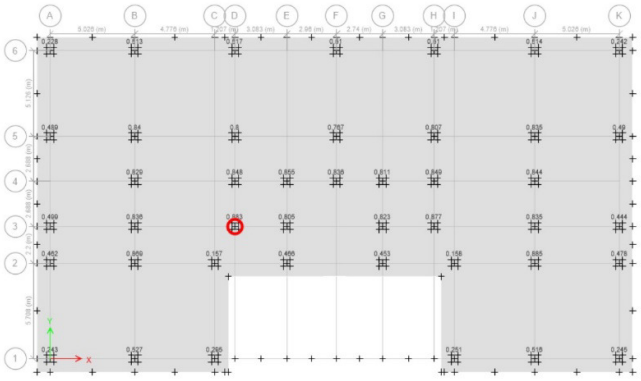


Fig. 33: Maximum Punching Shear Ratio for Columns on Mat Foundation

The SAFE software possesses the capability to verify the punching shear of modeled mats or slabs, ensuring their safety. In the present project, the SAFE software was utilized to examine the punching shear, and all the calculated values were below 1, signifying that the load shear remains below the mat's shear resistance. A graphical representation of the punching shear factors can be seen in Figure 3.2.8.2.

### 3) *Moment at X strip – transverse bars:*

➢ ***Moment Diagram at Transverse Bars***

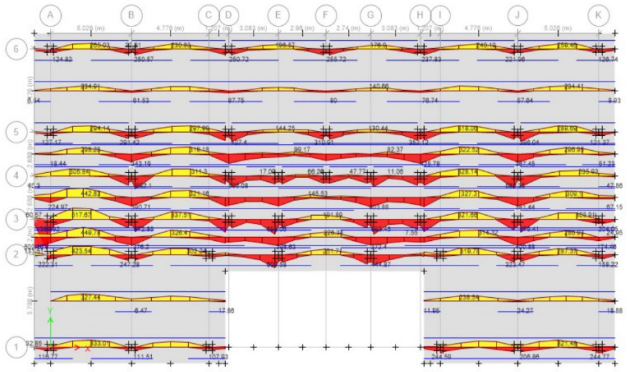


Fig. 34: Moment Diagram at Transverse Bars

➢ ***Maximum Moment Summary***

TABLE IV
Positive and Negative Maximum Moment along Column Strip and Middle Strip

| Strip Notation | Strip Field | Positive Max. Moment (kN-m) | Negative Max. Moment (kN-m) |
|---|---|---|---|
| MSx3 | Middle Strip | 442.83 | -403.88 |
| CSx4 | Column Strip | 517.67 | -689.06 |
| | | | |

### 4) *Moment at Y strip – longitudinal bars:*

➢ ***Moment Diagram at Longitudinal Bars***

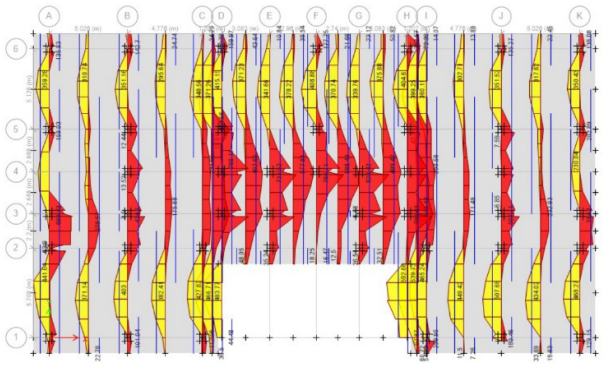


Fig. 35: M*oment Diagram at Longitudinal Bars*

➢ **Maximum Moment Summary**

| Strip Notation | Strip Field | Positive Max. Moment (kN-m) | Negative Max. Moment (kN-m) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| MSy8 | Middle Strip | 539.73 | -443.63 |
| CSy10 | Column Strip | 507.68 | -501.71 |

Fig. 36: Positive and Negative Maximum Moment along Column Strip and Middle Strip

5) ***Reinforcement Summary along Transverse and Longitudinal RSB:***

| Direction | X - Strip ( Transverse Reinforcement) | | | | Y- Strip ( Longitudinal Reinforcement) | | | |
|---|---|---|---|---|---|---|---|---|
| Location | Column Strip | | Middle Strip | | Column Strip | | Middle Strip | |
| Position | Top | Bottom | Top | Bottom | Top | Bottom | Top | Bottom |
| Bar Size (mm) | 28 Ø | 28 Ø | 28 Ø | 28 Ø | 28 Ø | 28 Ø | 28 Ø | 28 Ø |
| Spacing (mm) | 80 | 120 | 160 | 140 | 120 | 100 | 140 | 110 |

Fig. 37: Reinforcement Summary along X strip and Y strip

## 7. *STRUCTURAL DETAILING*

### 1) *Mat Foundation Details:*

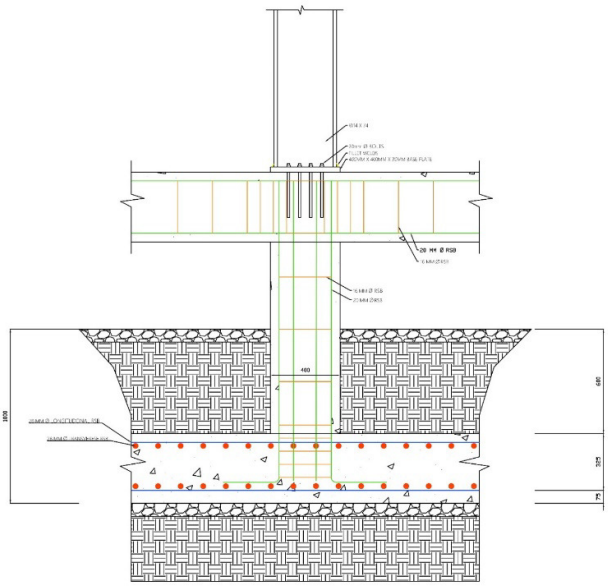


Fig. 38: Mat Foundation Details

### 2) *Connection Details:*

- **Column to Pedestal Connection Details**

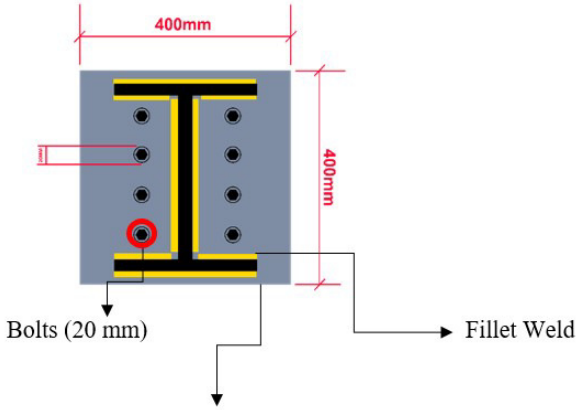



Fig. 39: Column and Pedestal weld and bolts connection

- **Column and Beam Connection**

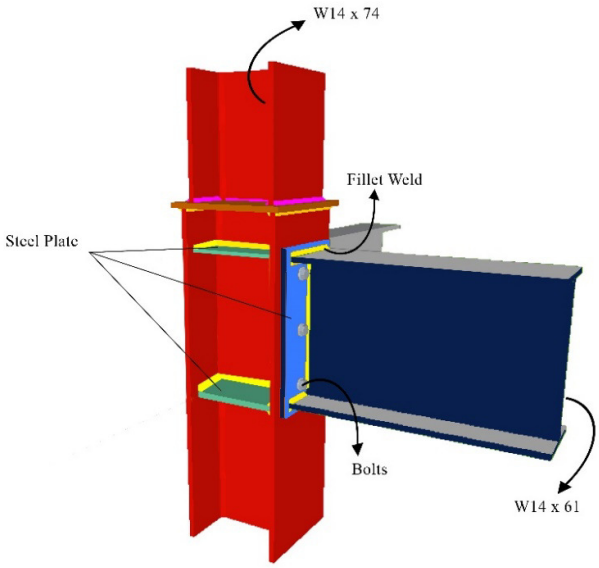



*Fig. 40: Welds and Beam Connection between Column and Beam*

- **Shipping Container to Structural Member Connection**

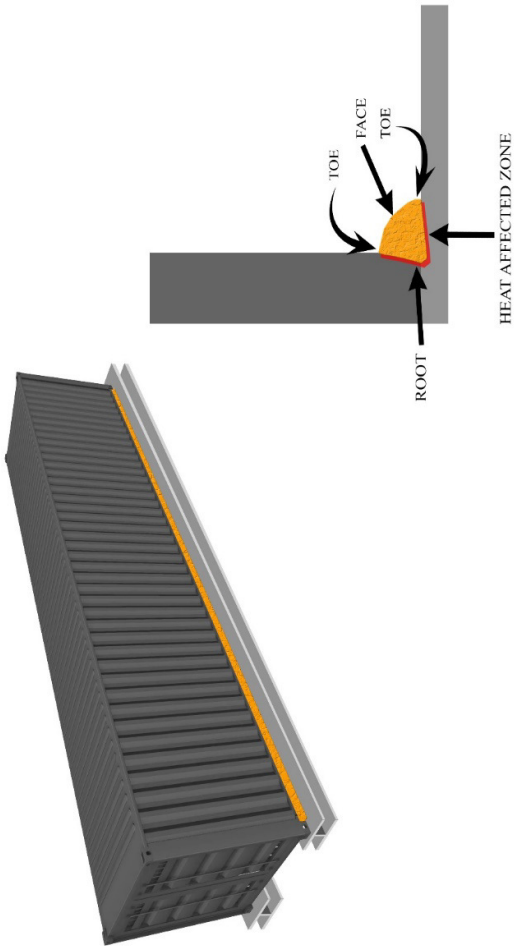



Fig. 41: Shipping Container to Steel Member Weld Connection

## 8. *COST ANALYSIS*

### *1) EXCAVATION WORKS/BACKFILLING:*

| NUMBER | DESCRIPTION | QTY | UNIT | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|
| 1 | Excavation Works | 606.27 | CU. M | 500.00 | 303,135.00 |
| 2 | Backfilling Works | 600.16 | CU. M | 350.00 | 210,056.00 |
| **TOTAL** | | | | | **513,191.00** |

### *2) CONCRETE WORKS:*

| NUMBER | DESCRIPTION | QTY | UNIT | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|
| 1 | CEMENT (40KG) | 1,281 | BAGS | 205 | 262,605.00 |
| 2 | SAND | 217 | 2.7 CU.M | 1,950 | 156,722.2 |
| 3 | GRAVEL | 407 | 2.7 CU.M | 2,600 | 391,925.9 |
| 4 | 4" CHB - Non Load Bearing | 1,281 | PCS. | 9.75 | 12,489.75 |
| Sub-Total | | | | | 823,742.9 |
| Labor Cost | | | | 25% | 205,935.7 |
| **Total** | | | | | **1,029,679** |

### *3) REBARS AND STEEL WORKS:*

| NUMBER | DESCRIPTION | QTY | UNIT | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|
| 1 | W14x61 | 130,221 | kg/m | 55 | 7,162,155.00 |
| 2 | W14x74 | 40,260 | kg/m | 55 | 2,214,300.00 |
| 3 | 28Ø mm RSB | 1,434 | pcs | 1,800 | 2,581,200.00 |
| 4 | 20Ømm RSB | 78 | pcs | 640 | 49,920.00 |
| 5 | 16Ømm RSB | 21 | pcs | 371 | 7,791.00 |
| 6 | .4mx.4mx.03m Base Plate | 43 | pcs | 2,300 | 98,900.00 |
| 7 | Pre-painted Metal Roofing Sheet GA 26, Long Span | 693 | sq. m. | 466 | 322,938.00 |
| 8 | Metal Decking | 1,010.299 | Lm | 661 | 667,807.4 |
| 9 | M20 Anchor Bolts | 244 | pcs | 360 | 87,840 |
| SUB-TOTAL | | | | | 13,192,851 |
| Labor Cost | | | | 30% | 3,957,855 |
| **Total** | | | | | **17,150,707.00** |

### 4) 20 ft SHIPPING CONTAINER:

| NUMBER | DESCRIPTION | QTY | UNIT | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|
| 1 | DELIVERY FOR 2 PCS | 39 | PCS | FREE | 0 |
| 2 | 20 FT USED SHIPPING CONTAINER | 78 | PCS | 60,000 | 4,680,000.00 |
| **TOTAL** | | | | | **4,680,000.00** |

### *5) FORMWORKS:*

| NUMBER | DESCRIPTION | QTY | UNIT | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|
| 1 | 1/4" Ordinary Plywood | 22 | 1 whole | 410 | 9,020.00 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | 2" x 3" x 10' COCOLUMBER | 2949 | pcs | 175 | 516,075.00 |
| **Total** | | | | | **525,095.00** |

***6) SOLAR PANEL:***

| NUMBER | DESCRIPTION | QTY | UNIT | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|
| 1 | 38 solar panels (15kWp) with an installation area of 86m^2 | 6 set | 38pcs / 86sq.m | 900,000 | 5,400,000.00 |
| **Total** | | | | | **5,400,000.00** |

***7) SUMMARY:***

| NO. | DESCRIPTION | MATERIAL COST | LABOR COST | TOTAL |
|---|---|---|---|---|
| I | CONCRETE WORKS | 823,742.8981 | 205,935.7245 | 1,029,679.00 |
| II | EXCAVATION WORKS/BACKFILLING | 513,191 | Included in material cost | 513,191.00 |
| III | 20FT HIGH CUBE SHIPPING CONTAINER | 4,680,000 | | 4,680,000.00 |
| IV | FORMWORKS | 525,095 | | 525,095.00 |
| V | REBARS AND STEEL WORKS | 13,192,851.45 | 3,957,855.434 | 17,150,707.00 |
| VI | SOLAR PANEL | 5,400,000 | Installation included in material cost | 5,400,000.00 |
| VII | MISCELLANEOUS (10% OF SUB TOTAL) | 2,929,867.15 | | 2,929,867.00 |
| **TOTAL** | | | | **32,228,539.00** |

9. ***DISCUSSION***

The design of a structural member involves verifying that the member can safely support the loads imposed on it without failing or exceeding allowable stresses. Multiple evaluations were performed to ensure the safety of the W14 x 61 beams and W14 x 74 columns. For compaction, the design of the beam was evaluated, including flexure, compression, tension force, and deflection. Compaction refers to the reduction in the size of the member due to the weight of the structure, while flexure refers to the beam's ability to resist bending. Compression and tension forces were also evaluated, as was a deflection, which measures the deformation or displacement under load.

In contrast, the design of the column was evaluated based on its slenderness ratio, critical buckling stress, and nominal compressive stress. The slenderness ratio determines if the column is too slender, which could lead to buckling or failure under compression. The maximum axial force was determined using STAAD software.

The weld design was evaluated to ensure that the welds could support the loads without failing. The baseplate design was also evaluated to ensure that the dimensions and thickness could safely transfer loads from the column to the foundation. Pedestal reinforcement was calculated by determining the number of reinforcement bars and spacing of lateral ties required to support the loads on the pedestal safely.

The SAFE software was used to design the mat footing, which was analyzed for its ability to safely support the loads without punching through the concrete. The moment reaction along the transverse and longitudinal directions was also illustrated by the software.

Finally, a cost analysis was performed to determine the total cost of materials and the proposed building. This analysis helped assess the project's feasibility and compare it with the construction budget.

## IV. CONCLUSION AND RECOMMENDATION

10. ***Conclusion***

Due to the increasing student population at DHVSU Apalit Campus, it is badly in need of an academic extension building. To handle the increasing number of students enrolling at the campus and to find an alternative construction method that doesn't generate a large quantity of waste, consume significant energy volume, and release a substantial scale of carbon emissions, the researchers develop a study that aims to build a sustainable three-story academic building using abandoned container trucks.

The study of the major materials to be used, and reviewing the specification of the material gave a major help to finding the stability of the future structure, and also, this study shows how much the cost of the project for a modern design structure using the material is. Concurring with the quantifiable data, studies, and design, the used

container vans are very durable and can be made for the project in a very short span of time which will lower the construction cost considering the cheaper cost of the chosen major materials which is the container van.

This researcher's concept is to create a better alternative construction method that will benefit not just the school but also improve our environment rather than just maintain it. Also adding features of a green building in the structure to make it more sustainable since it is one of the goals of the study. Based on the resulting calculations, whether they will be safe to use or not. As long as it is built properly and correctly, it can be an inspiration to build more such structures in the future. This will be a smooth change in building structures in the country.

With the knowledge and skill applied in this research study that the researchers obtained in the University programs and with the help of some mentors in the university and some suggestions from professionals outside the campus. All theories and principles regarding building construction specifically structural analysis, site investigation, cost estimates, and preparing technical specifications are implemented by the researchers in such ways that will benefit the future study on this kind of research.

With the researcher's dedication and effort, they come up with a unique idea and propose a sustainable academic three-story building using a used container van with futuristic and undeniably unique features.

11. ***Recommendations***

- The researchers would like to recommend the following to the next researchers who would like to further study this concept:
- Study the efficiency of installing new technologies in smart buildings such as solar panels, vertical gardens, Low-E glass, and water conservation techniques
- Research for additional aesthetics of the building to make it more presentable and pleasing to the eye.
- Further research about the use of Container Vans as a major material to build a structure.
- Other construction plans, such as the electrical and plumbing plans, may be taken into consideration.
- Wind Load assessment using STAAD v8i software may be conducted to evaluate the impact of wind on the proposed three-story academic building made from abandoned container trucks. Wind Load assessment is an important aspect of building design and it's used to calculate the force of wind that a structure is likely to experience during a severe storm or hurricane. By conducting this assessment, the researchers can identify potential weak points in the building's design and make necessary adjustments to ensure that the building can withstand strong winds and other natural calamities.
- Building management systems such as Internet of Things sensors, artificial intelligence, and augmented reality that may be used in a smart building to control and optimize its performance, must take into consideration.

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Again, thank you very much!

**THE RESEARCHERS**

## DEDICATION

This modest work is dedicated to our parents, who have been supporting, inspiring and giving their unconditional love throughout this study:

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**Mr. and Mrs. Rafael Baluyut and Agnes Baluyut**

**Mr. and Mrs. Benjamin Lapuz and Anita Lapuz**

**Mr. and Mrs. Edwin Macatuno and Nancy Macatuno**

**Mr. and Mrs. Arnel Tolentino and Bernadeth Tolentino**

To our very supportive and forbearing professors and educators;

To our beloved Alma Mater- DHVSU.

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