RESEARCH ARTICLE OPEN ACCESS

# Design of Permeable Pavement and Underdrain in Don Honorio Ventura State University Lubao Campus

Kim Chester M. Castro[1], Erika Ann G. Gaviola[2], Adrian R. Macaspac[3], Mikhaella D. Nicdao[4], Genelle D. Quinto[5], John Carlo M. Sanchez[6], Fraence Mark Y. Trapsi[7], Ma. Vannerie Issa S. Eusebio[8], and Raul O. Duya[9]

[1-7]Student, Don Honorio Ventura State University/College of Engineering and Architecture/Department of Civil Engineering, Cabambangan,Bacolor, Pampnga, Philippines, 2001

chestercastro07@gmail.com[1], gaviolaerika12@gmail.com[2], adrianmacaspac@gmail.com[3], nicdaomikhaella2@gmail.com[4], genellequinto@gmail.com[5], johncarlosanchez975@gmail.com[6], fraencemarktrapsi@gmail.com[7]

[8-9]Faculty, Don Honorio Ventura State University/College of Engineering and Architecture/Department of Civil Engineering, Cabambangan, Bacolor, Pampanga, Philippines, 2001

mseusebio@dhvsu.edu.ph[8], roduya@dhvsu.edu.ph[9]

----------------------------------------************************----------------------------------

## Abstract:

The health and safety of the community is one of the major concerns that need to be addressed regarding flooding issues since a safe home and a home free of diseases are essential things that need to be considered in life. Having the ease and freedom of mind that comes from having safety in your environment helps us to be stable. As the infrastructure has continuously developed, the capacity for natural drainage has been drastically diminished, resulting in low infiltration rates of soil and contaminated bodies of water. Based on the gathered data, the area of Sta. Catalina, Lubao, Pampanga (Don Honorio Ventura State University Lubao Campus) also faces the same issue due to its natural landscape, wherein the place is highly susceptible to flooding. If this is not treated, a lot of harmful diseases can be acquired. The health and safety of the community are at risk due to these factors, which is why designing a permeable pavement helps the personnel and students of Don Honorio Ventura State University's Lubao Campus and the community lessen the risk of flooding that may occur since the permeable pavement can store the water on its sub-base layer. Overall, permeable pavement helps keep the environment clean and free from flooding.

*Keywords* **—Health, Safety, Drainage, Permeable pavement**

----------------------------------------************************----------------------------------

## I. INTRODUCTION

The Philippines is vulnerable to both natural and man-made disasters. Numerous devastating typhoons, earthquakes, volcano eruptions, and other natural calamities have struck the country. This is due to its location, wherein the country is near the typhoon belt or Pacific Ring of Fire. The Philippines are susceptible to tropical cyclones such as Yolanda, also known as typhoon Haiyan, which was one of the Philippines' deadliest natural disasters in history. During Typhoon Haiyan, hundreds of people perished as a result of floods, improper garbage disposal, and man-made disasters, which are caused by changes in the earth's spheres (Wingard and Brändlin, 2013).

According to International Society for Concrete Pavements (2023), the community's sewer system has been overworked, resulting in flooding, as a consequence of natural terrain changes in metropolitan areas. The preservation of as much green area as possible is necessary to lessen precipitation runoff and ensure environmental stability. The usage of permeable pavements would be mandated under a suggested regulation. The drainage design allows water to pass through porous spots in the pavement and eventually percolate into the subsurface soil as a remedy to the floods and nuisance brought on by the rainy season.

The United States Environmental Protection Agency (UEPA) (2017) claims that urban catchment discharge is a key factor in the pollution of surface water in the country. Emission amounts, maximum flows, and pollution discharge all rise as impermeable land area increases. Governments around the US have been compelled by storm water legislation to install storm water control measures (SCMs) in order to achieve water supply and quality goals.

The Don Honorio Ventura State University (DHVSU) Lubao Campus is continuously being developed due to urbanization. Since the university is near the Municipality of Lubao, a lot of facilities are being developed. Due to this, the drainage system available at the location might experience overloading and may cause surface water impairment. The researchers are proposing a Design of Permeable Pavement and Underdrain to improve the precipitation runoff volumes and to combat the problems of urbanization and flooding.

Since permeable pavements can endure mechanical stresses while allowing for temporary water storage and percolation, they are regarded as environmentally friendly sewage technologies that may reduce surface discharge without compromising structural integrity. Numerous studies have shown the benefits of using this kind of pavement. According to Ball, J.E. and Rankin (2010), permeable pavements may minimize overflow by up to 42% compared to conventional pavements. The usage of permeable pavements, according to Pagotto et al. (2017), enhances the quality of storm water by eliminating the bulk of contaminants. Heavy metals can be decreased by up to 74%, particles can be kept in suspension by up to 87%, and hydrocarbons can be captured by up to 90%.

Due to the fact that it may be utilized for both parking and driving, permeable pavement is a popular Storm Water Control Measure (SCM). Runoff penetrates through a porous outer stratum and accumulates in a crushed stone sub-base before exfiltration or discharge reaches the groundwater or storm sewer systems through an underdrain. Permeable pavements absorb several pollutants by transpiration and precipitation in addition to decreasing the load of contaminants in collecting flows via exfiltration (Drake, J.; Bradford, A.; Van Seters, T., 2014).

The consistent increase in global temperatures induced by the release of greenhouse gases such as carbon dioxide ($CO_2$) has resulted in a variety of climate change and environmental problems. Consequently, the duration and frequency of severe weather events have risen, which results in more precipitation and shorter durations of intense precipitation (Hinge, G, 2022).

To reduce storm water discharge and enhance water quality, a variety of practices have been developed. These techniques include permeable surfaces, filter and infiltration trenches, retention basins, wetlands, ponds, and water harvesting. Permeable pavement systems are among the most beneficial sustainable urban drainage systems (SUDS) (Zhou, Q. A, 2014).

The researchers aim to design a permeable pavement and underdrain on the parking areas of DHVSU Lubao Campus. It is proven that permeable pavements are applicable in parking spaces. The design also saves the underlying soil because it filters the water that will flow on its surface, helps maintain the environment healthy, and prevents flooding that may occur because it can sip large amounts of water.

DHVSU Lubao Campus is situated in Barangay Sta. Catalina Lubao, Pampanga. The Barangay Santa Catalina is a peaceful community caring for nature and cleanliness, with a prosperous lifestyle under a government's safe, clean, and prudent leadership. The community aspires to lessen the risk associated with every calamity. Their only choice is to preservelives, decrease the number of injuries, and avoid additional damage to homes and people's livelihoods.

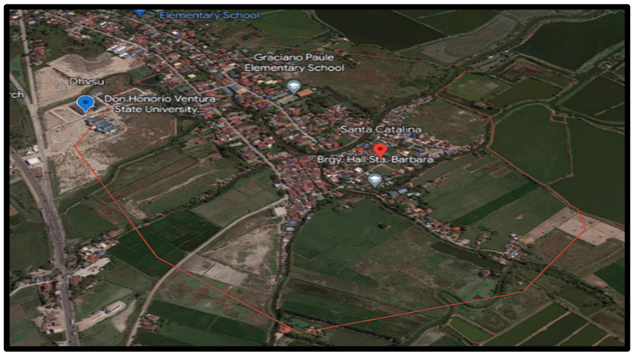



**Figure 1.** Sta. Catalina Lubao, Pampanga
*Reference:* Google Map

Barangay Sta. Catalina has an area of 4,522,427.04 hectares, of which 21,000 hectares are used in agriculture, while 13, 44395 hectares are households. Barangay Santa Catalina has a distance of one (1) kilometer from the center town where the Municipal Hall of the town is located. Barangay Santa Barbara is on the East side, Barangay Remedios is on the West, Barangay San Agustin is on the North, and Barangay Lubao Sasmuan River is on the South (Barangay Disaster Risk Reduction Management (BDRRM) of Sta. Catalina Lubao, Pampanga, 2017).

**Figure 2**. Flood in Sta. Catalina
*Reference:* Barangay Disaster Risk Reduction Management (BDRMM) of Sta Catalina Lubao Pampanga

Barangay Sta. Catalina has portions of low-lying areas that are susceptible to flash floods. Such areas in Purok 1 and Purok 2. The worst-case scenario was once experienced. The water reached six (6) feet deep near the shore of Malek Creek. The construction of the Box Culvert Bridge in Purok 2 and the flood mitigation structure built in Malek Creek, and the dredging that extended the area in 2017 have greatly helped in flood control (Barangay Disaster Risk Reduction Management (BDRMM) of Sta. Catalina Lubao, Pampanga, 2017).

**Table 1**. Knowing the Possible Dangers that the Barangay may Experience

| Danger | Probability | Effect | Basis | Alignment |
|---|---|---|---|---|
| Storm with strong wind and Rain | 4 | 5 | A large part of the barangay was exposed to the strong winds | 4.5 |
| Southwest monsoon that carries heavy rain for several days | 4 | 5 | The Philippines is the path of storms in the Pacific and tropical depressions often form every year | 4.5 |
| Flood | 4 | 4 | 2 wards are in the low lying area and the flood water is deep on the location | 4 |

For the probability: 1 (Least Probable), 2 (Low Probability), 3 (Possibly), 4 (High Probability), And 5 (Almost Certain). 1 (Negligent), 2 (Low Effect), 3 (Maintain Effect), 4 (High Effect), 5 (Devastating)

The Barangay Disaster Risk Reduction Management (BDRRM) of Sta. Catalina Lubao, Pampanga, has provided a Probability and Effect table to show the dangers that the barangay may experience. Table 1 shows that the location has a high probability that it will experience flooding, and the effects of the calamity have a high impact on the community.

**Table 2.** Number of Families and People who are Affected by any Kind of Danger

Table 2 shows that a total of four hundred eighteen (418) families might be affected due to flooding, according to Barangay Disaster Risk Reduction Management (BDRRM) of Sta. Catalina Lubao, Pampanaga (2017). To have the peace of mind that the children from every family have a safe environment free from flooding, the DHVSU LubaoCampus needs permeable pavement. Permeable pavement is an alternative design for common drainage systems. Due to overloading and urbanization, standard drainage design has a low impact on mitigating the effects of flooding.

In order to prevent inundation, the researchers proposed a design of permeable pavement and underdrain for the DHVSU Lubao Campus, which would be able to withstand any possible rainfall. The purpose of the pavement is to conserve green spaces and reduce precipitation runoff, thereby preserving the ecological balance.

### *1.1 Statement of the Problem*

This study aims to lessen the effects of flooding and create a design that benefits the community. Through this design, the water that the rain produces does not accumulate on the surface; instead, the Permeable Pavement sips the water before it falls into the underlying soil. The purpose of this study is to assist the community in preventing flood so that no additional lives or property are lost.

The following questions were addressed by the researchers:

1. What are the benefits that can be gained if this design is implemented?
2. What are the materials used to make this design?

### *1.2 Objectives of the Study*

In general, this study aims to design a permeable pavement and underdrain for the community of Sta. Catalina Lubao, Pampanga (DHVSU Lubao Campus), to prevent the possible flooding that may occur. These are the project's objectives:

1. To determine the maximum flood and rainfall elevation by conducting research and an analysis of rainfall at the designated location.
2. To design a standard permeable pavement and underdrain in DHVSU Lubao Campus

### *1.3 Significance of the Study*

Flood and rainwater are the things we do not consider that can be filtered and put to good use. Waste in the environment causes clogged drainage that results in flooding. The researchers focused on utilizing the rainwater and proposed a permeable pavement design and underdrain around the DHVSU Lubao Campus. Chemicals in the water will then be filtered through the sub-base layer before it falls to the surface, decreasing the chances of flood.

The findings of this study contribute to the beneficiaries by helping to design a permeable pavement and underdrain that can decrease the chances of flooding. This study also contributes to drainage development and lessens the risk of contaminated water since the design removes harmful substances.

The following stakeholders are the beneficiaries of the study:

**The Community.** The DHVSU Lubao students and personnel, since they are the main beneficiaries of this study, it helps them prevent the cause and effect of flooding in the area.

| PUROK | Number of Family | Number of Person | | Infant 0-11 Months | | Children (17 y/o & below) | | ADULT (18 to 59 y/o) | |
|---|---|---|---|---|---|---|---|---|---|
| | | B | G | B | G | B | G | B | G |
| 1 | 77 | 145 | 148 | 2 | 2 | 40 | 38 | 83 | 78 |
| 2 | 55 | 108 | 106 | 1 | 1 | 29 | 30 | 67 | 63 |
| 3 | 70 | 136 | 140 | 3 | 2 | 42 | 46 | 79 | 76 |
| 4 | 56 | 109 | 115 | 3 | 3 | 33 | 40 | 67 | 63 |
| 5 | 30 | 82 | 74 | 4 | 2 | 30 | 29 | 47 | 40 |
| 6 | 58 | 98 | 92 | 3 | 3 | 37 | 40 | 51 | 43 |
| 7 | 72 | 129 | 131 | 5 | 4 | 35 | 46 | 80 | 77 |
| **Total Number** | **418** | **807** | **806** | **21** | **17** | **246** | **269** | **474** | **440** |

**Local Government Unit (LGU).** This study can serve as a basis for their future projects related to drainages. It is also be helpful for possible plans for the LGUs in the area.

**Future Researchers.** This study can serve as a reference for information related to their studies.

### *1.4 Scope and Limitations*

The study focuses on designing a permeable pavement and underdrain in Don Honorio Ventura State University (DHVSU) Lubao Campus as a preventive measure for flood and rainwater problems.

This study helps prevent the effects of flooding in the proposed location, the DHVSU Lubao Campus, by proposing the Design of Permeable Pavement and Underdrain. Drainage improvements were achieved through this because no more clogging may occur during the rainy seasons.

This study does not provide the project's cost estimates, construction budget, and maintenance plan.

### *1.5 Study Area*


**Figure 3**. Don Honorio Ventura State University Lubao Campus
*Reference:* Google Map

The Design of Permeable Pavement and Underdrain is located at the well-known university in Pampanga, Don Honorio Ventura State University (DHVSU) Lubao Campus, situated in Sta. Catalina, Lubao Pampanga, as shown in Figure 3. The researchers chose this location to prevent possible flooding that may occur, and it also helps to maintain the cleanliness of the environment, making it sustainable.

DHVSU LubaoExtension Campus has a population of 1826as of 2021-2022. The employees in LubaoMunicipal Hall with a population of 467as of 2021. And the residents of Lubao with apopulationof173,502asof2021.

### *1.6 Review of the Related Literatures*

The term "permeable pavement" refers to paving materials that either absorb or permit water to permeate through the pavement. Before it is absorbed beneath the surface, the permeable pavement has the potential to filter out water and solid waste to prevent water pollution. Examples of "permeable pavement" materials include permeable concrete, porous interlocking concrete pavers, permeable concrete grid pavers, permeable asphalt, and any other material with similar characteristics.

The surface of permeable pavement is composed of concrete, pavers with open gaps, or bitumen, with a stone storage beneath. It absorbs water because it permits water to pass through it, as opposed to collecting on or running off of it. The precipitation water is deposited in a reservoir, from which it either drains through a drain tile or gently percolates into the ground below. The stone or gravel acts as a natural filter to purify the water. By restoring natural hydrologic equilibrium and minimizing runoff, permeable cement also aids in effectively managing storm water. It releases the water slowly into the earth instead of letting it run into storm drains (GreenBlue, 2016).

In providing essential water and air to urban trees' rooting zones, permeable pavement helps them grow into healthy plants. The soil moisture can fluctuate with fast soaking, drying, and re-aeration on permeable pavements, which act like a natural soil surface. Other benefits of porous paving include better control of erosion, siltation and better management of urban storm water runoff, which reduces pollution by capturing and degrading pollutants in the subgrade (GreenBlue, 2015).

The Permeable pavement consist of the following Layers:

1. Permeable Concrete Paver with non-pervious joints
2. Bedding Course
3. Reservoir Course
4. Under drained
5. Geotextile
6. Subgrade Sand

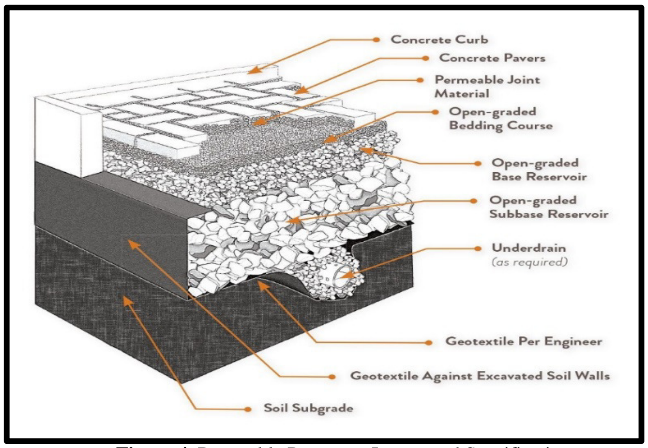



**Figure 4.** Permeable Pavement Layers and Specification
*Reference:https://www.researchgate.net*

The first layer, permeable concrete, is a quick-draining alternative to traditional concrete pavement. It is also known as "thirsty concrete" because of its capacity to soak up a lot of surface water. This new material system can potentially be used in creating environmentally friendly urban drainage systems (Designing Buildings Ltd, 2017). Permeable pavement can absorb up to 1,000 liters of water per minute per square meter due to its ability to discharge rapidly. After being absorbed, the water promptly drains into a perforated conduit. Hale (2015) states, "The high-tech concrete works by having a permeable layer on top, which allows water to drain through a matrix of large pebbles and then down into a loose base of rubble beneath."

Permeable concrete performs effectively in all climate conditions. In tests, it worked best when the traffic was moderate to light, and the speed limit was 30 miles per hour or less (Weller, 2015). Driveways, sidewalks, parking lots, and other surfaces can be constructed using the concrete. By redirecting precipitation into natural aquifers, the material would aid in reducing flood damage, alleviating pressure on aging storm water drainage systems, and even reducing the likelihood of water scarcity. The pavement functions as a reservoir in hefty rain; its sub-layer collects water and gently releases it at a rate the ground can tolerate (Matchar, 2015).

The second layer consists of an open-graded, two-inch-thick bedding course. The width of the paver fixing platform is 50 millimeters. It consists of tiny, open-graded angular aggregate, typically stone of American Society for Testing and Materials (ASTM) No. 8 dimension or less. (Institute for Interlocking Concrete Pavement, 2013).

Open-graded aggregates are porous, with noticeable air gaps between individual stones and few fines. However, they do not compact well to create a dense conglomerate. Therefore, these mixes drain effectively. Applications for base material and subsurface drainage on roads are included (dirtandgrave, 2021).

The third layer, the reservoir course, which consists of an open-graded base and sub base reservoir and coarse aggregate with high air vacancy percentages, is essential to the porous pavement's ability to effectively store water and slowly release it into the soil below (j.trgeo, 2018).

Open-graded base reservoir, this layer of aggregate is usually four (4) inches thick. Crushed stones, mainly the size of an inch, make up the primary material to 1.2 inches. The foundation layer must be at least six (6) inches thick for pedestrian applications. This highly permeable material acts as a smothering layer between the bedding and sub base layers, accumulating water between the stones of the base. Typically, the stone size is ASTM No.

57 or a comparable size. (Interlocking Concrete Pavement Institute, 2013).

Stone sizes in open-graded sub base reservoirs are often more significant than the base reservoir, ranging from three (3) to two (2) inches. Water is stored similarly to the foundation layer in the spaces between the rocks. The traffic and the need for water storage influence the sub base layer's thickness. A sub-base stratum may not be necessary for pedestrian and residential driveway applications. In such circumstances, the thickness of the base layer is enhanced to provide water support and storage (Interlocking Concrete Pavement Institute, 2013).

In the fourth layer, geotextiles mainly function as a separator between the sub base and subgrade, preventing sediment migration into the granular sub base or base (Interlocking Concrete Pavement Institute, 2013).

The last layer, the subgrade is the soil stratum directly beneath the aggregate base or sub-base. How rapidly the saturated subgrade infiltrates dictates how much water can escape from the aggregate into the underlying soils. Generally, subgrade soil is not condensed because it can substantially impede soil infiltration if it is. Nevertheless, certain clay soils with inadequate drainage are frequently compacted to ensure the integrity of the structure, especially when soaked. Because compaction reduces infiltration, the hydrological design must consider the base or sub base thickness and the use of perforated conduit underdrains to manage the flow of water (Interlocking Concrete Pavement Institute, 2013).

Under the fourth layer, underdrains are pipelines that aid in water removal from the sub base and base. Underdrains comprise perforated pipelines that drain to a swale or stream from an outlet structure or discharge. Underdrains can also be connected to plastic, concrete, or plastic crates as another option. These can store significant runoff (Interlocking Concrete Pavement Institute, 2013).

***Surface Water Runoff***

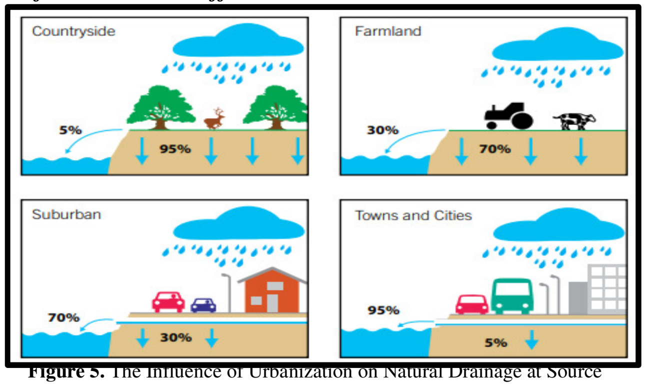



**Figure 5.** The Influence of Urbanization on Natural Drainage at Source
*Reference: https://www.paving.org.uk*

Due to the development of concrete landscaping, roads, sidewalks, spaces for parking, and even rooftops areas, the capacity for natural, sustainable drainage has been drastically reduced by urbanization. In highly populated urban areas, up to 95% of precipitation becomes groundwater discharge, putting additional strain on drainage systems that are already overburdened. In rural areas, only five percent (5%) of surface water discharge enters watercourses (Interpave, 2008, Permeable Pavement Guide to the design, construction and maintenance of concrete block. edition 5).

***Benefits***

There are numerous advantages to permeable concrete block paving, including the following crucial performance criteria:

1. Water flow is improved since it has the same mechanism with drainage systems meeting its design requirements
2. Water Quality Improvement, permeable pavement has the capacity to filter out chemicals and debris on water. This results to clean aquifers or groundwater.
3. Amenity, by building permeable pavement it lessens the impact of flooding. This helps the local environment to win stand any calamity that may occur.

In the vicinity of where rain falls to the ground, permeable pavements handle surface water. The

Sustainable Urban Drainage System (SUDS) philosophy's core idea is known as "source control." They assist in simulating green-field runoff characteristics from development sites by lowering peak rates, total volumes, and frequency of runoff. Additionally, they clean up runoff contamination. Therefore, they aid in resolving the issues brought on by typical drainage.

Permeable pavements may be used to satisfy planning and building regulation requirements for economical, ecological, and practical reasons. According to a study conducted by H. R. Wallingford Kellagher and Lauchlin (2003), permeable pavements are considered to be the most space-efficient SUDS components available, as they require no additional land take.

A study conducted in Davao City Entitled "Mainstreaming permeable Pavements, Eco-friendly Paving Alternatives in Keeping Davao City Green and Sustainable" by The Interface Development Interventions Inc. (IDS) Advocacy Program (2017) asserts that permeable pavements have advantages for both the environment and humans, particularly in terms of better storm water management, the urban ecosystem, general ambiance, a reduction in heat stress, and even advantages for businesses. Not all varieties, particularly in terms of maintenance and safety, are favorable in every way. As a result, the study evaluated its effectiveness and recommended a manual on how to use it correctly under various circumstances, particularly for People with Disability (PWD) access. The condition was claimed to be relevant for local policy because it provided the subjects with multiple advantages. Permeable pavements were suggested as a component of the neighborhood building code. Business owners and planners must adopt low-impact designs for sustainable development to protect open spaces and stop the ongoing environmental effects of traditional paving.

The IDS Advocacy Program investigated businesses using permeable pavements in Davao City's central business district. Five out of twenty (20) surveyed establishments were selected as case studies based on the accessibility of documents and the management's willingness to undergo interviews.

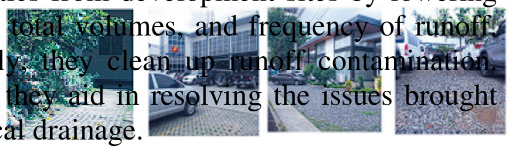


**Figure 6.** Images of Establishments with Permeable Pavement
*Reference: https://www.academia.edu*

All establishments reported no major flood cases after permeable pavement construction. They also claimed that porous pavements help manage storm water runoff. Furthermore, permeable pavements reduce urban heat, particularly during warm or arid seasons.

There are numerous varieties of permeable pavement, with the primary distinctions being the total void space, the spatial configuration of the bottom pervious layers, and the strength of the structure. Therefore, the researchers have compiled a list of five (5) distinct varieties of concrete blocks available on global and local markets. These are the most common kinds utilized by businesses;

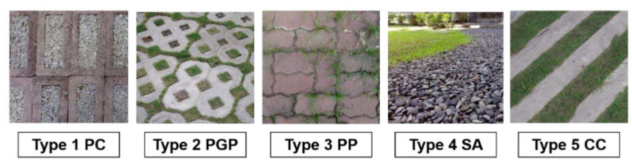



**Figure 7.** Types of Permeable Concrete Blocks
*Reference: https://www.academia.edu*

1. **Permeable Concrete or Asphalt (PC/PA).** The Permeable Concrete (PC) components include regular Portland cement, fly ash, cleaned gravel, and water. Contrary to conventional installations, porous concrete typically contains a void content of 15% to 25%, allowing water to infiltrate directly through the pavement surface to the subsurface. Permeable Asphalt (PA) is composed of fine and coarse aggregate sand, while permeable concrete typically contains a void content of 0.35 to 0.45 to one (1).
2. **Permeable Grid Pavers (PGP)**. Open-cell pavers have permeable grids. Gravel, sand, or a

growing substance that can be planted or promotes grass growth and other flora are used to fill the cells. This type of concrete is typically built of standard or porous concrete, clay, and even reinforcement made of plastic.

3. **Pervious and Porous Pavers (PP).** It comprises permeable interlocking concrete pavements formed of concrete units with open porous areas between them. This type also includes bricks made of clay. Storm water runoff can pass through the joints in clay pavers' resilient surface and even reach the material. As long as the design incorporates void spaces and gaps in between for runoff drainage, pervious and porous pavers can be made of various materials, including turfs, rocks, tiles, woods, or recycled tires.
4. **Single-sized Aggregate (SA)**. Commonly built without a binder, these structures are typically filled with loose gravel, broken stones, recycled materials, pebbles, and other materials after compacting the base (Green Building Alliance, 2016). It is frequently utilized in extremely slow-speed applications, such as driveways and walkways. Nearby stone vendors offer options based on the stone's size and aesthetic qualities.
5. **Concrete Pavement Cut outs (CC)**. Simply employing impermeable concrete with cuts or patches acting as permeable areas that can be filled with single-sized aggregates or grass plants is the design. When fixing or installing utilities like sewers, drainage systems, and other things, it is occasionally essential to dig trenches in some concrete pavements, especially in urban areas.

***1.7 Conceptual Framework***

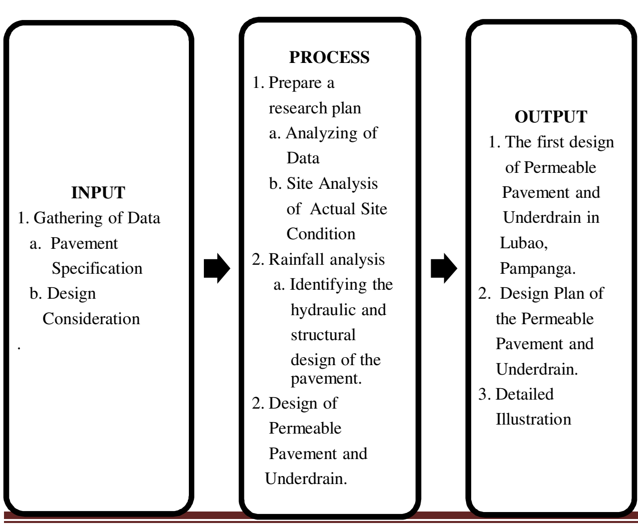



**Figure 8**. Conceptual Framework

Figure 8 demonstrates the conceptual framework of the research. The input is made up of related books, articles, and research regarding the design specification and consideration of permeable pavement. The researchers conducted a research plan, such as analyzing the actual site condition to know the things that need to be considered in designing the permeable pavement and underdrain; conducting rainfall analysis to interpolate the hydraulic and structural computation; and designing the permeable pavement and underdrain; these are all the steps in the process model. The output of this study will be the first design of permeable pavement and underdrain in Lubao, Pampanga. The design plan and detailed illustration of the permeable pavement and underdrain will also be the project's end result.

***1.8 Definitions of Terms***

**American Society for Testing and Materials (ASTM)**. The design consideration and specification of the permeable pavement are based on ASTM codes and manuals. The researchers adopted the codes and incorporated it on the computation to determine the sub-base thickness. This was done to make sure that the permeable pavement can win stand the load it may carry. ASTM is a global leader in developing voluntary consensus standards that individuals, enterprises, and other organizations adopt.

**California Bearing Ratio (CBR).**The subgrade strength of the Permeable pavement is based on the CBR values, this is to ensure that the Permeable Pavement have the enough capacity to store the water that may flow on the surface of the pavement. CBR is conducted predominantly to provide information for roadway pavement design. It was initially designed by the California Department of

Transportation. It is a test of penetration that is primarily used to assess the subgrade strength of roads, pavements, and foundations.

**Contaminant**. It is one potentially hazardous physical, chemical, or biological substance. It typically implies the introduction of hazardous substances created by humans.

**Pavement.** It is the uneven surface of a paved surface, region, road, or thoroughfare.

**Precipitation.** It is the result of the gravitational condensation of water vapor in the atmosphere

## II. METHODOLOGY

### *2. 1 Research Design*

This study designed a permeable pavement and underdrain that could help lessen the effects of flooding. The purpose of action research is to investigate and solve a problem simultaneously. In other words, action research, as its name suggests, combines research with actual action. According to Bryman, A., and Bell, E. (2011), action research is "a method in which an action researcher and the client engage in an assessment of a problem and the creation of an approach based on the analysis."

### *2.2 Research Instrument*

In designing the permeable pavement and underdrain, the researcher used one software application to show its two-dimensional view. This is the Automatic Computer-Aided Design (AutoCAD). An advanced, technically precise software application that helps designers and engineers visualize their own ideas, designs, and product illustrations. Autodesk developed the computer-aided design software AutoCAD, hence the name.

The researchers utilized Microsoft Excel to calculate the thickness of the sub-base and determine the proper size for the permeable pavement. The Microsoft Excel spreadsheet program can be downloaded for macOS, Windows, iOS, Android devices, and iPad OS. In addition, it includes pivot tables, graphing tools, calculation and the Visual Basic for Projects macro programming language. Excel is included as one of the applications in Microsoft 365.

In computing the site's slope, the researchers used Google Earth Pro to determine the highest and lowest points along the area. Google Earth Pro is a free software for visualization, assessment, overlay, and geospatial data creation. This user-friendly resource is frequently a useful intermediary for those engaged in discovering more about the Geographic Information System (GIS) and who wish to begin with more fundamental processes and tools.

### *2.3 Data Gathering*

Different kinds of systematic procedures were taken into consideration by researchers for effective data collection. The researchers meticulously measured, observed, and evaluated precise data to support the predicted outcome.

The researcher gathered information and understood the background of this study. They also gathered information from other researchers outside the country, especially in this research at the "Interlocking Concrete Pavement Institute." titled "Construction of Permeable Interlocking Concrete Pavement Systems" and the "Permeable Pavement Guide to the Design, Construction, and Maintenance of Concrete Block (Edition 5)."

And for the design of the proposed permeable pavement, researchers consulted their research adviser to know what to consider in designing the porous concrete, to locate the things that need to be evaluated, and to ensure that the study is suited for what the researchers are planning to design.

Research with the local government and agencies was conducted to determine the rainfall analysis and other details needed to design the permeable pavement and underdrain at the chosen location, the DHVSU Lubao Campus. All the information provided is essential to planning and designing the structure. Activities such as site investigation, determining the rainfall intensity, and measuring the lot area are the main properties in analyzing the needed data for the project's construction.

***2.4 Data Analysis***

The researchers based their design on the "Construction of Permeable Interlocking Concrete Pavement Systems (PICP)" project. Federal and state transportation and storm water agencies acknowledge it as a preferred practice in management and minimal impact development tool for reducing discharge and water pollution. In addition, PICP provides distinctive design options for handling overflows from combined sewers with green lanes and streets, as well as their use in parking and pedestrian areas (Interlocking Concrete Pavement Institute 2013, Construction of Permeable Interlocking Concrete Pavement Systems).

Planners, engineers, architects, and other decision-makers are supposed to benefit from the Porous Pavement Guidelines to the Design, Development, and Management of Concrete Block (version 5) while designing, building, and maintaining permeable roads composed of concrete blocks.

The researchers conducted research along with the government and Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) to determine the site and rainfall analysis and formulate the dimension of the permeable pavement sub-base, which is crucial in designing the project.

***2.4.1 Site Analysis***

As the foundation of the construction, the soil becomes one of the most crucial prerequisites when building or choosing a place for the project. That is why fundamental surveying is essential before constructing a project.

Based on the findings of the analysis, the permeable pavement's design was created. This helps build the plan to ensure that the depth of every layer can accommodate the weight of the water that will flow.

The researchers gathered data from the local government. The data from site analysis is vital to determine the soil classification and the percentage of passing of water based on the soil type of the target location. The American Association of State Highway and Transportation Officials (AASHTO) manual has provided the passing rate based on the sieve analysis per soil type.

According to the Lubao Municipality, the soil at the DHVSU Lubao Campus is made up of hydrosol, La Paz silt-fine sand, and Angeles coarse sand. Rice, the sugarcane plant and vegetables grow well in the sandy loam and fine-grained sand of La Paz. Quarry substance (gravel and sand) is the best application for Angeles coarse sand. The municipality's southern cities have hydrosol that is perfect for usage in mangrove or nipa swamps and fishponds.

***2.4.2 Structural Analysis***

The researchers adopted the load design from the company Interpave (2008). This section shows the computed loads to determine the depth of the sub-base layer of the Permeable Pavement by every category of its uses.

**Table 3.** Load Categories of Permeable Pavement

*Reference: https://www.paving.org.uk/*

The category of loads for each pavement design is shown in Table 3. A maximum capacity of 8,000 kg axles per mass classification is also displayed, assuming that pavements are constructed to withstand 25 years of traffic. Each row and column serve a particular purpose depending on how the permeable pavement was designed. Choose one of the first through sixth categories. The pavements created for load categories 2 and 3 are considerably different from one another. The pavement is constructed using Millions of Standard Axles (MSA). The term "standard axle" in the Indian context refers to an axle with two or four wheels, one or two oneither side, with a tyre pressure of roughly 0.56 MPa and bearing a maximum weight of 80 kN.

| **1 DOMESTICS** | **2 CAR PARKING** | **3 PEDESTRIAN** | **4 SHOPPING** | **5 COMMERCIAL** | **6 HEAVY TRAFFIC** |
|---|---|---|---|---|---|
| No Large Goods Vehicles | Emergency Large Goods Vehicles only | One Large Goods Vehicle per week | Ten large Goods Vehicles per week | 100 Large Goods Vehicles per week | 1000 large Goods Vehicles per week |
| Zero standard axles | 100 standard axles | 0.015msa | 0.015msa | 1.5msa | 15msa |
| Patio | Car parking bays and aisles | Town/city pedestrian street | Retail development delivery access route | Industrial premises | Main road |
| Private drive | Railway station platform | Nursery access | School/ college access road | Lightly trafficked public road | Distribution centre |
| Decorative feature | External car showroom | Parking area to residential development | Office block delivery route | Light industrial development | Bus station (bus every 5 minutes) |
| Enclosed playground | Sports stadium pedestrian route | Garden centre external display area | Deliveries to small residential development | Mixed retail/ industrial development | Motorway Truck Stop |
| Footway with zero vehicle overrun | Footway with occasional overrun | Cemetery Crematorium | Garden centre delivery route | Town square | Bus stop |
| | Private drive/footway crossover | Motel parking | Fire station yard | Footway with regular overrun | Roundabout |

*2.4.3 Rain Fall Analysis*

According to Harsha S. (2017), analysis of rainfall data is crucial since it aids in making decisions about the type of crops to be grown, when to plant them, how to build roads, and how to supply both urban and rural regions with drinking water.

Most of the time, it is not practical to build a structure that can survive the heaviest downpour that has ever taken place. Often, accepting an occasional failure is more cost-effective than planning for every severe storm. Data that shows the return times of storms with different strengths and durations is crucial for these purposes. The time period during which the depth of rainfall for a particular duration can, on average, be matched or surpassed once is referred to as the return period.

| **Return period** | **Intensity (*i*) mm/hr** | **Intensity (*i*) mm/min** |
|---|---|---|
| 2 | 113.15 | 1.88583333 |
| 5 | 137.88 | 2.298 |
| 10 | 154.14 | 2.569 |
| **20** | **171.48** | **2.858** |
| 25 | 174.45 | 2.9075 |

**Table 4.** Computed Extreme Values of Precipitation in mm

| **Pampanga River Basin Flood Forecasting & Warning Center(PRFFWC), San Fernando, Pampanga** | | | | | | |
|---|---|---|---|---|---|---|
| Monthly Point Rainfall Data in millimeters | | | | | | |
| Year | Jan | Feb | Mar | Apr | May | Jun |
| 2014 | 0.1 | 9.9 | 3.0 | 19.8 | 101.6 | 178.8 |
| 2015 | 8.9 | 1.8 | 0.1 | 1.8 | 116.3 | 191.5 |
| 2016 | 0.0 | 1.0 | 1.8 | 17.5 | 115.3 | 57.4 |
| 2017 | 10.9 | 0.3 | 2.5 | 11.9 | 124.2 | 51.6 |
| | | | | | | |
| Year | Jul | Aug | Sep | Oct | Nov | Dec |
| 2014 | 275.3 | 390.9 | 297.7 | 60.2 | 32.5 | 21.6 |
| 2015 | 589.5 | 252.0 | 205.5 | 237.2 | 0.5 | 188.0 |
| 2016 | 191.5 | 871.5 | 99.3 | 208.0 | 58.4 | 30.5 |
| 2017 | 459.5 | 401.8 | 184.4 | 108.5 | 125.5 | 11.9 |

**Table 5.** Computed Rainfall Intensity

The researchers chose the return period of 20 years. Because in building the drainage design, the considered year should be around 10-20 years to prolong the life and durability of the designed drainage.

As with the information stated above, the data serves as a guide in analyzing the rainfall period in the area. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) provided data to the researchers. The outcome served as a guide for the hydrological process utilized to construct the permeable pavement and underdrain to support the weight of rain or water.

### *2.5 Mechanism of Permeable Pavement*

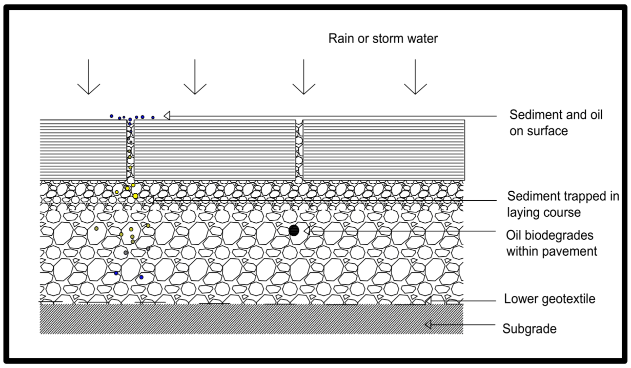



**Figure 9.** Fate of Pollutants in a Permeable Pavement.
*Reference: https://www.paving.org.uk/*

Concrete block pavements are effective at removing runoff pollution. Without gradients, pollutants may either remain on the asphalt's surface or discharged into the several layers of pavement below, where a lot of them are purified, trapped, or finally decompose.

Permeable pavement is created from open-pored pavement rocks, building materials, or bitumen and has a mineral storage underneath it. Permeable pavement collects rainwater and runoff from the streets, holding it in a storage vessel before allowing water to slowly seep into the soil below or out through a drainage plate.

According to a study by Construction Industry Research and Information Association (CIRIA)(2007), Permeable pavements are excellent at reducing pollutants. For instance, they can eliminate 70% to 90% of hydrocarbons and between 60% and 95%of total suspended particles. When subjected to low-intensity oil drips, such as those found in parking lots, the pavements can continue to biodegrade the hydrocarbons for an endless amount of time.

### *2.6 Standard Specification of Permeable Pavement*

In this section, the formulas for computing the sub-base depth, standard specifications and load design criteria are stated. The information is based on the American Society for Testing and Materials(ASTM) methods and Department of Public Works and Highways (DPWH).

#### *Permeable Pavement Design Consideration*

The researchers adopted the design consideration of the Association of Minnesota Pollution Control Agency, Minnesota Stormwater Manual (2022) in line with the American Society for Testing and Materials(ASTM) methods. Design considerations for permeable pavement must take into account its advantages and limitations.

1. **Available Space**. The need for land for detention facilities is diminished or eliminated by the capacity of permeable pavement to combine infiltration and detention with pavement.
2. **Soils**. The soil and infiltration rates affect how well an underdrain performs. Designers should evaluate the current soil quality during the initial location planning process in order to develop permeable pavement that preserves and maintains soils with the greatest infiltration rates.
3. **Geotextiles.** It is advised to use geotextiles instead of full-depth concrete curbs or impermeable liners to separate the reservoir layers from the surrounding soil subgrade at the (vertical) borders of permeable pavements.
4. **Contributing Drainage Area**. Runoff from adjacent areas, other pavements, and roofs can occasionally be captured by permeable pavements. Runoff from porous regions should not be used because permeable pavement may become clogged.

5. **Soil Subgrade Slope**. The slope of the soil subgrade should be as straight as possible to allow for the consistent dispersion and infiltration of storm water. The upper limit for lateral slopes should be 1%.
6. **Soil Subgrade Compaction**. Wherever feasible, avoid this to improve infiltration. In some situations, compression could be necessary to support the weight of moving vehicles.
7. **Excavation Methods**. The soil subgrade should not be compacted excessively during excavation. Wheeled equipment should not be used; instead, use tracked equipment.
8. **Surface Slope**. In order to provide backup drainage in the event that the surface completely fills up due to negligence, all permeable pavement types ought to have surface slopes that are at least 1%.
9. **Overflow Structures**. Permeable pavements are not meant to hold and absorb storm water from every storm. Therefore, a vent or vents are required to prevent water from rising into and over the surface.
10. **Minimum Depth to Seasonal High-water Table**. By allowing seepage into the base of permeable pavement, a high groundwater table could prevent complete drainage. The soil serves as a pollutant filter between the water table and the pavement's base. As a result, there needs to be at least three (3) feet between the seasonal high groundwater level and the base of the permeable pavement reservoir layer.
11. **Setbacks**. To avoid harmful seepage, permeable pavement shouldn't be hydraulically connected to building foundations unless an impermeable liner is placed up against the foundation or basement wall.
12. **Limitations**. Using permeable pavement has several limitations. Before conducting the construction of the pavement, the soil of the site must be tested for infiltration rates. Traffic analysis must be performed to carry the load capacity, this ensures the life and quality of the pavement. The limitations are summarized below.
    - 12.1 Permeable pavements shouldn't be used at places with high pollution loading. High-pollution loading sites are those that get silt, trash, and debris frequently.
    - 12.2 Permeable pavement works well in residential driveways, alleys, parking spaces, overflow parking areas, low-volume roads, and low-speed zones.
    - 12.3 The permeable pavement may become clogged by sand and other fine sediments that get into open spaces and the cracks between pavers. When frequent winter sanding is required, caution should be taken since the sand could block the material's surface.
    - 12.4 Hazardous substances may seep through asphalt and binder surfaces, and vehicles may leak fuel. For systems with porous pavement, the treatment of these contaminants is not desired.

***Collector Pipe Design or Underdrain***

According to Colorado Department of Transportation(2019), Collector pipes are frequently perforated or slotted, collecting water from the drainage layer and transferring it to an outlet. Collector pipes are often made of plastic or corrugated steel pipes. According to the requirements for corrosion resistance, cost, and availability, the choice of pipe should be decided for each site.

The capacity of the underdrain will be greatly increased by a collector pipe. Where the drainage layer porosity or drain cross-sectional region is inadequate to provide the required conveyance of subsurface flows, a collector pipe should be built.

It is advised to consider the following factors when designing and installing collection pipes:

1. The slope should never be less than 0.2 percent and should have a minimum slope of 0.5%;
2. A six-inch minimum diameter is required for underdrains. To lessen the effects of sedimentation, think about increasing the minimal size of the pipe to eight (8) inches for lengths greater than 500 feet;
3. Perforations and slots should be small enough to prevent drainage-layer debris from entering the conduit. The D85 value of the drainage layer material must exceed the utmost pipe opening.

***Permeable Pavement Load Design Criteria***

Based on the design criteria for permeable pavement in American Concrete Pavement Association(ACPA) Design Method, it offers details on the specifications, requirements, and design considerations for permeable pavement. The thickness of the base or sub base is determined using hydrological sizing and dynamic modeling in order to store water. Using structural design techniques, the thickness of the base and sub-bases for sustaining traffic is determined. It employs the more substantial of the two resulting designs.

Various structural designs are used to sustain vehicles based on the type of pavement. The American Society for Testing and Materials (ASTM) is presently developing test methods to characterize the compressive or flexural strengths of porous concrete. Multiple trials are required to assess fatigue under strain. As a first stage, the American Concrete Pavement Association (ACPA, 2010) developed fatigue equations based on the assumption that these inputs are comparable to those used in conventional concrete pavements.

Portland Cement Association and National Ready Mix Concrete Association (NRMCA) developed recommendations for pervious concrete surface thickness.

1. Regardless of the form of permeable pavement, structural design methods take the following into account when establishing surface and base depths to support vehicular traffic.
2. Life expectancy and total estimated traffic loads are expressed as single axle loads of 18,000 pounds. This method accounts for the extra pavement deterioration caused by vehicles.
3. The resistance value (R), or the resilient modulus (Mr)and saturated California Bearing Ratio (CBR), are expressed as soil strength.
4. The durability of the surface, base, and sub base materials.
5. Climate-related variables include frigid temperatures and prolonged subgrade soil saturation.

According to American Association of State Highway and Transportation Officials (AASHTO T-307), a geotechnical or civil engineer should examine the soil stability under traffic for each application, and the lowest projected soil durability or stiffness values under saturated conditions should be used for design. Typically, the design of the structure for vehicle applications is based on soil subgrades that have a California Bearing Ratio (CBR) of at least 4% or 6,500 pounds per square inch.

***2.6.1 Design Procedure***

Two objectives considered in the design of permeable pavements:

1. Support the volume of traffic
2. Manage surface water

The greatest permeable sub-base thickness from either computation is used as the design thickness, requiring two separate sets of analyses.

$$Tc = \frac{(L)^{1.15}}{51\,(H)^{0.385}}$$

Where:

Tc = Time of Concentration

L = Length of waterway

H = Difference in elevation between highest pt. & lowest pt.

$$Qp = \frac{C\,I\,A}{3.6}$$

Where:

Qp = peak run-off, in cubic meters per second

C = Run-off coefficient. depending on the characteristics of the watershed/drainage area

I = average rainfall intensity, in mm per hour

A = Area

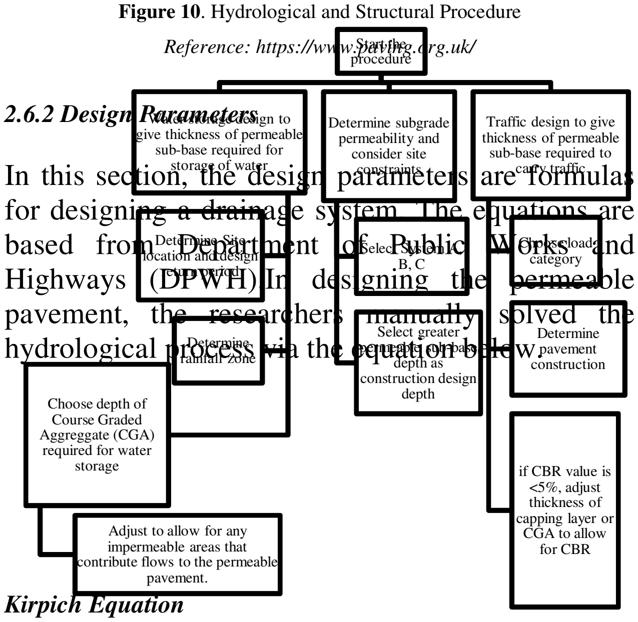



**Figure 10**. Hydrological and Structural Procedure

*Reference: https://www.paving.org.uk/*

***2.6.2 Design Parameters***

In this section, the design parameters are formulas for designing a drainage system. The equations are based from Department of Public Works and Highways (DPWH). In designing the permeable pavement, the researchers manually solved the hydrological process via the equation below.

***Kirpich Equation***

The standard method for calculating the time of concentration (Tc) within a certain watershed is the Kirpich equation. The period of concentration is the period of time required for water to move from the watershed's farthest point to its discharge.

***Peak Discharge Runoff***

The peak discharge is the maximum rate of runoff from a drainage area for a specific rainfall (volume per unit time, often cubic feet per second). Rain is the primary source of water that evaporates from the surface of small rural watersheds.

***Determination of Sub-base Size***

| Conduit Material | n |
|---|---|
| Brass, smooth | 0.01 |
| Cement, smooth | 0.011 |
| Concrete culvert, straight and clean | 0.011 |
| **Concrete, finished** | **0.012** |
| Steel, welded | 0.012 |
| Brick, glazed | 0.013 |
| Clay pipe, Common drainage tile | 0.013 |
| Brick, coated with sewage slime | 0.013 |
| Cast Iron, coated | 0.013 |
| Wrought Iron, Black | 0.014 |
| Cast Iron, uncoated | 0.014 |
| Concrete, smooth wood form | 0.014 |
| Concrete, sewer with manholes, etc., no bends | 0.015 |
| Brick, mortared | 0.015 |
| Clay pipe, Vitrified sewer | 0.015 |
| Wrought Iron, Galvanized | 0.016 |
| Steel, riveted | 0.016 |
| Stone masonry, cemented | 0.025 |

To calculate the Flow Rate, represented by Q, define the volume V and the duration that it flows by, identified by t, or Q = V/t. Moreover, Flow rate and velocity are connected by the equation Q = Av, in which A is the cross-sectional area of the flow and v is the mean velocity.

$$Q = AV$$

Where:

Q = Flow rate ( cum./sec.)

A = Cross-sectional area of flow (sq.m.)

V = Mean velocity across a cross section

V = $1/n\,(R)^{2/3}\,(S)^{1/2}$

n = Manning coefficient of roughness (in SI units)

R = Hydraulic radius (cross sectional area divided by the wetted perimeter)

S = Slope of the hydraulic gradient (non-dimensional)

### *2.6.3 Design Constant*

In this section, it shows the constant values that was used on the design of permeable pavement. The values were based on the actual site condition, this is determined by the site analysis of the study.

***Manning Coefficient of Roughness***

Manning's n coefficient measures how rough or frictionally the channel affects the flow. Though they can be back computed from field measurements, Manning's n-values are frequently chosen from tables.

**Table 6.**Manning's Roughness Coefficient Table
*Reference: https://www.engineeringtoolbox.com*

Based on the Actual Site Condition of the location which is DHVSU Lubao Campus, the parking areas are surrounded by impermeable footway or the service strip. The footway is made up of concrete, finished which has the value of 0.012 in Manning's Roughness Coefficient Table. The researchers used this value in determining the Hydrological process of the Permeable Pavement and Underdrain Design.

***Coefficient Permeability of the Soil***

Typically, soil permeability is expressed by the coefficient of permeability (k), in which k is the water flow rate per unit soil area when subjected to a unit hydraulic gradient. Low soil permeability can result in water pooling and subgrade deterioration during construction.

**Table 7.** Guidance on Soil Classification
*Reference: https://www.paving.org.uk/*

According to the Lubao Municipality, the DHVSU Lubao Campus is composed of hydrosol, Angeles coarse sand and La Paz silt-fine sand. Hence, the researchers used the Soil classification of Silty clay, it has a coefficient permeability of $10^{-9}$ to $10^{-8}$. This was used in the hydrological process of the Design of Permeable Pavement and Underdrain.

| Soil classification | Typical range for coefficient of permeability K (ms) | Typical range of CBR values |
|---|---|---|
| Heavy clay | $10^{-10}$ to $10^{-8}$ | 2 to 5 |
| **Silty clay** | $\mathbf{10^{-9}}$ **to** $\mathbf{10^{-8}}$ | **3 to 6** |
| Sandy clay | $10^{-9}$ to $10^{-6}$ | 5 to 20 |
| Poorly graded sand | 5 x $10^{-7}$ to 5 x $10^{-6}$ | 10 to 40 |
| Well graded sand | 5 x $10^{-6}$ to 5 x $10^{-4}$ | 10 to 40 |
| Well graded sandy gravel | $10^{-5}$ to $10^{-3}$ | 30 to 80 |

*2.6.4 Construction Procedure*

The company Technobloc (2019) has provided a construction sequence for building the permeable pavement design. The following steps show the arrangement of the construction:

**Step 1.** After stabilizing the complete drainage area, permeable asphalt is installed. Before beginning any excavation, it is essential to investigate the site for any existing utilities.

**Step 2.** Until the permeable pavement has been installed and at least 70 percent of the drainage areas have been stabilized with a uniform, perennial vegetative cover. During installation, all of the porous surface area must be protected from erosion and sedimentation with temporary controls or equivalent measures. To prevent erosion during and after excavation, specialized precautions, such as erosion-control fabrics, may be needed. During construction, the designed permeable pavement area must be protected from sediment intrusion.

**Step 3**. When possible, excavating should take place outside the dimensions of the permeable concrete region and from the edges (to avoid soil compaction). The designed porous pavement area can be divided into 500–1,000 square foot short-term cells with 10–15 foot-wide earth bridges linking them, enabling excavation from the side of the cells. This construction method is known as the "cell" approach. Ultimately, the earthen structures are demolished. The material that was excavated must be set away from the surface that is exposed in order to preserve the structural integrity of the side walls.

**Step 4.** Before adding aggregate, the native soils can be leveled and verified to a depth of three (3) to four (4) inches along the lowest point of the permeable pavement system.

**Step 5.** The margins of reservoir layer applications without concrete curbs spanning the base level should be lined with geotextile. At the discretion of the design engineer, geotextile may also be applied over the subgrade. American Association of State Highway and Transportation Officials (AASHTO) M-288 stipulates that each sheet's overlap must adhere to its guidelines.

**Step 6.** Place aggregate with a minimum of two (2) inches in diameter around underdrain pipelines. The slope of the underdrains should be at least 0.5% in the direction of the discharge. The upslope ends of drains underneath in the reservoir stratum should be obstructed. There should be no perforations within one foot of an underdrain pipe's attachment to a structure. Verify that there are no perforations no less than one foot beneath the surface of the clean-outs.

**Step 7.** Spread reservoir base stone with not more than six (6) inches of elevation. The material can be compacted more effectively if it is dampened prior to distributing. Layers of a reservoir containing stone larger than No. 57 should be compacted with a ten-ton roller for two static passes or until the aggregate is completely stationary. Perform two vibratory passes and two static passes for No. 57 or similar-sized stone layers, or until the aggregate is no longer visibly moving. Avoid crushing the aggregate with the roller. To compact corners and other difficult-to-reach areas, a vibratory disk roller with at least 13,500 pounds of force and a compaction indicator is utilized.

**Step 8.** Depending on the sort of pavement, install the sheeting or choker layer to the intended depth, as described below.

1. There is no foundation or barrier layer used in pervious concrete.
2. One inch of rinsed No. 57 stone composes the choker layer of the porous pavement.
3. Permeable Interlocking Concrete Pavement Systems (PICP): The foundation layer for open-joined pavement blocks should consist of a two-inch layer of cleansed No. eight stone. This stratum is compacted after pavers are installed and the spaces between them are filled with aggregate.

## III. RESULTS

### *3.1 Site Location*

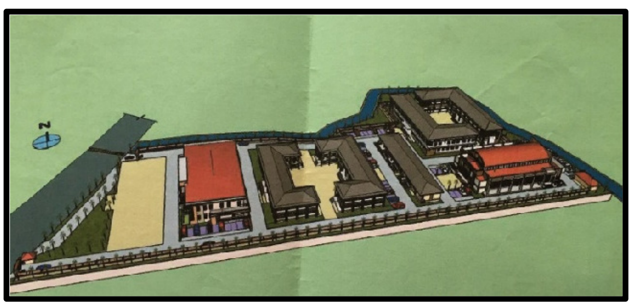
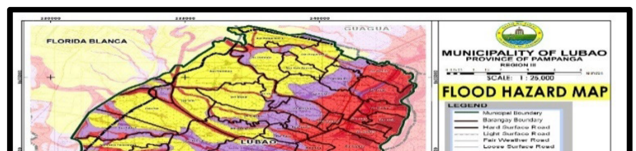


**Figure 11.** Don Honorio Ventura State University

The researchers conducted the study at Don Honorio Ventura State University (DHVSU) Lubao Campus, Barangay Sta. Catalina Lubao, Pampanga. Under the DHVSU system, the DHVSU Lubao Campus is an open-access extension campus. The campus was built in 2018 in support of the university's endeavor to introduce higher education to regions of the province with a high demand for education. Moreover, the campus is the most recent institution to be incorporated into the university. The university is located close to the Lubao Municipal Hall and the Lubao diversion road.

According to philatlas (2023), Santa Catalina is located at 4° 56' North, 120° 36' East in Lubao, Pampanga province. According to the results of the 2020 Census, its population was 5,648. This represented 3.26 percent of Lubao's total population. The population of the DHVSU Lubao Extension Campus is 1,826 as of 2021-2022. As of 2021, there are 467 employees working in the Lubao Municipal Hall.



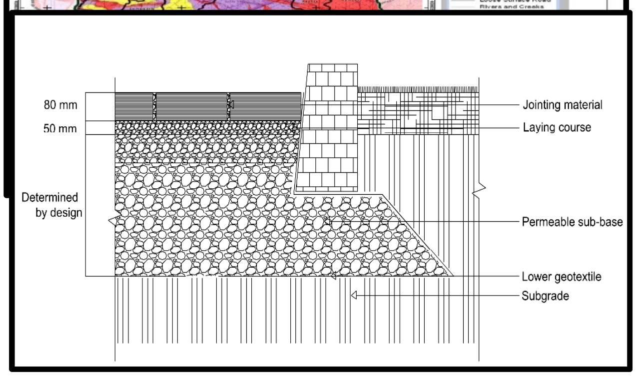




**Figure 12.** Lubao Flood Hazard Map

As shown in Figure 12, the target location DHVSU Campus is highly susceptible to flooding. That is why creating the design of Permeable Pavement has high significance to the study.

### *3.2 Vicinity Map*

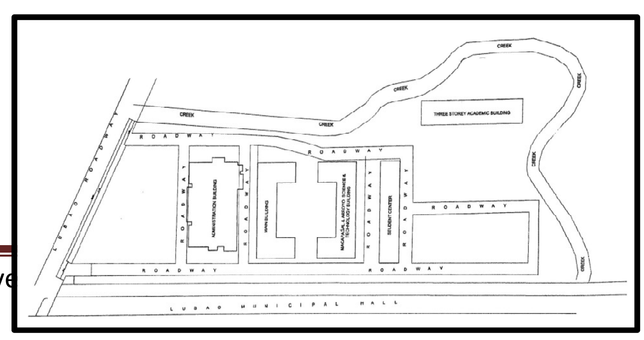


**Figure 13.** Site Development Plan

The Design of Permeable Pavement will be located at the parking areas of DHVSU Lubao Campus. The Design of the Pavement will be based on the soil classification in every site, and for every location, there is a corresponding load category (refer to Table 3) for its uses. Through the load category, the thickness of the sub-base will be determined.

### *3.3 Different Design Systems of Permeable Pavement*

The company Interpave has provided a manual entitled "Permeable Pavement Guide to the Design, construction, and Maintenance of concrete block (edition 5)" This manual shows the Different Design Systems, Required Load, Thickness, Hydrological, and Structural Processes in creating the design of a Permeable Pavement. The design is based on the required consideration according to American Association of State Highway and Transportation Officials (AASHTO) codes and manual.

**Figure 14.** System A

#### *A. System A – Total Infiltration*

This method enables all water that descends on the pavement to percolate through the constructed layers beneath it and into the subgrade via the connections or spaces between the concrete blocks. The permeable sub-base layer will temporarily retain moisture, allowing for initial retention, before allowing it to ultimately pass through.

As no additional water is discharged into conventional drainage systems from the new development, System A can be referred to as "Zero Discharge," which saves funds by eliminating the need for pipelines and gullies.

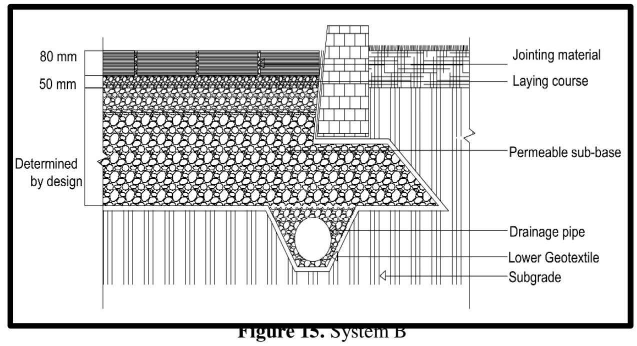



**Figure 15.** System B

#### *B. System B – Partial Infiltration*

System B is often used when the current subgrade cannot absorb most of the water. Consequently, this method may avoid the soil from becoming unstable. System B's permeable sub-base is connected to outflow pipelines that direct excess water to other drainage systems, such as sewage lines, swales, or waterways.

This indicates that a substantial portion of the rainfall, a fixed quantity of water, is frequently allowed to pass within the system. The excess water is collected and discharged into sewers or waterways at an agreed-upon peak discharge rate. This method is anticipated to reduce discharge volume without requiring storage for an extended period.

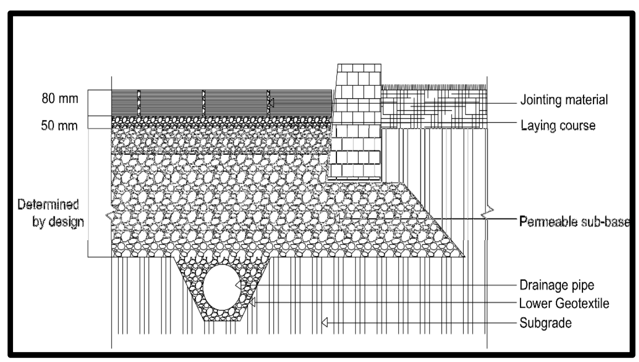



**Figure 16.** System C

### A. *System C – No Infiltration*

This design captures all water through the installation of an impermeable, adaptable membrane at the ground level and up the sidewalls of the permeable sub base. In some instances, it is utilized when the existing subgrade is fragile or has low permeability, and introducing more water would be detrimental. In sensitive areas, such as water extraction zones, it can also be used to collect water or prevent it from escaping into the ground. At strategic locations, discharge pipelines are constructed through the impervious material to transfer water to sewage lines, waterways, or treatment facilities.

System C is ideal for sites with contamination because it prevents contaminants from being carried deeper beneath the subgrade, where they could be dispersed into the groundwater. Additionally, it can function as an underground retention or detention region. At some instances, the collected water can be purified, preserved, and reused for irrigation or lavatory emptying (i.e., "rainwater reuse") (Rainwater Harvesting).

### *3.4 Selection of Pavement System*

**Table 8.** Appropriate Pavement System
*Reference: https://www.paving.org.uk/*

| | | System A Total Infiltration | System B Partial Infiltration | System C No Infiltration |
|---|---|---|---|---|
| Permeability of subgrade defined by coefficient of permeability k (m/s) | $10^{-6}$ to $10^{-3}$ | ✓ | ✓ | ✓ |
| | $10^{-8}$ to $-6$ | ✕ | ✓ | ✓ |
| | $10^{-10}$ to $10^{-8}$ | ✕ | ✕ | ✓ |
| Highest recorded water table within 1000mm of formation level | | ✕ | ✕ | ✓ |
| Pollutants present in subgrade | | ✕ | ✕ | ✓ |

When choosing a pavement system, it is crucial to take the subgrade permeability into account. Infiltration evaluations for conventional soak ways are typically conducted at depths greater than one (1) meter. Because permeable pavements infiltrate water into the ground at substantially shallower depths than conventional soak ways, infiltration measurements should be performed close to the pavement's ultimate formation stage. The level of permeability derived from infiltration investigations is included in Table 8's recommendations for subgrade conditions and pavement systems.

### *3.5 Selection of Pavement Course Materials and Thicknesses*

Choose the pavement course thickness and material categories using Figures 17 or 18 if the pavement is System A, B (full or partial infiltration), or System C. Note that the completed pavement shall be suitable for subgrades with a CBR of 5%. The California Bearing Ratio (CBR) should represent the lowest subgrade level anticipated to be encountered during the pavement's lifetime. This is typically the Equilibrium Suction Index CBR for System C (detention or fueled) pavements, where water is stored throughout the pavement, and the Soaked CBR for System A and System B infiltration pavements.

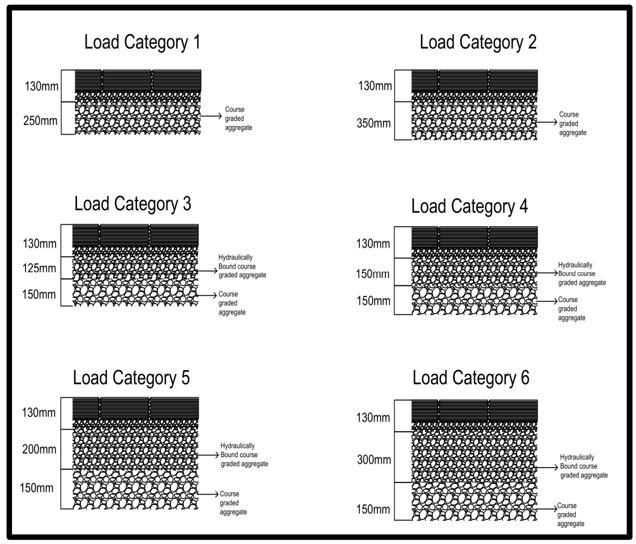



**Figure 17**. Design Chart for Systems A and B

| CBR of subgrade | Adjustment to thickness of coarse graded aggregate in the case of System A and System B (Infiltrating) pavement (mm) | Total thickness of capping material in case of System C (detention) pavement (mm) |
|---|---|---|
| **1%** | +300^ | 600 |
| **2%** | +175^ | 350 |
| **3%** | +125^ | 250 |
| **4%** | +100^ | 200 |
| **5%** | Use thicknesses in Design Chart | 150 |
| **8%** | | |
| **10%** | | |
| **15%** | | |

**Figure 18.** Design Chart for Systems C

***3.6 Adjustment to Pavement Design for Low CBR Subgrades***

Figures 17 and 18's Design Charts are applicable when the California Bearing Ratio (CBR) is less than 5%. When CBR values are lower, a correction must be applied. Typically, the modification of System C pavements involves either the addition of additional capping material or coarse gradated aggregate. System A and System B infiltrating pavers are provided with additional strength by increasing the depth of unbound coarse graded aggregate. Fines and other substances cannot be used in water. Notably, a sub-grade CBR of no more than five percent often indicates that the material may be too refined to function as an infiltration medium, which indicates Systems A. In many instances, a subgrade CBR of less than 5% suggests the substance is likely too fine to function as an infiltration substrate, indicating that Systems A and B are unable to be used.

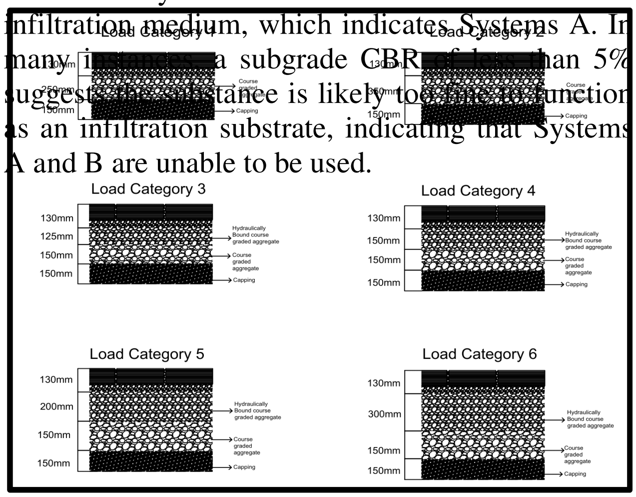



**Table 9.** Low Subgrade California Bearing Ratio (CBR) Adjustment
*Reference: https://www.paving.org.uk/*

The condition of the subgrade is dependent on the drainage characteristics of the site, the water table threshold, and the latest weather. The added capping thicknesses required for low CBR subgrades can only be estimated approximately throughout construction.

***3.7 Site Plan of Permeable Pavement***

***SITE A:***

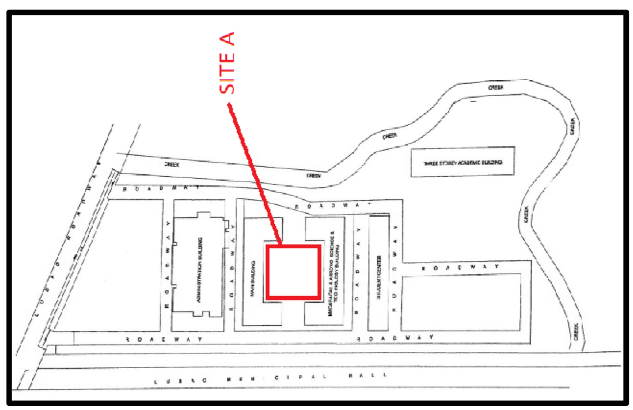



**Figure 19.** Site A

**Figure 22.** Site B Plan View

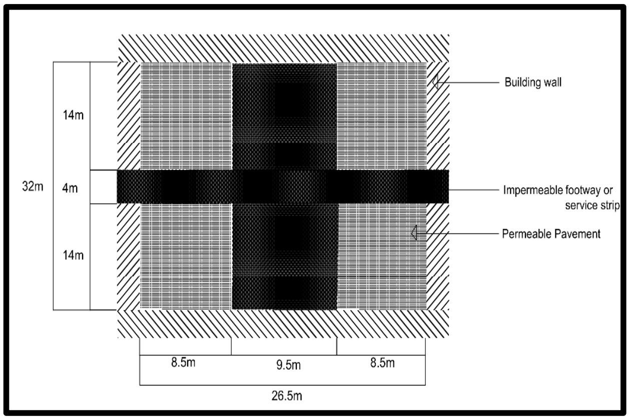



**Figure 20.** Site A Plan View

***SITE B:***

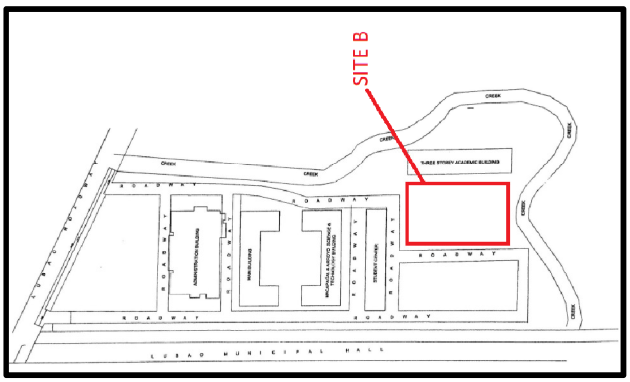
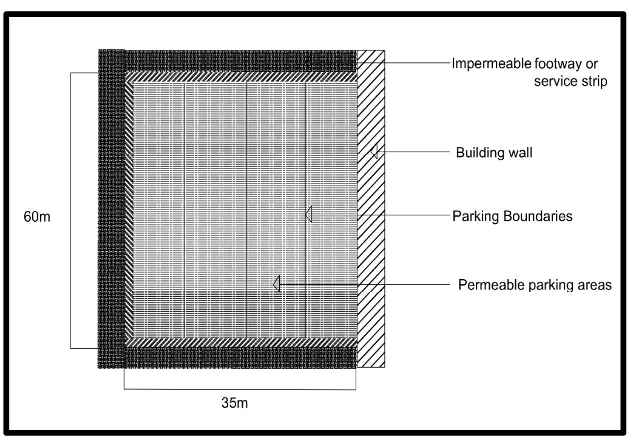



**Figure 21.** Site B




***SITE C:***

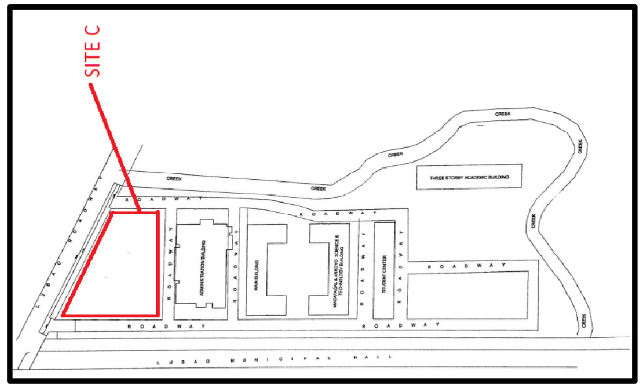



**Figure 23.** Site C

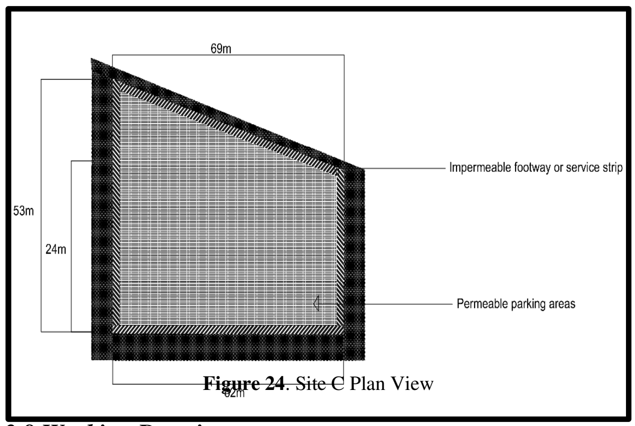



**Figure 24.** Site C Plan View

### *3.8 Working Drawings*

***SITE A:***

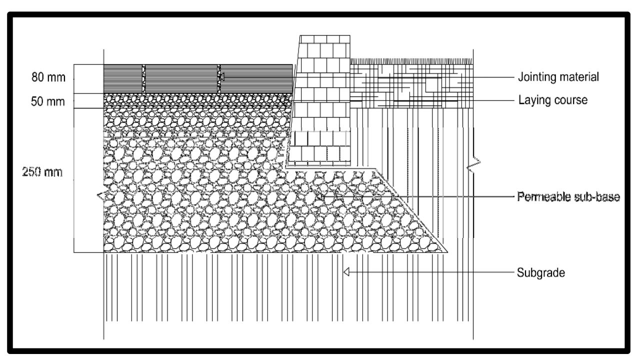



**Figure 25.** Site A Cross Section

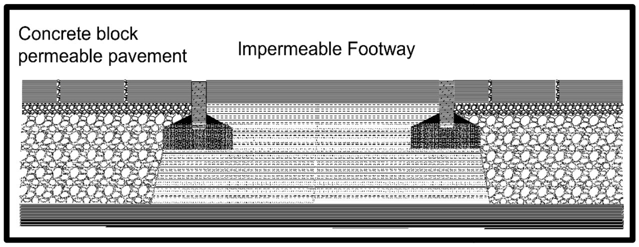



**Figure 26.** Site A Cross Section 2

**Table 10.** Summary of Details of Site A

The assessment in Site A shows that it has a total

| Summary of Details | Site B |
|---|---|
| Total Area | 2100 sq. m |
| Permeability Coefficient | 0.9 |
| Design System | C |
| Load Category | 4 |
| Total Thickness | 580mm |
| Slope | 1.67% |
| Time Concentration | 2.17 min |
| Peak Run-off | 0.090 cu. m/sec |
| Flow rate | 162.896 cu.m/sec |
| Geotextile | Required |
| Pipe diameter (Perforated) | 6 in or 152.4 mm (Standard) |

area of 848sq. m, and upon checking the site's actual condition, it has a soil type of silty sand or clay with a permeability coefficient of 0.9. It is applicable in System A, when choosing the types of system in Permeable Pavement design. It is also advised by the panels to use this type of design. The researcher chose Load Category 1 for systems A. The total thickness of the Pavement is 380 mm. Based on the computation from the highest point and lowest point of the site, it shows that it has a slope of 3.125% and the time concentration is 1.06min. The researchers set a 20 year return period to extend the pavement's life and durability. The maximum discharge rate is 0.036 cu.m/sec, with a flow rate of 58.787 cu.m/sec, which is considered safe.

***SITE B:***

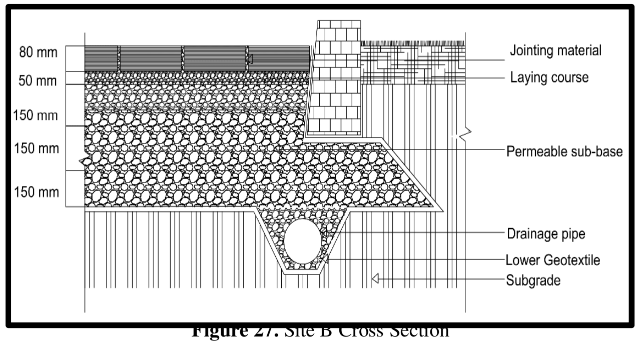



**Figure 27.** Site B Cross Section

| Summary of Details | Site A |
|---|---|
| Total Area | 848 sq. m |
| Permeability Coefficient | 0.9 |
| Design System | A |
| Load Category | 1 |
| Total Thickness | 380 mm |
| Slope | 3.125% |
| Time Concentration | 1.06 min |
| Peak Run-off | 0.036 cu. m/sec |
| Flow rate | 58.787 cu. m/sec |
| Geotextile | Not required |
| Pipe diameter (Perforated) | N/A |

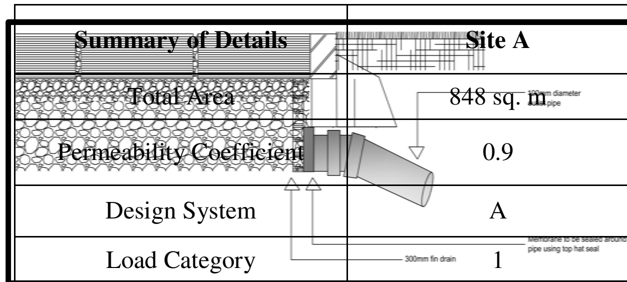



**Figure 28.** Water Collection to Drainage Site B

**Table 11.** Summary of Details of Site B

Site B has a total area of 2100 sq. m and a Permeability coefficient of 0.9. The researchers chose Design System C and load category four because System C supports the additional load-bearing capacity due to its capping layer. The total thickness is 580 mm. Based on the computation, the pavement is considered safe since it has a peak run-off of 0.090 cu.m/sec and a flow rate of 162.896 cu.m/sec, wherein the flow rate is greater than the peak run-off, which is considered safe.

***SITE C:***

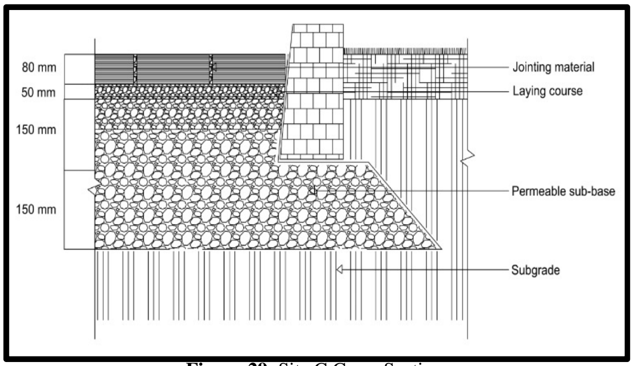



**Figure 29**. Site C Cross Section

**Table 12.** Summary of Details of Site C

| **Summary of Details** | **Site C** |
|---|---|
| Total Area | 2387 sq. m |
| Permeability Coefficient | 0.9 |
| Design System | A |
| Load Category | 4 |
| Total Thickness | 430mm |
| Slope | 3.77% |
| Time Concentration | 1.96 min along triangle<br>1.73 min along rectangle |
| Peak Run-off | 0.102 cu. m/sec |
| Flow rate | 47.437 cu. m/sec along triangle<br>142.760 cu. m/sec along rectangle |
| Geotextile | Not required |
| Pipe diameter (Perforated) | N/A |

Site C has a total area of 2378 sq. m and a permeability coefficient 0.9. As advised by the panels, the researchers chose the design System A. Based on the computation, the result shows that the design is safe since it has a peak run-off of 0.0102 cu.m/sec and a flow rate of 47.437 cu. m/sec along the triangle shape and 142.760 cu.m/sec along the rectangle.

## IV. DISCUSSION

***4.1 Summary of Findings***

The aims of the study is to propose a Permeable Pavement and Underdrain for the students and community of Don Honorio Ventura State University (DHVSU) Lubao Campus to solve the flood issues in the area.

Permeable pavement can aid in recharging underground aquifers, reduce peak flows and flooding by preventing storm water from accumulating and moving away. As a result, the stream flows more regularly and at a lower temperature, which supports a healthy environment. Due to its well-documented benefits, such as lower installation costs, enhanced water quality, decreased storm water discharge, and decreased soil erosion and inundation, permeable pavement is gaining popularity. They also help property owners save money on pricy compliance laws by removing the need to install expensive retention and drainage systems. Permeable pavement is one of the most popular types of pavement utilized today due to its advantages.

***4.2 Conclusions***

After gathering and interpreting all the data needed for the study regarding the Design of Permeable Pavement and Underdrain at DHVSU Lubao Campus, the following was concluded:

1. The area of Sta. Catalina Lubao, Pampanga (Don Honorio Ventura State University Lubao Campus) needs Permeable Pavement and

Underdrain due to its natural landscape, wherein the target location is highly susceptible to flooding.

2. The Design Permeable Pavement is a pavement that infiltrates the water through its layers. It is mainly composed of stones and pebbles. The pavement is designed according to the standards according to the American Association of State Highway and Transportation Officials (AASHTO) manual.
3. Constructing a Permeable Pavement and Underdrain in Don Honorio Ventura State University- Lubao Campus is a big help for the students and employees of the University since the pavement could help lessen the risk of flooding. Constructing a Permeable Pavement is also necessary due to possible plans for the development of the area, especially in parking areas.

***4.3 Recommendations***

The study is limited to the Design Plan, Structural Analysis, and Hydrological Analysis of the Design of Permeable Pavement and Underdrain. The dimensions are computed using formulas derived from calculating the drainage design, such as Flow rate, Runoff Coefficient, and Discharge runoff.

However, the study does not provide a complete set of detailed plans, the number of materials, construction budget, management and maintenance plan. Therefore, the following recommendations are made.

1. The research is broader than the target location. It can be adapted to local government units and implemented since this is a new design and not currently available in the locale area.
2. The future researcher could add a water treatment system to reuse the collected water for non-potable uses, such as water irrigation for crops and utility purposes. Other research has proved that the water could be recycled.
3. Future researchers could also identify the importance of collected water for reuse, whether treated or not. Additionally, the connection of water flow to the outlet could also be designed to determine if building a facility for water treatment is needed. If not, identify the endpoint in which the water will be collected.
4. Future researchers could also conduct a cost analysis to determine the cost and benefit of the Permeable pavement for further usage.

## ACKNOWLEDGEMENT

This study would not have been possible without the guidance and help of severalindividuals who in one way or another contributed and extended their valuable assistanceinthepreparationandcompletionofthisstudy.Theresearcherswouldlike toextendtheirdeepestgratitude and appreciation to the followingindividuals.

First and foremost, the researchers thank God Almighty for providing them withthe strength, patience, intelligence, and understanding necessary to complete this research project.Without His guidance,this success wouldnothavebeen possible.

The researchers would like to express their gratitude to those who assisted andcontributed to the completion of this research study, particularly the panelists, Engr. Miriam B. Villanueva, Engr. Ana Pauline B. Pagador and Engr. Rosemarie M. Luciano for their valuable inputs in the enhancement of the study. Without the assistance and guidance of the research adviser, Engr. Ma. Vanerrie Issa S. Eusebio and research coordinator, Engr. Raul O. Duya, thisresearch article would not have been possible. The researchers would like to give thanks to the Chairperson of the Civil Engineering Department, Engr. Irene R. Roque for guiding and imparting important information and for sharing their expertise.

The researchers would also like to express their gratitude to the Department of Public Works and Highways (DPWH) and Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) for providing the data neededforthestudy.

Finally, the researchers want to express their heartfelt appreciation to their Familyfortheirunwavering loveand support during thejourney.

## REFERENCES

[1] Alessandra Bonicelli, Gilberto Martínez, Arguelles, Guillermo Fuentes, Pumarejo. (2016). Improving Pervious Concrete Pavements for Achieving More Sustainable Urban Roads Universidad del Norte, Department of Civil and Environmental Engineering Retrieve From: https://cyberleninka.org/article/n/1409161

[2] Bean EZ, Hunt WF, Bidelspach DA (2004) Study on the surface infiltration rate of permeable pavements. In: Sehlke G., Hayes DF, Stevens DK, editors. Proceedings of the American Societyof Civil Engineers and EWRI 2004 world water and environmental resources congress, Salt Lake City, UT, USA, 27 June–1. Retrieved from: https://www.chijournal.org/Content/Files/R223-22.pdf

[3] Bryman, A. & Bell, E. (2011) Action research. Retrieve from: https://online-tesis.com/en/action-research-method/

[4] Concretenetwork (2017). Limitations of Pervious Concrete. Retrieved from: https://www.concretenetwork.com/pervious/limitations.html

[5] Cambridge Pavers (2013) Construction of Permeable Interlocking Concrete Pavement Systems. Retrieved from: https://www.cambridgepavers.com/dfiles/ICPI_Technical_Specification_18.pdf?fbclid=IwAR3PW_5jVq0HtDV9yoIYAdPeehDjw42AJ69r_y3M5fUaVXY3gkRJgBfm05

[6] Designing Buildings Ltd. (2017). Topmix Permeable. Retrieved from: https://www.designingbuildings.co.uk/wiki/Topmix_Permeable

[7] Engineering ToolBox, (2004) Manning's Roughness Coefficients. Retrieve from: https://www.engineeringtoolbox.com/mannings-roughness-d_799.html

[8] Elsevier B.V. (2022) Subgrade. Retrieved from: https://www.sciencedirect.com/topics/engineering/subgrade?fbclid=IwAR2QdULiZByhOjYXBrdOrOK0t6se6QJ7K-o7USAyfwal_-_wi7YgPXuNozk

[9] GreenBlue (2015) Pavement, Trees, and the Space Between. Retrieved from: https://www.greenblue.com/na/pavement-trees-the-space-between/

[10] GreenBlue (2017) Permeable Pavement: Pros and Cons you need to know. Retrieved from: https://www.greenblue.com/na/permeable-pavement-the-pros-and-cons-you-need-to-know/

[11] Figure 1: Google Maps (n.d.) Google map of Sta. Catalina Lubao, Pampanga. Retrieved from: https://www.google.com/maps/place/Santa+Catalina,+Lubao,+Pampanga/@14.9220031,120.5841561,2133m/data=!3m2!1e3!4b1!4m6!3m5!1s0x33965e9c71de74d9:0x8a37b1d031e42840!8m2!3d14.9211515!4d120.5897832!16s%2Fg%2F1tdwmmfk?entry=ttu

[12] Figure 3: Google Maps (n.d.) Google map of Don Honorio Ventura State University Lubao Campus. Retrieved from: https://www.google.com/maps/place/Don+Honorio+Ventura+State+University++Lubao+Campus/@14.9220031,120.5841561,2133m/data=!3m1!1e3!4m15!1m8!3m7!1s0x33965e9c71de74d9:0x8a37b1d031e42840!2sSanta+Catalina,+Lubao,+Pampanga!3b1!8m2!3d14.9211515!4d120.5897832!16s%2Fg%2F1tdwmmfk!3m5!1s0x33965fc843611e97:0x2d81ff7ad9340734!8m2!3d14.9270302!4d120.5897821!16s%2Fg%2F11f77_3_zx?entry=ttu

[13] Hale T. (2015) Thirsty Concrete can drain 1000 liters of water in just 1 minute. Retrieved from: http://www.iflscience.com/technology/thirsty-concrete-can-drain-over-800-gallons-one-minute/

[14] Harsha S. (2017) Role of Statistics in Monitoring Rainfall Retrieve From: https://www.iosrjournals.org/iosr-jestft/papers/vol11-issue%203/Version-3/B1103030719.pdf

[15] Hicks, P. C., and J. R. Lundy. (2008) Permeable Pavement: Research Update and Design Implications. North Carolina Cooperative Extension, Raleigh, NC. AG-588-14W

[16] Illinois Asphalt Pavement Association (2022) Porous Pavement. Retrieved from: www.ilasphalt.org/resources/pavementtechnologies/porouspavements/?fbclid=IwAR2dPW0QUK1HVnqOcK2GBP310CofG7gmPK2HGM0XVDaD47QT396Wk7oHPk

[17] Interpave (2008) Permeable Pavement Guide to the design, construction and maintenance of concrete block (edition 5). Retrieve from: https://www.paving.org.uk/home/design-construction-maintenance/

[18] Interface Development Interventions Inc. (2017) Establishments with permeable pavement and Types of Permeable Concrete blocks. Retrieve From: https://idisphil.org/wp-content/uploads/2018/04/KINAIYAHAN-NL-17.pdf

[19] Law Insider (2016) Permeable Pavement. Retrieved from: https://www.lawinsider.com/dictionary/permeablepavement?fbclid=IwAR1udEk9SbHEpvufK7H-0lOvED6FpNgrIx8Ual9SmEm0QnNpYagDmHUPxt0

[20] Manalo L. (2017) Assessment of Permeable Paving Systems of Selected Establishments Located in the Central Business District of Davao City, Philippines. Retrieve from: https://www.academia.edu/49148995/Assessment_of_Permeable_Paving_Systems_of_Selected_Establishments_Located_in_the_Central_Business_District_of_Davao_City_Philippines

[21] Matchar E. (2015) This Concrete can absorb Flood. Retrieved from: https://www.smithsonianmag.com/innovation/concrete-can-absorb-flood-180956830/

[22] Merriam-Webster, Incorporated (2022), Reservoir Retrieved from: https://www.merriamwebster.com/dictionary/reservoir?fbclid=IwAR2C7B27IGQDuJnAm2lD1OQDHsFQGh0pmpCr5qZvInHD2lnwO5cFgGqTHsc

[23] Minnesota Pollution Control Agency (2022) Design criteria for permeable pavement. Retrieve from: https://stormwater.pca.state.mn.us/index.php/Design_criteria_for_permeable_pavement

[24] Penn State University (2021) Center for Dirt & Gravel Roads Studies. Retrieved from: https://dirtandgravel.psu.edu/wpcontent/uploads/2022/06/TB_Aggregate_101.pdf?fbclid=IAR3WvMXasdAkga7ObvaI3BOHMHHmeYVxsKwBB-tXVXeKI-Lz9iz7JY47v-Q

[25] Techno-Bloc (2019) How to Build a Permeable Pavement with a Porous Concrete Overlay. Retrieve from: https://www.youtube.com/watch?v=VQ75vl7fdKY&ab_channel=Techo-Bloc

[26] Tchobanoglous G. (2014) waste water engineering: treatment and resource recovery, fifth edition (volume 2) New York, NY: Mc Graw-Hill Education

[27] Figure 4: Smith D. (2006) Profile of typical Permeable Pavement. Retrieve From: https://www.researchgate.net/figure/Profile-of-typical-permeable-pavement-Source-Smith-D-2006_fig2_242343118

[28] Sustainabletecnologies (2015) Underdrains for Infiltrating Practices. Retrieved from: https://wiki.sustainabletechnologies.ca/wiki/Underdrains?fbclid=IwAR1-XY1cple8N6ebcIMtDNR-WW5N2z68MsUi9OYQgQCygJiuw_GNxd4K0GM

[29] Weather spark (2016) Average precipitation and rainfall in lubao. Retrieve from: https://weatherspark.com/y/134604/Average-Weather-in-Lubao-Philippines-Year-Round#:~:text=Lubao%20experiences%20extreme%20seasonal%20variation,average%20rainfall%20of%2020.9%20inches

[30] Weller C. (2015) This thirsty concrete absorbs 800 gallons of water in a minute. Retrieved from: http://www.iflscience.com/technology/thirsty-concrete-can-drain-over-800-gallons-.one-minute/

[31] Wingard J., Brändlin A., (2013) Philippines: Prone to natural Disaster. Retrieve from: http://www.dw.com/en/philippines-a-country-prone-to-natural-disasters/a-17217404