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Flood mitigation system: Proposed permeable concrete road and drainage on Parian, Mexico Pampanga

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ABSTRACT

When water overflows onto normally dry ground, flooding occurs. Heavy rains, clogged drainage systems, and occasionally failed levees or dams can all result in flooding. This study was conducted to calculate the maximum load bearing capacity of the permeable concrete used in the road and drainage system and to test the infiltration rate of the permeable concrete. To identify the major issue of water stagnation and to provide a solution, a thorough investigation was conducted in the area, focusing on the Barangay Parian Mexico, Pampanga. In order to support the study and determine the appropriate mixture ratio for permeable concrete, data were gathered and analyzed. Following the data collection, a mixture with a 1:3:0 ratio of cement, aggregates, and water was produced. Using two sizes of coarse aggregates 1 inch and ¾ inch it was cured for seven and fourteen days, respectively. The compressive strength of the permeable concrete was measured once the curing process was complete. The results for the 1 inch size gravel after curing for 7 days varied between 996 to 1279 PSI on average. However, the results of its 14 days of compression testing ranged from 900 to 1360 PSI on average. On the 28 days curing the average strength is between 1111-1505 PSI. Upon trying the use of ¾ inch size of aggregates, the results of its compressive strength under 7 days curing was averaging from 1009 to 1137 PSI. Lastly, the compressive strength of 3/4-size gravel after 7 days of curing was between 1009 to 1137. Due to its increased infiltration capacity of 1312.982 inc/hr, 21.883 inc/sec, or 555.829 mm/sec, 0.556 m/sec, permeable concrete has a greater potential to be used as a solution to minimize flooding

difficulties. The permeable concrete road must, however, adhere to the required standards for provincial highways because the planned location is a provincial route. However, permeable concrete has a high likelihood of being used to reduce flooding problems in terms of infiltration. The results from the compressive testing machine did not meet the minimum requirements for a provincial road's maximum load bearing capacity.

Key Words— *Brgy. Parian, Mexico, Pampanga, permeable concrete, coarse aggregate, flood, curing*

1.1 Introductions

Water flows over generally dry ground, flooding occurs. Floods can happen as a result of heavy rains, clogged drainage systems, or occasionally failing levees or dams. The most frequent weather-related natural disasters are floods. Floods all over the world frequently have shown a significant threat and delay on development in human habitat and environment (Nwigwe, C et al., 2014). It is important to understand how much disruption in urban travel occurs as a result of the intense rainfall events or coastal flooding events that are expected to become more frequent over the 21st century (Suarez, P et al., 2005). Flooding significantly affects both environmental health and human well-being. The impacts of a flood vary depending on a variety of factors, such as the flood's duration, depth, size, and velocity as well as environmental dangers, the significance of the situation, and the relevance of the structure. It may take many days or longer for floods to have an impact on people, communities, society, finances, and the environment. Parian, Mexico, Pampanga is one of the places that frequently experience flooding due to inadequate infrastructure such as roads and drainage systems.

Procedures for withstanding flooding like other Pampanga towns, the Municipality of Mexico is frequently affected by floods brought on by persistent typhoons and high rains. Numerous wide, low-lying rice fields that are easily drowned, wide, scouring rivers, and bisecting narrow creeks all contribute to the detrimental effects of flooding on human life and other sectors of the economy. The following map, Figure 1.1.1 depicts the depth ranges (in meters) of floods in Mexico's frequently inundated areas with a 2-year return period. The most recent typhoon, "Pedring," which slammed the Central and Northern parts of Luzon on September 27-28, caused catastrophic flooding in a number of barangays inside the municipality. Some households were even forced to leave for a safer area. Severe flooding had occurred in the lower sections of several barangays, including Lagundi, San Pablo, San Lorenzo, Parian, Balas, San Jose Matulid, and San Carlos. Evacuees from the aforementioned barangays were moved to schools, chapels, and barangay halls with the assistance of the Municipal Disaster Risk Reduction and Management Council and the Department of Social Welfare and Development. The intensity of the flood was increased by the Abacan and Betis River floods. Bungang Guinto, a narrow river, was unable to hold back the water coming from the two rivers. The situation was the same in other creeks. A total of 450 hectares of reproductive agriculture, 2 hectares of fishponds, and 500 ha of mature agriculture were all devastated. Since Ondoy, it is believed that Pedring is the storm that has damaged the Municipality the most.

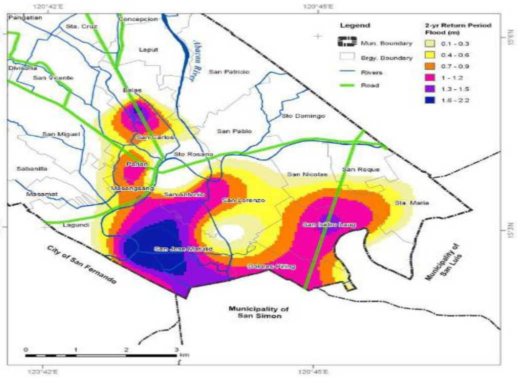


Figure 1.1.1 Range of Flood Depth in Frequently Inundated Barangays

Permeable concrete is an excellent alternative to traditional concrete for preventing stormwater runoff, permeable concrete can serve as a reservoir during times of heavy rain by allowing surface water to freely flow through the worn surface and into the ground underneath it according to Lafarge Tarmac. Permeable concrete is an emerging approach that has lately gained popularity. It is constructed of non-fine materials such as sand and gravel. This form of concrete can absorb rainfall through its void, reducing runoff and promoting groundwater recharge. Furthermore, porous concrete is intended to accumulate less vehicle loading (Hein, D. K et al., 2013).

Urban drainage is an essential part of water infrastructure systems in cities because it guards against health issues associated with flooding, safeguards property, and keeps disruptions to transportation services to a minimum (Fryd, O at el., 2012). Since urban drainage is a less evident method of reducing the risk of flooding than larger infrastructure like dams, seawalls, and reservoirs, it is often given a lesser priority. Poorly designed storm water systems continue to be a problem in developing areas as a result. Even small-scale flooding is made worse by these inefficient systems' frequent inability to handle the storm water runoff quantities produced by rainstorm events in expanding urban areas. Through analyzing the current urban drainage system, barriers may be filled and necessary action can be taken. By first locating the areas that require repair or replacement, an assessment of the current drainage networks can assist in leading cost-effective improvements. A comprehensive mapping of key urban drainage system attributes, like size and building materials, can also help with settlement-scale flood control. (See, L. S al., 2020). The maintenance of public cleanliness and the prevention of flooding have historically been the driving forces behind the design and operation of urban drainage systems. In order to protect the aquatic habitat, treatment facilities were only introduced later when pollution management became a significant issue (Rauch, W et al., 2002). This study aims to provide a solution to the flooding problem in Parian Mexico, Pampanga, as well as to reduce some of the factors that cause flooding, particularly in the transportation sector. Traffic congestion usually appears when there is a flood on the road, causing motorists to be delayed. Based on the most prevalent land use and the problems that the area is intended to address, all barangays were divided into clusters. For instance, Cluster A has barangays that are particularly vulnerable to flooding. The barangays of Cluster B are primarily residential. Lands used for agriculture make up Cluster C. Cluster D is made up of both rural and populated areas. Last but not least, Due to their proximity to the Highway, barangays in Cluster E are highly likely to improve. The list of barangay clusters is shown in the table.

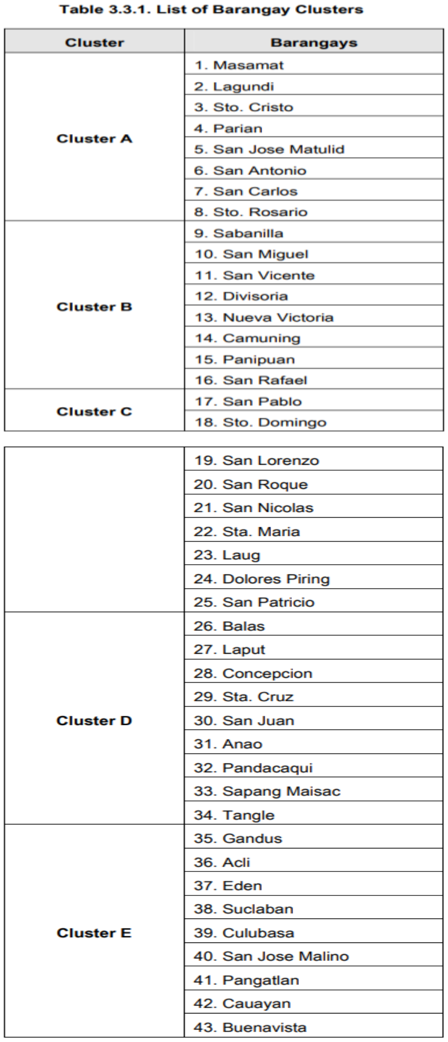


Table 3.3.1. List of Barangay Clusters

Cluster	Barangays
Cluster A	1. Masamat
	2. Lagundi
	3. Sto. Cristo
	4. Parian
	5. San Jose Matulid
	6. San Antonio
	7. San Carlos
	8. Sto. Rosario
Cluster B	9. Sabanilla
	10. San Miguel
	11. San Vicente
	12. Divisoria
	13. Nueva Victoria
	14. Camuning
	15. Panipuan
	16. San Rafael
Cluster C	17. San Pablo
	18. Sto. Domingo
	19. San Lorenzo
	20. San Roque
	21. San Nicolas
	22. Sta. Maria
	23. Laug
	24. Dolores Piring
	25. San Patricio
Cluster D	26. Balas
	27. Laput
	28. Concepcion
	29. Sta. Cruz
	30. San Juan
	31. Anao
	32. Pandacaqui
	33. Sapang Maisac
	34. Tangle
Cluster E	35. Gandus
	36. Acli
	37. Eden
	38. Suclaban
	39. Culubasa
	40. San Jose Malino
	41. Pangatlan
	42. Cauayan
	43. Buenavista

Figure 1.1.2 List of barangay clusters

Because typhoons occur frequently in the countries, it is also essential to comprehend the impact of flooding on our community in order to develop a long-term solution to the problem. This study proposed a possible solution to the flooding problem in Parian, Mexico, Pampanga to mitigate flooding.

1.2 Review of Related Literature

Floods are caused by the overflow of water on dry land, such as agricultural fields, cities, and highways. Flooding is is occur when drainage is blocked due to improper garbage disposal and also when lack of water catchment because of inadequate amount of space for a proper drainage system (Sholihah, Q et al., 2020). Because of the climate, increased precipitation and intensity are expected on a regular basis. There are existing methods for assessing the impact of flooding, but they have failed to collect the evolution and challenges associated with the interaction of floodwater and transportation systems (Pregnolato, M et al., 2017). Moreover, floods have a variety of impacts that are categorized based on the area impacted by the flood.
(Pyatkova, K et al., 2019). Flash floods are one of the common natural flood hazards known because of its destructive effect every year. Transportation sector and other infrastructure are also affected by this event (Diakakis, M et al., 2020). Reports in recent years have frequently focused on weather events, with floods being one of the most frequently reported due to the significant impact and disruption to societies and economies (Mendoza-Tinoco, D et al., 2017).

In recent years, drainage systems have played an important role in collecting and transporting wastewater and rainwater to reduce flooding in urban areas and to lessen the environmental impact of flooding on human life. It keeps rainwater from accumulating on the ground surface (Kumar, S et al., 2018). Infrastructure development has remained steady over time, and constructing an efficient drainage system has remained difficult, mostly because of the widely acknowledged effects of climate change and urbanization. (Huong, H. T. L., & Pathirana, A. 2013; Zhou, Q et al., 2014). Other factors to take into account when designing an urban drainage system include the location of the area where it is needed, as well as the amount and intensity of rainwater that will accumulate (Berggren, K et al., 2012). As a result, designing a sustainable and dependable drainage system entailed professional knowledge and experience (Zhou, Q. 2014).

Rainwater that reaches the ground surface primarily evaporates at the soil's surface. Permeable pavement takes a different approach to dealing with rainwater. Permeable concrete allows water to pass through its voids, converting rainfall into runoff through its own drainage system (Recanatesi, F et al., 2017; Xu, D et al., 2020). Concrete that is permeable to water might be referred to as pervious concrete because of its interconnected network of pores. The interest in pervious concrete, an environmentally benign material, has grown over the past century in the construction industry (Seifeddine, K., Amziane, S., & Toussaint, E. 2022). Because the majority of the structure of pervious concrete is composed of coarse aggregates that are largely joined by a thin layer of cement paste, pervious concrete has more voids than typical (Grubeša, I. N et al., 2018). The secret to making pervious concrete more durable is to improve its mechanical qualities (Sandoval, G. F et al., 2017).

The most widely used strategy to accomplish this is permeable pavements, which have been the subject of decades' worth of research (Marchioni et al. Marchioni and Becciu, 2014) made a synthetic review on the permeable pavement. They went into great detail about what permeable pavements are, how they work to reduce runoff volume, runoff quality, design life, and upkeep. As a result, the viability of permeable pavement as a workable strategy to encourage runoff volume reduction and pollutant removal was validated. The base, subgrade soil, and surface materials should be properly considered throughout the entire structure. (Kim et al. (2015) showed that porous pavements effectively reduce runoff using simulations from the Storm Water Management Model (SWMM) and trend analysis. The implementation of porous pavement might, according to the results, reduce the peak flow in each of the cases examined by about 33.4%. For the reservoir course of porous pavement, Koohmishi et al. (Koohmishi and Shafabakhsh, 2018) investigated the drainage potential of various particle size distributions. The results demonstrated that greater hydraulic conductivity was produced by uniform gradation with a constrained range of particle sizes. Alsubih et al. (2017) constructed a 1-m square pavement in the lab and conducted an experimental study to see how well a permeable pavement handled water runoff. According to the analysis, the chosen porous construction kept 50% of the total amount of rainfall.

1.3 Background of the Study

Due to climate change, which has increased the intensity and frequency of rainfall in recent years, the majority of people have experienced urban floods. In 2019, 194 floods and 91 big storms struck the world, affecting an estimated 64 million people (Cfroteod, C. 2020). Moreover, caused by floods roughly 40% of all economic damage in urban areas (Güneralp, B et al., 2015). It demonstrates the need of researching the relationship between flood mitigation and land-use change. Mostly in urbanized areas, large land-changes such as developing up and expanding impervious infrastructure are constantly present (Samal, D. R., & Gedam, S. S. 2015).

This study offers a new method to flooding mitigation through permeable pavement and a drainage system. Permeable pavement is made out of a layer of non-fine aggregates such as stone and gravel that allows rainwater to enter through its void (Mullaney, J et al., 2014). Rainwater that reaches the ground surface evaporates mostly at the soil's surface. Permeable pavement approaches rainwater management in a unique way. Water can move through the holes in permeable concrete, converting rainfall into runoff via its own drainage system (Recanatesi, F et al., 2017; Xu, D et al., 2020).

This study is to be conducted to contribute to Parian, Mexico, Pampanga to mitigate the flooding issue.In contrast to conventional sand-based concrete, permeable concrete is a type of concrete that is built on tiny broken granite particles that are packed loosely enough to allow water to pass through. Furthermore, this type of concrete is a more efficient solution to mitigate flooding and also because this form of concrete is unique in the Philippines, this study desired to introduce this magnificent infrastructure.

1.4 Study Area

Pampanga is known to be one of the flood prone areas in the Philippines. This research will be carried out in Parian, Mexico Pampanga, beginning at the road crossing leading to Parian Barangay Hall and ending at the bridge connecting Parian and San Vicente. The Municipality of Mexico has a land area of 117. 41 square kilometers. Additionally, the population of barangay Parian was 5,756 as of the 2020 census, which was 3.32% of the Municipality of Mexico Pampanga's overall population. Due to the area's poor drainage system, flooding and water stagnation are common occurrences. The water was both rainwater and from various household sources. The main road is 5.25 to 5.30 meters wide and 724 meters long, while the other areas are 3.2 meters wide and 186 meters long, and 3.4 meters wide and 94 meters long. The total length of the area is 1004 meters.

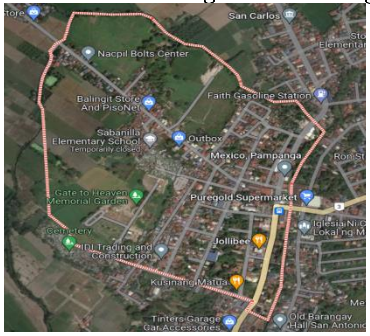


Figure 1.4 Map of Parian, Mexico
(https://www.google.com/maps/place/Parian,+San+Agustin,+Mexico,+Pampanga/data=!4m2!3m1!1s0x3396f9f8880ea2df:0xd5b8172dbf4462da?sa=X&ved=2ahUKEwj2uvLxhbT_AhXMa2wGHVuACcEQ8gF6BAgIEAI)

1.5 Objectives of the Study

General Objective

The study aimed to design a road and drainage using permeable concrete along Parian, Mexico Pampanga.

- To calculate the maximum load bearing capacity and design of the permeable concrete used in the road and drainage system;
- To differentiate the strengths of permeable concrete that has been cured for seven, fourteen and twenty-eight days;
- To test the infiltration rate of permeable concrete;

1.6 Significance of the Study

The following would benefit from this study's findings:

Direct Beneficiaries: The result of this study will benefit the residents of Barangay Parian, Mexico, Pampanga in lessening their experience with flooding or water stagnation in the area;

To the Public: The result of this study will reduce the traffic congestion experienced by the public by introducing permeable concrete roads and drainage systems on the said location;

School Administrations/Civil Engineering Department: The result of this study will provide data that can be used as a reference for future topics about road and drainage systems;

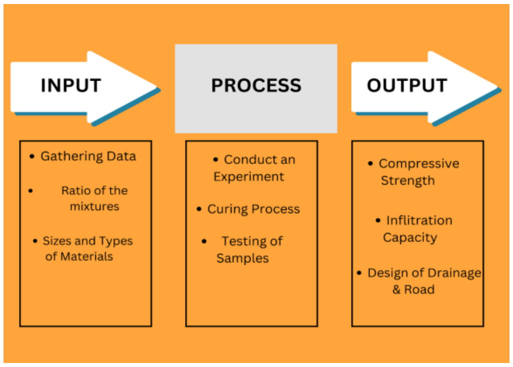
Local government/ Municipal Government: This current study may be adopted by the local/municipal government for future projects such as improving roads and drainage systems;

Future Researchers: This study will provide data for future research in the field and act as a platform for potential future findings.

1.7 Scope and Limitations

This research was limited to the design of a permeable concrete road and drainage system in Barangay Parian, Mexico Pampanga. The road that was constructed is 1.004 kilometers long and ends at the bridge of Barangay Parian connecting to San Vicente. It also covered the strength of the cement-coarse-fine aggregates ratio of 1:3:0, which was limited to 32:1 water-cement. This study used 1 inch and ¾ inch size coarse aggregate, and the aggregates will use gravel to know what is suitable to use in making permeable concrete and give the desired strength needed. This study was limited to the designing of the permeable road and an additional infrastructure like drainage system that will support the infiltration of the permeable concrete road. It also adopted the best result of the sample in terms of strengths and infiltration capacity. Costing of the material was on the limitation of the study.

1.8 Conceptual Framework



Definition of Terms

ASTM- Materials that are uneven and granular, like crushed stone, gravel, or sand.
Compressive stress-a material's volume is reduced as a result of the force that causes the substance to deform.
DPWH- Department of Public Works and Highways
Fine aggregates- they are basically any natural sand fragments extracted from the ground through mining.
Flow rate- the amount of fluid that flows in a given time.
Load Bearing capacity- the greatest amount of loading that a structural element or material can withstand before failing.
MPDC- Municipal Planning and Development Coordinator
Permeable concrete- a form of concrete that can absorb rainfall through its void, reducing runoff and promoting groundwater recharge.
Porosity- the quality of being porous, or full of tiny holes.

Chapter II

METHODOLOGY

This part of study shows how this research was conducted and executed. Through the study's systematic and scientific methodology, the experiments were able to determine the best proportion to use and take into account when designing the road. It covered the various activities that have been carried out to support the study. It emphasized the steps involved in producing and testing permeable concrete. Testing and experimentation were required to reach reasonable conclusions about the optimal curing days for permeable concrete. Making permeable concrete and applying loads until failure is the best method for determining compressive strength. This method was used to determine which ratio of curing days is best to use when designing the road. The drainage proposed in this study was a traditional drainage system that was connected to the road to help the permeable road infiltrate runoff that the road cannot infiltrate during heavy rainfall.

2.1 Data Gathering

This study gathered data on drainage systems and permeable concrete that would be appropriate in the area. The Department of Public Works and Highways (DPWH) offered various drainage designs, plans, and further details regarding permeable concrete. The Mexico Municipality, particularly Enp. Renato Caballa, Municipal Planning and Development Coordinator (MPDC), provides the slope and additional information about the active drainage system, as well as when the collected runoff from the permeable concrete road and drainage system can be discharged on the San Carlos bridge, and elevation and other data about the discharge routing of the water in their Municipality. The information acquired included various maps that helped in the study of the proposed Parian road and drainage system. Additionally, information about the annual rainfall from Hanging Habagat, which affected the Municipality of Mexico, was gathered from a website of weather and climate.

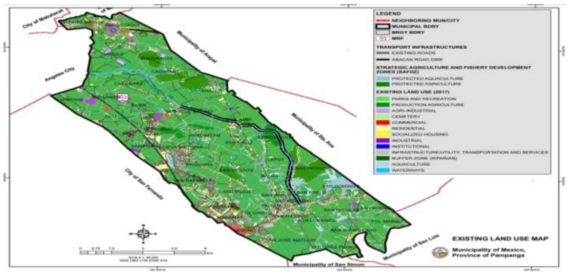


Figure 2.1.1 Mexico existing land use map
(https://www.mexicopampanga.gov.ph/Clup/2020/Zoning%20Map.pdf)

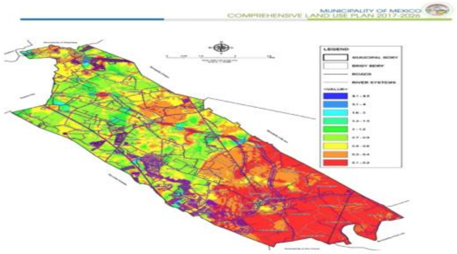


Figure 2.1.2 Slope map (https://www.mexicopampanga.gov.ph/Clup/2020/Zoning%20Map.pdf)

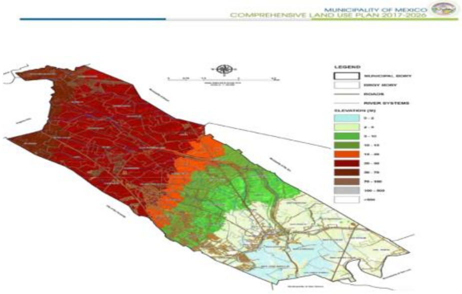


Figure 2.1.3 Elevation map (https://www.mexicopampanga.gov.ph/Clup/2020/Zoning%20Map.pdf)

2.2 Survey the Area

The survey began at the crossing near Shine and Glam establishment and ended at the Parian bridge connecting to San Vicente. The width of the main road and other roads connecting to it is measured in order to obtain an accurate measurement at each location. To get an accurate measurement of the road, the length was measured with a measuring wheel and a 50 meters measuring tape. The MPDC of Municipality of Mexico, Pampanga also provided water discharge routing information on the drainage system.

2.3 Conduct an Experiment

The experiment was conducted and provided the materials that were utilized in this activity. For the design of the road, the experiment was essential. Using a weighing scale, samples were made here in the ratio of cement, coarse, and fine aggregates 1:3:0. With two different coarse gravel such as G1 and ¾, and water, were measured according to the ratios provided. As shown in Figures 2.3.1a and 2.3.1b were used to mix the cement, aggregate, and water throughout the mixing processes. In the ratio, 3 samples of permeable concrete for the G1 gravel were taken over a period of 7, 14 and 28 days, and 3 samples of permeable concrete of ¾ gravel were taken. These are required in order to accurately calculate the permeable concrete's strength, which will be used for the road.

In order for the samples to reach the maximal strength shown in figure 2.3.2, the samples were cured by soaking them in water for 7, 14 and 28 days respectively. Test cylinders were filled in three layers in order to pass the proctor compaction test as standard. As depicted in figure 2.3.3, each layer underwent 25 blows from a tampering rod.

Figure 2.3.1a Materials to be mix

Figure 2.3.1b Shows how the mixing process done

Figure 2.3.2 Curing of Samples

Figure 2.3.3 Applying 25 blows in every layer

Samples were made by following the procedures in ASTM.The ASTM cement and concrete standards are significantly used in the assessment and testing of concrete, cement, and aggregates. Concrete can have a range of unique characteristics based on the cement, chemical admixtures, and material combination used to manufacture it. These components are combined with water to make concrete, which is the main building material. Through the use of these cement and concrete standards, concrete mixtures may be tested and assessed in labs all over the world to guarantee its sturdiness and safety. These standards make it easier to distinguish between concrete's many characteristics, such as strength, elasticity, hardness, and workability. After curing for 7 days, 14 days, and 28 days, they were delivered to a laboratory where they were tested for compressive strength to see if the ratio used will meet the required standard for provincial roads.

Additionally, 1 sample block was created for the permeable concrete infiltration test. The sample was placed in the 12"x12"x4" box indicated in figure 2.3.4 for infiltration. Prior to being tested for permeability, the sample block also underwent a 7-day cure. Spraying water on the sample's top is essential before covering it in a transparent plastic bag that will protect it. These aided in the equal curing of the concrete.

Figure 2.3.4 A 12"x12"x4" block, used for testing the infiltration

2.4 Testing of the Samples

Over the course of 7, 14 and 28 days, 3 samples of permeable concrete for the G1 gravel and 3 samples for the 3/4 gravel were taken in the ratio. Upon completion of the 7- and 14-day curing processes, the samples were delivered to the testing laboratory. The test conducted was a compressive strength test and it happened in the laboratory of the Department of Public Works and Highways (DPWH Region 3) in Sindalan City of San Fernando Pampanga.

2.4.1 Compressive strength

The cylinders' visible physical characteristics can offer preliminary information prior to any tests being conducted on them. For instance, cement will sink to the bottom of the cylinder if a mixture contains too much water. Reduced water permeability and clogging of the empty spaces at the base of the concrete would be the outcome. The cylinder's bottom would seem solid and devoid of any voids, giving it the appearance of normal concrete. Since there are no blank spaces, it is expected that these cylinders will have higher compressive strengths and reduced permeability rates. The top part of the cylinder may be weaker than the bottom because the cement has moved to the bottom of the cylinder. The cylinder's inside would eventually fail after the top surface. The end consequence could be a drawn-out process in which, after first crushing the top, the loading actually increases and continues until the entire cylinder fails.

Figures 2.4.1a, 2.4.1b, and 2.4.1c depict the testing of samples after 7 days of curing

Figure 2.4.1a Show three samples in every

Figure 2.4.1b Shows the testing of the samples ratio and the Universal Testing Machine

Figure 2.4.1c Result of the compressive stress

Testing of samples under the 14 days of curing were shown in the figure 2.4.1d, figure 2.4.1e, 2.4.1f

Figure 2.4.1d Samples for 14 days before testing

Figure 2.4.1e Sample of the test for 1:3 ratio

Figure 2.4.1f Result of the test done for sample1:30

2.4.2 Infiltration Test

In compliance with ASTM C1701, Standard Test Method for Infiltration Rate of Pervious Concrete (ASTM 2009), samples were tested for infiltration on the blocks. The ASTM C1701 test was performed by measuring the length of time it takes for a specific volume of water to permeate the sample. The water is applied to the sample in a ring with a predetermined area, and the area of the ring and the time it took for the water to penetrate the sample can be used to calculate the infiltration rate. A predetermined weight of water was delivered into the samples at a steady pace during the infiltration testing process, which is also known as a constant head test. It is crucial to mark the ring with two lines that are separated by .4 inches in order to maintain a steady head while testing the infiltration. Each sample underwent two tests in order to produce better findings.

Four (4) primary elements make up the infiltration or permeability test for permeable concrete:

1. Installing the Infiltration ring;
2. Pre wetting the concrete;
3. Testing the concrete;
4. Calculating the result

To maintain a consistent head, water is poured into the infiltration ring in Figure 2.4.2 and kept at a predetermined height. The infiltration rate in inches per hour is calculated using the amount of time that it took for the water to penetrate the sample.

The formula was used to solve the Infiltration rate of the sample of permeable concrete and also to get the average infiltration capacity of it.

$I = K(M) / D2 * t$

Wherein:

I = Infiltration (in/hr)
K = 126,870 (Constant)
M = Mass of water (lbs)
D = Diameter of the infiltration ring (in)
T = Time to infiltrate (sec)

Figure 2.4.2 Pouring of water to the concrete

2.5.1 Designing the Road

Consider the location where the area is proposed when designing the road to determine the rainfall intensity to be used. The frequency and duration were determined by weather data from Mexico (figure 2.5.1). In that area, it was recorded. The existing road in the crossing near Shine and Glam and ending at the Parian bridge connecting to San Vicente is considered a provincial road having the compressive strength capacity of 2500 psi, so the road design must meet or exceed the standard compressive strength of a provincial road. According to Mexico Weather data, the average precipitation in Mexico is 93.55 millimeters per Year or 0.26 millimeters per day, so the road will be designed to accumulate the average precipitation in Mexico, Pampanga especially on Parian to mitigate flooding issues in the area.

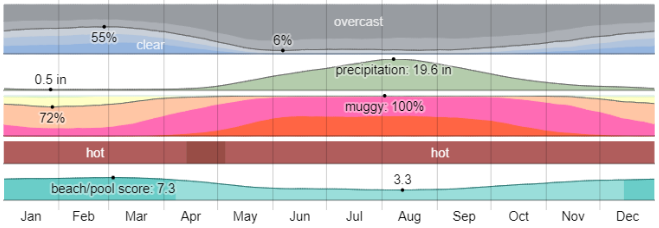


Figure 2.5.1 Mexico weather data (https://weatherspark.com/y/5674/Average-Weather-in-Mexico-City-Mexico-Year-Round)

2.5.2 Designing the Drainage

The type of the drainage that we used in this study is a surface drainage system that was adopted in the study of (Mukherjee, D. 2014). In order to evacuate water that has accumulated on the surface of the land as a result of precipitation or water discharge from buildings, surface drainage systems are used. To lessen traffic dangers and handle projected storm-water flows, the channels should be suitably positioned and formed.

Inlets an inlet is a component of a drainage system that gathers runoff at the surface and allows it to enter storm drains that are underneath. Inlets should not be blocked with rubbish to prevent design floods from passing through.

Figure 2.5.2.1 Road surface drainage

Storm Sewers These are underground pipes that carry runoff from a roadside inlet and discharge it into a body of water away from the road.

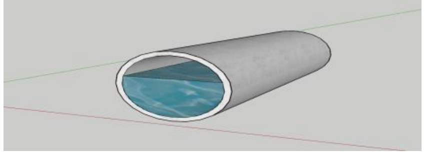


Figure 2.5.2.2 Inlets concrete pipe

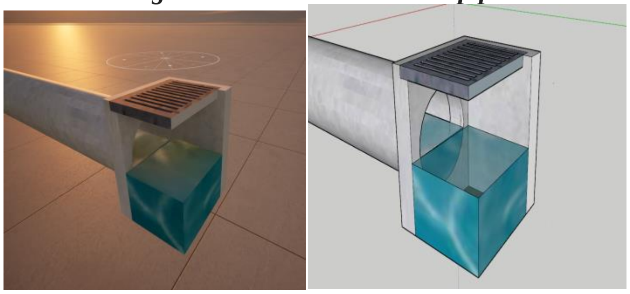


Figure 2.5.2.3 Sample layout of the drainage

CHAPTER III

RESULTS AND DISCUSSION

This chapter shows and discusses the results of the experiments described in the previous chapter. The test that has been performed on the samples determines what the outcome will be. It also addresses the findings and whether the samples can be used for driving. To demonstrate the impact, one has on the other, comparisons of pertinent interactions between water, aggregate, and cement were given. It includes the results of the various tests that were run on the samples. This section also displays the road design that was used for the study.

3.1 Testing of Permeable Concrete

Three samples of permeable concrete for the 1-inch size of gravel and three samples of the 3/4 inches size of gravel were taken over periods of seven and fourteen days, respectively. The samples were brought to the testing facility after the 7-, 14- and 28-days curing processes ended. The Department of Public Works and Highways' (DPWH Region 3) laboratory in Sindalan City, San Fernando, Pampanga, conducted the compressive strength test.

3.1.1 Strength of Permeable Concrete

When two various sizes of aggregates are tested, it was discovered that the 1 inch size of gravel increases compressive strength. Furthermore, the ¾ inches of gravel has a lower compressive strength than the 1 inch size of gravel. Despite having a higher compressive strength than ¾ inch size of gravel, 1 inch size of gravel did not meet the standards for a provincial road since the minimum standard Psi of a provincial road is 2500 psi and the highest compressive strength result of the permeable concrete is 1505 Psi. The findings of the samples' compressive strength testing were obtained by using the Compressive Testing equipment.

3.1.1.1 Water

Concrete development can suffer by the presence of water. Concrete that has been mixed with too much water will become soupy, which will reduce the concrete's strength. For two reasons, water is essential. The first is hydrating the cement, and the following step is making a usable product. The cement must be hydrated in order for binding it to combine with the aggregate, which in turn provides concrete its strength. Conversely, the presence of water-filled decay within the concrete has a negative impact on its strength. There are indications that the porosity and the water-cement ratio (W/C) directly affect the strength of concrete. This is demonstrated by the process of hydration. As the hydration process continues, the amount of particles in cement increases. This volume has taken the place formerly occupied by the unhydrated cement. An increase in solids volume suggests a reduction in porosity.

Strength is influenced by porosity, yet bonding produces strength in the first place. It is challenging to form bonds in mixes with high W/C ratios because of the spacing between the particles. A mixture with a high W/C ratio is one that is porous. Thus, a high porosity indicates weaker bonding, which consequently results in decreased strength.

Water and how it is used in permeable concrete are of the utmost importance. Since fine particles are removed from permeable concrete, the cement paste's bond and its interaction with the aggregate are what determine the concrete's strength. Similar to traditional concrete, insufficient water prevents bonding, while an excessive amount will cause the paste to settle at the pavement's base and clog the pores.

3.1.1.2 Aggregate Size/Type

When discussing the strength of concrete, the aggregate strength is often not taken into account. In compression testing, concrete specimens typically fail at the aggregate-paste contact. In permeable concrete, the cement paste content is constrained, and the surfaces that come into contact with one another provide the aggregate strength. So an aggregate that is harder, like granite or quartz, will have a higher compression strength than an aggregate that is softer, like limestone. Usually, aggregate between 1 inch size of gravel and ¾ inch size of gravel are used because it is easier to handle and place than any size greater. Because it would produce a rougher surface and larger void spaces. In this study, gravel is the type of aggregate used which has a 1 inch and ¾ inch dimension, to test what is more capable of giving the higher strength to use in permeable concrete roads.

3.1.1.3 Cement/Aggregate Ratio (C/A)

Another crucial aspect is how much aggregate there is in comparison to how much cement there is. As there is more cement paste available for compacting, the compressive strength rises. Again, this will clog the pores and impair the functionality of the permeable concrete. Several permeable concrete mixtures were created using an acceptable range of C/A ratios, and using data from prior studies, their compressive strength was assessed. The C/A ratio in this study is 1:3:0.

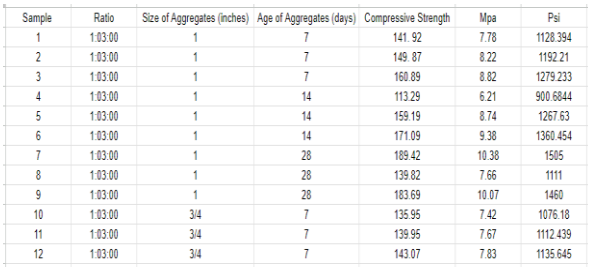
3.1.1.4 Compaction

The degree of compaction had a considerable effect on the performance of permeable concrete. The strength of the finished product directly increased with the level of compaction achieved during the concrete placement process. The densification and void reduction of the concrete cause this to happen. The water's permeability requires the same voids. As a result, excessive compaction will decrease the permeability of the concrete and result in the failure of the permeable concrete system. Other researchers' earlier efforts on permeable concrete included manual tamping, Proctor testing, and roller compaction. The amount of compaction imparted to each of the test cylinders was measured using the traditional and modified Proctor compaction tests.

3.2.1 Compression Testing

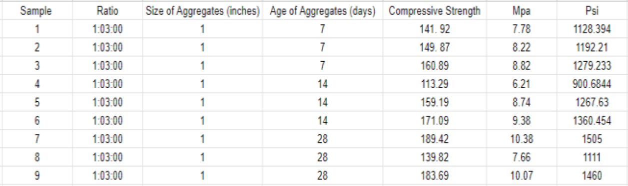
When comparing compressive strength with two different sizes of aggregates, it is discovered that the 1 inch size of gravel increases its strength. And the ¾ inch size of gravel has a lower compressive strength than the 1 inch size of gravel. Although the 1 inch size of gravel has a higher compressive strength than the ¾ inch size of gravel.

When two various sizes of aggregates were examined, it was discovered that the 1" size of gravel increases compressive strength. Furthermore, the 3/4" gravel has a lower compressive strength than the 1" gravel. Despite having a higher compressive strength than 3/4" gravel, 1" gravel did not meet the standards for a provincial road. The findings of the samples' compressive strength testing were obtained by using the Compressive Testing equipment. However, the minimum strength required for a provincial road was not met.



Sample	Ratio	Size of Aggregates (inches)	Age of Aggregates (days)	Compressive Strength	Mpa	Psi
1	1:03:00	1	7	141. 92	7.78	1128.394
2	1:03:00	1	7	149. 87	8.22	1192.21
3	1:03:00	1	7	160.89	8.82	1279.233
4	1:03:00	1	14	113.29	6.21	900.6844
5	1:03:00	1	14	159.19	8.74	1267.63
6	1:03:00	1	14	171.09	9.38	1360.454
7	1:03:00	1	28	189.42	10.38	1505
8	1:03:00	1	28	139.82	7.66	1111
9	1:03:00	1	28	183.69	10.07	1460
10	1:03:00	3/4	7	135.95	7.42	1076.18
11	1:03:00	3/4	7	139.95	7.67	1112.439
12	1:03:00	3/4	7	143.07	7.83	1135.645

Table 3.2.1.1 Result of the compressive strength of permeable concrete



Sample	Ratio	Size of Aggregates (inches)	Age of Aggregates (days)	Compressive Strength	Mpa	Psi
1	1:03:00	1	7	141. 92	7.78	1128.394
2	1:03:00	1	7	149. 87	8.22	1192.21
3	1:03:00	1	7	160.89	8.82	1279.233
4	1:03:00	1	14	113.29	6.21	900.6844
5	1:03:00	1	14	159.19	8.74	1267.63
6	1:03:00	1	14	171.09	9.38	1360.454
7	1:03:00	1	28	189.42	10.38	1505
8	1:03:00	1	28	139.82	7.66	1111
9	1:03:00	1	28	183.69	10.07	1460

Table 3.2.1.2 Comparison of strength of 1 inch gravel of 7 days, 14 days, and 28 days of curing

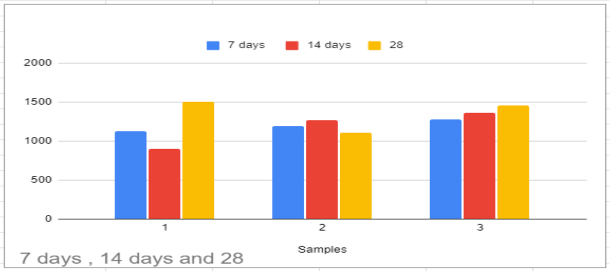
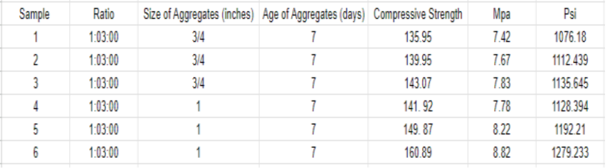


Table 3.2.1.3 Strength of 1 inch size gravel after 7 days, 14 days and 28 days of curing



Sample	Ratio	Size of Aggregates (inches)	Age of Aggregates (days)	Compressive Strength	Mpa	Psi
1	1:03:00	3/4	7	135.95	7.42	1076.18
2	1:03:00	3/4	7	139.95	7.67	1112.439
3	1:03:00	3/4	7	143.07	7.83	1135.645
4	1:03:00	1	7	141. 92	7.78	1128.394
5	1:03:00	1	7	149. 87	8.22	1192.21
6	1:03:00	1	7	160.89	8.82	1279.233

Table 3.2.1.4 Comparison of 1 inch to ¾ inches gravel in terms of strength that was cured for 7 days

The graph compares the strength of 1 inch of gravel to 3/4 inch of gravel. It demonstrates that the 1 inch gravel has a higher strength value than the 3/4 inch gravel but does not meet the provincial road standard strength.

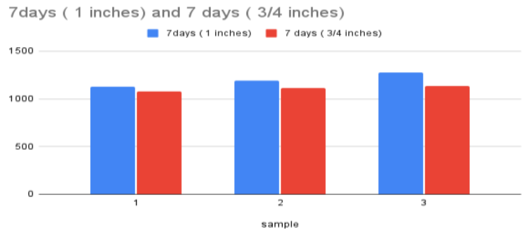


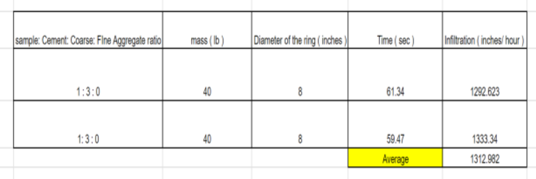
Table 3.2.1.5 Comparison of the strength of 7 days curing of 1 inch and ¾ inch gravel

The graph compares the strength of 1 inch of gravel to 3/4 inch of gravel. It demonstrates that the 1 inch gravel has a higher strength value than the 3/4 inch gravel but does not meet the provincial road standard strength.

3.2.2 Infiltration Test

The flow rate of permeable concrete shown on table 3.2.2 shows that the permeable concrete can infiltrate 1312.982 inc/hr, 21.883 inc/sec or 555.829 mm/sec, 0.556 m/sec.

The result of the infiltration test of the permeable concrete made in 1 inch gravel shows the value of the permeable concrete's infiltration capacity; we only tested the infiltration capacity of 1 inch gravel because 1 inch gravel has a higher compressive strength than 3/4 inches gravel.



sample: Cement: Coarse: FIne Aggregate ratio	mass (lb)	Diameter of the ring (inches)	Time (sec)	Infiltration (inches/ hour)
1 : 3 : 0	40	8	61.34	1292.623
1: 3 : 0	40	8	59.47	1333.34
			Average	1312.982

Table 3.2.2 Infiltration test result

3.3 Layout of Permeable Concrete and Drainage

The computed thickness has a 290 mm, but the thickness can be adjust if the strength of permeable concrete road does not reach the standard compressive strength of a provincial road, and a 50 mm meters of road concrete to prevent the soil to absorb the water, the PPR pipe that put under the permeable concrete road helped the permeable concrete to discharge the water that being absorb by the permeable concrete and deliver the runoff to the drainage system, the layout sample of a drainage system is shows in the figure 3.3 the sample drainage system is a surface drainage system.

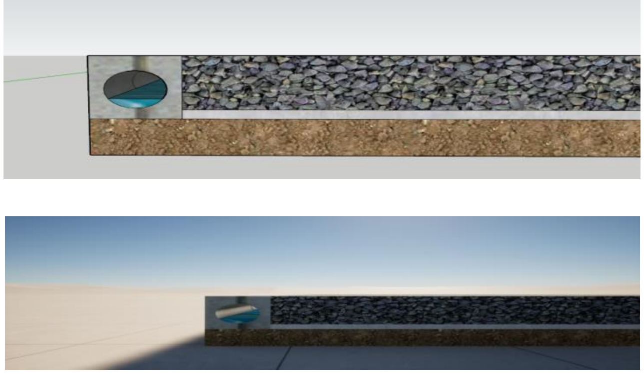


Figure 3.3 Possible layout of the permeable concrete and drainage system

Chapter IV

Conclusion and Recommendation

4.1 Conclusion

Future designs were influenced by past mistakes. Unfortunately, there isn't a perfect formula for permeable concrete that produces a material with a high compressive strength and porosity. The most effective technique for creating a range of values that result in a functional design is testing combined with study of already-existing systems.

In low traffic areas, permeable concrete was typically used as the surface for parking lots, walkways, and highways. In this study, permeable concrete was used on a road, more particularly, a provincial road. Compressive strength tests were performed to see whether it could be used on a provincial road. Permeable concrete testing provides additional information for choosing the right ratio for the road.

From the results of the compressive strength of samples with the ratio of 1:3:0. By examining the samples produced, it was discovered that the provincial road's standard strength was not being met. When two various sizes of aggregates were examined, it was discovered that the 1-inch size of gravel increases compressive strength. Additionally, the ¾ inch size of gravel's compressive strength is lower than the 1-inch size of gravel. Although the 1-inch size of gravel is higher in compressive strength, it did not meet the required strength for a provincial road.

The ratio 1:3:0 using a 1-inch size of aggregates under 7 days of curing, among the three samples made, the maximum strength obtained was only 1279 PSI. On the other hand, under the 14 days curing process, the strength of it was averaging to

900-1360 PSI. And on the 28th day curing the average strength is between 1111-1505 PSI. Upon trying the use of ¾ inch size of aggregates, the results of its compressive strength under 7 days curing were averaging from 1009 to 1137 PSI.

Permeable concrete has a higher capability to use as a solution to mitigate flooding issues due to its infiltration capacity of 1312.982 inc/hr, 21.883 inc/sec or 555.829 mm/sec, 0.556 m/sec. However, because the proposed area is a provincial road, the permeable concrete road must meet the standard strength for provincial roads. However, in terms of infiltration, permeable concrete has a high probability of being used to mitigate flooding issues.

4.2 Recommendation for the future

Future research needs to address a number of issues. In this investigation, only two aggregate sizes were employed. Higher compressive strength should be provided by larger, harder aggregate; the impact on porosity and permeability would need to be examined.

Future study must take into consideration various concrete compositions, as well as the use of admixtures or other substances that will reinforce permeable concrete or quicken the infiltration of permeable concrete.

There is a necessity to investigate permeable concrete study. This will make it easier for engineers to incorporate it into other designs, such as placing it on highways with heavy traffic. The more precise the data, the more precise the answer.

Compressive strength of cement-based concrete is primarily determined by a number of factors, including gravel size. Concrete's workability has increased as a result of the addition of larger aggregate sizes. (Ernesto J. Guades, 2019).

It is common knowledge that coarse aggregate is crucial to the success of concrete. According to research, changes in coarse aggregate can alter the strength and fracture qualities of concrete. Coarse aggregate typically makes up over one-third of the volume of concrete. There is compelling evidence that the type of aggregate affects the durability of concrete. compared four different types of coarse aggregate in four different concretes made with the same mix ratios. They came to the conclusion that whereas coarse aggregate strength has minimal bearing on compressive strength in normal-strength concrete, greater strength coarse aggregates often provide higher compressive strengths. (Ezeldin and Aitcin, 1991).

The appearance of recycled aggregate alleviates this problem. In order to fulfill the goal of cyclic utilization, recycled aggregate pertains to the crush of waste building concrete used as a coarse aggregate of pervious concrete, either entirely or partially replacing the natural aggregate. In the realm of construction, recycled aggregate (RA) is regarded as the most efficient way to deal with building waste, which supports the creation of sustainable infrastructure (Sagoe-Crentsil et al. 2001).According to Sata et al. (2016), pervious concrete, a type of green environmental material, offers many qualities that ordinary concrete lacks, including high permeability, minimal cement use, and ease of building. Additionally, it has some uses in permeable paving, hydraulic structures, and ecological slope protection. (Zhu, X., Chen, X., Shen, N., Tian, H., Fan, X., & Lu, J. 2018).

Only 14 days were the maximum cure days in this investigation. Concrete's strength, growth and durability are greatly influenced by curing. Despite the years of intensive research, there are still a number of issues with statistically forecasting how strength will develop at both young and old ages. The majority of theoretical formulations for the growth of concrete strength were developed based on isothermal curing. But in reality, practically all concrete is produced in temperature regimes that are not isothermal. Because of this, the current model can only be used to estimate roughly how strong concrete will be for curing temperatures that vary only slightly over time. In essence, the majority of the current maturity equations were developed with the presumption that the effects of varied curing temperatures at different curing times are equivalent (Kim, J. K., Moon, Y. H., & Eo, S. H. 1998). The correct forecast of concrete strength with curing temperature, according to Guo (9) however, could only be made by a function of temperature, taking into consideration both effects of curing temperatures at different ages (Xie, H., Shi, W., Issa, R. R., Guo, X., Shi, Y., & Liu, X. 2020).

The product may need to cure for up to 28 days to get the optimum strength of concrete, according to Mr. Joselito P. Sundiang, a Lab Technician II of the Department of Public Works and Highways in Region 3. Additionally, he claims that it is possible to achieve the standard compressive strength of the provincial road if the gravel used is more substantial. In all of the tests, the highest compressive strength was noted around 56 days old. Compressive strength rises with age. This suggests that strength development continues after the concrete has been thought to have reached its maximum strength, which is thought to be 28 days. (2018) Ogundipe, O. M., Olanike, A. O., Nnochiri, E. S., & Ale, P. O.

Permeable concrete will have various applications if future researchers can find the correct size, type, and quantity of cement and aggregates that have better compressive strengths without reducing the porosity of the concrete. For future researchers, they may adopt this study and its additional recommendations for them to improve the results.

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