LABORATORY INVESTIGATION OF THE HYDRAULIC PROPERTIES OF PERMEABLE LOW-DENSITY CELLULAR CONCRETE

by

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STATEMENT OF THESIS APPROVAL

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ABSTRACT

This study examines the hydraulic properties of permeable low-density cellular concrete (PLDCC) within a controlled laboratory environment. We also explore how these properties might be applied to sustainable and resilient infrastructure systems. The research involved conducting laboratory tests on 53 PLDCC samples varying between 25.0 to 32.6 pcf to determine the hydraulic conductivity, dry and partially saturated unit weight, water storage capacity, buoyant unit weight, and potential compatibility with geotextile materials. Our findings indicate that PLDCC exhibited a hydraulic conductivity ranging from 2.2E-03 cm/s to 2.7E-01 cm/s, comparable to clean sand or sand and gravel mixtures. This relatively high permeability for a cementitious material suggests that PLDCC's will efficiently drain surface water or allow groundwater flow when placed below the surface. Also, the high void ratio or porosity of PLDCC produces a partially saturated water storage capacity of up to 60% by volume, which is significantly higher than compacted earthen materials (e.g., sand and gravel). In addition, the partially saturated unit weight of PLDCC is similar to that of water, resulting in minimal to zero buoyance uplift when subject to groundwater inundation or rise. Additionally, laboratory assessments involving the integration of geotextile with PLDCC reveal negligible or no occurrence of clogging while preserving its infiltration ability. This initial finding suggests that nonwoven geotextile filter fabric can be integrated with PLDCC to reduce its plugging potential when placed in contact with fine-grained soils.

TABLE OF CONTENTS

LIST OF TABLES

Tables

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CHAPTER 1

INTRODUCTION

In recent years, the rapid growth of urbanization and population has placed an unprecedented demand on our infrastructure systems. Traditional construction methods using conventional materials face challenges in meeting the rising need for sustainable infrastructures that effectively incorporate environmental considerations. For instance, while commonly used concrete and asphalt exhibit strong load-bearing capabilities suitable for heavy traffic, their lack of hydraulic conductivity (permeability) often leads to increased surface water runoff and a heightened risk of flooding [1]. Additionally, water accumulation on impermeable surfaces can cause pavement cracking and deterioration [2]. Furthermore, rainwater runoff from paved surfaces can transport pollutants, sediments, and petrochemicals into nearby bodies of water, thereby causing damage to ecosystems [3]. To address these concerns, researchers have been investigating innovative materials and techniques that can mitigate these issues and potentially revolutionize the engineering application field.

Permeable lightweight cellular concrete (PLCC), also known as permeable low-density cellular concrete (PLDCC), is a notable material that has attracted growing interest. This specific material consists of Portland cement, water, and preformed foam. Owing to its distinctive internal interconnected bubble structures created by incorporating

a foaming agent, this material provides several benefits in terms of performance characteristics. These advantages include lower material density and higher water absorption capacity than conventional backfill materials [4].

While many properties of PLDCC can be studied, such as strength, stiffness, and durability, this research will mainly concentrate on analyzing the hydraulic characteristics of PLDCC, which includes examining its density in dry and partially saturated states, hydraulic conductivity, water storage capacity, and buoyant unit weight. Moreover, this research will also investigate the hydraulic behavior of PLDCC when combined with filtration materials such as geotextile and analyze any potential concerns regarding clogging effects that may occur from this combination.

Understanding the hydraulic properties of PLDCC is crucial from an engineering perspective. The behavior of PLDCC under different hydraulic conditions greatly influences its functionality and suitability for various geotechnical applications. The potential uses of PLDCC, such as drainage, water storage, filtration, and load reduction, can be further explored by thoroughly examining these hydraulic properties. Additionally, assessing the compatibility between PLDCC and geotextiles offers opportunities to develop integrated systems that enhance filtration effectiveness and contamination sequestration. While many functions of PLDCC are still being developed and limited literature data currently exists, this study's findings will contribute to the database and provide valuable insights into future applications based on its favorable hydraulic properties.

CHAPTER 2

LITERATURE REVIEW

American Concrete Institute 523 Guide defined Cast-in Place Low-Density Cellular Concrete (LDCC) as "concrete made with hydraulic cement, water, and preformed foam to form a hardened material having an oven-dry density of 50 lb/ft^3 (800 kg/m^3) or less"[5, p.4]. Predetermined amounts of liquid foaming agent and water are mixed to make the foam used to mix LDCC. The ratio of the foaming agent to water is typically 1:50. A foam generator is used to process this liquid mixture to create the foam that is subsequently mixed with water and cement to produce LDCC.

Since it was first introduced as an alternative to conventional building materials in the 1940s, LDCC has gained popularity. The uses of LDCC include, but are not limited to, the replacement of existing soil, soil stabilization, formation of raft foundations, stabilization of surplus structures, geotechnical rehabilitation, soil settlement, as well as prefabrication and installation of load-bearing or non-load-bearing walls and floor screeds in place of old sewer pipes and wells [6]. Cellular concrete offers several distinct advantages over traditional Portland cement concrete. These include a significant reduction in weight, with the potential for up to an 80% decrease. Furthermore, it possesses outstanding acoustic and thermal insulation properties and exhibits a high level of resistance to fire. In addition to these benefits, cellular concrete presents cost savings

regarding raw materials and proves easier for pumping and application purposes. Notably, this material does not require compaction or vibration during installation, eliminating the need for leveling procedures [7].

PLDCC, Permeable Low-Density Cellular Concrete, emerged as a novel technology in the early 2000s, garnering considerable public attention. While sharing similar advantages with LDCC over conventional concrete, PLDCC distinguishes itself by exhibiting hydraulic conductivity. In contrast to its non-permeable predecessors, PLDCC stands out because the bubbles utilized to construct the lightweight structure are interconnected rather than isolated. This fabric enables it to link and permits water retention and transfer at or above that of the natural soil. In comparison, PLDCC's non-permeable competitors cannot achieve these benefits [6].

For optimal hydraulic conductivity and infiltration, the target density of PLDCC is typically between 25 PCF (400 kg/m^3) and 35 PCF (561 kg/m^3). Successfully constructed PLDCC in this density range usually has a void factor between 86% and 90% and typically exhibits infiltration rates that attain about 150 to 1700 cm/hr. Also, the hydraulic conductivity values of PLDCC can reach approximately 200 to 700 cm/hr. The hydraulic conductivity is generally inversely proportional to the density of PLDCC [6].

The lightweight and highly water-absorbent characteristics of PLDCC can be favorable for some geotechnical applications. For example, the Tulane Stormwater Detention System, located in New Orleans, was constructed as a replacement for the inadequate stormwater management system of the former Capri Motel. An underground reservoir has been designed beneath the primary foundation slab, utilizing PLDCC technology, for the containment and management of stormwater discharge to comply

with the developmental regulations in this city. The installation entailed four team members placing 420 cubic yards of 30 PCF PLDCC within one day, showcasing its straightforward deployment methodology. Due to its outstanding water filtration capabilities, high compressive strength, and lightweight properties, the PLDCC system has demonstrated exceptional long-term performance results [8].

PLDCC has also demonstrated high effectiveness in reinforcing soft soil, evidenced by the success of the soft soil settlement remediation project conducted on West Lake Eloise Dive in Florida using PLDCC as an effective solution. The site featured exceptionally soft soil and a high water table, resulting in seasonal flooding, road closures, and significant maintenance and building costs due to ongoing settlement issues. To address these challenges, engineers from Madrid Engineering proposed utilizing PLDCC, which possesses superior strength compared to conventional compacted backfill with a 28-day compressive strength of 180 psi and density of 30 PCF. The PLDCC employed had a hydraulic conductivity of approximately 9E-01 cm/s, comparable to pure gravel. Its interlinked bubble formation enables water to move beneath the roadway and maintain uniform water levels on both sides without necessitating cross-drains. Additionally, this material's high infiltration capacity diminishes hydrostatic pressure, thus averting ground uplifts common with impermeable substances like concrete [6].

Another case study also shows that PLDCC can effectively deal with soil settlement. The Mission Rock Project conducted by the Port and City of San Francisco faces challenges in mitigating settlement and protecting against Sea Level Rise (SLR) due to its location on 16 acres of fill material and San Francisco Bay mud. The proposed

solution is to raise the site by up to five and one-half feet using lightweight cellular concrete (LCC) and stone columns to improve soil stability. The Technical Advisory Panel (TAP) has reviewed and approved using LCC as a reasonable, equivalent, and safe alternative for use as engineered fill, backfill, and pavement subgrade for the Mission Rock Project. The project employed LCC as a low-density material to serve as an infill and prevent consolidation settlement of the underlying "Bay Mud" [9].

The pavement design included a PLCC subbase, topped with an LCC base, PCCP, and asphalt-wearing surface. By utilizing PLDCC, it was possible to elevate the site's grade while establishing a foundation for the subsurface flow of stormwater, tidewater, and groundwater throughout the project area [9]. Figure 1 summarizes the hydraulic conductivity, saturated unit weight, and water storage capacity derived from the PLDCC samples employed in this study. According to the findings, PLDCC exhibited advantageous hydraulic conductivity, similar to that of clean sand, and possessed a lightweight property. These qualities render it appropriate as both a subbase material and a drainage medium for fulfilling the requirements of this particular project. The lightweight and highly absorbent nature of PLDCC makes it suitable for various applications, including infill and soft soil remediation. However, there are still concerns about its potential buoyancy force during heavy rain events due to the inability of PLDCC when saturated under water [4].

This problem could be resolved using a more advanced foaming agent while manufacturing Lightweight Cellular Concrete. This upgraded foam technology can improve hydraulic conductivity and reduce buoyancy forces in PLDCC. However, due to

limited published data, additional research is necessary before determining whether this enhancement would effectively address this issue.

Moreover, concerns have been raised about the potential accumulation of sediment in PLDCC, which could result in clogging and negatively impact its hydraulic properties. While empirical evidence concerning PLDCC is scarce, much research has highlighted similar issues encountered by other permeable pavement materials [10]. Researchers have conducted extensive studies in response to concerns regarding the hydraulic characteristics and potential for clogging in permeable pavement systems. It is essential to recognize that neither LDCC nor PLDCC should be directly exposed to the environment as a wearing surface. These materials are typically designed for use as backfill or subbase material and will be overlaid by other pavement layers. This precaution helps prevent possible clogging of PLDCC caused by sediment or debris from the topsoil [4].

Another critical area of investigation is the effectiveness of geotextiles in mitigating sediment accumulation within different types of porous pavements. Studies indicate that integrating geotextiles with a permeable pavement system can yield significant benefits [11]. Geotextiles are crucial in preventing soil congestion and limiting sediment migration when positioned above the permeable pavement layer. Alternatively, they can reduce pollution levels by impeding the infiltration of fine particles and pollutants into underlying drainage layers if placed below the permeable pavement layer [12].

The integration of geotextile in conjunction with other porous pavement systems can also be incorporated into PLDCC to improve water quality and mitigate blockage-

related problems. Nonetheless, the application of PLDCC presents potential challenges due to its cement-based slurry composition during formation; thus, it necessitates additional inquiry regarding whether such a mixture would obstruct the underlying geotextile when utilized for top-down construction purposes.

The available literature on the hydraulic behavior of PLDCC is limited, resulting in significant gaps in our knowledge. Recent advancements in foaming agent formulations for PLDCC production have not been thoroughly investigated. There is a lack of studies examining the use of these updated foaming agents with PLDCC. Furthermore, there needs to be more exploration into integrating PLDCC with other filtering materials like geotextiles. Despite the potential benefits of such combinations, research on hydraulic interactions between PLDCC and geotextiles remains scarce. Conducting further studies on this topic could provide valuable insights into how combined filtration systems using PLDCC and geotextiles perform hydraulically. Thus, given the knowledge mentioned above, gaps in research, and uncertainties surrounding PLDCC, it is imperative to conduct further studies that delve into its hydraulic properties and how it interacts with other materials.

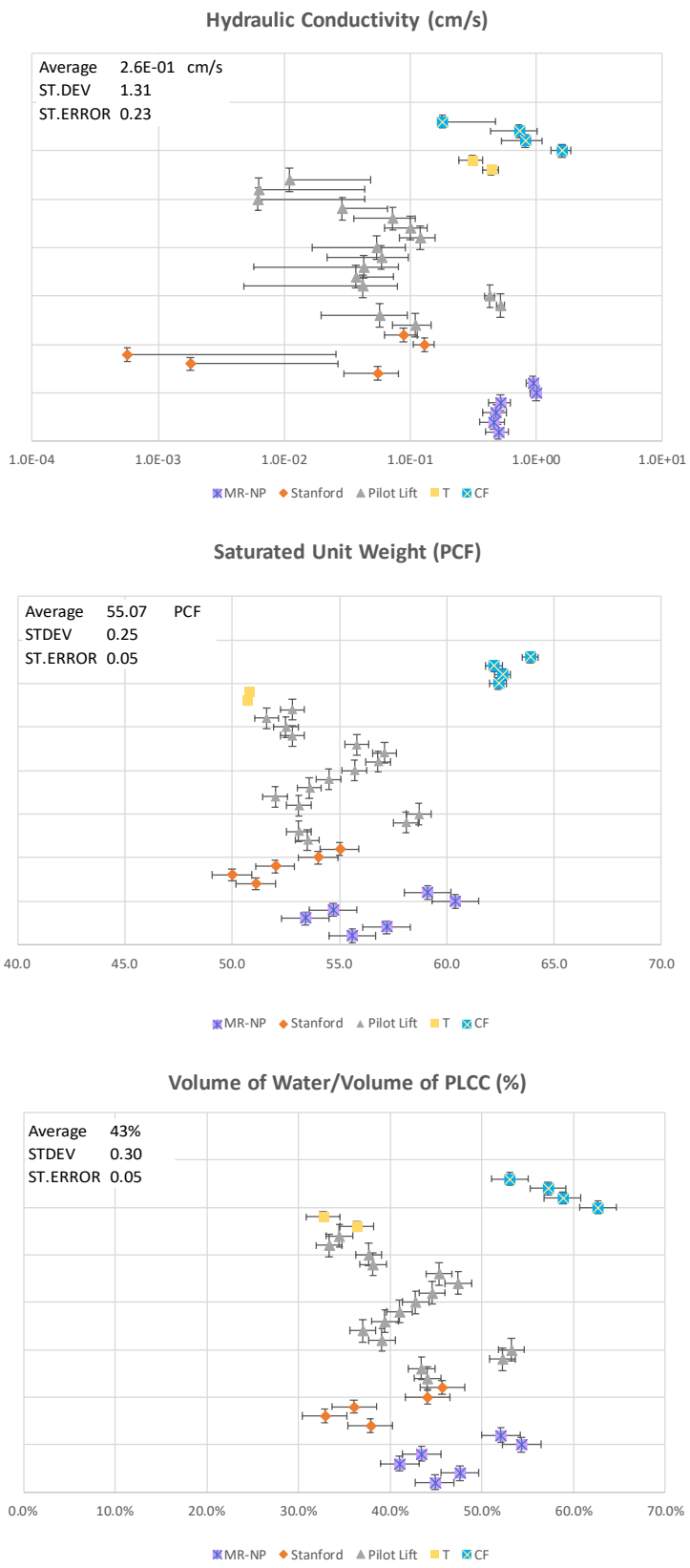

Figure 1. Hydraulic Properties of PLDCC Samples from the Mission Rock Project.

CHAPTER 3

METHODS

The study's objectives were accomplished through the implementation of a three-stage procedure. Firstly, the creation of PLDCC samples with densities varying from 25 to 32.6 PCF was done. Subsequently, laboratory tests were conducted to measure the hydraulic properties (e.g., hydraulic conductivity, saturated unit weight, water storage capacity, and buoyant unit weight) of the PLDCC specimens to compare them with existing data from the published literature. Lastly, the hydraulic performance of combining PLDCC with filtering material (i.e., nonwoven geotextile) was evaluated.

Samples Production

As mentioned, PLDCC is a composite material of Portland cement, water, and pre-foamed foaming agent. A total of six batches of PLDCC specimens were created for this research project. Table 1 shows the samples' batch numbers, IDs, and corresponding wet-cast densities. Batches 1 to 3 were produced using AERIX INDUSTRIES' foaming agents, namely AQUAERIX™ and AQUAERIX-LB™. The remaining three batches were cast at the soil laboratory of the University of Utah utilizing AQUAERIX-LB™ foam chemical provided by AERIX INDUSTRIES.

The foaming chemical used in producing the PLDCC sample was first diluted with water at a ratio of 1:50, then combined with a slurry consisting of Portland Cement Type I/II and water. The water-to-cement ratio was set at 0.55 while maintaining a foam density of 2.5 PCF according to the mix design recommended by AERIX INDUSTRIES. Figure 2 illustrates an overview of the production process for creating PLDCC specimens; Appendix B provides further details on the sample production procedure.

Constant Head Permeability Test of PLDCC

The hydraulic conductivity testing of PLDCC in this study followed the modified version of ASTM D2434-68, Standard Test Method for Permeability of Granular Soils. This modified procedure is consistent with the one used for the laboratory testing of PLDCC in the Mission Rock Project. Castle Rock Consulting, LLC, Castle Rock, Colorado, describes the modified testing procedure [9, p.17–24].

A Mariotte bottle with a height of 4 ft was constructed to maintain a consistent head for the permeability test of PLDCC. The construction process followed the guidelines by Bashyal, Mulvaney et al. [13]. Using the Mariotte bottle, water is discharged at a steady pressure level, allowing for more accurate and reliable maintenance of a constant head compared to manual methods [14]. Refer to Figure 3 for an illustration of the completed Mariotte bottle and setup used in conducting the constant head permeability test of PLDCC.

Naturally Saturated Unit Weight of PLDCC

The approach for determining the natural saturated unit weight of PLDCC also follows a modified procedure developed by Castle Rock Consulting, LLC [9, p.25–30]. A visual representation of the saturation process can be seen in Figure 4, depicting a PLDCC sample undergoing saturation. Once saturation is achieved, measurement parameters such as partially saturated unit weight, water storage capacity, and buoyancy unit weight can be determined.

Evaluation of Infiltration Rate and Clogging Impact of Combining PLDCC with Filtering Material

Geotextiles have numerous benefits across various applications. Nonwoven geotextiles demonstrate excellent filtration and separation properties for the applications we envision, making them ideal for applications that rely on water flow, filtration, and separation, such as permeable paving [11]. Therefore, this part of the study, which focuses on investigating the hydraulic behavior of PLDCC combined with a filtering material, used nonwoven geotextile as the target of interest. Figure 5 shows the nonwoven geotextile used in this study.

Four samples of PLDCC were produced in 6-inch diameter by 12-inch-tall cylinder concrete molds to be evaluated the joint behavior of PLDCC acting in concert with a geotextile. For these specimens, a geotextile of exact dimensions was deliberately placed at the bottom of the mold, serving as a foundation for the wet cast placement of PLDCC.

Before casting the sample, the plastic concrete molds were cut open on both ends, and their interior walls were roughened with sandpaper to ensure that the PLDCC would remain securely in place post-curing. A hole was drilled on each mold's side and fitted with a threaded ½ inch ID hose barb, and a cap with 6 inches of diameter was placed at the base of the concrete mold to maintain the slurry mixture within the mold during pouring. The cap may be detached for subsequent testing purposes.

A 5-gallon bucket was used for the testing. A hole of equal size and dimensions was drilled on one side, with a hose barb measuring ½ inch in inner diameter attached. After curing the PLDCC sample, remove the bottom cap and place the plastic mold inside a 5-gallon bucket. Fill the bucket with water to the level of a pre-drilled hole on its side before conducting any tests. Water was continuously supplied to the plastic mold throughout the test, maintaining a constant level at the same height as the hole drilled in the concrete mold. The experiment commenced as soon as the water began to flow from the side of a 5-gallon bucket. The rate of flow was measured at 1-minute intervals for one hour. The scheme of the setup constant head test device, as shown in Figure 6, is a modification of Sobolewski's [15] testing approach.

Each PLDCC sample underwent three separate tests. The first test assessed the infiltration rate (unsaturated behavior before steady state) with a geotextile attached to the cured sample. Following this initial test, the sample was allowed to air dry for approximately two weeks and then outfitted with a new piece of geotextile secured at its base in preparation for another round of testing. After this second evaluation, the sample was again dried through air exposure and subjected to a third round of testing without any accompanying geotextile layer. Figure 7 displays a schematic representation of the three

testing conditions for these samples. Ultimately, we compared the infiltration rate obtained from all three tests to determine whether changes had occurred in the PLDCC specimens with time.

Table 1. PLDCC Batch Information.

Batch #	Sample ID	Wet Cast PLDCC Density (PCF)		Foam Chemical	Cement	W/C Ratio	Produced By
		Target	Actual				
1	TY-5 to TY-14, TY-16 to TY-19	26	25.1	Aquaerix @ 1:50 Dilution	Quikrete Type I/II	0.55	Aerix Industries
2	TY-20 to TY-38	32.5	32.6	Aquaerix @ 1:50 Dilution	Quikrete Type I/II	0.55	Aerix Industries
3	A1 to A8	28	27.6	Aquaerix-LB @ 1:50 Dilution	Quikrete Type I/II	0.55	Aerix Industries
4	Y5, Y7,Y8, and Y10	25	25	Aquaerix-LB @ 1:50 Dilution	Quikrete Type I/II	0.55	Univeristy of Utah
5	Y14, Y16, Y17, and Y18	30	30	Aquaerix-LB @ 1:50 Dilution	Quikrete Type I/II	0.55	Univeristy of Utah
6	B1 to B4	25	25	Aquaerix-LB @ 1:50 Dilution	Quikrete Type I/II	0.55	Univeristy of Utah

Figure 2. Sample Production of PLDCC.

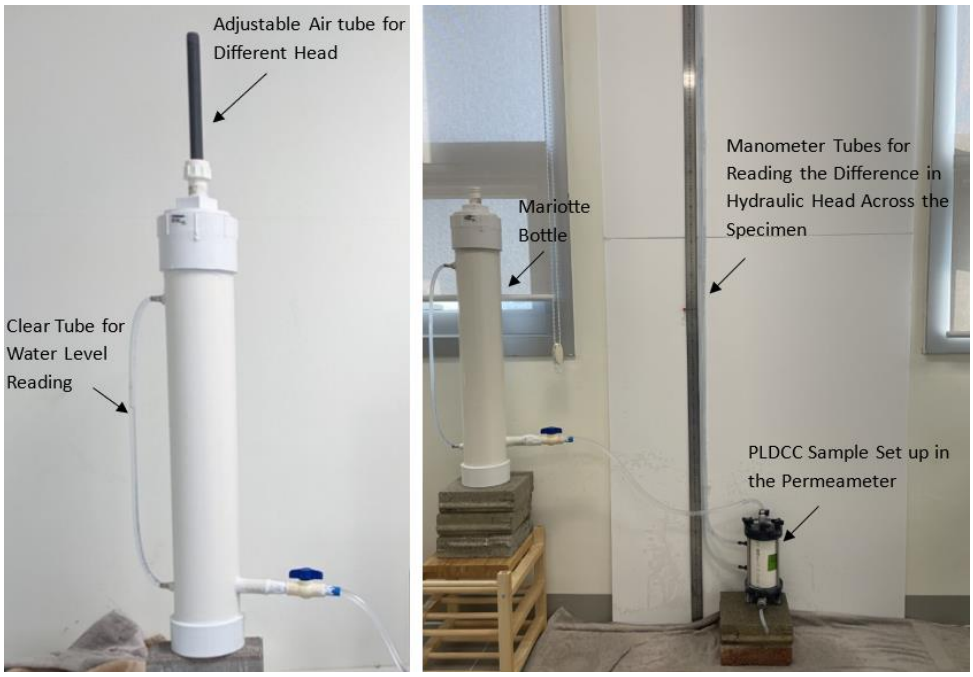

Figure 3. Constant Head Permeability Testing Device.

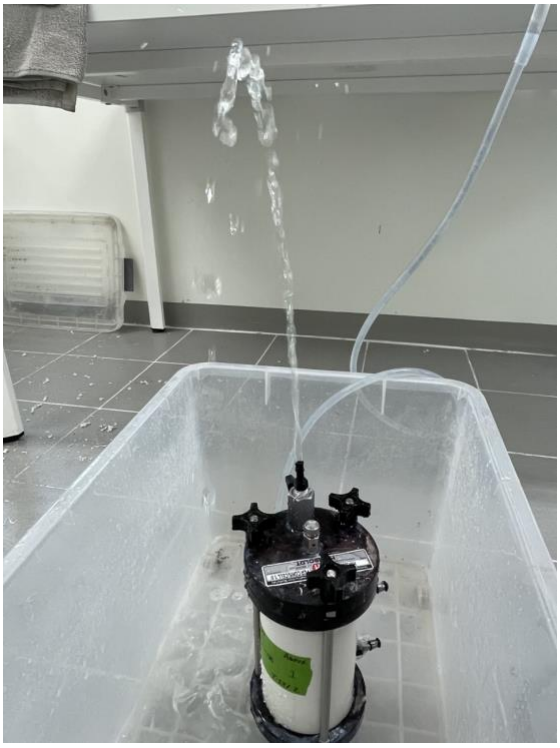

Figure 4. PLDCC Sample During Saturation.

Figure 5. Highly Permeable Nonwoven Geotextile.

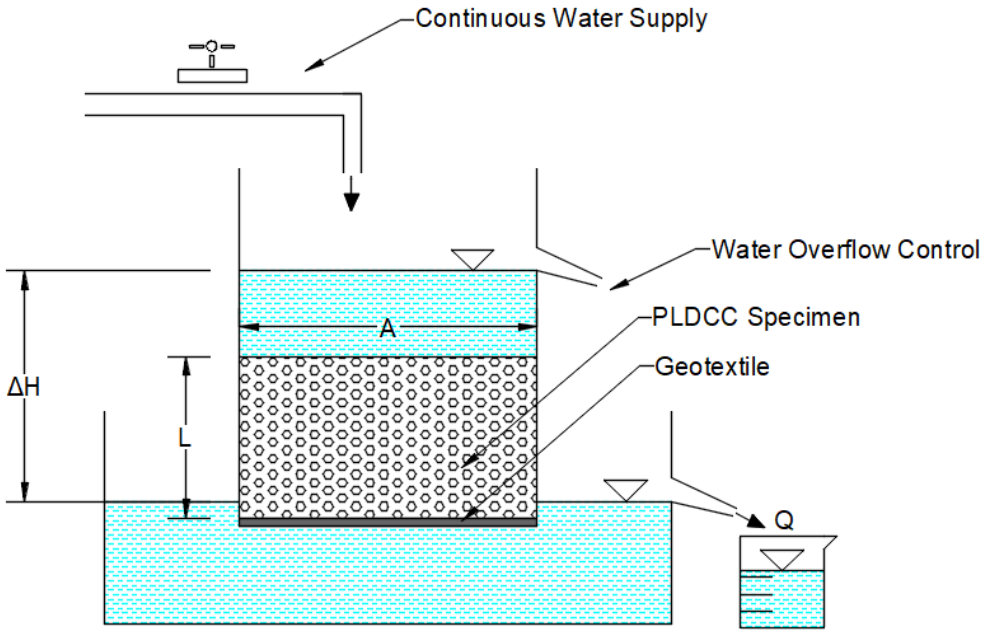

Figure 6. Constant Head Test Device.

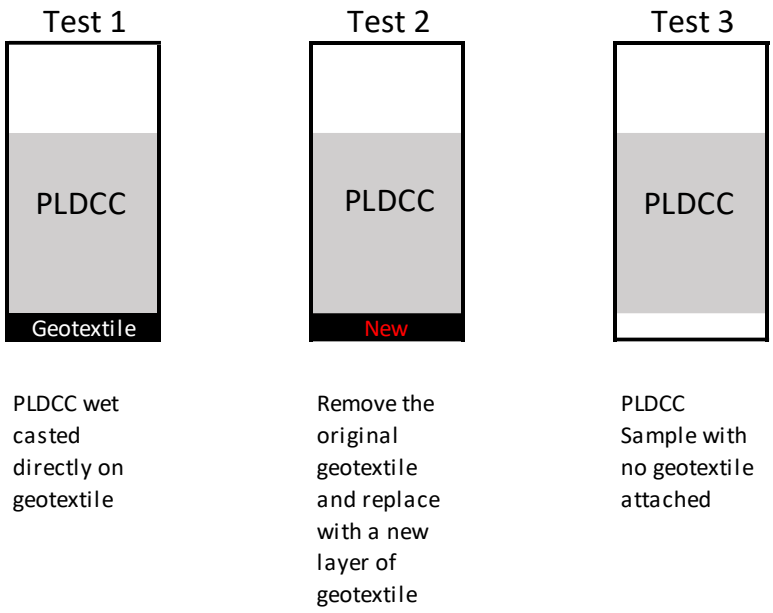

Figure 7. Sample Conditions for PLDCC and Nonwoven Geotextile Evaluations.

CHAPTER 4

RESULTS

A total of 6 batches of samples were produced for this study. Batches 1 through 5 were used to evaluate the hydraulic properties of PLDCC, including dry unit weight, hydraulic conductivity, saturated unit weight, water storage capacity, and buoyant unit weight. The specimens from batch 6 were utilized to assess the hydraulic behavior when the PLDCC was combined with a nonwoven geotextile.

Hydraulic Properties of PLDCC

AERIX INDUSTRY produced the first two batches of PLDCC specimens in their laboratory and later tested by us at the University of Utah. The initial batch consisted of 14 samples with a wet cast density measuring 25.1 PCF, while the second batch had a wet cast density of 32.6 PCF; both sets were manufactured using AQUAERIX™ foaming agent. Table 2 and Table 3 summarize batch 1 and 2 results.

The second batch of PLDCC samples demonstrates a decreased hydraulic conductivity range compared to the first, with a lower density. Upon comparing these results with those obtained from the Mission Rock Project (Figure 8), it becomes clear that neither batch met the expected range of hydraulic conductivity. These results

suggested less-than-desired properties when AQUAERIX™ is used in drainage and water storage applications.

After consulting with AERIX INDUSTRY, it was decided that a new batch would be manufactured using their still-in-development foaming chemical known as AQUAERIX-LB™. The abbreviation "LB" denotes "low buoyancy," indicating the updated aim to produce PLDCC with reduced buoyancy force while maintaining its high hydraulic conductivity. The third batch, featuring eight specimens produced utilizing AQUAERIX-LB™, exhibited a wet cast density of 27.6 PCF. Table 4 summarizes the tested hydraulic properties' results in this sample batch. Additionally, Figure 9 illustrates a comparison in hydraulic conductivity between the first and third batches.

After the evaluation of batch 3 samples, two more batches of samples were produced to conduct a more comprehensive analysis of the PLDCC manufactured with AQUAERIX-LB™ foaming agent. Both batches 4 and 5 consisted of four specimens. Batch 4 aimed for a lower density (25 PCF) than Batch 3, while Batch 5 was to reach around 30 PCF. The production process for both batches took place at the University of Utah's soil lab, utilizing AQUAERIX-LB™ foaming agent provided by AERIX INDUSTRY™. The results of the tested hydraulic properties in the samples from batches 4 and 5 are summarized in Table 5.

Investigation of the Infiltration Rate of PLDCC When Intergraded with a Nonwoven Geotextile

Four samples were evaluated in this part of the study. Figures 10-13 depict test results for each sample. Each plot represents three tests conducted on the sample: a wet

cast directly onto geotextile and tested for infiltration rate after curing; a second test with replacement of the original geotextile layer; and ultimately, a third test without any geotextile layer present.

Table 2. Hydraulic Properties on PLDCC Samples - Batch 1.

Batch 1 - Wet Cast Density: 25.1 PCF					
Sample ID	Dry UW (PCF)	Hydraulic Conductivity (cm/s)	Saturated UW (PCF)	Vol.water/ Vol.PLDCC	Buoyant UW (PCF)
TY-5	22.4	3.0E-03	51.0	46%	-11.4
TY-6	22.8	8.6E-03	51.2	46%	-11.2
TY-7	22.9	7.5E-03	49.3	42%	-13.1
TY-8	21.0	4.1E-03	50.1	47%	-12.3
TY-9	22.3	3.6E-02	50.2	45%	-12.2
TY-10	22.7	1.7E-02	45.8	37%	-16.6
TY-11	22.6	1.4E-02	47.5	40%	-14.9
TY-12	21.0	1.3E-02	51.5	49%	-10.9
TY-13	22.1	1.3E-02	49.7	44%	-12.7
TY-14	22.1	1.9E-02	48.4	42%	-14.0
TY-16	20.7	7.9E-03	50.3	47%	-12.1
TY-17	20.6	7.6E-03	50.3	48%	-12.1
TY-18	22.2	2.9E-02	49.0	43%	-13.4
TY-19	22.6	1.1E-02	49.6	43%	-12.8
Average	22.0	1.4E-02	49.6	44%	-12.8
ST.DEV	0.03	0.66	0.03	0.07	0.12

Table 3. Hydraulic Properties on PLDCC Samples - Batch 2.

Batch 2 - Wet Cast Density: 32.6 PCF					
Sample ID	Dry UW (PCF)	Hydraulic Conductivity (cm/s)	Saturated UW (PCF)	Vol.water/ Vol.PLDCC	Buoyant UW (PCF)
TY-20	29.0	1.4E-03	50.5	34%	-11.9
TY-21	28.4	8.3E-04	50.7	36%	-11.7
TY-22	28.8	1.7E-03	50.0	34%	-12.4
TY-23	28.5	1.6E-03	50.8	36%	-11.6
TY-24	28.4	1.3E-03	51.0	36%	-11.4
TY-25	28.0	2.1E-03	50.7	36%	-11.7
TY-26	28.5	1.5E-03	51.6	37%	-10.8
TY-27	28.7	2.6E-03	50.9	36%	-11.5
TY-28	29.1	2.1E-03	51.6	36%	-10.8
TY-29	28.3	1.6E-03	50.3	35%	-12.1
TY-30	27.7	9.1E-04	49.4	35%	-13.0
TY-31	29.2	1.3E-02	44.2	24%	-18.2
TY-32	28.0	2.1E-03	50.9	37%	-11.5
TY-33	28.8	1.4E-03	50.8	35%	-11.6
TY-34	28.9	2.0E-03	51.4	36%	-11.0
TY-35	28.1	1.2E-03	51.1	37%	-11.3
TY-36	28.2	2.1E-03	50.0	35%	-12.4
TY-37	27.7	1.0E-03	49.7	35%	-12.7
TY-38	29.6	1.1E-03	51.3	35%	-11.1
Average	28.5	2.2E-03	50.4	35%	-12.0
ST.DEV	0.02	1.15	0.03	0.08	0.13

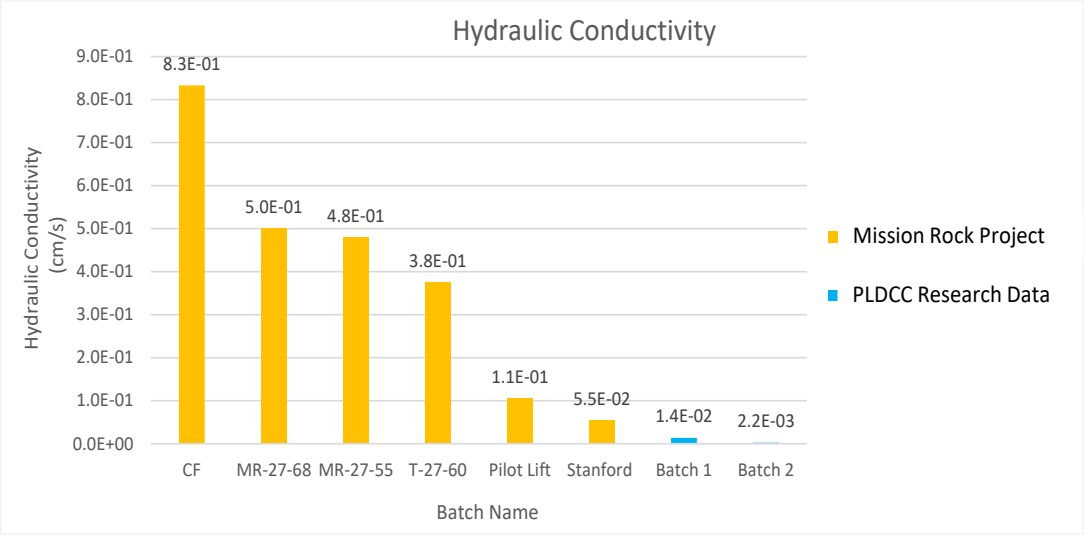

Figure 8. Hydraulic Conductivity of PLDCC Research Samples and Mission Rock Project Samples.

Table 4. Hydraulic Properties on PLDCC Samples - Batch 3.

Batch 3 - Wet Cast Density: 27.6 PCF					
Sample ID	**Dry UW (PCF)**	**Hydraulic Conductivity (cm/s)**	**Saturated UW (PCF)**	**Vol.water/ Vol.PLDCC**	**Buoyant UW (PCF)**
A1	26.2	2.3E-01	64.4	61%	2.0
A2	25.8	1.5E-01	63.6	61%	1.2
A3	25.5	3.6E-01	61.8	58%	-0.6
A4	26.1	2.9E-01	62.3	58%	-0.1
A5	26.8	3.5E-01	61.9	56%	-0.5
A6	25.7	3.1E-01	62.7	59%	0.3
A7	26.6	1.4E-01	61.7	56%	-0.7
A8	26.0	3.1E-01	61.3	57%	-1.1
Average	26.1	2.7E-01	62.5	58%	0.1
ST.DEV	0.02	0.32	0.02	0.03	16.21

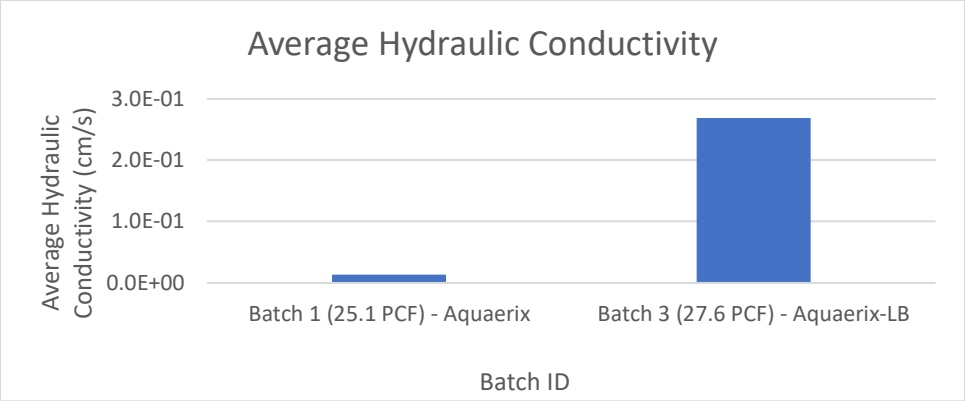

Figure 9. Hydraulic Conductivity of PLDCC Sample from Batch 1 and Batch 3.

Table 5. Hydraulic Properties on PLDCC Samples - Batch 4 and Batch 5.

Batch 4 - Wet Cast Density: 25 PCF					
Sample ID	**Dry UW (PCF)**	**Hydraulic Conductivity (cm/s)**	**Saturated UW (PCF)**	**Vol.water/ Vol.PLDCC**	**Buoyant UW (PCF)**
Y5	23.4	4.6E-02	51.9	46%	-10.5
Y7	23.8	4.1E-02	51.4	44%	-11.0
Y8	24.0	4.8E-02	51.8	45%	-10.6
Y10	23.7	4.1E-02	50.3	43%	-12.1
Average	23.7	4.4E-02	51.3	44%	-11.1
ST.DEV	0.01	0.08	0.01	0.03	0.07
Batch 5 - Wet Cast Density: 30 PCF					
Sample ID	**Dry UW (PCF)**	**Hydraulic Conductivity (cm/s)**	**Saturated UW (PCF)**	**Vol.water/ Vol.PLDCC**	**Buoyant UW (PCF)**
Y14	26.0	1.1E-02	54.1	45%	-8.3
Y16	26.1	8.8E-03	52.9	43%	-9.5
Y17	25.9	1.7E-02	54.2	45%	-8.2
Y18	26.0	1.2E-02	53.6	44%	-8.8
Average	26.0	1.2E-02	53.7	44%	-8.7
ST.DEV	0.00	0.27	0.01	0.02	0.07

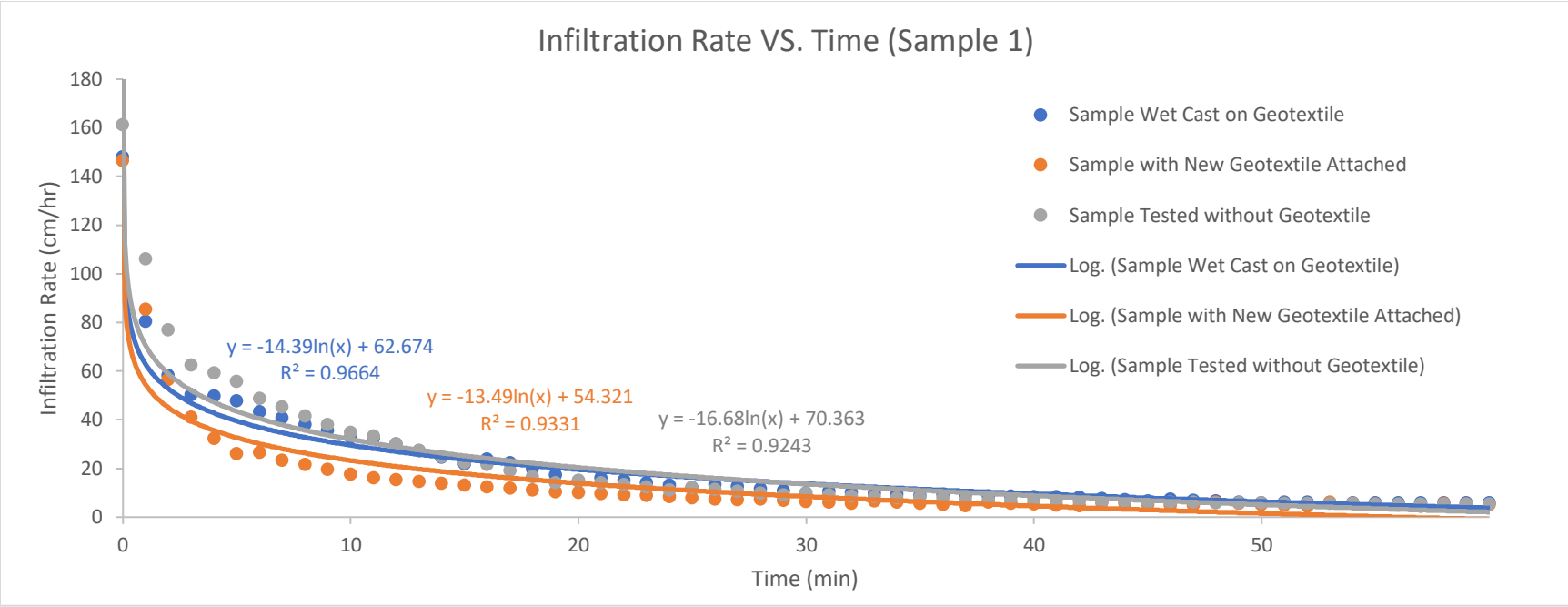

Figure 10. Infiltration Rates of PLDCC of Sample 1.

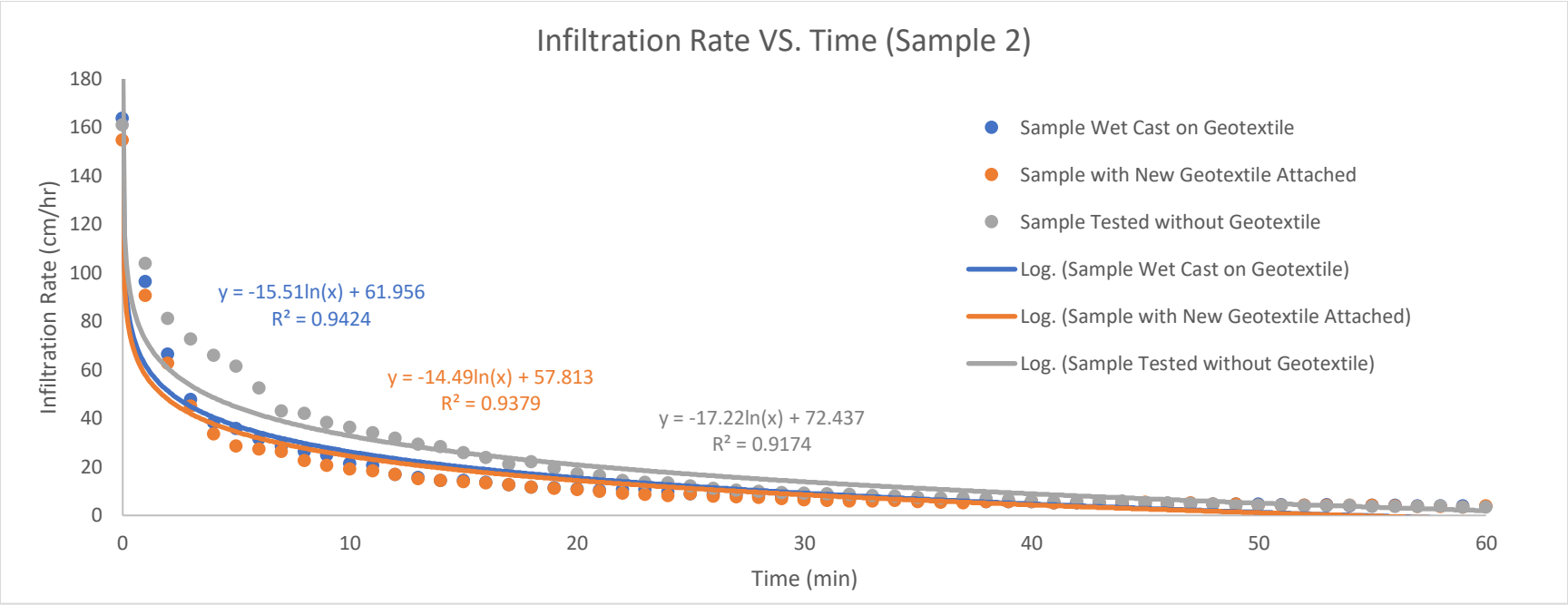

Figure 11. Infiltration Rates of PLDCC of Sample 2.

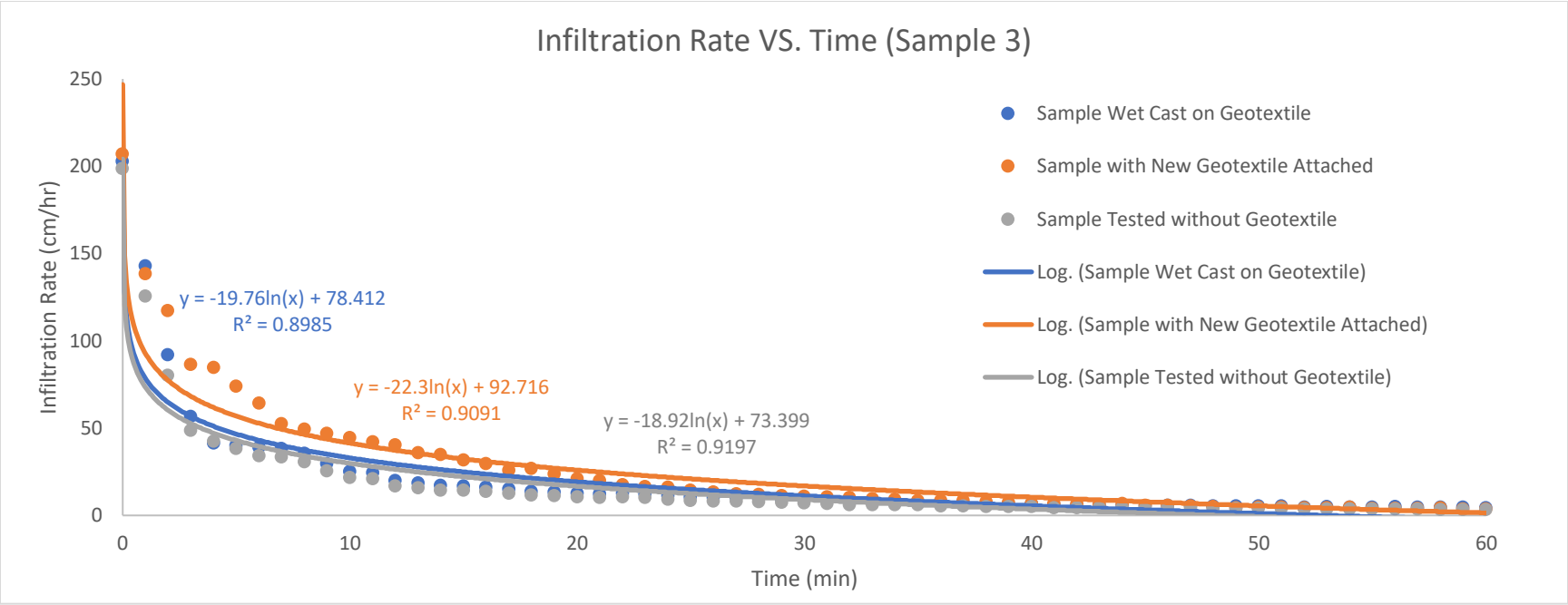

Figure 12. Infiltration Rates of PLDCC of Sample 3.

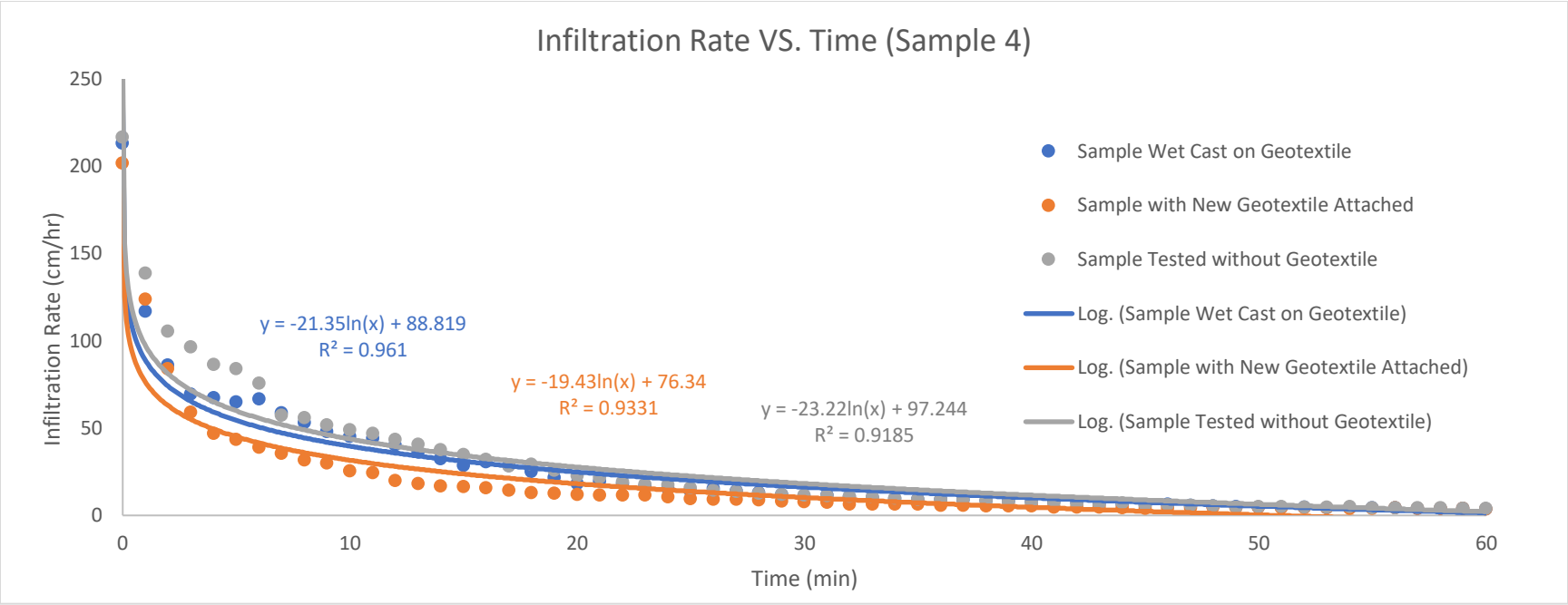

Figure 13. Infiltration Rates of PLDCC of Sample 4.

CHAPTER 5

DISCUSSION

Hydraulic Properties of PLDCC

Table 6 presents an overview of test results conducted on five batches of PLDCC samples, which include hydraulic conductivity, saturated unit weight, and water storage capacity. The first two batches were created using the AQUAERIX™ foaming agent. They yielded average hydraulic conductivity values around 1.4E-02 cm/s for samples with densities close to 25 PCF. In contrast, the average hydraulic conductivity value for samples with densities of about 32.6 PCF was measured at approximately 2.2E-03 cm/s. When comparing these results to typical backfill materials such as clean sand or combinations of clean sand and gravel, which generally exhibit permeabilities ranging between 1.0E-03 cm/s and 1.0E-00 cm/s [6], it is evident that the hydraulic conductivity of PLDCC specimens in batches 1 and 2 falls within this range, albeit towards the lower bound of the spectrum.

Batch 3, which incorporated the usage of AQUAERIX-LB™, a recently introduced foaming agent, demonstrated an average hydraulic conductivity rate of 2.7E-01 cm/s among samples with densities measuring 27.6 PCF. The observed hydraulic conductivity value was notably higher by a factor of twenty compared to that measured for batch one despite having lesser density, as shown in Figure 14. This batch of samples'

average saturated unit weight is approximately 62.5 PCF, which resembles the unit weight of water at 62.4 PCF, indicating that this material would exhibit small to negligible buoyancy when saturated under water and only a minimal amount of load is required to maintain its position under the pavement without any concerns regarding material upheaval or disruption from below. It is worth noting that due to its open-cell fabric that permits air pockets within the PLDCC, complete water saturation of the voids in in-situ conditions is not likely.

Compared to AQUAERIX™, the utilization of AQUAERIX-LB™ produced a more open and connected air bubble structure (Figure 15). As a result, the water storage capacity of the PLDCC sample taken from batch 3 attained an average value of 58%, demonstrated higher than that obtained from batches 1 (44%) and 2 (35%). This finding means that a 1 m^3 unit volume of placed PLDCC can accommodate nearly 0.6 m^3 of water. Additionally, the advantage of PLDCC's water storage capacity becomes apparent when comparing it to lightly compacted loam, clean sand, and aggregate/gravel, which have respective water storage capacities of 20%, 30%, and 40% [16].

As anticipated, there was an expectation that specimens with lower densities would exhibit higher hydraulic conductivity compared to those with higher densities [17]. However, the outcomes of batch 4 contradicted this assumption. Specifically, the specimen with a wet cast unit weight of 25 PCF displayed an average hydraulic conductivity rate of 4.4E-02 cm/s, six times lower than that observed in batch 3, containing specimens with a density value of 27.6 PCF, as shown in Figure 16. In addition to hydraulic conductivity, batch 3 demonstrates better values for saturated unit weight, water storage capacity, and buoyant unit weight compared to batches 4 and 5.

Considering that batch 4 was made in the soil laboratory of the University of Utah, as opposed to being manufactured by AERIX INDUSTRY, various batching and mixing factors may impact the cellular composition and consequently affect its hydraulic characteristics. The foam generator utilized in the manufacturing process of PLDCC has the potential to influence the foam quality. The foam generated by this machine, which resembles shaving cream with its dense consistency, should possess sufficient firmness and stability to withstand the pressure exerted by mortar until the cement sets, ultimately leading to forming of a robust concrete framework around air-filled voids, ensuring durability.

While it is worth noting that AERIX INDUSTRY provided the University of Utah with one of its laboratory-size foam generators, the equipment we used may differ from that employed in producing batch 3 samples by AERIX INDUSTRY. Consequently, disparities arising from variations in usage between different types or models of foam generators might give rise to differences in overall mixture properties.

Additionally, the structure of PLDCC can be influenced by the mixing method or apparatus employed during its production. While foam concrete may be compatible with commonly used mixers such as tilt drums or pan mixers utilized for concrete or mortar, improper blending techniques or excessive agitation could reduce foam content throughout the process [18].

Furthermore, the curing condition influences the hydraulic conductivity of PLDCC. While preliminary investigation indicated a 7-10 day cure duration for optimal readiness in conducting the permeability test, further exploration is essential to ascertain

whether an extended cure period would be necessary for achieving ideal hydraulic features in AQUAERIX-LB™ created samples of PLDCC.

Although the U of Utah produced samples with lower density did not achieve higher hydraulic conductivity when compared to those made by AERIX INDUSTRY, all AQUAERIX-LB™ results were still superior to those of batches 1 and 2, which utilized an AQUAERIX™ foaming agent. Furthermore, batch 4 (with an average hydraulic conductivity of 4.4E-02 cm/s) and 5 (with an average hydraulic conductivity of 1.2E-02 cm/s) demonstrated a level of hydraulic conductivity that falls within the median range for sand. These findings provide evidence for the beneficial hydraulic characteristics of PLDCC. However, it is suggested that further exploration and improvements in handling and equipment during production could lead to even higher conductivity values.

Additionally, it is noteworthy that there was a considerable range of variability in the hydraulic conductivity of the PLDCC sample within the same batch, which has almost identical wet-cast density. On the other hand, the saturated unit weight and water storage capacity of PLDCC do not have as much variability within the same batch of samples. This behavior can also be observed in the data collected from the Mission Rock project. The variability in different hydraulic properties can be visualized in Figure 17 to Figure 19. Furthermore, Table 7 presents the mean hydraulic conductivity values for each batch of PLDCC samples, along with the standard deviation and standard error.

The findings from the study conducted by Castle Rock Consulting on PLDCC hydraulic conductivity carry considerable credibility, considering their expertise and laboratory facilities. Their study also observed significant variability in the hydraulic conductivity of PLDCC specimens from the same batch, with differences up to one-half

order of magnitude, which implies that PLDCC samples with the same density can exhibit different levels of hydraulic conductivity. While density measures the mass per unit volume, the hydraulic conductivity of PLDCC depends on factors such as pore structure, void size distribution, and connectivity. Even if two PLDCC specimens have similar unit weights, their internal pore structures can differ significantly and result in varying levels of hydraulic conductivity. This same variation in hydraulic conductivity values is also seen when testing laboratory sands, such as Ottwa Sand.

Evaluation of the Infiltration Behavior PLDCC with Nonwoven Geotextile

When a cement-based PLDCC mixture is applied to a highly permeable geotextile fabric in its wet state, it may slightly obstruct the material's pores and impede the system's infiltration ability. To assess the effect of geotextiles placed in contact with PLDCC, we evaluated the infiltration rate following the procedure outlined in the methodology section, and the results were compared to determine if such obstruction could occur.

The experimentation commenced upon the complete desiccation of the sample, at which point it exhibited a high absorbency acting like a sponge. The water infiltration rate was rapid initially; however, within 10 minutes of commencement, there was a notable decrease in its flow rate. As the water began accumulating within the voids in the material, the overall flow gradually diminished until reaching a steady state. Following the initial half-hour of testing, a consistent flow rate was maintained for the duration of the experiment.

Upon wet casting the PLDCC directly onto geotextile, there was a strong adhesion between the two materials once fully cured. A certain degree of force was necessary for peeling off to remove the geotextile from this composite structure. Figure 20 provides a visual comparison depicting an undamaged piece of geotextile fabric and one separated from the PLDCC material. The cement compound of PLDCC has established itself within the geotextile following its maturation. Upon inspection, it was noted that water movement through the geotextile fabric was significantly disrupted due to portions of the fabric becoming obstructed by solidified cement.

Although it may appear that the presence of PLDCC can obstruct the geotextile during top casting, infiltration tests indicate otherwise. The test was conducted three times - first with a bonded preparation of geotextile and PLDCC, second with an undamaged highly permeable geotextile, and third without any geotextile. The findings indicated no significant change in infiltration rate among the three scenarios assessed during the experiment, and this applies for both initial and steady states of infiltration, suggesting that when PLDCC and geotextile are bonded together, they operate as an integrated entity, with negligible clogging impact on the latter.

While the PLDCC appears to have a minimal obstructive effect on the geotextile, it must be acknowledged that the trial was conducted in controlled laboratory settings. Further examination may be warranted, including assessing whether these findings remain valid when utilizing geotextiles with differing permeabilities and over longer durations. Additionally, there should be an investigation into whether large amounts of PLDCC used during field applications would reduce infiltration rates. Additionally, it is possible that the geotextile and PLDCC components of the filtration system may

experience blockages caused by fine-grained soil particles or other pollutants from higher layers. Additional system countermeasures may be required in some cases.

Table 6. Summary of Test Results.

Batch #	Wet Cast Density (PCF)	Average Permeability (cm/s)	Sat - UW (PCF)	Vol. Water/Vol. PLDCC (%)	Foam Chemical	Produced By
1	25.1	1.4E-02	49.6	44%	Aquaerix	Aerix Industries
2	32.6	2.2E-03	50.4	35%	Aquaerix	Aerix Industries
3	27.6	2.7E-01	62.5	58%	Aquaerix-LB	Aerix Industries
4	25	4.4E-02	51.3	44%	Aquaerix-LB	Univeristy of Utah
5	30	1.2E-02	53.7	44%	Aquaerix-LB	Univeristy of Utah

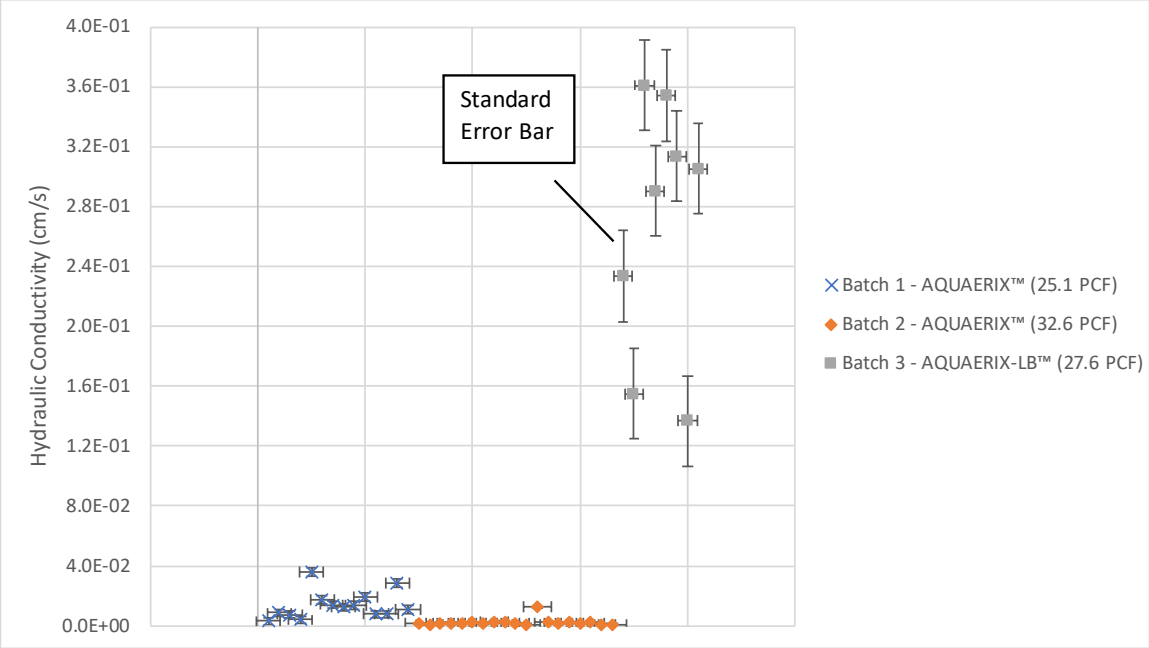

Figure 14. Hydraulic Conductivity of PLDCC with Different Foaming Agents.

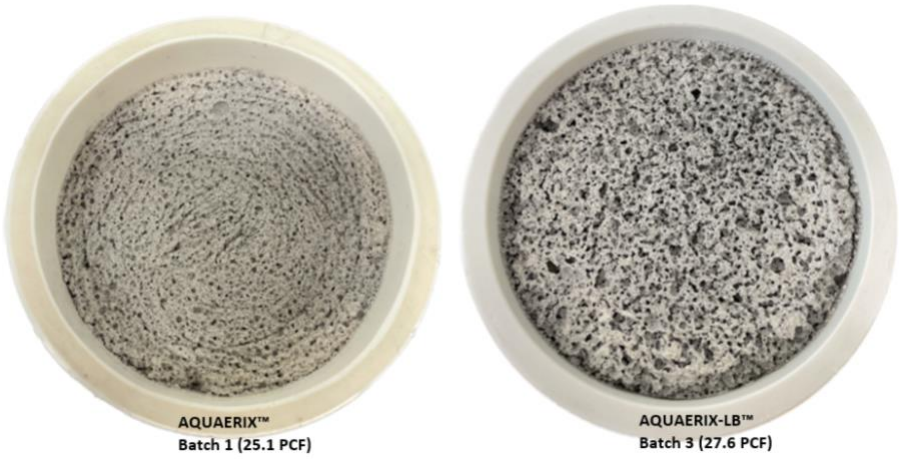

Figure 15. Comparison of Samples Produced by AQUAERIX and by AQUAERIX-LB.

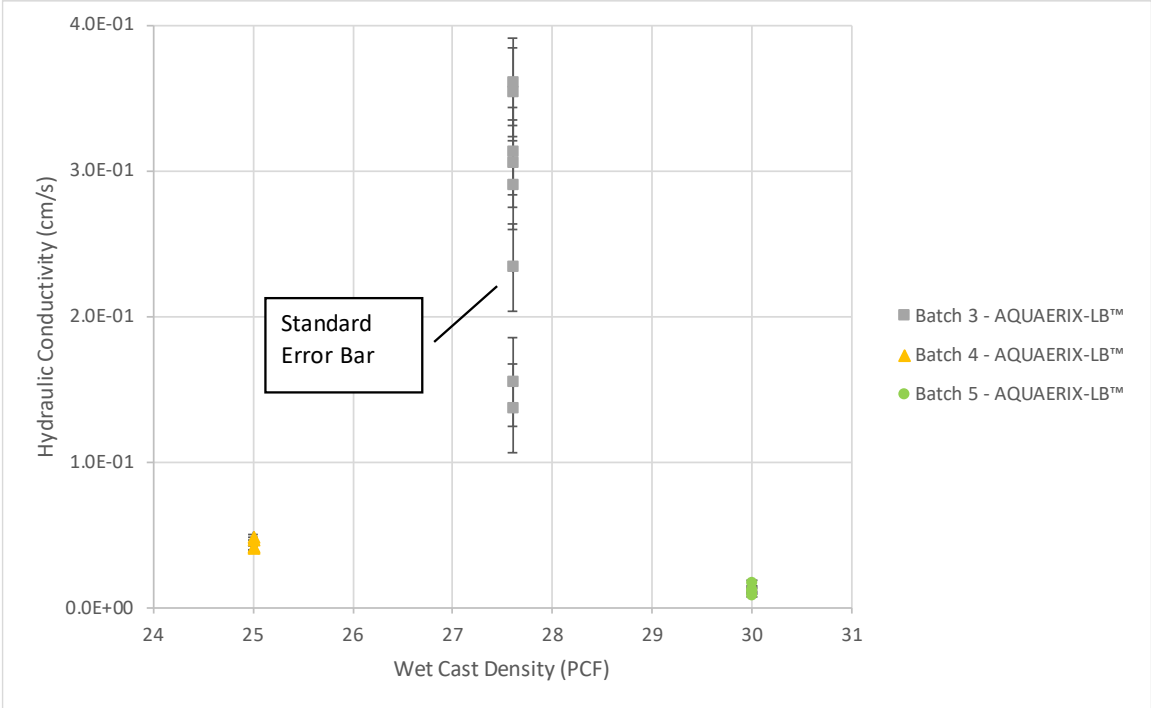

Figure 16. Hydraulic Conductivity of PLDCC with Different Foaming Agents.

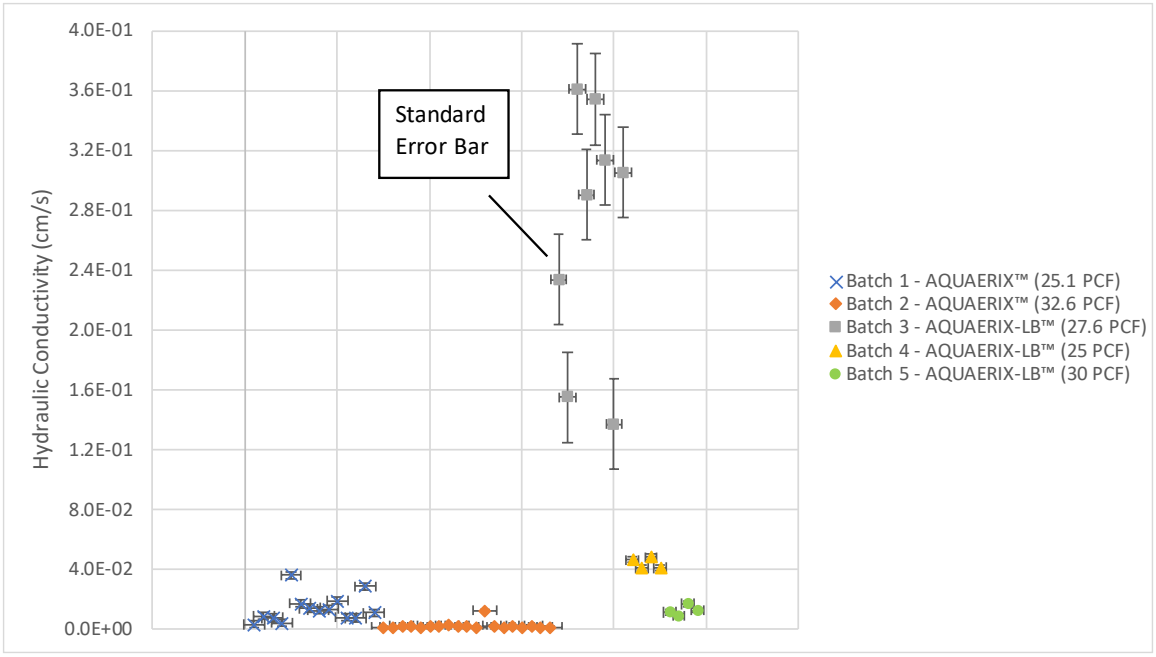

Figure 17. Within-Batch Sample Variability in Hydraulic Conductivity of PLDCC.

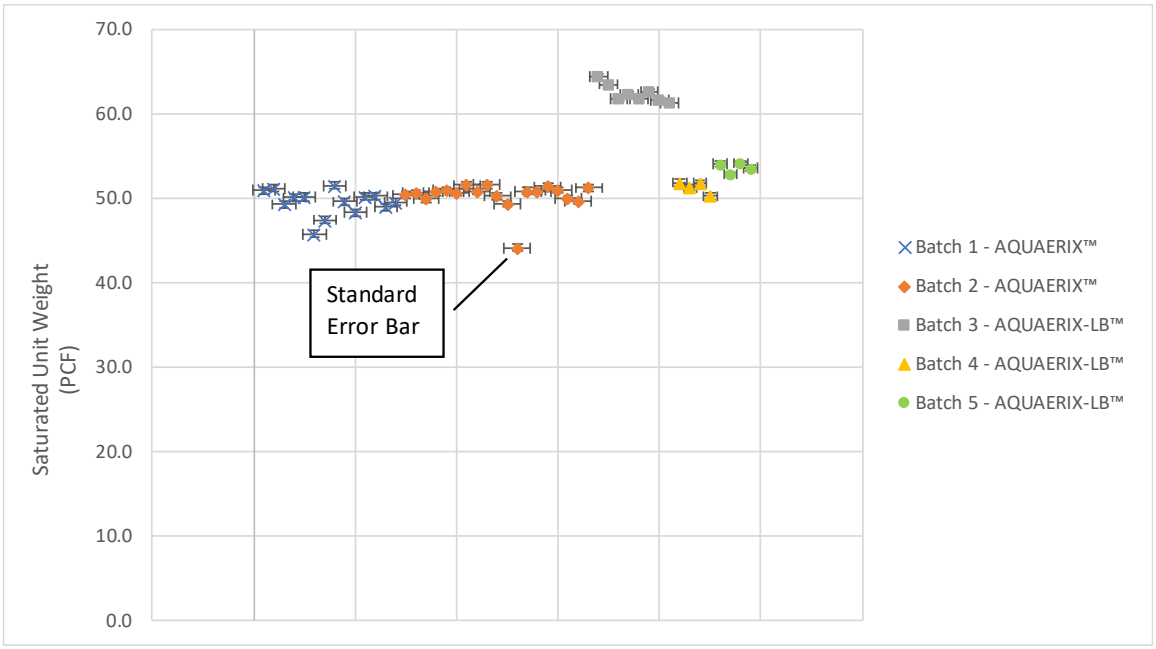

Figure 18. Within-Batch Sample Variability in The Saturated Unit Weight of PLDCC.

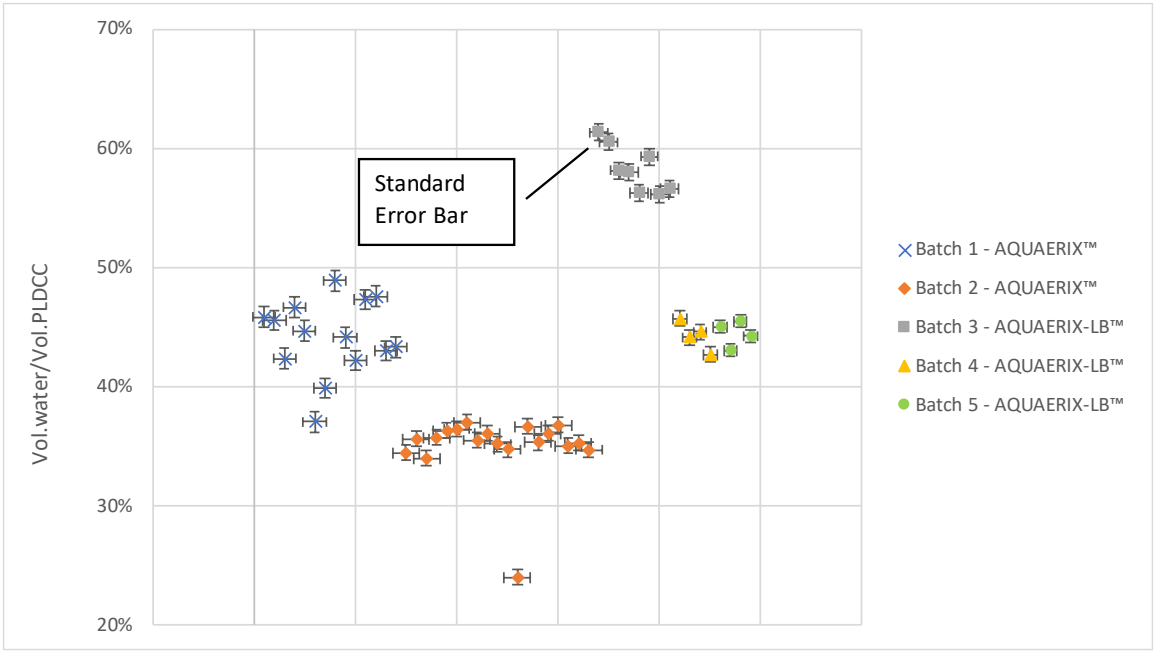

Figure 19. Within-Batch Sample Variability in The Water Storage Capacity of PLDCC.

Table 7. Summary of Mean, Standard Deviation, and Standard Error of Each Batch.

Hydraulic Conductivity (cm/s)					
Batch #	**1**	**2**	**3**	**4**	**5**
Average	1.4E-02	2.2E-03	2.7E-01	4.4E-02	1.2E-02
ST.DEV	0.66	1.15	0.32	0.08	0.27
ST.ERROR	0.18	0.26	0.11	0.04	0.14

Figure 20. Undamaged Geotextile and Geotextile Removed from PLDCC.

CHAPTER 6

CONCLUSIONS

This thesis has investigated the hydraulic characteristics of permeable low-density cellular concrete (PLDCC) and its potential role in sustainable infrastructure development. Valuable information has been obtained through laboratory experiments conducted on six batches of PLDCC samples, providing insights into the material's hydraulic conductivity, dry and saturated unit weight, water storage capacity, and buoyant unit weight. Furthermore, this research has also assessed the hydraulic performance of PLDCC when combined with geotextile by examining the infiltration rate of the combined system.

The relatively permeable, interconnected pores and open fabric of PLDCC lend to its use in surface and in-situ applications requiring transmission and storage of water. Findings from our laboratory-based hydraulic conductivity tests reveal that the hydraulic conductivity of PLDCC is comparable to clean sand or sand and gravel mixtures. This finding indicates the potential for PLDCC to serve as an efficient, lightweight drain in geosystems.

The open and connected fabric of PLDCC produces a lightweight material (weighing nearly four to five times less than conventional earthen materials) yet still achieves a partially saturated unit weight under laboratory conditions comparable to

water. This finding implies that PLDCC has a small to negligible buoyancy force for use below or within the water table. In addition, the water storage capacity of PLDCC significantly surpasses other types of compacted granular soil with a value of about 60% by volume. For example, compared to compacted loam or clear sand, it has three times more storage capacity and exceeds aggregate or gravel by approximately 1.5 to 2 times. This high storage capacity of PLDCC can potentially contribute to water storage for use in near-surface stormwater detention and retention facilities and cisterns.

Furthermore, laboratory experiments focused on utilizing PLDCC with a nonwoven geotextile beneath exhibited minimal to negligible influence on the system's infiltration ability. This observation suggests the practical feasibility of integrating PLDCC with geotextile, indicating system compatibility. By utilizing this combination, there is a possibility to enhance the overall filtration capacity and performance of the drainage-storage functions.

Despite the significant progress made in understanding the hydraulic characteristics of permeable low-density cellular concrete (PLDCC), it is vital to acknowledge the variability in hydraulic conductivity observed within the samples tested. This variation can be attributed to several factors, including disparities in foaming agent quality, mixture proportions, and mixing methods. All these variables can impact both size and distribution of the pores within PLDCC material. Therefore, upcoming research endeavors should focus on identifying and optimizing key factors that influence the hydraulic conductivity of PLDCC, such as foam generation techniques, foam stability, and foam distribution within the concrete matrix. Moreover, conducting comprehensive investigations into the repercussions of various curing conditions, mixing protocols, and

foam-to-cement ratios on the hydraulic characteristics of PLDCC would yield invaluable perspectives.

Moreover, it is crucial to investigate the long-term behavior and durability of PLDCC concerning its hydraulic performance, particularly in construction-scale settings, because discrepancies may arise between controlled laboratory conditions and actual field conditions due to variations in production techniques. Specifically, incorporating cement slurry with pre-foamed foam during field production can affect quality control measures and overall effectiveness. By conducting extensive studies on a field scale, valuable data can be gathered to refine design guidelines, optimize construction methodologies, and strengthen the dependability and efficiency of PLDCC as a solution for future infrastructure development.

Lastly, it is essential to recognize that although this investigation has primarily focused on the hydraulic properties of PLDCC, numerous other areas warranting future research exist. These include but are not limited to investigating the structural performance, environmental impact, thermal conductivity, air permeability, and fire resistance properties of PLDCC. Conducting extensive studies in these domains would uncover additional functionality and potential applications of PLDCC beyond its hydraulic characteristics.

APPENDIX A

LABORATORY HYDRAULIC CONDUCTIVITY TEST DATA

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

Y5

PVC Cell Height, h_m	154.94	mm	Height of PVC cell
PVC Cell Weight,w	235.61	g	Weight of PVC cell
PVC Internal Diameter, D	76.63	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	14.19	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	10.34	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1546.92	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2007.88	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2444.08	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	13.04	cm	
PLDCC Cross-sectional Area, A	46.12	cm^2	
Unsat. PLDCC Weight	225.25	g	
PLDCC Vol, V	601.45	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.37	g/cm^3	
	23.37	lb/ft^3	
Total Weight of Water, W_w	436.20	g	
Weight of Excess Cell Water, E_{wc}	113.12	g	
Weight of Saturated PLDCC, W_{sat}	500.19	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.83**	**g/cm^3**	
	51.89	**lb/ft^3**	
Vol. Water in PLDCC	274941.603	mm^3	
Vol. PLDCC	601448.6	mm^3	
Vol. Water/Vol. PLDCC	**45.71%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	213.31	g
Tare Weight, W_B	213.14	g
Tare Weight, W_C	211.98	g
Manometer H1	254.00	mm
Manometer H2	717.55	mm
Δh	46.36	cm
Vol. of Water + Tare A	610.20	cm^3
Vol. of Water + Tare B	600.78	cm^3
Vol. of Water + Tare C	592.96	cm^3
Average Flow, Q	388.50	cm^3
Length of Specimen Along Path of Flow	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**4.62E-02**	**cm/sec**

Figure 21. Permeability Test Report of Specimen Y5.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

Y7

PVC Cell Height, h_m	152.19	mm	Height of PVC cell
PVC Cell Weight,w	231.15	g	Weight of PVC cell
PVC Internal Diameter, D	76.70	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	14.89	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	11.48	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.20	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2000.15	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2426.79	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.58	cm	
PLDCC Cross-sectional Area, A	46.21	cm^2	
Unsat. PLDCC Weight	221.83	g	
PLDCC Vol, V	581.39	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.38	g/cm^3	
	23.81	lb/ft^3	
Total Weight of Water, W_w	426.64	g	
Weight of Excess Cell Water, E_{wc}	121.88	g	
Weight of Saturated PLDCC, W_{sat}	478.45	g	
Saturated PLDCC Unit Weight, Uw_s	**0.82**	**g/cm^3**	
	51.35	**lb/ft^3**	
Vol. Water in PLDCC	256624.9503	mm^3	
Vol. PLDCC	581393.5	mm^3	
Vol. Water/Vol. PLDCC	**44.14%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	213.31	g
Tare Weight, W_B	213.14	g
Tare Weight, W_C	211.98	g
Manometer H1	292.10	mm
Manometer H2	762.00	mm
Δh	46.99	cm
Vol. of Water + Tare A	573.02	cm^3
Vol. of Water + Tare B	564.27	cm^3
Vol. of Water + Tare C	555.53	cm^3
Average Flow, Q	351.46	cm^3
Length of Specimen Along Path of Flow	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**4.11E-02**	**cm/sec**

Figure 22. Permeability Test Report of Specimen Y7.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

Y8

PVC Cell Height, h_m	155.27	mm	Height of PVC cell
PVC Cell Weight,w	235.55	g	Weight of PVC cell
PVC Internal Diameter, D	76.30	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	16.79	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	10.44	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1548.17	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2008.50	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2442.21	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.80	cm	
PLDCC Cross-sectional Area, A	45.72	cm^2	
Unsat. PLDCC Weight	224.97	g	
PLDCC Vol, V	585.33	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.38	g/cm^3	
	23.98	lb/ft^3	
Total Weight of Water, W_w	433.71	g	
Weight of Excess Cell Water, E_{wc}	124.52	g	
Weight of Saturated PLDCC, W_{sat}	486.02	g	
Saturated PLDCC Unit Weight, Uw_{si}	**0.83**	**g/cm^3**	
	51.81	**lb/ft^3**	
Vol. Water in PLDCC	261052.1	mm^3	
Vol. PLDCC	585325.7	mm^3	
Vol. Water/Vol. PLDCC	**44.60%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	213.31	g
Tare Weight, W_B	213.14	g
Tare Weight, W_C	211.98	g
Manometer H1	273.05	mm
Manometer H2	666.75	mm
Δh	39.37	cm
Vol. of Water + Tare A	563.92	cm^3
Vol. of Water + Tare B	553.77	cm^3
Vol. of Water + Tare C	542.21	cm^3
Average Flow, Q	340.49	cm^3
Length of Specimen Along Path of Flow	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**4.80E-02**	**cm/sec**

Figure 23. Permeability Test Report of Specimen Y8.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

Y10

PVC Cell Height, h_m	153.94	mm	Height of PVC cell
PVC Cell Weight,w	234.09	g	Weight of PVC cell
PVC Internal Diameter, D	76.69	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	11.20	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	12.83	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1548.17	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2010.59	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2425.82	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.99	cm	
PLDCC Cross-sectional Area, A	46.19	cm^2	
Unsat. PLDCC Weight	227.74	g	
PLDCC Vol, V	600.11	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.38	g/cm^3	
	23.68	lb/ft^3	
Total Weight of Water, W_w	415.23	g	
Weight of Excess Cell Water, E_{wc}	110.97	g	
Weight of Saturated PLDCC, W_{sat}	483.87	g	
Saturated PLDCC Unit Weight, Uw_s	**0.81**	**g/cm^3**	
	50.31	**lb/ft^3**	
Vol. Water in PLDCC	256125.3	mm^3	
Vol. PLDCC	600108.1	mm^3	
Vol. Water/Vol. PLDCC	**42.68%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	213.31	g
Tare Weight, W_B	213.14	g
Tare Weight, W_C	211.98	g
Manometer H1	292.10	mm
Manometer H2	723.90	mm
Δh	43.18	cm
Vol. of Water + Tare A	540.26	cm^3
Vol. of Water + Tare B	532.18	cm^3
Vol. of Water + Tare C	530.46	cm^3
Average Flow, Q	321.49	cm^3
Length of Specimen Along Path of Flow	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**4.09E-02**	**cm/sec**

Figure 24. Permeability Test Report of Specimen Y10.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

Y14

PVC Cell Height, h_m	154.53	mm	Height of PVC cell
PVC Cell Weight,w	234.71	g	Weight of PVC cell
PVC Internal Diameter, D	76.55	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	18.39	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	16.05	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1548.17	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2003.52	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2458.92	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.01	cm	
PLDCC Cross-sectional Area, A	46.02	cm^2	
Unsat. PLDCC Weight	230.50	g	
PLDCC Vol, V	552.70	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.42	g/cm^3	
	26.02	lb/ft^3	
Total Weight of Water, W_w	455.40	g	
Weight of Excess Cell Water, E_{wc}	158.51	g	
Weight of Saturated PLDCC, W_{sat}	479.26	g	
Saturated PLDCC Unit Weight, Uw_{si}	**0.87**	**g/cm^3**	
	54.11	**lb/ft^3**	
Vol. Water in PLDCC	248756.6	mm^3	
Vol. PLDCC	552699.0	mm^3	
Vol. Water/Vol. PLDCC	**45.01%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	213.31	g
Tare Weight, W_B	213.14	g
Tare Weight, W_C	211.98	g
Manometer H1	254.00	mm
Manometer H2	781.05	mm
Δh	52.71	cm
Vol. of Water + Tare A	331.36	cm^3
Vol. of Water + Tare B	319.08	cm^3
Vol. of Water + Tare C	311.56	cm^3
Average Flow, Q	107.86	cm^3
Length of Specimen Along Path of Flow	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.13E-02**	**cm/sec**

Figure 25. Permeability Test Report of Specimen Y14.

LABORATORY CONSTANT HEAD PERMEABILITY TEST
Specimen ID:
Y16

PVC Cell Height, h_m	152.48	mm	Height of PVC cell
PVC Cell Weight,w	232.38	g	Weight of PVC cell
PVC Internal Diameter, D	76.58	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	20.29	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	14.79	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1548.17	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2006.85	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2449.32	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	11.74	cm	
PLDCC Cross-sectional Area, A	46.06	cm^2	
Unsat. PLDCC Weight	226.00	g	
PLDCC Vol, V	540.76	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.42	g/cm^3	
	26.08	lb/ft^3	
Total Weight of Water, W_w	442.47	g	
Weight of Excess Cell Water, E_{wc}	161.58	g	
Weight of Saturated PLDCC, W_{sat}	458.75	g	
Saturated PLDCC Unit Weight, Uw_s	**0.85**	**g/cm^3**	
	52.94	**lb/ft^3**	
Vol. Water in PLDCC	232748.2	mm^3	
Vol. PLDCC	540763.5	mm^3	
Vol. Water/Vol. PLDCC	**43.04%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	213.31	g
Tare Weight, W_B	213.14	g
Tare Weight, W_C	211.98	g
Manometer H1	215.90	mm
Manometer H2	885.19	mm
Δh	66.93	cm
Vol. of Water + Tare A	325.53	cm^3
Vol. of Water + Tare B	320.26	cm^3
Vol. of Water + Tare C	314.34	cm^3
Average Flow, Q	107.23	cm^3
Length of Specimen Along Path of Flow	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**8.84E-03**	**cm/sec**

Figure 26. Permeability Test Report of Specimen Y16.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

Y17

PVC Cell Height, h_m	154.20	mm	Height of PVC cell
PVC Cell Weight,w	234.67	g	Weight of PVC cell
PVC Internal Diameter, D	76.60	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	20.93	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	18.24	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1548.17	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2002.19	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2471.84	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	11.50	cm	
PLDCC Cross-sectional Area, A	46.08	cm^2	
Unsat. PLDCC Weight	219.75	g	
PLDCC Vol, V	530.09	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.41	g/cm^3	
	25.87	lb/ft^3	
Total Weight of Water, W_w	469.65	g	
Weight of Excess Cell Water, E_{wc}	180.51	g	
Weight of Saturated PLDCC, W_{sat}	460.75	g	
Saturated PLDCC Unit Weight, Uw_s	**0.87**	**g/cm^3**	
	54.24	**lb/ft^3**	
Vol. Water in PLDCC	241002.3	mm^3	
Vol. PLDCC	530088.1	mm^3	
Vol. Water/Vol. PLDCC	**45.46%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	213.31	g
Tare Weight, W_B	213.14	g
Tare Weight, W_C	211.98	g
Manometer H1	180.98	mm
Manometer H2	762.00	mm
Δh	58.10	cm
Vol. of Water + Tare A	397.74	cm^3
Vol. of Water + Tare B	391.99	cm^3
Vol. of Water + Tare C	383.88	cm^3
Average Flow, Q	178.39	cm^3
Length of Specimen Along Path of Flow	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.69E-02**	**cm/sec**

Figure 27. Permeability Test Report of Specimen Y17.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

Y18

PVC Cell Height, h_m	153.77	mm	Height of PVC cell
PVC Cell Weight,w	233.98	g	Weight of PVC cell
PVC Internal Diameter, D	76.78	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	22.59	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	17.76	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1546.64	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1999.76	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2467.21	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	11.34	cm	
PLDCC Cross-sectional Area, A	46.31	cm^2	
Unsat. PLDCC Weight	219.03	g	
PLDCC Vol, V	525.21	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.42	g/cm^3	
	26.02	lb/ft^3	
Total Weight of Water, W_w	467.45	g	
Weight of Excess Cell Water, E_{wc}	186.84	g	
Weight of Saturated PLDCC, W_{sat}	451.50	g	
Saturated PLDCC Unit Weight, Uw_s	**0.86**	**g/cm^3**	
	53.64	**lb/ft^3**	
Vol. Water in PLDCC	232471.6	mm^3	
Vol. PLDCC	525208.0	mm^3	
Vol. Water/Vol. PLDCC	**44.26%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	213.31	g
Tare Weight, W_B	213.14	g
Tare Weight, W_C	211.98	g
Manometer H1	298.45	mm
Manometer H2	908.81	mm
Δh	61.04	cm
Vol. of Water + Tare A	356.71	cm^3
Vol. of Water + Tare B	353.08	cm^3
Vol. of Water + Tare C	345.87	cm^3
Average Flow, Q	139.08	cm^3
Length of Specimen Along Path of Flow	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.25E-02**	**cm/sec**

Figure 28. Permeability Test Report of Specimen Y18.

LABORATORY CONSTANT HEAD PERMEABILITY TEST
Specimen ID:
TY-5

PVC Cell Height, h_m	150.50	mm	Height of PVC cell
PVC Cell Weight,w	221.05	g	Weight of PVC cell
PVC Internal Diameter, D	77.29	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	6.93	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	21.11	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1545.90	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1972.70	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2415.80	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.25	cm	
PLDCC Cross-sectional Area, A	46.91	cm^2	
Unsat. PLDCC Weight	206.25	g	
PLDCC Vol, V	574.47	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.36	g/cm^3	
	22.40	lb/ft^3	
Total Weight of Water, W_w	443.10	g	
Weight of Excess Cell Water, E_{wc}	131.54	g	
Weight of Saturated PLDCC, W_{sat}	469.67	g	
Saturated PLDCC Unit Weight, Uw_{sa}	**0.82**	**g/cm^3**	
	51.02	**lb/ft^3**	
Vol. Water in PLDCC	263424.5274	mm^3	
Vol. PLDCC	574473.9	mm^3	
Vol. Water/Vol. PLDCC	**45.85%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.50	g
Tare Weight, W_C	102.90	g
Manometer H1	530.00	mm
Manometer H2	1420.00	mm
Δh	89.00	cm
Vol. of Water + Tare A	154.30	cm^3
Vol. of Water + Tare B	145.10	cm^3
Vol. of Water + Tare C	152.10	cm^3
Average Flow, Q	49.67	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**3.02E-03**	**cm/sec**

Figure 29. Permeability Test Report of Specimen TY-5.

LABORATORY CONSTANT HEAD PERMEABILITY TEST
Specimen ID:
TY-6

PVC Cell Height, h_m	149.28	mm	Height of PVC cell
PVC Cell Weight,w	219.49	g	Weight of PVC cell
PVC Internal Diameter, D	77.27	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	9.71	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	18.01	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1557.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1984.50	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2422.40	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.16	cm	
PLDCC Cross-sectional Area, A	46.89	cm^2	
Unsat. PLDCC Weight	207.91	g	
PLDCC Vol, V	570.03	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.36	g/cm^3	
	22.76	lb/ft^3	
Total Weight of Water, W_w	437.90	g	
Weight of Excess Cell Water, E_{wc}	129.95	g	
Weight of Saturated PLDCC, W_{sat}	467.72	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.82**	**g/cm^3**	
	51.20	**lb/ft^3**	
Vol. Water in PLDCC	259810.67	mm^3	
Vol. PLDCC	570025.1	mm^3	
Vol. Water/Vol. PLDCC	**45.58%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.50	g
Tare Weight, W_C	102.90	g
Manometer H1	520.00	mm
Manometer H2	1220.00	mm
Δh	70.00	cm
Vol. of Water + Tare A	217.90	cm^3
Vol. of Water + Tare B	206.30	cm^3
Vol. of Water + Tare C	210.50	cm^3
Average Flow, Q	110.73	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**8.57E-03**	**cm/sec**

Figure 30. Permeability Test Report of Specimen TY-6.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-7

PVC Cell Height, h_m	149.61	mm	Height of PVC cell
PVC Cell Weight,w	219.66	g	Weight of PVC cell
PVC Internal Diameter, D	77.39	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	9.55	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	13.34	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1542.39	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1982.49	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2390.88	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.67	cm	
PLDCC Cross-sectional Area, A	47.04	cm^2	
Unsat. PLDCC Weight	218.44	g	
PLDCC Vol, V	596.13	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.37	g/cm^3	
	22.87	lb/ft^3	
Total Weight of Water, W_w	408.39	g	
Weight of Excess Cell Water, E_{wc}	107.68	g	
Weight of Saturated PLDCC, W_{sat}	471.02	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.79**	**g/cm^3**	
	49.30	**lb/ft^3**	
Vol. Water in PLDCC	252576.98	mm^3	
Vol. PLDCC	596127.8	mm^3	
Vol. Water/Vol. PLDCC	**42.37%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	0.00	g
Tare Weight, W_B	0.00	g
Tare Weight, W_C	0.00	g
Manometer H1	20.00	mm
Manometer H2	795.00	mm
Δh	77.50	cm
Vol. of Water + Tare A	221.70	cm^3
Vol. of Water + Tare B	208.80	cm^3
Vol. of Water + Tare C	212.30	cm^3
Average Flow, Q	214.27	cm^3
Length of Specimen Along Pa	7.62	cm
Interval of Time, t	60.00	sec
Hydraulic Conductivity, K	**7.46E-03**	**cm/sec**

Figure 31. Permeability Test Report of Specimen TY-7.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-8

PVC Cell Height, h_m	150.23	mm	Height of PVC cell
PVC Cell Weight,w	220.46	g	Weight of PVC cell
PVC Internal Diameter, D	77.38	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	12.76	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	15.11	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1545.90	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1960.30	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2408.00	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.24	cm	
PLDCC Cross-sectional Area, A	47.03	cm^2	
Unsat. PLDCC Weight	193.94	g	
PLDCC Vol, V	575.47	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.34	g/cm^3	
	21.03	lb/ft^3	
Total Weight of Water, W_w	447.70	g	
Weight of Excess Cell Water, E_{wc}	131.06	g	
Weight of Saturated PLDCC, W_{sat}	462.44	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.80**	**g/cm^3**	
	50.14	**lb/ft^3**	
Vol. Water in PLDCC	268504.81	mm^3	
Vol. PLDCC	575471.1	mm^3	
Vol. Water/Vol. PLDCC	**46.66%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	103.00	g
Manometer H1	310.00	mm
Manometer H2	975.00	mm
Δh	66.50	cm
Vol. of Water + Tare A	156.70	cm^3
Vol. of Water + Tare B	145.80	cm^3
Vol. of Water + Tare C	150.40	cm^3
Average Flow, Q	50.03	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**4.06E-03**	**cm/sec**

Figure 32. Permeability Test Report of Specimen TY-8.

LABORATORY CONSTANT HEAD PERMEABILITY TEST
Specimen ID:
TY-9

PVC Cell Height, h_m	150.13	mm	Height of PVC cell
PVC Cell Weight,w	220.06	g	Weight of PVC cell
PVC Internal Diameter, D	77.27	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	12.16	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	12.16	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1546.60	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1976.10	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2402.00	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.58	cm	
PLDCC Cross-sectional Area, A	46.90	cm^2	
Unsat. PLDCC Weight	210.94	g	
PLDCC Vol, V	590.00	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.36	g/cm^3	
	22.31	lb/ft^3	
Total Weight of Water, W_w	425.90	g	
Weight of Excess Cell Water, E_{wc}	114.05	g	
Weight of Saturated PLDCC, W_{sat}	474.65	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.80**	**g/cm^3**	
	50.20	**lb/ft^3**	
Vol. Water in PLDCC	263708.31	mm^3	
Vol. PLDCC	589998.5	mm^3	
Vol. Water/Vol. PLDCC	**44.70%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	0.00	g
Tare Weight, W_B	0.00	g
Tare Weight, W_C	0.00	g
Manometer H1	550.00	mm
Manometer H2	900.00	mm
Δh	35.00	cm
Vol. of Water + Tare A	232.50	cm^3
Vol. of Water + Tare B	232.31	cm^3
Vol. of Water + Tare C	232.31	cm^3
Average Flow, Q	232.37	cm^3
Length of Specimen Along Pa	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**3.60E-02**	**cm/sec**

Figure 33. Permeability Test Report of Specimen TY-9.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-10

PVC Cell Height, h_m	149.61	mm	Height of PVC cell
PVC Cell Weight,w	219.79	g	Weight of PVC cell
PVC Internal Diameter, D	77.47	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	12.48	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	16.53	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1555.50	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1983.50	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2379.00	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.06	cm	
PLDCC Cross-sectional Area, A	47.14	cm^2	
Unsat. PLDCC Weight	206.51	g	
PLDCC Vol, V	568.46	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.36	g/cm^3	
	22.67	lb/ft^3	
Total Weight of Water, W_w	395.50	g	
Weight of Excess Cell Water, E_{wc}	136.73	g	
Weight of Saturated PLDCC, W_{sat}	417.14	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.73**	**g/cm^3**	
	45.79	**lb/ft^3**	
Vol. Water in PLDCC	210632.94	mm^3	
Vol. PLDCC	568460.4	mm^3	
Vol. Water/Vol. PLDCC	**37.05%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	0.00	g
Tare Weight, W_B	0.00	g
Tare Weight, W_C	0.00	g
Manometer H1	0.00	mm
Manometer H2	532.00	mm
Δh	53.20	cm
Vol. of Water + Tare A	346.70	cm^3
Vol. of Water + Tare B	340.30	cm^3
Vol. of Water + Tare C	333.00	cm^3
Average Flow, Q	340.00	cm^3
Length of Specimen Along Pa	7.62	cm
Interval of Time, t	60.00	sec
Hydraulic Conductivity, K	**1.72E-02**	**cm/sec**

Figure 34. Permeability Test Report of Specimen TY-10.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-11

PVC Cell Height, h_m	149.32	mm	Height of PVC cell
PVC Cell Weight,w	219.39	g	Weight of PVC cell
PVC Internal Diameter, D	77.37	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	9.79	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	19.41	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1557.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1981.30	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2391.90	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.01	cm	
PLDCC Cross-sectional Area, A	47.02	cm^2	
Unsat. PLDCC Weight	204.51	g	
PLDCC Vol, V	564.81	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.36	g/cm^3	
	22.59	lb/ft^3	
Total Weight of Water, W_w	410.60	g	
Weight of Excess Cell Water, E_{wc}	137.30	g	
Weight of Saturated PLDCC, W_{sat}	429.67	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.76**	**g/cm^3**	
	47.47	**lb/ft^3**	
Vol. Water in PLDCC	225162.13	mm^3	
Vol. PLDCC	564812.9	mm^3	
Vol. Water/Vol. PLDCC	**39.86%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	0.00	g
Tare Weight, W_B	0.00	g
Tare Weight, W_C	0.00	g
Manometer H1	350.00	mm
Manometer H2	980.00	mm
Δh	63.00	cm
Vol. of Water + Tare A	180.41	cm^3
Vol. of Water + Tare B	153.61	cm^3
Vol. of Water + Tare C	159.80	cm^3
Average Flow, Q	164.23	cm^3
Length of Specimen Along Pa	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.41E-02**	**cm/sec**

Figure 35. Permeability Test Report of Specimen TY-11.

LABORATORY CONSTANT HEAD PERMEABILITY TEST
Specimen ID:
TY-12

PVC Cell Height, h_m	149.49	mm	Height of PVC cell
PVC Cell Weight,w	219.93	g	Weight of PVC cell
PVC Internal Diameter, D	77.13	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	11.98	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	19.01	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1953.30	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2417.00	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	11.85	cm	
PLDCC Cross-sectional Area, A	46.73	cm^2	
Unsat. PLDCC Weight	186.67	g	
PLDCC Vol, V	553.70	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.34	g/cm^3	
	21.04	lb/ft^3	
Total Weight of Water, W_w	463.70	g	
Weight of Excess Cell Water, E_{wc}	144.85	g	
Weight of Saturated PLDCC, W_{sat}	457.39	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.83**	**g/cm^3**	
	51.55	**lb/ft^3**	
Vol. Water in PLDCC	270716.5362	mm^3	
Vol. PLDCC	553696.1	mm^3	
Vol. Water/Vol. PLDCC	**48.89%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	103.00	g
Manometer H1	460.00	mm
Manometer H2	1260.00	mm
Δh	80.00	cm
Vol. of Water + Tare A	292.70	cm^3
Vol. of Water + Tare B	280.40	cm^3
Vol. of Water + Tare C	282.80	cm^3
Average Flow, Q	184.37	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.25E-02**	**cm/sec**

Figure 36. Permeability Test Report of Specimen TY-12.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-13

PVC Cell Height, h_m	150.16	mm	Height of PVC cell
PVC Cell Weight,w	220.32	g	Weight of PVC cell
PVC Internal Diameter, D	77.28	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	10.12	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	18.93	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1558.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1979.50	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2414.60	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.11	cm	
PLDCC Cross-sectional Area, A	46.90	cm^2	
Unsat. PLDCC Weight	201.38	g	
PLDCC Vol, V	568.09	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.35	g/cm^3	
	22.12	lb/ft^3	
Total Weight of Water, W_w	435.10	g	
Weight of Excess Cell Water, E_{wc}	136.25	g	
Weight of Saturated PLDCC, W_{sat}	452.09	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.80**	**g/cm^3**	
	49.66	**lb/ft^3**	
Vol. Water in PLDCC	250708.744	mm^3	
Vol. PLDCC	568093.3	mm^3	
Vol. Water/Vol. PLDCC	**44.13%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	103.00	g
Manometer H1	863.00	mm
Manometer H2	1265.00	mm
Δh	40.20	cm
Vol. of Water + Tare A	207.50	cm^3
Vol. of Water + Tare B	195.60	cm^3
Vol. of Water + Tare C	200.00	cm^3
Average Flow, Q	100.10	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.35E-02**	**cm/sec**

Figure 37. Permeability Test Report of Specimen TY-13.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-14

PVC Cell Height, h_m	149.75	mm	Height of PVC cell
PVC Cell Weight,w	219.62	g	Weight of PVC cell
PVC Internal Diameter, D	77.46	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	14.10	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	18.79	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1961.20	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2396.70	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	11.69	cm	
PLDCC Cross-sectional Area, A	47.13	cm^2	
Unsat. PLDCC Weight	194.68	g	
PLDCC Vol, V	550.70	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.35	g/cm^3	
	22.06	lb/ft^3	
Total Weight of Water, W_w	435.50	g	
Weight of Excess Cell Water, E_{wc}	155.03	g	
Weight of Saturated PLDCC, W_{sat}	427.01	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.78**	**g/cm^3**	
	48.38	**lb/ft^3**	
Vol. Water in PLDCC	232329.10	mm^3	
Vol. PLDCC	550699.3	mm^3	
Vol. Water/Vol. PLDCC	**42.19%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	0.00	g
Tare Weight, W_B	0.00	g
Tare Weight, W_C	0.00	g
Manometer H1	390.00	mm
Manometer H2	1040.00	mm
Δh	65.00	cm
Vol. of Water + Tare A	250.81	cm^3
Vol. of Water + Tare B	238.30	cm^3
Vol. of Water + Tare C	232.81	cm^3
Average Flow, Q	230.16	cm^3
Length of Specimen Along Pa	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.91E-02**	**cm/sec**

Figure 38. Permeability Test Report of Specimen TY-14.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-16

PVC Cell Height, h_m	150.65	mm	Height of PVC cell
PVC Cell Weight,w	220.91	g	Weight of PVC cell
PVC Internal Diameter, D	77.37	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	15.97	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	18.22	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1558.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1960.10	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2428.10	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	11.65	cm	
PLDCC Cross-sectional Area, A	47.02	cm^2	
Unsat. PLDCC Weight	182.09	g	
PLDCC Vol, V	547.62	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.33	g/cm^3	
	20.75	lb/ft^3	
Total Weight of Water, W_w	468.00	g	
Weight of Excess Cell Water, E_{wc}	160.74	g	
Weight of Saturated PLDCC, W_{sat}	441.21	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.81**	**g/cm^3**	
	50.28	**lb/ft^3**	
Vol. Water in PLDCC	259124.9576	mm^3	
Vol. PLDCC	547616.1	mm^3	
Vol. Water/Vol. PLDCC	**47.32%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	103.00	g
Manometer H1	285.00	mm
Manometer H2	1140.00	mm
Δh	85.50	cm
Vol. of Water + Tare A	231.70	cm^3
Vol. of Water + Tare B	220.30	cm^3
Vol. of Water + Tare C	225.30	cm^3
Average Flow, Q	124.83	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**7.89E-03**	**cm/sec**

Figure 39. Permeability Test Report of Specimen TY-16.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-17

PVC Cell Height, h_m	150.77	mm	Height of PVC cell
PVC Cell Weight,w	220.65	g	Weight of PVC cell
PVC Internal Diameter, D	77.20	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	9.03	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	18.91	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1957.50	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2409.90	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.28	cm	
PLDCC Cross-sectional Area, A	46.80	cm^2	
Unsat. PLDCC Weight	190.15	g	
PLDCC Vol, V	574.90	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.33	g/cm^3	
	20.64	lb/ft^3	
Total Weight of Water, W_w	452.40	g	
Weight of Excess Cell Water, E_{wc}	130.79	g	
Weight of Saturated PLDCC, W_{sat}	463.62	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.81**	**g/cm^3**	
	50.32	**lb/ft^3**	
Vol. Water in PLDCC	273469.0079	mm^3	
Vol. PLDCC	574902.8	mm^3	
Vol. Water/Vol. PLDCC	**47.57%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	103.00	g
Manometer H1	370.00	mm
Manometer H2	1325.00	mm
Δh	95.50	cm
Vol. of Water + Tare A	241.30	cm^3
Vol. of Water + Tare B	229.30	cm^3
Vol. of Water + Tare C	233.20	cm^3
Average Flow, Q	133.67	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**7.60E-03**	**cm/sec**

Figure 40. Permeability Test Report of Specimen TY-17.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-18

PVC Cell Height, h_m	150.76	mm	Height of PVC cell
PVC Cell Weight,w	220.64	g	Weight of PVC cell
PVC Internal Diameter, D	77.37	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	15.38	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	19.08	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1558.90	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1973.50	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2418.80	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	11.63	cm	
PLDCC Cross-sectional Area, A	47.01	cm^2	
Unsat. PLDCC Weight	194.56	g	
PLDCC Vol, V	546.76	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.36	g/cm^3	
	22.20	lb/ft^3	
Total Weight of Water, W_w	445.30	g	
Weight of Excess Cell Water, E_{wc}	161.99	g	
Weight of Saturated PLDCC, W_{sat}	429.73	g	
Saturated PLDCC Unit Weight, Uw_{sa}	**0.79**	**g/cm^3**	
	49.04	**lb/ft^3**	
Vol. Water in PLDCC	235174.53	mm^3	
Vol. PLDCC	546756.9	mm^3	
Vol. Water/Vol. PLDCC	**43.01%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	0.00	g
Tare Weight, W_B	0.00	g
Tare Weight, W_C	0.00	g
Manometer H1	450.00	mm
Manometer H2	890.00	mm
Δh	44.00	cm
Vol. of Water + Tare A	302.11	cm^3
Vol. of Water + Tare B	289.30	cm^3
Vol. of Water + Tare C	286.81	cm^3
Average Flow, Q	232.65	cm^3
Length of Specimen Along Pa	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**2.86E-02**	**cm/sec**

Figure 41. Permeability Test Report of Specimen TY-18.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-19

PVC Cell Height, h_m	150.04	mm	Height of PVC cell
PVC Cell Weight,w	220.88	g	Weight of PVC cell
PVC Internal Diameter, D	77.22	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	16.97	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	18.69	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1543.50	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	1959.69	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2406.80	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	11.44	cm	
PLDCC Cross-sectional Area, A	46.83	cm^2	
Unsat. PLDCC Weight	193.72	g	
PLDCC Vol, V	535.62	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.36	g/cm^3	
	22.57	lb/ft^3	
Total Weight of Water, W_w	447.11	g	
Weight of Excess Cell Water, E_{wc}	166.98	g	
Weight of Saturated PLDCC, W_{sat}	425.71	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.79**	**g/cm^3**	
	49.60	**lb/ft^3**	
Vol. Water in PLDCC	231992.50	mm^3	
Vol. PLDCC	535615.3	mm^3	
Vol. Water/Vol. PLDCC	**43.31%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	0.00	g
Tare Weight, W_B	0.00	g
Tare Weight, W_C	0.00	g
Manometer H1	50.00	mm
Manometer H2	845.00	mm
Δh	79.50	cm
Vol. of Water + Tare A	320.20	cm^3
Vol. of Water + Tare B	320.10	cm^3
Vol. of Water + Tare C	312.90	cm^3
Average Flow, Q	317.73	cm^3
Length of Specimen Along Pa	7.62	cm
Interval of Time, t	60.00	sec
Hydraulic Conductivity, K	**1.08E-02**	**cm/sec**

Figure 42. Permeability Test Report of Specimen TY-19.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-20

PVC Cell Height, h_m	149.96	mm	Height of PVC cell
PVC Cell Weight,w	220.19	g	Weight of PVC cell
PVC Internal Diameter, D	77.57	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	7.55	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	14.33	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1557.00	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2057.40	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2417.40	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.81	cm	
PLDCC Cross-sectional Area, A	47.25	cm^2	
Unsat. PLDCC Weight	281.01	g	
PLDCC Vol, V	605.20	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.46	g/cm^3	
	28.97	lb/ft^3	
Total Weight of Water, W_w	360.00	g	
Weight of Excess Cell Water, E_{wc}	103.41	g	
Weight of Saturated PLDCC, W_{sat}	489.46	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.81**	**g/cm^3**	
	50.47	**lb/ft^3**	
Vol. Water in PLDCC	208453.0	mm^3	
Vol. PLDCC	605195.9	mm^3	
Vol. Water/Vol. PLDCC	**34.44%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	445.00	mm
Manometer H2	1400.00	mm
Δh	95.50	cm
Vol. of Water + Tare A	131.70	cm^3
Vol. of Water + Tare B	120.40	cm^3
Vol. of Water + Tare C	124.50	cm^3
Average Flow, Q	24.67	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.39E-03**	**cm/sec**

Figure 43. Permeability Test Report of Specimen TY-20.

LABORATORY CONSTANT HEAD PERMEABILITY TEST
Specimen ID:
TY-21

PVC Cell Height, h_m	151.27	mm	Height of PVC cell
PVC Cell Weight,w	221.47	g	Weight of PVC cell
PVC Internal Diameter, D	77.24	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	7.02	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	11.27	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.40	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2052.00	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2407.60	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	13.30	cm	
PLDCC Cross-sectional Area, A	46.85	cm^2	
Unsat. PLDCC Weight	284.03	g	
PLDCC Vol, V	623.02	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.46	g/cm^3	
	28.45	lb/ft^3	
Total Weight of Water, W_w	355.60	g	
Weight of Excess Cell Water, E_{wc}	85.70	g	
Weight of Saturated PLDCC, W_{sat}	505.80	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.81**	**g/cm^3**	
	50.66	**lb/ft^3**	
Vol. Water in PLDCC	221766.7	mm^3	
Vol. PLDCC	623017.8	mm^3	
Vol. Water/Vol. PLDCC	**35.60%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	490.00	mm
Manometer H2	1410.00	mm
Δh	92.00	cm
Vol. of Water + Tare A	119.20	cm^3
Vol. of Water + Tare B	109.70	cm^3
Vol. of Water + Tare C	115.80	cm^3
Average Flow, Q	14.03	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**8.27E-04**	**cm/sec**

Figure 44. Permeability Test Report of Specimen TY-21.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-22

PVC Cell Height, h_m	150.87	mm	Height of PVC cell
PVC Cell Weight,w	221.68	g	Weight of PVC cell
PVC Internal Diameter, D	77.92	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	8.29	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	13.66	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1557.00	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2063.50	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2425.20	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.89	cm	
PLDCC Cross-sectional Area, A	47.69	cm^2	
Unsat. PLDCC Weight	283.62	g	
PLDCC Vol, V	614.75	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.46	g/cm^3	
	28.79	lb/ft^3	
Total Weight of Water, W_w	361.70	g	
Weight of Excess Cell Water, E_{wc}	104.69	g	
Weight of Saturated PLDCC, W_{sat}	492.49	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.80**	**g/cm^3**	
	49.99	**lb/ft^3**	
Vol. Water in PLDCC	208868.9	mm^3	
Vol. PLDCC	614754.0	mm^3	
Vol. Water/Vol. PLDCC	**33.98%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	500.00	mm
Manometer H2	1420.00	mm
Δh	92.00	cm
Vol. of Water + Tare A	136.60	cm^3
Vol. of Water + Tare B	124.90	cm^3
Vol. of Water + Tare C	129.50	cm^3
Average Flow, Q	29.47	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.71E-03**	**cm/sec**

Figure 45. Permeability Test Report of Specimen TY-22.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-23

PVC Cell Height, h_m	150.98	mm	Height of PVC cell
PVC Cell Weight,w	221.90	g	Weight of PVC cell
PVC Internal Diameter, D	77.51	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	12.11	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	13.52	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.40	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2040.50	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2420.90	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.54	cm	
PLDCC Cross-sectional Area, A	47.19	cm^2	
Unsat. PLDCC Weight	270.40	g	
PLDCC Vol, V	591.55	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.46	g/cm^3	
	28.52	lb/ft^3	
Total Weight of Water, W_w	380.40	g	
Weight of Excess Cell Water, E_{wc}	120.95	g	
Weight of Saturated PLDCC, W_{sat}	481.71	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.81**	**g/cm^3**	
	50.81	**lb/ft^3**	
Vol. Water in PLDCC	211308	mm^3	
Vol. PLDCC	591547.2	mm^3	
Vol. Water/Vol. PLDCC	**35.72%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	490.00	mm
Manometer H2	1350.00	mm
Δh	86.00	cm
Vol. of Water + Tare A	131.90	cm^3
Vol. of Water + Tare B	121.00	cm^3
Vol. of Water + Tare C	126.20	cm^3
Average Flow, Q	25.50	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.60E-03**	**cm/sec**

Figure 46. Permeability Test Report of Specimen TY-23.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-24

PVC Cell Height, h_m	148.69	mm	Height of PVC cell
PVC Cell Weight,w	217.47	g	Weight of PVC cell
PVC Internal Diameter, D	77.39	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	11.26	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	12.34	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2032.00	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2404.90	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.51	cm	
PLDCC Cross-sectional Area, A	47.04	cm^2	
Unsat. PLDCC Weight	267.63	g	
PLDCC Vol, V	588.45	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.45	g/cm^3	
	28.38	lb/ft^3	
Total Weight of Water, W_w	372.90	g	
Weight of Excess Cell Water, E_{wc}	111.02	g	
Weight of Saturated PLDCC, W_{sat}	481.37	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.82**	**g/cm^3**	
	51.05	**lb/ft^3**	
Vol. Water in PLDCC	213739	mm^3	
Vol. PLDCC	588448.3	mm^3	
Vol. Water/Vol. PLDCC	**36.32%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	102.90	g
Manometer H1	545.00	mm
Manometer H2	1390.00	mm
Δh	84.50	cm
Vol. of Water + Tare A	126.90	cm^3
Vol. of Water + Tare B	116.60	cm^3
Vol. of Water + Tare C	122.50	cm^3
Average Flow, Q	21.10	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.35E-03**	**cm/sec**

Figure 47. Permeability Test Report of Specimen TY-24.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-25

PVC Cell Height, h_m	150.66	mm	Height of PVC cell
PVC Cell Weight,w	220.55	g	Weight of PVC cell
PVC Internal Diameter, D	77.55	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	13.41	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	10.29	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1557.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2046.10	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2424.70	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.70	cm	
PLDCC Cross-sectional Area, A	47.24	cm^2	
Unsat. PLDCC Weight	269.15	g	
PLDCC Vol, V	599.69	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.45	g/cm^3	
	28.01	lb/ft^3	
Total Weight of Water, W_w	378.60	g	
Weight of Excess Cell Water, E_{wc}	111.98	g	
Weight of Saturated PLDCC, W_{sat}	487.63	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.81**	**g/cm^3**	
	50.74	**lb/ft^3**	
Vol. Water in PLDCC	218484.5	mm^3	
Vol. PLDCC	599694.8	mm^3	
Vol. Water/Vol. PLDCC	**36.43%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	102.90	g
Manometer H1	590.00	mm
Manometer H2	1250.00	mm
Δh	66.00	cm
Vol. of Water + Tare A	132.80	cm^3
Vol. of Water + Tare B	121.80	cm^3
Vol. of Water + Tare C	127.00	cm^3
Average Flow, Q	26.30	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**2.14E-03**	**cm/sec**

Figure 48. Permeability Test Report of Specimen TY-25.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-26

PVC Cell Height, h_m	151.10	mm	Height of PVC cell
PVC Cell Weight,w	221.18	g	Weight of PVC cell
PVC Internal Diameter, D	77.32	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	13.95	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	11.25	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1548.50	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2038.10	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2423.30	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.59	cm	
PLDCC Cross-sectional Area, A	46.96	cm^2	
Unsat. PLDCC Weight	270.42	g	
PLDCC Vol, V	591.19	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.46	g/cm^3	
	28.54	lb/ft^3	
Total Weight of Water, W_w	385.20	g	
Weight of Excess Cell Water, E_{wc}	118.35	g	
Weight of Saturated PLDCC, W_{sat}	489.13	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.83**	**g/cm^3**	
	51.63	**lb/ft^3**	
Vol. Water in PLDCC	218710.3	mm^3	
Vol. PLDCC	591188.7	mm^3	
Vol. Water/Vol. PLDCC	**36.99%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	102.90	g
Manometer H1	448.00	mm
Manometer H2	1310.00	mm
Δh	86.20	cm
Vol. of Water + Tare A	130.50	cm^3
Vol. of Water + Tare B	119.90	cm^3
Vol. of Water + Tare C	125.70	cm^3
Average Flow, Q	24.47	cm^3
Length of Specimen Along Path ℓ	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.54E-03**	**cm/sec**

Figure 49. Permeability Test Report of Specimen TY-26.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-27

PVC Cell Height, h_m	151.23	mm	Height of PVC cell
PVC Cell Weight,w	221.80	g	Weight of PVC cell
PVC Internal Diameter, D	77.36	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	6.65	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	12.80	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1558.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2063.80	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2423.30	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	13.18	cm	
PLDCC Cross-sectional Area, A	47.00	cm^2	
Unsat. PLDCC Weight	284.80	g	
PLDCC Vol, V	619.33	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.46	g/cm^3	
	28.69	lb/ft^3	
Total Weight of Water, W_w	359.50	g	
Weight of Excess Cell Water, E_{wc}	91.39	g	
Weight of Saturated PLDCC, W_{sat}	504.77	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.82**	**g/cm^3**	
	50.86	**lb/ft^3**	
Vol. Water in PLDCC	219973.2	mm^3	
Vol. PLDCC	619331.3	mm^3	
Vol. Water/Vol. PLDCC	**35.52%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	102.90	g
Manometer H1	495.00	mm
Manometer H2	1272.00	mm
Δh	77.70	cm
Vol. of Water + Tare A	144.80	cm^3
Vol. of Water + Tare B	132.50	cm^3
Vol. of Water + Tare C	136.20	cm^3
Average Flow, Q	36.93	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**2.57E-03**	**cm/sec**

Figure 50. Permeability Test Report of Specimen TY-27.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-28

PVC Cell Height, h_m	150.40	mm	Height of PVC cell
PVC Cell Weight,w	219.84	g	Weight of PVC cell
PVC Internal Diameter, D	77.48	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	11.87	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	12.92	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1546.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2039.20	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2417.80	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.56	cm	
PLDCC Cross-sectional Area, A	47.15	cm^2	
Unsat. PLDCC Weight	276.56	g	
PLDCC Vol, V	592.26	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.47	g/cm^3	
	29.14	lb/ft^3	
Total Weight of Water, W_w	378.60	g	
Weight of Excess Cell Water, E_{wc}	116.90	g	
Weight of Saturated PLDCC, W_{sat}	490.12	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.83**	**g/cm^3**	
	51.64	**lb/ft^3**	
Vol. Water in PLDCC	213562.3	mm^3	
Vol. PLDCC	592263.6	mm^3	
Vol. Water/Vol. PLDCC	**36.06%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	450.00	mm
Manometer H2	1055.00	mm
Δh	60.50	cm
Vol. of Water + Tare A	129.90	cm^3
Vol. of Water + Tare B	119.40	cm^3
Vol. of Water + Tare C	125.50	cm^3
Average Flow, Q	24.07	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**2.14E-03**	**cm/sec**

Figure 51. Permeability Test Report of Specimen TY-28.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-29

PVC Cell Height, h_m	150.50	mm	Height of PVC cell
PVC Cell Weight,w	220.46	g	Weight of PVC cell
PVC Internal Diameter, D	77.55	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	11.89	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	9.31	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1558.40	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2055.00	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2418.10	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.93	cm	
PLDCC Cross-sectional Area, A	47.24	cm^2	
Unsat. PLDCC Weight	277.34	g	
PLDCC Vol, V	610.75	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.45	g/cm^3	
	28.34	lb/ft^3	
Total Weight of Water, W_w	363.10	g	
Weight of Excess Cell Water, E_{wc}	100.14	g	
Weight of Saturated PLDCC, W_{sat}	492.16	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.81**	**g/cm^3**	
	50.28	**lb/ft^3**	
Vol. Water in PLDCC	214820	mm^3	
Vol. PLDCC	610750.4	mm^3	
Vol. Water/Vol. PLDCC	**35.17%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	525.00	mm
Manometer H2	1297.00	mm
Δh	77.20	cm
Vol. of Water + Tare A	128.40	cm^3
Vol. of Water + Tare B	118.30	cm^3
Vol. of Water + Tare C	123.90	cm^3
Average Flow, Q	22.67	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.58E-03**	**cm/sec**

Figure 52. Permeability Test Report of Specimen TY-29.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-30

PVC Cell Height, h_m	150.76	mm	Height of PVC cell
PVC Cell Weight,w	220.45	g	Weight of PVC cell
PVC Internal Diameter, D	77.72	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	7.10	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	11.50	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.70	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2045.20	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2399.30	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	13.22	cm	
PLDCC Cross-sectional Area, A	47.44	cm^2	
Unsat. PLDCC Weight	278.45	g	
PLDCC Vol, V	626.95	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.44	g/cm^3	
	27.71	lb/ft^3	
Total Weight of Water, W_w	354.10	g	
Weight of Excess Cell Water, E_{wc}	88.24	g	
Weight of Saturated PLDCC, W_{sat}	496.18	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.79**	**g/cm^3**	
	49.38	**lb/ft^3**	
Vol. Water in PLDCC	217727.1	mm^3	
Vol. PLDCC	626952.8	mm^3	
Vol. Water/Vol. PLDCC	**34.73%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	460.00	mm
Manometer H2	1335.00	mm
Δh	87.50	cm
Vol. of Water + Tare A	119.40	cm^3
Vol. of Water + Tare B	110.40	cm^3
Vol. of Water + Tare C	117.40	cm^3
Average Flow, Q	14.87	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**9.10E-04**	**cm/sec**

Figure 53. Permeability Test Report of Specimen TY-30.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-31

PVC Cell Height, h_m	149.78	mm	Height of PVC cell
PVC Cell Weight,w	218.76	g	Weight of PVC cell
PVC Internal Diameter, D	77.52	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	10.26	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	14.17	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1555.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2052.10	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2357.40	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.53	cm	
PLDCC Cross-sectional Area, A	47.20	cm^2	
Unsat. PLDCC Weight	276.74	g	
PLDCC Vol, V	591.63	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.47	g/cm^3	
	29.19	lb/ft^3	
Total Weight of Water, W_w	305.30	g	
Weight of Excess Cell Water, E_{wc}	115.32	g	
Weight of Saturated PLDCC, W_{sat}	418.58	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.71**	**g/cm^3**	
	44.15	**lb/ft^3**	
Vol. Water in PLDCC	141838.55	mm^3	
Vol. PLDCC	591630.3	mm^3	
Vol. Water/Vol. PLDCC	**23.97%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	0.00	g
Tare Weight, W_B	0.00	g
Tare Weight, W_C	0.00	g
Manometer H1	0.00	mm
Manometer H2	100.00	mm
Δh	10.00	cm
Vol. of Water + Tare A	40.50	cm^3
Vol. of Water + Tare B	48.30	cm^3
Vol. of Water + Tare C	48.70	cm^3
Average Flow, Q	46.33	cm^3
Length of Specimen Along Pa	7.62	cm
Interval of Time, t	60.00	sec
Hydraulic Conductivity, K	**1.25E-02**	**cm/sec**

Figure 54. Permeability Test Report of Specimen TY-31.

LABORATORY CONSTANT HEAD PERMEABILITY TEST
Specimen ID:
TY-32

PVC Cell Height, h_m	149.75	mm	Height of PVC cell
PVC Cell Weight,w	219.69	g	Weight of PVC cell
PVC Internal Diameter, D	77.38	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	13.70	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	13.11	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1559.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2038.00	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2424.00	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.29	cm	
PLDCC Cross-sectional Area, A	47.03	cm^2	
Unsat. PLDCC Weight	259.81	g	
PLDCC Vol, V	578.15	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.45	g/cm^3	
	28.04	lb/ft^3	
Total Weight of Water, W_w	386.00	g	
Weight of Excess Cell Water, E_{wc}	126.11	g	
Weight of Saturated PLDCC, W_{sat}	471.56	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.82**	**g/cm^3**	
	50.90	**lb/ft^3**	
Vol. Water in PLDCC	211753.2	mm^3	
Vol. PLDCC	578150.0	mm^3	
Vol. Water/Vol. PLDCC	**36.63%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	430.00	mm
Manometer H2	1282.00	mm
Δh	85.20	cm
Vol. of Water + Tare A	139.90	cm^3
Vol. of Water + Tare B	128.30	cm^3
Vol. of Water + Tare C	132.20	cm^3
Average Flow, Q	32.60	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**2.07E-03**	**cm/sec**

Figure 55. Permeability Test Report of Specimen TY-32.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-33

PVC Cell Height, h_m	150.56	mm	Height of PVC cell
PVC Cell Weight,w	220.55	g	Weight of PVC cell
PVC Internal Diameter, D	77.43	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	12.63	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	10.26	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1548.00	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2044.90	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2413.20	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.77	cm	
PLDCC Cross-sectional Area, A	47.08	cm^2	
Unsat. PLDCC Weight	277.35	g	
PLDCC Vol, V	601.07	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.46	g/cm^3	
	28.79	lb/ft^3	
Total Weight of Water, W_w	368.30	g	
Weight of Excess Cell Water, E_{wc}	107.79	g	
Weight of Saturated PLDCC, W_{sat}	489.72	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.81**	**g/cm^3**	
	50.84	**lb/ft^3**	
Vol. Water in PLDCC	212370	mm^3	
Vol. PLDCC	601072.9	mm^3	
Vol. Water/Vol. PLDCC	**35.33%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	331.00	mm
Manometer H2	1243.00	mm
Δh	91.20	cm
Vol. of Water + Tare A	129.20	cm^3
Vol. of Water + Tare B	118.80	cm^3
Vol. of Water + Tare C	125.10	cm^3
Average Flow, Q	23.50	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.39E-03**	**cm/sec**

Figure 56. Permeability Test Report of Specimen TY-33.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-34

PVC Cell Height, h_m	149.29	mm	Height of PVC cell
PVC Cell Weight,w	218.75	g	Weight of PVC cell
PVC Internal Diameter, D	77.30	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	13.02	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	12.47	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1560.20	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2046.60	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2423.80	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.38	cm	
PLDCC Cross-sectional Area, A	46.93	cm^2	
Unsat. PLDCC Weight	269.45	g	
PLDCC Vol, V	581.00	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.46	g/cm^3	
	28.94	lb/ft^3	
Total Weight of Water, W_w	377.20	g	
Weight of Excess Cell Water, E_{wc}	119.61	g	
Weight of Saturated PLDCC, W_{sat}	478.90	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.82**	**g/cm^3**	
	51.43	**lb/ft^3**	
Vol. Water in PLDCC	209447.9	mm^3	
Vol. PLDCC	580997.3	mm^3	
Vol. Water/Vol. PLDCC	**36.05%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	102.90	g
Manometer H1	514.00	mm
Manometer H2	1252.00	mm
Δh	73.80	cm
Vol. of Water + Tare A	135.40	cm^3
Vol. of Water + Tare B	123.20	cm^3
Vol. of Water + Tare C	127.80	cm^3
Average Flow, Q	27.93	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**2.05E-03**	**cm/sec**

Figure 57. Permeability Test Report of Specimen TY-34.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-35

PVC Cell Height, h_m	149.88	mm	Height of PVC cell
PVC Cell Weight,w	220.07	g	Weight of PVC cell
PVC Internal Diameter, D	77.46	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	10.32	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	10.90	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1558.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2048.90	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2420.00	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.87	cm	
PLDCC Cross-sectional Area, A	47.13	cm^2	
Unsat. PLDCC Weight	273.13	g	
PLDCC Vol, V	606.34	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.45	g/cm^3	
	28.11	lb/ft^3	
Total Weight of Water, W_w	371.10	g	
Weight of Excess Cell Water, E_{wc}	100.02	g	
Weight of Saturated PLDCC, W_{sat}	496.07	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.82**	**g/cm^3**	
	51.05	**lb/ft^3**	
Vol. Water in PLDCC	222939	mm^3	
Vol. PLDCC	606338.1	mm^3	
Vol. Water/Vol. PLDCC	**36.77%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	103.00	g
Manometer H1	430.00	mm
Manometer H2	1160.00	mm
Δh	73.00	cm
Vol. of Water + Tare A	120.90	cm^3
Vol. of Water + Tare B	111.60	cm^3
Vol. of Water + Tare C	118.20	cm^3
Average Flow, Q	16.00	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.18E-03**	**cm/sec**

Figure 58. Permeability Test Report of Specimen TY-35.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-36

PVC Cell Height, h_m	150.37	mm	Height of PVC cell
PVC Cell Weight,w	220.03	g	Weight of PVC cell
PVC Internal Diameter, D	77.67	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	18.62	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	12.72	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1546.10	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2020.20	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2414.30	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	11.90	cm	
PLDCC Cross-sectional Area, A	47.38	cm^2	
Unsat. PLDCC Weight	254.87	g	
PLDCC Vol, V	564.02	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.45	g/cm^3	
	28.20	lb/ft^3	
Total Weight of Water, W_w	394.10	g	
Weight of Excess Cell Water, E_{wc}	148.51	g	
Weight of Saturated PLDCC, W_{sat}	452.32	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.80**	**g/cm^3**	
	50.04	**lb/ft^3**	
Vol. Water in PLDCC	197450.2	mm^3	
Vol. PLDCC	564022.6	mm^3	
Vol. Water/Vol. PLDCC	**35.01%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	103.00	g
Manometer H1	664.00	mm
Manometer H2	1365.00	mm
Δh	70.10	cm
Vol. of Water + Tare A	134.30	cm^3
Vol. of Water + Tare B	122.70	cm^3
Vol. of Water + Tare C	126.90	cm^3
Average Flow, Q	27.07	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**2.07E-03**	**cm/sec**

Figure 59. Permeability Test Report of Specimen TY-36.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-37

PVC Cell Height, h_m	149.07	mm	Height of PVC cell
PVC Cell Weight,w	218.44	g	Weight of PVC cell
PVC Internal Diameter, D	77.81	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	13.89	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	11.58	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2026.00	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2402.30	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.36	cm	
PLDCC Cross-sectional Area, A	47.55	cm^2	
Unsat. PLDCC Weight	260.76	g	
PLDCC Vol, V	587.70	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.44	g/cm^3	
	27.69	lb/ft^3	
Total Weight of Water, W_w	376.30	g	
Weight of Excess Cell Water, E_{wc}	121.06	g	
Weight of Saturated PLDCC, W_{sat}	467.86	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.80**	**g/cm^3**	
	49.68	**lb/ft^3**	
Vol. Water in PLDCC	207102.7	mm^3	
Vol. PLDCC	587704.1	mm^3	
Vol. Water/Vol. PLDCC	**35.24%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	103.00	g
Manometer H1	480.00	mm
Manometer H2	1350.00	mm
Δh	87.00	cm
Vol. of Water + Tare A	121.40	cm^3
Vol. of Water + Tare B	111.80	cm^3
Vol. of Water + Tare C	118.20	cm^3
Average Flow, Q	16.23	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**9.97E-04**	**cm/sec**

Figure 60. Permeability Test Report of Specimen TY-37.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

TY-38

PVC Cell Height, h_m	150.80	mm	Height of PVC cell
PVC Cell Weight,w	221.61	g	Weight of PVC cell
PVC Internal Diameter, D	77.34	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	16.59	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	9.58	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1560.10	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2058.50	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2432.70	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.46	cm	
PLDCC Cross-sectional Area, A	46.97	cm^2	
Unsat. PLDCC Weight	278.09	g	
PLDCC Vol, V	585.45	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.48	g/cm^3	
	29.64	lb/ft^3	
Total Weight of Water, W_w	374.20	g	
Weight of Excess Cell Water, E_{wc}	122.93	g	
Weight of Saturated PLDCC, W_{sat}	481.23	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.82**	**g/cm^3**	
	51.29	**lb/ft^3**	
Vol. Water in PLDCC	203135.8	mm^3	
Vol. PLDCC	585445.4	mm^3	
Vol. Water/Vol. PLDCC	**34.70%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	103.00	g
Manometer H1	354.00	mm
Manometer H2	1400.00	mm
Δh	104.60	cm
Vol. of Water + Tare A	126.00	cm^3
Vol. of Water + Tare B	116.40	cm^3
Vol. of Water + Tare C	122.60	cm^3
Average Flow, Q	20.77	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.07E-03**	**cm/sec**

Figure 61. Permeability Test Report of Specimen TY-38.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

A1

PVC Cell Height, h_m	152.92	mm	Height of PVC cell
PVC Cell Weight,w	331.20	g	Weight of PVC cell
PVC Internal Diameter, D	77.30	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	7.90	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	18.96	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.20	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2126.40	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2663.40	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.61	cm	
PLDCC Cross-sectional Area, A	46.93	cm^2	
Unsat. PLDCC Weight	248.10	g	
PLDCC Vol, V	591.60	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.42	g/cm^3	
	26.17	lb/ft^3	
Total Weight of Water, W_w	537.00	g	
Weight of Excess Cell Water, E_{wc}	126.09	g	
Weight of Saturated PLDCC, W_{sat}	610.87	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**1.03**	**g/cm^3**	
	64.43	**lb/ft^3**	
Vol. Water in PLDCC	362774.6	mm^3	
Vol. PLDCC	591597.7	mm^3	
Vol. Water/Vol. PLDCC	**61.32%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.20	g
Tare Weight, W_B	95.80	g
Tare Weight, W_C	102.80	g
Manometer H1	330.00	mm
Manometer H2	435.00	mm
Δh	10.50	cm
Vol. of Water + Tare A	562.30	cm^3
Vol. of Water + Tare B	545.70	cm^3
Vol. of Water + Tare C	554.60	cm^3
Average Flow, Q	453.27	cm^3
Length of Specimen Along Path ℓ	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**2.34E-01**	**cm/sec**

Figure 62. Permeability Test Report of Specimen A1.

LABORATORY CONSTANT HEAD PERMEABILITY TEST
Specimen ID:
A2

PVC Cell Height, h_m	152.72	mm	Height of PVC cell
PVC Cell Weight,w	334.50	g	Weight of PVC cell
PVC Internal Diameter, D	77.10	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	6.78	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	16.32	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1557.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2142.30	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2664.60	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.96	cm	
PLDCC Cross-sectional Area, A	46.69	cm^2	
Unsat. PLDCC Weight	250.20	g	
PLDCC Vol, V	605.18	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.41	g/cm^3	
	25.80	lb/ft^3	
Total Weight of Water, W_w	522.30	g	
Weight of Excess Cell Water, E_{wc}	107.83	g	
Weight of Saturated PLDCC, W_{sat}	616.54	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**1.02**	**g/cm^3**	
	63.57	**lb/ft^3**	
Vol. Water in PLDCC	366335.5	mm^3	
Vol. PLDCC	605181.4	mm^3	
Vol. Water/Vol. PLDCC	**60.53%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.20	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	102.90	g
Manometer H1	210.00	mm
Manometer H2	305.00	mm
Δh	9.50	cm
Vol. of Water + Tare A	377.40	cm^3
Vol. of Water + Tare B	368.10	cm^3
Vol. of Water + Tare C	368.50	cm^3
Average Flow, Q	270.40	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**1.55E-01**	**cm/sec**

Figure 63. Permeability Test Report of Specimen A2.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

A3

PVC Cell Height, h_m	152.81	mm	Height of PVC cell
PVC Cell Weight,w	330.60	g	Weight of PVC cell
PVC Internal Diameter, D	77.13	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	10.95	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	15.85	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2117.90	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2633.60	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.60	cm	
PLDCC Cross-sectional Area, A	46.72	cm^2	
Unsat. PLDCC Weight	241.00	g	
PLDCC Vol, V	588.76	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.41	g/cm^3	
	25.54	lb/ft^3	
Total Weight of Water, W_w	515.70	g	
Weight of Excess Cell Water, E_{wc}	125.18	g	
Weight of Saturated PLDCC, W_{sat}	583.38	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.99**	**g/cm^3**	
	61.83	**lb/ft^3**	
Vol. Water in PLDCC	342382.3	mm^3	
Vol. PLDCC	588757.4	mm^3	
Vol. Water/Vol. PLDCC	**58.15%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.20	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	102.90	g
Manometer H1	345.00	mm
Manometer H2	423.00	mm
Δh	7.80	cm
Vol. of Water + Tare A	622.30	cm^3
Vol. of Water + Tare B	-	cm^3
Vol. of Water + Tare C	-	cm^3
Average Flow, Q	518.10	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	30.00	sec
Hydraulic Conductivity, K	**3.61E-01**	**cm/sec**

Figure 64. Permeability Test Report of Specimen A3.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

A4

PVC Cell Height, h_m	152.81	mm	Height of PVC cell
PVC Cell Weight,w	334.70	g	Weight of PVC cell
PVC Internal Diameter, D	77.09	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	11.91	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	19.49	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1557.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2130.60	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2654.00	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.14	cm	
PLDCC Cross-sectional Area, A	46.67	cm^2	
Unsat. PLDCC Weight	237.20	g	
PLDCC Vol, V	566.65	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.42	g/cm^3	
	26.12	lb/ft^3	
Total Weight of Water, W_w	523.40	g	
Weight of Excess Cell Water, E_{wc}	146.53	g	
Weight of Saturated PLDCC, W_{sat}	565.93	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**1.00**	**g/cm^3**	
	62.32	**lb/ft^3**	
Vol. Water in PLDCC	328727.4	mm^3	
Vol. PLDCC	566650.5	mm^3	
Vol. Water/Vol. PLDCC	**58.01%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.20	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	103.10	g
Manometer H1	230.00	mm
Manometer H2	291.00	mm
Δh	6.10	cm
Vol. of Water + Tare A	321.90	cm^3
Vol. of Water + Tare B	312.10	cm^3
Vol. of Water + Tare C	319.90	cm^3
Average Flow, Q	217.00	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	20.00	sec
Hydraulic Conductivity, K	**2.90E-01**	**cm/sec**

Figure 65. Permeability Test Report of Specimen A4.

LABORATORY CONSTANT HEAD PERMEABILITY TEST
Specimen ID:
A5

PVC Cell Height, h_m	152.34	mm	Height of PVC cell
PVC Cell Weight,w	333.50	g	Weight of PVC cell
PVC Internal Diameter, D	76.72	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	10.32	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	17.69	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2128.40	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2629.30	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.43	cm	
PLDCC Cross-sectional Area, A	46.23	cm^2	
Unsat. PLDCC Weight	246.60	g	
PLDCC Vol, V	574.71	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.43	g/cm^3	
	26.77	lb/ft^3	
Total Weight of Water, W_w	500.90	g	
Weight of Excess Cell Water, E_{wc}	129.51	g	
Weight of Saturated PLDCC, W_{sat}	569.86	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.99**	**g/cm^3**	
	61.87	**lb/ft^3**	
Vol. Water in PLDCC	323256.6	mm^3	
Vol. PLDCC	574711.7	mm^3	
Vol. Water/Vol. PLDCC	**56.25%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.20	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	102.90	g
Manometer H1	345.00	mm
Manometer H2	425.00	mm
Δh	8.00	cm
Vol. of Water + Tare A	448.80	cm^3
Vol. of Water + Tare B	439.40	cm^3
Vol. of Water + Tare C	446.10	cm^3
Average Flow, Q	343.83	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	20.00	sec
Hydraulic Conductivity, K	**3.54E-01**	**cm/sec**

Figure 66. Permeability Test Report of Specimen A5.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

A6

PVC Cell Height, h_m	152.63	mm	Height of PVC cell
PVC Cell Weight,w	335.50	g	Weight of PVC cell
PVC Internal Diameter, D	76.89	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	6.27	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	21.54	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2121.30	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2642.30	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.48	cm	
PLDCC Cross-sectional Area, A	46.43	cm^2	
Unsat. PLDCC Weight	238.50	g	
PLDCC Vol, V	579.53	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.41	g/cm^3	
	25.68	lb/ft^3	
Total Weight of Water, W_w	521.00	g	
Weight of Excess Cell Water, E_{wc}	129.09	g	
Weight of Saturated PLDCC, W_{sat}	582.27	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**1.00**	**g/cm^3**	
	62.70	**lb/ft^3**	
Vol. Water in PLDCC	343773.9	mm^3	
Vol. PLDCC	579530.9	mm^3	
Vol. Water/Vol. PLDCC	**59.32%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.20	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	103.10	g
Manometer H1	340.00	mm
Manometer H2	430.00	mm
Δh	9.00	cm
Vol. of Water + Tare A	449.40	cm^3
Vol. of Water + Tare B	440.40	cm^3
Vol. of Water + Tare C	444.90	cm^3
Average Flow, Q	343.93	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	20.00	sec
Hydraulic Conductivity, K	**3.14E-01**	**cm/sec**

Figure 67. Permeability Test Report of Specimen A6.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

A7

PVC Cell Height, h_m	152.27	mm	Height of PVC cell
PVC Cell Weight,w	327.60	g	Weight of PVC cell
PVC Internal Diameter, D	77.23	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	11.89	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	19.07	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1557.80	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2129.60	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2641.70	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.13	cm	
PLDCC Cross-sectional Area, A	46.84	cm^2	
Unsat. PLDCC Weight	242.60	g	
PLDCC Vol, V	568.21	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.43	g/cm^3	
	26.64	lb/ft^3	
Total Weight of Water, W_w	512.10	g	
Weight of Excess Cell Water, E_{wc}	145.05	g	
Weight of Saturated PLDCC, W_{sat}	561.51	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.99**	**g/cm^3**	
	61.66	**lb/ft^3**	
Vol. Water in PLDCC	318908.8	mm^3	
Vol. PLDCC	568207.0	mm^3	
Vol. Water/Vol. PLDCC	**56.13%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.10	g
Tare Weight, W_B	95.70	g
Tare Weight, W_C	102.90	g
Manometer H1	333.00	mm
Manometer H2	508.00	mm
Δh	17.50	cm
Vol. of Water + Tare A	397.40	cm^3
Vol. of Water + Tare B	391.90	cm^3
Vol. of Water + Tare C	397.30	cm^3
Average Flow, Q	294.63	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	20.00	sec
Hydraulic Conductivity, K	**1.37E-01**	**cm/sec**

Figure 68. Permeability Test Report of Specimen A7.

LABORATORY CONSTANT HEAD PERMEABILITY TEST

Specimen ID:

A8

PVC Cell Height, h_m	153.64	mm	Height of PVC cell
PVC Cell Weight,w	331.40	g	Weight of PVC cell
PVC Internal Diameter, D	77.07	mm	Internal Diameter of PVC cell
Top Gap Height, d_T	8.63	mm	Depth of the top surface of the PLDCC specimen to the cell rim (average)
Botton Gap Height, d_B	18.53	mm	Depth of the bottom surface of the PLDCC specimen to the cell rim (average)
Equipment Weight, W_E	1547.30	g	Weight of Permeameter with monometer plugs
Equipment + Dry sample, W_{dry}	2126.00	g	Weight of Permeameter cantained in un-saturated PLDCC sample
Equipment + Sat sample, W_{sat}	2634.80	g	Weight of Permeameter cantained in saturated PLDCC sample
Assembly Excess Water, EW	48.14	g	Weight of excess water contained in the Permeameter assembly
PLDCC Sample Height, Hs	12.65	cm	
PLDCC Cross-sectional Area, A	46.64	cm^2	
Unsat. PLDCC Weight	245.90	g	
PLDCC Vol, V	589.93	cm3	
Unsat. PLDCC Unit Weight, W_{unsat}	0.42	g/cm^3	
	26.01	lb/ft^3	
Total Weight of Water, W_w	508.80	g	
Weight of Excess Cell Water, E_{wc}	126.70	g	
Weight of Saturated PLDCC, W_{sat}	579.86	g	
Saturated PLDCC Unit Weight, Uw_{sat}	**0.98**	**g/cm^3**	
	61.34	**lb/ft^3**	
Vol. Water in PLDCC	333959.2	mm^3	
Vol. PLDCC	589925.9	mm^3	
Vol. Water/Vol. PLDCC	**56.61%**		%Water contained in PLDCC when saturated (water storage capacity)

Constant Head Permeability Test

Tare Weight, W_A	104.20	g
Tare Weight, W_B	95.60	g
Tare Weight, W_C	103.10	g
Manometer H1	337.00	mm
Manometer H2	430.00	mm
Δh	9.30	cm
Vol. of Water + Tare A	452.80	cm^3
Vol. of Water + Tare B	443.00	cm^3
Vol. of Water + Tare C	449.70	cm^3
Average Flow, Q	347.53	cm^3
Length of Specimen Along Path (	7.62	cm
Interval of Time, t	20.00	sec
Hydraulic Conductivity, K	**3.05E-01**	**cm/sec**

Figure 69. Permeability Test Report of Specimen A8.

APPENDIX B

LABORATORY SAMPLE PRODUCTION PROCEDURE OF PLDCC

Foam preparation:

a. Determine the amount of water and foaming agent needed. The recommended ratio of foam to water is 1:50, which means 20 grams of chemicals per liter of water.
b. Fill the mixing bucket with water.
c. Measure the amount of foaming agent in a graduate cylinder.
d. Pour the foaming agent into the mixing bucket and thoroughly mix it with water.
e. Insert the recirculating tube into the mixing bucket.

Adjusting the foam density:

a. Prepare several disposable cups.
b. Develop a spreadsheet with the following measuring parameters: measure the weight and volume of the disposable cups.

Cup weight (g)	Cup volume (cm^3)	Weight of foam + cup (g)	Weight of foam (g)	Foam density (g/cm^3)	Foam density (PCF)

c. Turn on the foam generator and allow the foam to run from the foaming tube for at least 30 seconds.
d. Collect the foam in the disposable cups and measure the weight of the foam + cup. Calculate the weight of the foam and determine the foam density. The recommended foam density is 2.5 PCF (AERIX INDUSTR), but it could change based on the mix design.
e. If the foam density is not as expected, adjust the foam density by turning the recirculate knob on the foam generator clockwise or counterclockwise. Repeat the process from (c) to (e) to calculate the foam density.

Mixing Slurry and Foam:

a. Determine the water-to-cement ratio. The recommended W/C is 0.55 (AERIX INDUSTR), but it could change based on the mix design. Weigh the cement and water accordingly.

b. Sprinkle water inside a slurry mixing bucket (Note: the slurry mixing bucket is different from the foam mixing bucket).

c. Pour the water into the slurry mixing bucket, followed by the cement.

d. Mix the cement and water for 2 minutes thoroughly using a handheld cement mixer.

e. Set aside two to three cups of cement slurry separately in case of foam overshooting.

f. Add a good amount of foam to the slurry mixing bucket and mix for at least 20 seconds.

g. Collect a full cup of foam-slurry mixture and calculate the density. If the density of the mix is not as expected, add more slurry (from (e)) or foam to increase or lower the density of the mixture until the desired value is achieved. After adding extra slurry or foam, the slurry-foam mixture needs to be thoroughly mixed.

Pouring and curing of the PLDCC Samples:

a. After the desired density of the PLDCC sample is achieved, pour the slurry mixture into the concrete mold and gently tap the mold to ensure uniform density across the sample.

b. Wet a towel, cover the concrete mold, and allow the concrete to cure for at least 10 days for permeability testing and 28 days for compressive strength testing.

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