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Applying Performance Assessment on Mixture Design to Permeable Concrete Pavements

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Abstract- The Indian economy is growing quickly; therefore, protecting its natural resources is essential to keeping nature and development in harmony. Any civilization may develop fully if it uses its water supply wisely, the most crucial resource. The demand for sustainable development is universal. In order to efficiently collect and transmit rain runoff, modern infrastructure design concepts advocate the use of impermeable materials like concrete and bitumen for parking lots, curbs, and gutters. In India, the United States, the United Kingdom, and other nations, conventional Portland cement concrete and asphalt are utilized for pavement building. The increased water runoff is due to the impermeable nature of certain building materials. Rapid, excessive, and increasingly polluted storm water flow into receiving water bodies under these conditions disrupts the natural equilibrium of the environment. The use of pervious concrete to create porous surfaces has the potential to address a number of environmental concerns, such as the depletion of groundwater. Parking lots, walkways, and driveways paved with pervious concrete can alleviate this issue. The aggregate particles in pervious concrete are coated in a thick paste made from regulated proportions of water and cementitious ingredients. The following sections outline the hypotheses for this study of past concrete. Newline Formulation of Past Concrete Mix Proportions 1. Newline Two: Putting in place a permanent concrete pavement and keeping an eye on it newline. The primary goal of this study is to formulate an optimal pervious concrete mixture design for pervious concrete pavement. Compressive strength, void ratio, permeability, and density are among the presumed target attributes of previous concrete that have informed the development of mixture design. Tensile strength, porosity, and compressive strength are the primary metrics of interest. .

Keywords- Pervious concrete, void ratio, permeability, Tensile strength, porosity, Density, Compressive strength.

I. INTRODUCTION

Rainwater drainage has become a major issue in many Indian cities due to rapid urbanization and unchecked changes to the natural terrain. The frequency of floods and other natural catastrophes increases the urgency of installing specialized water disposal systems in populated areas. Suburban or peri-urban neighborhoods. This issue is becoming worse as more and more cities in India lack updated drainage systems. As can be seen in Figure 1.1, during the Monsoon season, rainwater pools on the road's surface. Therefore mentioned problems can only be fixed by upgrading our current storm water management infrastructure.

A storm water management system can help with this issue. The fundamental idea behind a storm water management system is to collect runoff from highways and channel it into artificial connections for clean groundwater. Reasonable cost, coverage of large areas, and immediate implementation are all factors that contribute to the concept's success. Other factors that contribute to its success include the availability of more water, an improvement in water quality, more plants, the preservation of ecological equilibrium, and lower costs associated with maintaining and repairing roads. This technique will not only aid in reducing the devastation caused by storm water, but it will also raise the water table and expand properly.

Figure 1.1 Rain Water Collected on the Road Surface during Monsoon

Fig 1.

This water can then be re-injected into the aquifer. Detention ponds, onsite detention tanks, rainwater harvesting, and green roofing are all examples of modern storm water management in India's urban setting. Roadside runoff can be disposed of in a variety of ways.

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whereby permeable interlocking concrete pavers, concrete grid pavers, pervious concrete, porous asphalt, and plastic turf reinforcing grid are commonly employed. The various surface water disposal options are depicted in Figure 1.2. From therefore mentioned options, pervious concrete was chosen for this study for its ability to drain monsoon era surface runoff directly into subsurface aquifers.

Figure 1.2 Different Methods used for Disposal of Rain Water (Freeborn 2010)

Fig 2.

To create pervious concrete, cement, large particles, and water are combined. Pervious concrete is made without the use of fine particles. According to Mulligan (2005), just 15% to 40% of fine aggregate is required to create voids in pervious concrete. In developing mixture design of pervious concrete, coarse particles of a single size are often employed. Pervious concrete is made by combining aggregate with a paste made of water and cementitious ingredients in precisely measured proportions. It's not like regular Chapter 14 cement at all. Mulligan (2005) elaborated on the several ways in which the characteristics of pervious concrete diverge from those of regular concrete. The differences and similarities between regular and pervious concrete are laid forth in Table 1.1. In comparison to regular concrete, pervious concrete has been found to have weaker compressive strength, a higher vacancy ratio, and a lower density.

An example of a specimen made using pervious concrete is shown in Figure 1.3.

Table 1.1 Comparison of Properties of Conventional Concrete and Pervious Concrete

Properties	Conventional Concrete	Pervious Concrete
Void Ratio	3% - 5%	15% - 40%
Compressive Strength	20 MPa- 50 MPa	5 MPa – 25 MPa
Density	2400 kg/m^3 to 2500 kg/m^3	1800 kg/m^3 to 2100 kg/m^3

Figure 1.3 Pervious Concrete Cube

Fig 3.

2. Background:

According to Mulligan (2005), the use of• pervious concrete first appeared in Europe. In the nineteenth century, pervious concrete was utilized for a variety of purposes, including loadbearing walls, prefabricated panels, and pavement. In 1923, pervious concrete was once again considered a practical building material. After WWII, numerous places began regularly using pervious concrete. Due to the low cement output at the time, pervious concrete was the material of choice since it required less cement than regular concrete. Its principal function at the time was the building of homes. In the 1970s, the United States began experimenting with the use of pervious concrete.

According to the National Resource Conservation Service, pervious concrete is a cutting-edge management technique in the United States (NRMCA, 2004). Using pervious concrete is a best management practice, according to the Environmental Protection Agency (EPA). It can help with Chapter 1-5 national efforts like the EPA's Heat Island Reduction Initiative and Low Impact Development, and it may help you get points in the LEED (Leadership in Energy and Environmental Design) certification system for green buildings. After the year 2000, concrete was adopted in India. Initial studies on pervious concrete have been initiated at IIT Kharagpur. The many national groups for ready-mixed concrete each have their own set of standards. Despite the fact that the ready mix concrete organization in India has not yet created guidelines for pervious concrete, therefore, compared to other nations, India does not have a High need for pervious concrete.

Requests although previouconcretes have seen widespread use, theiinadequate strength has restricted their deployment. Tennis et al. (2004) reported numerous uses for pervious concrete, including: subbase of conventional concrete pavement; patios; artificial reefs; slope stabilization; well linings; tree gates in sidewalks; hydraulic structures; swimming pool decks; pavement edge drains; noise barriers; and tennis courts.

3. Benefits and Drawbacks:

There are several benefits and drawbacks to using pervious concrete instead of regular concrete. Pervious concrete, as stated by Mulligan (2005), has reduced shrinkage, a lower density, and higher thermal insulating qualities than regular concrete. Sites that use pervious concrete may be eligible for additional Green Building Rating System points. According to Tennis et al. (2004), pervious concrete pavements absorb less heat from the sun than asphalt roads.

Landscape designers and architects now have an• option with pervious concrete for incorporating vegetation into otherwise paved places like parking lots and city streets. From a performance perspective, pervious concrete is

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advantageous because it reduces the likelihood of floods, replenishes ground water levels, absorbs noise and thermal energy, and encourages the growth of plants, all of which are good for the environment (Aoki, 2009). Landscape designers and architects now have an• option with pervious concrete for incorporating vegetation into otherwise paved places like parking lots and city streets.

From a performance perspective, pervious concrete is advantageous because it reduces the likelihood of floods, replenishes ground water levels, absorbs noise and thermal energy, and encourages the growth of plants, all of which are good for the environment (Aoki, 2009). The following goals will guide the research, development, and building of pervious concrete pavement: Study the characteristics of previous concrete and construct its mixture design by adjusting the proportions of coarse aggregate, water, and cement.

The purpose of this project is to improve the formulation of pervious concrete by utilizing chemical additives and coarse particles. The goal of this lab experiment is to create a miniature version of a pervious concrete road. In order to build pervious concrete pavement in the field and study its performance over a longer period of time.

4. Aims of the Research:
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II. LITERATURE REVIEW

The repercussions of not managing urban rainwater in developing nations are significant. Avoidable fatalities and illnesses are caused by poor monsoon water management.and the destruction of homes, businesses, and livelihoods. Inadequate management of storm water also contributes to environmental degradation and wastes precious freshwater supplies. Lack of resources makes storm water management more challenging in underdeveloped nations (Parkinson and Ole, 2005).

The following are some of the causes for the poor quality of storm water management in developing nations.

- People need access to clean water and basic sanitary facilities on a regular basis. Management of storm water occurs in cycles.
- Managing storm water is mostly a community effort. The public and private sectors receive no direct advantages.
- City services form the basis for storm water management. Unplanned development prevents rainwater from being safely drained from roads.
- In many situations, the natural drainage system is messed up when new structures are constructed. This prevents water from entering the sewers. The growth of cities has resulted in a greater percentage of land covered by impermeable road surfaces. As a result, rain floods in cities are happening more frequently. Planning and construction delays in drainage infrastructure, which often flows into cities in developing nations, worsen this problem.
- While the devastating results of large-scale storm events are what most people think of when they hear the word "flood," regular minor flood occurrences can result in more local drainage difficulties owing to a lack of drainage infrastructure, as seen in Figure 2.1. The challenges connected with this sort of flood are perceived more of a problem by the impacted populations despite the fact that these minor incidences are normally not considered a severe worry compared to big flood disasters.

Figure 2.1 Lack of Drainage Infrastructure

Fig 4.

- The typical permeable pavement methods utilized for storm water management are shown in Figure 2.2.

Figure 2.2 Common type of Permeable Pavement Systems (Imran et al. 2013)

Fig 5.

- During the monsoon, water pools on the streets of most Indian towns Making the road surface permeable for quick runoff drainage is one solution to this issue. The effectiveness of permeable pavement was examined by

Gupta and Kim (2011). action to lessen the negative effects of urbanization and create greener buildings and transportation systems. Parking lots, walkways, and roads may all benefit from this without having to make any structural changes. It will increase infiltration, decrease peak flows and runoff volume, enhance water quality, and lessen thermal pollution. There is less of an effect on storm drains, and the ground water table is increased when permeable materials are used. Porous pavements and urban surfaces are possible to build with "Pervious concrete." In metropolitan areas, this permeable concrete can replace asphalt and low-permeability concrete in non-structural applications (Gupta and Kim, 2011). An in-depth analysis of the research done on pervious concrete is offered here.

The structural and technical qualities of pervious concrete, as well as its benefits to the environment, are discussed by Tennis et al. (2004). Pervious concrete is a more rigid material than regular concrete. Pervious concrete's range of allowable material proportions is listed in Table 2.1. Fly ash and slag are frequently employed as cementitious materials.

Table 2.1 provides a quick reference to the various mix proportions utilized in the creation of pervious concrete. The material attributes and laboratory trial batch results will determine the accuracy of the combination design. The compressive strength of pervious concrete decreases as the aggregate-to-cement ratio increases, as noted by the author.

Table 2.1 Mixture Proportions of Pervious Concrete [Tennis et al. (2004)]

Materials	Proportion
Cementitious materials	270 to 415 kg/m^3
Aggregate	1190 to 1480 kg/m^3
w/c	0.27 to 0.34
Aggregate : Cement ratio	4 to 4.5 :1
Fine : Coarse aggregate ratio	0 to 1:1

The use of supplementary cementitious material in the mixture design of pervious concrete is explored by Ravindraraja et al. (2011). Author replaced cement content by mass with 10%, 20% and 50% of fly ash. Aggregate cementitious ratio was taken as 4:1 and w/c taken as 0.35. Coarse aggregate size 10 mm is used for the investigation. It was seen that no significant change observed in the properties of pervious concrete.

With 374 kg/m3, McCain and Dewoolkar (2010) have a cement weight of 1660 kg/m3 aggregate. The ratio of aggregate to cement was 4.43:1. In addition to chemical admixtures like viscosity, the author also uses stabilizers, high-range water reducers, air-entraining admixtures, and modifying admixtures. A coarse aggregate of 10 mm size was employed in the formulation of the mixed design. The author shows the previous concrete's findings for compressive strength and permeability. It was WC's involvement in the evolution of previous mixture designs that was noted to be crucial concrete. When designing new mixtures, compaction techniques are crucial. Making permeable concrete designs. Suleiman et al. (2006) analyze how compaction energy affects fluid- permeable concrete. The author concludes that compression energy has a major impact on what makes pervious concrete so special. The research findings regarding lower cement content and its implications were provided by Sriravindraraja et al. (2012). Reusing crushed rock in permeable concrete Up to 70% of the cement weight can be substituted with GGBFS cement. The ratio of water to cement utilized in making pervious concrete was 0.33 pervious concrete writers also considered.

Properties of pervious concrete using acidic pumice as coarse aggregate were studied by Oz Hatice in 2018 aggregates. Crushed limestone and acidic pumice with coarse aggregate sizes of 10-12 millimeters made use of. Twelve batches of pervious concrete were made using the same water- to-cement ratio a 0.3:1 proportion. 300 kg/m3 of cement load and the mixture was proportioned at 420 kg/m made of porous concrete. Compressive and flexural strengths, as well as other concrete characteristics, tests were conducted to measure and compare things like strength, split tensile strength, void ratio, and permeability. It was revealed that the aggregate's compressive and flexural strengths decreased when acidic pumice was used.

Thus the tensile strength of pervious concrete can be divided. The research conducted on the combination design advancement of pervious specifically, we saw the following. A cement content of around 150 kg/m3 was employed to 412 kg/m3. The size of the coarse aggregate utilized was between 25 millimeters and 2.36 millimeters. The ratio of aggregate to cement utilized was between 10:1 and 4:1. The ratio of water to cement used was between 0.27 and 0.51 Section 2 18. In the present study, cement percentage was measured to aid in the formulation of pervious concrete blend designs. 250 kg / m3 to 400 kg / m3 ratios of 4: 1 for aggregate to cement and 0.3:0.4 for water to aggregate taken. It was decided to use a blend of 20mm-10mm-10mm-4.75mm natural coarse aggregate making permeable concrete designs. For the purposes of creating a, the aforementioned variables were chosen design of pervious concrete mixtures using the existing literature as a guide.

Characteristics of Water Permeable Concrete Since pervious concrete contains significant voids (15%-30%), its characteristics are crucial. in contrast to regular concrete. Benefits of pervious concrete include properties including pliability, void ratio, permeability, compressive strength, flexural strength, and density essential in a variety of fields. Pervious concrete's many qualities are described below. Workability There is currently no established norms for gauging the workability of pervious concrete literary works. In most cases, the slump test is the gold standard for determining the workability of ordinary cement. Nonetheless, the slump test is not an appropriate method for gauging the strength of pervious concrete workability. The consistency of pervious concrete is much more rigid than that of regular concrete. Because of this, the slump test is not recommended for determining the workability of pervious concrete. The results of the slump test often showed no slump. Transparent concrete handball may be fabricated, and its viability evaluated. This decline was explored by Obla (2007).

The permeable concrete values might be anything from 20 mm to 50 mm. Yukari and Sriravindraraja (2012) proposed a handball drill as a means of gauging the workability of pervious concrete during the mixing of concrete. A small number of sneaky people, according to Tennis et al. Figure 2.3 demonstrates that a ball of concrete will not crack when dropped. In particular, (a) enough water, not enough water, and an abundance of water, respectively. Since pervious materials may be shaped, the success of concrete depends on managing its water content. It is noted that current data is insufficient to evaluate the viability of pervious concrete. Therefore, it is important to establish reliable methods for gauging the viability of fluid-permeable concrete.

(a) (b) (c)

Figure 2.3 Workability of Pervious Concrete (Tennis et al. 2004)

Lafarge hydro media guideline (2010) suggested paste flow test measurement is useful for workability of pervious concrete. Generally one hour is recommended between placing and mixing for pervious concrete. Though, this can be controlled with chemical admixtures that prolong the working time up to 1.5 hours, depending on the dosage.

Fig 6.

III. EXPERIMENTAL PROGRAMME

An experimental examination is carried out to explore the attributes of pervious concrete, including its density, water permeability, compressive strength, flexural strength, void ratio, and infiltration rate, and they are presented in this chapter. This chapter also delves into the specifics of how to cast pervious concrete and its resulting characteristics.

Materials, mixture proportions, measurements, and the testing methodology utilized in this study are all detailed in this section.3.2 Components In this study; we used natural coarse aggregate, VSI coarse aggregate, cement, water, and chemical admixture to make pervious concrete. Standard Portland cement formulated per IS 12269 (2013) is employed here. Table 3.1 displays the typical Portland cement's physical characteristics.

Table 1.

Table 3.1 Physical Properties of Ordinary Portland Cement

Properties for 53 grade OPC	Result Availed	Specification in IS 12269 (2013)
Fineness in m^2/kg	351	Min 225
Soundness By Le chatelier method in mm	0.4	Max 10
Initial setting time in minutes	35	Min 30
Final setting time in minutes	240	Max 600
3 days compressive strength in MPa	28.75	Min 27
7 days compressive strength in MPa	39.85	Min 37
28 days compressive strength in MPa	54.47	Min 53
Specific Gravity	3.15	3.15

IV. RESULT AND DISCUSSION ON LABORATORY BASED ON MIXTURE DESIGN OF PERVIOUS CONCRETE

Lab work is done first to determine how much of each ingredient should be used in making pervious concrete pavement. The mix proportions chosen for preliminary laboratory research toward the creation of a mixture percentage of pervious pavers are displayed in Tables 3.9 and 3.10.concrete. Cement contents between 250 and 400 kg/m3 are employed in the creation of mixture design, as shown in Tables 3.9 and 3.10. For the purpose of developing the mixture design of pervious concrete, two sizes of aggregates have been studied in the lab.Coarse aggregates of the sizes 10 mm - 4.75 mm (Size-A) and 20 mm - 10 mm (Size-B) are employed in the mixture design development. Compressive strength, void ratio, permeability, and density are some of the concrete characteristics of previous discovered through laboratory testing concrete discovered through laboratory testing.

The following section presents the specifics of the investigation's findings

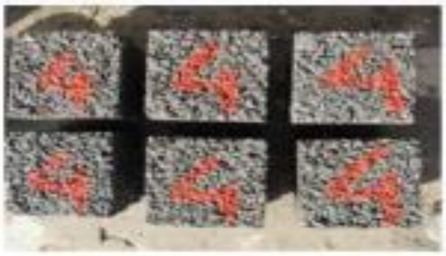

Figure 4.1 Texture of Size-A Coarse Aggregates

Fig 7.

Table 2.

Table 3.2 Physical properties of Natural Coarse Aggregates

Properties	20 mm	10 mm
Specific Gravity	2.82	2.79
Water Absorption (%)	1.37	1.01
Elongation index (%)	8.2	5.2
Flakiness Index (%)	28	30.52
Loose Bulk Density (kg/m^3)	1444	1350
Compacted Bulk Density(kg/m^3)	1671	1510

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Figure 4.2 Texture of Size B Coarse Aggregates

Fig 8.

Table 3.

Table 3.3 Gradation of Natural Coarse Aggregates (20 mm downsize)

Sieve size	Mass Retained (gms)	Mass Retained %	Cumulative % of Mass Retained	Cumulative % of Passing
20mm	0	0	0	100
10mm	635	63.5	63.5	36.5
4.75mm	325	32.5	96	4
2.36mm	40	4	100	0
1.18mm	0	0	100	0
600	0	0	100	0
300	0	0	100	0
150	0	0	100	0
Total	1000	100	728.5	--------
Fineness modulus = 728.5/100 =7.285				

Table 4.

Table 3.4 Gradation of Natural Coarse Aggregates (10 mm downsize)

Sieve size	Mass Retained (gms)	%Mass Retained	Cumulative % of Mass Retained	Cumulative % of Passing
20mm	0	0	0	100
10mm	63	6.3	6.3	93.7
4.75mm	902	90.2	96.5	3.5
2.36mm	35	3.5	100	0
1.18mm	0	0	100	0
600	0	0	100	0
300	0	0	100	0
150	0	0	100	0
Total	1000	100	602.8	--------
Fineness modulus = 602.8/100 =6.028				

Table 5.

Table 4.1 Properties of Pervious Concrete using Natural Coarse Aggregates Size A (10 mm – 4.75 mm)

Mix No.	Cement (kg/m³)	w/c	Compressive Strength (MPa)	Void content %	Permeability (mm/s)	Density (kg/m³)
M 1	250	0.3	3.71	24.12	23.24	1958.50
M 2		0.35	4.67	24.3	22.21	1978.10
M 3		0.4	5.12	23.7	21.98	2105.30
M 4	300	0.3	5.50	24.98	20.69	2003.20
M 5		0.35	6.10	23.95	19.76	2115.40
M 6		0.4	6.98	23.00	19.41	2158.80
M 7	350	0.3	7.51	24.1	18.6	2018.30
M 8		0.35	8.65	23.08	18.1	2127.20
M 9		0.4	9.10	22.97	17	2179.30
M 10	375	0.3	9.3	23.3	16.5	2028.21
M 11		0.35	13.49	22.80	15.37	2137.12
M 12		0.4	14	21.3	14.98	2185.3

Table 6.

Table 4.2 Properties of Pervious Concrete using Natural Coarse Aggregates Size B (20 mm – 10 mm)

Mix No.	Cement (kg/m³)	w/c	Compressive Strength (MPa)	Void content %	Permeability (mm/s)	Density (kg/m³)
M 16	250	0.3	3.10	25.5	24.29	1908.15
M 17		0.35	3.75	24.65	23.25	1935.70
M 18		0.4	3.98	23.8	22.28	2088.20
M 19	300	0.3	4.50	25.2	21.73	1998.90
M 20		0.35	4.98	24.55	20.77	2098.20
M 21		0.4	5.65	23.3	20.51	2115.20
M 22	350	0.3	5.98	24.88	19.79	2001.20
M 23		0.35	6.50	23.2	19.43	2117.20
M 24		0.4	6.98	23.1	18.79	2165.20
M 25	375	0.3	7.19	23.8	18.5	1989.2
M 26		0.35	8.28	23.95	17.98	2120.5
M 27		0.4	10.09	21.7	16.5	2161.4

V. CONCLUSION

Due to the presence of interconnecting air gaps, pervious concrete allows for a large amount of water to pass through it. Pervious concrete has low weight and weak compressive strength because of its large porosity in comparison to regular concrete. But in recent decades, pervious concrete's popularity has exploded as its flood-fighting and groundwater-recharging abilities have been widely recognized. In this research, we created a formula for calculating the ideal ratio of ingredients for pervious concrete, and we designed and built a pervious concrete road.

Before constructing a pervious concrete pavement, it was predicted to have a certain compressive strength, void ratio, permeability, and density. Two distinct sizes of coarse aggregates (10 mm - 4.75 mm and 20 mm - 10 mm) were used to produce the mixture proportioning of pervious concrete. Natural coarse aggregates in the 10–4.75 mm size range were shown to be optimal for both surface finish and compressive strength in pervious concrete. The final mixture proportions for the pervious concrete pavement were determined after optimization of the pervious concrete mixture. Few mixture proportioning were examined for optimization of pervious concrete mixture design based on the findings of preliminary inquiry. Further investigation into the impact of chemical admixtures, a paste flow test, and variations in aggregate type led to improvements in mixture proportioning.

The w/c ratio in the final mixed proportioning of pervious concrete pavement was determined with the use of a micro slump flow test. Additionally, tests were done utilizing VSI aggregates in place of natural aggregates Changes in context. The impact of aggregate type on pervious concrete characteristics was studied. At Nirma University and the NuVOCO Vistas RMC Plant in Ahmedabad, various experimental mixes were made to perfect the formulation of pervious concrete. Compressive strength, void ratio, and density were among the mechanical parameters of the pervious concrete tested in the lab. Results from Chapter 6 135 tests on pervious concrete met or exceeded expectations. Before the actual pervious concrete pavement was installed on the field, a scale model was created in the lab.

A pervious concrete walkway measuring 3 by 10 meters was built. The pervious concrete pavement was built using a tried and true method. The literature was used to develop a drainage system for the pervious concrete surface. Perforated pipes were utilized to determine the percolation capacity of the pervious concrete pavement.

On-site, the pervious concrete was compacted with hand rollers. The pervious concrete drainage system was created to ensure that all of the water is gathered. The methodology for measuring the infiltration rate of pervious concrete pavement in the field has been developed.

A maintenance checklist for pervious concrete pavement was created. After a pervious concrete pavement has been installed, upkeep procedures are performed once a month. The pervious concrete surface was cored. The density, void ratio, and compressive strength of pervious concrete cores were measured. Core samples of pervious concrete were analyzed, and the results were compared to those from laboratory tests. The results of pervious concrete tests in the lab were determined to be within the same ballpark as those reported in the field.

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