IMPLEMENTATION OF DIFFERENT TECHINIQUES ON STUDY OF PERVIOUS CONCRETE MIXTURE DESIGN AND COARSE APPLICATIONS

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ABSTRACT:
Current climatic changes are occurring due to various human and industrial activities. In particular, the effects of urbanisation and growing threat of global warming have likely caused increasing precipitation in many geographic regions. For many years, portland cement pervious concrete (PCPC) has been making an important contribution, as a sustainable urban drainage system (SUDS), on improving environmental conditions. pervious concrete could be more considered as environment friendly concrete for sustainable construction. Pervious concrete is generally used in sidewalks, for low-traffic volume roads and for parking this special class of concrete has several other environmental benefits such as reduce tire pavement interaction noise, improved road safety because it is able to enhance the skid resistance, and reduce urban heat-island effects. A pervious concrete overlay has several inherent advantages, including reduced splash and spray and reduced hydroplaning potential, as well as being a very quiet pavement. The good performance of this overlay in a particularly harsh freeze-thaw climate, Minnesota, shows pervious concrete is durable and can be successfully used in freeze-thaw climates with truck traffic and heavy snow plowing.
Keywords: Pervious concrete, porous concrete, permeability, Concrete mixtures, Fly ash

INTRODUCTION:
With population growth, continual urbanisation has led to an increase of impervious surface areas, which block the percolation of precipitation from rainfall and snow down through the ground. This increases the potential for excess surface runoff, which can lead to downstream flooding, bank erosion and possibly transport of pollutants into potable water supplies. On the other hand, permeable pavements have the ability to reduce runoff volume and improve water quality. Indeed, they can store storm water runoff until infiltrating into soil or conveyed downstream in the storm water management system by a drain. For this reason, many communities are now exploring their use as an alternative low impact development design for storm water control measures [1]. Such permeable pavement systems can contribute to solving drainage problems and reducing the risk of flash flooding, resulting from continuous urban developments. Pervious concrete also has structural, economic and road - user benefits in pavement systems [2]. However, there is a gap in research and use of pervious concrete as a pavement material. One of the major reasons being lack of standardized technique for material preparation and testing [3], [4]. Various studies have been carried out on various parameters like aggregate grading, type of aggregate, cement paste content , water-binder ratios etc [5]. The mechanical properties such as compressive strength, permeability and void content have been studies through these parameters

PERVIOUS CONCRETE: "Pervious concrete" is a term that represents a near zero-slump, a system that is gap graded, which is usually composed of cement, coarse aggregate, less or no sand, admixtures as well as water. Blending of these components is known to produce material that is hardened and permeable allowing easy passage of water. Permeability to water depicted by the pervious concrete tends to range from 1.4 mm/s to 12.2 mm/s while its compressive strength ranges between 2.8 MPa to 28 MPa (ACI 522R, 2010). Pervious concrete also referred to as enhanced porosity concrete, no-fine concrete and porous concrete, is a novel type of concrete which is rapidly becoming popular in majority of the countries due to its use in sustainable construction. This is attributed to its capability of infiltrating large water volumes with a short time.

Figure: Typical pervious concrete pavement cross section.

Applications: Pervious concrete has been used in pavement applications ranging from driveways and parking lots to residential streets, alleys, and other low-volume roads. Within these applications, pervious concrete has been used as the surface course, as a drainable base course (often in conjunction with edge drains to provide subsurface drainage), or as a drainable shoulder (to help provide lateral drainage to a pavement and prevent pumping). The focus in recent years has been on its use as a surface course as a means of providing storm water management.

Measuring Pervious Concrete Workability: Slump is not an effective means to quantify pervious concrete workability. Since pervious concrete for slip form placement is a combination of a self-consolidating concrete and a stiff slip-formable concrete, questions persisted on workability measurement. The current method of forming a ball with the plastic pervious concrete is impossible to specify due to the lack of quantifiable values and individual bias. A new test method based on gyratory compaction was developed to characterize the workability of pervious concrete. The new test method produces consistent concrete specimens, and the output from the test quantifies the workability and compactibility of pervious concrete. Ranges of the workability parameters are suggested that can be used to assist in designing pervious concrete mixtures for specific compaction methods and to allow quantification of placeability for overlay mixture development.

Pervious Concrete Overlay Mixture Development: To ensure good performance during both the construction and service periods, a PCPC mixture for a pavement overlay must possess the following properties:

1. High workability for ease of placement
2. Uniform porosity or void structure throughout the pavement for noise reduction
3. Adequate bond with underlying pavement and proper strength for traffic load
4. Sufficient resistance to wearing, aggregate polishing, and freeze-thaw damage

A systematic study using a large number of mix designs was conducted to investigate effects of a wide variety of concrete materials and mixture proportions on PCPC performance, including concrete workability, compaction density, strength, freeze-thaw durability, and overlay bond strength. The results indicate that PCPC mixtures can be designed to be highly workable, sufficiently strong, permeable, and with excellent freeze-thaw durability, suitable for pavement overlays. Such overlays will not only function well structurally for carrying designed traffic loads but also perform well environmentally for noise reduction, skid resistance, and splash and spray.

Pervious Concrete Overlay Field Durability and Performance: Condition surveys of the overlay were conducted in 2019, 2020. The primary distress to the overlay pavement was joint deterioration. With a minor amount of cracking, the joint deterioration is believed to be the result of the method of joint placement; saw cutting the joints would have resulted in less deterioration. The joint deterioration increased each year and is likely due to snow plow effects. The flow characteristics have been measured each year, with high infiltration results and good consistency from year to year. Operations during rain events indicate that the pervious overlay quickly removes rainwater from the pavement surface and that the water migrates lateral to the side of the pavement, indicating pervious concrete is a successful tool for mitigating splash and spray as well as reducing hydroplaning difficulties.

COARSE AGGREGATE PROPERTIES:

Table 1. Coarse aggregate properties

Property	Aggregate Type	
	Limestone	Pea Gravel
Specific gravity	2.45	2.62
DRUW - kg/m^3 (lb/ft^3)	1,390 (87)	1,640 (102)
Voids in the aggregate (%)	43	37
Absorption (%)	3.9	1.7
Micro deval abrasion (%)	36.4	14.4
Sieve	**Percent Passing**	
19.0 mm (3/4 in.)	100.0	100.0
12.5 mm (1/2 in.)	99.9	99.8
9.5 mm (3/8 in.)	88.5	99.7
4.75 mm (No. 4)	22.9	21.8
2.36 mm (No. 8)	4.3	1.2

The mixture proportions of the pervious concrete studied are shown in Table 2. The fine aggregate is standard concrete river sand with a specific gravity of 2.62 and a fineness modulus of 2.9. The cement is a Type II, marketed as a Type I/II, with a specific gravity of 3.15 and a Blaine fineness of 384 m2 /kg. A polycarboxylate-based high-range water reducer (HRWR) was used for all mixtures. The natural AEA (N) was a vinsol resin type, and the synthetic AEA (S) was olefin based. A total of ten mixtures was studied.

METHODOLOGY:

Materials and Methods: The work was carried out to find compressive strength, split tensile strength and permeability of pervious concrete by using locally available materials which are given below

Cement: The cement used was 53 grade Ordinary Portland Cement (Ultra Tech) confirming to properties like specific gravity, initial and final setting time and fineness.

Fine Aggregates: Natural river sand is used as fine aggregate in the study. The sand is tested for various properties like specific gravity, bulk density and water absorption. In this present study coarse aggregate is partially replaced with 0% , 5 % and 10% fine aggregates. The aggregate : cement ratios were maintained on the basis of weight not volume. Appropriate weights were taken to the second decimal to determine the amount of cement and aggregate required for each mix.

Coarse Aggregates: Crushed granite of 10 mm and 20 mm nominal size are used as coarse aggregate. A different proportion of (20 mm: 10 mm) in ratios of 50:50 was used. The normal maximum size is gradually 10-20 mm; however particle sizes up to 40mm or more have been used in self compacting concrete. Regarding the characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of interlocking of angular particles, while rounded aggregates improved the flow because of lower internal friction

.Locally available coarse aggregate having the maximum size of 20mm was used in this work.

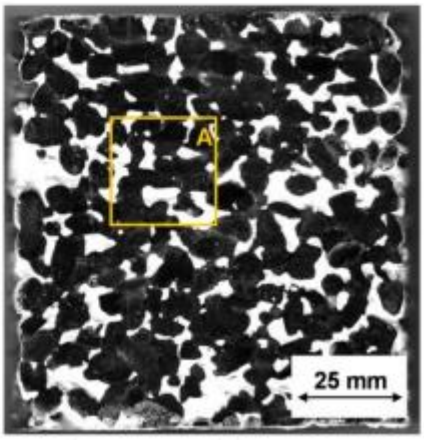
Water: Locally available water has been used for mixing and curing which is potable and free from impurities like oils, salts, sugar, organic materials etc. Water was added to various mixtures of aggregate and cement in experiments designed to maximize hydration and optimize compressive strength. The goal is to determine an appropriate range of W/C ratios that will yield high compressive strengths in the pervious concrete.

Admixtures: Commercially available fly ash, micro silica and nano silica are used as admixtures . The fly ash used was class F from Hyderabad industries Ltd., Its specific gravity is 1.97. Micro silica used in this work was obtained from Oriental Texxim pvt ltd). Its specific gravity is 2.2. Nano silica used was from Elkem industries, with its specific gravity as 2.12 and particle size of 17nm. Conplast SP 430– super plasticizer is used in this research. It is mixed with 0.7% by the weight of cement and then mixed with water.

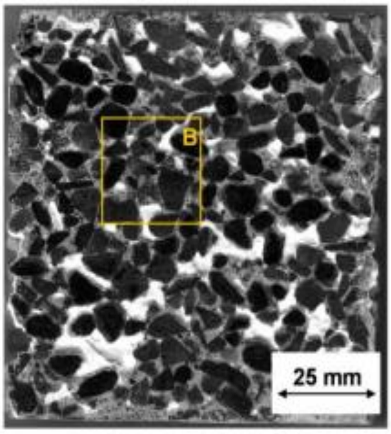
Figure: (a) Fly ash (b) Micro silica (c) Nano silica

Table 1: Pervious concrete mix designations with quantities of ingredients used in mixtures

S.No	Mix Designation	Cement Kg/m^3	Sand Kg/m^3	Coarse aggregate Kg/m^3	Water Kg/m^3	Fly ash Kg/m^3	Micro silica Kg/m^3	Nano silica Kg/m^3
1.	PCF0	350	0	1698	119	0	0	0
2	PCF5	350	85	1613	119	0	0	0
3	PCF10	350	169	1529	119	0	0	0
4	FPCF0	266	0	1843	129	114	0	0
5	FPCF5	266	92	1751	129	114	0	0
6	FPCF10	266	184	1659	129	114	0	0
7	MPCF0	342	0	1843	129	0	38	0
8	MPCF5	342	92	1751	129	0	38	0
9.	MPCF10	342	184	1659	129	0	38	0
10	NPCF0	388	0	1940	136	0	0	12
11	NPCF5	388	97	1843	136	0	0	12
12	NPCF10	388	194	1746	136	0	0	12



(a) Limestone with no AEA



(b) Limestone with double synthetic AEA

Figure: Images of typical pervious concrete samples

Table. Variation of Rapid Air tests for a typical sample

	Total Air (<4 mm)			Entrained Air (<1 mm)		
PG-N2	Air (%)	SpF (mm)	SSA (mm^{-1})	Air (%)	SpF (mm)	SSA (mm^{-1})
1 (0°)	16.53	0.054	22.47	7.04	0.057	50.09
2 (90°)	15.51	0.051	25.39	6.66	0.053	56.80
3 (180°)	15.21	0.050	26.70	8.89	0.051	44.23
4 (270°)	16.15	0.053	23.54	6.76	0.056	53.47
Average	15.85	0.052	24.53	7.34	0.054	51.15
Std dev.	0.60	0.002	1.89	1.05	0.003	5.36

RESULTS:

The research conducted at ISU included studies of the materials used in the pervious concrete, the mix proportions and specimen preparation, the resulting strength and permeability, and the effects of freeze-thaw cycling. A variety of aggregate sizes was tested and both limestone aggregates and river run gravels were used. The effects of the addition of sand, latex, and/or silica fume on the resulting behavior were investigated. The key parameters investigated were strength, permeability, and freeze-thaw resistance. The overall results can be summarized in Figure 1, where it can be seen that an interdependent relationship exists between the void ratio, seven-day compressive strength, and permeability of the pervious concrete. Shown in the figure is a target range of void ratio between 15% and 19% in which the strength and permeability are sufficient for the intended purpose. Subsequent freeze-thaw tests showed that a durable mix can be developed.

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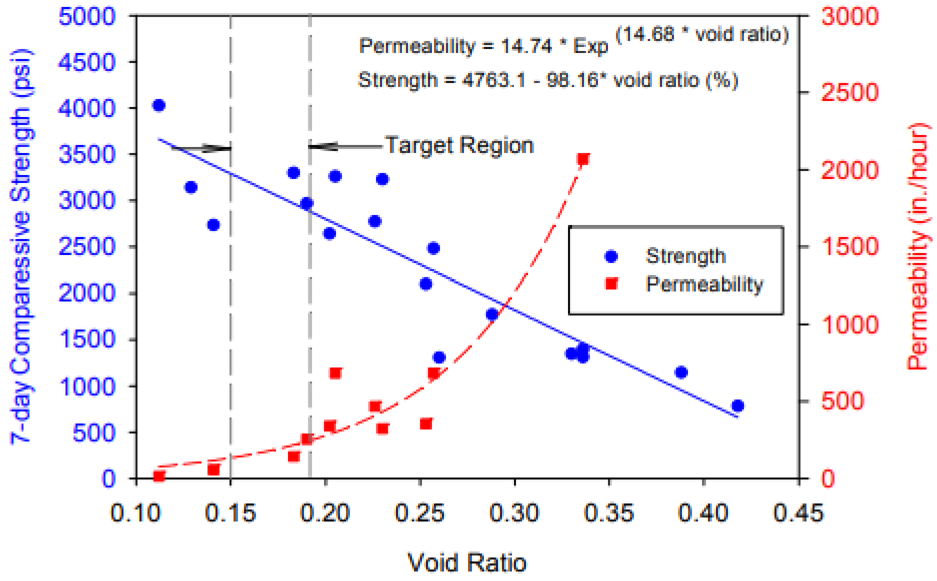

Figure 1. Relationship between pervious concrete void ratio, permeability, and seven-day compressive strength for all mixes placed using regular compaction energy

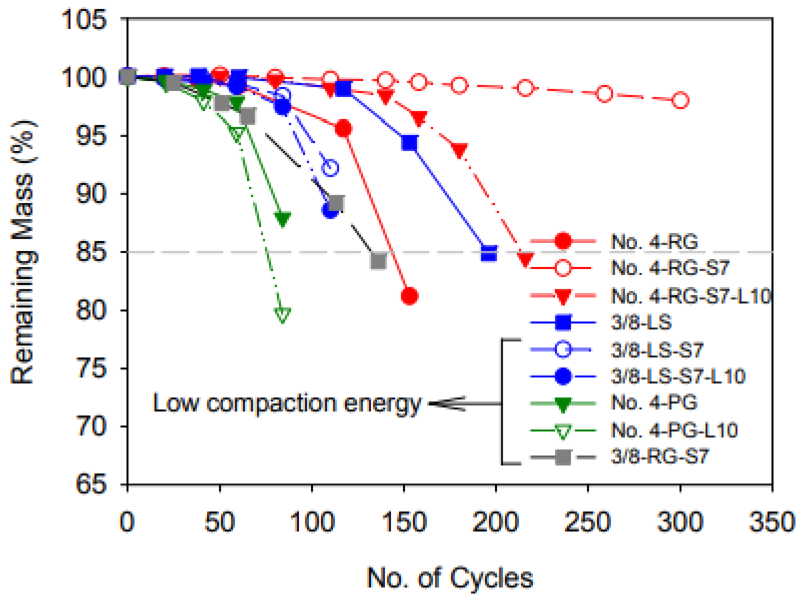

Figure. Results of freeze-thaw durability

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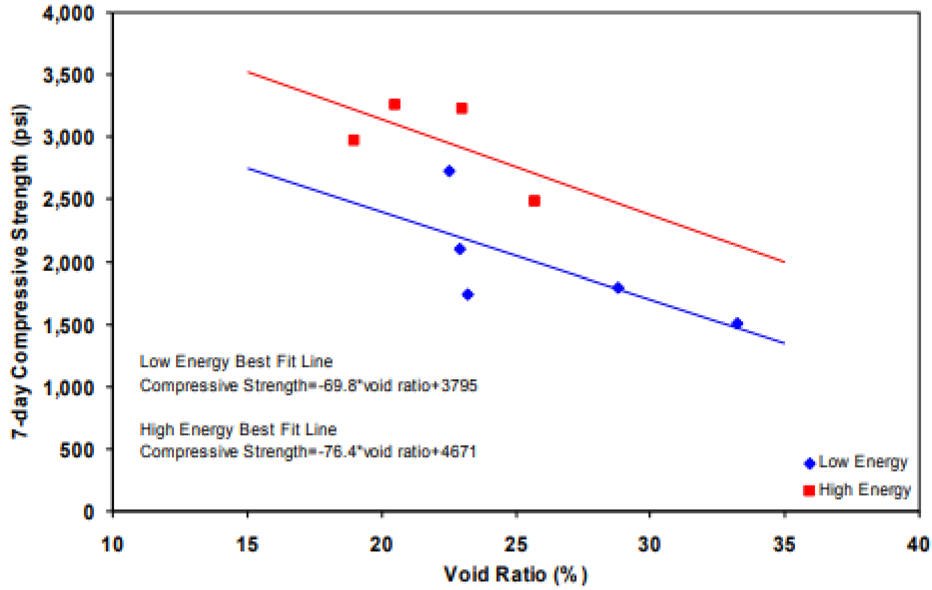

Figure. Comparison of results with two compaction energies

For the three sizes of river gravel (No. 4, 3/8 in., 1/2 in.), larger aggregate size produces concrete mixes with higher void ratio. Pervious concrete mixes made with aggregates of higher abrasion resistance results in higher-strength pervious concrete.

Pervious concrete engineering properties vary as a function of void ratio. The compressive strength decreases linearly as the void ratio increases, unit weight decreases linearly as the void ratio increases, and permeability increases exponentially as the void ratio increases, with rapid increase in permeability at void ratios greater than 25%.

Compaction affects pervious concrete properties by reducing compressive strength, split strength, and unit weight, as well as increasing permeability. For example, the average seven-day compressive strength at 22% void ratio is reduced from 2,603 psi to 2,315 psi, which represents an 11% reduction. Split tensile strength is reduced from about 12.3% to about 9.5% of the compressive strength as the compaction energy reduces from regular energy to low energy. However, the average permeability of pervious concrete at a void ratio of 22% increases from 372 in./hr to 614 in./hr, which represents a 65% increase.

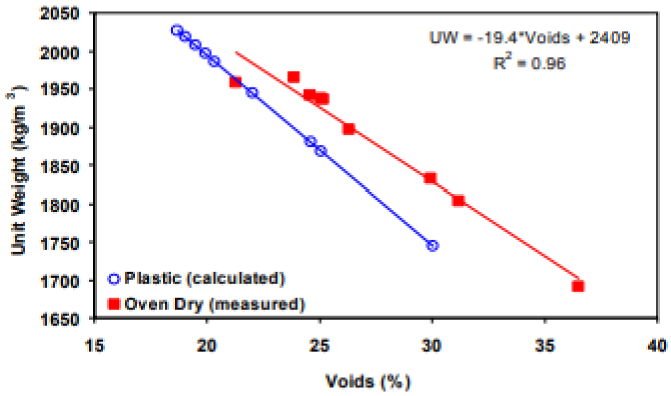

Figure. Relationship between voids and unit weight of pervious concrete samples made with gyratory compaction

The relationship between splitting tensile strength and compressive strength for pervious concrete is between 12% and 15% of the compressive strength (Schaefer et al. 2006). Since the determination of splitting tensile strength allows for any diameter and length specimen, splitting tensile strength was selected to report strength.

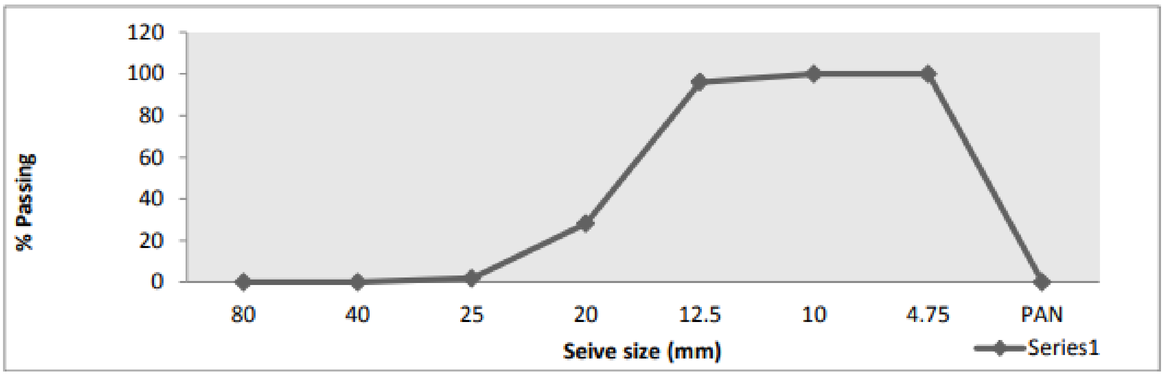

Figure: Fineness Modulus Graph for Coarse

CONCLUSION:

Based on the finding of the study, Pervious concrete, although not as strong as conventional concrete, may provide an acceptable alternative when used in low volume and low impact areas. It is normally used without any reinforcement due to high risk of corrosion because of the open pores in its structure. It can be gainfully used to some extent to allow ground water recharging and to control intensity of urban flooding as well as to keep thermal balance in buildup areas. Some applications include pervious pavement for parking lots, rigid drainage layers under exterior areas, greenhouse floors to keep the floor free of standing water, structural wall applications where lightweight or better thermal insulation characteristics, or both are required, elements where better acoustic absorption characteristics are desired, base course for roads, surface course for parking lots, tennis courts, zoo areas, animal barns, swimming pool decks, beach structures, seawalls, embankments, etc. Under real applications the water would have sent the cement completely through the aggregate and into the sub base, leaving the aggregate with little cement for bonding. Although a wide range of compressive strengths were obtained, none of the mixtures provide strength equal to that of conventional concrete.

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