

# Studying the Effects of Water to Cement Ratio on the Mechanical Properties of Concrete

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**INDEX TERMS** Pervious concrete

## I. INTRODUCTION

RAPID urbanization has led to extensive construction of impervious surfaces such as asphalt and conventional concrete pavements, which disrupt the natural hydrological cycle. These surfaces prevent water infiltration, resulting in increased surface runoff, urban flooding, and reduced ground-water recharge. In response to these environmental concerns, there has been a growing interest in sustainable construction materials that support stormwater management. One such material is pervious concrete, a special type of concrete with a high void content that allows water to pass through its structure.

Pervious concrete is composed of coarse aggregates, cement, water, and little to no fine aggregates. Its interconnected pore network enables infiltration of rainwater, making it suitable for sidewalks, parking lots, driveways, and low-traffic roads. In addition to hydrological benefits, pervious concrete can reduce the urban heat island effect, improve skid resistance, and contribute toward LEED (Leadership in Energy and Environmental Design) credits in green building certification systems.

Despite its advantages, the widespread use of pervious concrete has been limited due to challenges in achieving an optimal balance between permeability and mechanical strength. In this study, we focus on the effects of the water-cement ratio on the physical properties of pervious concrete. To this end, two batches of 6 pervious concrete cylinders, with the second batch having a lower water-cement ratio, were made, and tested for compressive strength, split tensile strength, and permeability. Superplasticizer (SP) was used to increase the workability of the mixes made with the second recipe.

## II. EXPERIMENTAL SETUP

Two batches of 6 cylinders each were cast. Common to both batches were the cementitious material which was a mixture of cement and fly-ash in the ratio of 4:1 by mass, coarse aggregates whose sizes ranged from 4.75-9.5 mm, and polypropylene fibres. The rest of the ingredients are given in table 1.

**TABLE 1. Mix Design**

	Batch 1	Batch 2
Cement, $\text{kg}/\text{m}^3$	280	280
Fly-ash, $\text{kg}/\text{m}^3$	70	70
Water, $\text{kg}/\text{m}^3$	119	—
SP, % <sup>1</sup>	—	0.5
<sup>2</sup> hi		

### III. UNITS

Use either SI (MKS) or CGS as primary units. (SI units are strongly encouraged.) English units may be used as secondary units (in parentheses). This applies to papers in data storage. For example, write “15 Gb/cm<sup>2</sup> (100 Gb/in<sup>2</sup>).” An exception is when English units are used as identifiers in trade, such as “3<sup>1/2</sup>-in disk drive.” Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity in an equation.

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The word “data” is plural, not singular. The subscript for the permeability of vacuum  $\mu_0$  is zero, not a lowercase letter “o.” The term for residual magnetization is “remanence”; the adjective is “remanent”; do not write “remnance” or “remnant.” Use the word “micrometer” instead of “micron.” A graph within a graph is an “inset,” not an “insert.” The word “alternatively” is preferred to the word “alternately” (unless you really mean something that alternates). Use the word “whereas” instead of “while” (unless you are referring to simultaneous events). Do not use the word “essentially” to mean “approximately” or “effectively.” Do not use the word “issue” as a euphemism for “problem.” When compositions are not specified, separate chemical symbols by en-dashes; for example, “NiMn” indicates the intermetallic compound Ni<sub>0.5</sub>Mn<sub>0.5</sub> whereas “Ni–Mn” indicates an alloy of some composition Ni<sub>x</sub>Mn<sub>1–x</sub>.

Be aware of the different meanings of the homophones “affect” (usually a verb) and “effect” (usually a noun), “complement” and “compliment,” “discreet” and “discrete,” “principal” (e.g., “principal investigator”) and “principle” (e.g., “principle of measurement”). Do not confuse “imply” and “infer.”

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The following list outlines the different types of graphics published in IEEE journals. They are categorized based on their construction, and use of color/shades of gray:

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**FIGURE 1.** Magnetization as a function of applied field. It is good practice to explain the significance of the figure in the caption.

**TABLE 2.** Units for Magnetic Properties

Symbol	Quantity	Conversion from Gaussian and CGS EMU to SI <sup>a</sup>
$\Phi$	magnetic flux	1 Mx $\rightarrow 10^{-8}$ Wb = $10^{-8}$ V·s
$B$	magnetic flux density, magnetic induction	1 G $\rightarrow 10^{-4}$ T = $10^{-4}$ Wb/m <sup>2</sup>
$H$	magnetic field strength	1 Oe $\rightarrow 10^3/(4\pi)$ A/m
$m$	magnetic moment	1 erg/G = 1 emu $\rightarrow 10^{-3}$ A·m <sup>2</sup> = $10^{-3}$ J/T
$M$	magnetization	1 erg/(G·cm <sup>3</sup> ) = 1 emu/cm <sup>3</sup> $\rightarrow 10^3$ A/m
$4\pi M$	magnetization	1 G $\rightarrow 10^3/(4\pi)$ A/m
$\sigma$	specific magnetization	1 erg/(G·g) = 1 emu/g $\rightarrow 1$ A·m <sup>2</sup> /kg
$j$	magnetic dipole moment	1 erg/G = 1 emu $\rightarrow 4\pi \times 10^{-10}$ Wb·m
$J$	magnetic polarization	1 erg/(G·cm <sup>3</sup> ) = 1 emu/cm <sup>3</sup> $\rightarrow 4\pi \times 10^{-4}$ T
$\chi, \kappa$	susceptibility	1 $\rightarrow 4\pi$
$\chi_\rho$	mass susceptibility	1 cm <sup>3</sup> /g $\rightarrow 4\pi \times 10^{-3}$ m <sup>3</sup> /kg
$\mu$	permeability	1 $\rightarrow 4\pi \times 10^{-7}$ H/m = $4\pi \times 10^{-7}$ Wb/(A·m)
$\mu_r$	relative permeability	$\mu \rightarrow \mu_r$
$w, W$	energy density	1 erg/cm <sup>3</sup> $\rightarrow 10^{-1}$ J/m <sup>3</sup>
$N, D$	demagnetizing factor	1 $\rightarrow 1/(4\pi)$

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

<sup>a</sup>Gaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

if the author chooses, however it is recommended that figures are not sized less than column width unless when necessary.

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## ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank . . . .” Instead, write “F. A. Author thanks . . . .” In most cases, sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page, not here.

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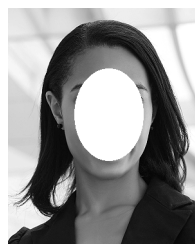


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