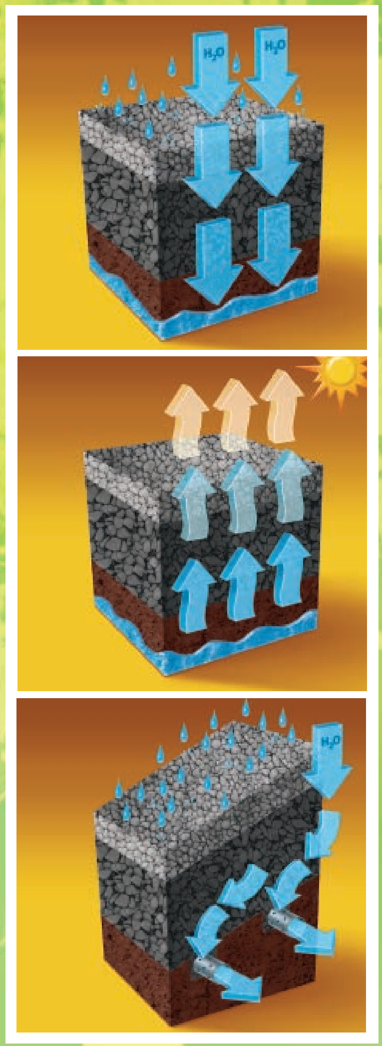
Construction

Pervious Concrete



- Recognized by USGBC
- Recharges ground water
- Reduces risk of flooding
- Improves quality of landscaping
- Allows natural filtration through soil
- Increases required permeable area

Sika®

Technology & Concepts

A Guide to Pervious Concrete

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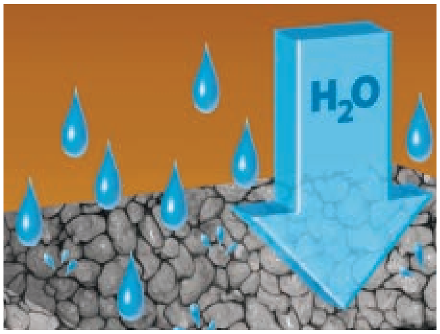
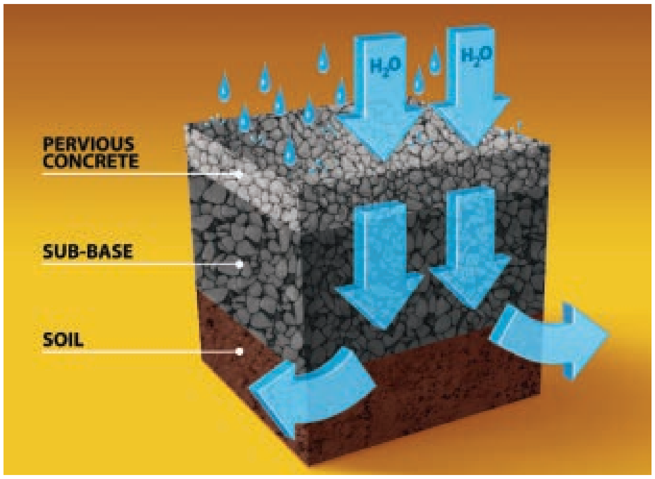


Introduction

Pervious Concrete

Over the last few years, pervious concrete has become a very relevant topic in the construction industry. More and more specifications call for pervious concrete in different applications. Some of these applications include parking lots, sidewalks and even pavers where in the past these were solely the domain of conventional concrete or black top. The popularity of pervious concrete continues to rise with the increased awareness of environmental protection and preservation. Pervious concrete is recognized by United States Green Building Council (USGBC), which sets the green building rating system known as the LEED program (The Leadership in Energy and Environmental Design). The LEED program is the nationally accepted benchmark for the design, construction, and operation of high performance “green” buildings.



Definition

Definition of Pervious Concrete

Pervious concrete, sometimes referred to as “no-fines concrete,” is a mixture of hydraulic cement, coarse aggregate of smaller size, admixtures and water. Pervious concrete allows the water to percolate through the concrete into the sub-base and recharge the underground water level. Typically, pervious concrete does not contain any sand and its air void content varies between 15 and 30%. A small amount of sand can be used for compressive strength improvement but air void content will be reduced and permeability lowered. It is important to maintain the proper volume of paste/mortar in the mix design so that the aggregate is equally coated but the excess of paste/mortar does not fill the void space within coarse aggregate. Voids within the pervious concrete should be interconnected so they create channels through which water can freely flow.

History

The History of Pervious Concrete

In Europe, pervious concrete, most commonly referred to as Gap graded concrete, has been used in the construction industry for approximately 150 years. The initial usage of this type of concrete in Europe was in applications such as prefabricated panels, steam-cured blocks or cast-in-place load-bearing walls for single and multi-story houses and, in some instances, in high-rise buildings.

In 1852, Richard Langley used a predecessor of pervious concrete for the construction of two concrete houses on the Isle of Wight in the United Kingdom. This concrete consisted of only coarse gravel and cement. It is not mentioned in the published literature again until 1923, when a group of 50 two-story houses were built with clinker aggregate in Edinburgh, Scotland. In the late 1930s, the Scottish Special Housing Association Limited adopted the use of pervious concrete for residential construction. By 1942, pervious concrete had been used to build over 900 houses.

A larger amount of pervious concrete was used after World War II when sufficient volumes of building brick could not be produced to support housing needs. Less expensive building construction methods were explored and pervious concrete was one of them. In some countries, coarse aggregate was used for the production of pervious concrete and in other countries, brick rubble was utilized. Over time, the brick rubble was exhausted and replaced by crushed or natural coarse aggregate. Lower production costs led to the acceptance of pervious concrete as a building material. Pervious or gap graded concrete was mostly used in construction housing applications. Many new houses were built using pervious concrete in the United Kingdom, Germany, Holland, France, Belgium, Scotland, Spain, Hungary, Venezuela, West Africa, the Middle East, Australia, and Russia.

Before World War II, the use of pervious concrete had been limited to two-story housing but after World War II, the pervious concrete technology had advanced and could be used in buildings up to ten stories high.

The reason that the usage of pervious concrete in the United States falls far behind the European countries is due to the fact that no building material shortages have been experienced in the United States, therefore little effort has been made to explore and develop new alternative materials.

Current applications are not as focused on building construction as they were in the past but today, pervious concrete is primarily used for the paving of parking lots, driveways or sidewalks. (ACI 522R-06)

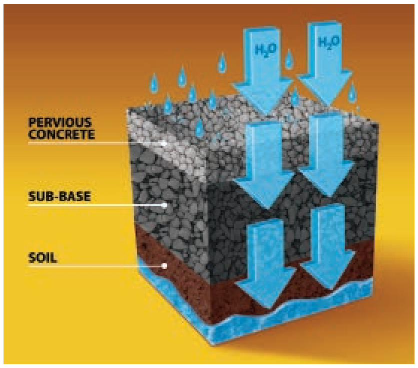
Advantages

The advantages of pervious concrete can be classified into 3 basic categories.

Environmental

More and more attention is being paid to the impact of the construction industry on our living environment. The Clean Water Act (1977) mandates State counties and Municipalities to adopt steps and procedures to reduce the amount of polluted storm water. Since parking lots are generally impermeable surfaces, they contribute significantly to this issue. The use of pervious concrete is well-suited for this application.

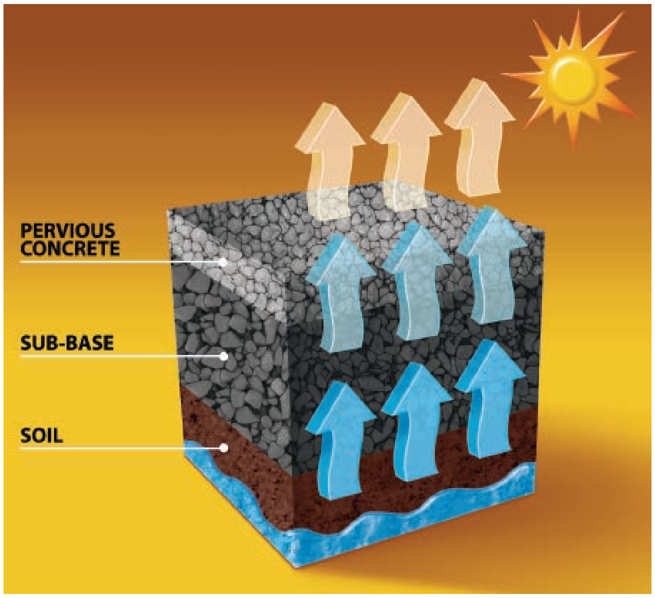
- ▲ Reduces the size and sometimes the need for storm water runoffs
- ▲ Recharges the ground water level
- ▲ Allows for the natural treatment of polluted water by soil filtration
- ▲ Does not create heat islands due to its light color
- ▲ Reduces risk of flooding and top soil wash away
- ▲ Improves the quality of landscaping and reduces the need for watering



Previous concrete allows for recharging the ground water level.

Safety

- ▲ Reduces tire noise – Due to open interconnected air void structure, pervious concrete has been found to act as an effective acoustic absorbent. The tire noise generated between tire and pavement is lower with pervious concrete as compared to conventional concrete or blacktop.
- ▲ Prevents glare – Pervious concrete allows the water to flow freely through the surface which reduces glare, especially at night when the road is wet.
- ▲ Reduces hydroplaning and flooding – When pervious concrete is designed correctly all the precipitation should be absorbed by sub-grade or diverted away from pavement by a drainage system (in case of low absorption sub-grade). This results in reduced flooding and a puddle-free surface, eliminating hydroplaning.



Part of the water absorbed by the soil under pervious concrete will change to water vapor. During this change, energy in the form of heat is absorbed, causing a natural cooling effect.

Economics

Savings and other benefits that come with the usage of pervious concrete are due mostly to the following factors:

- ▲ Reduces or eliminates the need for storm sewers or retention ponds
- ▲ Increases facilities for parking by reducing water retention areas
- ▲ Increases permeable area and may qualify for permeable area credit
- ▲ Recognized by Leadership in Energy and Environmental Development (LEED)
- ▲ Requires less costly repairs than black top
- ▲ Longer service life and lower life cycle cost than asphalt

Example A

Total project area :	**100%**	**40,000 sq.ft**
Minimum required pervious area :	**25%**	**10,000 sq.ft**
Retail area :	**50%**	**20,000 sq.ft**
Parking area :	**25%**	**10,000 sq.ft**

Area credit assigned to pervious concrete by local municipality is 50%

If parking lot is made of pervious concrete the owner would be given area credit equal to 50% of the pervious concrete area (10,000 x 0.5 = 5,000 sq.ft).

Therefore the retail area could be expanded by another 5,000 sq.ft (12.5%) while complying with local codes for required pervious area.

Keep in Mind...

Pervious concrete is only as good as its design and installation. The initial design and proper installation is absolutely critical for long term durability and proper functioning of the entire system. It is important for the designer and contractor to be fully aware of the possible consequences of improper design and installation, and to have a full understanding of the function of each component in a pervious pavement system.

- ▲ To function properly, pervious concrete should be used on flat/low grade areas
- ▲ In comparison with conventional pavements, pervious concrete requires stricter measures be taken when preparing the sub-base in order to achieve the required permeability
- ▲ Mechanical properties prohibit the use of pervious concrete in certain applications, such as high speed roads or roads exposed to heavy load traffic
- ▲ Maintenance such as vacuuming or sweeping may be required in certain areas to preserve pervious properties

Applications*

Low-volume traffic pavements	*Patios*	*Floors for greenhouses*	*Pavement edge drains*
Sidewalks and pathways	*Artificial reefs*	*Fish hatcheries*	*Groins and seawalls*
Parking areas	*Slope stabilization*	*Aquatic amusement centers*	*Noise barriers*
Driveways	*Well linings*	*Zoos*	*Walls (including load-bearing)*
Low water crossings	*Tree grates in sidewalks*	*Hydraulic structures*	*Residential roads and alleys*
Tennis courts	*Foundations*	*Swimming pool decks*	*Sub-base for conventional concrete pavements*

(*source NRMCA)

Mix Design

Pervious concrete contains large amounts of interconnected air voids which allow water to pass through rapidly. The typical air void content of pervious concrete is between 15–30% allowing a flow rate of 2–18 gal/min/ft². Structural properties can be altered by the addition of finer aggregate. A minimum of 15% air void content is necessary to provide sufficient permeability.

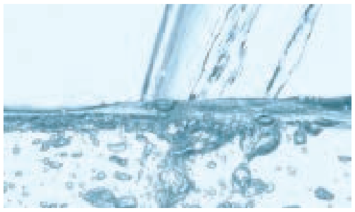
Aggregates

Pervious concrete has little or no fine aggregates in the mixture. Aggregate size is typically between 3/8 to1/2 inch maximum. Larger aggregate may not be suitable as it may cause the surface to be too coarse, which may not be acceptable for local codes in terms of surface roughness. Natural or crushed aggregate can be used. In general, rounded aggregate will require less compaction effort than crushed aggregate. The aggregate should be kept moist or wet especially when high temperatures are expected. If dry aggregate is used, the absorption and moisture content must be considered as pervious concrete mix designs work with low w/c ratio. Insufficient amount of free water can lead to excessive drying and possibly to improper compaction. Adversely, too much water will make the paste/mortar too thin, causing an improper bond between aggregates and allowing paste/mortar seepage. The paste/mortar seepage will result in lower permeability rates of the system.

The aggregate to cement ratio usually falls between 4:1 to 5:1. If fine aggregate or sand is used, special precautions must be taken in order to maintain the air void content and provide a sufficient water flow rate. The use of fine aggregate will improve the compressive strength but reduce the permeability rate.

Cementitious Materials

Typically Type I cement is used for the production of pervious concrete. The usage of other cement is possible but depends on local availability. The cement content varies between 450 lbs/cu.yd. up to 700 lbs/cu.yd. Supplementary cementitious materials such as flyash or slag can be used in exchange up to about 25% (flyash) and up to about 50% (slag) of cement.



Water

Water meeting standard requirements for conventional concrete can be used for the production of pervious concrete. No special requirements in terms of water quality are necessary. The water content of pervious concrete is determined in the same way as conventional concrete. Testing has indicated that a water/cement ratio in the range of 0.27– 0.35 allows for best dispersion of cement paste/mortar and best coating of aggregate particles. With lower w/c ratio, balling of the mix can be observed. In this case, a water reducing admixture should be added to improve workability.

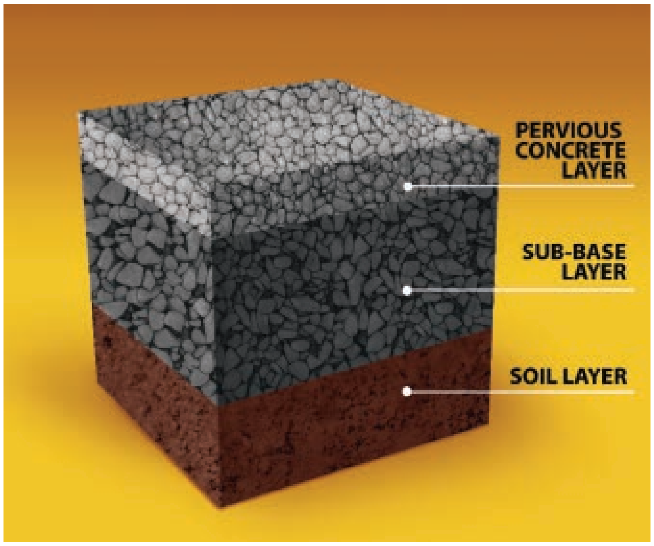
Admixtures

Chemical admixtures play a significant role in paste/mortar quality, which ultimately determines the quality of pervious concrete.

- Water reducing admixtures may be used for lowering w/c ratio and increasing the strength of paste/mortar.
- Retarding / Accelerating admixtures allow one to adjust the setting properties of concrete in relation to ambient conditions.
- Air Entraining Admixtures may be used to improve the freeze/thaw durability of the paste/mortar.
- Other specialty products such as Viscosity Modifying Admixtures (VMA), latex-based admixtures, or water repellents may be used to ease placement, compaction and improve placement speed. Water repellents have a positive impact on overall durability.
- Color/pigment additives in powdered or liquid form can be used for the production of colored pervious concrete. In general, it is recommended to use integral colorants as there is always initial raveling when a structure is put in service. External surface paints, if not applied properly, can also reduce the permeability of the pavement.

Typical composition of Pervious Concrete:

Pervious concrete describes a zero inch slump concrete made of gap graded coarse aggregate, portland cement, little or no fine aggregate, admixtures and water. Pervious concrete is not specified by w/c ratio or workability like other types of concrete. The quality of pervious concrete is measured by air void content, water permeability rate, and unit weight. These properties are important for the proper functionality of this material. Higher compressive strength is a plus but not a determining factor for quality.



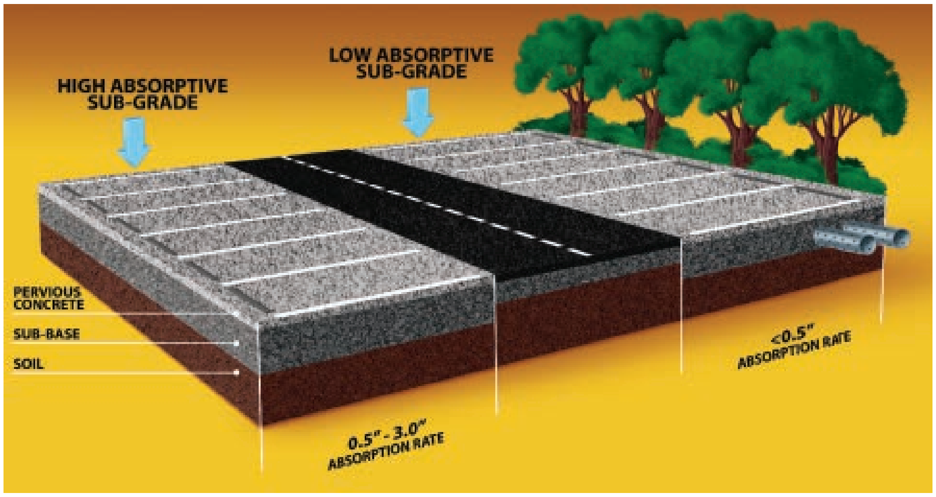
As compared to conventional or self-consolidating concrete, pervious concrete works as a system composed of several components. Each component is critical to the overall functionality of the final product. There are four basic parts in pervious composition:

1. The Pervious Concrete layer

The topmost layer of a pervious concrete system is in direct contact with traffic and the surrounding environment. It is made up of small, coarse aggregate (usually #8), cementitious materials, water and admixtures. The air void content of this layer is approximately 15–30%. This layer must be strong enough to withstand direct traffic and durable enough to resist various types of weather conditions. The typical thickness of a pervious concrete layer depends on the traffic load but usually falls between 5–10 inches.

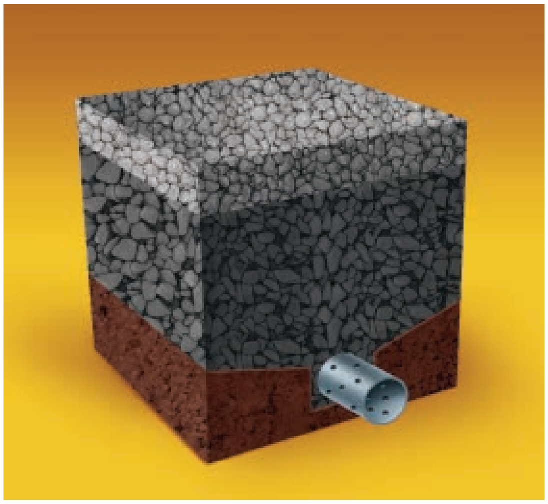
2. Sub-base layer

This section is placed underneath the pervious concrete layer. It is made up of coarser aggregate (up to 1½") and serves as a storage reservoir for water passing through the first layer. The thickness of this layer varies based on local conditions as well as the amount and size of average rainfall in the given area. In general, for the majority of projects the height of this layer is more than 9 inches.



3. Sub-grade layer

This is the undisturbed soil underneath the sub-base layer. Sub-grade layer infiltration rate determines how much water can be absorbed within a given time. This directly affects the size of the sub-base layer. If the infiltration rate is too low, larger sub-base or drainage should be considered. If the sub-grade is too fine, it may be necessary to place geo-textile in between the sub-base and sub-grade to minimize the migration of fine soil particles into the sub-base. Omitting this could lead to clogging and reduced retention capacity.



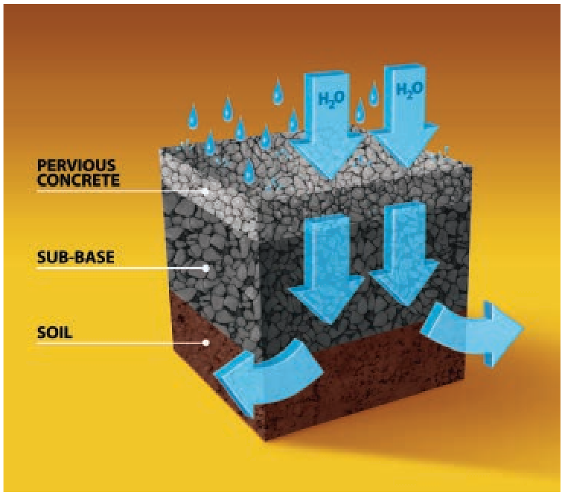
4. Drainage

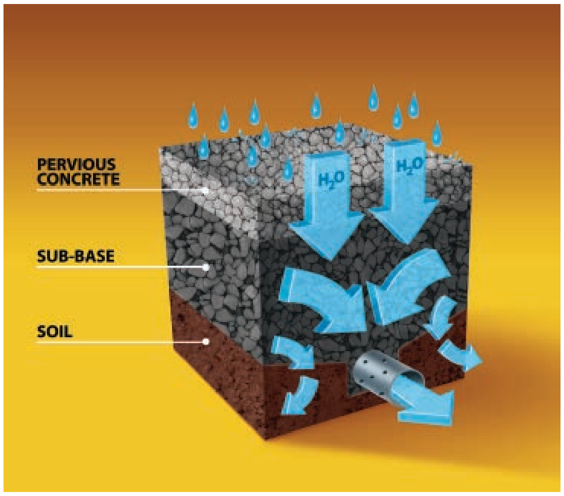
A drainage system is not always necessary but may be needed when the infiltration rate of the sub-grade layer is low and water contained in the sub-base cannot be absorbed by soil quickly enough. Drainage systems are very often incorporated in projects when pervious concrete is placed on graded sub-grade. In this case, drainage prevents excessive migration of water underneath the sub-base layer and reduces the possible transport of fine soil to the lowest spot of pavement, where clogging can occur.

The final composition of pervious concrete is to be determined by the designer/engineer.

Sub-grade Applications

Leveled and Elevated





Typical cross sections of pervious concrete pavements. On level sub-grades, stormwater storage is provided in the pervious concrete surface layer (15% to 25% voids), the sub-base (20% to 40% voids), and above the surface to the height of the curb (100% voids). (source ACI 522)

Leveled sub-grade

A well-prepared, uniform sub-grade at the correct elevation is essential to the construction of a quality pavement. The sub-grade should not be disturbed, muddy, saturated, or frozen when placement begins. The sub-grade soils should be moistened before concrete placement. Failure to provide a moist sub-base may result in a reduction in strength of the pavement and can lead to a premature pavement failure. If the sub-grade soil properties require that an aggregate recharge bed be incorporated into the drainage design of the site, it should be placed on the prepared sub-grade, compacted, and trimmed to the proper elevation.

Elevated sub-grade

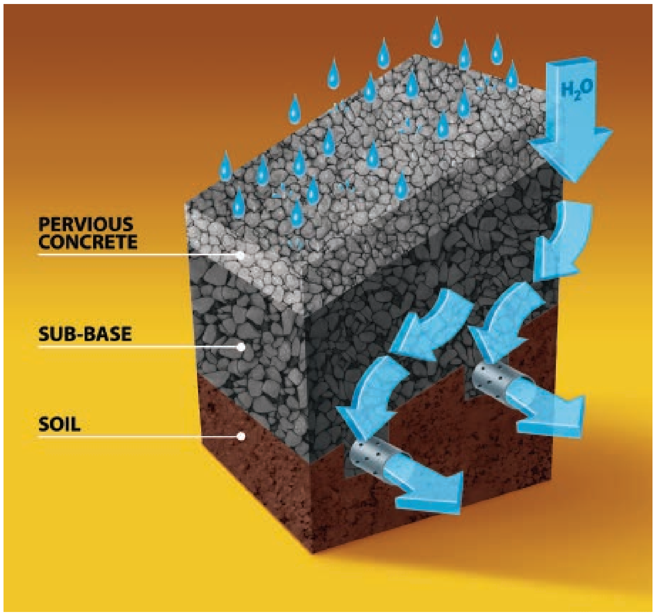
Pervious concrete can be placed on elevated sub-grades. To avoid issues such as low storage capacity at the lowest point of concreted area or soil washout and soil migration under the pavement, several factors should be considered.

The infiltration rate of soil should be high enough to absorb percolating water fast enough so there is a minimal amount of water freely flowing under pavement to the lowest spot. This will prevent flooding of the lowest part of the structure.

If an infiltration rate is not sufficient and water can't soak in fast enough, the reservoir in the lowest part of the structure should be enough to accommodate for the freely flowing water without flooding the top pavement.

In cases where this is not practical due to the size and slope of the structure, it may be necessary to create artificial trenches across the slope that are filled with coarse rock and/or drainage system in which free flowing water will be trapped and diverted to other areas where it can soak freely into the ground.

To prevent migration of soil and possible reduction of permeability of concrete, the use of geo-textile or filter fabric is recommended. This is important especially in cases when trenches must be made.



Testing

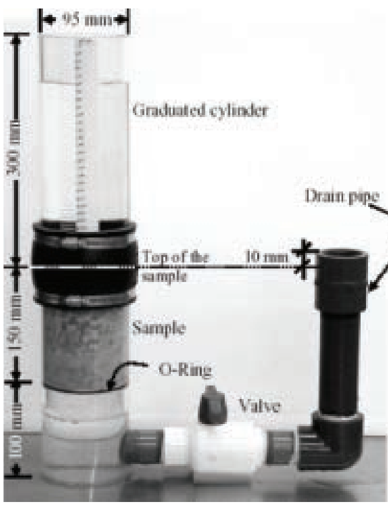
Permeability

Permeability is a measure of the ability of a material (typically unconsolidated material) to transmit fluids. The permeability can be determined by percolation rate. Percolation rate is expressed by gallons/ft^2/minute or liter/m^2/minute. Percolation rate can be determined experimentally by using a simple device called a ***permeameter***. The time needed for percolation of known volume of water through the sample is measured and the coefficient of permeability can be expressed as:

$$k = \left(\frac{A}{t}\right)$$

[in/s], where A = 0.35 in
and t = time required for water to fall from head h1 to head h2.

The flow rates of pervious concrete depend on factors such as materials used, type of placing, and compaction. Typical flow rates of pervious concrete are between 3–18 gallons /ft^2/minute 120–720 liter/m^2/minute.



Permeameter

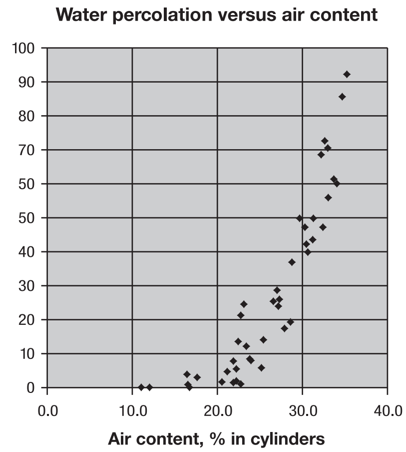
The permeability of pervious concrete can be measured by a simple falling head permeameter as shown above (Neithalath et al. 2003). Using this approach, the sample is enclosed in a latex membrane to avoid the water flowing along the sides of the specimen. Water is added to the graduated cylinder to fill the specimen cell and the draining pipe. The specimen is preconditioned by allowing water to drain out through the pipe until the level in the graduated cylinder is the same as the top of the drain pipe. This minimizes any air pockets in the specimen and ensures that the specimen is completely saturated. With the valve closed, the graduated cylinder is filled with water. The valve is then opened, and the time in seconds [*t*] required for water to fall from an initial head [*h1*] to a final head [*h2*] is measured. The equipment is calibrated for an initial head of 11.6 in. (290 mm) and a final head of 2.8 in. (70 mm).

(source ACI 522)

Unit Weight / Air Void Content

As slump is not an effective parameter for determining the quality of pervious concrete, unit weight can serve as an indicator value. Unit weight/air void content of pervious concrete can be determined by ASTM C 138 - Standard Test Method for Density (Unit Weight), Yield and Air Content of Concrete; however, there are currently test methods in development by ASTM designed specifically for measuring the unit weight and air void contents of pervious concrete. The following chart shows the relation between the percolation rate and air void content.

CHART 4.6 from ACI 522R-7



Durability

Several studies were conducted by various agencies to verify the durability of pervious concrete. Some of the studies have indicated that freeze/thaw durability is not sufficient and large scale deterioration was observed. The results are still under investigation and can very well be an indication that conventional testing methods such as ASTM 666 may not be the proper testing method for pervious concrete. Critical conditions required for freeze/thaw damage are:

1. ***Temperatures below 32°F (0°C)***
2. ***Concrete saturation must be higher than 91%***

When these two conditions are satisfied the pressure created during water transformation from liquid to solid stage will build up and cause the damage. The composition of pervious concrete and the entire concept should allow the water to travel through the concrete down to the sub-base and therefore fully saturated conditions should never occur in properly designed, installed and maintained pervious concrete. More information on the durability of pervious concrete can be found in the 2004 NRMCA report – Freeze Thaw Resistance of Pervious Concrete or directly on www.nrmca.org

Compressive and Flexural Strength

Compressive strength will vary with mix design. Typical values are between 2000 psi to 3000 psi. If a small amount of sand is used then compressive strengths over 4000 psi can be achieved. In cases such as this, special attention must be given to air void and percolation rate as these may be reduced with the introduction of fine aggregate.

The majority of pervious concrete, as indicated previously, is used in pavement applications. Flexural strengths are critical factors in the quality of pervious concrete. The flexural strength of pervious concrete ranges between 150 psi (1MPa) up to 550 psi (3.8MPa). The method and degree of compaction and placement techniques can vary and yield different final properties. Porosity and cement content will also affect the final result.

Compaction Methods

Roller compaction – the simplest compacting technique is compaction with steel rollers. Immediately after initial strikeoff concrete is rolled with heavy steel rollers to ensure for proper compaction. Rolling is performed in two perpendicular directions to guarantee plainness and smoothness of concrete. There are different sizes and weights of the rollers available for different placement sizes.

Compaction by plate compactors – faster than previous method, however, the disadvantage is that compaction may not be uniform and certain spots can be over compacted. Due to relatively small compaction area it takes an experienced operator to maintain evenness.

Mechanical / manual vibrating screeds – commonly used technique, which is simple and fast. However, this method can sometimes lead to surface roughness and tearing, especially when concrete is too dry. Attention must be paid to the frequency of vibration so the surface is not too tight (which can cause a reduction of air voids and overall permeability). This can be applied to all consolidation methods using vibration devices.

Compaction by spinning tubes – allows for fast and even compaction over larger areas. Rotating tube compacts and finishes the concrete and is easy to move forward and backward. This technique allows contractor to add more material where needed and finish it in quickly enough so that plastic cover can be placed on the concrete surface with minimal delays.

Areas of the placement that are difficult to reach with rollers or tampers, such as corners or edges, should be manually tamped.

For more details about placing and consolidation see ACI 522.

DO'S	DON'TS
▲ Pre-placement inspection of jobsite	▲ Place pervious concrete on dry sub-base
▲ Level sub-base, moisten sub-base layer and sub soil	▲ Delay placement, screeding or compaction processes
▲ Ensure that formwork is placed correctly	▲ Allow concrete to be exposed for more than 15 min after placing
▲ Install proper drainage systen if needed	▲ Place on frozen, muddy, or saturated sub-grade
▲ Use riser strips to provide accurate guides for even compaction	▲ Fail to provide a moist sub-base
▲ Cover freshly placed concrete with protective moisture barrier	▲ Forget to mist concrete before placing protective sheet
▲ Use a proper compaction technique	▲ Add water to improve workability

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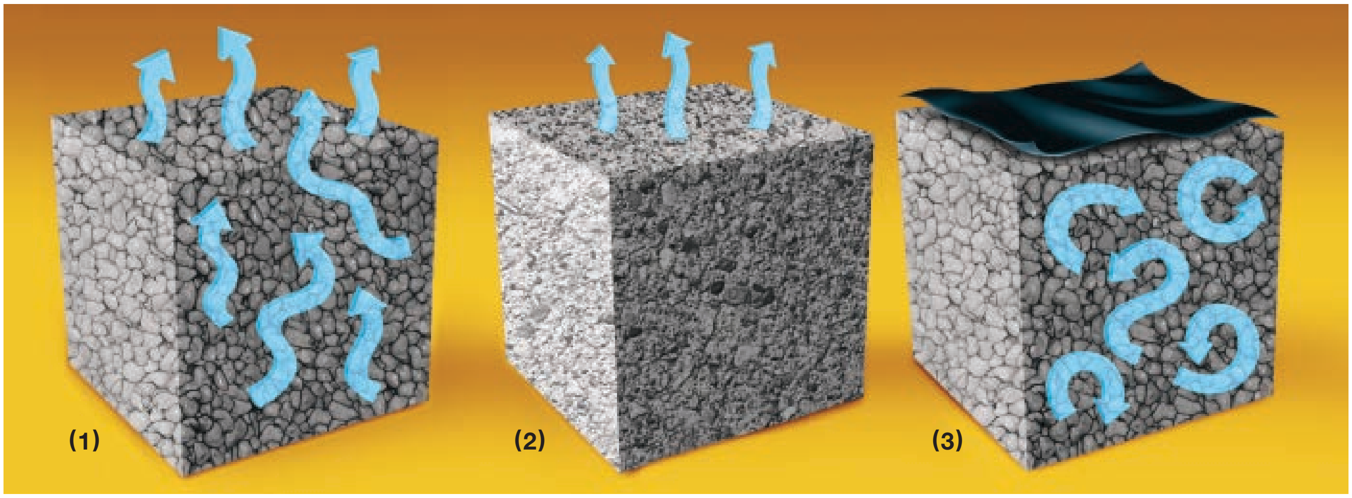
Curing

Special attention must be paid to proper curing. Pervious concrete (1) should always be placed on a pre-wet sub-base, which will provide additional moisture for curing. As the pervious concrete itself contains a lot of air voids, the exposed surface area that provides for the evaporation of mixing water is higher than that of conventional (2) concrete. It is necessary to protect the concrete being placed as soon as possible and prevent excessive moisture loss, which may result in the reduced performance of the concrete. It is recommended to slightly mist the concrete surface before applying the protective plastic sheet. (3) The plastic sheet should be placed over the surface immediately as the concrete is compacted, or no longer than 15 min. after placement. This will reduce the moisture loss and extend the hydration time necessary for cementitious materials to achieve the required properties.



Moisture loss in Pervious Concrete

Moisture loss in Conventional Concrete

Moisture loss retention after placement of protective sheet

To prevent moisture loss, it is critical to place a protective plastic sheet immediately after concrete is compacted.

Since 1910...

Since 1910, Sika has been at the forefront of innovation and technology when it comes to concrete admixtures. “Environmental Impact” and “Sustainability” are not just “buzz” words for Sika; we are committed to ensuring that we operate and manufacture in such a way that we limit our own environmental impact. Furthermore, we focus on the development of products that help our customers produce concrete that is more environmentally friendly.

Please read about our full line of concrete admixtures and construction products at **www.sikaconstruction.com**.

For additional information on pervious concrete:

- NRMCA’s Pervious Website - **www.perviouspavement.org**
- ACI 522 – Pervious Concrete
- ACI 522.1 – Specifications for Pervious Concrete

Look to Sika and its global presence for superiority in pervious concrete and construction products.

Sika Corporation has provided innovative, cutting edge technology and technical support to the concrete industry for nearly one hundred years. The global leader, whose contributions and involvement has increased concrete quality and performance around the world. From waterproofing admixtures at the turn of the century to self consolidating concrete technology at the dawn of the millennium, we've got the right mix!

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Retarders/Hydration Control...............Plastiment®, Sikatard 930®
Accelerators...SikaSet®, Rapid 1®
Viscosity Modifying...............................Sikament 300SC®
Pervious Concrete Admixture.............SikaMix PV-100®

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