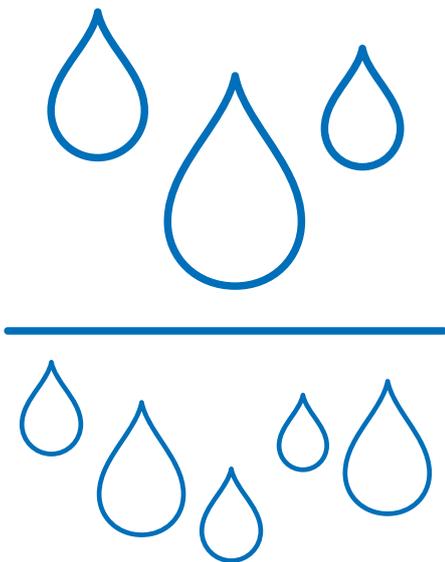


A close-up photograph showing water flowing through a thick layer of aggregate concrete. The water is captured in motion, creating a spray at the top and forming vertical streams with droplets as it passes through the porous concrete. The aggregate consists of light-colored, rounded stones.

PERVIOUS CONCRETE





PERVIOUS CONCRETE

Pervious concrete is a cementitious conglomerate. The proportions of the components used in the mix are such that, once the mix has hardened, it forms a system of interconnected voids that allow water to pass through.

Using pervious concrete is the most effective solution if streams of water flowing on the surface of a road need to be controlled, to stop puddles forming, to reduce the effect of urban heat islands or simply to create a surface with better soundproofing properties.

MIX



Just like any other type of cementitious conglomerate, pervious concrete is made from cement, aggregates, water and admixtures.

The principal difference between a mix design for conventional concrete and a mix design for pervious concrete is the proportion and size of the aggregates used in the mix.

While conventional concrete requires a combination of several different particle sizes to form a structure which is as closed as possible, pervious concrete uses only one particle size, preferably monogranular, in order to produce a more open structure which gives the element or structure a certain rate of hydraulic conductivity, depending on the maximum diameter used. Using aggregates made up of particles with the same diameter also gives a finer finish. Mixing the various components together, creates an agglomerate of stone particles bonded together by the cement paste which coats them.

This lack of fine aggregates produces a particular type of concrete with a high level of porosity which differs from lightweight concrete, in that it has a structure with open-cell voids. The voids in the structure are interconnected and form a network of channels which vary in size from as little as 1 mm up to a maximum of 5 mm. The size of this system of internal channels determines the drainage capacity of the structure.

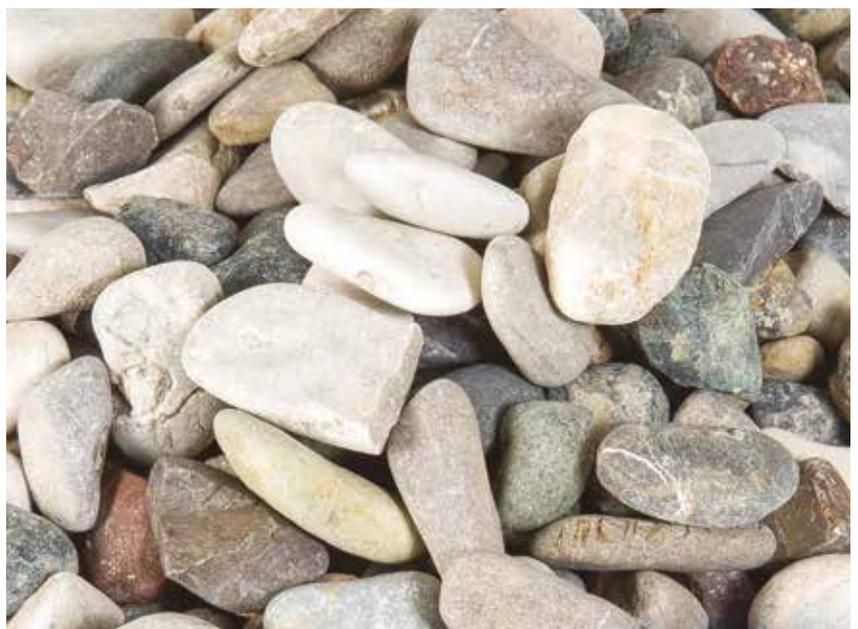
AGGREGATES



Pervious concrete is made using coarse aggregates in various maximum diameters, preferably monogranular. The sizes most commonly used are between 10 mm and 20 mm. Finer aggregates form a more closed and less permeable structure, whereas aggregates with D_{max} of 20 mm or larger form a structure that is more open and more permeable. Using larger size aggregates, however, means there will be less area of contact between the particles and, as a result, the mechanical properties and potential durability of the mixture will be reduced.

Round, natural aggregates are preferable to crushed aggregates for both aesthetic and technical reasons, in that they guarantee better adhesion between the particles and water is able to drain off more quickly.

Having said that, any type of aggregate may be used, but particles with a long, flat shape should be avoided.



CEMENT



Any type of cement that complies with current norms and standards may be used. The mix design for pervious concrete may also include cement combined with other minerals (fly-ash, slag, silica fume) that comply with the requirements of current norms and standards. The amount of binder in the mix is generally between a minimum of 270 kg/m^3 and a maximum of 420 kg/m^3 ; typical doses are $300 - 350 \text{ kg/m}^3$. The water/cement ratio for pervious concrete is usually between 0.25 and 0.45 and the amount of water used varies from a minimum of 100 l/m^3 to a maximum of 130 l/m^3 . The correct amount of water must be such that there is no leaching of the paste or the formation of concrete agglomerate. Too much water would lead to progressive clogging of the pores, whereas not enough water would make it more difficult to place.

Calculating how much water is required is a critical point when designing the mix because there is no single, universally-accepted way of calculating the correct quantity. One quick way of checking on site is to squeeze a sample of the pervious concrete in your hand to see how it behaves when you let it go; whether it crumbles [fig. 1] or it gives off slurry [fig. 3]. The amount of water is just right when you have neither of these conditions and you are able to form a round ball from the sample [fig 2].



[fig. 1]



[fig. 2]



[fig. 3]

HYDRAULIC CONDUCTIVITY

▼

The main property of pervious concrete is its hydraulic conductivity, that is, its capacity to drain off a certain amount of water from a surface. This property is closely connected to the void content, which is generally between 15% and 30%, and is known as its effective porosity. This figure is defined as the ratio between the volume of water released by gravity from a sample of perfectly saturated pervious material and the total volume of the sample. Hydraulic conductivity, therefore, depends on the effective porosity which, in turn, depends on the size of the voids and, above all, the channel system and the way they inter-communicate. The higher the amount of voids, the higher the drainage capacity of the concrete, to the detriment, however, of its mechanical properties, which are influenced by a more open structure. Conversely, a lower amount of voids will reduce the drainage capacity but gives concrete better mechanical properties. The hydraulic conductivity of pervious concrete is normally measured in situ with a permeameter for asphalt, calculating the time required to empty a column of water from a graduated cylinder.



Permeameter for asphalt (EN 12697-40)

COMPRESSIVE STRENGTH



Compressive strength: failure phases of a cube of pervious concrete

The amount of mixing water required for pervious concrete is very important in order to achieve just the right consistency to place the concrete and finish off the surface, but it is not such an important factor as far as the development of its mechanical properties is concerned. In fact, other factors have a far greater impact on the mechanical properties of pervious concrete than its water/cement ratio. The D_{max} of the aggregates, the amount of cementitious paste, the void content and the way the voids are interconnected all play a very important role in achieving its mechanical properties. The compressive strength of pervious concrete, which is measured using the same methods as for conventional concrete, does not depend on its water/cement ratio, but rather on the level of compaction and the level of cohesion established between the particles. It must be noted, therefore, that the traditional methods adopted by current norms and standards to prepare samples should be reviewed in order for them to be applicable also to pervious concrete.

ADMIXTURES



The performance properties of pervious concrete are closely connected to its mix design, how the mix is prepared, the method and time taken to place the concrete and, above all, on the surrounding conditions. However, the physical and mechanical characteristics and durability of pervious concrete may be improved accordingly by using appropriate chemical admixtures.



MAPECRETE DRAIN L



Mapecrete Drain L is a special latex rubber-based liquid admixture specifically developed for pervious concrete. **Mapecrete Drain L** improves adhesion between the aggregate particles, thereby increasing the binding capacity of the cement paste. It also improves the cohesion of the mix, making it easier to place and reducing its modulus of elasticity. High doses of this particular admixture give pervious concrete more resistance to freeze-thaw cycles and the action of de-icing salts.





MAPECRETE DRAIN P



This product is available in powder form and is a valid alternative to **Mapecrete Drain L** when there are production constraints that do not allow for the use of liquid admixtures. **Mapecrete Drain P** combines into a single product the adhesion properties of **Mapecrete Drain L** latex rubber and the set retarding properties of **Mapetard**, which is required to help maintain sufficient workability when placing concrete. **Mapecrete Drain P** is available in handy, water-soluble packagings that may be added to the concrete during the mixing phase.



MAPETARD



As the moisture content in pervious concrete reduces, its workability time is also reduced. Because of the open structure and low water content of the concrete, the evaporation process tends to take place more quickly. Using a set retardant such as **Mapetard** is generally recommended to extend workability and postpone setting of the cement paste.



SYNTHETIC FIBRES



Polypropylene microfibres, such as **Mapefibre NS18**, prevent wear of the concrete surface due to detachment of the aggregates. When placing the concrete, the microfibers also reduce the risk of over-compacting the mix if it is too moist and help the paste and aggregates adhere when the mix is particularly dry.

It is recommended to disperse the fibres to the mixing water before adding it to the mix so that they are more evenly distributed in the concrete.

MIX DESIGN



The following table shows three different mix designs for pervious concrete with different rates of hydraulic conductivity.

Components	Mix 1	Mix 2	Mix 3
	<i>Kg/m³</i>	<i>Kg/m³</i>	<i>Kg/m³</i>
Sand 0/4	-	150	100
Gravel	1200 (8/10)	1200 (8/10)	1250 (12/16)
Cement	330	330	400
Water	110	110	130
Water/cement ratio	0.33	0.33	0.32
Density	1635	1727	1850
Mapecrete Drain L	3.5	3.5	4.5
Mapetard	2	2	2
Mapefibre NS 18	0.6	0.6	0.6
Voids index	30%	23%	25%
R_c_m	15	20	25
Hydraulic conductivity	1200 mm/h	286 mm/h	727 mm/h

COLOURING THE MIX



Pigments may be added to pervious concrete so that it blends in with the surroundings or other designs and patterns.

Mapei offers the possibility of colouring pervious concrete with pigments from the **Mapecolor Pigment** range, or by treating the surface with products from the **Mapecrete Mineral** range.

MAPECOLOR PIGMENT



Mapecolor Pigment is a range of coloured pigments that may be added to the concrete.

Product	Dose
Mapecolor Pigment (for available colours refer to the Technical Data Sheet)	3% - 6% by weight of cement





MAPECRETE MINERAL



Coloured mineralising product for concrete paving specifically developed to harden, consolidate and colour the surface of all types of concrete substrates.

Mapecrete Mineral is available in various colours and is applied with a roller or by spray on the surface of new or existing concrete to make it more attractive and increase its durability over the years.

Product	Dose
Mapecrete Mineral (for available colours refer to the Technical Data Sheet)	200-250 g/m ² substrates with low porosity
	250-300 g/m ² porous substrates



POURING AND COMPACTION



Since pervious concrete does not contain fine aggregates and is less workable, pumping is not possible. Therefore, before placing the concrete, it is important to make sure the site is accessible to the equipment required to off-load it.

Concrete trucks equipped for transporting pervious concrete should carry a maximum load of 6 cubic metres. The drum of the mixer should not be completely full because the concrete itself is drier and may need more time to be off-loaded than traditional concrete, but also because mixing a larger mass of pervious concrete will put too much load on the motor that drives the drum. Pervious concrete should be completely off-loaded from the truck within one hour of starting the mixing cycle.

In order to place the concrete correctly and successfully, it is important that the substrate has no uneven areas, steps or hollows that could affect the flatness of the road surface.

Pervious concrete must be compacted with a roller, preferably equipped with a vibration plate and a screed roller. The weight of the roller should be the only load used to compact the concrete because, if too much pressure is exerted on the concrete, it could cause the voids to collapse and reduce its drainage capacity. If the concrete is not sufficiently compacted, however, it could be less durable and there could be a problem of delamination.

It is recommended to complete all placing operations within 15 minutes of off-loading the concrete to minimise the risk of problems during compaction, due mainly to it setting too quickly and water evaporating from the surface.



JOINTS



Drying shrinkage in pervious concrete is generally lower than in normal concrete because of its lower content of cement and mixing water. However, contraction joints should be included to help orientate any cracks that form on the surface. The pitch between the joints is calculated using the general rule $L = (18 \times h) + 100$, where L is the length of the slab and h is the thickness in cm.

The joints should be made at ninety degrees to the direction in which the concrete was placed immediately after going over the surface with the roller and before carrying out the curing operations.

CURING



As with traditional concrete, the curing cycle for pervious concrete is very important to ensure the cementitious binder is correctly hydrated. The open structure that characterises pervious concrete exposes it to a higher rate of evaporation because there is a larger amount of exposed surface. For this reason, the damp curing cycle must start as soon as possible. Correct curing starts before placing the concrete by saturating substrate so that it does not draw off moisture from the concrete. Curing of the surface should start within 20 minutes from placing the concrete, unless otherwise specified and agreed upon by all those involved in the work. The surface of the concrete must be wetted or dampened with water and then immediately covered with polyethylene sheets for a period of at least 7 days.

PLACING THE CONCRETE



Pervious concrete may be placed on an existing substrate if made from incoherent material, such as sand and gravel. In this case, the substrate should be compacted beforehand so that it has a more stable, uniform surface. In the case of a clay or silt substrate (low permeability), the most suitable solution is to scarify the surface so that it has better infiltration, lay on a sheet of non-woven fabric and then apply a layer of loose material, the thickness of which will vary according to the hydraulic capacity required for the road surface.

Other drainage systems could be specified by the design engineer if the hydrological conditions of the area are such that the concrete is unable to discharge the water sufficiently. In the case of a substrate with low permeability, you may choose to cover its surface with a waterproof membrane and then install a system of channels in the loose material to collect and direct the water towards the edge of the road. Once the channel system has been installed and the drainage layer on the substrate has been completed, you may then proceed with placing the pervious concrete.

The layer of loose aggregate must always be carefully wetted before placing the concrete to prevent the dry material drawing water off from the wet concrete and stop it setting and drying too quickly.

When used for road surfaces, the thickness of pervious concrete is usually between 15 cm and 20 cm. Thinner layers may be used for car-parks and their thickness increases as the amount of traffic increases. There is no minimum thickness specified when pervious concrete is used to make pavements and cycle lanes.



1 Substrate

2 Geofabric

3 Loose aggregates

4 Pervious concrete



HEADQUARTERS

MAPEI SpA

Via Cafiero, 22 - 20158 Milan

Tel. +39-02-37673.1

Fax +39-02-37673.214

Internet: www.mapei.com

E-mail: mapei@mapei.it

