TECHNIK

MUFLEDRAIN TECHNICAL MANUAL

The collection and disposal of surface water from either meteoric precipitation or agricultural and industrial processes have always played a major role in man's activities.This need has been increasing considerably over the last few years because of climatic changes and morphological changes in the territory.

The MufleDrain drainage system is an ideal solution in that it combines the technical features required by designers and the practical and cheap installation required by installers. This Technical Manual is intended to help the designer make up a versatile and efficient drainage system. For this purpose general designing criteria concerning the calculation of water flow capacity and the construction of concrete supports needed to install drainage channels are described

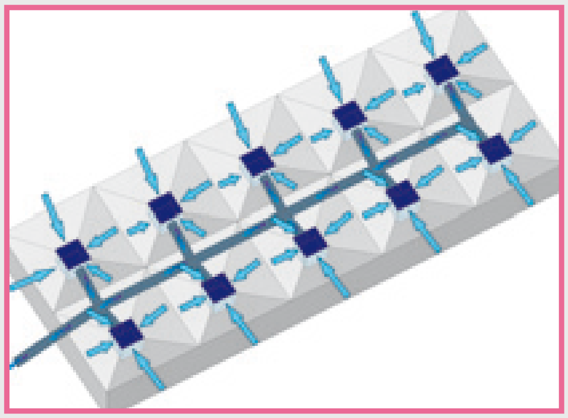
Punctual and linear drainage systems

In order to dispose of surface water (either from meteoric events or urban/industrial waste) on a waterproof surface or a soil with poor drainage, you need to design and construct a suitable collection and disposal system that makes it possible to channel liquids into a final receptacle. Current solutions are of two different kinds:

1. Punctual drainage;
2. Linear drainage.

PUNCTUAL DRAINAGE

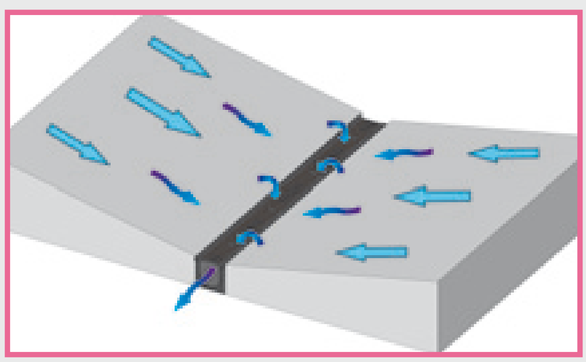
At predetermined points in the area concerned buried boxes are installed on which a collection grating equipped with a suitable containment frame (cover) will be placed. In this way the drainage area is divided into different subareas, each having the relevant containment frame as its disposal point. All the subareas shall have 4 inclinations in order to convey the liquids into the collection point. All the boxes shall be connected to each other through a thick network of buried pipes leading into the final receptacle.This type of drainage has disadvantages from the technical and construction points of view as well as from the economic point of view:



- difficult designing due to the complex subdivision of the area into subareas and difficult assignment of different inclinations to each of them;
- difficult designing of correct inclinations;;
- difficult construction of the buried piping network and consequently expensive work;
- considerable depth at which the boxes are to be laid;
- difficult and expensive maintenance due to the inaccessibility of the drain pipes, which make the whole system useless if they get clogged with solid material;
- uncomfortable road conditions because the area is characterised by rises once the work has been completed;
- large presence of boxes and gratings in valuable architectural areas which may not look very nice.

LINEAR DRAINAGE

Prefabricated drainage channels to be buried are used. Continuous stretches as long as a few hundred metres can be made up with them. The system is equipped with a proper covering system by means of gratings.
Rainwater is made to flow into the channels, which will collect it with the gratings and convey it to the final receptacle simply by connecting the drain points in the channels to a single properly-sized pipe. So there is no need for a thick network of buried pipes to convey the water.
The system can be positioned according to the natural inclination of the ground. If there is no such inclination, the drainage area can be given a single inclination.
A number of benefits are available with this system:



- easy designing;
- easy construction;
- cheaper product;
- higher operating reliability thanks to the reduced presence of buried pipes (smaller clogging risk);
- very easy maintenance and cleaning work;
- aesthetical compatibility with any application environment.

RESISTANCE OF HD-PE TO CHEMICAL SUBSTANCES

DESCRIPTION	%	DESCRIPTION	%	DESCRIPTION	%
Amyl acetate		Picric acid	1% acqueous	Beer	
Ammonium acetate		Propionic acid		Sodium disulphate	
Butyl acetate	pure	Prussic acid	50%	Sodium disulphite	10%
Methyl acetate	pure	Hydrosulphuric acid		Borax	
Lead acetate		Sulphuric acid		Potassium borate	
Sodium acetate		Sulphuric acid, aqueous		Potassium bromate	10% acqueous
Wine vinegar		Sulphuric acid, aqueous	80% acqueous	Sodium bromate	saturated, cold
Acetone		Sulphurous acid	40%	Potassium bromide	acqueous
Fatty acids	pure	Stearic acid		Sodium bromide	
Bath acids	700 mg.	Succinic acid	pure	Butadiene	pure
Acetic acid	50%	Tannic acid		Butandiol	10%
Dichloroacetic acid	50%	Tartaric acid, aqueous		Butanol - aqueous	
Trichloroacetic acid	50%	Trichloroacetic acid		Ammonium carbonate	50%
Adipic acid		Mineral water		Sodium carbonate	
Arsenic acid	80%	Hydrogen peroxide		Cyanide	
Benzoic acid		Drinking water, chlorinated	10%	Potassium cyanide	
Watery boric acid		Acrylonitrile		Cyclohexane	
Hydrobromic acid	50%	Allyl alcohol		Cyclohexanol	
Butyric acid	pure	Amyl alcohol	96%	Cyclohexanone	pure
Hydrocyanic acid		Benzyl alcohol		Potassium chlorate	
Citric acid	10%	Ethyl alcohol	pure	Sodium chlorate	
Hydrochloric acid	10% acqueous	Ethyl alcohol+Acetic acid	96%	Sodium chlorite	diluted, acqueous
Cloroacetic acid (mono)	50%	Furfuryl alcohol		Chlorine-Ethanol	
Chromic acid	50% acqueous	Fat alcohol, Coconut oil		Aniline chlorydrate	saturated, acqueous
Dichloroacetic acid	50%	Methyl-alcohol	pure	Aluminium chloride	10%
Trichloroacetic acid	pure	Propargyl alcohol		Ammonium chloride	10%
Diglycolic acid	30%	Acetic aldehyde	7%	Antimony chloride	90%
Hydrofluoric acid	40% acqueous	Crotonic aldehyde	pure	Lime chloride	
Siliconfluoric acid	32%	Chromic alum	pure	Calcium chloride	
Formic acid		Starch, aqueous		Magnesium chloride	
Phosphoric acid, aqueous	85%	Ammonia		Potassium chloride	
Phosphoric acid, aqueous	30%	Acetic anhydride		Copper chloride	
Phthalic acid		Carbon dioxide	pure	Sodium chloride	
Glycolic acid	37%	Sulphyric anhydride		Tin chloride	
Lactic acid	10%	Auto Anti-freeze liquid		Zinc chloride	
Maleic acid		Photographic fixers		Ferric chloride	
Malic acid	1%	Benzaldehyde	normal	Cresol - aqueous	90% acqueous
Nitric acid	6.3%	Petrol (Gasoline)		Potassium chromate	acqueous, saturated, cold
Oleic acid	pure	Sodiumbenzoate		Sodium chromate	diluted, acqueous
Oleic acid		Sodium bicarbonate		Dextrose - aqueous	
Oxalic acid, aqueous		Potassium bichromate		Synthetic detergents	5% acqueous
Acid for accumulators	80% acqueous	Carbon dioxide		Diisobutyl ketone	pure
Perchloric acid, aqueous	70% acqueous	Sulphur dioxide		Dimethlammine - liquid	

The substances related below have no influence on the HD-PE at a temperature of 60°, in some cases the maximum concentration is shown. For other substances and/or temperatures and concentrations consult our Technical Office.

RESISTANCE OF HD-PE TO CHEMICAL SUBSTANCES

DESCRIPTION	%	DESCRIPTION	%	DESCRIPTION	%
Dimethylformamide		Isoctane		Hydrogen peroxide	90% acqueous
Dioxan		Isopropanol	acqueous	Potassium, Sodium persulphate	
Distillations generally		Lanoline		Petroleum	pure
Distilled wine	pure	Milk		Pyridine	
Paraffin emulsion	pure	Yeast	pure	Sodium pyrosulphite	acqueous
Photographic emulsions		Liqueurs		Potash	saturated cold 90%
Tannic vegetable extracts		Jam			acqueous
Petroleum ether		Molasses		Caustic potash	50%
Ethylenediamine	pure	Mercury		Propane	pure, liquido
Acetic acid ethyl ester	700 mg.	Metilammina		Photographic developers	normal
Mono chlorate	50%	Acetic acid methyl ester		Kitchen salt	
Phenol	50%	Diclorate		Silver, barium salts	
Potassium ferricyanide	50%	Acetic acid methyl ester		magnesium, mercury, nickel,	
Fertilisers (salts)		Monoclorate	32% acqueous	copper, zinc	
Ammonium fluoride	80%	Methyl ethy ketone		Starch syrup	
Copper fluoride		Sulphurphosphoric mixture		Sugar syrup	
Sodium fluoride	50%	Morpholine		Butyl sebacate	pure
Formaldehyde	pure	Must of Molasses		Cider	
Formamide		Fermented must	pure	Sodium silicate	
Ammonium phosphate	10%	Movilit d	30%	Soda	
Potassium phosphate	10% acqueous	Naphtalene		Caustic soda	10%
Sodium phosphate	50%	Ammonium nitrate		Aluminium sulphate	
Tributylphosphate	50% acqueous	Silver nitrate		Aluminium, potassium sulphate	50%
Phospur chlorate	50%	Calcium /potassium nitrate	normal	Ammonium sulphate	10%
Petrol (gasoline)	pure	Copper/sodium nitrate	pure	Hydroxylamine sulphate	
Glycerine	30%	Sodium nitrite	saturated acqueous	Potassium sulphate	
Glycol	40% acqueous	Nitrobenzene	50%	Sodium sulphate	
Butylene glycol	32%	Nitrotoluene		Sodium sulphite	
Ethylene glycol		N-propanol	acqueous	Ammonium sulphide	
Propylene glicole	85%	Vegetable oils and greases	saturated cold	Sodium sulphide	
Glycine	30%	Lubricating oils	pure	Soap solutions	
Glucose		Mineral oils	pure	Fruit juices	
Chloral hydrate	37%	Coconut, linseed, corn oils		Surfactants	
Hydrazine hydrate	10%	Olive oil		Lead tetraethyl	pure
Hydrogen		Palm oil		Sodium thiosulphate	
Sodium hydrosulphate	1%	Paraffin oil		Tricresyl phosphate	
Ammonium hydroxide	6.3%	Silicone oil		Triethanolamine	
Barium hydroxide	pure	Urine		Urea	30%
Calcium hydroxide		Sodium oxalate		Wine, white and red	
Potassium iodide		Propylenic oxide		Grape sugar	
Sodium iodide	80% acqueous	Phosphurous pentoxide			
Calcium hypochlorate	70% acqueous	Potassium perchlorate	acqueous		
I-propanol	1% acqueous	Potassium permanganate	saturated cold		

The substances related below have no influence on the HD-PE at a temperature of 60°, in some cases the maximum concentration is shown. For other substances and/or temperatures and concentrations consult our technical office.

Introduction

This Manual is meant as a simple practical guide as well as a convenient technical support to all those who are faced with the problems involved in designing and installing a surface drainage system.

Surface drainage systems make it possible to collect, channel and dispose of all the water that may accumulate on a given surface. The water can be of meteoric type, i.e. originating from atmospheric precipitation or from human activities connected with industry, construction, agriculture etc.

During the phases involved in the design of a surface drainage system, a clear distinction has to be made between open-air surfaces and covered surfaces.

While the former, comprising roads, squares, gardens etc., require knowledge and analysis of the data related to atmospheric precipitation; the latter include areas used for industrial production. In covered surfaces the drainage system will predominantly have to dispose of liquids deriving from work processes, which sometimes are chemically aggressive.

The project of a drainage network starts therefore from the general data of the surface to be drained (type, nature and size) and the knowledge of the flow rates of the liquids to be drained.

In the case of covered areas such as industrial buildings, the volume and nature of the liquids to be disposed of depend on the type of industrial processes that are carried out. As a consequence the discharge flow data will have to be supplied by the client.

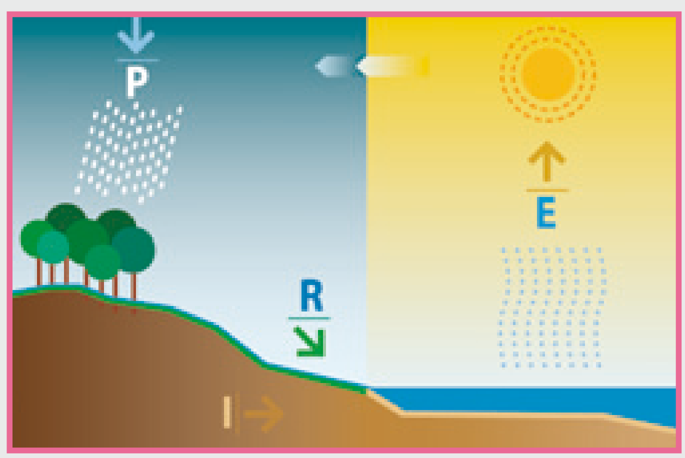
For open-air sites, on the contrary, the volume of water runoff is determined by studying the meteorological data. That is why a few simple hydrologic concepts about rainfall, historical data and the relevant statistical processing are shown below.

The water or hydrologic cycle

The hydrologic cycle is the path the water follows from the oceans through the atmosphere and the ground until it returns to the oceans. In spite of the fact that such a cycle - generated by solar energy - is quite complex, the process of water circulation can be represented as follows (Fig.1) :

- the water evaporates from the oceans surfaces, forming clouds;
- the clouds, driven by the winds even for long distances, give rise to precipitations in the form of rain, snow and hailstones;
- the most precipitations fall over the sea and the rest on the emersed land;
- a certain quantity of that water re-evaporates directly, another part is withheld by the vegetation and then given back to the atmosphere through the plants' evaporation or transpiration, and another part reaches the ground and flows on the surface until it reaches the sea. The remaining part filters into the ground, thus feeding underground water tables: in this way it returns to the sea too.

1. HYDROLOGIC CYCLE



P stands for atmospheric rainfall;
E is the water that evaporates from the ground, vegetation etc.;
R is the surface streaming;
I is the water that filters into the ground.
Therefore the water balance can be expressed through the following relationship:

$$P = E + R + I$$

Rainfall and pluviometric measurements

The quantity of falling water P is measured in rainfall height and is expressed in mm. That is, the height of the layer of water that would rest on the ground, supposing evaporation, surface streaming and evapotranspiration to be zero. This measurement is obtained from the volume of water fallen on a horizontal plane in a given area. One millimetre of rainfall means that an area of one square metre is covered by a 1-millimetre-thick layer of water for a total volume of one litre. Consequently:

$$P\,(\text{mm}) = \frac{\text{Volume}}{\text{Area}} = \frac{1\ \text{litro}}{1\ \text{m}^2} = \frac{\frac{1}{1000}\text{m}^3}{1\ \text{m}^2} = \frac{1}{1000}\text{m} = 1\ \text{mm}$$

The ratio between the precipitation height P and the precipitation duration t defines the average intensity of precipitation I expressed in mm/h:

$$I\left[\frac{\text{mm}}{\text{h}}\right] = \frac{P}{t}$$

The measurement of the precipitation is carried out with a Pluviometer or Pluviograph. The pluviometer is a simple funnel-shaped receptacle with dimensions such that each litre of water corresponds to 10 mm of rain.

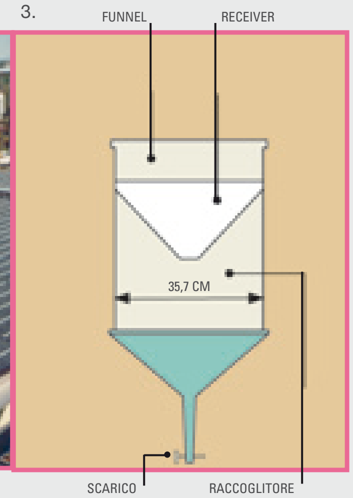
$$\text{Superficie} = \pi \cdot r^2 = 3{,}14 \cdot \left[\frac{0357\text{m}}{2}\right]^2 = 0{,}1\ \text{m}^2$$

$$\Longrightarrow\ 1\ \text{lt d'acqua} = 10\ \text{mm di pioggia}$$

The water height is taken every 24 hrs, thus obtaining the rainfall height in the previous 24 hrs. The pluviograph is a more complex system, which directly provides a diagram showing the rainfall height instant by instant (pluviogram - 4). The stations equipped with pluviographs are particularly important as they make it possible to derive data for intervals smaller than 24 hrs (Figures 2-3).

2.

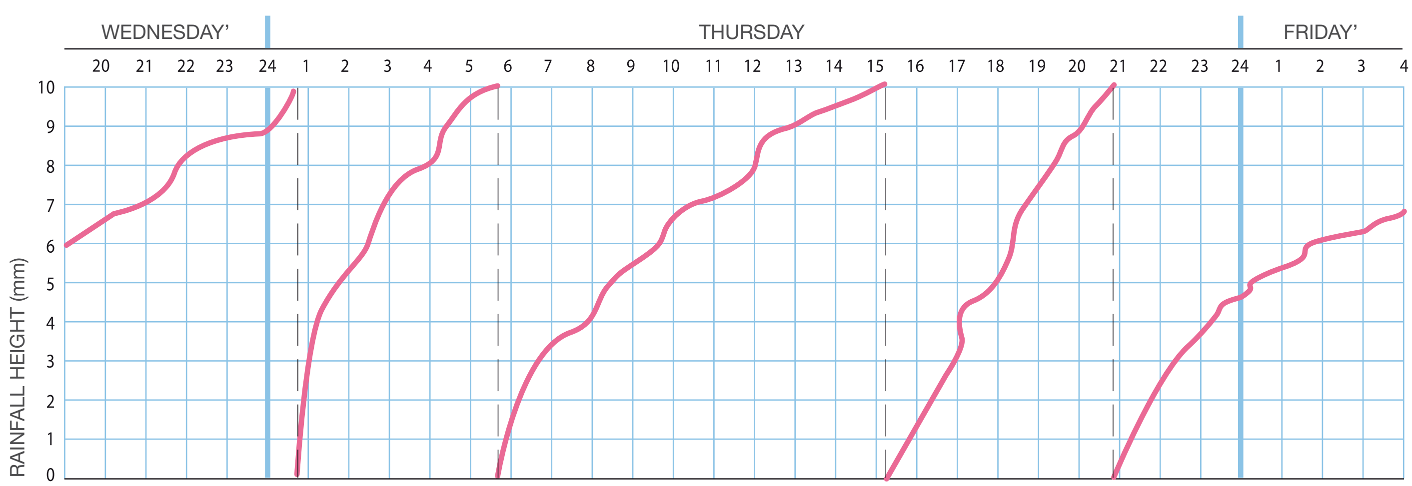
3.



There is a wide network of monitoring stations all over Italy that supply a series of pluviometric data (rainfall height, average intensity of precipitation, rainy days etc.). This data is collected and published annually by the Hydrographic Service or other bodies such as Istat.

4.

Example of pluviogram



Processing pluviometric data

CONCENTRATION TIME T_C

Clearly the volume of the water flow to be drained does not depend only on the precipitation but also on its duration. If the precipitation has height P and duration t (with average intensity P/t) and occurs over the entire draining area, the maximum volume is reached when contributions from all the parts making up the surface reach the runoff section.

This time interval is defined as concentration time t_cIt is simply the time that the most distant drop of water takes to reach the end of the drainage system.
Based on this, when processing the pluviometric data, it is necessary to consider the precipitation according to concentration time in order to determine maximum capacity.

For example, in drainage systems that serve relatively small surface areas, concentration time ranges from few minutes to dozens of minutes. Therefore brief and intense precipitations (showers of rain) should be analysed with maximum duration of 1 hour.

EQUATIONS OF PLUVIOMETRIC POSSIBILITY

The processing of the pluviometric data supplied by a monitoring station consists in looking for the mathematical relationship between the height of precipitation P and its duration t:

$$P = P(t)$$

Obviously, from the statistical point of view, its reliability depends on the amount of data available. Consequently the observation period must be long enough. It is believed that an observation period not smaller than 30/35 years can provide valid statistical results, although in some case observations not older than 10 years have to be used.

The many observations available have made it possible to see that, as time passes, rainfall diminishes. So the relationship we are looking for is of exponential type and can be expressed as follows:

$$P = a\, t^n$$

Where P and t are usually expressed in mm and hours respectively. The parameters dimensionless n and a ($mm \cdot h^{-n}$) are characteristic of a curve and can be determined from time to time as they depend on the pluviometric characteristics of the area where the monitoring station in located. The exponent n is obviously less than the unit.

Such relationships are called pluviometric possibility equations. They define curves on the Cartesian plane (P, t) known as pluviometric possibility indication curves.

RETURN TIME TR AND PROBABILITY OF NOT EXCEEDING THE CONCERNED

In order to determine the functional link between the precipitation height, its duration and the probable frequency with which such height can occur, the relationship becomes:

$$P(Tr) = a(Tr)\, t^{n(Tr)}$$

Where Tr is the so-called return time, that is the time poeriod in which the meterological event will on average be equalled or exceeded; it more simply defines the probability that the considered event is not exceeded; this probability results from the Gumbel distribution.

Generally speaking low values of return time (2 to10 years) are used to measure a drainage system for meteorological water.

STATISTIC ANALYSIS OF THE PRECIPITATIONS

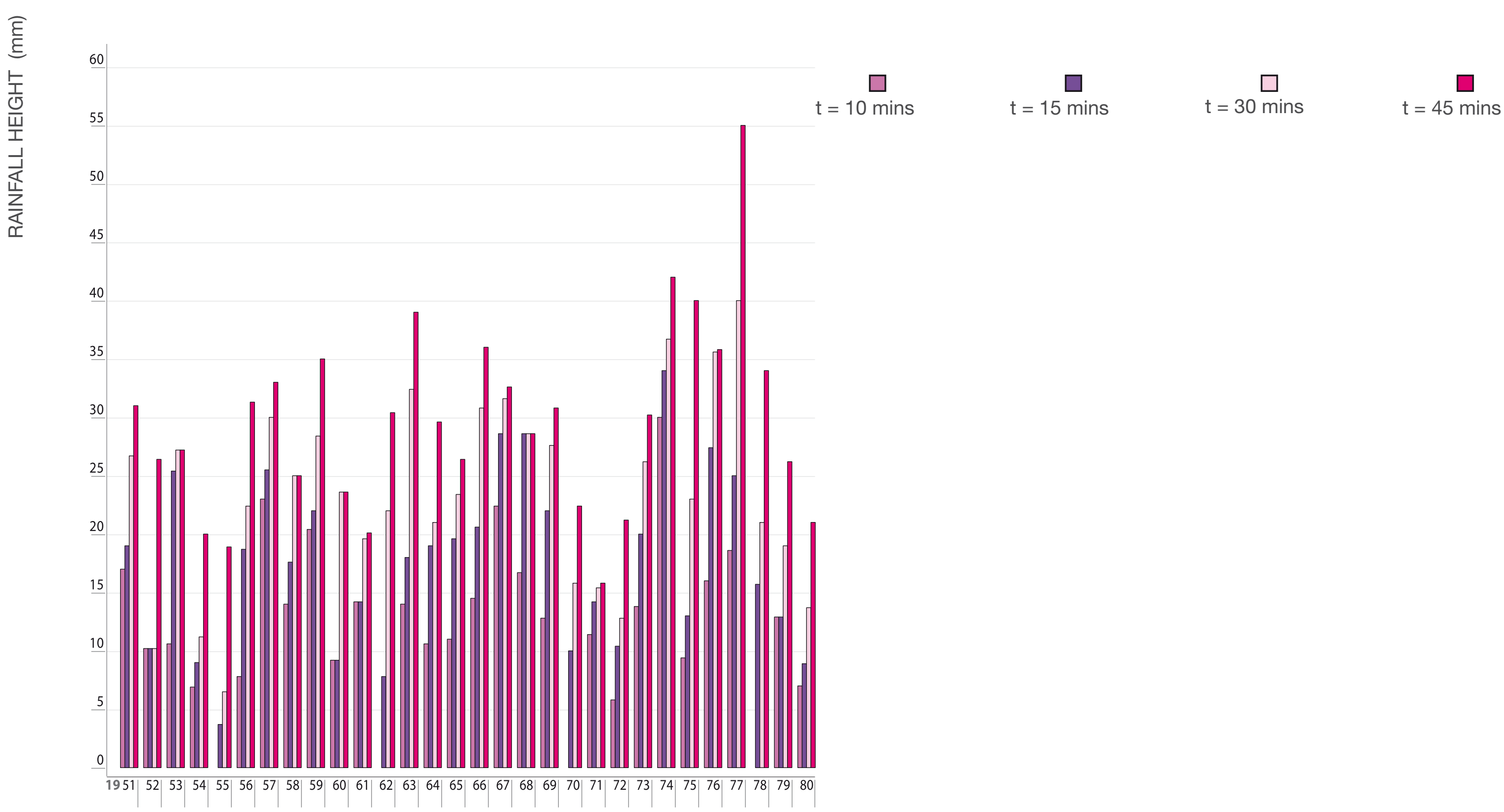
It is supposed that the maximum brief and intense precipitation values recorded by a theoretical pluviometric station X for a certain number of years Y are available.

By ordering this data, a table with a number of lines equal to the observation years Y and a number of columns equal to the lengths of observation (10,15, 30 and 45 minutes) is obtained.

BRIEF AND INTENSE PRECIPITATIONS RECORDED IN A THEORETICAL PLUVIOGRAPHIC STATION

DURATION	t = 10 min	t = 15 min	t = 30 min	t = 45 min
OBSERVATION YEAR	Rainfall height P (mm)			
1951	17	19	26.7	31
1952	10.2	10.2	10.2	26.4
1953	10.6	25.4	27.2	27.2
1954	6.9	9	11.2	20
1955	0	3.7	6.5	18.9
1956	7.8	18.7	22.4	31.3
1957	23	25.5	30	33
1958	14	17.6	25	25
1959	20.4	21	28.4	35
1960	9.2	8.2	23.6	23.6
1961	14.2	14.2	19.6	20.1
1962	0	7.8	22	30.4
1963	14	18	32.4	39
1964	10.6	19	21	29.6
1965	11	19.6	23.4	26.4
1966	14.5	20.6	30.8	36
1967	22.4	28.6	31.6	32.6
1968	16.7	28.6	28.6	28.6
1969	12.8	22	27.6	30.8
1970	0	10	15.8	22.4
1971	11.4	14.2	15.4	15.8
1972	5.8	10.4	12.8	21.2
1973	13.8	20	26.2	30.2
1974	30	34	36.7	42
1975	9.4	13	23	40
1976	16	27.4	35.6	35.8
1977	18.6	25	40	55
1978	0	15.7	21	34
1979	12.9	12.9	19	26.2
1980	7	8.9	13.7	21

Rainfall Histogram



For each duration interval the mean value m_t and the standard deviation σ_t of the recorded values are calculated:

STATISTICS	DURATION			
	t = 10 min	t = 15 min	t = 30 min	t = 45 min
	t = 0,167 hours	t = 0,25 hours	t = 0,5 hours	t = 0,75 hours
Mean value m_t	12,60	18,21	24,21	29,90
Standard devation σ_t	7,018	7,535	8,234	8,375

At this point reference is made to the Gumbel probability distribution to process the statistics:

$$G(P_t) = e^{-e^{-y}}$$

where y (called reduced variable) is given by:

$$y = \frac{P_t - M_t}{S_t}$$

with:

$$M_t = m_t - 0,577\,\sigma_t$$

mean value of the reduced variable

$$S_t = 0,779\,\sigma_t$$

standard deviation of the reduced variable.
So you will get:

STATISTICS	DURATION			
	t = 10 min	t = 15 min	t = 30 min	t = 45 min
	t = 0,167 ore	t = 0,25 ore	t = 0,5 ore	t = 0,75 ore
Mean value M_t	5,47	5,86	6,48	6,52
S.Q.M. S_t	8,55	13,87	19,41	25,07

Knowing that the probability of not exceeding the event is expressed according to the return time:

$$G(P_t) = \frac{Tr - 1}{Tr}$$

and processing the Gumbel expression, you get:

$$P_t(Tr) = M_t - S_t Ln\left[Ln\left(\frac{Tr}{Tr-1}\right)\right]$$

In this way, having set a return period Tr, it is possible to establish the corresponding maximum value of precipitation P for each time period t, that is the precipitation height that occurs, on average, every Tr years.

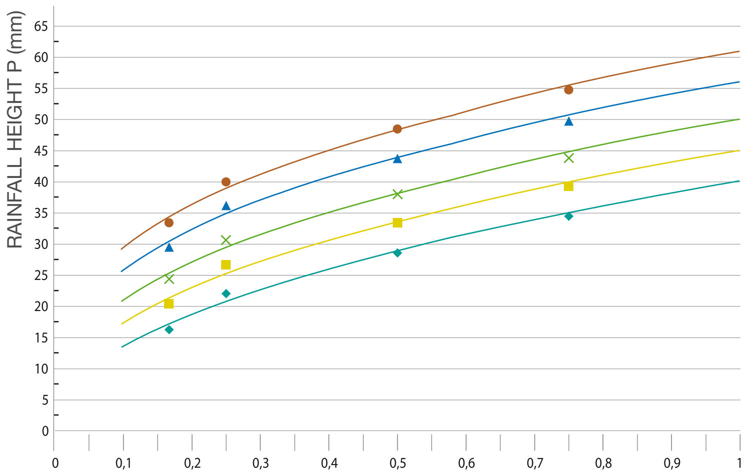
DURATION RETURN TIME Tr	DURATION			
	t = 10 min	t = 15 min	t = 30 min	t = 45 min
	t = 0,167 hours	t = 0,25 hours	t = 0,5 hours	t = 0,75 hours
5 years	16,75	22,66	29,13	34,85
10 years	20,86	27,06	34,00	39,75
20 years	24,79	31,28	38,67	44,45
50 years	29,89	36,74	44,71	50,52
100 years	33,70	40,84	49,24	55,08

By placing the values obtained for each return period Tr into the plane (P,t) it is possible to plot equation regression curves

$$P(Tr) = a(Tr)\, t^{n(Tr)}$$

which represent the pluviometric possibility curves we were looking for.

PLUVIOMETRIC POSSIBILITY CURVES (DURATION T < 1 HOUR)



Return Time Tr = 5 years

$P(5) = 40{,}417t^{0{,}4652}$
$R^2 = 0{,}9775$

Return Time Tr = 20 years

$P(20) = 50{,}111t^{0{,}3737}$
$R^2 = 0{,}9820$

Return Time Tr = 10 years

$P(10) = 45{,}325t^{0{,}4113}$
$R^2 = 0{,}9803$

Return Time Tr = 50 years

$P(50) = 56{,}370t^{0{,}3375}$
$R^2 = 0{,}9834$

Return Time Tr = 100 years

$P(100) = 61{,}091t^{0{,}3166}$
$R^2 = 0{,}9841$

The values of the coefficients a and n, obtained by varying the return period Tr for precipitations of less than 1 hr, are shown in the table opposite.

The correlation coefficients of the regressions performed R^2 are shown in the last column.

RETURN TIME Tr	a ($mm \cdot h^{-n}$)	n	CORRELATION COEFFICIENT R^2
5 years	40,717	0,4652	0,9775
10 years	45,325	0,4113	0,9803
20 years	50,111	0,3737	0,9820
50 years	56,370	0,3375	0,9834
100 years	61,091	0,3166	0,9841

AVERAGE PRECIPITATION INTENSITY I

Apart from obtaining the heights of precipitation that occur on average every Tr years for every rainfall duration t, it is obviously possible to also derive the corresponding average precipitation intensity (I) from pluviometric possibility equations.

Consequently: $I = \left(\frac{mm}{h}\right) = \frac{P}{t} = \frac{at^n}{t} = at^{(n-1)}$

EQUATIONS OF NATIONAL PLUVIOMETRIC POSSIBILITY

Clearly enough, to follow this procedure is extremely complex and articulated. And it is also difficult to collect a sufficient amount of pluviometric data regarding the drainage system area.
For these reasons we have tried to concentrate our resources on the search for pluviometric possibility equations that could have general validity, i.e. those that could be used for every area on the Italian territory.
The study started from the geographical distribution of the pluviometric data available. We analysed the precipitation as distributed in the areas that have historically shown homogeneity: Northern Italy, Tyrrhenian side of central Italy, Adriatic side of central Italy, Southern Italy, Sardinia.

Subsequent statistical processing made it possible to determine the following relationships for durations t < 1 hour.

EQUATIONS OF PLUVIOMETRIC POSSIBILITY
$P (Tr = 5) = 37{,}23\ t^{0{,}423}$
$P (Tr = 10) = 42{,}84\ t^{0{,}405}$
$P (Tr = 20) = 49{,}13\ t^{0{,}396}$
$P (Tr = 50) = 56{,}81\ t^{0{,}383}$
$P (Tr = 100) = 64{,}57\ t^{0{,}375}$

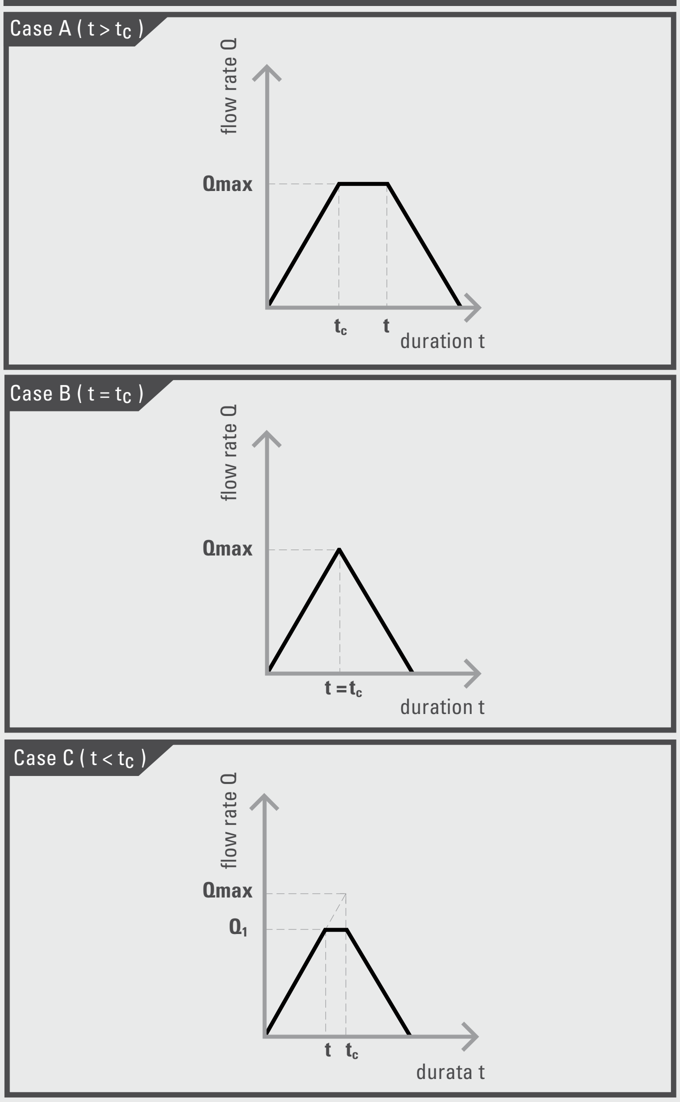
RETURN TIME TR	a ($mm \cdot h^{-n}$)	n
5 anni	37,23	0,423
10 anni	42,84	0,405
20 anni	49,13	0,396
50 anni	56,81	0,383
100 anni	64,57	0,375

The application of these equations speeds up the calculation operations but it involves an approximation of about 10 %. Therefore for special projects where accuracy is required, it is advisable to try and find the equation of the local pluviometric possibility.

Calculating maximum runoff capacity

The most popular method to calculate the flow rate resulting from a given precipitation is the kinematic method, also known as the rational method.
It is especially applicable to draining surfaces that are not too extensive and it is very suitable when designing drainage lines.

FLOOD HYDROGRAPH ACCORDING TO THE KINEMATIC METHOD



According to this method the condition of maximum flow rate is reached when the precipitation lasts for the same time as the critical rain, that is the concentration time:

$t\,(Q_{max}) = t_c$ critical duration
$I\,(t\,(Q_{max})) = I_{cr}$ critical intensity

The calculation relationship called kinematic formula is:

$$Q_{max} = \phi\, A I_{cr}$$

where:

A is the area of the draining surface;
I_{cr} is the critical intensity;
ϕ is the flow coefficient
(dimensionless size of which is discussed further on).

Knowing that: $$I_{cr} = \frac{P}{t_c} = \frac{a t_c^{\,n}}{t_c} = a t_c^{\,(n-1)}$$

Therefore: $$Q_{max} = \phi\, A a t_c^{\,(n-1)}$$

RUNOFF COEFFICIENT ϕ

At this point it is important to underline that not all the precipitation water that flows onto a surface contributes to calculating the volume to be drained. Some of this water will be absorbed by the ground - the more permeable the draining surface, the greater this amount will be.
Bituminous conglomerate or concrete pavings are much less permeable than a garden.
The fraction of water that contributes to the calculation of runoff capacity - to be collected by the drainage network - is given by the runoff coefficient ϕ, which will obviously depend on the type of surface.

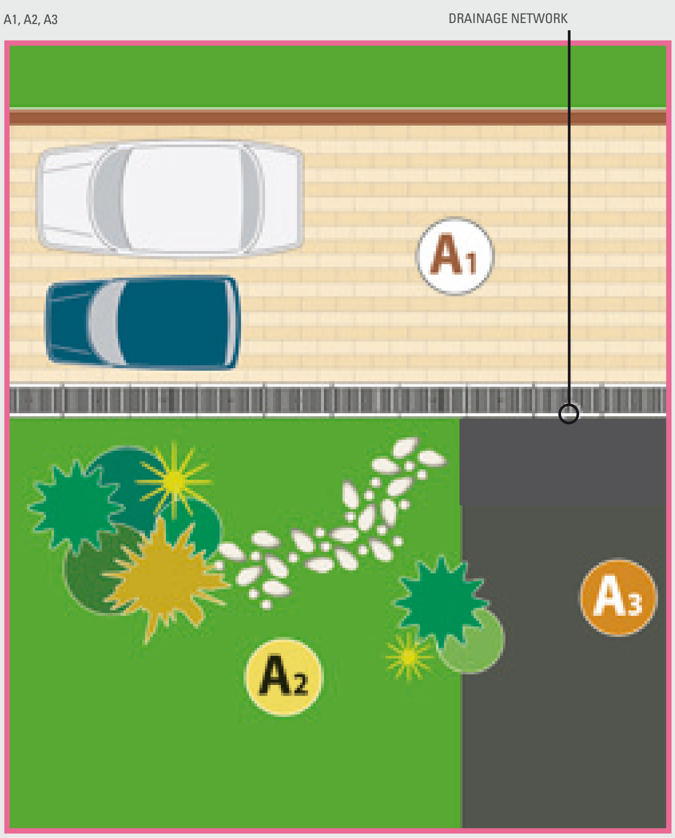
VALUES OF RUNOFF COEFFICIENT ϕ

Types of surfaces	Runoff coefficient ϕ
Roofs and terraces	0,90 - 0,95
Concrete paving	0,90
Asphalt paving	0,85 - 0,90
Stone and brick paving with cemented connections	0,80
Stone and brick paving with non cemented connections	0,60
Gardens, lawns, woods	0,40
City areas completely built up	0,70 - 0,90
City areas averagely built up	0,50 - 0,70
City areas slightly built up	0,40 - 0,50

You will actually find situations in which the draining surface is made up of surface portions of different types, therefore having different runoff coefficients. In such cases it is enough to calculate the weighed average of the runoff coefficients for the various areas.

EXAMPLE	
A1	Brick surface area = A1 runoff coefficient = $\phi 1$
A2	Grassy surface area = A2 runoff coefficient = $\phi 2$
A3	Asphalted surface area = A3 runoff coefficient = $\phi 3$

$$\phi = \frac{\Sigma A_i\phi_i}{\Sigma A_i} = \frac{A_1\phi_1 + A_2\phi_2 + A_3\phi_3}{A_1 + A_2 + A_3}$$



CALCULATING CONCENTRATION TIME T_C

Concentration time - see definition above - depends on the average inclination, type and size of the contributing surfaces. To determine its value is not that easy.

A lot of empiric formulas exist in books that, based on experience, have no general validity and may even cause considerable inaccuracy. The following expression makes it possible to calculate the concentration time of a drainage surface as used in road construction. It is suitable to our cases:

$$t_c\,(sec) = \left[\frac{26^n\left(\frac{L}{K}\right)^{0,6}}{i^{0,3}a^{0,4}}\right]^{\left(\frac{1}{0,6+0,4n}\right)}$$

where:
L (m) is the width of the surface (perpendicular to the drainage line);
i (%) is the average incline of the surface;
a (mh^{-n}) and n are the parameters of the equation for the pluviometric possibility for a set return time;
K ($m^{1/3}/s$) is a coefficient that depends on the type of surface.

SURFACE	K
Asphalt	50 - 75
Bricks	20 - 30
Grass	2 - 2,5

The value of concentration time for very small surfaces is normally in the order of a few minutes and is in no way comparable to effective rainfall time, even if brief and intense. To assume said values would mean to overestimate the flow rates. It can be a precautionary measure if generally valid pluviometric possibility equations are used.

Given the difficulty in accurately calculating concentration time, we propose a direct method of calculation that is user-friendly and applicable in the designing stages. The method, which is based on Mufle's wide experience in different areas in Italy and in the most varied situations, makes it possible to define the unitary maximum flow rate, i.e. by linear metre of drainage system, for a fixed return time Tr through the following formula:

$$q\left(\frac{m^3}{h}\right) = FL^P$$

where:

L (m) is the width of the surface (perpendicular to the drainage line);
F e P are two parameters that depend on the runoff coefficient, the average inclination of the surface and coefficients a and n for a given return time. These values can be derived from the tables on pages 307 and 308, which are valid for return times of 5 and 10 years respectively. You advised to select the return time Tr using the following criterion:

5 years	Pedestrian areas, terraces, large squares, green zones and car parks
10 years	Road draining, access to car parks, industrial estates and airport areas

Tr = 5 years

PARAMETER F

INCLINE i	RUNOFF COEFFICIENT											
	0,4	0,45	0,5	0,55	0,6	0,65	0,70	0,75	0,80	0,85	0,90	0,95
0,1%	0,0138	0,0289	0,0458	0,0645	0,0852	0,108	0,1332	0,1608	0,1912	0,2246	0,2611	0,301
0,5%	0,0181	0,0377	0,0589	0,0818	0,1067	0,1335	0,1625	0,1938	0,2274	0,2636	0,3026	0,3444
1,0%	0,0204	0,0422	0,0656	0,0907	0,1175	0,1463	0,1771	0,21	0,2451	0,2825	0,3224	0,3649
1,5%	0,0219	0,0451	0,0699	0,0963	0,1244	0,1543	0,1862	0,22	0,256	0,2941	0,3346	0,3775
2,0%	0,023	0,0473	0,0731	0,1004	0,1295	0,1603	0,1929	0,2275	0,264	0,3027	0,3435	0,3867
2,5%	0,0239	0,049	0,0756	0,1038	0,1336	0,1651	0,1983	0,2334	0,2705	0,3095	0,3506	0,394
3,0%	0,0247	0,0505	0,0778	0,1066	0,137	0,1691	0,2029	0,2384	0,2758	0,3152	0,3566	0,4
3,5%	0,0253	0,0518	0,0797	0,1091	0,14	0,1726	0,2068	0,2427	0,2804	0,3201	0,3616	0,4052
4,0%	0,0259	0,053	0,0814	0,1113	0,1427	0,1756	0,2102	0,2465	0,2845	0,3243	0,3661	0,4098
4,5%	0,0265	0,054	0,0829	0,1132	0,145	0,1784	0,2133	0,2499	0,2881	0,3282	0,3701	0,4138
5,0%	0,0269	0,0549	0,0843	0,115	0,1472	0,1809	0,2161	0,2529	0,2914	0,3316	0,3736	0,4175
5,5%	0,0274	0,0558	0,0855	0,1166	0,1492	0,1831	0,2187	0,2557	0,2944	0,3348	0,3769	0,4208
6,0%	0,0278	0,0566	0,0867	0,1182	0,151	0,1853	0,221	0,2583	0,2972	0,3377	0,3799	0,4239
6,5%	0,0282	0,0573	0,0878	0,1196	0,1527	0,1872	0,2232	0,2607	0,2998	0,3404	0,3827	0,4268
7,0%	0,0285	0,058	0,0888	0,1209	0,1543	0,1891	0,2253	0,263	0,3022	0,3429	0,3853	0,4294
7,5%	0,0289	0,0587	0,0898	0,1221	0,1558	0,1908	0,2272	0,2651	0,3044	0,3453	0,3878	0,4319
8,0%	0,0292	0,0593	0,0907	0,1233	0,1572	0,1924	0,229	0,2671	0,3065	0,3475	0,3901	0,4342
8,5%	0,0295	0,0599	0,0915	0,1244	0,1585	0,194	0,2308	0,2689	0,3086	0,3496	0,3923	0,4364
9,0%	0,0298	0,0605	0,0924	0,1254	0,1598	0,1954	0,2324	0,2707	0,3105	0,3516	0,3943	0,4385
9,5%	0,0301	0,061	0,0931	0,1265	0,161	0,1968	0,234	0,2724	0,3123	0,3535	0,3963	0,4405
10,0%	0,0303	0,0615	0,0939	0,1274	0,1622	0,1982	0,2354	0,274	0,314	0,3554	0,3981	0,4424

Tr = 5 years

PARAMETER P

INCLINE i	RUNOFF COEFFICIENT											
	0,4	0,45	0,5	0,55	0,6	0,65	0,70	0,75	0,80	0,85	0,90	0,95
0,1%	0,7134	0,709	0,7046	0,7002	0,6959	0,6915	0,6872	0,6829	0,6787	0,6745	0,6703	0,6661
0,5%	0,7589	0,755	0,7511	0,7472	0,7433	0,7395	0,7357	0,7319	0,7281	0,7243	0,7206	0,7168
1,0%	0,7793	0,7757	0,772	0,7684	0,7648	0,7612	0,7576	0,754	0,7505	0,7469	0,7434	0,7399
1,5%	0,7916	0,788	0,7846	0,7811	0,7776	0,7742	0,7707	0,7673	0,7639	0,7605	0,7571	0,7537
2,0%	0,8003	0,7969	0,7936	0,7902	0,7868	0,7835	0,7802	0,7768	0,7735	0,7702	0,7669	0,7637
2,5%	0,8072	0,8039	0,8006	0,7973	0,7941	0,7908	0,7876	0,7843	0,7811	0,7779	0,7747	0,7715
3,0%	0,8129	0,8097	0,8064	0,8032	0,8	0,7968	0,7937	0,7905	0,7873	0,7842	0,7811	0,7779
3,5%	0,8177	0,8146	0,8114	0,8082	0,8051	0,802	0,7989	0,7958	0,7927	0,7896	0,7865	0,7834
4,0%	0,8219	0,8188	0,8157	0,8126	0,8095	0,8065	0,8034	0,8003	0,7973	0,7943	0,7912	0,7882
4,5%	0,8256	0,8226	0,8195	0,8165	0,8135	0,8104	0,8074	0,8044	0,8014	0,7984	0,7954	0,7925
5,0%	0,829	0,826	0,823	0,82	0,817	0,814	0,811	0,8081	0,8051	0,8022	0,7992	0,7963
5,5%	0,832	0,8291	0,8261	0,8231	0,8202	0,8172	0,8143	0,8114	0,8085	0,8055	0,8026	0,7998
6,0%	0,8348	0,8319	0,8289	0,826	0,8231	0,8202	0,8173	0,8144	0,8115	0,8087	0,8058	0,8029
6,5%	0,8374	0,8345	0,8316	0,8287	0,8258	0,8229	0,8201	0,8172	0,8144	0,8115	0,8087	0,8059
7,0%	0,8398	0,8369	0,834	0,8312	0,8283	0,8255	0,8227	0,8198	0,817	0,8142	0,8114	0,8086
7,5%	0,842	0,8392	0,8363	0,8335	0,8307	0,8279	0,8251	0,8223	0,8195	0,8167	0,8139	0,8112
8,0%	0,8441	0,8413	0,8385	0,8357	0,8329	0,8301	0,8273	0,8246	0,8218	0,819	0,8163	0,8135
8,5%	0,846	0,8433	0,8405	0,8377	0,835	0,8322	0,8294	0,8267	0,824	0,8212	0,8185	0,8158
9,0%	0,8479	0,8451	0,8424	0,8397	0,8369	0,8342	0,8315	0,8287	0,826	0,8233	0,8206	0,8179
9,5%	0,8497	0,8469	0,8442	0,8415	0,8388	0,8361	0,8334	0,8307	0,828	0,8253	0,8226	0,82
10,0%	0,8513	0,8486	0,8459	0,8432	0,8405	0,8379	0,8352	0,8325	0,8298	0,8272	0,8245	0,8219

Tr = 10 years												
PARAMETER F												
INCLINE i	RUNOFF COEFFICIENT											
	0,4	0,45	0,5	0,55	0,6	0,65	0,70	0,75	0,80	0,85	0,90	0,95
0,1%	0,0278	0,0396	0,0531	0,0684	0,0857	0,1053	0,1272	0,1519	0,1795	0,2246	0,2451	0,2837
0,5%	0,0432	0,0606	0,0799	0,1011	0,1246	0,1504	0,1787	0,2098	0,2438	0,2636	0,3218	0,3662
1,0%	0,0522	0,0727	0,0952	0,1196	0,1463	0,1753	0,2068	0,2411	0,2782	0,2825	0,3618	0,4088
1,5%	0,0583	0,0809	0,1054	0,132	0,1607	0,1918	0,2253	0,2615	0,3004	0,2941	0,3875	0,4359
2,0%	0,0631	0,0873	0,1134	0,1415	0,1718	0,2044	0,2394	0,277	0,3173	0,3027	0,4068	0,4563
2,5%	0,0671	0,0926	0,12	0,1494	0,181	0,2148	0,251	0,2897	0,3311	0,3095	0,4224	0,4727
3,0%	0,0705	0,0971	0,1256	0,1562	0,1888	0,2236	0,2608	0,3005	0,3428	0,3152	0,4357	0,4866
3,5%	0,0735	0,1012	0,1306	0,1621	0,1957	0,2314	0,2695	0,3099	0,353	0,3201	0,4472	0,4987
4,0%	0,0763	0,1048	0,1351	0,1674	0,2018	0,2384	0,2772	0,3184	0,362	0,3243	0,4574	0,5094
4,5%	0,0788	0,1081	0,1392	0,1723	0,2074	0,2447	0,2841	0,326	0,3702	0,3282	0,4666	0,519
5,0%	0,0811	0,1111	0,143	0,1768	0,2125	0,2504	0,2905	0,3329	0,3777	0,3316	0,475	0,5277
5,5%	0,0832	0,1139	0,1465	0,1809	0,2173	0,2558	0,2964	0,3394	0,3846	0,3348	0,4827	0,5358
6,0%	0,0852	0,1166	0,1497	0,1848	0,2217	0,2608	0,3019	0,3453	0,391	0,3377	0,4899	0,5432
6,5%	0,0871	0,1191	0,1528	0,1884	0,2259	0,2654	0,3071	0,3509	0,397	0,3404	0,4966	0,5501
7,0%	0,0889	0,1214	0,1557	0,1918	0,2298	0,2698	0,3119	0,3562	0,4027	0,3429	0,5028	0,5567
7,5%	0,0906	0,1237	0,1584	0,195	0,2335	0,274	0,3165	0,3611	0,408	0,3453	0,5087	0,5628
8,0%	0,0922	0,1258	0,161	0,1981	0,237	0,2779	0,3208	0,3658	0,413	0,3475	0,5143	0,5686
8,5%	0,0938	0,1278	0,1635	0,201	0,2404	0,2817	0,325	0,3703	0,4178	0,3496	0,5196	0,5741
9,0%	0,0953	0,1297	0,1659	0,2038	0,2436	0,2853	0,3289	0,3746	0,4224	0,3516	0,5247	0,5793
9,5%	0,0967	0,1316	0,1682	0,2065	0,2467	0,2887	0,3327	0,3787	0,4268	0,3535	0,5295	0,5843
10,0%	0,0981	0,1334	0,1704	0,2091	0,2496	0,292	0,3363	0,3826	0,4309	0,3554	0,5341	0,5891

Tr = 10 years												
PARAMETER P												
INCLINEi	RUNOFF COEFFICIENT											
	0,4	0,45	0,5	0,55	0,6	0,65	0,70	0,75	0,80	0,85	0,90	0,95
0,1%	0,7349	0,7334	0,7318	0,73	0,7281	0,726	0,7237	0,7214	0,7188	0,7162	0,7134	0,7106
0,5%	0,7256	0,7271	0,7284	0,7296	0,7306	0,7314	0,7322	0,7327	0,7331	0,7334	0,7335	0,7335
1,0%	0,7216	0,7243	0,7269	0,7294	0,7317	0,7338	0,7358	0,7377	0,7394	0,7409	0,7424	0,7437
1,5%	0,7193	0,7228	0,7261	0,7293	0,7323	0,7352	0,7379	0,7406	0,743	0,7454	0,7476	0,7497
2,0%	0,7176	0,7216	0,7255	0,7292	0,7328	0,7362	0,7395	0,7426	0,7456	0,7485	0,7513	0,7539
2,5%	0,7164	0,7208	0,725	0,7291	0,7331	0,737	0,7407	0,7442	0,7477	0,751	0,7542	0,7573
3,0%	0,7153	0,72	0,7246	0,7291	0,7334	0,7376	0,7416	0,7456	0,7494	0,753	0,7566	0,76
3,5%	0,7144	0,7194	0,7243	0,729	0,7336	0,7381	0,7425	0,7467	0,7508	0,7547	0,7586	0,7623
4,0%	0,7137	0,7189	0,724	0,729	0,7338	0,7386	0,7432	0,7476	0,752	0,7562	0,7603	0,7643
4,5%	0,713	0,7185	0,7238	0,729	0,734	0,739	0,7438	0,7485	0,7531	0,7575	0,7619	0,7661
5,0%	0,7124	0,7181	0,7236	0,7289	0,7342	0,7393	0,7444	0,7493	0,754	0,7587	0,7633	0,7677
5,5%	0,7119	0,7177	0,7234	0,7289	0,7343	0,7397	0,7449	0,75	0,7549	0,7598	0,7645	0,7692
6,0%	0,7114	0,7173	0,7232	0,7289	0,7345	0,74	0,7453	0,7506	0,7557	0,7608	0,7657	0,7705
6,5%	0,7109	0,717	0,723	0,7289	0,7346	0,7402	0,7458	0,7512	0,7565	0,7617	0,7667	0,7717
7,0%	0,7105	0,7167	0,7229	0,7288	0,7347	0,7405	0,7462	0,7517	0,7572	0,7625	0,7677	0,7728
7,5%	0,7101	0,7165	0,7227	0,7288	0,7348	0,7407	0,7465	0,7522	0,7578	0,7633	0,7686	0,7739
8,0%	0,7098	0,7162	0,7226	0,7288	0,7349	0,741	0,7469	0,7527	0,7584	0,764	0,7695	0,7749
8,5%	0,7094	0,716	0,7224	0,7288	0,735	0,7412	0,7472	0,7531	0,7589	0,7647	0,7703	0,7758
9,0%	0,7091	0,7158	0,7223	0,7288	0,7351	0,7414	0,7475	0,7535	0,7595	0,7653	0,7711	0,7767
9,5%	0,7088	0,7156	0,7222	0,7288	0,7352	0,7416	0,7478	0,7539	0,76	0,7659	0,7718	0,7775
10,0%	0,7085	0,7154	0,7221	0,7287	0,7353	0,7417	0,7481	0,7543	0,7605	0,7665	0,7725	0,7783

Calculation example

The general characteristics of the area are the basis of proper drainage line projects. You should be able to infer said characteristics either from project drawings or - should they be unavailable - from a detailed description of the place as provided by the client.
The following are required:

- Typology of ground (flat, steep, on a bend etc).
- Nature of ground (asphalt, paved, green, mixed etc.).
- Geometry of ground (length x width, inclination).
- Any peculiarities such as the presence of flat roofs pouring water onto the area concerned, the typology of liquids to be drained into the channel, any constraints due to limited space or unavoidable positions of the final drain, the presence of purification plants etc.

Designing does not consist only in **determining the rain flow rates** and the **drain outlet diameters** to be connected to the drainage line, but also in choosing the **model of channel**, the type of **grating** and the relevant **load class**. This list must include another essential aspect, i.e. you need to know in advance:

- the usage destination of the area (parking lot, airport area, underground rooms, areas for industrial processing etc).

The first distinction to be made is between covered and open-air surfaces to be drained.
Covered areas are used for industrial processing and the water to be disposed of may be polluted by chemicals (even dangerous chemicals). You need to know their typology and concentration in order to be sure about their compatibility with HD-PE (ASVOX stainless-steel drainage channels should be used if compatibility is low), the type of vehicles travelling through the area and the quantity of liquids to be drained in order to determine the size of the channels and the number of drain outlets that need opening up.
As concerns open-air areas, there are many more possibilities - see the following case just as an example.

PARKING AREA IN A COMMERCIAL CENTRE WITH SELF-LOCKING PAVEMENT	
Area to be trained A	5.000 m²
Type of groun	FLAT
Nature	80% self-locking pavement, 20% green area
Geometry	L=100m, l=50m
Average inclination i	2,5 %
Peculiarities	The parking area has a boundary wall on three sides

As the ground is flat and you can choose the position of the drainage line, you may want to place it along the short side (50 metres) and to give the surface an average inclination of 2.5%.

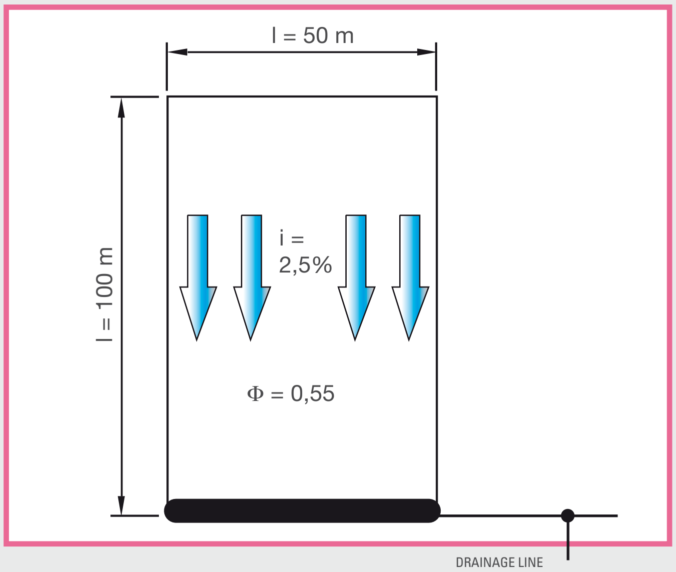
As this is a car park in a commercial centre, return time Tr can be assumed to be = 5 years. The calculation formula on page 257 and the tables on pages 264-265 - with values $\Phi = 0.55$ (calculated as shown on page 263) and i = 2.5 % in the table for Tr = 5 years - make it possible to find that:

F = 0,1038
P = 0,8082

Consequently, unitary runoff capacity will be:

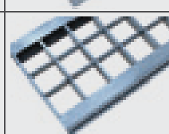
$q = 0{,}1038 \bullet 100^{0{,}8082} = 4{,}29\ (m^3/h) = 1{,}19$ litres/sec

To determine the total capacity to be drained, just multiply value "q" by the width of the surface. Therefore:
Q = q x l = 1,19 (l/sec x m) x 50 (m) = **59.5 l/sec**
The water shall be collected through channels perpendicular to the drainage direction and installed along the whole length of the parking area (l) upstream, as determined at the beginning.
Assuming that the line is installed very close to the boundary wall, we recommend using a MufleDrain channel mod. VIP_{20} 150/160 with its ductile iron drainage grating mod. VIP_{20} 150 class B125 with a square mesh. This choice is due to the low inclination of the ground (there is no risk of water growing too fast and bypassing the grating), to the fact that the gratings will not be driven over (installation very close to the wall) and to the fact that it is a self-locking parking area. The choice of a square mesh matches the aesthetical appearance of the environment. As there are no height constraints, the higher grating should be used in order to have more storage capacity and consequently more safety. For further details on the choice of the grating, please see the following page.
Have collected the rainwater, you need to open up a proper number of drain outlets to be connected to each other by means of a PVC round-section pipe connected to the sewer system. In this example, the preinstalled drain outlets on the side of the channel with diameter 110 mm can be opened up. By giving the pipe an inclination of 1% you are able to dispose of about 9.9 l/sec per drain outlet. So 6 of them should be opened up: 1 every 83 metres approximately. In practical terms, we recommend opening up 8 drain outlets (1 every 6 metres approximately) in order to consider any load losses, clogging and other risk factors.



Calculating drainage capacity of gratings and drainage into the sewer system

Having determined the volume of water to be drained (as shown in the example on page 309), it is essential to select the type of grating from those available for the MufleDrain System channel that is capable of meeting the load and drainage characteristics required. The first test to be carried out on the gratings is resistance to the load required. An extract from Standard EN 1433 about the load class to be used in all situations of pedestrian and vehicular traffic is shown on page 13 of MufleDrain's Catalogue. Having identified the type and load class to be used, select the channel to be installed according to absorption capacity per ml as shown in the table below, taking into account possible obstacles such as leaves and residues. MufleDrain channels are available in 4 inner widths: 100, 150, 200, 300 mm. In special cases such as having to drain large flow rates in short stretches or with fast flowing water on the grating, two parallel drainage lines (recommended distance 50-100 cm) should be installed instead of a single wider line.

CHARACTERISTICS OF GRATINGS			ABSORPTION OF GRATING BASED ON CHANNEL WIDTH		
Type of grating		Class of load	154	204	254
			(litres per second per linear metre)		
Run grating		A15	3,4	4,0	4,6
Mesh grating		B125 C250	9,0	13,0	17,0
Ductill ductile iron grating		C250 D400 E600 F900	4,5	7,3	10,0
HD-PE grating		Walkable-Driveable	7,5	10,5	13,5

NOTE: This table only lists some gratings from the MufleDrain range as an example.
For further information please contact our Technical Department (address: tecnico@mufle.com).

Flow capacity of PVC round pipes

Before installing the channel selected you need to determine the sizes of the drain outlets to be connected to the drainage line for the sewer system. The flow rates of round PVC pipes normally used in the building industry are shown below. Although the flow rate changes according to the inclination, to avoid load losses and the presence of any residues either drain outlets with a large diameter or several outlets should be used. The MufleDrain channel is equipped with a series of pre-installed drain outlets that speed up connection.

Incline	Ø Pipe				
	100	110	125	160	200
	(litre for second)				
0,5 %	5,0	6,5	9,8	15,9	34,3
1,0 %	7,6	9,9	13,9	22,5	48,5
1,5%	9,2	11,0	17,0	27,5	59,4
2,0 %	10,7	12,1	19,6	31,7	68,6
3,0 %	13,1	15,8	24,0	38,9	84,1
5,0 %	16,9	20,3	31,0	50,2	108,5
10,0 %	23,9	28,7	43,8	71,1	153,4

NOTE: The table of drain outlets that can be applied to channels and boxes is available in the Catalogue.

Introduction

MufleSystem gives instructions on how to install its channels in compliance with Standard EN 1433 for type-M channels. Dimensions H and S of the installation bed and props are specified together with the concrete class to be used, the details on the reinforcement framework (if any) and advice on proper installation. This information is shown in the Catalogue for each product family.

Underlying layer and propping

The underlying layer has the function of absorbing and distributing the stresses from the surface without giving way - this would jeopardise the functionality of the water channelling system (fig. 1). For this reason it must be suitably prepared and tamped in order to achieve a bearing capacity suitable to the load classes specified.
Owing to the loads applied the pavings (road, industrial or airport pavings) are subjected to compression and bending traction stresses. They may also break due to fatigue owing to the effects brought about by the cyclical action of the loads (repeated passage of vehicles).

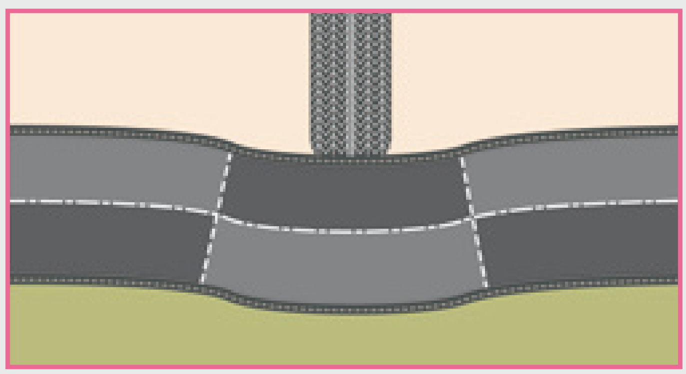
(FIG. 1) • MUFLEDRAIN INSTALLATION UNDERLYING LAYER

Concrete

COMPRESSION STRENGTH R_{ck}

The concrete used for the channels' installation bed and props needs to be resistant enough to withstand the above-mentioned stresses due to the paving (fig. 2). Although concrete has high compression strength [R_{ck}], it has poor resistance to bending traction [F^{cfm}] (around 10% of R_{ck}): as this is directly proportional to R_{ck}, high compression-strength concrete should be used to oppose tensile stresses. When tensile stresses are very high (load classes E 600, F 900) a lightweight reinforcement framework should be used (electrowelded mesh or Ø8 rods with spacing 15 cm).

(FIG. 2) • STRESSES INDUCED IN THE PAVING



A = STETCHED ZONE
B = COMPRESSED ZONE

CONSISTENCY CLASS

The special geometry of the external side surfaces of the channels, made up of anti-torsion ribs and pre-arranged drains (for improved adhesion between concrete and polyethylene), the presence of a reinforcement framework (if any), and the little thickness of the installation layer and props make installation quite difficult.

•(FIG. 3) • FENOMENI DI SEGREGAZIONE

For this reason we recommend using a type of concrete that, when fresh, has high fluidity without causing segregation phenomena in the components (fig. 3).

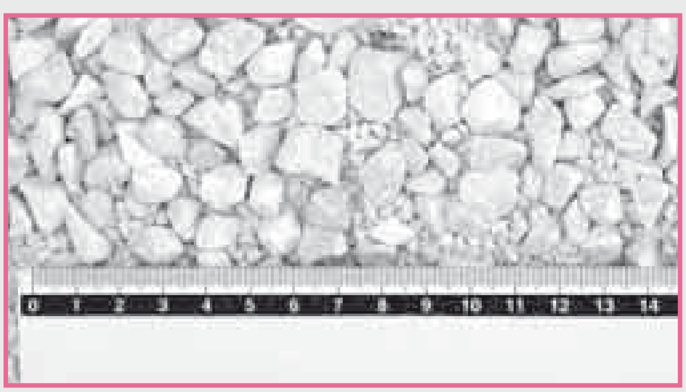
Thanks to these characteristics the concrete is able to move easily inside the formwork as far as the least accessible areas. It is important to be able to achieve the right compactness in the concrete and to fill the slits completely and with no difficulty, i.e. by means of ordinary vibration means used on all building sites.
It is advisable therefore to use concrete with a class of consistency S4 (fluid) or better even S5 (superfluid) (UNI 9858, Ministry Guideline of LL.PP.) measured with Abrams' cone method (UNI 9418).

Consistency Class S5 is necessary where, for very heavy loads, reinforcement framework is provided for in the concrete used for installation.

MAXIMUM DIAMETER D_{max} OF STONE AGGREGATE

The special geometry also requires a suitable maximum dimension or Maximum Diameter D_{max} in the stone aggregate.

•(FIG. 4) • MAXIMUM DIAMETER D_{MAX}



To let the concrete reach the least accessible areas we recommend using stone aggregate with Maximum Diameter D_{max} of 15 mm (fig.4).

Fluidity of concrete		
Consistency Classes	Cone slump (mm)	Name
S1	10 ÷ 40	Damp
S2	50 ÷ 90	Plastic
S3	100 ÷ 150	Semifluid
S4	160 ÷ 210	Fluid
S5	>210	Superfluid

WATERPROOFNESS

Concrete is basically made up of a mixture of cement paste and stone aggregate. Each material has internal micro and macro cavities. Therefore it would not be correct to consider concrete a waterproof material in the real sense of the term. Standard UNI 9858 defines waterproofness as resistance against penetration of water (UNI 7699). According to this Standard a mixture is suitable to make waterproof concrete when the result of water penetration gives a maximum value smaller than 50 mm and average values smaller than 20 mm. Furthermore the water/cement ratio must not exceed 0,55.

Please note that Standard UNI 7699, mentioned in UNI 9858, only specifies water permeability; it does not provide for the measurement of waterproofness of water under pressure.
If this measurement is needed reference to ISO 7031 or DIN 1048 should be made. Following these rules, concrete which is almost waterproof will show (28 days after being laid) the following waterproofness value:

Darcy coefficient → $k=1 \bullet 12^{-11}$ [m/s]

i.e. it should have maximum waterproofness of 20 mm under maximum pressure 7 bars.
In practical terms, if waterproof concrete is needed, it is necessary to reduce the number and sizes of the internal cavities, as well as their connections especially with the external environment. This can be achieved with:

- low w/c ratio (0.4 - 0.5 recommended);
- adequate dose of cement (300 - 400 kg/m^3);
- good fluidity and resistance tosegregation so as to achieve adequate compacting of the cement;
  • accurate drying and protection of the casting.

WATERPROOFNESS OF CONCRETE		
Ratio a/c	Penetration of the water	Average penetration of the water
< 0,55	<50 mm	< 20 mm

DURABILITY

The useful life of a drainage system also depends on the durability of the concrete in which it is set.
Durability of a concrete structure means the ability to last over time while ensuring the function for which it was designed.
Contrary to what is often thought, concrete is not an indestructible material but one that deteriorates more or less quickly over time. For this reason you will need to analyse the deterioration phenomena and how they become apparent in order to increase the durability of concrete.

There are two main degenerative causes affecting concrete durability:

- The aggression due to substances present in the surrounding environment;
- The permeability of the mixture.

The causes of aggression and deterioration due to the external environment are subdivided as follows:

- Chemical
- Physical
- Mechanical

Generally such actions do not occur individually, but there are several causes that contribute to the deterioration of the material, even though it is always possible to detect the main cause that triggered the whole process.
Deterioration shows more or less strongly and quickly according to the permeability or porosity of concrete: a very porous material lets the aggressive agents reach the innermost tissue thus starting and spreading the degradation process much more easily and quickly.

CAUSES OF AGGRESSION		
Chemical	Physical	Mechanical
Sulphatic attack	Ice-Thawing	Shocks
Carbon dioxide action	Hydrometric variations	Erosion
Chloride action	Hydration heat	Abrasion
Alkali action	Fire	
Industrial chemical agent action		

This clearly shows how essential it is to make virtually waterproof cement conglomerate that is able to oppose the penetration of aggressive agents. To this end, we recommend carefully assessing which actions of deterioration will take place during the usage period and using concrete that is able to oppose such actions. Special attention should be paid to the mixing, laying and drying processes.

The standards of reference are as follows: UNI 9858 "Concrete. Performance, production, laying and principles of conformity", UNI 8981 "Durability of concrete construction and handwork", Ministry Guideline of LL. PP., UNI EN 206-1 "Concrete. Specification, performance, production and conformity".
Some schematic information on the most frequent degenerative processes is outlined below together with how to oppose them.

DRAINAGE SYSTEMS TO BE USED IN THE ADRIATIC COASTAL AREA: SENSITIVITY TO ALKALI

It has been seen that in the stone aggregate of the Adriatic coast there can be particular types of amorphous silica, opal and chalcedony which can react with the alkali in the cement thus giving rise to disruptive phenomena that take place through a network of cracks and small surface craters (pop-out) even over quite a long time.
Phenomena of this type can get under way in industrial pavings or along roads where de-icing salt is used. Possible solutions to prevent deterioration are as follows:

- To use stone aggregate not sensitive to alkali (Standard UNI 8520/22)
- Use of pozzolanic or blast furnace cement.

DRAINAGE SYSTEMS TO USE IN VERY COLD CLIMATES: FROST AND THAW CYCLES

The alternate action of frost and thaw cycles can bring about disruptive phenomena caused by the penetration of water into the concrete pores. When the water freezes, its volume increases thus generating internal pressure that can cause cracks and crumbling. In order to prevent this type of degeneration:

- Use an aerating additive that develops air as microbubbles able to mitigate freezing stresses;
- Use frost-proof stone aggregate (Standard UNI 8520/20);
- Reduce concrete porosity.

DRAINAGE SYSTEMS TO BE USED WHERE SULPHATES ARE PRESENT

Sulphates - found in the water and in the ground - can react with the concrete mixture thus giving rise to swelling and expansion phenomena that can cause the progressive disruption of concrete even after some time.

In such cases, once the presence of sulphates has been ascertained, we recommend:

- Using sulphate-resistant cement;
- Using the least permeable concrete possible.

RESISTANCE TO FATIGUE

The plastic channel buried in a suitably made cement body can suffer breakage caused by concrete fatigue as a result of the repetitive action of the loads over time. The reasons behind this kind of fracture can be outlined as follows:

- The possible presence of microcracks, defects and cavities mainly located in the cement paste-stone aggregate interface makes the cement matrix weaker due to internal bleeding and the accumulation of calcium hydroxide crystals. Such microcracks can be emphasised by shrinkage and thermal changes (frost and thaw);
- The application of cyclic stresses higher than 50-60% of static-induced breaking stress causes the microcracks in the structure to expand and branch off;
- The increase in microcracks brings about the collapse by fatigue of the concrete matrix and consequently of the channel.

According to the above, we can say that the breaking of concrete due to fatigue occurs only when induced stress exceeds a certain value defined as Fatigue Limit.

If the material is subjected to compression stresses, this limit is equal to 60% of the resistance. It is 50% if breaking by fatigue is caused by bending tensile stresses.

Clearly enough, it is hardly ever possible to determine with sufficient accuracy the number of load cycles (vehicle passages etc.) before the collapse.
The problem can be solved by adopting a security factor S equal to 2. In this way, as the maximum tensile stresses affecting the concrete are equal to the Fatigue Limit (50% of resistance), breaking by fatigue cannot occur over an infinite number of passages

Apart from the number of passages, as a rough estimate during the design stage, a security factor ranging between 1,4 and 2,0 according to the type of load can be assumed.

NOTE
Please see the Sheet at the end of each Chapter about the specific installation of the different product lines.