# SLOVENSKI STANDARD
# oSIST prEN 12390-19:2021

**01-december-2021**

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**Preskušanje strjenega betona - 19. del: Ugotavljanje upornosti**

Testing of hardened concrete - Part 19: Determination of resistivity

Prüfung von Festbeton - Teil 19: Bestimmung des elektrischen Widerstands

Essais pour béton durci - Partie 19 : Détermination de la résistivité électrique



**Ta slovenski standard je istoveten z: prEN 12390-19**



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**ICS:**

| | | |
|---|---|---|
| 91.100.30 | Beton in betonski izdelki | Concrete and concrete products |

**oSIST prEN 12390-19:2021** **en,fr,de**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

**DRAFT**
**prEN 12390-19**

October 2021

ICS 91.100.30

English Version

# Testing of hardened concrete - Part 19: Determination of resistivity

Prüfung von Festbeton - Teil 19: Bestimmung des elektrischen Widerstands

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 104.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. prEN 12390-19:2021 E

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# European foreword

This document (prEN 12390-19:2021) has been prepared by Technical Committee CEN/TC 104 “Concrete and related products”, Subcommittee SC1 “Concrete - Specification, performance, production and conformity”, the secretariat of which is held by SN.

This document is currently submitted to the CEN Enquiry.

A list of all parts in the EN 12390 series can be found on the CEN website.

## Introduction

This test method is one of a series concerned with testing hardened concrete.

This document is based on current national standards and in particular the Spanish standard UNE PNE 83988 Part 1 and Part 2.

Resistivity is a property that quantifies how strongly a given material opposes the flow of electric current. Resistivity is the electrical resistance of a unit volume (e.g. 1 $m^3$) of a concrete. It is the inverse of conductivity, and it is obtained from the ratio between the voltage drop and the current (Ohm's law).

The resistivity of a water-saturated concrete is mainly a function of the pore size distribution and the connectivity/tortuosity of the pore system. It also depends on the pore solution composition, which is strongly affected by the cement type, additions, w/c ratio, aggregate type and the degree of hydration of the cement.

Resistivity is also dependent on temperature and for quality control testing, the temperature of the concrete specimens should be held within a defined range for comparable results.

The standard is applied to water saturated concretes because the resistivity is affected by the degree of water saturation. A reduction in the moisture content increases the resistivity. Loss of continuity of the pore system by drying may have more impact on the resistivity value than a change in the volume of capillary porosity because drying may produce changes of more than one order of magnitude while a change in capillary porosity may be reflected in changes of two or three times.

In present standard a 4-electrode is recommended due to it avoids the frequency dependent voltage drop produced by the concrete/electrode interfacial resistance. This interfacial resistance may appear when using only two electrodes placed in the parallel faces of the specimen, electrodes which apply the current and measure the voltage in the same geometrical point. If two electrodes are used, calibration is recommended with the 4 electrodes arrangement described in present standard.



The measured resistivity is also affected by the electrical frequency of testing ([1], [2], [3], [4]) and so the measured resistivity could be increased by reducing the electrical frequency. In addition, for the same electrical frequency, the measured resistivity is depending on the specific pattern of the electrical field across the specimen. Notwithstanding these differences, where the electrical resistivity is determined in the same conditions, in a frequency range where the electrode polarization phenomena are independent of its variation, changes in resistivity reflect changes occurring in the concrete.

If the aggregate is electrically conductive or porous also influences the magnitude of concrete resistivity. This fact should be taken into account when establishing threshold values. It prevents comparison of resistivity values between concretes if the aggregates show difference of half an order of magnitude (higher or lower) of resistivity. The same effect of decreasing the measured resistivity is produced when metallic or electricity conducting fibres or particles, are present.

# 1 Scope

This document describes a method for determining the electrical resistivity of concrete in water saturated conditions. Two methods of measuring the resistivity are standardized: the volumetric method (see 3.1.3), which is the reference method, and the surface method (see 3.1.4).

NOTE The volumetric method is applicable to cast specimens or cores, while the surface method is suitable for use on cast specimens, cores and on construction site, but not all these applications are covered in this document.

The method can be applied to the normal range of concretes covered by current standards. It does not cover the concretes made with porous aggregates or having metallic components.

The use of resistivity to assess the potential for corrosion of reinforcement in existing structures is not specified in this document.

The use of resistivity to assess cores taken from an existing structure, which need pre-condition on water saturation, is not directly specified in this document.

# 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.



EN 12390-2, *Testing hardened concrete — Part 2: Making and curing specimens for strength tests*



# 3 Terms and definitions



## 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

**3.1.1**
**electrical resistance**
**$R_e$**
voltage drop divided by current (in Ohm)

$$R_e = \frac{U}{I} \quad (1)$$

where

U is the difference in voltage drop before and after the application of the current between the voltage electrode; and

I is current circulating through the current electrodes

**3.1.2**
**resistivity of a concrete**
**ρ**
material parameter independent of the geometry of the specimen which indicates the resistance of the material to the circulation of an electrical current (in Ohm· m)

$$\rho = R_e \times A / l \tag{2}$$

Note 1 to entry: It is the proportionality constant between electrical resistance and geometry of the specimen. Assuming a regular geometry of a cube the resistivity is equal to the electrical resistance multiplied by the cross section area (A) an divided by the width of the cube (l).

Note 2 to entry: Some commercial equipment expresses the resistivity in alternative units, e.g. kOhm·cm. The conversion between Ohm·m and kOhm·cm is: 1 Ohm·m = 0,1 kOhm·cm.

**3.1.3**
**volumetric resistivity**
**$\rho_v$**
resistivity when the electrodes for applying the current are placed on the top and bottom of a cylindrical, cubic or prismatic specimen and cover all these top and bottom surfaces

$$\rho_v = R_e \cdot F_{gv} = R_e \cdot \frac{Cross\ section\ area}{Distance\ between\ voltage\ electrodes} \tag{3}$$




Note 1 to entry: Its value results from multiplying the measured resistance $R_e$ by the volumetric geometrical factor $F_{gv}$. The volumetric resistivity is taken as the reference value for the resistivity of a concrete.



Note 2 to entry: The volumetric geometrical factor $F_{gv}$ is equal to the relation A/l in Formula (2). The voltage electrodes are the clamps as shown in Figure 2.

**3.1.4**
**surface resistivity-infinite medium**
**$\rho_{s,inf}$**
resistivity value obtained when four equally spaced electrodes of cylindrical shape are placed on the specimen surface

$$\rho_{s,inf} = R_e \cdot F_{gs} = R_e \cdot 2 \cdot \pi \cdot d \tag{4}$$

Note 1 to entry: Its value results from multiplying the measured resistance by the surface geometrical factor $F_{gs}$, which is equal to 2π multiplied by the distance (d) between every of the four equally spaced electrodes.

Note 2 to entry: This is the electrical resistivity known as Wenner method for a quasi-infinite medium.

**3.1.5**
**surface resistivity-finite medium**
**$\rho_s$**
resistivity when four equally spaced electrodes are placed aligned on the specimen surface and the obtained value is multiplied by a form factor, $F_f$ that depends on the geometry and size of the specimen and is required to equal the volumetric resistivity to the surface resistivity

$$\rho_s = \rho_{s,inf} \cdot F_f = \rho_v \tag{5}$$

**3.1.6**
**volumetric geometrical factor**
$\mathbf{F_{gv}}$
in the volumetric method, relationship between the measured electrical resistance and the resistivity

Note 1 to entry: This factor is the cross-sectional area of the test specimen (A) divided by the distance between voltage electrodes (d):

$$F_{gv} = \frac{Cross\ section\ area}{Distance\ between\ voltage\ electrodes} \quad (6)$$

**3.1.7**
**surface geometrical factor**
$\mathbf{F_{gs}}$
in an infinite medium using the four equally aligned electrodes arrangement, this factor is 2π times the distance, d between the electrodes (see Formula (4))

$$F_{gs} = 2 \cdot \pi \cdot d \quad (7)$$

**3.1.8**
**form factor**
$\mathbf{F_f}$
in the surface method, factor that equals the volumetric resistivity and the surface resistivity as indicated by Formula (8)



$$F_f = \frac{\rho_s}{\rho_{s,inf}} \quad (8)$$

## 3.2 Symbols

For the purposes of this document, the following symbols apply:

| | |
|---|---|
| A | In the volumetric method, the cross-sectional area of the test specimen [$m^2$] |
| d | In the volumetric method, the distance between the voltage electrodes (see Figure 2, distance in inch); in the surface method, the centreline to centreline distance between each of the four electrodes (see Figure 3) [m] |
| I | Current flowing in concrete specimen introduced by the outer pair of current electrodes [A] |
| U | Difference in potential drop before and after the application of the current between the inner pair of voltage electrodes [V] |

# 4 Principle

In the volumetric method (Formulae (1) and (3)), the electrical resistance of a concrete cylinder, prism or cube is measured by passing a current of known magnitude (I) through the whole volume of the water-saturated specimen and measuring the resulting voltage drop (U) over the central part of the specimen. This procedure of placing the voltage electrodes in the central part of the specimen avoids the possible nonlinear ohmic-drop at the concrete/electrode interface.

In the surface method (Formulae (4) and (5)), the determination of concrete resistivity is by means of the application of a current between the two outer electrodes and the measurement of the difference in voltage drop between the two inner electrodes located in between and aligned with the outer two electrodes. All the four electrodes are placed on the surface of the cylinder, prism or cube. The measurement provides the concrete electrical resistance ($R_e$) with that disposition of electrodes. Knowing the distance between electrodes and the dimensions of the specimen, the surface geometrical and form factors are applied to calculate the resistivity. Then, the surface resistivity is obtained by multiplying the 4-electrode resistivity by the form factor (see Formula (5)).

## 5 Apparatus

**5.1 Resistivity meter** or convenient voltage sources and multi-meters for measuring the voltage drop and current between the electrodes. If the equipment applies an AC (alternating current) its frequency should be between 40 and 10 000 Hz. If a DC (direct current) is applied, the measurement should be as short as possible and then, equipment shall be able to show/record results at least each second. The measurement is taken between 2 s and 5 s when an enough stable value is measured. Figure 1 shows an example of arrangement of hand-made resistivimeter based on a battery and two multimeters, in addition to the four points probe.

NOTE 1 The use of DC current is only feasible if the measurement is lasting very short time, to avoid polarization of the electrodes. In the DC measurements the typical minimum applied voltage is of ≥ 4,5 V.

NOTE 2 The conversion from the time domain (DC measurement) to the frequency domain (AC measurement) is not straight forward, which prevents to calculate the equivalent frequency from the waiting time, unless the amplitude of the AC signal or the voltage applied is known. The equivalence of DC resistivity values to the AC ones is based in empiric correlations.




**Key**

1 Current

2 Voltage

3 Battery ≥4,5 V

4 Sponges

NOTE 3 The left-hand side figure shows a hand-made resistivimeter with two multimeters and one battery. The central figure shows the probe with small sponges inserted in the bottom of the electrodes and fixed with an elastic rubber. The right-hand side figure shows the connections.

**Figure 1 — Hand-made resistivimeter**

**5.2 Data logger** for the simultaneous recording of voltage drop and current. It is optional but recommended.

NOTE 4 Commercial equipment is available that fulfils the requirements in 5.1 and 5.2.

**5.3 Electrodes** of stainless steel or copper free for surface impurities (e.g. rust, other oxides). For the volumetric method, they shall be a mesh or plain sheet with dimensions equal or larger in size/diameter to that of the contact faces of the specimens, i.e. for a 150 mm diameter cylinder, the electrode shall have a diameter of ≥ 150 mm. For the voltage drop measurement in the volumetric method, two stainless steel clamps of around 1 cm wide or copper wires with a diameter of 1 mm to 2 mm shall be placed to ensure good electrical contact with the concrete surface. If a 4-electrodes-type probe is to be used for measuring the resistivity, the volumetric method requires 4 cables with the corresponding plugs to connect the 4 electrodes of the probe to the two current and two voltage electrodes.

For the surface method the four electrodes shall be round bars of diameter in the range 4 mm to 10 mm made of stainless steel, carbon steel, copper or any other conducting metal free for surface impurities (e.g. rust, other oxides) and embedded in a non-conducting rigid framework at a centreline to centreline spacing in the range 35 mm to 50 mm.

The width/diameter of the specimen in the volumetric method and the distance between the current electrodes shall be at least 2,5 times the maximum aggregate size.

**5.4 Sponges** (or equivalent concrete-contacting material such as some porous polymers), four synthetic sponges or equivalent conductors that cover the tips of the four electrodes in the surface method. In the volumetric method, two thin synthetic sponges with an identical area to that of the electrodes.



**5.5 Wetting liquid at the sponge/concrete interface.** It is usually enough to use potable water; however, it is also permitted to use a substance for improving wettability (see NOTE 5). This substance shall neither cause the corrosion of the electrode, impair the surface of the specimen nor migrate into the specimen thereby affecting its resistivity.

NOTE 5 According to IEC 62631-3-1:2016 [6], a pharmaceutically obtainable jelly of the following composition is suitable as a conductive adhesive:

— anhydrous polyethylene glycol of molecular mass 600: 800 parts by mass;

— water: 200 parts by mass;

— soft soap (pharmaceutical grade): 1 part by mass;

— potassium chloride: 10 parts by mass.

Soft soap is a non-corrosive, neutral soap used for medical purposes.

# 6 Preparation of test specimens

## 6.1 Minimum number of specimens/readings to obtain a test result for a concrete

The minimum number of test specimens and readings to obtain a test result for a specific concrete at a specific age is given in Table 1.