**BSI Standards Publication**

# Tests for mechanical and physical properties of aggregates

Part 11: Determination of compressibility and confined compressive strength of lightweight aggregates

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# Tests for mechanical and physical properties of aggregates - Part 11: Determination of compressibility and confined compressive strength of lightweight aggregates

Essais pour déterminer les caractéristiques mécaniques et physiques des granulats - Partie 11: Détermination de la compressibilité et de la résistance à la compression triaxiale des granulats légers

Prüfverfahren für mechanische und physikalische Eigenschaften von Gesteinskörnungen - Teil 11: Bestimmung der Verdichtbarkeit und Druckfestigkeit bei behinderter Querdehnung von leichten Gesteinskörnungen

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**Management Centre:  Avenue Marnix 17,  B-1000 Brussels**

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# Contents

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# Foreword

This document (EN 1097-11:2013) has been prepared by Technical Committee CEN/TC 154 "Aggregates", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2014, and conflicting national standards shall be withdrawn at the latest by January 2014.

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## 1 Scope

This European Standard specifies the reference method used for type testing, and in case of dispute, for determining the compressibility and confined compressive strength of lightweight aggregates (LWA). For other purposes, in particular factory production control, other methods may be used provided that an appropriate working relationship with the reference method has been established.

The test is applicable to LWA passing the 32 mm sieve.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 932-2, *Tests for general properties of aggregates — Part 2: Methods for reducing laboratory samples*

EN 932-5, *Tests for general properties of aggregates — Part 5: Common equipment and calibration*

EN 1097-5, *Tests for mechanical and physical properties of aggregates — Part 5: Determination of the water content by drying in a ventilated oven*

prEN 13055:2012, *Lightweight aggregates for concrete, mortar, grout, bituminous mixtures, surface treatments and for unbound and bound applications*

## 3 Terms and definitions

For the purpose of this document, the terms and definitions given in prEN 13055:2012 and the following apply.

**3.1**
**bulk density**
mass of loose filled or compacted aggregates divided by the part of the volume of the container that they occupy

Note 1 to entry:     The measurement of this bulk density is different from the one defined in EN 1097-3.

**3.2**
**test specimen**
sample used in a single determination when a test method requires more than one determination of a property

## 4 Principle

First, a test specimen is placed in a steel container and compacted by vibration for the purpose of determining the compressibility and bulk densities before and after vibration. Second, the steel container filled with this test specimen is subjected to a compression test with a constant loading rate until a given percentage of deformation is reached. During this second step, the load and displacement are continuously recorded in order to determine the confined compressive stress–deformation curve and to calculate the confined compressive strength.

## 5 Apparatus

Unless otherwise stated, all apparatus shall conform to the general requirements of EN 932-5.

**5.1** **Ventilated oven**, thermostatically controlled to maintain a temperature of (110 ± 5) °C.

**5.2** **Polyethylene bags**, of suitable sizes.

**5.3** **Balance**, of adequate capacity with an actual scale interval of ± 0,1 g.

**5.4** **Cylindrical test container made of stainless steel**, with an internal diameter and height of (200 ± 0,5) mm. Minimum thickness of the cylinder shall be 7,5 mm (see Figure 1). The inside of container shall be free of protrusions resulting for example from welding.

Dimensions in millimetres
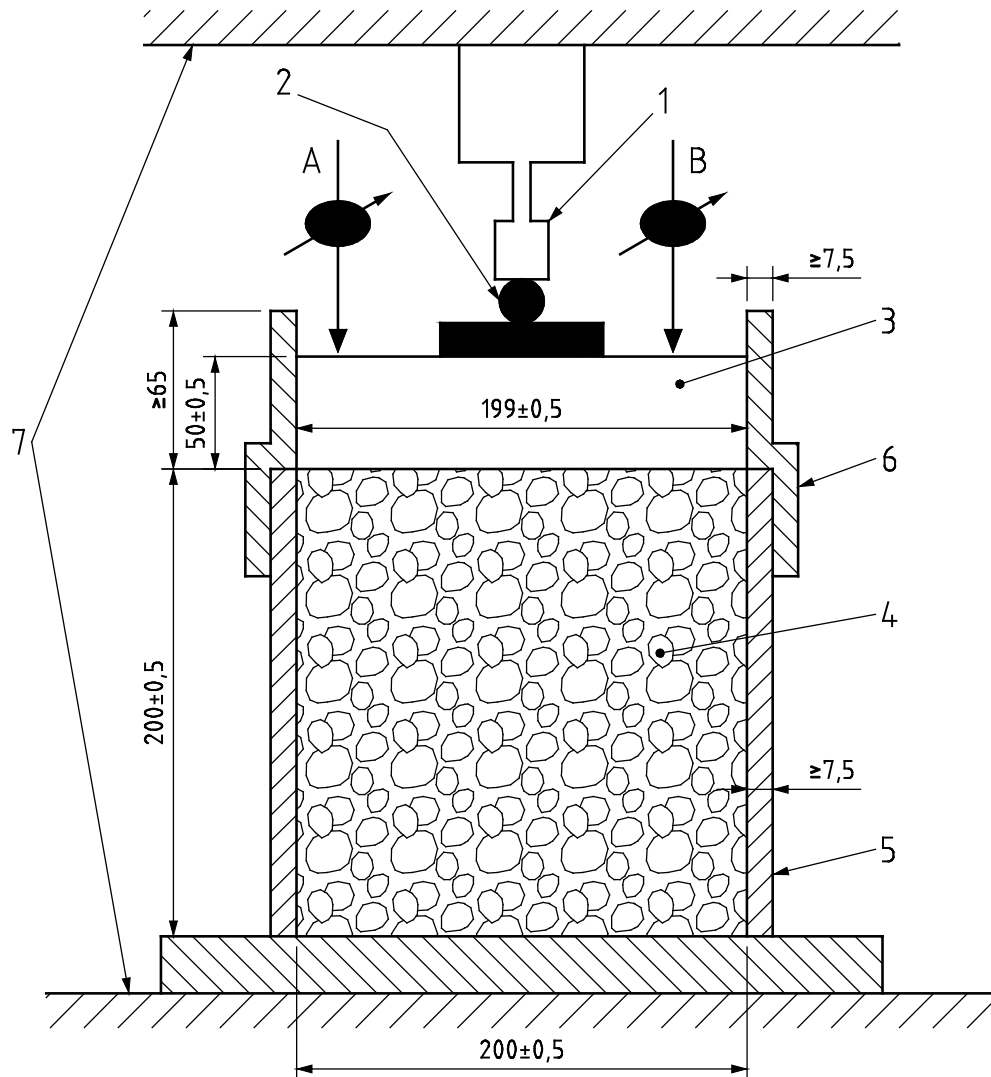


**Key**

| | | | |
|---|---|---|---|
| 1 | load cell | 5 | cylindrical test container |
| 2 | spherical seating | 6 | removable extension |
| 3 | load distribution steel plate | 7 | hydraulic press |
| 4 | test specimen | A, B | dial gauges |

**Figure 1 — Example of test apparatus**

**5.5** **Vibrating table**, capable of vibrating the steel container vertically with a frequency of (50 ± 2) Hz and an amplitude (0,50 ± 0,10) mm.

The steel container should be tightened to the vibration table if a free steel container causes unstable amplitude.

**5**

**5.6    Removable extension**, that tightly fits on top of the cylindrical container, acting as a guide for the load distribution steel plate (5.7). Minimum height of the extension shall be 65 mm (see Figure 1).

**5.7    Load distribution steel plate**, with a mass of $(12,1 \pm 0,2)$ kg, diameter $(199 \pm 0,5)$ mm and thickness $(50 \pm 0,5)$ mm (see Figure 1).

The steel plate should have a diameter at least 0,5 mm smaller than the container inside diameter.

**5.8    Spherical seating** or any other appropriate device to ensure an even distribution of the load.

**5.9    Dial gauges**, with an actual scale interval of $\pm 0,02$ mm.

**5.10   Slide calliper**, with an actual scale interval of $\pm 0,1$ mm.

**5.11   Hydraulic press**, or similar device capable to apply a continuous increase in load of $(0,060 \pm 0,002)$ kN/s.

**5.12   A monitoring system**, such as a computer with an acquisition unit, capable of monitoring the load applied by the hydraulic press and recording both the load and the displacements at a minimum frequency of 10 Hz.

## 6    Preparation of test specimens

Prepare three test specimens of volume 8 l each according to EN 932-2.

Dry the test specimens at $(110 \pm 5)$ °C to constant mass according to EN 1097-5. Allow to cool to ambient temperature.

In case moist materials are tested, the moisture content shall be recorded.

## 7    Procedure

### 7.1 Measurement of height $h_0$

Insert the steel plate into the empty container so that it lies on the bottom. Tightly fit the extension on top of the container. Measure the distance between the top of the extension and the steel plate, $h_0$, using the slide calliper (see Figure 2). Remove the extension and steel plate from the container.

NOTE        Height $h_0$ does not need to be determined each time a test is performed.

### 7.2 Filling of the container

Weigh and record the mass of the container, $M_0$. Place the first test specimen in a plastic bag. Then place the opening of the bag in the bottom of the test container. Slowly lift the bag and fill the container with the test specimen. Level the surface with a straight edge taking care not to compact it. Weigh the container with the test specimen, $M_1$. Calculate the mass of the test specimen, $M_2 = M_1 - M_0$.

### 7.3 Compressibility

Place the filled container on the vibrating table and tighten it to the table. Tightly fit the extension on top of the container. Place the load distribution steel plate on the surface of the test specimen and measure the distance between the top of the extension and the steel plate, $h_1$, using the slide calliper (see Figure 2). Vibrate the test specimen for $(180 \pm 5)$ s and measure the distance between the top of the extension and the steel plate, $h_2$, using the slide calliper.

Dimensions in millimetres
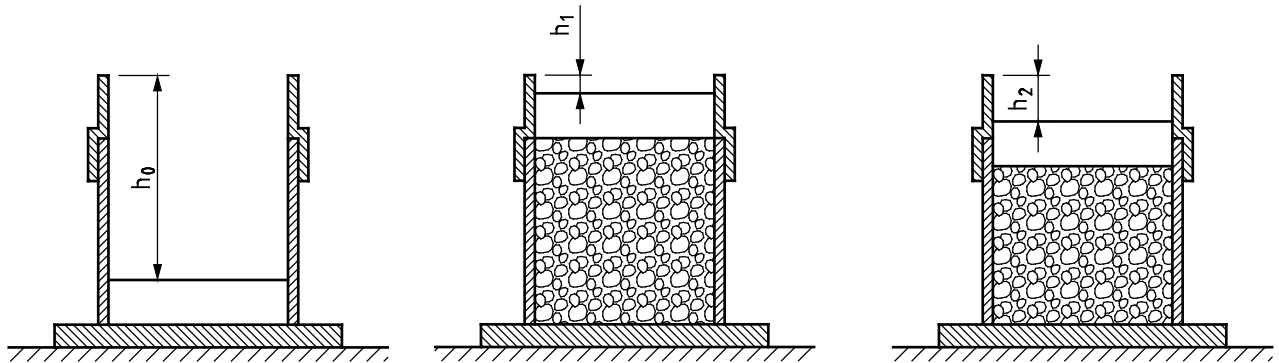


**Key**

$h_0$   distance between the top of the extension and the steel plate at the bottom of the empty container

$h_1$   distance before vibration between the top of the extension and the steel plate

$h_2$   distance after vibration between the top of the extension and the steel plate

**Figure 2 — Height measurements to be carried out before and after vibration**

## 7.4 Load and deformation measurements

Place the filled container with its extension and steel plate inside the press and zero the dial gauges. Apply the load, $F$, continuously at a rate of $(0,060 \pm 0,002)$ kN/s. Increase the load until the displacement, $\delta$, reaches at least 10 % of the height after vibration, $h_0 - h_2$. Record the displacement continuously as the mean value of a minimum of two gauges and record the load, $F$.

Repeat 7.2 to 7.4 with the remaining test specimens.

## 8 Calculation and expression of results

### 8.1 Bulk density

For each test specimen, calculate the bulk densities before vibration, $\rho_0$, and after vibration, $\rho_1$, in accordance with the following formulae:

$$\rho_0 = \frac{M_2}{(h_0 - h_1) \cdot A} \cdot 10^6 \tag{1}$$

and

$$\rho_1 = \frac{M_2}{(h_0 - h_2) \cdot A} \cdot 10^6 \tag{2}$$

where

    $M_2$   is the mass of the test specimen, in kilograms;

    $A$   is the area of the load distributed steel plate, in square millimetres;

    $h_0$   is the distance between the top of the extension and the steel plate at the bottom of the empty container, in millimetres;

$h_1$    is the distance before vibration between the top of the extension and the steel plate, in millimetres;

$h_2$    is the distance after vibration between the top of the extension and the steel plate, in millimetres.

The bulk density before and after vibration, expressed in megagrams per cubic metres, shall be stated to three decimal places.

Calculate and report the mean bulk density of the three test specimens before vibration to two decimal places.

Calculate and report the mean bulk density of the three test specimens after vibration to two decimal places.

## 8.2 Compressibility

Calculate the compressibility, $C$, of each test specimen after vibration, expressed as a percentage of the initial height, in accordance with the following formula:

$$C = 100 \frac{h_2 - h_1}{h_0 - h_1}$$ (3)

where

$h_0$    is the distance between the top of the extension and the steel plate at the bottom of the empty container, in millimetres;

$h_1$    is the distance before vibration between the top of the extension and the steel plate, in millimetres;

$h_2$    is the distance after vibration between the top of the extension and the steel plate, in millimetres.

The compressibility shall be expressed as a percentage to one decimal place.

## 8.3 Confined compressive stress–deformation curve

The confined compressive stress–deformation curve shall be calculated according to the following steps:

a)  Sample recorded values of the load and displacement to retain a point for any variation of the load larger than 0,02 kN or any variation of the displacement larger than 0,02 mm.

b)  Calculate the confined compressive stress, $\sigma(F)$, from the load at any of these points according to the following formula:

$$\sigma(F) = \frac{F}{A}$$ (4)

where

$\sigma(F)$ is the confined compressive stress, in megapascals;

$F$    is the load, in newtons;

$A$    is the area of the load distribution steel plate, in square millimetres.

The confined compressive stress, $\sigma(F)$, at load $F$ shall be rounded to three decimal places.

c)  Calculate the deformation, $D_F$, from the displacements at any of these points according to the following formula:

$$D_F = 100 \frac{\delta}{h_0 - h_2}$$

(5)

where

$\delta$ is the mean value of the displacements measured by at least two dial gauges, in millimetres;

$h_0$ is the distance between the top of the extension and the steel plate at the bottom of the empty container, in millimetres;

$h_2$ is the distance after vibration between the top of the extension and the steel plate, in millimetres.

The deformation, $D_F$, at load $F$ shall be expressed as a percentage rounded to two decimal places.

d) Fit the sampled points with an interpolation curve to smoothen the curve.

Figure 3 shows an example of a confined compressive stress–deformation curve.
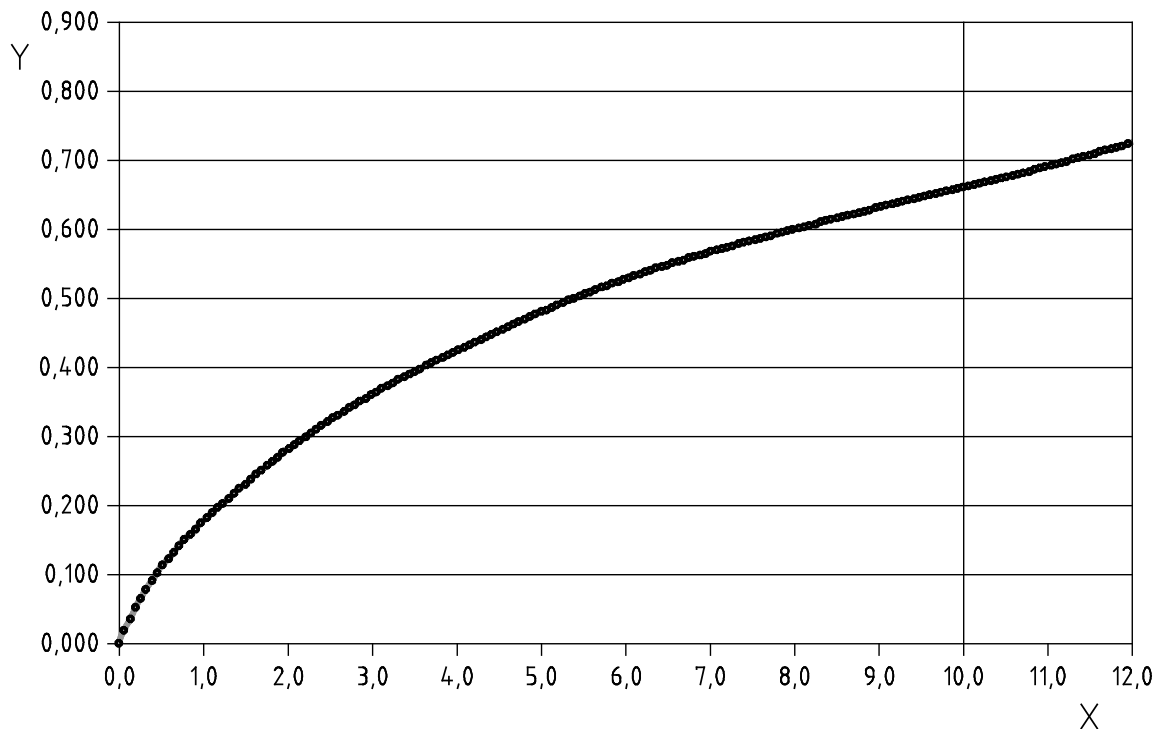


**Key**

Y stress [MPa]

X deformation [%]

**Figure 3 — Example of a confined compressive stress–deformation curve**

## 8.4 Confined compressive strength

Calculate the confined compressive strength, $CS(10)$, corresponding to the confined compressive stress $\sigma(F)$ at 10 % deformation, when $D_F = 10$ %, in accordance with the following formula:

$$CS(10) = \frac{F_{10}}{A}$$

(6)

where

$CS(10)$ is the confined compressive strength, in megapascals;

$F_{10}$ is the load recorded when $D_F = 10$ %, in newtons;

$A$ is the area of the load distribution steel plate, in square millimetres.

If required calculate the confined compressive strength, $CS(D_F)$, at another deformation, (e.g. when $D_F = 2$ %).

The confined compressive strength shall be stated as the mean value of the three test specimens to three decimal places.

## 9 Test report

### 9.1 Required data

The test report shall include the following information:

a) reference to this European Standard;

b) identification of the test sample, including identification of the source and date of sampling;

c) sample reception date if different from sampling date;

d) identification of the laboratory;

e) compressibility, $C$;

f) confined compressive stress–deformation curve;

g) confined compressive strength at 10 % deformation, $CS(10)$;

h) bulk density before, $\rho_0$, and after, $\rho_1$, vibration;

i) moisture content of LWA if tested in moist conditions;

j) deviations from the reference method – if any.

## 9.2 Optional data

The test report can include the following information:

a)    date of test;

b)    reference to the chosen sampling procedure;

c)    reference to the chosen sample reduction procedure;

d)    mass of test portion;

e)    confined compressive strength at intermediate rates % of deformation, $CS(d)$;

f)    test results of individual specimens;

g)    other influencing parameters.

# Annex A
(informative)

# Precision

The precision values of the test procedures for compressibility, bulk density and confined compressive strength have not yet been established.

# Bibliography

EN 932-1, *Tests for general properties of aggregates — Part 1: Methods for sampling*

EN 1097-3, *Tests for mechanical and physical properties of aggregates — Part 3: Determination of loose bulk density and voids*

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