BRITISH STANDARD

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Determination of compressive strength of lightweight aggregate concrete with open structure

The European Standard EN 1354:2005 has the status of a British Standard

ICS 91.100.30

National foreword

This British Standard is the official English language version of EN 1354:2005. It supersedes BS EN 1354:1997 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/523, Prefabricated components of reinforced autoclaved aerated concrete and lightweight aggregate concrete, which has the responsibility to:

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Determination of compressive strength of lightweight aggregate concrete with open structure

Détermination de la résistance à la compression du béton de granulats légers à structure ouverte

Bestimmung der Druckfestigkeit von haufwerksporigem Leichtbeton

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Foreword

This European Standard (EN 1354:2005) has been prepared by Technical Committee CEN/TC 177 "Prefabricated reinforced components of autoclaved aerated concrete or light-weight aggregate concrete with open structure", the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by January 2006, and conflicting national standards shall be withdrawn at the latest by January 2006.

This document supersedes EN 1354:1996.

In order to meet the performance requirements as laid down in the product standard for prefabricated components of lightweight aggregate concrete with open structure, a number of standardized test methods are necessary.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This European Standard specifies a method of determining the compressive strength of lightweight aggregate concrete with open structure (LAC) according to EN 1520.

The reference test method uses test specimens (cores or cubes) taken from prefabricated components.

Test specimens cast separately in moulds may also be used. This alternative procedure is described in Annex A.

2 Normative references

The following referenced documents are indispensable for the application 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 992, *Determination of the dry density of lightweight aggregate concrete with open structure*

EN 1520, *Prefabricated reinforced components of lightweight aggregate concrete with open structure*

EN 12350-1, *Testing fresh concrete - Part 1: Sampling*

EN 12390-1, *Testing hardened concrete - Part 1: Shape, dimensions and other requirements for specimens and moulds*

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

EN 12390-4, *Testing hardened concrete - Part 4: Compressive strength - Specification for testing machines*

EN 12504-1, *Testing concrete in structures - Part 1: Cored specimens - Testing, examining and testing in compression*

3 Principle

The compressive strength is determined on test specimens taken from prefabricated components. It is defined as the ratio between the rupture load in axial compression and the cross-sectional area of the test specimen.

4 Apparatus

a) A compression testing machine which meets the requirements of EN 12390-4 for testing machines of machine class 1 or 2;

b) calipers, capable of reading the dimensions of the test specimens to an accuracy of 0,1 mm;

c) straight-edge (at least as long as the longest diagonal of the test specimen surfaces, in the case of cylinders: at least as long as the generatrices) and a 0,5 mm-feeler gauge;

d) equalising layers of soft fibreboard with a thickness of (12 ± 2) mm and a density of (250 to 400) kg/m³ to be inserted between the loadbearing surfaces of the test specimens and the platens of the compression testing machine (not required in the case of levelling the loadbearing surfaces by grinding or capping). The edge length or the diameter of the equalising layers shall not exceed that of the loadbearing surfaces of the test specimen by more than 5 mm (see NOTE 1);

e) balance, capable of determining the mass of the test specimens to an accuracy of 0,1 %;

f) ventilated drying oven, capable of maintaining a temperature of (105 ± 5) °C (see NOTE 2);

g) equipment for drilling cores from reinforced components, with water cooled diamond bit and sufficiently rigid so that the cores can be obtained with straight sides with a minimum of surface irregularities and disturbances;

h) any saw suitable for cutting reinforced LAC components.

NOTE 1 The use of equalising layers with larger size may give higher strength results, especially for LAC in the lower strength range, due to the effect of lateral restraint.

NOTE 2 In addition a ventilated drying oven capable of maintaining a temperature of (40 to 60) °C can be helpful for conditioning of test specimens.

5 Test specimens

5.1 Sample

The sample for the preparation of the test specimens (usually at least one prefabricated component) shall be taken in such a manner that it is representative of the product to be investigated.

5.2 Shape and size of test specimens

The test specimens shall be cores with a length equal to the diameter, or cubes. The preferred diameter or edge length, respectively, is 100 mm (reference test specimens).

NOTE 1 Experience has shown, that the strength results are practically the same in both cases. In EN 1520 both are considered as cube strength.

NOTE 2 In the case of hollow core components or multilayer components it may be necessary to use smaller test specimens.

5.3 Number of test specimens

A test set shall consist of at least three test specimens. If test specimens with a diameter or an edge length below 70 mm or less than three times the maximum aggregate size are used, at least six test specimens shall be tested.

5.4 Preparation of test specimens

The test specimens shall preferably be taken from the following areas of components:

— solid and hollow core components: from the compression zone; if the shear strength shall be derived from the compressive strength, it may be necessary to take test specimens also from the weakest zone of the component (see NOTE 1) or, if applicable, from the webs between the hollow cores.

— multilayer components: from the weakest part of the middle layer (see NOTE 2).

Cores shall be taken and prepared according to EN 12504-1 unless otherwise stated in this European Standard. If possible, the axis of the cores shall be chosen parallel to the direction of the compressive stresses in the component. Cubes shall be cut by means of a saw, preferably a circular saw with water-cooled carborundum or diamond blade. One axis of the cubes shall be parallel to the direction of the compressive stresses in the component.

The test specimens shall not contain any reinforcing bars in, or close to, the direction of the compressive force during the test. One or two reinforcing bars approximately perpendicular to the direction of the compressive force and with a diameter not exceeding 10 mm may be permitted, but should be avoided, if possible. The presence of steel within a test specimen shall be mentioned in the test report.

The test specimens shall be drilled or cut within a period of (1 to 7) days before the compression test and stored until the test in air at (20 ± 5) °C and (50 ± 15) % relative humidity. The moisture content at the compression test shall be ≥ 4 % by mass. If the moisture content is found to be lower, the test specimens shall be wetted and subsequently stored under the conditions specified above for at least 1 day prior to the compression test.

NOTE 1 Depending on the manufacturing process, the strength can decrease or increase from top to bottom.

NOTE 2 In general, it will not be possible to take test specimens with the required dimensions for the compression test from the thin outer layers of multilayer components. A feasible method would be to take several cores perpendicular to the plane of the component, to separate the outer layers of the cores by cutting and to glue several of these discs one on top of the other until the required length (see 5.2) has been attained. In order to prevent impermissible strength increase by partly filling the interstitial pores with glue, only a minimum amount of glue should be used, and the glue, preferably epoxy resin or cement paste, should have a plastic rather than a liquid consistency. Another possibility would be to add an additional length to the component and make it homogeneous, using concrete of the outer layers, and to take the test specimens from this part of the component. This method can also be used in the case of hollow core components, where it is not normally possible to take test specimens with the required dimensions from the thin top and bottom layers.

5.5 Checking the dimension and the shape of test specimens

The dimensions and the shape of the test specimens shall be checked according to EN 12504-1.

Each dimension shall be determined to an accuracy of 0,2 % by at least two measurements, taken at different positions, and the considered dimension is determined by the mean value.

The length of cylinders shall not deviate from their diameter by more than $\pm$ 5 %.

5.6 Treating of loadbearing surfaces

The loadbearing surfaces shall not depart from perpendicularity with the longitudinal axis of the test specimen by more than 1°.

In the case of cubes the surfaces approximately perpendicular to the compressive stresses in the component when in use shall be chosen as the loadbearing surfaces.

The loadbearing surfaces of the test specimens shall be plane within 0,5 mm. Planeness shall be checked across two orthogonal diameters or across the two diagonals, respectively, using a straight-edge and, if necessary, a 0,5 mm-feeler gauge.

Necessary corrections of perpendicularity and/or planeness shall be made by cutting or grinding or, if applicable, by capping of the loadbearing surfaces.

5.7 Determination of mass of test specimens in air-dry state

Immediately before the compression test the mass of the test specimens shall be determined in the actual air-dry state.

NOTE The term "air-dry" is not related to a strictly defined moisture content. The air-dry mass or density is therefore no absolute value but may be used for comparing the individual test specimens within a test set or for the calculation of the volume of a concrete sample taken from a crushed compression specimen to determine the dry density in accordance with EN 992.

6 Compression test

The platens of the compression-testing machine shall be wiped clean, and the test specimen shall be positioned in the compression testing machine. In the case of test specimens where the loadbearing surfaces have not been capped or levelled by grinding and depart from planeness by more than 0,2 mm, equalising layers of soft fibreboard, as specified in 4 d), shall be inserted between the loadbearing surfaces of the test specimen and the platens of the compression testing machine. In this case, for each compression test a new set of fibreboard equalising layers shall be used.

The test specimen shall be seated centrally and loaded uniformly (see NOTE 1).

The load shall be applied until rupture in a continuous and uniform manner, without shock, at a constant rate in order to reach the maximum load within (30 to 120) s (see NOTE 2). The maximum load carried by the test specimen shall be recorded.

After the compression test the test specimen or at least 80 % of its mass shall be dried at (105 ± 5) °C to constant mass in order to determine the dry density of the LAC according to EN 992 and to determine the actual moisture content during the compression test (see, however, the note in Clause 7).

NOTE 1 In order to obtain uniform load transmission, it may be necessary to adjust the spherically seated upper platen of the compression testing machine by hand so that it is parallel to the upper loadbearing surface of the test specimen before it is brought to contact with it.

NOTE 2 For LAC with unknown strength a value of (0,1 ± 0,05) MPa per s may be assumed as a guidance value of loading rate.

Constant rate of loading should be maintained at least during the latter half of the loading phase. During the application of the first half of the anticipated maximum load a higher rate of loading is permitted.

7 Test results

The compressive strength of the test specimen i is determined according to equation (1):

$$f_{ci} = \frac{F_i}{A_{ci}} \qquad i = 1, 2, 3\ (4, 5, 6) \tag{1}$$

where

f_{ci} is the compressive strength of the test specimen i, in MPa;

F_i is the maximum load at failure, in Newton's;

A_{ci} is the loadbearing cross sectional area of the test specimen, determined from the dimensions measured according to 5.5, in square millimetres.

The compressive strength of each individual test specimen and the mean value of the test set shall be expressed to the nearest 0,1 MPa.

NOTE 1 If in exceptional cases a test set includes test specimens of different sizes (e.g. cylinders with a diameter of 50 mm and 100 mm) it is recommended to convert the strength results of the test specimens with the smaller diameter (or

edge length) to the strength of test specimens with 100 mm diameter or edge length, because the mean value can only be calculated if the strength is related to test specimens with the same size. Conversion factors can be taken from EN 1520.

The moisture content of the test specimen is calculated according to equation (2):

$$\mu_{\mathrm{m,t}} = \left(\frac{m_{\mathrm{hum}}}{\rho V} - 1 \right) 100 \qquad (2)$$

where

$\mu_{\mathrm{m,t}}$ is the mass related moisture content, in percent;

m_{hum} is the mass of the test specimen in the air-dry (= humid) state determined immediately before the compression test (see 5.7), in kilograms (see NOTE 2);

ρ is the dry density of the LAC determined on the test specimen or parts thereof according to EN 992, in kilograms per cubic metre (see NOTE 2);

V is the initial volume of the test specimen calculated from the dimensions measured in accordance with 5.5, in cubic metres (see NOTE 2).

The moisture content of the test specimens shall be indicated in the test report.

The air-dry density is calculated according to equation (3):

$$\rho_{\mathrm{hum}} = \frac{m_{\mathrm{hum}}}{V} \qquad (3)$$

where

ρ_{hum} is the air-dry density, in kilograms per cubic metre.

The air-dry density of each individual test specimen shall be expressed to the nearest 5 kg/m³ and the mean value shall be rounded to the nearest 10 kg/m³.

The dry density of the individual test specimens determined according to EN 992 and the mean value of the test set shall be indicated in the test report.

If the test specimen contains sections of reinforcing bars, the mass and the volume of the steel shall be not included when calculating the moisture content, the air-dry density and the dry density of the LAC.

NOTE 2 In the case of test specimens with capped loadbearing surfaces it is difficult to determine the dry density on the test specimens themselves, and it can be necessary to determine it on companion specimens.

8 Test report

The test report shall include the following:

a) identification of the product;

b) date of manufacture of the component(s) from which the test specimens have been taken;

c) place and date of testing, testing institute and person responsible for testing;

d) number and date of issue of this European Standard;

e) shape and size of the test specimens and relative position within the component;

f) compressive strength of each individual test specimen and mean value;

g) size and position of steel bars, if present, in the test specimens;

h) air-dry density of each individual test specimen and mean value;

i) dry density of each individual test specimen and mean value;

j) actual moisture content of each individual test specimen during the compression test and mean value;

k) (if unusual) observations on the appearance of the test specimens;

l) (if appropriate) deviations from the standard method of testing;

m) a declaration that the testing has been carried out in accordance with this European Standard except as detailed in 8 l).

Annex A
(normative)

Determination of compressive strength of lightweight aggregate concrete with open structure on test specimens cast in moulds

A.1 Scope

This normative Annex specifies the procedures to be used, when the compressive strength of LAC shall be determined on test specimens cast separately in moulds.

A.2 Principle

Test specimens are cast in moulds, using fresh concrete taken from mixer batches used for the production of prefabricated components. The test specimens are cured for the specified period and tested in compression when the concrete has achieved the required age. The density of the LAC in the fresh state, the air-dry density at the compression test, and the dry density after the compression test are also determined.

A.3 Apparatus

In addition to Clause 4 of this European Standard the following items are required:

a) moulds capable of providing test specimens of which the dimensions and tolerances conform to EN 12390-1. The moulds shall be watertight and made of non-absorbent material which does not react upon cement;

b) a filling frame. If a filling frame is used, this shall be fitted tightly to the mould;

c) a device for compacting the fresh concrete in the mould;

d) (if required) a device for determining the fresh density in situ of the LAC in prefabricated components as described in Annex B.

The items g) and h) specified in Clause 4 of this European Standard are not required in this test method.

A.4 Test specimens

A.4.1 Sample

The concrete for the production of the test specimens shall be taken from mixer batches used for current manufacture of prefabricated components. Sampling shall be performed in accordance with EN 12350-1 and shall be done in such a manner that the fresh concrete is representative of the product to be investigated.

A.4.2 Shape and size of test specimens

The test specimens shall be cylinders with a diameter of 150 mm and a height of 300 mm or cubes with an edge length of 150 mm (reference test specimens). The test specimens shall comply with EN 12390-1 unless otherwise specified in this Annex.

Test specimens of other shapes and sizes may be used, provided that the compressive strength determined on such test specimens can be directly related to the compressive strength of the above named reference test specimens.

A.4.3 Number of test specimens

A test set shall consist of at least 3 test specimens. For each test specimen, the concrete shall be taken at random from a different mixer batch, distributed approximately uniformly over the production period to be investigated.

A.4.4 Making and curing test specimens

Unless otherwise specified in this Annex, the test specimens shall be made and cured according to EN 12390-2.

The concrete in the moulds shall be compacted in such a way that the fresh density differs by not more than +3 %/–10 % (individual test specimens) or +1 %/–5 % (mean value of the test set), respectively, from the fresh density of the concrete in the prefabricated component(s) of which the test specimens shall be representative (see notes 1 and 2).

The fresh density shall be determined by determining the mass of the fresh concrete in the mould, as the difference between the mass of the filled and the empty mould, and dividing it by the volume of the test specimen.

Overvibration of the test specimens causing segregation and augmentation of the mortar content near the bottom of the mould shall be avoided. The surface of the test specimens shall retain its open structure during the compaction and the finishing procedure.

Test specimens shall not be removed from the moulds until danger of damage to the test specimens is past. In any event, at the latest, however, within 7 days after casting.

During the first 7 days after casting the test specimens shall be cured in moisture saturated atmosphere and protected against moisture loss. Contact with liquid water (sprinkling or immersion) shall be avoided.

After this initial curing period the test specimens shall be stored in air at (20 ± 5) °C and (50 ± 15) % relative humidity until the compression test. The moisture content at the compression test shall be at ≥ 4 % by mass.

NOTE 1 The required grade of compaction can be achieved, for example, by weighing the required quantity of fresh concrete for the individual test specimen, filling it into the mould and compacting it to such a degree that the mould is completely filled after compaction and levelling, without being necessary to add or to remove fresh concrete.

NOTE 2 The fresh density of the concrete in the prefabricated components can be determined in situ by using the water replacement method described in Annex B or by means of another appropriate method. In the case of solid components or hollow core components the mean fresh density can be determined by weighing the component after casting, before appreciable moisture loss has occurred, and dividing its mass by the volume of the concrete, making allowance for the mass and the volume of the reinforcement and, if any, the volume of the airfilled hollow cores.

A.4.5 Determining the dimensions and the shape of test specimens

The dimensions and the shape of the test specimens shall be determined according to EN 12504-1.

Each dimension shall be determined to an accuracy of 0,2 % by at least two measurements, taken at different positions, and the considered dimension is determined by the mean value.

The length of cylinders shall not deviate by more than ± 5 % form twice the diameter.

A.4.6 Treating of loadbearing surfaces

5.6 of this European Standard applies, with the exception that in the case of cubes two opposite moulded surfaces shall be chosen as loadbearing surfaces.

A.4.7 Determination of mass of test specimens in air-dry state

5.7 of this European Standard applies.

A.5 Compression test

Clause 6 of this European Standard applies.

A.6 Test results

Clause 7 of this European Standard applies.

In addition, the fresh density of the LAC shall be calculated according to A.4.4. The fresh density of each individual test specimen shall be expressed to the nearest 5 kg/m³ and the mean value of the test set shall be rounded to the nearest 10 kg/m³.

A.7 Test report

The test report shall include the following:

a) identification of the product;

b) number and date of issue of this European Standard (Annex A);

c) place and date of testing, testing institute and person responsible for testing;

d) concrete age at testing;

e) shape and size of test specimens;

f) compressive strength of each individual test specimen and mean value;

g) fresh density of each individual test specimen and mean value;

h) air-dry density of each individual test specimen and mean value;

i) dry density of each individual test specimen and mean value;

j) actual moisture content of each individual test specimen during the compression test and mean value;

k) mean fresh density of the considered concrete type in the corresponding prefabricated component and the method used for determining this property (if the method in Annex B has been used: position of the samples);

l) (if unusual) observations on the appearance of the test specimens;

m) (if appropriate) deviations from the standard method of testing;

n) declaration that the testing has been carried out in accordance with this European Standard, except as detailed in 8 m).

Annex B
(informative)

Determination of the fresh density of LAC in situ by means of the water replacement method

B.1 Scope

This informative Annex specifies a test method of determining the fresh density of LAC in a prefabricated component in situ, using a water balloon apparatus (water replacement method).

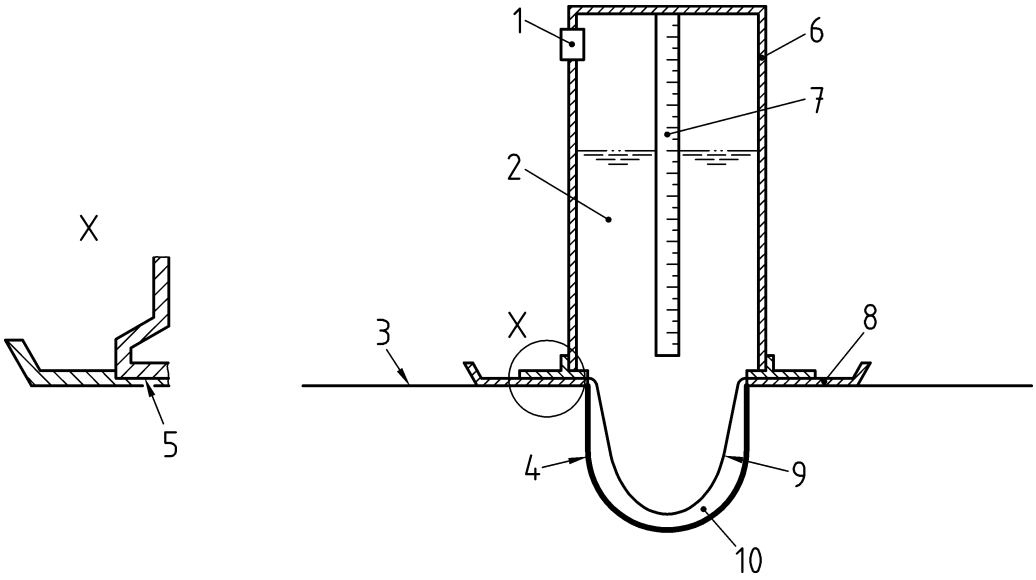
B.2 Principle

The volume of an excavated hole in the surface of the component is determined by spreading a thin flexible rubber membrane in the hole and filling the membrane with water from a calibrated vessel thus displacing the membrane to fill the hole completely. The required amount of water is equivalent to the volume of the hole. The in-situ fresh density is calculated by dividing the wet mass of the concrete removed by the volume of the hole.

The method is described in detail in ASTM D 2167.

B.3 Apparatus

B.3.1 Balloon apparatus: This is a calibrated vessel with a diameter of at least 150 mm containing a liquid (usually water) within a relatively thin, flexible, elastic membrane (rubber balloon), designed for measuring the volume of a test hole dug in the concrete layer or zone under investigation of a prefabricated component.



Key

1 Provision for applying and holding constant external pressure or vacuum
2 Contained liquid (usually water)
3 Concrete surface
4 Test hole
5 Detail of typical base plate recess
6 Calibrated vessel
7 Volume indicator
8 Base plate, either fixed or removable
9 Flexible membrane (rubber balloon)
10 Void to be filled when external pressure is applied

Figure B.1 — Schematic drawing of calibrated vessel indicating principle (not to scale)

An example for the essential elements for this apparatus is shown in Figure B.1. The flexible membrane should be of such size and shape as to fill the test hole (minimum volume 300 cm³) completely without wrinkles or folds when inflated within the test hole due to the water pressure. There should be an indicator for determining the volume of the test hole to the nearest 10 cm³.

B.3.2 Base plate: A rigid metal plate machined to fit the base of the balloon apparatus. The outer diameter should be at least twice the test hole diameter to prevent deformation of the test hole while supporting the apparatus.

B.3.3 Balance of 2 kg capacity and an accuracy of 1 g.

B.4 Testing procedure

The concrete surface at the test location is prepared in such a manner that it is reasonably plane. The base plate and the rubber balloon apparatus are assembled on the test location and after applying the operating pressure an initial reading of the volume indicator is taken and recorded. The apparatus is then removed from the base plate (see note) which remains in place through completion of the test.

Using spoons, screw drivers or other necessary tools a hole is dug within the base plate, exercising care so that the concrete around the hole is not disturbed. The test hole should be of a minimum volume of 300 cm³,

and at least three tests at three different places should be performed. Larger test hole volumes will provide improved accuracy and should be used where practical. The test hole should be kept as free from pockets and sharp obtrusions as possible. All the concrete removed from the test hole shall be placed in a moisture tight container for later mass determination.

After the test hole has been dug, the apparatus is again placed in position over the base plate and, applying the same pressure as used for the initial reading, a final reading of the volume indicator is taken and recorded. The difference between the final and the initial readings is the volume V_n of the test hole.

Subsequently the mass m_{wet} of the fresh concrete removed from the test hole and stored meanwhile in the container is determined to the nearest 0,001 kg.

NOTE Removal of the water filled balloon apparatus may be facilitated by applying a slight vacuum which draws the rubber membrane back into the container.

B.5 Calculation of the fresh density

The fresh density of the concrete removed from the test hole should be calculated according to equation (B.1):

$$\rho_{fr} = \frac{m_{wet}}{V_n} \quad \text{(B.1)}$$

where

ρ_{fr} is the fresh density, in kilograms per cubic metre;

m_{wet} is the mass of the fresh concrete removed from the test hole, in kilograms;

V_n is the volume of the test hole in cubic metres.

The fresh density of the LAC at the individual test holes and the mean value should be expressed to the nearest 10 kg/m³.

Bibliography

[1] ASTM D 2167:1994, *Standard Test Method for density and unit weight of soil in place by the rubber balloon method*

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