poznan university of technology
institute of building engineering
division of building and building materials

BUILDING MATERIALS – PRACTICAL SESSION

Lab 3

PROPERTIES OF HYDRAULIC BINDERS

Cement: determination of standard consistence, setting time, consistence of fresh mortar, flexural and compressive strength of cement (strength class)

European Standard

PN-EN 196-1:2016-07 Methods of testing cement. Part 1: Determination of strength.

PN-EN 196-3:2016-12 Methods of testing cement. Part 3: Determination of setting times and soundness.

PN-EN 1015-3:2000 Methods of test for mortar for masonry. Part 3: Determination of consistence of fresh mortar (by flow table).

PN-EN 1015-3:2000/A1:2005 Methods of test for mortar for masonry. Part 3: Determination of consistence of fresh mortar (by flow table).

PN-EN 1015-3:2000/A2:2007 Methods of test for mortar for masonry. Part 3: Determination of consistence of fresh mortar (by flow table).

Principle

The setting time is determined by observing the penetration of a needle into cement paste of standard consistence until it reaches a specified value. Cement paste of standard consistence has a specified resistance to penetration by a standard plunger. The water required for such a paste is determined by trial penetrations of pastes with different water contents.

Consistence is measure of the fluidity and/or wetness of the fresh mortar and gives measure of the deformability of the fresh mortar when subjected to a certain type of stress. The consistence however is not directly associated with the manner in which fresh mortar handles when used by a craftsman. The flow value is measured by the mean diameter of a test sample of the fresh mortar which has been placed on a defined flow table disc by means of a defined mould, and given number of vertical impacts by raising the flow table and allowing it to fall freely through a given height.

The method comprises the determination of the compressive, and optionally the flexural, strength of prismatic test specimens 40 mm x 40 mm x 160 mm in size. These specimens are cast from a batch of plastic mortar containing one part by mass of cement, three parts by mass of CEN Standard sand and one half part of water (water/cement ratio 0,50). In the reference procedure the mortar is prepared by mechanical mixing and is compacted in a mould using a jolting

apparatus. The specimens are stored in the mould in a moist atmosphere for 25 h and, after demoulding, specimens are stored under water until strength testing. At the required age, the specimens are taken from their wet storage, broken in flexure, determining the flexural strength where required, and each half tested for strength in compression.

Apparatus

Mixer.

Vicat apparatus with the plunger (see the figure below).

Flow table.

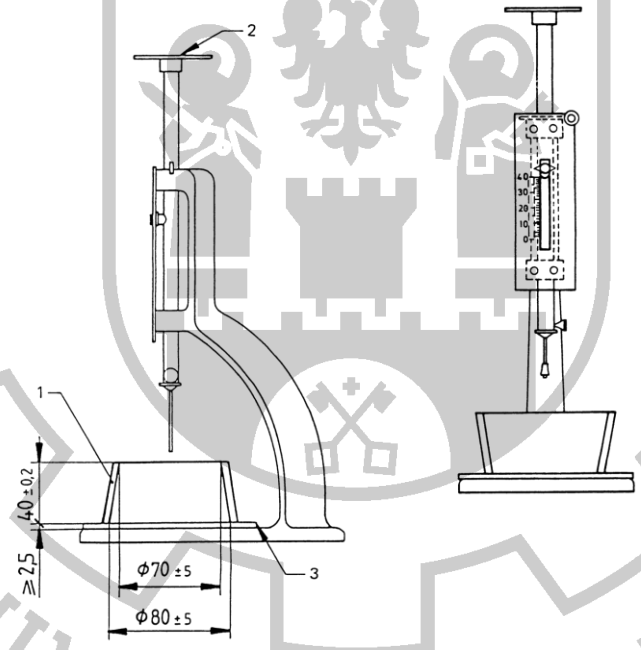
Moulds which shall consist of three horizontal compartments so that three prismatic specimens 40 mmx 40 mm in cross section and 160 mm in length can be prepared simultaneously.

Jolting apparatus.

Flexural strength testing apparatus.

Compressive strength testing machine.

Balance, capable of weighing to an accuracy of ±1g.



(a) Side view with mould in upright position for initial setting time determination

(b) Front view with mould inverted for final setting time determination

1. Hard rubber mould
2. Platform for correcting weights
3. Glass plate

Dimensions in millimetres

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TEST PROCEDURE

Determination of standard consistence and setting time

Preparation of cement paste

Weigh, to the nearest 1 g, 500 g of cement. Weigh a quantity of water, e.g. 125 g, in the mixer bowl or measure the water from the graduated cylinder or burette and place it into the mixer bowl. Add the cement carefully to the water in order to avoid loss of water or cement. The time of addition shall be not less than 5 s nor more than 10 s. Note the time of completion of the addition as zero time from which later measurements of time shall be made. Start the mixer immediately and run at low speed for 90 s. Stop the machine after 90 s for 15 s during which remove with a suitable scraper any paste adhering to the bowl outside the mixing zone and return it to the mix. Restart the machine and run at low speed for a further 90 s. The total mixer running time shall be 3 min. Transfer the paste immediately to the mould, which has previously been placed on a lightly greased plane glass base-plate, and fill it to excess without undue compaction or vibration. Remove the excess by a gentle sawing motion with a straight-edged implement in such a way as to leave the paste filling the mould and having a smooth upper surface.

Determination of standard consistence

Calibrate the Vicat apparatus with the plunger, attached in advance of the test, by lowering the plunger to rest on the base-plate to be used and adjusting the pointer to read zero on the scale. Raise the plunger to the stand-by position. Immediately after levelling the paste, transfer the mould and base-plate to the Vicat apparatus and position it centrally under the plunger. Lower the plunger gently until it is in contact with the paste. Pause in that position for between 1 s and 2 s in order to avoid initial velocity or forced acceleration of the moving parts. Then release the moving parts quickly and allow the plunger to penetrate vertically into the centre of the paste. The release of the plunger shall occur 4 min after zero time. Read the scale when penetration has ceased or 30 s after the release of the plunger, whichever is the earlier. Record the scale reading, which indicates the distance between the bottom face of the plunger and the base-plate, together with the water content of the paste expressed as a percentage by mass of the cement. Clean the plunger immediately after each penetration. Repeat the test with pastes containing different water contents until one is found to produce a distance between plunger and base-plate of (6 ± 2) mm. Record the water content of that paste to the nearest 0,5 % as the water for standard consistence.

Determination of setting time

Remove the plunger and replace it by the needle which shall be of steel and in the form of a right cylinder of effective length (50 ± 1) mm and diameter (1,13 ± 0,05) mm. The total mass of moving parts shall be (300 ± 1) g. Their movement shall be truly vertical and without appreciable friction, and their axis shall coincide with that of the needle. Lower the needle gently until it is in contact with the paste. Pause in that position for between 1 s and 2 s in order to avoid initial velocity or forced acceleration of the moving parts. Then release the moving parts quickly and allow the needle to penetrate vertically into the paste. Read the scale when penetration has ceased, or 30 s after the release of the needle, whichever is the earlier. Record the scale reading, which indicates the distance between the end of the needle and the base-plate, together with the time from zero. Repeat the penetration test on the same specimen at conveniently spaced positions, not less than 10 mm from the rim of the mould or from each other, at conveniently spaced intervals of time, e.g. at 10 min intervals. Clean the Vicat needle immediately after each penetration. Record the time measured from zero at which the distance between the needle and the base-plate is (6 ± 3) mm as the initial setting time of the cement to the nearest 5 min. The required accuracy may be assured by reducing the time interval between penetration tests near the end-point and observing that successive results do not fluctuate excessively.

<u>Determination consistence of fresh mortar, flexural and compressive strength of cement</u>

Preparation of mortar

The proportions by mass shall be one part of the cement, three parts of Standard sand, and one half part of water (water/cement ratio = 0,50). Each batch for three test specimens shall consist of (450 ± 2) g of cement, (1 350 ± 5) g of sand and (225 ± 1) g of water. The cement, sand, water and apparatus shall be at the laboratory temperature (4.1). Carry out weighing by means of a balance accurate to ± 1 g.

Mix each batch of mortar mechanically using the mixer. With the mixer in the operating position:

a) pour the water into the bowl and add the cement;

b) then start the mixer immediately at the low speed and, after 30 s, add the sand steadily during the next 30 s. When separate sand fractions are used, add the required quantities of each fraction in succession starting with the coarsest. Switch the mixer to the high speed and continue the mixing for an additional 30 s;

c) stop the mixer for 1 min 30 s. During the first 15 s, remove by means of a rubber scraper all the mortar adhering to the wall and bottom part of the bowl and place in the middle of the bowl;

d) continue the mixing at the high speed for 60 s.

The timing of the various mixing stages shall be adhered to within ± 1 s.

Determination consistence of fresh mortar

Wipe the glass disc by the wet cloth, event. lubricate it by the mineral oil. Place the mould centrally on the discs of the flow table (by the larger diameter down) and put on it the filling adapter. Introduce the mortar in two layers, each layer being compacted by at least 10 short strokes of the tamper. During filling, hold the mould firmly on the disc (one person holds the mould, second introduces the mortar, third person compacts). Remove the adapter and skim the excess mortar with the ruler and wipe the free area of the disc clean and dry. After approximately 15 s, slowly raise the mould vertically and tuck it away. Jolt the flow table 15 times by rotation of the crank at constant frequency of approximately one per second (check the time on the watch). Immediately after last rotation measure the diameter of the mortar in two directions at right angles to one another. State the result in mm to the nearest 5 mm. Calculate the mean value of the two measurements and write it down into the testing record.

NOTE Determine the consistence for standard mortar and after an addition of superplasticizer.

Determination flexural and compressive strength of cement

With the mould and hopper firmly clamped to the jolting table, introduce, using a suitable scoop, in one or more increments, the first of two layers of mortar (each about 300 g) into each of the mould compartments, directly from the mixing bowl. Spread the layer uniformly using the larger spreader, held vertically with its shoulders in contact with the top of the hopper and drawn forwards and backwards once along each mould compartment. Then compact the first mortar layer using 60 jolts. Introduce the second layer of mortar, level with the smaller spreader and compact the layer with a further 60 jolts. Lift the mould gently from the jolting table and remove the hopper. Immediately strike off the excess mortar with the metal straightedge held almost vertically and moved slowly, with a transverse sawing motion once in each direction. Smooth the surface of the specimens using the same straightedge held almost flat. Label or mark the moulds to identify the specimens and their position relative to the jolting table. Carry out demoulding with due precautions. Carry out demoulding, for 24 h tests, not more than 20 min before the specimens are tested. Carry out demoulding, for tests at ages greater than 24 h, between 20 h and 24 h after moulding.

NOTE Demoulding may be delayed by 24 h if the mortar has not acquired sufficient strength at 24 h to be handled without risk of damage. Mention delayed demoulding in the test report. Keep the demoulded specimens selected for testing at 24 h (or at 48 h when delayed demoulding was necessary) covered by a damp cloth until tested. Suitably mark specimens selected for curing in water for identification later, e.g. by water-resistant ink or crayon.

Submerge the marked specimens without delay in a convenient manner, either horizontally or vertically, in water at (20 ± 1) °C in suitable containers. With horizontal storage, keep vertical faces as cast vertical, and the struck-off surface uppermost.

Place the specimens on non-corrodible gratings and keep them apart from each other so that the water has free access to all six sides of the specimens. At no time during storage shall the spaces between the specimens or the depth of water above the upper faces of the specimens be less than 5 mm.

NOTE Wooden gratings are not suitable.

Only store specimens made with cements of similar chemical composition in each container. Use tap water for initial filling of the containers and for occasional topping up to maintain a reasonably constant level. During storage of the specimens, complete replacement of water is not permitted. Remove the specimens required for testing at any particular age (other than 24 h or 48 h in cases of delayed demoulding) from the water not more than 15 min before the test is carried out. Remove any deposit on the test faces. Cover the specimens with a damp cloth until tested.

Calculate the age of specimens from the time of mixing of the cement and water at the beginning of the test. Make strength tests at different ages within the following limits:

- 24 hours ± 15 minutes
- 48 hours ± 30 minutes
- 72 hours ± 45 minutes
- 7 days ± 2 hours
- 28 days ± 8 hours

Flexural strength

Place the prism in the testing machine with one side face on the supporting rollers and with its longitudinal axis normal to the supports. Apply the load vertically by means of the loading roller to the opposite side face of the prism and increase it smoothly at the rate of (50 ± 10) N/s until fracture. Keep the prism halves damp until tested in compression.

Calculate the flexural strength R_f in N/mm^2 from:

$$R_f = \frac{1{,}5 \cdot F_f \cdot l}{b^3}$$

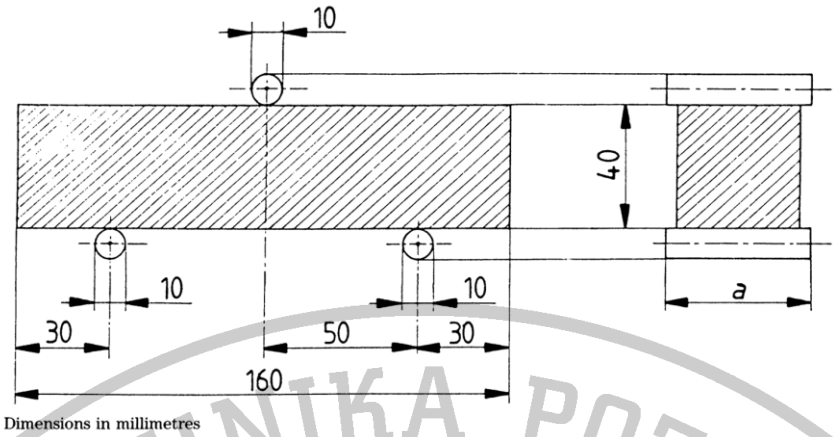
where:

R_f is the flexural strength, in Newtons per square millimetre;

b is the side of the square section of the prism, in millimetres;

F_f is the load applied to the middle of the prism at fracture, in Newtons;

l is the distance between the supports, in millimetres.



Dimensions in millimetres

Compressive strength

Centre the prism halves laterally to the platens of the machine within ± 0,5 mm, and longitudinally such that the end face of the prism overhangs the platens or auxiliary plates by about 10 mm. Increase the load smoothly at the rate of (2400 ± 200) N/s over the entire load application until fracture. Where the load increase is regulated by hand, make adjustment for the decrease of the loading rate near the fracture load.

Calculate the compressive strength R_c in N/mm^2 from:

$$R_c = \frac{F_c}{1600}$$

where

Rc is the compressive strength, in Newtons per square millimetre;

Fc is the maximum load at fracture, in Newtons;

1600 = 40 mm × 40 mm is the area of the platens or auxiliary plates, in square millimetres.

The test result is expressed as the arithmetic mean of the six compressive strength determinations made on a set of three prisms. If one result within the six determinations varies by more than ± 10 % from the mean of the six, discard this result and calculate the mean of the five remaining results. If a further result within these five determinations varies by more than ± 10 % from their mean, discard the set of results.

From the individual strength results obtained from prism halves expressed to the nearest 0,1 N/mm^2 calculate the mean and express this to the nearest 0,1 N/mm^2.

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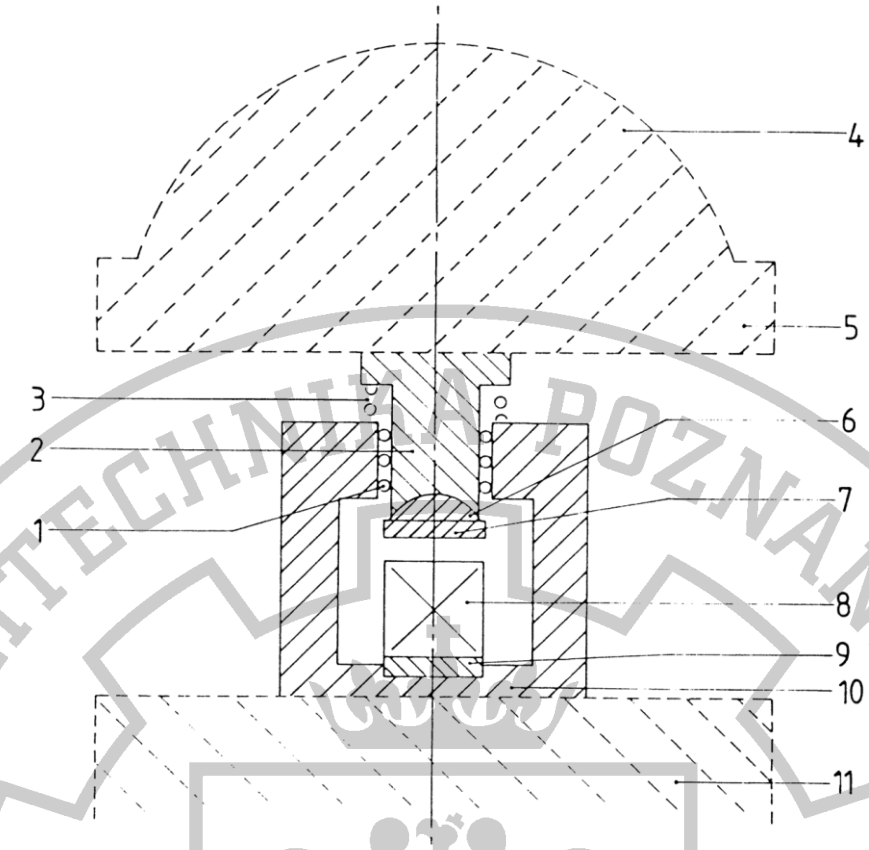

1. Ball bearings
2. Sliding assembly
3. Return spring
4. Spherical seating of machine
5. Upper platen of machine
6. Spherical seating of the jig
7. Upper platen of the jig
8. Specimen
9. Lower plate
10. Lower platen of the jig
11. Lower platen of machine

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Hydraulic lime: determination of flexural and compressive strength

European Standard

PN-EN 196-1:2016-07 Methods of testing cement. Part 1: Determination of strength.

PN-EN 459-2:2010 Building lime. Part 2: Test methods.

TEST PROCEDURE

Determine the compressive strength in accordance with EN 196-1, “lime with hydraulic properties” being substituted where “cement” is mentioned. The modifications given in Table below shall apply.

Type of product	Bulk density kg/m^3	Water/binder ratio	Mass of water g
HL 5; NHL 5; FL 5	> 0,6	0,50	225 ± 2
HL 2; NHL 2; FL 2; HL3,5; NHL 3,5; FL 3,5	> 0,6	0,55	248 ± 2
HL 2; NHL 2; FL 3,5; HL 3,5; NHL 3,5; NHL 5; FL 5	≤ 0,6	0,60	270 ± 2
FL2	≤ 0,6	0,65	292,5 ± 2

Increase the compressive load at a rate of (400 ± 40) N/s for all types of lime with hydraulic properties.