

## 13. CEMENT - DETERMINATION OF STRENGTH

### 13.1 Preparing Samples

Compressive, event. flexural strength determinates on 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 and three parts by mass of standard sand with a water-cement ratio of 0,50.

The mortar is prepared by mechanical mixing and is compacted in a mould using a standard jolting apparatus. Alternative compaction equipment and techniques may be used provided that they have been shown to give cement strength results which do not differ significantly from those obtained using the standard jolting apparatus.

The specimens in the mould are stored in a moist atmosphere for 24 h and then the demoulded specimens are stored under water until strength testing.

At the required age, the specimens are taken from their wet storage, broken in flexure into two halves and each half tested for strength in compression.

#### 13.1.1 Mortar Constituents

**Sand.** According EN 196-1 **CEN Standard sand** is used. This sand shall have been granted a CEN certificate by the national standardization organisation. In view of the difficulties of specifying CEN Standard sand completely and unambiguously it is necessary during certification and quality control testing to standardise the sand against the CEN Reference sand , described in EN 196-1.

**CEN Reference sand** is a natural, siliceous sand consisting preferably of rounded particles and has a silica content of at least 98 %. The moisture content is less than 0,2% expressed as percentage by mass of the dried sample. Its particle size distribution lies within the limits defined in Tab.:28

Tab.:28 Particle size distribution of the CEN reference sand

Square mesh size [mm]	Cumulative sieve residue [%]
2,0	0
1,6	7 ± 5
1,0	33 ± 5
0,5	67 ± 5
0,2	87 ± 5
0,08	99 ± 5

CEN Standard sand may be delivered in separate fractions or premixed in plastic bags with a content of 1350 ± 5 g.

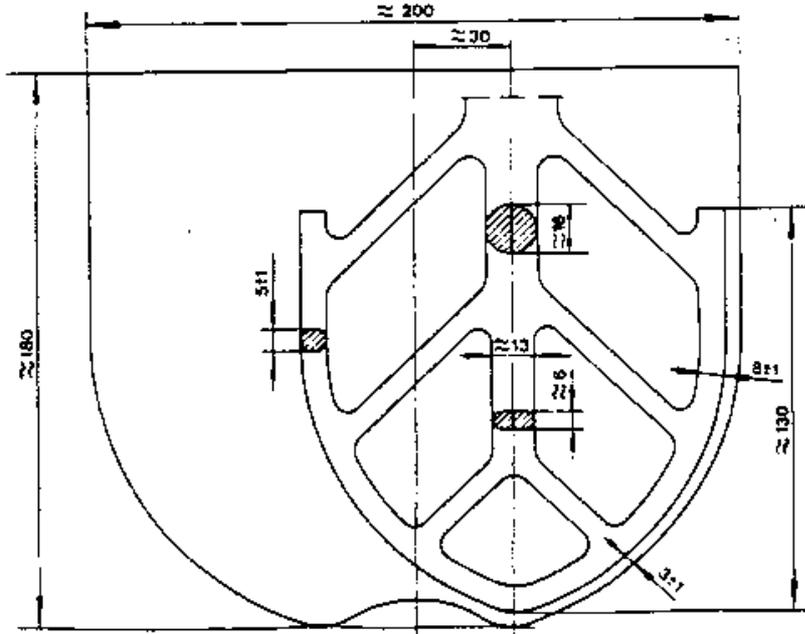
**Cement.** When the cement to be tested is kept for more than 24 h between sampling and testing, it shall be stored in completely filled and air tight containers made from material which does not react with cement.

**Water.** Distilled water shall be used for reference testing. For other test, drinking water may be used.

### 13.1.2 Equipment

**Mixer** shall consist from stainless steel bowl with a capacity of about 5 l and stainless blade ( shape and size shown in Fig.:32)

Fig.:32 Bowl and blade



Bowl has to be provided with means by which it can be fixed securely to the mixer frame during mixing and by which the height of the bowl in relation to the blade and the gap between blade and bowl can be finely adjusted and fixed. The blade is revolving about its own axis as it is driven in planetary movement around the axis of the bowl by an electric motor. The two directions of rotation shall be opposite and the ratio between two speeds shall not be a whole number. The mixer shall operate at the speeds given in Tab.:29

Tab.:29 Speeds of mixer blade

	Rotation [ $\text{min}^{-1}$ ]	Planetary movement [ $\text{min}^{-1}$ ]
Low speed	$140 \pm 5$	$62 \pm 5$
High speed	$285 \pm 10$	$125 \pm 10$

**Moulds.** The mould shall consist of three horizontal compartment so the three prismatic specimens 40 mm x 40 mm in cross section and 160 mm length can be prepared simultaneously. A typical design is shown in Fig.:33. A thin film of mould oil shall be applied to the internal faces of the mould. To facilitate the filling of the mould a tightly fitting hopper shall be provided.

### 13.1.3 Preparation of Test Specimens

- each batch for three test specimens shall consist of
  - 450  $\pm$  2 g of cement
  - 1350  $\pm$  5g of sand
  - 225  $\pm$  1g of water (water/cement ratio = 0,50)
- the cement, sand, water and a apparatus shall be at the laboratory temperature

Mix each batch of mortar mechanically using the mixer (13.1.2) :

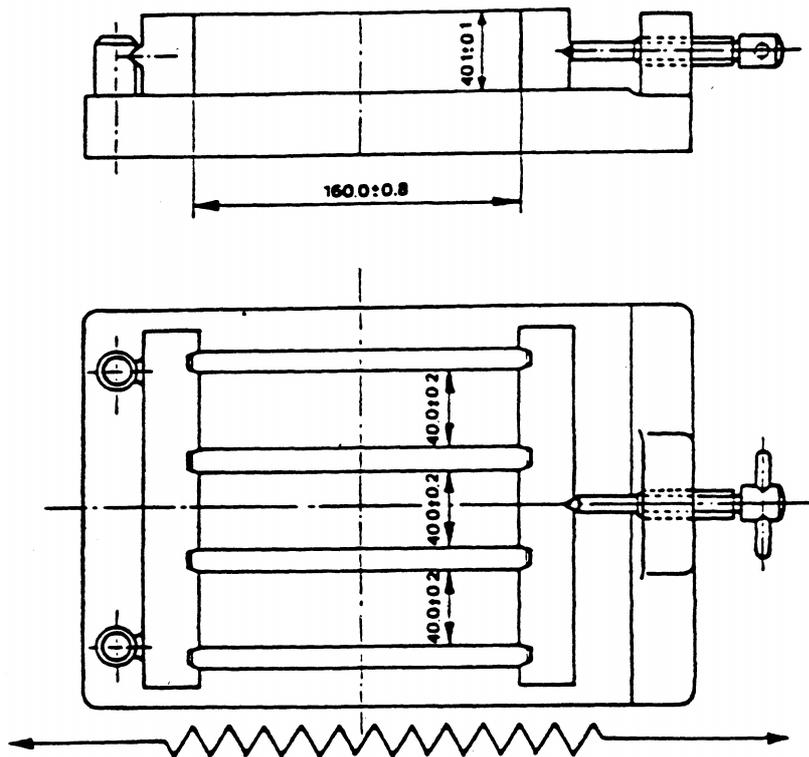
- pour the water into the bowl and add the cement
- start the mixer immediately at low speed (see Tab.:29) and, after 30 s add the sand steadily during the next 30 s. ( when separate sand fractions are used, add the add the required quantities of each fraction in succession starting with the coarsest)
- switch the mixer to the higher speed and continue for an additional 30 s
- stop the mixer for 1 min 30 s. During the first 15 s remove by means of a rubber scraper all the mortar adhering the wall and bottom part of the bowl and place in the middle of the bowl
- continue the mixing at the high speed for 60 s.

The timing of the various mixing stages shall be adhered to within  $\pm 1$  s.

Automatic devices for control of these operations and timings can be used.

- mould the specimens immediately after the preparation of the mortar. With the mould and hopper firmly clamped to the jolting table. Introduce first layer of mortar (about 300 g) into each of the mould compartments. Spread the layer uniformly and compact the first layer using 60 jolts.
- introduce the second layer of mortar, level it and compact with a further 60 jolts
- lift the mould gently from the jolting table and remove the hopper
- strike off the excess mortar with the metal straight edge, held almost vertically and moved slowly, with transverse sawing motion. Smooth the surface of the specimens using the same straight edge held almost flat
- label or mark the moulds to identify the specimens

Fig.:33 Typical mould



#### 13.1.4 Curing of Test Specimens

- place a 210 mm x 185 mm plate glass sheet (or from other impermeable material such a steel) of 6 mm thickness on the mould
- place each covered mould on a horizontal base in the moist air room. Mould shall not be stacked one upon the other
- each mould shall be removed from storage at its appropriate time for demoulding
- carry out demoulding with due precautions

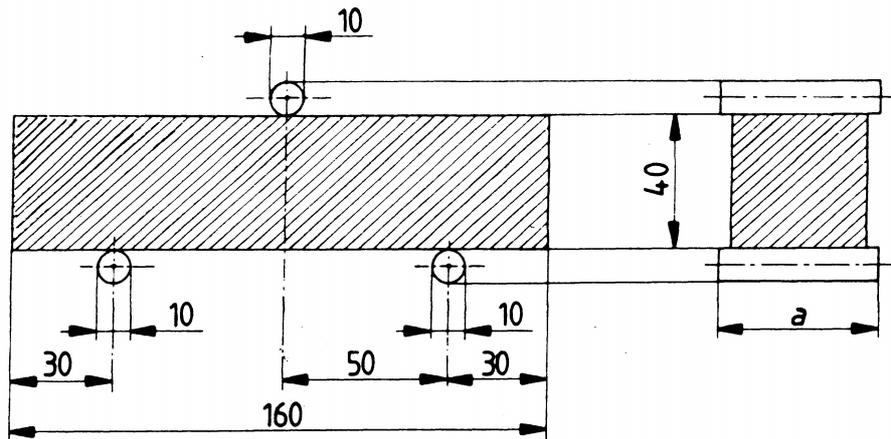
- keep the demoulded specimens selected for testing at 24 h covered by a damp cloth until tested
- suitably mark specimens ( by water resistant ink or crayon) and submerge them either horizontally or vertically in water at  $20 \pm 1$  °C. With horizontal storage, keep vertical face s as část certical, 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 specimen. At no time during storage shall the spaces between the specimens or depth of water above the upper faces of the specimens be less than 5 mm
- remove the specimens from the water not more than 15 min before the test is carried out. cover the specimens with a damp cloth until tested

## 13.2 Testing the Specimens

### 13.2.1 Flexural Strength

Place the prism in the testing machine (see Fig.:34 ) with one side face on the supporting rollers and with its longitudinal axis normal to the supports. The distance between supports is  $100 \text{ mm} \pm 0,5 \text{ mm}$  Apply the load vertically by means of the loading roller to the opposite side face of the prism of the prism and increase it smoothly at the rate of  $50 \pm 10 \text{ N/s}$  until fracture.

Fig.:34 Arrangement of loading for determination of flexural strength



Calculate the flexural strength  $R_f$  from :

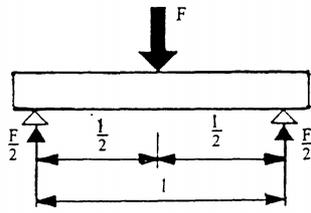
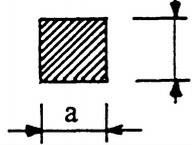
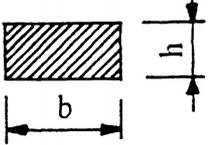
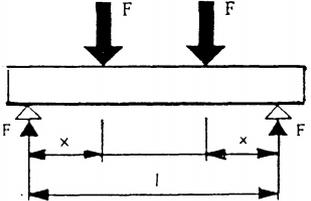
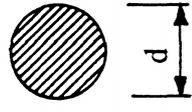
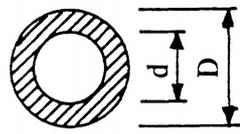
$$R_f = \max \sigma_f = \frac{\max M}{W}$$

where  $R_f$  is flexural strength [ MPa ]  
 $\sigma_f$  maximum flexural stress [ MPa ]  
 $M$  bending moment [ N.mm ]  
 $W$  section modulus [  $\text{mm}^3$  ]

The terms bending moment and section modulus shall be explained in the course Structural mechanics.

Some basic examples of loading and appropriate formulas for bending moment and section modulus are given in Tab.:30

Tab.:30 Basic examples of bending moment and section modulus

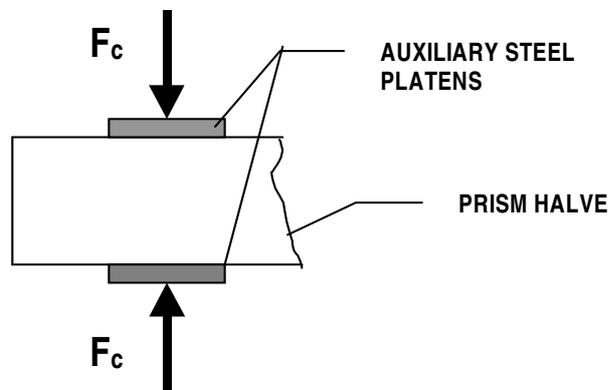
Loading diagram	Bending moment	Form of section	Section modulus
	$M = \frac{1}{4} F \times l$		$W = \frac{1}{6} a^3$
			$W = \frac{1}{6} bh^2$
	$M = F \times X$		$W = \frac{\pi}{32} d^3 = 0,1d^3$
			$W = \frac{\pi (D^4 - d^4)}{32 D}$

### 13.2.2 Compressive Strength

The prism halves (after test of flexural strength) are tested in compression. Centre the prism halves laterally to the auxiliary platens of hard steel, which exactly determine the compressive area (because the prism halves have an irregular form). According EN 196-1 the size of the platens is 40 mm x 40 mm and they are at least 10 mm thick. During loading the relative attitude of the upper and lower platens shall remain fixed. The resultant of the forces shall pass through the centre of the specimen.

Increase the load smoothly at the rate of  $2400 \pm 200$  N/s over the entire load application until fracture.

Fig.:35 Scheme of loading for compressive test.



Compressive strength is calculated from:

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

where  $R_c$  is compressive strength [ MPa]  
 $\sigma_c$  compressive stress [ MPa]  
 $F_c$  maximum load at fracture [ N ]  
 1600 the area of the platens ( = 40 mm x 40 mm ) [ mm<sup>2</sup> ]

A test result is defined 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  $\pm 10\%$  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  $\pm 10\%$  from their mean, discard the set of results.

The results shall comply with the requirements of standard EN 197-1, given in Tab.:31.

Tab.:31 Mechanical and physical requirements for cement

Class	Compressive strength [ MPa]				Initial setting time [min]	Expansion [mm]
	Early strength		Standard strength			
	2 days	7 days	28 days			
32.5	-	$\geq 16$	$\geq 32.5$	$\leq 52.5$	$\geq 60$	$\leq 10$
32.5 R	$\geq 10$	-				
42.5	$\geq 10$	-	$\geq 42.5$	$\leq 62.5$		
42.5 R	$\geq 20$	-				
52.5	$\geq 20$	-	$\geq 52.5$	-	$\geq 45$	
52.5 R	$\geq 30$	-				



## Vocabulary

auxiliary platen	<i>přídavná destička</i>
batch	<i>záměs</i>
bending moment	<i>ohybový moment</i>
compressive strength	<i>pevnost v tlaku</i>
expansion	<i>objemová stálost (rozepnutí)</i>
flexural strength	<i>pevnost v ohybu</i>
fracture	<i>porušení</i>
jolting apparatus	<i>zhuťňovací zařízení</i>
mortar	<i>malta</i>
particle size	<i>velikost zrn</i>
reference (standard) sand	<i>referenční (standardní) písek</i>
section modulus	<i>průřezový modul</i>
strength	<i>pevnost</i>
stress	<i>napětí</i>
water-cement ratio	<i>vodní součinitel</i>