

# Evaluation of loading methods for determination of material and elastic constants of cement fiber board

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**Abstract.** Cement fiber boards (CFB) are special group that are used in a wide range of structural civil engineering. For the correct design of a cement fibre board structure, it is important to define their material and elastic constants, which are usually determined by destructive tests. The paper deals with a definition of a suitable method of loading for the determination of basic materials and elastic constants of cement fiber boards reinforced with organic fibers loaded in the mid-plane. The publication compares and evaluates load tests by three-point and four-point bend.

## 1. Introduction

Composite boards based on cement and organic fibers (referred to as cement fiber boards) are today an environmental, universal and durable building material. It serves as a substitute for natural wood and wood products, such as plywood or oriented strand boards (OSB). The properties of cement fiber boards as a building material use a variety of uses in a wide range of building structures. Those that include cladding of ventilated facades (Figure 1) for the reconstruction of new buildings, internal and external ceilings, cladding of internal and external structures, cable bridges or fire protection structures.



**Figure 1.** Ventiladed facade, application of cement fiber boards 0

Currently, the Hatschek method is one of the most widely used processes for the production of cement fiber boards 0. This production process consists in laying individual thin layers (called monolayers) on top of each other until the required thickness is reached, this layer is then pressed. In

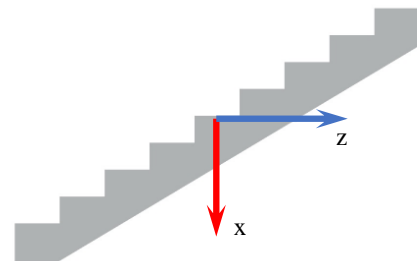


this way of production, the reinforcing fibers are divided in a board-plane, they are oriented in the direction of production.

In the case of normal use, cement fiber boards are loaded and tested (Figure 2) primarily in the y-z (y-z) direction, and y-x (x-y). In the case of innovative use, for example in the form of stairs (Figure 3), the slabs are stressed primarily in the x-z (z-x) direction, the methodology for experimental testing in this direction is not defined.



**Figure 2.** Scheme of loading directions with regard to the direction of production of cement fiber boards produced by the Hatschek method



**Figure 3.** Stairs, the main supporting element of the stair staircase, marking of the primary directions of loading

## 2. Calculation methods

Determination of material and elastic constants for flat cement fiber boards (direction y-z and y-x) is governed by ČSN EN 12467 + A2 0. Here it is recommended to choose test specimens with dimensions of 250 × 250 mm, regardless of the thickness of the board. It is recommended to perform the load by three-point bending (index 3) with a constant path increment. Subsequently, the values of modulus of elasticity (*MOE*) and tensile strength in bending (*MOR*) are determined according to equations (1) and (2).

$$MOE_3 = \frac{(F_2 - F_1) \cdot l_s^3}{4 \cdot b \cdot e^3 (f_2 - f_1)} \quad (1)$$

$$MOR_3 = \frac{3 \cdot F \cdot l_s}{2 \cdot b \cdot e^2} \quad (2)$$

where *MOE* is modulus of elasticity in [N/mm<sup>2</sup>];  $F_1$  and  $F_2$  are forces in two points located in the linear part of the loading displacement diagram graph expressing dependence between vertical displacement and applied load in [N];  $l_s$  is a distance between supports, in [mm];  $b$  and  $e$  is the width and thickness of specimens, in [mm];  $f_1$  and  $f_2$  are vertical displacements corresponding with the selected load, in [mm],  $F$  is failure force, in [N].

*Ranachowski and Schabowicz* describes in 0 as a suitable method of loading (for direction y-z and y-x) by four-point bending (index 4), where the values of modulus of elasticity (*MOE*) and tensile strength in bending (*MOR*) are determined by relations (3) and (4).

$$MOE_4 = \frac{23 \cdot (F_2 - F_1) \cdot l_s^3}{108 \cdot (w_2 - w_1) \cdot b \cdot h^3} \quad (3)$$

$$MOR_4 = \frac{F_{\max} \cdot l_s}{b \cdot h^2} \quad (4)$$

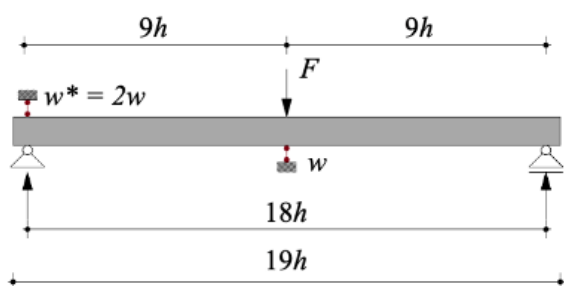
where  $F_{max}$  is failure force in [N];  $h$  is height, respectively thickness, in [mm];  $F_1$  is force, in [N], corresponding to 10 % of failure force ( $F_{max}$ );  $F_2$  is force, in [N], corresponding to 40 % of failure force ( $F_{max}$ );  $w_1$  is vertical displacement of testing specimens corresponding to  $F_1$ , in [mm];  $w_2$  is vertical displacement of testing specimens corresponding to  $F_2$ , in [mm].

Equations (1) to (4) are based on European standards and are in principle applicable to flat plates, ie. for the basic directions y-z and y-x (Figure 2).

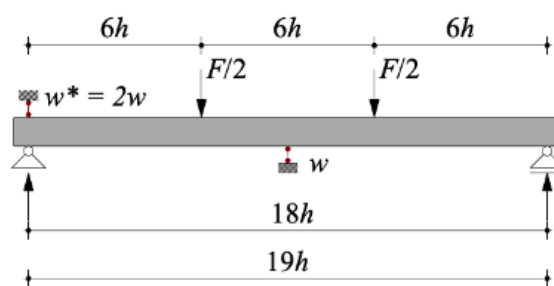
In the case of defining material and elastic constants in the z-x direction, the procedures from ČSN EN 408 0 can be applied analogously, similarly to Pěncík in 0 for wooden beam specimens. The position of the loading forces and the size of the test specimens are described in Figure 5. The modulus of elasticity ( $MOE_4$ ) in this case can be determined according to equation (5)

$$MOE_4 = \frac{l^3 \cdot (F_2 - F_1)}{bh^3 \cdot (w_2 - w_1)} \left[ \left( \frac{3a}{4l} \right) - \left( \frac{a}{l} \right)^3 \right] \tag{5}$$

where  $a$  is the distance between the load and the nearest bend test support in [mm] and  $l$  the bending span in [mm].



**Figure 4.** Description of tests under three-point bend loading.

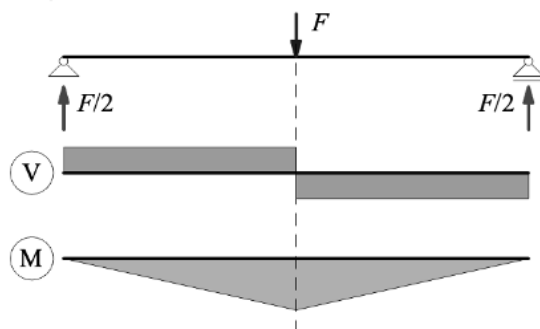


**Figure 5.** Description of tests under four-point bend loading.

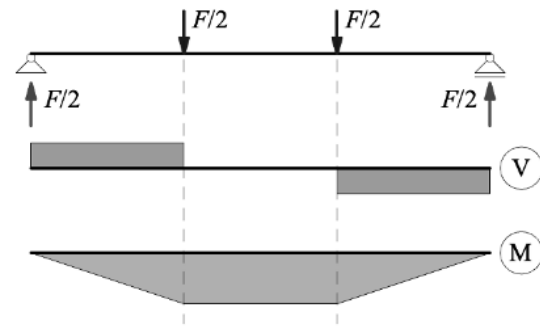
To create a complex material model, ie. in the directions y-x, y-z, x-z (x-y, z-y, z-z) it is appropriate in all cases to choose the size of test specimens defined according to ČSN EN 408 0 (Figure 4) and (Figure 5) on the basis of the search. To determine the modulus of elasticity ( $MOE_3$ ) and tensile strength in bending ( $MOR_3$ ) under three-point bending loading, it is appropriate to apply equations (1) and (2) on the basis of research. To determine the modulus of elasticity ( $MOE_4$ ) and tensile strength in bending ( $MOR_4$ ) under loading by four-point bending, it is appropriate to apply equation (4) and (5) on the basis of research.

### 3. Comparison of three-point and four-point bend test

The essential difference between the three-point and four-point bend test in the course of internal forces. During the three-point bend test, one point is exposed to the maximum shear force ( $V$ ) and at the same time to the maximum bending moment ( $M$ ), the course of internal forces is shown in (figure 6). In the case of four-point bend load, the bending moment is evenly distributed between the forces and thus allows a more accurate determination of the modulus of elasticity during the bending test (Figure 7).

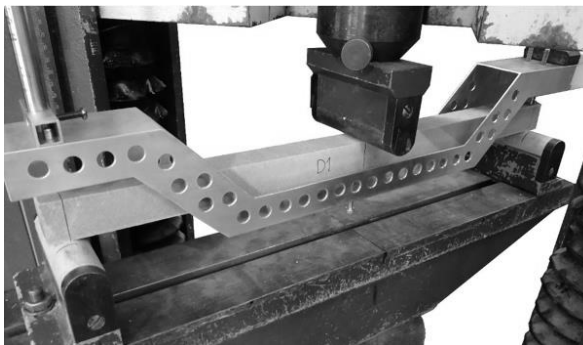


**Figure 6.** Diagram of the course of shear forces (V) and bending moment (M) under loading by three-point bending.

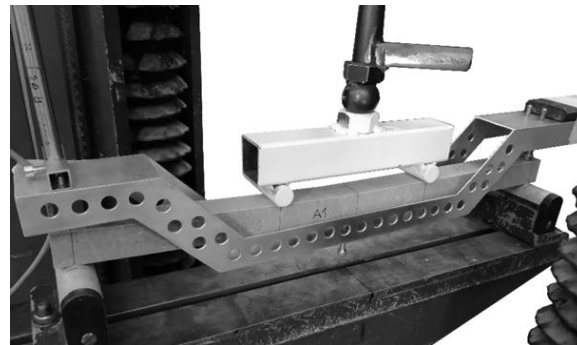


**Figure 7.** Diagram of the course of shear forces (V) and bending moment (M) under loading by four-point bending.

The four-point bend test is suitable for brittle materials with low shear stress. The magnitude of the flexural tensile strength depends on the toughness and severity of the defects of the test specimens. In the case of cement fiber boards produced by the Hatschek method, delamination and cracking very often occur due to the natural maturation of the material. Exposure of one point to maximum stress (Figure 8) will reduce the measured flexural strength because there is an increased likelihood that cracks will reach a critical length at the applied load. Four-point bend test (Figure 9) is suitable for determining the strength of joints, the location of the joint area is repeatable.



**Figure 8.** The real test arrangement in three-point bend load.



**Figure 9.** The real test arrangement in four-point bend load.

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