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INFLUENCE OF MOISTURE SORPTION ON DEFORMATIONS OF BUILDING MATERIALS

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INTRODUCTION

Variations sorption moisture in the surface layer of enclosures result in moisture-caused deformations which must be evaluated together with sorption-desorption processes in the construction.

With increased time of exposure to the environment, materials begin to degrade, which can result in either a catastrophic failure or gradual drift out of tolerance of a critical performance property of material. The durability problem is concerned with the deterioration of the material to such a level that an undesirable or unsafe condition for the material or component is attained.

INVESTIGATION OF MOISTURE - CAUSED DEFORMATIONS

- According to the methods described in this work, the dependence of deformations (ε_u) of various construction materials (concrete, silicate and ceramic bricks, lime cement mortars, porous concrete) upon moisture and changes therein was investigated: $\varepsilon_u = f(u)$.

- Investigation methods were improved and developed on the ground of a cement-wood chip board example; afterwards they were applied for investigation of other materials.

- The basic point of the developed methods intended for investigation of moisture-caused deformations is investigation of the groups of specimens by measuring deformations in the environment of fixed sorption moisture using four models:

- Model *I* - specimens were soaked in water at temperature (18-25) ºC till absolute absorption. Afterwards, the specimens were dried under room conditions at the air temperature (18±2) ºC and RH ϕ = (45-50) % until equilibrium state was reached. The above state reached, the specimens were dried at an ambient temperature (105±2) ºC until a dry state was achieved;

- Model *II* - specimens were soaked at 60 ºC in polyethylene bags. The bags contained such volume of water which was almost totally absorbed by the specimen. Then the specimens were dried at the same temperature in empty (no water) polyethylene bags so that more identical conditions were created for distribution of moisture;

- Model *III* - specimens were tested under the conditions identical to those of Model *I*, however, they were moistened gradually in the course of entire sorption process up to complete absorption, while soaked in water;

- Model *IV* - specimens were tested under the conditions identical to those of Model *II*, however, they were moistened gradually according to sorption process and then up to the total absorption.

- For evaluation of the deformations, the length of a dry specimen was taken as the basic length. The length of each specimen was measured at 0.0001 mm accuracy; the mass accuracy of 0.01 g.

- Moisture-caused deformations of specimens were valued by two parameters:

- Linear deformations of a material ε_u, [mm/m]:

$$\Delta l = l_u - l_b ;$$

$$e_u = \Delta l / l_b$$

where l_b is basic length of a specimen, mm; l_u is measured length of a damp specimen, mm.

Relative moisture elongation of material *K*, mm/(m·%)]:

$$K = \varepsilon_u / \Delta u$$

where $\Delta u = (u_2 - u_1)$, % - accrual of material moisture (essentially, the sorption moisture), %, within the interval from moisture u_1 to moisture u_2.

K is a significant comparative property of the material indicating relative change of material length with moisture change of one percent.

- The process of moisture transfer is an inert one and therefore the experiment of investigation of moisture-caused deformation is time-consuming; precision of measurements depends on escaping from the influence of accidental effects. Measuring practices indicated that negligible accidental deviations resulted in distortion of the result and required repetition of the experiment already well-advanced.

Results

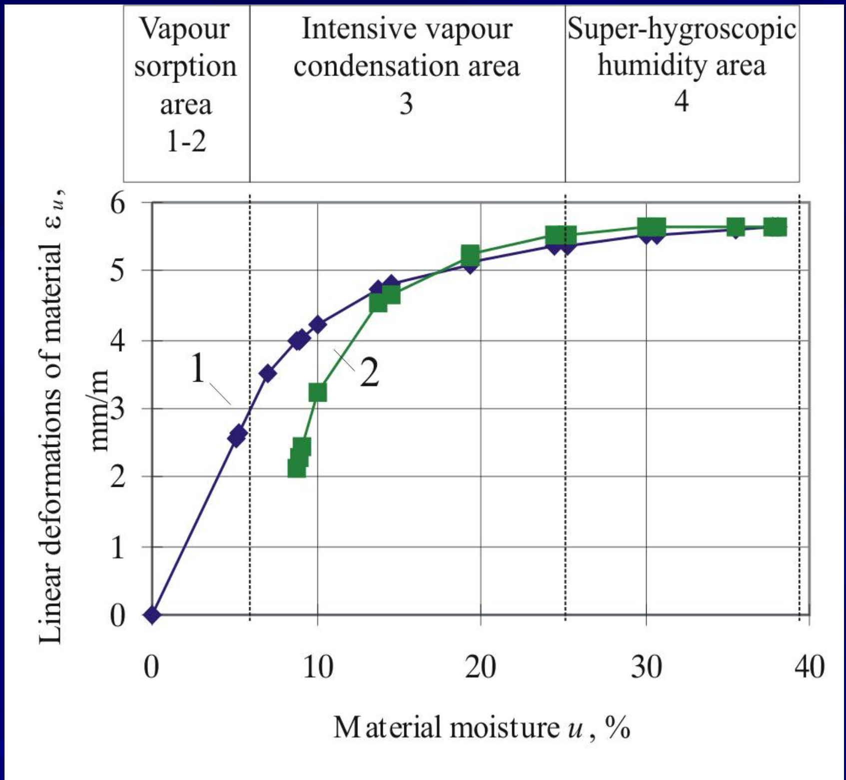

Fig. 1. Linear deformations caused by moistening (1) and drying (2) of cement-wood chip boards according to Model *III*.

In Figures 1-6 the field of deformations is divided into three areas: in the 1st area, the moisture of the specimen corresponds to vapour-state sorption moisture of the material; including adsorption moisture (*1-2*); in the 2nd area (*3*), moisture of the specimen complies with that of an intensive capillary condensation; and in case of the 3rd area (*4*) the specimen is moistened by free moisture.

Analysing of moisture-caused deformations of materials with different capillary structures enables us to provide - in a very concise form-some references concerning value and nature of deformations.

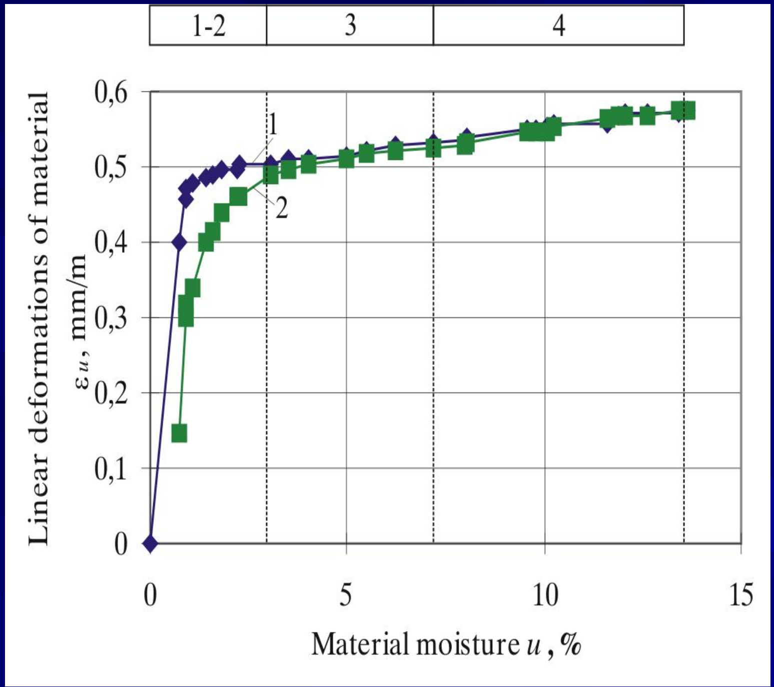

Fig. 2. Linear deformations caused by moistening (1) and drying (2) of silicate brick according to Model *III.*

- Relative moisture elongation of materials of the articles possessing fine capillary and homogenous structure, e.g. deformations of a silicate brick, grew abreptly and rapidly in the area of sorption moisture (Fig. 2) (Hedenblad, 1995 & Bednar, 1999). It was determined that when the articles were dried in the environment of temperature 105 ^{o}C, about 0.5% of non-eliminated moisture remained therein, and residual deformations proportional to the quantity of non-eliminated moisture were observed.

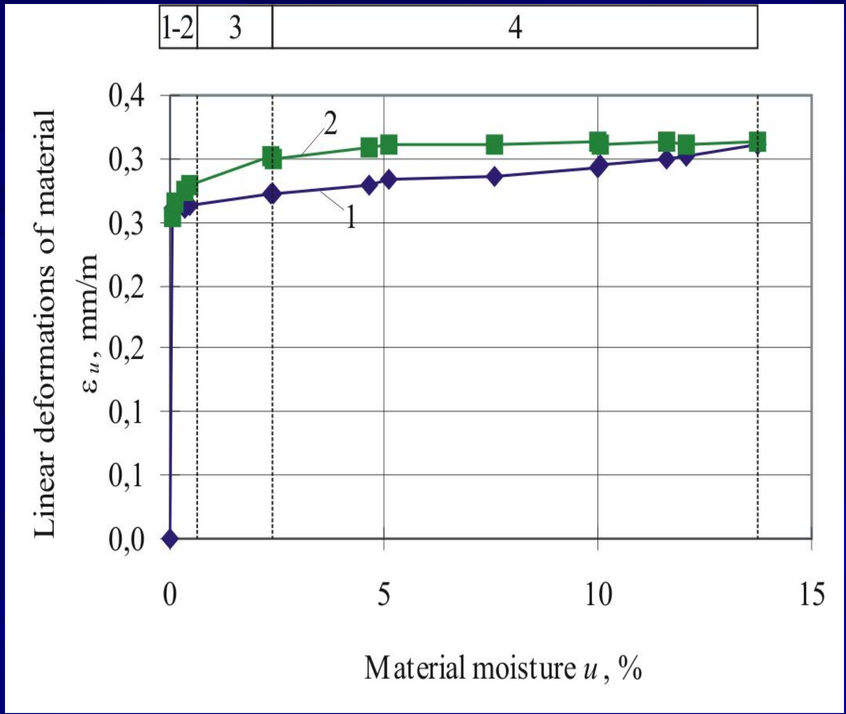

Fig. 3. Linear deformations caused by moistening (1) and drying (2) of lime mortar (1:3) according to Model *II.*

- Weakly-bonded structures such as specimens of lime mortar undergo deformations in quite a different way (Fig. 3). When soaked in water, they swell rapidly. When water temperature reaches 60 ^{o}C and water viscosity decreases (according to Model *II*), the mortar gets water-saturated in several minutes. Moisture-caused deformations do not increase with further moistening. Residual deformations of the specimens correspond to the value reached during intense swelling.

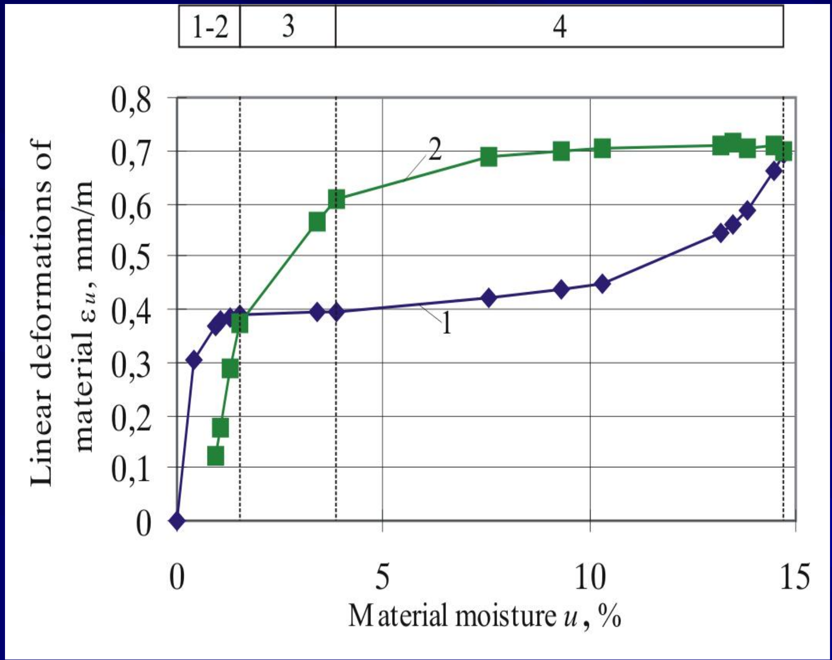

Fig. 4. Linear deformations caused by moistening (1) and drying (2) of lime cement mortar (1:1,2:6,8) according to Model *I*.

- Intensive swelling was also observed while testing lime cement mortar according to Models *I* (Fig. 4) & *II* (soaking in water). In the above case, high hysteresis of isotherms' drying and moistening as well as a characteristic shape of moistening isotherm were observed. Within the interval u = (1.5-4)% (intense capillary condensation area), relative moisture elongation of the lime cement mortar $K \approx 0$ (the material stops to extend). Afterwards, the elongation slowly grows, later more rapidly up to the limit characteristic of the lime cement. The above can be explained by the presence of two materials (lime and cement) with different abilities of water absorption.

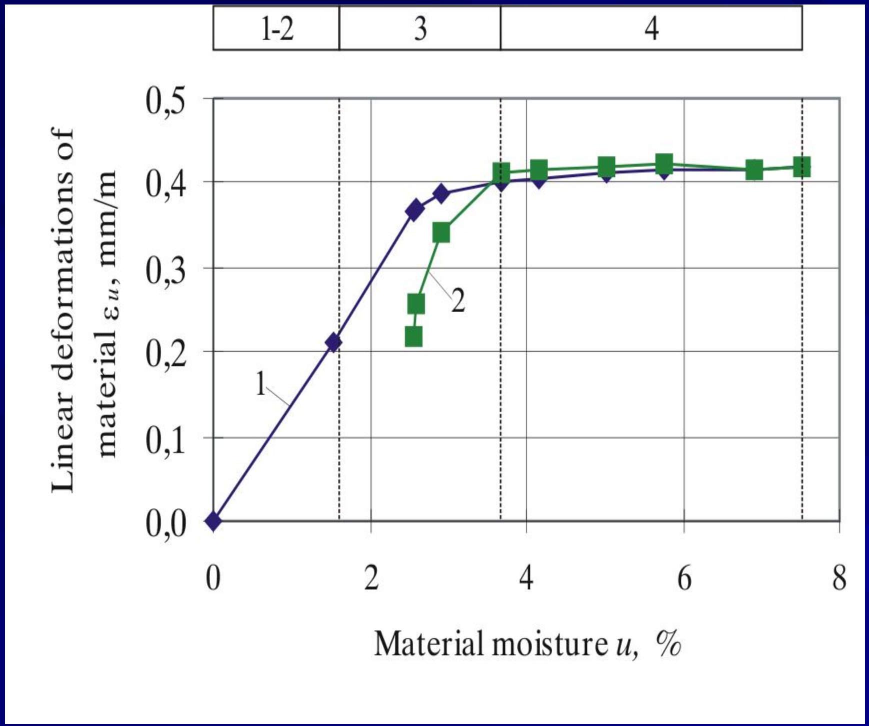

Fig. 5. Linear deformations caused by moistening (1) and drying (2) of concrete according to Model *I.*

- At the beginning the lime absolutely disturbs for cement to adsorb water vapour ($u < 4\%$). During saturation the lime less and less disturb for cement to absorb water. Relative moisture elongation at the end of saturation reaches value $K = 0.12$ mm/(m·%) ($u \approx 15\%$). During the drying process of the mortar the recurrence of volume is very slow, the hysteresis is high.

- When heavy concrete is moistened at 20 ^{o}C temperature environment according to Model *I* (Fig. 5), moistening rate is practically constant until complete humidification in the area of capillary condensation.

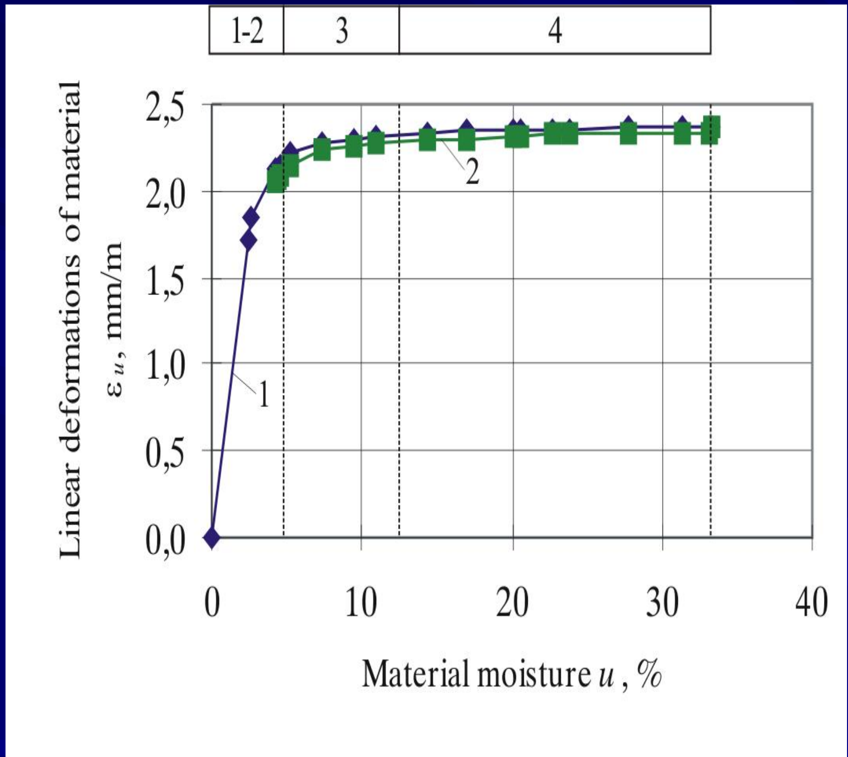

Fig. 6. Linear deformations caused by moistening (1) and drying (2) of porous concrete according to Model *I.*

- Samples of porous concrete, tested according to Models *I* (Fig. 6) & *II* (temperature θ, 20 º and 60 ºC respectively; moistened by direct contact with water) up to the moistening corresponding to the (*1-2*) sorption area, were also getting intensively moistened in proportion to ambient moisture accrual.

- In this case, relative moisture elongation of material *K* = (0,46-0,57) mm/(m·%), at humidity level up to *u* ≤ (3-4)% depends on the ratio of rapidly water-filled open pores and narrow water-sucking capillaries linking the pores.
- The more open porosity is, the bigger is the relative moisture elongation *K* of the material and, consequently, more rapidly linear deformations develop up to the limit of their moisture-caused deformation.
- Isotherms of drying practically correspond to moistening isotherms up to polymolecular (filmy) level of moisture; once the level is reached they practically break - residual deformations and residual moisture are already fixed in the gas concrete.
- The influence of temperature is low and fits within the limits of testing accuracy (precision).

- Investigation results indicated that functional dependence of material deformations upon moisture might be put into a certain variation curve close to that of parabola; different are function variation parameters which depend on the nature of the material, microstructure and molecular link of moisture with the framework of the material. However, variation parameters of the function $\varepsilon_u = f(u)$ are different for each material and should be calculated individually.

CONCLUSIONS

- All tested construction materials usually get deformed in the area of sorption moisture before reaching the state of intense capillary condensation. Moisture-caused deformations do not increase in the area over hygroscopic point. Exception: lime cement mortar.

- Linear moisture-caused deformations of basic construction materials (concrete, silicate and ceramic bricks, lime cement mortars, porous concrete) vary within the limits of 0.33 - 0.77 mm/m. In case of articles containing organic fillings linear moisture-caused deformations can reach up to 6 mm/m.

- In case of a material containing plastifying additives, including lime, residual moisture and residual deformations are observed.

- The highest relative moisture elongation *K* of a material is observed in vapour area; it is directly proportional to moisture growth at a large relative surface of capillaries and pores per volume unit, i.e. when the material is of a fine capillary structure.

- Relative moisture elongation *K* of the tested materials with the outset of intense capillary condensation varies from 0.05 mm/(m·%) to 0.51 mm/(m·%).

THANK YOU FOR YOUR ATTENTION !