Elastic and plastic deformations of plaster units under uniaxial compressive stress

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The suitability of plaster building units to structural application is determined not only by the strength behaviour but to a large degree also by the deformation behaviour. In plaster units under permanent load there occur elastic, retarded elastic, and plastic deformations, which primarily depend on the quality of the raw materials, on placing and hardening conditions, on the structure of the hardened material, on the stress applied, and on the moisture content.

The interrelations between the deformation behaviour and the above mentioned effects were investigated and — as far as possible — plotted and mathematically evaluated. For characterizing the building material specific values such as moduli of elasticity and creep values and the conditions for its application are given.

1 - LIST OF TERMS USED IN THE EQUATIONS HEREIN

- $a, b$: Constants
- $E_d$: Modulus of compressive elasticity
- $E_{do}$: Tangent modulus
- $m_k$: Inelastic transverse contraction number
- $P$: Force
- $t$: Time [d]
- $u$: Moisture content p.c. by weight
- $w$: Water-binder-ratio related to mass
- $x$: Linear deformation
- $a$: Spring constant
- $\Delta$: Difference
- $e$: Total deformation [mm/m]
- $e_{el}$: Elastic deformation [mm/m]
- $e_k$: Creep deformation [mm/m]
- $e_{k1}$: Creep deformation at $\cdot 0 = 1 \text{ kg/dm}^3$
- $e_{\infty}$: Total deformation for $t \to \infty$
- $\cdot 0$: Bulk density with $u$ 0.2 p.c. by weight [kg/dm$^3$]
- $\sigma_d$: Compressive stress [kp/cm$^2$]
- $\sigma_{dB}$: Compressive strength [kp/cm$^2$]
- $\tau$: Retardation period
- $\Phi$: Fluidicity
- $\varphi$: Creep number

2 - INTRODUCTION

The increase in building production is a social demand which can only be satisfied by a preceding increase in building materials production.

Gypsum rock deposits are abundant in nature throughout the world and as such they are a real resource of raw materials. Gypsum is one of the oldest...
building materials. In modern civil engineering gypsum is used to a small degree only. One reason is that gypsum is not able to harden hydraulically, the other is that the deformation behaviour of gypsum under permanent loads to which a building element is subject in application is not yet completely known.

In this paper we endeavour to contribute to better knowledge of this problem and to help form the basis for a reasonable application of gypsum.

3 - AIM OF THESE INVESTIGATIONS

Beginning with a theoretical consideration of the structure of hardened plaster and of its behaviour under short-term mechanical stress, these investigations aim at analysing deformations of plaster units occurring under permanent load by means of creep curves and comparing their most efficient dependences. In conformity with these aims, we apply the technical-empirical method of work and single-factor variation. The investigations are limited primarily to \( \beta \)-semi-hydrate plaster from the Harz region, which is the richest gypsum deposit in the GDR.

The effect of moisture is here of special importance, as an increase in moisture causes reduction in quality.

4 - STRUCTURE OF HARDENED PLASTER MASSES

Together with the pure phenomenological treatment, the approach to problems of deformation requires an appropriate consideration of the interior structure.

As most solid bodies, hardened plaster has a polycrystalline structure. The crystal form is monocrinally prismatic and often characterized by twin growth [1]. The size of the bar and of the fibre shaped crystals is very different and depends upon the basic material and the conditions of formation.

Between the crystals there may exist a more or less amorphous substance which acts as a binding material and plays an important part in the cohesion of the crystal aggregate. According to Freudenthal [2] this plaster structure could be considered as a two-phase system, the mechanical behaviour of which resulting from the behaviour of the single particles and of the materially random interfaces.

The sensitive mechanical and rheological reaction of gypsum building materials to a small amount of adsorbed water could prove the existence of those random intercrystalline layers, provided that the water is particularly adsorbed by these layers and this reduces the sliding resistance between the neighbouring particles.

According to most authors [3, 4, 5, 6] the solid plaster is formed by intergrowth of the dihydrate crystals, which form beyond in the phase of solution.

As a result of his own petrographic investigations Perederij [7], however, mentions a porphyry-type structure of plaster, composed of non- or only superficially hydrated semi-hydrate cores and new formations of dihydrate, the latter bonding the semi-hydrate particles to a durable compound. The comparatively easy solubility of new formations of dihydrate is according to Perederij [8] the reason for the reduction of strength under the effect of moisture. However, taking into account, that strength is reduced to half of its dry value already with 1% of the weight of moisture content and that only 0.2% of the weight of dihydrate solves in water at 20°C, the extremely low quantity of only 0.002% of the weight of the total plaster mass in a plaster unit should be responsible for this enormous loss of strength. It is not probable that only the dissolution of the newly formed dihydrates can be the reason for the decline of mechanical properties, but that the adsorption of water at the interfaces and thus the diminution of sliding resistance play an even greater part.

There are also different opinions on the reasons for the different mechanical behaviour of the plaster products made of \( \alpha \) and \( \beta \) semi-hydrate plasters.

Perederij [7] holds responsible the non-hydrated \( \alpha \) semi-hydrate particles contained in the plaster aggregate, which are a kind of reinforcement and counteract an interior displacement. Plaster made of ordinary stucco contains also porphyryically deposited semi-hydrate particles, but due to their low density and small size they possess, under mechanical stress, a lower resistance and thus, in a particularly disagreeable form, the property of creep.

Eipeltauer [9] shares this opinion: he also mentions the comparatively high density of the non-hydrated \( \alpha \) semi-hydrate particles as a reason for the favourable mechanical behaviour of hardened plaster.

These explanations given by Perederij [7] and Eipeltauer [9] should however be accepted with caution, because determinations of hydrate water in set plaster masses, shortly after mixing with water, justify the conclusion that there is an almost complete hydration. Gravimetrical measurements at the various plaster units resulted in quantities of hydrate water between 14.0 and 16.4% of the weight. As pure calcium