Experimentální Analýza Napětí 2010
Experimental Stress Analysis

# Determination of Compressive and Bending Strength of Hardened Gypsum

Pavel Padevet,[1] Andrea Wilczynská,[2] Pavel Tesarek[3]

**Abstract:** In present time it appears that use of gypsum and gypsum-based products is very advanced. Gypsum can be used for bearing and non-bearing structural elements. For this reason, it is necessary to know the basic material properties of gypsum, so important for the design of structures. The contribution is devoted to experimental observation above parameters gypsum and gypsum-based products. The results of the tested gypsum are particularly affected by environmental influences and therefore they are given due attention.

**Keywords:** Gypsum, Strength in Compression, Specimen

## 1. Introduction

The basic utility properties of using gypsum in building constructions are as follows: high workability, fast setting and hardening of a gypsum paste, the production of gypsum-based commodity does not need exacting technologies, it expands while setting. The products are easy workable (by cutting, grinding, drilling), they have a soft surface. After the gypsum paste hardens, this material possesses relative good strength – mainly compressive strength and boon thermal, sound insulation and fire resistance properties.

The fundamental regulating standard, which has been in force in our country till the present day, is the Czech standard ČSN 72 23 01 Gypsum binders – Classification, General technical specifications, Test methods of 1979 [1]. In accordance with this standard, gypsum is classified and divided into several groups. The basic classification of gypsum is based on its compressive strength after two hours. Here, gypsum may be classified into the total of 12 groups (G-2 to G-25). The lowest compressive strength must comply with the requirements for individual classes, i.e. the minimum strength values. Another criterion of the classifications is the setting time, where the types of plasters are divided into fast-setting, normal-setting and slow-setting, marked A to C. The essential criterion is the start and the length of the setting time in minutes. It is an analogy to the tests of cement under the

[1] *Ing. Pavel Padevet, Ph.D.; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague; Thákurova 7, 166 29 Prague 6, Czech Republic; pavel.padevet@fsv.cvut.cz*
[2] *Bc. Andrea Wilczynská; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague; Thákurova 7, 166 29 Prague 6, Czech Republic; andrea.wildczynska@fsv.cvut.cz*
[3] *Ing. Pavel Tesárek, Ph.D; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague; Thákurova 7, 166 29 Prague 6, Czech Republic; tesarek@fsv.cvut.cz*

*Experimentální analýza napětí 2010*, Petr Šmíd, Pavel Horváth, Miroslav Hrabovský, eds.,
May 31 - June 3 2010, Velké Losiny, Czech Republic (Palacky University, Olomouc; Olomouc; 2010).

Czech standard ČSN EN 196-3 Methods of cement testing, Specification of setting times and volume stability. The last criterion is the fineness of grinding, where the binder is divided into coarse, medium and fine ground and the fineness of grinding is marked I to III. The over on a sieve with the mesh dimensions of 0.2 mm are relevant. According to this standard, we should get sufficient information about the respective gypsum binder from the basic value of a two-hour compressive strength plus the consideration of the other two parameters, the fineness of grinding and the specification of the start and the length of the setting time.

## 2. Effect of conditions on mechanical properties of gypsum

The process changing gypsum – hemihydrate – into hardened gypsum – dihydrate – is hydration; it is typical effect for hydraulic binders. During this process, a solid material structure is formed, and the accompanying phenomenon is the generation of hydration heat and a volume increase – expansion. Hydration is set off after mixing water with gypsum.

The process of gypsum hydration and setting relies on multiple factors: the temperature during preparing of the gypsum paste, the water-gypsum ratio, the method of gypsum mixing, the mixing intensity and time, the fineness of grinding etc. [2].

One of the important factors, as has already been said, is the water-gypsum ratio. It is the ratio of the mass of water and gypsum. The water-gypsum ratio has a fundamental influence on the basic characteristics of hardened gypsum, such as its volume density, open porosity and other related characteristics like its moisture, mechanical, thermal and sound insulation properties. The theoretical water-gypsum ratio necessary for the hydration of calcium sulphate hemihydrate into calcium sulphate dihydrate is 0.187. Additional water, in a so-called over-stoicheiometric quantity, is necessary for the processing of the hardening gypsum paste. Depending on the value of the water-gypsum ratio necessary during the processing of the gypsum paste, the following technological production procedures are distinguished: pressing 0.3–0.4, vibrating 0.4–0.6 and casting 0.6–0.8.

## 3. Mechanical experimental methods

The principle of the compressive strength test of gypsum consists in the determination of the lowest load causing the sample failure, i.e. the exceeding of its compressive strength after Czech standard CSN 72 2301. The strength is determined on samples prepared from gypsum paste with a standard consistency for the respective water-gypsum ratio after CSN 72 2301 too, which was specified during the standard consistency specification test. The test is performed 2 hours after mixing the gypsum binder with water. The test was carried out on the WPM 100 kN press, with a scale of 0–20 kN. Test bars with dimensions of 40×40×160 mm were prepared in a stainless mould, which is subdivided into three sections. In each set, three bars were made. The samples were prepared from a gypsum binder with a mass of 1.0 kg. Gypsum was poured inside a beaker with water for 20 seconds. While it was poured and for 60 seconds after the whole amount of gypsum had been

poured, the mixture was intensively stirred with a manual stirrer until a uniform paste was obtained. Then, the paste was poured inside the mould so that all three sections would be simultaneously filled. To remove air into a gypsum paste, the mould was shook 5x after filling using a standard shake (the mould is lifted at its face side to a height of 10 mm and dropped). As soon as the paste started to set, its surface was cut off in the direction perpendicular to the bar surface. After 15 minutes, i.e. after the finish of setting, the mould was removed and the samples were marked and placed in the test room at an average temperature of 25 °C and a relative humidity of 50 %. The compressive strength was tested on six sample halves, obtained after the bending test. The samples were placed between two plates in such a way that the lateral edges, which adjoined the longitudinal mould walls during the sample preparation, would be situated on the plate planes. This restricted the effect of the geometry imperfections on the bar surface, which had been cut off. The test itself was made in compliance with the corresponding standard procedures.

The value of the F [kN], corresponding to the press loading area of 40×40 mm was read on the devices, and the compressive strength was calculated using the known relations. The resulting compressive strength value of one set (3 times 2 sample halves) was calculated as the mean of the results of the six tests with the elimination of the highest and the lowest values reached.

Bending strength was provided after CSN 72 2301. This test is not used for the classification of gypsum binders, but it is also described in the respective standard; it is usually an inseparable part of testing procedures aimed at the specification of basic mechanical characteristics. After its completion, the break-up of the test bars, the halves of the samples were used for the determination of compressive strength, as was described above. The test was performed on the WPM 50 kN device, with a scale of 0–10 kN. The sample was placed so that its edges, which were horizontal during its preparation, would be in a vertical position. The test involved three-point bending, with a distance of the supporting rollers of 100 mm. The value of the force F [kN] was read on the apparatus. The tensile bending strength was calculated using the standard evaluation procedure as the mean of three values.

Currently are possibilities for determination of mechanical properties using non-destructive methods, e.g.

## 4. Mechanical properties of gypsum

Tested samples were made from the gypsum grey G2 BII which is produced by company Gypstrend. This binder is calcined from two different dihydrates – naturally gypsum and gypsum from a chemistry industry, ratio is half to half. Used water-gypsum ratio was 0.71 and corresponded with normal consistence of gypsum paste after standard CSN 722301.

Quantity of water in gypsum depend on the choice the water- gypsum ratio. At figure 1 is possible see, as water from specimen die away. During the 14 day specimens lost about 100g of weight.

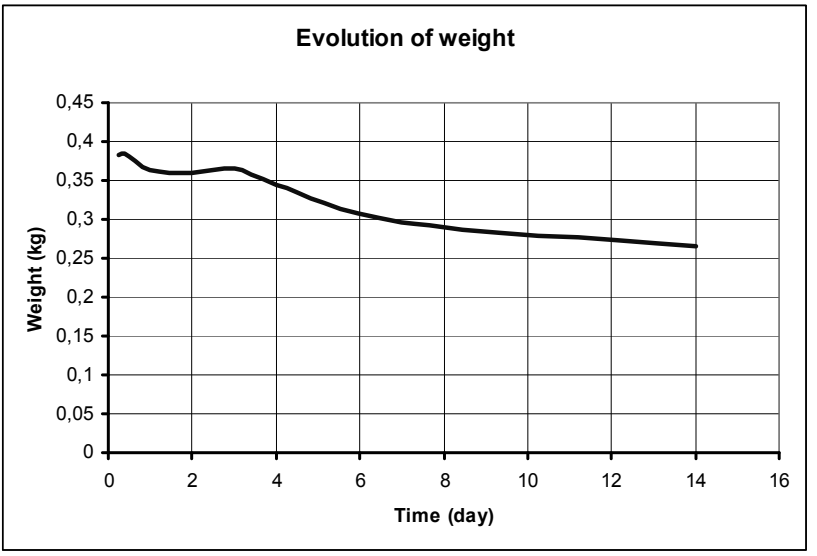


**Fig. 1.** Evolution of weight of the specimens.

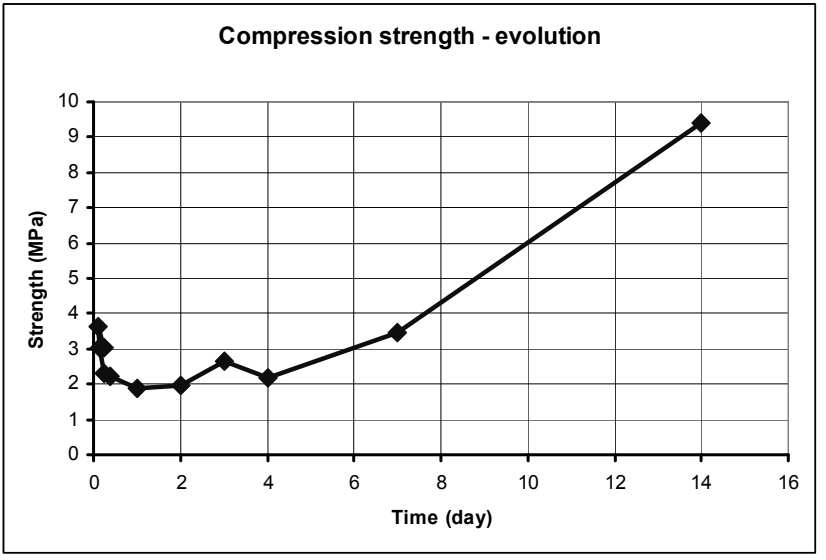


**Fig. 2.** Evolution of compression strength of gypsum.

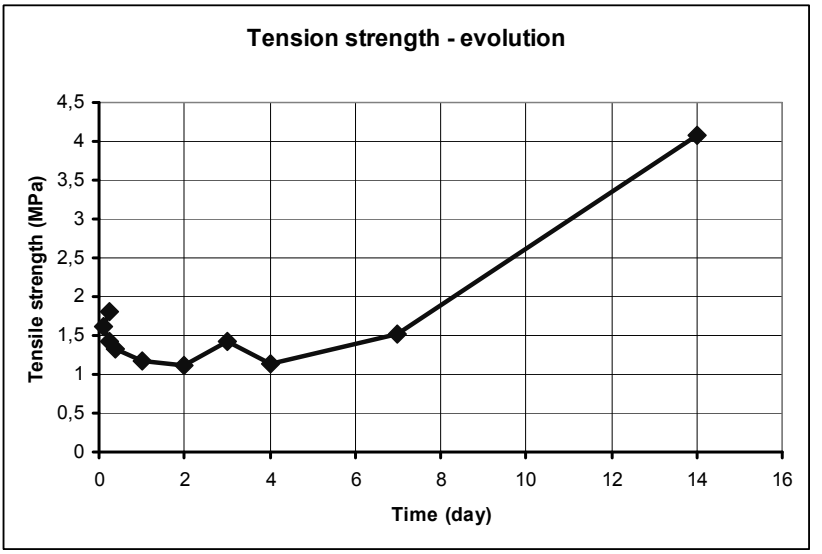


**Fig. 3.** Evolution of tensile strength of gypsum.

Compressive strength similarly like a tensile strength has evolution in the time characterized by decrease the value in first days. After few days (one week) strength start increase. 14$^{th}$ day value of the strength in compression is about 2.5MPa higher than strength at start (see Fig. 3).

## 5. Conclusion

From results is possible come to conclusion that gypsum strength in tension and compression is comparable. Tested specimens had only 2 times lesser strength in tension versus the compression strength.


## Acknowledgements

This work has been supported by MŠMT under No. MSM 6840770003.


## References


[1] ČSN 72 2301. *Gypsum binding materials*, Czech standard (in Czech), (Bureau for Normalization and Measurement, Prague, 1979), 17 p.

[2] Šatava V., "Strength and microstructure of cast gypsum," *Ceramics – Silikáty*, **40**(2), pp. 72-76 (1996). ISSN 0862-5468.

[3] Plachý T. and Polák M., "Fatigue damage identification on concrete structures using modal analysis," in *Proceeding of the 3rd WSEAS International conference on applied and theoretical mechanics [CD-ROM]*, Benra F.-K. et al., eds., Tenerife, December 2007 (World Scientific and Engineering Society Press, Athens, 2007), pp. 191-196. ISBN ISBN 978-960-6766-25-1.