Warsaw University of Technology

Faculty of Civil Engineering

Department of Building Materials Engineering

BUILDING MATERIALS

LABORATORY TASK

Non-hydraulic building binders: Gypsum binders

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1. Aim of the task

Introduction to the subject of the types of building gypsum binders and plasters, their properties and test methods. Performance of the test:

- water to gypsum ratio (w/g),
- beginning of the gypsum setting time,
- compressive strength of gypsum paste.

2. Theoretical background

2.1. Definitions according to standard PN-EN 13279-1:2009

- **gypsum binder** – binder consisting of calcium sulfate with varying degrees of hydration, e.g. hemihydrate ($CaSO_4 \cdot ½\ H_2O$) and anhydrite ($CaSO_4$)
- **gypsum plaster** – plaster consisting of at least 50% calcium sulfate as the main binding component and not more than 5% of lime (calcium hydroxide)
- **gypsum-based plaster** – gypsum plaster consisting of less than 50% calcium sulfate as the main binding component and not more than 5% lime (lime hydroxide)
- **light gypsum plaster** – gypsum plasters that contain inorganic lightweight aggregates, such as expanded perlite or vermiculite, or organic lightweight aggregates
- **gypsum plaster with increased surface hardness** – gypsum plaster with a special composition that meets the requirements for increased surface hardness

2.2. Introduction

The raw gypsum, material of natural origin for the production of gypsum binders is **calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$)**. Gypsum binders are also produced from industrial wastes containing calcium sulfate (so-called synthetic or chemical gypsum). The production of gypsum binders consists in dehydrating (by roasting) the comminuted raw material and gypsum milling. Depending on the temperature of the dehydrating process, different types of gypsum can be obtained – **hemihydrate gypsum ($CaSO4 \cdot ½\ H_2O$)**, anhydrites ($CaSO_4$) or Estrich gypsum ($CaSO_4$ + 5% CaO). The main component of all varieties of gypsum is calcium sulfate with varying degrees of hydration. Gypsum binder, which is the subject of the practical task is hemihydrate gypsum and is produced by dehydration of calcium sulfate dihydrate at a temperature of 150 ÷ 200°C, which occurs according to the reaction:

$$CaSO_4 \cdot 2H_2O \rightarrow CaSO_4 \cdot ½H_2O + ¾H_2O \uparrow$$

The process of binding of gypsum binders (in this case: hydration) consists in joining their solid particles into a coherent mass after mixing with water, resulting in the formation of calcium sulfate dihydrate – like a raw material for the production of gypsum binders. The setting time (time elapsing from making the gypsum with water until it loses plasticity) depends on:

- type and amount of contaminations,
- amount of mixing water,
- gypsum granulation,
- temperature at which the binding process takes place.

The advantages of gypsum binders include:

- white colour of hardened gypsum paste,
- it is ecological (water is a by-product of production),
- it is easy and cheap in production (low energy consumption),
- good density/strength ratio,
- good thermal insulation properties,
- ability to regulate indoor humidity,
- fine granulation (ease of forming and obtaining smooth surfaces)
- short setting time (an advantage when performing e.g. small repairs).

The disadvantages of gypsum binders include:

- short setting time (when performing on large areas),
- corrosive effect on metal elements,
- no resistance in case of contact with water.
- low impact resistance.
- dependence of strength on humidity.

According to the standard PN-EN 13279-1: 2009, gypsum binders should be classified as binders for direct use as well as for further processing, e.g. into various types of gypsum plaster and mortars or gypsum pre-cast elements (plasterboard, gypsum boards, etc.) – see table 1.

Table 1. Types of gypsum binders and gypsum plasters according to standard PN-EN 13279-1:2009

Purpose	Mark
Gypsum binders: • for direct use or for further processing (loose products) • for direct use on site • for further processing (e.g. into gypsum boards, gypsum elements for suspended ceilings, fiber reinforced gypsum boards)	**A** A1 A2 A3
Gypsum plasters: • gypsum plaster • gypsum based plaster • gypsum-lime plaster • light gypsum plaster light gypsum based plaster light gypsum-lime plaster • gypsum plaster with increased surface hardness	**B** B1 B2 B3 B4 B5 B6 B7
Gypsum plasters and mortars for special purposes: • gypsum mortar for products with the addition of fibers • gypsum mortar (to joint bricks or blocks) • acoustic gypsum plaster • gypsum plaster for thermal insulation • fireproof gypsum plaster • thin-layer gypsum plaster • finishing gypsum plaster	**C** C1 C2 C3 C4 C5 C6 C7

Tests of type A gypsum binders given in the standard PN-EN 13279-1:2008 include the analysis of:

- water/binder (water/gypsum) ratio,
- determination of start time of setting,
- hardness,
- flexural strength,
- compressive strength,
- adhesion to the substrate,
- sound insulation.

3. Practical task:

3.1. Water/gypsum binder ratio by backfilling method (procedure according to standard PN-EN 13279-2:2006)

3.1.1. Materials and equipment

- gypsum binder for direct use (of type A),
- tap water,
- glass container of diameter of 66 mm and height of 66 mm with marking made on the height of 16 and 32 mm,
- stopwatch,
- laboratory scale.

3.1.2. Task completion

The task goal is to determine the mass of gypsum binder in grams, which can be saturated with 100 g of water during backfilling. The determination starts by pouring 100 g of tap water into the glass container in such a way that it does not wet its upper part. The total mass of water together with the mass of container (m_o) is recorded with an accuracy of 0.5 g. A specimen of gypsum binder is taken into the bowl, and in the next step it is put into the water (until it covers the surface of the water) in such a way that after 30 seconds the gypsum level reaches the first marking of the glass container (16 mm) and after 60 seconds – the second marking (32 mm). Backfilling continues until the gypsum paste reaches a height of approximately 2 mm below the water level (after time of 90 ± 10 s). In the next 20 ÷ 40 seconds the binder put into container should cover the water surface. The binder must be saturated with water. Finally, the mass of the glass vessel with water and gypsum binder (m_1) is recorded with an accuracy of 0.5 g, and the water/gypsum binder ratio R (referred sometimes also as "w/g" ratio) is calculated according to the formula 3.1.

$$R = \frac{100}{m_1 - m_o} \tag{3.1}$$

where:
R – water/gypsum binder ratio [g/g],
m_o – total mass of water and container [g],
m_1 – total mass of gypsum saturated with water and container [g].

3.1.3. Results and evaluation

The standards PN-EN 13279-1:2008 and PN-EN 13279-2:2006 do not contain the requirements for the gypsum binder of the type A regarding the water/binder ratio.

3.1.4. Elaboration of results

The results should be presented in the form of a table (table 2).

Table 2. Example of the table presenting the results obtained during the test

Tested material: gypsum binder of type A			
Measurement	**I**	**II**	**III**
m_o **– mass of water and container [g]**			
m_1 **– mass of water, container and gypsum [g]**			
m_{av} **– average value of gypsum mass**			
water mass	**100 g**		
water/gypsum binder ratio, *R*			

3.2. Determination of start time of gypsum setting by cutting method (procedure according to standard PN-EN 13279-2:2006)

3.2.1. Materials and equipment

- gypsum binder for direct use (of type A),
- tap water,
- plastic bowl,
- stirrer,
- glass plate,
- metal knife,
- laboratory scale.

3.2.2. Task completion

The method of cutting with a knife can be used to examine gypsum binders and gypsum plasters. In order to perform the test, the specimen of 200 g of water and gypsum binder altogether should be prepared. The exact mass of water and gypsum binder should be determined on the basis of water/gypsum binder ratio test result. The binder is poured into the water in the bowl and the measurement of time is started. After thoroughly mixing the ingredients, the prepared paste is poured onto a glass plate in such a way as to form three circular specimens with dimensions of 100 ÷ 120 mm and a thickness of about 5 mm. Two of the formed circular specimens are cut with a knife at intervals indicated by the teacher (after each cut clean the knife!), And the third specimen is intended for a later control cut. The beginning of setting time is the time counted from pouring the gypsum binder into the water

until the moment when edges of the knife cut made into gypsum circular specimen do not merge.

3.2.3. Results and evaluation

The standards PN-EN 13279-1:2008 and PN-EN 13279-2:2006 do not contain the requirements for the gypsum binder of the type A regarding the start time of setting.

3.2.4. Elaboration of results

The results should be presented in the form of a table (table 3).

Table 3. Example of the table presenting the results obtained during the test

Tested material: gypsum binder of type A **Test procedure source:** PN-EN 13279-2:2006										
Measurement	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
Time [s]										
Cutting edges: **a – merging** **b – not merging**										
Measurement	**XI**	**XII**	**XIII**	**XIV**	**XV**	**XVI**	**XVII**	**XVIII**	**XIX**	**XX**
Time [s]										
Cutting edges: **a – merging** **b – not merging**										
Conclusion: According to method given in standard PN-EN 13279-2:2006 the start time of gypsum binder setting is … [s]										

If the subsequent students teams receive different water/gypsum binder ratio values, an analysis of the influence of the ratio value on the start setting time of the gypsum binder should be carried out. A graph should be prepared showing the dependence of the start time on the value of water/gypsum binder R ratio (see Fig. 1).

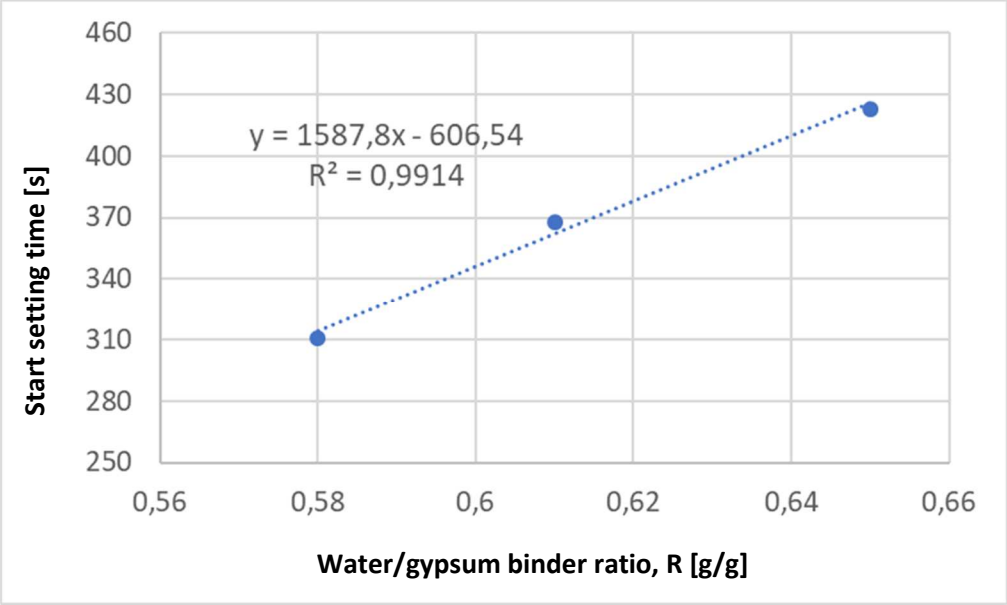

Fig. 1. Example graph* presenting relation between the start setting time of gypsum paste and water/gypsum binder ratio of the paste

*) above is an example scatter chart with a trend line prepared in an MS Excel spreadsheet, however students can use other software to prepare the graph)

3.3. Preparation of specimens of gypsum binder of type A for strength testing (procedure according to standard PN-EN 13279-2:2006)

3.3.1. Materials and equipment

- gypsum binder for direct use (of type A),
- tap water,
- plastic bowl,
- stirrer,
- molds – set of 3 beams of dimensions of 40 x 40 x 160 mm

3.3.2. Task completion

The specimens for testing flexural strength and compressive strength have dimensions of 40 x 40 x 160 mm and are prepared from a mixture of gypsum binder and water. The proportions of water and binder are determined on the basis of the determined water/gypsum binder coefficient. To make the specimens, prepare the correct mass of type A gypsum binder (indicated by the teacher) and proper amount of tap water into a dry bowl. Fill the mold thoroughly with the gypsum paste and remove air bubbles by lowering each edge of the mold 5 times from a height of 10 mm. Scoop out excess paste with a straight blade like sawing motions. Prepared beams (at least three), are stored for 7 days in laboratory conditions (at 23

± 2°C, relative humidity 50 ± 5%), and then dried to constant weight at 40 ± 2°C and cooled to room temperature.

Properly prepared and cured beams are first subjected to a bending strength test by applying a centrally acting bending force to the bar supported on two supports (so-called simply supported beam with a concentrated load at mid-span). The supports are spaced apart and 100 mm apart. The flexural strength (R_g) in MPa is calculated from the formula (3.2).

$$R_g = \frac{M}{W} = \frac{PL}{2W} \quad \left[\frac{\mathrm{N}}{\mathrm{mm}^2} = \mathrm{MPa}\right] \tag{3.2}$$

where:
M – bending moment [N·mm],
W – elastic section modulus, a geometric property for a given cross-section which depends on the dimensions of the cross-section of the specimen (for a square cross-section it is $W = b^3/6$),
P – bending force [N],
L – vector distance at which the bending force applies (half of the distance between the supports) [mm].

Compressive strength is tested on halves of broken beams by applying compressive force to them, using steel plates with dimensions of 40 x 40 mm (area 1600 mm^2). The tested specimens are compressed for destruction, and the compressive strength (R_c) in MPa is calculated by the formula (3.3).

$$R_c = \frac{F_c}{1600} \quad \left[\frac{\mathrm{N}}{\mathrm{mm}^2} = \mathrm{MPa}\right] \tag{3.3}$$

where:
R_c – compressive strength [N/mm^2 or MPa],
F_c – destructive force [N],
1600 – compressed area in mm^2 (metal plate area).

3.3.3. Results and evaluation

The standards PN-EN 13279-1:2008 and PN-EN 13279-2:2006 do not contain the requirements for the gypsum binder of the type A regarding the flexural strength and compressive strength. However on should compare the results of the particular test and make the basic statistical analysis. Also important is the relations between the values of average values of flexural strength and compressive strength of the tested gypsum paste.

3.3.4. Elaboration of results

The results should be presented in the form of a table (table 4).

Table 4. Example of the table presenting the results obtained during the tests

Tested material: gypsum binder of type A **Test procedure source:** PN-EN 13279-2:2006							
Test result							
Flexural strength				**Compressive strength**			
No	***P* [N]**	***P*$_{av}$ [N]**	***R*$_g$ [Mpa]**	**No**	***F*$_c$ [N]**	***F*$_{c\,av}$ [N]**	***R*$_c$ [MPa]**
1				**1A**			
				1B			
2				**2A**			
				2B			
3				**3A**			
				3B			

4. Laboratory report

The laboratory report should include:

I. Subject, aim and scope of research (containing basic information about tested materials/products, test methods, requirements)

II. Tests results with proper units (results obtained in the laboratory prepared in the indicated manner, e.g. put in the proper tables)

III. Conclusions (bulleted statements formulated based on the results obtained)

IV. Bibliography (list of references to the literature or www used to prepare the report)