Pergamon

Cement and Concrete Research 32 (2002) 1725–1728

CEMENT AND CONCRETE RESEARCH

The optimization of a gypsum-based composite material

M. Arikan[a], K. Sobolev[b,*]

[a]Civil Engineering Department, Middle East Technical University, Ankara, Turkey
[b]Civil Engineering Department, European University of Lefke, Gemikonagi Lefke via Mersin 10, KKTC, Turkey

Received 15 May 2001; accepted 6 May 2002

Abstract

Contemporary requirements for gypsum-based composite materials (GBCM) for rendering or plastering include controlled setting time, good workability, sag resistance, high compressive and flexural strength, perfect bond to concrete or brick, water resistance, and improved heat and noise insulation. The application of a number of chemical admixtures and mineral additives was found to be necessary to provide the required performance for gypsum-based materials. Among the necessary chemical admixtures are the following: a retarding admixture, a water-soluble polymer (MC), an air-entraining admixture (AE), and a superplasticizer (SP). This paper describes the effect of the different admixtures on the consistency, setting time, and the compressive strength of GBCM. It also discusses the application of the stepwise optimization (SWO) method for the evaluation of the GBCM composition.

Keywords: Gypsum; Composite; Admixture; Polymer; Compressive strength

1. Introduction

In the past few decades, gypsum-based renders and plasters have become the material of choice for indoor finishing in many countries. Excellent performance, attractive appearance, easy application, and its healthful contribution to living conditions have made gypsum a most popular finishing material for centuries [1–3]. This building material is abundant in Turkey and has high purity. The natural gypsum rock reserves of Turkey are estimated to be about 1.2 billion tons. Availability, the relatively low level of start-up investments, and a favorable market situation, all provide conditions for growth and the profitable industrial production of gypsum-based materials in Turkey [4].

The majority of gypsum-based composite materials (GBCM) can be specified within the following groups [5]:

- plasters and renders,
- adhesives,
- jointing/filling compounds.

Multicomponent mixtures of modern GBCM are produced as dry, premixed mortars in highly automated plants with precisely controlled dosing and batch processing. Since additives must be used in exact doses, precise control is the key to the manufacture of GBCM to the required standards of performance [5,6].

The most important component of GBCM is a water-soluble polymer, which is usually based on cellulose ethers: methyl cellulose (MC) or modified methyl cellulose (MMC). MC provides high water retention, improved consistency, as well as adhesion and plasticization of gypsum systems. A retarding admixture is required to control the setting process and provides GBCM application within the required time limits (about 1–3 h as described in Refs. [7,8]). The application of an air-entraining admixture is important for the stabilization of mechanically entrained air voids and so improving workability and smoothness of finishing surface. It also increases the plaster yield and improves heat and sound insulation properties. A plasticizer or superplasticizer (SP) is an important component of advanced GBCM, which gives control over the workability at a low water-to-gypsum ratio (W/G).

The relatively large number of components used in GBCM requires the development of a special approach to optimizing the composition. A stepwise optimization (SWO)

* Corresponding author. Tel.: +90-392-660-2066; fax: +90-392-727-7528.
E-mail address: sobolev@consultant.com (K. Sobolev).

0008-8846/02/$ – see front matter © 2002 Published by Elsevier Science Ltd.
PII: S0008-8846(02)00858-X

Table 1
Specification of chemical admixtures

Admixture type	Designation	Brand name	Main component	Dosage range [5] (% by weight)
Retarding admixture	R	–	Citric Acid	0.05 – 0.2
Water-soluble polymer	MC	Tylose	Modified Methyl Cellulose	0.05 – 1.5
Air-entraining admixture	AE	Hostapur	Olefine Sulfonate Sodium Salt	0.005 – 0.08
Superplasticizer	SP	Melment	Melamine Formaldegide Sulfonate	0.1 – 1.0

method was found to be effective in the investigation of multicomponent cements and in determining the optimal dosage for chemical admixtures [9]. Therefore, it could be effective in a GBCM optimization process.

2. Experimental program

2.1. Materials used

Four different commercially available chemical admixtures were used: a retarding admixture (R), a water-soluble polymer (MC), an air-entraining admixture (AE), and a superplasticizer (SP). The type and the dosage range of the admixtures are presented in Table 1.

Table 2 summarizes the properties of the hemi-hydrate gypsum (known in a local market as ABS gypsum), used as the main component of GBCM (according to methods described in Refs. [8,10]). The particle size distribution of the ABS gypsum is presented in Fig. 1.

2.2. Mixture proportioning

The properties of about 15 different gypsum compounds were investigated. An SWO method [9] was used to obtain gypsum mixtures with strength values and a setting time meeting the requirements of the Turkish Standard TS 370 "Gypsum Building Plasters" [8].

According to the SWO method, each step involved the addition of a new admixture and optimization of its dosage. This optimal admixture's dosage was used as the starting point for the next step. The test results and mixture proportioning of investigated GBCM are presented in Table 3. Chemical admixtures were applied in a dosage range of 0.01 – 0.2% (by weight) above 100% of gypsum. The water-to-gypsum ratio (W/G) was 0.45 to satisfy consistency requirements (at a flow of 140 – 160 mm [8]).

Table 2
Gypsum properties

Type	Water content (%)	Compressive strength (MPa)	Density (kg/dm^3)	SO_3 content (%)
ABS	2.5	11.3	2.597	72.4

2.3. Preparation of specimens

Using a laboratory mixer, dry, premixed samples of GBCM were produced by the precise mixing of certain amounts of gypsum and chemical admixtures as required by the test program (Table 3). The preparation of gypsum compounds was conducted by mixing the required amounts of water and dry, premixed GBCM. Prepared compounds were cast into 50 × 50 × 50 mm cube molds following the TS 370 procedure [8].

2.4. Curing of specimens

After the compaction procedure, the molds were placed in a humidity cabinet for 24 h at a relative humidity of 95% and a temperature of 20 °C. Later the specimens were removed from the molds and kept in an oven at 100 ± 5 °C until the constant weight was obtained.

2.5. Tests performed

The setting time of GBCM was determined using a Vicat apparatus in accordance with the TS 370 procedure [8].

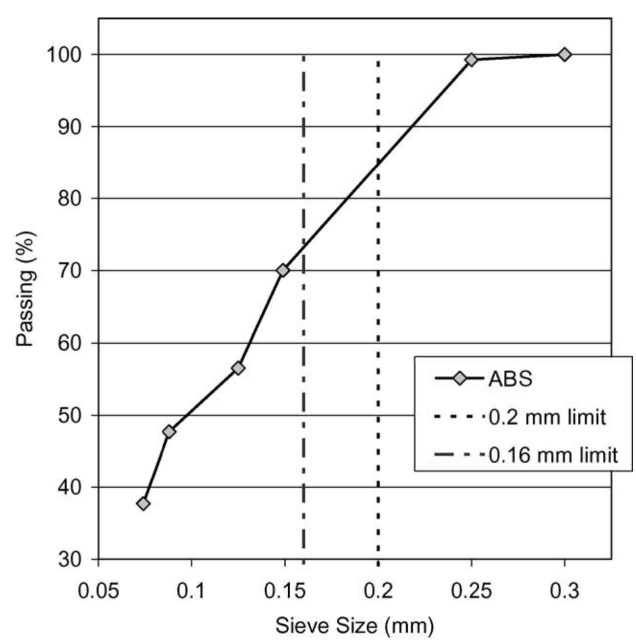

Fig. 1. The particle size distribution of gypsum.

Table 3
Composition of mixtures and test results

No.	Admixture dosage (%)				W/G	Consistency (mm)	Setting time (h:min)	Compressive strength (MPa)	Density (kg/dm^3)	
	Retarder	MC	AE	SP					20 °C	100 °C
1	0.05	–	–	–	0.45	160	1:00	11.3	1.86	1.28
2	0.10	–	–	–	0.45	155	1:30	9.7	1.89	1.29
3	0.15	–	–	–	0.45	150	2:40	8.2	1.92	1.29
4	0.10	0.10	–	–	0.45	130	2:30	7.4	1.80	1.20
5	0.05	0.05	–	–	0.45	145	1:15	13.6	1.76	1.30
6	0.05	0.10	–	–	0.45	140	1:25	12.8	1.76	1.26
7	0.05	0.20	–	–	0.45	130	1:35	14.7	1.69	1.26
8	0.05	0.05	0.013	–	0.45	145	1:35	7.2	1.68	1.19
9	0.05	0.05	0.025	–	0.45	145	1:45	5.5	1.55	1.11
10	0.05	0.05	0.033	–	0.45	145	1:55	5.7	1.55	1.12
11	0.05	0.15	0.033	–	0.45	140	2:10	4.8	1.40	1.01
12	0.05	0.05	0.013	0.025	0.45	155	1:55	5.7	1.65	1.18
13	0.05	0.05	0.013	0.050	0.45	160	1:55	5.0	1.62	1.16
14	0.05	0.05	0.013	0.150	0.45	170	1:55	6.5	1.64	1.18

Consistency was determined using a flow table as described in TS 370 [8]. Compressive strength tests were performed using 50 × 50 × 50 mm cube specimens dried to a constant weight. The reported results are the average of the three compressive strength values.

These quantitative measurements were followed by a trial application. Plaster was placed on to the surface of a clay brick wall to obtain additional visual information about smoothness of the layer, sag resistance, adhesion to surface, color, etc.

3. Test results and discussion

The effect of chemical admixtures on properties of GBCM is summarized in Table 3.

3.1. Effect of retarding admixture

According to the test results, the increase in the retarding (R) admixture dosage from 0.05% to 0.15% allows the extending of the setting time from 1 to 22/3 hours. Further, it results in a slight loss of workability and also a reduction in the compressive strength from 11.3 to 8.2 MPa (Table 3). For the next optimization step, R admixture dosage was set at 0.05%.

3.2. Effect of water-soluble polymer

It was found that by increasing the water-soluble polymer (MC) dosage to 0.2% the improvement of compressive strength from 11.3 to 14.7 MPa was obtained (at fixed 0.05% dosage of retarding admixture). Some reduction of flow, as well as increase in setting time, was observed in this case (Table 3). Based on the obtained results, MC dosage was fixed at 0.05% for subsequent tests.

3.3. Effect of AE

The increase of the AE dosage up to 0.033% resulted in excessive air entrainment (up to an additional 12% when compared with a non-AE plaster). It was found that AE delays the setting time and has no effect on flow.

The observed decrease in density imparted by entrained air bubbles was followed by a sharp strength loss, to 5.7 MPa (Table 3). Taking into consideration the importance of entrained air for the performance of plaster and as a result of this step, the AE dosage was fixed at 0.013%, which provided up to 4.5% additional air in the mixture.

3.4. Effect of SP

An SP at a dosage of up to 0.15% provided a significant increase in flow value (Table 3). At the same time, the use of SP resulted in some increase in setting time and some loss of strength, as low as 6.5 MPa compared with 7.2 MPa (strength without SP). Based on these results, the SP dosage was set in the range of 0.025–0.1%.

4. Conclusions

(1) According to the test results, the consistency of the GBCM is significantly reduced by increasing the dosage of water-soluble polymer. The retarding agent slightly reduces the consistency of the gypsum system. The AE demonstrated no effect on flow. The SP significantly increases consistency.

(2) It was found that within the investigated range, the water-soluble polymer, the AE, and the SP all slightly increase the setting time of the gypsum system. The application of a retarding admixture allows the complete control of a setting time of 1 to 3 hours.

(3) At a constant W/G ratio, the compressive strength is reduced when a retarding admixture is used; even more strength loss was observed in the case of the application of the AE. While the SP has little effect on the strength of the gypsum system, a water-soluble polymer improves it.

(4) The application of the SWO method provided a design of GBCM mixtures with the required performance. The research results demonstrated that GBCM with the optimal dosage of admixtures [the retarding agent 0.05%, the water-soluble polymer (MC) 0.05%, the AE 0.013%, and the SP 0.025%] provides the necessary properties in respect to consistency (> 150 mm), setting time (>1½ h) and compressive strength (>5 MPa).

(5) Further improvement of GBCM properties can be expected if mineral additives, fillers, and aggregates are used in GBCM composition. The application of other forms or types of gypsum (including waste gypsum) may provide additional benefits to the obtained GBCM. It was found that the tests set by TS 370 may not be sufficient for the specification of GBCM mixtures, especially when bond strength is important. The development and specification of GBCM bond strength test may be suggested for inclusion in a new revision of TS 370.

References

[1] H.-J. Arpe, Ullmann's Encyclopedia of Industrial Chemistry, Calcium Sulfate, vol. A4, Wiley-VCH, Verlag, Germany, 1984, pp. 555–584.
[2] S.K. Duggal, Building Materials, A.A. Balkema Publishers, Rotterdam, 1998, pp. 368–373.
[3] L.A. Ragsdale, E.A. Raynham, Building Materials Technology, Edward Arnold, London, 1972, pp. 243–248.
[4] M. Topkaya, F. Karayazici, I. Oral, S. Sezen, Chemical Investigation on Gypsum Rock and Anhydrite, Kimya 23 (2), Istanbul, 1980, pp. 11–19 and 68–81.
[5] Modern and Efficient Building with Tylose and Auxiliaries, Clariant, Frankfurt-am-Main, 1998, pp. 6–18.
[6] V.S. Ramachandran, Concrete Admixtures Handbook, Noyes Publications, New Jersey, 1995, pp. 1025–1070.
[7] ASTM C 28 standard specification for gypsum plasters, Annual Book of ASTM Standards, vol. 04.01, ASTM, Easton,1993, pp. 37–38.
[8] TS370—Gypsum Building Plasters, TSE, Ankara, 1989.
[9] K.G. Sobolev, High-Strength Concrete with Low Cement Factor, PhD Dissertation, Chemical Admixtures Lab, Research Institute of Concrete and Reinforced Concrete, NIIZhB, Moscow, 1993, pp. 72–171.
[10] ASTM C 22 standard specification for gypsum, Annual Book of ASTM Standards, vol. 04.01, ASTM, Easton,1993, pp. 7–8.