EVALUATION OF INDIGENOUS PLASTER OF PARIS AND THE EFFECT OF ACCELERATORS AND RETARDERS ON ITS PHYSICAL PROPERTIES

MOHAMMAD ASLAM, *Paints and Plastics Research Division*

AND

S. TEHZIBUL HASAN, *Building Materials Research Division*

Central Laboratories, Pakistan Council of Scientific and Industrial Research, Karachi

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The quality of indigenous Plaster of Paris has been evaluated by determination of the quality factor, q, introduced by Schiller. The influence of retarders and accelerators on the setting time and the physical properties has been studied. From the results it is shown that the quality of local plaster is inferior and needs improvements. The study of retarders and accelerators has brought out the interesting observation that the physical properties of the retarded plaster appears to depend only on the setting time of the plaster and is independent of the retarder used.

Introduction

Plaster of Paris is one of the oldest building materials in the world, and its structural uses were known to the ancients, who used crudely made plaster as mortar and as a base for painting. Today it is used for wall plasters, structural gypsum products and plaster boards. Retarders and accelerators are used to control the natural set of plaster of Paris to suit the different applications, particularly in respect of handling and moulding of the plaster mix. Although gypsum is abundantly and extensively available in Pakistan, yet its use is so far mostly confined to fertilizer and portland cement industries. It should therefore be possible to extend its use to meet the growing need for better houses at comparatively low costs. The process of converting gypsum into plaster of Paris is simple, but the quality of the product depends on several factors like its origin, purity, manufacturing method and processing conditions. There is thus a need for systematic investigations on this aspect of the subject, before gypsum could be effectively utilised in the building industry. The present paper deals with the examination and evaluation of locally manufactured plaster of Paris and the study is divided into three parts: (i) control of setting properties of the plaster, (ii) evaluation of the quality of the plaster, and (iii) influence of accelerators and retarders on the physical properties of the plaster.

Raw Materials

Plaster of Paris used in the present investigation was specially prepared in an imported kettle-type of plant in one batch to ensure uniformity of the material to be studied. The sieve analysis of the plaster is given in Table 1.

TABLE 1.—SIEVE ANALYSIS OF INDIGENOUS PLASTER OF PARIS.

Sieve Numbers	Percentage retained	Percentage finer than
50	0.00	100.0
100	3.55	96.45
200	78.00	18.45

The quality of other materials used is specified below:—

1. Keratin solution: A 10% solution was prepared in the laboratory by digestion of animal hair with dilute alkali, the pH of the final solution being adjusted at 8-9.
2. Glue solution: A 25% solution was prepared by soaking glue in water overnight.

Control of Setting Properties of the Plaster

Data on the effect of (i) retarders, (ii) accelerators and (iii) water/plaster ratio, on the setting time of the plaster is presented in Table 2. Since the setting time of the commercial plaster was very short, it was retarded with 0.03% keratin solution for study of the accelerators. The setting time as reported is thus arbitrary, but has been determined with the help of a Vicat needle as used for determining the setting times in portland cement. The initial setting time is noted when the mass has set and starts emitting heat and the final setting time is taken when the set mass is hard and the needle does not leave any mark due to its own weight on the surface. The additives were dissolved in the water used for preparing the plaster mix.

Evaluation of the Quality of Plaster

The strength of the set plaster depends on its porosity and water/plaster ratio. In the case of neat plaster, the porosity is determined almost entirely by the quantity of water in the mix which is in excess of that required for hydrating the hemihydrate which sets in accordance with the equation:

$$CaSO_4,\ \tfrac{1}{2}H_2O + 3/2\ H_2O \rightleftharpoons CaSO_4,\ 2H_2O.$$

TABLE 2.—INFLUENCE OF RETARDERS, ACCELERATORS AND WATER/PLASTER RATIO ON SETTING OF THE PLASTER.

Reference No.	Water/ plaster ratio	Additive % by weight of plaster	Initial setting time (minutes)	Final setting time (minutes)
1.	0.3	Nil	1.5	2.0
	0.4	,,	3.0	4.0
	0.5	,,	3.5	4.5
	0.6	,,	4.0	5.0
	0.7	,,	5.5	8.0
2. Keratin solution	0.3	0.3	6.5	8.0
	0.4	0.3	14.0	16.0
	0.4	0.2	9.5	11.0
	0.4	0.1	7.0	8.0
	0.5	0.3	16.0	18.0
	0.5	0.5	175.0	—
	0.6	0.3	19.0	24.0
	0.6	0.2	11.0	15.0
	0.6	0.1	8.0	10.0
	0.7	0.3	21.0	32.0
3. Glue solution	0.5	0.1	6.0	8.0
	0.5	0.2	9.0	12.0
	0.5	0.3	14.0	20.0
	0.5	0.5	26.0	35.0
	0.5	1.0	60.0	90.0
4. Borax	0.5	0.25	10.0	12.0
	0.5	0.50	16.0	22.0
	0.5	1.00	150.0	—
5. Sodium sulphate	0.5	0.25	11	13
	0.5	0.50	8	10
	0.5	1.00	4.5	6.0
6. Magnesium sulphate	0.5	0.25	16	20
	0.5	0.50	13	16
	0.5	1.00	12	14
7. Sodium chloride	0.5	0.25	16	18
	0.5	0.50	10	12
	0.5	1.00	6	8
8. Sodium carbonate	0.5	0.5	16	19
	0.5	1.0	12	17
9. Alum	0.5	0.25	14	17
	0.5	0.50	14	16

The amount of water required for hydration is calculated to be 18.6% of the dry weight of the plaster. The excess water which has to be added for getting proper working consistency dries out and leaves behind interconnecting pores in the set mass. The mathematical relationship between porosity (p) and water/plaster ratio has been found, by calculation to be,

$$p = \frac{W - 0.15}{W + 0.36}.$$

Schiller[1] has introduced a quality factor, q, which characterises the strength of the set plaster without reference to the amount of the water used and derived the following equation:

$$S = q \log \frac{p_{cr}}{p}$$

where S is the strength, p_{cr} is the critical porosity at which strength becomes negligible. According to Schiller, if compressive, flexural or tensile strength is plotted against logarithm of porosity, straight lines must be obtained, which, since the plaster must lose all three types of strength for the same critical porosity, must intersect at the same point.

Compressive strength of the set plaster was measured on one inch cubes and flexural strength on 7×1 cm. bars at a span of 3.92 cm., the specimens being tested after 8 days of casting. For each mix prepared for this test, the correct

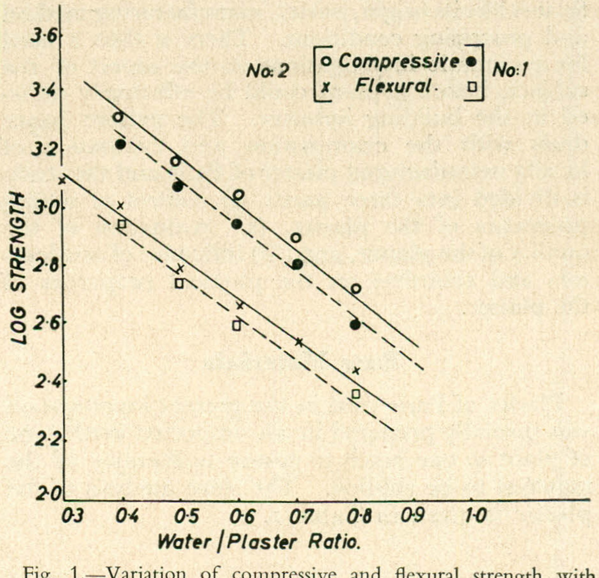

Fig. 1.—Variation of compressive and flexural strength with water/plaster ratio for commercial and retarded plaster.

amount of plaster was added to the calculated quantity of water and the mixture was then stirred by hand until it was smooth and free from lumps, when it was poured into the moulds. These measurements have been carried out on commercial plaster as such and after retarding with 0.3% keratin solution. The relationship between water/plaster ratio and logarithm of strength as shown in Fig. 1 is linear. Even though it is clear from this graph that retarded plaster is better than the unretarded type, it is not easy to evaluate the difference quantitatively.

In Fig. 2(a) strength has therefore been plotted against logarithm of porosity and, as postulated by Schiller, the lines for compressive and flexural strength meet at the same point, the critical porosity. The quality factor 'q' has been calculated using equation (2) and found to be 5600 (compressive) and 2750 (flexural) for normal and 6,700 (compressive) and 2900 (flexural) for retarded plaster. These values are very much lower than the reported 10000-11000 (compressive) for pan and 14000-16000 for autoclaved plaster. The results of Russell and Blakey[2] have also been plotted in Fig. 2(b) and the quality q found to be 11000 (compressive) and 2750 (tensile). In order to make sure that the differences in q values are not due to methods of testing, an imported quality of the plaster of Paris was evaluated. The results are shown in Fig. 2(c), q values being 9,300 (compressive) and 3,300 (flexural). The critical porosity has been found to be 0.66 for normal and 0.676 for retarded plaster. Comparative values reported in literature are 0.56-0.79 for pan type and 0.88 for autoclaved plasters.

It was found that there was 4-6% increase in strength from 8 to 28 days, and hardly any change thereafter. The plaster of Paris was ground to pass 200 mesh in order to study the effect of particle size on the quality, and the results did not show any significant change in the properties of the plaster.

Influence of Retarders and Accelerators on the Physical Properties of the Plaster

Water/plaster ratio was fixed at 0.5 and the influence of retarders and accelerators in different proportions on the compressive and flexural strength was determined. For study with accelerators 0.3% of keratin solution was added to retard the setting time of plaster mix. The data is presented in Table 3. It appears that with retarded plasters, the physical properties are a function of setting time and are independent of the nature of the retarder used. Figure 3 shows

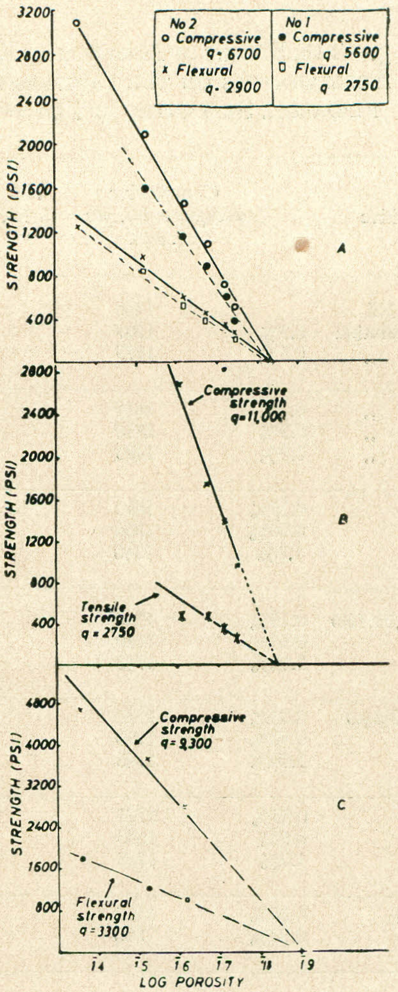

Fig. 2.—Relationship between strength and porosity of (a) commercial and retarded plasters (b) Australian plaster as reported in literature (c) imported plaster.

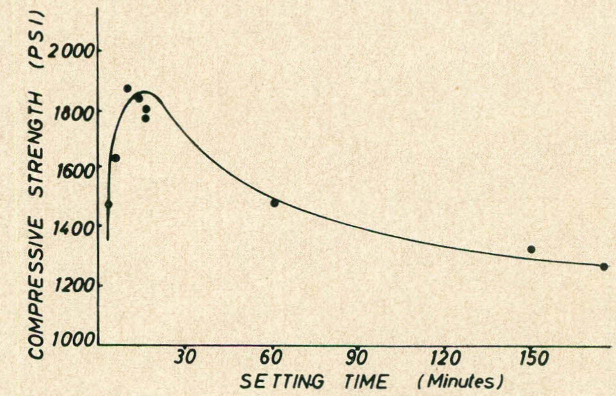

Fig. 3.—Relationship between compressive strength and setting time.

TABLE 3.—THE EFFECT OF ADDITION OF RETARDERS AND ACCELERATORS ON THE COMPRESSIVE AND FLEXURAL STRENGTHS OF PLASTER.

Additive		Compressive strength in lbs. per sq. inch	Flexural strength in lbs. per sq. inch
Nil		1480	685
Keratin solution	0.3%	1787	765
,, ,,	0.5%	1275	525
Glue ,,	0.1%	1650	725
,, ,,	0.3%	1850	750
,, ,,	1.0%	1480	560
Borax	0.25%	1890	810
,,	0.50%	1800	890
,,	1.0%	1340	640
$Na_2SO_4,10H_2O$	0.25%	1756	736
	0.50%	1730	725
	1.00%	1743	716
$MgSO_4,7H_2O$	0.25%	1780	755
	0.50%	1793	745
	1.00%	1745	737
NaCl	0.25%	1721	710
	0.5%	1635	610
	1.0%	1285	550
Na_2CO_3	0.25%	1575	680
	0.50%	890	475

the relationship between compressive strength and the setting time of the plaster. On the other hand, the accelerators have their own specific effect on the physical properties of the plaster and it is observed that, of all the accelerators studied, sodium sulphate gives the best results.

Conclusion

The quality of the indigenous plaster of Paris is inferior and needs improvement. It would be necessary to examine the various deposits of gypsum in the country and study the conditions under which they would give plaster of Paris of desired quality.

The study of retarders and accelerators has brought out the interesting observation that the physical properties of the retarded plaster appear to depend only on the setting time of the plaster and are independent of the retarder used. Highest values for compressive and flexural strength are obtained, when the setting time of the plaster is 12-14 minutes. The effect of accelerators depends on the material used and of all the accelerators studied, sodium sulphate has been found to give the best results.

References

1. K. K. Schiller, Brit. J. Appl. Physics., **11**, 338-42 (1960).

2. J. J. Russell and F. A. Blakey, Aust. J. Appl. Sci., **7**, 176 (1956).