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GYPSUM PLASTER AS MATERIAL OF CONSTRUCTION

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The shortage of portland cement can be partially substituted by gypsum plaster in Pakistan. A historical perspective of use of plaster in European countries is reported in this paper. The details of researches conducted recently at Peshawar Laboratories are given. The cheap additives like calcined magnesite, dolomite, limestone and gypsum improve the strength and hardness of ordinary gypsum plaster. An organic retarder is used to control the setting time.

INTRODUCTION

Gypsum plaster is one of the oldest building materials in the world. In ancient Egypt a badly made gypsum plaster was used, which the very dry climate afforded a reasonable permanence out of doors. It was also used as plaster, in the interior of Pyramids, to provide a surface on which painting work could be done. For this purpose its chemical neutrality (being alkali free) made it ideal so that some of the paintings in the Pyramids are still in good condition after thousands of years.

In Spain the Arabs used gypsum plaster for the interior decoration of Alhamra Palace. In France gypsum quarries worked by Romans have been preserved as monuments. Evidence is available that gypsum plaster was used in the construction of Shah Jehan Mosque and in some other Moghual monuments.

Pakistan is endowed with vast resources of gypsum comparable in quality to the best in the world. Unfortunately it has not found its way in the building industry. Only a small fraction is mined for use in cement manufacture and as moulding plaster.

Production of Plaster. Gypsum rock is calcium sulphate dihydrate. For making plaster the rock is pulverized to about 50 mesh and heated in kettle or rotary furnace upto 160°. At this temperature the dihydrate losses 1.5 molecules of water or roughly 14% of its weight. The product is ground to about-100 mesh to obtain hemihydrate or plaster of paris.

The plaster, thus obtained, has an average initial setting time of 10 minutes and final setting occurs at about 18 minutes of gauging. After the final setting the plaster becomes hard to work. This interval of about 8 to 10 minutes is too short for a mason to apply it to the wall and finish it smoothly.

To overcome the above difficulty certain additives have been used to delay the setting time of plasters. Inorganic salt like sodium sulphate, sodium chloride, calcium chloride, potassium sulphate, borax, potassium citrate, etc. delay the setting of plaster. Usually keratin derivatives from hoofs and horns are employed as excellent retarders and are sold under trade names.

Retarders wheather of inorganic or organic nature, only delay the setting time, the plaster is gauged with water (about 70%) and is in the form of a thin slurry which cannot be applied to the wall. To improve the consistency and make maximum use of the interval between gauging and hardening, thickening agents are added.

In the past the major plaster-using countries had by evolution developed and used different materials as additives, according to their availability and performance. In Britain and Germany lime putty is used as thickening agent. The addition of lime improves cohesion and increases the working time, it gives a smooth white surface which on ageing (carbonation) improves hardness. But the presence of lime (alkali) is not ideal for painting.

Amongst the developed countries France uses the largest tonnage of gypsum in the building industry. There are nearly 300 active quarries and some 50 industrial units making different kinds of plaster, production of each unit ranging from 250 tons to 1000 tons per day. Till 1960 for every 100 tons of cement 16 to 20 tons of gypsum as plaster was used, mostly for interior plastering, partition walls, roof-panels sound and heat insulation boards, and for fire proofing of structures.

In the early 20th century researchers like Fritsch, Leduc and Maurice Pellet proved that gypsum heated at 450-500° does not completely lose the property of setting,

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rather it slowly hydrates and the end product has higher compressive strength as it requires small quantity of water for guaging. This fraction when mixed with hemi-hydrate plaster upto 25-30% makes the plaster of construction used in France. It gives an average working time of about 35 minutes as against 8-10 minutes of pure hemi-hydrate plaster.

As compared with the British and German practice where lime is used, the addition of calcined gypsum in French plaster has distinct advantages which are as follows:

a) It is alkali free and gives a smooth surface for painting.
b) It is cheaper to make as burning of lime at 950° is costlier than that of gypsum at 450°.
c) During application, calcined gypsum initially plays the role of thickening agent, the product requires less water for guaging, but ultimately the whole mass sets slowely to give a hard surface.
d) Main disadvantage of British and German practices is the difficulty of mixing lime putty. The quicklime has to be submerged in water for 1-3 days prior to use.

EXPERIMENTAL

Keeping in view the different practices and application of plaster, the work was undertaken to develop a process on appropriate technology level suitable to the local conditions. Gypsum hemi-hydrate plaster was made in the Laboratory oven to study all the parameters.

Any additive for gypsum plaster should meet the following requirement:

a. It should be locally available at cheap rates.
b. Any processing required before adding should be simple and economical.
c. It should be white in colour.
d. It should improve the physical properties of plaster and must not have any deleterious effect.

In view of the above the following processed minearls/ organic materials were studied.

1. Hydrated lime.
2. Calcined dolomite.
3. Calcined magnesite.
4. Calcined gypsum.
5. Organic retarders and thickening agents.

RESULT AND DISCUSSION

Effect of Additives on Setting Time and Compressive Strength:

A. Mineral Additives. Table 1 shows that the above mineral additives have positive effect on setting time, i.e., they all extend the setting period, but most prominent effect is with magnesite. The addition of magnesite also improves the workability and brightness of the surface. With 20-30% addition of calcined magnesite a milk-white bright and smooth surface is obtained. It can be used in the preparation of super white plasters. However hydrated lime being cheaper is normally used in UK., Germany and USA.

The strength of gypsum plaster (Table 2) gradually falls with the increased quantity of these additives. The fall in strength is prominent in the case of lime and calcined dolomite. However, the long term strength does record some increase due to carbonation. There is significant increase in strength with the addition of 5 and 10% calcined magnesite and calcined gypsum. The higher percentage of latter additive has no adverse effect, and the original strength is maintained.

B. Organic Additives. Two types of organic additives were studied.

a. Retarder.

Table 1. Effect of additives on setting time of gypsum plaster.

Additive	Hydrate lime		Calcined dolomite		Calcined magnesite		Calcined gypsum	
%	Initial mnts.	Final mnts.	Initial mnts.	Final mnts.	Initial mnts.	Final mnts.	Initial mnts.	Final mnts.
0	12	18	12	18	12	18	12	18
5	18	28	18	30	26	43	14	20
10	18	25	23	32	25	40	14	20
15	18	29	23	35	28	43	21	32
20	18	29	23	32	30	44	21	32
25	18	29	24	32	25	40	21	33

Table 2. Effect of mineral additives on compressive strength of gypsum plasters.

Additive Percentage	Calcined dolomite psi	Calcined magnesite psi	Hydrate lime psi	Calcined gypsum psi	Period
0	1850	1800	1800	1800	
5	1250	2000	1775	2337	
10	1200	1600	1650	2275	Tested after
15		1575	1500	1800	one month
20	1000	1512	1475	1800	
25	906	1350	1450	1736	
30	–	–	–	1625	
5	1525	2050	1800		
10	1400	1775	1750	2306	
15	–	1770	1625	1875	Tested after
20	1300	1550	1550	1784	two months
25	1225	1450	1500	1775	
30	–	–	–	1750	
5	1625	2150	1800	–	
10	1600	1800	1775	2350	
15	–	1725	1700	1900	Tested after
20	1325	1600	1650	1833	three months
25	1250	1625	1575	1800	
30	–	–	–	1791	

b. Thickening agent.

a. Retarder. Although the mineral additives extend the setting time of gypsum plaster but the working period of about 30 minutes is still too short for the mason to apply and finish it properly. To overcome this difficulty a retarder prepared by hydrolysing hooves and horns meal was used in powderd form.

This has very prominent effect on setting time extension but adversely effects the compressive strength when higher dosage is used. The effect of this retarder on gypsum plaster having lime, dolomite and magnesite as accelerators is rather peculiar. These mineral additives act as accelerators in thre presence of the organic retarder. Individually the mineral additives extend the setting times of plaster of paris. The small amount of organic retarder 0.1 to 0.15%; which is sufficient to extend the setting time of pure gypsum plaster to about 1 hour; becomes insufficient in the presence of these additives. And thus higher dosage of retarder is needed, which adversely effect the strength. To obviate this difficulty the use of calcined gypsum is recommended which does not behave like other minerals. The setting time and strength properties of gypsum plaster having calcined gypsum and poweder retarder remain within acceptable limits.

b. Thickening Agents. As mentioned earlier gypsum plaster requires about 60 to 70% water for guaging, and forms a thin slurry which is difficult to apply. The mineral additives to some extent act as thickening agents, particularly calcined gypsum which requires less amount of gauging water.

In modern practice the use of synthetic organic thickneing agents is being largely advocated. Carboxy Methyl Cellulose (CMC) is excellent thickening agent and a very small amount 0.15-0.2% by wt was successfully used. This amount had no adverse effect on strength, it improves cohesion and extends the setting period.

C. Surface Hardness. Surface hardness of plaster samples (Table 3) was determined according to B.S.S. No. 1191 at 3 days, one month and 3 months. Neat gypsum plaster gives a surface hardness of 3.85 mm at three days and 3.8 mm after one month. The addition of lime and dolomite (Figs. 1&2) has similar effects on hardness as in the case of

compressive strength. With the increased addition of these minerals the hardness decrease. Although it shows some increase with the passage of time due to carbonation.

The effect of addition of calcined magnesite and calcined gypsum on (Figs. 3 & 4) on surface hardness of plaster is more favourable. Considerable increase in hardness is noted with the addition of higher percentage of these minerals.

d. Effect of Addition of Sand. Table 4 gives the effect of addition of sand to gypsum plaster on the compressive strength. It is noted that unlike cement the gypsum plaster has poor aggregate carrying capacity. For internal plastering 3 to 4 parts of sand may be a safely used for the undercoat, and a thin surface coat of neat plaster may be applied.

Advantages of Gypsum Plaster. The gypsum plaster has several advantages over ordinary cement plaster which are as follows:

1. The manufacture of gypsum plaster is easy, only grinding of the rock and heating upto 160° is required. The machinery can be fabricated locally.
2. The cost of production is low as compared with lime or cement. Fuel consumption in the production of gypsum plaster is 1/5th of that of lime and 1/8th of that of cement.
3. It also offers the advantages of ease and speed of application, smooth finish and faster drying.
4. It does not need any water curing like cement plaster.
5. Being alkali free, it provides a surface safe for oil based paints.
6. Gypsum plaster and wall panels are fire-proof.
7. Gypsum partition blocks have half the density as compared with cement blocks, thus in multistoried building and framed structures, the use of gypsum partition blocks will reduce the dead-weight on foundation, resulting in economy in the design of structure. Table 5. summarizes the comparative physical properties of gypsum and cement plaster.

Keeping in view the few advantages listed above, the use of gypsum in building industry in Pakistan assumes added importance as acute shortage of cement was felt in recent years and about 1-million tons was imported in

Table 3. Hardness test results* of gypsum plaster (B.S.S. No: 1191) with mineral additives.

Additive	Percentage	3-days	One month	Two months	Three months
	–	3.85 mm	3.80 mm	3.80 mm	3.80 mm
Calcined limestone	10	4.62	4.20	4.25	4.11
”	20	4.1	3.75	3.72	3.68
”	30	4.1	4.0	3.97	3.92
Calcined dolomite	10	4.45	4.20	4.15	4.12
”	20	4.85	4.2	4.18	4.16
”	30	4.5	4.1	4.07	4.05
Calcined magnesite	10	3.85	3.75	3.70	3.67
”	20	3.95	3.90	3.76	3.73
”	30	4.00	3.97	3.87	3.85
Calcined gypsum	10	3.65	3.55	3.50	3.47
”	20	3.70	3.58	3.56	3.53
”	30	3.85	3.75	3.72	3.68

*Each figure is average of six observations.

Table 4. Compressive strength of plaster cubes with different proportions of sand.

Plaster	Sand	Compressive strength psi
1	0	1850
1	1	1785
1	2	1631
1	3	1050
1	4	1170
1	5	524

1978-79. The use of gypsum will partially reduce the consumption of cement which will be saved for important nation building projects. The early introduction of gypsum in building industry will generate new employment opportunities for local people of less developed areas of Pakistan as a result of expansion of gypsum mining activity and plaster making industries.

Extension Work. After completion of laboratory studies a pilot plant for production of ½ ton of gypsum plaster per day was set up and about 10 tons of plaster was prepared. In collaboration with construction and works department of the Government of NWFP two rooms in a school building in Peshawar were plastered. The plaster had an average setting time of about 40 minutes. The mason accustomed to use cement plaster which can be worked for hours, felt it very difficult to finish the batch before its setting. It was noted that training of masons and labour will be a very important factor in introducing this new material in the building industry.

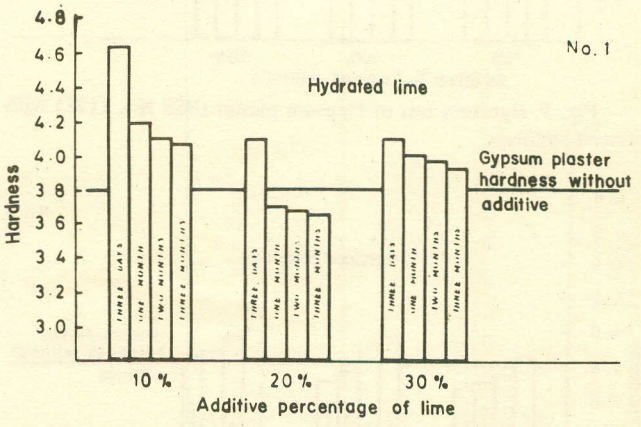

Fig. 1. Hardness test of gypsum plaster (BSS No. 1191) with mineral additives.

Table 5. Comparative physical properties of gypsum and cement plaster

S.No.	Property	Gypsum plaster	Cement and cement plaster
1.	Bulk density	1.00	1.50
2.	Thermal conductivity	1.1 BTU/sq.ft./hr.	5-6BTU/sq.ft./hr.
3.	Setting time:		
	i) Initial	40 minutes	Note less than 2 hr.
	ii) Final	50 minutes	Not more than 10 hr.
4.	Working time	45 minutes	4 hrs. average
5.	Water ratio	60%	30%
6.	Curing	No curing required	Prolonged curing required involving large quantity of water and labour.
7.	Surface	a) Smooth, white or off white b) No paint, distemper required if premixed with pigments	Grey Painting distempering and colour washing required.
8.	Shrinkage	No shrinkage cracks	Shrinkage and hair cracks can not be avoided.
9.	Fire resistance	Resists fire upto 2 hours. without spalling or cracking.	Cracking occurs with immediate fall in strength on heating.

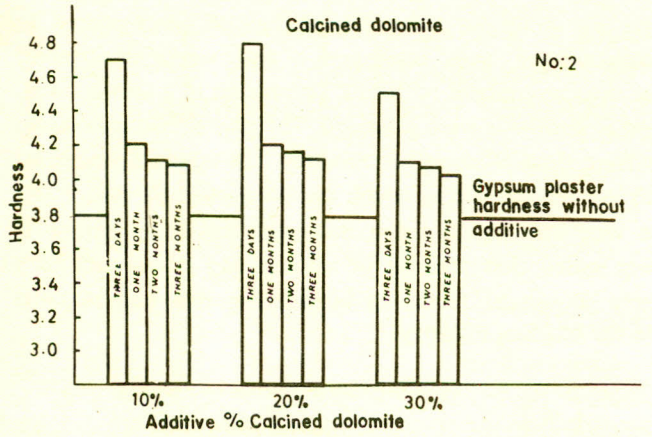

Fig. 2. Hardness test of Gypsum plaster (BSS No. 1191) with mineral additives.

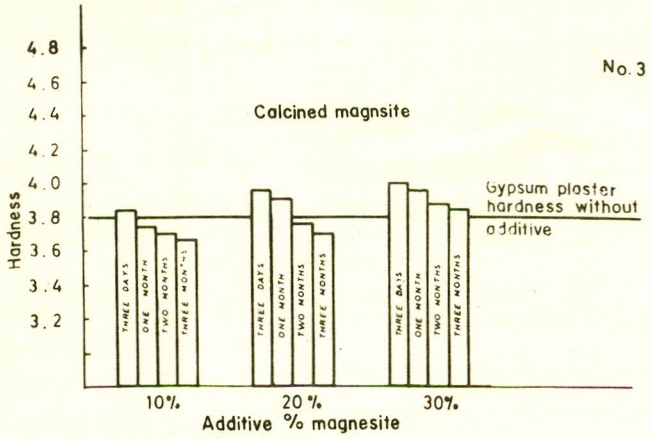

Fig. 3. Hardness test of Gypsum plaster (BSS No. 1191) with minral additives.

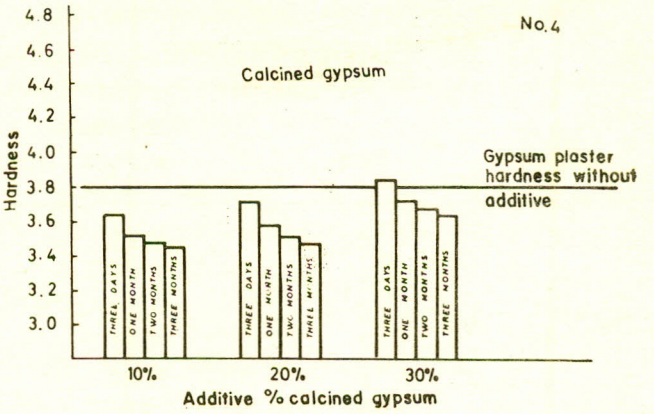

Fig. 4. Hardness test of Gypsum plaster (BSS No. 1191) with minral additives.

CONCLUSIONS

From the above discussion it is concluded that the addition of calcined gypsum to hemihydrate plaster is more favourable to get the commercial plaster. It gives a compositon having higher strength and improved surface hardness. It accommodates the organic retarder and the thickening agent (CMC) with more favourable properties. Calcined magnesite can also be used as an additives for making super white plaster where it is economically available.