Gypsum Plaster as Building Material from Kohat Gypsum

S. A. KHAN*, M.Z.CHUGHTAI, H.KHAN, M.FAISAL AND F.KANWAL
PCSIR Laboratories Complex, Jamrud Road Peshawar-25120, Pakistan

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Summary: The present study deals with the physiochemical evaluation of gypsum deposits of Kohat region for their feasibility as gypsum plaster . Sixteen representative samples from Mami Khel and Lachi Jutta Ismail Khel areas of Kohat district were collected. After detailed laboratory investigations it was observed that by using cheap retarders in very small amounts in calcined gypsum (Plaster of Paris) of all the gypsum samples except a few may bring it feasible as gypsum plaster in accordance with the specifications.

Introduction

Gypsum is a useful industrial material found abundantly on the earth's crust. It is inexpensive to mine and process and its calcined products have a wide range of readily controlable properties such as strength, density and setting time. It is calcium sulphate with two molecules of combined water ($CaSO_4.2H_2O$), which are responsible for most of its useful properties. After moderate heating (up to 160°C) three fourths of this combined water is removed and gypsum becomes a plaster which "sets" with addition of water. At higher temperatures of calcination, gypsum loses all of its water of hydration and is called anhydride.

Gypsum plaster or hemihydrate is one of the oldest building materials in the world [1]. 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 Pramids are still in good condition after thousand 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 has large reserves of gypsum comparable in quality to the best in the world. These deposits are located in the eastern Suleman Range of D.G. Khan [2], Muzaffarabad area of Azad Kashmir [3] and eastern Kohat region [4]. But 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.

Geology of Kohat gypsum

Gypsum is plentiful in the Kohat district [4]. Nearly the entire southern half of the map area (Fig.1), about 2,000 square miles, apparently is underlain by gypsum of variable quality ranging from 5 to more than 140 feet in stratigraphic thickness. At Bahadur Khel, Mami Khel and South Lachi the gypsum is thick and of good quality. The gypsum appears to be a bedded sedimentary evaporite deposit in the Eocene rock sequence. It is found in anticlinal structures which commonly have overturned south flanks. At places, such as at the Shiwakki and Karak deposits, sandstone of the Murree or Kamlial Formations or Siwalik Group is faulted against the gypsum and gypsiferous clay.

The following succession is generally found in the areas:

Miocene to Pliocente; Murree Formation; Kamlial formation and formations of the Siwalik group

Greenish-grey to purple sandstone interbedded with soft red claystone. Conglomerate at the base of the Murree Formation is over 300 feet.

Eocene; Kohat Limestone

Green to grey, finely crystalline, very fossiliferous, lower part shaly and contains Ostrea shells. Thickness is as much as 500 feet .

*To whom all correspondence should be addressed.

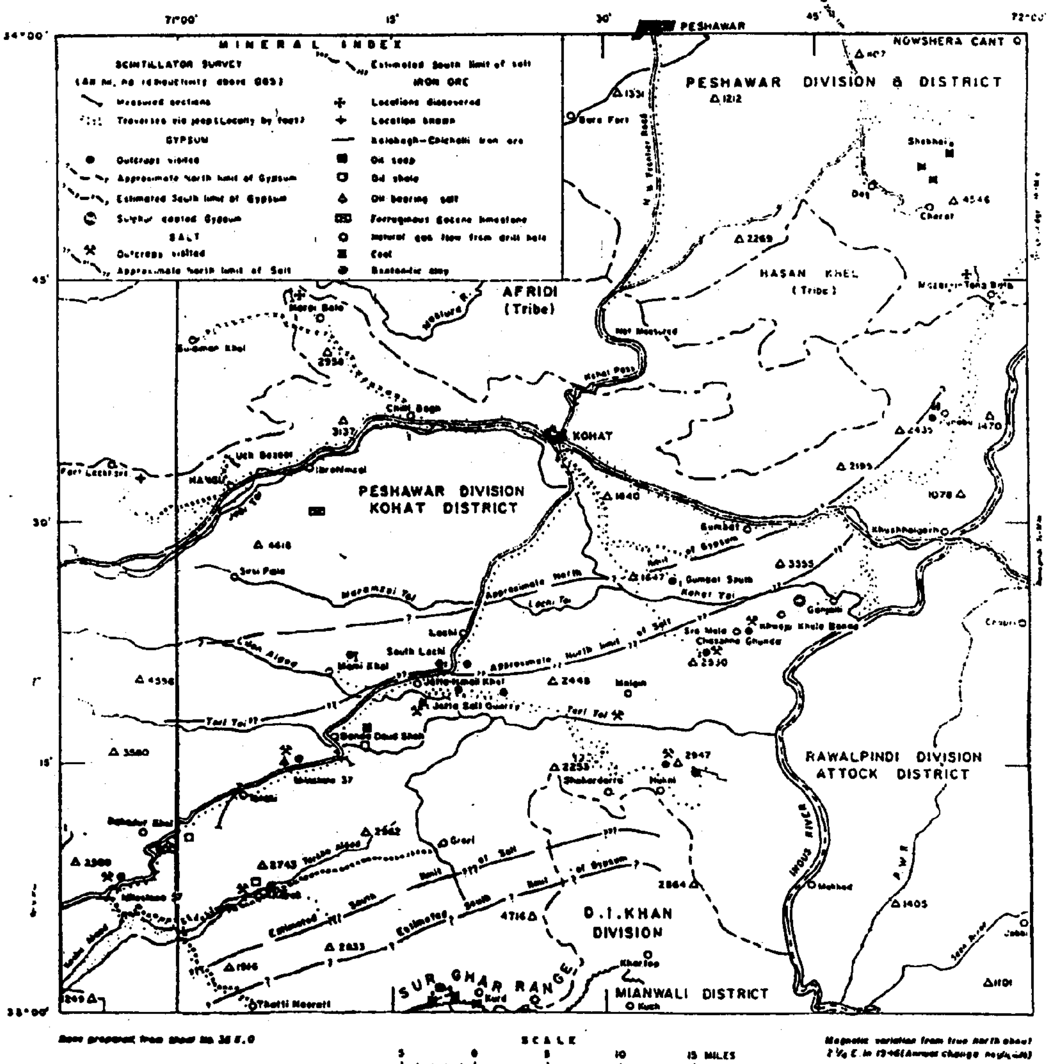

Fig. 1: MAP showing location of mineral desposits of Kohat region, West Pakistan.

Eocene; Mami Khel Clay

Red to dull red, soft friable. Thickness is as much as 200 feet.

Eocene; Shekhan Formation (Jatta Gypsum)

Greyish green, layered, massive, associated with green clay, and gypsiferous clay, rock salt, limestone. Thickness is as much as 500 feet.

The present study deals with the physio-chemical evaluation of gypsum deposits of Kohat region for their feasibility as gypsum plaster. Sixteen representative samples from Mami Khel and Lachi Jutta Ismail Khel areas of Kohat district were collected. The physical tests reveal that "Plaster of Paris" produced from these samples conform to the standard specification of gypsum plasters.

Results and Discussion

Chemical evaluation of gypsum deposits

Chemical analysis of 16 gypsum samples from various deposits under study is presented in Table-1.

Table 1. Chemical evaluation of gypsum samples of Kohat district

S.No	Sample No	CaO	SO_3	MgO	Fe_2O_3	Al_2O_3	SiO_2	CO_2	Combined water	$CaSO_4.2H_2O$
1	Mansoor Garh I	32.60	43.26	0.01	0.19	0.41	1.80	2.11	19.40	92.94
2	Mansoor Garh II	33.00	43.78	Nil	0.23	0.53	0.78	2.38	18.94	93.37
3	Darwazi I	31.20	45.40	0.01	0.18	0.40	0.92	1.44	19.94	95.71
4	Darwazi II	31.33	45.40	0.08	0.15	0.35	0.56	1.34	20.05	96.14
5	Pehla I	31.70	46.07	Nil	0.09	0.25	0.36	1.29	20.00	96.98
6	Pehla II	31.10	45.50	Nil	0.20	0.42	0.68	1.43	20.00	95.53
7	Shuiki I	31.40	45.20	0.07	0.10	0.30	2.10	1.74	18.62	94.88
8	Shuiki II	31.00	45.50	0.10	0.11	0.27	1.72	1.37	19.60	94.88
9	Shuiki III	30.20	43.00	0.40	0.21	0.59	23.92	0.79	1.17	74.27
10	Shuiki IV	33.00	44.60	0.40	0.18	0.42	0.62	2.49	18.80	94.62
11	Shuiki V	29.00	41.26	0.70	0.43	0.59	25.66	0.41	1.72	71.86
12	Shuiki VI	32.00	41.45	Nil	0.44	0.58	2.20	4.80	18.88	89.34
13	Shino Kundu I	31.64	44.47	0.12	0.25	0.45	1.52	2.22	19.08	94.68
14	Shino Kundu II	33.50	42.53	Nil	0.17	0.38	2.18	3.24	17.66	89.96
15	Lachi I	32.42	44.90	0.38	0.16	0.40	0.72	2.54	18.76	95.09
16	Lachi II	32.30	44.50	0.46	0.17	0.43	0.80	3.32	17.85	93.50

Table 2. Chemical composition of Plaster of Paris samples

S.No	Sample No	CaO	SO_3	MgO	Fe_2O_3	Al_2O_3	SiO_2	CO_2	$CaSO_4.1/2\ H_2O$
1	Mansoor Garh I	38.48	51.06	0.01	0.22	0.48	2.14	2.49	78.74
2	Mansoor Garh II	38.75	51.41	Nil	0.27	0.62	0.92	2.79	79.51
3	Darwazi I	36.92	53.72	0.01	0.21	0.47	1.09	1.70	80.88
4	Darwazi II	37.09	53.75	0.09	0.18	0.41	0.66	1.59	81.21
5	Pehla I	37.44	54.42	Nil	0.11	0.30	0.42	1.52	82.10
6	Pehla II	36.82	53.86	Nil	0.24	0.50	0.80	1.69	80.70
7	Shuiki I	36.80	52.97	0.08	0.12	0.35	2.46	2.04	80.96
8	Shuiki II	36.60	53.71	0.12	0.13	0.32	2.03	1.62	80.37
9	Shuiki III	30.76	43.52	0.40	0.21	0.60	24.21	0.80	73.39
10	Shuiki IV	38.65	52.24	0.47	0.21	0.49	0.73	2.92	80.78
11	Shuiki V	29.53	42.01	0.71	0.44	0.06	26.13	0.42	70.57
12	Shuiki VI	37.80	48.96	Nil	0.52	0.68	2.60	5.67	75.64
13	Shino Kundu I	37.25	52.36	0.14	0.44	0.53	1.79	2.61	80.42
14	Shino Kundu II	39.02	49.53	Nil	0.20	0.44	2.54	3.77	77.24
15	Lachi I	37.98	52.61	0.44	0.19	0.47	0.84	2.98	81.16
16	Lachi II	37.62	51.83	0.54	0.20	0.50	0.93	3.87	80.27

All samples were analysed to determine calcium oxide, hydrated water, magnecium oxide,silica, iron oxide, carbon dioxide and sulphur trioxide. It is found that lime content varies from 29.0 to 33.5% whereas sulphite content varies from 41.26 to 46.07%, hydrated water ranges from 1.72 to 20.05% and calcium sulphate dihydrate content ranges from 71.98 to 97.77%.

According to ASTM specifications dihydrate must not be less than 70% in producing Plaster of Paris. By considering the whole data it is suggested that gypsum deposits of different areas of Kohat district under report are suitable for Plaster of Paris as far as chemical analysis is concerned.

Physiochemical analysis of plaster of paris derived from gypsum rock samples

Sixteen representative samples of gypsum were converted into hemihydrate (Plaster of Paris) by heating up to 165°C. Investigations were carried out to determine the suitability of these hemihydrate as gypsum plaster in accordance with the methods given in ASTM [5] which include chemical composition, rate of setting, retardation of the set, fineness, water requirement and compressive strength.

Chemical analysis of the samples given in Table-2 shows that all samples possess the necessary constituents as specified in ASTM. The amount of sulphur trioxide, lime and hemihydrate ranges from 42.01 to 54.42%, 29.53 to 39.02% and 73.39 to 82.10% respectively.

Physiomechanical testing of all the samples given in Table-3 shows that the initial setting time varies from 10 minutes to 14 minutes while the final setting time varies from 17 minutes to 21 minutes which are below the specified values of 40 minutes and 50 minutes as initial and final setting times respectively as given in ASA method [6] . All the

Table 3. Effect of different concentrations of retarder solution on setting time and compressive strength of Plaster of Paris samples.

S.No.	Sample No.	Initial and final setting time (min)							28-day compressive strength* (PSI)						
		A	B	C	D	E	F	G	A	B	C	D	E	F	G
Mansoor Garh Gypsum															
1	MG-I	12-20	22-30	28-36	32-41	25-32	45-52	65-75	2400	1975	1750	1625	2250	2125	1950
2	MG-II	12-20	23-30	30-36	35-42	30-38	52-60	70-75	2350	1925	1750	1600	2200	2125	1975
	Average	12-20	22-30	29-36	34-42	28-35	48-56	68-75	2375	1950	1750	1612	2225	2125	1962
Darwazi Gypsum															
3	D-I	11-18	22-30	27-35	32-40	24-31	41-50	60-68	2050	1725	1550	1425	1925	1825	1725
4	D-II	13-20	22-28	28-36	34-40	31-38	54-60	65-75	2000	1675	1520	1400	1925	1825	1675
	Average	12-19	22-29	28-36	33-40	28-34	48-55	62-72	2025	1700	1535	1412	1925	1837	1700
	Pehla Gypsum														
5	P-I	12-18	17-25	22-27	25-30	35-40	53-60	75-81	2010	1625	1500	1150	1825	1650	1450
6	P-II	13-20	18-25	24-29	28-35	36-42	56-65	80-90	2050	1575	1520	1200	1850	1700	1525
	Average	12-19	18-25	23-28	26-32	36-41	54-62	78-86	2030	1600	1510	1175	1837	1675	1488
Shuiki Gypsum															
7	S-I	12-18	21-26	25-31	30-36	27-33	38-45	65-72	2400	1950	1725	1650	2270	2120	1975
8	S-II	11-18	18-25	22-28	28-35	25-32	35-42	62-70	2375	1925	1700	1625	2225	2100	1950
9	S-III	Does not set within 24 hours, may need an accelerator in order to enhance the setting time.													
10	S-IV	10-17	16-22	23-28	27-35	23-30	32-38	60-68	1900	1650	1500	1125	1800	1725	1600
11	S-V	Does not set within 24 hours, may need an accelerator in order to enhance the setting time.													
12	S-VI	12-18	20-25	26-34	30-36	31-37	50-58	70-78	1925	1670	1500	1150	1825	1750	1625
	Average	11-18	19-24	24-30	29-36	26-33	39-46	64-72	2150	1799	1606	1388	2030	1924	1788
Shino Kundu Gypsum															
13	SK-I	12-18	16-23	22-28	25-32	30-37	42-50	68-75	1750	1525	1375	1050	1650	1525	1325
14	SK-II	14-21	17-25	21-28	25-33	31-38	44-52	70-80	1825	1550	1400	1100	1675	1550	1350
	Average	13-20	16-24	22-28	25-32	30-38	43-51	69-78	1788	1538	1388	1075	1663	1538	1338
	Lachi Gypsum														
15	L-I	10-18	15-22	20-27	24-31	25-32	35-42	58-67	2100	1650	1575	1350	1975	1850	1200
16	L-II	11-18	17-25	22-28	26-32	28-32	38-45	62-70	2075	1635	1550	1300	1950	1820	1600
	Average	10-18	16-24	21-28	25-32	26-32	36-44	60-68	2088	1642	1562	1325	1962	1835	1440

*Standard compressive strength of the Plaster of Paris samples should not be less than 1800 PSI (ASTM C 59-83, 1987).

A-original samples; B- with 0.25% borax solution; C- with 0.5% borax solution ; D- with 1.0% borax solution ; E- with 0.025% citric acid solution ; F- with 0.05% citric acid solution ; G-with 0.1% citric acid solution.

gypsum samples under investigation were not feasible as gypsum plaster as far as the setting time is concerned.

In order to extend the setting times of plaster of paris, small amounts of organic retarders such as borax solution and citric acid solution with concentrations of 0.25-1.0% and 0.025-0.1% respectively were used. The results showed (Table-3 and Figure 2-5), that the setting times increased with the increase in concentration but the compressive strengths of the samples decreased.

When the samples of plaster of paris were treated with borax solution, the average initial setting time increased from 11.8 minutes to 18.9 minutes but the compressive strength decreased from 2076 psi to 1705 psi at a concentration of 0.25% borax solution. Though the setting time further increased with increase in borax concentration; but at the same time significant decrease occurred in the compressive strengths. These results indicate (Fig.2, 4) that the setting times as well as compressive strength of all the samples were less than the specified standards when treated with borax solution.

Encouraging results were obtained with citric acid solution. The solution was added in the range of 0.025 to 0.1% concentration. As shown in Table-3 as well as in Figures 3 & 5, an optimum condition of

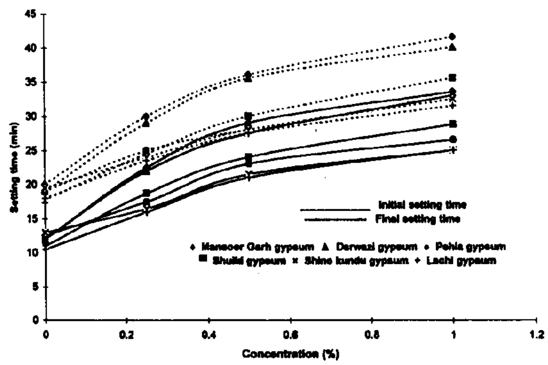

Fig. 2: Effect of borax (retarder) solution on setting time of plaster of paris.

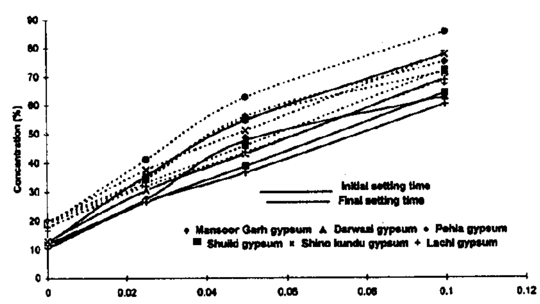

Fig.3: Effect of citric acid (retarder) solution on setting time of plaster of paris.

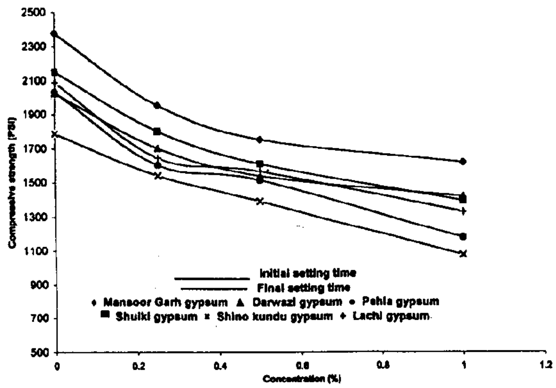

Fig. 4: Effect of borax (retarder) solution on compressive strength of plaster of paris.

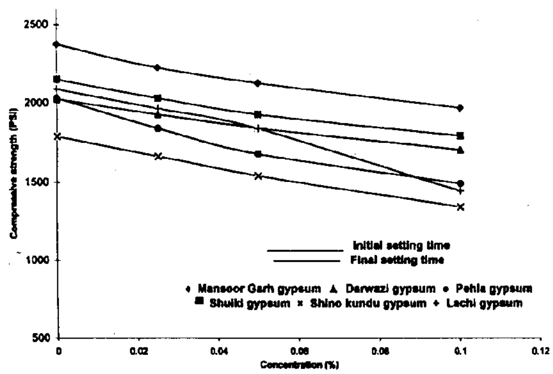

Fig. 5: Effect of citric acid (retarder) solution on compressive strength of plaster of paris.

setting time and compressive strength was established at citric acid concentration of 0.025%. At this concentration the initial setting time increased from 11.8 minutes (average) to a maximum of 36.0 minutes and compressive strengths ranging from 1825 psi to 2270 psi. These results indicate that the compressive strengths of almost all the samples were more than the specified standards, while the setting time were in conformity with the standard specification.

Experimental

Chemical tests

Chemical analysis of 16 representative gypsum samples, 2 from Mansoor Garh, 2 from Darwazi, 2 from Pehla, 6 from Shuiki, 2 from Shino Kundu and 2 from Lachi, were carried out using standard methods [7]. The samples were analysed to determine lime content CaO, MgO, Fe_2O_3, Al_2O_3, SO_3, SiO_2, combined water, insoluble matter and loss on ignition. Anhydrous gypsum was also determined as calcium sulphate. The results are presented in Table -1.

Preparation of plaster of paris

The gypsum samples were ground to 50 mesh, which were latter on converted to hemihydrate or by heating upto 165 ^{0}C for three hours. This Plaster of Paris material was further ground to 100 mesh in accordance with the standard method [8].

Setting time

The initial and final setting time of each sample of powdered gypsum was determined on vicat apparatus [9]. The initial and final setting time of Plaster of Paris was adjusted with citric acid and borax as retarders.

Compressive strength

Compressive strength was determined according to the standard procedure [7]. Specimen cubes of 2"x2" were prepared from each Plaster of Paris sample.

Conclusions

Detailed analysis report of Kohat district gypsum deposits indicate that almost all deposits of Mami Khel and Lachi Jutta Ismail Khel areas with few exceptions are of very good quality and by mixing a minute amount of citric acid (0.025%) as retarder, these deposits may prove feasible for Plaster of Paris.

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