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THE STRENGTH EFFECT OF MINERAL ADMIXTURES ON SAND-LIME PRODUCTS

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Different mineral admixtures, e.g. china-clay, Na_2CO_3, $CaSO_4$ $2H_2O$, slate, fire-clay and Na_2SiO_3 have been incorporated in the hydrothermal reactions of sand-lime in order to know the strength effect on the products. The compressive strength and mineralogy of the various mixtures were determined after they had been autoclaved at a steam pressure of 0.1 MPa (100°) for 6,12,18,24 and 48 hrs. It has been observed that the maximum compressive strengths are recorded when china-clay, slate, Na_2SiO_3 are used while Na_2CO_3, $CaSO_4 2H_2O$ and fire-clay do not increase the strength markedly, though the later has a composition similar to that of china-clay.

Key words: Strength, Mineral admixtures, Sand-lime.

Introduction

Silica sand and limestone are abundantly available in Pakistan. These indigenous natural raw materials are an interesting source to manufacture high strength building materials such as sand-lime bricks, if treated hydrothermally. Solar energy can partly replace coal or gas fuels since the materials do not require a high temperature for their preparation.

In a preceding paper [1] investigations on the hydrothermal reactions of silica sand and $Ca(OH)_2$ were presented. Effect of china-clay on the compressive strength was also studied and it was found that materials with 48 hrs strength of 28.1 MPa (19.7 MPa as wet strength) could be obtained with the following composition.

Silica sand : 65%
$Ca(OH)_2$: 30%
China-clay : 5%

Silica sand/[$Ca(OH)_2$ + china-clay] = 1.8

An optimal higher strength of 25.0 MPa (17.5 MPa as wet strength) was also obtained after 48 hrs reaction between 80% silica sand, 15% lime and 5% china-clay which are comparable with those of good common clay bricks used in Pakistan having the compressive strength in the range of 14-17 MPa (tested wet or dry).

This paper reports the effect of different mineral admixtures such as china-clay, Na_2CO_3, $CaSO_4.2H_2O$, slate, fire-clay and Na_2SiO_3 on the compressive strength of the products containing 15% lime and 85% sand.

Experimental

Starting materials. CaO was prepared by heating $CaCO_3$ at 1000-1100° and then hydrolyzed to $Ca(OH)_2$. Two silica sand samples were used, of particle sizes minus 100 µm (47%) and 200-300 µm (53%) respectively, both contained 99.0% SiO_2. Table 1 lists chemical composition of the materials used. The two particle size fractions were used in order to achieve maximum pore-filling. All these materials are locally available. $Ca(OH)_2$ and the other additives were of particle size minus 100 µm.

Preparations. Different dry mixes of silica sand, hydrated lime and aggregate fines were prepared, in different proportions by weight as shown in Table 2 and 3.

Cylindrical specimens of 3.8 cm diameter by 5.1 cm in height were moulded at a pressure of 30.7 MPa after the requisite amount of water (8% wt of total solids) had been added. These were then autoclaved for 6, 12, 18, 24 and 48 hrs. at a steam pressure of 0.1 MPa (100°).

TABLE 1. CHEMICAL COMPOSITION OF VARIOUS INDIGENOUS AGGREGATE FINES (%).

Composition	Silica sand (Mianwali)	Salte (Attock)	Gypsum (Kohat)	Fire clay (Attock)	China clay (Swat)
SiO_2	98.90	63.22	2.25	42.68	45.44
Fe_2O_3	0.07	6.56	Nil	1.55	0.80
Al_2O_3	0.33	19.10	0.71	38.49	38.52
TiO_2	Nil	Nil	–	2.90	0.16
MnO	Nil	–	–	–	–
P_2O_5	Nil	–	–	–	–
SO_3	–	–	44.10	–	–
CaO	0.10	0.90	30.98	–	0.08
MgO	Traces	1.10	1.14	0.08	0.08
Na_2O	Nil	0.72	0.40	0.28	0.66
K_2O	0.03	3.33	0.20	0.49	0.14
L.O.I.	0.50	5.02	1.58	–	–
H_2O	–	–	19.22	14.07	14.20
Total	99.93	100.01	100.58	100.54	100.08
Mineral	Quartzite	Quartz chlorite biotite feldspar pyrite haematite	Selenite gypsite	Kaolinite	Kaolinite

At the end of each autoclaving period, the specimens were removed and placed in a desiccator to cool and were retained under dry CO_2 - free conditions until they were needed for further examination. "Gypdri", the locally prepared material was used as desiccant which is more economical and efficient. The specimens were tested for compressive strength and examined by X-ray diffraction (Cu K α radiati on) and infrared analysis.

Results and Discussion

Strength development. The dependence of the compressive strength on the autoclaving time is shown in Fig. 1-3 for

TABLE 2. COMPRESSIVE STRENGTHS OF AUTOCLAVED SILICA SAND -$Ca(OH)_2$ AND MINERAL ADMIXTURES MOULDS.

Slica sand (200-300μm) %	Silica sand (–100μm) %	Na_2CO_3 (–100μm) %	$CaSO_4\,2H_2O$ (–100μm) %	China clay (–100μm) %	Slate (–100μm) %	Fire clay (–100μm) %	Na_2SiO_3 (–100μm) %	$Ca(OH)_2$ (–100μm) %	*Compressive strength (MPa) 6 hrs	12 hrs	18hrs	24 hrs	48 hrs
45.05	38.95	1.00	–	–	–	–	–	15.00	6.20	8.56	9.76	9.76	9.76
45.05	36.95	3.00	–	–	–	–	–	"	6.72	8.79	9.76	14.82	14.82(10.4)
45.05	37.95	–	2.00	–	–	–	–	"	4.14	5.52	6.72	6.72	6.72
45.05	37.95	–	–	2.00	–	–	–	"	6.62	7.24	8.55	8.55	10.53
45.05	34.95	–	–	5.00	–	–	–	"	11.32	14.83	17.57	18.27	24.98(17.5)
45.05	32.45	–	–	7.50	–	–	–	"	8.62	10.15	11.72	14.44	17.95
45.05	34.95	–	–	–	5.00	–	–	"	9.62	10.93	13.27	15.62	17.93(12.5)
45.05	32.45	–	–	–	7.50	–	–	"	7.18	9.76	12.88	12.24	15.51
45.05	34.95	–	–	–	–	5.00	–	"	3.12	4.69	7.03	9.56	9.56
45.05	34.95	–	–	–	–	–	5.00	"	7.80	8.96	9.76	13.27	14.05(9.8)
45.05	39.95	–	–	–	–	–	–	"	5.52	6.89	8.79	9.65	10.17

*Wet compressive strengths in parentheses.

TABLE 3. EFFECT OF Na_2CO_3 AND $CaSO_4 . 2H_2O$ ON COMPRESSIVE STRENGTHS OF SILICA SAND - CHINA CLAY $Ca(OH)_2$ MOULDS.

Slica sand (200-300μm) %	Silica sand (–100μm) %	Na_2CO_3 (–100μm) %	$CaSO_4\,2H_2O$ (–100μm) %	China clay (–100μm) %	$Ca(OH)_2$ (–100μm) %	Compressive strength* (MPa) 6 hs	12 hrs	18hrs	24 hrs	48 hrs
45.05	33.95	1.00	–	5.00	15.00	7.03	7.43	8.58	9.76	10.15
45.05	30.45	2.00	–	7.50	"	7.03	10.15	13.27	14.05	16.37(11.4)
45.05	35.95	2.00	–	2.00	"	7.61	9.73	11.86	14.44	14.44
45.05	32.95	–	2.00	5.00	"	6.72	8.58	10.93	12.40	17.96(12.6)
45.05	39.95	–	–	–	"	5.52	6.89	8.79	9.65	10.17

*Wet compressive strengths in parentheses.

TABLE 4. X-RAY AND INFRARED ANALYSIS RESULTS OF 80% SAND, 15% LIME, 5% CHINA-CLAY REACTION PRODUCTION.

Reaction period	d-Spacings with intensity	Infrared absorption frequency (cm^{-1})
6-Hours	2.98A(50)	3705(w), 3460(broad), 1100(s)
	2.83A(15)	970(m), 900(s), 805(m)
	1.80A(13)	468(m)
24-Hours	10.10A(24)	3460(broad) 1100(w), 970(s)
	7.80(20)	900(w), 805(m), 468(m)
	2.98A(25)	
	2.83A(49)	
	1.80A(45)	
48-Hsours	10.10A(50)	3460(broad), 1100(w), 970(s)
	7.80A(47)	900(w), 805(w), 468(w)
	2.98A(15)	
	2.83A(30)	
	1.80A(25)	

Abbreviations: *KBr disc, s = strong, m = medium, w = weak.

the various pastes investigated.

Sand-lime with different mineral admixtures. It is known [2] that finely divided siliceous materials (including clays, zeolites and diatomite) can react with free lime of cement leading to formation of hydrated products having binding properties. Small additions of basic materials like NaOH [3] are found to be good accelerators.

Figure 1 and 2 give a comprehensive picture of the compressive strengths obtained with different mineral admixtures of the sand-lime reaction. Various additives e.g., china-clay, slate, Na_2CO_3, Na_2SiO_3, fire-clay and $CaSO_4.2H_2O$ have been incorporated in variable proportion in order to know their effect on the strength. 15% (w/w) lime has been used throughout while the 48hrs maximum strength (25 MPa) with 5% china clay is consistent with the results from the earlier study [1]. Slate, Na_2CO_3, Na_2SiO_3 and fire-clay give lower compressive strengths whereas the presence of $CaSO_4.2H_2O$ has an adverse effect on the strength possibly because sulphate solution retards the formation of the hydrated calcium silicate product [4]. Fire-clay has a composition almost similar to that of china-

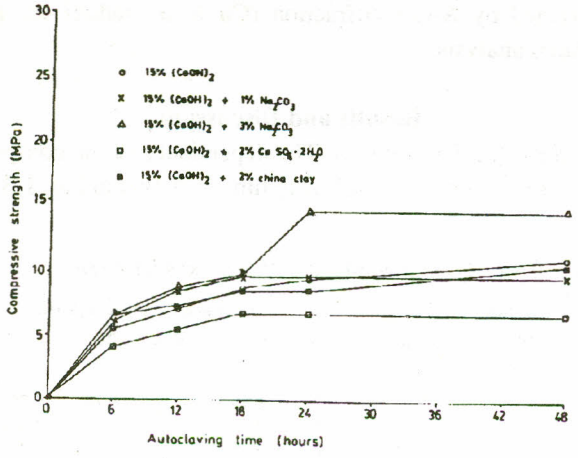

Fig. 1. % $Ca(OH)_2$ and mineral admixtures added to silica sand.

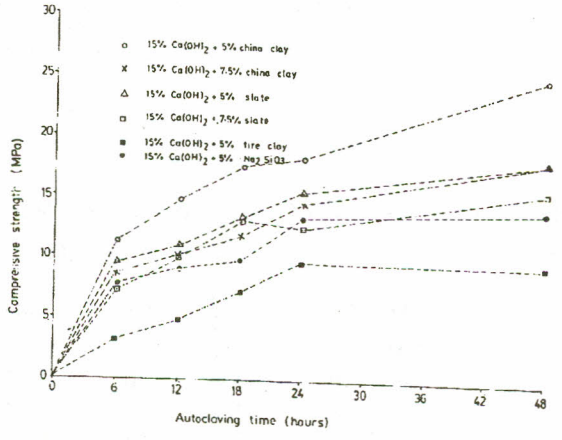

Fig. 2. %Ca $(OH)_2$ and mineral admixtures added to silica sand.

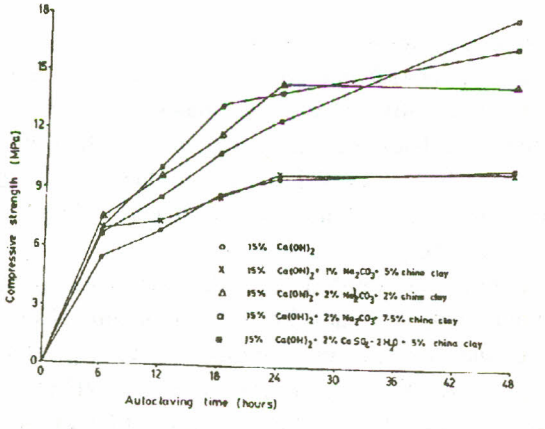

Fig. 3. % $Ca(OH)_2$ and mineral admixtures added to silica sand.

clay, except having TiO_2 on higher side which lowers the rate of dissolution of silica and as a result gives lower compressive strength.

Effect of Na_2CO_3 and $CaSO_4.2H_2O$ on sand-lime-china clay mixture. It is known [5] that Na_2CO_3 is a good activator that can be used to get high strength hydrated calcium silicate products. In our study we tried to show the effect of Na_2CO_3 and $CaSO_4.2H_2O$ on the strength, when incorporated into sand-lime-china clay mixture (Fig. 3). It can be concluded from the results presented in Fig. 3 that the compressive strengths do not increase markedly in the presence of these additives and that china-clay alone is the most important activator when mixed with sand-lime mixture.

Characterisation of the products. X-ray diffraction analysis were performed on the products, giving the higher optimal compressive strength. In addition to the final material diagram, other patterns in intermediate samples taken throughout the reactin were recorded. During the early hours, the main line of $Ca(OH)_2$ is detected at 2.98 Å, which is followed by the other four lines at 2.83 A°, 1.80 A°, 10.10 A° and 7.80 A° respectively. The later four lines, which are attributable to the different phases of the "calcium silicate hydrate" (C-S-H) . These symbols used by cement experts C=Ca; $S=SiO_2$; H = H_2O become more intense on the completion of the reaction.

The products can be authenticated in the light of infrared spectrometry results. It is known [6] that the amorphous silica gives characteristic bands at 1100 cm^{-1}, 805 cm^{-1}, 468 cm^{-1}, attributed to the SiO and Si valence vibrations and to the SiO deformation vibrations, respectively.

During the course of reaction, it was observed that the 1100 cm^{-1} band was decreasing as the reaction proceeded. A new stretching mode was observed at 970 cm^{-1}, a characteristic of the C-S-H, which became more intense at later stage of the reaction.

The X-ray and infrared data of the 80% sand, 15% lime, 5% china-clay reaction products are presented in Table 4.

Conclusion

The compressive strength can be improved in the presence of some indigenous additives and it has been observed that higher strengths can be obtained when china-clay, slate and Na_2SiO_3 are incorporated in the silica-lime reactions. On the other hand, Na_2CO_3, $CaSO_4.2H_2O$ and fire-clay have a little effect on the strength.

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