STUDIES ON SOME INDIGENOUS MATERIALS FOR THEIR PUZZOLANIC PROPERTIES

SHAGUFTA NASREEN*
MOHAMMAD ZUBAIR*
F.A. SIDDIQI*
M.A. QAISER*
AINUL HASAN KHAN*

SUMMARY: Puzzolanic activities of indigenous materials such as clays, shales, slates, volcanic ash and laterite from different localities of Pakistan are studied. Puzzolanic properties of rice hush ash are also discussed. All of these materials except laterite, behave as good quality puzzolanas. Correlation between the type of clays and their puzzolanic reactivities have been discussed. The commercial use of these materials is recommended.

Key Words: Puzzolana.

INTRODUCTION

Puzzolanas are materials containing constituents which combine with lime at ordinary temperature in the presence of water to form stable insoluble compounds possessing cementing properties. Puzzolanas may be natural or artificial materials. The natural puzzolanas are of volcanic origin e.g. volcanic glass, volcanic ash etc; and artificial puzzolanas are prepared by giving heat treatment to clays of shales etc.

Prior to the invention of Portland Cement in early nineteenh century, people had been using the puzzolanas in history for hydraulic structures and in monumental buildings.

Romans (1) were first to use volcanic ash, from the village Puzzoli near Naples, as building material. Hence the name puzzolana is derived. Egyptians used burnt clay from Nile valley and called it "Humra". In Indo-Pak subcontinent burnt bricks were ground and used in structures. The material was named as "Surkhi". The monumental buildings of Mughal Empire are fine examples of the use of this material.

In recent history Japan, India, USA and USSR (2) have done systematic and scientific work for the introduction of puzzolanic materials in construction of dams, sea shore construction etc.

*From Pakistan Council of Scientific and Industrial Research, Peshawar, Pakistan.

DESCRIPTION OF THE SAMPLES

Thirteen representative samples of puzzolanic materials were taken for the present study from different parts of Pakistan and one from Azad Kashmir (Figure 1). The brief description of the samples follows:

CL-1 Akora Khattak Clay: The deposits of clay are near Akora Khattak, about 50 km east of Peshawar (NWFP) on the left bank of Kakul River. The thickness of the clay occurences range from a few inches to 4 feet. The clay beds occur as zones in the unconsolidated sediments of post-tertiary period. The clays of the area mainly composed of illite with subordinate amounts of free quartz, felspar, mica and heavy minerals (3).

CL-2 Bach Clay: The clay deposite occur at the top of the denuded hillock about 1 km SE of the village Bagh in Attock District (Punjab). The denuded hillock is one of the spurs of the Kala Chitta hills. The river Indus flows about 1.5 km NW of the deposits. The exact age of the clay deposits in not certain. However, they occur in association with limestone of Eocene age. The Bagh clays are composed of Kaolinite with subordinate amounts of diaspore, hematite and rutile (4).

CL-3 Bostan Clay: Huge deposits of clay in the form of mounds same 30 m high occur near Bostan (Baluchistan) on Quetta-Muslim Bagh Road. The clay is reddish in colour and highly plastic. It belongs to illite group.

CL-4 Chinji Clay: The red clay occurs near Chinji (Punjab) in the salt range near the coal mining areas. The

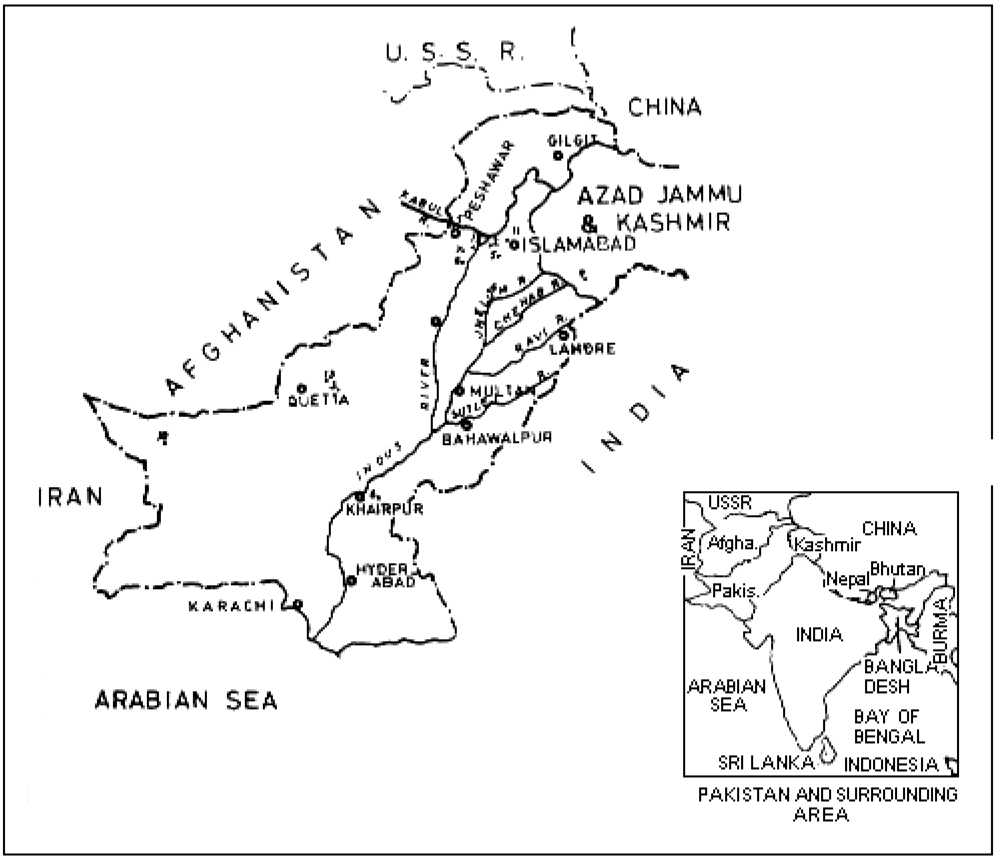

Figure 1: Map of Pakistan Showing Locations of samples.

clay deposits seem to be localised and in small pockets. This clay also belongs to illite group.

CL-5 Dherikol Clay: White clay bed occurs near the Dherikot village, about 10 km SW of Attock City (Punjab). The village is near the left bank of Haro River, a tributary of the river Indus. The area is considered to be a part of the Kala Chitta hills which constitute the outer ranges of the Himalayas. These clays are composed of montmorilonite with subordinate amounts of felspar and quartz (5).

CL-6 Khairpur Clay: A thick bed of clay runs about 12 km along the base of a scrap formed by the Eocene rocks in the Shadi Shahid hills, about 5 km east of Khairpur (Sind). The clay minerals seem to be illite with some interstratification with montmorillonite. Quartz, gypsum and some kaolinites are found in subordinate amounts (6).

CL-7 Kirk Clay: The clay deposit near Kirk is about 65 km from Kohat (NWFP). The clay consists of mixed layer montmorillonite and illite.

VA-8 Cherat Volcanic Ash: Small occurences of volcanic ash deposits have been located by the Geological Survey of Pakistan in Shamshatu area, Cherat hills at about 25 km to the SE of Peshawar (NWFP). The material consists predominantly of illite with mixed interlayers of montmorillonite and quartz.

VA-9 Poonch Volcanic Ash: Extensive deposits of volcanic ash are found in upper Haveli tehsil, Poonch district, Azad Kashmir. Their thickness varies from 9 to 30 metres and are exposed intermittantly for 16 kilometers.

VG-10 Kohl-I-Sultan Volcanic Glass: The sample of the volconic glass from Baluchistan was provided by the Geological Survey of Pakistan Quetta. The detailed information about the deposits in not available.

SH-11 Sangjani Shale: The deposits of shale are located in Dhok Juri and Sarai Kharbuza near Sangjani in Islamabad area. The shales form part of the Kuldane Formation of Early to Middle Eocene age. The Kuldana Formation is mostly comprised of shale with subordinate amounts of limestones and siltstone (7).

SL-12 Attock Slate: Massive deposits of the rock are found near Attock bridge on the river Indus. On the right bank eit extends to Cherat Range and Manki area (NWFP). The shale belongs to the Manki Formation which consists of thick sequence of slate and phyllitic slate with subordinate intercalations of quartzite and limestone (7).

LT-13 Ziarat Laterite: The largest deposits of laterite occur near Ziarat (Baluchistan). The laterite bearing area lies along the two sides of Quetta-Loralai Road. The laterite band generally occurs at the juction of Parh and

Table 1: Chemical Analyses

% Composition	CL-1	CL-2	CL-3	CL-4	CL-5	CL-6	CL-7	VA-8	VA-9	VG-10	SH-11	SL-12	LT-13	RHA-14
SiO_2	51.50	43.44	43.00	54.12	52.49	47.50	52.27	58.70	62.53	56.83	56.35	59.37	9.18	88.40
TiO_2	0.79	2.17	0.44	0.06	0.03	0.74	0.59	0.58	0.73	-	-	0.73	4.48	-
Al_2O_3	22.46	39.44	21.52	13.38	17.17	23.59	18.71	6.40	23.55	25.93	17.44	27.99	55.64	1.99
Fe_2O_3	1.98	0.12	4.71	9.44	2.01	7.82	5.98	3.04	0.28	1.17	7.75	0.11	15.80	0.57
CaO+MgO	9.38	-	11.76	7.02	6.90	3.22	7.90	5.14	2.08	3.73	8.14	5.39	1.59	2.08
Na_2O+K_2O	3.45	0.11	2.38	2.83	1.47	4.97	2.12	2.82	4.95	4.75	3.85	2.97	0.35	2.14
L.O.I.	10.49	14.20	16.30	11.35	18.67	12.64	11.86	11.89	4.45	6.90	6.79	3.62	10.83	4.00
Total:-	100.05	99.48	100.11	98.20	98.74	100.48	99.43	98.57	98.57	99.31	100.32	100.18	97.87	99.18

Table 2: Lime Reactivity Test of Puzzolanas.

Sample No.	CL-1	CL-2	CL-3	CL-4	CL-5	CL-6	CL-7	VA-8	VA-9	VG-10	SH-11	SL-12	LT-13	RHA-14
Heat Treatment °C	950	900	950	950	950	950	900	900	900	-	950	950	900	600-700
Lime Reactivity (Comp. Strength in PSI)	1075	1687	1125	1050	1550	1000	1275	1150	1333	875	1050	650	300	1500

Dunghan Formations. It is late cretaceous to Paleocene in age and has developed along a regional disconformity (8).

RH-14 Rich Husk Ash: Controlled burning of rice husk from Guiranwala yields ash containing 88% of active silica (9).

EXPERIMENTAL AND RESULTS

Chemical Analysis: All the samples were analyzed by conventional and instrumental methods. The results are summarized in Table 1.

Differential Thermal Analysis: 1 gm of sample and 1 gm of inert (ignited alumina) in two separate porcelain crucibles were subjected to a uniform rise in temperature (10°C/min) in a vertical furnace. The thermograms were recorded on a recorder (Servogors). The thermograms of typical clays are shown in Figure 2.

On the basis of DTA results proper heat treatment was given to the samples and ground to fineness of 4200 Blain to obtain Reactive Surkhi (puzzolanic material).

Lime Reactivity Test: Lime reactivity of samples was determined according to Indian Standard Specification IS: 1727-1768. Compressive strengths in PSI average of three observations were taken as measure of lime reactivity and the results are summarized in Table 2.

Partial substitution of Surkhi in Portland Cement: 5 cm cubes were cast using partially substituted OPC with 25 percent of Surkhi and Sand in 1:3 ratio. After curing under water for 7,28,90 days and 1 year compressive strength were determined. The results are summarized in Table 3.

Comparison of Compressive Strength of OPC: Sand: and Lime: Surkhi: Sand Mortars: A series of cubes with lime, Surkhi obtained from sample CL-2 and silica sand in the ratio's of 1:2:8, 1:2:2:12, 1:2:18 and 1:3:8 were cast.

Table 3: Comparatvie Strength of Cement Mortar and Partially Substituted OPC Mortars.

Compressive Strength				
Samples	7 days	28 days	90 days	1-year
Portland	100	100	100	100
Cement (OPC-control)	(1650)*	(2800)*	(3150)*	(3325)*
CL-1	110	102	96	106
CL-2	121	98	104	109
CL-3	100	91	90	116
CL-4	118	90	84	106
CL-5	121	118	127	145
CL-6	124	98	115	125
CL-7	122	100	125	129
VA-8	113	103	141	140
VA-9	124	99	115	112
VG-10**	106	90	90	121
SH-11	99	127	122	145
SL-12	80	90	83	89
LT-13	88	80	81	78
RHA-14	124	111	101	-

* Actual values in PSI
** Used in natural form

Table 4: Comparative Strength of Cement Sand Mortars and Lime Puzzolana Sand Mortars.

			Compressive Strength in PSI			
Ingredients	Ratio	Moisture Binder	7 days	28 days	90 days	1 year
Cement : Sand	1:6	0.66	1075	1400	1500	1650
Cement : Sand	1:8	0.80	800	925	1025	1150
Lime:Surkhi:Sand	1:2:8	0.53	700	1350	1700	2000
Lime:Surkhi:Sand	1:2:8	0.45	700	1450	-	-
Lime:Surkhi:Sand	1:2:10	0.53	750	1350	1525	1650
Lime:Surkhi:Sand	1:2:10	0.45	1000	1750	-	-
Lime:Surkhi:Sand	1:3:8	0.40	850	1500	2000	2400
Lime:Surkhi:Sand	1:3:8	0.45	800	1608	-	-
Lime:Surkhi:Sand	1:2:12	0.70	800	1050	1100	1300
Lime:Surkhi:Sand	1:2:18	0.80	400	525	950	1000

Binder = Lime + Surkhi

* Mianwali Silica Sand Fineness Modulus.

These cubes were cured at ambient temperature and at 90 percent relative humidity for 7,28,90 days and 1 year. Compressive strengths of these cubes were compared with that of the cubes which were prepared by cement and sand in the ratios of 1:6 and 1:8. The results are tabulated in Table 4.

DISCUSSION

Most of the samples except LT-13 meet the chemical constituent requirements mentioned in Indian Standard Specification IS:1344-1959 for good puzzolanic reactivity that is SiO_2 should not be less than 40 percent; total of SiO_2, Al_2O_3 and Fe_2O_3 should not be less than 70 percent; CaO should not be greater than 10 percent; and total of Na_2O and K_2O should not be greater than 3 percent. Low content of SiO_2 (9.18%) in LT-13 explains its poor behaivor as a puzzolana indicated by the lime reactivity test. Samples CL-6, VG-10 and VA-9 have slightly higher Na_2O+K_2O than the specification but it does not affect the lime reactivity test for puzzolana.

The samples were classified as kaolinite, montmorillonite, illite and mixed layers of illite and montmorillonite by DTA. Sample CL-2 is kalinite; CL-5 and CL-7 are bentonite type; CL-1, CL-3, CL-4, CL-6 and SL-12 are illite type; VA-8 and VA-9 seems to be mixed layers of illite and montmorillonate. Typical thermograms of different clay types are in Figure 2.

Lime reactivity is plotted against samples Nos. (Figure 3). Kaolinite, bentonite, volcanic ash and rice husk ash are in the range of high reactivity (10) (above 1200 Ibs/sq. inch). Illite and volcanic glass falls in the range of medium reactivity (800-1200 Ibs/sq. inch) wheares slate and laterite are in the low range of reactivity (below 800 Ibs/sq. inch). Differential thermal analysis seems to be a better

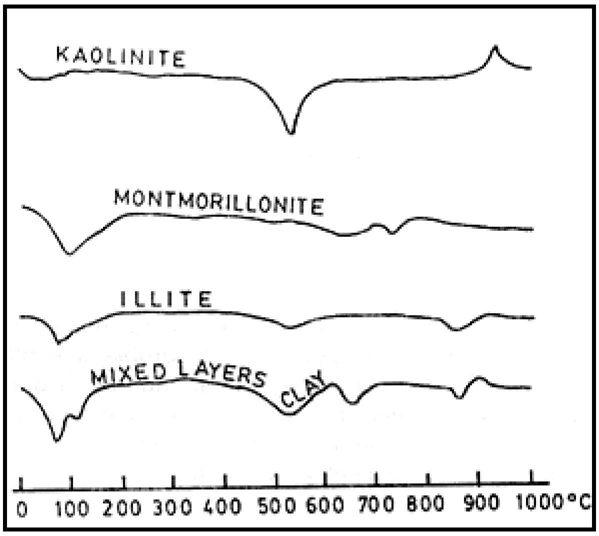

Figure 2: Thermograms of Typical Clays.

and easier method to classify the materials for puzzolanic properties.

Early experiments (1) have shown that in case of very active puzzolana, upto 40% replacement of OPC does not effect the ultimate strength. In our experiments 25% substitution was made with each material. Results of compressive strength after 7,28,90 days and one year were compared with that of cement for the same period. Dherikot clay, Sangjani shale and Cherat volcanic ash show remarkable increase in compressive strength after one year as compared to that of OPC. Other samples except salte and laterite give appreciable compressive strength (102 to 129) Lime reactivity test of volcanic glass (without heat treatment) falls in the region of medium reac-

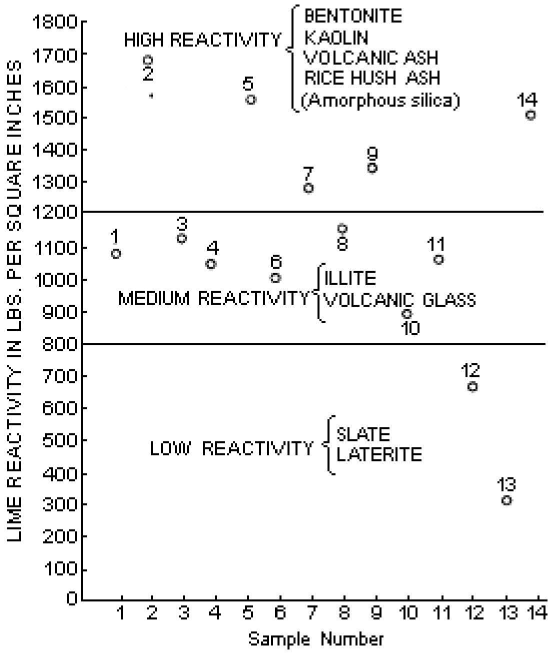

Figure 3: Lime reactivity v/s Sample number.

tivity where as 25% substitution studies give appreciable results after one year.

Considering the results of studies on lime reactive surkhi mixtures as total substitute of cement, the mortars of lime reactive surkhi sand in the ratio 1:2:8 and 1:2:10 develop comparable strength comparable to that of cement sand mortars (1:6 and 1:8 usually adopted for brick laying and plastering). One year strength of the lime reactive-surkhi surpases that of cement sand mortars.

CONCLUSION

The reintroduction of lime surkhi and other indigenous puzzolana materials as partial and total substitute of OPC will provide a cheap media of construction and save a considerable quantity of cement for large national building projects.

REFERENCES

1. Lea FM: The Chemistry of Cement and concrete, Edward Arnold Ltd., London, 1956.

2. Proceedings of Symposium on Puzzolanas, Central Road Research Institute, New Delhi, 1964.

3. Khurshid Jahan and Ainul Hasan Khan : Akora Khattak Clays of Nowshera Tehsil. Pak Jr Sci Ind Res, vol. 17, 1974.

4. Qasir MA, MK Ali and AH Khan : Mineralogy of Clay Deposits near Bagh, Cambellpur District, Rawalpindi Division, Pak Jr Sci Ind Res, vol. 12 (1970).

5. Alauddin M, MA Qaiser, SM Akhtar and AH Khan, Mireralogy and Chemistry of Dherikot Clays, Campbellpur District, Sc Ind, vol 8 , 1971.

6. Maqsood A, FA Siddiqi, MA Qaiser and AH Khan : Mineralogy and Chemistry of Clays from Khairpur, Sind Province. Pak Jr Sci ÿInd Res, Vol. 26, 1983.

7. Hussain A, MA Choudhry, FA Siddiqi, MZ Chughtai : Lightweight Aggregate - A Study of Raw Materials in Pakistan, Records Geological Survey of Pakistan vol. 66, 1983.

8. Shan SHA : The Laterite Band of Ziarat, Sibi and Loralai Districts, Baluchistan, Pakistan. Records Geological Survey of Pakistan, vol 37, 1975.

9. Shah RA, AH Khan, MA Choudhry and MA Qaiser : Utilization of RHA for the Production of cement like Materials in Rural Areas. Pak Jr Sci Ind Res, vol. 24, 1981.

10. Srinivasan NR : Development of Clay Puzzolana Industry, Part-II Research and Industry-India, vol 11, 1967.

Correspondence:
Shagufta Nasreen
P.C.S.I.R. Laboratories,
Peshawar, PAKISTAN.