Lightweight Characteristics of the Naka Pabni Shale in Pakistan

HAMID ULLAH KHAN AND SHAH ALAM KHAN
PCSIR Laboratories, P.O. Peshawar University Peshawar 25120, Pakistan

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Summary: An investigation into bloatable raw material comprising of shale, suitable for use in making lightweight aggregate has been made to exist in large quantities in the region of Naka Pabni located in Kirthar province to the North of Karachi. Field studies have revealed that extensive deposits of shale occur in the region. Test results indicate that the material can be bloated successfully at 1,100°C and the resultant bloated material becomes considerably lighter than the conventional aggregate. The expanded aggregate is hard, highly cellular and has a tough water resistant skin and uniform structural strength.

Introduction

Lightweight concrete aggregates are materials weighing less than the usual aggregate of sand, gravel and crushed rock. Lightweight aggregate, may be natural or manufactured material or by-products from other commercial operations. Manufactured aggregates include expanded perlite, vermiculite, slag, clay, shale and slate [1,2].

Bloating studies on some alluvial clays were carried out by adding organic materials [3] while crushing strength and other tests were performed on some locally expanded clay aggregates [4,5]. However, all these investigations failed to identify a mineable raw material source which could be economically bloated without any additive.

Lightweight, load bearing low moisture cementitious compositions containing 40-99V% aq. cementitious mixtures consisting of cement and expanded mixture of shale, clay and slate and balance microsized polystyrene foam have been manufactured earlier [6-8]. Artificial lightweight aggregate has been prepared by heating a mixture of sewage sludge ash and coal ash [9]. Extensive literature is available on the manufacture of lightweight concrete containing shale [10-15].

Preliminary investigation conducted by the Geological Survey of Pakistan [16] revealed that most of the shale deposits of Margalla Range of Pakistan can be bloated for lightweight aggregates.

Extensive deposits of shale are found in different parts of Pakistan, including the Margalla and the Attock-Cherat Ranges near Islamabad and Peshawar and the Naka Pabni area in the North of Karachi [16,17].

The present investigation is an extension to other parts of the country for production of lightweight aggregate from self bloating lightweight aggregate raw materials in order to fulfill the country demand for building purposes.

Local Geology of the Area

Naka Pabni (26 46'N; 60 31'E; toposheet No.35K.0) deposits are located between Korara Lak and Haji Lakar Karn to the Pab Range in Kirthar Province at 40 km. to the North of Karachi (Fig.1). These early Cretaceous shale contains barite [18]. The strata at the Pabni Naka levy port consist of argillaceous rocks of the Jakkar group that overlie the Pab sandstone. The argillaceous rocks are believed to be of Paleocene age [19] and the strata consist of thick sequence of dark-grey to black and greenish-grey to brownish-grey calcareous shale with the interbedded nodular limestone. Shale also contains nonduler of phosphorite. Shale in the Pab range is brown and sandy in Lakhi Range and Pale grey, white, pale green and maroon in the Axial belt (between Shinkai and Shinghar).

Stratigraphy at Pabni Chowki

Shale with interbedded limestone, Nisai Formation overlying Ranikot Formation consists of limestone, mart, shale with subordinate sandstone and conglomerate (Fig.2). Shale is grey-green maroon,yellow and brown usually calcareous in places, lateritic or carbonaceous, soft, earthy, flaky

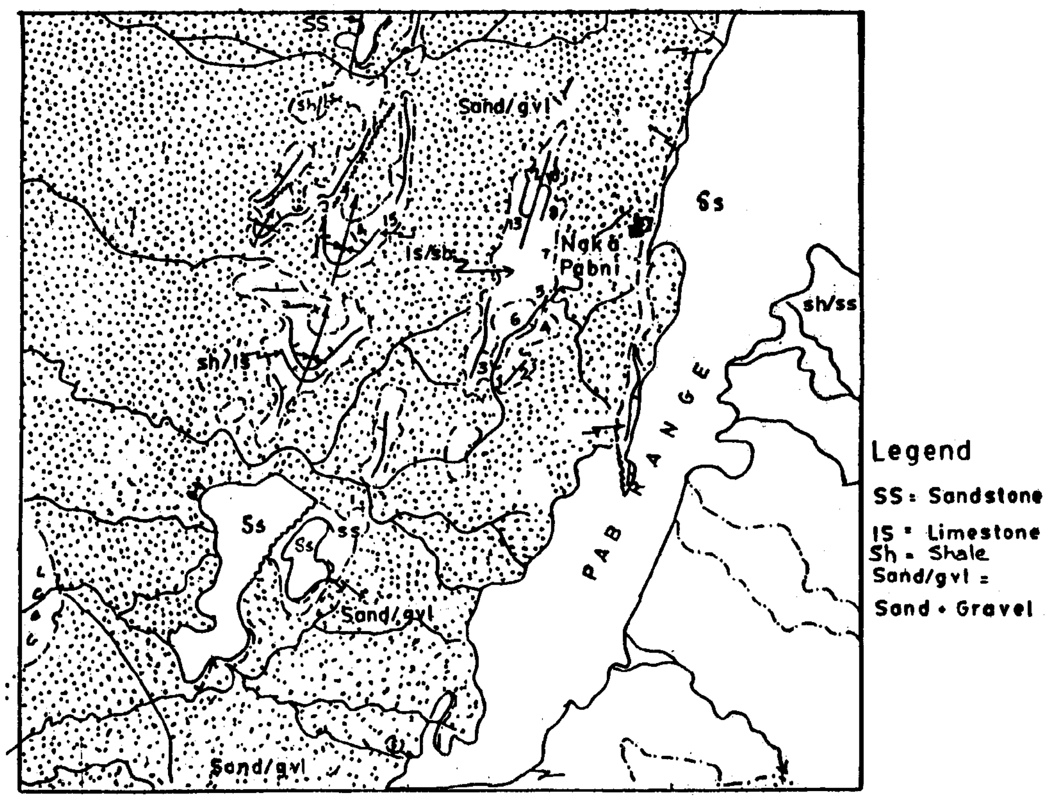

Fig. 1: Geological map of Noka Pubrange area and adjacent ports shwoing location of samples (Geological map No. 6, a colombo plan project).

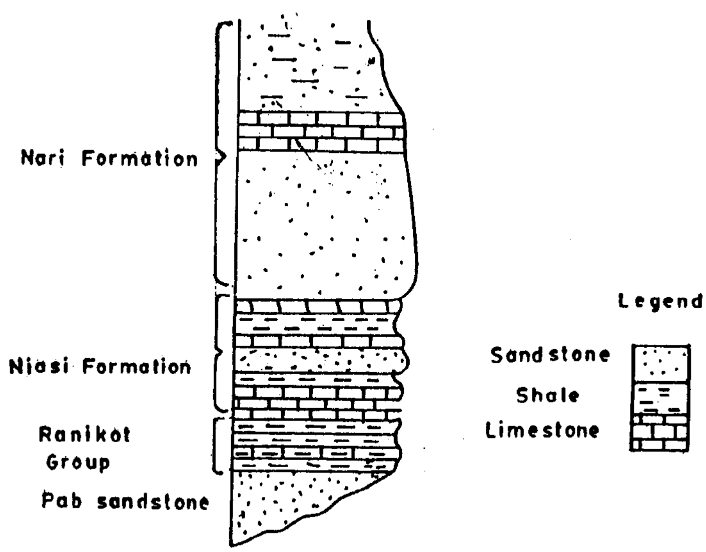

Fig. 2: Stratigraphy at Pobni Chowki (After, Ahmad, H, and Ghani, M.A. 1967)

Table-1. Chemical Composition of Shale from Naka Pubni Area (%).

Composition	1	2	3	4	9	10	11	12	13	14	15	16
SiO_2	38.5	39.8	40.5	42.8	60.8	49.2	57.5	51.6	37.1	37.0	39.9	40.2
Fe_2O_3	10.3	12.3	11.5	13.5	4.6	7.1	3.2	3.4	8.2	9.5	10.2	10.0
Al_2O_3	16.3	15.3	16.2	15.3	14.7	16.9	15.6	19.1	18.3	20.7	23.9	22.3
MnO	0.05	0.10	0.08	0.09	0.06	0.11	0.18	0.12	0.16	0.21	0.22	0.21
P_2O_5	0.37	0.46	0.43	0.47	0.14	0.14	0.18	0.15	0.73	0.46	0.70	0.65
TiO_2	1.8	1.8	1.9	2.3	0.97	0.79	0.98	0.84	2.1	2.1	2.6	2.4
CaO	12.9	11.0	11.1	8.0	3.3	4.5	4.1	4.0	10.4	8.3	4.2	4.4
MgO	1.8	2.5	2.7	3.0	3.3	4.6	4.7	4.8	5.2	5.9	5.6	5.6
Na_2O	0.20	0.39	0.46	1.20	2.25	2.49	2.42	2.41	0.77	0.71	0.99	1.03
K_2O	1.7	1.6	1.8	1.7	2.7	2.4	2.5	2.9	2.3	2.1	1.4	1.8
L.O.I	15.3	14.3	13.6	11.2	6.5	12.3	8.8	11.0	14.9	13.6	10.4	11.1
Total	99.4	99.6	100.3	99.8	100.3	100.6	100.1	100.3	100.2	100.5	100.1	99.7

to fissile and hard. Overlying it is Nari Formation in the Kirthar Range. It also consists of sandstone, shale and subordinate limestone.

Results and Discussion

Keeping in view the bloatability nature of the samples, only twelve samples were subjected to chemical analysis. Their chemical composition is presented in Table1, according to which SiO_2 ranges from 37-60 wt%, $Al_2O_3 + TiO_2$:15-26 wt%; Fe_2O_3; 3-13 wt%, alkaline earths (CaO+MgO) and alkalies (Na_2O+K_2O): 11-16 wt%; and loss on ignition: 6-15wt%.

It has been reported previously [20] that the bloating clay usually contains 6% or more of iron oxides and approximately 6% of alkalies and/or alkaline earth. A certain amount of free silica is also necessary. The Naka Pabni shale contains the required amount of chemical constituents needed for bloatability.Table 2 shows that most of the shale samples bloat at 1100°C. The lower bloating temperature of shale is due to its higher content of total alkalies and iron oxide with corresponding low fusion temperature.

Samples No.9,11 and 12 show discouraging result as these samples contain lesser amount of Fe_2O_3 (4.5%) and very high content of alkalies and alkaline earths. The average content of alkalies (Na_2O+K_2O) and alkaline earths (CaO+MgO) is about 13.2%. The higher alkali content causes fusion and stickness which is observed in these samples.

Samples No.1-4 and 13-16 according to their chemical composition are ideal for bloating. In these samples Fe_2O_3 content is 10.3-13.5 wt% and the

Table-2. Bloating Tests of Shale from Naka Pubni Area.

Sample No.	Optimum bloating temp.(°C)	Water absorption (%)	Bulk density lbs/ft^3 (kg/m^3)	Remarks
1	1150	3.90	37.4 (598)	High expansion, strong particles.
2	1150	4.71	25.5 (408)	High expansion, strong particles.
3	1150	6.68	23.1 (370)	High expansion, strong particles.
4	1100	7.22	29.6 (474)	High expansion, strong particles.
5	1100	8.37	16.0 (256)	High expansion, strong particles.
6	1050	36.48	20.0 (320)	High expansion, strong particles.
7	1100	9.13	13.7 (219)	Medium expansion, strong particles.
8	1100	48.20	8.1 (130)	High expansion, strong particles.
9	1100	3.83	58.6 (938)	No expansion.
10	1100	7.65	31.2 (499)	Medium expansion.
11	1150	2.76	(43.6) (698)	Medium expansion.
12	1150	4.21	27.5 (440)	Medium expansion.
13	1100	13.77	(19.0) (304)	High expansion, strong particles.
14	1100	6.02	37.0 (592)	High expansion, strong particles.
15	1050	18.41	15.0 (240)	High expansion, strong particles.
16	1050	15.43	12.5 (200)	Medium expansion, weak particles
17	1050	7.03	22.5 (360)	High expansion, strong particles.
18	1050	16.19	21.3 (341)	High expansion, strong particles.
19	1100	14.29	11.5 (184)	High expansion, strong particles.
20	1100	19.73	10.3 (165)	High expansion, strong particles.

combined alkalies and alkaline earths are about 13-16 wt%. These aggregates have sufficient amount of gas forming mineral fluxing and fusion agents. Further advantage of this type of clay for making bloated aggregates is that bloating occurs at comparatively lower temperature. As is observed in Table 2 on quick firing test, bloating starts at little over 1000 °C, consequently resulting fuel economy. Medium to good expansion with strong particle is resulted within a range of 1020°C to 1050°C. Samples 1,2,3,4,13 and 14 when subjected to quick firing test at higher temperature of 1100 °C or above, instead of bloating in a usual manner, sudden spurting and disintegration of particles is observed. The reason for this unusual phenomenon is the sudden evolution of enormous volume of gases. The chemical analysis of these samples shows a very high percentage of $CaCO_3$ and $MgCO_3$ resulting earlier evolution of gases before the fusion occurs to allow the gas bubbles to cause bloating. Therefore, the spurting action takes place.

Experimental

Collection of Samples

A total of twenty representative channel samples were collected from the shale deposits of the investigated area. Out of these, twelve samples were selected for chemical analysis. The sampling was carried out by making trenches of approximately 3 metres in length and 0.5 metre in depth.

Sample Preparation and Physical Tests

The following steps were followed in the sample preparation and other physical tests.

1. Each sample of the aggregate was broken into pieces with a diameter of 2-4 cm and thickness of 1-2 cm.

2 The small fragments were then divided into three equal sets after quartering and coning process. One set was used for chemical analysis and the other two sets were used for quick firing and other physical tests.

3. Quick firing test was performed on small pieces of shale (approx. 2 cm across) already dried at 110°C. The sample was then placed in a small muffle furnace preheated to 1000°C. The heating was continued for 20-25 minutes in which time an optimum temperature of bloating was determined to be between 1050°C to 1150°C

4. After firing the bloated sample was cooled, weighed and soaked in water for 24 hours in order to find out the absorption percentage.

5. For chemical analysis only twelve representative samples were selected. Each sample was ground to pass through 300 mesh sieve prior to its analysis by the established methods [21,22].

6. The optimum bloating temperature, % absorption, bulk density and chemical analysis of all the shale samples are given in Tables 1 and 2.

Conclusion

Test results indicate that shale of the Naka Pabni area can be bloated successfully at 1050°C and the resulting bloated material becomes considerably lighter than the conventional aggregate. The expanded aggregate is hard, highly cellular and has a tough skin and uniform structural strength. It is suitable for use in construction where weight saving, strength, chemical stability, thermal and moisture resistance and sound insulation are required. Very few samples showing weakness on bloating may be used as loose fill insulation material.

A similar evaluation for lightweight aggregate is recommended for other parts of the country and particularly in areas where natural aggregates are not available within easy reach. Such investigations should include geological mapping, channel and drill log sampling, chemical analysis, XRD, DTA, quick firing tests, rotary kiln evaluation, strength tests and cost estimation.

References

1. H.M.Carl, in Industrial Minerals and Rocks" Elsevier, NY. pp 85-96 (1984).
2. O.M. Clarke and M.E. Tyrrell, *Alabama Geol. Survey Circ.* 100, 1-35 (1976)
3. W.Kinniburgh, *Buil. Res. Station London*, 4, 1-9 (1969).

4. A Hasan, *West Pakistan Engg. Cong. Lahore*, **15**, 39-49 (1970).
5. M.Khan, N.A. Parker, *Geol. Survey Pakistan Rec.*, **20**, 1-17 (1970).
6. D.M.Shalman, *U.S Patent*, **9**, 809, 667 (1998).
7. D.M.Shalman, *U.S Patent*, **5**, 725,, 652 (1998).
8. C.E. Cornwel, *US Patent*, **5**, 824, 148 (1998).
9. Y.Shimizu, *Japan Patent*, **1**, 135, 356 (1999).
10. M.L. Nisnevich and B.I. Kompaneetz, *US Patent* **5**, 772, 751 (1998).
11. A.D. Shiltrina and V.M. Selivanov, *Izv. Vyssh. Vchebn. Zaved. Stroit.* (2) 53-56 (1998).
12. W.Yao and Y.Feng, *Feijin Shupkuang* **23** (I) 39-40 (1998).
13. K.Watanabe and S.Kawabi, *Japan Patent* **11**, 116, 357 (1999).
14. Y.Fan, S.Yin, X.Wu, J.Zhang, J.Zhong and Y.Keng, *China Patent* **1**,120, 525 (1996).
15. E.L. Didamong and M. Latfala, *Ind. Ceram.* **18** (2) 81-86 (1998).
16. A Hussain, M.A. Chaudhri, F.A.Siddiqui, and M.Z. Chughtai, *Geol. Survey Pakistan Rec.* **66**, 1-27 (1983).
17. R.A.K. Tahirkheli, *Geol. Bull. Univ. Peshawar*, **5**, 26 (1970).
18. Hunting Survey Corporation (1960). Reconnaissance Geology of part of West Pakistan (Pub. by Govt. of Canada). for Govt of *Pakistan Geol. Survey of Pakistan* Quetta page 410.
19. A.Zaki Record, *Geol. Survey Pakistan* **15**, Part 3, pp 57
20. T.A. Klinefelter in "Industrial Minerals and Rocks" AIMMPE, NY pp 487-495 (1960).
21. N.H. Furman, in "Standard Methods of Chemical Analysis" D.Van Nostrand Co. Inc., NY p 1 (1962).
22. A:Vogel in "Quantitative Inorganic Analysis", Longman, Green and Co., London (1951).