An Assessment of Aluminosilicate Refractories from In-Situ Deposits

by

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Abstract: It is possible to predict the behaviour of Aluminosilicates prior to its use in iron and steel practice. The methods adopted by the author comprise extraction of the material from bore holes, beneficiation and fabrication into suitable specimens for carrying out specific tests. Particular care was taken for the grog preparation, size grading, mixing and powder pressing prior to the heat treatment. In short, this paper summarises the test methods developed by the author to examine the grade of in-situ specimens, recovered from bore hole surveys.

The raw materials used in refractory manufacture need to fulfil five requirements, namely:

1. It must be available
2. It must have consistent composition
3. It must be a commercially competitive material
4. It must be chemically stable within its working environments
5. It must be thermally stable at its working environment.

It must also be stated that the techniques required to manufacture a refractory brick is an all embracing subject including a thorough study of the raw materials, fabrication routes and the firing techniques, with the ultimate aim of producing a brick suitable for the particular environment to which it is exposed.

The scheme shown in Fig. 1 for the assessment of refractory materials is highly beneficial to the third world countries, particularly where potential refractory materials are available and yet in those countries, the iron and steel industry is in its infancy. The route 11 of the scheme shows the testing of suitably fabricated materials under the influence of different types of hot metal without the need for a large scale refractory plant.

Some of the methods adopted are given below :

Experimental :

Bore hole survey for the recovery of samples

A hand auger is utilised for the withdrawal of in-situ samples from the three deposits which are located at Boralesgamuwa, Dediyawela and Meetiyagoda (off Ambalangoda). Fig 2.

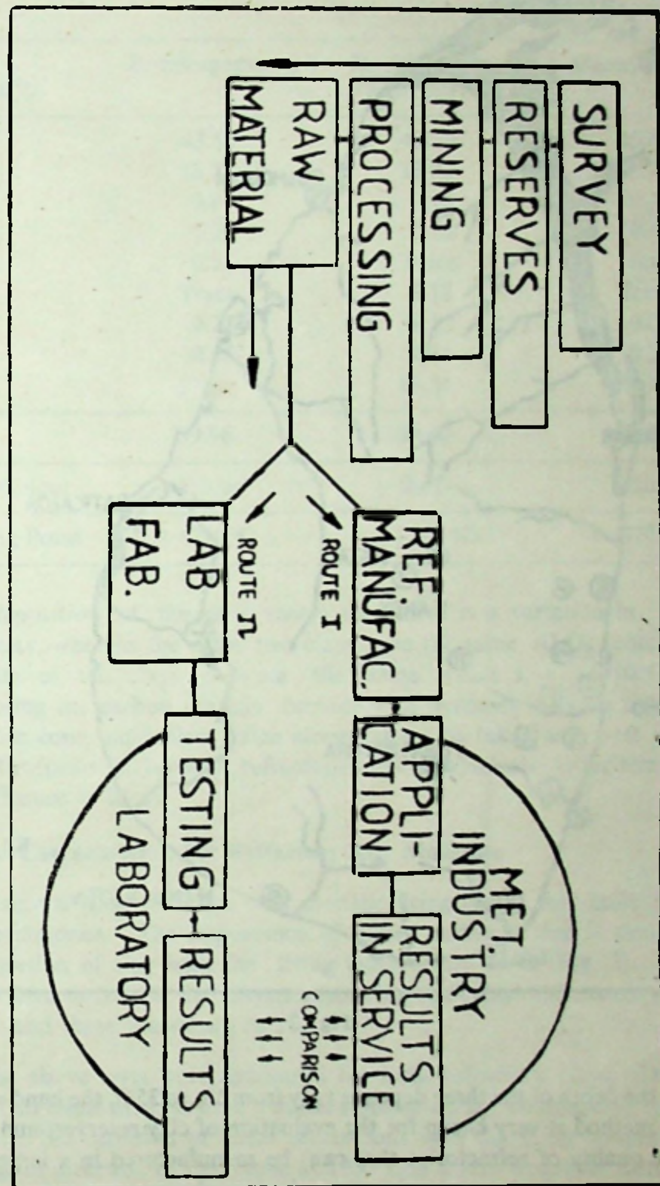

SURVEY
RESERVES
MINING
PROCESSING
RAW MATERIAL
ROUTE I
ROUTE II
REF. MANUFAC.
LAB FAB.
APPLI-CATION
TESTING
MET. INDUSTRY
RESULTS IN SERVICE
COMPARISON
RESULTS
LABORATORY

Fig. 1

MAP OF SRILANKA SHOWING MINERAL DEPOSITS & LOCATIONS OF PROCESSING PLANTS

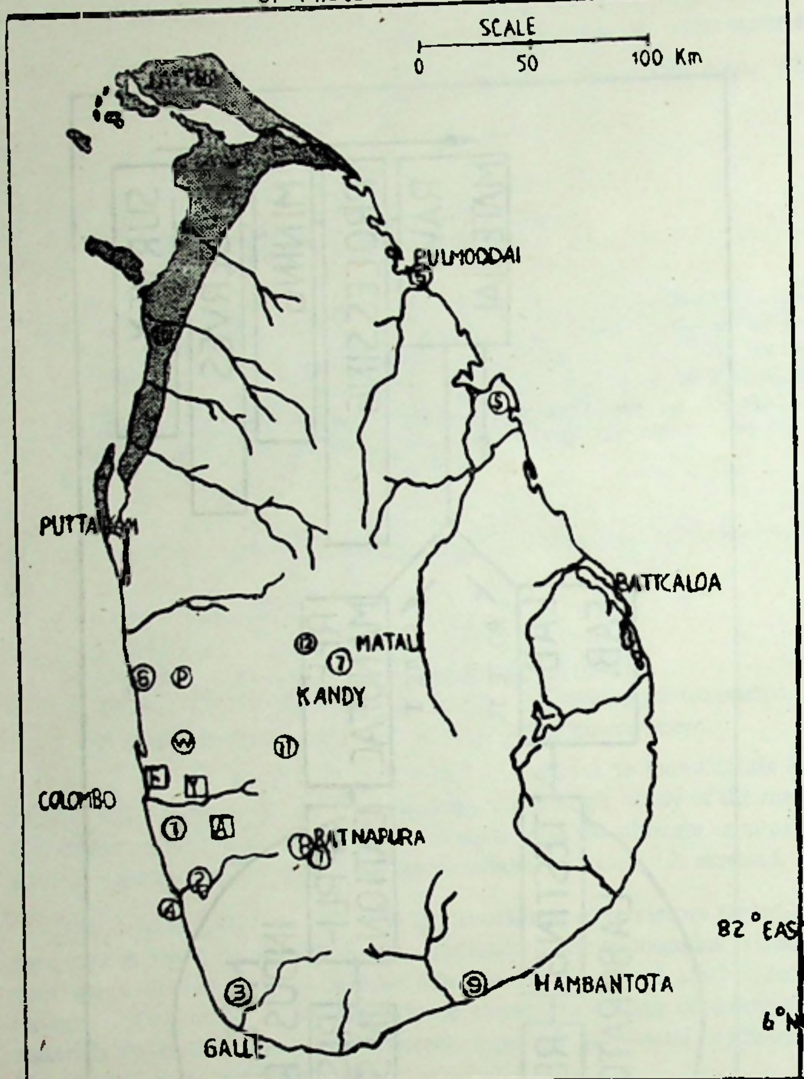


Fig 2

Since the depth of the three deposits vary from 2ft. to 35 ft, the hand-auger sample extraction method is very cheap for the evaluation of clay reserves, and above all to predict the quality of refractories that can be manufactured in a large scale plant. The laboratory methods pertaining to such an evaluation are not available in the literature probably due to the fact that this information is regarded as classified by refractory manufacturers.

Chemical Analysis

The chemical analysis is carried out on the clays, using the classical methods and the results are tabulated in Table 1.

TABLE 1

Constituent %	Boralesgamuwa	Dediyawela (Kalutara)	Meetiyagoda
SiO_2	43.60	49.73	45.46
Al_2O_3	38.22	33.02	38.77
TiO_2	0.85	0.16	0.79
Fe_2O_3	0.97	2.16	0.42
CaO	0.11	Trace	0.13
MgO	Trace	0.12	Trace
Na_2O	0.22	0.12	0.08
K_2O	0.16	0.75	0.29
L.O.I.	15.83	14.34	14.14
Total	99.96	100.40	100.08
Fired Colour	White	Buff	White
Melting Point	+1710°C	+1710 °C	+1710 °C

The composition of the clay shows that there is a variation in Al_2O_3 for Dediyawela clay, whereas the other two clays have the same Al_2O_3 content. The melting points of the clays indicate the same value i. e. 1710°C and is carried out using the carbon granule furnace with pyrometric cones as standards. The pyrometric cone equivalent value alone cannot be taken as a best method of assessment of refractories because, refractories fail at relatively lower temperatures, under the influence of loads.

Firing Curves Characteristics For Refractory Raw Materials

It has been shown[1] that there are characteristic firing curves for ladle brick and casting pit refractories. The importance of these curves is that it shows linear shrinkage variation of clay with the firing temperature as in (Fig. 3). Also, the firing curves characteristic for ball clays, engineering brick clays and excessive bloating are available, and these are shown in Fig. 4[2].

When the above tests were conducted for local refractory clays, Dediyawela clay indicated an interesting pattern, a pattern possessed by bloating clay types. The Fig. 5 indicates the variation of linear dimensions with the firing temperature. A sudden change in direction of the curve at 1250°C is a very desirable feature, particularly where the bricks have to be used in teeming ladles. This type of bloating effectively seals up the gaps between the bricks leading to a monolithic structure.

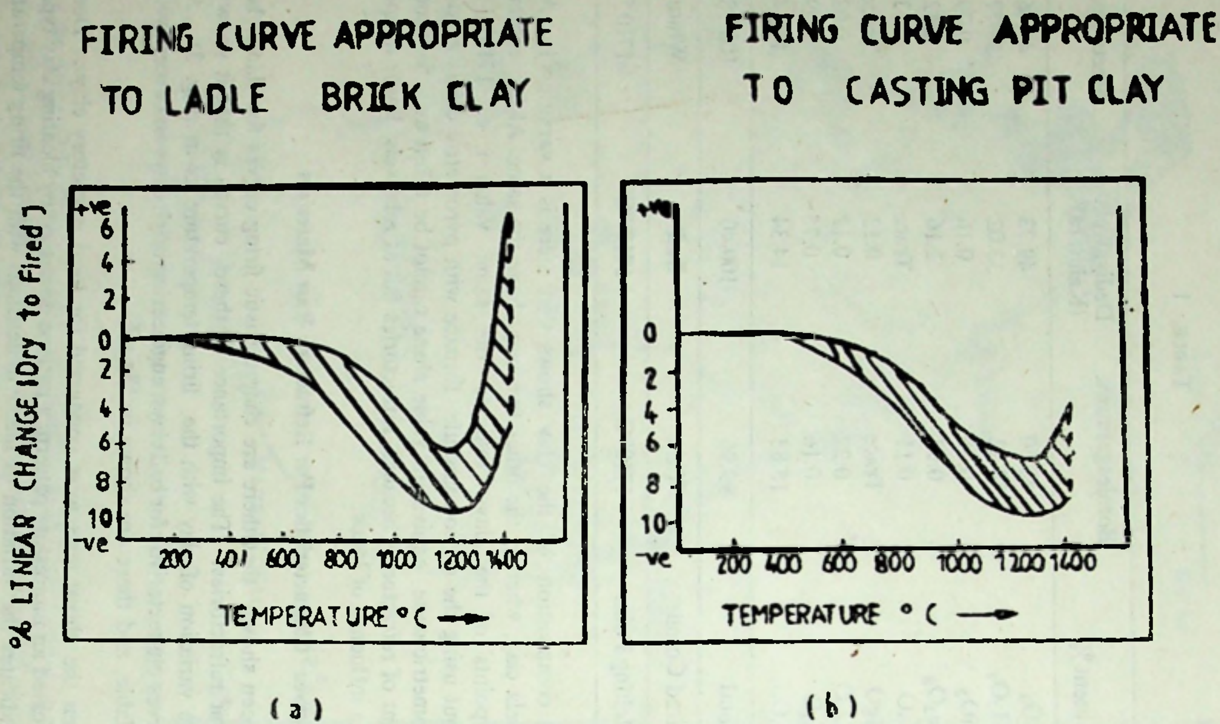

FIRING CURVE APPROPRIATE
TO LADLE BRICK CLAY
% LINEAR CHANGE (Dry to Fired)
+ve
6
4
2
0
2
4
6
8
10
-ve
200
400
600
800
1000
1200
1400
TEMPERATURE °C
(a)
FIRING CURVE APPROPRIATE
TO CASTING PIT CLAY
+ve
0
2
4
6
8
10
-ve
200
400
600
800
1000
1200
1400
TEMPERATURE °C
(b)

Fig. 3

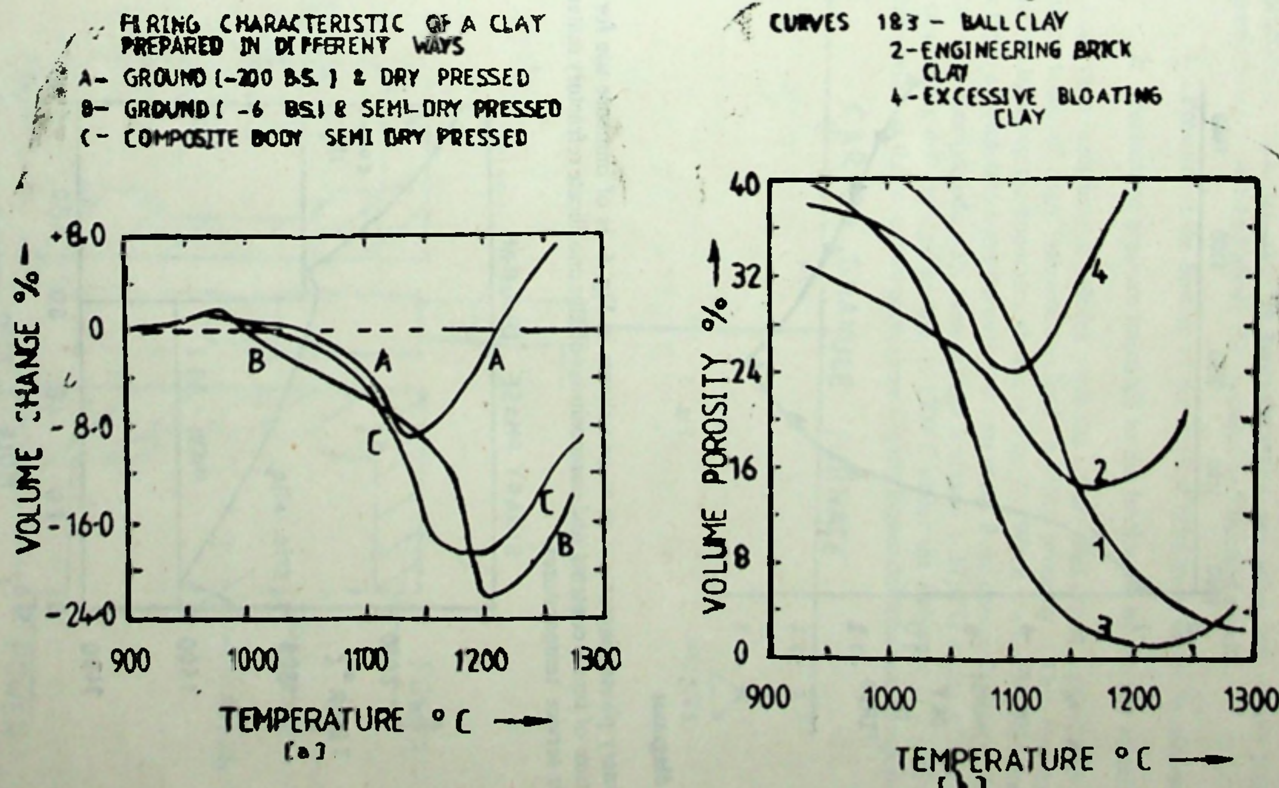

FIRING CHARACTERISTIC OF A CLAY PREPARED IN DIFFERENT WAYS
A- GROUND (-200 B.S.) & DRY PRESSED
B- GROUND (-6 B.S.) & SEMI-DRY PRESSED
C- COMPOSITE BODY SEMI DRY PRESSED
VOLUME CHANGE %
+8.0
0
-8.0
-16.0
-24.0
900
1000
1100
1200
1300
TEMPERATURE °C
(a)
CURVES 1&3 - BALL CLAY
2-ENGINEERING BRICK CLAY
4-EXCESSIVE BLOATING CLAY
VOLUME POROSITY %
40
32
24
16
8
0
900
1000
1100
1200
1300
TEMPERATURE °C
(b)

Fig. 4

SAMPLE - KALUTARA CLAY
VARIATION OF % LINEAR CHANGE (DRY TO FIRED)
WITH HEAT TREATMENT

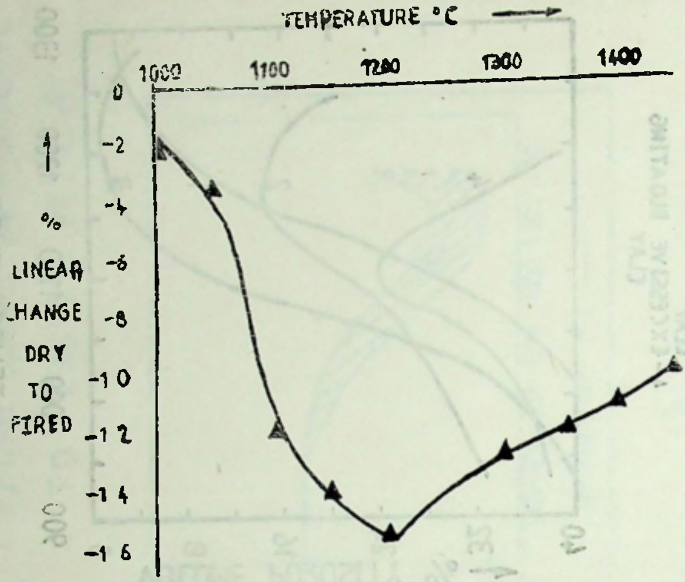


Fig. 5

Phase diagrams

The binary phase diagrams such as one shown in Fig. 6 is of immense use for the prediction of liquid contents and compositions of aluminosilicate refractory materials at their service temperatures.

BINARY PHASE DIAGRAM

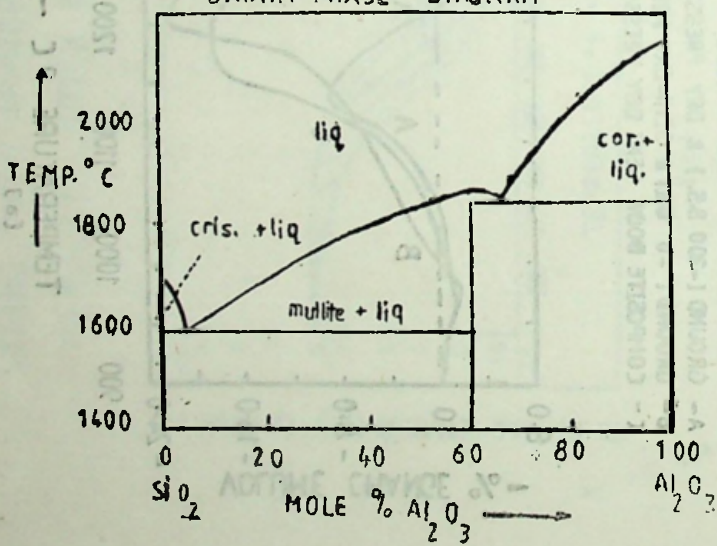


Fig. 6

Requirements of Clay based refractories in teeming ladles

In practice, refractories used in teeming ladles are subjected to the following mechanical forces over and above the chemical and thermal shock.

1. Pressure at the bottom of the stacked brickwork under its own weight.

2. Ferrostatic pressure imparted to the brickwork by the hot metal.

These can cause catastrophic failures while the refractories are in service, and hence the importance of high temperature load bearing property. This test can be conducted by using the apparatus shown in Fig. 7. When the test is conducted for three types of refractory clays the curves shown in fig. 8 are obtained. From this it is evident that Meetiyagoda clay, even though it shows + 1710°C in the refractoriness test, can in fact, deform significantly, at 1300°C under the influence of 2 Kgf/sq. in. pressure, whereas the other two clays show slightly higher deformation temperatures.

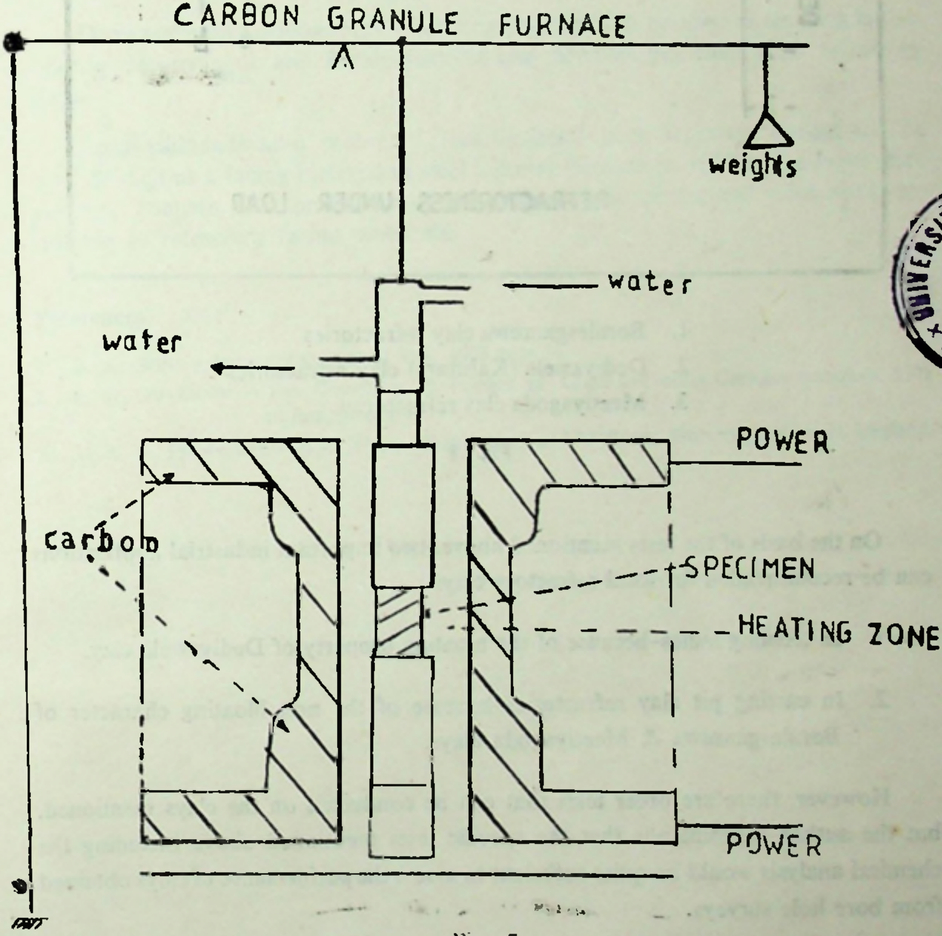
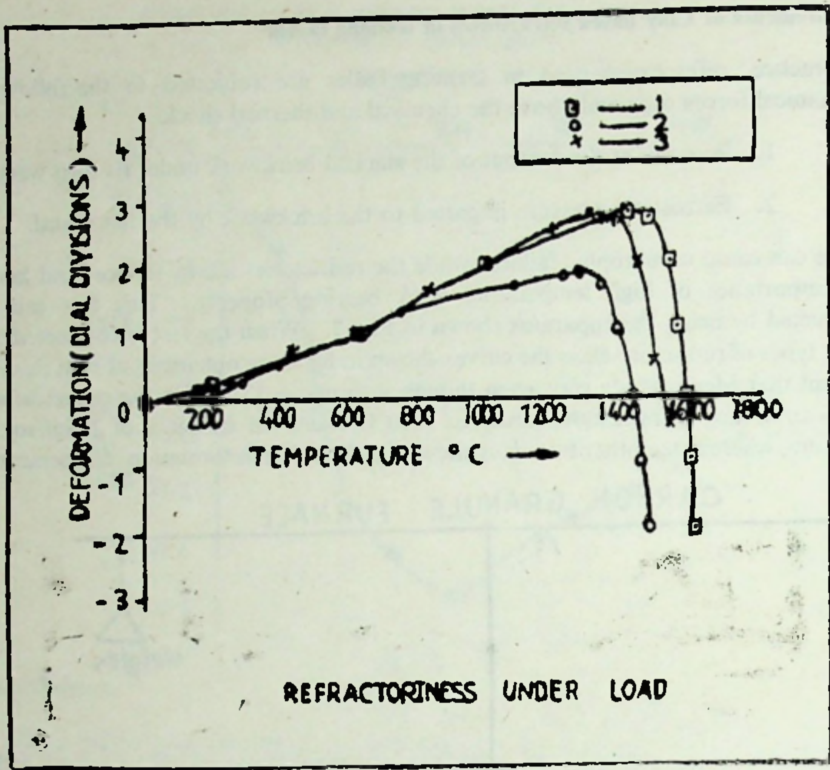


Fig: 7



1. Boralesgamuwa clay refractories
2. Dediyawela (Kalutara) clay refractories
3. Meetiyagoda clay refractories.

Fig. 8

On the basis of the tests mentioned above, two important industrial applications can be recommended for local refractory clays.

1. In teeming ladles–because of the bloating property of Dediyawela clay.

2. In casting pit clay refractories–because of the non bloating character of Boralasgamuwa & Meetiyagoda clays.

However, there are other tests that can be conducted on the clays mentioned, but the author recommends that the specific tests mentioned above including the chemical analysis would be quite sufficient to assess the performance of clays obtained from bore hole surveys.

The other refractory raw materials that are available in Sri Lanka are Silimanite sand and Zircon sand. Silimanite, in its pure form, has a high melting temperature (circa - 1850 °C), but the material obtained from the beach sand show an extremely low refractoriness probably due to the impurities present. Zircon sand (Beruwela) and Silica sand (Marawila) possess very good refractory properties, particularly when used as facing sands in foundry industry. The microstructure of the sand metal interface show multitude of fractures in silica sand grains, whereas Zircon sands show thermal decomposition due to the reaction $ZrSiO_3 - - ZrO_2 + SiO_2$ at the metal sand interface. The details of the methods are given elsewhere.[3]

Conclusion

The assessment of aluminosilicate refractory raw materials can be carried out on samples drawn out at various points in a refractory deposit. The tests such as load bearing capacity, refractoriness under load and the contact with hot metals play a very important role in such an assessment.

Dediyawela clay behaves like a bloating clay and can be used in teeming ladles, whereas Meetiyagoda and Boralesgamuwa clay behaves like casting pit refractory clays.

Local silimanite sand, recovered from the beach near Beruwala, should not be used as such as a facing material in steel industry because it vitifies at a lower temperature compared to pure silimanite, whereas local zircon and silica sands are suitable as refractory facing materials.

References:

1. B. Jackson — Refractories Journal Sept. 1978 page 14.
2. R. W. Grimshaw — The Chemistry & Physics of Clays and other Ceramic materials, 1971 edition, page 859.
3. W. L. W. Fernando — Ph.D. Thesis - Department of Metallurgy, University of Leeds, England.