Evaluation of clay samples for suitability for extrusion and production of REBs

Report prepared by

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Thiruvananthapuram

April, 2011

I. Characterisation of Clays

The physical properties of clays, which determine their commercial value, depend on whether or not the various types are admixed, what types of clays are present and their percentages, the percentage and composition of non-clay materials present, and other factors. Important physical properties are firing temperature, shrinkage or swelling percentage on firing, plasticity index, bloating characteristics, firing color, percentage of fines (slack) produced upon crushing, and fired strength. Many of the physical characteristics facilitate the successful moulding of the bricks and lead to good green strength during drying. The chemical constituents decide the strength of the fired bricks as well as the fired colour. Therefore, the selection of the clay is very significant in order to arrive at good quality bricks. The various methods of shaping decide the compaction efficiency and dimensional perfection.

On heating the brick clays, first the water present in the clays will escape, then the organic matter in the clays burn off, and further certain chemical changes take place at temperatures above 600^{o}C and finally the brick results in strength, colour and density at temperatures above 900^{o}C. In order to have these changes, the raw material should have high content of clay fraction, sufficient quantity of fine and coarse fractions in order to control the shrinkage and enhance the packing characteristics and sufficient content of iron compounds and fluxes in order to form a liquid phase to lead to high densities at reasonable temperatures.

II. Tests for selection of clays suitable for brick making:

A few properties are to be qualified before good quality clay is identified for bricks. The main properties are:

1. Slaking Nature: Clays are alumino silicates having layered structure and some clays when immersed in water will start shattering to smaller particles fast. On the other hand certain other types take long time to slake to powder. The former clays are called slaking clays and such clays are necessary for wet shaping since the clay lumps can get easily broken to smaller particles. These small particles will be able to pack themselves during molding to provide good strength. Those clays which can slake very fast are also not advisable, since such clays may contain non clay materials such as sand, silt or other minerals.

2. Particle size distribution: The natural clays are fine particles which will have also large particles of various constituents such as sand, calcium salts and hard rock like particles. By passing a sample of clay through a set of sieves of defined mesh size, it is possible to find the percentage of fine particles and this has to be above 70% for further shaping to bricks and blocks. Coarse clay will not be good for shaping and such bricks will have low strengths. The sieves are of standard mesh size and by passing defined quantity of clay through the set of sieves and taking weight of the various fractions; it is possible to find out the distribution of particles. A specimen sample from the raw material stock can be analysed. Usually the fraction passing through the finest sieve (350 mesh) should be above 70%, preferably above 80%. For further detailed distribution of the fine particles present in a typical clay sample, sophisticated instrumental techniques are used such as the Malvern/ Cilas laser particle size analyser. Figure provided below provides set of sieves used in the laboratory. On the right side, the sieve analysis procedure is demonstrated to industry representatives.

Fig 1. Set of sieves to analyse for the particle size distribution of clay raw material.

3. Plasticity: The exclusive quality of clays is the capacity to wet with water and result in a formable mass at the right amount of water and then undergo drying when the solid mass will gain sufficient strength for handling. There are many factors which control the plasticity such as the chemical constitution of clay, the physical nature, presence of impurities, fineness, presence of organic content and absence of large quantity of free silica. The plasticity of a clay can be judged by a simple method of taking a piece of clay and wetting with water and roll within the palm of the hand when the clay should form a non breakable solid cylinder or a regular shape like a ball can be dropped to the earth to find the extend of deformation. If the clay ball deforms easily and completely, it is less plastic. A plastic mass will retain the shape to a large extent. Technically the plasticity of clays can be determined systematically by two methods, using Atterberg apparatus or Pfefferkorn index apparatus. These equipments will measure the plasticity rather on a scale which can be classified for the clay for use in brick making, tiles, hand moulding, extrusion forming or plastic forming. Further, the maximum and minimum water needed by clay for forming to shapes can be determined from these measurements.

Fig 2: Pfefferkorn Index Apparatus.

25 mm diameter and 40 mm high cylindrical samples are made from clay containing different percentage of water and are subjected to the pressure from the calculated height in the apparatus. The extent of deformation from 40 mm is measured and from the deformation – water demand curve, the optimum clay composition and water demand are calculated. Usually a number >23 is good for making bricks while for extrusion for tiles, index as high as 30 or above is used. For making bricks by hand molding, plasticity index as low as 18 is also employed, although variations in size and strength is quite common in such case.

4. Drying Shrinkage: The selection of clay is most important in order to obtain a composition which will have low shrinkage during drying and this avoids many defects in the shaped body such as warping, crack development, low strengths and fired properties. In order to control the shrinkage, often blending of various clays is done. Sometimes addition of fine sand is also done. A plastic clay mass will be blended using sand or coarse clay or sometimes burnt clay. Therefore the drying is dependent on factors such as homogeneous mixture of fine raw materials and presence of non plastic materials. A shrinkage less than 10% is recommended for bricks and tiles.

5. **Firing of clays:** The dried clay body is fired for obtaining high strength, stability and brick red colour. Many changes take place during firing such as evolution of water vapour present in clays, burning of organic matter, chemical constitutional changes and formation of new compounds which are stable at high temperatures. The optimum firing temperature is determined by following the high temperature dilatometric (shrinkage/ expansion) properties. It is necessary that the clay once fired at optimal conditions, should attain the required properties as per standards, in order to qualify it for a good raw material.

6. **Red burning clay or Brick/tile clays**

Red burning clay or potter's clay constitutes a mixture of iron oxide, alumina ($Al2O3$and kaolinite along with quartz. This clay is obtained as overburden on the surface of paddy field and hence, contains free silica content high and iron oxide presence is responsible for the color of the clay. Red clay is suitable for the manufacture of heavy clay products, such as building and paving bricks, terracotta tiles, and sewer pipes and has been utilized for many years. To manufacture heavy clay products, the natural material must possess certain working and drying properties, the most important include plasticity when wet, little shrinkage when drying and being fired, and good strength as both a green (unfired) and fired product. The fired color of the clay is important to both the consumer and manufacturer. Building-brick/tile clay that fires white may also be developed commercially by the addition of various minerals; the color may be modified to meet whatever is popular among consumers. Clay comparable in size and clay quality that fires to a red to orange color is commercially suitable for the brick and terracotta tiles industry

7. Details of the work carried out on the clays collected - (Identified by NIIST and jointly collected by PSCST and TERI)

Sample description:

Sample 1: Ghaziabad-1

Sample 2: Derabassi -1

Sample 3: Derabassi -2

Sample 4: Ludhiana -1

Sample 5: Ludhiana -2

Sample 6: Jalandhar-1

Sample 7: Jalandhar -2

Sieve Analysis:

These clay samples were yellowish grey in colour and were red burning. They were moderate in slaking and fine in texture. The sieve analyses of the samples were carried out in wet condition and the results are provided below. The analysis is done by passing a suspension of 100 g clay in fixed quantity of water and this suspension is passed through set of sieves. The fractions separately are collected. It can be seen that except sample 5 and 7, all samples have finer sizes (<45 microns) above 70%. Sample 7 has very coarse portion above 25% and therefore such clays need further processing or blending. In general the clays investigated are fine in nature.

SIEVE ANALYSIS OF CLAY SAMPLES

Sl No.	*Sieve Size*	*Sample 1 % weight)*	*Sample 2 % weight)*	*Sample 3 % weight)*	*Sample 4 % weight)*	*Sample 5 % weight)*	*Sample 6 % weight)*	*Sample 7 (% weight)*
1.	*+30 mesh*	*0.4*	*0.6*	*0.6*	*0.5*	*0.7*	*12.5*	*1.3*
2.	*+30+ 100 mesh*	*4.3*	*3.7*	*8.3*	*4.9*	*9.9*	*3.1*	*29.8*
3.	*-100 + 200 mesh*	*9.3*	*10.5*	*11.6*	*10.1*	*15.6*	*3.4*	*10.0*
4.	*-200 + 350 mesh*	*11.4*	*7.2*	*8.8*	*9.6*	*9.6*	*3.0*	*5.2*
5.	*Total*	*25.4*	*22.0*	*29.2*	*25.2*	*35.8*	*21.9*	*46.3*
6.	*-350 mesh*	*74.6*	*78.0*	*70.8*	*74.8*	*64.2*	*78.1*	*53.7*

Plasticity of the clays:

The plasticity index of the various clay samples investigated are provided below. The highest index is for the clay number 6 while the other clays have in between 21 and 28. A higher plasticity index is advisable for favourable extrusion and also moulding of composite high plasticity and good slaking nature are most important to fabricate shapes by extrusion. Water of plasticity, also an important parameter for easy extrusion, can also be determined for the type of clays. Similarly, optimum water content facilitates the extrusion.

Pfferkon Plasticity Index

Sl No.	Samples	Plasticity Index Number
1	Sample 1	21
2	Sample 2	23
3	Sample 3	19
4	Sample 4	21
5	Sample 5	20
6	Sample 6	28
7	Sample 7	19

Percentage water of Plasticity

Sl No.	Samples	% water of Plasticity
1	Sample 1	22
2	Sample 2	25
3	Sample 3	23
4	Sample 4	23
5	Sample 5	22
6	Sample 6	32
7	Sample 7	21

Loss on ignition:

The loss which happens when clay is heated over a range of temperatures is an important parameter to decide on the total shrinkage of the shaped body or also the densification of the clays. The ignition loss may be due to the organics present in clays or due to certain constitutional changes which may happen in the clay. An ignition loss of less than 10% is an important feature necessary for the clays. The present clay samples have much less than 10% and there fore the clays do not contain much of organics. How ever, too low ignition loss means that the clay can contain higher quantities of free silica. Or in other words, the clay content in the raw material may not be adequate. This will be a parameter which decides the firing temperature.

Loss on Ignition

Sl No.	Samples	Loss on ignition (%)
1	Sample 1	5.09
2	Sample 2	6.07
3	Sample 3	4.3
4	Sample 4	4.2
5	Sample 5	4.31
6	Sample 6	7.52
7	Sample 7	4.20

Shrinkage features:

Control on the Shrinkage of the clays after moulding to bricks/ hollow sections is most important in aesthetics as well as dimensional tolerance. Every effort is made in industry for shrinkage less than 10%. The analysis of the clays for loss on ignition indicates that the clays have much less organics, and therefore, could not have the burden of large shrinkage parameters.

Physical properties of the clay samples
(Firing temp. 1000°C)

Sample No	Wet to dry %	Dry to Fired %	Total %
Sample 1	6.1	2.2	8.3
Sample2	7.3	3.8	11.1
Sample 3	5.8	1.3	7.1
Sample 4	6.0	1.4	7.4
Sample 5	5.4	1.1	6.5
Sample 6	7.7	4.9	12.6
Sample 7	5.5	1.1	6.6

Compressive strengths (Cold crushing strength) :

The final test of any clay raw material is the strength of the fired clays. Since actual size extruded blocks could not be made in the laboratory studies, the tests were conducted on solid blocks of size 50 mm x 50mm x50 mm. All shaping, drying and firing conditions were maintained as in the case of hollow or perforated blocks. The strength determination was done following the usual procedures. The cold crushing strengths were quite satisfactory and the firing did not result in problems such as crack formation, warping or efflorescence. All the samples qualified the tests. Sample 6 was exceptionally good with highest strength. This is justified due to the fineness of the clay and also the good plastic characteristics.

Cold crushing strength on blocks 50mmx50mmx50mm

firing temp. 1000°C

Sample No.	Crushing strength, Kg/cm2
1	89
2	197
3	93
4	126
5	85
6	315
7	89

Extruded blocks:

In order to see the technical feasibility of the clays for making REBs, samples were actually extruded through a laboratory extruder, keeping the conditions near identical to the commercial situations. Due to inadequate facilities, only laboratory model prototypes were made, which has size scaled down from the actual commercial size, recommended by Indian Standards. The properties will be nearly representative in the laboratory samples compared to actual sizes. The water of plasticity and plasticity index were optimised, the drying parameters were controlled and the firing was done in an electric furnace under oxidising conditions. Brick red coloured extruded blocks could be obtained without any defects and this demonstrates the feasibility of the clays under investigation for making extruded blocks. Of course, there is variation in the strengths and the extrusion characteristics, with sample 6 and sample 2 being the best of the lot. In specific cases of commercial implementation large scale testing of representative raw material may be necessary on specific samples in order to decide the engineering parameters. However, these tests provide a reasonable indication on the possibility of using the respective clays for machine made extruded blocks on commercial scale.

Fig: 3 Extruded Blocks

Conclusions from the evaluation

1) The clays selected for evaluation have particle size distribution, 60-70% less than 45 microns.
2) The clays have plasticity index in the range 20-28, and is just reasonable.
3) The clays in general contain high silica content and hence requires 1000°C or higher, for firing
4) Total Shrinkage is within limits <10%. An expansion of 2-3% is seen in all clays when fired in the range 600-800°C. Bentonite clay is present as an impurity.
5) The fired strengths on solid blocks made out of the clays are above standards and colour is brick red and is quite acceptable
6) Suitable blending and mixing is recommended for improvement in properties.