CHAPTER V

UTILIZATION AND BENIFICIATION POTENTIAL

Owing to some important intrinsic properties of the ball clay, notably, high degree of plasticity and high dry strength; low dry shrinkage; white- with exception of some red-burning, the ball clay is therefore an established and integral part of ceramic industries. Generally, the ceramic product can be classified into 2 main categories, namely, the "high-value" ceramics, and the structural clay products. The "high value" ceramics include earthenware, porcelain or chinaware, stoneware, sanitary ware, wall and floor tiles, refractory, and electrical insulator. The structural clay products embrace brick, roof tile, and etc. Besides, lower grade ball clay is increasingly finding applications as sealing materials for landfill waste disposal sites.

At present, the Mae Than ball clay has been commercially exploited for ceramic industries, i.e. sanitary ware, wall and floor tiles, porcelain, and electrical insulator. For the whiteware manufacturing, the essential properties of clay used are its workability, plasticity, and ability to be white burning to give a clean body. To obtain the best properties, ball clay and china clay are usually mixed together in blends to attain the optimum combination required for the specific type of whiteware. Commonly, the ceramic ware composition in terms of ball clay weight per cent of total solids are as follows : sanitary ware 20 to 30 per cent, wall and floor tiles 30 per cent, electrical insulator 30 per cent, and porcelain or chinaware 10 per cent.

In order to determine the appropriate utilization of ball clay, a number of important properties must be taken into consideration. These properties are : chemical compositions, grain size distribution, modulus of rupture, fired shrinkage, water absorption and loss on ignition.

Chemical compositions

Aluminum oxide (Al_2O_3)

The alumina content of the ball clay is essentially important in the refractoriness and vitrification of the ceramic end products. The higher the alumina content gives rise to the higher refractoriness as well as the higher vitrified temperature. In general, the alumina content of the ball clay varies between 17 to 36 per cent with an average of 30 per cent.

The Mae Than clude ball clay has the alumina content between 19 to 25 per cent with an average of 21 per cent, whereas the -45 micron grain size fraction contains approximately 19 per cent alumina, and the -2 micron fraction contains approximately 26 per cent alumina. Upon comparison of alumina contents of the ball clay from the Mae Than basin with those from Devon and Dorset of England, there are compatible (Fig. 5.1).

Silicon dioxide (SiO_2)

The silica content in the ball clay represents both the free state of crystalline quartz and the constituent of clay minerals. The effects of free silica are a reduction in plasticity, drying and firing shrinkage, fired strength, refractoriness and increased in thermal expansion.

Generally, the total silica content of the ball clay varies between 47 to 69 per cent with an average of 55 per cent. The total silica content of the Mae Than crude ball clay varies between 70 to 77 per cent with an average of approximately 74 per cent. In addition, the -45 micron grain size fraction contains approximately 71 per cent silica, and the -2 micron fraction contains approximately 61 per cent silica.

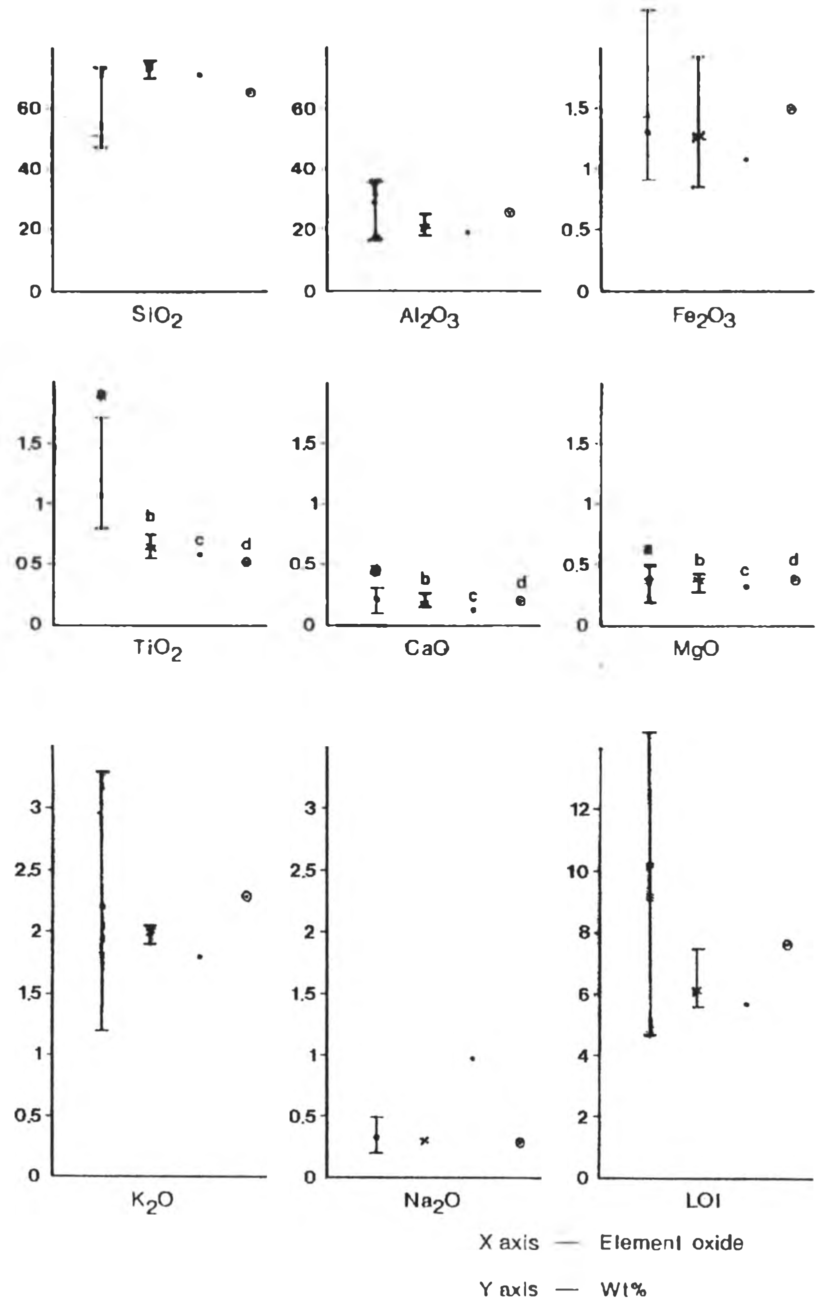

Fig. 5.1 Each major element oxides and loss on ignition (LOI) plots of the Mae Than crude ball clay, -45 micron and –2 micron size fractions compared with the English ball clay. (a : the English ball clay, b : the Mae Than crude ball clay, c : -45 micron size fraction, d : -2 micron size fraction)

Upon comparison of the total silica contents of the ball clay from the Mae Than basin with those from Devon and Dorset of England, it is noted that the total silica content of the Mae Than ball clay is slightly higher (Fig. 5.1).

Total iron oxides (Fe_2O_3)

The total iron oxides of the ball clay are derived from several varieties of iron oxides, sulfides, carbonates, hydroxides, and silicates, i.e. magnetite, hematite, goethite, pyrite, siderite, and etc. (Lawrence and West, 1982). The iron oxides are very susceptible to oxidation-reduction reactions, and the effects of ferric oxide and ferrous oxide are very different. The ferric oxide is red in colour and is responsible for the various shades of the red coloration (Lawrence and West, 1982).

Generally, the total iron oxides of the ball clay vary between 0.9 to 2.3 per cent with an average of 1.3 per cent. The Mae Than clude ball clay has the total iron oxides between 0.84 to 1.92 per cent with an average of 1.29 per cent, whereas the -45 micron grain size fraction contains approximately 1.09 per cent the total iron oxides, and the -2 micron fraction contains approximately 1.50 per cent the total iron oxides.

Upon comparison of the total iron oxides of the ball clay from the Mae Than basin with those from Devon and Dorset of England, it is apparent that they are compatible (Fig. 5.1).

Titanium oxide (TiO_2)

The titanium oxide content of the ball clay is essentially contributed from the mineral anatase, TiO_2. The presence of titanium causes the yellow coloration of the ceramic end products.

Generally, the titanium oxide of the ball clay vary between 0.8 to 1.7 per cent with an average of 1.2 per cent. The Mae Than crude ball clay contains titanium oxide between 0.53 to 0.72 per cent with an average of approximately 0.62 per cent, whereas the -45 micron size fraction contains 0.58 per cent titanium oxide, and -2 micron fraction contains 0.50 per cent titanium oxide.

Upon comparison of titanium oxide content of the Mae Than crude ball clay with those from Devon and Dorset of England, it is interesting to noted that the Mae Than crude ball clay has exceptionally lower content (Fig. 5.1).

Alkalies and Alkaline-earths compounds
(Na_2O, K_2O, MgO, and CaO)

Alkalies and alkaline-earths compounds are usually associated with alumina compounds and have great effects on properties. Feldspars, micas or hydrous micas are the principal alkaline-bearing accessory minerals. Alkalies and alkaline-earths may be present as a result of adsorption of these ions on the surface of clay minerals. Alkalies also occur in clays as soluble salts, such as, sulfates and chlorides, whereas, alkaline-earths are the constituent of illite and montmorillonite.

Alkalies and alkaline-earths have the strong fluxing action and therefore reduce the refractoriness and vitrified temperature of the clays. Besides, the presence of alkalies may change the plastic property of the clays, especially, if they are soluble alkalies. A clay containing alkalies will not be as plastic as one without it. It will not retain its shape after forming.

Upon comparison, the contents of alkalies and alkaline-earths of the Mae Than crude ball clay with those from Devon and Dorset of England, it is interesting to noted that they are very compatible indeed (Fig. 5.1).

Grain Size Distribution

The grain size distribution of the ball clay can be reported either by the weight percentage coarser or finer than specific grain size diametre, i.e., +125 micron, +53 micron, -5 micron, -2 micron, -1 micron, and -0.5 micron, or by the weight per cent of the residue on sieve, i.e., 120 mesh, 200 mesh, and 325 mesh.

Generally, the grain size property determines the plasticity and the requirement for grinding of the ball clay for specific utilization. In almost all cases, the finer the grain size, the higher plasticity is obtained.

Upon comparison of the grain size distribution of the Mae Than crude ball clay with those from Devon and Dorset of England, it is noted that the coarser particle sizes are compatible, but the finer particle size of the Mae Than ball clay is inferior to those of the English ball clay (Fig. 5.2).

Modulus of Rupture

The modulus of rupture of a ball clay is defined as the value of the maximum transverse stress at fracture in a three points test for cylindrical bars produced and tested under the specified condition.

Ball clays are noted for their high dry strength, which is why they are used in pottery bodies and to a small extent in vitreous china. The dry strength of the ball clay, commonly defined as the modulus of rupture, depends on the proportion of "clay substance", on its fineness, on the exchangeable cations, and on the amount of the organic matters present.

Upon comparison of the modulus of rupture of the Mae Than crude ball clay with those of the English ball clay, it is apparent that the modulus of rupture of the Mae Than ball clay is much inferior to the English ball clay (Fig. 5.2).

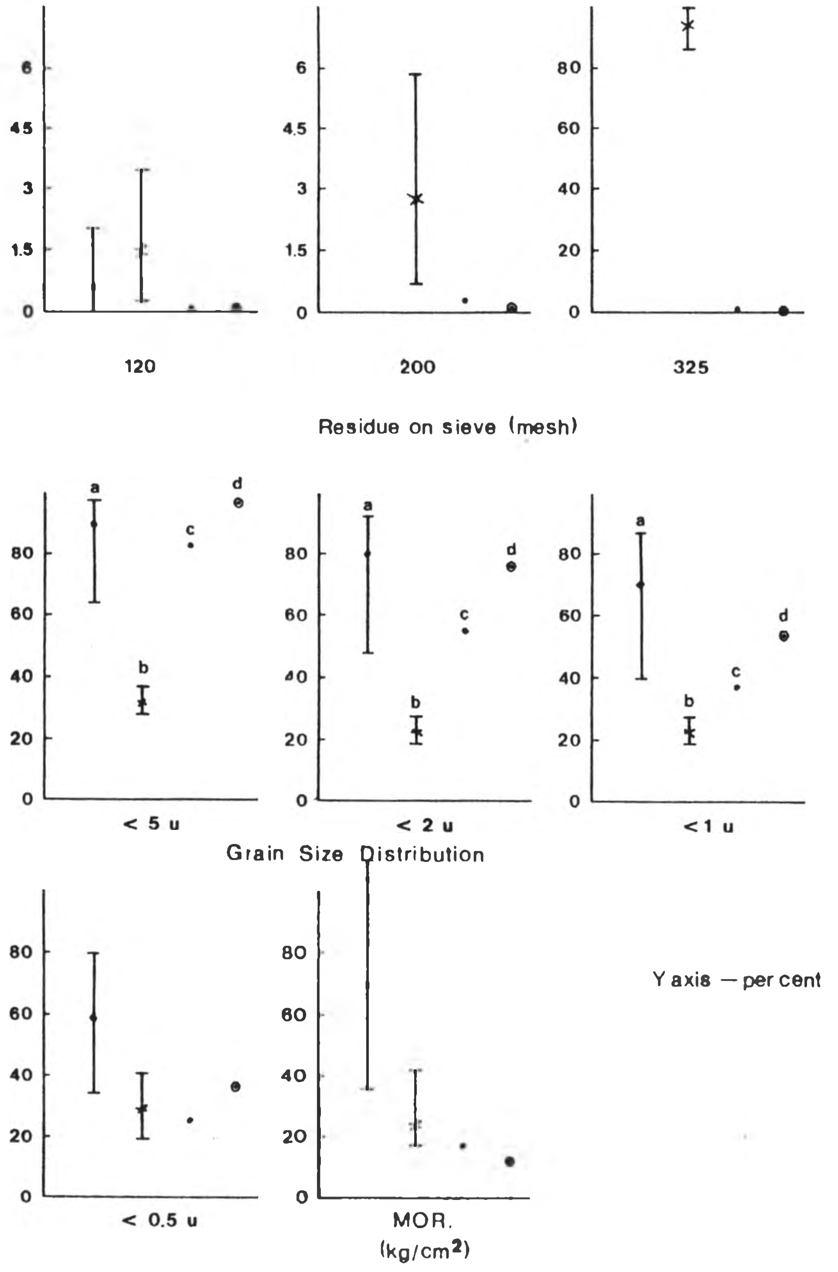

Fig. 5.2 Grain size distribution of the Mae Than crude ball clay, -45 micron and –2 micron size fractions compared with the English ball clay. (a : the English ball clay, b : the Mae Than crude ball clay, c : -45 micron size fraction, d : -2 micron size fraction)

Contraction

Contraction is the percentage decrease in diametre during firing. This property determines the molding of the raw materials for ceramic industry to be appropriated with the designed dimension. The higher the fired shrinkage means the higher content of the finer particle size.

Almost all the Mae Than ball clay samples show that the fired shrinkage falls within the compatible range with the English ball clay from those Devon and Dorset (Fig. 5.3).

Water Absorption

Water absorption after firing at a specified nominal temperature is defined as the weight percentage of water adsorbed by a test piece, produced using the specified method, when soaked under vacuum.

The water absorption after firing directly reflected the permeability and porosity of the ceramic end products and the vitrified temperature of the ball clay. The higher water absorption means the higher permeability and porosity as well as the higher vitrified temperature.

The Mae Than ball clay shows the relatively lower water absorption as compared with those of the English ball clay from Devon and Dorset. This is the superior property of the Mae Than ball clay (Fig. 5.3).

Loss on Ignition

The loss on ignition content of the ball clay embraces the organic carbon, the carbonate carbon, the total water, and the total sulfur. The loss on ignition of the ball clay indicates the weight loss upon firing between 100°C to 1,000°C.

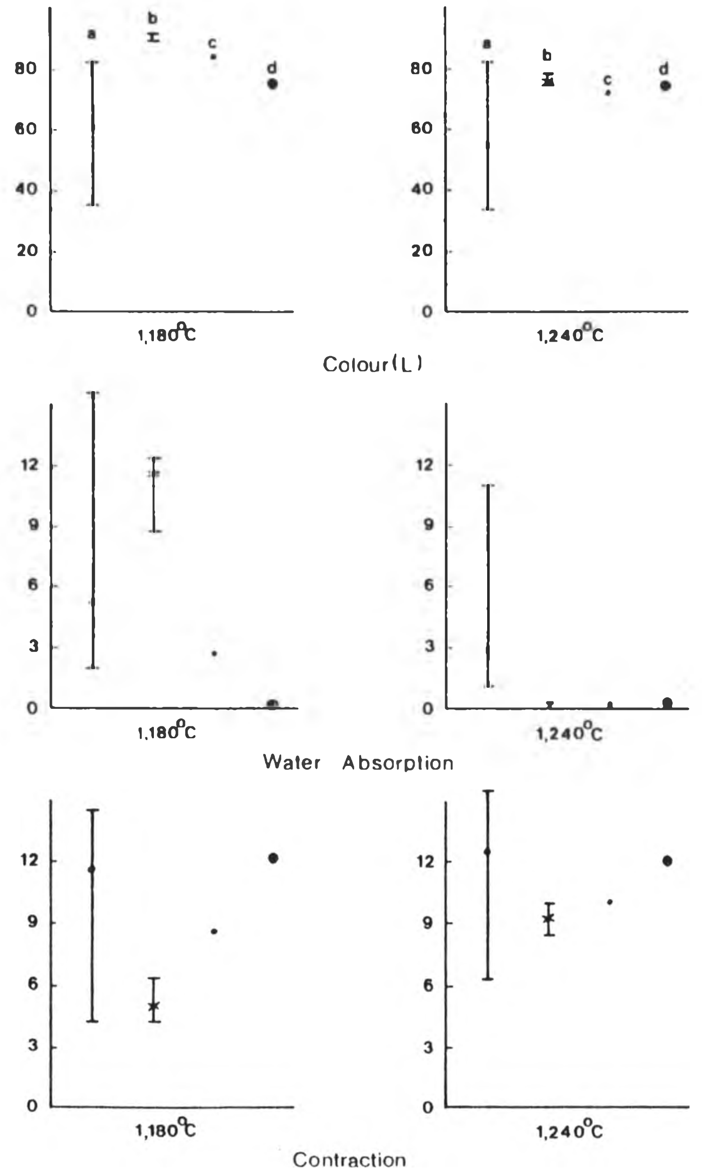

Fig. 5.3 Some physical properties of the Mae than crude ball clay, -45 micron and –2 micron size fractions compared with the English ball clay. (a : the English ball clay, b : the Mae Than crude ball clay, c : -45 micron size fraction, d : -2 micron size fraction)

Generally, the loss on ignition of the ball clay varies between 4.7 to 14.5 per cent with an average of 10.24 per cent. The Mae Than crude ball clay contains the loss on ignition between 5.6 to 7.5 per cent with an average of approximately 6.1 per cent, whereas the -45 micron size fraction contains 5.73 per cent the loss on ignition, and the -2 micron fraction contains 7.75 per cent the loss on ignition (Fig. 5.3).

In order to conduct the utilization potential study of the Mae than ball clay, and attempt has been earlier made to compared the important properties of the Mae Than ball clay with the commercialized "world class" English ball clay from Dorset and Devon. The following conclusions are reached on the assessment :

a) With respect to the chemical composition, the Mae Than ball clay are inferior in the too high the SiO_2 content, moderately low in the Al_2O_3 content, compatible in the Fe_2O_3 content, and moderately low in the loss on ignition. However, the Mae Than ball clay has the superior quality with respect to relatively low the TiO_2 and alkalies contents.

b) Regarding the grain size distribution pattern of the Mae Than ball clay, it is noted that the coarse-grained fraction above 325 mesh is slightly high to too high, whereas the fine-grained fraction below 325 mesh is too low. These are the inferior quality.

c) The dry strength in terms of the modulus of rupture of the Mae Than ball clay is too low, and is apparently another inferior property.

d) The fired shrinkage of the Mae Than ball clay is moderately low, and is considered to be the superior property.

e) The water absorption of the Mae Than ball clay is considered to be relatively compatible.

The comparison of some important properties of the Mae Than ball clay and English ball clay are summarized in Table 5.1.

Considering the utilization and beneficiation potential of the Mae Than ball clay as assessed from some important properties for five main industries, namely, sanitary ware, floor and wall tiles, stoneware, and porcelain (vitreous china and insulator porcelain) The following conclusion and recommendation are reached :

Sanitary ware

The important properties which have been taken into consideration are casting rate, loss on ignition, moisture, modulus of rupture, residue on sieve, and colour firing. It is noted that the Mae Than ball clay quality is generally slightly lower than the standard specification for sanitary ware. However, it is recommended that the refining of the ball clay by wet process in order to eliminated the some coarse-grained fraction combined with the appropriate blending of different grades of ball clay and the dewatering process will enable the optimal exploitation of the ball clay from this deposit for the sanitary ware industry (Table 5.2). The elimination of some coarse-grained fraction will improve the casting rate, loss on ignition, modulus of rupture, and residue on sieve. Besides, the SiO_2 content will be reduced and the Al_2O_3 content will be increased automatically as required.

Floor and wall tiles

The important properties which have been taken into consideration are the modulus of rupture, shrinkage, water absorption, and the Fe_2O_3 content. The most inferior property of the Mae Than ball clay, as compared with specification for floor and wall tiles, is too low in the modulus of rupture. It is therefore recommended that the quality improvement of the Mae Than ball clay can be achieved by blending with the relatively finer grained ball clay obtained from selective mining from the same deposit (Table 5.3).

Table 5.1 The comparison of some properties of the Mae Than ball clay and the English ball clay.

Properties	English ball clay	Mae Than ball clay	Remarks
- Chemical			
SiO_2	55	74.12	inferior, too high
Al_2O_3	29	20.94	inferior, moderately low
Fe_2O_3	1.3	1.29	compatible
TiO_2	1.2	0.62	superior, too low
Alkalies	3.12	2.82	superior, moderately low
LOI	10.24	6.1	inferior, moderately low
- Grain size distribution			
+ 120 mesh	0.60	1.42	inferior, slightly high
+ 200 mesh		2.74	inferior, slightly high
+ 325 mesh		94.12	inferior, too high
< 5 μ	90.24	7.05	inferior, too low
< 2 μ	79.24	31.78	inferior, too low
< 1 μ	70	22.9	inferior, too low
< 0.5 μ	58.79	29	inferior, too low
- Modulus of Rupture	69.95	24.1	inferior, too low
- Fired shrinkage	11.52, 12.73	4.96, 9.2	superior, moderately low
- Water absorption	5.17, 2.85	11.6, 0.2	compatible

Table 5.2 Specification of ball clay for sanitary ware compared with the Mae Than ball clay (Chaisam and Nissapa, 1994)

Properties	Specification	Mae Than ball clay	Remarks (+/-)
- Casting rate	2.5-4	8.2 (45μ), 4.4 (2μ)	-
- Loss on Ignition	12-14	5-7	-
- Moisture	15 (max.)	-	
- Modulus of Rupture	50	18-42	-
- Residue on Sieve (200#)	5	0.7-5.9	+
- Colour firing	white	White	+

Table 5.3 Specification of ball clay for floor and wall tiles compared with the Mae Than ball clay (Chaisam and Nissapa, 1994).

Properties	Specification	Mae Than ball clay	Remarks (+/-)
- Modulus of Rupture	150	24.1	-
- Shrinkage (max.)	7	4.96, 9.2	+
- Water absorption	12-13	11.6, 0.2	+
- Fe_2O_3	1-2	1.29	+

Table 5.4 Specification of ball clay for stoneware compared with the Mae Than ball clay (Chaisam and Nissapa, 1994).

Properties	Specification	Mae Than ball clay	Remarks (+/-)
- Loss on Ignition	10-13	6.1	+

Table 5.5 Specification of ball clay for porcelain compared with the Mae Than ball clay(Chaisam and Nissapa, 1994).

Properties	Specification	Mae Than ball clay	Remarks (+/-)
- Residue on Sieve (230#)	1 % (max.)	20	-

Stoneware

The important property which has been taken into consideration is the loss on ignition that is essentially governing by the content of organic matters. Besides, plasticity of the ball clay is also the important required property. Considering the Mae Than ball clay, it is noted that both the loss on ignition and plasticity are slightly lower than standard specification for stoneware. However, it should fall within the exceptable range for the stoneware industry (Table 5.4).

Porcelain (vitreous china and insulator porcelain)

The most important property which has been taken into consideration is the residue on sieve number 230 mesh not exceed 1 per cent. For the Mae Than ball clay, the residue on sieve number 230 mesh is very high, approximately 20 per cent. It is therefore recommended that the refining of the ball clay by means of wet process to eliminate the coarse-grained fraction coupled with the dewatering process, or dry milling/dry classifying processes to minimized the coarse-grained fraction is essentially required to meet the specification for porcelain industry (Table 5.5).

For the high quality ball clay, approximately 30 per cent is used in the body mixes of floor and wall tiles, vitreous china, stoneware, sanitary ware and insulator porcelain. The plastic clays of lower grade are used in heavy products, i.e., pipes, bricks, and tiles. The ball clays are also used in refractories, as anti-caking agents in animal feed stuffs, and as fillers in rubber and plastics. Last, the installation of a low permeability clay barrier at the base of the land-fill site at least 3 feet thick (USEPA) or 1.0 metre thick (UK practise), and have a hydraulic conductivity of less than $1x10^{-3}$ metre per second, is increasingly important if the deposit is not for away from the land-fill site.

In Thailand, there has been growth in production and demand during the last five years in both energy and industrial minerals, whereas there is a declined in metal production and exportation. This reflects the development of manufacturing in Thailand. The ball clay is among one of the most active commodities in a country. In order to present acceptable qualities of ball clay to the markets, careful selection, testing and blending to achieve consistent properties which suite the needs of the customer must be undertaken. The ball clay musts be mined selectively from individual seams, and then undergoes refining and processing to produce blend with properties suitable for particular market and to optimize the exploitation of variable grades. The refining process of the ball clay aims at producing a clay free from harmful impurities with reasonably constant characteristics.