4 Evaluation of Raw Materials as Seen from the Manufacturing Viewpoint by Product

According to the evaluation made in the present study, on the raw materials available locally (particularly in Java island), no potential raw material, which is expected to contribute to new ceramic product development, was identified. For the Indonesian ceramic industries, Kalimantan and Sumatra seem to be more promising as the sites to establish new ceramic industries, if the industries do not insist on the domestic markets, since, as analyzed in the other part of this report, the raw materials endowed in Java have limitations in their quality because of geographic reason. Therefore, the development of ceramic industries in Java on the basis of locally available raw materials would be under such technical restrains. The ceramic industries to be established in Java will be of the nature to rely basically on local market, but not insist on the raw materials available locally. Further, it should be noted that the current tendency of new ceramic establishments are mostly making most of the availability of labor force and targeting export markets using imported raw materials, and neither insist on local materials nor local markets.

The evaluation of raw materials in this chapter was undertaken in view of use of local raw materials for higher-grade products, which will increasingly become important even in the existing subsector like tableware and sanitary ware. The use for refractories was also evaluated as a case to use local materials in the areas not active to use in present.

4.1 From the Viewpoint of Manufacturing Sanitary Ware

4.1.1 Methods of evaluation

4.1.1.1 Outline of raw materials for sanitary ware

Major raw materials used as sanitary ware bases are kaolin, toseki, feldspar, and quartz. Because evaluating sanitary ware raw materials requires understanding features of individual raw materials by origin, the outline of each raw materials is given here.

(1) Kaolin-based raw materials

The major components of kaolin used for sanitary ware are clay minerals called kaolinite and halloysite. Kaolin can be classified by origin as follows:

1) Eluvial deposit kaolin

When granite and the like undergo weathering under a warm and moist climate, kaolin of good quality is formed. Although it is mixed with granular quartz and mica, they are removed in the mineral dressing process. Major producing centers of kaolin are Britain, the Czech Republic, the United States, and China; most imported kaolin is of this kind.

2) Sedimentary deposit kaolin

Sedimentary deposit kaolin is sedimentation in lakes of kaolin-based clay formed by weathered granite; it is rich both in gairome clay composed of quartz grains and kaolin and in carbonized materials. Typical of this kind of kaolin is ball clay, which exhibits strong plasticity. Major producing centers of sedimentary deposit kaolin are the United States, Britain, China, Japan, and Indonesia. Imported ball clay is of this kind; kaolin and clay from Belitung, Bangka, and Kalimantan are also of this kind.

3) Hydrothermal alterated deposit kaolin

Hydrothermal alterated deposit kaolin is kaolinite or halloysite into which pyroclastic rock, volcanic rock, granite and the like were changed through hydrothermal alteration. Its mineralogical composition varies greatly depending on its mother rock and conditions of formation. Its major producing centers are Japan and Indonesia; most clay from Java is of this kind.

As described above, there is no clear difference between kaolin in kaolin-based clay, ball clay, and clay.

(2) Feldspar as a raw material

Feldspar used as sanitary ware bases comes mainly from potassium feldspar and sodium feldspar, which are produced in mixture in most cases. By origin, feldspar is roughly classified into the following species:

1) Pegmatite feldspar

Pegmatite feldspar is composed of giant quartz and feldspar crystals and produced in granite in the form of dikes and masses. It is produced the world over; in Indonesia, it was produced in Pangaribuan. Most imported feldspar is of this species.

2) Aplite feldspar

Aplite feldspar is leuco rock consisting of fine-grained feldspar and quartz, occurring as dikes and small stocks together with granite; the major producing centers are the United States and Japan.

3) Alterated granite- and weathering granite-based feldspar

They were formed by hydrothermal alteration and weathering which leach away iron and magnesium minerals contained in granite. Its major producing centers are the United States and Japan; minerals called "saba" or "sokei" in Japan are of this species.

4) Alteration pyroclastic rock- and alterated volcanic rock-based, and weathered pyroclastic rock- and weathered volcanic rock-based feldspar

They were formed by hydrothermal alteration and weathering which leach away iron and magnesium minerals contained in tuff, rhyolite, and the like. Most of the feldspar deposits in Java Island in Indonesia are of this species.

(3) Toseki as a raw material

Toseki was produced in a process in which hydrothermal alteration caused the feldspar content of igneous rock such as rhyolite to change into sericite or occasionally kaolin. It generally forms massive deposits; when dikes are formed by mother rock, the entire dikes change into toseki, forming veined deposits. Its major producing centers are Japan and China.

(4) Quartz as a materials

Silica sand and quartz rock are used as quartz materials for pottery.

1) Silica sand

Silica sand is accumulation of quartz grains as hydromorphic deposits, weathered deposits, or beach sand. Large-scale sheet deposits of silica sand exist the world over; some of them exist in Belitung and Kalimantan Islands in Indonesia. Silica sand is also produced by separating quartz grains from kaolin occurring in probiosis with kaolin. Water elutriated silica sand collected from Belitung Island in Indonesia and collected from gairome clay in Japan is of this species.

2) Quartz rock

Quartz rock occurs with feldspar in pegmatite; also of this species is veined quartz produced through hydrothermal alteration.

4.1.1.2 Basic properties required of sanitary ware products

Sanitary ware includes products such as toilet basins, urinals, flushing tanks, wash basins, and clean-up sinks, exhibiting largest and complex shapes among pottery products. Standards are usually established for appearance, quality, performance, and size of products. These standards specify detailed criteria by type of product; however, they specify the same quality for all products, with sanitary ware manufacturers currently using the same prepared body regardless of the type of product; sanitary ware differs from tableware that uses different prepared bodies, such as heat resisting bodies and high strength bodies, depending on the type of product.

In the following, the inspection or test items are described in connection with the raw material preparation:

(1) Appearance

Among the rejectable defects associated with the appearance, those originating in body preparation are cracks, warpage, blisters, crazing, and dunting; cracks and warpage are related to the casting properties of a body, and blisters, crazing, and warpage to the firing properties. Crazing and dunting are related to the thermal expansion coefficient and water absorption properties of a fired product. Among the visual inspection items, the whiteness of a product is not specified by standards. Current sanitary ware includes products glazed in many different colors including white; therefore, it is not necessary to grade products according to the whiteness, though it is a practice with tableware. In addition to this, because glazes for sanitary ware contain zirconium opacifier, the coloration of a body is not so serious a problem as it once was. However, the whiter the coloration of a body is, the less zirconium is needed in a glaze; this allows the glaze to be thinner and improves the color of a colored glaze. Therefore, the smaller the quantity of Fe_2O_3 in the body is, the better result is obtained. In Japan, the Fe_2O_3 content in bodies for sanitary ware is usually 0.5 - 1.2%[1].

(2) Quality

The quality test is conducted on the following three items:

1) Ink permeation

The ink permeation is a criterion to evaluate the degree of sintering (water absorption property) of a product; it is related to the strength and susceptibility to crazing of a product. The proportion of flux components in a prepared body, consisting of feldspar, dolomite, and sericite, to kaolin, clay, and quartz and the particle size of the prepared body must be properly selected so that the product may be sintered at the specified sintering temperature (in the vicinity of 1,200℃ or 1,300℃).

2) Thermal shock resistance

The thermal shock resistance is used to check cracks (crazing) produced not only by the thermal expansion coefficient of the body but also by the difference in the thermal expansion coefficient between the body and the glaze, being related to dunting of the product. It is necessary to limit the quantity of quartz in the prepared body to an appropriate value.

3) Crazing resistance

Crazing resistance is used to check cracks (crazing) developed in the glaze by moisture expansion; this is related to cracks in the glaze occurring after an extended

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[1] Source: Ceramics Handbook

period of use. Because these cracks can be prevented from occurring by improving sintering of the body, the body must be prepared in such proportion.

(3) Performance

The performance test items include the flushing, the washout, and the water seal performance; these are not only the specifications for product design but also inspection items for defects occurring in the manufacturing processes. Because of the large size and complex shapes of sanitary ware, cracks and deformation in the casting process, cracks and deformation in the sintering process, changes in shrinkage and the like cause defects. This is related to the forming and sintering properties of the prepared body, being the most important factor in selecting raw materials.

(4) Shape and size

As in the performance test described in Paragraph (3), the shape and size inspection is related not only to the specifications for product dimensions, a matter related to designing, but also to an inspection item to check defects arising from products not fired to the design. Causes for this are deformation in the forming process, excessive or insufficient shrinkage in the firing process, deformation under load at high temperatures, improper modification, and the like.

Regarding the forming properties, especially the sintering properties of a prepared body, raw materials must be selected and mixed so that the proportion of the flux component in the prepared body to kaolin, clay, quartz, and other components and the grain size of the body may be appropriate.

As described above, raw materials for sanitary ware must be suitable for bodies of which a product can be efficiently manufactured whose appearance, quality, performance, and dimensions conform to the required specifications.

4.1.1.3 Basic properties required of a prepared body

Because items of sanitary ware are large and complicatedly shaped, all of them are manufactured by the slip casting method. In addition, because shape-related manual work involving cutting and bonding is frequently required, a body with good workability is required.

(1) Main property requirements

1) Properties of slip

Dispersibility, viscosity, casting rate, and others

2) Properties of the cast
Water content, plasticity (deformation resistance, thixotropic resistance, workability)
3) Properties of a dry body
Shrinkage, strength, packing density, and others
4) Firing properties
Sinterability, firing shrinkage, high temperature strength, and others
5) Properties of a fired body
Strength, thermal expansion coefficient, dunting resistance, water absorption, coloration, and others

(2) Basic properties of different raw materials (basic roles that different materials play)
1) Kaolin, clay, and toseki: Form and maintain the shape of a product and maintain the strength during high temperature processing.
2) Feldspar: Accelerates as vitrification, reduces water absorption.
3) Quartz rock (silica sand): Maintains the mechanical strength of a product and controls rates of thermal expansion and contraction.

Manufacturers utilize the properties of the different raw materials listed above, using raw materials having best workability and mixing them so that they may be satisfactorily sintered.

4.1.1.4 Sanitary ware manufacturer's procedure for evaluating raw materials

Raw materials evaluating methods generally adopted by sanitary ware factories are outlined below.

(1) Procedure for evaluating raw materials
1) Obtain information on raw materials producing mines and samples from suppliers.
2) Test samples for mineral composition, chemical composition, grain size, refractoriness, coloration, and other items
3) Investigate the reserve, quarrying conditions, quality control, dispersion, and other items concerning specific mines and conduct sampling tests.
4) Examine dispersion and other quality control items by increasing sample of a raw material in question to supplement the sample test described in item 2). Examining the test results, evaluate the practicality of using the raw materials as mixing materials (the primary evaluation).
5) Replacing part of the current body (the prepared body currently in use) with trial raw materials, conduct small-scale mixing tests. Be sure to prepare a small amount of the current body to compare between it and the trial body on the slip properties, forming properties, sintering properties, and the sintered products. Using the results of the

small-scale tests, examine the possibility of replacement, proper mixing proportions, and benefits of the contemplated replacement (secondary evaluation).

6) Prepare a body sufficient to make a few actual products as a large-scale mixing test, manufacture products at the factory, and compare between the current and the new materials (tertiary evaluation).

7) As a transition test, put the replacement raw materials in the current body and use the body to investigate change in the yield; if the replacement is comparable to or better than the current materials, judge the replacement to be acceptable and continue using it.

The present investigation extends as far as the primary evaluation described in item 4). The materials being used by some manufacturers are evaluated with reference being made to the comments from those manufacturers in 4.1.2.

Based on the evaluation procedure described above, the criteria for accepting or rejecting raw materials on the basis of manufacturers' point of view are typically as described in the following section.

(2) Criteria for accepting or rejecting raw materials

1) The reserve is large enough to provide raw materials constantly at reasonable prices.

2) Mineral composition, chemical analysis, coloration, and other test items in single component raw materials tests show promising results.

3) In the body mixing test, tests using replacement materials are conducted; after basic tests have been finished, actual products are made by using the replacement raw materials; the results obtained from the manufacture of the actual products are used to evaluate the acceptability of the replaced raw materials. Ceramic raw materials even with the same mineral and chemical composition usually differ in their properties depending on their production sites and origins; therefore, the acceptability of a raw material is evaluated on the basis of body mixing tests.

However, a mixing test by one manufacturer yields evaluation different from that obtained by another manufacturer, because different manufacturers use different body composition (combination of raw materials); therefore, evaluation differs between manufacturers, and even between different factories of a manufacturer.

A guide for determining the acceptability of raw materials, provided by the manufacturers is shown in Table 4-1, as an example.

4.1.1.5 Key factors in selecting raw materials

In selecting a prepared body, it is necessary, first from the viewpoint of the sintering properties, to have the quantities of kaolin, feldspar, sericite, and quartz, the main ingredients, in specified proportions. These proportions vary depending on the type of product to be manufactured, firing temperature, and other factors, and different manufacturers own different know-how. Following this, the species and quantities of kaolin clay, feldspar, and quartz are determined from the viewpoint of workability.

(1) Selection of kaolin-based clay

Kaolin-based clay differs in its properties depending on its origin and producing site, and kaolin-based clay with a particular origin or from a particular producing site exhibits its unique characteristics. It is difficult, therefore, to obtain all properties required by using a single type of clay; it is a common practice to combine several types of raw material with the quality stability, supply stability, and price taken into account. In Europe and the United States, kaolin and ball clay are separately used, while in Japan raw materials are selected through combination of gairome clay and ball clay with sericite clay from toseki.

In Indonesia, kaolin-based clay from the islands of Belitung, Bangka, and Kalimantan is used; however, because this clay does not provide satisfactory properties, it is used together with imported kaolin and ball clay.

(2) Selection of toseki raw materials

Japanese-owned enterprises use bases comprising toseki. Toseki is used to make use of the effect of sericite on the sintering and the forming properties. Because the major components of toseki are quartz and sericite, it is necessary to select that toseki which allows sericite components to be sufficiently dispersed in a crushed state to act as clay. In addition, because toseki consists mainly of quartz, it is necessary to limit the quantity of quartz originating in other raw materials when a larger quantity of toseki is used. For this reason, using clay containing a larger quantity of quartz or alkaline-poor feldspar is limited.

Indonesia depends totally on imported toseki because quality toseki is not constantly supplied.

(3) Selection of types of feldspar

Many types of feldspar are used for mixing: one of them with an alkaline content of not less than 14% contains a very small amount of quartz while another with an alkaline content of as low as a few percent contains a large amount of quartz; there are types of feldspar containing an intermediate amount of quartz. Feldspar is used as a flux in a body, and the absolute amount of feldspar a body requires changes depending on the body to be considered. A type of feldspar low in alkaline content must be used in a larger quantity; for this reason, the quantity of quartz arising from other raw materials must be reduced. If the consideration is to be limited to this point, the possibility of using low-alkaline types of feldspar is greater with the kaolin-feldspar-quartz-based mixing than with the toseki-based mixing. However, to reduce use of inexpensive and constant quality quartz to use low-alkaline feldspar, not only the price and quality but also the stability of quality must be considered.

The discussion thus far has been centered on the major raw materials; however, attention must be directed also to impurities, especially to iron contents, because they degrade firing coloration. Although using zirconium opaque glaze improves coloration of a base considerably, the Fe_2O_3 content in a base must be less than about 1.2%. In this way, a number of types of raw material are used in mixing and this suggests that a number of types of raw material may be used if they are in small quantities. In reality, however, the types of domestic raw material that can be used are limited; the consumption of domestic raw materials by the major sanitary ware manufacturers is about 50% of the total they use.

4.1.2 Evaluation of domestic raw materials

As described above, the method of manufacturing sanitary ware is the slip casting method. Sanitary ware is generally divided into large high-grade and small low-grade items. As the manufacturing methods for each group differ from each other slightly, different properties are required of mixtures of raw materials for each group. Since small-sized low-grade items are small and simple in their shapes, they are manufactured in small factories and all of them are made from domestic raw materials. Large high-grade items being large and complex in their shapes, it is difficult to cast them in a single mold at a time; they are first cast in separate parts and then the separate parts are bonded or reinforced by being partially glued. In addition, they frequently undergo processing such as drilling; therefore, the product yield depends on the workability. Among many factors affecting the manufacture of these items, the most important one is the plasticity (workability) of clay.

4.1.2.1 Test methods

(1) Raw materials to be tested

The raw materials evaluation this time was conducted on raw materials produced in Indonesia with the focus of evaluation on high-grade sanitary ware.

- Kaolin-based raw materials

  1) Kaolin from Belitung Island, 2) Kaolin from Bangka Island, 3) ball clay from Kalimantan Island

  From Java Island: 4) Parungpanjang clay, 5) Sukabumi clay, 6) Cipeundeuy clay
- Feldspar-based raw materials

  Sumatra Island: 7) Pangaribuan feldspar, 8) Lampung feldspar

  Java Island: 9) Banjarnegara feldspar, 10) Narawita feldspar, 11) Jepara feldspar
- Toseki and agalmatolite

  12) Pacitan toseki

The 12 types of raw material produced in Indonesia, as listed above, were evaluated this time.

(2) Study and test items

The following studies and tests were conducted on these raw materials:

- Mine study

  General topography and geology, conditions of existence of mineral resources, present state of quarrying, beneficiation, utilization, and the like
- Analytic test of samples obtained through sampling

  Mineral composition analysis, chemical composition analysis, grain size distribution, sintering coloration test, plasticity test, slip characteristics test, dry strength test, sintering characteristics test
- Beneficiation test

  Study of the possibility of beneficiation by means of grading, magnetic separation and deironation, and floatation

The details of the studies and tests described above are shown in the preceding Chapter 3.1 through 3.4.

4.1.2.2 Evaluation

In this evaluation, good quality clay and feldspar were not found. In manufacturing high-grade sanitary ware, good clay is needed to improve formability and feldspar of good quality (having a rich alkaline content) is needed to improve sintering. Better formability leads to a better product yield; the improvement in the product yield has a much greater effect than prices of raw materials.

It is thought that, with the present lack of clay and feldspar of good quality in Indonesia, importing raw materials of good quality to fill the gap between the demand and the domestic supply is unavoidable[2].

Evaluation of individual raw material is as follow:

(1) Belitung kaolin

This is water elutriated kaolin from Belitung Island; its reserve is large and its quality is stable. Consisting mainly of kaolinite, it is quality kaolin with high kaolin purity and a low iron content, and it possesses plasticity, in which kaolin is usually poor. Because it poses no problems in making slip for casting, it can be a main body raw material, to be used with clay, for sanitary ware production.

(2) Bangka kaolin

This is water elutriated kaolin from Bangka Island; like Belitung kaolin, its reserve is large and its quality is stable. Consisting mainly of kaolinite, it is quality kaolin with high kaolin purity and a low iron content. Although casting tests were not conducted on this type of raw material, it is estimated on the basis of the properties of the kaolin in question and other data that this can be a main body raw material, to be used in combination with clay, for sanitary ware production.

For information of the readers of this document, rumor often has it that Belitung kaolin is not good but Bangka kaolin is good or vice versa; this is not essential evaluation of kaolin because properties of other raw materials used with Belitung or Bangka kaolin, manufacturing conditions, and other factors may make either of the two types of kaolin easier to use.

(3) Parungpanjang clay

This clay is produced in the western part of Java Island and its reserve is large. Since the iron content in this clay varies from 2 to 12% depending on the location, stabilization of its quality is uncertain; strict quality control at quarrying sites is required. It consists mainly of halloysite and also contains montmorillonite and cristobalite. Although it is graded as clay of lower than middle class, the montmorillonite it contains makes it very plastic. When evaluated from the plasticity point of view only, it can be said to be the best of domestic clay. The result of the casting test using high quality Super Clay (GP-1) showed poor dispersibility due to the presence of the montmorillonite content and proper slip was not produced. Therefore, this material is not suitable for sanitary ware production.

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[2] Banjarnegara feldspar and Lampung feldspar are poor in alkaline contents; therefore, it is necessary to carry out research into refining methods that will increase alkaline contents beyond 10%.

(4) Sukabumi clay

This clay is produced in the western part of Java Island and its reserve is large; however, stability of its quality and its steady supply are uncertain. The iron content in this clay varies remarkably from 4 to 15% depending on the quarrying site. Needless to say, quarried clay should be put to quality control. The problem lies with the quarrying method, in particular; it is necessary to abandon the current mining quarrying by individuals and to adopt a modern, streamlined quarrying method.

The major components are kaolinite, sericite, and quartz. When viewed from the viewpoint of the alumina content, it is a type of clay close to low-grade clay and in addition, it is very rich in iron. The result of the casting test using iron-poor clay (CS-1) shows good dispersibility but problems with plasticity (workability, in particular) and the casting rate. In addition, it is rich in iron (4.18%). These properties make it unsuitable as a raw material for sanitary ware. It will offer the possibility of being used for sanitary ware if the quarrying method is improved in the future and it becomes possible to quarry quality clay (Super White Clay) on a stable basis in deeper layer of deposit.

(5) Cipeundeuy clay

It is produced in an area to the southeast of Bandung City; its reserve is large and its quality is stable. The quarrying site is located halfway up a mountain, and the quarried clay is manually carried down to the foot of the mountain because only footpaths bordered by farms and narrow mountain paths are available for traffic and transportation. Being unable to use vehicles to transport clay poses a great bottleneck to increasing shipment. The clay consists mainly of kaolinite and cristobalite, with some sericite contained. Judging from the alumina content, it is clay of a middle grade. Although casting tests were not conducted, the test conducted on the clay in question shows coarse grains and low plasticity; in addition, it contains cristobalite. All these properties make it unsuitable as a raw material for sanitary ware production. Judging from its appearance and other features, the Cipeundeuy clay is considered to be a type of kaolin rather than clay and suitable as a raw material for refractory materials.

(6) Monterado clay

This clay is produced in western Kalimantan, with its reserve being large and its quality stable. It consists mainly of kaolin and quartz; its kaolin purity in particular is high and few colored impurities are contained. Although its grains are slightly coarse for a type of clay, its plasticity is satisfactory. The result of casting tests showed excellent dispersibility and sufficient plasticity, showing the best properties among those of the raw materials tested; therefore, this clay can be a main body raw material for sanitary ware production. At present, Clayindo Company (a joint venture of WBB) is developing the mine on a large scale, promising to be a producer of quality clay[3].

(7) Pacitan toseki

It is produced in the East Java; the samples were taken from a lower outcrop of agalmatolite now being quarried. Judging from the result of test conducted on the toseki in question conducted on the samples, the main components are quartz and sericite; however, because the sericite content is small, it is low-grade toseki. With the iron content (Fe_2O_3) of 0.08% and the titanium content (TiO_2) of 0.28%, it is a raw material with good coloration. Casting a small piece (a teacup) by using a body from crushed Pacitan toseki resulted in a finished piece; this shows that the material has this much plasticity. Although the possibility of using this toseki as an auxiliary raw material for sanitary ware production may be taken up, transportation costs, which could run up depending on the distance between the producing and the consuming center, lowers that possibility. In the face of the present lack of toseki, however, it is recommended that the reserve be investigated when the time is ripe for it, because there is some possibility that toseki of good quality may exist in the inner part of the ore body.

(8) Pangaribuan feldspar

It is produced in the northern part of Sumatra Island; it consists mainly of almost pure microcline. Analytical tests of samples give a Fe_2O_3 content of 0.09% and trace quantity of TiO2, which suggests good coloration. However, the feldspar had already been quarried to the limit; it could be used if new ore veins of good quality would be discovered and developed.

(9) Jepara feldspar

The producing site and reserve of the Jepara feldspar are unknown; it is evaluated on the basis of the results of the test conducted on the samples obtained. It consists mainly of sanidine, nearly pure feldspar; therefore, it melts easily but a rich iron (Fe_2O_3) content of 2.15% makes its coloration very poor. Although it is evaluated as having a good feldspar content, an excessive iron content and the resulting poor coloration make it an auxiliary material at best, according to the result of the evaluation.

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[3] From the viewpoint of plasticity, even the only quality Monterado clay is thought to be slightly inferior to ball clay in Britain and gairome clay in Japan.

(10) Narawita feldspar

It is produced in an area about 65 km to the east of Bandung City; the mine is widely spread and the ore veins are said to extend as far as 1 to 2 km in all direction; therefore, a large reserve is expected. Regarding the working method, however, only the portions that are thought to be of good quality are dug out, in such a way as to leave a tunnel, with scant layers with good coloration left. Although they look white apparently, portions with poor coloration are mixed, impairing the stability; these conditions allow one to estimate that only a few percent of the total reserve may be commercially used. It consists mainly of sanidine, cristobalite, and partially mixed sericite. Because of a low alkaline (Na_2O + K_2O) content of about 6%, it melts poorly. It is not suitable as a raw material for sanitary ware production.

(11) Banjarnegara feldspar

It is produced in the central Java and its reserve is large. It consists mainly of albite, quartz, and microcline. The alkaline content, which is the main component of feldspar, is as low as 7 - 8%, and therefore it melts poorly. Although a high iron content makes its coloration poor, the results of studies using magnetic separation and beneficiation tests suggest the possibility of deironation. There are three mines in a 15 km long area; the results of sampling conducted at many locations in each of the three mines show stable quality without dispersion. There is a good possibility of using kaolin-feldspar-silica stone-based mixtures as raw materials for sanitary ware production.

(12) Lampung feldspar

It is produced in the southern part of Sumatra Island, with its reserve being large. The mineral deposit is divided into massive portions and sandy portions; the ratio of the quantities shipped of the massive to the sandy portion is 30:70, with the materials from the massive portions being used for floor tiles.

The result of the chemical analysis of samples gives an alkaline content of 7% and an iron content of about 0.35%, offering the prospect of this feldspar being used for sanitary ware in kaolin-feldspar-silica stone-based mixtures. However, because of the low alkaline content, sintering is poor and the quality is far inferior to imports. The imports have an alkaline content of about 14% and cost Rp.130/kg. If Lampung feldspar, with an alkaline content of 7%, is to be used, the quantity needed of the feldspar is twice that of imported feldspar; this increases the price to Rp.95/kg x 2 = Rp.190/kg, favoring use of the imports with respect to the price, too. Because future shortage of imported feldspar resources is conceivable, future measures against this possibility, such as beneficiation, should be taken. In addition, to stabilize the quality, the quarrying method should be examined.

Over all evaluation results are summarized in Table 4-2.

4.2 From the Viewpoint of Manufacturing Tiles

4.2.1 Evaluation methods

4.2.1.1 Description of raw materials for tile production

Types of tile are classified into earthenware, stoneware, and porcelain. Besides classification by nature, they are classified by designation. The relation between the classification by nature of the base and that by designation is as follows:

Nature of the Base	Designation
Porcelain	Interior tile, exterior tile, floor tile, mosaic tile
Stoneware	Interior tile, exterior tile, floor tile
Earthenware	Interior tile

The designations "Interior Tile," "Exterior Tile," and "Floor Tile" originate in the major applications of those tiles: interior tiles are used mainly for indoor walls and floors, exterior tiles mainly for outdoor walls, and floor tiles mainly for outdoor floors. The designations described above are associated with JIS classification; in Indonesia, they are called "Floor Tiles," "Wall Tiles," and "Mosaic Tiles." Regarding the volume of production, the floor tiles represent 70%, the wall tiles 30%, and the mosaic tiles a very small percentage of the total production. When viewed from the viewpoint of the nature of the bodies used, floor tiles stand about the middle between the stoneware and earthenware, while wall tiles are of earthenware.

Raw materials for tile bodies are clay, feldspar, and quartz for floor tiles, clay, feldspar, kaolin, agalmatolite, limestone, and quartz for wall tiles, and feldspar and clay for mosaic tiles; all the tiles mentioned are made from domestic raw materials. In the following, the raw materials used are described.

(1) Clay

Clay used as a raw material for tiles is a mixture of quartz and kaolinite-based or halloysite-based clay which was formed through hydrothermal alteration of pyroclastic or volcanic rock; some contains sericite. A large iron content is mixed. The typical clay for tiles is Sukabumi clay.

(2) Feldspar

Feldspar used as a raw material for tiles was formed through hydrothermal or weathering alteration of pyroclastic or volcanic rock; it is a mixture of potassium feldspar, albite, and quartz. The typical species is Banjarnegara feldspar.

(3) Kaolin

The type of kaolin used as a raw material for tiles is beneficiated kaolin, which is manufactured by elutriating clay from sedimentary deposits, formed in lakes by deposition of kaolin-based clay formed by weathered granite, to remove quartz, mica, and the like. Kaolin from Belitung Island and Bangka Island is a representative type.

(4) Quartz

The type of quartz used as a raw material for tiles is silica sand, which originates in granite and sandstone and exists in beach silica sand or inland alluvial plains. Quartz from Bangka Island, Belitung Island, and Kalimantan is a representative type.

(5) Limestone

Limestone is widely distributed and one of the most abundant resources. Post tertiary period limestone distributed in the western and central Java is mainly developed and used.

(6) Agalmatolite

Volcanic rock such as rhyolite underwent acid hydrothermal alteration to change into agalmatolite consisting of agalmatolite and quartz. Pacitan agalmatolite is a representative type.

4.2.1.2 Basic properties required of products

Most of tiles manufactured in Indonesia are floor and wall tiles, with a very slight amount of mosaic tiles added. The typical mixture ratios used for manufacturing floor and wall tiles (according to information from ASAKI) and for mosaic tiles (information from manufacturers) are as follows:

	Floor Tiles (%)	Wall Tiles (%)	Mosaic Tiles (%)
Clay	58	46	30
Feldspar	32	7	70
Quartz	10	21	
Kaolin		10	
Limestone		16	

A floor tile consists of clay, feldspar, and quartz, having a water absorption percentage of 3 - 10% in most cases. A wall tile contains less feldspar but more limestone, having a water absorption percentage of not less than 10%; in addition, since a wall tile contains less iron in the body and a higher water absorption percentage than a floor tile does, it turns white and hence is called "White Body." By contrast, a floor tile turns red and hence is called "Red Body[4].

A mosaic tile contains more feldspar and fired at a temperature as high as 1,300℃ to reduce the water absorption percentage below 1.0%. By contrast, floor and a wall tile product are usually fired at temperatures between 1,150℃ and 1,200℃.

The quality, shapes, dimensions, and appearance required of these tile products and their relations with preparation of raw materials are described in the following.

(1) Quality

1) Warpage and irregularity

"Warpage" is a generic term for curvature in tiles, while irregularities refers to misalignment observed in two sides facing each other. They arise from difference in shrinkage due both to local temperature difference during firing and to difference in the density of a body occurring in the forming process; one of the causes is the change in the fluidity and similar properties in granulated powder due to dispersion of the quality of raw materials.

2) Water absorption percentage

JIS specifies the following water absorption percentages:

Porcelain	Not more than 1.0%
Stoneware	Not more than 5.0%
Earthenware	Not more than 22.0%

These values are specified because a tile should be used where its water absorption properties allow it to be used. Earthenware tiles are limited to indoor walls and floors. In Indonesia, floor tiles manufactured by different manufacturers exhibited different water absorption percentages: tiles from a manufacturer exhibited water absorption percentages ranging from 3 to 6%, those from another from 4 to 6%, and those from still another from 6 to 10%. Judging from the representative floor tile mixture proportions given by ASAKI and firing temperatures of 1,150 - 1,185℃, the water absorption percentage of a common floor tile is estimated at values in the neighborhood

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[4] Source: ASAKI

of 3 - 10%. The only figures available regarding wall tiles are a value exceeding 10% given by a company and a percentage of 17% given by another company; the water absorption percentage of typical earthen-based bodies in Japan ranges from 11.0 to 16.0%[5]. In deciding on a mixture proportion, the water absorption percentage is the condition to be set first along with the firing temperature. When earthen ware with a higher water absorption percentage is used, the mixture for a body contains less feldspar and more limestone or talc; to obtain a less water absorbing base close to stoneware, the mixture should be a clay-feldspar-quartz-based one containing more feldspar.

3) Crazing resistance

This inspection is conducted on the crazing occurring in glazes on glazed tiles. A type of crazing, called direct crazing, occurs due to the tensile stress acting on the glaze during cooling when the thermal expansion coefficient of the glaze is greater than that of the body.

By contrast, there is another type of crazing that does not occur until several years after firing; this is called delayed crazing. Delayed crazing is caused by water absorbed by the body, which expands by the action of moisture after a long storage period in the body and exerts tensile stress on the glaze. The crazing resistance test is an inspection to check delayed crazing. Delayed crazing tends to occur in bodies with high water absorption; it does not occur in porcelain. Accordingly, when a mixing proportion is examined for a high water absorption tile like earthenware, it is a general practice to prepare a body that contains less feldspar to reduce Na ion and Ka ion tending to cause moisture expansion but more limestone and talc. In Indonesia and Japan, mixtures containing more limestone are used.

4) Abrasion resistance

JIS specifications require that outdoor use floor tiles undergo the abrasion resistance inspection. In Japan, floor tiles are stoneware- or porcelain-based; in Indonesia, by contrast, floor tiles are made from raw materials ranging from stoneware to earthenware and therefore outdoor use products should be distinguished from indoor use floor tiles with respect to abrasion resistance. For outdoor use floor tiles, a mixture of raw materials should have a proportion equal to that of stoneware with a water absorption percentage of not more than 5%.

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[5] Source: Ceramics Engineering Handbook

5) Bending strength

JIS standards give the following specifications for the bending strength of tiles:

Specifications for Bending Strength

Classification by designation	Bending fracture load /1cm of width (Not less than N/cm (kg-f/cm))	
Interior tile		
Wall use	12	(1.23)
Floor use	60	(6.12)
Exterior tile		
For a dimension of not more than 155mm	80	(8.16)
For a dimension exceeding 155mm	100	(10.20)
Floor tile	120	(12.24)
Mosaic tile	60	(6.12)

Bending strength of a tile represents the bending strength of the very product, not the strength of the material from which the product is made. Even when the strength of a material is the same, the strength of a product greatly varies depending on its thickness. When a material itself is weak, the weakness can be compensated for by increasing the thickness. Since the strength becomes lower as the water absorption increases, a floor use tile must be made from a base with lower water absorption or provided with a greater thickness.

(2) Shape, dimension, and tolerance

The shape and dimensions of a tile are determined by design and manufacturing specifications, while the tolerances provide standards for inspecting dispersion in shapes and dimensions. Tolerances for earthenware-based products are very narrow compared with those for stoneware- and porcelain-based products. Dispersion in shapes and dimensions arises mainly from variation in prepared bodies. With clay, there are variations in the proportion of kaolin and quartz and in the quantity of feldspar inclusions; with feldspar, dispersion in the proportion of feldspar and quartz results in dispersion in the composition of a mixed base. In addition, dispersion in the composition of a mixed body may be caused by variation in moisture at the time of the receiving of the materials or variation in firing conditions.

(3) Appearance

Inspection items for the appearance of a product are as follows:

Break, crazing, crack, layer chipping, chip, small hole, convex, depression, warpage, irregularity, uneven color, and uneven luster

Among these items, breaks, cracks, and chips are related to the strength of a body, especially to the strength of a dry body, being controlled by the quantity of plastic clay which acts as a binder. Crazing, warpage, and irregularities have already been described.

Unevenness in colors is often caused by change in contents of colored minerals in raw materials, especially Fe_2O_3 contents in raw materials; it occurs also when variation in the composition of a body causes the degree of sintering to change.

Tiles, like sanitary ware, are not classified on the basis of the whiteness of a body. Furthermore, use of zirconium opacifier causes the color of a body to be covered with a glaze and, at the same time, a colored glaze colors the body; therefore, the iron-rich "Red Body" is used both for floor tiles and for wall tiles. A floor tile commercially available in Indonesia contained 3.3% of Fe_2O_3 in the body. On the other hand, since a whiter body makes the colors on the surface stand out more distinctly and enables subtle patterns to be created, wall tiles using the "White Body" are manufactured.

4.2.1.3 Basic properties required of mixed bases

Of the tiles manufactured in Indonesia, floor tiles have water absorption percentages of 3 - 10% and wall tiles have water absorption percentages of not less than 10%; both types of tile are formed through a pressing process using granulated powder. New factories are equipped with roller hearth kilns for firing. The processes are simple and the requirements for the properties of bodies are not so severe as those for sanitary ware.

(1) Basic properties required of mixed raw materials for tile bases

1) Properties of granule

Viscosity of slip, evenness of shapes of granulated powder, fluidity, and the like

2) Properties of pressing bodies

Dry strength, packing density, cracks, and the like

3) Firing properties

Degree of sintering, thermal deformation, shrinkage factor, temperature sensitivity, and the like

4) Properties of a fired body

Shape, dimensional accuracy, water absorption percentage, strength, coefficient of thermal expansion, crazing resistance, coloration, and the like

The roles that different raw materials play in controlling these required properties are as follows:

(2) Basic roles played by different raw materials

1) Clay: Acts as a binder that provides strength both of granulated powder and of formed products.
2) Clay, kaolin, and pyrophyllite: Maintain the strength at the time of firing.
3) Feldspar: Accelerates the sintering process during firing.
4) Silica sand: Reduces drying and firing shrinkage and controls thermal expansion and contraction of a fired body.
5) Limestone: Prevents a fired body from expanding by the action of moisture.

4.2.1.4 Procedure of evaluation by manufacturers

In general, a manufacturer evaluates a raw material through the following three steps prior to adoption of the raw material:

(1) The reserve is sufficient to supply the material stably at a reasonable price.

(2) Test conducted on a raw material in question allow the mineral composition, chemical analysis, coloration, and other factors to be evaluated as promising.

(3) In the mixing test on a body, a replacement test using the raw material under consideration is conducted; after basic tests, products are made using the raw material, and the result is used for evaluation of acceptability of the raw material. Ceramic raw materials even with the same mineral and chemical composition usually differ in their properties depending on their production sites and origins; therefore, the acceptability of a raw material is evaluated on the basis of body mixing tests. However, a mixing test by one manufacturer yields evaluation different from that obtained by another manufacturer, because different manufacturers use different body composition (combination of raw materials); therefore, evaluation differs between manufacturers, and even between different factories of a manufacturer.

4.2.1.5 Key factors in selecting raw materials

Most Indonesian floor tiles are fired at firing temperatures between 1,150℃ and 1,185℃, with their water absorption percentage ranging from 3 to 10%. According to ASAKI, the typical mixture proportion for these tile bodies is that of the "Red Body," a mixture of 58% of clay, 32% of feldspar, and 10% of quartz. In one factory using the old method, wall tiles are biscuit fired and then fired in sagger; in another factory, a roller hearth kiln is used for glost firing after biscuit firing. In still another factory, a roller hearth kiln is used for both processes. According to ASAKI, a typical mixture proportion for a wall tile is 46% of clay, 7% of feldspar, 21% of quartz, 10% of kaolin, and 16% of limestone. Regarding floor tiles, the proportions of raw materials consumed by most of the factories are close to the representative ratio given by ASAKI. However, some wall tile manufacturers use mixture proportions considerably different from the typical mixture proportion given by ASAKI. The following table gives examples of chemical composition of Japan's typical earthenware tile base (Ceramics Engineering Handbook) and that of Indonesia's floor tile products:

	Japan's Earthenware Tile	Indonesia's Floor Tile
SiO_2	66~72	73.60
Al_2O_3	18~20	14.86
Fe_2O_3	0.7~0.9	3.34
CaO	6.0~8.0	1.47
MgO	0.4~0.5	1.60
K_2O	1.0~1.5	2.50
Na_2O	0.1~0.5	1.88
TiO_2	0.4~0.5	0.52

Raw materials mixing proportions for earthenware tiles must be, as given by the representative example provided by ASAKI, low in feldspar, rich in limestone and kaolin contents, and low in iron contents.

(1) Selection of clay as a raw material

Sukabumi clay, whose reserve is said to be abundant beyond concern, is produced in the western part of Java Island, and if this raw material is to be properly used, it will make a sufficient raw material for floor tiles. However, because it contains too much iron for a "White Body" for wall tiles, raw materials with lower iron content and stable production are required. Clay from Belitung Island was used by two wall tile manufacturers; it is probably lower in iron contents than Sukabumi clay.

(2) Selection of feldspar as a raw material

Regarding feldspar as a raw material, Banjarnegara feldspar, which is said to be very abundant in reserve, exist in Java Island; it is thought that they can be used for floor tiles without particular problems. Their Fe_2O_3 content is in the 1% range, which is a little too large for a raw material for wall tiles (White Body). However, they can be used because only a small amount of them is used.

(3) Selection of quartz as a raw material

Since silica sand of good quality is produced in Belitung Island, Bangka Island, Kalimantan Island, and other places, the point is to look for inexpensive silica sand.

(4) Selection of kaolin

Elutriated kaolin as a raw material for kaolin poses no problem as to supply quantity. However, it is expensive. If Al_2O_3 rich clay is available, using it may serve the purpose; another method will be replacing kaolin and quartz with toseki and pyrophyllite as practiced in Japan for preparing earthenware-based tile mixtures. For this purpose, it will be necessary to develop mines of toseki and pyrophyllite that will be capable of supplying these raw materials at low prices.

(5) Selection of toseki and pyrophyllite as raw materials

At present, toseki and pyrophyllite are used by very few factories in Indonesia for tile bodies, but they are promising as low iron content raw materials. In Japan, toseki and pyrophyllite are used as earthenware body, while toseki is used as stoneware body.

4.2.2 Evaluation of domestic raw materials

4.2.2.1 Test methods and related details

(1) Raw materials studied

Indonesian domestic raw materials studied at this time are the following 12 items:

● Kaolin-based raw materials:

1) Kaolin from Belitung Island; 2) Kaolin from Bangka Island; 3) ball clay from Kalimantan Island

Java Island: 4) Parungpanjang clay; 5) Sukabumi clay; 6) Cipeundeuy clay

● Feldspar-based raw materials:

Sumatra Island: 7) Pangaribuan feldspar; 8) Lampung feldspar

Java Island: 9) Banjarnegara feldspar; 10) Narawita feldspar; 11) Jepara feldspar

● Toseki and pyrophyllite

12) Pacitan toseki

(2) Study and test items

The following studies and tests were conducted on these raw materials:

1) Mine study

General topography and geology, conditions of existence of mineral resources, present state of quarrying, beneficiation, utilization, and the like

2) Analytic test of samples obtained through sampling

Mineral composition analysis, chemical composition analysis, grain size distribution, firing coloration test, plasticity test, slip characteristics test, dry strength test, sintering characteristics test

3) Beneficiation test

Study of the possibility of beneficiation by means of classification, magnetic deironation, and floatation

(3) Acceptability evaluation method

The results of the study and tests described above and the results of factory interviews were used for evaluation. Regarding raw materials for floor tiles, Sukabumi clay, which is a typical floor tile use raw material, Banjarnegara feldspar, and silica sand were used to prepare a basic raw material mixture with the typical ASAKI mixing proportion (consisting of 58% clay, 32% feldspar, and 10% silica sand); in the evaluation, this test mixture was used as a replacement mixture to see whether problems would arise or not. For wall tiles, the typical ASAKI mixture proportion (consisting of 46% clay, 7% feldspar, 21% quartz, 10% kaolin, and 16% limestone) and the chemical composition of Japanese earthenware tile bodies were used as the references to study and evaluate problems arising from trial raw materials.

4.2.2.2 Evaluation

(1) Kaolin from Belitung Island

This type of kaolin is produced by water elutriating sedimentary deposit kaolin formed by weathered granite; it consists mainly of kaolinite, is low in iron content and is highly pure. Although its quality allows it to be used for tiles, its high price makes it unsuitable for that application. It is used for wall tiles, though in a small quantity. Replacing it with less expensive raw materials should be considered, if possible.

(2) Kaolin from Bangka Island

Evaluation for this type of kaolin is the same as that for kaolin from Belitung.

(3) Parungpanjang clay

It is produced in Bogor Prefecture, 60 km to the west of Jakarta, being favorably situated. Parungpanjang clay consists mainly of halloysite into which pyroclastic rock was changed by hydrothermal and weathering action; it contains montmorillonite. It is characterized by fine grain size and high plasticity. Its iron content is high as a whole. Although it can be used in a small quantity as a binder for floor tiles, its montmorillonite content prevents it from being a main raw material; in addition, the high iron content makes it unsuitable for wall tiles.

(4) Sukabumi clay

Sukabumi clay is produced in an area about 80 km to the south of Jakarta and about 80 km to the west of Bandung, being favorably located for tile manufacturers centered in the West Java area and for those in the Central Java area. Sukabumi clay consists, as a mixture, of kaolin-based clay, into which pyroclastic rock was changed by hydrothermal and weathering action, and clay; sericite is occasionally mixed with them. It has fine grain size and high plasticity. Chemical analysis shows the presence of iron, which poses problems for use for wall tiles, but it can be used for floor tile bodies without problems. Calculating the Fe_2O_3 content, in a body prepared in typical wall tile proportions using Sukabumi clay, Banjarnegara feldspar, and kaolin from Belitung Island, yielded a figure of 2.24%. It does not suit the White Body which requires whiteness. Tile manufacturers agree that the reserve will pose no problems both at present and in future. According to DSM, the quarrying site area is 500 ha, area of the site already quarried 20 ha, and the thickness of the layers is 20 m. Accordingly, it is satisfactory from the viewpoint of quality, quantity, and cost, and its annual consumption is several hundreds of thousand tons. However, tile manufacturers point to problems with dispersion in the quality, and instability of supply. Because it is a lifeline raw material at present and in future, it is required to break away from the traditional quarrying and shipping methods and adopt large-scale, rationalized quarrying methods and quality control methods, thereby stabilizing the quality and supply and preserving the raw material at the same time.

(5) Cipeundeuy clay

The producing site is located at a site about 60 km to the east-southeast of Bandung; the deposit was formed by hydrothermal and weathering alteration of pyroclastic rock, with a mineral composition comprising kaolinite, halloysite, cristobalite, and sericite. Judging from the results of chemical analysis, grain size, plasticity, iron content, and other features, the clay has quality that allows it to be used as a raw material for floor tiles, but contains too much iron to be used for wall tiles. Besides, there are problems with mining and transportation, coupled with the small quantity of the reserve, all of these factors making the clay unsuitable for use as a tile raw material.

(6) Monterado clay

Monterado clay is produced in an area 120 km to the north of Pontianak City in Kalimantan Island. The clay is kaolin-based clay arising from weathered granite, being clay from sedimentation deposit. At present, Clayindo Company, a joint venture business with WBB, quarrying and ships the clay product, with the quality control and transportation route established. Judging from the results of analysis, it can be used for floor tiles. Calculating the chemical composition of a mixed base on the assumption that Monterado clay, Banjarnegara feldspar, and kaolin from Belitung Island are used in a typical wall tile mixture consisting of 46% clay, 7% feldspar, and 10% kaolin resulted in 63.08% SiO_2, 23.00% Al_2O_3, and 0.75% Fe_2O_3. Monterado clay is judged to be capable of being used without problems if the combination of 46% of clay, 21% of quartz, and 10% of kaolin is adjusted. In addition, calculation suggests that the Al_2O_3 content of clay used in a typical wall tile mixture ranges from 23 to 27%. The price of the Belitung clay used for wall tiles is 23 RP/kg at a factory in Belitung Island and 51 RP/kg at a factory in Western Java. In contrast to this, the price of Monterado clay was 100 RP/kg at a factory in Western Java; the price is the problem.

(7) Pacitan agalmatolite and toseki

They are produced in Pacitan Prefecture in the eastern part of Java Island, located in a mountainous area about 200 km to the east of Yogyakarta City. The agalmatolite consists of pyrophyllite and sericite into which volcanic rock was changed by acid hydrothermal action, while toseki consists of sericite into which volcanic rock was changed by hydrothermal action. According to DSM, the agalmatolite reserves are estimated at about 5 million m^3; after a monthly production of 6,000 ton continued 1984 through 1987 for shipment for tile production, no shipment of the Pacitan produces has been made. Sample analysis showed that both Pacitan agalmatolite and toseki consist of sericite-based toseki mixed with pyrophyllite. They are low in iron content, 3% in K_2O content, and possess quality which allows them to be used as main raw materials for tiles. The problems are very unfavorable quarrying and transportation conditions and cheaper competition like Sukabumi clay. If production of wall tiles increases and consequently demand for low iron White Body increases in the future, it is possible that agalmatolite and toseki, which are low in iron content and rich in reserves, will be in greater demand. Competition with agalmatolite produced in Argomulyo, which is presently used for wall tile production, may occur.

(8) Pangaribuan feldspar

The producing site, a pegmatite feldspar mine, is located at a site about 180 km to the south-southeast of Medan City in Northern Sumatra. The mine is said to have produced feldspar of good quality, but it has been dug to the limit with only weathered granite left. Weathered granite could be used for tile production if its quality is stable after the beneficiation process including washing and sieving; however, transportation charges make it unsuitable for use at tile factories in Java Island.

(9) Jepara feldspar

According to the result of analysis of the samples collected by BBK, the mineral composition consists of sanidine and a slight amount of quartz; its alkaline contents (Na_2O + K_2O) is 12.26% and its Fe_2O_3 content 2.15%, making its coloration poor. In addition, results of the study show that a U.S. owned sanitary ware company uses the feldspar. Insufficiency of information prevents the feldspar from being evaluated as a raw material for tiles.

(10) Banjarnegara feldspar

The producing site is located to the south of Banjarnegara City in the central part of Java Island, with a relatively favorable access to transportation. The feldspar produced here is made of partially weathered pyroclastic rock, with a mineral composition comprising albite, microcline, and quartz. The alkaline content is about 8% and the iron content in the 1% range. Viewed from the point of view of quality, it can be used for both floor and wall tiles. According to DSM, Kalitengah Mine and Kebon Dalem Mine alone occupy an area of about 700 ha with a layer thickness of 50 - 60 m, having a large reserve. Banjarnegara feldspar is an important raw material used for tiles in the largest quantity second to Sukabumi feldspar. In the future, the mine operators should streamline quarrying methods and transportation and reinforce quality control to stabilize the quality and supply.

(11) Narawita feldspar

The production center is located 65 km to the east of Bandung City; the Narawita feldspar was made of partially weathered pyroclastic rock, with its mineral composition comprising sanidine, tridymite, cristobalite, and quartz; its alkaline content is about 6%, while white feldspar contains about 0.5% iron and colored portions 1.5% iron. Although the composition allows it to be used as a tile raw material, the location of the producing center to the east of Bandung in West Java and smaller reserves compared with those of Banjarnegara Mine reduce the usefulness of Narawita feldspar as a raw material for tiles.

If, however, feldspar with an iron content of about 0.5% can be constantly shipped, it could be used for wall tiles.

(12) Lampung feldspar

The production site is located about 60 km to the northwest of Bandar Lampung City in the southernmost part of Sumatra Island, with a good transportation route to the port. The feldspar mine here is based on weathered granite and produces massive ore rich in feldspar and sandy ore rich in silica stone. The sandy ore contains about 7% alkalis and about 0.3% iron. Viewed from the quality point of view, the sandy ore can be used for tile production. According to DSM, the size of the mine site is estimated at 12.5 million m^3, hence being large reserves; however, there are price problems with the Lampung feldspar.

4.3 Evaluation from Perspective of Tableware Production

4.3.1 Evaluation criteria

4.3.1.1 Major properties required for tableware

Tableware is manufactured by using a variety of molding methods, including roller machine, jiggering, pressing, and cast-in molding. In any molding method, plasticity is the most important property required for tableware materials, which governs workability on a commercial scale and the percentage of product acceptance after firing. In fact, this is not limited to tableware, but constitutes a critical and common property required in the industrial process to produce all the types of ceramic products (including new ceramics).

In Japan, rapid advancements of molding machines and kilns in the ceramic industry are demanding less strict requirements for certain aspects of the material's (base) property. On the other hand, properties required for tableware are increasingly emphasizing physical properties such as disruptive strength and thermal shock resistance, and external appearance including artistic value, such as whiteness and tone.

4.3.1.2 Criteria

To evaluate the suitability of a raw material for tableware production, the project image in a complete form should be clearly defined, and preliminary proportions of raw materials required for the project are determined. Then the substitution test is conducted on the basis of the proportions and by using raw materials to be evaluated, and the results are compared.

Raw materials for tableware production are evaluated separately for three criteria, physical properties, productivity improvement, and external appearance. Naturally, actual evaluation needs to be done by carefully weighing the three criteria which are often in complex trade-off relations. In addition, evaluation results are affected strongly by cost issues that should take into account the level of production technology which varies with equipment, and product value perceived by users (which properties are weighed).

When a given product gives priority to physical properties, e.g., heavy-duty tableware used by hotels and restaurants, the use of alumina as a raw material may be effective, or sintering of the body can be selected to obtain hard ceramic structure. By the same token, when a heat resisting product is desired, a material with a low coefficient of thermal expansion is effective, somewhat limiting the kinds of starting materials. Since starting materials vary greatly with what type of product is contemplated, it becomes apparent only after the project is made that a certain material is suitable for making a low-expansion product, not a high-strength product, or that other material adds strength to the project but deteriorates workability.

When external appearance is given of priority, e.g., to make a high-grade whit porcelain, impurities contained in raw materials, such as iron and titan, must be minimized. On the other hand, ordinary porcelain targeting the medium-grade market usually tolerates a higher impurity content. At an extreme end, the impurity content may be neglected if the material's own color is concealed by using a color glaze or a white emulsion glaze. Since the content of color impurities in a raw material can govern the type of the product, it is difficult to conclude that a specific iron or titan content makes a certain material acceptable or unacceptable. A primary example is kaolinite clay which has a good post-firing color but lacks plasticity to prohibit molding if it is used alone.

Finally, there is a case when the improvement of mixing proportions is desired for a tableware product currently in production because of its deficient workability due to poor plasticity or a high percentage of rejection. In this case, a cause for defect is identified through analysis and adequate raw materials are selected to improve productivities. For instance, a raw material which has good plasticity but shows an unfavorable color may be selected if productivity is improved by raising the proportion of this material, sacrificing the resultant color. Thus, the material is considered to have high, or desirable quality.

Among the three criteria, physical properties and productivity improvement are basically same as evaluation criteria used for tile and sanitary ware materials. Here, tableware materials are evaluated from external appearance, the most important criteria for tableware products.

4.3.2 Evaluation

4.3.2.1 Testing methods

(1) Basic composition of mixed materials

To evaluate properties related to external appearance, the basic oxidized ceramic composition was used, consisting of 30% toseki (Pacitan), 30% feldspar (Pangaribuan, Banjarnegara, Narawita), and 40% clays (including kaolin: Belitung, Sukabumi, Parungpanjang, Monterado).

(2) Preparation of specimen

Among mixed materials, TP4, FP, FB1, FB1W, FN, and FI were separately crushed in a pot mill and sieved (those passing 150 mesh). Plastic materials, CP1, CS2, and CM2, were dried and sieved (those passing 60 mesh), and KB and KN were used as supplied by manufacturers (in powder form).

(3) Mixing

Proportions of individual materials are shown in Table 4-3. Their typical values on chemical analysis (calculated) are shown in Table 4-4. As shown in Table 4-3, they were measured to attain 15g for one sample mixture. The measured materials in a powder form were mixed in a mortar for approximately 15 minutes.

(4) Forming

7g of the mixture were taken and dry pressed by using a ϕ 30mm mold under forming pressure of 200kg/cm^2.

(5) Firing

The formed blanks were fired in an electric oven, ADVANTEC KS 1503, by raising temperature to 1,250℃ along heat curves shown in Figure 4-1.

4.3.2.2 Evaluation

The test pieces after firing were analyzed by a color difference meter, Tokyo Denshoku ERP-80WX, for color measuring, followed by measurement of coefficient of water absorption. Table 4-5 shows the measurement results and iron contents. The results of color measuring and iron contents are shown in Figures 4-2 through 4-6.

Here, a high value of L represents a higher level of whiteness, while a lower value indicates a darker (black) color. The value of a indicates red on a higher scale and green on a lower scale. A higher value of b denotes yellow and a lower value blue.

With an increase in iron content, the value of L decreases and the value of b increases, while the value of a does not show a significant trend. The decrease in L and the increase in b indicate that the iron content deteriorates the color after firing. The test results disclose that L does not exceed 80 unless the content of Fe_2O_3 generally falls below 0.4%. The product having the L value of 80 is rated as medium-grade, and high-grade products require the L value of at least 85.

In other words, to attain the L value of 85, the content of Fe_2O_3 must be controlled at least in the range between 0.15% - 0.2%. No plastic materials available in Indonesia do not satisfy this requirement, while only the Pangaribuan feldspar meets the requirement.

Based on external color, each material was evaluated for its suitability for each product grade. The results are presented in Table 4-6 and indicate that only the Belitung kaolin and the Pangaribuan feldspar are suitable for use in medium- and high-grade products.

The external color is chiefly governed by the iron content and can only be improved by reduction of iron.

While the Banjarnegara feldspar and the Lampung feldspar can be used for medium-grade and high-grade products through beneficiation, there is little hope for clay materials, except for the Monterado clay which can be used for the medium-grade product.

4.3.2.3 Evaluation of Local Materials

(1) Belitung kaolin

This has good quality in terms of a relatively small iron content. It has some degree of plasticity, but which is not sufficient to use it as a plastic material for tableware to constitute a clay material. It contains white and fire resistant constituents. Overall, it appears to be suitable for high-grade products to some degree.

(2) Bangka kaolin

This also has a relatively small iron content. Plasticity is relatively high for kaolin, but not high enough to be used as a plastic material for tableware to constitute a clay material. It contains white and fire resistant constituents. Overall, it appears to be suitable for high-grade products to some degree.

(3) Parungpanjang clay

This contains montmorillonite which gives very high plasticity, while making slurry adjustment very difficult. It is thus not suitable for the wet production process (involving wet crushing in a ball mill, or cast-in molding).

The iron content is high to make it unsuitable for medium or higher grade products.

(4) Sukabumi clay

Low plasticity and a very high iron content make the clay relatively unsuitable for tableware production.

It can be used for red ceramic materials, such as terra-cotta.

(5) Cipeundeuy clay

While plasticity is low, it has a relatively low iron content, suggesting suitability for tableware production. High fire resistance indicates possible application for ceramic refractory materials, but the cristobalite content requires care in use.

(6) Monterado clay

It has adequate plasticity and a relatively low iron content to be suitable for tableware production. At the current level and with the color after backing, it is promising for use in medium-grade products.

(7) Pacitan toseki

Although not high-grade toseki (because of a low sericite content), a low iron content and favorable coloring make it suitable for a primary material of tableware. However, it lacks plasticity to set off whiteness, and unless combined with plastic clay with good coloring, the value of this toseki is significantly reduced. It is suitable for medium-grade tableware production.

(8) Pangaribuan feldspar

This is potassium feldspar with a low iron content and good coloring, highly suitable for tableware production. Unfortunately, however, this type of feldspar has been largely excavated.

(9) Jepara feldspar

A high iron content and resulting poor coloring make it unsuitable for medium or higher grade tableware production. On the other hand, the ease of sintering is suitable for stoneware allowing some color and color glazed materials.

(10) Narawita feldspar

Although an iron content is not very high, an alkali content is very low for feldspar, so result in low value. Relatively good coloring makes it useful for medium-grade products, but a large amount must be added to form porcelain materials. As a result, it cannot serve as feldspar by itself.

(11) Banjarnegara feldspar

It has consistent quality and can be used as a raw material for tableware. However, it contains mica which works against coloring, and if mica is removed properly, application will expand (possible to be used for high-grade products)

(12) Lampung feldspar

Sandy portions of the upper layer currently excavated do not contain much feldspar. As mining extends to the lower part in future, an alkali content will increase. With a relatively low iron content, it is well suitable for tableware production.

(13) Beneficiated Banjarnegara feldspar

The results of the firing test using the mixed materials indicates that the coloring value of L for mixture I (using FB-3) is 79, compared to 86.6 for mixture II (using T-9F; passed FB-3's magnetic ferro filter), resulting in improvement of whiteness. This agrees with the change in the L values for single FB-3 crude ore and single T-9F, 54 versus 79. Also the color improvement is suggested by a decrease in iron oxide content from 1.12% for FB-3 and 0.12% for T-9F. Similarly, the value of L increases (become white) between mixture III (FNK-1S: crushed, 1mm pass) and mixture IV (FNK-1: 1-2mm).

A major problem lies in the alkali content of refined materials; the alkali content in FB-3 (before beneficiation) is 8.68%, and that in T-9F (after beneficiation) 6.83%, a nearly 2 percentage point decline. In practice, the alkali content in a suitable feldspar material should be more than 12%, at least 10%, and preferably 14% or more. The alkali content of 6.83% means the proportion of feldspar must be raised in mixing accordingly, making porcelain composition practically impossible.

Thus, the coloring factor alone makes it suitable for high-grade tableware production, but the alkali content is too low to be used as a feldspar material.

4.3.3 Use of imported materials

While locally available feldspar materials become usable for medium- and high-grad products as a result of beneficiation, plastic materials, particularly clays available in Indonesia have a high iron content and thus has very low quality, so that plastic, low iron content clays need to be imported to produce high-grade ceramics.

4.4 Evaluation from Perspective of Novelty Production

4.4.1 Evaluation criteria

4.4.1.1 Material properties required for novelty products

In manufacturing novelty products, a major issue is not the quality of raw materials, Rather it is important to optimize composition and method of a particular body, and the methods and conditions for molding and firing, for the purpose of minimizing defects such as black spots, cracks, distortion, and color mottles, and improving product yield.

Novelty products vary greatly from small articles such as souvenirs, medium-sized articles such as vases and ornaments, large articles including garden ornaments, bowls and pots, to commodity products, and art work. Raw materials consist of clays produced from each area, and kaolin, feldspar, and quartz sand obtained from other areas. Products range in size according to locally available materials such red clay and white clay. Designs range from Indonesian, Chinese, to European, and the Middle East, and coating may be glazed, unglazed, painted, or uses mixed glaze, natural glaze, synthetic color or zaffer, depending on the place of production.

The manufacturing method varies with products, such as slip casting and throwing. Kilns may be of ascending type, or use simple natural drop type fuel oil furnaces, or even shuttle kilns. While the methods are different between places, most of them rely on manual work in traditional styles, and unlike industrial products, consistent quality is difficult to attain. In fact, quality variation is often preferred in making novelty goods as it adds unique, artistic value.

Thus, it is not necessarily a good practice to mechanically assume a certain quality level to be desirable, regardless of availability of materials, and replace present materials with those having higher quality or improve their quality through beneficiation. A typical example is found in Plered, where clays containing color impurities are used to produce a variety of products in varying size that match unique colors produced by the raw materials. These products are appreciated as the Plered pottery (in Japan, there is a similar local pottery called Tokoname-yaki). If raw materials are partially changed to produce white porcelains, they do not have unique characteristics of the Plered pottery. They are different novelty products. Similarly, ceramic products in Kiara Condong, referred to as white porcelains, are not as white as ordinary white porcelains in Japan, are somewhat grayish in tone, and have black spots on the surface (usually considered as defect) caused by color impurities. Nevertheless, this color and defect are sometimes preferred as having a classic atmosphere.

It does not necessarily mean that white porcelains need not be white. As white materials permit a variety of colors to be applied for coating and produce bright colors, they are highly demanded all the time.

4.4.1.2 Criteria

In evaluating raw materials for novelty products, evaluation criteria include those for tableware and sanitary ware production. For instance, in the case of slip casting, evaluation results should agree with those based on criteria applied to sanitary ware. In the case of throwing, evaluation results agree with those based on criteria for tableware. However, it should be noted that novelty products vary in size, design and other characteristics, regardless of which method was employed (slip casting or throwing), as mentioned earlier, so that a different evaluation method applies to each project. For this reason, novelty products should be evaluated by making actual products according to 4.4.2 and 4.4.2.1. The present study, however, attempted to make general (common) evaluation on the basis of chemical composition analysis, grain size distribution, slip castability, plasticity, and color after firing.

For evaluation, two types of the Kiara Condong body (for slip casting and throwing) and one type of the Malang body (for throwing) were selected as representative samples to look at their suitability for high value added white porcelain production. The samples were taken from actual process. According to the manufacturers, the composition of the both bodies for slip casting and throwing are basically same. Evaluation and testing methods are summarized as follows.

(1) Chemical composition analysis

X-ray fluorescence analysis was conducted by Taiko Refractory Co., Ltd. in Japan.

(2) Grain size distribution

Grain size distribution was measured by BBK's new particle-size distribution measuring equipment (made by Horiba Seisakusho, CAPA-300) according to test procedures described in 3.1.5.

(3) Firing / coloration

The test specimen were fired in BBK's new electric oven (made by ADVANTEC, KS-1530T) according to the firing/coloration test method described in 3.1.1, and tone was measured by BBK's new color difference meter (made by Tokyo Denshoku Technical Center, ERP-80WX). For comparison, the firing/coloration test was conducted for body samples for general grade in Mino, Japan.

(4) Evaluation of slip castability

Slip castability was evaluated according to the method described in 3.1.8, evaluation of slip castability of clay materials under the mixing test.

(5) Evaluation of plasticity

Since the body is already mixed with kaolin, feldspar, and quartzite, the testing method for plasticity of clay described in 3.1.6 does not apply. Instead, BBK's conventional method (a string of the stretched body is bent to form a 10cm diameter circle and plasticity is evaluated on the basis of cracks occurring on the body surface).

4.4.1.3 Evaluation

Many of problems related to the Kiara Condong body are attributable to the body mixing method (traditional manual work) and proportions of raw materials in the body. By introducing new body premixing equipment and evaluating and optimizing mixing conditions, it is possible to reduce product defects and improve product yield.

To produce white porcelains of high grade in Kiara Condong, white clays with high plasticity like Monterado, and feldspar with a higher alkali content than the Narawita feldspar should be used, while increasing the proportion of quartzite as much as possible. However, the use of these materials inevitably results in cost increase and makes the Kiara Condong business infeasible. Furthermore, ceramic raw materials available in Indonesia, be it clay or feldspar, have a high titan content. Titan, while not presenting a problem in the oxidization firing process, turns into black under reduced firing conditions which are designed to minimizing coloring due to the iron content. As a result, the level of whiteness attained by local materials is limited, around the level of general grade in Japan.

Naturally, high-grade white porcelains can be produced by using imported materials, but it is not necessarily taken place in Kiara Condong. In fact, it is possible to make high quality products by using high quality materials virtually everywhere. Logically, Kiara Condong products cannot simply compete with products manufacture near sources of high quality materials (not necessarily in Indonesia). In this case, cost structure becomes critical. Manufacturers of tiles, sanitary ware and tableware products can afford to buy high quality materials at a relatively high cost as they can establish price competitiveness in various areas, including production technology, financial base (scale of economy) and technologies adding functions to products. On the other hand, as novelty products depend upon personal skills and raw material prices are directly reflected in product cost, it is rational for them to use raw materials available economically in a local area.

Under these circumstances, simple reliance on product development by changing raw materials should be avoided. Instead, flexible measures are desirable to compete on design and other factors and identify market demand (including the changes in requirements) timely in order to introduce new products.

Detailed evaluation results are shown below.

Test results for each sample are summarized in Table 4-7.

(1) Results of chemical composition analysis

While raw materials for the Kiara Condong body were identified during the field survey, their mixing proportions were not known. From the results of the chemical composition analysis (Table 4-7), the body is estimated to be made up of kaolin 40-30% (Belitung), feldspar 35% (Narawita), quartzite 0-10% (Narawita), and clay 25% (Sukabumi). Comparing these proportions with those for the Malang body reveals the following findings:

1) Ignition loss is very high due to a high percentage of clay portions (kaolin and clay) (two-third). This leads to various defects such as cut in the firing process.
2) The content of Al_2O_3 is higher than that in the Malang body, because of the high content of clay and kaolin.
3) With this mixing, sintering to porcelain does not occurs at 1,250℃, thus considered to be a ceramic material.

(2) Results of grain size analysis

Grain distributions of the Kiara Condong and Malang bodies are compared as follows:

1) The Kiara Condong body has the smaller particle size, attributable to a high clay content and a low quartz sand content.
2) On the other hand, the Kiara Condong body is more remained in a 325-mesh sieve, probably because it uses raw materials containing a large amount of coarse particles or grading control in the mixing process is insufficient, i.e., no grading adjustment is carried out. In Kiara Condong, purchased materials are mixed and used without any treatment in the case of throwing. In the case of slip casting, they are treated to pass a 120-mesh sieve to remove foreign materials such as wood waste and stone. Thus, no grading adjustment is made in the mixing process. On the other hand, Malang has body premixing facilities where grading control is carried out, such as the crushing in the ball mill. The difference in mixing method is directly reflected in the results of grain size analysis.

(3) Firing / coloration

In the firing/coloration test at 1,250℃, the Kiara Condong and Malang bodies showed a higher value of L than those for general grade in Mino, Japan. Based on the L value alone, the Kiara Condong body was brightest, while the Mino body was poorest in brightness. Comparing the iron content that causes coloring (although the titan content affects coloring, it has little influence in the oxidization firing process), the Kiara Condong and Malang bodies contain 1% or more iron, whereas the Mino body for general grade generally has a 0.4% content. Obviously, the relationship between the results of the coloration test and the iron content is inconsistent with the results in 4.3 (negative correlation between the iron content and whiteness of the baked product). Major reasons for this are summarized as follows:

1) As mentioned earlier, the Kiara Condong body in the given composition cannot attain an sufficient level of sintering at 1,250℃, with variation among specimens after firing. The results of the mixing test in 4.3 show the difference in value of L between specimens attaining sufficient sintering and those not, in the range between 5% and 10%. This seems to contribute to the above data inconsistency.
2) Generally, the value of L represents brightness and the value of b bluing/yellowing effect (the higher the positive value is, the stronger the yellowing effect becomes, otherwise the bluing effect takes over). However, brightness (higher L) and no coloring (when b takes a positive value) are what makes a specimen look white to human eyes. Thus, the degree of whiteness varies proportional to the value of L and inversely proportional to the value of b. These relationships are illustrated in Figure 4-7. As a result, the Mino body for general grade is considered to be whiter.

Empirically, the body having the high level of whiteness generally shows a high value for L and small values for a and b after sintering. Overall, therefore, the Kiara Condong and Malang bodies have less whiteness than the Mino body for general grade. Mixing compositions of the Kiara Condong and Malang bodies indicate that the Belitung kaolin represents 40%, presumably to produce white-based products while maintaining a certain level of plasticity. If novelty products in these areas use "whiteness" as major feature appealing to customers, it is difficult to supply products without defects (crack, dent) unless plastic, white clay (e.g., the Monterado clay) is used.

(4) Slip castability

The slip casting test was conducted for the Kiara Condong and Malang bodies (Table 4-7), and relatively good molds were obtained from the Malang body. On the other hand, molds obtained from the Kiara Condong clay were soft and easily breakable, although the body seemingly stick to the gypsum mold. Novelty products made by slip casting do not meet strict material requirements compared to sanitary ware production as their molds are not as thick and large as those for sanitary ware. Although they can be produced under the current mixing conditions, therefore, the body has relatively poor slip castability.

The Malang body is made at premixing facilities where mixing conditions are studied and established under the assistance of BBK and private enterprises in East Java. On the other hand, in Kiara Condong, mixing is mostly done manually, and mixing proportions are based on these made by predecessors and do not seem to be established through scientific examination of possible mixing conditions. Obviously, the difference in such efforts is directly reflected in the quality gap which needs to be narrowed through appropriate improvement measures.

(5) Plasticity

Compared on plasticity, the Kiara Condong body is lower than the Malang body so far as the test results show (Table 4-7). This result seems to be inconsistent with the fact that the former uses large amounts of clay materials. There are two possible reasons for this:

1) The difference in plasticity between the Sukabumi and Bantur clays
2) The Malang body goes through grading control at a ball mill or other premixing facilities, resulting in better plasticity.

Plasticity is one of fundamental properties required for production of ceramic products. Regardless of molding method, whether slip casting or throwing, plasticity directly affects workability and product quality. To improve plasticity as well as other properties, Kiara Condong needs to install a body premixing factory to produce body in volume. This way, problems can be clarified to allow examination and improvement of mixing conditions, resulting in productivity and quality improvements.

4.5 Other Comments from the Viewpoint of Refractory Products

4.5.1 Background of evaluation

Some raw materials are evaluated from the viewpoint of manufacturing refractories whose demand is expected to be increase in near future in Indonesia. With these prospects being taken into consideration, the four types of raw material, namely 1) Cipeundeuy clay, 2) Parungpanjang clay, 3) Pacitan toseki, and 4) Belitung kaolin, are considered suitable candidate materials for production of refractories, chosen among the Indonesian ceramic raw materials studied by this Investigating Commission; to include raw materials studied in the past, 5) Kijang bauxite may be chosen.

As Indonesia's economy develops and comes closer to that of an industrialized country, the consumption of iron is increasing. Per-capita iron consumption in industrialized countries is 600 - 700 kg/year. Based on this figure, future iron consumption of Indonesia will be estimated at 120 million - 140 million ton/year for a population of about 200 million. On the other hand, Japan's crude steel production is about 100 million ton/year including exports; accordingly, when Indonesia has developed into a modern nation, it will consume more crude steel than Japan currently does. However, since the present crude steel production in Indonesia is only 3 million - 4 million ton/year, a rapid increase in iron production is expected. Actually, newspapers report say that PT. Krakatau Steel, Indonesia's largest steel mill, will double its production capacity by 2000 and aim at becoming a integrated iron and steel works by introducing the blast furnace ironmaking method. Accordingly, an increase in iron production will cause the production of refractories, absolutely necessary for producing iron, to increase rapidly. The amount of refractories necessary for producing a ton of crude steel, that is the unit consumption of refractories, is about 100 kg in developing countries and about 10 kg in Japan; therefore, about 1 million tons of refractories will be needed in Indonesia in the near future. On the assumption that those refractories contain about 40% clay base raw material, clay consumption will be estimated at about 400,000 tons.

The results of the examination made on the individual raw materials for the possibility of using them for production of refractories are given as follows.

4.5.2 Evaluation of domestic raw materials

(1) Cipeundeuy clay

Cipeundeuy clay has high refractoriness but its plasticity is low. Accordingly, the most promising method of using this clay is to form this into pellets, and fire them into chamottes, which are used at a temperature of 1,300 - 1,350℃ as aggregates for general purpose fireclay refractory bricks and fireclay unshaped refractories. Depending on the results of the measurement of the permanent linear change on reheating, some fireclay refractory bricks may be used in green condition. It is not necessary to take the iron oxide content into account except for refractories for changeable atmosphere kilns; an iron oxide content of less than 2 - 3% does not pose problems of firing coloration with refractories.

(2) Parungpanjang clay

Being excellent in plasticity, Parungpanjang clay is considered the most suitable as a binder for general purpose fireclay bricks and as bonding clay for prepared unshaped refractories, especially plastic refractories. In addition to these applications, when this clay is used as a binder for refractory mortar, its excellent workability and bonding strength will be appreciated.

(3) Pacitan toseki

Pacitan toseki contains sericite in addition to quartz as the major mineral; therefore, it is considered to be excellent in volume stability at high temperatures and sinterability. For this reason, it is best suited to being used without being fired and in green condition as an aggregate for ladle bricks for casting steel. In addition, if this toseki is formed and fired into shaped products like bricks, there may be room for considering using it as an aggregate for refractory castables which are characterized by their application in atmosphere gas furnaces and quick setting, because the toseki contains less iron oxide.

(4) Belitung kaolin

Because Belitung kaolin contains a relatively small quantity of impurities, has great homogeneity, and is produced in quantities, processing it for use as a high alumina aggregate for refractories is considered advisable. In other words, there is a possibility of manufacturing high alumina synthetic mullite by mixing and firing Belitung kaolin and Bayer-processed alumina. However, because different mullite synthesizing methods have been developed to match different raw materials, further tests and studies are necessary to determine which method is the best. Since refractories necessary for producing clean steel tend to be replaced by mullite-based or high alumina-based refractory bricks and prepared unshaped refractories, raw materials for synthetic mullite have a lot of future potential. There is another possibility of mixing and firing Belitung kaolin and talc or magnesite to manufacture synthetic cordierite which is to be used as an aggregate for kiln furniture when pottery is fired.

(5) Kijang bauxite

Being low in iron oxide content, Kijang bauxite will find very many applications if high alumina clinker can be manufactured by forming Kijang bauxite into pellets or the like and firing them at high temperatures. At present, the world's bauxite clinker-producing countries are limited, with aluminous shale from China (fired products) and bauxite clinker from the Guianas in South America being the mainstream products, which countries in need of bauxite import. The high alumina clinker, which is a fired product made from high alumina natural raw materials, can be less expensive than synthetic mullite if it has physical properties as a refractory raw material, and demand for it will be great and the prospect for its exportation will be bright. However, because quantities of impurities such as titania change high temperature properties, thorough investigation on this point is necessary.

Table 4-1 Standard for the Evaluation of the Material

An example in some maker

The makers which produces only one kind of product has settle their own base combination and slip casting method, and generally each company/factory has already possessed the standard of evaluation based on the long term experience or raw material test. This is an example of ordinal standard of evaluation of sanitary ware material.

(1) One Raw Material

Kaolin	Not less than 33% of Al_2O_3, not more than 2.0% of Fe_2O_3, Few impurities (Montmorillonite, Alunite)
Clay	Not less than 30% of Al_2O_3, Not more than 2.0% of Fe_2O_3, few impurities, superior plasticity (Plasticity not less not less than 74%)
Sericite Based Toseki	Not less than 15% of Al_2O_3, Not more than 0.5% of Fe_2O_3, few impurities,
Feldspar	Not less than 10% of Alkaline content ($Na_2O + K_2O$), Not more than 0.5% of Fe_2O_3

(2) Mixing Test

Properties of Slip	Concentration not less than 342g/200cc,	
Casting Rate	note less than 6mm in 20 minutes,	
Plasticity	good result in deformation resistance, thixotropic resistance and workability of the cast (difficult to represent by values, evaluate by its appearance and touch)	
Strength of a Dry Base	Strength to bear when move the cast is necessary, no problem when the test material has superior plasticity because it is proportional to its plasticity	
Sintering Properties	Shrinkage (dry-shrinkage + Sintering shrinkage)	Not more than 15%
	Firing Bend (Bending)	Not more than 30mm
	Absorbency rate (ink)	Not more than 3mm

Table 4-2 Evaluation of Raw Material for Sanitary wares

1) The raw materials which can be used for sanitary wares are 3 types: Bangka Kaolin, Belitung Kaolin, Monterado Clay.
2) The raw materials which may be used for supplemental material (use a little) are 2 types: Pacitan Toseki, Jepara feldspar.
3) Pacitan Toseki has not developed yet. The mining situation of Jepara feldspar is unknown.

No.	Item		Estimate	Reason and Supplemental Explanation
1	Bangka Kaolin		○	High quality of Kaolin though less plasticity. Usable when it mixed with the clay containing a little Fe_2O_3.
2	Belitung Kaolin	KB	○	same as above.
3	Parungpanjang Clay		×	Superior plasticity, but unable to slip proper slip because containing montomorilionite.
4	Sukabumi Clay	CS–1	×	Inferior workability. Much Fe_2O_3, little Al_2O_3.
5	Cipeundeuy Clay	CC	×	Inferior plasticity.
6	Monterado Clay	TP–4	○	Inferior plasticity but comparatively little Fe_2O_3, superior workability. It may become a high quality material depending on a mixing ratio.
7	Pacitan Clay		△	Low class Sericite based Toseki. As containing little Fe_2O_3, this may be used as supplemental material.
8	Pangaribuan Clay		×	Nearly pure feldspar and containing little Fe_2O_3, and has high quality but it has digged up.
9	Jepara Feldspar		△	Soluble feldspar containing Na_2 50% K_2O 50% and alkali 12%. Its defect is not less than 2% of Fe_2O_3. It may be used as supplemental material enhancing the solution.
10	Banjarnegara Feldspar	FB–1	×	6～7% of alkali, difficult
11	Dissolved Narawita Feldspar	FN–1, 2	×	same as above
12	Lampung Feldspar	FL	×	same as above
13	Banjarnegara Refining Feldspar		○	May be used because it is improved by reducing the alkali amount to 10%

Notes: ○ be able to use △ be able to use as auxiliary material × be unable to use

Table 4-3 Material Mixing Ratio for Firing Coloration

Test No.	PB-1	PB-2	PB-3	PB-4	PB-5	NB-1	NB-2	NB-3	NB-4	NB-5
TP-4	50	40	30	20	10	30	20	10	-	-
FP	10	20	30	40	50	-	-	-	-	-
FN-1	-	-	-	-	-	30	40	50	60	70
KB	40	40	40	40	40	40	40	40	40	30

Test No.	BB-1	BB-2	BB-3	BB-4	BB-5	B(W)B-1	B(W)B-2	B(W)B-3	B(W)B-4	B(W)B-5
TP-4	40	30	20	10	-	40	30	20	10	-
FB-1	20	30	40	50	60	-	-	-	-	-
FB-1-W	-	-	-	-	-	20	30	40	50	60
KB	40	40	40	40	40	40	40	40	40	40

Test No.	PP-1	PP-2	PP-3	PP-4	PP-5	PS-1	PS-2	PS-3	PS-4	PS-5
TP-4	50	40	30	20	10	50	40	30	20	10
FP	10	20	30	40	50	10	20	30	40	50
CP-1	40	40	40	40	40	-	-	-	-	-
CS-2	-	-	-	-	-	40	40	40	40	40

Test No.	PM-1	PM-2	PM-3	PM-4	PM-5
TP-4	50	40	30	20	10
FP	10	20	30	40	50
CM-2	40	40	40	40	40

Test No.	IB-1	IB-2	IB-3	IB-4	IB-5	IN-1	IN-2	IN-3	IN-4	IN-5
TP-4	50	40	30	20	10	50	40	30	20	10
FI	10	20	30	40	50	10	20	30	40	50
KB	40	40	40	40	40	-	-	-	-	-
KN	-	-	-	-	-	40	40	40	40	40

Test No.	BR-1	BR-2	BR-3	BR-4
TP-4	20	20	20	20
FB-3	40	-	-	-
T-9F	-	40	-	-
FNK-1S	-	-	40	-
FNK-1	-	-	-	40
KB	40	40	40	40

FI: Indian feldspar
KN: New Zealand kaolin

Table 4-4 Chemical Composition
(Calculated from Analysis Data of Individual Raw Material)

Sample	Na_2O	K_2O	Al_2O_3	SiO_2	Fe_2O_3	TiO_2
BB1	0.96	2.30	23.79	65.52	0.48	0.27
BB2	1.38	2.39	23.88	64.98	0.57	0.24
BB3	1.81	2.47	23.98	64.44	0.67	0.20
BB4	2.23	2.56	24.07	63.90	0.76	0.17
BB5	2.65	2.64	24.16	63.36	0.85	0.13
BWB1	0.78	2.23	23.37	66.20	0.38	0.27
BWB2	1.11	2.28	23.26	65.97	0.46	0.23
BWB3	1.45	2.34	23.15	65.75	0.53	0.20
BWB4	1.78	2.39	23.03	65.52	0.61	0.16
BWB5	2.11	2.44	22.92	65.29	0.68	0.12
PB1	0.20	3.22	24.24	64.94	0.30	0.30
PB2	0.29	4.31	24.88	63.23	0.30	0.26
PB3	0.37	5.40	25.52	61.52	0.30	0.22
PB4	0.46	6.49	26.16	59.80	0.30	0.17
PB5	0.54	7.58	26.80	58.09	0.30	0.13
NB1	0.56	2.53	23.56	64.53	0.39	0.30
NB2	0.72	2.66	23.54	63.82	0.42	0.28
NB3	0.87	2.79	23.52	63.11	0.45	0.26
NB4	1.02	3.06	22.17	64.25	0.45	0.26
NB5	1.17	3.32	20.81	65.39	0.45	0.25
IB1	0.40	3.07	24.14	65.10	0.30	0.30
IB2	0.69	4.01	24.67	63.55	0.30	0.26
IB3	0.97	4.96	25.20	61.99	0.30	0.22
IB4	1.26	5.90	25.73	60.44	0.30	0.17
IB5	1.54	6.84	26.26	58.88	0.30	0.13
IN1	0.38	2.84	22.97	66.71	0.13	0.25
IN2	0.67	3.78	23.50	65.16	0.13	0.21
IN3	0.95	4.72	24.03	63.61	0.13	0.17
IN4	1.24	5.66	24.56	62.05	0.13	0.12
IN5	1.52	6.60	25.09	60.50	0.13	0.08
PM1	0.23	3.51	21.38	67.81	0.51	0.73
PM2	0.32	4.60	22.02	66.10	0.51	0.69
PM3	0.40	5.69	22.67	64.39	0.51	0.65
PM4	0.49	6.78	23.31	62.67	0.51	0.60
PM5	0.57	7.87	23.95	60.96	0.51	0.56
PP1	0.27	3.84	19.61	69.99	0.88	0.52
PP2	0.36	4.93	20.25	68.28	0.88	0.48
PP3	0.44	6.02	20.90	66.56	0.88	0.44
PP4	0.53	7.11	21.54	64.85	0.88	0.39
PP5	0.61	8.20	22.18	63.13	0.88	0.35
PS1	0.17	3.25	17.73	66.39	6.03	0.72
PS2	0.26	4.34	18.37	64.68	6.03	0.68
PS3	0.34	5.43	19.02	62.97	6.03	0.64
PS4	0.43	6.51	19.66	61.26	6.02	0.59
PS5	0.51	7.60	20.30	59.55	6.02	0.55

Table 4-5 Firing Coloration Test Result for Sample Mixture

Sample	L	A	B	Fe_2O_3 Content	Water Absorption
BB1	86.94	0.98	10.15	0.48	2.30
BB2	79.68	0.45	9.34	0.57	0.13
BB3	75.93	0.10	9.14	0.66	0.05
BB4	74.65	−0.34	9.21	0.75	0.00
BB5	72.98	−0.61	9.46	0.85	0.00
BWB1	88.75	0.92	9.13	0.38	3.35
BWB2	84.46	0.62	9.36	0.46	0.81
BWB3	79.93	0.20	8.78	0.53	0.03
BWB4	78.24	−0.26	8.60	0.60	0.03
BWB5	77.66	−0.84	8.61	0.68	0.03
PB1	90.07	0.61	7.30	0.30	3.88
PB2	85.69	0.36	8.29	0.30	0.62
PB3	82.64	0.28	8.39	0.30	0.10
PB4	80.21	0.02	8.00	0.30	0.05
PB5	80.36	−0.50	7.53	0.30	0.02
NB1	90.07	0.22	8.45	0.39	3.68
NB2	88.42	−0.01	9.34	0.41	2.13
NB3	84.84	−0.63	8.47	0.42	0.57
NB4	82.34	−1.17	7.89	0.43	0.08
NB5	78.27	−1.13	8.01	0.45	0.04
IB1	89.33	0.65	8.53	0.30	3.08
IB2	83.74	0.48	8.41	0.30	0.11
IB3	80.95	0.37	8.25	0.30	0.03
IB4	80.81	−0.10	7.90	0.30	0.00
IB5	81.73	−0.77	7.49	0.30	0.00
IN1	89.63	0.89	6.99	0.13	2.77
IN2	86.15	0.95	7.42	0.13	0.45
IN3	83.98	0.65	6.50	0.13	0.03
IN4	84.01	0.19	5.72	0.13	0.00
IN5	86.16	−0.42	4.99	0.13	0.00
PM1	82.09	1.39	11.62	0.51	1.37
PM2	75.05	1.18	10.17	0.51	0.17
PM3	71.98	1.05	9.43	0.51	0.05
PM4	70.64	0.77	8.92	0.51	0.00
PM5	69.82	0.35	8.34	0.51	0.00
PP1	67.15	1.23	10.46	0.88	0.08
PP2	64.92	0.96	9.41	0.88	0.03
PP3	65.02	0.73	9.37	0.88	0.02
PP4	65.10	0.42	9.33	0.88	0.02
PP5	64.35	0.17	9.28	0.88	0.00
PS1	32.13	3.32	2.69	6.03	0.10
PS2	31.70	2.79	2.60	6.03	0.00
PS3	31.85	3.43	4.23	6.03	5.42
PS4	32.23	3.89	5.68	6.03	10.24
PS5	33.55	4.63	6.44	6.02	15.04

Table 4-6 Material Evaluation from the View of Table ware Production

Sample	High grade		Medium grade		
	Porcelain	Bone China	Porcelain	Hard porcelain	Stone ware
FP	△	△	○	○	○
FB	×	×	△	△	○
FL	×	×	△	△	○
FN	×	×	△	△	○
FJ	×	×	×	×	△
CP	×	×	×	×	△
CS	×	×	×	×	△
CC	×	×	×	△	△
CM	×	×	○	○	○
KB	△	△	○	○	○
TP	△	×	○	○	○
Beneficiation FB	△	×	○	○	○

Table 4-7 Quality of Pre-mixed Material in Indonesia (1/2)

Pre-mixture	Kiara Condong				Malang		Plered			
Application	Throwing		Slip casting		Throwing		Throwing (1st grade)		Throwing (2nd grade)	
Material composition	Quarrying site	Mixing ratio (%)	Quarrying site	Mixing ratio (%)	Quarrying site	Mixing ratio (%)	Quarrying site	Mixing ratio (%)	Quarrying site	Mixing ratio (%)
Kaolin	Belitung	(40–30)*	Belitung	(40–30)*	Belitung	42	Belitung	5		–
Feldspar	Narawita	(35)*	Narawita	(35)*	Lodoyo	28		–	(Lime stone)	5
Quartz	Narawita	(0–10)*	Narawita	(0–10)*	Tuban	22	(Sand clay)	3	(Sand clay)	3
Clay	Sukabumi	(25)*	Sukabumi	(25)*	Bantur	8	Plered	92	Plered	92
Wall thickening test										
Concentration	333		326		332					
Viscosity	47		67		57					
Viscosity (30min.)	100		101		59					
Wall thickness	5/6		x/x		4/5					
Water content	25/25		–		21/22					
Particle (<10 μ)	61		–		46					
Cast condition	soft		too soft		good					
Dry shrinkage	–		–		2.5					
Dry strength	–		–		18.0					
Firing shrinkage	–		–		8.5					
Firing strength	–		–		520					
Bending test	–		–		17.0					
Water absorption										
Bending piece	–		–		40.0					
Shrinkage piece	–		–		31.0					
Plasticity	no good		no good		good					
Firing coloration							<Reference: General grade of Mino in Japan>			
L	77.2		77.4		70.9		68.8			
a	0.5		0.4		2.3		–1.1			
b	13.0		13.6		13.7		8.4			

Table 4-7 Quality of Pre-mixed Material in Indonesia (2/2)

Pre-mixture	Kiara Condong				Malang		Plered	
Application	Throwing		Slip casting		Throwing		Throwing (1st grade)	Throwing (2nd grade)
Chemical composition (%)								
Ig. Loss	9.19		9.78		6.72			
SiO_2	61.84		59.91		67.31			
Al_2O_3	24.66		25.61		20.55			
Fe_2O_3	1.19		1.24		1.15			
TiO_2	0.61		0.68		0.29			
MnO	0.01		0.01		0.01			
CaO	0.09		0.10		0.10			
MgO	0.33		0.38		0.05			
Na_2O	0.39		0.59		0.09			
K_2O	1.60		1.61		3.69			
P_2O_5	0.03		0.03		0.02			
Cr_2O_3	0.02		0.02		0.01			
ZrO_2	0.04		0.04		0.02			
Total	100.00		100.00		100.01			
Particle size (μ)	Distribution (%)	Accumulation (%)	Distribution (%)	Accumulation (%)	Distribution (%)	Accumulation (%)		
10μ <	38.70	100.00	65.80	110.00	56.60	100.00		
10–9μ	0.00	61.30	0.00	44.20	0.00	43.40		
9–8	1.80	61.30	0.00	44.20	0.00	43.40		
8–7	2.30	59.50	0.00	44.20	2.90	43.40		
7–6	5.00	57.20	0.40	44.20	5.30	40.50		
6–5	7.40	52.20	5.10	43.80	6.70	35.20		
5–4	8.50	44.80	5.00	38.70	6.00	28.50		
4–3	7.40	36.30	6.40	33.70	4.80	22.50		
3–2	8.00	28.90	7.30	27.30	6.80	17.70		
2–1	13.80	20.90	13.50	20.00	7.70	10.90		
1μ >	7.10	7.10	6.50	6.50	3.20	3.20		
D-median	5.71μ		10.43μ		14.61μ			
+325#	7.10%		6.50%		3.20%			

Note: * are the estimation from chemical composition analysis data.

Figure 4-1 (1)
Heating Up Program of Electric Kiln for Firing
Coloration Test of the Sample Mixture for Table Ware

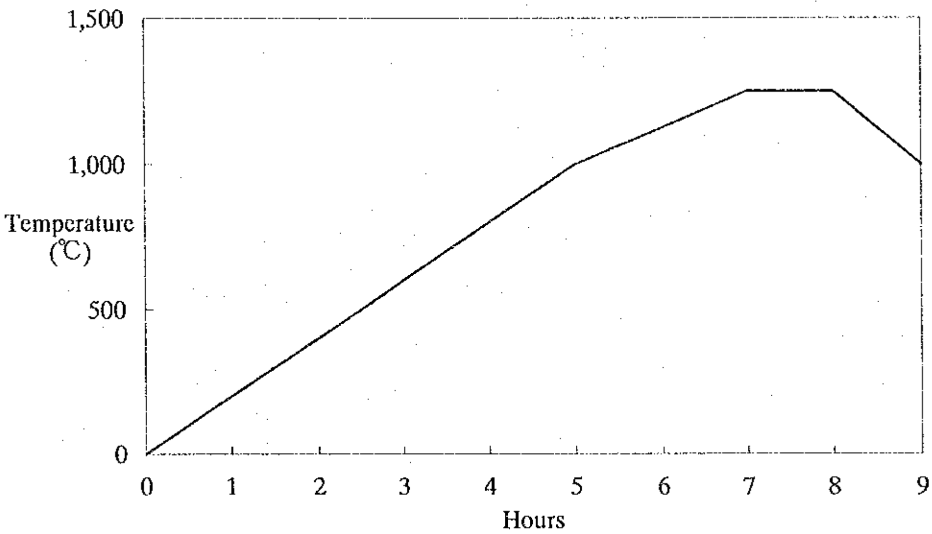

Figure 4-1 (2)
Heating Up Program of Electric Kiln for Firing
Coloration Test of the Sample for Sanitary Ware

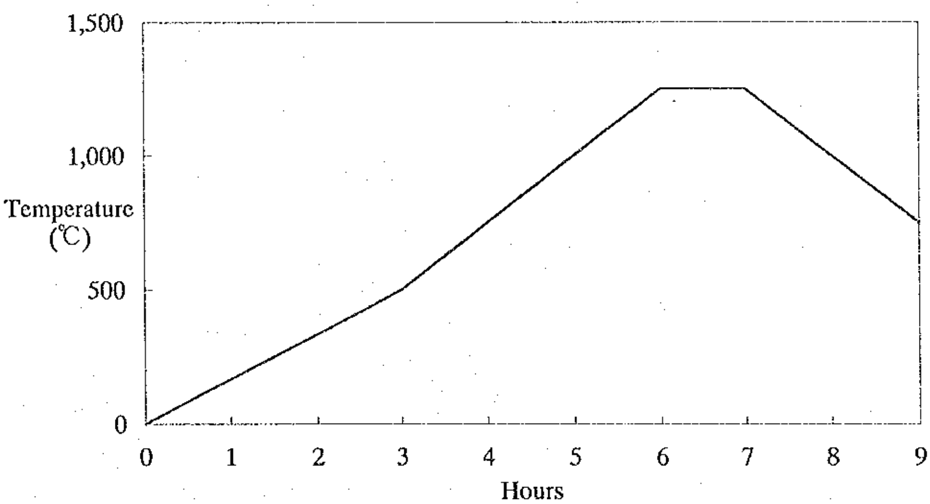

Figure 4-2 Fe_2O_3 - L Value

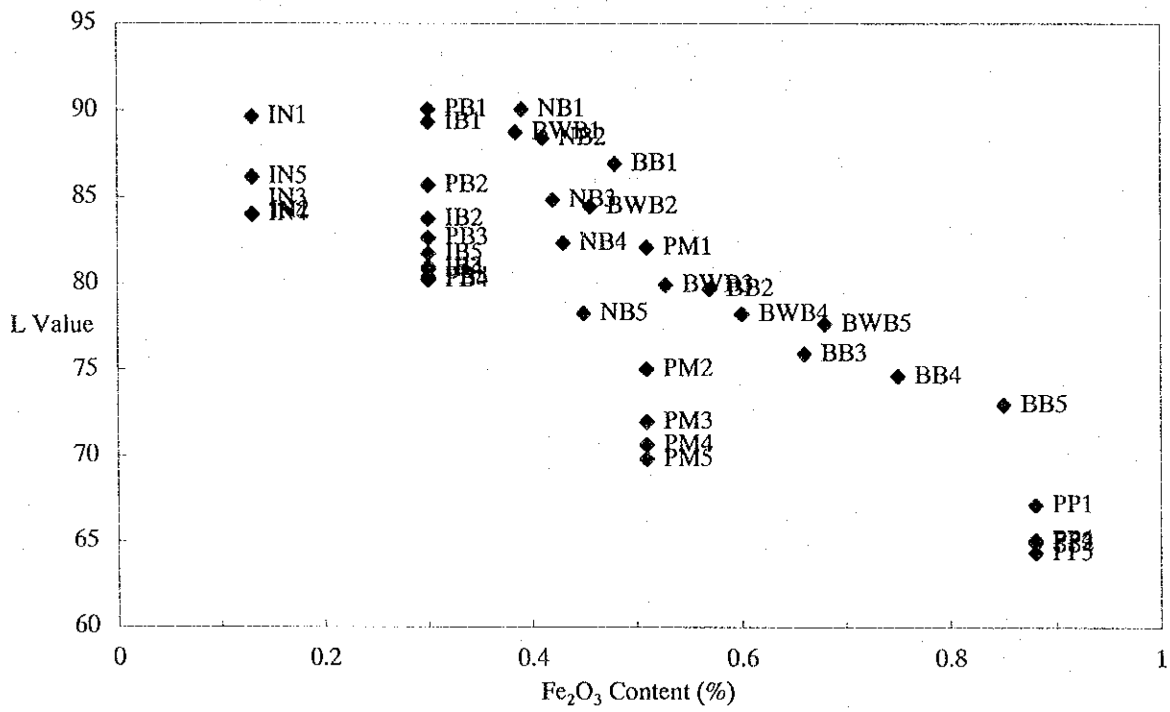

Figure 4-3 Fe_2O_3 - L Value Well Sintered

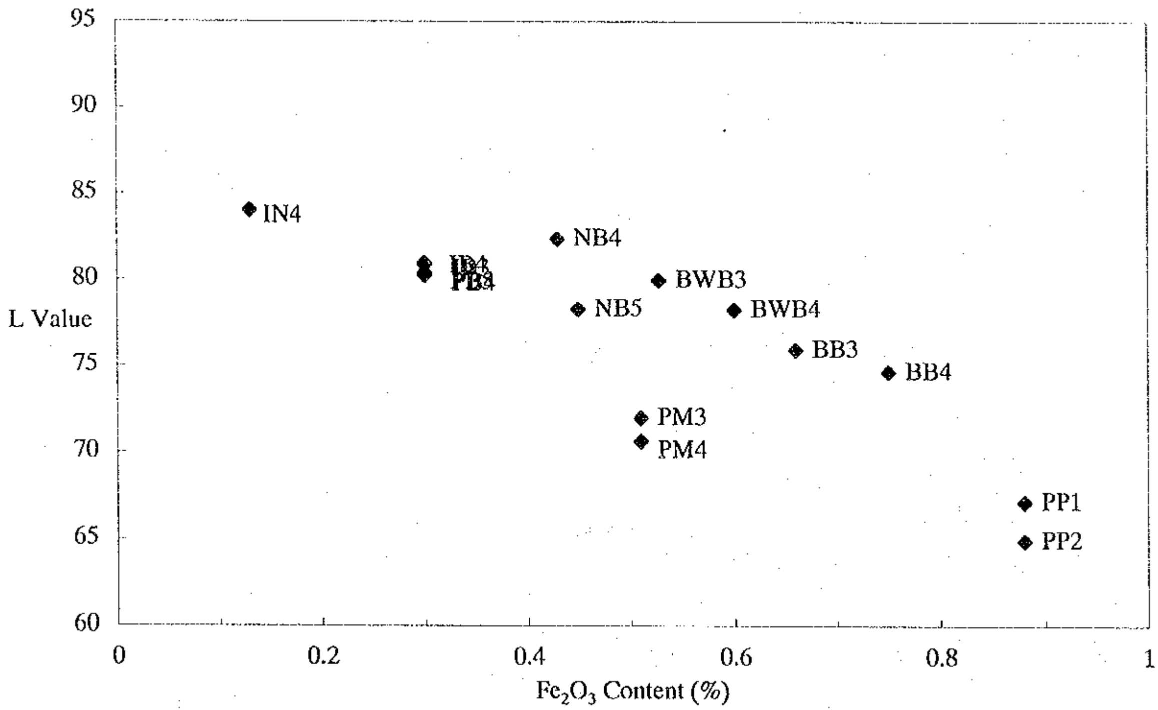

Figure 4-4 Fe_2O_3 - A Value

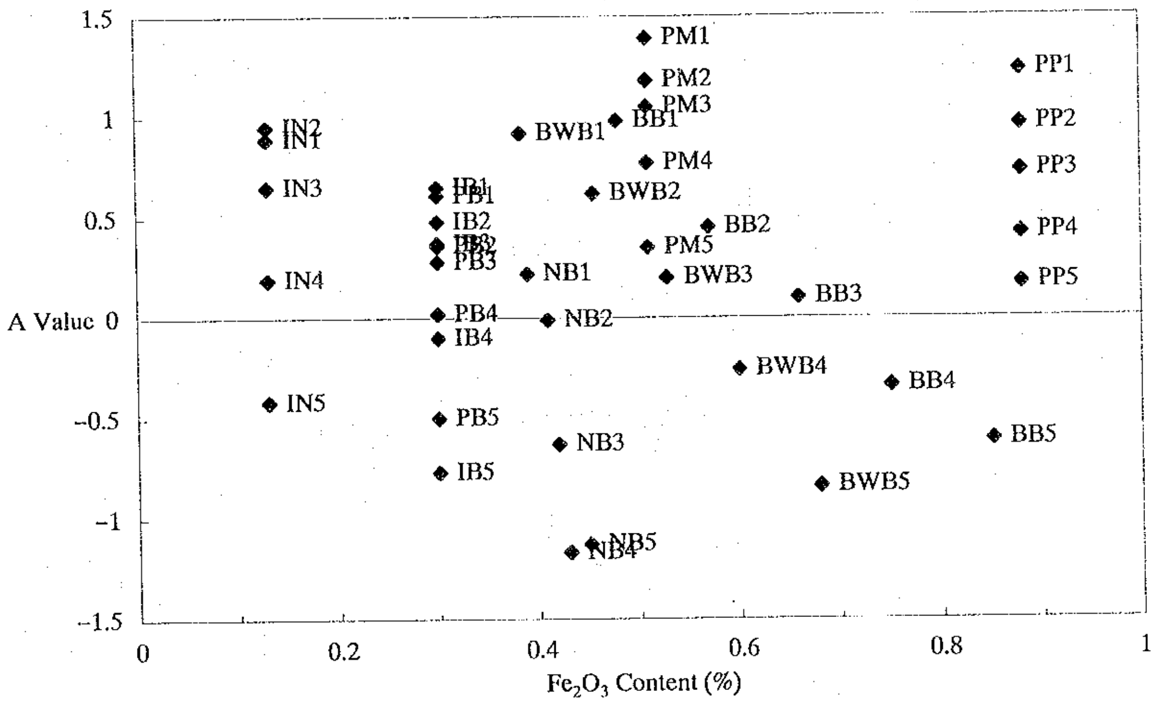

Figure 4-5 Fe_2O_3 - B Value

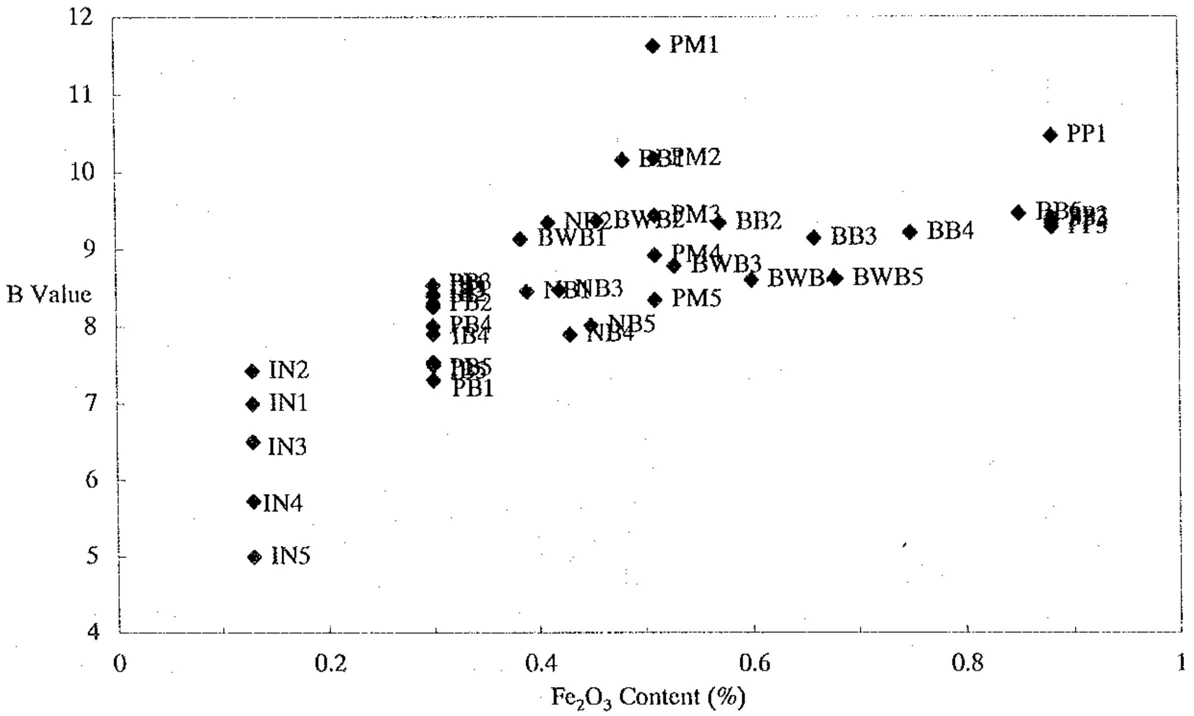

Figure 4-6 Fe_2O_3 - B Value Well Sintered

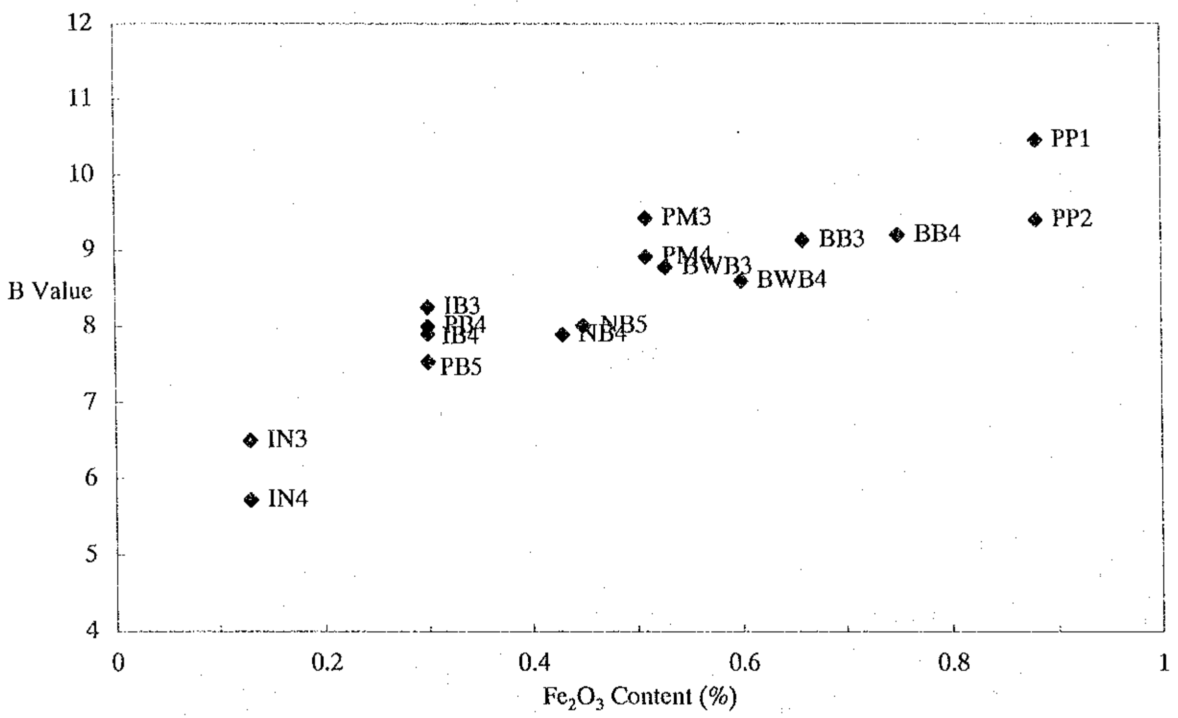

Figure 4-7 Firing Coloration Test Result on Pre-mixed Clay Body of Indonesia and Japan