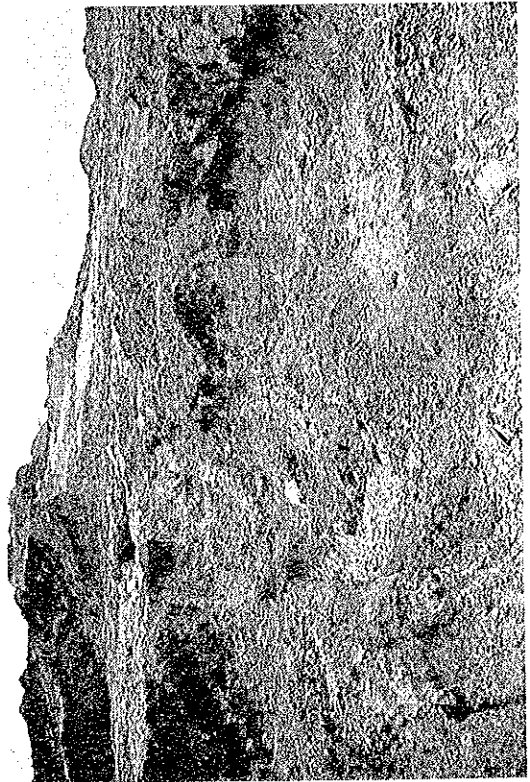
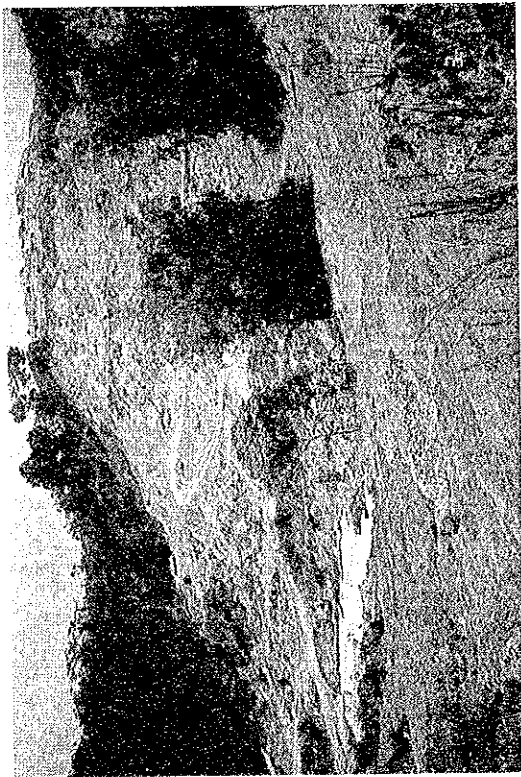
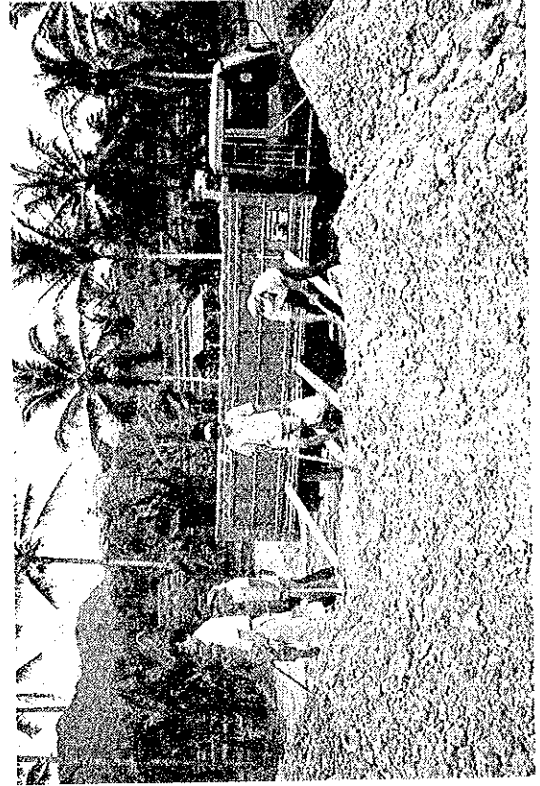
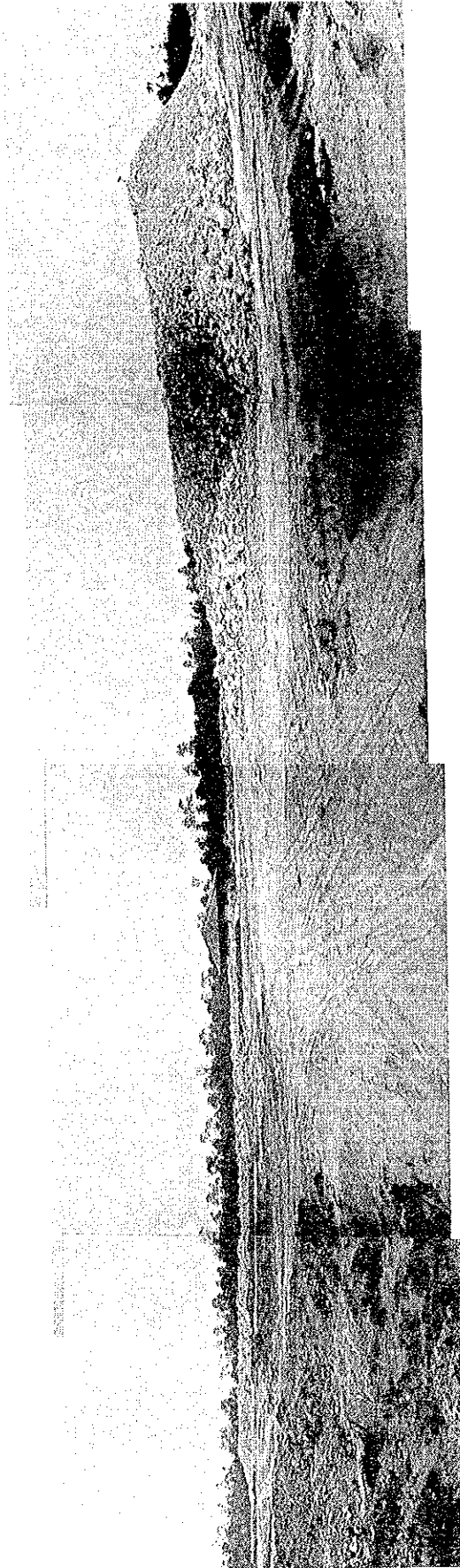


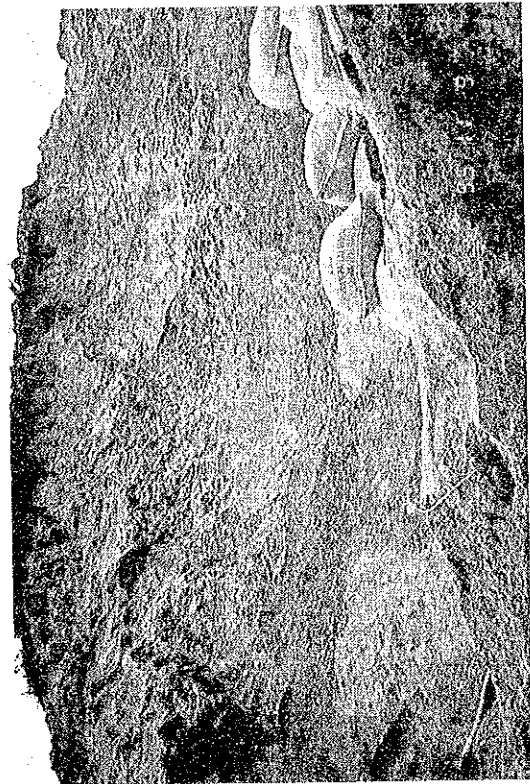
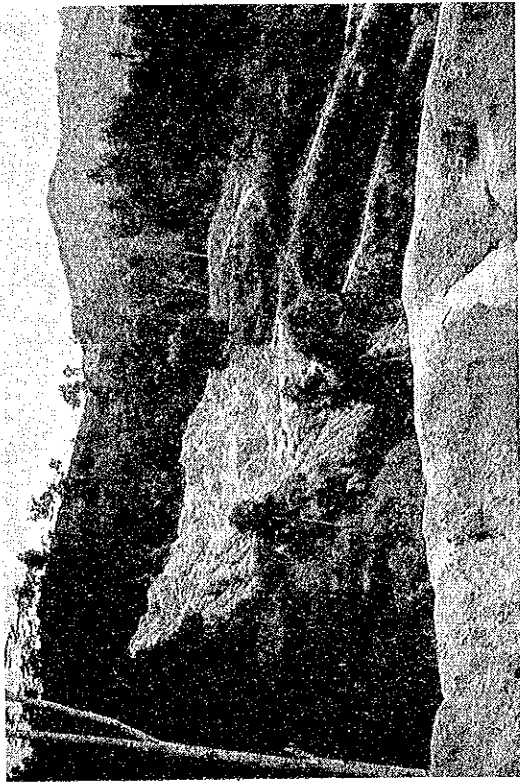
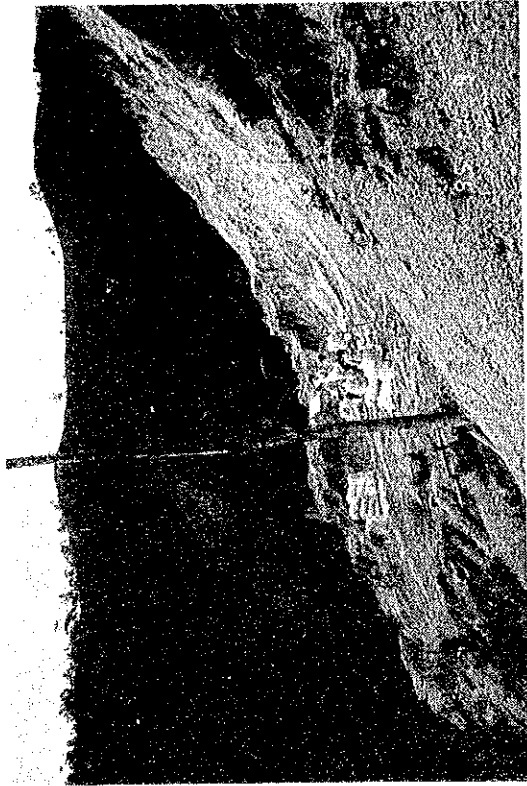
Picture 2-1 (1) Sukabumi North Quarrying Site



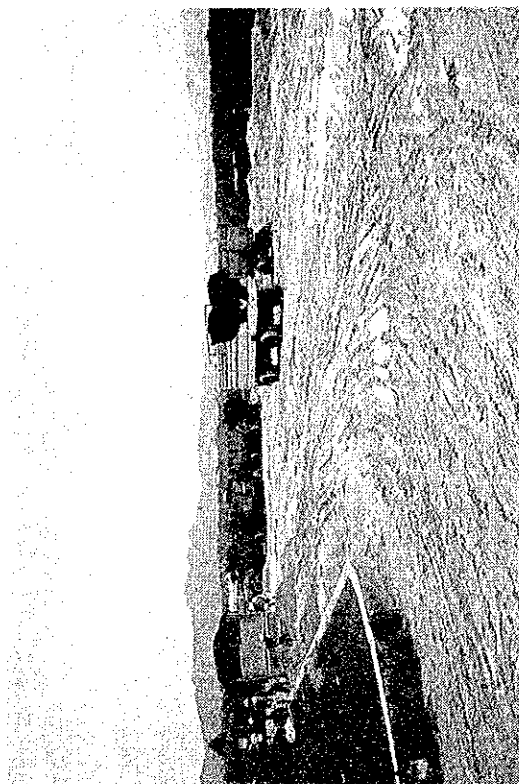
Picture 2-1 (2) Sukabumi South Quarrying Site



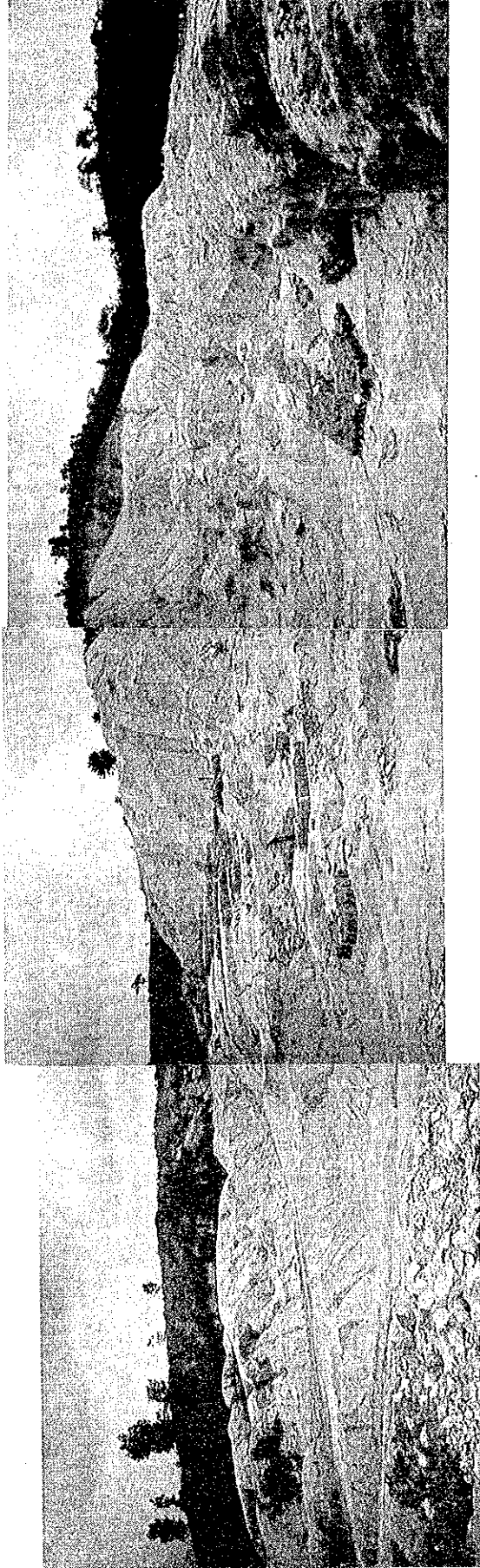
Picture 2-2 Monterado (Capkala Mandor) Quarrying Site



Picture 2-3 (1) Banjarnegara Quarrying Site (Kalitengah, Kebon Dalem)



Picture 2-3 (2) Banjarnegara Quarrying Site (Kebutih Jurang, Stock yard)



Picture 2-4 Lampung, Kalimantan Mine



Picture 2-5 Lampung, Trenggalok Mine

3 Summary of the Analysis and Evaluation of Ceramic Raw Materials

3.1 Analysis and Evaluation Method and Procedure

3.1.1 Test method for firing coloration

(1) Objectives and organizations responsible for test

Firing coloration originates in impurities contained in raw materials such as Fe_2O_3 and TiO_2 . For white pottery raw materials, those exhibiting high whiteness under the firing coloration test are required.

The firing coloration test was conducted both at Saga Ceramics Research Laboratory (SCRL) and at BBK in Indonesia, with the results of analysis coordinated between the two research organizations.

(2) Tests at the SCRL

1) Samples

Each ceramic raw material was pulverized in a porcelain mortar to a particle size of 60 mesh and smaller and then used as a test sample.

2) Formation of test pieces

The sample was formed to a 50mm Φ x 10 mm disk under a pressure of 200 kg/cm^2 , and three different test pieces for each sample were prepared by: (i) oxidative firing in an electric kiln at 1,250°C, (ii) reductive firing in an electric kiln at 1,250°C and (iii) reductive firing in an actual 1300°C kiln.

3) Test method

The color of each test piece was measured by a color difference meter according to JIS Z 8722. The optic condition was 0-45 S20 W20 and the measurement area was either 6 mm Φ or 30 mm Φ .

(3) Tests at the BBK

1) Samples

Each ceramic raw material was pulverized in a porcelain mortar to a particle size of 60 mesh and smaller and then used as a test sample.

2) Formation of test pieces

Clays (includes kaolin) and toseki were used in their powder form, and as for

feldspars, 1% CMC solution was added to by 3-5 wt.% to provide casting test materials.

10g of each test material was put into a metal mold and cast under the pressure of 200kg/cm² into a disc with the diameter of 30 mm and the thickness or 13-18 mm, which was provided as a test piece. Two test pieces were prepared for each test material.

The test pieces were left at room temperature for more than 12 hours without passing through a drying process, and were provided for the test of firing coloration.

3) Firing of the test pieces

The test pieces were fired in an electric kiln and a gas kiln.

4) Electric kiln

The temperature rose upto 1,000°C in 6 hours, then that temperature was maintained for 1 hour. After that the heating was stopped to cool the test pieces in the kiln. The annealing atmosphere is judged to be close to oxidation condition.

5) Gas kiln

The temperature rose upto 1,250°C in 3-4 hours, then that temperature was maintained for 1 hour. After that the heating was stopped to cool the test pieces in the kiln. The firing atmosphere is not clear.

Neither forge was equipped to be able to control the speed of the temperature rise strictly.

6) Observation of the color exhibited after firing.

The color was visually checked after firing. The following is the general classification of colors.

- a) White
- b) Cream
- c) Light Orange ~ Orange ~ Heavy Orange
- d) Light Beige ~ Beige ~ Heavy Beige
- e) Light Gray ~ Gray ~ Dark Gray
- f) Light Brown ~ Brown ~ Dark Brown
- g) Reddish Brown
- h) Light Red ~ Red ~ Dark Red
- i) Black

(Note) For the same color, a number was added in (parentheses). The darker the color was, the larger the given number was. The whiteness (L value) was also measured by using a color difference meter (ERP-80WX) manufactured by Tokyo Denshoku Technical Center.

3.1.2 Method of analyzing mineral composition by X-ray diffractometry

(1) Objectives and organizations responsible for analysis

The mineral composition of a raw material is closely associated with the cause of origin, presence of impurities, plasticity, and fired properties, and greatly affects processes for manufacturing products.

The mineral composition of each sample was analyzed using X-ray diffractometry in the Saga Ceramics Research Laboratory in Japan and BBK in Indonesia.

(2) Samples

Ten grams of each ceramic raw material was pulverized in a mortar until the finger tips could not feel that they were made of particles.

(3) Measurement conditions

1) Tests at the SCRL

Method:	Continuous scanning method
Scanning speed:	2.0 deg/min
Voltage:	40KV
Current:	20mA
Filter:	Ni
Target:	Cu
Sampling:	0.01 deg.

Mac Science's MXP-III, equipped with a computer, was used in the measurement.

2) Tests at the BBK

Diffractometer type:	PW3710 Based
Tube anode:	Cu
Generator tension (KV):	40
Generator current (mA):	35
Wavelength α 1(\AA):	1.54060
Wavelength α 2(\AA):	1.54439

Intensity ratio ($\alpha 2/\alpha 1$):	0.500
Divergence Slit:	1°
Receiving Slit:	0.3
Start angle [$^{\circ} 2 \theta$]:	5
End angle [$^{\circ} 2 \theta$]:	70
Step size [$^{\circ} 2 \theta$]:	0.020
Time per step [s]:	0.500
Type of scan:	Continuous

(4) Analysis of measurement results

1) Tests at the SCRL

ICDD's Mineral Powder Diffraction File, a software installed in the measuring equipment, produces a pattern search and match report automatically. However, since such reports identify a number of potential minerals, the quality of the analysis depends eventually on the skill of the researcher who is engaged in the measurement.

2) Tests at the BBK

The positions of five peaks of which I/I_o values (ratios of the height of peaks) show the five largest were compared respectively between the ones from many positions of measured peaks (2θ or d-value) and the ones from all positions of peaks which were provided by minerals shown in ASTM card. According to the comparison, the kinds of minerals existed were identified.

The following are the minerals used in the tests.

(Feldspars)

Orthoclase, Microcline, Albite, Sanidine, Plagioclase, Anorthite

(Clays)

Kaolinite, Halloysite, Montmorillonite

(Micas)

Sericite, Muscovite, Biotite

(SiO₂s)

Quartz, Cristobalite, Tridymite

(Toseki)
Pyrophyllite
Sericite

3.1.3 Method for determining ignition loss

(1) Objectives and organizations responsible for measurement

The ignition loss value provides an index for the abundance in and plasticity of clay minerals and impurity contents of each type of clay and can be easily measured; therefore, it can be used as an item of quality control at the mine. An ignition loss value of clay closer to the theoretical value of the mineral is preferable; an ignition loss value of feldspar is preferably smaller.

The ignition loss was determined at both SCRL in Japan and BBK in Indonesia and the measurements were compared.

(2) Analytical sample

The same analytical samples used in the analysis of mineral composition were used.

(3) Analytical method

1) Tests at the SCRL

A sample was measured into a platinum crucible, kept for an hour in an electric kiln at 1,050°C, and its weight was measured. The loss was calculated as the percentage of the original weight.

2) Tests at the BBK

A sample was measured into a porcelain crucible, and the temperature of the crucible was raised in an electric kiln to 1,000°C over 2 hours. It was kept there for one hour and cooled naturally in the kiln. The loss was calculated as a percentage.

3.1.4 Method of analyzing chemical composition

(1) Objectives and organizations responsible for analysis

The chemical composition of a raw material is determined by the minerals of which it is composed; a greater deviation from that composition indicates a greater impurity content. Clay consists chemically of SiO_2 , Al_2O_3 , and Ig. loss (H_2O), with other components being impurities; feldspar consists chemically of SiO_2 , Al_2O_3 and alkalis ($\text{Na}_2\text{O} + \text{K}_2\text{O}$), with other components being impurities. A species of feldspar

containing more alkalis and less iron is one with higher quality.

The chemical composition was analyzed at both SCRL in Japan and BBK in Indonesia, and the measurements obtained were compared.

(2) Analytical sample

Analytical samples were identical to those used in the analysis of mineral composition.

(3) Analytical method

1) Tests at the SCRL

Analytical test pieces were prepared by a glass-beat method, and the chemical component was determined using an X-ray fluorescence analysis, in which the height of each wave length specific to each element is compared with a calibration curve installed in a computer. System 3070 of Rigaku Denki was used in the determination.

2) Tests at the BBK

Analytical test pieces were prepared by a powdering method, and the chemical component was determined using an X-ray fluorescence analysis, in which the height of each wave length specific to each element is compared with a calibration curve prepared by using a standard sample.

3.1.5 Measurement of the distribution of particle sizes of clay

(1) Objectives and organizations responsible for measurement

The grain size distribution of clay is closely related to plasticity of the clay and the crystallinity of a clay mineral; the finer the grain size of clay is, the higher its plasticity and the lower its crystallinity.

The distribution of particle sizes of clay was determined at both SCRL in Japan and BBK in Indonesia.

(2) Samples

The sample was the same as that used in the analysis of the mineral composition. However, it was subjected to pre-treatment by wetting and passing through a 100 mesh sieve.

(3) Measurement method

The sample and dispersant were added in distilled water. After being dispersed using an ultrasonic wave, the distribution of particle sizes was measured. The equipment was

Microscan of the Ionics Co., Ltd. (X-ray transmission gravitational settling method) in Japan, and CAPA-300 of Horiba Seisakusho Co., Ltd. (Natural and centrifugal settling photo transmission method) in Indonesia.

3.1.6 Test method for plasticity of clays

(1) Objective

The plasticity of clay is an important factor on which the workability and quality of a ceramic product depend, and which determines the quality of a clay raw material. Generally, clay with higher plasticity is preferable.

(2) Outline of the test

A variety of mixture with different ratio of clay and silica sand which is a non-plastic material should be prepared, and some water should be added to each mixture, which should be kneaded very well. Each mixture should be pressed by a finger to see if the fingerprint remains on the surface and the clay does not stick to the finger. If this condition is satisfied, the mixture should be formed into a stick. Judging from how the stick expands and how difficult for the stick to get cracks, the mixture which indicates the utmost plasticity is chosen. This mixture should be used to compare the plasticity of clays.

It should be judged that the more the mixture includes silica sand, the larger the plasticity of the clay is. To confirm the correctness of this judgment, a test piece should be cast from each mixture and dried. Then the surface of the test piece should be rubbed by a finger to check the amount of silica sand which will fall off from there. Moreover, it is possible to amend the figure of the silica sand ratio in the mixture, which indicates the plasticity of the clay, by measuring the amount of residue on +325 mesh when 100g of the clay is sieved.

(3) Test method

1) Preparing the standard silica sand

- a) Silica sand produced in Belitung should be chosen as a non-plastic material in case of BBK.
- b) The above chosen silica sand should be washed very well in the water so that foreign matter like mire are removed.
- c) Silica sand of which grain size ranges between 60 to 100 mesh should be collected in the flow of water by using sieves of 60 mesh and 100 mesh.
- d) The above collected silica sand should be dried then stored to be used as the

standard silica sand for the plasticity test.

- e) It is desirable that the standard silica sand is prepared in a large amount at a time, then stored

2) Preparing test materials

- a) Clay as a test material should be dried well at 70°C or lower.
- b) The dried clay should be ground in a mortar to powder with a grain size of 60 mesh or less.

3) Test procedure

- a) Determination of mixing ratio of silica sand and clay

In case new clay is used for the first time, a mixing ratio of silica is unknown. The following ratio should be referred to reduce the number of tests to determine the ratio.

	Silica Sand (%)	Clay (%)
Ball Clay	76	24
Clay	72	28
Kaolin	68	32

As for the amount of a mixture for one test, about 50g of the sum of silica sand and clay is enough.

- b) Weigh silica sand and clay. Mix them well in the state of powder. Then add some water to this mixture and knead it very well.
- c) Keep kneading the mixture while adding gradually some more water to it until the mixture becomes the state where a fingerprint remains on the surface and no clay sticks to a finger when the mixture is pressed by the finger.
- d) While forming the mixture into a stick, check if it expands well. Then bend the stick to see if it gets any crack on it.
- e) In case good plasticity of the stick is shown in d) with no cracks, prepare another mixture with higher ratio of silica sand. In case good plasticity of the stick is not shown in d) with some cracks, prepare another mixture with lower ratio of silica sand. In either case, repeat the procedure b)-d) with the newly prepared mixture.
- f) The mixture ratio of silica sand should be varied. The test should be repeated until the point where the further increase of it will cause cracks as it worsen the plasticity. In case of decreasing, the test should be repeated until the point where the further decrease of it will eliminate cracks as it improve the plasticity.
- g) Determine the mixture ratio of silica sand which gives the best plasticity without causing any cracks on the mixture.

h) Judge the order of the plasticity according to how large the figure of silica sand mixture ratio determined in g) is.

4) Weighing the silica sand come off from the surface of dried test piece

a) Form the mixture determined in test 3) to a rectangular parallelepiped of 15mm x 10mm x 130mm by pressing in a wood frame with a finger, then dry it at 105°C for more than 10 hours.

b) Rub 10 times lightly each of the two 15mm x 130mm surfaces of the dried rectangular parallelepiped with a fingertip. Weigh the powder (mixture of silica sand and clay) which fell off from the surfaces when they are rubbed with a fingertip.

c) Weigh the powder gained in the same way as the above test procedure a) and b) for a variety of mixture of the same clay and silica sand.

d) Compare the figures of the coming-off powder weight and of the mixture ratio of silica sand to see if the figure of the mixture ratio of silica sand determined in test 3) is correct.

e) If the amount of the coming-off powder is just as little as a trace, judge it to be correct.

f) When it is possible to carry out test 3) precisely, this weighing of coming-off powder could be omitted.

5) Measuring the amount of an alien substance in clay

a) Weigh out 100g of test material ground to 60 mesh powder.

b) Put 300cc of water into a blender and add the clay gradually to it while rotating the blades of the blender.

c) Add 1cc of 25% aq. solution of water glass into the blender, which should be going for 3 min. after that to prepare slurry of clay and water.

d) Filter out the residue in the slurry with a sieve of 325 mesh. Then collect the residue on the sieve. Get it dried, then weigh it.

e) In case the residue is in a large amount, make sure if the clay is completely removed. Namely, rub the residue with a fingertip to see if the water becomes muddy. The muddy water shows the clay still remains in the residue so the residue should put back into the blender to be stirred in the water. Then the procedure d) should be repeated to measure the correct amount of the residue.

f) The residue gained through +325 mesh sieve should be considered non-plastic material in the clay. Therefore the amount of it should be taken into consideration when the mixing ratio of silica sand determined in test 3) is evaluated.

3.1.7 Test method of clay dispersibility

(1) Objectives

In the casting of slip, clay with good dispersiveness and slip with low viscosity and spinnability are the most important requirements. Dispersiveness of the clay, which requires less amounts of both water and water glass contained in dispersant in order to optimize the slip viscosity, is considered desirable. Clay with better dispersibility makes better slip.

(2) Basic formula of test slip

- 1) Clay: 125g
- 2) Silica sand: 375g (Belitung quartz 325 mesh or less)
- 3) Quantity of water to be added initially: 210cc
- 4) Quantity of water glass to be added initially: 1cc (Indonesia-made 25% aqueous solution of water glass)

Indonesia-made water glass is a special product which has the following composition and is not available in Japan.

Na ₂ O	39.89%
K ₂ O	7.11%
SiO ₂	36.01%
H ₂ O	16.99%

(3) Test procedures

- 1) 210 cc of water and 1cc of water glass is put in a mixer and mixed thoroughly.
- 2) 375g of silica sand is added gradually to the mixer while stirring.
- 3) 125 g of test clay is then added gradually while stirring.
- 4) Water glass is then added if no slip is produced.
- 5) If no slip is produced by the addition of water glass, water is added in order to generate slip.
- 6) The viscosity of the produced slip is measured using a Mariotte tube, and then water glass and water are added to bring the viscosity to 60-80sec/100cc.
- 7) The quantities of both water glass and water required to make a viscosity of 60-80sec/100cc are recorded.

(4) Evaluation

It is regarded that clay requiring less amounts of both water glass and water has a higher dispersiveness. If the amount of required water is equal, the clay requiring less water glass is considered to have better dispersiveness.

3.1.8 Evaluation of a raw material through a mixing test

(1) Objectives

In the slip-casting of large products with complicated shapes, such as a sanitary ware, the viscosity and thickening speed of slip are very important elements. Material manufacturing plants should ship material to a slip-casting factory after confirming that such viscosity and thickening speed data are equivalent with standard values.

Slip-casting factory should start forming after confirming the thickening speed and determining an optimal casting time for each product. A preferred casting rate is 6 - 9 mm in 30 minutes.

The dry properties and sintering properties as well as the slip properties described above of a mixture are required to meet the target values set for the product and manufacturing process.

(2) Standard mixing composition

Mixing composition for tableware bodies adopted by BBK are taken as references, with the suffix S added to the raw materials held in the BBK inventory to distinguish them as references.

Feldspar	FLS	30%
Clay	CSS	20%
Kaolin	KBS	30%
Quartz sand	QBS	20%

(3) Raw materials to be tested (collected samples)

Kaolin	Belitung Kaolin (KB)
Clay	Sukabumi Clay (CS-1)
	Monterado Clay: 2 types (CM-2, CM-K2)
	Parungpanjang Clay (CP-1)
Body	Kiara Condong (for throwing, slip casting)
	Malang (for throwing)
	8 types in total

(4) Drying of raw materials

The required amount of the raw material to be tested and that of the reference raw material were thoroughly dried.

(5) Crushing of raw materials

Feldspar and silica sand were dry crushed into grains below 200 mesh; clay was crushed into grains below 60 mesh. Because kaolin was in a fine powder condition it was used without processing.

(6) Mixing

In the test on the kaolin KB, for example, the KB was used instead of the above standard kaolin KBS; other raw materials were mixed with the standard materials FLS, CSS, and QBS. In testing the clay CM-2, the CM-2 was used instead of the CSS, while standard raw materials were used in other tests. In preparing mixtures, 6 kg (2kg x 3 batches) of raw material mixture was mixed and the 2kg was crushed in a pot mill for 3 hours. After crushing, the 6 kg of raw materials in the pot mill were thoroughly mixed and 4 kg of the mixture was taken out by weighing to be used to make slip. The remaining mixture was reserved for correction, in case concentration and viscosity adjustment was not successful.

(7) Preparation of slip

- 1) 40% of water was added to 4 kg of sample, and the sample was thoroughly dispersed by a powerful stirrer, with water glass being added little by little.
- 2) After slip had been prepared, it was passed through a 100 mesh sieve to remove foreign matters and large size particles, while being continuously stirred by a small stirrer.
- 3) The concentration was measured and adjusted at a value of $342g \pm 1g/200cc$; then, water glass was added by using a Mariotte tube to adjust the viscosity immediately after at values between 40 and 60 sec/100 cc.
- 4) The sample was left standing at room temperature overnight (for not less than 16 hours) after adjustment; it is desirable to age the sample after going through the stirring process.
- 5) After the slip was stirred by a small stirrer for not less than 1 hour in the following morning, it was again adjusted for its properties, to fall within the following ranges:
Concentration of the slip: $342g \pm 1g/200 cc$
Viscosity of the slip: 40 - 60 sec/100 cc

Temperature of the slip: 23 - 27°C (because of lack of a temperature regulator, the temperature of the slip followed the room temperature; the temperature of the slip is preferably constant.)

Viscosity after 30 minutes: (Measured) sec/100 cc

A Mariotte tube was used to measure viscosity.

(8) Evaluation of casting rate and plasticity

- 1) The slip was cast in a triangular gypsum mold; after having been left to stand for 20 minutes, the remaining slip was discharged; the cast body was left to stand in the mold for an additional 20 minutes, and was then taken out from the mold.
- 2) The casted body, taken out from the mold, was cut at its approximate mid-section into 2 pieces (A and B); the A piece was cut further into squares with a 3 - 4 cm long side, which were used to measure the thickness of the body with a graduated magnifier; the rest of the cut piece was used to measure the water content.
- 3) The B piece was used to evaluate the plasticity (deforming resistance, thixotropy, workability).

The plasticity was evaluated according to the following criteria.

- a) The shape of a casted body is firmly maintained and the shape does not collapse under small vibration.
- b) The slip discharge surface is smooth.
- c) The slip does not collect at the corners.
- d) The casted body was judged to be satisfactory if it allows a knife to cut it smoothly with a clean cut surface without burrs.

(9) Preparation of test pieces for the shrinkage, strength, firing bend, ink, and other tests

Six test pieces (10 x 30 x 300mm) were cast and molded.

Two of them were used to measure the dry strength.

Two of the remaining samples were used to measure the dry shrinkage, firing shrinkage, firing strength, and ink test values.

The last two were used to measure the firing bend and ink test values.

(10) Different test methods using test pieces

1) Dry shrinkage

A test pieces with a 200 mm long marking was molded in testing plaster mold; after drying, the dimension of the marking was measured:

$$(200 - \text{Measured value}) \times 100/200 = (\text{Dry shrinkage})\%$$

2) Dry strength and firing strength

The strength tester owned by BBK was used for measurement (kgf/cm²).

3) Firing shrinkage

A dry test pieces was marked with a 200 mm long marking, and after firing, the dimension of the marking was measured.

$$(200 - \text{Measured value}) \times 100/200 = (\text{Firing shrinkage})\%$$

4) Firing bend (bending)

After the test pieces, supported with a 200 mm span by sharp-edged supportors, was fired, the degree of bending of the sample was measured with a dial gage (in mm).

5) Water absorption test (ink test)

The surface of a firing test measurement piece was covered with paraffin to stop water absorption except the fracture plane, and then soaked in a 1.0% eosin Y solution for 1 hour. After taking the piece out of the solution, the test piece was subjected to fracture and the ink permeation from the lower fracture section was measured by using a graduated magnifier (in mm).

6) Firing temperature

The test sample was fired at 1,250°C in an electric kiln using silicon carbide heaters.

3.2 Results of Evaluation

3.2.1 Raw material evaluation

Fourteen types of mineral materials collected by BBK and 13 types collected by the study team - a total of 27 types (see Table 3-1) - were subject to preliminary evaluation covering (1) firing coloration, (2) mineral composition, (3) plasticity. The results are shown in Table 3-2 and Picture 3-1 for firing coloration, Table 3-3 for mineral composition, and Table 3-4 for plasticity.

Firing coloration test and mineral composition analysis by X-ray diffractometry were carried out in Japan for cross-checking as the secondary evaluation. Results of the firing coloration and mineral composition are shown in Table 3-5, Figures 3-1 and 3-2, and Table 3-6, respectively. Results of (4) ignition loss, (5) chemical composition using X-ray fluorescent, (6) the distribution of particle sizes of clay, and (7) dispersiveness of clay, are

shown in Table 3-7, Figure 3-3, Tables 3-8, 3-13 and 3-9, respectively. Further more slip properties and firing properties were measured through basic mixing test. The results are shown in Tables 3-10 through 3-12.

The evaluation result on each mineral material is summarized as follows.

(1) Pangaribuan feldspar (FP, FP-2, FP-3)

Pangaribuan feldspar, as shown in Tables 3-3 and 3-6 representing the result of X-ray analysis, is of pegmatite mainly composed of microcline and has low content of quartz and other foreign matters. As shown in Tables 3-2, 3-5, Figures 3-1 and 3-2, they shows the highest level of whiteness after firing. Thus, it may be used for high-grade porcelain. It is also easily crushable as this type feldspar because of low content of quartz.

However, the sample subjected to the evaluation had been collected previously by the BBK, and the third field survey of the site from which the sample was mined revealed that most of the high quality feldspar had been dug out. What still remained was the raw material called country rock, which is a mixture of feldspar, silica sand and kaolin produced by weathering and which contains a smaller amount of feldspar. The analysis conducted on the country rock made it clear that the raw material contains about 6% of alkalis and about 2% of iron as is shown in Table 3-7; therefore, it is judged to be capable of being used for tile production.

(2) Banjarnegara feldspar (FB-1, FB-2, FB-3, FB-4, FB-5, FB-6)

Banjarnegara feldspar is rhyolite which is volcanic rock with relatively high feldspar content, and as shown in Tables 3-3 and 3-6, major components are albite and microcline with some inclusion of quartz. Quarrying sites are distributed in wide area and have same mineral composition except in certain sites where the rocks contain muscovite.

All of the specimen from the six sources produce beige to light brown color upon firing, as shown in Tables 3-2, 3-5 and Picture 3-1, with dark brown spots caused by iron (Note: These spots are expected to have a uniform color when the specimen are crushed into fine powder). From the data of Tables 3-5, Figures 3-1 and 3-2, even if all the samples of Banjarnegara are rather low quality in firing coloration compared to other feldspar, FP, FN-1 and FL-2, all the points of color value gather within narrow area in Figure 3-1 (L vs. a) and Figure 3-2 (L vs. b). This means that the quality of the products from 3 mines is uniform, which seems to be in a same stratum spreading widely.

As for alkali content, all samples except FB-5 are almost same and in the range of 8.06 - 8.66% which are higher than FN-1 and FN-2, but lower than FP and FJ.

Since the mines have sufficient reserves and are homogeneous, the feldspar can be used as primary material for floor tile production and also as one of the auxiliary

materials for fine ceramics such as wall tile, sanitary ware and table ware, even if its iron content is high and alkali content is low.

(3) Lampung feldspar (FL-1, FL-2, FL-3, FL-4, FL-5)

Lampung feldspar seems to originate in granite. As shown in Table 3-1, FL-1 contains a mixture of seeming very hard materials as well as soft ones, with varying color. As shown in Tables 3-3 and 3-6, it is marked by complex structure containing albite and microcline with inclusion of quartz and cristobalite. It has high alkali content and was melted at 1,250°C, as shown in Picture 3-1. The melted specimen has turned into black, with high content of iron and other color components.

On the other hand, FL-2 is relatively homogeneous compared to FL-1, and as shown in Tables 3-3 and 3-6, it is mainly composed of albite and microcline and contains quartz and mica. It turned into gray color after firing with black spots.

Judging from these results, Lampung feldspar can only be used only as raw materials for tile production or the like under the present circumstances. Commercial use is attended with the problem of mixing of very hard materials. The FL-3, FL-4, and FL-5 samples, collected at a mine (Kp. Kalimati Mine) different from the one where the FL-1 and FL-2 samples was collected during the third field investigation, are mixtures of silica stone and feldspar created from weathered granite; the FL-3 sample has undergone the strongest weathering, with the FL-4 coming next; the FL-5 sample consists of fresh rock (stone). As shown in Table 3-7, chemical analysis of a mixture containing the equal amount of the FL-3 and FL-4 samples exhibits about 7% of alkaline contents ($\text{Na}_2\text{O} + \text{K}_2\text{O}$); therefore, this mixture is judged to be low grade feldspar mixed with a large amount of silica stone. Though low in alkaline contents, coincidence of a relatively low iron content of 0.35% may allow this mixture to be used as an auxiliary raw material for feldspar.

(4) Narawita feldspar (FN-1, FN-2, FN-3/QN)

It originates in volcanic tuff, and as shown in Tables 3-3 and 3-6, it is essentially made up of sanidine, which is high temperature type orthoclase, with inclusion of tridymite and cristobalite.

FN-1 is whitish soft stone that appears to contain clay minerals. Firing coloration and data of Table 3-7 do not indicate significantly high iron content. If it can be successfully treated, such as by acid, to remove iron content, it is a promising material for white china and porcelain.

FN-2 has more or less the same mineral composition as FN-1, but color after firing indicates a relatively high iron content. Additionally, the two samples, FN-1 and FN-2,

have much different color after firing (see Figures 3-1 and 3-2), even if those are collected from same quarrying site. Strict quality control at the site is required for getting quality satisfaction from users.

In any case, the beneficiation process to remove iron is required if it is to be used for white china and porcelain. Sufficient reserves are expected.

Finally, FN-3/QN, as shown in Table 3-3, has a low feldspar content while having a high silica sand content. As a result, it is considered to be usable as a silica stone material with adequate sinterability.

(5) Jepara feldspar (FJ)

According to the result of X-ray diffraction analysis in Table 3-3, Jepara feldspar is mainly composed of sanidine, while silica stone content appears to be low. On the other hand, as shown in Table 3-2 and Picture 3-1, the firing test at 1,250°C resulted in melting of specimen, with a high iron content. Under present conditions, it is not suitable for white china and porcelain. Rather, it is a suitable sintering material for tiles and other similar products.

(6) Parungpanjang clay (CP-1, CP-2, CP-3, CP-4)

Parungpanjang clay, as shown in Table 3-4, is highly plastic clay mainly composed of halloysite with inclusion of quartz and cristobalite as shown in Table 3-3. One of major reasons for high plasticity is montmorillonite content.

The result of the firing coloration test indicates an increase in iron content in order of CP-1, CP-2 and CP-3. Especially CP-2, CP-3 and CP-4 have high iron content (see Table 3-5). CP-1 shows rather better firing coloration among the samples (see Figures 3-1 and 3-2). But it has a possibility of contamination by other grades, CP-2, CP-3 and CP-4, if no strict quality control at the site is carried out. There seems not much mineral composition among them.

CP-4 has a silica stone content as well as a high iron content, suitable for a reinforcing material at the same level of drying strength as ordinary tile and roof tiles.

Note that Parungpanjang clay with high plasticity is limited in blending proportion when it is used as a material for slip. At the same time, it seems to be suitable for press molding and plastic molding.

(7) Monterado clay (CM, CM-2, CM-K1, CM-K2, CM-K3)

Regarding Monterado clay, evaluation tests were conducted on a small amount of sample (CM) elutriated at BBK, sample of the materials being used at PT. Sumberaya Kendimasindo (CM-2), and 3 different samples collected in the site visit of the 4th field

work (CM-K1, CM-K2, CM-K3). X-ray diffraction test revealed that all samples contain kaolinite as the major component and quartz and gibbsite as impurities. Special mention should be made to the difference in +325 mesh residue (quartz) among CM-K1, CM-K2, and CM-K3; the amount of residue is 3.3% for CM-K1 and 1.6% for CM-K2, both very low in the amount of residue and similar to CM-2. In contrast to these, CM-K3 contains a great amount of coarse grain quartz reaching as much as 51.7%. Regarding the iron content, Table 3-7 shows that all samples contain not more than 1.3% of iron, which is a normal value for Ball clay. The CM-K3 sample containing a large amount of +325 mesh residue contains less kaolinite and hence is low in plasticity; therefore, when it is used as Ball clay, it should be elutriated. One thing noteworthy of all clay samples is that they contain a relatively large amount of TiO_2 and K_2O . The results of the firing coloration tests give L values over 85 for all clay samples, indicating no problems with the samples.

CM, CM-2, CM-K1, and CM-K2 exhibit satisfactory plasticity and dispersibility; by contrast, the CM-K3 sample with a large quantity of +325 mesh residue is accordingly low in plasticity. The grain size of the clay cleared of +325 mesh residue by elutriation is about the same for all samples, with the D (MEDIAN) value being below 1 micron as shown in Table 3-13.

The results described above indicate that CM-3 can be used as Ball clay if elutriated.

(8) Sukabumi clay (CS-1, CS-2, CS-3)

Sukabumi clay, as shown in Table 3-3, is mainly composed of kaolinite with inclusion of mica minerals, such as sericite, and quartz. As shown in Table 3-4, it does not have very high plasticity.

The firing test and chemical analysis result indicate a relatively high iron content, which makes it unsuitable as a material for white china and porcelain. Without beneficiation, it is rather suitable as a plastic material for low-cost tiles including roof tiles.

CS-2, as shown in Table 3-4, has a higher quartz content than CS-1 does, resulting in lower plasticity and higher iron content.

CS-3 is lower in iron content and higher in quartz content than CS-1 and CS-2. Thus it seems to be suitable for silica sand use, rather than clay.

(9) Cipeundeuy clay (CC)

Cipeundeuy clay, as shown in Table 3-3, contains kaolinite as a major component, with inclusion of cristobalite and sericite. The firing test at $1,250^{\circ}C$ resulted in cream color to suggest a relatively low iron content. It was later confirmed, however, that light

color originated from insufficient sintering due to high refractoriness. In fact, in the preliminary test using a specimen to which Indian feldspar was added for increased sintering, gray color was obtained to indicate a high content of color impurities.

As shown in Table 3-4, low plasticity came mainly from high silica sand content as well as the use of the specimen having high moisture content.

Cipeundeuy clay has excellent fire resistance and seems to be suitable as a material for kiln furnitures, in the form of chamotte, to be used in the porcelain firing process.

(10) Belitung kaolin (KB)

Belitung kaolin, as shown in Table 3-3, is basically elutriated kaolin mainly composed of kaolinite. As shown in Tables 3-4 and 3-2, it has high plasticity as kaolin, and good color after firing. KB seems suitable as a material for high-grade china and porcelain as far as color is concerned.

Cast molding test is required in detailed evaluation as the raw material for high grade porcelain, because it contains gibbsite.

(11) Pacitan agalmatolite/toseki (TP-1, TP-2, TP-3, TP-4)

TP-1 and TP-2 are agalmatolite containing pyrophyllite, small amounts of sericite, and quartz, and TP-3 and TP-4 are toseki containing sericite as shown in Table 3-3. The firing test did not show sufficient color development because of poor sintering. By adding Indian feldspar, sufficient sintering occurred and light gray color was obtained. From these results, they have relatively small iron content. Chemical analysis result shown in Table 3-7 also indicate very low content of iron in it.

Thus, agalmatolite can be used as a tile material to regulate expansion and contraction by taking advantage of its low rate of firing shrinkage and small hydrated expansion due to low alkali content.

On the other hand, toseki can be used as a material for sanitary ware and tableware.

3.2.2 Results of the evaluation of raw materials through the mixing test

For the purpose of evaluating raw materials, 8 different mixtures were made, which were KB, CS-1, CM-2, CP-1, CS-1W, CM-K2, a mixture of CS-1 and CP-1, and an extended version of the mixture CM-2, plus the standard mixtures; they were of 9 different types in all. Indonesia's representative 3 bodies for producing novelties (2 types from Kiara Condong, and a type from Malang) were evaluated also. Table 3-10 shows the mixing proportions and results of property test on the slip and the results of evaluation of dry formed bodies. In addition, Table 3-10 shows the results of evaluation

conducted by firing the dry formed bodies at 1,250°C by an electric kiln. The results obtained are summarized as follows:

(1) Properties of Slip by Raw Material

- 1) The casting rate and plasticity of the samples CM-2 and CM-K2 were satisfactory; their workability was the best of all the mixtures tested.
- 2) The CM-2 and CM-K2 samples are estimated to be of the same type; differing from other clay raw materials produced in Indonesia, they exhibit satisfactory dispersion even when less water glass was consumed by the dispersion agent.
- 3) The CS-1 sample is inferior to the CSS sample in casting rate and plasticity.
- 4) The CP-1 sample is satisfactory in terms of plasticity; however, because it contains montmorillonite, normal slip cannot be obtained from the sample. This is because that montmorillonite consists of three layers as a crystal structure, and swells by absorbing water in between the layers.
- 5) The CS-1W sample is of clay refined by a water cyclone from the CS-1 sample; it has better plasticity than the sample CS-1, but its casting rate is inferior.
- 6) The mixture of the CS-1 and CP-1 samples is prepared with a mixing proportion of 3:1; the mixture produces normal slip with improved plasticity, with the casting rate still inferior.
- 7) Improved plasticity may be attained by examining a proper mixing amount of CP-1 with CS-1 or replacing CS-1 with CS-1W; this mixture is inferior in the casting rate but can be used for tableware bodies, novelty bodies, and the like as far as plasticity concerned.
- 8) KB is about the same as the KBS with the basic mixture proportion in the casting rate and plasticity.
- 9) The results of the tests on the properties of slip were based on comparative tests conducted under given guideline conditions, because no standards for slip with a basic mixture proportion were available at all; therefore, it has been concluded that preparing slip satisfying adequate conditions will improve the casting rate and plasticity.
- 10) It is recommended that BBK conduct various tests including the firing conditions for the basic mixture proportion and establish adequate references.
- 11) Because of restrictions on time in preparing mixtures for slip, the blunger adjustment method (the method by which raw materials are separately crushed and mixed at the time of preparation) was adopted; however, the best result would be obtained through adjusting slip by mixing and crushing raw materials by using a pot mill.
- 12) The casting test method and references for properties of slip such as viscosity and

casting rate should match the specific product to be manufactured; they are not absolute.

(2) Firing properties by raw material

- 1) The KB sample is slightly inferior to the KBS sample in degree of sintering; besides, it exhibits larger bending.
- 2) The CS-1 sample is much better than the CSS sample in degree of sintering; however, little difference was observed in bending.
- 3) The CS-1W sample is much better than the CSS sample in degree of sintering; besides, it exhibits less bending and firing shrinkage. What is common both to the CS-1 and the CS-1W sample is special properties such as a very good degree of sintering coupled with small bending.
- 4) The CP-1 sample is better than the CSS sample in degree of sintering; in addition, it exhibits less firing shrinkage and bending.
- 5) The CM-2 and CM-K2 sample are worse than the CSS in degree of sintering, with smaller firing shrinkage and bending. The CM-2 and the CM-K2 sample have about the same firing properties.

(3) Discussion on the firing test results

Table 3-11 shows the results of the calculation of the chemical composition of the raw materials in question for the test bodies. Under the same firing condition, the sintering condition (ink test) of a fired product becomes generally better as Al_2O_3 contents decrease and hence SiO_2 contents increase, especially total alkaline contents ($Na_2O + K_2O$) increase. As shown in Table 3-12 which summarizes the results of the test on the mixed bodies, the No. 1, No. 2, and No. 3 samples exhibit about the same chemical composition, forming the best densified group. Next come the No. 5, No. 9 and No. 10 sample; the No. 4 and No. 7 sample were found to be most difficult to sinter.

Table 3-12 and Fig. 1 shows the relation between the results of the actual ink test and the total alkaline contents ($Na_2O + K_2O$). As shown in Fig. 1, the ink test and the alkaline contents are well correlated except in the case of the No. 1 and the No. 2 sample. It is thought that there was some abnormality in the No. 1 and the No. 2 sample; further examination is needed of the abnormality with the CSS sample.

Next, Table 3-12, Fig. 2 and Fig. 3 shows the relations between ink test and shrinkage and between ink test and bending as seen in the results of the firing test. As shown in Fig. 2, all samples except the No. 1, 2, and 10 samples exhibit a good correlation. The No. 1 and No. 2 samples exhibit greater bending for their sintering and deviate unfavorably, exhibiting greater sintering for their shrinkage. By contrast, the No. 10 sample exhibits smaller bending and shrinkage for its sintering, deviating favorably.