Chapter 4
Conclusions

This scientific work, establishes the following essential results:

4.1 Characterization and valuation of the Lampang clay.

Lampang clay is a quartz rich clay with clay minerals such as kaolinite, illite, and montmorillonite. Most of the quartz has a grain size larger than 10 microns. Technological properties depend on grain size. Generally the clay minerals have lower grain size than the quartz. However quartz is the larger proportion of the smallest particles. Simultaneously the illite-montmorillonite clay mineral content increases in opposite direction as kaolinite clay minerals. The shift of quartz to the clay fraction corresponds to changes of Al_2O_3 content. A small increase in the fraction of feldspar is correlated with a small increase of the K_2O content in the fraction with smallest grain size. No essential incorporation of alkali-ions has taken place in the clay-mineral lattice. This is confirmed in the later firing tests. Lampang raw clay is separated into samples according to different particle sizes. The technological attributes of each sample have been measured. Samples are produced by wet sieving. About 85 % of the raw material consists of particles < 63 microns, about 70 % of the material that passes the 63 microns sieve consists of particles < 40 microns, and the remaining raw material consists of particles < 10 microns. Essential technological attributes include the following: the finest particles have obvious influence on rheological behavior. Increasing clay-mineral content results in higher moisture content for a plastic sample of the moist clay and higher maximum formability. This could be due to the enrichment with triple layer clay-minerals. Therefore, a total improvement of the plasticity behavior is noticeable. The sample < 40 microns has optimal or near optimal behavior. The deflocculation of the finer grain clay material with higher clay-mineral content generally has a higher viscosity. Simultaneously, the thixotropic behavior is decreased and the flow behavior will is improved. Flow becomes dilatant instead of structurally viscous. The flow curve shows an alteration to a more Newtonian-flow-behavior. In total, the change are found to be improvements. Also, in this case we show that the sample < 40 microns is the best of all the Lampang clay sample studied. The drying behavior of the sample with finest particles results in more shrinkage (bad) and a higher dry strength (good). The relative high drying shrinkage of the fraction < 10 microns can lead to drying problems, if this fraction is used alone. The firing behavior reported here as firing shrinkage, porosity and bending strength seem to be largely independent of particle size. Significant differences only appear when the test pieces are fired above 1200^{0}C. A pronounced sintering takes place first above 1100^{0}C. This observation corresponds with the minutely greater alkali-ions concentration in particles < 40 microns. The particle fraction < 10 microns shows an intensive sintering above 1000^{0}C and a densification at 1200^{0}C. The whiteness of the test pieces in oxidation and reduction firing correlates well with the Fe_2O_3 content. After increasing the temperature to approximately 1000^{0}C, brownish color due to the formation of Fe_3O_4 is seen to decrease whiteness. The fine particles have a higher iron-content than the medium and coarse samples. Through reduction of the iron from Fe_3O_4 to FeO above 1200^{0}C the whiteness of the test piece increases again. Using reduction firing above 1100^{0}C, completes FeO reduction resulting in 65-70 % improvement of whiteness when compared to that of an oxidation firing.

4.2 Possibilities for refining Lampang clay.

There are other technologies by which Lampang Clay could be refined. The results of this study are that Lampang clay can be divided into different samples on the basis of grain size. Grain size classification is simple, effective, and economic. Special attention should be given to the grain size range < 40 microns. About 70 % from the raw material consist of particles < 40 microns. Separation by grain size range < 40 microns is technologically feasible. However, a better technology would be to use different hydrocyclones. In a first step, the raw material must be wet sieved with a course screen 160 microns screen is recommended. The fraction < 160 microns can be separated by employment of hydrocyclones to isolate a fraction < 40 microns (about 70 % of the material) and a fraction about 40 microns to 160 microns. A specific problem is the higher iron-oxide content in fine grain size. About 60 % of the iron-ions are located on the surface of the grains. A disposal of this iron content appears to be possible by either a chemical or magnetic treatment. Both methods are tested. The chemical treatment decreased the iron-oxide content about 65 % in the fraction of < 40 microns but the chemical method is expensive and very difficult to carry out. The magnetic treatment decreased the iron-oxide content about 25 % in the fraction of < 40 microns. The employment of high field magnet equipment is necessary. This operation is also expensive.

One solution to the problem of iron contamination might be to elimination of the fine fraction all together. This would indisputably reduce the iron content and correspondingly improve whiteness of the fired clay. However, the complete absence of fine particles is likely to change other technological properties such as plasticity, rheology of the slip, etc. The properties of the clay, striped of its finest particles ought to be studied and is recommended for further investigation. The F fraction of Lampng clay contains a disproportionate amount of quartz. Removed of this material is likely to alter the temperature at which the clay matures.

4.3 Uses of the refined Lampang clay.

The refined fraction of < 40 microns of Lampang raw clay can be used to produce a white ceramic product of the porcelain type. In general, this part of Lampang clay can be used to produce a high value porcelain with dense body and more than 75 % whiteness. The production of porcelain body can be achieved using more than 80 % of the constituents from Lampang. A good mixture for a porcelain body has the composition 40 % Lampang clay which passes a 40 micron screen, 40 % ground Lampang stone and 20 % kaolin. This porcelain body sinters at about 1370^{0}C in a reducting atmosphere. The usual porcelain firing is between about 1100^{0}C to 1300^{0}C, and produces fired shrinkage of about 12 %. Fired porcelain body has a real density of about 2.45 g/cm^3, bending strength more than 60 MPa and whiteness more than 75 % compared with a standard sample of $BaSO_4$. This sample develops a porcelain structure. The fraction of Lampang clay between 40 to 160 microns which is not used to make porcelain body can be used to a produce floor tiles. A mixture consisting of Lampang clay about 30 % (fraction 40 to 160 microns), about 30 % Lampang stone (ground and served) and about 40 % of a clay from the north area (maybe Maetan clay) can give a product with water adsorption < 6 % and bending strength > 25 N/mm^2 if fired to about 1200^0C.

Thus, the quest for ways to upgrade Lampang clay for use in making a white porcelain body has been successes.