INFLUENCE OF PREPARATION ON PLASTICITY OF SOME ALUMINO-SILICATES

P.S. Kwawu Kume, *BA, MPhil*
Department of Industrial Art,
University of Science and Technology,
Kumasi.

ABSTRACT

The basis of good quality ceramic product development lies in the nature and the preparation of the clays selected and their relative plasticity attributes in forming processes. In this paper, the effects of various pre-treatments such as filter pressing, ageing for one month and ageing for six months on the plasticity of clays have been studied with the compression plastometer. Experimental results have been obtained with the compression plastometer for (a) filter pressed clay (b) unprocessed clay (c) aged clay for one month (d) and ageing for six months called (further ageing period). Results indicate that the compression plastometer is sensitive to particle packing density and that processed filter pressed clay has lower plasticity index than unprocessed clay as measured by the compression plastometer.

Keywords: Preparation, Plasticity, Ageing, Compression plastometer.

INTRODUCTION

Plasticity of clays is generally believed to offer clays and clay bodies cohesiveness, which is capable of being moulded under stress to any desired shape. The higher the plasticity of the clays the more non-clay particles that can be incorporated for various ceramic product development. Generally, in the manufacturing of refractories the more non-plastic components (grog) that can be added to the clay with minimum effect on plasticity the higher the refractoriness and stability of the products. Plasticity therefore is very important in ceramic systems.

Plasticity of clays is frequently attributed to their lamella or platy nature, and the degree of packing density, which is a function of distribution of the fine and coarse particles. A system of equal-sized spherical particles generally packs very loosely, but by adding a certain proportion of coarse particles to the fine or vice versa, the proportion of void space is reduced and plasticity of either may be enhanced. It is also known that fibrous particles such as those found in attapulgites, or rod shaped particles as in Japanese Kibushi and gairome clays, which are halloysites, are capable of producing plastic masses due to the elutriation processing methods embarked on.

In the developing countries, the major processing route is to sieve the clays through 67-micron sieves followed by filter pressing and drying. This is what we generally believe as the best way of enhancing plasticity of our clays. Mellor [1] has suggested that a distribution of grains of various sizes permit the closest packing that gives a maximum plasticity, whilst Shurecht [2] concluded that (a) loosely cemented aggregates of clay grains are more plastic than closely compacted ones also (b) fine-grained aggregates are more plastic than the coarse grained ones. Whatever the state of aggregation, the fact still remains that larger particles of clay are often agglomerations of the smaller particles and possess the same properties, though some aggregates break down more readily than others.

Ageing is known to enhance the plasticity of clays probably chemically and also by the breakdown of large particles to fine ones irreversibly. [3] The time taken in ageing is known to vary from one company to the other, therefore has become a kind of trade secret since it is one of the key factors that enhances quality of the finished products. In this paper, attempt has been made to find out if ageing increases plasticity of our clays as measured by the compression plastometer within six months period of time. The findings of this investigation could enable us use this single equipment to determine the type of plasticity one needs within a time period in controlling our processing requirements.

EXPERIMENTAL PROCEDURE

The instrument used for the determination of plasticity was the compression plastometer designed to B.C.R.A. specifications. It consists of a base plate on which a cylindrical specimen of the clay to be tested is mounted. Above the base plate is a similar upper plate fixed to a flexible steel beam on the middle of which rests a dial gauge. In operation, the lower plate is driven upwards at a constant rate by a synchronous electric motor, thus compressing the specimens against the upper plate. The percentage compression is read directly from a circular scale driven by a motor, whilst the stress is calculated from the deflection of the beam as indicated by the dial gauge and the area of the test piece.

Since the latter increased continuously during compression, the initial calculated value of stress is corrected for each value of compression, assuming that the volume of the test piece remained constant (i.e. true stress).

Processed, unprocessed, aged clays and further aged clays were mixed, wedged and kneaded by hand and beaten into a rough cube on a glass plate until the paste ceased to be sticky but was still deformable.

Cylindrical test pieces were made from the plastic clay using a two-part brass mould and stress-strain curves were obtained.

DETERMINATION OF SPECIFIC SURFACE AREA

The specific surface area of the aged and unaged clay samples were calculated by determining the amount of dye required to form a monomolecular layer by the following method.

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Ten separate 1-gram samples of clay powder were weighed out and each placed in a separate dry test tube. Using a 10ml pipette, 1ml of M/100 methylene blue solution was added to the first tube, 2ml of the solution added to the second and so on up to the tenth tube. The total volume of liquid in each tube was then made up to 15ml by adding the requisite amount of distilled water and the content of each tube mixed thoroughly.

The tubes were allowed to stand until the clay in each one settled to form a sediment, leaving the supernatural liquid clear. The minimum addition of the dye required to give a permanent colour gave approximately the amount required to form a monomolecular layer. From this, the specific surface area of clay in m^2g^{-1} was calculated assuming that the effective area of the dye molecule was $0.25nm^2$ and Avogaadro's number is $6.0x10^{23}$ mol^{-1}.

PREPARATION OF CLAYS

Processed Clay

In the ceramic industry, raw materials are usually wet-mixed for efficiency and the beneficial effect on plasticity; a great deal of excess water is inevitably used and this must be removed to convert the clay into a plastic state for shaping articles.

The necessary de-watering is accompanied by filter pressing, a process in which the slurry is filtered under pressure through fine filter cloths. Pressed clays formed by this process have considerable thickness and it is clearly the permeability of water through the filter press-cakes that determines, along with pressure, the rate of filter pressing. In order to obtain high permeability, the clay is not deflocculated before mixing, hence the particles pack loosely and enable water to penetrate readily.

In this investigation, approximately 2kg of clay were added to about two to three litres of water in a Hobart mixer and stirred for about four to five hours, by which time the clay aggregates were broken down. The resulting slip was passed through 67 micron sieve into a cylinder of the filter press and de-watered at 25 p.s.i. A (PA20B) filter press was used in de-watering the slip.

The resulting wet paste was then placed on a plaster of Paris slab for further de-watering and then wedged and kneaded to homogenise it. The clays to be aged were then put into sealed polythene bags, and stored in the laboratory for several months before testing.

Unprocessed Clay

The unprocessed clay (raw clay as mined) was mixed with water in a Hobart mixer with a suitable proportion of water and stirred for about four hours. The clay was then dried on a Plaster of Paris slab for further de-watering.

TYPES OF CLAY USED

Clays used in this investigation were Teteku Bokasso kaolin in the Western Region, Cape Coast Clay in the Central Region and Afari brick clay in Ashanti Region. The ball clay used in this investigation is from W.B.B. of UK with known properties as standard in evaluating the local clays.

RESUTLS AND DISCUSSION

Results obtained with the compression plastometer agrees with Moore [4] work that the ratio of stress at 10% compression and that of 50% is independent of moisture content.

Dry clay has zero plasticity and with progressive addition of water, the clay becomes plastic. With too much water, that plasticity is lost as the clay turns into slip. Somewhere between zero plasticity and formation of slip, a maximum plasticity is attained. However, it is difficult to determine the exact water content needed to achieve this maximum plasticity. The range of moisture content used in this paper is from 20.7% to 59.2%, which represents the workability of the local clays by which they are found to be mouldable.

The result below (Table 1) indicates how little moisture content affects the various plasticity index values. However, there is a clear indication that aged clays have higher plasticity index values than the unaged clays. This might be the result of physico-chemical changes in the state of aggregation of the aged clays leading to higher plasticity index values. The high values obtained for aged clays could probably be due to the decomposition of the organic matter present, with the formation of dilute acid which coagulate the fine grains of clays and thus increase the plasticity. [5]

Table 1: Plasticity Index Values of all the Clays Investigated.

Type of Clay	Preparation	% M.C.	Plasticity Index
Cape Coast Clay	Filter pressed	28.1	0.61
	Unprocessed	27.1	0.66
	Aged	30.0	0.80
Teteku Bokassa	Filter pressed	59.2	0.62
	Unprocessed	53.1	0.66
	Aged	54.8	0.76
Afari Brick Clay	Filter pressed	28.3	0.61
	Unprocessed	20.7	0.79
	Aged	22.7	0.80
Ball (W.B.B.) Clay	Filter pressed	42.0	0.72
	Unprocessed	31.5	0.76
	Aged	43.0	0.90

One other reason for the high plasticity index for aged clays could be attributed to the production of more fine particles as the system is continuously aged hence affecting the packing density positively leading to high plasticity.

Many investigators, including Moore and Lockett [6] and Wilkinson and Dinsdale [7] in their contribution to plasticity attributed the effect of packing of particles to high plasticity while Buessen and Nagy [8] attributed the increase of plasticity to gliding process connected with the rotation of fine clay particles as the contributing feature of deformation of the clay water systems.

The latter investigators contrasted the plasticity index values of raw clays and fine clays by pointing out how the unprocessed clays contain more non-clay particles and hence increase the frictional force between particles. In this investigation, the unprocessed clay has higher plasticity index values than the filter pressed clays which is a clear indication of the role packing density plays in plasticity of clays as measured by the compression plastometer.

The findings of this paper agrees with Worrell [9] in his assertion that the irreversible changes associated with ageing are caused by irreversible breakdown of aggregated clay particles by the action of water. From the foregoing, aged clays are more plastic than the unaged clays. This finding is an established fact and generally accepted.

However, as the clays were continuously aged (six months) the plasticity index values dropped (ref. Tables 3,4,5,6,7) indicating further subdivision of the particles with a net packing density that does not favour right packing density as measured by the compression plastometer. This finding is contrary to available literature on plasticity of clays.

This position has been confirmed by the size distribution measurement, which shows a progressive increase in the proportion of the fine particles as the system is aged. Evidently, the break down of aggregates to ultimate particles increases the available surface areas, so that the contact between particles is increased which intend increases the yield value and viscosity.

Comparing the aged clays with unaged clays further, the aged clays have higher specific surface area and it is therefore not unexpected that the plasticity indices are higher as in Table 2.

Table 2: Specific Surface Area for Aged and Unaged Industrial Kaolinites

Aged Clays S.S.A. (m2g-1)		Further aged clays +6 months	Unaged clays S.S.A. (m2g-1)
Ball Clay	18.5	28.5	15.05
Teteku Bokasso	9.03	12.0	6.02
Afari Brick Clay	11.58	14.0	10.3
Cape Coast Clay	18.05	28.0	16.5

Table 3: Compression Plastometer Test.
Type of Clay: Cape Coast Clay

Material	Moisture Content %	Plasticity Index
Filter Pressed Cape Coast	28.1	0.61
Clay	27.1	0.66
Unprocessed Clay	30.1	0.75
	29.1	0.76
Aged Clay	30.0	0.80
	29.1	0.82
	30.6	0.78
Further Aged Clay	37.5	0.58

Table 4: Compression Plastometer Test
Type of Clay: Teteku Bokasso Kaolin

Material	Moisture Content %	Plasticity Index
Filter Pressed	59.2	0.62
	53.4	0.64
	56.3	0.63
Unprocessed Clay	53.1	0.66
	53.4	0.64
	53.4	0.64
Aged Clay	54.8	0.76
	53.5	0.75
Further Aged Clay	44.0	0.56
	37.5	0.57

Table 5: Compression Plastometer Test
Type of Clay Afari Brick

Material	Moisture Content %	Plasticity Index
Filter Pressed	28.3	0.61
	27.1	0.66
Unprocessed Clay	20.7	0.76
	22.3	0.76
Aged Clay	26.0	0.78
	24.5	0.79
Further Aged Clay	21.7	0.62
	27.5	0.68

Table 6: Compression Plastometer Test
Type of Clay: English Ball Clay (Standard)

Material	Moisture Content %	Plasticity Index
Filter Pressed	42.0	0.72
	36.7	0.74
Unprocessed Clay	31.5	0.76
	31.4	0.76
	38.9	0.74
Aged Ball Clay	43.0	0.90
	42.0	0.92
Further Aged Clay	44.0	0.56
	37.5	0.57

Table 7: Stress/Strain Values for Compression Plastometer Specimens for English Ball Clay
Compressive Stress (KN/m^2)

Compressive Strain %	Unprocessed	Processed Filter Pressed	Aged	Further Ageing Period
10	37.1	26.04	33.6	34.9
20	39.4	28.49	37.73	52.6
30	44.17	30.31	42.14	58.7
40	48.23	33.32	42.70	58.8
50	49.0	35.84	37.70	61.6
60	-	34.70	-	64.2
Plasticity Index	0.76	0.73	0.90	0.57
Water of workability % dry basis	31.5	42.0	42.0	37.5

Table 8: Stress/Strain Values for Compression Plastometer Cape Coast Clay Specimens
Compressive Stress (KN/m^2)

Compressive Strain %	Unprocessed	Processed Filter Pressed	Aged	Further Ageing Period
10	23.94	20.7	26.32	18.6
20	26.10	22.75	28.07	22.5
30	28.60	24.78	28.91	25.4
40	30.86	26.04	30.87	26.0
50	31.80	28.35	32.83	27.8
60	-	28.42	32.62	30.1
Plasticity Index	0.75	0.73	0.80	0.67
Water of workability % dry basis	30.30	27.1	30.8	44.0

Teteku Bokasso, which is a form of China clay, had a high plasticity index, which is unexpected. This is due to the fact that China clays have a narrow size range distribution that gave it a high plasticity index.

However, the further aged clays (6 months) though showed higher specific surface area indicating further introduction of fine materials through ageing showed a drop in plasticity index values as referred to in Tables 7-10. Clearly, the compression plastometer is sensitive to packing density.

Table 9: Stress/Strain Values for Compression Plastometer Afari Brick Clay Specimens

Compressive Stress (KN/m²)

	Afari Brick Clay			
Compressive Strain %	**Unprocessed**	**Processed Filter Pressed**	**Aged**	**Further Ageing Period**
10	50.64	24.43	41.65	13.9
20	55.52	29.61	47.04	18.5
30	61.42	32.62	49.63	19.9
40	65.64	34.51	51.52	20.9
50	63.97	37.03	54.53	22.4
60	-	37.59	54.46	24.6
Plasticity Index	0.79	0.66	0.76	0.62
Water of workability % dry basis	20.7	28.3	28.8	21.7

Table 10: Stress/Strain Values for Compression Plastometer - Teteku Bokasso Kaolin Specimens

Compressive Stress (KN/m²)

Compressive Strain %	**Unprocessed**	**Processed Filter Pressed**	**Aged**	**Further Ageing Period**
10	50.64	24.43	41.65	4.99
20	55.52	29.61	47.04	11.66
30	61.42	32.62	49.63	16.52
40	65.64	34.51	51.52	17.33
50	63.97	37.03	54.53	18.30
60	-	37.59	54.46	21.5
Plasticity Index	0.97	0.66	0.76	0.30
Water of workability % dry basis	20.7	28.3	28.8	63.8

CONCLUSION

The results of this investigation reveals that processed clays by filter pressing have lower plasticity index than the unprocessed clay as measured by the compression plastometer. This is contrary to what is generally believed. The sieving through the 67 microns before filter pressing probably removed certain particle size ranges, which might have affected the packing density; hence the plasticity index as measured by the compression plastometer. It is also recommended that plasticity measurements should be related to the type of forming process envisaged. In this regard, product development by the use of forming by pressure would benefit from this investigation whilst product development by extrusion should use plasticity measurements based on extrusion experiments.

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