Title	Effect of Particle Size of Raw Materials on the Characteristics of Porcelain
All Authors	Thwe Linn Ko
Publication Type	Local Publication
Publisher (Journal name, issue no., page no etc.)	Universities Research Journal 2012, Vol. 5, No.4
Abstract	In this research, washed clay materials were used to prepare different porcelain bodies. Physico-chemical properties and mechanical properties were determined for different clay materials. Procelain bodies were prepared by using very basic compositions (50% clay portion and 50% flux and filler portion) with different mesh size (200 and 300 mesh)and sintered at two different temperatures (1190ºC and 1225ºC) in the shuttle kiln. Physico-chemical and mechanical properties of different porcelain bodies were determined. Particle size, composition of raw materials and sintering temperature clearly affected the strength of porcelain.
Keywords	Clay, porcelain bodies, mesh size, sintering temperature
Citation	
Issue Date	2012

Universities Research Journal 2012, Vol. 5, No.4

Effect of Particle Size of Raw Materials on the Characteristics of Porcelain

Thwe Linn Ko[1], Khin Thet Ni[2]

Abstract

In this research, washed clay materials were used to prepare different porcelain bodies. Physico-chemical properties and mechanical properties were determined for different clay materials. Porcelain bodies were prepared by using very basic compositions (50% clay portion and 50% flux and filler portion) with different mesh size (200 and 300 mesh) and sintered at two different temperatures (1190°C and 1225°C) in the shuttle kiln. Physico-chemical and mechanical properties of different porcelain bodies were determined. Particle size, composition of raw materials and sintering temperature clearly affected the strength of porcelain.

Key words: clay, porcelain bodies, mesh size, sintering temperature

Introduction

One important characteristic of the ceramic industry is that it is basic to the successful operation of many other industries. For example, refractories are a basic component of the metallurgical industry, abrasives are essential to the machine-tool and automobile industries. Glass products are essential to the automobile industry as well as to the architectural, electronic, and electrical industries. Various special electrical and magnetic ceramics are essential to the development of computers and many other electronic devices. Newly designed devices incorporate ceramic materials because of their useful chemical, electrical, mechanical, and structural properties. Ceramics are important, first, because they comprise a large and basic industry and, second, because their properties are critical for many applications.

Porcelain is made of all-natural raw materials; quartz, feldspar and kaolin. It possesses all the major characteristics of technical ceramics. The more demands on ceramic components for electric power generation and distribution systems and mechanical engineering uses, the better material properties and the development of new manufacturing methods. It is

[1] Lecturer, Department of Industrial Chemistry, Dagon University
[2] Professor and Head, Department of Industrial Chemistry, University of Yangon

important to understand the physical, mechanical and thermal properties of porcelain bodies that are formed by slip casting, extruding and pressing. Porcelain insulators are widely used in electrical applications such as power transmission and distribution. The objective of this study is to study the effect of particle size of raw materials on the characteristics of porcelain.

Materials and Methodology

Materials

Locally available five clay materials: ball clay (Taungnaut) from Kyaukpadaung Township, Mandalay Region, ball clay (Yankintaung) from Minhla Township, Bago Region, china clay (Kanpauk) from Kyaukpadaung Township, Mandalay Region, china clay (Shwetaung) from Shwetaung Township, Bago Region, china clay (Yozayat) from Pakoku Township, Magwe Region were prepared and some were used for the preparation of porcelain. Feldspar from Tharzi Township, Mandalay Region was used as a flux material and quartz (Myeik) from Thanintharyi Region was used as filler.

Methodology

Physico-chemical Properties of Clay Materials

Color, shrinkage (drying shrinkage and firing shrinkage), water absorption, bulk density and apparent porosity of clays materials were determined.

Mechanical Properties of Clays

Flexural Strength Apparatus/Automatic MOR Machine was used to find out the breaking load as well as the calculated dry Modulus of Rupture value directly. A simple three point bending technique is employed to find out the values.

Studies on Preparation of Different Porcelain Bodies

Preparation of Slip and Test Circular Bars

Slip for various bodies were prepared with composition described on Table 1. 25% by weight of water was added to form the required consistency. The slip was obtained after operating the pot mill for 8 hr. The slip obtained was poured into POP molds to get round shaped test bars (approximately 2 cm in dia and 15 cm in length). After that, these test bars were dried at 110ºC for 12 hr. Test circular bars for both 200 mesh and 300 mesh were prepared with different body compositions (B_1, B_2, B_3 and B_4).

Sintering the Test Circular Bars at 1190°C and 1225°C

Circular bars were sintered in the shuttle kiln. 6 hr sintering was required to reach 300°C and 12 hr for 600°C. Those were smoking period. 2 hr was needed to 650°C and 6 hr for 950°C. 2 hr was required for 950°C - 1000°C and 6 hr for 1000°C - 1190°C. The annealing time was 2 hr and cooling time was 29 hr. So the total firing cycle was 65 hr (cold-cold) for test bars. Circular bars were also sintered as described above but final temperature was 1225°C.

Physico-chemical Properties of Bodies

Physico-chemical properties of test circular bars (color, drying shrinkage, firing shrinkage, water absorption, bulk density and apparent porosity) were determined.

Mechanical Properties of Bodies

Mechanical properties of different bodies such as dry Modulus of Rupture (dry MOR) and fired Modulus of Rupture (fired MOR) were determined. Some dry circular bars were used to determine dry MOR whereas sintered circular bars were used to determine fired MOR.

Table 1 Compositions of Porcelain Bodies

Body	Ball clay (YKT) (%w/w)	China clay (ST) (%w/w)	China clay (YZY) (%w/w)	Feldspar (TZ) (%w/w)	Quartz (Myeik) (%w/w)
B1	25	25	-	25	25
B2	30	20	-	30	20
B3	25	-	25	25	25
B4	30	-	20	30	20

YKT = Yankintaung, ST = Shwetaung, YZY = Yozayat, TZ = Tharzi

Results and Discussion

Character of the raw material is very important to obtain right body composition for good porcelain. Washed clay materials were used to reduce free silica, since free silica was very difficult to combine in the reactions. The required compound from feldspar is alkali. Silica in quartz gave increase refractoriness. Both feldspar and quartz are not carbonate stone and free silica had already been removed by washing. The grain size of quartz is also important; the finer the grain size, the better for porcelain.

Table 2 Physico-chemical Properties of Circular Bars of Clay Materials

Sr. No	Property	Ball clay (TN)	Ball clay (YKT)	China clay (KP)	China Clay (ST)	China clay (YZY)
1	Particle size used (mesh)	200	200	200	200	200
2	Firing temperature (°C)	1200	1200	1200	1200	1200
3	Firing color	brown	cream	light brown	cream	white
4	Firing cycle (hr)	48	48	48	48	48
5	Drying shrinkage (%)	7.0	8.0	8.8	5.0	2.5
6	Firing shrinkage (%)	15.0	18.0	18.5	14.0	10.0
7	Total shrinkage (%)	22.0	26.0	27.3	19.0	12.5
8	Water absorption (%w/w)	3.3	2.6	4.6	8.8	11.3
9	Bulk density (g/cm^3)	2.6	2.5	2.3	2.3	2.0
10	Apparent porosity(%w/w)	8.5	1.5	8.4	3.0	7.5

Fired color also varies, and this is an important consideration in the selection of clay for a particular purpose. Generally, drying shrinkage of clay samples was proportional to firing shrinkage and also total shrinkage. The bulk density of clays lined between 2 g/cm^3 to 2.6 g/cm^3. It was found that, bulk densities of ball clays were higher than that of china clays. Bulk density, water absorption, and apparent porosity are closely connected with each other and they are very important factors to judge the refractory quality. The physico-chemical properties and the finess of raw materials have a critical effect on properties of porcelain.

Table 3 Mechanical Properties of Clays

Sr. No	Property	Ball clay (TN)	Ball clay (YKT)	China clay (KP)	China clay (ST)	China clay (YZY)
1	Dry MOR (kg/cm^2)	16.6	15.4	32.5	7.4	8.7
2	Fired MOR (kg/cm^2)	302.3	450.5	300.9	105.5	197.8

Table 4 Physico-chemical Properties of Bodies, using Different Particle Sizes (Sintering temperature = 1190°C)

Sr. No	Property	200 mesh Body				300 mesh Body			
		B1	B2	B3	B4	B1	B2	B3	B4
1	Firing cycle (hr)	65	65	65	65	65	65	65	65
2	Bulk density (g/cm^3)	2.5	2.1	2.2	2.2	2.1	2.4	2.3	2.4
3	Water absorption (%w/w)	5.9	8.5	8.6	9.0	4.5	5.5	6.7	6.7
4	Apparent porosity (%w/w)	12.5	12.3	13.6	18.5	11.5	12.5	11.7	10.5
5	Drying shrinkage (%)	3.0	4.5	3.5	4.5	3.0	4.0	3.5	5.0
6	Firing shrinkage (%)	7.0	7.0	6.0	6.0	7.0	7.0	6.5	8.0
7	Total shrinkage (%)	10.0	11.5	9.5	10.5	10.0	11.0	10.0	13.0

In fabrication of bodies with basic composition, ball clay (YKT), china clay (ST), and china clay (YZY) were selected for clay part. But in preparation of body mixtures, only one ball clay (YKT) with only one china clay (ST) or (YZY) were used.

By using 50% clay part and 50% flux and quartz part, four bodies composition were prepared with different mesh sizes and fired at different temperatures. Their physic-chemical properties and mechanical properties were determined and the results are shown in Tables 4, 5, and 6. The firing cycle of all the bodies was 65 hr. It can clearly be seen from the data that, water absorption and apparent porosity were lowered as particle size was reduced. Moreover, increased sintering temperature could be given lower water absorption and lower apparent porosity than reduced sintering temperature for all bodies. The shrinkages of all bodies were not greatly different.

Table 5 Physico-chemical Properties of Bodies, using Different Particle Sizes

(Sintering temperature = 1225°C)

Sr. No	Property	200 mesh Body				300 mesh Body			
		B1	B2	B3	B4	B1	B2	B3	B4
1	Firing cycle (hr)	65	65	65	65	65	65	65	65
2	Bulk density (g/cm^3)	2.5	2.2	2.2	2.2	2.2	2.3	2.2	2.2
3	Water absorption (%w/w)	4.5	5.3	5.6	5.4	2.5	1.1	5.0	1.3
4	Apparent porosity (%w/w)	11.4	11.7	10.8	11.9	2.8	2.6	6.5	3.0
5	Drying shrinkage (%)	3.0	4.5	3.5	4.5	3.0	4.0	3.5	5.0
6	Firing shrinkage (%)	7.0	7.0	6.0	6.0	7.0	7.0	6.5	8.0
7	Total shrinkage (%)	10.0	11.5	9.5	10.5	10.0	11.0	10.0	13.0

It can clearly be observed from Table 6 that, fired MOR of 200 mesh bodies sintered at 1190°C were between 203 kg/cm^2 to 335 kg/cm^2, fired MOR of 300 mesh bodies sintered at the same temperature were between 287 kg/cm^2 and 645 kg/cm^2. Fired MOR of 200 mesh bodies sintered at 1225°C were between 206 kg/cm^2 and 385 kg/cm^2, but for 300 mesh bodies sintered at that temperature were between 287 kg/cm^2 and 645 kg/cm^2. Thus, roughly, the mechanical properties of all bodies were increased when the particle size of raw materials reduced, and when sintering temperature increased, mechanical properties of all bodies were also increased.

Table 6 Mechanical Properties of Bodies, using Different Particle Sizes and Sintering Temperatures

Body	Particle Size Used (mesh)	Sintering Temperature (°C)	Modulus of Rupture (kg/cm^2)	
			Before Sintered	After Sintered
B1	200	1190	4.5	203.0
	300	1190	9.8	335.3
	200	1225	4.5	206.4
	300	1225	9.8	402.5
B2	200	1190	4.8	215.0
	300	1190	8.2	269.0
	200	1225	4.8	256.8
	300	1225	8.2	286.9
B3	200	1190	4.8	223.0
	300	1190	9.8	328.0
	200	1225	4.8	245.3
	300	1225	9.8	389.7
B4	200	1190	5.7	335.3
	300	1190	8.6	384.3
	200	1225	5.7	385.3
	300	1225	8.6	645.0

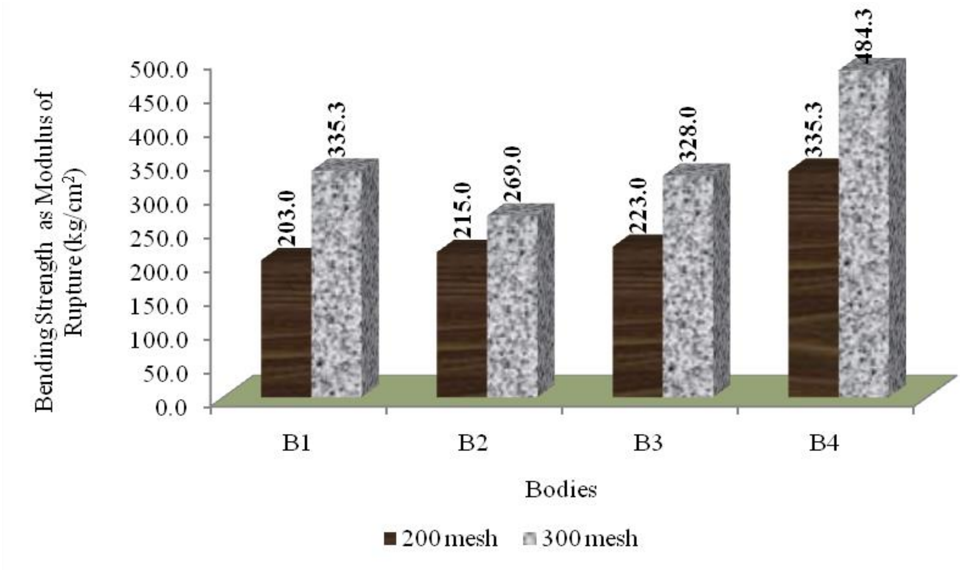

Fig 1 Effect of Particle Size Used on Bending Strength of Porcelain Bodies Sintered at 1190°C

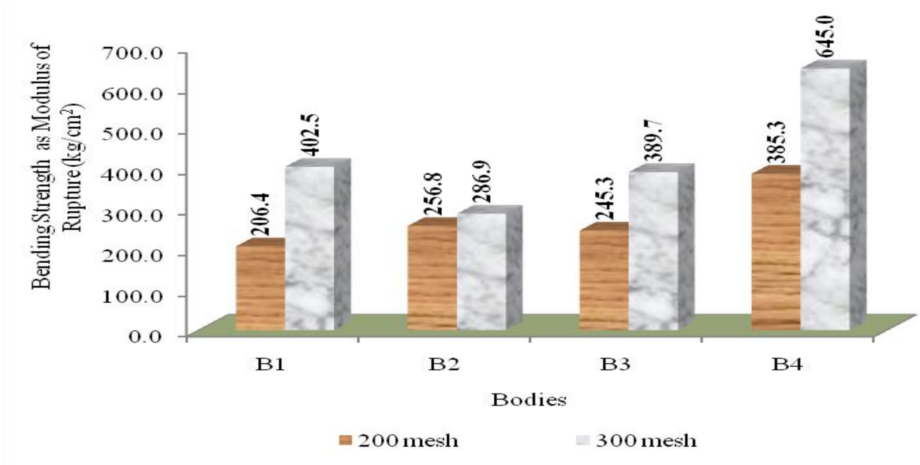

Fig 2 Effect of Particle Size Used on Bending Strength of Porcelain Bodies Sintered at 1225°C

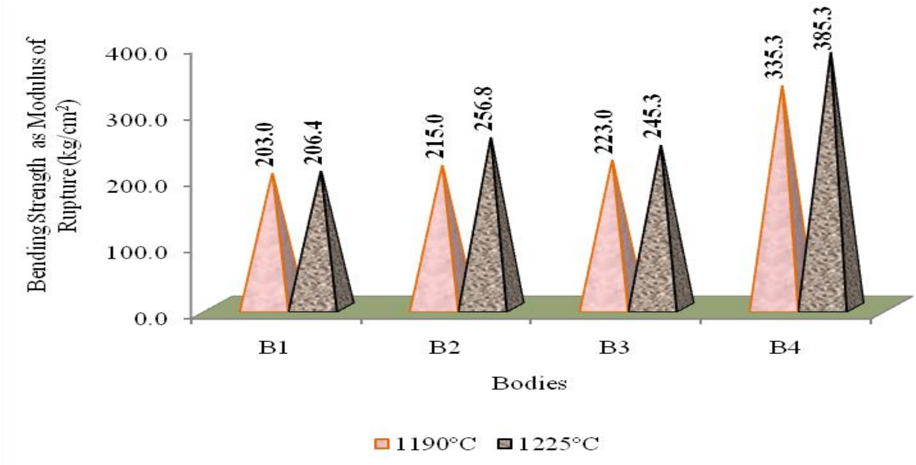

Fig 3 Effect of Sintering Temperature on Bending Strength of Porcelain Bodies (200 mesh)

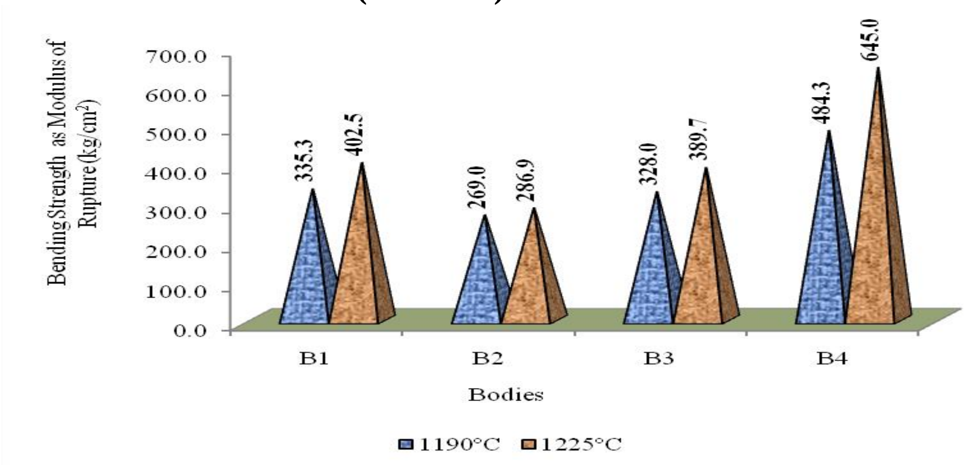

Fig 4 Effect of Sintering Temperature on Bending Strength of Porcelain Bodies (300 mesh)

As the temperature increases to the sintering stage, the porosity changes from an open to closed network; and the object shrinks due to decreasing porosity. This behavior leads to high density and improved mechanical strength. Kneading was also affected on the strength of the porcelain body. The repeated kneaded body was found to be higher strength than less kneaded body. The fired product is hard, dense, more durable, impermeable to liquids, and brittle.

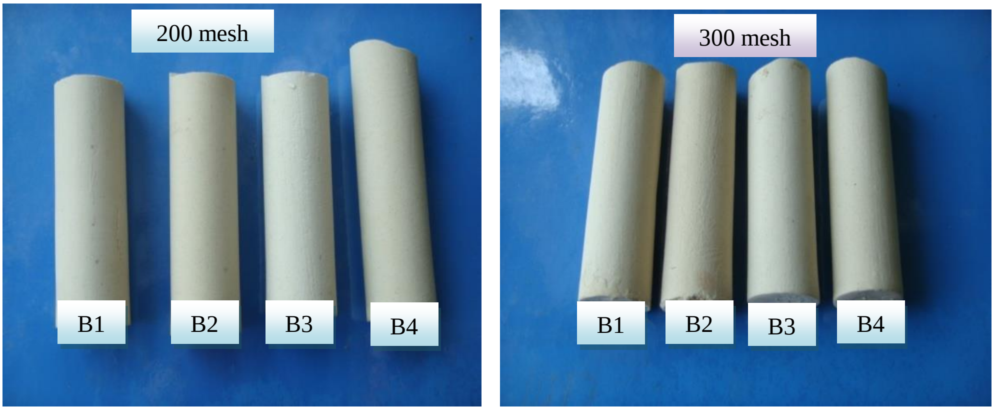

Fig 5 Porcelain Bodies of Different Mesh Sizes Sintered at 1190°C

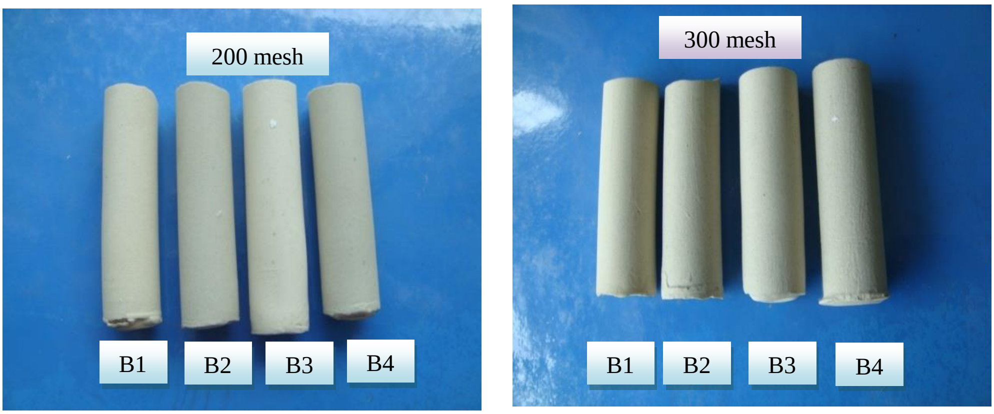

Fig 6 Porcelain Bodies of Different Mesh Sizes Sintered at 1225°C

Conclusion

Raw materials for the production of ceramic are structurally modified alumino silicates. For higher strength porcelain, a good transparency glassified bond should be built by using right proportion of silica and alumina. The workability of clay was influenced by the physico-chemical property. Thus clays were blended to obtain the most favorable results. The properties of the finished bodies vary to a remarkable extent depending upon the raw materials even though the chemical composition is exactly the same. Generally, the strength of porcelain increased when: (a) the particle size was decreased and (b) the temperature was increased to a certain limit. Superior combination was also important to resist the coincidence forces. Properties of the finished bodies vary to a remarkable extent depending upon the sintering temperatures. If sintering temperature was low, the feldspar proportion should be higher than normal, consequence is low quartz percent. Superior combination was also important to resist the coincidence forces. The relative density of the samples depended on the composition of the samples, and it was also observed that, if mechanical property of the samples increased, the relative density also increased.

Acknowledgements

The author is grateful to supervisor, Professor Dr Khin Thet Ni, Head of the Department of Industrial Chemistry, University of Yangon, for giving permission to perform this research, guidance, invaluable suggestions and advice throughout this research work. Special thanks are to Professor Dr Yin Shwe, Head of the Department of Industrial Chemistry, Dagon University, for her invaluable suggestions and kind support in carrying out this research work.

I would like to express my gratitude to U Than Tun, Assistant General Manger and also Head of Quality and Process Control Department, High-tension Insulator Factory, Ministry of Industry, Chauk Township, Magwe Region, and wife Daw Khin Than Win, Manager, Development Centre of Ceramic Technology, Insein Township, for their invaluable discussion, providing research facilities.

References

Carty, W. M., and Senapati, U., 1998. Porcelain Raw Materials, Processing, Phase Evolution and Mechanical Behavior, Journal of American Ceramic Society 81(1), 3-20

Ceramic Engineering, 1981. Nagoya International Training Center, Japan, International Co-operation Agency, (J.I.C.A), Japan

Fahrenholtz, W. G., 2004. Ceramic Engineering 111, Sintering, Ceramic Engineering Department University of Missouri-Rolla (Unpublished)

Harper, A. C., 2001. Handbook of Ceramics, Glasses, and Diamonds, McGraw-Hill Co., Inc., United States of America

M/S Myanmar Ceramic Industries, 2001. Refractories Bricks Manufacturing Plant: Operation manual and quality control manual, Mino Yogyo Co., Ltd

Norton, F. H., 1970. Fine Ceramics Technology and Application, Mc Graw-Hill Book Company, Kogakusha Ltd., Tokyo

Patil, K. C., 1993. Advanced Ceramics: Combustion synthesis and properties, Bulletin Material Science, Vol 16, 6, 533-541

Ryan, W., 1978. Properties of Ceramic Raw Materials, 2nd Edition in SI/Metric Units, Copyright by Ryan, W., Printed by Briddles Ltd., Great Britain