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Florida kaolin as the chief clay ingredient for a sanitary ware casting body

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FLORIDA KAOLIN AS THE CHIEF CLAY INGREDIENT FOR A SANITARY WARE CASTING BODY.

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TABLE OF CONTENTS

PAGE.

FLORIDA KAOLIN AS THE CHIEF CLAY INGREDIENT FOR A SANITARY WARE CASTING BODY.

INTRODUCTION

Purpose of the Investigation

The purpose of this investigation was to utilize a large percentage of Florida Plastic Kaolin in a new sanitary ware casting body. Such a body, when worked out to be satisfactory, could be produced at a lower cost than those bodies being used in American plants at present. This particular plastic kaolin is available in large quantities in the southeastern portion of the United States. It is the intention of this work to substitute this American clay for the more costly imported English China Clay now being used in sanitary ware casting bodies.

According to C. F. Binns,[1] Florida kaolin is a refractory or white ball clay. It is sticky, but short and is difficult to slip. It was thought that by removing some of the water of hydration that these difficulties would be more or less overcome. W. M. Kennedy[2] found that the temperature between which the bulk of the combined water was driven off was 450 and 600 degrees centigrade. However, the preheat treatment given the Florida kaolin in all of this work was thought best to be kept under 325 degrees centigrade, as it was not desired to remove all of the water of hydration.

The raw materials used, consisted primarily of Klondyke Washed Florida kaolin, Pennsylvania flint, Canadian feldspar, and No. 5 and number 9 Tennessee ball clays. Two electrolytes were employed to prevent the slip from settling out; sodium carbonate and sodium silicate, the chemical analysis of the latter is given later in this report. The water used in bringing the slips up to the desired viscosity and specific gravity was entirely free of iron and free alkalies.

With the above considerations in mind the chief objective of the investigation was to produce a superior, cheaper and more satisfactory sanitary ware casting body, which would embody in its composition a large percentage of the particular kaolin above mentioned.

METHOD OF INVESTIGATION

PRELIMINARY STUDY

In order to have some basis upon which to begin the investigation it was deemed advisable to determine just what proportions of this kaolin would cast satisfactorily when mixed with the other ingredients. Three bodies were taken which embodied a wide variation of amounts of ingredients and which indicated good casting properties. The percentage of kaolin in these bodies varied from 35% in body "A" to 50% in body "C". The percentage variation of the other ingredients will be shown later under the procedure.

Both raw and heat-treated kaolin were used in making up the preliminary bodies and it was found that the kaolin which had received the preheat treatment gave a more satisfactory slip than the raw material. The desired specific gravity and time of flow was obtained by varying the amount of water in each slip. The percentage of electrolyte was kept constant at .25%.

PROCEDURE

Bodies "A", "B" and "C", as obtained from the preliminary study, were compounded as shown in Table 1.

Table 1.

	A	B	C
Kaolin------	35%	40%	50%
Flint-------	34%	28%	31%
Feldspar----	16%		19%
Ball Clay---	15%	32%	

Fig. 1. shows a 10 member triaxial system prepared from the above bodies as 100% end members. In any body where the percent of ball clay amounted to 10% or more the amount was equally divided into No. 9 and No. 5 Tennessee ball clay. This precaution reduced, to some extent, possible variation in either ball clay.

Fig. 1. Triaxial Diagram.
(A-B-C)

Table 2.

	1.	2.	3.	4.	5.	6.	7.
Kaolin ----	36.63%	39.96%	38.30%	41.63%	44.96%	43.29%	46.62%
Flint -----	31.97%	32.97%	29.97%	30.97%	31.97%	29.97%	29.97%
Feldspar --	10.66%	17.08%	5.32%	11.65%	17.98%	6.33%	12.65%
Ball Clay -	20.64%	9.99%	26.31%	15.65%	5.00%	21.31%	10.66%

Table 2., shows the percentage composition of the members of the triaxial shown in Fig. 1.

The blunging of the different slips was effected in porcelain lined, Abbe, pebble mills. After filling the pebble mills with approximately half of the estimated amount of water for blunging, the raw materials were added. The ball clay was blunged for 30 minutes and then the electrolyte in solution was added and the whole thoroughly mixed. To this mixture the kaolin, which had previously been reduced to half inch size, was added along with more water. After the kaolin had been thoroughly slaked, the feldspar and flint were introduced and the whole blunged for at least one hour, the object being to mix rather than grind. When the body had been blunged sufficiently, the specific gravity was adjusted to 1.8 and the time of flow of the slip determined. The slip was then run through a 60 mesh screen, agitated for a time, and then cast in plaster molds into test bars. These bars were of standard dimensions, 1" by 1" by 6".

In controlling the time of flow, the slip was poured through a 200 cc glass funnel, which had an outlet .21 inches in diameter.

Enough slip was run out to fill a 100 cc graduated cylinder and the time required for this amount of flow was recorded. A constant head of slip was maintained in the funnel during this determination, in order to get the same rate of flow for all slips. The cylinder of slip was then weighed. The actual weight of the slip divided by the volume gave the specific gravity direct. The time of flow for the various slips varied from 108 to 124 seconds.

Ten test bars were used in determining the properties of the body in the dry state, and 10 bars were used in determining the properties in the burned state. Burning of the test pieces was accomplished in a sagger placed in a direct oil fired kiln. The highest temperature to which the test pieces in this investigation were subjected, was cone 9 inside the sagger.

In securing the information contained in the tables of this report only standard methods were used.

Table 3.

Body	% Dry Shrink.	% Burn Shrink	% Total Shrink	% Vol. Shrink	Dry M of R	Burn. M of R	Spec. Grav.	% Absorpt.
A	2.04	10.00	12.04	31.90	113.1	3015	1.81	11.02
B	2.24	7.00	9.24	25.20	203.5	1755	1.79	9.11
C	2.00	9.60	11.70	31.10	42.5	750	1.82	3.97
1	1.92	8.80	10.72	28.80	155.7	2571	1.79	5.10
2	1.67	8.00	9.67	26.30	79.7	1802	1.79	5.98
3	1.28	9.60	10.88	29.20	176.1	1162	1.82	13.60
4	1.80	8.40	10.20	27.50	98.8	1992	1.81	7.43
5	1.90	8.60	10.50	28.50	60.2	1739	1.81	4.77
6	1.56	7.21	8.70	23.90	160.8	1364	1.79	12.23
7	1.4	7.50	8.90	24.40	85.60	1405	1.80	10.71

Having determined the above data on the members of the triaxial; it was then necessary to select one of those bodies for an end member in a binary study, in order to secure the desired degree of vitrification. It was decided to vary the flint, feldspar percentage of the new series as shown in Fig. 2, in order to strike this desired degree of vitrification at cone 9.

Body No. 5 was selected because it possessed the best casting properties; it showed no cracking or warping either when dry or when burned, and showed no tendency to core. Although the modulus of rupture of No. 5 was somewhat lower than the other bodies, in consideration of its casting properties, 60.2 pounds per sq. in. was considered safe enough for handling in the dry state.

In the new series, shown in Fig. 2 below, the percentage of flint in No. 5 was used as a maximum, while in the other end member "D" the percentage of feldspar was used as a minimum for flint. The same relation was reversed to get the variable for maximum and minimum feldspar. The percentage of other ingredients remained constant in each body in this study.

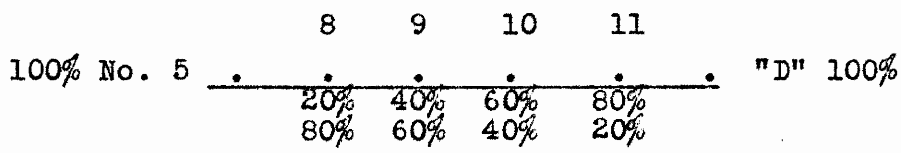

Fig. No. 2 Binary diagram
(NO. 5-D)

The Percentage composition of the above series are shown in the table below;

Table 4.

	NO. 5	NO. 8	NO. 9	NO. 10	NO. 11	D
Kaolin ----	44.96	44.96	44.96	44.96	44.96	44.96
Flint -----	31.97	29.17	26.37	23.58	20.79	17.98
Feldspar --	17.98	20.79	23.58	26.37	29.17	31.97
Ball Clay -	5.00	5.00	5.00	5.00	5.00	5.00

The procedure followed for the bodies in the triaxial system was duplicated for the above bodies and the data recorded as shown in table 5.

Table 5.

Body	% Dry Shrink	% Burn Shrink	% Total Shrink	% Vol. Shrink	Dry M of R	Burn M of R	Spec. Grav.	Absorp.
8	2.16	11.20	13.36	35.0	58.6	2006	1.80	2.24
9	2.16	11.20	13.36	35.0	63.4	2054	1.79	1.45
10	2.20	11.56	13.75	35.8	62.1	2156	1.80	1.31
11	1.86	12.00	13.86	36.1	60.8	2315	1.81	1.19
D	1.79	12.39	14.19	36.8	60.6	2462	1.80	.83

Interpretation of Results

From the observations made on the bodies resulting from the triaxial study it was shown that No. 2 and No. 5 possessed the greatest possibilities. Even though they lacked enough feldspar to produce the desired degree of vitrification at cone 9, their casting properties were such as to indicate adaptability for practical use. The pieces cast from either of these bodies showed little or no tendency to crack, except at places where strains had been set up caused by removal from the mold. It was noted that as the amount of ball clay in the bodies was reduced, the dry modulus of rupture was reduced, but also at the same time that the time of release from the molds was increased. Where the ball clay content was under 10%, the cast pieces were found to release within a 2 hour limit with no attendant sticking or balling. The sticking and balling occurred most in those bodies high in ball clay. This was attributed to the colloidal matter introduced by the ball clay which hindered the passage of water from the body to the mold.[4] All of the bodies, with the exception of "C", possessed good flowing quality.[5] None of the bodies in this study showed any tendency to warp. Body No. 5 was thought to be superior to body No. 2 since it gave a slightly more solid bar in less setting time and indicated slightly less absorption at cone 9.

In the second study, Fig. 2, the object was to determine only the proportions of flint and feldspar that would be necessary for body No. 5 to produce the desired vitrification at cone 9. This vitrification was found in No. 9, a body which burned to an almost white color and which had a very low absorption figure. Body No. 10 was equally as good, showing slightly more vitrification and fired strength. The total volume change was found to increase with increase in feldspar content.

Conclusions

More than 25 different bodies were made up in this investigation. In most cases it was found this particular kaolin worked satisfactorily as the chief clay ingredient. Low temperature calcination of the kaolin, before incorporation in the body, had the effect of reducing the drying shrinkage as well as its extreme stickiness.

The results of this work indicated that it was practical to substitute this type of kaolin for the English China clay commonly used, and for at least part of the ball clay in a sanitary ware casting body. A series of good hard bodies have been made, as above, vitrifying below cone 10.

Whether such bodies are superior to those in use at present can only be determined by actual plant trial, however, it is reasonably safe to state that such bodies worked out satisfactorily in the laboratory and that they are cheaper to produce.

RECOMMENDATIONS

In making recommendations for further work on this subject it would be advisable to go into the study of the kaolin, ball clay ratio in an attempt to increase the dry strength of the body and to reduce possible cracking. To make such a study it would only be necessary to select a body, such as No. 2, or as No. 5, and, while keeping the other ingredients constant, vary the kaolin and ball clay to get maximum and minimum relations, as in Fig. 2. A study of this nature was intended in this investigation but time would not permit.

An intensive study could be made on the proper proportions of electrolyte necessary for controlling the segregation of the materials in the body.

Determining a suitable sanitary ware glaze for this type of body also offers another interesting line of investigation.

APPLICATION TO THE INDUSTRY

Although the slips in this investigation were prepared direct from the raw material, thus eliminating the operation of filter-pressing and reblunging, it was thought that the body would also be adaptable for filter pressing and fine lawing. This assumption is based on the fact that the slips were very porous and the ease with which the water was taken out. However, just how much of the soluble material of these bodies would be removed by filter-pressing is another problem for further investigation.

ACKNOWLEDGMENT

The writer wishes to acknowledge the kind assistance and practical advice given to him by Mr. Paul and Prof. C. M. Dodd.

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ABSTRACTS

Practical Aspects of the Casting of Heavy Vitrified Clay Products. C. C. Treischel, The Ceramist 4, 204, (1924)

The amount of ball clay used varies from 5 to 25 % depending upon their characteristics. It is good practise to use two kinds. For heavy vitreous wares American ball clays are equal if not superior to imported. A factory method of testing colloidal content is to shake 100 grams of ball clay with 200 grams of water and let stand 48 hours in a long narrow tube. The degree of turbidity is an index of colloidal content. Substitution of American secondary kaolin, such as those from South Carolina, Georgia and Florida, for English kaolin will cause trouble. American clays may be used but the bodies are characteristically different.

Casting slips may be either premixed or raw. The first are blunged and filter pressed, and are added to the water and electrolytes. The raw slips are prepared by mixing the body materials, salts and water. In this latter case the general practise is to mix in a ball mill. Premixing has the disadvantage of removing certain organic compounds which are deflocculating agents. Slips used for core casting should weigh 30 ounces to the pint or more. Slips for drain casting should weigh 28 ounces to the pint. The author recommends adding 3/4 of the necessary amount of electrolytes to the water in the blunger or ball mill. To this is added the materials and finally the remainder of the salts. Care must be exercised in testing the weight and viscosity of the slips. The storage of casting slips is important because it affords an opportunity to free the slip from as much air as possible. A thickening of the slip on standing is attributed to adsorption of the salts by colloidal material.

Vitreous Sanitary Ware; Survey of the Industry Including Manufacturing Process, Organization Chart, Detailed Manufacturing Costs, Investment Required, and List of Requirements. W. A. Darrah A. C. S. Abst. Vol. 4, 1925.

The Effect of the Method of Preparation on the Viscosity of a Casting Slip. J. A. C. S. Vol. 4, 1921, By V. S. Schory.

In general, firmness of cast is a very desirable property in the casting process and this fact recommends certain methods of preparation above others. Discussion.

The influence of varying alkali and silica contents in water-glass upon the casting properties of ceramic materials. E. Kieffer, Sprech. 59, 167-68, 1926.

It is necessary to have a water-glass with a high silica content to prepare slips casting easily with kaolins, while for clays having a high, humous content perhaps a water-glass of high NaOH content is best.

Dehydration of Clays.

G. H. Brown and E. T. Montgomery, Tech papers Bur. Stds, 21, Apr. 1913.

Gives a resume on the work done on the dehydration of clays. H. E. Ashleys sumation. Kennedy found that Flo. kaolin loses combined water at 475 degrees centigrade. Most of the combined water can be expelled at the lower temperatures. Even all could be expelled at low temperatures if the time was long enough. Dehydration does not necessarily destroy plasticity. Neither presence of organic matter or the drying shrinkage are criteria for plasticity.

The Dehydration of Clays.

H. H. Brown and E. T. Montgomery A. C. S. Trans.

Vol. 4, 1912.

The loss in plasticity due to heating to constant weight at different temperatures was determined. This varied widely for different clays. The kaolins decreased in plasticity at 450 degrees centigrade. The possible loss in plasticity of a clay preheated to temperatures below 450 degrees centigrade seems to be partially governed by the amount of water given off. The loss of plasticity does not seem to be closely connected with the loss of combined water. Where preheating causes a loss of plasticity the amount of the loss is a function of the time as well as of the temperature.

The Effect of Preliminary Heat Treatment on Drying of Clays. A. V. Bleininger U. S. Bur. Stds. Bull. 7, 143.

To determine a process for the use of exceedingly plastic clays. Describes what happens when pore water and interstatial water are evaporated. Preheating offers a practical method for using clays of excessive plasticity.

Notes on the Preheating of clays. A. V. Bleininger Trans. A. C. S. Vol. 12, 1910.

A continuation of work on the preheating of clays. Preheating tends to set the colloids. It should be carried on at as low a temperature as possible. High temperatures excessive pore space.

Experiments on Drying of Certain Clays.

Edw. Orton Jr. Trans. A. C. S. Vol. 13, 1911.

Gives a geological, economical, and geographical discussion of the clays worked on. These clays were very sticky in the plastic state. Clays warped and cracked badly upon drying. The total drying shrinkage and firing shrinkage ranged from 14 to 18 %, which includes an abnormal drying and a workable burning shrinkage. The tests consisted of using anti-plastic bodies, chemical coagulants, use of heat to break down organic or inorganic bodies which cause drying trouble. Preheating to 100, 200, and 300 degrees centigrade caused some improvement. Higher temperatures did not improve drying consistently. Short time and high temperature in a rotary kiln gave right effect.

Note on the Relation Between the Preheating Temperature and Volume Shrinkage. R. K. Hursh Trans. A. C. S. 14, 1912.

A decided change was noted in properties of most clays by Bleininger, when heated between 200 degrees to 300 degrees centigrade. The plasticity decreased and the clay became granular. Decrease in volume shrinkage and increase in pore water.

Notes on Casting.

Bleininger and Horning. Trans. A. C. S. 17, 1915.

Gives a discussion of alkalies on deflocculation of clays in slips. The age of a slip has an effect on its viscosity. Sodium silicate is a more effective reagent as far as the reduction of viscosity is concerned than sodium carbonate. The ball clay content in a casting body should be reduced to a minimum.

What is the Best Substance to Prevent Clay From Settling in the Casting Process? What is the Effect of This Substance on the Body in Firing? Discussion.

Trans. A. C. S. Vol. 13, 641.

Purdy used sodium silicate. Mayer used both but mixed them with dry clay before blunging. This had little effect when added to the slip. Sodium silicate increases the vitrification. Watts used sodium silicate and sodium carbonate.