CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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Mines Branch Investigation Report IR 58-28

AN INVESTIGATION TO OBTAIN A SAFE DRYING BODY SUITABLE FOR THE MANUFACTURE OF DRAIN TILE FROM HOME BRICK LIMITED RAW MATERIALS

by

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INTRODUCTION

Home Brick Limited, Bracebridge, Ontario is manufacturing drain tile and face brick with the bulk of the production being 4 inch drain tile. The Company has been experiencing difficulty with core bridge separation, lamination and excessive drier loss. The percentage ware rejected at the driers and at the kilns has been abnormally high. Mr. Baron, manager of the plant contacted the Ceramic Section of the Mines Branch for assistance in trying to eliminate or reduce the manufacturing losses. It was suggested that the company forward a representative sample of approximately 100 pounds of their local plant clay and approximately 25 pounds of the fired and rejected ware. The latter was to use as a grog addition to the clay. It was decided also that possibly a small addition of soda ash (Na_2CO_3) might reduce the drying difficulties and reduce the lamination tendencies. An investigation was planned in which the drying and fired properites of mixtures of clay and grog, and mixtures of clay, grog, and soda ash were studied. The principal objective was to develope a mixture which would dry safely and be suitable for production of drain tile.

PROCEDURE

The clay as received was dried and crushed to pass a 16 mesh Tyler screen. The grog was crushed to pass an 8 mesh Tyler screen. A screen analysis was made of the grog. Trial briquettes of various bodies containing clay and grog only and clay, grog, and soda ash were prepared for an investigation of the drying and fired properties. The composition of the

bodies are shown in Table 1. The percentages of clay and grog are by volume and the percentage of soda ash by weight.

Table 1 - Composition of Bodies

Body Number	Laboratory Number	Percent Bracebridge Clay	Percent Grog	Percent Soda Ash
1	83	100	0	0
2	83-1	90	10	0
3	83-2	85	15	0
4	83-3	80	20	0
5	83-4	75	25	0
6	83-5	70	30	0
7	83-6	100	0	0.5
8	83-7	85	15	0.5
9	83-8	80	20	0.5
10	83-9	75	25	0.5

Each body was weighed and mixed with water to form a stiff plastic mass. The amount of water was measured and the water of plasticity was calculated. Trial briquettes 4" x 1½" x 1¼" were hand molded in steel molds. The drying behaviour of one briquette from each body was observed under rapid drying conditions at 185°F. The balance of the briquettes were air dried for 24 hours and dried finally at 212°F for 24 hours. The drying shrinkage was measured. The briquettes were then fired at cones 06 (1816°F), 04 (1922°F) and 02 (2014°F) in an electric laboratory furnace. The temperature was brought up slowly overnight to approximately 1500°F and the firing completed

in approximately 4 to 5 hours the next day. The atmosphere was oxidizing. The fired shrinkage, colour, hardness, and water absorption after a 24 hour soak in cold water were obtained. The pyrometric cone equivalent (P.C.E.) was determined on the clay only. The P.C.Es. of the bodies would be approximately the same.

A differential Thermal analysis curve of the Bracebridge clay (body #1) was obtained principally to estimate the percentage free quartz present.

RESULTS

The results of the physical tests on the various bodies are shown in Table 2. Differential thermal analysis indicates the material was a heterogenous mixture of approximately 40% illitic or chloritic clay mineral, approximately 22% free quartz, a small amount of organic material and the balance mainly inert rock flour.

The grog size used in the tests was - 8 mesh + 20 mesh - 27.50%; -20 mesh + 65 mesh 43.0%; -65 mesh 29.5%.

DISCUSSION OF RESULTS

The results of the tests on the Bracebridge clay (body #1) indicate that it has good plasticity and workability. The clay is difficult to dry safely. The firing range is very short if an absorption of approximately 8% or less is desired. Examination of the fired properties in Table 2 show that between cone 04 (1922°F) and Cone 02 (2014°F) there is a sudden increase in shrinkage and a rapid drop in absorption. At Cone 04 the test briquettes were hard, the fired shrinkage was fairly low

Table 2 Properties of the Bodies

Clay No.	UNFIRED CHARACTERISTICS	P.C.E.	FIRED CHARACTERISTICS					REMARKS
			Cone No.	Fired Skg. %	Abs. %	Colour	Hardness	
1 100% Clay Lab. 83	Common non calcareous grey clay, very plastic, works well, water of plasticity 25.3%, slight tendency to crack in rapid drying, drying shrinkage 6.4%	2	06 04 02	0.3 1.8 8.0	15.9 12.5 1.2	Salmon Dark salmon Dark red	fairly hard hard Steel hard	This clay is inclined to be difficult to dry. It has a short firing range if low absorption and red colour are desired.
2 90% Clay 10% grog Lab 83-1	The mixture was plastic and had a slightly better workability than #1, water of plasticity 25%, slight tendency to crack in rapid drying, drying shrinkage 5.7%.		06 04 02	0.3 2.1 8.8	15.8 11.6 1.2	salmon dark salmon dark red	fairly hard hard steel hard	The mixture is inclined to be difficult to dry It has a short firing range if low absorption and a red colour are desired.
3 85% clay 15% grog Lab 83-2	The mixture had plasticity and workability similar to #2. The water of plasticity was 24.5%. There was a slight tendency to crack in rapid drying; drying shrinkage 5.1%.		06 04 02	0.5 2.3 9.0	16.5 13.3 1.4	Salmon dark salmon dark red	fairly soft fairly hard steel hard	Same comments as #2
4 80% clay 20% grog Lab 83-3	The plasticity and workability of this mixture is similar to #2; water of plasticity 25.8%; safe drying, drying shrinkage 5.0%.		06 04 02	0.3 2.5 9.1	16.7 13.4 1.7	salmon dark salmon dark red	fairly soft fairly hard steel hard	This mixture dried safely in the laboratory with rapid drying otherwise the properties are similar to sample #2.
5 75% clay 25% grog Lab 83-4	This mixture has much the same plasticity and workability as sample #2. The water of plasticity is 25.6%. The mixture is safe drying and has a drying shrinkage of 4.7%.		06 04 02	0.7 2.1 9.1	17.6 14.0 2.0	salmon dark salmon dark red	fairly soft fairly hard steel hard	Same comments as for sample #4

Table 2 - (Cont.)

Clay No.	UNFIRED CHARACTERISTICS	P.C.E.	FIRED CHARACTERISTICS					REMARKS
			Cone No.	Fired Shrinkage %	Absorption %	Colour	Hardness	
6 70% clay 30% grog Lab 83-5	The plasticity and workability are similar to sample #2. The water of plasticity is 25.5%. The material dried safely and has a drying shrinkage of 4.8%.		06	0.8	18.5	salmon	fairly soft	Same comments as for sample #4
			04	2.3	15.1	dark salmon	fairly hard	
			02	9.8	1.8	dark red	steel hard	
7 100% clay 0.5% Na_2CO_3 Lab. 83-6	Good plasticity, works well; water of plasticity 25.3%, slight tendency to crack in rapid drying (more cracking than with Na_2CO_3 omitted); drying shrinkage 5.5%		06	0.3	15.2	salmon	fairly soft	The clay plus soda ash i is difficult to dry. There is evidence of scumming. The firing range is short
			04	1.0	13.6	salmon	fairly hard	
			02	8.1	0.7	dark red	steel hard	
8 85% clay 15% grog 0.5% Na_2CO_3 Lab 83-7	Good plasticity, works well, water of plasticity 25.9%, slight tendency to crack in rapid drying, drying shrinkage 5.3%.		06	0.1	18.0	salmon	fairly soft	The mixture is difficult to dry. There is a slight tendency to scum. The Firing range is short.
			04	1.8	15.2	salmon	fairly hard	
			02	9.8	0.9	dark red	steel hard	
9 80% clay 20% grog 0.5% Na_2CO_3 Lab. 83-8	Plasticity and workability are good; water of plasticity is 26.7%, slight tendency to crack in drying, shrinkage 4.9%		06	0.1	18.2	salmon	fairly soft	same comments as #8
			04	1.8	15.1	salmon	fairly hard	
			02	8.8	2.0	dark red	steel hard	
10 75% clay 25% grog 0.5% Na_2CO_3 Lab. 83-9	Plasticity and workability are good water of plasticity 27.8%, slight tendency to crack in drying, drying shrinkage 4.9%		06	0.3	17.7	salmon	fairly soft	same comments as #8
			04	1.8	15.0	dark salmon	fairly hard	
			02	8.6	1.9	red	steel hard	

(1.8%) and the absorption was 12.5%. The colour was a dark salmon. Thus, except for the drying characteristics, this material should be suitable for drain tile manufacture or common brick but difficulty might be experienced in producing a hard, well burned, uniformly sized face brick unless very careful control of firing was maintained.

Additions of 10 and 15% (bodies 2 and 3) grog to the Bracebridge clay did not improve the drying behaviour of this material. The plasticity and workability remained good. The fired properties remained essentially the same.

Additions of 20%, 25% and 30% grog (bodies 4, 5, and 6) to the Bracebridge clay produced mixtures which dried safely. The plasticity and workability of these bodies were good. The fired properties were much the same as in the previous ones although there is a slight increase in absorption and in fired shrinkage at cones 04 and 02 with an increase in grog. The dried shrinkage decreased slightly with an increase in grog content.

Additions of soda ash to various mixtures of Bracebridge clay and grog (bodies 7, 8, 9, and 10) made drying more difficult. The bodies containing 20% or more grog without soda ash dried safely while bodies containing soda ash and 20 or 25% grog had a tendency to crack in rapid drying. The briquettes containing soda ash had a tendency to scum slightly. The plasticity, workability, drying shrinkage and fired properties of these mixtures were approximately the same as equivalent mixtures without soda ash.

Additions of approximately 20% sand (usually mainly free quartz) instead of the grog would probably affect the drying properties in much the same manner as the grog. However, since the clay already contains approximately 22% free quartz it probably would not be wise to add too large a percentage of this material. The quartz undergoes a rapid change in dimensions at approximately 1060°F. When a large percentage of free quartz is present there is a danger of cracking the ware if too rapid a cooling cycle is followed through this temperature range. Frequently a large excess of free quartz will produce "punk" ware with a poor ring. Trials using a mixture of approximately 20% sand and 80% clay could be carried out at the plant and the results noted.

Best results would likely result from an addition of 20 to 25% grog to the clay. If the supply of grog becomes limited then possibly a mixture of sand and grog could be added. In any case, the addition of a non-plastic material should help to prevent laminations as well as improving the drying characteristics.

CONCLUSIONS

The Bracebridge clay is a common low grade surface clay consisting of a heterogeneous mixture of clay mineral, free quartz, and rock flour. It is plastic and works well. It has a tendency to crack in drying. The firing range is short between 1900 to 2000°F.

It was found that additions of grog prepared from burned scrap ware helped to improve the drying characteristics. It was necessary to add at least 20% grog by volume to prevent cracking with rapid drying in the laboratory. The grog acted as a non-plastic and opened up the pores in the clay to allow the water to move with greater ease from the interior to the exterior of the trial pieces. With up to 30% grog additions at least, the plasticity and workability remained good. In general the fired characteristics of all mixtures were the same. There was a slight increase in absorption and fired shrinkage with an increase in grog additions. The drying shrinkage was reduced slightly by grog additions.

Additions of 0.5% soda ash to the clay-grog mixtures increased the tendency to crack in drying. Other properties such as plasticity, workability, drying and fired shrinkage, and absorption remained approximately the same as equivalent mixtures without soda ash. The test briquettes containing 0.5% soda ash had a slight tendency to scum.

It is recommended that a mixture of 20% grog and 80% clay be given a plant trial. Careful control of the proportioning and mixing of the clay and grog must be maintained. Initial drying should be carried out under humid conditions at a relatively low temperature. The ware should be thoroughly heated before any appreciable evaporation of moisture takes place. After this condition exists the temperature should be increased and the humidity reduced at a rate which will remove

the moisture from the ware without cracking it. If some cracking still occurs when the above conditions are followed then a mixture of 25% grog (or grog and sand) and 75% clay should be tried.

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APPENDIX I TO MINES BRANCH INVESTIGATION REPORT IR 58-28 - EFFECT OF HYDRATED LIME ON BRACEBRIDGE CLAY

Subsequent to the issuing of the above report further work was carried out in an attempt to find an additive which would improve the drying properties of Bracebridge clay, (Lab. #83). The procedure outlined in the body of the report was adhered to for this work. It was found that small additions of hydrated lime - $Ca(OH)_2$, which is commonly used for agricultural purposes, tended to prevent drying cracks. At the same time the workability and plasticity were affected depending on the percentage hydrated lime used. The body compositions and the effects on drying, workability and plasticity along with other physical properties are shown in Table 1A.

Table 1A - Effect of Hydrated Lime on Unfired Bracebridge Clay

Sample Number	Sample Composition	Unfired Characteristics
83-10	Clay 83 1% $Ca(OH)_2$	Fairly plastic but inclined to be weak; safe drying, drying shrinkage 6.1%, water of plasticity 29.7%
83-11	Clay 83 0.5% $Ca(OH)_2$	More plastic and a little stronger than 83-10; safe drying, drying shrinkage 6.7%, water of plasticity 29.8%.
83-12	80% Clay 83 20% grog 0.3% $Ca(OH)_2$	Plasticity and workability similar to 83-11; safe drying, drying shrinkage 6.0%, water of plasticity 29.1%.

The fired characteristics of the briquettes are shown in Table 2A.

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Table 2A - Fired Characteristics

Lab. No.	Firing Temp. Cone	Fired Shrinkage %	Absorption %	Color	Hardness	Remarks
83-10	06	0.5	22.7	creamy salmon	very soft	scummed
	04	3.0	16.6	cream	fairly soft	"
	02	11.5	2.3	cream	very hard	"
83-11	06	0.7	18.5	salmon	fairly soft	white specks
	04	2.5	15.0	"	fairly soft	white specks
	02	9.3	3.5	red	very hard	white specks
83-12	06	0.5	18.6	salmon	soft	few specks
	04	3.3	14.4	dark salmon	fairly hard	" "
	02	10.5	0.3	dark red	very hard	" "

DISCUSSION OF RESULTS

Bracebridge clay is a difficult clay to dry properly. Additions of hydrated lime tended to improve the drying properties. At the same time the hydrated lime reduced the plasticity and produced a weak body. The fired properties were also affected. Excess $Ca(OH)_2$ appeared as a white scum on the fired briquettes and produced a softer more porous product.

Briquettes containing 1% hydrated lime and no grog were weak in the unfired state. When fired, these briquettes were covered with a white scum. Obviously 1% $Ca(OH)_2$ was greatly in excess of the hydrated lime required.

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The briquettes containing 0.5% $Ca(OH)_2$ and no grog were stronger and more plastic than those containing 1% $Ca(OH)_2$. When fired the briquettes contained many white specks. Each of the above bodies were safe drying.

The briquettes made up of 80% Bracebridge clay, 20% grog and 0.3% $Ca(OH)_2$ were safe drying. The plasticity and workability were fairly satisfactory. There were a very few white specks on the fired briquettes. Thus, indications are that 0.3% is the optimum percentage $Ca(OH)_2$ allowable in a mixture if scumming is to be at a minimum.

RECOMMENDATIONS AND CONCLUSIONS

Additions of hydrated lime to Bracebridge clay or a mixture of Bracebridge clay and grog produced safe drying briquettes in the laboratory. An excess of hydrated lime produced a weak body which contained a white scum or white specks after firing. The results indicated that 0.3% $Ca(OH)_2$ (by weight) was the optimum percentage required for satisfactory results.

It was recommended previously that a mixture of 80% clay and 20% grog be given a plant trial. If $Ca(OH)_2$ is used as an additive it appears likely that the percentage grog can be reduced. Indications are that a mixture of 90% clay, 10% grog (by volume) and 0.2% to 0.3% $Ca(OH)_2$ (by weight) may produce a satisfactory product. It is possible that the grog may be

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eliminated entirely and a mixture of 100% clay and approximately 0.3% $Ca(OH)_2$ may prove satisfactory. Carefully controlled plant trials should be set up to investigate these mixtures. At all times careful control of proportioning, mixing and drying must be maintained.

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APPENDIX II TO MINES BRANCH INVESTIGATION REPORT IR 58-28 - EFFECT OF HYDRATED LIME ON BRACEBRIDGE CLAY

A visit was made to the plant of the Home Brick Company Ltd. Bracebridge to observe the plant in operation and to try and offer any advice possible on correcting some of the problems introduced by the addition of hydrated lime to the clay. The visit was made by S. Matthews and J.G. Brady on June 3rd and 4th.

It was found that the hydrated lime aided the drying tremendously. The company was getting very little drier loss with no drying cracks or bridge cracks. However, introduction of the lime introduced an extrusion problem because of the reduced plasticity of the clay. It was found that insufficient mixing was given to the clay-water-lime mixture with existing facilities.

Extrusion tests carried out in the ceramic laboratory during the last week of May indicated that there should be no difficulty in extruding a clay-water-lime mixture. Various plant tests indicate with the dry weather prevailing at the time that a mixture of .075% hydrated lime plus .075% free flowing sand prevented dryer loss and bridge cracking. However, even with this low percentage of lime there was still some difficulty with extruding a column at a fast enough rate. The sand was added in the feeder hopper with the lime in order to promote a more free flowing column of lime into the clay. The company requested that further work be carried out in the laboratory with percentage of hydrated lime varying from .075% up to .3% which was the original percentage recommended in Appendix I of this report. Recommendations were made at the plant to improve mixing and extrusion.

The results of these tests are shown in Table 2B. It was not considered necessary to fire the test briquettes since there would be very little difference to the previous firing results.

Table 2B - Effect of Hydrated Lime on Unfired Bracebridge clay

Sample Number	Sample Composition	Unfired Characteristics
83	100% Bracebridge clay	Very plastic works well, water of plasticity 25%, slight crack in rapid drying.
83-13	Clay 83 .075% $Ca(OH)_2$	Same plasticity as 83, water of plasticity 25.8%, very slight crack on top.
83-14	Clay 83 0.1% $Ca(OH)_2$	Water of plasticity 26.6% good plasticity and works well, safe drying.
83-15	Clay 83 0.2% $Ca(OH)_2$	Not quite as plastic as 83-14, safe drying.
83-16	Clay 83 0.3% $Ca(OH)_2$	Plasticity similar to 83-15, water of plasticity 28.3% safe drying.
83-17	Clay 83 0.15% lignisol type BD	Very plastic, water of plasticity 24.2%, slight crack in drying.

The results of these unfired tests indicate that ~~.01~~ 0.1% $Ca(OH)_2$ is sufficient to transform a Bracebridge clay to a safe drying condition. Consequently, it is recommended an addition of at least 0.1% and preferably 0.15% be added ~~to~~ at the plant. It is possible that the present addition of .075 may be satisfactory and this will no doubt be determined under plant conditions. The lime must be mixed thoroughly with the clay to achieve satisfactory extrusion. With existing facilities the clay-hydrated lime-water should be added to the extrusion machine as far removed from the

die as possible. This will insure that a thorough mixing of these ingredients is achieved. The augers should fit closely to the barrel so that no clay will back up and cause undue friction.

Lignisol type BD was not found to be a suitable additive to Bracebridge clay.

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