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FURTHER EVALUATION OF CLAY SAMPLES FROM THE WABAMUN AREA, ALBERTA

by

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MINERAL PROCESSING DIVISION

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SUMMARY OF RESULTS

Five samples of fire clay were examined, reportedly representative of a wide area of two seams of the deposit. All had P.C.E.'s in the Cone 30 to Cone 30½ range. The samples had closely similar forming (dry-press) and firing behaviours, which were judged to be suitable for the manufacture of medium-duty fire-clay brick. Additions of grog would be required to reduce firing shrinkages: such additions would also serve to even out minor differences in vitrification rates from sample to sample.

Neither the fire clay from the Wabamun deposit nor two less refractory clays from adjacent seams were judged to be satisfactory for processing by the plastic process, owing to their poor drying properties. Mixtures of the clays, suggested as potentially useful for stoneware, showed no improvement in drying properties. Additions of up to 50 per cent of fly ash did not completely overcome the drying difficulties. The better of the mixtures did not respond satisfactorily to further treatment with electrolytes known to be usually effective with clays of similar behaviour.

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INTRODUCTION

A number of samples of clay from northern Alberta were submitted in November, 1970, by Mrs. J. McLaws of the Research Council of Alberta, for evaluation of their ceramic potential by this Division. The results were reported in Test Report MPT 71-2, "Evaluation of Five Clay Samples from Alberta", by L. K. Zemgals of the Ceramic Section.

Only two of the samples were of interest. The first, a Pleistocene lacustrine clay, appeared to mature at a relatively low temperature and to have a wide vitrified range and thus to be potentially useful for stoneware. It was, however, exceedingly plastic with high drying shrinkage, and cracked even on slow drying, rendering it unsuitable for use in the plastic condition. The second, a coal measures clay, proved to be a fire clay having a Pyrometric Cone Equivalent (P.C.E.) in the medium-duty range (Cone 30^{+}). It was judged to be unsuitable for use in the plastic condition owing to its poor plasticity and questionable drying behaviour (cracked on rapid drying). These characteristics might stem from its high organic content, mostly coal.

Subsequently, Dr. W. N. Hamilton, Industrial Minerals Geologist, Research Council of Alberta, requested that further work be done in connection with these materials. Five new samples of fire clay, reported to be representative of several localities and of the two beds of clay, were submitted for tests to establish the uniformity of the deposit. The results of these tests form Part A of this report. In addition, it was suggested by Dr. Hamilton that mixtures of the two clays might have plastic and drying characteristics superior to those of either clay, and by Mr. J. G. Brady, of this Division, that these properties might be improved through additions of fly ash from the thermal generating station at Wabamun, near the clay deposits. Consequently, further samples of mixed clays and of flyash were submitted, with the aim of developing a suitable stoneware-type body. The results of this investigation constitute Part B of this report.

PART A

Raw Materials

The five samples of fire clay were assigned the follow-

ing laboratory numbers for identification:

Lab. No. 2814 -	ground	brown	clay,	marked	"B3-W"
2815 -	"	"	" ,	"	"B3-C"
2816 -	"	"	" ,	"	"B3-E"
2817 -	"	"	" ,	"	"B4-W"
2818 -	"	"	" ,	"	"B4-C"

Procedure

A representative portion of each sample, as received, was thoroughly mixed with water to a stiff-plastic consistency and formed into cones, which were used to determine the P.C.E's according to the standard method of test: ASTM Designation C24-56. A representative portion (1500 grams, dry basis) of each sample was mixed with a measured amount of water, in a Hobart mixer, to a suitable condition for dry-pressing*, as judged by an experienced operator. Test specimens measuring 1 inch wide by 7 inches long by approximately 3/4 inch deep were pressed at 1000 psi. One specimen of each mixture was immediately placed in an oven maintained at 85°C (185°F), the remainder were air-dried for about 24 hours and then finally dried at 100°C (212°F). Duplicate specimens of each sample were fired at each of cones 5, 10, and 14. Shrinkages were determined from shrinkage marks applied immediately after pressing: water absorptions of the fired specimens were determined by the 2-hour boil method prescribed in ASTM Designation C20-70.

Results

All of the samples showed satisfactory forming properties: the pressed specimens were smooth with sharp corners and showed no evidence of lamination cracking; wet and dry strengths were not determined, but were judged more than ample for normal handling; some minor and apparently superficial crazing was observed on all fast-dried and on some slow-dried specimens, probably owing to the previously noted inhomogeneous dispersal of water. The unfired properties of the specimens are shown in Table 1 and the fired properties in Table 2.

Discussion of Results

The samples are essentially of equal refractoriness, but samples No. 2817 and 2818 (the B4 series) are less open-firing than the others, requiring some 100 Celsius degrees less temperature for equal absorptions (in the firing range studied). However, absorption and/or variations therein are not normally considered critical nor specified for medium-duty fireclay brick.

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* All of the samples showed a tendency to ball up in the mixer, resulting in some inhomogeniety of water dispersal throughout the mass.

TABLE 1

Unfired Properties of Fire Clays from Edmonton Area

Sample No.	Water Content (%, as pressed)	Drying Shrinkage (% of wet length)	Remarks
2814(B3-W)	9	1.7	Slight surface crazing on fast drying, none on slow drying.
2815(B3-C)	8	2.3	Some surface crazing on both fast and slow drying.
2816(B3-E)	8	2.0	" "
2817(B4-W)	9.5	2.0	" "
2818(B4-C)	8	2.3	No crazing on fast drying, some on slow drying.

TABLE 2

Fired Properties of Fire Clays from Edmonton Area

Sample No.	P.C.E.	Firing Shrinkage (% of wet length)			Fired Absorption (% of dry fired wt)		
		Cone 5	10	14	Cone 5	10	14
2814(B3-W)	30 (1636°C)	6.4	8.3	9.7	19.7	16.8	13.9
2815(B3-C)	30½ (1650°C)	7.3	8.9	10.0	16.8	14.0	11.7
2816(B3-E)	30½	7.3	8.3	9.6	17.6	15.1	12.3
2817(B4-W)	30	8.0	8.8	10.3	13.9	11.9	9.7
2818(B4-C)	30	7.3	8.7	9.4	13.0	10.9	9.0

The indicated firing shrinkages are too high for commercial firing but should be readily reduced and controlled through the normal practice of adding grog (pre-fired clay). It is considered unlikely that the required grog additions would have seriously adverse effects on forming properties or upon green or dry strengths. The observed tendency to craze is considered to be a function of the laboratory preparation method and is unlikely to be significant: nevertheless, provision for adequate drying before firing should be provided.

PART B

Raw Materials

The clay mixtures and fly ash provided for this part of the investigation were given the following laboratory numbers for identification.

Lab. No. 2819 - marked 20 B3-G2G4 (20% fire clay)
2820 - " 35 B3-G2G4 (35% fire clay)
2821 - " 50 B3-G2G4 (50% fire clay)
2822 - grey plastic clay marked G2G4-C
2823 - fly ash from Wabamun power plant, designated as unclassified run-of-the-stack material

Procedure

Owing to the relatively limited size of the samples, it was elected to first evaluate each mixture at a different level of fly ash content: the content of fly ash that eliminated cracking, if any, could then be translated to the other mixtures. It seemed impractical to exceed 50 per cent fly ash content. Weighed dry quantities of the samples and predetermined proportions of fly ash were dry mixed and then mixed with measured amounts of water in a Hobart mixer to a stiff-plastic condition. Specimens measuring 1 by 1 inches by approximately 8 inches were formed in a deairing hydraulic extrusion press under full vacuum (28 to 28.5 in. Hg). The specimens were marked for identification, and shrinkage marks were applied. One representative specimen of each mixture was, immediately after forming, inserted in a drying oven maintained at 85°C and its drying behaviour was examined periodically. The remainder of the specimens were placed on perforated racks in an area protected from drafts and allowed to dry slowly at room temperature. The results of these initial trials are shown in Table 3 (Nos. 2819A, 2820A, 2821A, 2822A, and 2819B).

Although none of the results of the initial tests were considered to be satisfactory, there were significant differences

in the nature of the drying cracks according to the fly ash content. With the smaller additions, the cracks followed the random crazing pattern normally associated with excessively plastic and/or bentonitic clays. At fly ash levels of 45 and 50 per cent, however, nearly all of the cracks originated at the corners and propagated across the column more-or-less at right angles to the direction of flow, indicative of stressing arising from poor flow properties. (At such high levels of fine-grained non-plastics, dilatancy would not be unexpected). Therefore, a further series of trials was undertaken, featuring minor additions of electrolytes that have previously been shown to be successful for improving this type of extrusion behaviour and/or for reducing cracking. The results of these tests are shown in Table 3 (Nos. 2820B, 2821B and 2822B).

Discussion of Results

Additions of up to 50 per cent fly ash do not improve the drying properties of the mixtures sufficiently to merit further testing or firing trials. Inasmuch as the desired end product is a material suitable for stoneware production, which normally involves large and complex shapes of heavy and variable thickness, excellent drying properties are mandatory; the cracking and warping behaviour of these mixtures renders them unsuitable for this purpose.

The reasons for the poor drying behaviour are not immediately self-evident. The grey clay, sample #2822, was examined by differential thermal analysis (DTA). A moderately sized endothermic peak at about 150°C indicates the removal of adsorbed water, normally associated with expandable clay minerals of the montmorillonitic or vermiculitic types, either of which can be the source of drying problems. The indicated quantity of this type of material is not excessively large and would normally have been expected to respond to treatment with the types and quantities of electrolytes employed. The DTA curve also indicates a very large exothermic reaction peaking at 400° to 450°C, considered to correspond with the oxidation of organic material. It seems reasonable to assume that much of this material might be present in colloidal form, which could account for the poor drying behaviour of the samples and the relative lack of response to the quantities of electrolytes employed. In this event, it is unlikely that additions of non-plastics other than flyash would be more successful.

CONCLUSIONS

The samples of fire clay should be satisfactory for the manufacture of medium-duty firebrick. The five samples are closely similar in refractoriness and in firing behaviour. The forming characteristics of the samples are good; plasticities of

TABLE 3

Extrusion and Drying Behaviour of Clay Fly Ash Mixtures

Sample No.	Composition (wt %)	Extrusion (full vacuum)	Drying
2819A	85% #2819 15% #2823 + 24.5% water	Very good, smooth, stiff column at moderate power; slightly laminated.	Crazed very badly on fast drying; warped and slightly cracked on slow drying. Drying shrinkage 6.7%.
2820A	70% #2820 30% #2823 + 23.0% water	Very good, smooth, stiff column at moderate power; no visible laminations.	Crazed very badly on fast drying; slightly warped, and slightly cracked on slow drying. Drying shrinkage 6.0%.
2821A	55% #2821 45% #2823 + 23.0% water	Extrudes satisfactorily, (slight tearing at corners) at moderate power, significantly weaker than above; no visible laminations.	Slightly crazed on fast drying; cross-cracked on slow drying. Drying shrinkage 2.5%.
2822A	50% #2822 50% #2823 + 25.0% water	Very good, smooth, stiff column at slightly reduced power; only a trace of laminations.	Badly cross-cracked on rapid drying; slightly warped, cross-cracked on slow drying. Drying shrinkage 4.0%.
2819B	50% #2819 50% #2823 + 24.5% water	Very good, smooth column at reduced power; no visible laminations.	Cross-cracked on both fast and slow drying. Drying shrinkage 3.7%.

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TABLE 3 (cont'd)

Extrusion and Drying Behaviour of Clay Fly Ash Mixtures

Sample No.	Composition (wt %)	Extrusion (full vacuum)	Drying
2820B	66.7% #2820 33.3% #2823 + 0.3% calgon +25.0% water	Very good, smooth, stiff column at moderate power; no visible laminations.	Badly crazed on rapid drying; slightly crazed, heavily cross-cracked on slow drying. Drying shrinkage 5.7%.
2821B	66.7% #2821 33.3% #2823 + 0.2% NaCl +24.0% water	Extrudes very well at reduced power consumption, but column is weak. No significant lamination.	Badly crazed on rapid drying; some cross-cracks on slow drying. Drying shrinkage 5.5%.
2822B	50% #2822 50% #2823 + 0.25% Na_2CO_3.	Very good, smooth, stiff column at moderate power. Not obviously laminar.	Heavily cross-cracked with some crazing on fast drying; slightly warped and cross-cracked on slow drying. Drying shrinkage 3.7%.

the samples are judged to be sufficiently high to accommodate substantial additions of graded grog without unduly reducing green and dry strengths. Additions of grog would be necessary to reduce and control the high firing shrinkages. They would have the further advantage of serving to reduce variations in fired properties with location, although these are not of themselves of significant proportions.

Part B of the investigation confirms the previous conclusion that drying difficulties render the samples unsuitable for use in the plastic state. Additions of non-plastic Wabamun flyash do not affect a sufficient improvement in drying behaviour, nor do additions of electrolytes that have been shown to be effective in apparently similar circumstances. Neither the samples alone nor their mixtures are suitable for manufacture of stoneware.

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