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REPORT ON THE CLAYS OF THE
CARIBOO COAL AND CLAY SYNDICATE

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OPEN FILE

R E P O R T

ON THE

CLAYS OF THE CARIBOO

COAL & CLAY SYNDICATE

I N D E X

PRELIMINARY

The following report is made consequently and to ascertain a certain number of analysis and test carried on samples of clay that were given to me for the above purpose and described as being samples of the clays of the "CARIBOO COAL AND CLAY SYNDICATE".

The tests were carried under constant control and the analysis and descriptions foregoing, made in conformity of the said tests.

At the end of the report I included an appendice dealing specially with the alumina-cements for the manufacture of which one the clays, with addition of lime, is suitable.

INTRODUCTION

CLAYS

The term clays is applied to fine-grained unconsolidated materials which possess the property of plasticity when wet, while they lose this property and harden on being strongly heated. Being as explained below, the finer debris resulting from the decay of many different kinds of rocks, the clays will naturally differ greatly among themselves in composition, etc.

ORIGIN OF CLAYS

When rocks of any kind are exposed to atmospheric action, more or less rapid disintegration sets in. This is due partly to chemical and partly to physical causes. It is hastened, for example, by the dissolving out of any soluble minerals that may occur in the rocks, by the expansion and contraction due to freezing, and by the action of the organic acids set free by decaying vegetable matter. The more soluble ingredients of the rocks are usually removed in solution by surface or percolating waters, while the more insoluble portions are either left behind or are carried off mechanically by streams. These relatively insoluble materials when sufficiently fine-grained constitute the clays.

When they are left as a deposit in the spot where the original rock disintegrated, they are called residual clays, when they are carried off by surface waters and finally deposited in the sea or along river beds they are transported or sedimentary clays.

Based on the facts above stated as to the origin and the deposition, clayey materials may be classified as follows:

A. RESIDUAL CLAYS: Resulting from the decay in place of pre-existing rocks. According to the parent rock the clays may be derived:

  A 1. From decay of more or less clayey limestones

  A 2. From decay of shales or slates

  A 3. From decay of igneous rocks.

B. TRANSPORTED CLAYS: Resulting from the transportation by water (or more rarely by ice or wind) of either the residual clays of Class A or of other finely ground rock; and the deposition of such material at more or less distance from its point of origin. The sub-classes are:

B 1 Water-borne clays; carried by water and deposited

    (a) In sea basins

    (b) Along stream valleys

    (c) In lakes

B 2 Ice-borne or glacial clays

B 3 Wind-borne clay

As nature is engaged in the disintegration of the igneous rocks, the transportation, classification and deposition of the products of disintegration, it is also engaged in the re-combination of these loose sediments, by heat, pressure, chemical activity or crystallization into dense masses, which often resemble the original igneous rocks.

The clays must not contain too great a quantity of the unaltered igneous rocks or of the re-hardened metamorphic rocks.

The addition of vegetable and other organic matter from growing things, the pressure of overlying strata or crystal movement of the earth; possible heat from volcanic activities; alteration from steam and other gases; and metamorphic changes from chemical hardening or colloidal setting are all important factors upon the qualities or defects of the clays.

Very often clays occur in the coal bearing formations. There is no special reason for this so far and the main point found by several authorities is that the conditions which allowed the formation of the coal bearings is favorable for the deposition of clays.

The clays that are examined in this report are:

1. Aluminous clay or Bauxite

With a high alumina content a long vitrification range and high melting point is specially suitable for a superior type of fire-brick. Has a high shrinkage under its natural condition, but which can be much lowered by pre-heating.

Similar clays are found in Arkansas and Georgia.

2. Flint Fire-clays

A hard, dense, high aluminous, flint-like (not high in silica) clay material, which in the original condition break with a conchoidal fracture. The plasticity is rather

low with the ordinary tempering methods, but may be partially restored by ball mill or wet-pan grinding in water.

As a very high fired shrinkage and crack badly. However, very suitable for the manufacture of alumina cement. Similar clays are found in Kentucky.

3. Low Refractory clay

A low refractory clay with a medium vitrification range and low melting point.

Specially suitable for architectural terra-cotta and pottery such as stoneware.

Also suitable for an ordinary quality of firebrick. Similar clays are found in Wash. Ore, Ohio, Pennsylvania and California.

4. Fine Alumina Clay

A very fine alumina clay having a very fine grain and burning to a very light redish color, specially suitable for ornamental terra-cotta such as vases.

5. Kieselguhr

A very light material having a very low conductivity heat which makes it very suitable for insulation purposes.

CLAY NO. 1.

CHEMICAL ANALYSIS

Alumina (Al_2O_3)	25.42
Silica (SiO_2)	55.20
Magnesia (MgO)	0.34
Lime (CaO)	0.96
Ferric oxide (Fe_2O_3)	3.26
Soda (Na_2O)	0.99
Potash (K_2O)	0.89
Water (H_2O)	12.94
	100%

CLAY NO. 1.

PHYSICAL ANALYSIS

Density 2.05

Plasticity.......................... 1.04

Fineness { 87% under .... 0.0004 m/m

13% above 0.0004 and

under 0.0008

Absorption (water) .... 885 millimicrons

Exothermic reaction .... 956° c.

Loss in weight by heat 14.8%

Porosity under 50 kg cm2 .... 15 m/m

Absorption 4%

Vitrification range .... 1250-2175° c.

Fusion point .... 2425° c.

TEST ON FIRED SAMPLES

Porosity under 50 kg cm2 .... 1 m/m

Absorption 0.03%

Compression strength lbs. per

                squars inch .... 2.843 lbs.

Tensil strength lbs. per square

                inch .... 328 lbs.

CLAY NO. 2.

CHEMICAL ANALYSIS

Alumina (Al2O3) 38.80

Silica (SiO2) 50.80

Magnesia (MgO) 0.21

V Lime (CaO) 0.90

Ferric oxide (Fe2O3) 2.03

Soda (Na2O) 0.67

Potash (K3O) 0.60

Water(H2O) .... Diff. (5.99(

_____

100%

PHYSICAL ANALYSIS

Density 1.98

Plasticity 0.34

Fineness { 81% under .... 0.0004 m/m

19% above 0.0005 and

under .... 0.0008 m/m

Absorption (water) .... 438 millimicrons

Exothermic reaction .... 942° c.

Loss in weight by heat 8.83%

Porosity under 50 kg cm2 .... 27 m/m

Absorption 9%

Vitrification range .... 1050-1420° c.

Fusion point .... 1524° c.

CLAY NO. 2.

TEST ON FIRED SAMPLES

Porosity under 50 kg cm2 .... 1.8 m/m

Absorption 0.05%

Compression strength lbs. per

square inch .... 2.121 lbs.

Tensil strength lbs. per square inch 289 lbs.

CLAY NO. 3.

CHEMICAL ANALYSIS

Alumina (Al_2O_3) 19.50

Silica (SiO_2) 65.30

Magnesia (MgO) 0.37

Lime (CaO) 0.87

Ferric oxide (Fe_2O_3) 2.08

Soda (Na_2O) 1.29

Potash (K_2O) 1.60

Water (H_2O) .... Diff. (8.99)

100.00%

CLAY NO. 3.

PHYSICAL ANALYSIS

Density 2.3

Plasticity 1.27

Fineness $\begin{cases} 83\% \text{ under } .... & 0.0004 \text{ m/m} \\ 17\% \text{ above } 0.0004 \text{ and} \\ \text{under } .... & 0.0008 \text{ m/m} \end{cases}$

Absorption (water) .... 438 millimicrons

Exothermic reaction .... 936° c.

Porosity under 50 kg cm² ...... 29 m/m

Absorption 9.2%

Vitrification range .... $1,480-1860^\circ$ c.

Fusion point .... $1,983^\circ$ c.

TEST ON FIRED SAMPLES

Porosity under 50 Kg cm2 .... 2.7 m/m

Absorption 0.19%

Compression strength lbs. per

         square inch .... 1.715 lbs.

Tensil strength lbs. per square

           inch .... 121 lbs.

CLAY NO. 4.

CHEMICAL ANALYSIS

Alumina (Al2O3) 64.20

Silica (SiO2) 21.00

Magnesia (MgO) 0.83

Lime (CaO) 0.61

Ferric oxide (Fe2O3) 1.07

Soda (Na2O) 0.42

Potash (K3O) 0.51

Water (H2O) .... Diff (11.36)

_____

100.00%

CLAY NO. 4.   15.

PHYSICAL ANALYSIS

Density 0.51

Plasticity 0.85

Fineness { 96% under .... 0.0004 m/m

          2% under 0.0004 and

          under .... 0.0005 m/m

Absorption (water) .... 667 millimicrons

Exothermic reaction .... 922° c.

Porosity under 50 Kg cm2 ...... 38 m/m

Absorption 12%

Vitrification range .... 1.390-1970° c.

Fusion point .... 2.245° c.

CLAY NO. 4.   16.

TEST ON FIRED SAMPLES

Porosity under 50 Kg cm2 .... 12.9 m/m

Absorption 2.0%

Compression strength lbs. per

square inch ..... 1.220 lbs.

Tensil strength lbs. per square

inch .... 90 lbs.

CHEMICAL ANALYSIS

Silica (SiO2) 75.65

Alumina (Al2O3) 9.66

Lime (CaO) 0.29

Ferric oxide (Fe2O3) 2.92

Soda (Na2O) 1.63

Water (H2O) 6.37

                                      _____

                                      100.00%

PHYSICAL ANALYSIS

Density 0.61

Plasticity 0.81

Fineness { 92% under .... 0.0003 m/m

8 above 0.0003 and

under .... 0.0005 m/m

Absorption (water) .... 823 millimicrons

Exothermic reaction .... 780 $^\circ$ c.

Porosity under 10 Kg cm2 ...... 43 m/m

Absorption 14%

Fusion point .... 2420° c.

From the tests and analyses carried and exhibited in the other sections of this report, some of these clays compare with several of the important world clays. However, they are very difficult to work as they have upon firing a very high shrinkage and sometimes cracking. This would require a perfect equipment as well as very skilled labor.

The high vitrification range of one of these clays as well as its high fusion point makes it very suitable for fire brick or fire-cement; mixed with the infusorial earth it would make a good insulative fire-cement.

The clays naturally burnt are not in my opinion suitable for manufacturing purposes, but they could be employed mixed with the clays for the manufacture of large pieces of terra cotta.

I was not able of avoiding the warpage of the fire-clays but this warpage would not restrict the manufacture of fire-bricks and fire-cements.

Another of these clays is very suitable for the manufacture of high class alumina-cements which have qualities incomparable with all the other cements as it will be seen in the appendix of this report.

Respectfully submitted,

"Jean deSouza Costa"

I.E.C.

Vancouver, B.C., January 22nd. 1930.

ACTUAL COMPOSITION OF COMMERCIAL ALUMINA CEMENTS

In Table I, I have grouped a number of analyses of actual alumina cements as now made in different countries and by different processes. As to geographic location, this table includes six cements from France, two from Switzerland and two from the United States. As to method of manufacture, it includes six from coke furnaces, three from electrics and one from a rotary kiln.

It may be noted in passing that although the iron in alumina cement analyses is commonly reported as ferric oxide, in conformity to cement tradition, this is never true except in rotary kiln cements, where reduction is incomplete or non-existent. For all alumina cements fused in a furnace, whether by coke or by electricity, the iron in the cement is normally present mostly as FeO, partly as Fe_3O_4. At times, even, a little metallic iron may get through to the finished cement.

RESISTANCE TO SULPHATE AND SEA WATERS

It has always been known that Portland cement was susceptible to attack by sea water in alkaline water, much more so in fact than either the natural cements or the hydraulic limes. The most that could be said in its defence was that if extreme care were taken in mixing and placing the concrete, so that water could not gain access to the interior of the mass, the decay would be delayed and perhaps prevented. Another remedy was the addition of trass or other puzzolanic material to the Portland concrete, so as to afford a means of taking up the surplus lime disengaged during its setting.

The chief engineering gain of the invention of alumina cement lies in the fact that we are here presented with a type of cement which is naturally chemically resistant, and which does not require either exceptional care or admixtures in order to avoid decay. There is now abundant experimental evidence on this point, and we have in addition fifteen years or so of actual large-scale experience in European engineering works.

The most severe and conclusive tests to which cements have ever been subjected are undoubtedly the series carried out, from 1915 to 1921 and even later, under direction of Monsieur Sejourne, Chief-engineer of the Paris-Lyon-Mediterranian Railroad. These results have never been published. The railroad had no interest in the matter except securing the safety of its line, and the only cement manufacturer who had any reason to be proud of the results still had a large Portland cement investment to salvage. The summary below is prepared from copies of documents in the files of the line.

Even before the world war there had been minor
failures of concrete work along the P.L.M. line into Italy,
where salt water on the sea side and sulphate ground water
on the land side gave a maximum of chemical attack. A semi-
disaster in 1915 brought matters to a point, and in 1916-17
a long series of cements were placed under test in tanks
filled with sulphate water, mortar and concretes of various
proportions being subjected under precisely similar con-
ditions to the chemical attack, whose progress was noted
at frequent intervals. Summarizing the final results very
briefly, we can say that Alumina cement was entirely un-
damaged, that the Portland failed rather rapidly, and that
the product which ranked second to alumina was one particular
natural cement. The alumina cement tested was tried out not
only with ordinary sand and crushed stone, but with half the
sand replaced by ground gypsum, and again with half the sand
replaced by gypsum powder, under all of which trying circum-
stances it showed no decomposition whatever even after four
years and more of exposure to the free action of sulphate
waters, while all of its competitors failed more or less
completely and rapidly.

In one P.L.M. report which I have in hand there are
fourteen series of tests, differing in the cements tested
and in the character of admixtures, and in each series there
were three different percentages of sand and gravel employed.
Out of the whole mass of evidence, I am quoting in table 2
portions of series, 9, 10 and 14, which are sufficiently con-
clusive and give a very fair idea of the average results.

With these conclusive results in hand, the adoption
of alumina cement by the P.L.M. lines was an obvious effect.
From there its use has spread into the North African Rail-
ways, where similar climatic and ground-water troubles are
encountered.

Some time after the P.L.M. experiments were under way,
Feet included alumina cement test pieces in his sea water
exposure at Bologne. At the end of two years - the longest
period on which records are available - the alumina test
pieces still gave compressive strengths 70% higher than their
nearest competitor which as it happens was not Portland cement
but a grappier cement and 57% higher than the best of the
Portland concretes, which was a trass-Portland mixture. As
against the ordinary straight Portland concrete, the alumina
results were slightly more than 100% better.

Jeanneret compared directly the resistance of
alumina cement and Portland to the action of sulphate
waters, the test pieces being made up of 1 part cement,
1 part gypsum and 2 parts sand. On immersion in tanks
the Portland samples commenced to disintegrate at the end
of the 2 months, the rapidity of the decay increasing at

three and four month periods. The alumina-cement, a
Swiss electric brand, was entirely unaffected. Compressive tests showed 3815 lbs. per square inch for
alumina, as against 1415 and 1500 lbs. respectively
for the two Portlands.

Later Jeanneret extended the tests to cover
permeability, and included a broader series of products, giving the results special importance. They
are summarized herein table 3.

PHYSICAL PROPERTIES OF ALUMINA CEMENTS

Alumina cements ordinarily range in specific
gravity between 3.0 and 3.2; a cement falling below
the lower limit suggests that clinkering instead of
fusion has been attempted; a cement with a gravity
above 3.2 or 3.25 probably contains an excess of iron,
either as magnetic oxide or as metallic iron. As to
color, alumina cements made in the furnace or electric
are dark, almost or quite black; other colors suggest
the presence of unreduced (ferric) iron.

In setting time, alumina cements are entirely
similar to Portlands, their rapid hardening coming only
after a normal setting interval. When properly made,
by fusion, they are always and necessarily "sound"; it
is impossible for a real alumina cement to contain "free
lime". Since they do not require the addition of gypsum,
sulphur trioxide limits need no discussion. Alumina
cements set without difficulty at very low temperatures;
they disengage considerable heat on setting; they must be
kept damp while hardening.

The high early strength of alumina cements is,
of course, well known; they should show a twenty-four hour
strength equal to the 28 day Portland requirements. They
have the further advantage that their strength in mortars
and concretes is relatively even better than their strength
tested neat. All this means that they can safely be used
in far leaner concretes than any Portland - fact which is
rarely suggested to the engineer.

TENSILE AND COMPRESSIVE STRENGTHS

Though alumina cement was invented for the sake
of its great chemical resistance, it was soon found to
possess certain other important technical properties.
Its very high strength at very early periods, along with
remarkable resistance given in compression as mortars
and concretes, has been the chief basis of its present
commercial development. As to these points a few tables
will cover the matter.

As a preliminary to the permeability tests
recorded above in Table 3, Jeanneret had carried out
a series of interesting comparative tests on the tensile
and compressive strength of the different cementing
materials. These are reported in Table No. 4.

Tensile and compressive tests on the oldest
and best known of the alumina cements - that of the
Lafarge millet Le Teil, France - show the results
tabulated in table No. 5 as reported by E.C.Blano.

These test results bring out clearly the two
remarkable physical properties of well-made alumina
cements - their very high strengths at very early periods,
and the relatively high strengths shown by mortars and
concretes as against neat-cement tests. Both of these
properties are of great engineering value, and neither
has as yet been utilized to its possible maximum by any
engineer in any country.

For comparison with these early results on
established foreign brands, table No. 6 contains the
results of tests on an alumina cement made in the
United States, the brand sold under the trade name of
"Lumnite", as reported in manufacturers advertisements.

A series of long-time tests on Lafarge Alumina cements reported by Haegermann gives results over a longer period. These show, for tensile strength in 1-3 mortar an average of 374 lbs. per square inch at one day; 404 lbs. at 3 days; 508 lbs. at 1 year and 550 lbsl at 2 years. The compressive strengths in 1-3 mortars were respectively 6029 lbs. at one day; 7252 lbs. at 3 days; 10,025 lbs. at 6 months and 9712 lbs. at two years. For comparison it may be noted that five ordinary Portlands averaged 6399 lbs. at one year; while a special high-strength Portland gave 9214 lbs. at one year and 9086 lbs. at 2 years.

TABLE I
ANALYSES OF ALUMINA CEMENTS

Silica	Alumina	Iron Oxides	Lime	Magnesia	Al2O3 + CaO	SiO2+ FeO + Al2O3
3.13	45.00	10.11	41.19	0.33	1.09	0.29
10.68	44.32	4.90	40.26	0.57	1.10	0.35
10.16	42.96	6.48	38.16	0.6	1.13	0.38
10.24	41.85	7.09	40.17	0.48	1.04	0.41
10.04	40.22	5.85	43.08	0.33	0.93	0.39
15.0	40.0	10.0	32.0	1.0	1.25	0.63
2.59	39.53	15.41	39.91	0.73	0.98	0.45
8.36	39.82	10.98	34.70	0.67	1.15	0.48
5.55	38.20	19.10	35.10	0.15	1.09	0.65
3.81	42.6	14.34	32.64	0.26	1.30	0.42
8.85	42.87	6.89	40.57	0.46	1.05	0.37

TABLE 2.
COMPARISON OF ALUMINA AND PORTLAND RESISTANCE (SEJOURNE)

	Test Started	Decomposition commenced	Condition on Dec. 31, 1921
Sand and ground gypsum	July 7,1917	None to date	Intact
Alumina cement	Jan.22,1917	Feb.28,1917	Totally decom-
Portland, Brand A.....	Jan.22,1917	Feb.28,1917	posed, reduced
Portland, Brand B.....	Jan.22,1917	Feb.28,1917	to mud
Portland, Brand C.....	Jan.22,1917	Feb.28,1917	
Sand and powdered gypsum			
Alumina cement	Jan.26,1917	None to date	Intact
Portland, Brand A.....	Jan.26,1917	Feb.28,1917	Totally decom-
Portland, Brand B.....	Jan.26,1917	Mar.15,1917	posed; reduced
Portland, Brand C.....	Jan.26,1917	Feb.28,1917	to mud

Note: The last line in table I is the average of what are, in my judgment, the best 5 of the cements whose analyses are tabulated.

TABLE 3
PERMEABILITY TESTS (JEANNERET)

	Alumina Cement	Portland Cement	NATU-ral Cement	HYDRAU-LIC LIME	LIME
Permeability,mm.,in neat cement 3 months in air after making the test-pieces	None	1.0	1.2	7.8	12.15
Permeability,mm., 1-3 mortar, 28 days old, kept in moist air	0.5	1.2	1.3	4.5	10.15
Permeability,mm., 1 - 3 mortar, 28 days old, kept in water	None	1.	1.2	4.5	
Permeability,mm., 1-3 mortar 1 year old, kept in air	2.3	2.3	2.3	6.7	10/11
Permeability,mm., 1-3 mortar, rammed; kept in air; 28 days old	0.5	3.4	3.4	5.7	

Alumina cement in this series only 3 months old; all other cements 1 year.

TABLE 4
COMPARATIVE STRENGTHS OF ALUMINA AND OTHER CEMENTS
(JEANNERET)

	Tensile strength,1;3 mortar,28 days,lbs. per square inch.	Compressive strength, neat cement,28 days lbs. per square inch
Alumina cement	882	11,378
Portland cement	462	4,978
Natural cement	365	3,840
Hydraulic lime,1st grade ...	262	2,845
Hydraulic Lime,2nd grade ...	....	2,133
Lime	....	1,920

TABLE 5
TENSILE AND COMPRESSIVE STRENGTH,
ALUMINA CEMENT (BLANC)

	Strengths in Pounds per square inch				
	1 day	2 days	3 days	7 days	28 days
Tensile, neat cement	540	924	995	1,066	1,136
Tensile, 1-3 plastic mortar	497	526	533	540	555
Compression, neat cement ...	11,378	12,445	13,156	13,667	15,289
Compression, 1;3 plastic mortar ...	5,760	6,258	6,542	6,898	7,040

TABLE 6
STRENGTH OF ALUMINA CEMENT MORTARS AND CONCRETE (U.S.A.)

	Strengths in pounds per square inch			
	1 day	7 days	28 days	One year
A. Tensile, 1;3 Mortar	464	537	561	628
B. Compression 1-3 mortar	4725	4985	5004	5724
C. Compression 1;2;4 concrete	3441	4391	4462	5072
D. Compression 1;3;6 concrete	2071	2663	2691	3460

A. Briquettes; 1-3 Ottawa Sand, R.W.Hunt & Co.

B. Cylinders 2x4 inches, 1;3 Ottawa Sand, R.W.Hunt & Co.

C. Cylinders 6x12 inches, E.L.Conwel & Co.

D. Cylinders 6x12 inches, E.L.Conwel & Co.