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RESTRICTED

19th November, 1986
English

15479

ESTABLISHMENT OF A CERAMIC RESEARCH

AND DEVELOPMENT LABORATORY

US/SRL/78/207

SRI LANKA

FINAL REPORT BASED ON THE WORK OF M. CORSI

ASSOCIATE EXPERT IN GEOLOGY

TF/SRL/85/001/11-01/32.1.B.

Prepared for the Government of the Democratic Socialist Republic of Sri Lanka by the United Nations Industrial Development Organisation, acting as executing agency for United Nations Development Programme

This report has not been cleared with the United Nations Industrial Development Organization which does not, therefore, necessarily share the view presented

ABSTRACT

TF/SRL/001/11 - 01/32.1.B.

I was appointed as Associate Expert in Geology on a 12 months assignment (12.12.85 - 11.12.86.) and attached to the Ceramic Research Laboratory (CRL), now re-named the Ceramic Research and Development Centre (CRDC), Piliyandala, which was established jointly by UNIDO and the Ceylon Ceramics Corporation (CCC).

The purpose of this project, financed by the Italian Government, according to my job description, was to increase local self-sufficiency in ceramic research and development work and thus in the overall field of ceramic manufacture.

After my arrival at the Duty Station and following the request of the UNIDO Resident Representative and the Management of the Ceylon Ceramics Corporation, I concentrated, in particular, on the evaluation of properties of local ceramic raw materials and in the tentative replacement of imported raw materials with locally available ones. With this purpose in mind, I demonstrated the manner in which studies should be carried out, using all necessary equipment in the laboratory, on ceramic research.

Meanwhile, great importance was given to the field visits (raw material deposits and factories) and field work, to reach a good knowledge of the situation and problems of the ceramic industry in Sri Lanka, as a whole.

CONTENTS

ABBREVIATIONS

CCC ....Ceylon Ceramics Corporation

CRL .... Ceramic Research Laboratory

CRDC .... Ceramic Research and Development Centre

X-RD .... Xray Diffractometer

STA .... Simultaneous Thermal Analysis

INTRODUCTION

Under the Project US/SRL/78/207 "Establishment of a Ceramic Research & Development Laboratory", I was appointed as Associate Expert in Geology, for a period of 12 months to co-operate with the local counterpart staff for the development of the following duties, according to the Job Description TF/SRL/85/001/11 - 01/32.1.3. :

1. Assist in the investigation of local non-metallic minerals including, in particular, raw materials for the ceramic industry.

2. Contribute to the elaboration of an integrated system of raw material testing, making optimum use of the equipment and staff resources of the laboratory.

3. Advice on the possibility of introducing new and improved local raw materials into the domestic ceramic and other non-metallic mineral based industries.

Hence, as indicated below, the main steps of my activities during the assignment period were :

a. study of available data through bibliographic research;

b. meetings with the Management of the CCC, CRL(CRDC) staff and visits to various factories, in order to identify some important research cases for the Ceramic Industry in Sri Lanka;

c. execution of complete and integrated studies at the Pilivandala Ceramic Laboratory, on the above identified cases;

d. field work (drillings and ceramic raw materials evaluation) in close co-operation with the local Geological Survey Department.

e. general matters - advice on purchase of new equipment for the laboratory; delivering of slides taken during field visits (raw material deposits and plants , to the CRDC Management, for teaching purposes, etc., etc.

ACKNOWLEDGEMENTS

I wish to express my thanks to all who assisted me during all phases of my mission and who were involved in the activities concerned with my assignment.

In particular, my gratitude to:

- Mr. N. Biering, UNIDO Headquarters, Vienna
- Mr. T. Schroll, UNIDO, SIDFA, Colombo
- Mr. S. Ericsson, UNIDO JPO, Colombo
- Dr. C.T.S.B Perera, General Manager, CCC
- Dr. J.W. Herath, Head/CRDC
- Mr. D. Jayawardene, Director/Geological Survey Department, Colombo
- Mr. H.D.N.C. Pathirana, Deputy Director/Geological Survey Department, Colombo
- The Staff of the CRL(CRDC)

Many thanks also to Dr. Z.A. Engelthaler, Dr. Y. Kato, Mr. F.A. El-Sobky (UNIDO Experts on short-term assignments in 1986)

PROJECT ACTIVITIES

Following preliminary meetings with the SIDFA of UNIDO in Colombo, the General Manager of the CCC, the Head of the CRDC (appointed at the beginning of January 1986) and the Director of the Geological Survey Department, Colombo, it was emphasized that the most important areas according to my specialization in the Ceramic Industry were:

- better and more complete knowledge on the technological properties of known raw materials and new raw materials, which may be potentially important for the Ceramic Industry in Sri Lanka.

- tentative replacement of imported raw materials with others which are locally available.

- evaluation, in close co-operation with the Geological Survey Department, of the reserves of the most important raw materials in the island.

With this purpose in view, after studying the available data and reports on the ceramic raw materials of Sri Lanka, I started on visits to deposits and factories, in order to negotiate and discuss the main problems and requirements of each plant, to be studied as research cases, in the laboratory.

Several interesting problems were identified and in close co-operation with the laboratory staff, we made complete and integrated studies and the results were shown and discussed with the General Manager of the CCC and other Ceramic Managers, after submission of written reports.

The most important studies concerned were:

1) Determination of the main properties of a new raw material named 'red ochre', located in the south-coast (Hungama), present in large quantities and not exploited at all. This study showed that this material, rich in Fe_2O_3 (mostly due to hematite), can be very

useful, not only in the ceramic industry (red firing items) but also in other industries of the island (such as the paint industry).

During this study, we introduced for the first time, the Dilatometer Test on unfired body (this Dilatometer Test is complementary to the other thermal tests and can be very useful with any ceramic raw material, in order to have a knowledge of the mineral composition and properties during firing)
[Annex I: "REPORT ON RED OCHRE TESTINGS (HUNGAMA DEPOSIT)"]

2. As an application of the above study and following a specific request by Lanka Refractories (pvt.) Ltd., Meepe, we checked the possibility of introducing the red ochre (as pigment) in the body composition, for the production of unglazed red floor tiles (by the pressing method), in order to diversify the production in the Meepe Factory. The results were quite satisfactory and hopefully they will be useful for this purpose.

Most probably, the same material could be used for the production of extruded items (bricks and roofing tiles).

[ANNEX II: "EXPERIMENTAL BODY MIXTURE FOR THE PRODUCTION OF UNGLAZED RED FLOOR TILES (PRESSING POWDER METHOD)"]

3. Complete study on the composition and technological properties of the different ball clay types present in the Dediyawela deposit (south-coast) - the most important known deposit of ball clay in the island. This study was necessary, in order to determine exactly the differences present in the three layers found in the deposit at Dediyawela (yellow and blue types have been exploited at present, whereas a black layer, which has not yet been introduced to the ceramic industry, probably would be useful in the future) and then determine the proper use of each of these ball clays. At the same time, we compared also these ball clays with an imported British ball clay, used at present at the Piliyandala Factory for the production of sanitaryware.
[ANNEX III: "STUDY ON BALL CLAYS FROM DEDIYAWELA DEPOSIT - WASKADUWA"]

4) a full investigation was done on the body mixture used by Lanka Walltiles Ltd.(Balangoda) for the production of glazed wall tiles (white burning body). The purpose of this study was the tentative replacement of pyrophillite (imported from Korea) with local raw materials.

According to our laboratory results, it seems difficult to arrive at a complete exclusion of the pyrophillite, but most probably it is possible to reduce its content, in the body mixture from 24% used at present to 14% and at the same time to decrease the biscuit firing temperature by 50°C (from 1100°C to 1050°C).

According to tests done, a small addition of glass rejects, as a flux, in the body mixture can lower the water absorption of the tiles (more suitable according to ASTM Standards) but some other technological properties are affected.

[ANNEX IV: "EXPERIMENTS FOR THE TENTATIVE REPLACEMENT OF PYROPHILLITE IN A BODY MIXTURE USED FOR THE PRODUCTION OF GLAZED WALL TILES (WHITE BURNING BODY)"]

In order to show the correct manner to study the above - 1,2,3 & 4, the same procedure was adopted, as follows:

- discussions with Managers involved in the Ceramic Industry to ascertain the main problems connected with different production situations (i.e., better knowledge regarding raw materials, introduction of new raw materials, improvement or changes in the production of body mixtures etc.) and collection of representative samples.
- complete study, under the laboratory conditions, making use of all the equipment available (to determine mineralogical and chemical properties and also the technological behaviour of raw materials and ceramic body mixtures).
- meeting the Managers in the Ceramic Industry to discuss the results of laboratory testing and also ways and means of implementing these results to factory conditions.

While proceeding with the work in the laboratory, I joined the Geological Survey Department, Colombo and together with the geologists of the department, I took part in field work related to ceramic raw materials.

In particular:

- execution of drillings in the Kandy area, in order to find the availability of red-burning plastic clays, for the production of roofing tiles.
- execution of drillings in the Meetiyagoda Kaolin Deposit and the surrounding areas, in order to evaluate quality and extension of the raw materials available.

During my visits to the plants and deposits, photographic reports were made and submitted to the laboratory management, for teaching purposes.

Finally, I suggested that the CRDC should purchase a hammer mill for the Pilot Plant, to minimize the time necessary for the grinding of hard raw material.

FACTORIES VISITED

1. Lanka Porcelain Ltd. - Matale

Personnel met:

Mr. P. Khongahage - General Manager
Mr. T. Jayaweera - Factory Manager

2. Ceramic Factory - Negombo of the CCC

Personnel met:
Mr. R.S. Kuruppu - Factory Manager

3. Lanka Refractories (pvt.) Ltd. - Meepe, Padukka

Personnel met:
Mr. T. Kularatne - General Manager
Mr. Lal Samarasekera - Deputy General Manager

4. Lanka Walltiles (pvt.) Ltd. - Balangoda

Personnel met:
Mr. R. Munamalpe - Factory Manager
Mr. P. Wickramasinghe - Assistant Factory Manager
Mr. K. Nanayakkara - Production Executive

5. Lime Plant, Ceylon Ceramic Corporation - Hungama

Personnel met:
Mr. Wijenayake - Factory Manager

6. Tile Factory, Ceylon Ceramics Corporation - Uswewa

7. Lanka Tiles (pvt.)Ltd. - Hanwella

Personnel met:
Mr. P. Piyasena - Production Manager

RAW MATERIAL DEPOSITS VISITED

1. Boralesgamuwa Kaolin Deposit
2. Meetiyagoda Kaolin Deposit
3. Dediyawela Ball Clay Deposit

4. Matale Quartz Deposit
5. Matale Feldspar Deposit
6. Hungama Sea-shells Deposit
7. Hungama Red Ochre Deposit
8. Balangoda Kaolin Deposit
9. Balangoda Calcite Deposit
10. Balangoda Quartz Deposit

OBSERVATIONS

The Ceramic Research and Development Centre shows, after only two years in existence (from September 1984) a great capacity of self-sufficiency and an important improvement was reached with the appointment of the Head of the Laboratory in January 1986.

The laboratory is very well equipped and very sophisticated instruments are present, which permit the coverage of all aspects of ceramic research. The Research Officers are well trained and very enthusiastic.

A constant recurring problem exists in the CRDC Laboratory regarding the delay in repairing, servicing and the non-availability of spare parts in the case of break-downs, due to the geographical position of Sri Lanka. This results at times, in the sophisticated equipment being out of order for several months, causing a considerable loss in revenue to the laboratory. Besides, some equipment (mostly the X-RD and STA)are overloaded with routine analyses. One of which (thermal expansion tests) could be done in the quality control section of the Piliyandala Factory.

RECOMMENDATIONS TO THE CEYLON CERAMICS CORPORATION

During my mission here and according to my experience, I would like to suggest that some targets should be achieved in the future, which would be very important to the Ceramic Industry of Sri Lanka, as a whole.

Firstly, it would be very useful, for a proper planning to be done on the exploitation of raw materials, to obtain a complete knowledge on the quantity and quality of the raw materials available in the deposits, through systematic field surveys (drillings and collection of samples covering all areas of the deposit) and subsequent laboratory testings done at the CRDC Piliyandala. The results of this connected field-laboratory work could be represented on appropriate quality control maps, showing the main properties of each deposit. This type of work has been done very successfully, for example, for the Meetiyagoda Kaolin deposit and should be extended to other raw material deposits (in particular the ball clay deposit at Dediyawela).

The close co-operation with the Geological Survey Department is of fundamental importance for the success of the above programme. It would be very useful for at least one officer of the CRDC to join in the field work carried out by the Survey Department, in order to strengthen the relationship between field and laboratory findings.

In order to reduce the contamination of raw material in the mines, I wish to mention the following:

a) removal of the overburden of a large extent of the area before mining and introduction of efficient drainage systems, to prevent the contamination due to rain water flowing from the surrounding areas into the pit (in particular, it is very important for kaolin deposits, such as the one at Meetiyagoda, to maintain the high quality of the raw material).

b) regarding the kaolin refineries, it is very important that during the processing operations, clean water and not dirty or muddy water should be used, as the use of unclean water, could result in contamination of pure kaolin (i.e., increase in the iron content and other impurities).

c) the people working in the mines, should be taught, during exploitation to select the good material from the poor quality material.

d) it would useful to carry out a more systematic type of mining, specially for the blending and homogeneity of the raw materials; for this purpose, it would be good to accumulate large stocks in the mines before delivery to the factories (maintaining large stocks in the factories too would be benficial).

I would like also to stress the great importance of a strict quality control on the raw materials, as the relationship between the defects in the raw materials and the defects in the final product, is underestimated. Hence, the establishment of a proper Raw Material Division, responsible for periodic and complete testing checks on all the raw materials used in the Ceramic Industry, both local & imported raw materials (these periodic tests should be done at least once every 3 months), would be of maximum importance. In order to achieve a systematic recording of the results, I wish to suggest the use of technological sheets, in which it is possible to summarize all aspects regarding each particular raw material, such as mineralogical composition, chemical composition, technological properties etc. (as an example of such a sheet, see Annex V). It would be very useful, finally, whether for internal purposes or for external customers, the preparation and printing of "Information Booklets", for each raw material containing:

- information about the mine (location, type of mining, reserves estimated, production/year, type of processing etc.,etc.)
- information on the properties (checked in the CRDC Laboratory), making use of the sheets mentioned above.

This work could give technical information and publicity about the CCC and CRDC, to all people involved in the ceramic field in Sri Lanka.

place	country	client	n.

analyses enclosed				description raw material
differential thermal	☐	X ray diffraction	☐	
thermogravimetric	☐	particle size distribution	☐	
green dilatometry	☐	rheological behaviour	☐	

CHEMICAL ANALYSIS %		MINERALOGICAL ANALYSIS			
SiO_2		kaolinite		albite	
Al_2O_3		chlorite		calcite	
TiO_2		fire-clay		dolomite	
Fe_2O_3		halloysite		oxides and hydroxides Fe/Al	
CaO		illite		micas	
MgO		montmorillonite		orthoclase	
K_2O		vermiculite		quartz	
Na_2O		other			
I.L.		clayey components		non clayey components	
SO_3					

description

		residue on seives (mesh)	total (%)
total carbonates %		80	
organic matter %		120	
total soluble salts %		230	

POWDER PREPARATION

wet	ball mill	☐
	stirrer	☐
dry	hammer mill	☐
	cone crusher	☐
control screen mesh		
residue %		

SLIP CHARACTERISTICS

slip water	%	
type of electrolyte		
electrolyte content	%	
slip viscosity	☐ E ☐ Cp	
slip density	Kg/l	
slip pH		

PHYSICAL-CERAMICS CHARACTERISTICS

pressed body	moisture content for pressing	%	
	working pressure	Kg/cm²	
	expansion after pressing	%	
	green bending strength	Kg/cm²	
	dry bending strength	Kg/cm²	
	drying shrinkage	%	
biscuits	cubic expansion coefficient	10^{-7} °C⁻¹	
	bending strength	Kg/cm²	
	I.L.	%	

FIRING
electric kiln
electric gradient kiln

temp. °C	change in dimensions %	water absorption %	remarks

ANNEX I

CERAMIC RESEARCH LABORATORY
established by
United Nations Industrial Development Organization (UNIDO)
and Ceylon Ceramics Corporation

Piliyandala
30th April, 1986.

General Manager/ Dr. J.W. Herath

REPORT ON RED OCHRE TESTINGS (HUNGAMA DEPOSIT)

1. INTRODUCTION

The purpose of these analyses was to identify the main technological and compositional characteristics of the material - red ochre- and to determine an initial evaluation regarding its suitability for the Ceramic Industry, through laboratory testings done in the Ceramic Research Laboratory in Piliyandala.

2. GEOGRAPHIC LOCATION OF THE DEPOSIT

A preliminary visit to the red ochre deposit was made, together with Mr. S. Silva (Senior Research Officer, CRL, Piliyandala), on 21st March, 1986. During this survey, we collected samples, for analysis, in the laboratory and photographs of the deposit were taken (general views & details). The red ochre deposit is found close to hungama (south-coast), about 200 km. from Colombo.

The deposit appears to be very large and homogeneous (even though it is not possible to assess the quantity of the material available, without proper investigations) and no over-burden is present. Hence, very easy mining is possible. The raw material appears dark red in colour, partly fine, powdery and with very low hardness. However, at the same time, bigger fragments of quartz and hematite (up to 3 - 4cm.) are also present. Besides, scattered here and there, it is possible to find some blocks of another rock (probably serpentinite).

3. CHEMICAL AND MINERALOGICAL COMPOSITION

The chemical analysis showed an interesting iron oxide content (Fe_2O_3 = 22%) , due mainly, to the presence of hematite; the SiO_2 content is low and so is the Al_2O_3 content and this is typical of basic rocks. No carbonates are present and loss on ignition is low (6.3%).

According to the X-ray Analysis, only quartz and hematite can be recognized in the sample but with thermal analyses (DTA, TG and green dilatometry) it is possible to check also the presence of a small amount of kaolinite (about 11%).

4. TECHNOLOGICAL TESTINGS

During this phase of study, we tried to obtain information about the grain size composition and the behaviour of the material during and after firing.

A wet sieve analysis was made and the results are as follows:-

Sieves		Residue on the Sieves	Residue Total
Mesh	mm	(%)	(%)
12	1.41	9.75	9.75
35	0.50	5.39	15.14
100	0.149	18.63	33.77
120	0.125	4.19	37.96
230	0.063	10.48	48.44

After that, we proceeded with the identification of the residues with the help of a microscope. The main components are, of course, quartz and hematite (through visual estimation we noticed that the quartz content increases with the decreasing of the grain size and vice versa for hematite); a very small quantity of mica is present. Besides, it appears, that the material contains some fragments of magnetite and laterite, as well.

In the meantime, after dry grinding, some tiles (4 x 4 cm. each) were pressed in the laboratory at the specific pressure of

300 Kg/cm^2 and with approximately 4% of moisture content. After that, we fired the tiles in the laboratory gradient kiln, reaching the maximum temperature (1200°C) in about 4 hours . On checking the shrinkage after firing, very small contractions were seen, up to the maximum temperature (2.7% at 1200 C). Due to the poor hardness of the tiles, it was not possible to carry out the determination of water absorption.

The green dilatometry confirms the negligible shrinkage of the raw red ochre after firing (max. temp. 1050°C)

The gradient kiln firing test confirms also a low clay mineral content in sample.

The colour range of the tiles changes from dark red(lower temperatures) to brown (higher temperatures).

5. CONCLUSIONS

The red ochre is a material rich in iron oxide (hematite), devoid of carbonates and with a high percentage of non plastic and hard minerals (the sand fraction is about 50%); which means, high dimensional stability and the capacity to reduce shrinkage during drying and firing processes.

In the meantime, it would be interesting to find out whether this red ochre could be used as a red pigment, in the ceramic industry. After this preliminary study, it is advisable to continue the laboratory testings, to find out suitable experimental body mixtures (for instance- pressed red tiles, bricks and roofing tiles) adding the proper percentage of red ochre, to the plastic red firing clay, already used for the manufacture of bricks & tiles.

At present a negligible quantity of red ochre is used as a glaze stain in the ceramic industry.

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Piliyandala

Problems of mining are not present; the only problem may be due to the distance and geographic location of the deposit and to the presence of coarse fragments of quartz in the raw material (probably the coarse fragments could be got rid off during the exploitation of the ochre, using a screen or grid, prior to transportation). Finally, the red ochre may found to be useful in industries other than the ceramic industry.

M. Corsi

M Corsi

place	country	client	n.
HUNGAMA	SRI LANKA		

analyses enclosed

differential thermal	☐	X ray diffraction	X
thermogravimetric	☐	particle size distribution	X
green dilatometry	X	rheological behaviour	☐

description raw material

RED OCHRE
(iron oxide deposit,
moisture content = 6

CHEMICAL ANALYSIS	%	MINERALOGICAL ANALYSIS			
SiO_2	53.2	kaolinite	(X)	albite	
Al_2O_3	9.2	chlorite		calcite	
TiO_2		fire-clay		dolomite	
Fe_2O_3	22.1	halloysite		oxides and hydroxides Fe/Al	
CaO	4.93	illite		micas	
MgO	0.20	~~montmorillonite~~		orthoclase	
K_2O	0.93	vermiculite		quartz	X
Na_2O	2.4	other		hematite	X
L.L.	6.32	clayey components		non clayey components	
SO_3					

description residues :
hematite, quartz; mica,
(magnetite), (laterite).

			residue on sieves (mesh)	to[illegible]
total carbonates	%	0	35	15.
organic matter	%		120	37.
total soluble salts	%		230	48.

POWDER PREPARATION

wet	ball mill	☐
	stirrer	☐
dry	hammer mill	☐
	cone crusher	☒
control screen	mesh	
residue	%	

SLIP CHARACTERISTICS

slip water	%	
type of electrolyte		
electrolyte content	‰	
slip viscosity	☐ °E ☐ Cp	
slip density	Kg/l	
slip pH		

PHYSICAL-CERAMICS CHARACTERISTICS

pressed body	moisture content for pressing	%	
	working pressure	Kg/cm²	300
	expansion after pressing	%	
	green bending strength	Kg/cm²	
	dry bending strength	Kg/cm²	
	drying shrinkage	%	
[illegible]	cubic expansion coefficient	[illegible]	
	bending strength	[illegible]	

FIRING electric kiln / electric gradient kiln

temp. °C	change in dimensions %	water absorption %	remarks
1200°	-2.7	-	
1180°	-2.7	-	
1150°	-1.7	-	
1110°	-1.7	-	
1090°	-1.7	-	
1060°	-1.4	-	
1040°	-1.0	-	
1010°	-1.0	-	
[illegible]	-0.7		

CERAMIC RESEARCH LABORATORY

established by
United Nations Industrial Development Organization (UNIDO)
and Ceylon Ceramics Corporation

Piliyandala

18th Fab. 1986

Results of Laboratory Order No. 1557 given by Dr. S. Corsi

X-Rd analysis of reddish-brown powder (from Hungama)

The sample was ground in the tetrabor mortar to bring to the required particle size. The material was passed through a 0.050 mm sieve and fixed in the special Al holder to prevent any preferred orientation.

Instrumentation Used

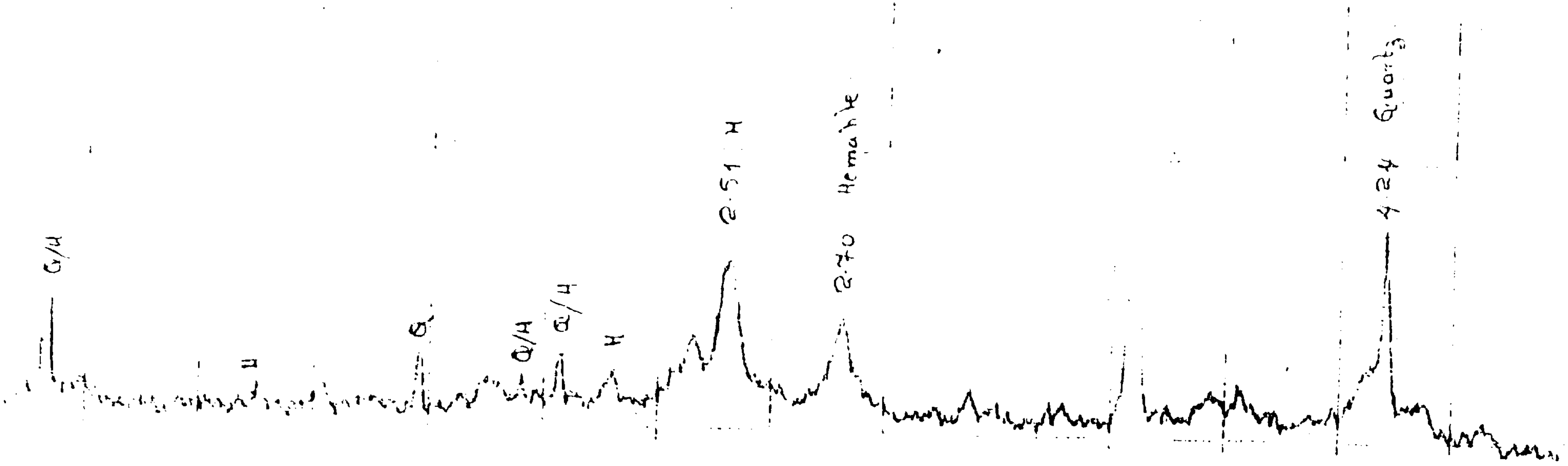
A Philips X-ray generator - PW 1730/10 at 40 kv and 40 mA
Goniometer Scanning Range - from 5° to 140° ; 2θ
Selected Full Scale Countes per second - $5x10^{3}$
The traces were obtained using Cr, K_{α} filtered radiation

CONCLUSION

The diffractrogram is attached herewith.

According to the "d" spaces and relative intensities the sample contains a) Quartz (SiO_2) (Hexagonal crystal form)
b) Hematite (Fe_2O_3) (Hexagonal crystal form)

[illegible]	4.9457	999	
28.303	4.6853	1032	
31.170	4.2636	1695	Q
31.803	4.1809	1271	
36.274	3.6798	1202	
40.019	3.3477	9037	Q
45.585	2.9569	1116	
47.798	2.8275	1041	
52.635	2.5837	1078	
54.159	2.5163	1633	H
55.531	2.4589	1383	
61.560	2.2384	1209	
65.090	2.1293	1133	Q
68.721	2.0296	1113	
70.668	1.9807	1071	
78.070	1.8189	1329	H/Q
86.395	1.6734	1204	
95.901	1.5426	1524	Q
103.185	1.4618	1106	Q/H
107.674	1.4189	1030	Q
109.030	1.4068	989	[illegible]
111.079	1.3893	976	[illegible]
111.839	1.3830	1145	[illegible]
112.332	1.3790	1019	[illegible]



CERAMIC RESEARCH LABORATORY

INTERNAL LABORATORY ORDER No. 1639

DATE: 27/3/86

given by Mr. Corsi
(Customer, Factory, Name of officer)

(personal) signature of forwarding person i.e. Administrative Secretary)

To find the suitability of red ochre for the production of pressed floor tiles

Kind of sample: Red ochre.

Label Inscription :

Sent by :

Brought by :

Collected by :

Received on : 27/3/86.

Kind of Order

Pilot plant -

To be settled by :
(Laboratory, Name, Lab. Spec. No.)

Carry out wet sieve analysis of the above sample.

Result(s) Moisture content of the sample given 6.5%

		%	TOTALS
Residue		9.75	9.75
		5.39	15.14
	0.50	18.63	33.77
	0.[illegible]	4.19	37.96
	0.[illegible]	10.48	48.44
	0.063		

[illegible] 18.4.86

Date 18/4/86

Signature of Research Officer

CERAMIC RESEARCH LABORATORY

established by
United Nations Industrial Development Organization (UNIDO)
and Ceylon Ceramics Corporation

Piliyandala
24th March, 1986.

Analysis of Red Ochre sample given by Mr. M. Corsi

Laboratory Order No. 1627 dated 19/03/86.

Chemical Analysis

LOI	6.32%
SiO_2	53.2 %
Al_2O_3	9.2 %
Fe_2O_3	22.1 %
CaO	4.93%
MgO	0.20%
Na_2O	2.4 %
K_2O	0.93%

K.A.N. Dharmasiri
Research Officer

G.M.

CERAMIC RESEARCH LABORATORY

established by

United Nations Industrial Development Organization (UNIDO)
and Ceylon Ceramics Corporation

Piliyandala
24th March, 1986.

Result of Laboratory Order No. 1597 given by Mr. Corsi

Part I

Dilatometric Analysis

Sample :- Reddish - Brown Clay

Test :- Dilatometric Analysis (raw clay)

Sample Preparation:-

The sample was ground in an agate mortar and sieved using a 355 µm sieve. The residue/that remained on the sieve could not be ground in the agate mortar alone, a boron carbide mortar (manual) was used to grind the residue. Finally the total sample was again sieved using a 355 µm sieve. The samples were mixed well and moistened with water. [illegible] moisture content was found to be nearly 7%. Small tiles ([illegible]x[illegible]x0.6 cm.) were pressed from the prepared powder under a pressure of 300 $kgfcm^{-2}$. Small sample rods approximately of the size 25x5x5 mm were carefully cut from the tiles. [illegible] were kept in an oven at 40°C. The initial length [illegible] measured before starting the analysis.

Parameter Selection

Dilatation measuring range :- 500 [illegible]

Derivation Measuring Range - [illegible] 1 [illegible] Filter [illegible]

X_2 = [illegible]

Heating Rate - [illegible]

[illegible] - [illegible]

[illegible] - [illegible]

[illegible] - [illegible]

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Order No. 1597 (contd.)

Results

(see graph N. DIL 24)

Initial length of the sample = 24.75 mm

Dilatation curve registered the following behaviour.

Temp or Temp. Interval °C	Expansion or Contraction (Graphical)	Possible reaction or inversion	Remarks
50 - 200	Contraction	Removal of physical water from the test sample.	
235 - 250	Expansion	α-Cristobalite ⇌ (Tetragonal) β-Cristobalite (Cubic)	
575 - 585	Marked Expansion	α-Quartz ⇌ β-Quartz (Hexagonal) (Hexagonal)	The reverse reaction was observed at 555 - 580 °C during the cooling process
585 - 865	Contraction	[illegible] → [illegible] [illegible] of [illegible]	
865 - onwards	Contraction	[illegible]	

[illegible] tion was done, [illegible] [illegible]

Order No. 1597 (contd.)

Part II - Simultaneous Thermal Analysis

Sample :- Reddish Brown Clay

Test :- STA

Sample Preparation

The above procedure was followed as for part I, up to the mositenin of the sample. Then the sample was dried at 40°C and subjected to analysis.

Parameter Selection

TG Measuring Range	-	50 mg
DTA " "	-	200 µV
DDTA " "	-	100 µV (5)

$X_p = 4$ $T_n = 5$.

Heating Rate	-	10°C min^{-1}
Program	-	UP
Final Temp.	-	1000°C
Atmosphere	-	Static Air
Thermostat	-	30°C
Room Temp.	-	[illegible]°C

Results

Weight of the sample used = [illegible]1.0 [illegible].

(see graph STA 113)

TG curve shows three steps, of which [illegible] be attributed to the removal of physi[illegible] [illegible] combustion of organic matter in the sample. [illegible], [illegible] reactions are not well separated. These [illegible] [illegible] to weight loss of 1.4% and 3.4% from the [illegible] weight.

Order No. 1597 (contd.)

The third step was identified as the weight loss due to dehydroxylation of kaolinite. In this sample, this reaction had taken place at a fairly low temperature (525 °C), than usual. This reaction showed a weight loss of 1.5% from the initial weight. Assuming that no other reaction had taken place, [illegible] the reaction -

kaolinite ⟶ Metakaolinite

the kaolinite content was found to [illegible] 11%.

The very small endothermic indication at [illegible], may have been cause by the presence of hematite (no weight loss).

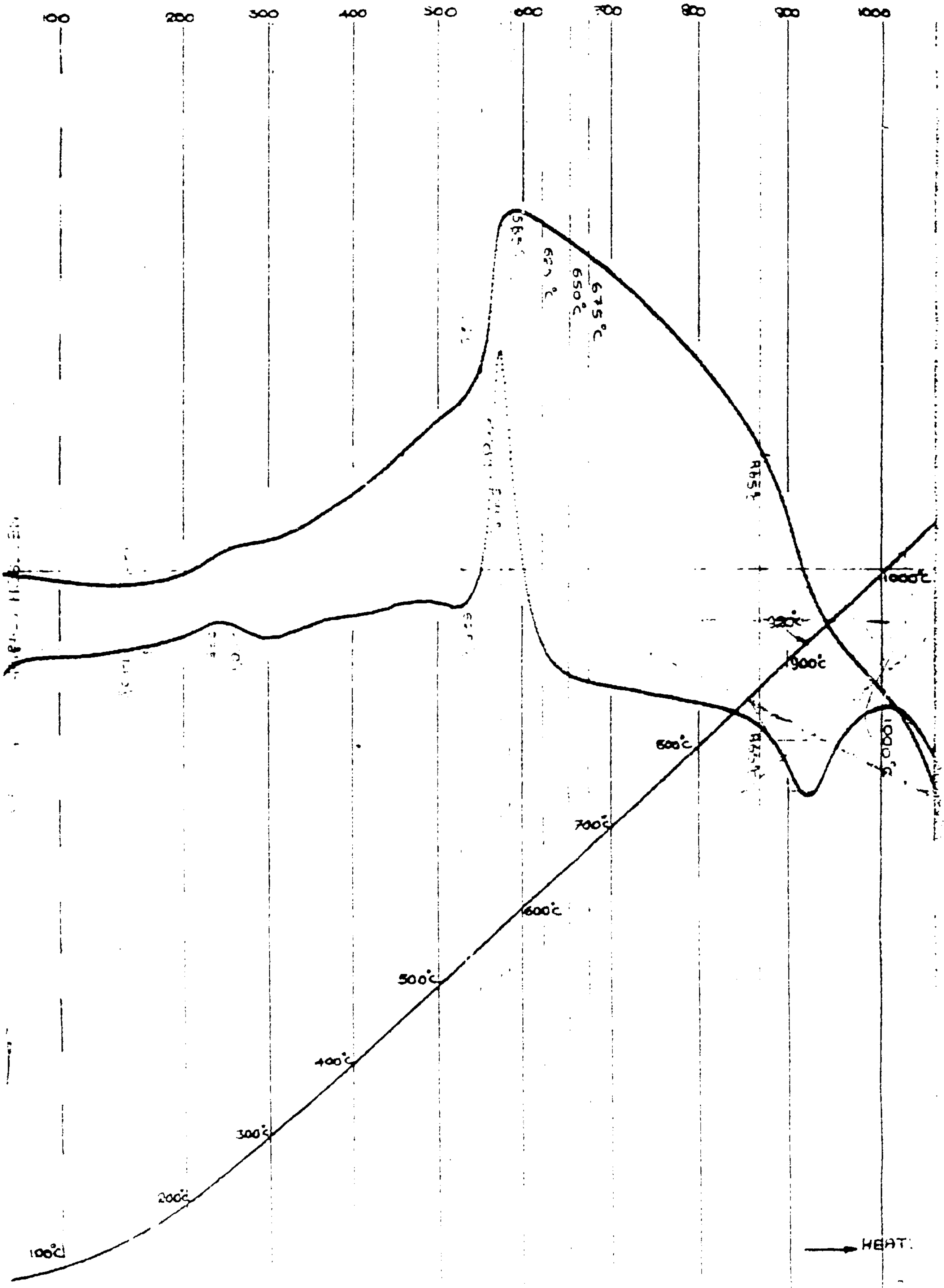
Slight exothermic indication at 9[illegible] [illegible] the structural reorganiion of alumina (no wieght loss).

References

1. Mackenzie R.C. " Differential [illegible] investigation of Clays" pp 276

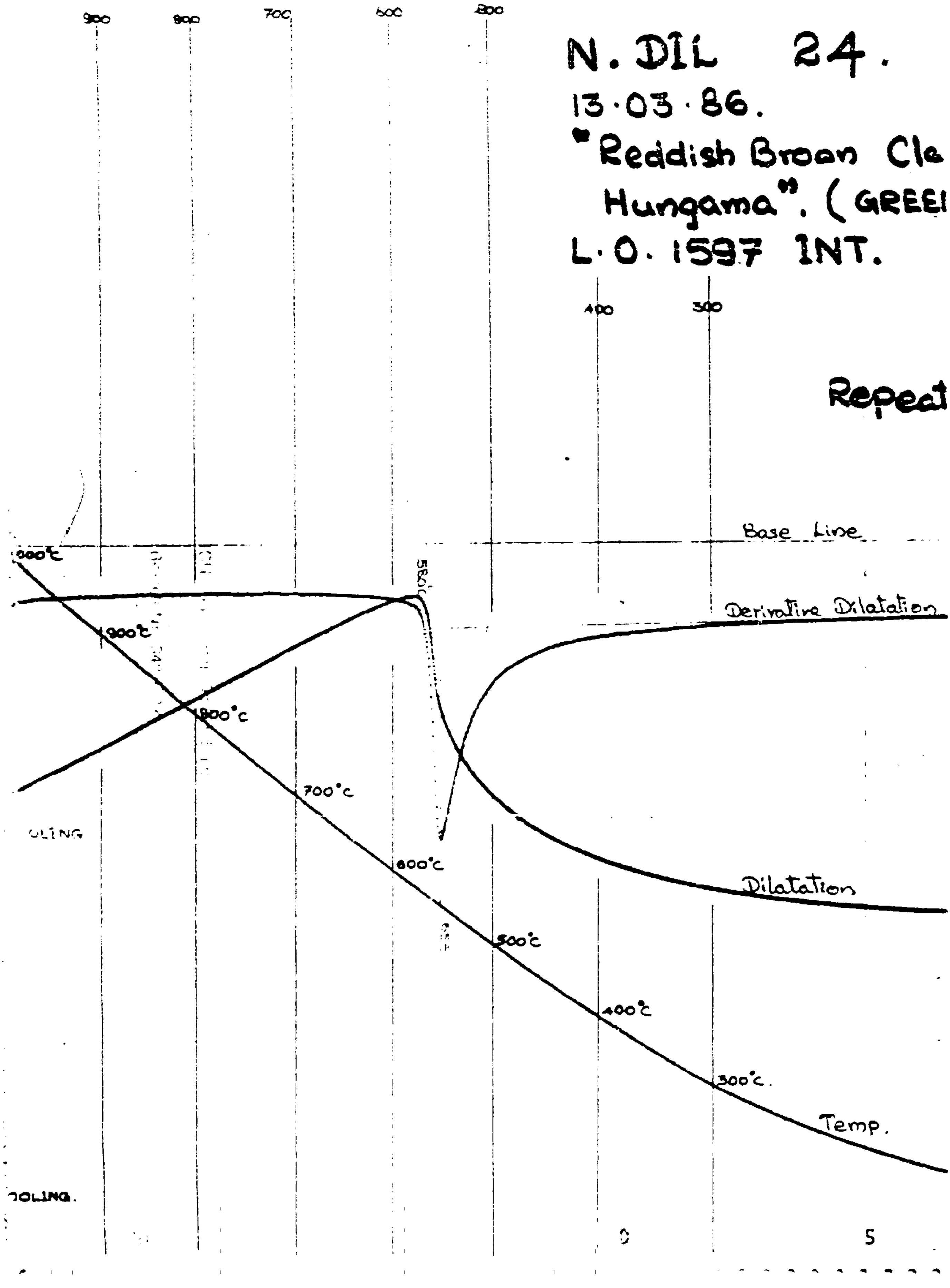
2. NETZSCH literature on [illegible]

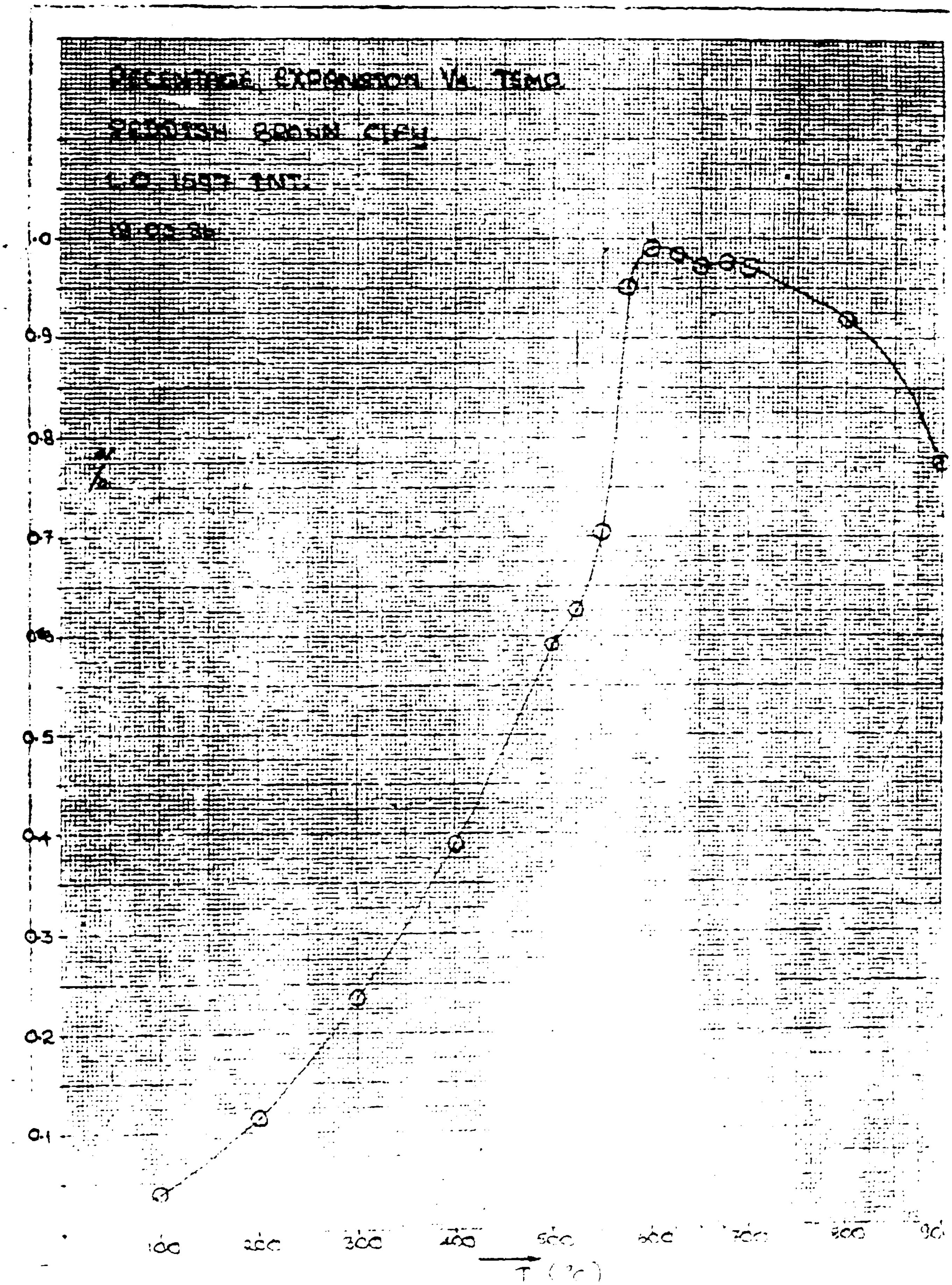
[illegible]



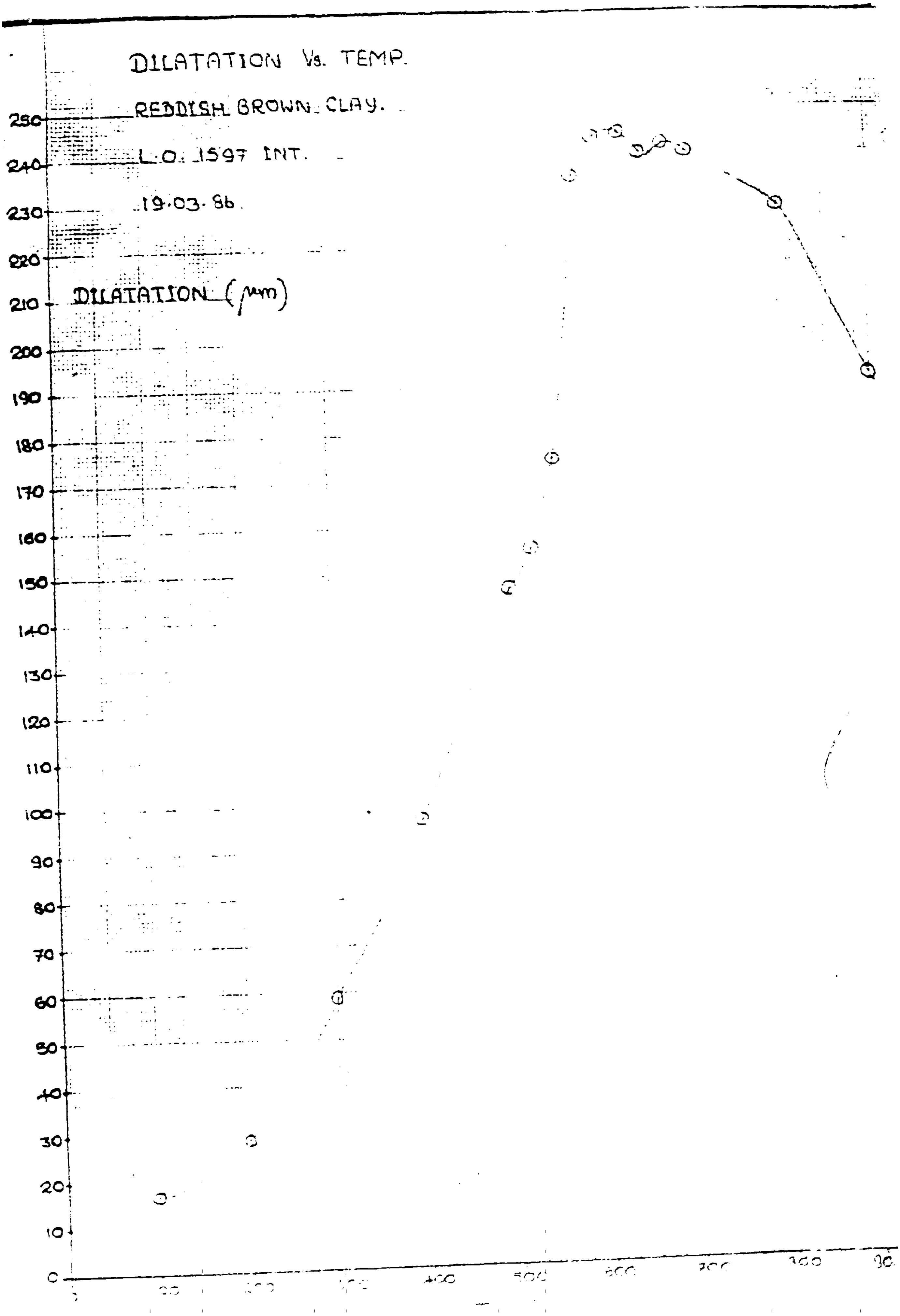
100
200
300
400
500
600
700
800
900
1000
675°C
650°C
920°C
1000°C
900°C
800°C
700°C
600°C
500°C
400°C
300°C
200°C
100°C
HEAT

N. DIL 24.
13·03·86.
"Reddish Broon Cle
Hungama". (GREE
L·O· 1597 INT.

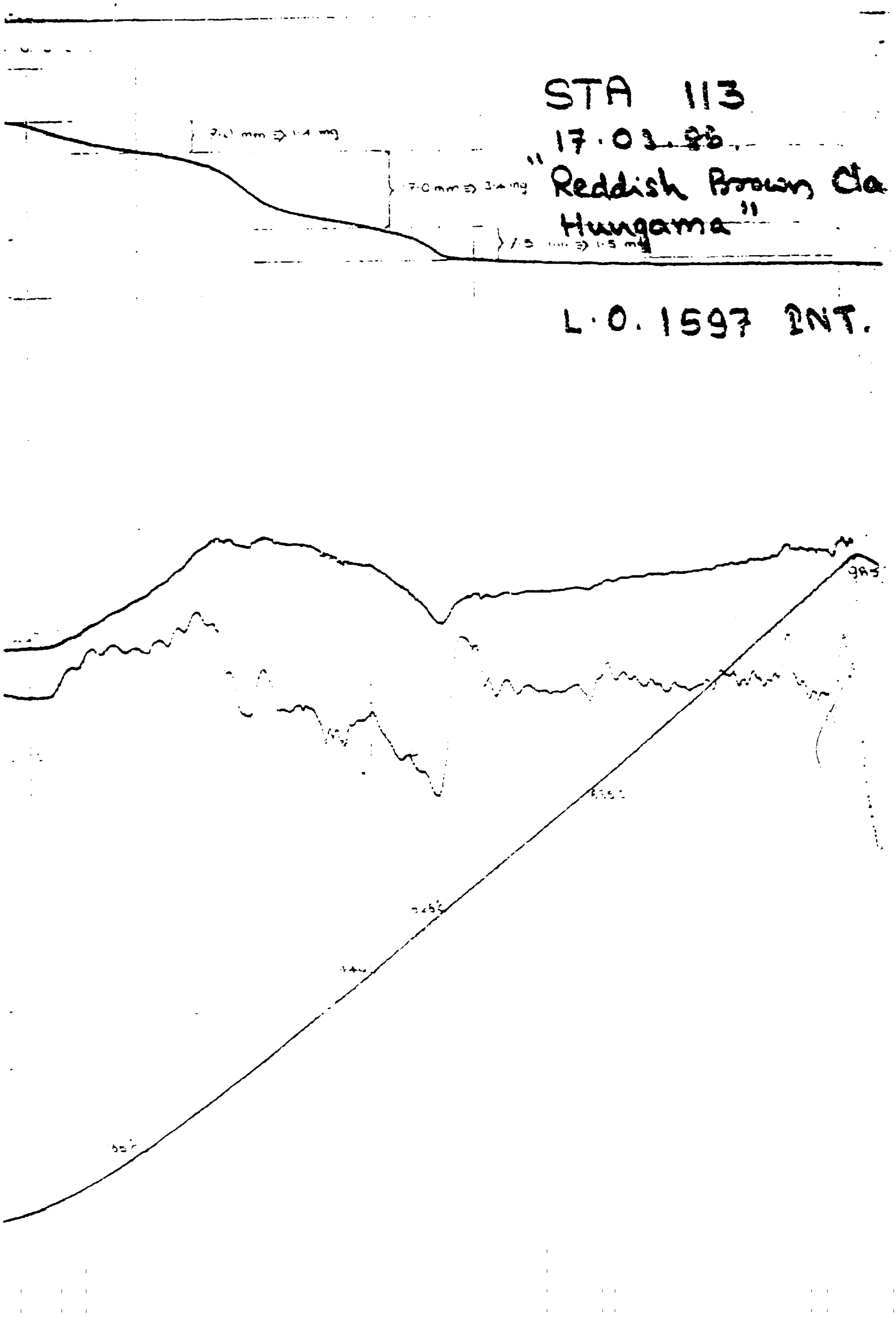




1.0
0.9
0.8
0.7
0.5
0.4
0.3
0.2
0.1
300
400
600
800



DILATATION Vs. TEMP.
REDDISH BROWN CLAY.
L.O. 1597 INT.
19.03.86
DILATATION (μm)
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
400
500


STA 113
17.03.86
"Reddish Brown Cla
Hungama"
L.0.1597 INT.

ANNEX II

CERAMIC RESEARCH & DEVELOPMENT CENTRE ~~LABORATORY~~
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and Ceylon Ceramics Corporation

Piliyandala
15/6/86

General Manager, Ceylon Ceramics Corporation
Dr. J. W. Herath, Head/Ceramic Research & Development Centre
General Manager, Lanka Refractories (pvt) Ltd, Meepe

EXPERIMENTAL BODY MIXTURE FOR THE PRODUCTION OF UNGLAZED RED FLOOR TILES (PRESSING POWDER METHOD)

1. INTRODUCTION

The purpose of the experimental testing done at the Ceramic Research & Development Centre, was to find a new body mixture, suitable for the production of unglazed red floor tiles, by the powder- pressing method, at Lanka Refractories (pvt) Ltd., Meepe.

The main component of the body mixture was a yellow clay, located close to the above factory. However, due to the unsuitable colour of this clay after firing, it was necessary to introduce another material, as a pigment, to obtain a more reddish colour tile. For this purpose, we added different perdentages of red ochre (a material rich in iron oxide) from deposit at Hungama to the yellow clay at Meepe, as follows:-

	MP/A %	MP/B %	MP/C %	MP/C %
Meepe Clay	100	95	90	80
Red Ochre	-	5	10	20
	100	100	100	100

2. PREPARATION OF BODY MIXTURES AND TESTS

The grinding of the different mixtures was done in ball mills (dry grinding) for two hours and after sieving through 45 mesh (0.355 mm), we sprayed the different powder mixtures with an appropriate quantity of water. The mixtures were then pressed using a press in the laboratory, working at 300 kg/cm^2. Several tiles of 4 x 12 cm each, were pressed to check the following characteristics:-

1. Expansion after pressing
2. Green bending strength
3. Dry shrinkage
4. Dry bending strength

Some of these tiles were fired in a laboratory electric muffle kiln to 970°C , with a cycle of about 4 hours, from room temperature to 970°C. The fired tiles were used to check the following:-

a) shrinkage after firing
b) bending strength
c) water absorption
d) ignition loss
e) colour

The firing of these tiles was repeated at the same temperature, but with 45 minutes soaking time at the maximum, to check if any variation in colour would occur.

3. RESULTS

The moisture content of the pressed tiles varied between 7.3% (MP/C) and 8.2% (MP/A). The results of tests carried out on the different tiles, before firing, showed a great homogeneity in all the four different compositions, with very good values for bending strength, whether before or after drying and low dry shrinkage (0.4%). The shrinkage after firing (970°C) was somewhat high, but it was clear that on the addition of red ochre, the shrinkage could be reduced (see attached result sheets). The same result was obtained for loss on ignition (a small decrease). The bending strength after firing always showed low values (from 99 kg/cm^2 to 67 kg/cm^2), compared with the good behaviour before firing. This strange result may be explained on observation of the fired tiles: all these tiles show on the surface and within the tile, a dark stain, due to incomplete combustion of the organic matter, because the firing cycle was too fast and the loading of the tiles in the laboratory kiln, could not be done in a suitable manner, due to the small area of the kiln. Usually this incomplete firing causes a reduction in the mechanical properties of the pieces. In any case, a logical decrease in the bending strength was observed, according to the decrease of the clay percentage in the body mixture (the value of the mechanical strength may be increased with a more suitable loading space and a slower firing cycle.

The water absorption is almost the same for all the different mixtures (between 23% and 25%).

The colour after firing varied from yellow (MP/A) to light red(MP/D) showing that the addition of red ochre can improve the colour of the tiles but only very slightly.

On repeating the firing with a 45 minute soaking time, we note that no difference occured in the colour of the tiles .

4. CONCLUSION

According to the above laboratory tests, it could be concluded that the addition of red ochre to the body mixture could improve the technological properties of the tiles (particularly shrinkage after firing and loss on ignition). The introduction of red ochre may improve also the colour of the tiles, but probably it is necessary to add a higher percentage of this material to reach a very good reddish colour. However, an economic evaluation must be done to support this decision (high percentage of red ochre, high transport costs, etc.)

M. Corsi

15/6/86

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5.6.1986

Results of Laboratory order No. 1727 B

		MP/A	MP/B	MP/C	MP/D
Bending Strength before drying	kg/cm^2	19.72	20.[illegible]	18.78	18.02
	N/cm^2	193.26	196.09	184.04	176.59
Bending Strength After drying	kg/cm^2	42.30	41.20	40.20	39.00
	N/cm^2	414.54	403.76	393.96	382.20
Bending strength After firing	kg/cm^2	99.1[illegible]	[illegible]3.20	82.80	67.10
	N/cm^2	971.1[illegible]	[illegible]	811.44	657.58
% of water absorption		24.2	[illegible]	[illegible].0	23.1

[illegible]
[illegible], Pamarlia
[illegible]

	country	client	n.
MEEPE	SRI LANKA	LANKA REFRACTORIES	MP/A

analyses enclosed				description raw material
differential thermal ☐		X ray diffraction ☐		Meepe clay 100%
thermogravimetric ☐		particle size distribution ☐		
green dilatometry ☐		rheological behaviour ☐		

MINERALOGICAL ANALYSIS

%					
	kaolinite		albite	
	chlorite		calcite	
	fire-clay		dolomite	
	helioysite		oxides and hydroxides Fe/Al	
	illite		micas	
	montmorillonite		orthoclase	
	vermiculite		quartz	
	other			
	clayey components		non clayey components	

ion			residue on seives (mesh)	totals (%)
	total carbonates %		80	
	organic matter %		120	
	total soluble salts %		230	

POWDER PREPARATION

X	ball mill	☐
	stirrer	☐
	hammer mill	☐
	cone crusher	☐
screen	mesh	45
	%	

SLIP CHARACTERISTICS

slip water	%	
type of electrolyte		
electrolyte content	‰	
slip viscosity	☐ °E ☐ Cp	
slip density	Kg/l	
slip pH		

PHYSICAL-CERAMICS CHARACTERISTICS

moisture content for pressing	%	8.2
working pressure	Kg/cm²	300
expansion after pressing	%	0.5
green bending strength	Kg/cm²	19.7
dry bending strength	Kg/cm²	42.3
drying shrinkage	%	0.4
cubic expansion coefficient	10^{-7} °C^{-1}	
bending strength 970°C	Kg/cm²	99.1
L. 970°C	%	17.1

FIRING

electric kiln ☒
electric gradient kiln ☐

temp. °C	change in dimensions %	water absorption %	remarks
970°	-3.2	24.2	4 hours cycl

place	country	client	n.
MEEPE	SRI LANKA	LANKA REFRACTORIES	MP/B

analyses enclosed

differential thermal	☐	X ray diffraction	☐
thermogravimetric	☐	particle size distribution	☐
green dilatometry	☐	rheological behaviour	☐

description raw material

Meepe clay 95%
Red ochre 5%

CHEMICAL ANALYSIS	%	MINERALOGICAL ANALYSIS			
SiO_2		kaolinite		albite	
Al_2O_3		chlorite		calcite	
TiO_2		fire-clay		dolomite	
Fe_2O_3		halloysite		oxides and hydroxides Fe/Al	
CaO		illite		micas	
MgO		montmorillonite		orthoclase	
K_2O		vermiculite		quartz	
Na_2O		other			
I.L.		clayey components		non clayey components	
SO_3					

description

			residue on sieves (mesh)	
total carbonates	%		60	
organic matter	%		120	
total soluble salts	%		230	

POWDER PREPARATION

wet	ball mill	☐
	stirrer	☐
dry X	hammer mill	☐
	cone crusher	☐
control screen mesh		45
residue %		

SLIP CHARACTERISTICS

slip water	%	
type of electrolyte		
electrolyte content	‰	
slip viscosity	☐ °E ☐ Cp	
slip density	Kg/l	
slip pH		

PHYSICAL-CERAMICS CHARACTERISTICS

FIRING: electric kiln / electric gradient kiln

		unit	value	temp. °C	change in dimensions %	water absorption %	remarks
pressed body	moisture content for pressing	%	7.9				
	working pressure	Kg/cm²	300	970°	-3.0	24.5	4 hou
	expansion after pressing	%	0.5				
	green bending strength	Kg/cm²	20.0				
	dry bending strength	Kg/cm²	41.2				
	drying shrinkage	%	0.4				
biscuits	cubic expansion coefficient	1/°C					
	bending strength 970°C	Kg/cm²	93.2				
	I.L. 970°C	%	16.6				

plant	country	client	n.
MEEPE	SRI LANKA	LANKA REFRACTORIES	MP/C

analyses enclosed				description raw material
differential thermal	☐	X ray diffraction	☐	Meepe clay 90%
thermogravimetric	☐	particle size distribution	☐	Red ochre 10%
green dilatometry	☐	rheological behaviour	☐	

CHEMICAL ANALYSIS	%	MINERALOGICAL ANALYSIS			
SiO_2		kaolinite		albite	
Al_2O_3		chlorite		calcite	
TiO_2		fire-clay		dolomite	
Fe_2O_3		halloysite		oxides and hydroxides Fe/Al	
CaO		illite		micas	
MgO		montmorillonite		orthoclase	
K_2O		vermiculite		quartz	
Na_2O		other			
I.L.		clayey components		non clayey components	
SO_3					

description

			residue on seives (mesh)	
total carbonates	%		80	
organic matter	%		120	
total soluble salts	%		230	

POWDER PREPARATION

wet		ball mill	☐
		stirrer	☐
dry	X	hammer mill	☐
		cone crusher	☐
control screen		mesh	45
residue		%	

SLIP CHARACTERISTICS

slip water	%	
type of electrolyte		
electrolyte content	‰	
slip viscosity	☐ °E ☐ Cp	
slip density	Kg/l	
slip pH		

PHYSICAL-CERAMICS CHARACTERISTICS

FIRING: electric kiln / electric gradient kiln

				temp. °C	change in dimensions %	water absorption %	remarks
pressed body	moisture content for pressing	%	7.3				
	working pressure	Kg/cm²	300	970°	-2.6	25	4 hour
	expansion after pressing	%	0.5				
	green bending strength	Kg/cm²	18.8				
	dry bending strength	Kg/cm²	40.2				
	drying shrinkage	%	0.4				
biscuits	cubic expansion coefficient	10^{-7} °C^{-1}					
	bending strength 970°C	Kg/cm²	82.8				
	I.L. 970°C	%	1[illegible].9				

site	country	client	n.
MEEPE	SRI LANKA	LANKA REFRACTORIES	MP/D

analyses enclosed

differential thermal	☐	X ray diffraction	☐
thermogravimetric	☐	particle size distribution	☐
green dilatometry	☐	rheological behaviour	☐

description raw material

Meepe clay	80%
Red ochre	20%

CHEMICAL ANALYSIS	%	MINERALOGICAL ANALYSIS			
SiO_2		kaolinite		albite	
Al_2O_3		chlorite		calcite	
TiO_2		fire-clay		dolomite	
Fe_2O_3		halloysite		oxides and hydroxides Fe/Al	
CaO		illite		micas	
MgO		montmorillonite		orthoclase	
K_2O		vermiculite		quartz	
Na_2O		other			
I.L.		clayey components		non clayey components	
SO_3					

description

			residue on seives (mesh)	
total carbonates	%		80	
organic matter	%		120	
total soluble salts	%		230	

POWDER PREPARATION

wet	ball mill	☐
	stirrer	☐
dry X	hammer mill	☐
	cone crusher	☐
control screen mesh		4?
residue %		

SLIP CHARACTERISTICS

slip water	%
type of electrolyte	
electrolyte content	‰
slip viscosity	☐ °E ☐ Cp
slip density	Kg/l
slip pH	

PHYSICAL-CERAMICS CHARACTERISTICS

FIRING: electric kiln / electric gradient kiln

				temp. °C	change in dimensions %	water absorption %	remarks
pressed body	moisture content for pressing	%	7.7				
	working pressure	Kg/cm²	300	970°	-2.5	23.1	4 hours
	expansion after pressing	%	0.5				
	green bending strength	Kg/cm²	18.0				
	dry bending strength	Kg/cm²	39.0				
	drying shrinkage	%	0.4				
biscuits	cubic expansion coefficient	10^{-7} °C^{-1}					
	bending strength 970°C	Kg/cm²	67				

established by
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ANNEX III

Piliyandala

15th September, 19[illegible]

To

General Manager - Ceylon Ceramics Corporation

Dr. J.W. Herath - Head/CRDC

STUDY ON BALL CLAYS FROM DEDIYAWELA DEPOSIT - WASKADUWA (South Coast)

1. INTRODUCTION

The Ball Clay Deposit at Dediyawela (Kalutara Area), exploited by the Ceylon Ceramics Corporation, actually supply two different ball clays to the Ceramic Industry of the island. These ball clays, yellow (white - yellow colour) and blue (blue - white colour), are mined and delivered separately to the customers.

The Dediyawela deposit shows, below the overburden (1.5') a yellow ball clay layer (approx. 4.5'), overlaying another layer of blue ball clay (approx. 4 - 5'). Besides, a third type of bal[illegible] clay, a black one, is also present, but not mined. According to the people working on the mine, this type of ball clay is not sp[illegible] homogeneously in the deposit and no data is available on the thi[illegible]ness of this layer.

After drying, the colour of yellow and blue ball clays becomes similar (greyish in colour) and it is very difficult to distingu[illegible] one from the other. Further, the blue clay lumps, after drying, often appear with a yellow surface, probably due to oxidizing re[illegible] [illegible] in contact with the atmosphere. It is clear, that sometim[illegible] because of these colours, misunderstandings can occur during the delivery of the raw clay to the factories.

The purpose of this study, is the comparison of the characteristics of these three types of ball clays (with an additional distinction between blue and blue with yellow surface ball clay), based on the laboratory testings done at the Ceramic Research & Development Centre at Piliyandala. Further, the results obtained were compared with those of an imported ball clay from U.K. (High Cast Ball Clay), actually used in the Piliyandala Factory, in the manufacture of sanitaryware. The comparison between local and imported ball clay was done, taking into consideration the specifications indicated by the supplier of the imported ball clay (the methods used for determining the specifications were not mentioned by the supplier).

2. CHEMICAL AND MINERALOGICAL COMPOSITION

The chemical analysis of the blue ball clays (blue and blue with yellow surface: Annex I) showed exactly the same composition and also the yellow clay appears similar (even the Fe_2O_3 content is only slightly higher in the yellow sample: Annex II). The black ball clay showed a lower content of SiO_2 (2 - 3% less than the others) and Al_2O_3 (2 - 3% less than the others) but a very high loss on ignition (19%), due to the high quantity of organic matter present (Annex II).

The chemical analysis of the High Cast Ball Clay (U.K.) given by the supplier is as follows:

SiO_2	- 52.00 %
Al_2O_3	- 31.00 %
Fe_2O_3	- 1.20 %
TiO_2	- 1.00 %
MgO	- 0.20 %
CaO	- 0.40 %
K_2O	- 2.00 %
Na_2O	- 0.20 %
L.O.I.	- 11.00 %

Please see Annex I and II for comparison.

According to the X-RD analysis (Annex III), the only difference between the two blue ball clay samples is, that one contains kaolinite (main component with quartz in these clays) in Triclinic form and the other in Monoclinic form. The STA (Simultaneous Thermal Analysis) of these two samples (Annex IV), showed again a similar mineralogical composition: kaolinite content between 51% and 53% and a minute quantity of gibbsite. In Annex IV the results of STA testing regarding High Cast Ball Clay done at the CRDC at Piliyandala, showed a kaolinite content of approximately 45%.

Unfortunately, due to technical problems with the equipment, it was not possible to undertake the X-RD and STA analyses of yellow and black ball clays. However, we can expect a similar mineralogical composition for all three different types of ball clays from Dediyawela.

3. PARTICLE SIZE DISTRIBUTION

The particle size study has been divided into two parts:

- wet sieve analysis (fraction greater than 0.063 mm (230 mesh)
- analysis by sedimentation (fraction below 0.063 mm 230 mesh)

The wet sieve analysis of the sand-size particles showed the following values:

		1.	2.	3.	4.
Mesh	mm	% > than	% > than	% > than	% > than
35	0.50	0.14	0.13	0.06	0.18
120	0.125	0.61	0.24	0.13	0.58
230	0.063	1.[illegible]	0.33	0.24	0.84

1. = yellow ball clay
2. = blue ball clay
3. = blue ball clay with yellow surface
4. = black ball clay

The two blue ball clays show the same percentage of sand size particles; the yellow and the black clays show a slightly higher amount (both approx. 1% greater than 230 mesh). However, all these values appear negligible and the samples are similar. The composition of the residues by Optical Microscope examination always showed quartz, carbonaceous fragments (mostly in the black clay) and traces of metallic sulphides (probably pyrite).

From this point, it was decided to consider that there was only one type of blue ball clay (as mentioned earlier, the yellow surface appears only after drying, while the inner area remains blue in colour). The particle size distribution of the fraction below 230 mesh (0.063 mm) is shown in Annexes V and VI.

The blue, yellow and black clays showed almost the same grain size composition for particles bigger than 3 µm. A slight difference occurs for 3 and 2 µm diameters and a larger difference for the size lower than 1 µm: in particular the finest is the blue (79% less than 1 µm) and then the black clay (77.5% less than 1 µm). The yellow ball clay is the most coarse (70.15% less than 1 µm). The High Cast Ball Clay (U.K.) seems coarse when compared with the local ball clays (data given by the supplier):

- 33 % greater than 5 µm
- [illegible]4 % less than 5 µm
- [illegible] % less than 1 µm

4. TECHNOLOGICAL PROPERTIES

The three ball clays were blunged and sieved ([illegible] mesh/0.063 mm) and after preparation of the powders, were pressed in the Pilot Plant at 310 kg/cm^2 (moisture content around 5.5%) into 4 x 4 cm. tiles. These tiles were fired in the gradient kiln up to 1260°C with a cycle of 7h 30min. (from room temperature to the maximum temperature). These tiles were used to check (see Annex VII):-

- dry to fired shrinkage
- water absorption
- colour

According to this test, the complete vitrification point was not obtained but at the maximum temperature, the water absorption was always less than 1%. At the highest temperatures, the blue clay seemed to be the most fusible, but around 1160° - 1170°C, the black ball clay had the lowest value for water absorption (3.0%) and the highest shrinkage (17.5%). In general, the yellow ball clay has a greater refractoriness, when compared with the other two clays. The colour of the three samples is simil the whiteness of the black clay appears to be slightly better than the other two clays and the yellowness of the yellow clay is a little higher when compared with the others. The samples were always of a light and pleasant colour.

Meanwhile, we prepared several bars, by the casting method (water content of clay slip, without deflocculant was around 40 - 45%), to determine bending strength after drying (at 110°C) and after firing (1180°C with 6h 15min firing cycle).

Unfortunately, it was not possible to determine the properties of the ball clays before and after firing, due to the presence of cracks and a considerable warping of the bars, which gave results of no importance.

Loss on ignition (L.O.I.) was repeated using the above bars at 1180°C, the results showed a slightly higher value compared with those determined during chemical analysis (lower temperature): blue ball clay 14.5%, black ball clay 1[illegible]%, yellow ball clay 14.8%.

We repeated the test for checking bending strength (yellow, blue and black ball clay and High Cast ball clay) by the pressing powder method (310 kg/cm^2 - 5% moisture content), at the same firing temperature (1180 ^{o}C).

The dried bending strength test gave the following results:-

	Yellow	Blue	Black	High Cast
kg/cm^2	21.2	23.[illegible]	25.0	18.3

The shrinkage dry - fired confirmed the values obtained by firing in the gradient kiln. A very low contraction was seen in the High Cast ball clay, when compared with the local clays:

	Yellow	Blue	Black	High Cast
% contraction	14.8	10.0	13.2	10.1

Again, it was not possible to check the bending strength of the fired pieces, due to the presence of small cracks. The High Cast ball clay showed no cracks and the value of the bending strenght was 250 kg/cm^2. According to the high level of sintering of local ball clays, we can consider an approximate value of bending strength around 350 - 400 kg/cm^2.

The water absorption determination gave these results:

	Yellow	Blue	Black	High Cast
%	5.0	1.2	2.0	7.1

It is very clear that the High Cast ball clay has a greater refractoriness than the local clays and among this group, the yellow ball clay shows a higher refractoriness when compared to the blue and black clays (which are similar to each other).

Finally, we found out the rheological behaviour of the local ball clays (compared with High Cast clay) by determining the maximum deflocculant demand (using sodium silicate as the deflocculant). Annex VII shows the deflocculating curves (viscosity vs. deflocculant %) of the four samples. According to our laboratory conditions, the lower deflocculant demand is shown by the High Cast ball clay (0.5%), the closest to this figure is the yellow clay (0.7%). The black & blue samples have similar values, around 1%. We can notice also that the yellow clay has the lowest viscosity (at the maximum deflocculant demand) and that around 0.6% of sodium silicate, the yellow clay is better than the High Cast clay. It is possible that the behaviour of the clay, would change remarkably, if another deflocculant (e.g. sodium carbonate, pent- sodium etc., etc.) is used.

5. CONCLUSIONS

This comparative study, permitted to reach a good knowledge regarding the main properties of the Dodiyawela Ball Clays (yellow, blue & black); in particular, it seems that the blue and black clays have similar behaviour and characteristics (they are more plastic, finer particle size composition, lower sintering temperature) and the black clay, actually not mined, probably can be used in a similar manner as the blue clay.

The yellow clay has a slightly higher refractoriness and coarser particle size distribution (mainly in the clay fraction), but in general, its characteristics are not so different from the other two ball clays. The High Cast ball clay shows remarkable differences: high refractoriness, lower plasticity and coarser particle size composition, better reaction with the deflocculant.

Following this general study, it would be advisable to prepare experimental body mixtures, caording to the different technological requirements, using one or another of the ball clays or a blend of them, to check the properties of these clays when mixed with other raw materials (in paricular non plastics).

Finally, it must be noted, that the laboratory results cannot be transf exactly to the production line, because of the change, in the many working parameters, but these results are useful to have a general idea regarding the properties of raw materials and ceramic body mixtures.

M. Corsi

M Corsi

CERAMIC RESEARCH LABORATORY
established by
United Nations Industrial Development Organization (UNIDO)
and Ceylon Ceramics Corporation

Piliyandala

7.5.1986.

Analysis of Ball Clay

(Results of Laboratory order No.1627 given by Mr.Corsi)

	Yellow Ballclay(°)	Bluish Ballclay
SiO_2	44.38	44.45
** Al_2O_3	38.09	38.5
Fe_2O_3	2.16	1.97
CaO	0.22	0.24
MgO	0.52	0.52
Na_2O	0.12	0.12
K_2O	0.766	0.739
LOI	13.74	13.46

(°) Blue ball clay with yellow surface

** This figure indicates the sum of Al_2O_3 and TiO_2. In general content of TiO_2 in BallClays approximately 2% or less than it.

K.A.N.Dharmasiri /Research Officer

ANNEX II

CERAMIC RESEARCH LABORATORY

established by
United Nations Industrial Development Organization (UNIDO)
and Ceylon Ceramics Corporation

Piliyandala

11.8.1986

Results of Laboratory order No. 1806 given by Mr. Corsi

Description of Samples :- 1. Brownish - Black colour ball Clay
2. Yellowish colour Ball Clay (real yellow)
(Both samples were from Dediyawela)

	Black	Yellow
SiO_2	42.1	44.92
Al_2O_3	33.46 (o)	35.45 (o)
Fe_2O_3	2.14	2.27
CaO	0.25	0.31
MgO	0.67	0.71
Na_2O	0.21	0.22
K_2O	0.72	0.74
LOI	18.97	13.83
	98.52	98.45

(o) This figure indicates the content of Al_2O_3 without TiO_2

K.A.N.Dharmasiri
Research Officer / Chemical Laboratory

ANNEX III

CERAMIC RESEARCH LABORATORY

established by
United Nations Industrial Development Organization (UNIDO)
and Ceylon Ceramics Corporation

Piliyandala
28th Feb. 1986.

Results of Laboratory Order No. 1575 given by Dr. M. Corsi

X-RD analysis of Dediyawela Blue & blue with yellow surface clay

The samples were ground in the tretrabor mortar, to obtain the required particle size. then the materials were passed through a 0.050 mm sieve and fixed in the special Al holder to prevent any preferred orientation.

Instrumentation Used

A Philips X-ray Generator - PW 1730/10 at 40 kv and 40 mA
Goniometer Scanning Range - from 5° to 125° : 2θ
Selected full sale counts per second - 5×10^3; 2×10^3
The traces were obtained by using Cr, Kα filtered radiation.

CONCLUSIONS

Diffractograms are attached herewith.
According ot the "d" spaces obtained, the mineralogical compositions are as follows:=

Blue clay

Kaolinite $Al_2Si_2O_5(OH)_4$
- Quartz SiO_2

Gibbsite - $Al(OH)_3$

Blue clay with Yellow surface

Kaolinite Al-Si-O-OH-H_2O
-Quartz SiO_2

Slight indication of Mica & Halloysite

The major difference in the two samples is that the Kaolinite in the Blue Clay is in the Triclinic form and the Kaolinite in the Yellow Clay is in Monoclinic form.

H.W.S.Siritunga
Research Officer

ANNEX IV

Piliyandala

18th November 1986

General Manager,
Ceylon Ceramics Corporation
Colombo 3.

EXPERIMENTS FOR THE TENTATIVE REPLACEMENT OF PYROPHILLITE IN A BODY MIXTURE USED FOR THE PRODUCTION OF GLAZED WALL TILES (WHITE BURNING BODY)

1. INTRODUCTION

Purpose of this study, done at CRDC , Piliyandala, was the tentative replacement, partial or complete , of pyrophillite in the body composition used in the Lanka Walltiles factory, Balangoda , for the production of glazed wall tiles (double firing). At present, the pyrophillite, imported from Korea, is used in large quantities (about 400 tons/month) increasing the production costs and , due to this, it would be very useful to utilize, as much as possible, raw materials available in Sri Lanka.

Besides according to the Balangoda factory Management, at times, the tiles show a water absorption value a little bit higher than that % required by the ASTM Standards. It would be also beneficial to reduce this value at least by 0.5% in the final product. During a visit to the Balangoda factory (May '86), we collected samples of the raw materials used in the body composition as follows:

contd....(2)

- Dediyawela Ball Clay (Yellow type);
- Nattandiya silica sand;
- Korean pyrophillite;
- Balangoda raw kaolin;
- Balangoda calcite;
- biscuit rejects;

and in addition:

- production powder ready for pressing(spray dried);
- 6"x 6" biscuits;
- sodium poliphosphate (penta sodium);
- sodium silicate

2. TESTINGS ON PRODUCTION OF BISCUITS

The following properties were determined on the biscuits which were collected from the Balangoda factory.

- Water absorption;
- Bending strength;
- thermal expansion.

Depending on these results we can distinguish two different groups of tiles:

a) water absorption = 20%
   bending strength = 130 kg/cm^2

b) water absorption = 19%
   bending strength = 155 kg/cm^2

The thermal expansion graph is shown in Annex I. The coefficent of thermal expansion checked in the range 20°C ÷ 500°C is 66.04 $.10^{-7}$ °C^{-1} (this value is slightly lower when compared with the usual values)

contd....(3)

3. PREPARATION OF EXPERIMENTAL BODY MIXTURES AND TESTINGS(FIRST PHASE)

As the working conditions in the factory are different from those of the lab., we decided on the one hand to check the properties of Lanka WallTiles body mixture using the powders, collected before pressing, from the factory (LWL/P) and, on the other hand, using the same composition the tiles were produced under the CRDC conditions (LWL/A) for comparison results.

In the LWL/B composition we tried to reduce the pyrophillite content to 14% (instead of 24% in the present production body mixture)

LWL/C,/E,/F and /H were prepared using local raw materials in different percentages only. LWL/D introduces the Matale Feldspar on a experimental basis.

All the compositions are shown in Annex II.

The body mixtures were ground by the wet method using the ball mill and screened by 0.125mm sieve. The powders obtained, after addition of proper quantity of water by spraying, were pressed in the laboratory press at 310 kg/cm^2(specific pressure) in 4 x 4cm and 4 x 12 cm tiles.

The 4 x 4 cm tiles were fired in the gradient kiln up to 1150°C (4 hours firing cycle from room temperature to maximum temp.) in order to determine the changes in shrinkage and water absorption of the tiles with the increase in temperature.

The 4 x 12cm tiles were used to check the following properties (before and after firing in a small electric kiln)

- expansion after pressing (%) ;
- green bending strength (kg/cm^2);
- Wet to dry shrinkage (%);
- Dry bending strength (kg/cm^2);
- Dry to fired shrinkage(%) ;
- fired bending strength (kg/cm^2);
- water absorption (%)
- loss on ignition (%);

contd........(4)

Subsequently depending on the above determinations, a few body mixtures, were selected. The thermal expansion (fired pieces) of these selected body mixtures and the reaction with the deflocculants used in the Balangoda factory were determined.

RESULTS OF THE FIRST PHASE TESTINGS

All the results were recorded in the technological sheets enclosed.

The moisture content of the powders was always between 6.5 and 7.5%; the LWL/P only (which was ready for pressing in the factory) showed a higher water content (7.8%). The properties of all the different compositions before firing were similar and always good.

The results of the gradient kiln firings in the CRDC (maximum temperature 1150°C but biscuit firing temperature in the Balangoda factory is 1100°C in the tunnel kiln) always showed oscillating values regarding water absorption; this behaviour was due mainly to the presence of calcite (dissociation reaction of carbonates with releasing of carbon dioxide) and too fast firing under laboratory conditions. Dry to fired shrinkage of LWL/P was little lower compared with all the other mixtures (the different results obtained on the same body mixture can be explained by the differences in grinding and preparation of powders in the factory and in the laboratory)

In general, increase in the ball clay content, results of course, in a slight increase in the shrinkage.

In the LWL/D sample, feldspar reacts as flux only at a temperature around 1150°C but not at lower temperatures. However all the compositions have a great stability with the increase of firing temperature. For this reason (great stability) it was decided to fire the 4 x 12 cm tiles not only at 1100°C (same temperature as in the Balangoda factory tunnel kiln) but at 1050°C too. The firing cycle was about 6 h 30 min (from room temperature to the maximum temperature) without soaking time (3 hours soaking time at maximum temperature in the factory).

LWL/A and LWL/B showed similar shrinkage and water absorption; the bending strength is slightly higher in LWL/A (probably due to finer grinding).

It is also very important to note that decreasing the firing temperature by 50°C , we have only very small changes in the technological properties of the tiles, which remain, in any case good. The LWL/P (powder prepared in the factory) had a lower bending strength and shrinkage and a slightly higher water absorption, compared with LWL/A (same composition but different preparation methods) and LWL/B.

The body mixture of LWL/D does not give good results, because the feldspar does not act as a flux at these temperatures (1100°C and 1050°C) and the tiles show a low bending strength. The body compositions, excluding pyrophillite show a deterioration in the technological properties of the tiles: among these, LWL/C is one of the best (considering shrinkage - water absorption - bending strength) but only the shrinkage is similar to the one shown by those bodies prepared with pyrophillite, while water absorption increases and bending strength decreases. The colour of LWL/A and LWL/B is whiter than those prepared without pyrophillite.

The loss on ignition at 1100°C showed an increase with the increase of calcite, ball clay and kaolin content and with the reduction in the content of pyrophillite.

Regarding the behaviour of the different body compositions on the addition of deflocculants (it was decided to check only LWL/A, /B and /C, as the others were not of any interest) the same chemicals were used and the same percentages as in the factory (0.2% pentasodium + 0.33% sodium silicate) and a standard water content of 35%.

The results of this test, which is not an accurate one, are shown in Annex III. All three body compositions had a very good reaction (viscosity around 160 - 190 cP), using the above parameters.

The thermal expansion analyses are shown in Annexes IV (samples fired at 1100°C) and V (samples fired at 1050°C).

The coefficients of thermal expansion (checked in the range of 20 - 500°C) for tiles fired at 1050°C were often a little higher as usual when compared with the others fired at 1100°C ; decreasing the pyrophillite content, we noted a decrease in the thermal expansion. The values of LWL/C were low, compared with the others. LWL/P showed lower coefficients of thermal expansion than LWL/A (influenced mostly by a different grinding method) and LWL/B (these two, at 1050°C and 1100°C , have good values).

5. PREPARATION OF EXPERIMENTAL BODY MIXTURES AND TESTINGS (SECOND PHASE)

Following the first range of testing, we decided to carry out new experiments (second phase) in order to check the possibility of reducing water absorption of the fired pieces, adding a strong flux in the body mixture, which would react at such low temperatures prevalent in the Balangoda factory (feldspar was of no use, in this case).

We next gave our attention to the use of glass reject (already used at the Negombo factory of the CCC, for the manufacture of sanitaryware) and this was introduced as a raw material, first in the present body mixture, used in the production of tiles (LWL/I) and later in the LWL/C composition, then referred to as LWL/L.

Annex VI shows the new experimental compositions -

All tests done on these two new mixtures were the same as those done for the other samples (first phase) and the results are shown in the technological sheets enclosed.

The values obtained on unfired pieces were in the usual range. The gradient kiln firings showed again oscillating results (same reasons explained as in 4.), but the check on 4 x 12 cm tiles permitted us to note that the water absorption was reduced to 18.5% (both in LWL/I and LWL/L) firing at 1100°C. Unfortunately, at the same time, bending strength decreased and shrinkage increased in LWL/I, when compared with LWL/A and when LWL/L was compared with LWL/C, the results were slightly better, but not completely satisfactory.

The deflocculation test (Annex VII) gave again good results.

The thermal expansion of LWL/I showed negligible diference, when compared with LWL/I (Annexes IV and V); in LWL/L the thermal expansion was not determined.

6. CONCLUSIONS

According to the laboratory tests done at the CRDC, Piliyandala, we can conclude as follows:

1. It appears that it would not be possible to replace the pyrophillite in the body mixture totally with local raw materials and to maintain the same quality of the wall tiles.

2. The present body mixture could be changed by decreasing the pyrophillite percentage from 24% to 14% (composition LWL/B) with negligible differences in the properties of the tiles.

3. The biscuit firing temperature could be reduced by 50°C (from 1100°C to 1050°C).

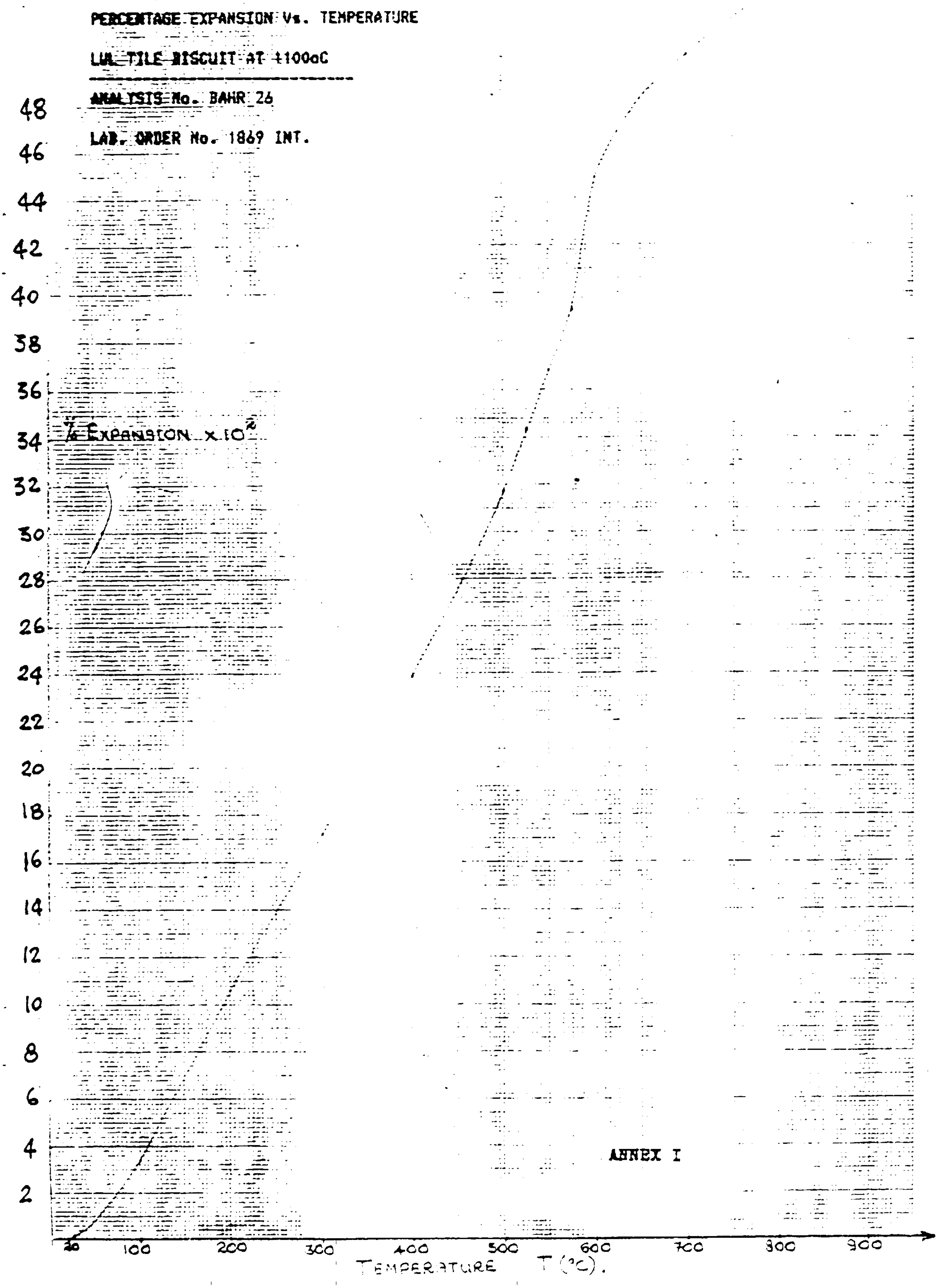
4. Regarding the attempt to reduce the water absorption of the tiles:
   - feldspar did not act as a flux at the low temperatures mentioned.
   - glass rejects, when used reduced the water absorption but some other technological properties (such as bending strength and shrinkage) were affected.

5. In the production of tiles, at present, there seems to be two different groups of tiles (different bending strength and water absorption), probably due to the presence of two different presses in the factory.

It is obvious, that the positive results mentioned in points 2) and 3) have to be confirmed by semi-industrial tests done at the Balangoda Factory, as it is known that laboratory conditions are different from those of the factory.

M. Corsi

M Corsi


PERCENTAGE EXPANSION Vs. TEMPERATURE
LUL TILE BISCUIT AT 1100oC
ANALYSIS No. BAHR 26
LAB. ORDER No. 1869 INT.
% EXPANSION x 10²
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
20
100
200
300
400
500
600
700
800
900
TEMPERATURE T (°C).

ANNEX I

BODY MIXTURE COMPOSITIONS

	LWL/A* %	LWL/B %	LWL/C %	LWL/D %	LWL/E %	LWL/F %	LWL/G %	LWL/H %
Dediyawela Ball clay(yellow type)	34.6	36.6	36.6	39.1	40.0	40.0	40.0	45.0
Balangoda raw Kaolin	10.4	14.4	26.4	14.4	28.0	35.0	23.0	25.0
Balangoda Calcite	13.3	14.8	17.0	14.8	17.0	17.0	17.0	15.0
Nattandiya silica sand	17.5	20.0	20.0	17.5	15.0	8.0	15.0	15.0
Pyrophillite(Korean)	24.2	14.2	-	-	-	-	5.0	-
Matale feldspar	-	-	-	14.2	-	-	-	-
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Biscuit rejects	10	10	10	10	10	10	10	10

* Same composition as LWL/P (production body mixture)

Annex II

country: SRI LANKA — client: LANKA WALLTILES

analyses included — description raw material: LWL/F

differential thermal ☐ — X ray diffraction ☐
thermogravimetric ☐ — particle size distribution ☐
green dilatometry ☐ — rheological behaviour ☐

MINERALOGICAL ANALYSIS

kaolinite	
chlorite	
fire-clay	
halloysite	
illite	
montmorillonite	
vermiculite	
other	
clayey components	

RAW MATERIALS

Dedivawala ball clay	34.
Balangoda raw kaolin	10.
Balangoda calcite	15.
Nattandiya silica sand	17.
Korean pyrophillite	24.
TOTAL	100
Biscuit rejects	10

description: Powders collected in the Balangoda factory before pressing.

total carbonates % —
organic matter % —
total soluble salts % —

residue on sieves (mesh): 80 —; 170 —; 230 —

POWDER PREPARATION

ball mill ☐
stirrer ☐
hammer mill ☐
cone crusher ☐

of screen — mesh

SLIP CHARACTERISTICS

slip water %
type of electrolyte
electrolyte content %
slip viscosity Cp
slip density Kg/l
slip pH

PHYSICAL-CERAMICS CHARACTERISTICS

FIRING: electric kiln; electric gradient kiln X

moisture content for pressing	%	7.8
working pressure	Kg/cm²	310
expansion after pressing	%	0.4
green bending strength	Kg/cm²	14.4
dry bending strength	Kg/cm²	28.9
drying shrinkage	%	0
expansion coefficient 1050°C	10⁻⁷ °C⁻¹	58.13
expansion coefficient 1100°C		64.17
bending strength 1050°C	Kg/cm²	159.5
bending strength 1100°C		170
1100°C	%	10.1

temp. °C	change in dimensions %	water absorption %	remarks
1150°	-0.5	19.8	
1125°	-0.4	20.3	
1090°	-0.4	20.5	
1050°	-0.4	19.9	
1010°	-0.4	19.7	
970°	-0.3	19.7	
940°	-0.3	19.8	

water absorption % 20.2 (1050°C) 19.4 (1100°C)
dry-fired shrinkage [illegible] (1050°C) [illegible] (1100°C)

country	client
SRI LANKA	LANKA TILES

analyses enclosed / description raw material

differential thermal	☐	X ray diffraction	☐	LWL/A
thermogravimetric	☐	particle size distribution	☐	
green dilatometry	☐	rheological behaviour	☐	

CHEMICAL ANALYSIS %		MINERALOGICAL ANALYSIS		RAW MATERIALS	
SiO_2		kaolinite		Dediyawela ball clay	34.6
Al_2O_3		chlorite		Balangoda raw kaolin	10.4
Fe_2O_3		fire-clay		Balangoda calcite	13.3
TiO_2		halloysite		Kottaniiya silica sand	17.5
CaO		illite		Korean pyrophillite	24.2
MgO		montmorillonite			
		vermiculite			
K_2O		other		TOTAL	100
		clayey components		Biscuit rejects	10

description

total carbonates	%	residue on seives (mesh) 80	
organic matter	%	120	
total soluble salts	%	230	

POWDER PREPARATION

ball mill	X
stirrer	☐
hammer mill	☐
cone crusher	☐
control screen mesh	
residue %	

SLIP CHARACTERISTICS

slip water	%	35
type of electrolyte	sodium silicate 0.33%	
electrolyte content	penta sodium 0.2%	
slip viscosity	X Cp	160
slip density	Kg/l	
slip pH		

PHYSICAL-CERAMICS CHARACTERISTICS

moisture content for pressing	%	7.1
working pressure	Kg/cm²	310
expansion after pressing	%	0.4
green bending strength	Kg/cm²	13.3
dry bending strength	Kg/cm²	24.0
drying shrinkage	%	0
expansion coefficient 1050°C	10^{-7} °C⁻¹	72.29
expansion coefficient 1100°C		71.88
bending strength 1050°C	Kg/cm²	190.5
bending strength 1100°C		203.8
LI 1100°C	%	10.2

FIRING — electric kiln / electric gradient kiln X

temp. °C	change in dimensions %	water absorption %	remarks
1150°	-0.7	19.7	
1125°	-0.6	20.0	
1090°	-0.6	20.8	
1050°	-0.5	20.4	
1010°	-0.4	20.7	
970°	-0.4	20.9	
940°	-0.4	20.7	

Water absorption 19.9 (1050°C) 19.2 (1100°C)
dry-fired shrinkage 0.7 (1050°C) 0.7 (1100°C)

country: SRI LANKA
client: LANKA WALLTILES

analyses enclosed | description raw material

- differential thermal ☐
- thermogravimetric ☐
- green dilatometry ☐
- X ray diffraction ☐
- particle size distribution ☐
- rheological behaviour ☐

LWL/B

ICAL ...318	%	MINERALOGICAL ANALYSIS	
		kaolinite	
		chlorite	
		fire clay	
		halloysite	
		illite	
		montmorillonite	
		vermiculite	
		other	
		clayey components	

RAW MATERIALS	
Dediyawela ball clay	36.[illegible]
Balangoda raw kaolin	14.[illegible]
Balangoda calcite	13.[illegible]
Nattandiya silica sand	17.[illegible]
Korean pyrophillite	14.2
TOTAL	100
Biscuit rejects	10

...ription

total carbonates %	
organic matter %	
total soluble salts %	

residue on seives (mesh)	
80	
120	
230	

POWDER PREPARATION

- ball mill ☐
- stirrer ☐
- hammer mill ☐
- cone crusher

...l screen   mesh

...ue

SLIP CHARACTERISTICS

slip water	%	35
type of electrolyte	sodium silicate penta sodium	0.35% 0.2 %
electrolyte content	%	
slip viscosity	K,Cp	160
	Kg/l	

PHYSICAL CERAMIC CHARACTERISTICS

moisture content for pressing	%	7.5
working pressure	Kg/cm²	310
expansion after pressing	%	0.4
green bending strength	Kg/cm²	15.9
dry bending strength	Kg/cm²	25.5
drying shrinkage	%	0
expansion coefficient 1050°C	10^{-7} °C	68.33
expansion coefficient 1100°C	10^{-7} °C	71.88
bending strength 1050°C	Kg/cm²	176.3
bending strength 1100°C	Kg/cm²	18[illegible].2
...L. 1100°C	%	11.2

electric kiln
electric gradiant kiln X

temp. °C	change in dimensions %	water absorption %	remarks
1150°	-0.7	20.5	
1125°	-0.7	20.6	
1090°	-0.6	20.8	
1050°	-0.5	19.9	
1010°	-0.4	20.5	
970°	-0.4	20.7	
940°	-0.4	21.1	

water absorption 19.7 (1050°C) 1[illegible] (1100°C)
dry-fired shrinkage [illegible]

country: [illegible] client: [illegible]

analyses enclosed — description raw material: [illegible]

differential thermal	☐	X ray diffraction	☐
thermogravimetric	☐	particle size distribution	☐
green dilatometry	☐	rheological behaviour	☐

MINERALOGICAL ANALYSIS

kaolinite	
chlorite	
fire-clay	
halloysite	
illite	
montmorillonite	
vermiculite	
other	
clayey components	

RAW MATERIALS

[illegible] ball clay	[illegible]
[illegible] raw kaolin	26.[illegible]
[illegible] calcite	17
[illegible] silica sand	20
TOTAL	100
biscuit rejects	10

total carbonates %	
organic matter %	
total soluble salts %	

residue on seives (mesh)	
80	
120	
230	

POWDER PREPARATION

ball mill	☒
stirrer	☐
hammer mill	☐
cone crusher	

screen — mesh

SLIP CHARACTERISTICS

slip water	%	35
type of electrolyte	sodium silicate	0.33 %
electrolyte content	~~penta sodium~~	~~0.2 %~~
slip viscosity	Cp	190
density	Kg/l	

PHYSICAL CERAMIC CHARACTERISTICS

kiln / gradient kiln X

			T °C	change in dimensions %	water absorption %	remarks
moisture content for pressing		[illegible].7				
working pressure	Kg/cm²	310	1150°	-0.6	21.3	
expansion after pressing	%	[illegible].4	1125°	-0.6	21.8	
green bending strength	Kg/cm²	15.3	1090°	-0.6	21.2	
dry bending strength	Kg/cm²	23.4	1050°	-0.5	20.6	
drying shrinkage	%	0	1010°	-0.5	21.0	
expansion coefficient 1050°C		64.7[illegible]	970°	-0.4	20.3	
expansion coefficient 1100°C		60	940°	-0.4	20.0	
bending strength 1050°C	Kg/cm²	114.5				
bending strength 1100°C	Kg/cm²	139				
L. 1100°C	%	12.3				
~~water absorption~~		[illegible] (1050°C)		[illegible] (1100°C)		
dry-fired shrinkage	%	0.5 "		0.6 "		

country: SRI LANKA | client: LANKAWALLTILES

analyses enclosed | description raw material

- differential thermal ☐
- thermogravimetric ☐
- green dilatometry ☐
- X ray diffraction ☐
- particle size distribution ☐
- rheological behaviour ☐

LWL/D

...ICAL ...YSIS	%	MINERALOGICAL ANALYSIS	
...O_2		kaolinite	
...O_3		chlorite	
...O_3		fire-clay	
...O_3		...illoysite	
...O		illite	
...O		montmorillonite	
...O		vermiculite	
...O		other	
		clayey components	

RAW MATERIALS	
Dedivawela ball clay	39.[illegible]
Balangoda raw kaolin	14.[illegible]
Bala-ngoda calcite	14.[illegible]
Nattandiya silica sand	17.[illegible]
Matale feldspar	14.2
TOTAL	100
Biscuit rejects	10

...ription

total carbonates	%	
organic matter	%	
total soluble salts	%	

residue on seives (mesh)	
80	
120	
230	

POWDER PREPARATION

ball mill	☒
stirrer	☐
hammer mill	
cone crusher	☐
...al screen mesh	
...e %	

SLIP CHARACTERISTICS

slip water	%	
type of electrolyte		
electrolyte content	%	
slip viscosity	Cp	
slip density	Kg/l	
slip pH		

PHYSICAL-CERAMICS CHARACTERISTICS

moisture content for pressing	%	6.8
working pressure	Kg/cm²	310
expansion after pressing	%	0.4
green bending strength	Kg/cm²	13.9
dry bending strength	Kg/cm²	23.8
drying shrinkage	%	0
expansion coefficient	10⁻⁷/°C	
bending strength 1050°C	Kg/cm²	89.6
1100°C		101.2
L.L. 1100°C	%	10.8
water absorption		20.3 (1050°C)
dry-fired shrinkage	%	0.4

FIRING — electric kiln / electric gradient kiln X

temp. °C	change in dimensions %	water absorption %	remarks
1150°	-1.7	18.3	
1125°	-0.9	19.7	
1090°	-0.7	20.4	
1050°	-0.6	20.0	
1010°	-0.5	19.6	
970°	-0.5	20.3	
940°	-0.5	20.2	

[illegible] (1100°C) 0.6

country: SRI LANKA | client: LANKA WALLTILE

analyses enclosed | description raw material

- differential thermal ☐
- thermogravimetric ☐
- green dilatometry ☐
- X ray diffraction ☐
- particle size distribution ☐
- rheological behaviour ☐

LWL/E

CHEMICAL ANALYSIS	%
O₂	
O₃	
O₃	
O₃	
O	
O	
O	
O	
O	
description	

MINERALOGICAL ANALYSIS	
kaolinite	
chlorite	
fire clay	
halloysite	
illite	
montmorillonite	
vermiculite	
other	
clayey components	

RAW MATERIALS	
Dediyawela ball clay	40
Balangoda raw kaolin	28
Balangoda calcite	17
Nattandiya silica sand	15
TOTAL	100
Biscuit rejects	10

total carbonates	%
organic matter	%
total soluble salts	%

residue on seives (mesh)	%
80	
120	
230	

POWDER PREPARATION

ball mill	X
stirrer	☐
hammer mill	
cone crusher	
screen	mesh
	%

SLIP CHARACTERISTICS

slip water	%
type of electrolyte	
electrolyte content	%
slip viscosity	Cp
slip density	Kg/l
slip pH	

PHYSICAL-CERAMIC CHARACTERISTICS

moisture content for pressing	%	6.8
working pressure	Kg/cm²	310
expansion after pressing	%	0.4
green bending strength	Kg/cm²	14.8
dry bending strength	Kg/cm²	33.2
drying shrinkage	%	+0.1
expansion coefficient	10⁻⁷/°C	
bending strength 1050°C	Kg/cm²	106.6
bending strength 1100°C	Kg/cm²	127.6
FL 1100°C	%	13.1
water absorption	%	20.8 (1050°C) 19.[illegible] (1100°C)
dry-fired shrinkage	%	0.6 / 0.7

FIRING — electric kiln; electric gradient kiln X

temp °C	change in dimensions %	water absorption %	remarks
1150°	-0.7	20.9	
1125°	-0.7	21.4	
1090°	-0.7	21.4	
1050°	-0.7	20.7	
1010°	-0.7	19.7	
970°	-0.6	20.4	
940°	-0.[illegible]	19.5	

country: .RI LANKA | client: LANKA [illegible]

analyses enclosed | description raw material

differential thermal	☐	X ray diffraction	☐	LWL/F
thermogravimetric	☐	particle size distribution	☐	
green dilatometry	☐	rheological behaviour	☐	

CHEMICAL ANALYSIS	%	MINERALOGICAL ANALYSIS		RAW MATERIALS	
O_2		kaolinite		Dediyawela ball clay	40
O_3		chlorite		Balangoda raw kaolin	35
O_2		fireclay		Balangoda calcite	17
O_3		halloysite		Nattandiya silica sand	8
O		illite			
O		montmorillonite			
O		vermiculite			
O		other		TOTAL	100
		clayey components		Biscuit rejects	10

description

			residue on sieves (mesh)	
total carbonates	%		80	
organic matter	%		120	
total soluble salts	%		230	

POWDER PREPARATION

ball mill	X
stirrer	☐
hammer mill	☐
cone crusher	

SLIP CHARACTERISTICS

slip water	%	
type of electrolyte		
electrolyte content	%	
slip viscosity	cP	
density	Kg/l	

... screen ... mesh

...ue

PHYSICAL CERAMIC CHARACTERISTICS — firing: electric gradient kiln X

			temp °C	change in dimensions %	water absorption %	remarks
moisture content for pressing	%	5.5				
working pressure	Kg/cm²	310	1150°	-1.0	21.3	
expansion after pressing	%	0.4	1125°	-1.0	21.0	
green bending strength	Kg/cm²	16.4	1090°	-1.0	21.4	
dry bending strength	Kg/cm²	35.7	1050°	-1.0	20.9	
drying shrinkage	%	+0.1	1010°	-0.9	19.5	
expansion coefficient	10^{-7}/°C		970°	-0.9	19.0	
bending strength 1050°C	Kg/cm²	151.6	940°	-0.9	20.0	
bending strength 1100°C	Kg/cm²	168.3				
T.L. 1100°C	%	14.4				

water absorption % 20.5 (1050°C) 19.4 (1100°C)

dry-fired shrinkage % 1.1 ... 1.2

country	client
SRI LANKA	LANKA WALLTILES

analyses enclosed — description raw material: LWL/G

differential thermal	☐	X ray diffraction	☐
thermogravimetric	☐	particle size distribution	☐
green dilatometry	☐	rheological behaviour	☐

MINERALOGICAL ANALYSIS: kaolinite, chlorite, fire-clay, halloysite, illite, montmorillonite, vermiculite, other, clayey components

RAW MATERIALS

Raw material	%
Dediyawala ball clay	40
Balangoda raw kaolin	23
Bala-ngoda calcite	17
Nattandiya silica sand	15
Korean pyrophillite	5
TOTAL	100
Biscuit rejects	10

total carbonates %; organic matter %; total soluble salts %

residue on sieves (mesh): 80, 120, 230

POWDER PREPARATION: ball mill ☒; stirrer ☐; hammer mill ☐; cone crusher ☐

SLIP CHARACTERISTICS: slip water %; type of electrolyte; electrolyte content %; slip viscosity Cp; density Kg/l; pH

PHYSICAL-CERAMICS CHARACTERISTICS

FIRING: electric kiln; electric gradient kiln X

moisture content for pressing	%	6.5
working pressure	Kg/cm²	310
expansion after pressing	%	0.4
green bending strength	Kg/cm²	14.6
dry bending strength	Kg/cm²	27.7
drying shrinkage	%	0
expansion coefficient	10⁻⁷ °C⁻¹	
bending strength 1050°C	Kg/cm²	126.1
bending strength 1100°C	Kg/cm²	141.9
TL 1100°C		13.4

temp °C	change in dimensions %	water absorption %	remark
1150°	-0.9	20.5	
1125°	-0.7	20.9	
1090°	-0.7	20.6	
1050°	-0.7	19.2	
1010°	-0.7	19.6	
970°	-0.6	19.3	
940°	-0.6	20.3	

water absorption — 20 (1050°C) — 19.2 (1100°C)

[illegible] — 0.7 — 0.9

place	country	client	n.
	SRI LANKA	LANKA WALLTILES	

analyses enclosed — description raw m...

differential thermal	☐	X ray diffraction	☐
thermogravimetric	☐	particle size distribution	☐
green dilatometry		rheological behaviour	☐

LWL/H

CHEMICAL ANALYSIS	%	MINERALOGICAL ANALYSIS		RAW MATERIALS	
SiO_2		kaolinite		Dediyawela ball clay	45
Al_2O_3		chlorite		Balangoda raw kaolin	25
TiO_2		fire clay		Balangoda calcite	15
Fe_2O_3		halloysite		Nattandiya silica sand	15
CaO		illite			
MgO		montmorillonite			
K_2O		vermiculite			
Na_2O		other		TOTAL	100
LL		clayey components		Biscuit rejects	10
SO_3					

description

			residue on sieves (mesh)	
total carbonates	%			
organic matter	%		80	
total soluble salts	%		170	
			230	

POWDER PREPARATION

wet	ball mill	☒
	stirrer	☐
dry	hammer mill	☐
	cone crusher	☐
control screen	mesh	
residue	%	

SLIP CHARACTERISTICS

slip water	%
type of electrolyte	
electrolyte content	%
slip viscosity	☐ E ☐ Cp
slip density	Kg/l
slip pH	

PHYSICAL-CERAMICS CHARACTERISTICS

FIRING: electric kiln; electric gradient kiln X

			temp °C	change in dimensions %	water absorption %
moisture content for pressing	%	5.5			
working pressure	Kg/cm²	310	1150°	-1.2	20.6
expansion after pressing	%	0.4	1125°	-1.1	21.0
green bending strength	Kg/cm²	17.1	1090°	-1.0	20.8
dry bending strength	Kg/cm²	33.0	1050°	-0.9	19.6
drying shrinkage	%	0	1010°	-0.9	20.0
			970°	-0.9	19.5
expansion coefficient	10^{-7}/°C		940°	-0.7	12.3
bending strength 1050°C / 1100°C	Kg/cm²	109.8 / 156.1			
LL 1100°C		[illegible].4			
water absorption	%	19.5 (1050°C)			[illegible].3 (1100°C)
drying shrinkage		[illegible]			

name | country | client | n.

analyses enclosed | description raw ma

differential thermal	☐	X ray diffraction	☐
thermogravimetric	☐	particle size distribution	☐
green dilatometry	☐	rheological behaviour	☐

CHEMICAL ANALYSIS	%	MINERALOGICAL ANALYSIS		RAW MATERIALS	
SiO_2		kaolinite		Dediyawela ball clay	34.
Al_2O_3		chlorite		Balangoda raw kaolin	10.
TiO_2		fire clay		Balangoda calcite	13.
Fe_2O_3		halloysite		Nattandiya silica sand	17.
CaO		illite		Pyrophillite (Korean)	24.
MgO		montmorillonite			
K_2O		vermiculite			
Na_2O		other		TOTAL	100
L.L.		clayey components		Biscuit rejects	7
SO_3				Glass rejects	3

description

			residue on sieves (mesh)	
total carbonates	%			
organic matter	%		80	
total soluble salts	%		120	
			230	

POWDER PREPARATION

	ball mill	☑
	stirrer	☐
	hammer mill	☐
	cone crusher	☐

control screen mesh

residue

SLIP CHARACTERISTICS

slip water		% 35
type of electrolyte	sodium silicate	0.35%
	penta sodium	0.2%
electrolyte content		%
slip viscosity		Cp 190
slip density		Kg/l
pH		

PHYSICAL-CERAMIC CHARACTERISTICS | FIRING | electric kiln / electric gradient kiln X

			temp	change dimensions	water absorption %	re
moisture content for pressing		5.6				
working pressure		310	1150°	-1.0	19.8	
expansion after pressing	%	0.4	1125°	-0.9	20.6	
green bending strength	Kg/cm²	13.7	1090°	-0.7	19.6	
dry bending strength	Kg/cm²	23.4	1050°	-0.7	20.3	
drying shrinkage	%	0	1010°	-0.7	20.1	
expansion coefficient 1050°C	10^{-7} °C	71.46	970°	-0.7	19.6	
expansion coefficient 1100°C		72.	940°	-0.7	19.8	
bending strength 1050°	Kg/cm²	156.7				
bending strength 1100°		177.6				
L.L. 1100°C	%	10.4				

Water absorption 19.4 (1050°C) 17.5 (1100°C)

dry-fired shrinkage % 0.7 " 0.85 "

country: SRI LANKA — client: LANKA WALLTILES

analyses enclosed — description raw material

differential thermal	☐	X ray diffraction	☐	LWL/L
thermogravimetric	☐	particle size distribution	☐	
green dilatometry	☐	rheological behaviour	☐	

MINERALOGICAL ANALYSIS	%
kaolinite	
chlorite	
fire-clay	
...oysite	
illite	
montmorillonite	
vermiculite	
other	
clayey components	

RAW MATERIALS	
Dediyawela ball clay	36.[illegible]
Balangoda raw kaolin	26.[illegible]
Balangoda calcite	17
Nattandiya silica sand	20
TOTAL	100
Biscuit rejects	7
Glass rejects	3

total carbonates %	
organic matter %	
total soluble salts %	

residue on sieves (mesh)	
80	
120	
230	

POWDER PREPARATION

ball mill	☒
stirrer	☐
hammer mill	☐
cone crusher	☐
...l screen mesh	
...e %	

SLIP CHARACTERISTICS

slip water %	35
type of electrolyte	sodium silicate 0.33% penta sodium 0.2 %
electrolyte content %	
slip viscosity ...E Cp	180
slip density Kg/l	
slip pH	

PHYSICAL-CERAMIC CHARACTERISTICS

moisture content for pressing	%	5.7
working pressure	kg/cm²	310
expansion after pressing	%	0.4
green bending strength	Kg/cm²	14.5
dry bending strength	Kg/cm²	23
drying shrinkage	%	0
expansion coefficient 1050°C	10^{-7} °C⁻¹	115.4
bending strength 1100°C	kg/cm²	148.5
...L 1100°C		12.2

FIRING — electric kiln; electric gradient kiln X

temp °C	change in dimensions %	water absorption %	remark
1150°	-0.6	21.5	
1125°	-0.6	21.8	
1090°	-0.5	20.9	
1050°	-0.[illegible]	20.4	
1010°	-0.5	20.2	
970°	-0.5	19.7	
940°	-0.5	19.3	

water absorption 2[illegible] (1050°C) 19.5 (1100°C)
dry-fired shrinkage % 0.65 0.75

Results of Laboratory Ordet No. 1981 given by Mr.M.Corsi

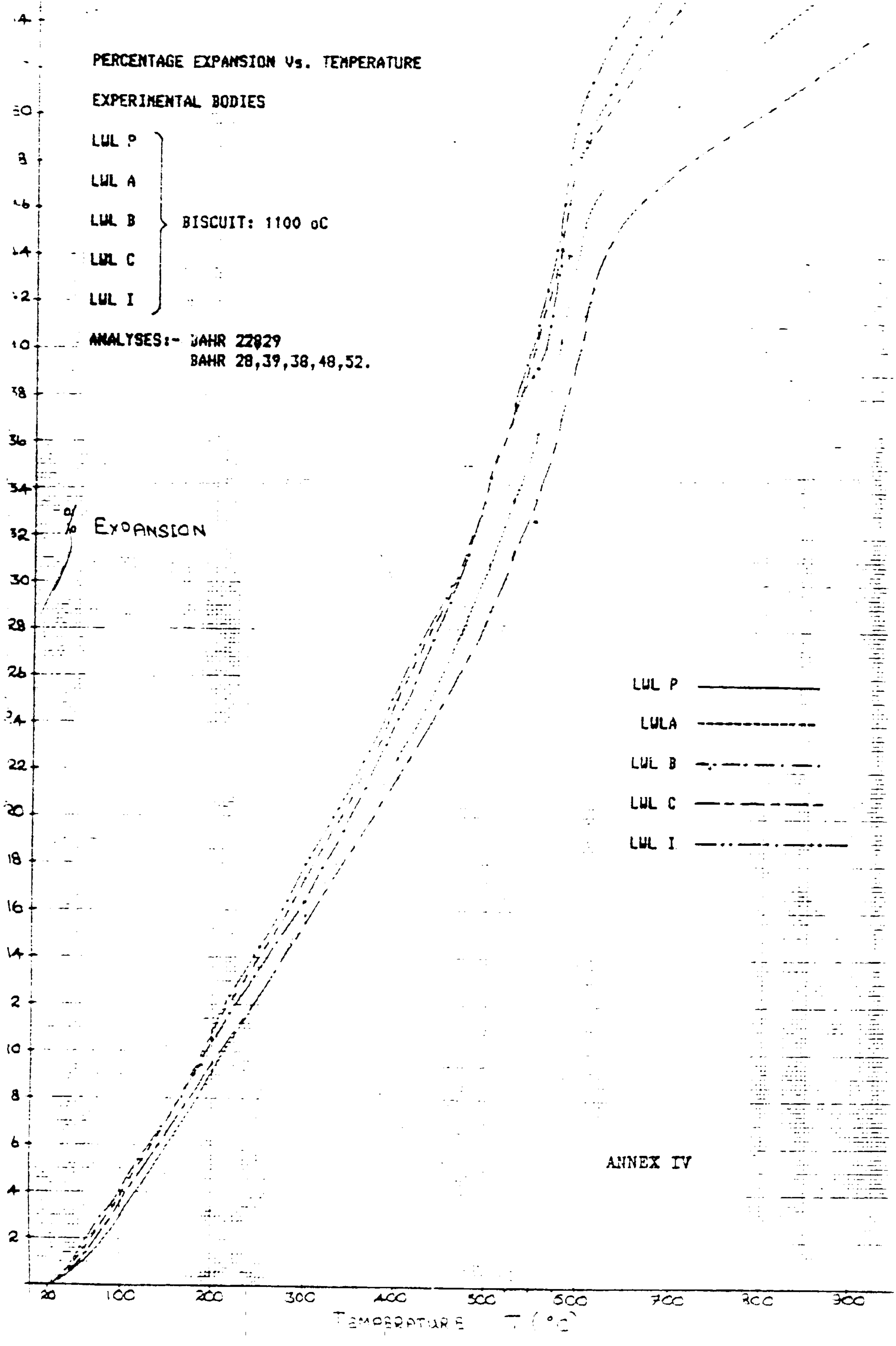
Sample	Viscosity(cP)
LWL A	160
LWL B	160
LWL C	190

Sodium Silicate = 0.33%
Penta Sodium = 0.2%
Water content of silp = 35%

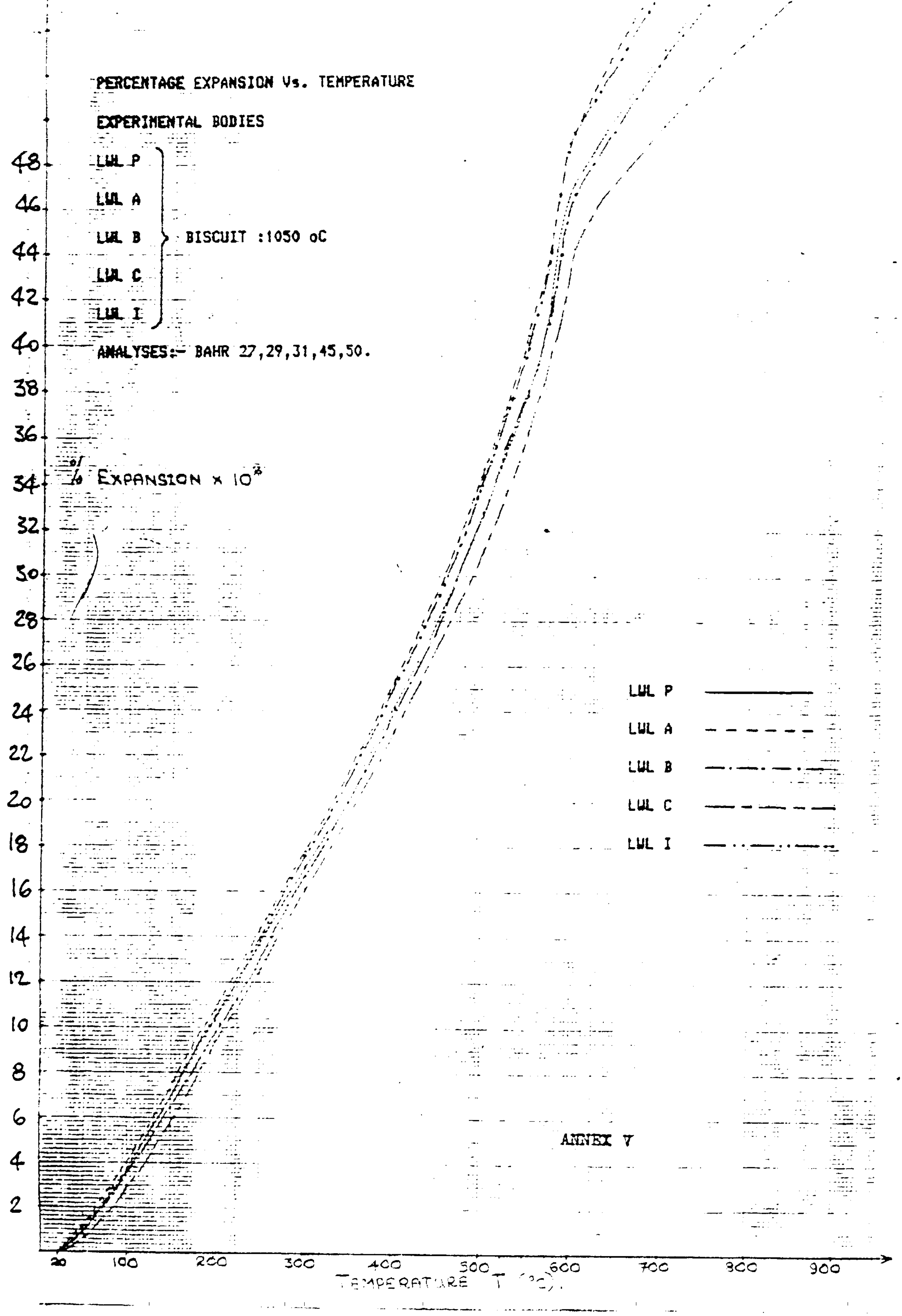
G.M.A.G.B.Gaspe

Research Officer - Pilot Plant

13th Nov.1986


PERCENTAGE EXPANSION Vs. TEMPERATURE
EXPERIMENTAL BODIES
LUL P
LUL A
LUL B
LUL C
LUL I
BISCUIT: 1100 oC
ANALYSES:- BAHR 22829
BAHR 28,39,38,48,52.
% EXPANSION
LUL P
LULA
LUL B
LUL C
LUL I
TEMPERATURE T (°C)

ANNEX IV


PERCENTAGE EXPANSION Vs. TEMPERATURE
EXPERIMENTAL BODIES
LWL P
LWL A
LWL B
LWL C
LWL I
BISCUIT :1050 oC
ANALYSES:- BAHR 27,29,31,45,50.
% EXPANSION x 10
TEMPERATURE T (°C)
LWL P
LWL A
LWL B
LWL C
LWL I

ANNEX V

	LWL/I (°) %	LWL/L (°°) %
Dediyawala ball clay	34.6	36.6
Balangoda raw kaolin	10.4	26.4
Balangoda calcite	13.3	17
Nattandiya silica sand	17.5	20
Korean pyrophillite	24.2	-
	100	100
Biscuit rejects	7	7
Glass rejects	3	3

(°) Same composition as LWL/A but with addition of glass rejects
(°°) " " " LWL/C " " " " " "

Annex VI

Results of Laboratory Order No. 1981 given by Mr.M.Corsi

Sample	Viscosity (cP)
I	190
L	180

Sodium Silicate = 0.33%

Penta Sodium = 0.2%

Water content of slip = 35%

G.M.A.G.B.Gaspe

Research Officer - Pilot Plant

13th Nov.1986

CERAMIC RESEARCH LABORATORY

established by
United Nations Industrial Development Organization (UNIDO)
and Ceylon Ceramics Corporation

Piliyandala

5th March, 1986.

Result of Laboratory Order No.1567 given by Mr. Sarath Silva

Samples: - 1. High Cast Ball Clay

2. Dediyawela Ball Clay (Blue)

3. Dediyawela Ball Clay (Blue with yellow surface)

Test:- Simultaneous Thermal Analysis

Procedure:- Samples were collected from the Piliyandala Factory. Care was taken to collect representative samples. three samples were dried and ground separately under identical conditions. Samples were kept in a desiccator, until they were subjected to analyses.

In this analyses only the heating-up program was taken into consideration.

Instrumental Parameters

TG Measuring Range = 50 mg.

DTA Measuring Range = 100 μV

Derivation Measuring Range = 100 μV; Filter 4

$X_p = 4$, $T_n = 5$

Heating Rate = $10^{\circ} C\ min^{-1}$

Final Temperature = $1050^{\circ}C$

Results

1. High Cast Ball Clay - (see curve STA 99)

Weight of sample used = 99 mg.

Evaporation of physical water was observed around $70^{\circ}C$. Characteristic endothermic peak of dehydration of Kaolinites was registered at $560^{\circ}C$. This peak attributes a loss of weight of 6.2 mg. Also and exothermic peak at $975^{\circ}C$ represents the Metakaolinites ⟶ Mullites formation.

Any other minerals were not indicated on the DTA curve. Weight loss that has taken place at $560^{\circ}C$ showed a kaolinite content of 45% in the sample.

In order to check the repeatability of the result, the same analysis was carried out once again. (see

Order No.1567 (contd.)

Piliyandala

curve STA 100) this analysis also showed a kaolinite content of 45.5%.

Possible Reactions

$$\text{Kaolinites} \xrightarrow{560^{\circ}C} \text{Metakaolinites}$$
$$\text{Metakaolinites} \xrightarrow{980^{\circ}C} \text{Mullites}$$

2. Dediyawela Ball Clay (Blue) - (see curve STA 101)

Weight of the sample used = 101 mg.
a small endothermic peak was observed at 290°C. Then the characteristic peaks of kaolinites (an endotherm at 560°C and an exotherm at 965°C) were also observed. A very small inflection was registered on the DTA curve at 490°C, at the very beginning of the endotherm of Kaolinites ---→ Metakaolinit formation. Endothermic peak at 290°C and the inflection at 490°C may be attributed to the presence of Gibbsite. However, Gibbsite gave a very weak signal on the curve.
Kaolinite content of this sample was found to be 51%. Repeated analysis of the same sample showed a kaolinite content of 52% (see curve STA 103).

Possible Reactions:-

$$\underset{\gamma - Al(OH)_3}{\text{Gibbsite}} \xrightarrow{290^{\circ}C} \underset{\gamma - AlOOH}{\text{Boehmite}}$$
$$\underset{\gamma - AlOOH}{\text{Boehmite}} \longrightarrow \gamma - Al_2O_3$$
$$\text{Kaolinites} \xrightarrow{560^{\circ}C} \text{Metakaolinites}$$
$$\text{Metakaolinites} \xrightarrow{965^{\circ}C} \text{Mullites}$$

X-RD analyses also indicates the presence of Gibbsite, in this sample.

3. Dediyawela Ball clay (yellow)* -(see curve STA 104)
Weight of the sample used = 103 mg.
This sample showed a mineralogical composition similar to that of the Blue colour clay sample. Weight loss due to the kaolinite ------→ Metakaolinite formation showed a

Pilliyandala

Order No. 1567 (contd.)

kaolinite content of 53%. the content of Gibbsite in this sample was found to be lower than that of the blue colour sample.

Summary of Results

Sample	Graph	Kaolinite content	Gibbsite **
High Cast Ball Clay	STA99	45%	nil
High Cast Ball Clay (repeated)	STA100	45.5%	nil
Dediyawela Ball Clay (Blue)	STA 101	51.0%	yes
Dediyawela Ball Clay (Blue) (repeated)	STA 103	52.0%	yes
Dediyawela Ball Clay (yellow)	STA 104	53.0%	yes

* Only the surface of the lump of clay was yellow. The interior of the lump was grey in colour

** The peak corresponding to Gibbsite of the Dediyawela Clays was small in comparison to the High Cast Ball Clay. High Cast Ball Clay appears to have a higher content fo organic matter, than Dediyawela Ball Clay.

In addition to the above results, I would like to give results of the previous analyses on Ball Clays.

Sample	Date	Graph No.	Kaolinite Content	Gibbsi
High Cast Ball Clay	20/09/85	STA 76	50.6%	nil
Dediyawela Ball Clay	18/09/85	STA 74	54.0%	yes
Lanka San Shread Ball Clay	23/12/85	STA 85	49.0%	nil
EWVA Ball Clay	20/09/85	STA 75	74.6%	nil
EWVA Ball Clay	23/12/85	STA 86	60.6%	nil

C. Ranatunga
Research Officer

ANNEX V

CENTRE

CERAMIC RESEARCH LABORATORY

established by
United Nations Industrial Development Organization (UNIDO)
and Ceylon Ceramics Corporation

Piliyandala

14/8/86.

Test Results of Laboratory Order No. 1805 given by Mr. M. Corsi

Particle Size Analysis of Dediyawela Yellow and Black Ball Clays

Particle Size Diameter less than um	Dediyawela Ball Clay-Yellow	Dediyawela Ball Clay-Black
40	98.79 %	98.80 %
20	98.03 %	98.25 %
15	97.52 %	97.62 %
10	97.07 %	97.25 %
5	95.78 %	95.80 %
3	91.20 %	92.00 %
2	87.00 %	88.50 %
1	70.15 %	77.50 %
Residue on 0.063 mm sieve	0.77 %	0.82 %

A.S. Pannila
Research Officer

ANNEX VI

Test results of Laboratory order No 1863 given by Mr.Corsi

Particle size analysis of Dediyawela Blue Ballclay.

Particle size Diameter less than um	Dediyawela Blue Ball Clay
40	98.80
20	98.15
15	97.60
10	97.00
5	96.00
3	92.50
2	89.15
1	79.00

Residue on 0.063 mm sieve is 0.50 %

A.S.Pannila
Research Officer -Physical Laboratory

Results of Laboratory order No. 1891 given by Mr.Corea

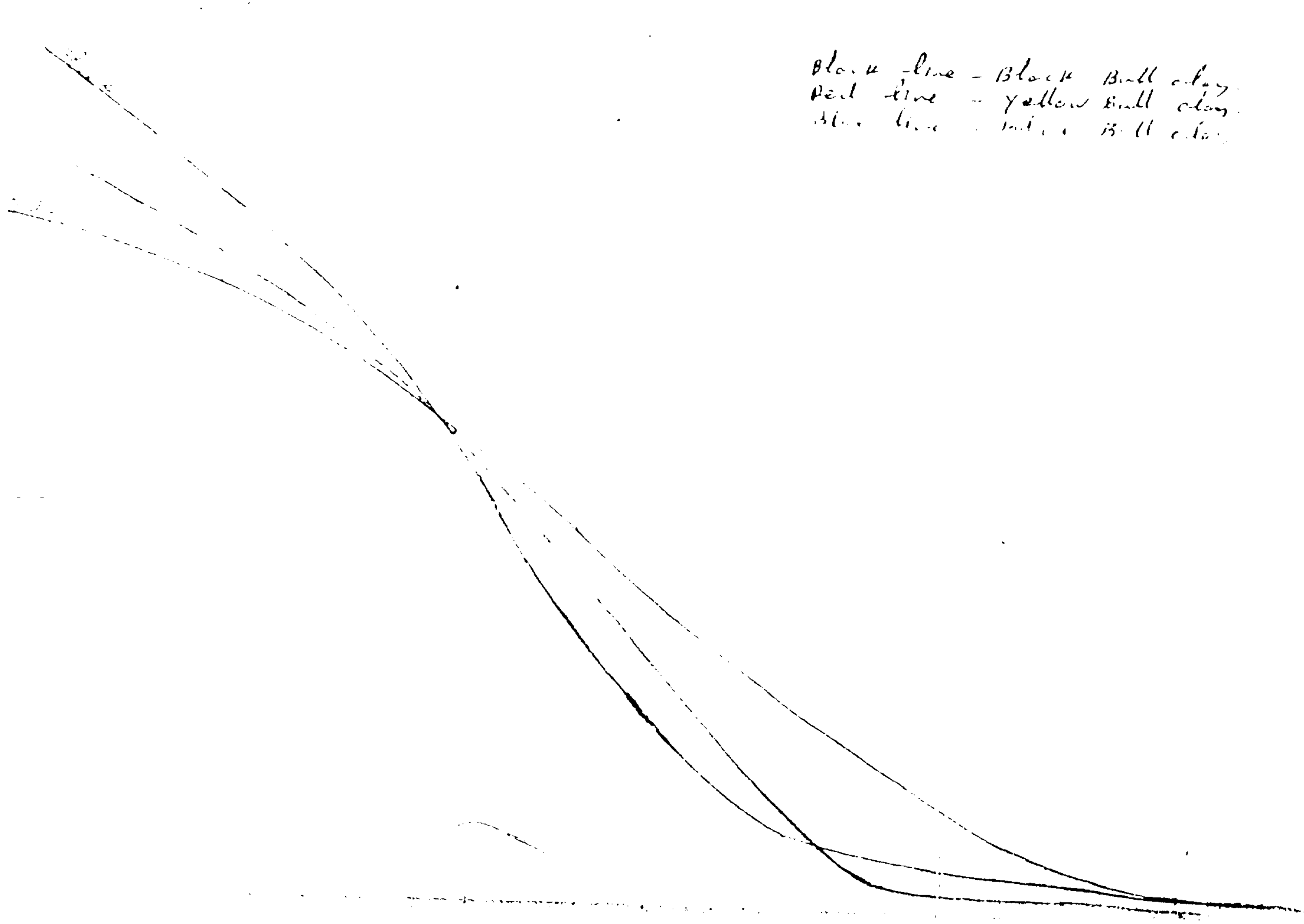
Temperature °C	Water Absorption		
	Black ball clay	Yellow Ballclay	Blue Ballclay
1050°	29.0	24.4	26.2
1080°	24.0	21.7	22.3
1110°	16.4	17.4	17.0
1140°	8.0	12.4	10.2
1170°	2.8	7.7	3.4
1200°	1.6	3.6	0.7
1230°	1.0	1.2	0.6
1250°	0.6	0.7	0.2

Temperature °C	Shrinkage		
	Black Ballclay	Yellow Ballclay	Blue Ballclay
1050°	5.8	4.4	5.3
1080°	8.0	5.9	6.9
1110°	12.0	8.4	10.4
1140°	15.3	11.2	14.0
1170°	17.6	13.6	17.2
1200°	18.7	15.5	18.7
1230°	18.7	10.7	19.0
1250°	18.7	17.7	19.2

Kumudu Jayakody

Research Officer -Physical Laboratory

Water absorption Vs Temperature



ANNEX VIII

Results of Laboratory order No. 1899 given by Mr.Corsi

Deflocculation Test

Description of Samples a)Black Ball Clay
b)Blue Ball Clay
c)Yellow Ball Clay
d)Hycast Ball Clay

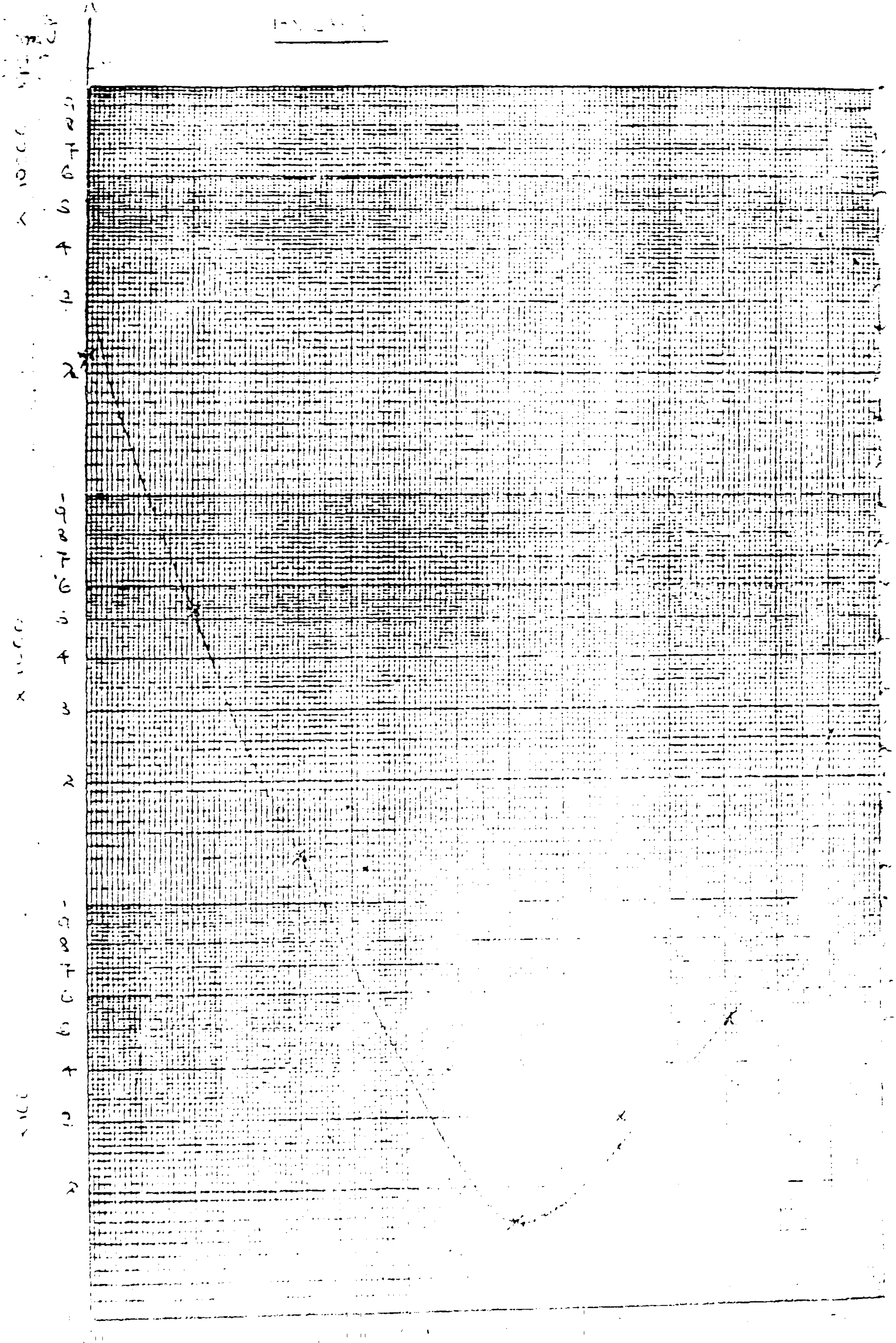
Deflocculant ;- Sodium Silicate

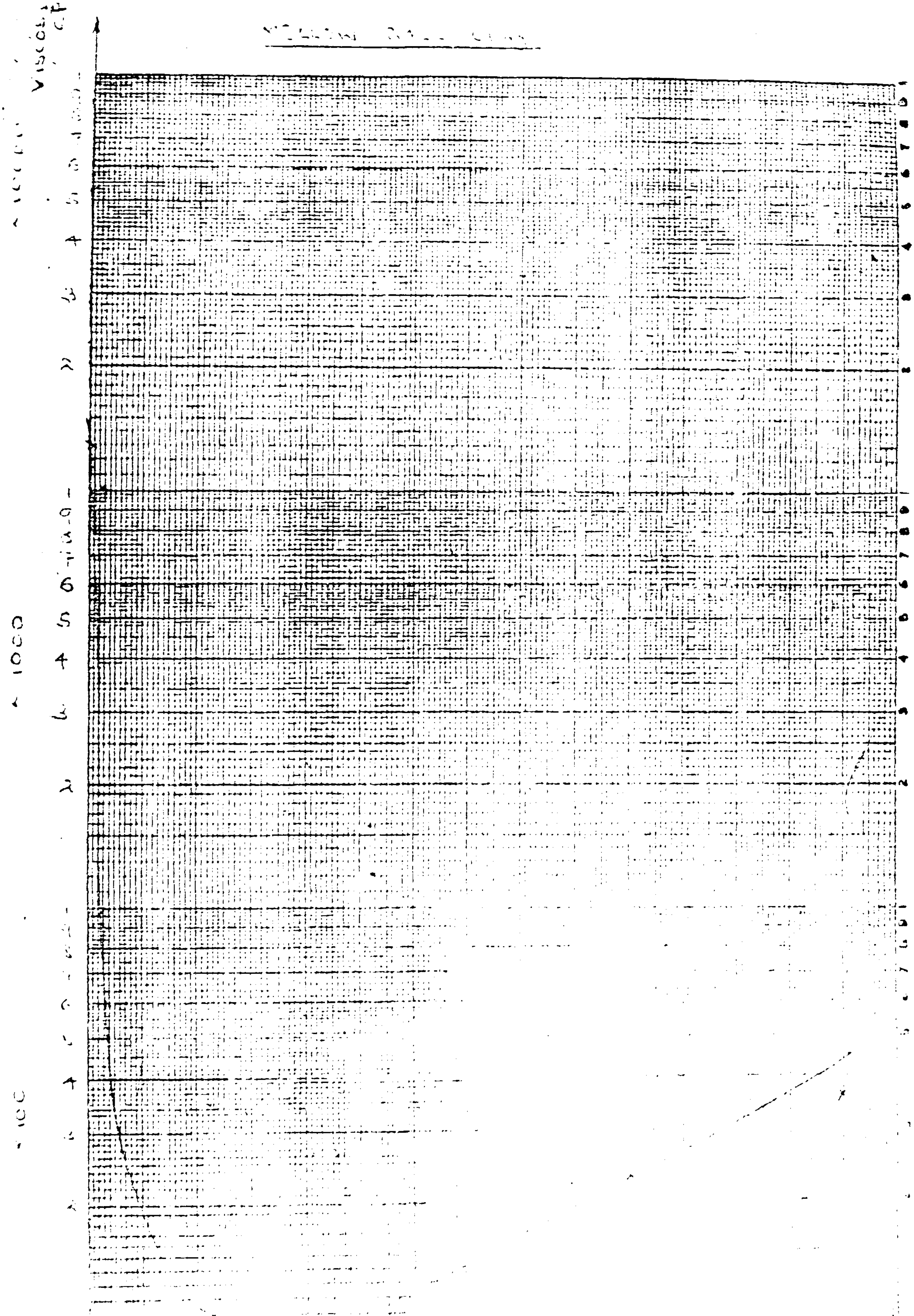
Deflocculant demands of the clay	a)Black Ball Clay	-	1.05%
	b)Blue Ball Caly	-	1.1%
	c)Yellow Ball Clay	-	0.7%
	d)Hycast Ball Clay	-	0.5%

Slip Density = 1.3 g/ml

Gallenkamp Torsion Viscometer was used to measure the viscosity.
(Graphs Annexed)

G.M.A.G.B.Gaspe
Research Officer - Pilot Plant





Viscosity
1000
100
6
5
4
3
2