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MOUNT GAMBIER

PROGRESS AND FINAL REPORTS TO LICENCE EXPIRY / RENEWAL, FOR THE PERIOD 23/12/1971 TO 22/6/1972

Submitted by
RMC Minerals Pty Ltd
1972

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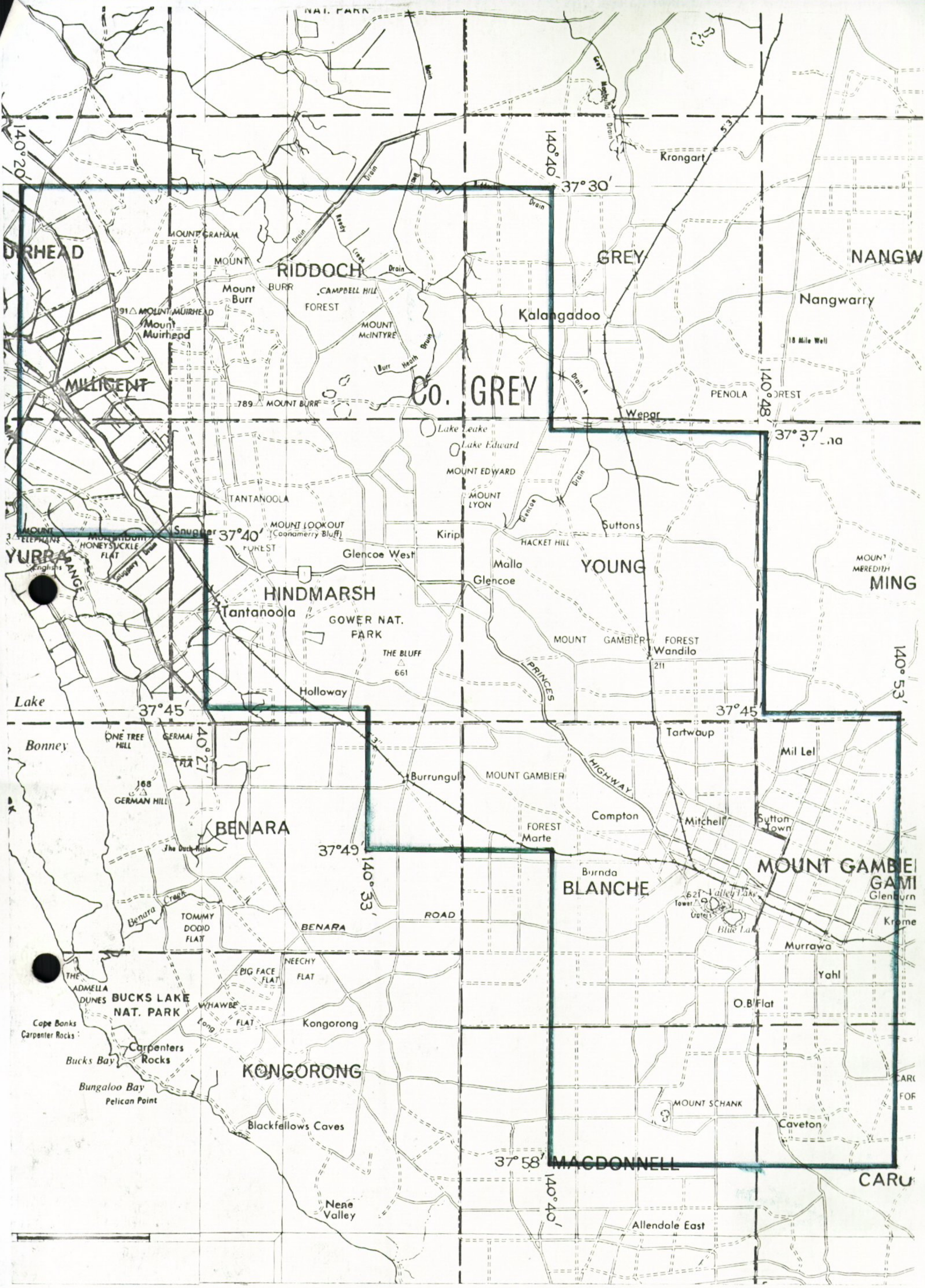
Government of South Australia
Primary Industries and Resources SA



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R.M.C. MINERALS PTY.

DOCKET DM 1217/71 AREA 548 SQ MILES

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LOCALITY

S.M.L. No. 655 EXPIRY DATE 22·6·72

CONTENTS ENVELOPE 1852 DM 1217/71

TENEMENT: S.M.L. 655

TENEMENT HOLDER: R.M.C. Minerals Pty. Ltd

REPORTS:

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READY MIXED CONCRETE INDUSTRIES LIMITED

CENTRAL RESEARCH LABORATORY

Technical Report

No. 48

EVALUATION OF SOUTH AUSTRALIAN GROUND VOLCANIC ASH

88 RESERVE ROAD, ARTARMON 2064. - P.O. Box 9, Artarmon 2064 - Telephone: 439-1611

AUSTRALIA

The Central Research Laboratory has been established within Ready Mixed Concrete Industries Ltd. to carry out research and development projects for that Company, Blue Metal Industries Ltd. and the Ready Mixed Concrete Ltd. Group of Companies in Australia. In addition, as an Approved Research Organisation within the terms of the Commonwealth Industrial Research and Development Grants Act, it is available for the execution of Contract Research for any other Organisation.

READY MIXED CONCRETE INDUSTRIES LIMITED

CENTRAL RESEARCH LABORATORY

TECHNICAL REPORT NO. 48

November 22, 1971.

EVALUATION OF SOUTH AUSTRALIAN GROUND VOLCANIC ASH

INTRODUCTION

In ancient Rome naturally occurring ashes, originating from the explosive types of volcanic eruptions, were mixed with lime to produce a cementitious material. Many structures in which this form of cement was used as a binder still stand today. Pozzuoli district was particularly rich in volcanic ashes and these have given the name "Pozzolans" to any siliceous finely divided inorganic material which upon reaction with lime at room temperature forms a hard and insoluble compound.

The United States Bureau of Reclamation adopted the following classification for pozzolans:-

(1) Clays and shales (must be calcined to activate):
- Kaolinite type
- Montmorillonite type
- Illite type

(2) Opaline materials (calcination may or may not be required):
- Diatomaceous earth
- Opaline cherts and shales

(3) Volcanic tuffs and pumicites (calcination may or may not be required):
- Rhyolitic types
- Andesitic types
- Phonolitic types

(4) Industrial by-products:
Blast furnace slag
Fly ash
Silica fume

In Australia, use of pozzolans in concrete has found official recognition in the publication of the Australian Standards on

Blended Cements - A181-1971
and Fly Ash for Use in Concrete - A.S. 1129 and 1130-1971.

Many valuable properties of pozzolans in concrete such as reduced Heat of Hydration, Reduced Permeability and the ability to control Alkali-Aggregate reaction, as well as the increased resistance to Aggressive Environment, has changed industrial pozzolans from being waste by-products into the premium priced materials.

Therefore the Utilization of Natural Pozzolans, particularly in those areas where the Industrial by-product forms are not available, is of paramount importance to the Australian Building Industry.

METHODS OF EVALUATION

The Australian Standard Code of Practice for the Use of Fly Ash in Concrete - A.S. 1130-1971 - requirement for pozzolans is based on their performance in concrete, rather than on chemical or mineralogical composition of these materials.

Concrete is a heterogeneous material and hence to achieve homogenuity on the results, relatively large quantities of Pozzolans must be tested. Therefore, in the initial stages of investigation, it sometimes becomes necessary to evaluate the potential reactivity of Pozzolans in mortars.

The Central Research Laboratory has adopted a Pozzolanic Activity Test with hydrated lime based on A.S.T.M. C595.

This method consists in mixing 1 part hydrated lime to 9 parts of graded silica sand (from Ottawa, Illinois) by weight, plus an amount of oven dry pozzolan equal to twice the weight of the lime multiplied by a factor obtained by dividing the specific gravity of pozzolan by the specific gravity of the lime. The amount of mixing water is such that the flow of mortar is 110 ± 5 per cent when measured in accordance with A. C. T. M. C109.

Three cylindrical specimens $2 \pm 1/8$ in. diameter and $4 \pm 1/8$ in. high are made from each batch. These are stored at $73.4 \pm 3^{o}F$ for 24 ± 2 hours and then at $131 \pm 3^{o}F$ for 6 days until $4 \pm \frac{1}{4}$ hours before the time of testing. They are cooled then to $73.4 \pm 3^{o}F$ and tested in compression at the loading rate of 100 to 500 p. s. i. per min.

Minimum pozzolanic strength according to A. S. T. M. C595 should be 800 p. s. i.

RESULTS

Pozzolanic Activity

The results obtained with South Australian Ground Volcanic Ash are as follows:-

C. R. L. No.	S. A. Identification	Pozzolanic Strength to A. S. T. M. C595
P1611	- 200 North end	1300 p. s. i.
P1612	- 200	1070 p. s. i.

Best Australian Fly Ashes have Pozzolanic Strength of 1100 p. s. i.

FINENESS

It must be noted, however, that the degree of pozzolanic activity is closely related to the fineness of pozzolana. Dr. K. Alexander in his paper "Observations on the Blaine method for determining Fineness and on the Relationship between Surface Area and Pozzolanic Reactivity" published in the Australian Journal of Applied Science, Vol. 6, 1955, gives an optimum fineness of 8000 cm^2/g for pozzolana-lime and hence pozzolana-cement reaction. The fineness is calculated from the Blaine equation -

$$Sw = \frac{14}{d(1-e)}\sqrt{\left[\frac{e^3APt}{VnL}\right]}$$

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where

Sw	=	specific surface (cm^2/g)
d	=	density of powder (g/cm^3)
e	=	porosity
A	=	cross section of plug (cm^2)
P	=	mean effective pressure difference across the plug (g/cm^2)
t	=	time measurement (sec)
V	=	total measured volume of gas passing through plus (ml)
n	=	viscosity of gas (poises)
L	=	length of plug (cm)

The method is covered in Section 3 of the Australian Standard A2-1963 "Portland Cement" and by the A. S. T. M. C204 "Fineness of Portland Cement by Air Permeability Apparatus".

When applied to pozzolans the method gives approximate values of the specific surface only.

Following results were obtained:-

C. R. L. No.	S. A. Identification	Approximate Specific Surface
P1611	- 200 North end	7500 cm^2/g
P1612	- 200	6500 cm^2/g

Hence, the sample P1611 is ground to almost optimum specific surface according to Dr. Alexander.

It must be noted at this stage that only very small proportion of Fly Ash collected from the flue gas by means of cyclones and electrostatic precipitations is of the high order of fineness, stated above.

Sand Replacement in Mortar

In addition to A. S. T. M. C595 tests, direct sand replacement with South Australian Ground Volcanic Ash (Sample P1612) was attempted.

Results yielded:-

Mortar Mix	Proportions - gms.				Flow %	Compressive Strength psi.	
	O. P. Cement	Ash	Ottowa Sand	Water		24 hours	3 days
Plain control	500	nil	1375	245	105	2100	2630
with Pozzolana	500	125	1250	260	108	3160	4420

CONCLUSIONS

Provided reasonable fineness can be economically achieved, these data indicate that South Australian ground Volcanic Ash will be a most efficient pozzolan.

A. SAMARIN,
Research Engineer.

W. G. RYAN,
Chief Concrete Engineer.

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ANALYTICAL REPORT

Analytical Report No.:	J 157
Reference:	Mr. I. Haddow
Identification:	Mt. Schanck Ash
Date Received:	21. 12. 71

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Equipment

1. Ball Mill: dimensions: diameter 31.4cm. (12¾")
   length 39.4cm. (15½")
   r.p.m. = 21
   Ball charge wt. = 51 kilos.

2. Volcanic Ash (Mt. Schanck)

3. ¼" jaw crusher

4. 44 mesh sieve (B.S.S.)

5. 100 mesh sieve (B.S.S.)

6. 200 mesh sieve (B.S.S.)

7. 10 Kgm. spring balance (for weighing ash loads for mill accurate to 200g.)

8. Balance for weighing fractions (accurate to 1/10th gm.)

9. 25 gallon plastic bucket with ½" sieve fitted to top (for collection of balls when emptying mill after grinding)

10. Galvanised iron sheets for drying sample

11. Mortar and pestle

Experimental Procedure

1. The original sample (approx. 110 kilos) was spread out on galvanised iron sheets to dry out (not enough oven space) in the open.

2. When dry, the sample was put through the ¾" jaw crusher and then, after crushing was thoroughly homogenised. (method for hand mixing mortar - using a shovel)

3. The sample was then split and bagged in 10 kilo (approx.) portions (giving 11 bags of material).

4. A sieve analysis was carried out on a 10 kilo sample (see Results, Table A and Graph A)

5. Approx. 2 kilos of another portion was hand ground and enough - 63 micron material was gained for chemical analyses. Analyses were conducted to determine the L.O.I. and also the level of SiO_2; Al_2O_3; CaO; Fe^{+++}; Fe^{++}; MgO; Mn; S.

6. Another 10 kilo portion was subjected to 1 hour of grinding in the Ball Mill (description see "Equipment"). After grinding was completed, a sieve analysis was carried out (Results: Table A, Graph A). The -100 mesh +200 mesh fraction and the -200 mesh fraction were sent for a blaine determination.

7. The ball charge weight (51 kilos at the start of the tests) was to be checked every third grind.

8. A further sample, this time 2 kilos, was ground in the mill for 2 hours. A sieve analysis (see Results Table A, Graph A) and a blaine (on the -100 mesh +200 mesh and the -200 mesh fraction) were done.

9. It was considered sufficient that, for a ball mill such as the one used here, with a ball charge wt. of 51 kilos; 5 kilos of sample per grind would be used. (this is so for all subsequent grinds unless otherwise stated)

10. So a 2 hour grind was run, using 5 kilos of sample. After grinding was completed the whole sample was passed through a 44 mesh. A representative sample of 500g. was screened at 100 mesh (see Results Table B) A blaine test was run on the -44 mesh fraction and the -100 mesh fraction. (the percentage of + and - 100 mesh fractions were recorded - table B)

11. At this stage a check was made on the weight of the ball charge.

.....2/

12. A further 2 grinds of 2 hours each were completed. The ground material was passed through 44 mesh. The +44 mesh fraction was recorded and the (approx.) 10 kilos of -44 mesh material was bagged. 500g. of this 10 kilos was taken and screened at 200 mesh. The + and - fractions were weighed and the weights recorded. Meanwhile a blaine was done on the -200 mesh fraction. (see Table B)

13. The next grind was run for 2½ hours; the ground material then screened at 44 mesh; a representative 500g. sample was screened at 200 mesh; the weights were recorded and a blaine test was done on the -44 mesh and the -200 mesh fraction. (See table B)

14. The ball charge weight was again checked.

15. Another grind, to be run for 3 hours was commenced. The ground material was then passed through 44 mesh. (+44 mesh fraction weighed and recorded). As in previous grinds, a representative 500g. sample was screened at 200 mesh. The + and - fractions were weighed and recorded and a blaine determination done on the -44 mesh fraction of the 200 mesh fraction. (Table B)

16. 6 more 3 hour grinds were undertaken to gain approximately 35 kilos of -44 mesh material for further tests at the concrete laboratory.

17. A four, a five and a six hour grind were done. The procedure with the ground material from these 3 grinds was as for the 3 hour grind (see 15 above) (Results Table C)

18. A check was made on the ball charge weight.

19. A 7hr. grind was run according to above procedure (Results)-table C.

Results

I. **Table A**

Micron	Mesh	%Wt. →	Original Sample *	%Wt. →	1 hour grind	%Wt. →	2 hour grind
+2.80mm	5	3.46	(100.05)	-		-	
+710	22	28.33	(96.59)	-		-	
+500	32	9.16	(68.26)	2.06	(99.99)	-	
+250	60	13.09	(59.10)	15.07	(97.93)	1.82	(100.01)
+180	90	7.08	(46.01)	13.33	(82.86)	12.70	(98.19)
+125	120	4.32	(38.93)	5.97	(69.53)	6.71	(85.49)
+63	240	19.18	(34.61)	38.45	(63.56)	29.05	(78.78)
+45	+350	12.20	(15.43)	17.68	(25.11)	49.73	(49.73)
-45	-350	3.23	(3.23)	7.43	(7.43)	(combined) -63μ	
Blaines (cm^2/gm)	-100+200 mesh	1135		1190		855	
	-200 mesh	3865		3460		3420	

Notes: (1) Original Sample * refers to sample after having been crushed in the ¼" jaw crusher. (See "Experimental Procedure" part 2)

(2) Blaine figures quoted in tables were done by R.M.C.I. N.S.W. (Ready Mixed Concrete Industries). Samples of -200 mesh from above were also sent to A.M.D.L. (Australian Mineral Development Laboratories) for a blaine - below are the comparative figures.

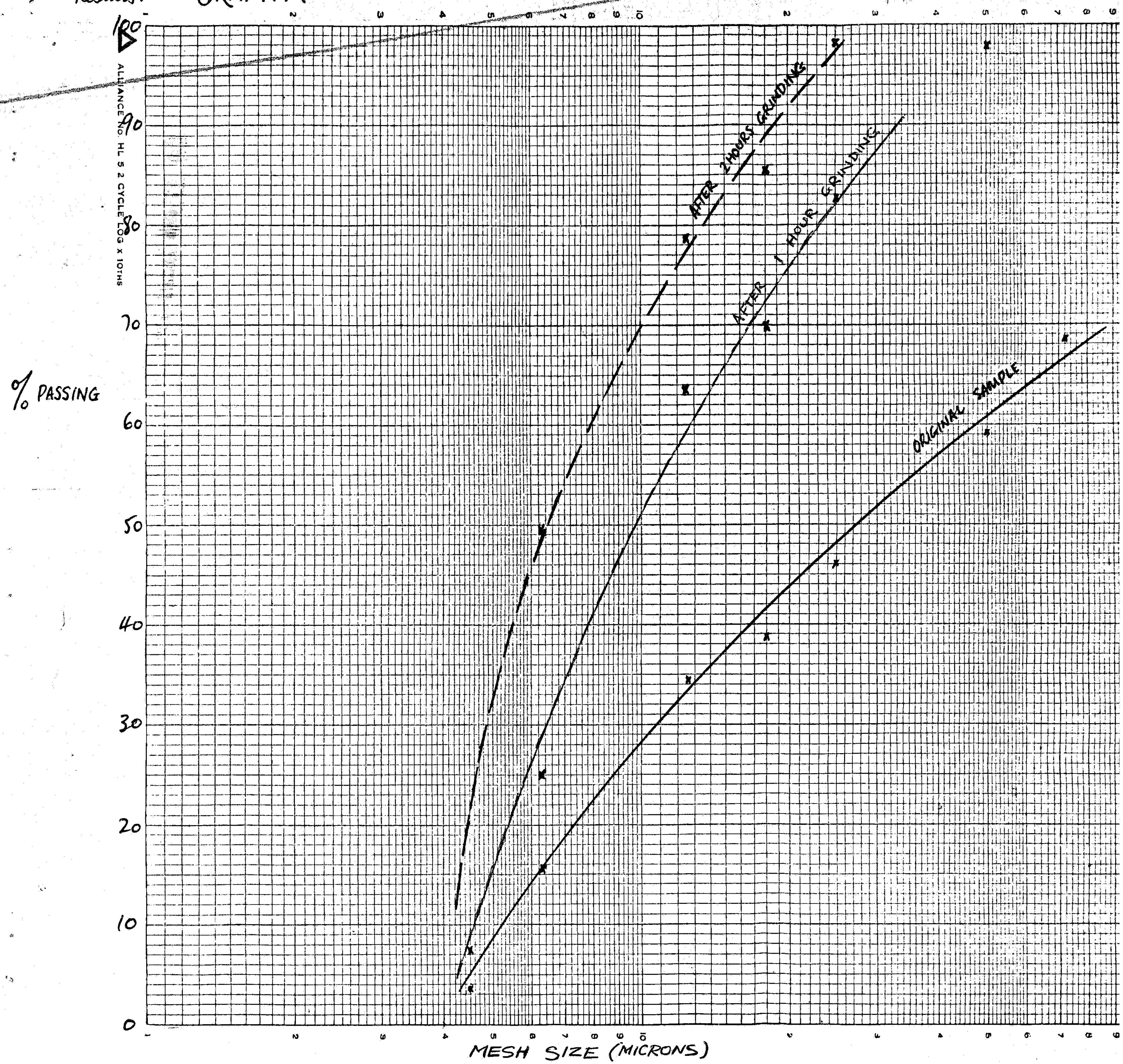
	Original Sample	1 hour grind	2 hour grind
Blain (cm^2/gm)	3860	3510	3260

(3) The following figures are the percentages by weight of material which was -250 micron.

	Original Sample	1 hour grind	2 hour grind
%	46.01	82.86	98.19

II. Throughout the series of tests, the ball charge weight (initially 51 kilos) did not alter sufficiently for it to be measurable on a balance accurate to 200g.

Results. "GRAPH A"



III. Chemical analysis and Results

Assay For

SiO_2	50.1
Al_2O_3	17.6
MgO	5.89
CaO	9.32
Fe^{+++}	12.66
Fe^{++}	
MnO	0.10
S.	
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IV.

TABLE B

	2 hour grind		2½ hour grind		3 hour grind	
Mesh Size x	%Wt.	Blaine cm^2/gm	%Wt.	Blaine cm^2/gm	%Wt.	Blaine cm^2/gm
+44	0.14		.04		.04	
-44	99.86	2605	99.96	3060	99.96	3300
+100	0.7					
-100	99.2	2630				
+200	15.90		11.20		7.36	
-200	84.10	3255	88.80	3435	92.64	3580

Notes: (1) Mesh size x The whole sample was screened at 44 mesh (100% = 5 kilos). A representative sample of 500g. was used for the 100 mesh and the 200 mesh (Separate) sieve analysis. (100% = 500g.)

(2) A 100 mesh sieve analysis was done only on the 2 hour grind.

(3) Although the +44 mesh fraction was, by weight and percent very small, it consisted of hard lumps, which, if taken as spherical were roughly 5mm. in diameter as a maximum. The average was 2 or 3 mm.

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TABLE C

	4 hour grind		5 hour grind		6 hour grind		7 hour grind	
Mesh Size x	%Wt.	Blaine cm^2/gm	%Wt.	Blaine cm^2/gm	%Wt.	Blaine cm^2/gm	%Wt.	Blaine cm^2/gm
+44	0.05		0.03		0.01			
-44	99.95	3915	99.97	4325	99.99	4980	100	5620
+100								
-100								
+200	2.12		1.16		0.18		.10	
-200	97.88	4170	98.84	4439	99.82	5080	99.90	5650

28th February, 1972.

THE READYMIX GROUP (S.A.)

(Technical Division) 018

INTERIM REPORT ON GROUND VOLCANIC ASH.

1. Introduction.

Initial pozzolanicity tests conducted by C.R.L. (Technical Report No. 48) indicated that the volcanic ash was a potentially good pozzolan. The two samples used for the tests had specific surface areas of 6500 $cm.^2/g$ and 7500 $cm.^2/g$.

Follow-up trials in production concrete design mixes at Brompton Laboratory were then planned. It was decided that such trials would use the volcanic ash with a lesser specific surface area (fineness), with a value in the region of normal Portland cement (3500 $cm.^2/g$) being selected.

2. Grinding.

All grinding of the volcanic ash was performed at R.M.C. Minerals Lab. and a separate report on this aspect has been compiled. The ash for the concrete trials received 3 hours grinding in the small ball mill and samples despatched to C.R.L. had the following fineness values:-

Passing	44 mesh	3300 $cm.^2/g$.
Passing	200 mesh	3580 $cm.^2/g$.

70 lbs. of this material was ground for use in the concrete trials.

3. Trial Details.

Standard mix designs were used for trial batches mixed in a 2 cu.ft. capacity tilting bowl mixer of the type used for domestic purposes. The range of mixes and replacement values were as described in the results below.

Replacement values were on the basis of the stated percentage being the percentage by weight of cement replaced by an equal absolute volume of volcanic ash.

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4. **Results.**

All mixes - Coarse aggregates Riverview Dolomite ¾" " " ⅜"
Fine aggregate A.B.M. Noarlunga Sand.

Mix		Slump (ins.)	COMPRESSIVE STRENGTH (P.S.I.) 3 days	7 days	14 days	28 days	28 days Avg.	Var. to Plain	Remarks
A1.	600 lbs./c.yd. Adelaide N.P.	3.25	2400	3550	4150	4650 4700	4675	-	Setting Time 310 mins.
A2.	15% ash replacement	3.50	1950	2650	3300	3850 3950	3900	- 775	Setting Time 305 mins.
A3.	25% ash replacement	3.75	1600	2200	2750	3400 3350	3375	- 1300	Setting Time 325 mins.
A4.	400 lbs./c.yd. Adelaide N.P.	3.00	-	2200	2800	3150 3050	3100	-	
A5.	15% ash replacement	3.00	-	1550	2000	2300 2300	2300	- 800	
A6.	25% ash replacement	3.00	-	1300	1550	1900 1900	1900	- 1200	
B1.	600 lbs./c.yd. Brighton N.P.	3.25	2350	3250	3800	4350 4400	4375	-	Air Content 0.7%
B2.	25% ash replacement	3.50	1550	2200	2750	3200 3350	3275	- 1100	Air Content 1.0%
B3.	400 lbs./c.yd. Brighton N.P.	2.75	-	2100	2650	3050 3050	3050	-	
B4.	25% ash replacement	3.25	-	1200	1700	1950 2000	1975	- 1025	
C1.	600 lbs./c.yd. Geelong N.P.	3.25	2600	3400	3700	4200 4200	4200	-	
C2.	25% ash replacement	3.25	1850	2450	2750	3350 3350	3350	- 850	
C3.	400 lbs./c.yd. Geelong N.P.	3.25	-	2250	2450	2750 2750	2750	-	
C4.	15% ash	3.00	-	1650	1900	2100 2000	2050	- 700	
BC1.	600 lbs./c.yd. Adelaide Blended (20% fly ash)	3.5	2150	3150	3750	4500 4500	4500	- 175	
BC2.	400 lbs./c.yd. Adel. Blended	3.25	-	1800	2300	2900 3000	2950	- 150	

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Note: 1. Further cylinders were cast for testing at 6 months.
2. Very slight improvement in workability noted with use of ash.

Analysis of Results.

Ash replacements affected cement contents as follows:-

600 lbs./c.yd. mixes	-	15% ash repl. reduced cement by	90 lbs./c.yd.
	-	25% " " " " "	150 " "
400 lbs./c.yd. mixes	-	15% " " " " "	60 " "
	-	25% " " " " "	100 " "

Assuming a reduction of 10 lbs. N.P. cement / cu. yd. decreases 28 day compressive strength by 100 p.s.i., the following table can be compiled using the above trial results:-

	Adelaide N.P.		Brighton N.P.		Geelong N.P.	
	lbs/c.yd. 400	lbs/c.yd. 600	lbs/c.yd. 400	lbs/c.yd. 600	lbs/c.yd. 400	lbs/c.yd. 600
Expected Strength reduction due to 15% less cement (psi)	600	900			600	
Actual strength reduction in trials (psi)	800	775			700	
∴ Increase attributable to ash (psi)	~~- 200~~	125			~~- 100~~	
Expected Strength reduction due to 25% less cement (psi)	1000	1500	1000	1500		1500
Actual strength reduction (psi)	1200	1300	1025	1100		850
∴ Increase attributable to ash (psi)	~~- 200~~	200	~~- 25~~	400		650

Note: Refer to attached graphs for rate of strength gain of all mixes.

CONCLUSIONS

The inclusion of the ground volcanic ash appears to have had little or no effect on strength increase of the mixes.

It must be considered that pozzolanic properties of the volcanic ash are not effective at the degree of fineness used, i.e. approx. 3500 cms.^{2}/g.

A further set of trials, on the same arrangement of mixes, will be performed using volcanic ash ground to a fineness value of approx. 5000 cm.^{2}/g.

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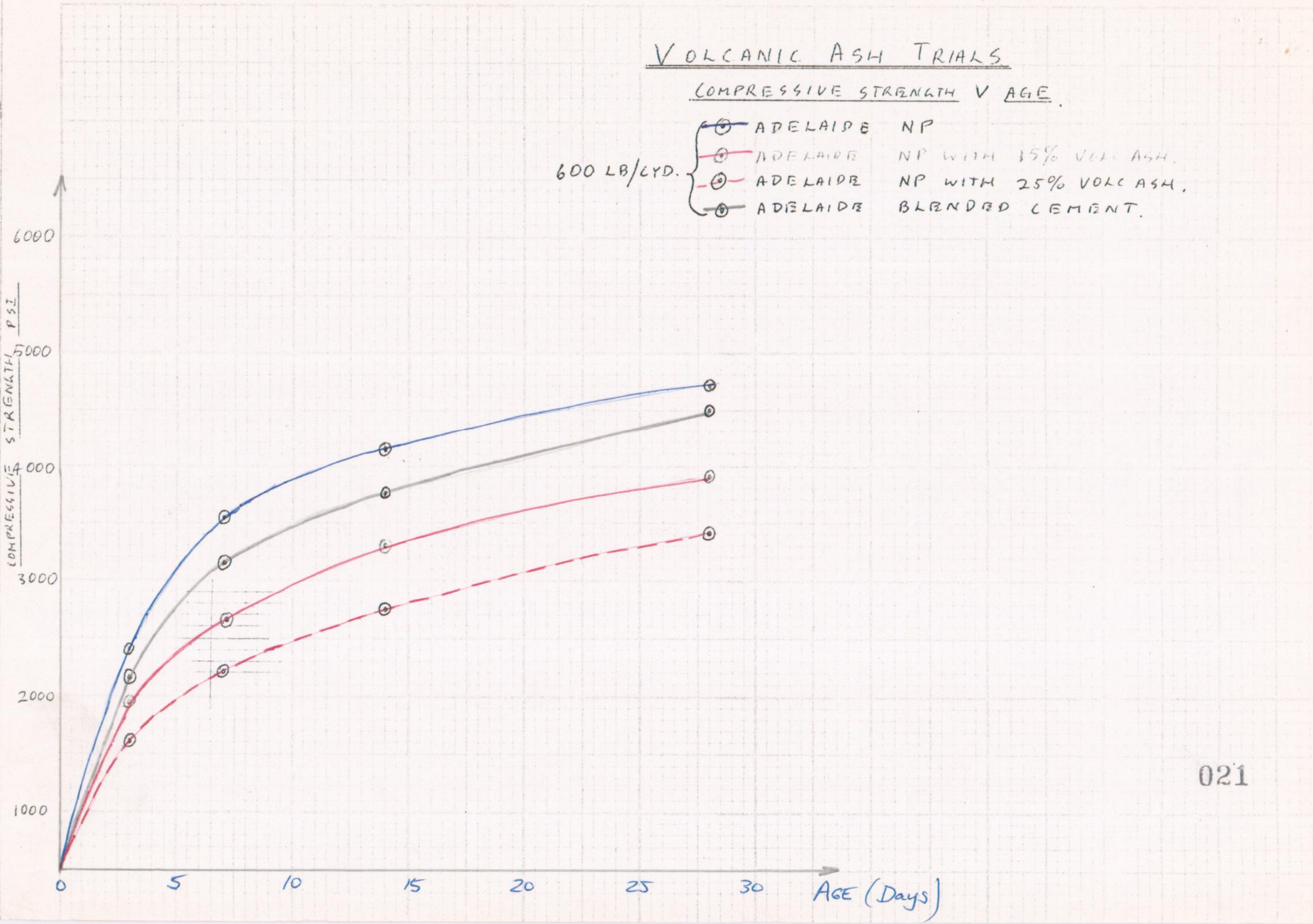

VOLCANIC ASH TRIALS
COMPRESSIVE STRENGTH V AGE.
600 LB/CYD.
ADELAIDE NP
ADELAIDE NP WITH 15% VOLC ASH.
ADELAIDE NP WITH 25% VOLC ASH.
ADELAIDE BLENDED CEMENT.
COMPRESSIVE STRENGTH PSI
6000
5000
4000
3000
2000
1000
0
5
10
15
20
25
30
AGE (Days)

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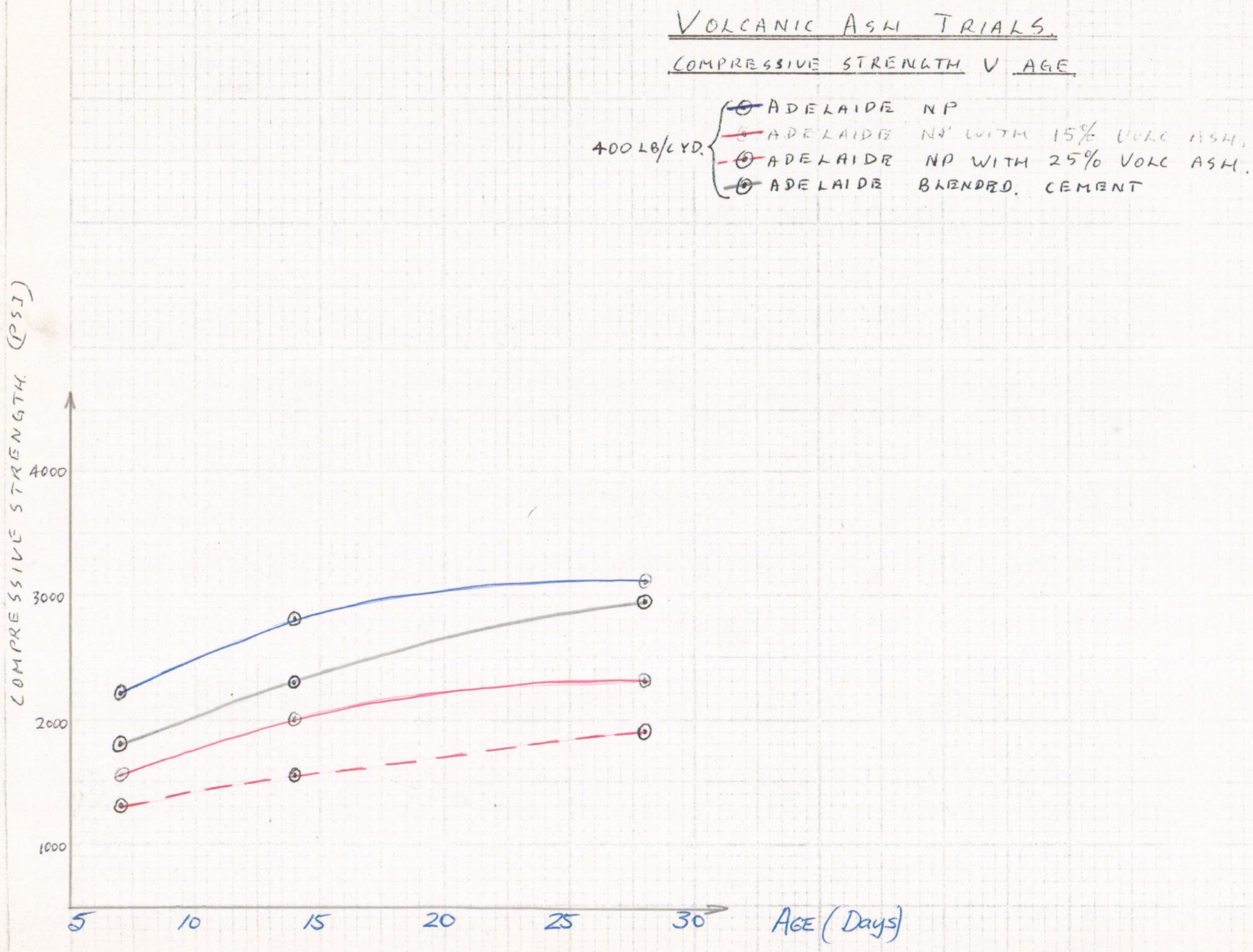
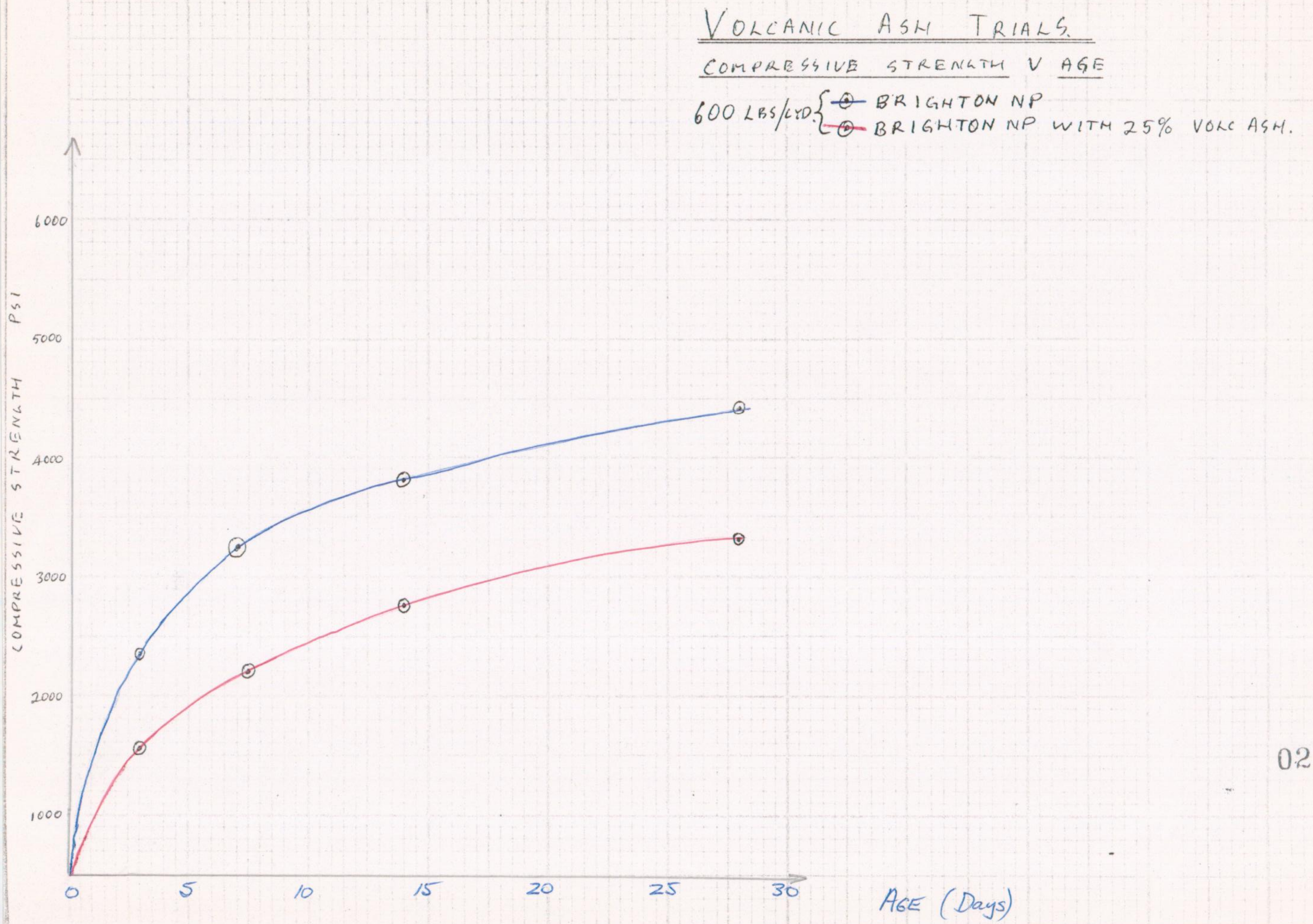

VOLCANIC ASH TRIALS.
COMPRESSIVE STRENGTH V AGE
400 LB/CYD.
ADELAIDE NP
ADELAIDE NP WITH 15% VOLC ASH.
ADELAIDE NP WITH 25% VOLC ASH.
ADELAIDE BLENDED. CEMENT
COMPRESSIVE STRENGTH (PSI)
4000
3000
2000
1000
5
10
15
20
25
30
AGE (Days)

022


VOLCANIC ASH TRIALS.
COMPRESSIVE STRENGTH V AGE
600 LBS/CYD.
BRIGHTON NP
BRIGHTON NP WITH 25% VOLC ASH.
COMPRESSIVE STRENGTH PSI
6000
5000
4000
3000
2000
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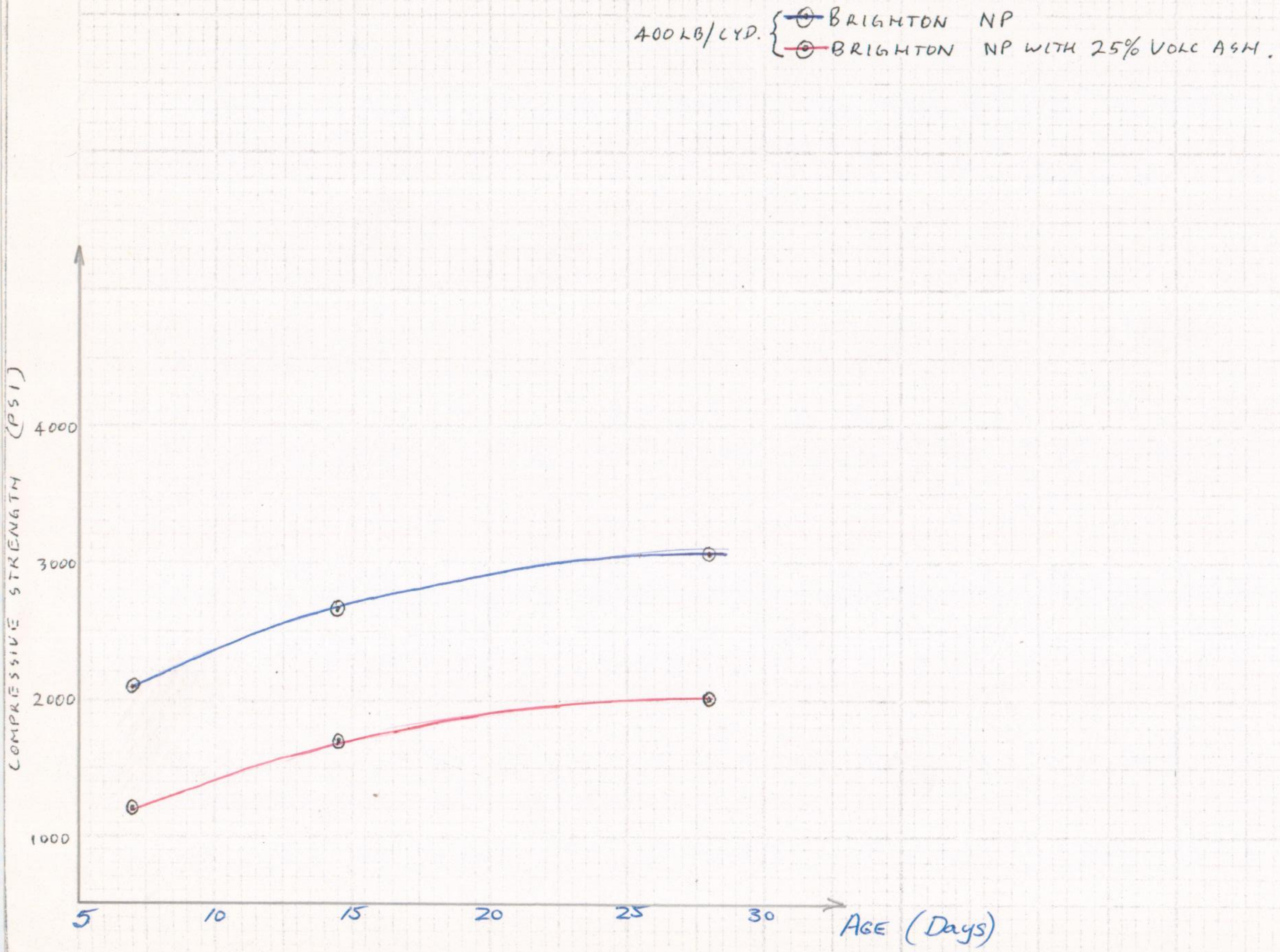
30
AGE (Days)

023

VOLCANIC ASH TRIALS.

COMPRESSIVE STRENGTH V AGE.



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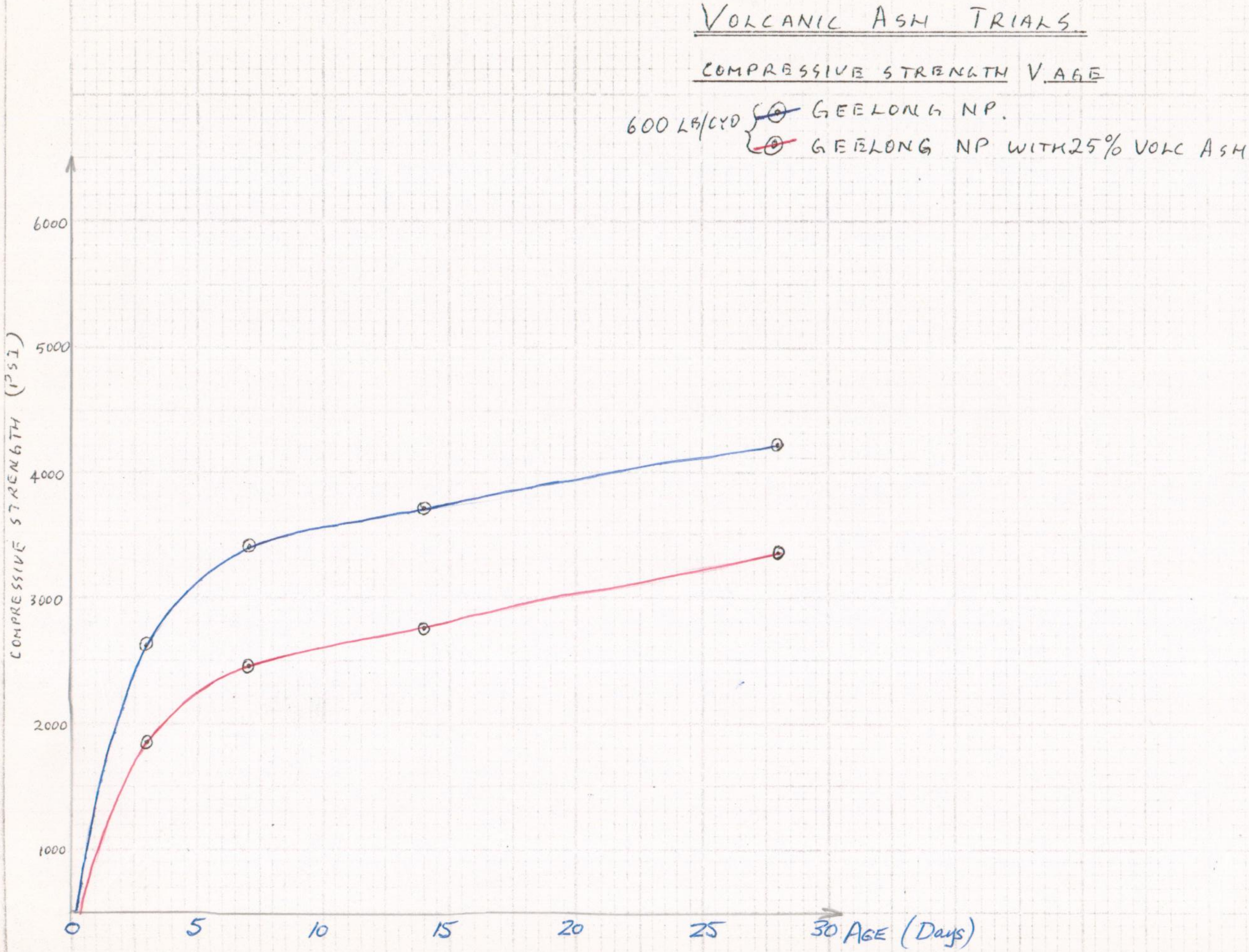
VOLCANIC ASH TRIALS.
COMPRESSIVE STRENGTH V. AGE
600 LB/CYD
GEELONG NP.
GEELONG NP WITH 25% VOLC ASH
COMPRESSIVE STRENGTH (PSI)
6000
5000
4000
3000
2000
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5
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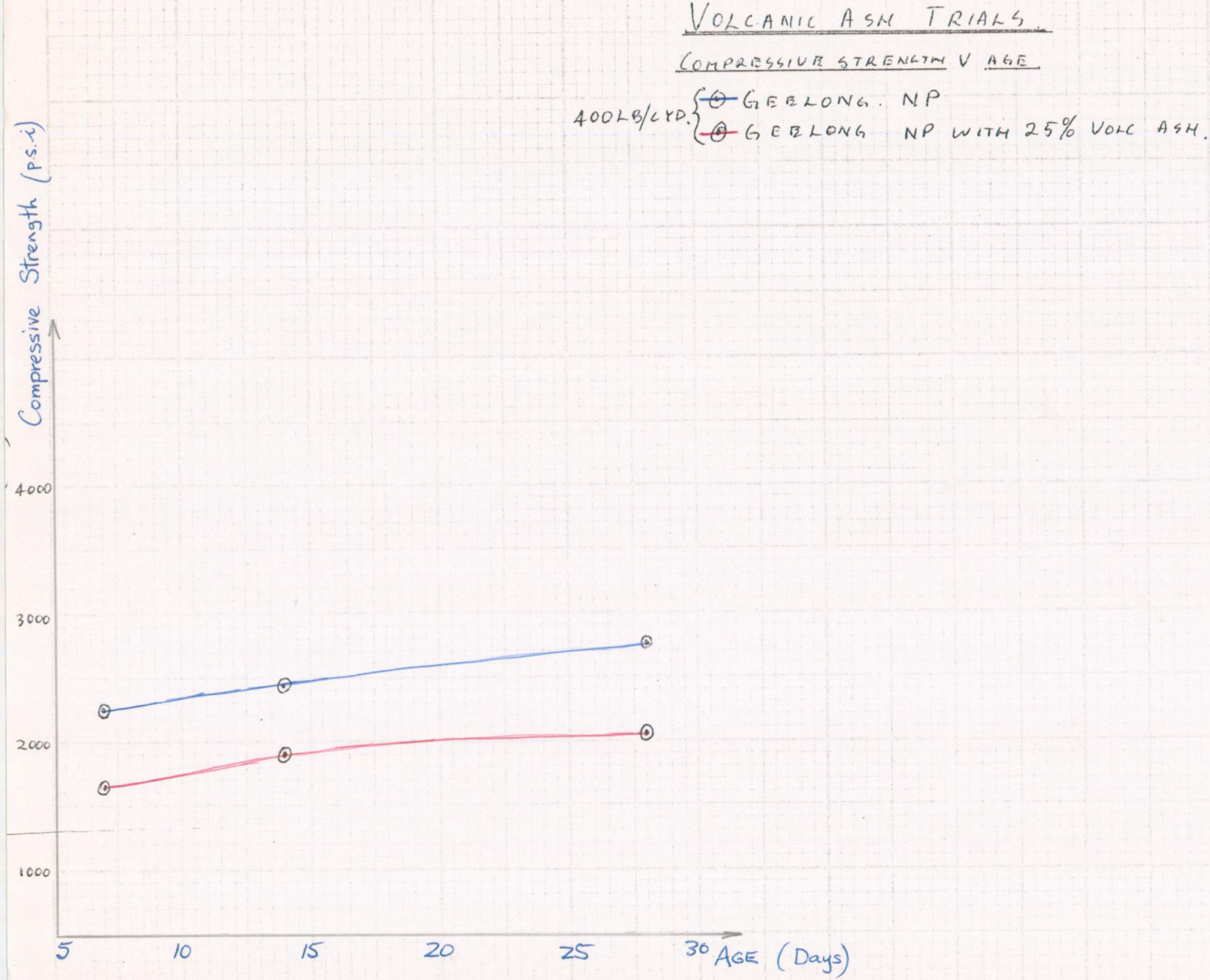
30
AGE (Days)



VOLCANIC ASH TRIALS.
COMPRESSIVE STRENGTH V AGE
400LB/CYD.
GEELONG. NP
GEELONG NP WITH 25% VOLC ASH.
Compressive Strength (p.s.i)
4000
3000
2000
1000
5
10
15
20
25
30
AGE (Days)

026

QUARTERLY PROGRESS REPORT

S.M.L. 655

MOUNT GAMBIER

B.C. Param
9-3-72

CONTENTS

Introduction

The potential commercial value of fly ash has long been recognised in America, Europe, Japan, Russia and other areas. In Australia, use of pozzolans in concrete has found official recognition in the publication of the Australian Standards on:

Blended Cements	A 181 - 1971
and Fly Ash for use in Concrete	A.S. 1129 and 1130 - 1971.

The source for Pozzolans in Australia has been derived from industrial by-products; fly ash being the most commonly used. The reclamation of the huge quantities of fly ash produced by power generating stations into useful products has changed the economics of the concrete industry.

One of the difficulties limiting the total utilisation of fly ash produced has been the fact that the composition and other qualities of fly ash are not consistent. This problem is non-existent with natural pozzolans. Therefore the utilisation of natural pozzolans, particularly in those areas where the industrial forms are not available, is of paramount importance to the Australian Building Industry.

It is recognised that certain volcanic effusives make excellent natural pozzolans. These are:

a) Volcanic ash
b) Rhyolitic type materials
c) Andesitic type materials
d) Phonolitic type materials

Mount Gambier Volcanics

Geology

The area under review comprises mainly Tertiary and Quatenary rocks. The dominant outcropping rock type is the mid-Tertiary Marine Limestone and Lower Tertiary clays and sands are restricted to outcrop, while outcropping pre-Tertiary rocks are rare. The latter comprises early Palaeozoic plutonic and hypabyssal rocks.

The volcanic rocks are of late Pliocene or younger age. It is these that will concern us and therefore be the centre of our activities.

Volcanic activity occurred in the Mount Gambier area in late Tertiary and Pleistocene times. At least 16 cone eruptions occurred in South Australia. The activity was entirely basaltic, frequently with plentiful olivine. The various vents occurred along lines of fissuring and true fissure eruption was very restricted. Minor flows apparently preceeded cone formation in each case. Where remnants of the old basalt fissures can be seen, as on the west rim of the Blue Lake, and at the north-western foot of Mount Schank, the basalt is highly Vesicular.

The volcanism occurred in two definite periods. The earlier groups of these newer basalts exemplified by Mount Burr and Mount McIntyre, are late Pliocene and early Pleistocene, the later group by Mount Gambier and Mount Schank are late Pleistocene.

.....3/

Mount Gambier Volcanics in Natural Pozzolans

The Australian Standard Code of Practice for the use of Fly Ash in Concrete requirement for pozzolans is based on their performance in concrete rather than on chemical and mineralogical composition of these materials. However, it is critical that a certain degree of fineness is achieved in grinding the material. Hence this operation of grinding may well decide the economic use of the particular material as a pozzolan.

So far in our investigations we have only chosen volcanic ash samples because of their very fine constituents. It would be relatively easier to grind to perfection the ash than say other crystalline rocks. Further, an ash deposit is more homogenous in its composition than other volcanic products.

At a later stage in our investigations it is hoped that we will be able to test such rock types as scoria, tuffs and pumicites which are again relatively 'softer' than Rhyolites and Phonolites.

R.M.C. Investigations

Samples collected from the Mount Schank area were firstly tested in Sydney at our Central Research Laboratory. Their report is attached herewith. Tests have shown that the sample submitted will make a most efficient pozzolan.

Further samples were collected also from the same area and similar tests were undertaken in Adelaide in our own Laboratories. The various Laboratory reports are attached.

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These reports indicate that the required fineness had not been obtained and further work is continuing. As soon as the fineness and pozzolanic activity of the material is established it is hoped to systematically carry out a search for more deposits of similar nature in the area.

FINAL REPORT

S.M.L. 655

MOUNT GAMBIER

B.C. Param
8-8-72

CONTENTS

Summary

Laboratory tests on the volcanic ash samples were carried out at our laboratories. Details of the tests are included in the Technical Report by D. Mudie, which is appended to this report.

The ash was ground to a fineness of 6950 sq. cms./gm. and replaced for cement in quantities up to 15%, 20% and 25%. These were used in concrete tests and the concrete strength determined after periods of 7 days and 28 days.

Results indicate that an ash replacement of 5% gives the required strength in concrete while higher ash content gives correspondingly lower strengths. However, our Sydney laboratories have conducted independent tests and found that the ash is an extremely good pozzolan.

More ash samples were obtained and further tests are now in progress.

Volcanic Ash Samples

An Auger drill was used to test the suitability of the various ash deposits within the S.M.L. While the pozzolanity is the major criteria that determines the usefulness of the ash, it is quite significant to establish the nature of the deposit. Very well compacted or consolidated material is less preferred to loose material. The amount of overburden in the area is another important economic factor.

It was established that the two areas where likely ash deposits with economic potential are located at Mt. Schank and Lake Leake areas. Both these areas are close to a major city and the ash deposits are not so well consolidated with little or no overburden.

.....2/

Each sample was required to be at least 50 lbs. before grinding. These bulk samples were obtained using mechanical shovels after establishing the presence of ash deposits by auger drilling.

Grindability

If the various concrete tests prove that the ash can be economically substituted for cement then the next factor would be to establish the grindability of the material.

In order to market the commodity commercially, the ash has to be ground very finely and blained to a fineness of about 6500 sq. cms./gm.

This is a very low priced commodity and hence the economic viability of the project needs to be determined very carefully.

The accompanying laboratory report on the concrete tests show that a replacement of 15% or more by ash gives significantly reduced strength. The difference is greater in the 600 lbs. mix than in the 400 lbs. mix. Further, earlier tests in our Sydney laboratory indicate that the ash is a most effective pozzolan.

Hence we have decided to carry out further tests in conjunction with our Sydney laboratories.

Conclusion

At present the fate of the ash deposit depends upon further laboratory tests. If tests are more favourable then we will re-examine some of the ash deposits in the area. For the present the two areas - Mt. Schank and Lake Leake appear to provide the greatest potential.

.....3/

amdel
The Australian Mineral Development Laboratories
Flemington Street, Frewville, South Australia 5063
Phone 79 1662, telex AA82520

Please address all correspondence to the Director
In reply quote: ME 3/115/1/0

9 February 1972

R.M.C Minerals Pty Ltd
287 Churchill Road
PROSPECT SA 5082

REPORT: ME 2782/72

YOUR REFERENCE:	Application No.3907.
MATERIAL:	Natural Ash.
DATE RECEIVED:	30 November 1971.
WORK REQUIRED:	Grinding investigations.

Investigation and Report by: Z. Sawicki, C. Biggs and L.J. Weir.

Officer in Charge,
Mineral Engineering Section: G.A. Dunlop,

G. A. Dunlop

for F.R. Hartley
Director

lt

GRINDING OF ASH

1. INTRODUCTION

A sample of natural ash was received for grinding investigations to assist the client's programme of testing to assess the pozzolanic qualities of the materials.

It was proposed to carry out a Bond grindability test, the screen size at which the test was to be done to be determined by the surface area of the ground powder in relation to that of portland cement. Because of the pozzolanic properties of the material, no wet sizing could be practiced, and dry screening throughout the grindability test was therefore specified.

During the early stages of the grinding investigation, it was clear that Blaine surface area of ash ground to passing 200 mesh was well below that of normal portland cement; however, because the degree of grinding required to achieve a pozzolanic character was unknown at that time, and in view of the anticipated difficulties in determination of grindability at finer product sizes due to the necessity for dry screening, the sponsor agreed that grindability should proceed at 200 mesh.

2. PROCEDURE AND RESULTS

2.1 Sample Preparation

The sample received for testing was moist, and contained some coarse hard lumps, up to 3/4 inch in size, of both light and dark-coloured material in a matrix of generally friable agglomerates of ash.

It was decided to crush the total sample, after drying, to a size at which the ash agglomerates were essentially broken. The material was stage reduced by jaw and rolls crushers, to pass an 18-mesh screen.

Portions of the crushed material were riffled out, for screen sizing and for grindability testing. Replicate samples of 200 g each were sized by screening on a nest of 8-inch diameter laboratory sieves, using a Pascall screen shaker, for times of 10, 15 and 20 minutes, with the results shown in Table 1. From these screenings, and examination of the size fractions, it was concluded that a shaking time of 15 minutes gave satisfactory sizing, and this procedure was adopted for all subsequent sizings.

2.2 Grindability Testing

Grindability determination was commenced at a screen size of 200 mesh. The Bond method entails dry grinding a standard volume charge in a mill of specified size and with a specified graded-size of ball charge. The ground material is then sized on the grindability screen and oversize material is made up to the standard volume with new feed, and re-ground in successive stages, for a number of mill revolutions calculated to produce a circulating load of oversize return of 250% of new feed.

The product from each grinding stage was sampled for surface area measurement by the Blaine method, with the results shown in Table 2.

The grinding test was continued until stable conditions of circulating load and ground product were established, and from the latter stable cycles of the test, the work index for grinding was calculated.

Detailed results of the grinding test are shown in Table 3. Sizings of grindability feed and product are shown in Figure 1.

Surface area determinations of sized fractions of the grindability product from Stage 3 are shown in Table 4.

Surface area measurements were also conducted on three samples of the material submitted by the Client. This material was said to have been screened at 240 mesh and two portions of the undersize ground for one and two hours respectively. The remaining portion was unground. The results are shown in Table 5.

TABLE 1: SIZING OF GRINDABILITY FEED WITH VARIATION IN SIEVE SHAKING TIME

Size Fraction Mesh B.S.S.	Weight % Shaking Time, Min.		
	10	15	20
- 18 + 44	39.0	38.5	38.2
- 44 + 60	10.7	10.5	10.4
- 60 + 85	8.6	8.4	8.3
- 85 +120	9.8	9.7	9.6
-120 +170	7.2	7.2	7.2
-170 +200	3.8	3.8	3.8
-200 +240	3.7	3.7	3.6
-240 +350	7.0	6.2	6.0
-350	10.2	12.0	12.9
	100.0	100.0	100.0

TABLE 2: SURFACE AREA MEASUREMENT OF STAGE GRINDABILITY PRODUCTS

Grindability Stage	Surface Area of Product cm^2/g (Blaine)
1	2690
2	2265
3	2161
4	2050
5	2010
6	2000
Cement Standard	3715

TABLE 3

Form 98
Project No. 3/115/1/0-2782/72

AMDEL

Test by: Z. Sawicki

GRINDABILITY RESULTS

Ball Mill Grindability at 200 mesh (P_1 = 75 microns)

Sample: Natural Ash (-18#)   Finished material in feed (F) = 21.9 %   Date: December, 1971.

Stage	A Weight of 700 Feed g	A_1 Weight of New Feed g	Y Mesh in Feed g	X Gross Product for 250% Circulating Load	R Number of Grinding rev.	B Screen Overside g	C Gross Product g	D Net Product g	G Grindability g/rev.	L Circulating Load %
1	1185	-	260	-	(E) 50	880	305	45	0.90	-
2	1115	235	51	352	334	825	290	239	0.71	284
3	1134	309	68	330	369	820	314	246	0.67	261
4	1134	314	69	328	387	775	359	290	0.75	216
5	1135	360	79	310	308	812	323	244	0.79	251
6	1136	324	71	325	322	811	325	254	0.79	250
7	1137	326	71	324	320	813	324	253	0.79	251

(E) Estimated.

Unit Volume: 700 ml = 1136 g in mill equivalent to 101 lb/cubic foot of broken ore.

Average of Stages: 5-7 inclusive - 250% circulating load,
G_{bp} = 0.79 g/rev.

$A_1 = A - B_p$ $C = A - B$ $Y = \frac{A_1 \times F}{100}$ $X = \frac{100\ B_p}{250}$

$D = C - Y$ $G = \frac{D}{R}$ $R = \frac{X - Y}{G}$ $L = \frac{100\ B}{C}$

Note: B_p = B from previous grinding stage.

Calculation of Work Index: Feed size F = 540 microns
Product size P = 62 microns

$$\text{Work Index (Wi)} = \frac{44.5}{P_1^{0.22} \times G_{bp}^{0.8} \left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right)} = \frac{44.5}{75^{0.22} \times 0.79^{0.8}\left(\frac{10}{\sqrt{62}} - \frac{10}{\sqrt{540}}\right)} = 24.8$$

TABLE 4: SURFACE AREA MEASUREMENT OF SIZE FRACTIONS OF GRINDABILITY PRODUCT (FROM STAGE 3)

Size Fraction Mesh B.S.S.	Surface Area of Product cm^2/g (Blaine)
-240	2430
-350	3055
Total (-200)	2.61

TABLE 5: SURFACE AREA OF MINUS 240 MESH MATERIAL

Sample Mark	Grinding Time	Blaine Surface Area (cm^2/g)
J157/1	Nil	3860
J157/2	1 hour	3510
J157/3	2 hours	3260

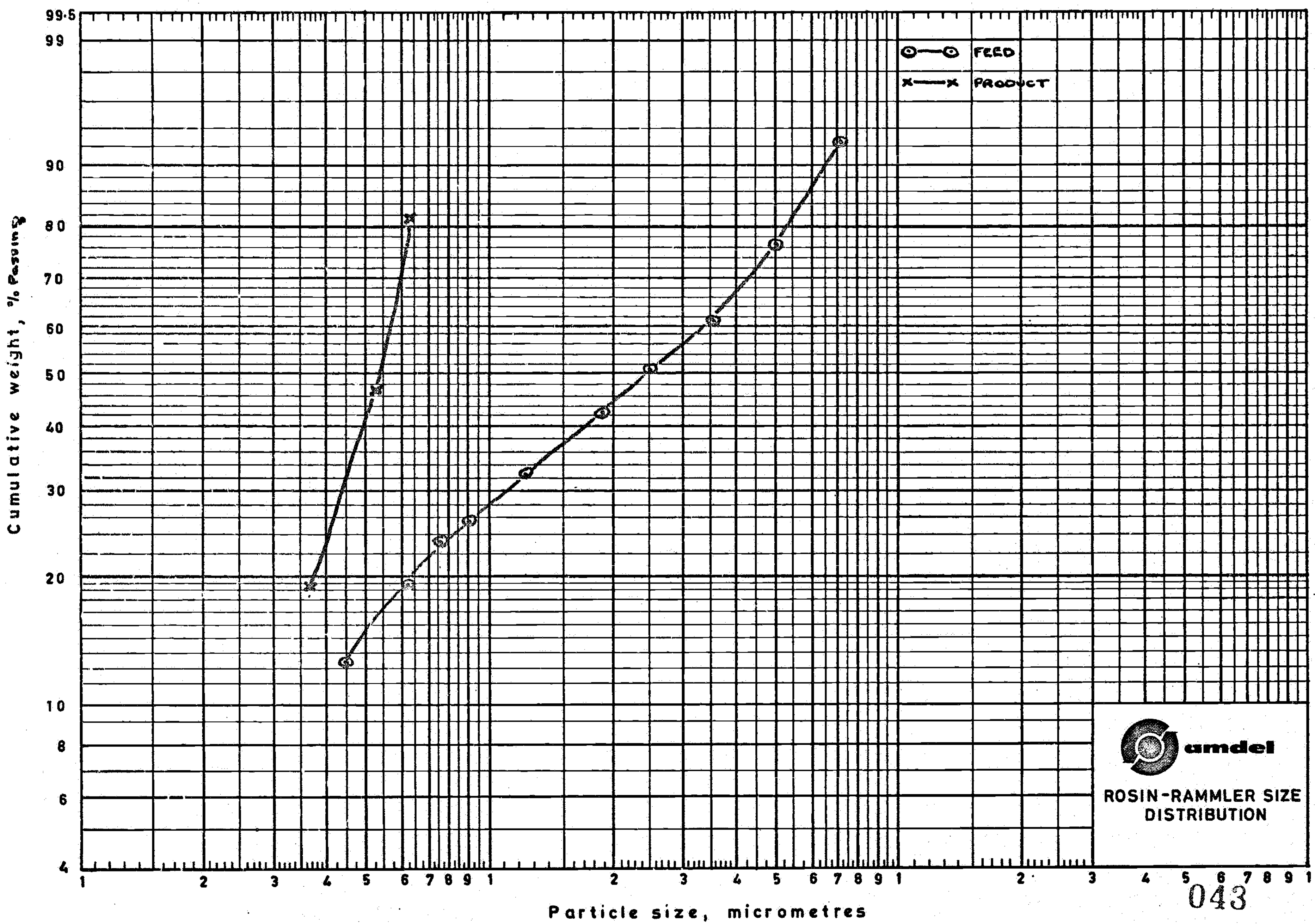


FIGURE 1 : GRINDABILITY FEED AND PRODUCT SIZINGS

THE READYMIX GROUP (S.A.)

(TECHNICAL DIVISION)

POZZOLANIC EVALUATION OF GROUND VOLCANIC ASH.

SECOND INTERIM REPORT.

1. Introduction.

Results of work summarized in the Interim Report dated 28th February, 1972, indicated finer grinding of the volcanic ash was necessary for effective pozzolanic activity.

This report covers work carried out on volcanic ash with a fineness of approx. 5000 cms^2/gm. Procedures were the same as for the first trial series.

2. Replacement Basis.

Cement replacement was on the basis of replacing the stated percentage (15% or %25) of cement by weight with an equal absolute volume of fly ash. In addition 5% sand replacement was made.

3. Results.

All mixes - Coarse aggregate - Riverview Dolomite.
- Fine aggregate - A.B.M. Noarlunga Sand.

Mix.	Slump (ins)	Compressive strength (p.s.i.)						Density (lbs/c.ft.)	Actual Total Water (gall/c.yd)
		7 days	14 days	28 days	28 days Avge.	28 Day* Corrected	Variat. from Plain.		
600 lbs Adel.NP.	2.75	3950	4800	5100 5400	5250	5200		151.6	35.6
15% ash Replacet.	2.5	3900	4550	5100 5250	5175	5075	-125	152.0	31.5
25% ash repl.	3.0	2700	3400	3950 4000	3975	3975	-1225	151.2	36.8
400 lbs Adel.NP.	3.25	1600	2150	2550 2700	2625	2675		150.0	36.4
15% ash Replcmt.	2.75	1500	2000	2550 2450	2500	2450	-225	150.0	33.8
25% ash Replcmt.	3.25	1200	1650	2150 2200	2175	2225	-450	149.6	35.3
600 lbs. Brighton N.P. . . .	3.0	3700	4350	4900 4900	4900	4900		152.4	36.8
25% ash Replc.	3.0	2900	3400	4200 4200	4200	4200	-700	152.0	34.0

	Slump (ins)	7 days	14 Days	28 Days	28 Days Avg.	28 Day Cort*	Variat. From Plan.	Density lb/c.ft.	Actual Total Water galls/c
400 lbs. Geelong HP	3.0	2400	2850	3350 3200	3275	3275		150.8	32.2
25% ash Repl.	2.75	1550	1850	2200 2150	2175	2125	-1150	150.0	34.5

*Corrected to 3" slump equivalent, assuming 1" slump increase = 200 p.s.i. decrease.

Note:- The attached graphs have all been plotted on actual (notcorrected) strength results.

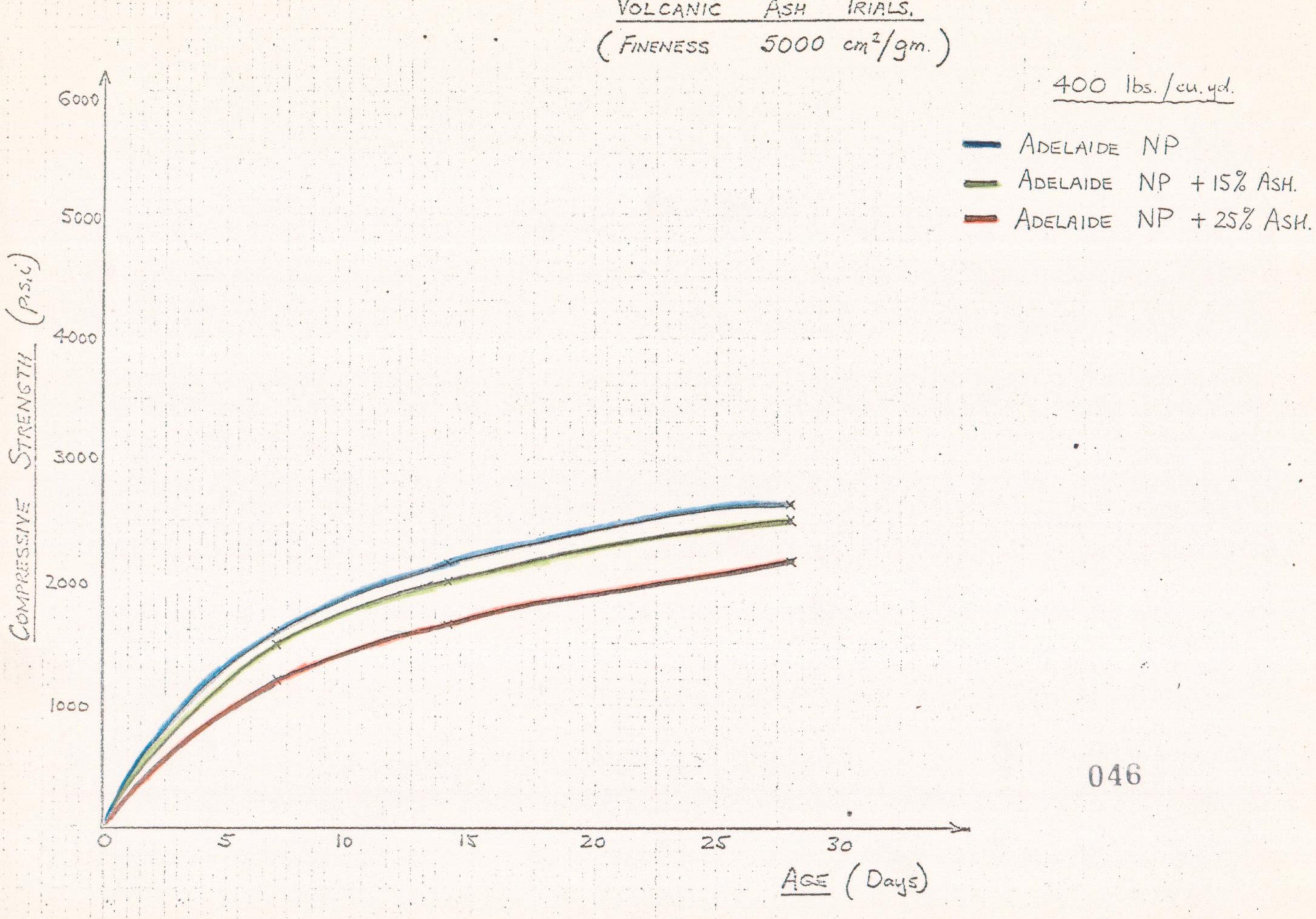
Conclusions.

The volcanic ash, with a fineness of approx. 5000 cms ^{2}/gm., has given encouraging results with 15% cement replacement in Adelaide HP mixes.

However, 25% cement replacement has yielded similar strength deficiencies, with respect to the control mixes, as the first trials with coarser ash. Correlation of both trials is difficult due to the large variation in the control mixes i.e. approx. 500 p.s.i., strength increase in 600 lbs/cu.yd. Adelaide HP control mix and 400 p.s.i. decrease for the 400 lbs/cu. yd. Adelaide HP control mix for the second trials compared with the first trials.

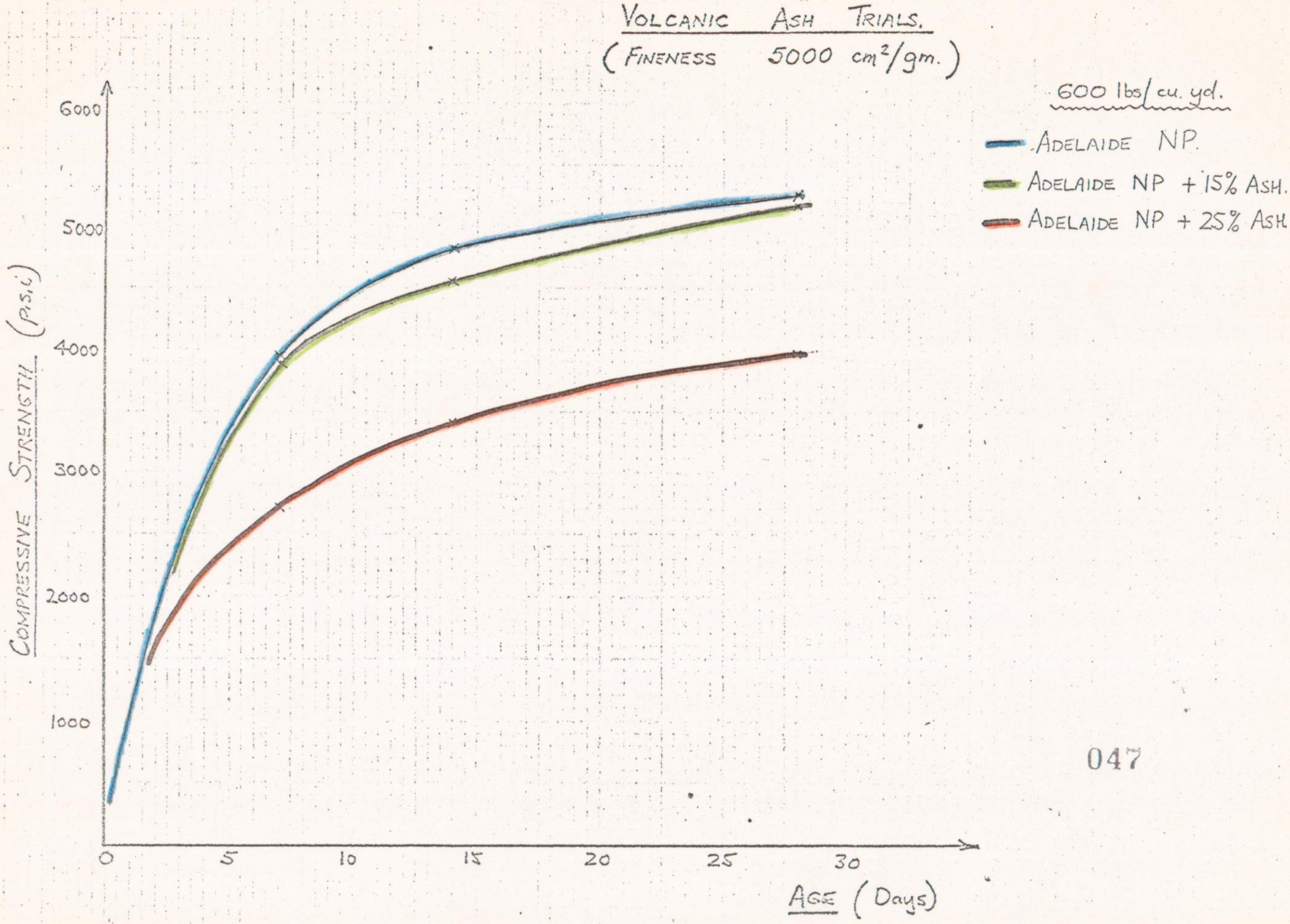
It does appear that future work should concentrate on the ash having a fineness index of 5000 cm ^{2}/g or greater.

Dundie



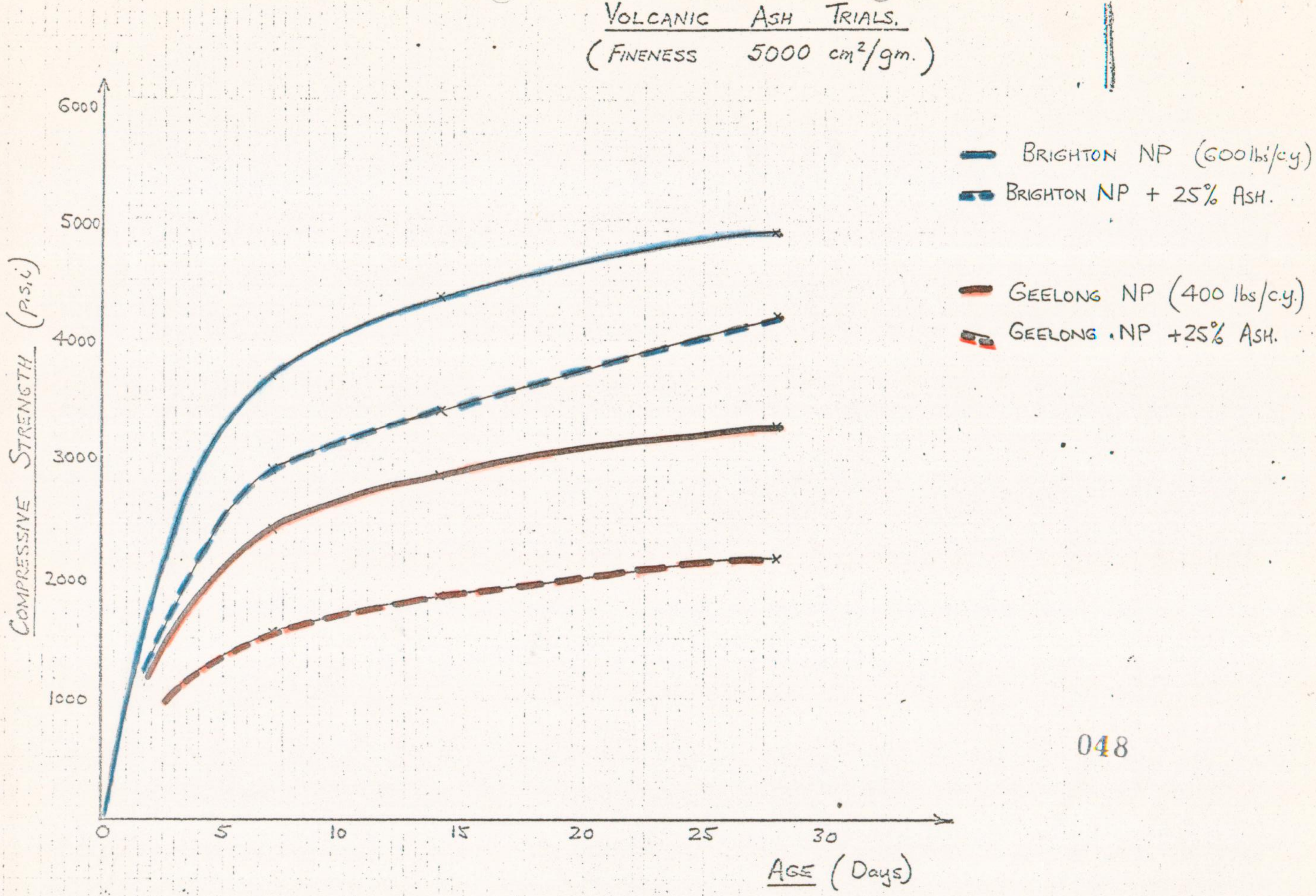
VOLCANIC ASH TRIALS.
(FINENESS 5000 cm²/gm.)
400 lbs./cu.yd.
ADELAIDE NP
ADELAIDE NP + 15% ASH.
ADELAIDE NP + 25% ASH.
COMPRESSIVE STRENGTH (p.s.i.)
6000
5000
4000
3000
2000
1000
0
5
10
15
20
25
30
AGE (Days)

046



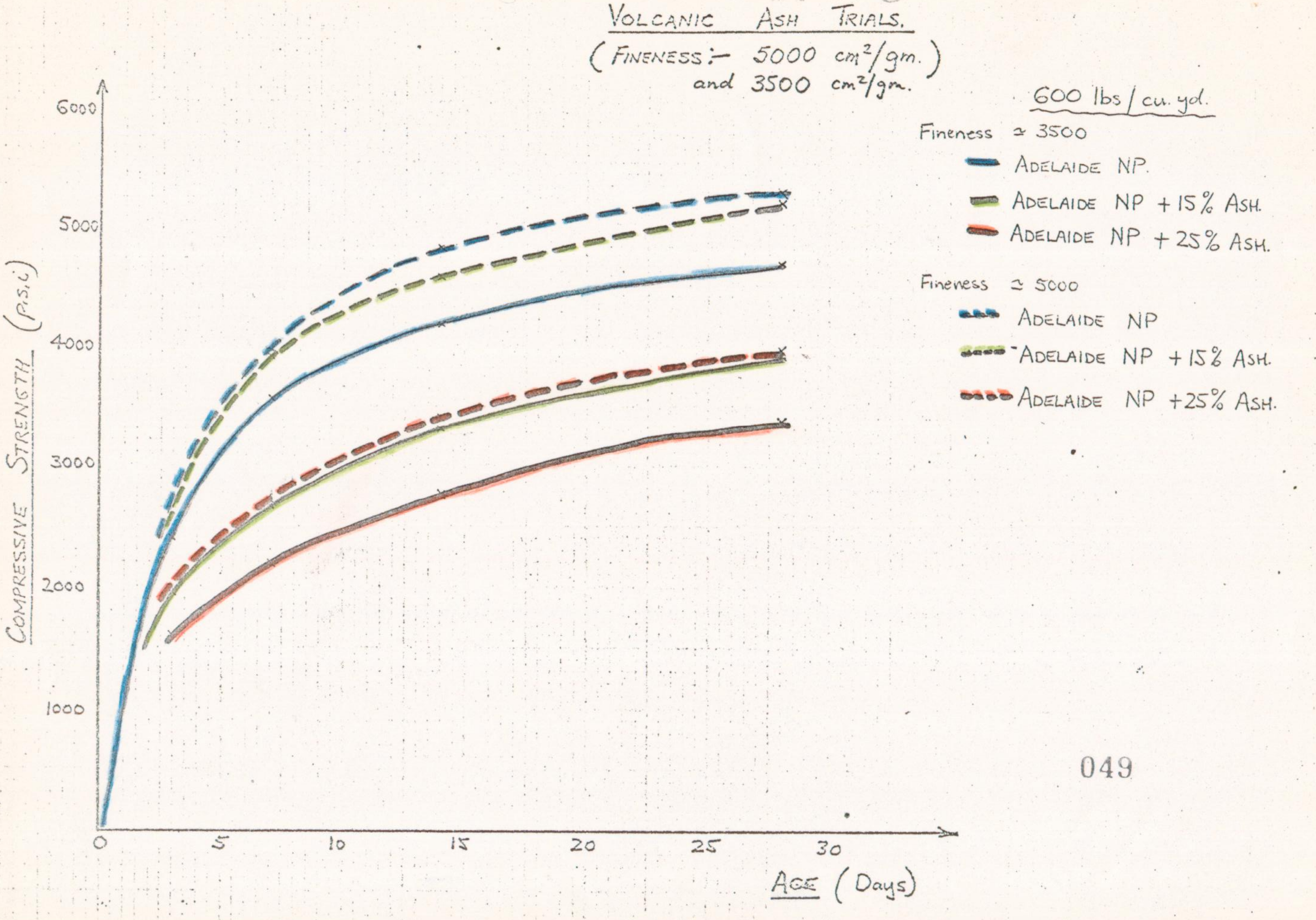
VOLCANIC ASH TRIALS.
(FINENESS 5000 cm²/gm.)
600 lbs/cu. yd.
ADELAIDE NP.
ADELAIDE NP + 15% ASH.
ADELAIDE NP + 25% ASH
COMPRESSIVE STRENGTH (P.S.I.)
6000
5000
4000
3000
2000
1000
0
5
10
15
20
25
30
AGE (Days)

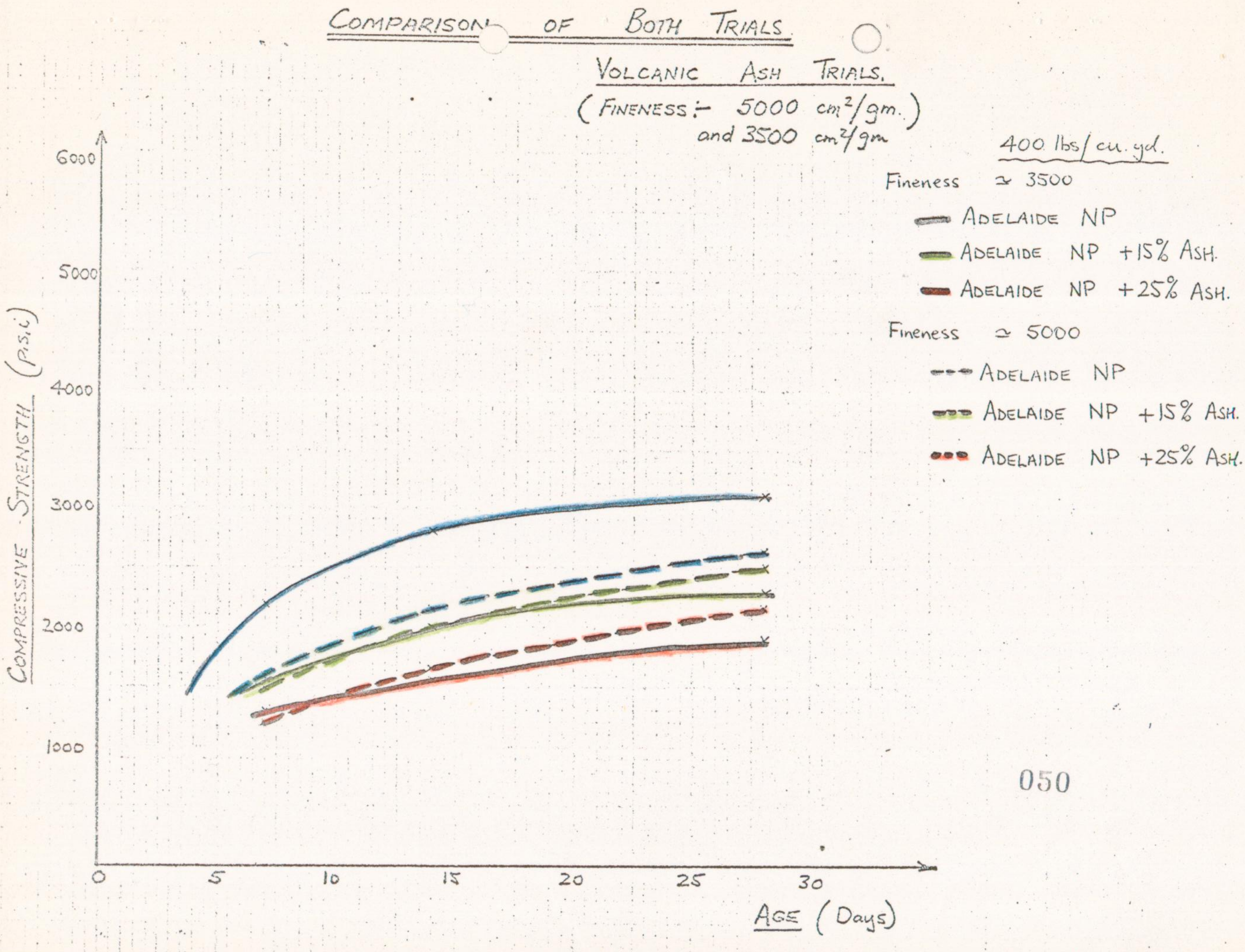
047


VOLCANIC ASH TRIALS.
(FINENESS 5000 cm²/gm.)
6000
5000
4000
3000
2000
1000
COMPRESSIVE STRENGTH (P.S.I.)
0
5
10
15
20
25
30
AGE (Days)
BRIGHTON NP (600 lbs/c.y.)
BRIGHTON NP + 25% ASH.
GEELONG NP (400 lbs/c.y.)
GEELONG NP +25% ASH.

048

COMPARISON OF BOTH TRIALS.




COMPARISON OF BOTH TRIALS
VOLCANIC ASH TRIALS.
(FINENESS :- 5000 cm²/gm.)
and 3500 cm²/gm
400 lbs/cu. yd.
Fineness ≃ 3500
ADELAIDE NP
ADELAIDE NP +15% ASH.
ADELAIDE NP +25% ASH.
Fineness ≃ 5000
ADELAIDE NP
ADELAIDE NP +15% ASH.
ADELAIDE NP +25% ASH.
6000
5000
4000
3000
2000
1000
COMPRESSIVE STRENGTH (p.s.i.)
0
5
10
15
20
25
30
AGE (Days)

050

14th July, 1972.

THE READYMIX GROUP (S.A.)

(Technical Division)

POZZOLANIC EVALUATION OF GROUND VOLCANIC ASH.

REPORT NO. 3.

051

1. INTRODUCTION.

This report covers pozzolanic evaluation of volcanic ash ground for 9 hours to a fineness of 6950 sq. cms. / gm.

Cement replacement was on the basis of replacing the stated percentage (15%, 20% or 25%) of cement by weight with an equal absolute volume of fly ash. An additional 5% sand replacement was also made.

2. RESULTS.

A. Pozzolanic Activity Test according to A.S.T.M. C.595.

This test was performed by our Central Research Laboratory (C.R.L.) in Sydney, and a copy of the test procedure is appended to this report.

Minimum compressive strength at 7 days required for pozzolan 800 p.s.i.
Actual compressive strength of ash achieved by C.R.L. 1200 p.s.i.

(S.G. of volcanic ash = 2.78. Fineness = 6950 sq. cms./gm.)

B. Concrete Trials performed at Brompton.

Standard aggregates - Riverview Dolomite, A.B.M. Noarlunga Sand.

MIX	Slump (ins.)	COMPRESSIVE STRENGTH (P.S.I.)					Actual Total Water (gals./cu.yd.)
		7 days	28 days	28 days Avg.	*28 day Correct.	Variation from Plain	
600 lbs. Adel. N.P.	2.5	3850	5800 5950	5875	-		33.7
15% ash repl.	2.5	3300	5350 5450	5400	-	- 475	32.5
20% ash repl.	2.5	3250	5250 5350	5300	-	- 575	32.5
25% ash repl.	2.5	3150	5050 4950	5000	-	- 875	32.0
400 lbs. Adel. N.P.	2.5	2050	3250 3300	3275			34.0
15% ash repl.	2.25	1800	3150 3050	3100	3050	- 225	31.0
20% ash repl.	2.75	1800	2900 2950	2925	2975	- 300	31.0
25% ash repl.	2.75	1450	2550 2700	2625	2675	- 600	31.8

* Corrected strength for slump equal to plain mix, assuming 1" slump increase = 200 p.s.i. decrease.

052

3. CONCLUSION.

The above results tend to align with our previous findings for ash ground to 3500 and 5000 sq. cms./gm. fineness, with the ash adequately meeting standard A.S.T.M. pozzolanicity requirements, but not performing satisfactorily in concrete mixes.

In all cases, 15% cement replacement has given the closest strengths to the plain mixes. 5% replacement to achieve parity with plain mixes appears likely, but further trials concentrating in this region of percentage replacement are necessary.

SUMMARY OF ALL TRIALS.

Compressive strengths converted from actual values to equivalent at 3" slump.

Ash Fineness	600 lbs. Plain	15% Ash	Variation from Plain	25% Ash	Variation from Plain
3500 sq.cms./gm.	4725 p.s.i.	4000	- 725	3525	- 1200
5000 "	5200 "	5075	- 125	3975	- 1225
6950 "	5975	5500	- 475	5100	- 875
Ash Fineness	**400 lbs. Plain**	**15% Ash**	**Variation from Plain**	**25% Ash**	**Variation from Plain**
3500 sq.cms./gm.	3100 p.s.i.	2300	- 600	1900	- 1200
5000 "	2675 "	2450	- 225	2225	- 450
6950 "	3175 "	2950	- 225	2875	- 300

Many anomalies occur between mix strengths in the above table, making conclusions difficult. However, the pozzolanic activity of the volcanic ash has increased with increasing fineness.

All testing so far indicates that cement replacement in the region of 5% is the likely break-even point with plain mixes with respect to strength.

D. MUDIE

DM/MEC

c.c. Mr. G.H. Quinn.
Mr. W.G. Ryan.

ABSOLUTE

I. POZZOLANIC ACTIVITY TEST TO A.S.T.M. C595

This method consists of mixing 1 part hydrated lime to 9 parts of graded silica sand (from Ottawa, Illinois) by weight, plus an amount of oven dry pozzolan equal to twice the weight of lime multiplied by a factor obtained by dividing the specific gravity of pozzolan by the specific gravity of the lime. The amount of mixing water is such that the flow of mortar is 110 ± 5% when measured in accordance with A.S.T.M. C109.

Three cylindrical specimens $2 \pm \frac{1}{8}$ in. in diameter and $4 \pm \frac{1}{8}$ in. high are made from each batch. These are stored at 73 ± 3^{o}F for 24 ± 2 hours and then 131 ± 3^{o}F for 6 days until $4 \pm \frac{1}{2}$ hours before the time of testing. They are cooled then to 73.4 ± 3^{o}F and tested in compression at the loading rate of 100 to 500 p.s.i. per mix.

Minimum pozzolanic strength according to A.S.T.M. C595 should be 800 p.s.i.

Copies: M/s. G.H.Q., [illegible]., Bala Param, and file.
W.C. Ryan

14th July, 1972.

THE READYMIX GROUP (S.A.)
(Technical Division.)

GROUND VOLCANIC ASH - ECONOMIC EVALUATION.

Metro. Materials Prices (Average)

Adelaide N.P. Cement	$20.50 per ton.
Sand	$2.00 per ton.

Consider ash replacement on mixes with average cement content of 450 lbs./c.yd., and 5% sand replacement in all cases.

5% Ash Replacement

Materials costs per cu. yd.

Plain Mix

450 cement	$4.12
1200 sand	1.07
	$5.19

Ash Mix

425 cement	$3.89
80 ash	?
1140 sand	1.02
	$4.91 +

10% Ash Replacement

Plain Mix

450 cement	$4.12
1200 sand	1.07
	$5.19

Ash Mix

405 cement	$3.71
100 ash	?
1140 sand	1.02
	$4.73 +

For example only, consider 10 cents per cu. yd. saving expected by Concrete Division. As capital expenditure on storage would be required, and another variable is added to concrete quality control, this figure of 10 cents is probably far too low, but will be used in this analysis.

5% Ash Replacement:

∴ Ash mix max. cost $5.09
∴ 80 lbs. ash max. cost $0.18
∴ Max. cost ash into Metro. bins $5.05 / ton.

10% Ash Replacement:

Ash mix cost $5.09
∴ 100 lbs. ash max. cost $0.36
Max. cost ash into Metro. bins $8.05 / ton.

Note: Mt. Gambier approx. 290 miles from Adelaide.

Adelaide-Brighton indicate a price of $12.50 (approx.) per ton for fly ash delivered to Adelaide plants. This material is not processed by Adelaide-Brighton, and is just a matter of collection from the Power Station stack at Pt. Augusta (200 miles).

DM/MEC

D. Mudie
D. MUDIE