CONTENTS ENVELOPE 2210

TENEMENT: Exploration Licence No. 13

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

REPORT:

PLANS:

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SIX MONTHLY PROGRESS REPORT

EXPLORATION LICENCE 13

SOUTH EASTERN SOUTH AUSTRALIA

B.C. Param
P. Gray

24-3-73

CONTENTS

Introduction

During the post-war years rapid industrial development has taken place within Australia. The Concrete Industry has advanced in parallel with Australia's growth, and now commands recognition for a product equal in quality to that manufactured elsewhere throughout the world. In order to advance at such a rate, many technological problems have been overcome in a relatively short time, however, this work must continue into the future.

In recent years our Company realised the importance of lowering raw materials costs, to off-set the continued rise in labour costs, and therefore stabilize prices within the concrete industry. The most attractive means of reducing these basic costs of materials, was to either synthesize the basic component of concrete, "cement", or to replace a portion of the total cement content within a given mix, with a commodity of cheaper production costs, at no sacrifice to quality. Of the two alternatives, the former is not practical at this stage in time, therefore the latter was decided upon.

In the manufacture of substances for replacement of Portland Cement, two methods have been in use for some years throughout European countries, where either artificially produced, or natural occurring "pozzolanas" are utilized as the blend material.

Artificial pozzolans are commonly derived as fly-ash, a waste product precipitated from the burning of brown coals in power stations and other industrial complexes, whilst natural pozzolanas are produced by the milling of scoriaceous or tuffaceous ashes from naturally occurring volcanic sources.

In 1972 our Company realised the possible economic potential of deposits situated in the South Eastern Province of South Australia, at Mt. Schank, Mt. Gambier, and in the vicinity of the Lakes, Edward and Leake.

.....2/

After an inspection of the South Eastern Volcanics, a Special Mining Lease (No.655) was taken up, and work proceeded. Emphasis was placed on proving the pozzolanic qualities of the youngest volcanics, which are situated at Mt. Schank. Although this deposit appeared attractive because of it's very loose, unconsolidated nature of deposition, and ease of grinding and milling in laboratory trials, the material proved to be of no value as a pozzolana.

After considerable time and expenditure, Special Mining Lease number 655 was allowed to expire, and the area in the vicinity of Lake Leake and Lake Edward was applied for. An Exploration Licence No.13 was granted to our company on 21st. September, 1972, for a period of 12 months. Work proceeded immediately and the results of the first six months of investigations are contained in this report.

....3/

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Geology

Regional

The area under review comprises mainly Tertiary and Quaternary materials. The dominant outcropping rock type is the mid-Tertiary marine bryozoal limestone. Lower Tertiary fluviatile and paralic clays and sands are restricted in outcrop, whilst outcropping pre-Tertiary rocks are rare.

The area is essentially a sub-coastal plain with a minor seaward slope. The greater part is less than 300 feet above sea-level, and is practically devoid of any obvious surface drainage features. Superimposed upon this depressed terrain there is a well developed system of sub-parallel ranges aligned in sympathy with the modern coast.

These ranges are stranded ocean, coastal dunes of Quaternary age. In relation to their inter-dune flats, they rarely exceed 100 feet in height. Marshes, swamps and lagoons are prominent features of the inter-dune areas and an extensive flooding normally takes place in the wet winter season. Although practically the whole area is underlain by porous Tertiary limestones, downward percolation is impeded by the proximity of groundwaters to the surface, and by a veneer of impervious soil travertine and swamp clays.

Volcanicity

The volcanic areas are those of greatest topographic relief, and although only rising to a maximum of 802 feet, they form prominent landmarks, such as Mt. Burr (802'), Mt. Gambier (630'), Mt. Graham (676'), and Mt. Schank (520'). Late Cainozoic volcanicity has produced massive accumulations of basalt as at Mt. Burr and The Bluff, the building of several volcanic cones, as at Mt. Schank, and the spreading of ash and the formation of the subsidence calderas at Mt. Gambier.

Volcanic activity occurred in the Mt. Gambier area in late Tertiary and Pleistocene times. The outbursts, although spectacular were only an outlying manifestation of a much wider regional phenomenon. Approximately 16 cone eruptions occurred in S.A., whereas there were more than 150 throughout Victoria.

.....4/

Fissure eruption played a major role in the Victorian eruptions with the development of extensive basalt sheets covering more than 10,000 square miles of the Western District plains and highlands. Within S.A. the various vents occurred along lines of fissuring, where minor flows apparently preceded cone formation in most cases, but later, rapid accumulations of steam led to the development of explosion craters.

The volcanic area of the South Eastern Province is distributed over quite a large area, extending from Mt. Schank in the south-east to Mt. Graham in the north-west, a distance of some 40 miles. The various volcanoes and fissure eruptives have been extensively modified by erosion and masked by ocean beach sand drift. Ocean coastal erosion during middle and late Pleistocene has also made considerable inroads on the seaward margins of some of these accumulations. Erosion in some instances has eliminated the true form of some of the vents. Two such modified and eroded volcanic occurrences are the subjects dealt with in this report.

Lake Leake

Sub-circular in shape and approximately a 1/2 mile in diameter, this lake is bounded along the western and southern margins by swamp. The eastern banks of the lake are low and rise gradually eastwards whilst at the northern end a vertical cliff, some 70 feet in height is present, from which a gentle downwards slope continues away to the north.

Lake Edward

Separated by low hills from Lake Leake, this lake is somewhat smaller in area but is similarly margined by swamps along it's western and southern boundaries and by low cliffs on the eastern boundary.

Volcanic Activity

Both volcanic occurrences consist of Subsidence Calderas, with asymmetrical distribution of ash along the northern and eastern margins of the lakes. The Pyroclastic material shows distinct bedding, which dips outward from the crater at the same low angle as the surrounding ground surface. The ash beds probably originated from periodic ejections during a single eruption, with the material becoming sorted during it's descent.

....5/

In an exposure near the northern portion of Lake Leake, cross-bedding is present in the outward dipping ash, indicating that wind action plays some minor part in the sorting and deposition of this material.

Near the base of the sheer faces at each lake, there is a considerable variation in the amount of country rock contained within the ejectementa.

Ash deposition within the vicinity of both lakes is in an advanced stage of consolidation, and invariably has a considerable depth (5'+) of overburden in the form of paralic clays and sands. Transformation of the consolidated ash, by weathering, to volcanic soil is minimal.

Basically, the pozzolanic ash is composed of a mixture of silicates and contains both glass and crystalline particles. The volcanic ash and dust from which they were formed has undergone rapid cooling, and in some instances has suffered considerable chemical alteration. This alteration is generally attributed to the action of super-heated steam and carbon dioxide below the earth's surface. The effect of this action has been to convert much of the original material into a more chemically reactive modification, whilst the basic constituents have been partially removed under the combined influence of the carbon dioxide and water.

Field Investigations

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Field investigations commenced immediately after the granting of Exploration Licence No. 13.

Work to date includes the following:

(1) Prospecting - The area was closely inspected to determine the extent of (a) volcanic ejectementa deposition, (b) bedding planes of consolidated ejectementa, and (c) stages of weathering of beds.

(2) Mapping - On completion of a geological survey, notes were compared, and a plan was prepared. A copy of the plan is appended to this report.

(3) Drilling - A small drill program commenced after careful selection of hole locations by B. Param. Drill holes were carried down to a maximum depth of 30 feet, so the program was planned strictly for the purpose of gaining sufficient sample material for mix trial purposes.

Drill type: Gemco Model Wagon Drill, equipped with 4" diameter spiral coring auger, using triple head cutting bit.

(4) Sampling - Approximately 2 cubic feet of drilled material was collected from each bore hole, together with bulk samples derived from ash exposures surrounding the two Lakes. These samples were bagged and submitted for Laboratory Tests, at R.M.C. Minerals.

Sample Preparation

Equipment

(1) 9" Jaw crusher
(2) 3/4" to 1/8" Jaw crusher
(3) Pulverizer (1/8" to 100 mesh)
(4) Drying oven (300°C)
(5) 1/8" to 25 mesh Sieves (B.S.S.)
(6) 10 Kg. Spring balance (acc. to 200gm.)
(7) 2.5 Kg Beam balance (acc. to 1/10th gm.)
(8) Ball Mill - Dimensions: diameter $12\frac{3}{4}$"
length $15\frac{1}{2}$"
r.p.m. 21

Ball charge 51.0kg.

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Method (for preparation of bulk samples where material is $+\frac{3}{4}$" diameter)

(1) Pass total sample through large jaw crusher - product = $-\frac{3}{4}$"

(2) Pass total sample through small jaw crusher - product = $-\frac{1}{8}$"

(3) Weigh 10 kg. of sample correct to 1/10th. gm.

(4) Place 10 kg. sample in drying oven for 24 hours at 300°C.

(5) Remove sample from drying oven and weigh, to determine loss of moisture.

(6) Add extra dried material to sample to correct to 10 kg.

(7) Pass sample through pulverizer - product = -25 mesh.

(8) Screen sample through 25 mesh sieve and return oversize to pulverizer.

(9) When total sample is pulverized to -25 mesh, weigh out 5 kg. sample for charge to ball mill.

(10) Place 5 kg. sample in ball mill with a ball charge of 51 kg.

(11) Grind sample in ball mill for desired period.

(12) Discharge ball mill contents into 3/8" mesh sieve collector receptacle.

(13) Weigh sample

(14) Weigh ball charge after completion of processing 3 samples.

Particle Sizing

Represented below are Blaine sizings from various grinding periods, where the feed size to ball-mill prior to grinding was -25 mesh. These figures (Blaine) were determined by The Readymix Group's Central Research Laboratories (N.S.W.)

Milling Time	Blaine cm^2/gm
2 hours	2360
$2\frac{1}{2}$ hours	3060
3 hours	3300
4 hours	4170
5 hours	4325
6 hours	4980
7 hours	5620

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Concrete Trials

Evaluation of Pozzolans

In the past a Portland-Pozzolan cement has been manufactured by blending 5 to 30 percent by weight of pozzolanic material with portland cement, either by simple mixing or by intergrinding with cement clinker. The calcium hydroxide liberated during the process of hydration of the cement combines slowly with the pozzolan to give it cementitious properties, thereby contributing to water-tightness and long continued gain in strength of the concrete. All types of Portland cement may be mixed with a pozzolan, the quantity of which is lessened if it has a high water requirement. The pozzolanic action of these materials varies widely, therefore evaluation of materials must be determined by trial mixes and the standard physical tests for cement, together with long term strength and durability tests of moist cured and adiabatic mass-cured specimens.

The strength of portland-pozzolan cement concrete is always at first lower than that for straight portland cement concrete which is made with the same proportions of mix. The former, with age, gradually increases in strength and subsequently becomes stronger than the latter. Pozzolans containing amorphous silica are usually more active than those containing crystalline silica, the rate of reaction depending on the chemical composition, pore structure and fineness of the material.

Economic benefits from the effects accompanying the use of portland-pozzolan cement in concrete manufacture are summarised below.

(a) Improved workability
(b) Reduction of segregation and bleeding with hydration
(c) No increase in drying shrinkage when air-entrainment is used.
(d) Protracted impermeability to pure and soft waters.
(e) Increased plastic flow and stress adjusting characteristics.
(f) Improved resistance to dilute sulphate solutions and weakly acidic waters.
(g) Long, continued gain in compressive and tensile strengths after slow development of same at early ages. This feature is more marked in lean (cement) mixes than in rich ones.
(h) Appreciable saving in cost over concrete manufactured entirely with portland cement when the pozzolan is readily available.

....9/

Methods of Evaluation

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The method used in preliminary mix trials was based upon a standard developed early this century for the evaluation of both artificial and natural pozzolans. The system was to replace a given percentage of cement (5 to 30 percent) with an equal absolute volume of the pozzolanic material. Normal procedure entailed the mixing of a portland cement concrete of a specified design as a control standard. Using the specified mix design as a basis, each new mix had a progressive increase of pozzolan added to replace the same volume of cement. Four test cylinders (6" dia. x 12" length) were then cast for each separate blend. The cylinders are stripped of the casting mould after a period of 24 hours, when each cylinder is then placed in a curing tank (water filled) and kept at a constant temperature until the expiry of 7 days from mixing. At 7 days, one cylinder is taken for compression tests, whilst the remaining 3 of the original 4 cylinders remain in curing. 2 cylinders are extracted after 28 days for compression tests, whilst the 1 remaining cylinder is crushed after 90 days curing time.

Replacement of cement for pozzolan on an equal volume basis has not proven successful, therefore a further method recommended by The Readymix Group's Central Research Laboratory (Sydney), was initiated. This method was described by Robert W. Cannon in his paper, "Proportioning Fly-Ash Concrete Mixes for Strength and Economy", (A.C.I. Journal, November 1968). A copy of this paper is appended to this report. Although the cement-pozzolan ratio differs between the former and latter methods, the curing period is not altered.

Result of Tests

The result of tests carried out to date, both short and long term, are contained within this report.

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Conclusion

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Results gained from cement-pozzolan mix trials to date, indicate a maximum possible pozzolan replacement rate, not exceeding 10 percent of the cement content of the pozzolan mix.

Strength gain of pozzolan replacement concretes has been considerably lower than the strength gain of the normal portland cement standard control mix, at 28 days. Strength gains from 28 days to 90 days in the pozzolan mixes has increased at a greater rate than that of the control mix. Although this gain at 90 days appears very promising, concrete production "Standards" of today, require that maximum strength must be had at 28 days.

Because the pozzolanic qualities and action of this material in physical tests varies greatly, further work is required in determining it's economic use within our industry.

Expenditure to date on Exploration Licence 13

0015

General Survey of area for land use and to delineate ash areas	$	250.00
Auger drilling - Reconnaissance and some deep holes in promising areas	$	455.00
Travel and accommodation, operating expenses, fuel, sample bags etc.	$	465.00
Sample preparation (crushing and milling to a fineness of 6000 cm^2/gm) 17 samples at approximately $30 per sample	$	510.00
Pozzolan/cement mixed trials - 17 samples at $50	$	850.00
Supervision of field work and technical supervision	$	500.00
Overheads and administration, say	$	200.00
Total	$	3,230.00

11/12/72

The Readymix Group (S.A.)

Pozzolanic Evaluation of Ground Volcanic Ash 0016

Report No. 1 - Exploration Licence 13

Scope

This report covers the evaluation of ground volcanic ash from Lake Leake. Sample preparation included oven drying, crushing, screening, and grinding. The material was ground for a total of 6 hours, to an approximate Blaine of 5000 cm^2/gm.

Mix Trials

Cement replacement was on the basis of replacing the stated percentage (10%, 15% and 20%) of cement by weight, with an equal absolute volume of fly-ash. An additional 5% sand replacement was also made.

Results (Sample No. P.46)

Batches of 1.0 cu. ft. mixed in portable bowl mixer at Brompton Laboratory on 1/11/72.

Mix	Slump (inches)	Compressive Strength (P.S.I.)					Actual Total Water (galls. c.yd.)
		7 days	28 days	28 days (Av.)	28 days corrected to 2.5" Slump	Variation from Plain	
400 lbs. Adelaide N.P.	2.75	1550	2450 2500	2475	2525		35.4
10% Ash replacement	2.5	1450	2550 2400	2475	2475	- 50	35.1
15% Ash replacement	2.5	1200	2200 2200	2200	2200	-325	33.5
20% Ash replacement	2.75	1050	2000 2000	2000	2050	-475	34.0
600 lbs. Adelaide N.P.	2.5	3450	4950 5050	5000	5000		34.0
10% Ash replacement	2.5	3300	4800 4800	4800	4800	-200	34.0
15% Ash replacement	2.5	3050	4550 4550	4550	4550	-450	34.0
20% Ash replacement	2.75	2450	4050 3950	4000	4050	-950	34.0

Note: 28 day strength corrected to 2.5" slump on basis of 1.0" slump increase = 200 p.s.i. decrease

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Conclusions

The results from these tests indicate a maximum possible ash replacement of 10%, with 5% a more likely figure. The economics of such a level of replacement were briefly outlined within an appendage to Report No. 3 (Mt. Schank Volcanics).

(Paul Gray)
11/12/72

The Readymix Group (S.A.)

Pozzolanic Evaluation of Ground Volcanic Ash

Report No. 2 - Exploration Licence 13

Introduction

Previous work on the volcanic ash indicated little benefit to 28 day strengths from the ash.

Recently Alex Samarin of Central Research Laboratory (Readymix Group N.S.W.) suggested a different method of mix proportioning that had been proven in other pozzolan investigations. The method was described by Robert W. Cannon, in his paper - "Proportioning Fly-Ash Concrete Mixes for Strength and Economy (A.C.I. Journal, November 1968). A copy of this paper is attached.

Currently our trial mixes are designed for optimum strength at 28 days, with no consideration at this stage for economics. If the subsequent results had shown satisfactory pozzolanic effect, then the following stage of investigations would include modification of the mix design for economic advantage.

Mix Trials

Three different volcanic ash contents were used in mix trials carried out at Brompton Laboratory on 4/12/72. Using the replacement method contained in the paper by R.W. Cannon, ash contents were 15%, 20% and 25%, respectively of the cement content of the ash mix. (These contents correspond to 7.7%, 10.8% and 13.1% by weight cement replacement, on comparison with past mix trials).

Source of Samples

No. P.47	Drill Hole DH-2	Grinding Period 6 hrs.	Blaine 5000cm^2/gm
P.48	Drill Hole DH-3	Grinding Period 6 hrs.	Blaine 5000cm^2/gm
P.49 (a)	Drill Hole DH-1	Grinding Period 6 hrs.	Blaine 5000cm^2/gm
P.49 (b)	Drill Hole DH-1	Grinding Period 9 hrs.	Blaine 7000cm^2/gm

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Results

Mix	Slump (inches)	Compressive Strength (P.S.I.) 7 days	28 days	28 days (Av.)	28 days corrected to 3" Slump	Varia -tion from Plain	Actual Total Water (galls/ c.yd.)
P.47 400 lbs. Adelaide N.P.	4.0	1600	2700 2750	2725	2925		37.3
15% ash/cement	3.25	1500	2550 2700	2625	2675	-250	36.4
20% ash/cement	3.5	1600	2500 2550	2525	2625	-300	35.8
25% ash/cement	3.0	1600	2550 2550	2550	2550	-375	35.9
400 lbs. Geelong N.P.	4.0	1700	2400 2400	2400	2600		37.3
15% ash/cement	3.25	1700	2400 2550	2475	2525	- 75	36.4
P.48 400 lbs. Adelaide N.P.	4.0	1600	2800 2750	2775	2975		37.1
15% ash/cement	3.25	1600	2700 2550	2625	2675	-300	36.0
20% ash/cement	3.0	1550	2350 2400	2375	2375	-600	35.6
25% ash/cement	3.0	1750	2700 2800	2750	2750	-225	35.5
P.49 (a) 400 lbs. Adelaide N.P.	2.75	1750	2900 2900	2900	2850		37.1
(6 hr. milling) 15% ash/cement	3.0	1600	2850 2850	2850	2850	0	36.0
25% ash/cement	3.5	1300	2700 2650	2675	2775	- 75	35.5
P.49 (b) (9 hr. milling) 15% ash/cement	3.0	1600	2800 2850	2825	2825	- 25	36.0
25% ash/cement	3.2	1450	2850 2750	2800	2850	0	35.5

Note: 28 day strengths correct to 3" slump on basis of 1.0" slump increase = 200 p.s.i. increase

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Conclusions

(a) Sample No. P.47 - This ash has not performed very well with Adelaide N.P. cement, however, when combined with Geelong N.P. cement the variation from Plain is reduced considerably. Further work is required for a true assessment.

(b) Sample No. P.48 - Strengths indicate negligible benefit from this volcanic ash.

(c) Samples P.49(a) and P.49(b) - Both samples have given encouraging results with 15% and 25% ash/cement mixes (equivalent to 7.7% and 13.1% respectively, cement replacement). The 28 day strengths were equal to the plain mix, considering the expected experimental accuracy. No apparent benefit was gained in milling sample P.49(b) to a greater fineness than sample P.49(a)

Paul Gray
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(Paul Gray)

March 1973

The Readymix Group (S.A.)
Pozzolanic Evaluation of Ground Volcanic Ash
Report No. 3 - Exploration Licence 13

0021

Introduction

Results contained herein are for long term (90 days) compressive strengths, of mixes detailed within Reports No. 1 and 2.

Results

Sample No.	Mix	Compressive Strength (P.S.I.) Av. 28 days	90 days	Gain
P.46	400 lbs. Adelaide N.P.	2775	3300	525
	15% ash/cement	2625	3200	575
	20% ash/cement	2375	2950	575
	25% ash/cement	2750	3350	600
P.47	400 lbs. Adelaide N.P.	2725	3050	325
	15% ash/cement	2625	3350	725
	20% ash/cement	2525	3400	875
	25% ash/cement	2550	3250	700
	400 lbs. Geelong N.P.	2400	2600	200
	15% ash/cement	2475	2900	425
P.49 (a)	400 lbs. Adelaide N.P.	2900	3300	400
	15% ash/cement	2850	3650	800
	25% ash/cement	2675	3300	625
P.49 (b)	400 lbs. Adelaide N.P.	2900	3300	400
	15% ash/cement	2825	3650	825
	25% ash/cement	2800	3450	550

Conclusions

The above ash samples, with the exception of Sample No. P.46, show greater strength gains from 28 to 90 days than the plain N.P. mixes. Although the gain appears very promising, concrete production standards currently require that specified maximum concrete strength be gained upon termination of a 28 day period. Therefore, such an acceptance criterion is only feasible for concrete utilized for non-structural purposes.

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(Paul Gray)

0022

Proportioning Fly Ash Concrete Mixes for Strength and Economy

By ROBERT W. CANNON

A method is presented for proportioning fly ash with cement to produce concrete of equal strengths at 28 and 90 days to concrete without fly ash. The method was developed by the Tennessee Valley Authority (TVA) as a result of using fly ash in all classes of concrete for the past 12 years. Effects of differing proportions of fly ash on water requirements, strength, and economy are given along with a discussion of the effects of fineness and carbon content of fly ash and variations in strength of cements on cement requirements. Comparisons are made between the cement requirements as determined by this method with the cement actually required by tests from the Corps of Engineers, TVA, and Bays Mountain Construction Company using at least nine different suppliers of cement and eight different fly ashes, four of which would not meet Federal and ASTM specifications.

Keywords: air content; carbon analysis; cement content; cements; compressive strength; concretes; costs; fineness; fly ash; mix proportioning; slump tests; specific surface; water-cement ratio; water content; water reducing agents.

THE PRINCIPAL METHOD USED by most mix designers to proportion fly ash in concrete is to substitute fly ash for cement. This substitution is generally made on a one-for-one basis either by weight or by volume in order to make sense out of the existing water-cement ratio requirements of specifications. Fly ash concrete mixes proportioned by this method will nearly always have lower strengths than their control mixes at ages up to 28 days, but frequently equal or higher at 90 days and beyond. These lower early strengths have led many designers to conclude that fly ash is only desirable or economical in mass concrete where strength is not the principal requirement. An exception to this approach is the method developed by Lovewell and Washa[1] based on proportioning fly ash mixes for equal 28-day strength to control mixes. In their method the amount of fly ash added always exceeded the amount of cement removed.

Initial investigation by TVA into the potential use of fly ash from TVA steam plants prompted TVA to substitute 2 lb of fly ash for each pound of cement replaced in an effort to utilize a coarser fly ash than was acceptable under Federal and ASTM specifications.[2] TVA found that its fly ash mixes when proportioned by this method had strengths equal to the strength of control mixes at about 60 days. Today with the addition of electrostatic precipitators, some TVA steam plants produce fly ash which meets or exceeds the fineness requirements of Federal and ASTM specifications. During the past 5 years TVA has conducted extensive investigations into the proportioning of fly ash mixes for equal strength concrete at 7, 28, and 90 days using both specification and nonspecification fly ash. Present TVA policy is to use the source of fly ash which offers the greatest economy in the concrete for each particular construction project regardless of whether or not the fly ash meets Federal and ASTM specifications.

The following procedure for proportioning fly ash mixes has evolved from TVA investigations. It is readily adaptable to different strengths of Types I and II cement and to different qualities of fly ash. This method is intended only for porportioning cement and fly ash and does not

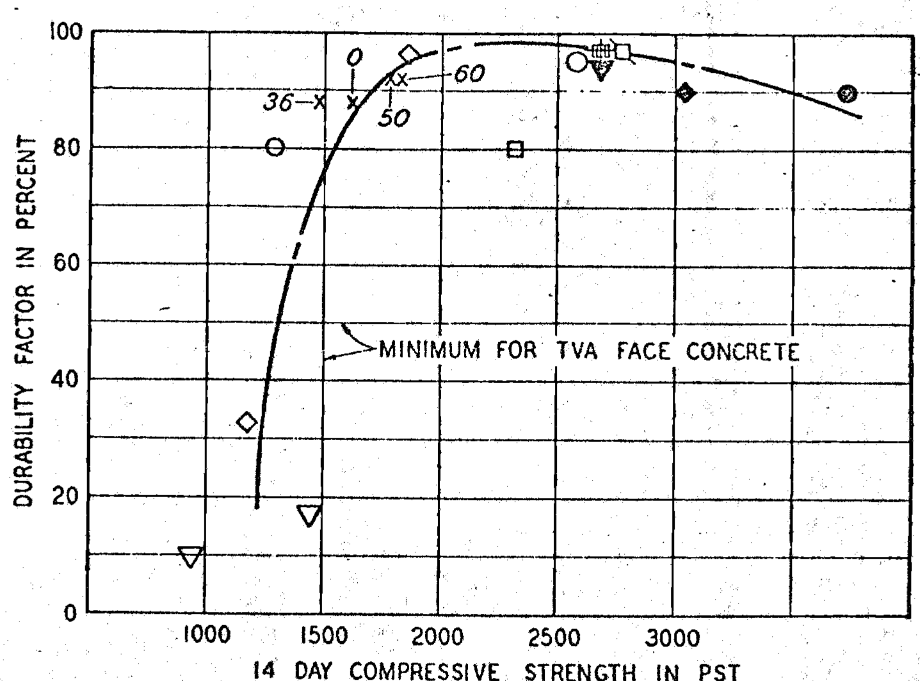
ACI member **Robert W. Cannon** is principal civil design engineer, Research and Development Staff, Tennessee Valley Authority, Knoxville, Tenn. Mr. Cannon had 12 years of structural design experience with TVA and the Aluminum Company of America prior to entering concrete research with TVA in 1961. He is a registered professional engineer in the State of Tennessee, a member of ACI Committee 207, Mass Concrete, and TVA's representative on the ad hoc committee on Federal specifications for hydraulic cements.

deal with the proportioning of aggregates or the determination of the basic water requirements. The procedure is applicable regardless of the efficiency and inefficiency of proportioning aggregates. It does assume that the quantity and gradation of the coarse aggregate is the same in comparable mixes and that the difference in yield due to the larger volume of cementitious material in the fly ash mix is balanced by a reduction of the sand content. When the quantity of coarse aggregate differs in comparable mixes adjustments will be required to account for this difference as will be shown later.

TVA has also conducted extensive investigations into the freezing and thawing resistance of concretes containing various proportions of fly ash to cement. These investigations reveal that freezing and thawing resistance is independent of fly ash proportions for concrete proportioned for equal strength and air contents. Fig. 1 shows the results of TVA tests with limestone aggregates. With good aggregate and proper air contents, concrete having 14-day strengths greater than 1500 psi should have good freezing and thawing resistance irrespective of the makeup of the cementitious material.

VARIATION IN CEMENT STRENGTH

The water-cement ratio curves of Fig. 2 represent the average of tests from seven different cement manufacturers in the TVA region using Type II cement with 7.5 percent ± air content by volume of mortar in the compacted test specimen. The variation in strength of the cement from the different mills from these 28- 90-day averages was 10 percent ± of any given water-cement ratio. Corrections should be made for the difference between Fig. 2 strengths and the actual strengths



SYMBOLS	FLY ASH % CMT BY WT	FLY ASH % TOTAL BY VOL	TYPE II CEMENT MILL	LIMESTONE AGG. SOURCE
▽	80	50	VII	NICKAJACK
▼	60	43	"	"
◇	80	50	PII	"
◆	60	43	"	"
○	80	50	"	BULL RUN
●	60	43	"	"
□	40	33	"	MARYVILLE
⊟	40	33	LII	"
⧮	40	33	SII	"
⌑	40	33	SMII	"
x - 0	0	0	SII	BROWNS FERRY
x - 36	40	36	"	"
x - 50	80	50	"	"
x - 60	120	60	"	"

Fig. 1—Freezing and thawing resistance of concrete containing fly ash of varying proportions.

of the cement to be used on the job as indicated in the procedure.

VARIATION IN STRENGTH DUE TO FLY ASH

The fineness of fly ash is generally recognized as one of the principal factors affecting the quality of fly ash. To the author's knowledge no one has succeeded in attaching any particular significance to the chemical makeup of fly ash other than to loss on ignition normally considered herein as carbon content, which does appear to be a definite factor affecting ash quality. We have found that a decrease in fineness of 1000 cm^2/gm in specific surface area of the fly ash as measured by the modified Blaine method[3] will require an increase in cement content of 5 to 6 percent for ashes of equal carbon content to maintain the same concrete strength. TVA fly ashes generally have very little variation in carbon content and although we have conducted no experiments on the effect of variations in carbon content, we feel that variations will have a more pronounced effect on cement requirements in the lower ranges of carbon content than equal variations in the upper ranges.

In general, the variation in fineness and carbon content will be small from a modern steady load and efficiently operated powerplant. Based on TVA's experience, variations in strength of approximately 4 percent may be expected due to variations in the fly ash. The addition of fly ash as another variable in the concrete does not normally mean an increase in the coefficient of variation of the concrete as produced since fly ash concrete at a given concrete plant will almost always have an equal or lower coefficient of variation for a properly designed mix than a comparable mix without fly ash. Tests conducted by TVA using a single source of fly ash and cements from seven different sources consistently showed lower coefficients of variation in the fly ash mixes at all proportions and strength levels than in the control mixes without fly ash.

In the author's opinion, fly ash can contribute to the strength of concrete in three distinct ways; first, by direct water reduction; second, by increasing the effective volume of paste in the mix; and, third, by pozzolanic reaction. The first two ways contribute to the immediate or early strength of the concrete and the third way contributes to the long range strength gain of fly ash concrete. Direct water reduction can be measured and is considered in the following paragraph. By partially filling the sand voids of the mortar with solid particles of fly ash (the fine fly ash particles may be securely held in the paste by molecular attraction thus increasing the volume of paste without loss of paste strength) the average thickness of paste surrounding the sand particle is increased providing a stronger bond of paste to sand particles thereby increasing mortar strength particularly in leaner concrete mixes having a deficiency of paste without fly ash. This

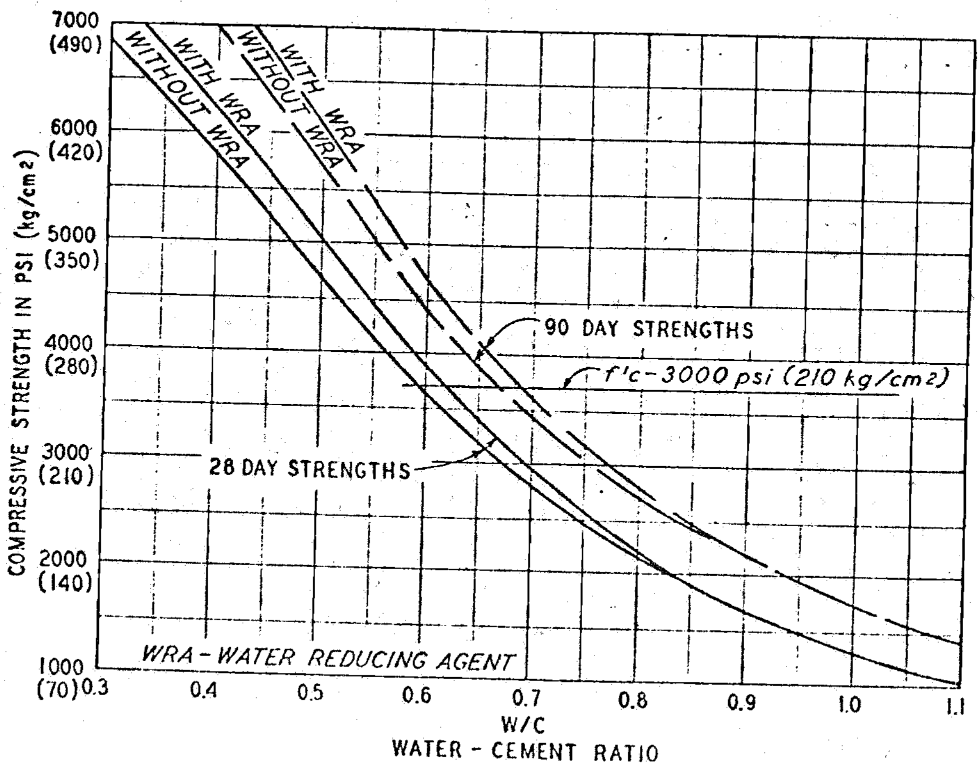


Fig. 2—Water-cement ratios strengths of control mixes for an average Type II cement, limestone sand, and 7.5 percent ± mortar air content

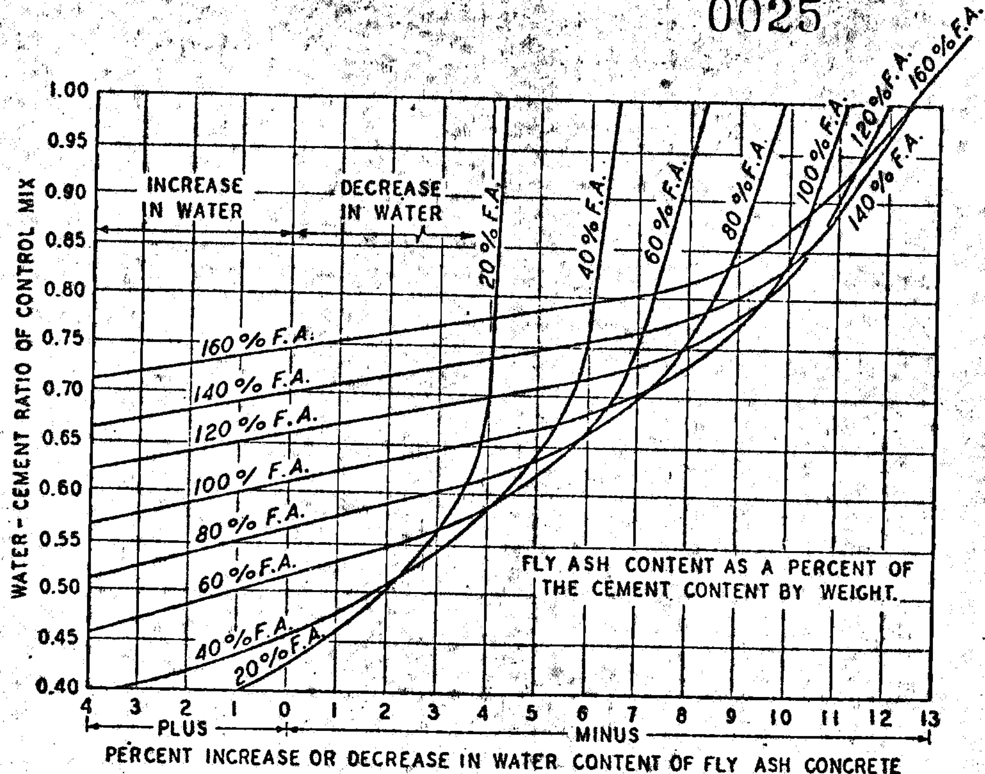


Fig. 3—Comparison of water requirements of concrete with and without fly ash equally proportioned for 28-day strength, identical slump, and air contents

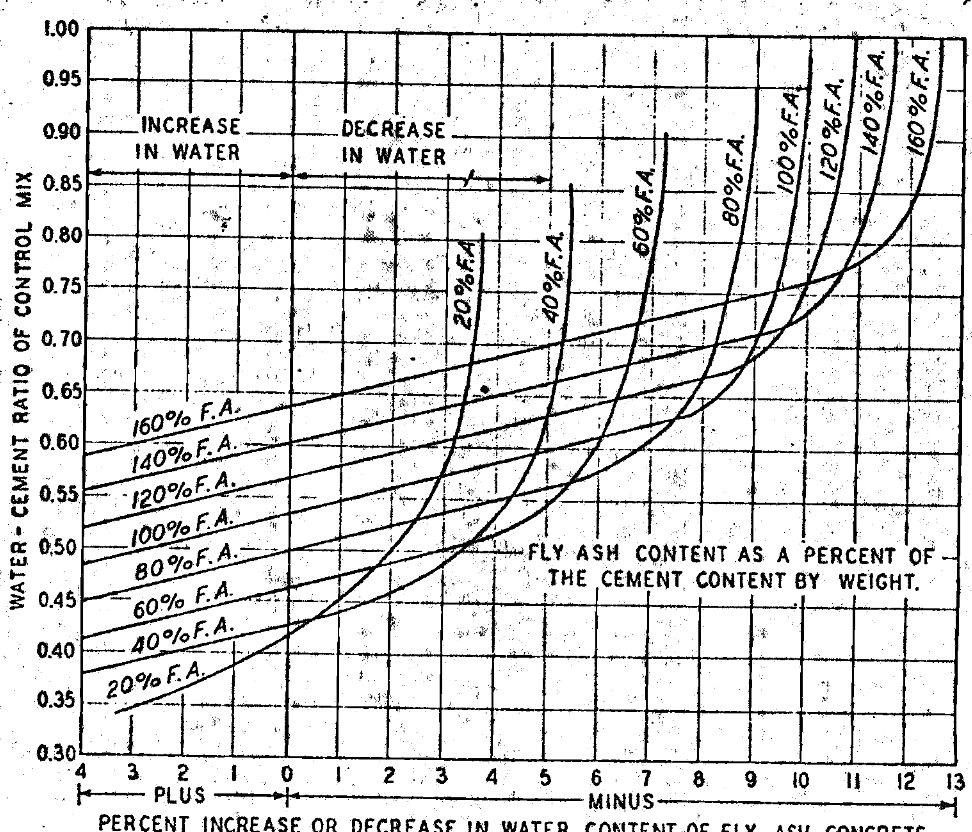


Fig. 4—Comparison of water requirement of concrete with and without fly ash equally proportioned for 90-day strength, identical slump, and air contents

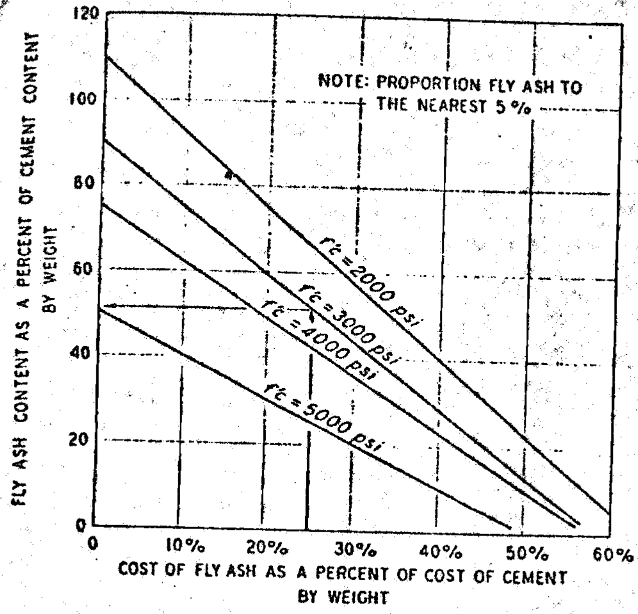


Fig. 5—Economic proportions of fly ash for 28-day strength concrete

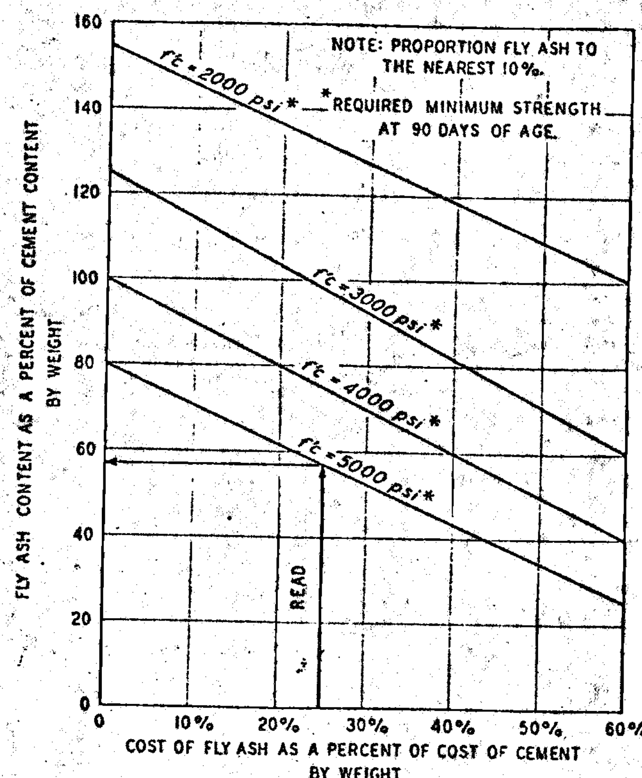


Fig. 6—Economic proportions of fly ash concrete for 90-day strength concrete

is the only logical explanation which the author can offer for the concrete strengths of very high proportions of fly ash with a given cement content since there is neither enough calcium hydroxide available from the cement for complete pozzolanic reaction with all of the fly ash or enough direct water reduction to account for the strengths.

EFFECT OF FLY ASH ON WATER CONTENTS

For a given set of concrete materials, the water required to produce a uniform consistency for a given mortar volume and air content is dependent entirely on the quantities of cement and fly ash. Fig. 3 (28-day strengths) and Fig. 4 (90-day strengths) show the comparison of water requirements for equal strength concrete in terms of the proportions of fly ash to cement used and the water-cement ratio of control mixes. These curves are based on an average TVA fly ash having approximately 2 percent loss on ignition and a specific surface area of 2500 cm²/gm. They are also based on the average results of Type II cements from seven different mills.

Another fly ash with differing specific surface area and ignition loss may differ in water requirements from Fig. 3 and 4. The effect of differences in water requirements is minimized, however, in using these curves for proportioning mixes when the mix is checked for actual water requirements as in Step 10 of the procedure which follows. Fly ashes do not produce the same water reduction with all cements, but fortunately fly ash effects a greater water reduction in the cements which require higher water contents themselves. This leveling effect on water requirements at a given slump level is, we believe, the principal reason for lower coefficients of variation of fly ash concrete. The reason for differences in water requirements for comparative 90-day strengths (Fig. 4) over that of comparative 28-day strengths (Fig. 3) for given control mix water-cement ratios is the much greater reduction in cement requirements for 90-day strengths in fly ash mixes.

ECONOMIC PROPORTIONS

The economy of using fly ash depends entirely on the relative cost of fly ash to cement, the quality of ash, and the strength requirements of the concrete. Fig. 5 (28-day strengths) and Fig. 6 (90-day strengths) show the economic proportions for an average fly ash to provide the minimum combined cost of cement and fly ash in the mix. They are based on recommended average concrete strengths normally required to provide the minimum strength concrete indicated.

REDUCTION IN CEMENT CONTENT

Fig. 7 and 8 give the comparative cement requirements of various fly ash proportions to produce concrete of equal strengths at 28 and 90 days of age to mixes without fly ash. These curves are developed from a series of strength versus water-cement plus fly ash curves by making allowances for the differences in water requirements at the various levels of strength using Fig. 3 and 4.

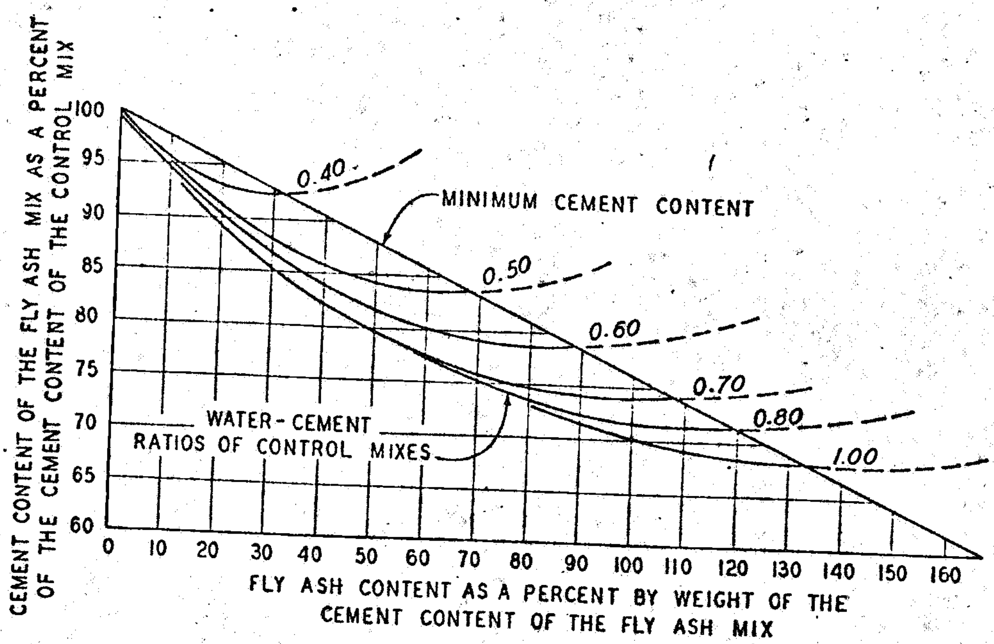


Fig. 7—Relative cement requirements for various fly ash proportions of concrete equally proportioned for 28-day strength, identical slump, and air contents

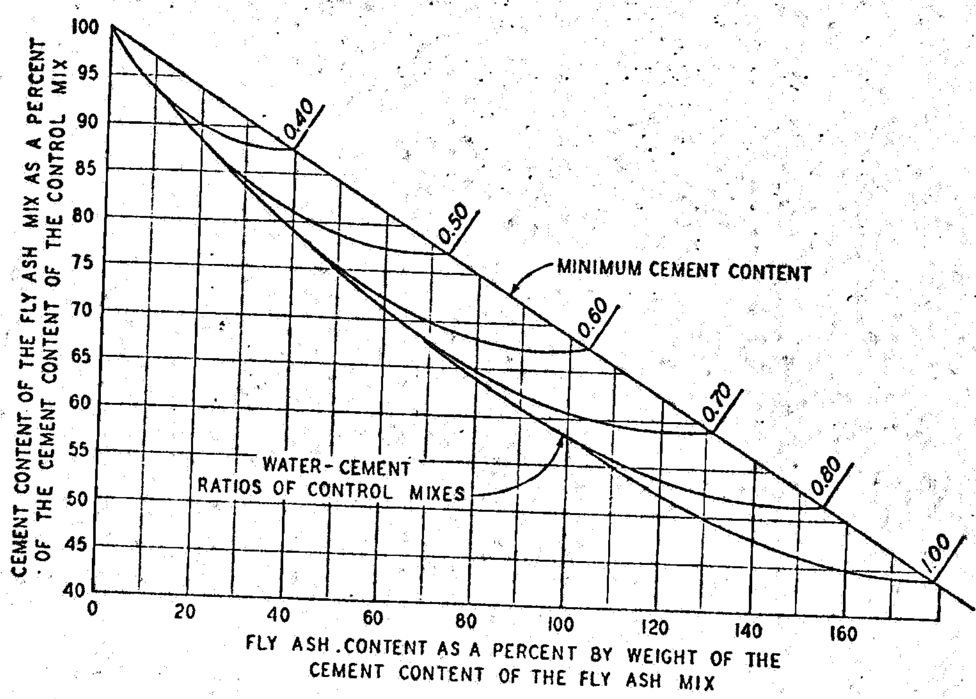


Fig. 8—Relative cement requirement for various fly ash proportions of concrete equally proportioned for 90-day strength, identical slump, and air contents

PROCEDURE FOR PROPORTIONING MIXES

Designing for a required strength

Step 1 — Select the volume of coarse aggregate per unit volume of concrete from Table 6 of ACI 613-54. (In making this selection the fineness modulus of the sand should be reduced by 0.20 to allow for the effect of the larger volume of cementitious material in the fly ash mix.)

Step 2 — Estimate the water requirements for the maximum size of aggregate to be used and the required slump (use ACI 613-54 as a guide).

Step 3 — Select from Fig. 2 the water-cement ratio required for a given strength concrete.

Step 4 — Select the fly ash proportion to be used (for economic considerations, use either Fig. 5 or 6 using the appropriate relative cost of fly ash and required strength to select the fly ash proportion).

Step 5 — Using the water-cement ratio of Step 3 and fly ash proportion of Step 4, determine the water reduction from Fig. 3 or 4.

Step 6 — Using the estimated water requirements of Step 2 for the control mix, determine the water requirements of the fly ash mix by using the water reduction of Step 5.

Step 7 — Determine the cement requirements of the control mix by dividing the control mix water requirements by the water-cement ratio of Step 3.

Step 8 — Select the proportionate cement requirement of the fly ash mix from Fig. 7 or 8 (depending on the age-strength requirements) using the water-cement ratio of Step 3 and the fly ash proportion of Step 4.

Step 9 — Using methods in ACI 613-54 determine the solid volume of sand for the mix by subtracting the solid volumes of coarse aggregate, cement, fly ash, and water plus the required volume of air from the unit volume of concrete in the mix.

Step 10 — Check the mix for slump and air content and repeat the procedure for the actual water required to provide the desired slump and air contents.

Step 11 — If trial mix strengths differ significantly from the required strength an adjustment in cement and fly ash contents will be required in the final mix. This adjustment is in direct proportion to the water-cement ratio in Fig. 2 corresponding to the trial mix strength divided by the original water-cement ratio used in design.

Example problem

Design a 28-day, 3000-psi (210 kg/cm²) concrete with 1-½-in. (38 mm) maximum size aggregate, 5 percent air content, 2-½-in. (64 mm) slump, no water reducing agent, fly ash cost at 25 percent of cement cost.

Step 1 — Assume Table 6 requires 12 cu. ft (0.34 m³) of coarse aggregate or 2000 lb (905 kg) for specific gravity of 2.67.

Step 2 — From Table 3 of ACI 613-54, approximately 30 gal. or 250 lb (113 kg) of water are required in the control mix.

Step 3 — From Fig. 2, water-cement ratio = 0.59 for 3700-psi (260 kg/cm²) strength.

Step 4 — From Fig. 5, for fly ash cost at 25 percent of cement the economical proportion of fly ash is 50 percent of the cement content by weight.

Step 5 — From Fig. 3, the water reduction is 4 percent for a water-cement ratio = 0.59 and fly ash at 50 percent.

Step 6 — Water content of fly ash mix is 250 (0.96) = 240 lb. 113 (0.96) = 108 kg.

Step 7 — Control mix cement = $\frac{250}{0.59} = 425$ lb

$$\frac{113}{0.59} = 192 \text{ kg}$$

Step 8 — From Fig. 7, the fly ash mix cement content = 82 percent for water-cement ratio = 0.59 and 50 percent fly ash.

Fly ash mix cement = 0.82 (425) = 348 lb

0.82 (192) = 157 kg

Fly ash content = 0.5 (348) = 174 lb

0.5 (157) = 79 kg

Step 9 — Calculate weights and volumes of concrete ingredients

Ingredient	Weight		Volume	
	lb	kg	cu ft	m³
Coarse aggregate	2000	905	12.0	0.340
Cement	348	158	1.76	0.050
Fly ash	174	79	1.16	0.033
Water	240	109	3.48	0.098
Air	—	—	1.35	0.038
Subtotal	—	—	19.75	0.560
Sand (Specific gravity = 2.65)	1200	545	7.25	0.205
Total	3962	1796	27.00	0.765

COMPARISON OF DIFFERENCES

Ingredient	Fly ash mix				Control mix			
	Weight, lb	Volume, cu ft	Cost		Weight, lb	Volume, cu ft	Cost	
			Unit	Total			Unit	Total
Cement	330	1.67	$1.15/100 lb	$3.80	404	2.04	$1.15/100 lb	$4.63
Fly ash	165	1.10	$0.29/100 lb	0.48	—	0	—	—
Water	240	3.84	—	—	250	4.00	—	—
Added sand	0	—	—	—	94	0.57	$0.10/100 lb	0.09
Total	735	6.61	—	$4.28	748	6.61	—	$4.72

Difference in cost = $0.44/yd ($0.57/m³)

Step 10 — Assume actual slump is within ± ¼ in. of design slump. No adjustment necessary.

Step 11 — Assume trial mixes had an average strength of 4000 psi. (280 kg/cm²) instead of 3700 psi (210 kg/cm²)

From Fig. 2, 4000 psi (280 kg/cm²) corresponds to a water-cement ratio of 0.56. Adjustment = $\frac{0.56}{0.59} = 0.95$ for trial mix strength

Or control mix requires:

0.95 (425) = 404 lb cement
0.95 (192) = 182 kg cement

Final fly ash requires 0.95 (348) = 330 lb cement and 165 lb fly ash

0.95 (157) = 149 kg cement and 75 kg fly ash

Sand adjustment = + 0.15 cu ft (0.004 m³)

COMPARISON WITH ACTUAL TESTS

When control mixes are run in conjunction with fly ash mixes, as was done in Reference 1, Steps 2, 3, and 7 of the above procedure are eliminated and actual values from the control mix should be used. With the water-cement ratio and cement content of the control mix known, the cement content of the fly ash mix can be determined directly from Fig. 7 or 8 for any given ratio of fly ash to cement in the fly ash mix. Since the above procedures are based on identical quantities of coarse aggregate in the control mix and fly ash mix, any difference in coarse aggregate quantities must be accounted for in determining the quantities of cement and water in the fly ash mix. This is simply done by proportioning the volume of mortar in the fly ash mix to the volume of mortar in the control mix as shown in the following comparison of mix proportions using the above procedure and Mixes "M" and "S" of Table 5 in Reference 1.

Example 1

Control mix "M", cement content = 470 lb per cu yd (279 kg/m³); water-cement ratio = 0.63; net water = 296 lb per cu yd (176 kg/m³)

Fly ash mix "S", fly ash as percent of cement content = 32 percent (for comparison purposes the percent of fly ash must be the same in comparable mixes).

From Fig. 7, the fly ash mix cement content = 86 percent for water-cement ratio = 0.63 and 32 percent fly ash.

Correction for aggregate (using coarse aggregates of Mixes "M" (1910 lb or 865 kg) and "S" (1990 lb or 904 kg) and assuming specific gravity of 2.72 for aggregate.

$$\text{Correction} = \frac{27(62.5)(2.72) - 1990}{4600 - 1910} = 0.97$$

$$\frac{0.765(2720) - 904}{2080 - 865} = 0.97$$

Fly ash mix cement = 470 (0.86) (0.97) = 391 lb per cu yd. 279 (0.86) (0.97) = 233 kg/m³

Fly ash content = 391 (0.32) = 125 lb per cu yd. (233) (0.32) = 75 kg/m³

From Fig. 4 the water reduction is 4½ percent for Water-cement ratio = 0.63 and 32 percent fly ash.

Fly ash mix water content = 296 (0.955) (0.97) = 274 lb per cu yd. (176) (0.955) (0.97) = 163 kg/m³

A comparison of all mixes reported in Table 5 of Reference 1 is given in Table 1.

For purposes of comparing this fly ash mix design procedure with fly ash mix test data where control mixes were not used the strength of cement, quality of fly ash, and air content of the concrete must all be considered. This is necessary since this procedure is based on cement and water contents of control mixes and any error in estimating control mix requirements from 28- or 90-day compressive strength test data will reflect directly on the accuracy of calculating the fly ash mix requirements.

Air content affects strength approximately 5 percent for each percent change in air content for a given water-cement ratio and the difference in air contents between plain and air-entrained concrete is approximately 3-½ percent for 1-½-in. (38 mm) maximum size aggregate mixes and 4

TABLE 1—COMPARISON OF ACTUAL AND DESIGN CEMENT AND WATER REQUIREMENTS OF FLY ASH MIXES BASED ON CONTROL MIXES

Mix		Cement content					Water content				
	Fly ash, percent ±	Fig. 7* (design)		Table 5[1] (actual)			Fig. 3* (design)		Table 5[1] (actual)		
		lb per cu yd	kg/m³	lb per cu yd	kg/m³	Actual / Design	lb per cu yd	kg/m³	lb per cu yd	kg/m³	Actual / Design
F	62	276	164	281	167	1.020	276	164	292	173	1.055
G	47	325	193	335	199	1.030	293	174	288	171	0.985
H	35	372	221	385	228	1.035	296	176	297	176	1.000
I	27	428	254	438	260	1.020	298	177	295	175	0.990
J	20	488	289	490	291	1.005	305	181	301	179	0.985
P	54	286	170	283	168	0.990	277	164	269	160	0.975
R	41	335	199	336	200	1.000	271	161	270	160	1.000
S	32	391	232	388	230	0.995	274	163	272	161	0.990
T	26	442	262	442	262	1.000	281	167	272	161	0.970
U	20	495	294	494	293	1.000	276	170	278	171	1.010
Average of ratios						1.010					0.995

*Calculated using charts as per above example.

±Fly ash in percent of cement content by weight.

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percent for ¾-in. (19 mm) aggregates. In using Fig. 2 the strengths of non-air-entrained concrete should be multiplied by 0.825 for 1½-in. aggregate mixes and 0.80 for ¾-in. aggregate mixes in estimating the water-cement ratio of non-air-entrained control mixes.

In comparisons of this sort it is likely that no information will be available on the strength of cement or quality of ash used in the test data. However, the difference between estimated and actual quantities for a number of tests should be fairly constant for a given cement or fly ash.

To illustrate this procedure the same fly ash Mix "S" of Reference 1 is estimated without regard to control Mix "M."

Example 2

Given — 28-day strength of non-air-entrained concrete = 4345 psi (304 kg/cm²) for 1½-in. (38 mm) aggregate, air-entrained concrete at the same water-cement ratio $f_c' = 4345\ (0.825) = 3590$ psi or (251 kg/cm²)

From Fig. 2, water-cement ratio = 0.61.

Net water content of Mix "S" = 272 lb per cu yd (161 kg/m³).

From Fig. 3, water reduction for water-cement ratio = 0.61 and 32 percent fly ash = 4 percent.

$$\text{Cement content of control mix} = \frac{272}{(0.61)(0.96)} = 465 \text{ lb per cu yd}$$

$$\frac{161}{(0.61)(0.96)} = 276 \text{ kg/m}^3$$

From Fig. 7, the fly ash mix cement content = 86 percent for water-cement ratio = 0.61 and 32 percent fly ash.

Fly ash mix cement content = 0.86(465) = 400 lb per cu yd. 0.86(276) = 238 kg/m³

$$\frac{\text{Actual}}{\text{Design}} = \frac{388}{400} = 0.97$$

Fig. 9 and 10 show comparisons of cement contents required by design using the above procedure and actual cement contents used in various tests at different levels of control water-cement ratio. Fig. 9 is a comparison with tests reported in Reference 4, and Fig. 10 is a comparison with other laboratory tests. The average of all ratios of actual cement required to design cement required based on 28-day strengths (similar to that shown in Table 1) was 0.98 irrespective of the differences in cements and fly ashes. For 90-day strengths the average of all ratios was 1.00. The coefficient of variation of all ratios with respect to these averages was 9.2 percent for 28-day comparisons and 8.0 percent for 90 days. Accounting for the average differences in cement and fly ash the coefficient of variation of all ratios was 4.5 and 3.6 percent for 28- and 90-day designs, respectively.

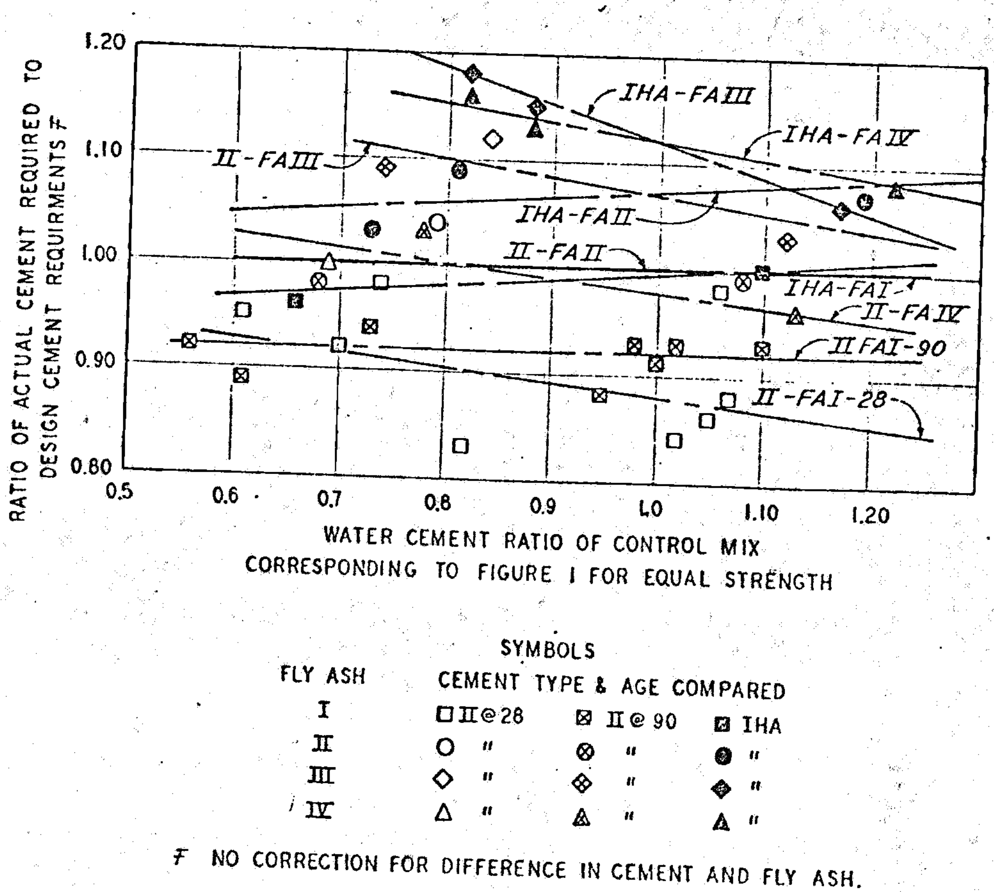

Fig. 9—Comparison of design cement requirements with actual cement requirements in tests reported in Reference 4

It is evident in Fig. 9 and 10 that differences in cement and fly ash do not affect the ratio of actual cement required to design cement requirements uniformly at all levels of control water-cement ratio. The strength contribution of fly ash in the high range of cement contents generally decreases with cements requiring lower than average water content for consistency and increases with cements requiring higher than average water contents.

The quality of fly ash is also more significant in the high range of cement contents such that effectiveness in reducing cement requirements in this range is related directly to ash quality. In lower range of cement contents the quality of ash is not so significant especially at 90 days and later ages.

CONCLUSIONS

1. Abram's law concerning water-cement ratio, if used correctly, refers only to adjusting a concrete of a given set of materials from one strength level to another. Used in this manner the law is valid for fly ash concrete provided the proportions of fly ash to cement remain in a fixed relationship with each other. The normal license taken with Abram's law is to associate water-cement ratio with a given level of strength. Used in this manner the law completely loses its meaning with fly ash or other pozzolans since it is possible to arrive at the same general level of strength using many different proportions of cement and fly ash or pozzolan.

2. Fig. 2 through 8 can be used to proportion any fly ash concrete mix for strength and economy.

3. Fly ash can and should be proportioned in concrete on the basis of economy and equal strength requirements and not as a straight substitution for cement either on a weight or volume basis.

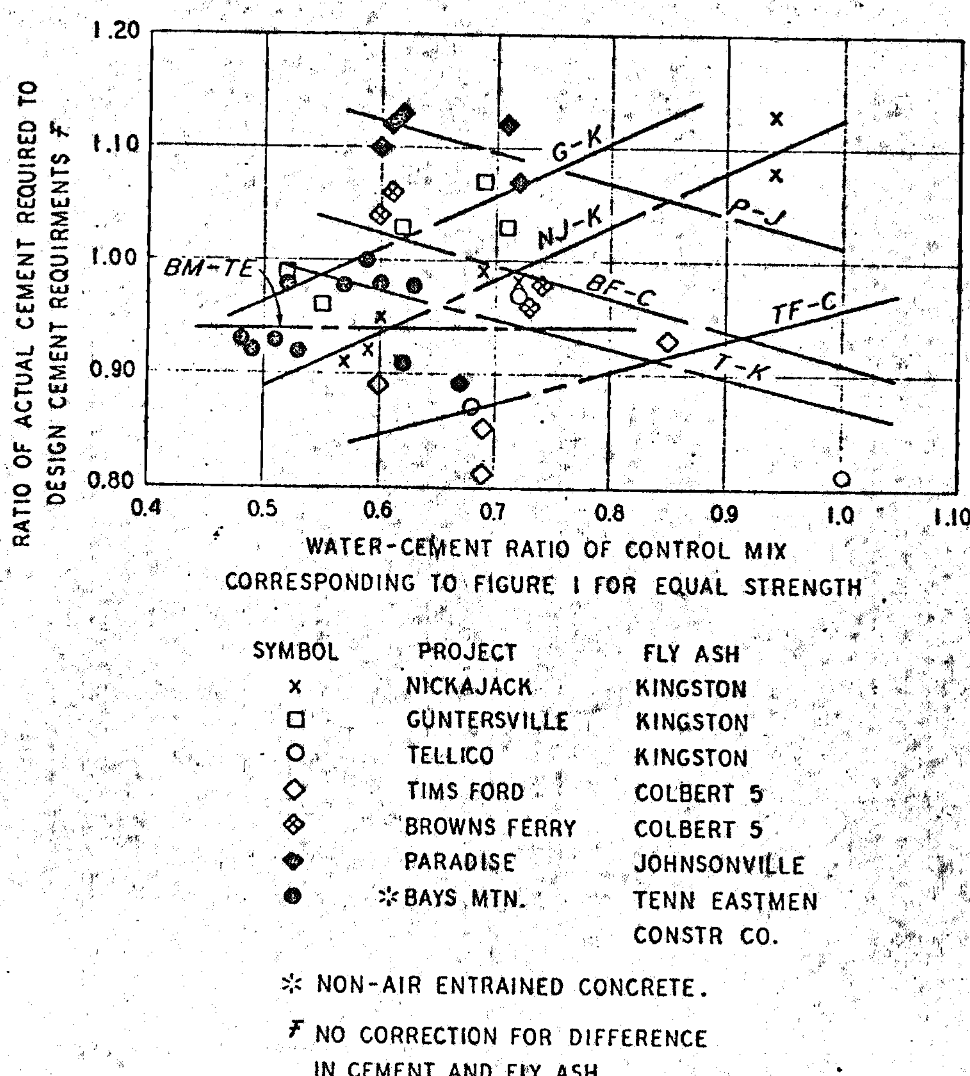

Fig. 10—Comparison of design cement requirements with actual cement requirements in tests conducted by TVA and Bays Mountain Construction Company

4. In proportioning concrete mixes, economy should be the only restriction placed on the proportions of fly ash to cement used.

5. Although fly ash becomes more economical as the strength requirements decrease, savings in material costs may be realized even in concrete requiring 5000 psi in 28 days.

6. In general, fly ash concrete will have a lower coefficient of variation than nonfly ash concrete for the same control efforts and for equal strength concrete.

7. The significance of the quality of fly ash increases with increased strength requirements of the concrete. Fly ashes in the low ranges of loss on ignition which do not presently meet Federal and ASTM specifications for fineness can be used economically in many concrete operations. The principal factors to be used in selecting a fly ash for use in concrete should be: the delivered cost of the ash, the quality of the ash, and the strength requirements of the concrete.

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This paper was received by the Institute Mar. 15, 1968.

Sinopsis — Résumé — Zusammenfassung

Proporcionamiento de Mezclas de Concreto con Ceniza Volante para Resistencia y Economia

Se presenta un método para proporcionar ceniza volante con el cemento y producir concreto de igual resistencia a los 28 y 90 días que los concretos sin ceniza volante. El método fué desarrollado por la Autoridad del Valle de Tennesee (AVT) como resultado de usar ceniza volante en todas las clases de concreto durante los últimos 12 años. Se presentan los efectos de las diferentes proporciones de ceniza volante en los requisitos de agua, resistencia y economía conjuntamente con una discusión de los efectos de finura y contenido de carbón de la ceniza volante, así como las variaciones en la resistencia de los cementos en los requisitos del cemento. Se comparan los requisitos del cemento determinados por este método con el cemento realmente requerido por los ensayos del cuerpo de Ingenieros, AVT y Base Mountain Construccion Co., usando por lo menos 9 diferentes suministradores de cemento y 8 cenizas volantes diferentes, cuatro de las cuales no satisfarían las especificaciones Federales y de la ASTM.

Proportion de Cendres Volantes dans les Mélanges de Béton pour Résistance et Economie

Une méthode est présentée pour proportionner les cendres volantes avec le ciment afin de produire un béton d'égale résistance après 28 et 90 jours à un béton sans cendres volantes. La méthode a été mise au point par le Tennessee Valley Authority (TVA) à la suite des résultats obtenus en utilisant des cendres volantes dans toutes classes de béton durant les 12 dernières années. Les effets de changement des proportions de cendres volantes selon les proportions d'eau, la résistance et l'économie, sont donnés en même temps qu'une discussion des effets de finesse et de proportion de carbone de cendres volantes et les variations de résistance des ciments sur les impératifs de qualité des ciments. Des comparaisons sont faites entre les impératifs de qualité des ciments qui sont déterminés par cette méthode avec les ciments effectivement exigés par les essais par le corps des Ingénieurs TVA et la compagnie de construction de Bays Mountain utilisant au moins neuf différents fournisseurs de ciment et huit différentes cendres volantes, Quatre desquelles ne correspondant pas aux spécifications fédérales et de l'ASTM.

Der Entwurf von Betonmischungen mit Flugaschezusätzen in Hinblick auf Festigkeit und Wirtschaftlichkeit

Eine Methode wird beschrieben, mit deren Hilfe Betonmischungen mit Flugaschezusätzen entworfen werden können, sodass die Festigkeit nach 28 und 90 Tagen ebenso gross wie die Festigkeit von Beton ohne Zusätze ist. Die Methode wurde von der Tennessee Valley Authority (TVA) entwickelt und baut auf Erfahrungen, die bei der Verwendung von Flugasche in Betonen aller Arten während der letzten 10 Jahre gewonnen wurden. Der Einfluss des Gehaltes an Flugasche auf Wasseranspruch, Festigkeit und Wirtschaftlichkeit werden gegeben, und die Wirkung des Feinheitsgrades und des Kohlegehaltes der Flugasche sowie der Festigkeit und Art des Zementes in Bezug auf die Auswahl eines geeigneten Zementes werden diskutiert. Vergleiche über die Anforderungen an den Zement nach dieser Methode und den Eigenschaften des Zementes, die auf Grund von Versuchen des Corps of Engineers, TVA und Bays Mountain Construction Company gefordert werden, wurden angestellt. Dabei wurden zumindest 9 Zementmarken und 8 Arten von Flugasche verwendet. In vier Fällen erfüllte die Flugasche nicht die staatlichen und die ASTM Anforderungen.

THE READYMIX GROUP (S.A.)

FINAL REPORT

EXPLORATION LICENSE NO. 13

SOUTH EASTERN SOUTH AUSTRALIA

B.C. PARAM
P.R. GRAY

19th September 1973

CONTENTS

0033

SUMMARY

0034

Investigations proceeded during late 1972, in evaluating the pozzolanic properties of ash derived from the ejectamenta of volcanic sources located within the south eastern province of South Australia.

Preliminary drilling and associated geological mapping indicated large reserves of consolidated and semi-consolidated volcanic ash surrounding the Lakes, Edward and Leake. Both volcanic occurrences consist of Subsidence Calderas, with an assymetrical distribution of ejectamenta along the northern and eastern margins of the Lakes.

The ash-beds appear to have originated from periodic ejections during a single eruption with the material becoming sorted during its descent. Bedding of the material dips outward from the craters at the same low angle as the surrounding land surface. Minor cross-bedding exposed within existing excavations indicates a moderate change in the prevalent wind direction during the deposition period. Ash within the vicinity of both Lakes, is in an advanced stage of consolidation and invariably has a thin coverage of paralic clays and sands.

Basically, the ejectamenta is composed of a mixture of silicates and contains both glass and crystalline particles. At the time of vulcanism the ejectamenta has undergone rapid cooling and in some instances has suffered considerable chemical alteration, the effect of which has been to convert much of the original material into a more chemically reactive modification, whilst the basic constituents have been partially removed under the combined influence of carbon-dioxide and sub-surface waters during ejection.

Exploratory drilling of the consolidated ash-beds was confined to the perimeter of Lake Leake only, where considerable accumulations of ash with little soil cover was encountered. Outcrop of the consolidated bedding is prominent in this area, together with minor exposures from which the semi-hard material has in the past been extracted for use in road-making. These exposures enabled detailed geological interpretation of the mode of distribution of ejectamenta during the deposition phase.

Sampling of pozzolanic ash derived from auger-boring entailed the collection of a 20 Kg. parcel from the respective drill holes, together with sampling of outcrop and surface exposures located both within and without the crater rim.

Although bedding of the ash is in an advanced stage of consolidation, drilling with the aid of modified auger cutting bits enabled complete recovery of sample material, which when extruded from the auger hole consisted of angular to sub-rounded fragments a maximum half inch diameter.

Preparation of samples including dry, crushing, pulverising and milling was carried out in the laboratory of RMC Minerals Pty. Ltd., prior to submission for mix/strength trials at the laboratory of Readymix Concrete (S.A.) Pty. Ltd. Details of sample preparation methods and procedure of mix/strength trials, were contained within the Six Monthly Report on Exploration License 13.

UTILIZATION OF POZZOLANS

Pozzolans are used in lime/pozzolan mortars, in blended pozzolanic/ Portland Cement's, and as a direct addition to a concrete mix.

The addition of pozzolanic materials derived both from natural and artificial sources, and blended with Portland Cement concrete mixes has been a common practice for many years in European countries, where, because of its desirable resistance to water, whether saline or fresh, it has been used for such complexes as docks, harbours, inland waterways and bridges.

Formerly, the method of application was to add the pozzolan as a separate constituent to the concrete mix, but in more recent years it has become the practice to pre-mix the pozzolan with Portland Cement in suitable dry mixers before transferring to the concrete batch-mixer.

In the past, considerable attention has been given to developing methods for evaluating the activity of pozzolans by means which are more rapid than the direct testing of the rate of development of strength in concrete or mortar mixes. However, the nature of the constituents to which the pozzolanic properties of natural pozzolans is due, has been a controversial matter which is not yet entirely solved.

In the history of testing of pozzolanic materials, many difficulties are presented by the fact that pozzolans have no basic cementitious properties in themselves, and only develop these desirable qualities when mixed with lime or cement, therefore, physical strength tests must be carried out to evaluate the durability of pozzolan-lime or pozzolan-cement concretes.

POZZOLANS - DEFINITION

Pozzolans are usually defined as materials which though not cementitious in themselves, contain constituents which will combine with lime at ordinary temperatures in the presence of water to form stable insoluble compounds possessing cementing properties.

Pozzolans can be divided into two groups containing the natural and artificial products respectively. The natural pozzolans are for the most part materials of volcanic origin, but include also certain diatomaceous earths. The artificial pozzolans are mainly products obtained by the heat treatment of natural materials, such as, clays and shales and certain siliceous rocks.

Pozzolans of volcanic origin consist of tuffs arising from the deposition of volcanic dust and ash. They may occur, as does the Rhenish Trass, in a consolidated rock-like form underlying material deposited subsequently, or in a more fragmentary and unconsolidated state like some of the Italian pozzolans.

contd ..2

 0036

In Europe the materials which have been most exploited are the Italian Pozzolans, Santorin Earth obtained from the Grecian Isle of Santorin and the German Trass, which is found in the neighbourhood of Coblenz on the Rhine.

Deposits of unconsolidated and semi-consolidated volcanic ash are distributed sparingly throughout the world, however, until recently this natural resource has been largely untapped due to the high costs involved in processing the material, although much attention has been given to utilizing artificial or synthetic pozzolans in the form of fly-ash produced as waste product from precipitation of fired brown coal.

NATURAL POZZOLANS - TYPES

1. Tuff pozzolans are composed of a mixture of silicates and contain both glass and crystalline particles formed by rapid cooling and in some instances may have undergone considerable chemical alteration attributed to the action of super-heated steam and carbon-dioxide below the earth's surface.
2. Trass is a trachytic tuff, which has been subjected to the action of carbon-dioxide bearing waters for such a long period of time, that a large part of the minerals originally present, have become hydrated and decomposed. When altered as such, the development of zeolitic characteristics is not uncommon.
3. Zeolites are a group of insoluble hydrated alumino-silicates of the alkalis and alkaline earths. These compounds have the property of exchanging some of their base constituents for other bases when in contact with salt solutions.

POZZOLANS - HISTORY

The use of cements in building is not met with below a relatively advanced stage of civilization, where the earliest structures are composed of earth, sometimes raised in the form of walls or domes by ramming successive layers, or of stone blocks set one above another without the aid of any cementing material as in prehistoric megalithic structures, such as the Cyclopean masonary of Greece. Although remarkable works have been accomplished by such a method of construction, notably in the domed chambers of Mycenae, where stone wedges are driven between the large blocks in order to tighten the joints, Cyclopean work has always given way in later times to masonry or brickwork erected with the aid of some plastic jointing material.

Both the Greeks and the Romans were aware that certain volcanic deposits, which if finely ground and then mixed with sand and lime, yielded a cementing agent with advantageous properties if mixed into a mortar and placed between the building blocks or rough-hewn stone. This mortar also had the superior properties of high strength and durability in resisting the action of water, whether fresh or salt.

contd ...3

POZZOLANS - HISTORY (contd)

The Greeks employed for this purpose the volcanic Tuff from the island of Thera (now known as Santorin) and this material now called Santorin Earth, still enjoys a high reputation as a natural cement in the Mediterranean area. The mortar used at the present day by the peasants of Santorin (an island destitute of timber for building) is identical in its composition and preparation with that of ancient times. The corresponding material of the Roman builders was the red or purple volcanic tuff found at different points on and near the Bay of Naples. As the best of this material was found in the neighbourhood of Pozzoli (or Pozzouli) the material acquired the name of "Pozzolanna" (now referred to as Pozzolan) and this designation has been extended to the whole class of mineral matters of which it is a type.

In testament of the desirable qualities within the early Roman pozzolanic concretes, is the famous Roman building, the "Pantheon", with walls some twenty feet in thickness, consisting of both tuff and pozzolan concrete thinly faced with brick, whilst the dome, one hundred and forty two feet in span is cast solid in concrete containing pumice and pozzolan. Wooden boards were used as moulds and the concrete was filled in, in a semi-fluid condition. The present condition of many Roman buildings of this class is a sufficient testimony to the excellence of the material.

If volcanic materials did not happen to be available in certain areas, the Romans made use of powdered tiles or pottery, which produced artificial pozzolan.

The Romans carried their knowledge of the preparation of pozzolanic mortars and cements with them to the more remote parts of the Empire, and the Roman brickwork found in England for example, is equal to the best of that in Italy. Ground or pulverised tiles were the most commonly used artificial pozzolan in England. However, in a few districts, deposits bearing some resemblance to the natural pozzolans of the Bay of Naples were found and utilized. The use of Rhenish volcanic tuffs known as "Trass" was probably introduced at this time and like pozzolan, is still largely employed at the present day.

A gradual decline in the quality of the mortar used in buildings set in after the collapse of the Roman Empire and continued throughout the Middle Ages. Saxon and Norman buildings for instance, constantly exhibit evidence of badly mixed mortars consisting primarily of imperfectly burnt lime with little or no pozzolanic content. It is apparent that during the ninth, tenth and eleventh centuries, the art of burning lime was almost completely lost, with the lime being used in badly burned lumps, without the addition of ground tiles or naturally occurring pozzolans. From the twelth century onwards, the quality improved due to consistant experimental work carried out in both England and Europe, by blending and upgrading the various materials used. The Roman mixture of lime and natural or artificial pozzolans long retained its supremacy as the only suitable material for use under or exposed to water.

When we come to more recent times, the use of natural pozzolans of volcanic origin became obsolete and with improvements in burning kilns and mechanical equipment, together with new discoveries in the blending of calcined materials, synthetic or artificial cements were produced.

contd 4

POZZOLANS - HISTORY (contd) 0038

This newly developed synthetic material was given the name "Portland Cement", the name being derived from the resemblance of the cement colour after drying, to that of Portland Stone.

Portland Cement, in spite of its great cost of production during the early stages, gradually superseded the use of naturally occurring cements, mainly because quality is easily controlled by blending of the ingredients within the artificial mixture.

The development of hydraulic cements of various types has proceeded in a series of stages throughout the past years, however in this gradual evolution there have arisen some cements, which attained at one time a considerable degree of importance, but have now fallen partly or entirely into disuse. The natural cements from volcanic sources are perhaps the best example of this group.

The growth of new varieties of cement has however far outweighed any decrease due to the disappearance of former products until today; their number is apt to become bewildering. Many of these cements are used only for certain limited purposes and their output is only a very small fraction of that of ordinary Portland Cement, which still represents the greater part of world production.

During the early part of this century, systematic work in development and improvement of Portland Cements led to new investigations into once again utilizing pozzolans, including both artificial and natural, within concrete manufacture.

During the post-war years, pozzolans have become a standard component of raw materials used in the manufacture of concrete throughout the world, where the common method for utilization is to proportionally replace up to twenty five percent of the total Portland Cement content with an equal or greater volume of natural or artificial pozzolan.

CONCLUSIONS

Although information derived from both exploratory drilling and associated geological studies have indicated considerably large reserves of semi-consolidated and consolidated volcanic ash present in the area of Lake Leake, laboratory tests have not yielded promising results to date.

Original research into the properties of various volcanic materials carried out by our Central Research Laboratory (Sydney) have shown that some desirable properties were present in both the loose unconsolidated ash from Mt. Schank and the more consolidated material from the Lake Leake area.

During the currency of Special Mining Lease No. 655, exhaustive tests were carried out on the Mt. Schank material, all to no avail.

When Exploration License No. 13 was taken up, the methods previously used in evaluating the ash were employed. However, once again tests proved unfavourable. New methods of evaluation and applications were then sought and a method recently developed by the Tennessee Valley Authority (U.S.A.) was employed. Basically, the new method employed is to apportion the amount of pozzolanic material added, to exceed the volume or weight of cement removed from a specified concrete mix. The old method was to replace a given volume or weight of cement, by an equal volume of pozzolan.

The new method was introduced to laboratory experiments during the former 6 months of the currency of E.L. 13 and although some interesting results have been achieved, the trials as a whole have not performed as expected.

The basic aim of our Company was to gain equal strength from Pozzolan/Portland cement concretes at the termination of a 28 day curing period, as can be gain from a Normal Portland cement concrete of the same age. This target has only been met in a few instances.

EXPENDITURE

0040

Drilling	$ 600.00
Transport	190.00
Wages	750.00
Accommodation	145.00
Sample Preparation	520.00
Concrete Trials	800.00
Technical Supervision	300.00
Sundry Expenses	240.00
	$ 3,545.00
Expenditure for previous Six months	$ 3,230.00
TOTAL	$ 6,775.00

APPENDIX I

Results of Concrete Trials

THE READYMIX GROUP (S.A.)

POZZOLANIC EVALUATION OF GROUND VOLCANIC ASH

REPORT NO. 4 - EXPLORATION LICENSE 13

Sample No.	Mix/Blend	Slump(Inches)	Compressive Strength P.S.I.					Corrected Total Water (galls/c.yd.)
			7 Days	28 Days	28 Days (av.)	28 Days Equiv. @ 1.5" Slump	Variation from Plain @ 1.5" Slump	
P.52 (27.3.73)	Control 400 lbs. Adelaide N.P.	2.0	1650	2400 2500	2450	2550		37.0
	15% Ash /Cement	1.5	1550	2400 2450	2425	2425	-125 (-5%)	35.9
	25% Ash /Cement	1.5	1400	2450 2400	2425	2425	-125 (-5%)	35.3

15% Ash/Cement corresponds to 7.7% by Weight Cement Replacement with an Equal Volume of Ash

25% Ash/Cement corresponds to 13.1% by Weight Cement Replacement with an Equal Volume of Ash

THE READYMIX GROUP (S.A.)

POZZOLANIC EVALUATION OF GROUND VOLCANIC ASH

REPORT NO. 5 - EXPLORATION LICENSE 13

Sample No.	Mix/Blend	Slump(inches)	Compressive Strength P.S.I.					Corrected Total Water (galls/c.yd.)
			7 Days	28 Days	28 Days (av.)	28 Days Equiv.	Variation from Plain	
P.53 (6.4.73)	Control 400lbs Adel N.P.	1.75	1750	2900 3000	2950	2950		37.0
	15% Ash/Cement	1.25	1650	2750 2700	2725	2625	-325 (-11%)	35.9
	25% Ash/Cement	1.50	1500	2450 2450	2450	2400	-550 (-19%)	35.4
P.54 (6.4.73)	Control 400lbs Adel N.P.	3.00	1450	2600 2500	2550	2550		37.0
	15% Ash/Cement	2.00	1600	2650 2800	2725	2625	+ 75 (+ 3%)	35.9
	25% Ash/Cement	2.50	1550	2600 2500	2550	2450	-100 (- 4%)	35.4
P.55	Control 400lbs Adel N.P.	2.75	1700	2600 2550	2575	2575		37.0
	15% Ash/Cement	2.50	1600	2450	2525	2475	-100 (- 4%)	35.9
	25% Ash/Cement	2.50	1450	2300 2350	2325	2275	-300 (-12%)	35.4
P.56 (3.4.73)	Control 400lbs Adel N.P.	2.25	1600	2450 2450	2450	2450		37.0
	15% Ash/Cement	2.25	1600	2550 2600	2575	2575	+125 (+ 5%)	35.9
	25% Ash/Cement	2.25	1500	2550 2550	2550	2550	+100 (+ 4%)	35.4

Strengths assessed for slumps equal to control mixes on basis of 1" slump increase = 200 PSI

THE READYMIX GROUP (S.A.)

POZZOLANIC EVALUATION OF GROUND VOLCANIC ASH

REPORT NO. 6 - EXPLORATION LICENSE 13

Sample No.	Mix/Blend	Slump (inches)	Compressive Strength P.S.I. 7 Days	28 Days	28 Days (av.)	28 Days Equiv. @ 2" Slump	Variation from Plain @ 2" Slump	Corrected Total Water (galls/c.yd.)
P.57 (28.3.73)	Control 400lbs Adel N.P.	1.50	1700	2700 2650	2675	2575		37.0
	15% Ash/Cement	2.50	1450	2050 2100	2075	2175	-400 (-16%)	35.9
	25% Ash/Cement	3.00	1200	1800 1850	1825	2025	-550 (-21%)	35.3
P.58 (28.3.73)	Control 400lbs Adel N.P.	2.25	1650	2700 2800	2750	2800		37.0
	15% Ash/Cement	1.75	1750	2850 2750	2800	2750	- 50 (- 2%)	35.9
	25% Ash/Cement	1.25	1550	2850 2850	2850	2650	-150 (- 5%)	35.3
P.59 (11.4.73)	Control 400lbs Adel N.P.	1.50	1650	2400 2250	2325	2225		37.0
	15% Ash/Cement	1.00	1350	2200 2100	2150	1950	-275 (-12%)	35.9
	25% Ash/Cement	1.50	1250	2100 2200	2150	2050	-175 (- 8%)	35.3

28 Days Equivalent Strengths at 2" Slump Based on 1" Slump Increase = 200 PSI Strength Decrease

THE READYMIX GROUP (S.A.)

POZZOLANIC EVALUATION OF GROUND VOLCANIC ASH

REPORT NO. 7 - EXPLORATION LICENSE 13

0045

Sample No.	Mix	Compressive Strength (P.S.I.)			
		28 Days	28 Days (av.)	90 Days	Gain/Loss
P.52	Control 400 lbs Adel N.P.	2400 2500	2450	2800	+ 350
	15% Ash/Cement	2400 2450	2425	3050	+ 625
	25% Ash/Cement	2450 2400	2425	2950	+ 525
P.53	Control 400 lbs Adel N.P.	2900 3000	2950	3350	+ 400
	15% Ash/Cement	2750 2700	2725	3400	+ 675
	25% Ash/Cement	2450 2450	2450	2900	+ 450
P.54	Control 400 lbs Adel N.P.	2600 2500	2550	3050	+ 500
	15% Ash/Cement	2650 2800	2725	3300	+ 575
	25% Ash/Cement	2600 2500	2550	3100	+ 550
P.55	Control 400 lbs Adel N.P.	2600 2550	2575	2950	+ 375
	15% Ash/Cement	2450 2600	2525	2700	+ 175
	25% Ash/Cement	2300 2350	2325	2800	+ 475
P.56	Control 400 lbs Adel N.P.	2450 2450	2450	2800	+ 350
	15% Ash/Cement	2550 2600	2575	3050	+ 475
	25% Ash/Cement	2550 2550	2550	3000	+ 450
P.57	Control 400 lbs Adel N.P.	2700 2650	2675	3200	+ 525
	15% Ash/Cement	2050 2100	2075	2550	+ 475
	25% Ash/Cement	1800 1850	1825	2350	+ 525
P.58	Control 400 lbs Adel N.P.	2700 2800	2750	3050	+ 300
	15% Ash/Cement	2850 2750	2800	3450	+ 650
	25% Ash/Cement	2850 2850	2850	3450	+ 600
P.59	Control 400 lbs Adel N.P.	2400 2250	2325	2800	+ 475
	15% Ash/Cement	2200 2100	2150	3050	+ 900
	25% Ash/Cement	2100 2200	2150	3000	+ 850

0046

APPENDIX II

Exploration of License No. 13

Log of Auger Bore-holes

Quarry floor – Section A   Hundred of Riddoch

R.M.C. MINERALS PTY. LTD.   Driller. J.P. & G.N.

Date. 4-12-72   Prospect/Project No. E.L. 13   Assistant.

Hole No.	From	To	Description, Geology, Remarks.
DH 1	0'	11'	Light brown semi-consolidated ash with occasional pyrite nodules.
	11'	35'	Light and dark brown consolidated ash with horizons of both fine and coarse grained fragments. – occasional limestone fragments.
	35'	57'	Dark brown ash and limestone fragments
17·4	57'	60'	Fossil limestone – water entering hole.
			Drilling discontinued at 60'
		18·29	
			Sample Recovery – approx 95 lbs.

Quarry floor - Section A Hundred of Riddoch

R.M.C. MINERALS PTY. LTD. Driller J.P. & G.N.

Date 4-12-72 Prospect/Project No. EL 13 Assistant

Hole No.	From	To	Description, Geology, Remarks.
DH 2	0'	14'	Brown semi-consolidated ash and occasional minute pyrite granules
	14'	31'	Extremely hard dark brown consolidated ash with increasing content of fossil limestone with depth.
			Drilling discontinued at 31' due to extreme hardness of material.
			Sample Recovery - approx 50 lbs.

Quarry floor - Section A Hundred of Riddoch

R.M.C. MINERALS PTY. LTD. Driller. J.P. & G.N. ....

Date. 6-12-72 Prospect/Project No. EL 13 ....Assistant.................

Hole No.	From	To	Description, Geology, Remarks.
DH3	0'	5'6"	Light brown and yellow semi-consolidated ash.
	5'6"	6'	Black hard material - (Basalt?)
			Hole discontinued at 6' due to hardness of material intersected
			Sample Recovery - approx 15 lbs.

Quarry floor - Section A   Hundred of Riddoch

R.M.C. MINERALS PTY. LTD.   Driller J.P. & G.H.

Date 6-12-72   Prospect/Project No. EL 13   Assistant

Hole No.	From	To	Description, Geology, Remarks.
DH 3(a)	0'	13'	Light brown and yellow semi-consolidated ash containing some finely divided white material(?) and occasional pyrite grains.
	13'	29'	Hard light and dark brown horizons of ash with increasing fossil limestone content with depth.
			Hole discontinued at 29'
			Sample Recovery - approx 45 lbs
			Note: this hole drilled because of failure to penetrate in previous location (DH 3)

Slope alongside road - Section A Hundred of Riddoch

R.M.C. MINERALS PTY. LTD. Driller..J.P. & G.N.........

Date..6-12-72 Prospect/Project No....EL 13.......Assistant..........................

Hole No.	From	To	Description, Geology, Remarks.
DH 4	0'	3'	Red clay and surface soil.
	3'	7'	Moist black-brown clayey soil with fine ash distributed sparingly throughout.
	7'	10'	Marl and fossil limestone - moist.
		~~3.0~~ 3.05	Hole discontinued due to non-intersection of volcanics
			Not Sampled.

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R.M.C. MINERALS PTY. LTD. Driller...JP & GN.........

Date...7-12-72 Prospect/Project No....EL 13......Assistant..................

Hole No.	From	To	Description, Geology, Remarks.
DH5	0'	3'	Grey to black sandy volcanic soil.
	3'	6'6"	Black to brown soft partially consolidated granular ash - particle size medium to fine grained
	6'6"	30'	Brown consolidated ash - fine grained
	30'	34'	Grey sand - extremely moist
	34'	36'	Fossil limestone
			Hole discontinued at 36'
			Sample Recovery - 3' to 30' = approx 40 lbs

Alongside Road - Section 372 Hundred of Hindmarsh

R.M.C. MINERALS PTY. LTD. Driller..J.P. & G.N.........

Date..16-1-73 Prospect/Project No...EL 13.......Assistant.....................

Hole No.	From	To	Description, Geology, Remarks.
DH 6	0'	4'6"	Surface soil overlying red plastic clay.
	4'6"	7'	Weathered coarse grained loose to semi-consolidated ash, becoming harder with depth.
	7'	28'	Consolidated brown-black ash with some finely disseminated green glass (olivine?)
	28'	29'	Grey-black sandy soil.
			Hole discontinued at 29'
			Sample Recovery - 4'6" to 28' = approx 40 lbs.

Section 246 Hundred of Young. 0054

R.M.C. MINERALS PTY. LTD. Driller....JP. & GN.......

Date...16-1-73 Prospect/Project No....EL 13.......Assistant..................

Hole No.	From	To	Description, Geology, Remarks.
DH7	0'	2'	Grey-black sandy surface soil.
	2'	7'	Red plastic clay.
21	7'	13'6"	Black-brown earthy, soft to semi-consolidated ash
	13'6"	14'	Limestone.
4.1		4.27	
			Unable to penetrate beyond 14'
			Not sampled.

Section A Hundred of Riddoch

R.M.C. MINERALS PTY. LTD. Driller..J.P. & S.N.........

Date...27-3-73 Prospect/Project No...E.L. 13........Assistant......................

Hole No.	From	To	Description, Geology, Remarks.
DH 8	0'	1'	Sandy black surface soil.
	1'	4'	Brown and black horizons soft ash - particle size - medium to fine
	4'	24'	Brown and yellow/brown semi-consolidated ash with numerous black glass and olivine fragments at 22'
	24'	43'	Dark brown hard consolidated ash with increasing ammount of limestone with depth - some black scoriaceous material near base.
	43'	47'	Sandy limestone
			Hole discontinued at 47' due to discontinuity of volcanic material.
			Sample Recovery - 1' to 43' = approx 65 lbs.

S.E corner Section A Hundred of Riddoch 0056

R.M.C. MINERALS PTY. LTD. Driller JP & GN

Date 27-3-73 Prospect/Project No. EL 13 Assistant

Hole No.	From	To	Description, Geology, Remarks.
DH 9	0'	3'	Weathered brown ash.
	3'	49'	Brown and yellow-brown horizons of semi-consolidated coarse grained ash - numerous vesicular particles containing fine white crystals (?).
	49'	62'	Dark brown consolidated ash becoming harder with depth - nodular limestone abundant with depth.
			Hole discontinued at 62' due to extreme hardness of material.
			Sample Recovery - approx 100 lbs.

Roadside - Section 373 Hundred of Hindmarsh 0057

R.M.C. MINERALS PTY. LTD. Driller JP & GN

Date 28-3-73 Prospect/Project No. EL 13 Assistant

Hole No.	From	To	Description, Geology, Remarks.
DH 10	0'	3'	Soil and red clay.
0.9	3'	11'	Coarse grained soft semi-consolidated ash - highly weathered in upper portion
	11'	35'	Brown-black consolidated ash with black glass and minor olivene bomb fragments - nodular limestone present and increasing in quantity below 22' 7m
10.9	35'	39'	Nodular fossil limestone and scoriaceous fragments.
	39'	40'	Sand
		12.19	
			Hole discontinued at 40'
			Sample Recovery - approx 45 lbs

Section 372 Hd. of Hindmarsh

0058

R.M.C. MINERALS PTY. LTD. Driller: JP & SN

Date: 29-3-73 Prospect/Project No.: EL 13 Assistant:

Hole No.	From	To	Description, Geology, Remarks.
DH 11	0'	2'	Sandy grey-black surface soil
	2'	7'	Red-brown clay
	7'	26'	Brown-black coarse and fine laminations of semi-consolidated ash partly weathered in upper portion
	26'	31'	Brown hard ash and limestone fragments
	31'	33'	Sandy limestone - influx of water at 31'
			Hole discontinued at 33'
			Sample Recovery - 7' to 31' = approx 35 lbs

N. of Section 376 Hundred of Hindmarsh

R.M.C. MINERALS PTY. LTD. Driller...JP. & G.N.........

Date....30-3-73 Prospect/Project No...EL 13.......Assistant.....................

Hole No.	From	To	Description, Geology, Remarks.
DH 12	0'	3'	Extremely wet sandy black soil
	3'	5'6"	Black soil with some coarse to medium granular ash - saturated
	5'6"	7'6"	Marl and sandy limestone - saturated
			Hole discontinued at 7'6"
			Not Sampled

Bulk Samples

R.M.C. MINERALS PTY. LTD. Driller J.P. & G.N.

Date 31-3-73 Prospect/Project No. EL 13 Assistant

Hole No.	From	To	Description, Geology, Remarks.
		(1)	250 lbs sample gained from quarry face on Section A Hundred of Riddoch
		(2)	250 lbs sample gained from cliff face along northern end of Lake Leake
		(3)	250 lbs sample gained from outcrop along eastern side of Lake Leake
		(4)	250 lbs sample gained from cliff face on N.E. side of Lake Edward.


37°35'
140°34'
140°37'
37°35'
N
H^D of Riddock
H^D of Grey
H^D of Hindmarsh
H^D of Young
D.H.4
D.H.5
D.H.1
D.H.2
D.H.3
Quarry face
Cliff face
Lake Leake
D.H.6
Lake Edward
Forest Reserve
37°36'
140°34'
37°36'
140°37'
Legend
Volcanic soil
Consolidated volcanic ash
Swamp marginal Land
Hundred boundary
Quarry face
Drill holes
D.H.1
Forest Reserve
Ready Mixed Concrete (S.A.) Pty Ltd
Lake Leake Area 19.2 Kilom
east of Millicent
Date 28-3-73
Drawn. L.D.S.

ENV 2210-1


37°35'
140°34'
140°37'
N
Hd of Riddoch
Hd of Grey
Hd of Hindmarsh
Hd of Young
Quarry face
Cliff face
Lake Leake
Lake Edward
FOREST RESERVE
D.H.5
D.H.10
D.H.11
D.H.12
D.H.7
37°38'
Legend
Volcanic soil
Consolidated volcanic ash
Swamp marginal land
Hundred boundary
Quarry face
Drill holes prior to April 1973
" " to Sept 1973
D.H.
D.H.10.
Forest Reserve
READY MIXED CONCRETE (S.A.) PTY LTD
Lake Leake Area 19·2 kilom
east of Millicent.
Date: 28-3-73
Drawn: L.D.S.
Scale: 1inch: 176 yds
Drg No: B-EXP-418.

ENV 2210-2