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89/3408E/3379

LAVA MINING & QUARRYING CO. S.A.

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STRUCTURAL CONCRETE USING YALI PUMICE COARSE AND FINE AGGREGATE

89/3408E/3379. OCTOBER 1990

REPORT ON CONCRETE MIX DESIGN
FOR STRUCTURAL CONCRETE USING YALI
PUMICE COARSE AND FINE AGGREGATES

CONTENTS

89/3408E/3379

STATS
CONSULTING ENGINEERS
& MATERIALS SCIENTISTS

STATS Scotland Ltd, Stats House, Linwood Avenue, East Kilbride, Scotland G74 5NR. Telephone: 03552 38285. Fax: 03552 22090
also at St. Albans and Manchester

BJB/LB/89/3408E/3379

Client: Lava Mining & Quarrying Co. S.A. October 1990

REPORT ON CONCRETE MIX DESIGN FOR STRUCTURAL CONCRETE USING YALI PUMICE COARSE AND FINE AGGREGATE

1.0 INTRODUCTION

1.1 Further to the agreement between Lava Mining & Quarrying Co. S.A. and STATS Scotland Ltd of May 1989, STATS have carried out an assessment of Yali Pumice as coarse and fine aggregate for use in structural concrete.

1.2 The aggregate from Yali Island in the Eastern Mediterranean, was supplied by LAVA in two size grades:-

Besser (8-0mm) and German (18-0mm)

1.3 16 tonnes of Besser (8-0mm) and 24 tonnes of German (18-0mm) were received by STATS East Kilbride Laboratory on 20 July 1989.

1.4 This report is presented in four parts with accompanying appendices. Part One deals with the initial laboratory mix designs, Part Two with the testing of proven structural mixes, Part Three with laboratory and field trials of pumpable structural concrete and Part Four contains our conclusions on the production and use of pumice lightweight aggregate concrete.

B J Brown
BSc PhD CEng FIMM FIHT FGS
Managing Director

2.0 PART ONE
LABORATORY MIX DESIGNS

2.0 PART ONE: LABORATORY MIX DESIGNS

2.1 Purpose of Assessment

The assessment was carried out in order to determine the suitability of Yali pumice coarse and fine aggregates to produce structural concrete within normal cement content and workability ranges and to produce mix design data for such concrete.

No admixtures or additions of other ingredients apart from pumice coarse and fine aggregates, cement and water were to be used in the initial assessment.

2.2 Mix Design Method

The design method adopted examined the materials over a range of cement contents, producing mix design data in the range 200kg/m^3 to 450kg/m^3.

This was achieved by designing mixes individually at aggregate/cement ratios of 2/1, 3/1 and 4/1 by weight. The mix designs were carried out in two stages. Firstly, preliminary trials were undertaken at each aggregate/cement ratio, to determine in each case, the required fine aggregate content for optimum plastic properties in the concrete. These preliminary trial batches were each produced initially with insufficient fine aggregate to produce homogenous concrete. The fines contents were then increased, whilst maintaining the aggregate/cement ratio, by the addition of small fine aggregate/cement increments in proportion with the total aggregate/cement ratio in use. The addition of such increments was continued, increasing the fines in stages until, in each case, the concrete displayed optimum plastic properties, within the selected workability range.

Workability range in this context is taken to be the properties of the concrete that include general cohesiveness, its mobility and its ability to produce a "closed face" against a form surface.

Having established the required percentage of fines for each aggregate/cement ratio, secondary trials were then carried out in order to determine the free water demand, plastic density and strength.

Information and test results derived from the completed trials were then used to produce main relationships, linking various mix design parameters to unit cement content, thus allowing mix proportions or unit weights to be obtained at any point within the cement content range, as previously indicated.

In accordance with the agreement, all trials were conducted using ordinary portland cement of local manufacture, complying with the requirements of BS 12: 1978 and 1989. It should be noted that no additives or admixtures of any kind were used in the concrete in the initial assessment.

2.3 Results

When carrying out secondary trials Series 1, it was noted that the mixes appeared slightly less cohesive than they had at similar fines contents, during preliminary trials. The reasons for this situation are discussed in section 2.4 of the report.

As such, a further set of secondary trials were carried out at slightly increased fines contents, these trials being referred to in this report as secondary trials Series 2 and representing mixes with optimum fines content.

Whilst the loss of cohesiveness in Series 1 mixes was not severe, it was felt that fines contents were below optimum. Series 1 trials are therefore reported for comparison purposes only, indicating the effects of the change in fines contents on the various parameters observed.

Full trial mix details and main relationships derived are presented in appendices as follows:

Appendix 1	Preliminary Trial Mix Details
Appendix 2	Secondary Trial Mix Details - Series 1
Appendix 3	Secondary Trial mix Details - Series 2
Appendix 4	Main Relationships - Series 1
Appendix 5	Main Relationships - Series 2

Throughout the mix design procedure, measurement of workability or flow characteristics was based on the use of the slump test, in accordance with BS 1881: Part 102: 1983.

In all cases, reported strength values were derived from compressive strength tests conducted on 100mm concrete cubes which were cast, water cured and tested in accordance with BS 1881: Parts 108, 111 and 116: 1983 respectively.

Reported cube densities were derived from saturated mass at time of testing and measured dimensions of cubes, in accordance with BS 1881: Part 114: 1983.

2.4 Discussion and Conclusions

On considering the possible causes for the apparent reduction in fines between preliminary mixes and Series 1 secondary mixes, the following conclusions have been made.

During the preliminary mixes it is felt that a proportion of the coarse (German) aggregate in the concrete was broken down under the mechanical action of the pan mixer during the extended mixing periods which were required to accommodate the addition of fine aggregate/cement increments to the concrete. Consequently, the actual percentage fines in the concrete was increased to a value greater than that physically added, bringing about the situation observed.

Whilst these mix design trials attempted to produce concretes of optimum proportions, it was generally noted throughout the range of cement contents, that the mixes did not display particularly good plastic flow characteristics. Apart from the "feel" of the concrete in the mixer, several other observations relate particularly to this comment.

The free water demand required to produce workability in the selected range was high, certainly in relation to that expected and required for most normal weight aggregates.

It was also noted that the concrete had a tendency to "bleed" and to segregate; in both cases the situation worsening as workability levels were increased. For this reason a target slump range of 35-50mm was adopted for the main trials reported. It should be noted that, as concrete "slumps" under the influence of gravity, lightweight concrete having a lower mass than conventional material, is less affected by gravity and therefore at equal workability levels, should record a lower slump value than concrete containing normal weight aggregates.

The mix design trials indicate that concrete produced with Lava pumice coarse and fine aggregates is capable of achieving structural strengths within the normally accepted range of cement contents. Recorded strengths suggest that a ceiling value is reached at cement contents in excess of 400kg/m^3, of between 30.0N/mm^2 and 35.0N/mm^2.

However, for practical production of pumice aggregate lightweight concrete either by on-site batching or by ready-mix plant it is felt that improvement in the plastic properties of the mixes is required. This could be achieved by the incorporation of simple plasticising or air entraining admixtures. Whilst the use of air entraining admixture could require minor alterations to mix proportions, correctly selected admixture could reduce the free water demand of the concrete, as well as reducing its tendency to segregate and bleed, all of positive benefit in the practical production of structural lightweight concrete.

Given the nature of the aggregates and the observations made above regarding the plastic properties of the concrete, we do not consider that the mix designs presented in this part of the report would be suitable for placing by concrete pump. With the known difficulties in the area of pumping lightweight aggregate concrete, we feel that any attempt to produce pumpable material would require design in its own right and would certainly require the use of chemical admixtures, if not the addition of further dry constituents such as natural sand fine aggregate.

The results of additional tests relating strength grade to various concrete properties (modulus of elasticity, water absorption, carbonation etc) are presented in Part Two of this report.

The mix design results for pumice lightweight structural concrete suitable for practical ready mix or site batch production and for pump emplacement will be presented in Part Three.

APPENDIX 1

PRELIMINARY TRIAL MIX DETAILS

PRELIMINARY TRIAL MIX RECORD. TRIAL DATE : 31-8-89
REF : PRTR2

A/C RATIO : 2.0 / 1 INITIAL FINES CONTENT : 32 %

FREE MOISTURE CONTENTS : COARSE AGG. (GERMAN 18-0mm) = 5.6 %
: FINE AGG. (BESSER 8-0mm) = 9.9 %

TRIAL BATCH WEIGHTS :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	2.50 kg		2.50 kg
FINES 8-0mm	1.60 kg	9.9	1.76 kg
COARSE 18-0mm	3.40 kg	5.6	3.59 kg

APPEARANCE OF CONCRETE AS BATCHED : HARSH.
SAND / CEMENT INCREMENTS ADDED TO MIX AT RATIO OF 2/1 BY WEIGHT, IN ORDER TO INCREASE PERCENTAGE OF FINES TO AN ACCEPTABLE LEVEL, WHILST MAINTAINING INITIAL A/C RATIO.

ADDITIONAL MATERIAL ADDED :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	0.67 kg		0.67 kg
FINES 8-0mm	1.35 kg	9.9	1.48 kg

TOTAL SURFACE DRY WEIGHTS BATCHED :

O.P.CEMENT	(2.50 + 0.67)	= 3.17 kg
FINES 8-0mm	(1.60 + 1.35)	= 2.95 kg
COARSE 18-0mm		= 3.40 kg

RECALCULATED MIX PROPORTIONS :

A/C RATIO : 2.0 /1
FINES 8-0mm : 46.5 %

PRELIMINARY TRIAL MIX RECORD. TRIAL DATE : 31-8-89

REF : PRTR3

A/C RATIO : 3.0 / 1 INITIAL FINES CONTENT : 40 %

FREE MOISTURE CONTENTS : COARSE AGG. (GERMAN 18-0mm) = 5.6 %
: FINE AGG. (BESSER 8-0mm) = 9.9 %

TRIAL BATCH WEIGHTS :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	2.00 kg		2.00 kg
FINES 8-0mm	2.40 kg	9.9	2.64 kg
COARSE 18-0mm	3.60 kg	5.6	3.80 kg

APPEARANCE OF CONCRETE AS BATCHED : HARSH.
SAND / CEMENT INCREMENTS ADDED TO MIX AT RATIO OF 3/1 BY WEIGHT, IN ORDER TO INCREASE PERCENTAGE OF FINES TO AN ACCEPTABLE LEVEL, WHILST MAINTAINING INITIAL A/C RATIO.

ADDITIONAL MATERIAL ADDED :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	0.65 kg		0.65 kg
FINES 8-0mm	1.95 kg	9.9	2.14 kg

TOTAL SURFACE DRY WEIGHTS BATCHED :

O.P.CEMENT	(2.00 + 0.65)	=	2.65 kg
FINES 8-0mm	(2.40 + 1.95)	=	4.35 kg
COARSE 18-0mm		=	3.60 kg

RECALCULATED MIX PROPORTIONS :

A/C RATIO : 3.0 /1
FINES 8-0mm : 54.7 %

PRELIMINARY TRIAL MIX RECORD.
REF : PRTR4

TRIAL DATE : 31-8-89

A/C RATIO : 4.0 / 1

INITIAL FINES CONTENT : 53 %

FREE MOISTURE CONTENTS : COARSE AGG. (GERMAN 18-0mm) = 5.6 %
: FINE AGG. (BESSER 8-0mm) = 9.9 %

TRIAL BATCH WEIGHTS :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	1.50 kg		1.50 kg
FINES 8-0mm	3.18 kg	9.9	3.49 kg
COARSE 18-0mm	2.82 kg	5.6	2.98 kg

APPEARANCE OF CONCRETE AS BATCHED : HARSH.
SAND / CEMENT INCREMENTS ADDED TO MIX AT RATIO OF 4/1 BY WEIGHT, IN ORDER TO INCREASE PERCENTAGE OF FINES TO AN ACCEPTABLE LEVEL, WHILST MAINTAINING INITIAL A/C RATIO.

ADDITIONAL MATERIAL ADDED :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	0.59 kg		0.59 kg
FINES 8-0mm	2.36 kg	9.9	2.59 kg

TOTAL SURFACE DRY WEIGHTS BATCHED :

O.P.CEMENT	(1.50 + 0.59)	=	2.09 kg
FINES 8-0mm	(3.18 + 2.36)	=	5.54 kg
COARSE 18-0mm		=	2.82 kg

RECALCULATED MIX PROPORTIONS :

A/C RATIO : 4.0 /1
FINES 8-0mm : 66.2 %

APPENDIX 2

SECONDARY TRIAL MIX DETAILS

SERIES - 1

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SECONDARY TRIAL MIX RECORD.
REF : SETR2

TRIAL DATE : 01-9-89

A/C RATIO : 2.0 / 1

FINES CONTENT : 46.5 %

FREE MOISTURE CONTENTS : COARSE AGG. (GERMAN 18-0mm) = 5.6 %
: FINE AGG. (BESSER 8-0mm) = 9.9 %

TRIAL BATCH WEIGHTS :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	3.00 kg		3.00 kg
FINES 8-0mm	2.79 kg	9.9	3.07 kg
COARSE 18-0mm	3.21 kg	5.6	3.39 kg

RECORDED SLUMP VALUE : 45 mm

WATER ADDED AT MIXER : 1.50 litre

FREE WATER IN AGGREGATES : (0.18 + 0.28) = 0.46 litre

FREE WATER/CEMENT RATIO : (1.50 + 0.46) / 3.00 = 0.65

RECORDED PLASTIC DENSITY : 1610 kg/m3

CUBE TEST RESULTS: 100 mm CUBES

CUBE REF.	TEST AGE (DAYS)	DENSITY (kg/m3)	STRENGTH (N/mm2)
A1	7	1628	27.5
A2	14	1610	27.5
A3	28	1613	30.8
A4	28	1611	31.9

SECONDARY TRIAL MIX RECORD. SHEET # 2
REF : SETR2B

MIX PROPORTIONS :

O.P.CEMENT	:	1.00
TOTAL AGGREGATE	:	2.00
WATER	:	0.65
SUM OF PROPORTIONS	:	3.65

PLASTIC DENSITY : 1610 kg/m3
FINES CONTENT : 46.5 %

SURFACE DRY BATCH WEIGHTS / m3 (BASED ON PLASTIC DENSITY)

O.P.CEMENT	=	441	kg/m3
FINES 8-0mm	=	410	kg/m3
COARSE 18-0mm	=	472	kg/m3
WATER	=	287	litre/m3

ABSOLUTE VOLUME, YIELD CALCULATIONS:

RELATIVE DENSITY VALUES :

O.P.CEMENT	:	3120	kg/m3	(ASSUMED)
BESSER 8-0mm	:	1645	kg/m3	(40 HOUR SOAK)
GERMAN 18-0mm	:	1420	kg/m3	(60 HOUR SOAK)

O.P.CEMENT	:	441	/	3120	=	0.14135
FINES 8-0mm	:	410	/	1645	=	0.24924
COARSE 18-0mm	:	472	/	1420	=	0.33239
WATER	:	287	/	1000	=	0.28700
			ABSOLUTE VOLUME		=	1.00998

MAXIMUM THEORETICAL DENSITY 1594 kg/m3

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SECONDARY TRIAL MIX RECORD.
REF : SETR3

TRIAL DATE : 01-9-89

A/C RATIO : 3.0 / 1

FINES CONTENT : 54.7 %

FREE MOISTURE CONTENTS : COARSE AGG. (GERMAN 18-0mm) = 5.6 %
: FINE AGG. (BESSER 8-0mm) = 9.9 %

TRIAL BATCH WEIGHTS :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	2.50 kg		2.50 kg
FINES 8-0mm	4.10 kg	9.9	4.51 kg
COARSE 18-0mm	3.40 kg	5.6	3.59 kg

RECORDED SLUMP VALUE : 40 mm

WATER ADDED AT MIXER : 1.68 litre

FREE WATER IN AGGREGATES : (0.19 + 0.41) = 0.60 litre

FREE WATER/CEMENT RATIO : (1.68 + 0.60) / 2.50 = 0.91

RECORDED PLASTIC DENSITY : 1565 kg/m3

CUBE TEST RESULTS: 100 mm CUBES

CUBE REF.	TEST AGE (DAYS)	DENSITY (kg/m3)	STRENGTH (N/mm2)
B1	7	1574	24.0
B2	14	1570	25.5
B3	28	1565	27.0
B4	28	1549	26.3

SECONDARY TRIAL MIX RECORD.
REF : SETR3B

SHEET # 2

MIX PROPORTIONS :

O.P.CEMENT	:	1.00
TOTAL AGGREGATE	:	3.00
WATER	:	0.91
SUM OF PROPORTIONS	:	4.91

PLASTIC DENSITY : 1565 kg/m3
FINES CONTENT : 54.7 %

SURFACE DRY BATCH WEIGHTS / m3 (BASED ON PLASTIC DENSITY)

O.P.CEMENT	=	319	kg/m3
FINES 8-0mm	=	510	kg/m3
COARSE 18-0mm	=	446	kg/m3
WATER	=	290	litre/m3

ABSOLUTE VOLUME, YIELD CALCULATIONS:

RELATIVE DENSITY VALUES :

O.P.CEMENT	:	3120	kg/m3	(ASSUMED)
BESSER 8-0mm	:	1645	kg/m3	(40 HOUR SOAK)
GERMAN 18-0mm	:	1420	kg/m3	(60 HOUR SOAK)

O.P.CEMENT	:	319	/	3120	=	0.10224
FINES 8-0mm	:	510	/	1645	=	0.31003
COARSE 18-0mm	:	446	/	1420	=	0.31408
WATER	:	290	/	1000	=	0.29000
			ABSOLUTE VOLUME		=	1.01635

MAXIMUM THEORETICAL DENSITY = 1539 kg/m3

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SECONDARY TRIAL MIX RECORD. TRIAL DATE : 01-9-89
REF : SETR4

A/C RATIO : 4.0 / 1 FINES CONTENT : 66.2 %

FREE MOISTURE CONTENTS : COARSE AGG. (GERMAN 18-0mm) = 5.6 %
: FINE AGG. (BESSER 8-0mm) = 9.9 %

TRIAL BATCH WEIGHTS :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	1.80 kg		1.80 kg
FIES 8-0mm	4.77 kg	9.9	5.24 kg
COARSE 18-0mm	2.43 kg	5.6	2.57 kg

RECORDED SLUMP VALUE : 35 mm

WATER ADDED AT MIXER : 1.59 litre

FREE WATER IN AGGREGATES : (0.14 + 0.47) = 0.61 litre

FREE WATER/CEMENT RATIO : (1.59 + 0.61) / 1.80 = 1.22

RECORDED PLASTIC DENSITY : 1518 kg/m3

CUBE TEST RESULTS: 100 mm CUBES

CUBE REF.	TEST AGE (DAYS)	DENSITY (kg/m3)	STRENGTH (N/mm2)
C1	7	1546	16.0
C2	14	1550	19.5
C3	28	1557	21.0
C4	28	1540	20.8

SECONDARY TRIAL MIX RECORD. SHEET # 2
REF : SETR4B

MIX PROPORTIONS :

O.P.CEMENT	:	1.00
TOTAL AGGREGATE	:	4.00
WATER	:	1.22
SUM OF PROPORTIONS	:	6.22

PLASTIC DENSITY : 1518 kg/m3
FINES CONTENT : 66.2 %

SURFACE DRY BATCH WEIGHTS / m3 (BASED ON PLASTIC DENSITY)

O.P.CEMENT	=	244 8kg/m3
FINES 8-0mm	=	646 kg/m3
COARSE 18-0mm	=	329 kg/m3
WATER	=	298 litre/m3

ABSOLUTE VOLUME, YIELD CALCULATIONS:

RELATIVE DENSITY VALUES :

O.P.CEMENT	: 3120	kg/m3	(ASSUMED)
BESSER 8-0mm	: 1645	kg/m3	(40 HOUR SOAK)
GERMAN 18-0mm	: 1420	kg/m3	(60 HOUR SOAK)

O.P.CEMENT	:	244	/	3120	=	0.07820
FINES 8-0mm	:	646	/	1645	=	0.39270
COARSE 18-0mm	:	329	/	1420	=	0.23169
WATER	:	298	/	1000	=	0.29800
		ABSOLUTE VOLUME			=	1.00059

MAXIMUM THEORETICAL DENSITY = 1517 kg/m3

APPENDIX 3

SECONDARY TRIAL MIX DETAILS

SERIES - 2

SECONDARY TRIAL MIX RECORD. TRIAL DATE : 05-9-89
REF : SETR2A

A/C RATIO : 2.0 / 1 FINES CONTENT : 50.0 %

FREE MOISTURE CONTENTS : COARSE AGG. (GERMAN 18-0mm) = 5.6 %
: FINE AGG. (BESSER 8-0mm) = 9.9 %

TRIAL BATCH WEIGHTS :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	3.00 kg		3.00 kg
FINES 8-0mm	3.00 kg	9.9	3.30 kg
COARSE 18-0mm	3.00 kg	5.6	3.17 kg

RECORDED SLUMP VALUE : 40 mm

WATER ADDED AT MIXER : 1.46 litre

FREE WATER IN AGGREGATES : (0.17 + 0.30) = 0.47 litre

FREE WATER/CEMENT RATIO : (1.46 + 0.47) / 3.00 = 0.64

RECORDED PLASTIC DENSITY : 1601 kg/m3

CUBE TEST RESULTS: 100 mm CUBES

CUBE REF.	TEST AGE (DAYS)	DENSITY (kg/m3)	STRENGTH (N/mm2)
D1	7	1599	30.4
D2	14	1586	29.6
D3	28	1603	31.5
D4	28	1607	31.5

SECONDARY TRIAL MIX RECORD. SHEET # 2
REF : SETR2AB

MIX PROPORTIONS :

O.P.CEMENT	:	1.00	PLASTIC DENSITY	:	1601 kg/m3
TOTAL AGGREGATE	:	2.00	FINES CONTENT	:	50 %
WATER	:	0.64			
SUM OF PROPORTIONS	:	3.64			

SURFACE DRY BATCH WEIGHTS / m3 (BASED ON PLASTIC DENSITY)

O.P.CEMENT	=	440	kg/m3
FINES 8-0mm	=	440	kg/m3
COARSE 18-0mm	=	440	kg/m3
WATER	=	281	litre/m3

ABSOLUTE VOLUME, YIELD CALCULATIONS:

RELATIVE DENSITY VALUES :

O.P.CEMENT	:	3120	kg/m3	(ASSUMED)
BESSER 8-0mm	:	1645	kg/m3	(40 HOUR SOAK)
GERMAN 18-0mm	:	1420	kg/m3	(60 HOUR SOAK)

O.P.CEMENT	:	440	/	3120	=	0.14102
FINES 8-0mm	:	440	/	1645	=	0.26748
COARSE 18-0mm	:	440	/	1420	=	0.30986
WATER	:	281	/	1000	=	0.28100
				ABSOLUTE VOLUME	=	0.99936

MAXIMUM THEORETICAL DENSITY = 1602 kg/m3

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SECONDARY TRIAL MIX RECORD. TRIAL DATE : 05-9-89
REF : SETR3A

A/C RATIO : 3.0 / 1 FINES CONTENT : 59.0 %

FREE MOISTURE CONTENTS : COARSE AGG. (GERMAN 18-0mm) = 5.6 %
: FINE AGG. (BESSER 8-0mm) = 9.9 %

TRIAL BATCH WEIGHTS :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	2.50 kg		2.50 kg
FINES 8-0mm	4.43 kg	9.9	4.86 kg
COARSE 18-0mm	3.07 kg	5.6	3.25 kg

RECORDED SLUMP VALUE : 35 mm

WATER ADDED AT MIXER : 1.66 litre

FREE WATER IN AGGREGATES : (0.18 + 0.43) = 0.61 litre

FREE WATER/CEMENT RATIO : (1.66 + 0.61) / 2.50 = 0.91

RECORDED PLASTIC DENSITY : 1528 kg/m3

CUBE TEST RESULTS: 100 mm CUBES

CUBE REF.	TEST AGE (DAYS)	DENSITY (kg/m3)	STRENGTH (N/mm2)
E1	7	1560	24.2
E2	14	1556	26.6
E3	28	1553	27.0
E4	28	1564	27.0

SECONDARY TRIAL MIX RECORD. SHEET # 2
REF : SETR3AB

MIX PROPORTIONS :

O.P.CEMENT	:	1.00
TOTAL AGGREGATE	:	3.00
WATER	:	0.91
SUM OF PROPORTIONS	:	4.91

PLASTIC DENSITY : 1528 kg/m3
FINES CONTENT : 59 %

SURFACE DRY BATCH WEIGHTS / m3 (BASED ON PLASTIC DENSITY)

O.P.CEMENT	=	311	kg/m3
FINES 8-0mm	=	551	kg/m3
COARSE 18-0mm	=	383	kg/m3
WATER	=	283	litre/m3

ABSOLUTE VOLUME, YIELD CALCULATIONS:

RELATIVE DENSITY VALUES :

O.P.CEMENT	:	3120	kg/m3	(ASSUMED)
BESSER 8-0mm	:	1645	kg/m3	(40 HOUR SOAK)
GERMAN 18-0mm	:	1420	kg/m3	(60 HOUR SOAK)

O.P.CEMENT	:	311	/	3120	=	0.09968
FINES 8-0mm	:	551	/	1645	=	0.33495
COARSE 18-0mm	:	383	/	1420	=	0.26972
WATER	:	283	/	1000	=	0.28300
				ABSOLUTE VOLUME	=	0.98735

MAXIMUM THEORETICAL DENSITY = 1547 kg/m3

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SECONDARY TRIAL MIX RECORD. TRIAL DATE : 05-9-89
REF : SETR4A

A/C RATIO : 4.0 / 1

FINES CONTENT : 71.0 %

FREE MOISTURE CONTENTS : COARSE AGG. (GERMAN 18-0mm) = 5.6 %
: FINE AGG. (BESSER 8-0mm) = 9.9 %

TRIAL BATCH WEIGHTS :

	SURFACE DRY	FREE MOISTURE %	ADJUSTED WEIGHT
O.P.CEMENT	1.80 kg		1.80 kg
FINES 8-0mm	5.11 kg	9.9	5.62 kg
COARSE 18-0mm	2.09 kg	5.6	2.20 kg

RECORDED SLUMP VALUE : 45 mm

WATER ADDED AT MIXER : 1.60 litre

FREE WATER IN AGGREGATES : (0.11 + 0.51) = 0.62 litre

FREE WATER/CEMENT RATIO : (1.60 + 0.62) / 1.80 = 1.23

RECORDED PLASTIC DENSITY : 1479 kg/m3

CUBE TEST RESULTS: 100 mm CUBES

CUBE REF.	TEST AGE (DAYS)	DENSITY (kg/m3)	STRENGTH (N/mm2)
F1	7	1525	14.4
F2	14	1518	17.4
F3	28	1535	17.0
F4	28	1512	20.5

SECONDARY TRIAL MIX RECORD. SHEET # 2

REF : SETR4AB

MIX PROPORTIONS :

O.P.CEMENT	:	1.00
TOTAL AGGREGATE	:	4.00
WATER	:	1.23
SUM OF PROPORTIONS	:	6.23

PLASTIC DENSITY : 1479 kg/m3
FINES CONTENT : 71 %

SURFACE DRY BATCH WEIGHTS / m3 (BASED ON PLASTIC DENSITY)

O.P.CEMENT	=	237	kg/m3
FINES 8-0mm	=	674	kg/m3
COARSE 18-0mm	=	275	kg/m3
WATER	=	292	litre/m3

ABSOLUTE VOLUME, YIELD CALCULATIONS:

RELATIVE DENSITY VALUES :

O.P.CEMENT	:	3120	kg/m3	(ASSUMED)
BESSER 8-0mm	:	1645	kg/m3	(40 HOUR SOAK)
GERMAN 18-0mm	:	1420	kg/m3	(60 HOUR SOAK)

O.P.CEMENT	:	237	/	3120	=	0.07596
FINES 8-0mm	:	674	/	1645	=	0.40973
COARSE 18-0mm	:	275	/	1420	=	0.19366
WATER	:	292	/	1000	=	0.29200
		ABSOLUTE VOLUME			=	0.97135

MAXIMUM THEORETICAL DENSITY = 1523 kg/m3

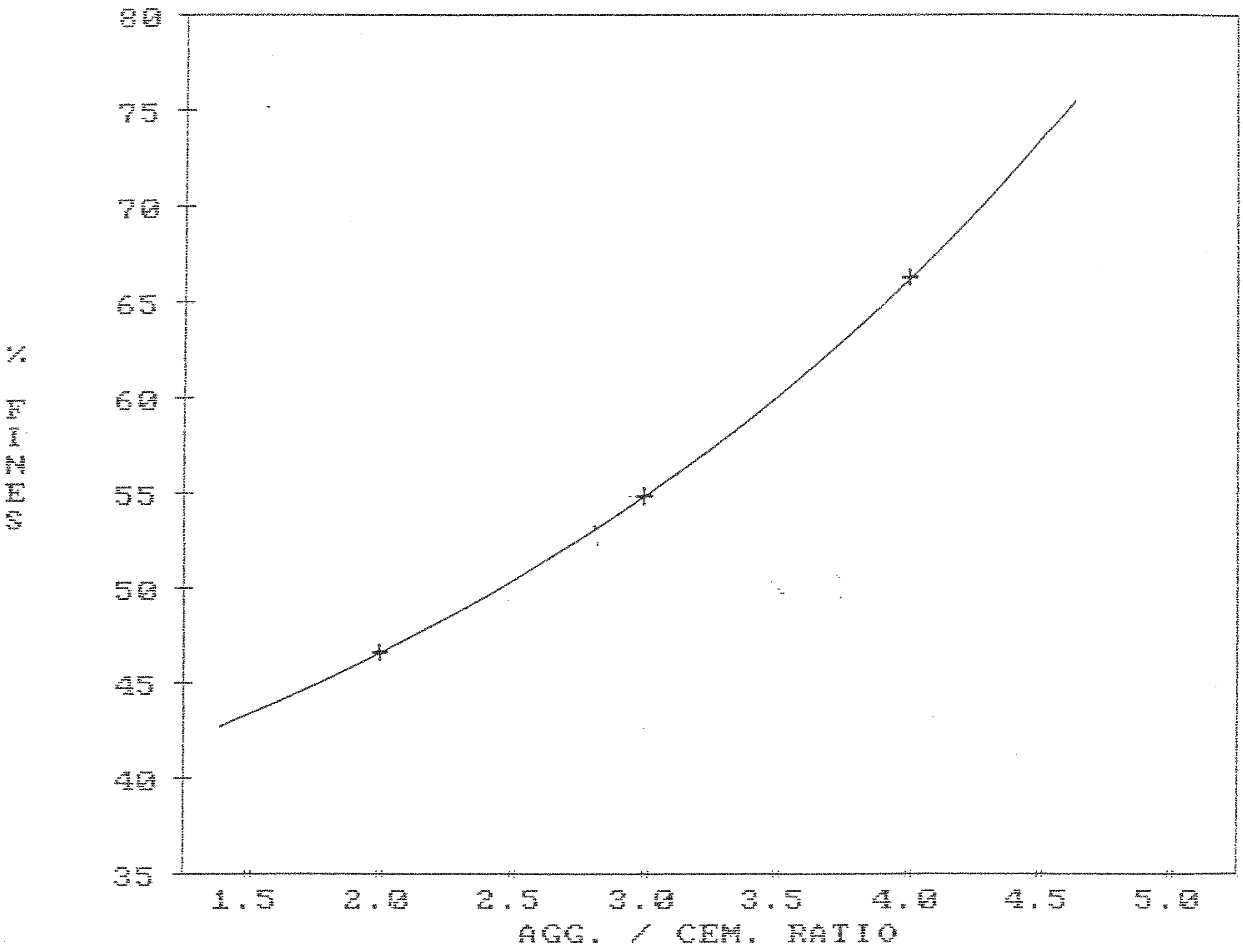
APPENDIX 4

MAIN RELATIONSHIPS

SERIES - 1 MIXES

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 1 FINES CONTENTS

RELATIONSHIP : % FINES / AGGREGATE/CEMENT RATIO



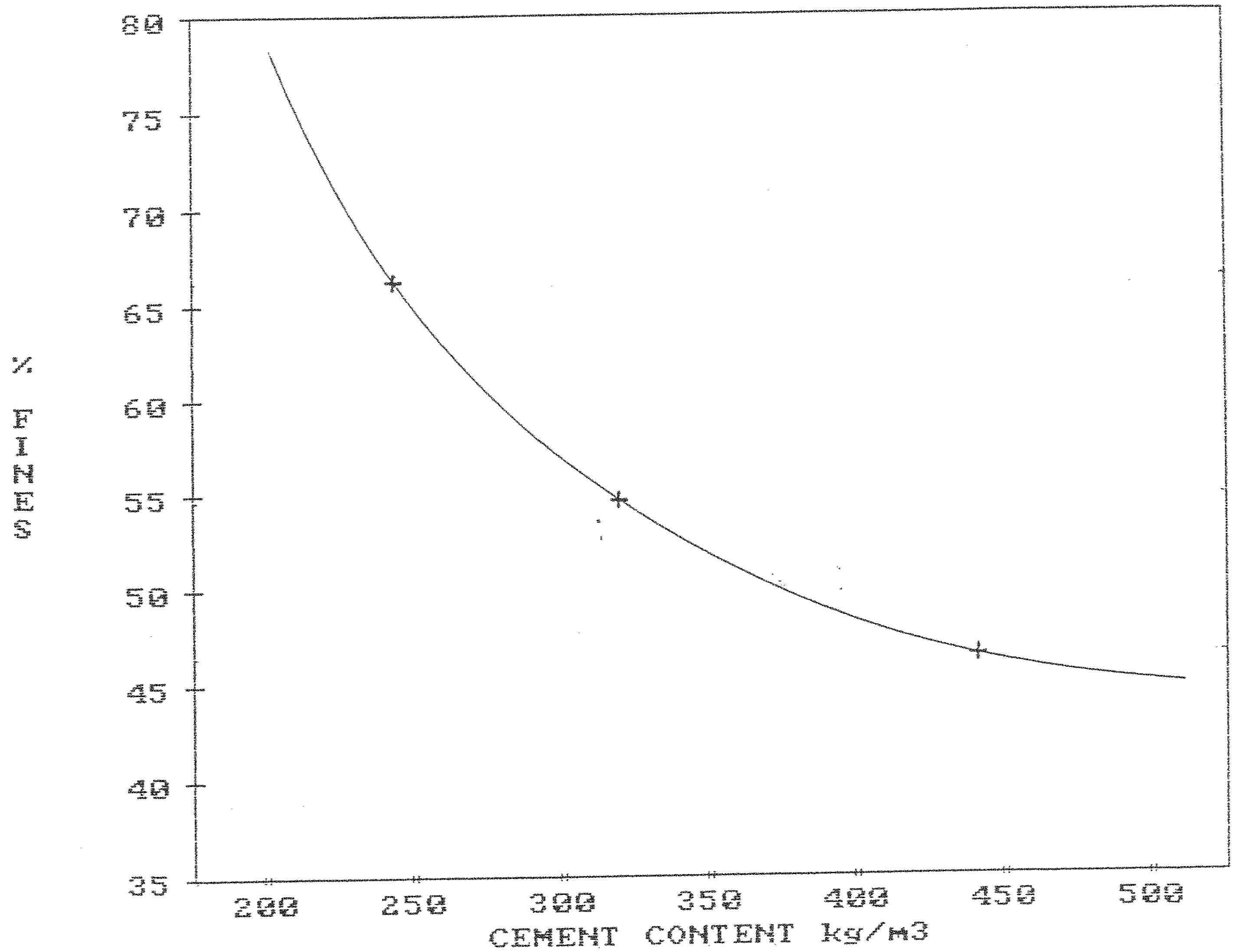
MATERIALS :

CEMENT	:	ORDINARY PORTLAND
FINE AGGREGATE	:	PUMICE, BESSER 8-0mm
COARSE AGGREGATE	:	PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	:	NONE
WORKABILITY RANGE	:	35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 1 FINES CONTENTS

RELATIONSHIP : % FINES / UNIT CEMENT CONTENT



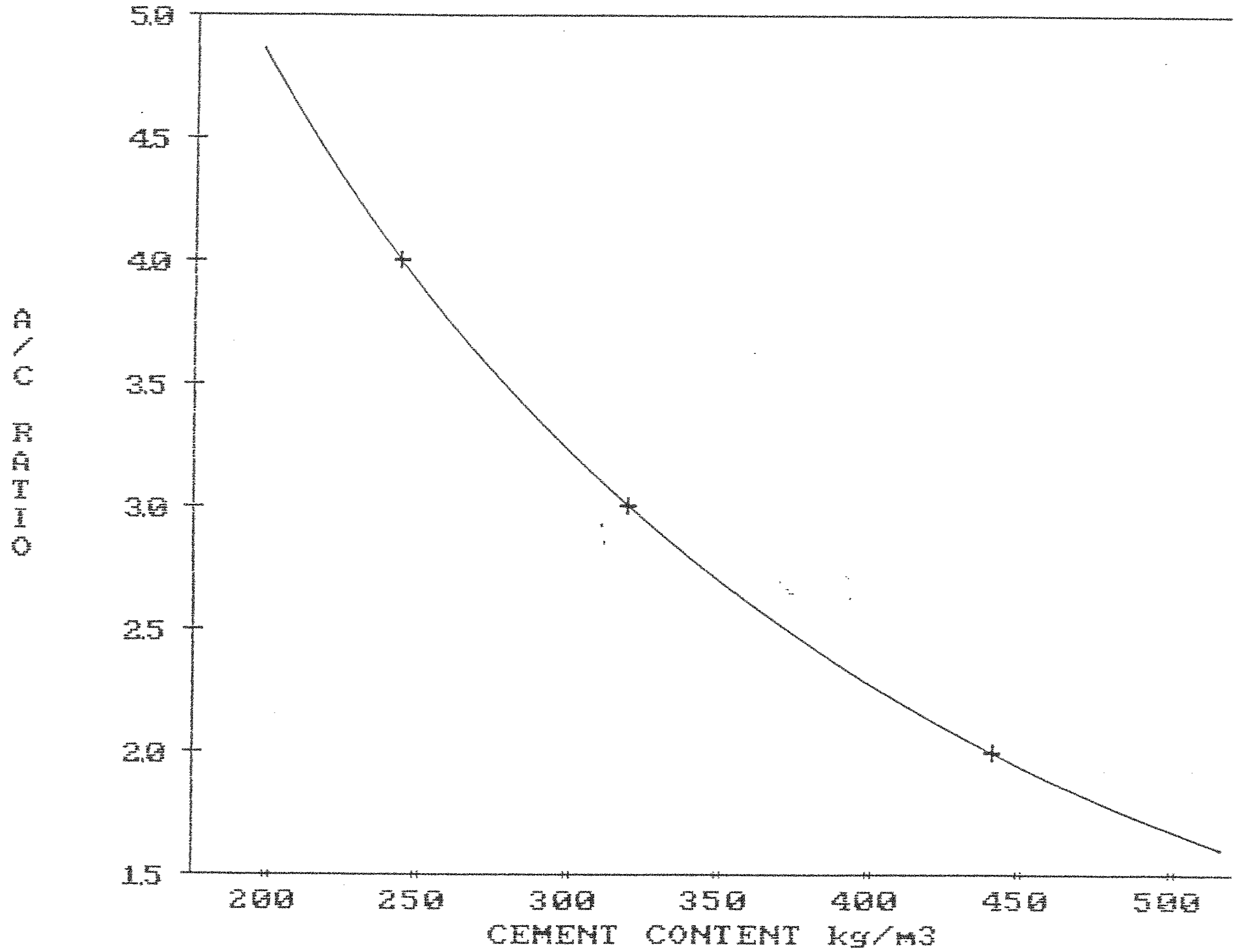
MATERIALS :

CEMENT	:	ORDINARY PORTLAND
FINE AGGREGATE	:	PUMICE, BESSER 8-0mm
COARSE AGGREGATE	:	PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	:	NONE
WORKABILITY RANGE	:	35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 1 FINES CONTENTS

RELATIONSHIP : AGGREGATE/CEMENT RATIO / UNIT CEMENT CONTENT



MATERIALS :

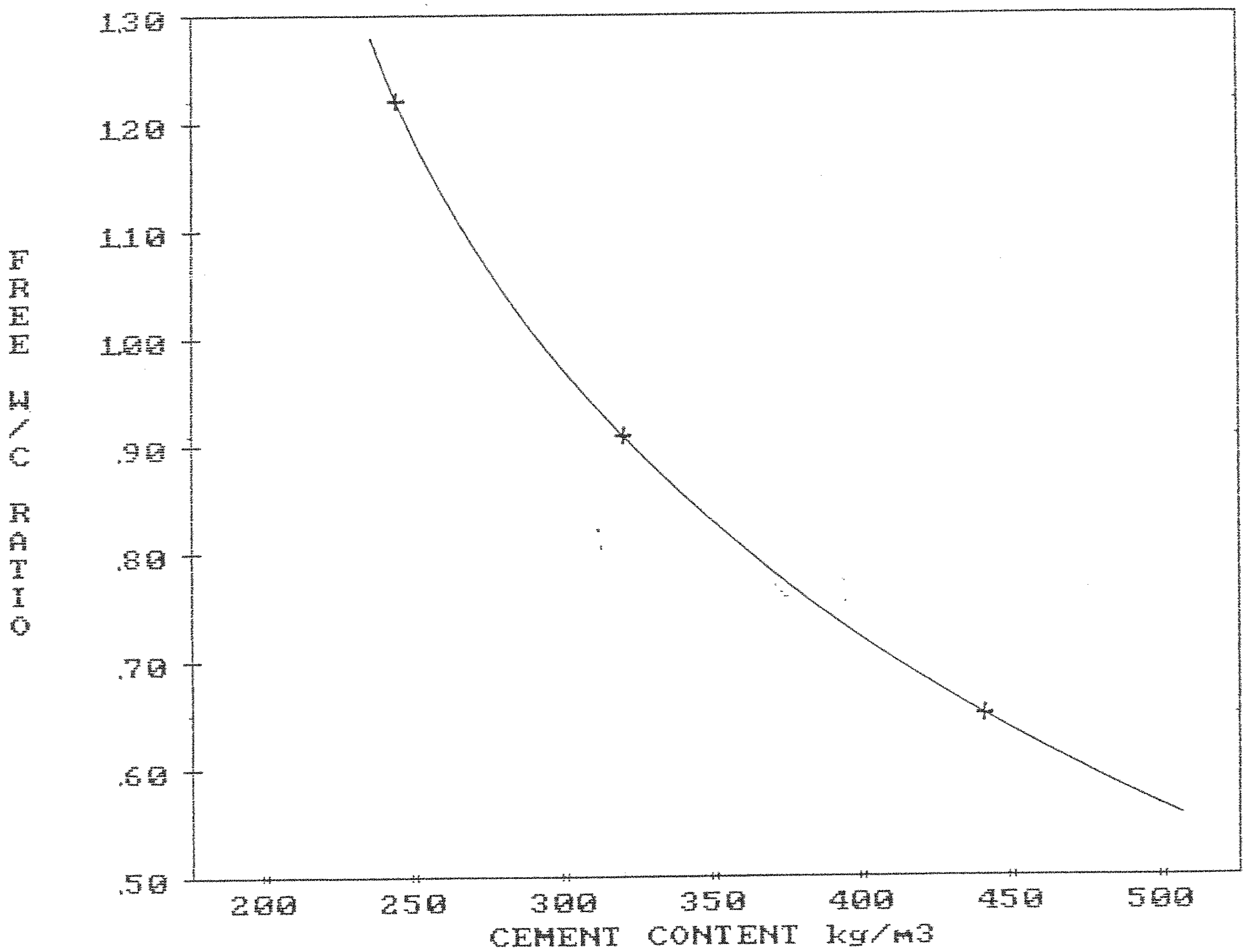
CEMENT : ORDINARY PORTLAND
FINE AGGREGATE : PUMICE, BESSER 8-0mm
COARSE AGGREGATE : PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE : NONE

WORKABILITY RANGE : 35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 1 FINES CONTENTS

RELATIONSHIP : FREE WATER/CEMENT RATIO / UNIT CEMENT CONTENT



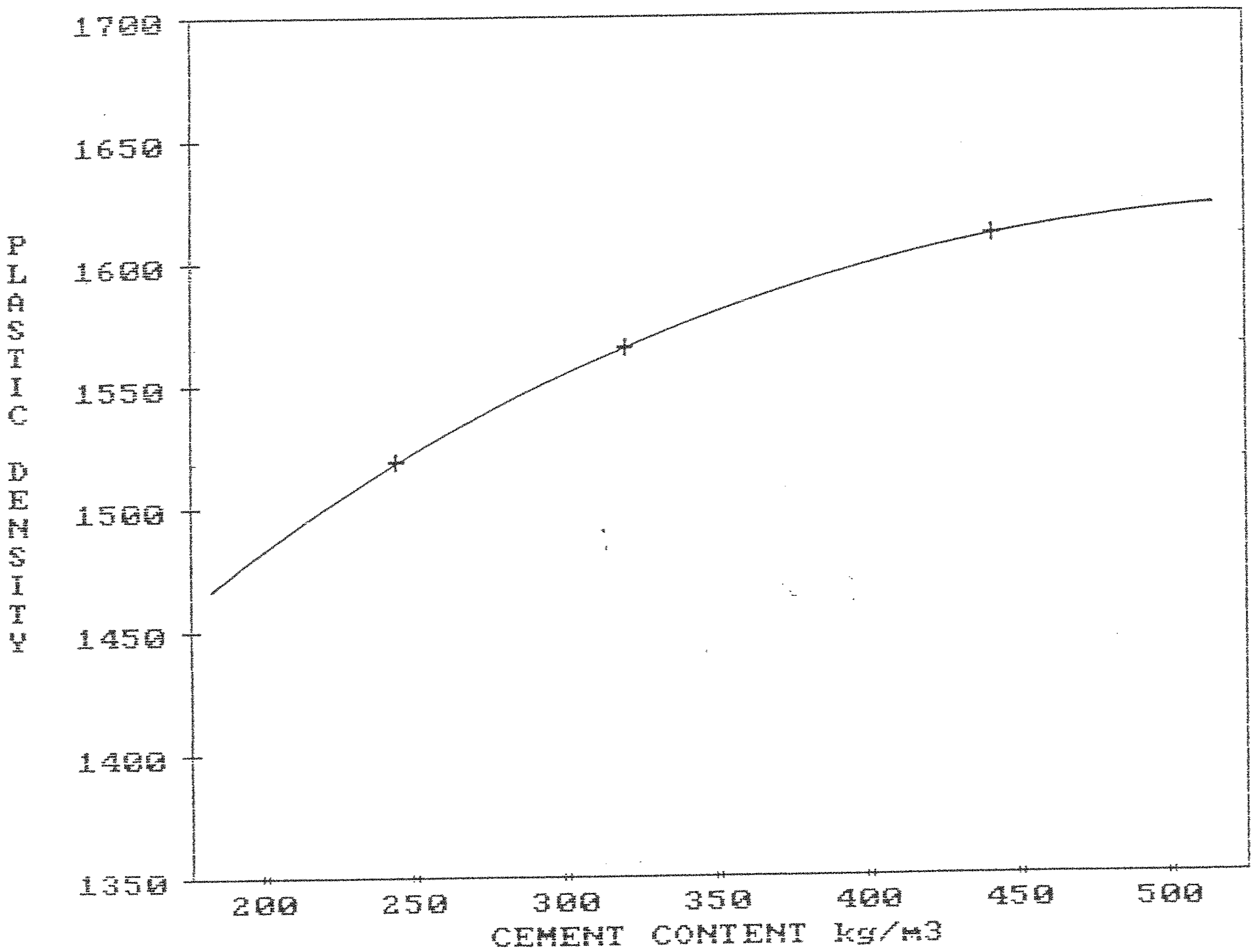
MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 1 FINES CONTENTS

RELATIONSHIP : PLASTIC DENSITY kg/m3 / UNIT CEMENT CONTENT



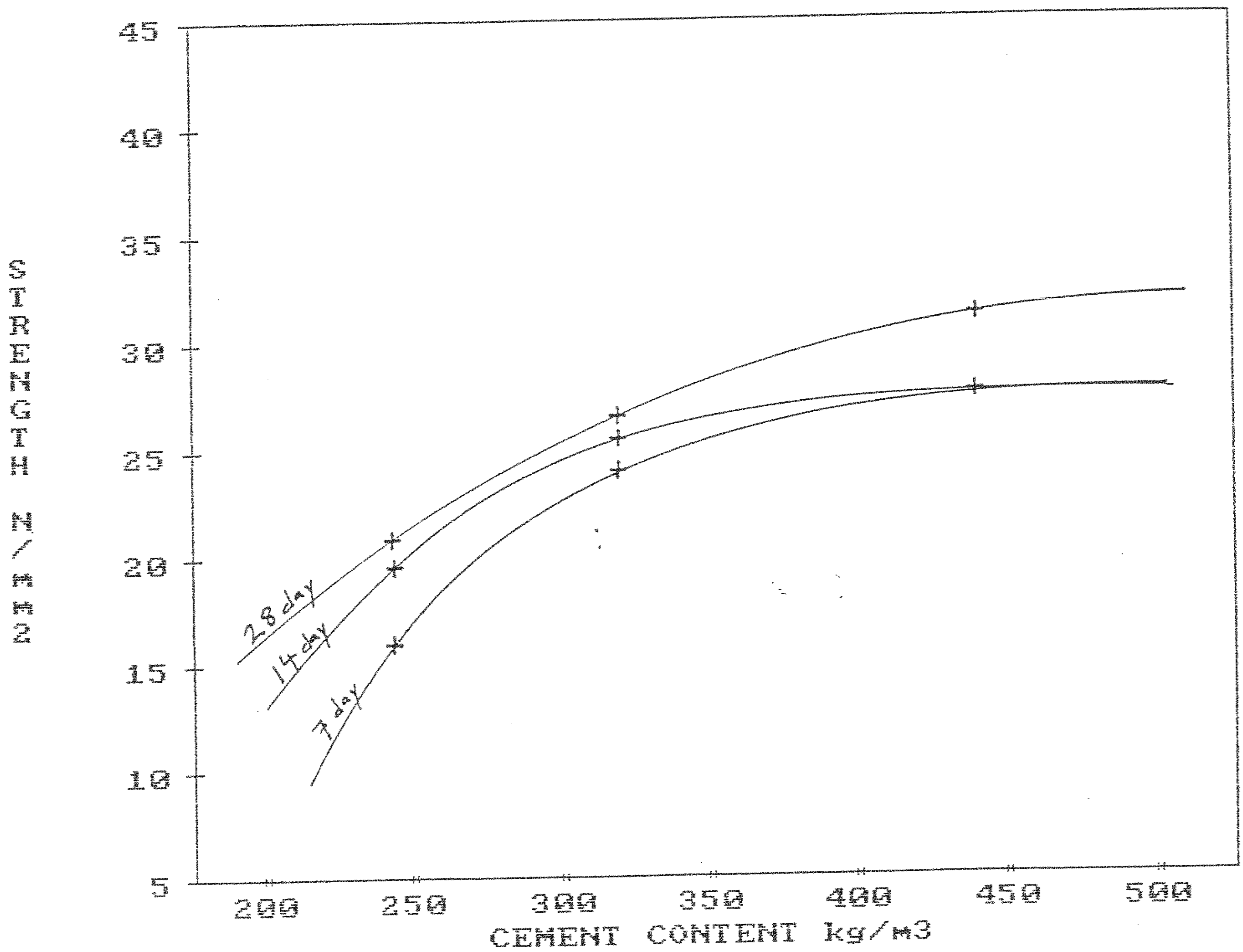
MATERIALS :

CEMENT	:	ORDINARY PORTLAND
FINE AGGREGATE	:	PUMICE, BESSER 8-0mm
COARSE AGGREGATE	:	PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	:	NONE

WORKABILITY RANGE : 35 - [illegible]0 mm SLUMP

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 1 FINES CONTENTS

RELATIONSHIP : COMPRESSIVE STRENGTH / UNIT CEMENT CONTENT



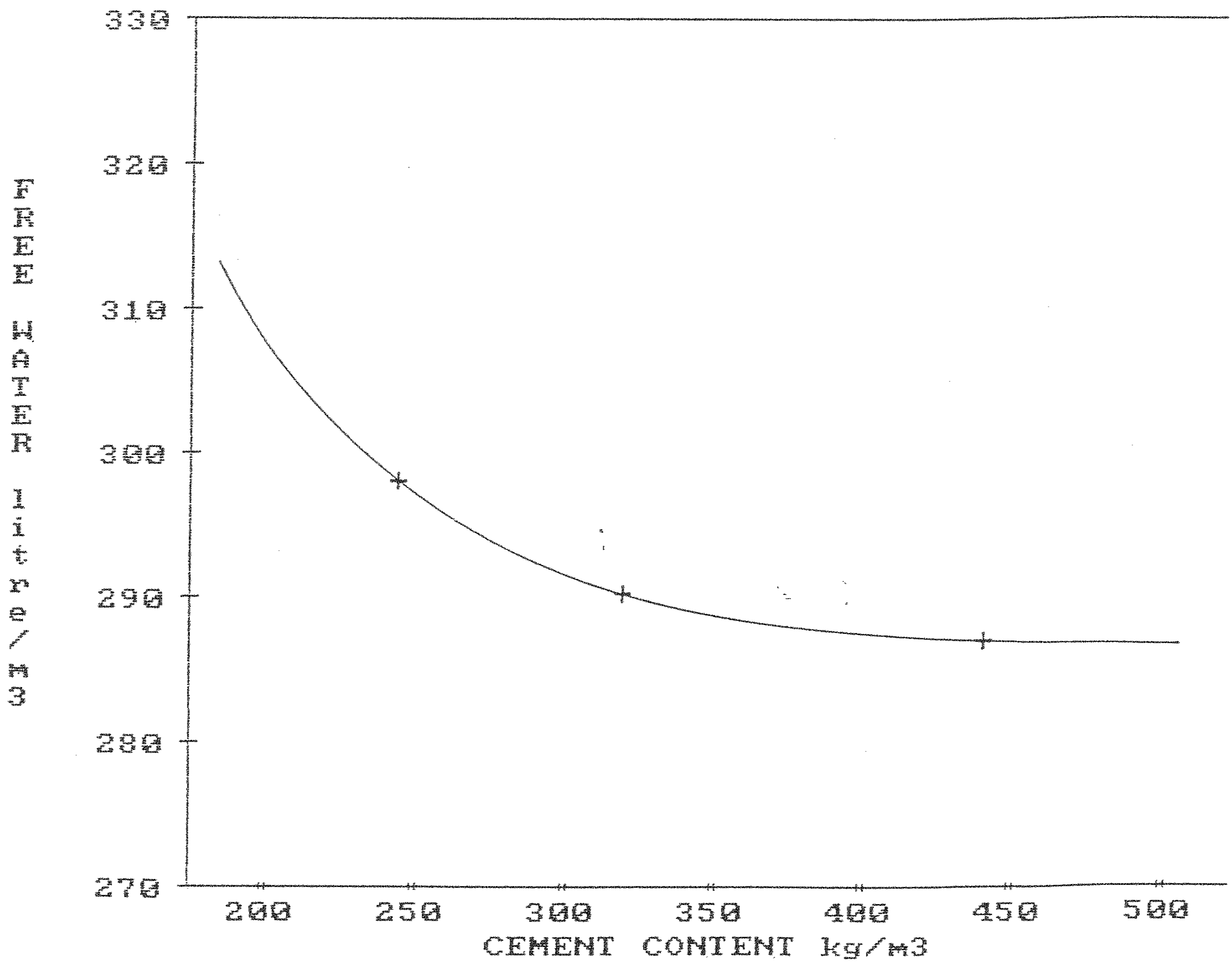
MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 1 FINES CONTENTS

RELATIONSHIP : FREE WATER CONTENT / UNIT CEMENT CONTENT



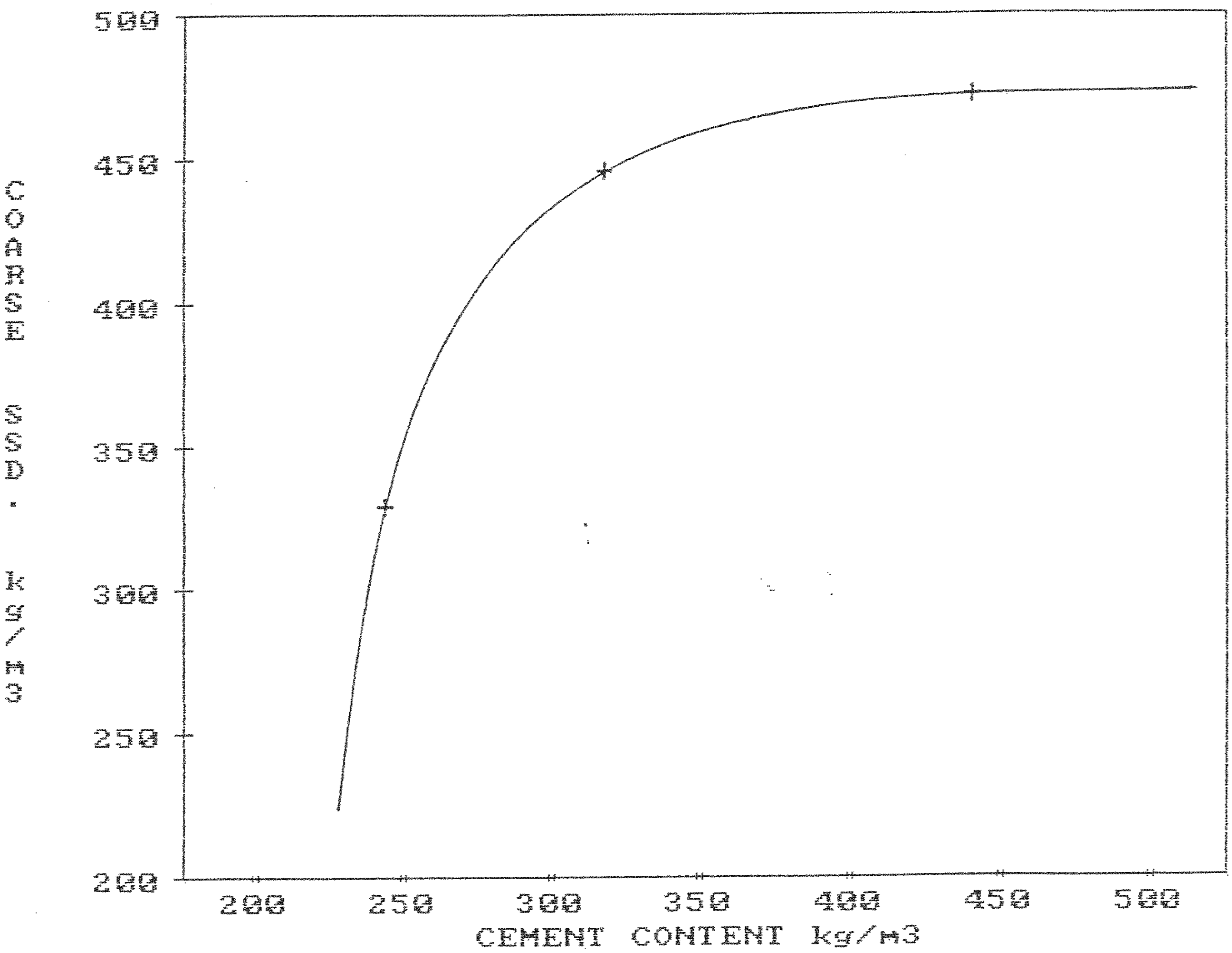
MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 1 FINES CONTENTS

RELATIONSHIP : UNIT COARSE AGGREGATE MASS / UNIT CEMENT CONTENT

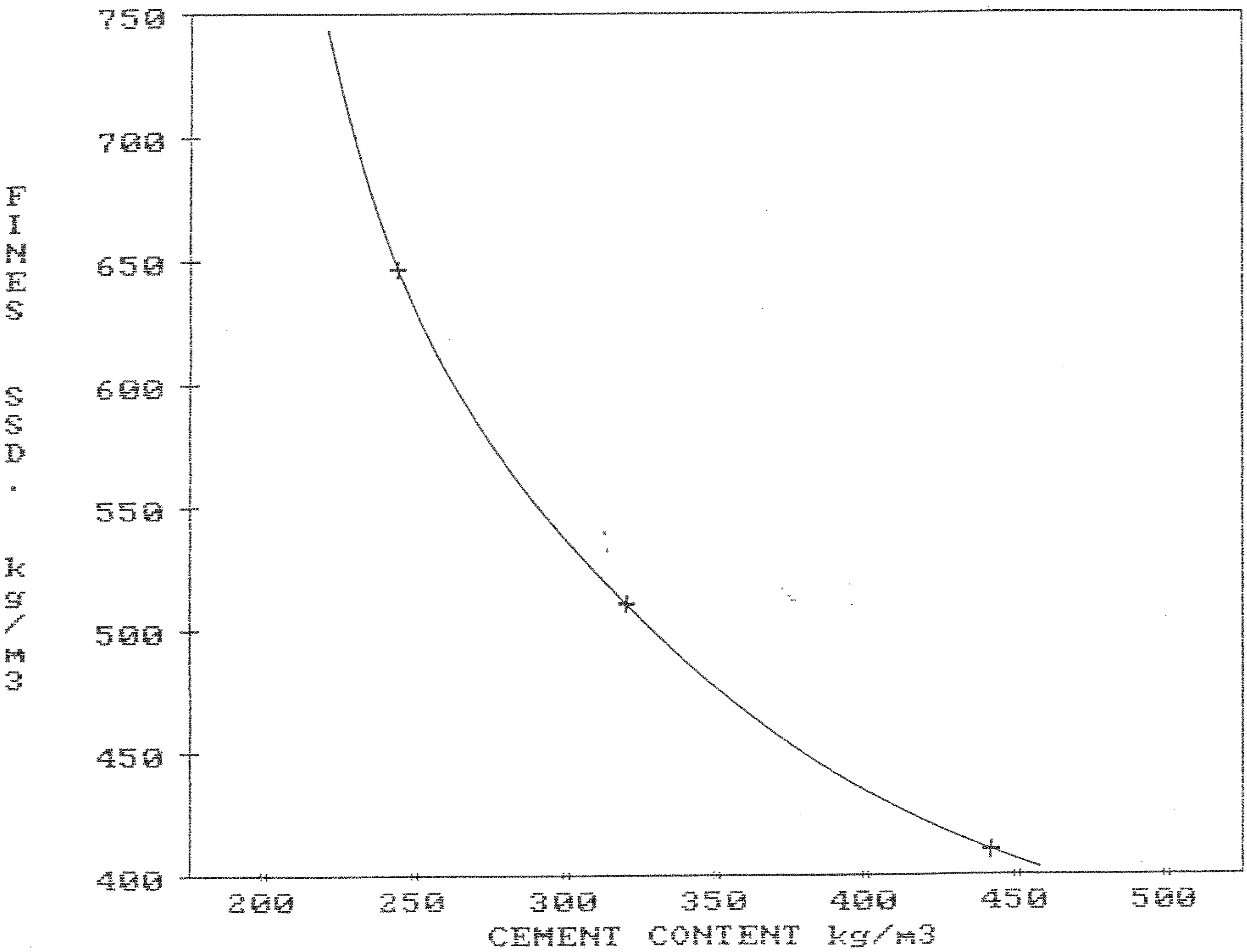


MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 1 FINES CONTENTS

RELATIONSHIP : UNIT FINE AGGREGATE MASS / UNIT CEMENT CONTENT



MATERIALS :

CEMENT	:	ORDINARY PORTLAND
FINE AGGREGATE	:	PUMICE, BESSER 8-0mm
COARSE AGGREGATE	:	PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	:	NONE

WORKABILITY RANGE : 35 - 50 mm SLUMP

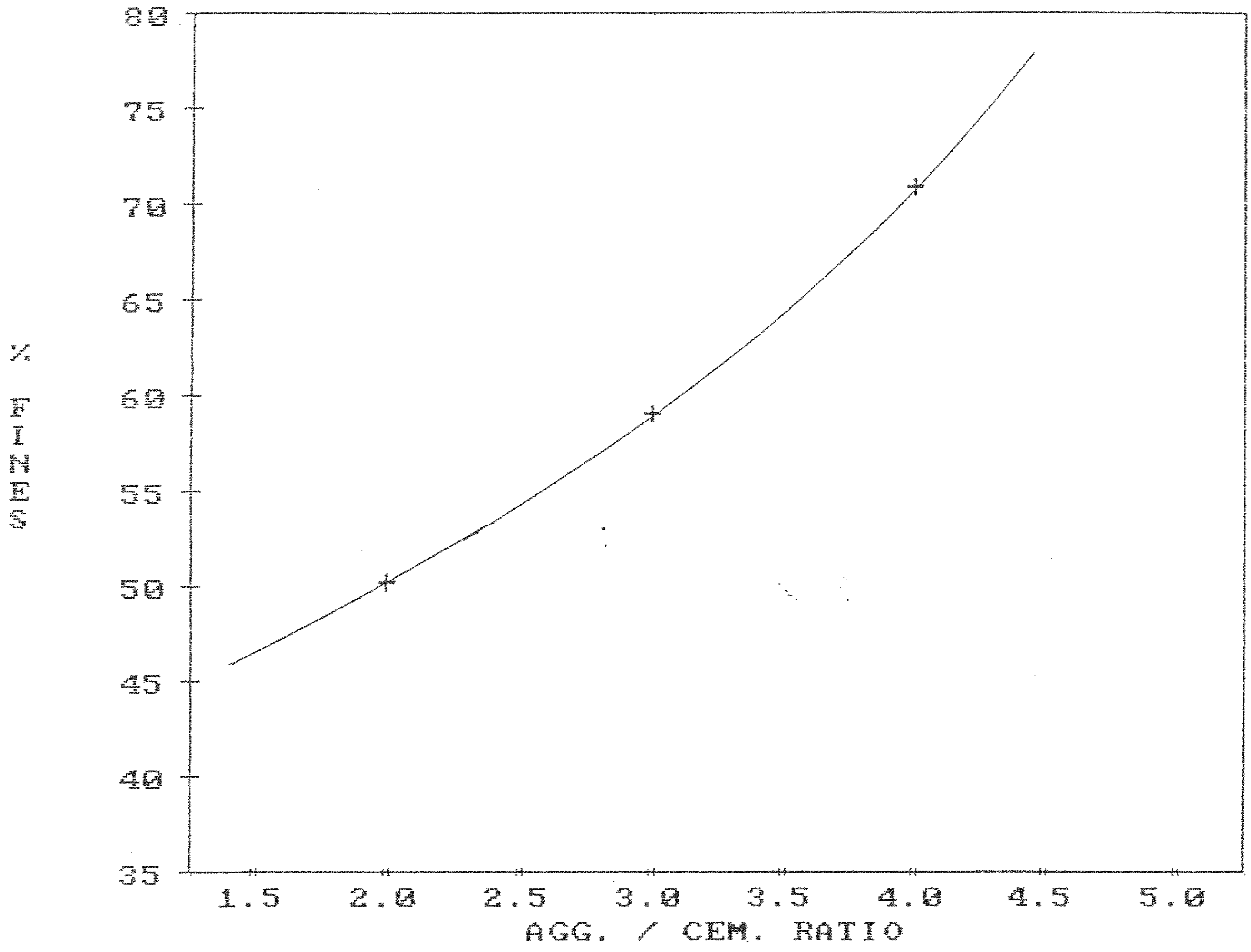
APPENDIX 5

MAIN RELATIONSHIPS

SERIES - 2 MIXES

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 2 FINES CONTENTS

RELATIONSHIP : % FINES / AGGREGATE CEMENT RATIO



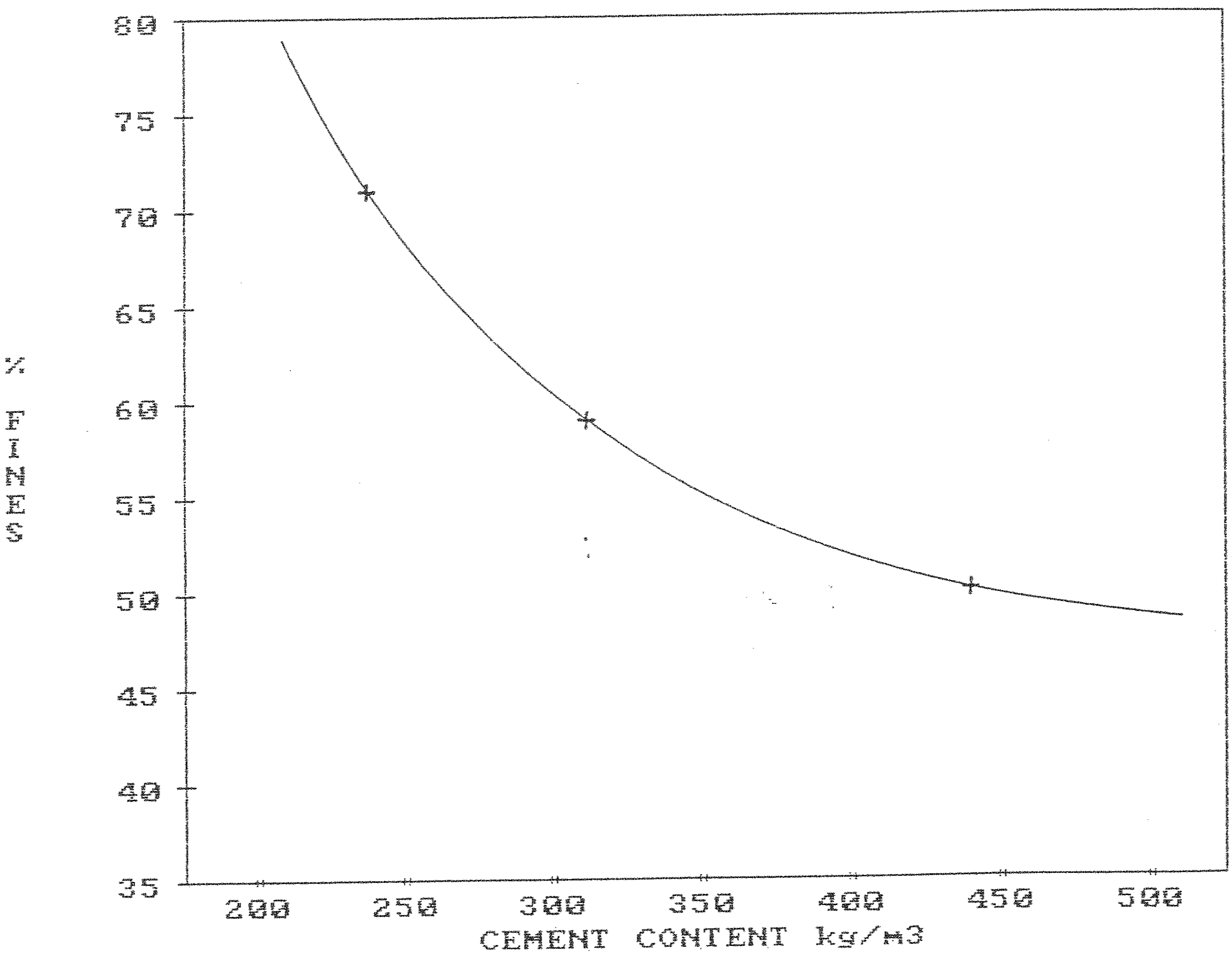
MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 2 FINES CONTENTS

RELATIONSHIP : % FINES / UNIT CEMENT CONTENT

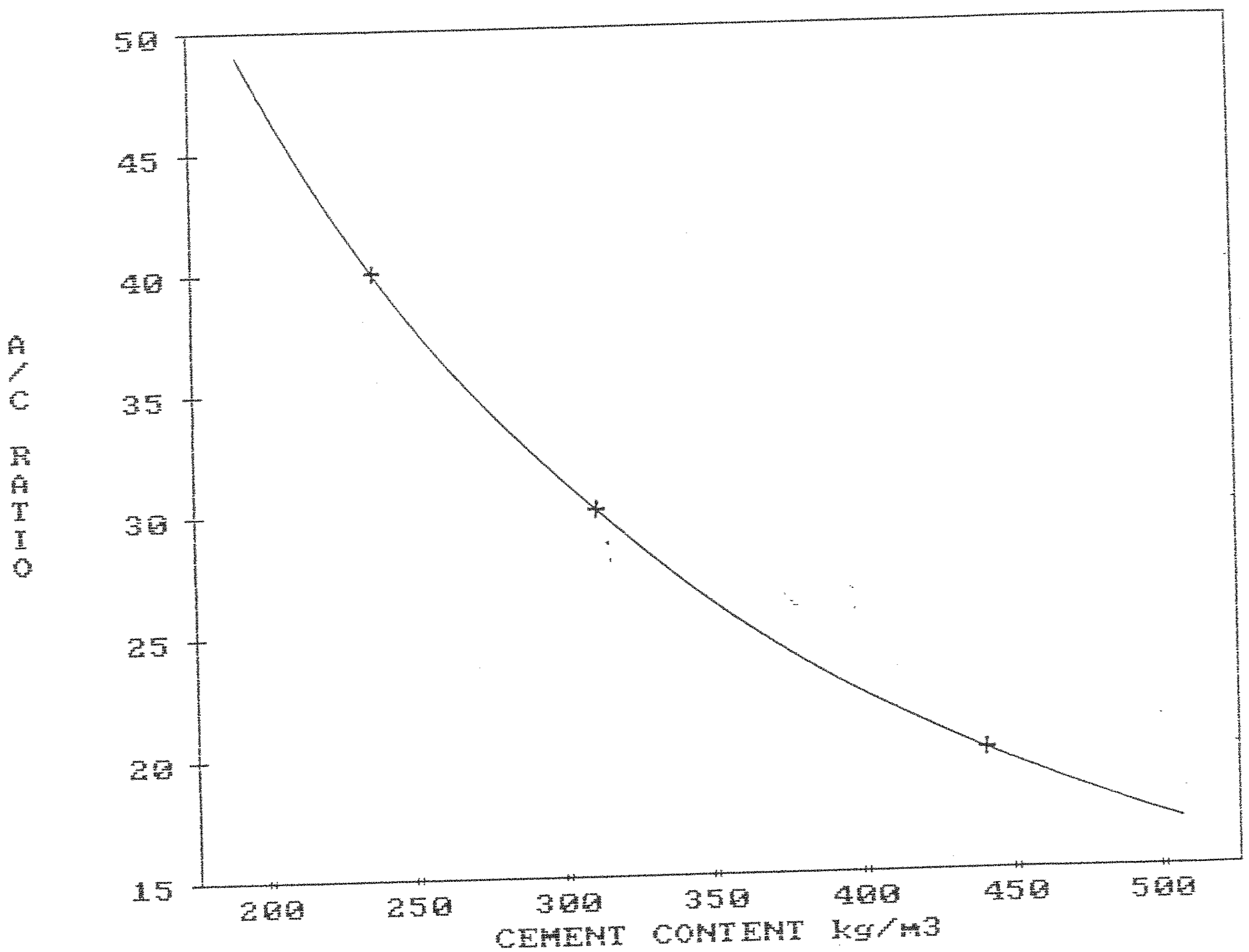


MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 2 FINES CONTENTS

RELATIONSHIP : AGGREGATE/CEMENT RATIO / UNIT CEMENT CONTENT



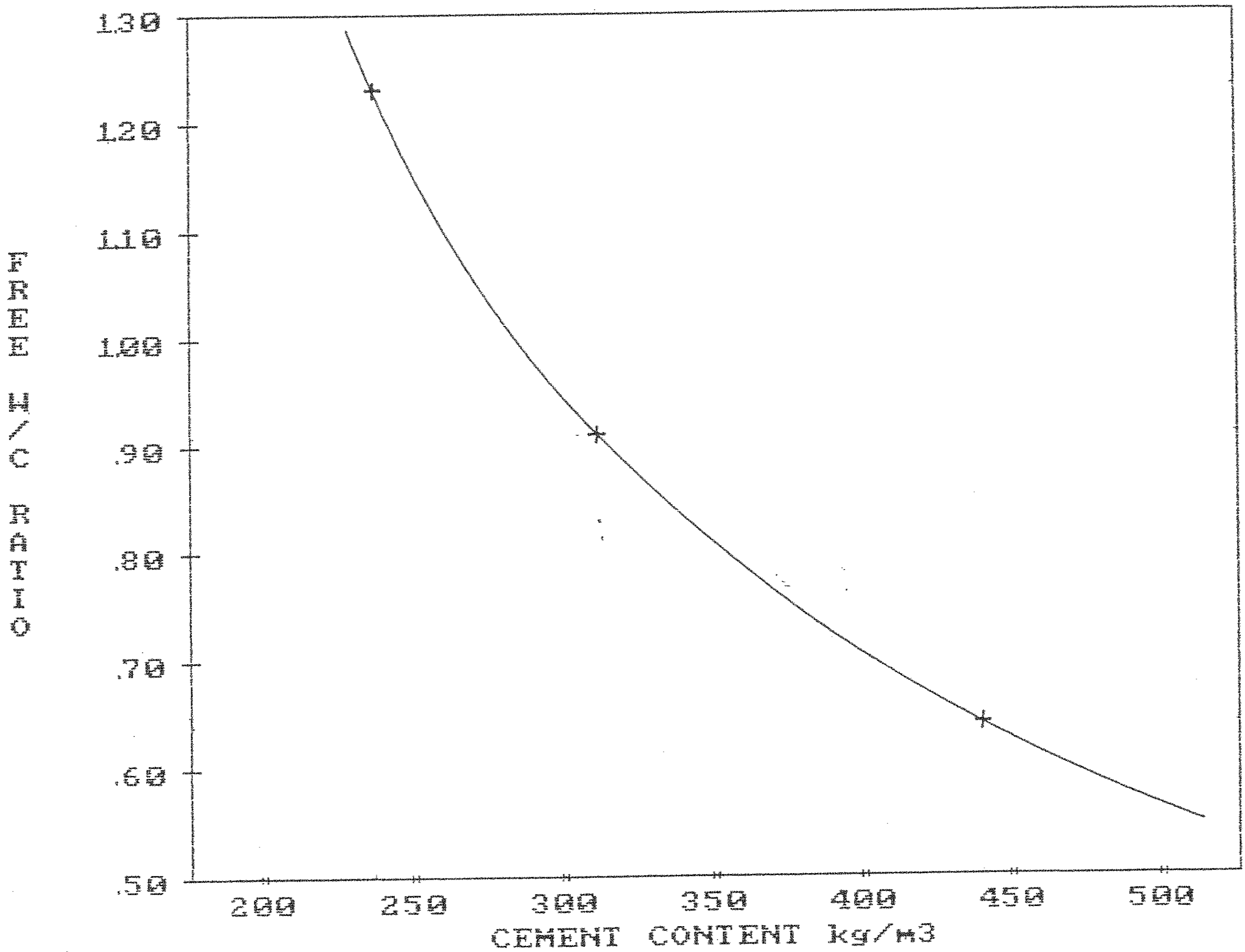
MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 2 FINES CONTENTS

RELATIONSHIP : FREE WATER/CEMENT RATIO / UNIT CEMENT CONTENT



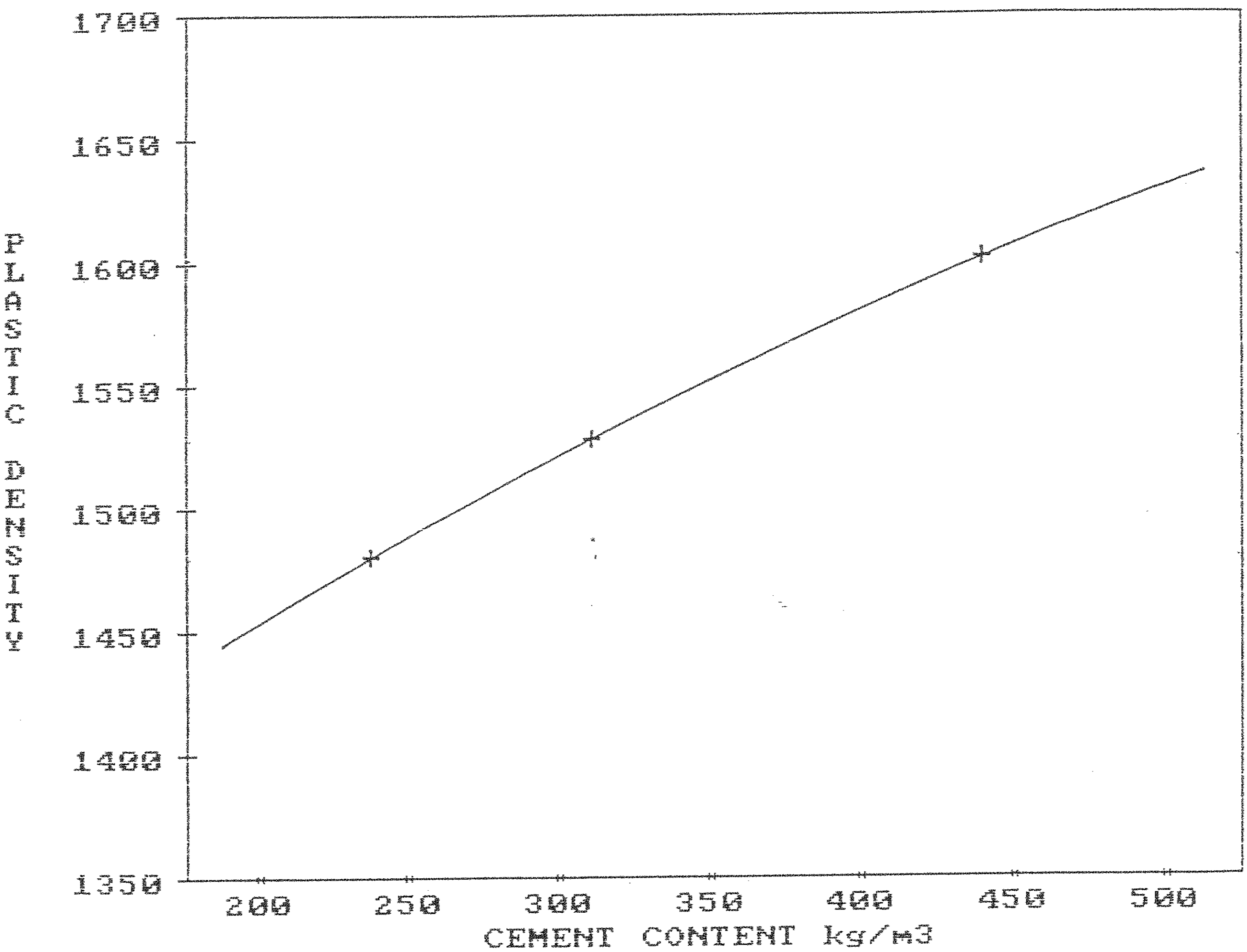
MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 2 FINES CONTENTS

RELATIONSHIP : PLASTIC DENSITY kg/m3 / UNIT CEMENT CONTENT

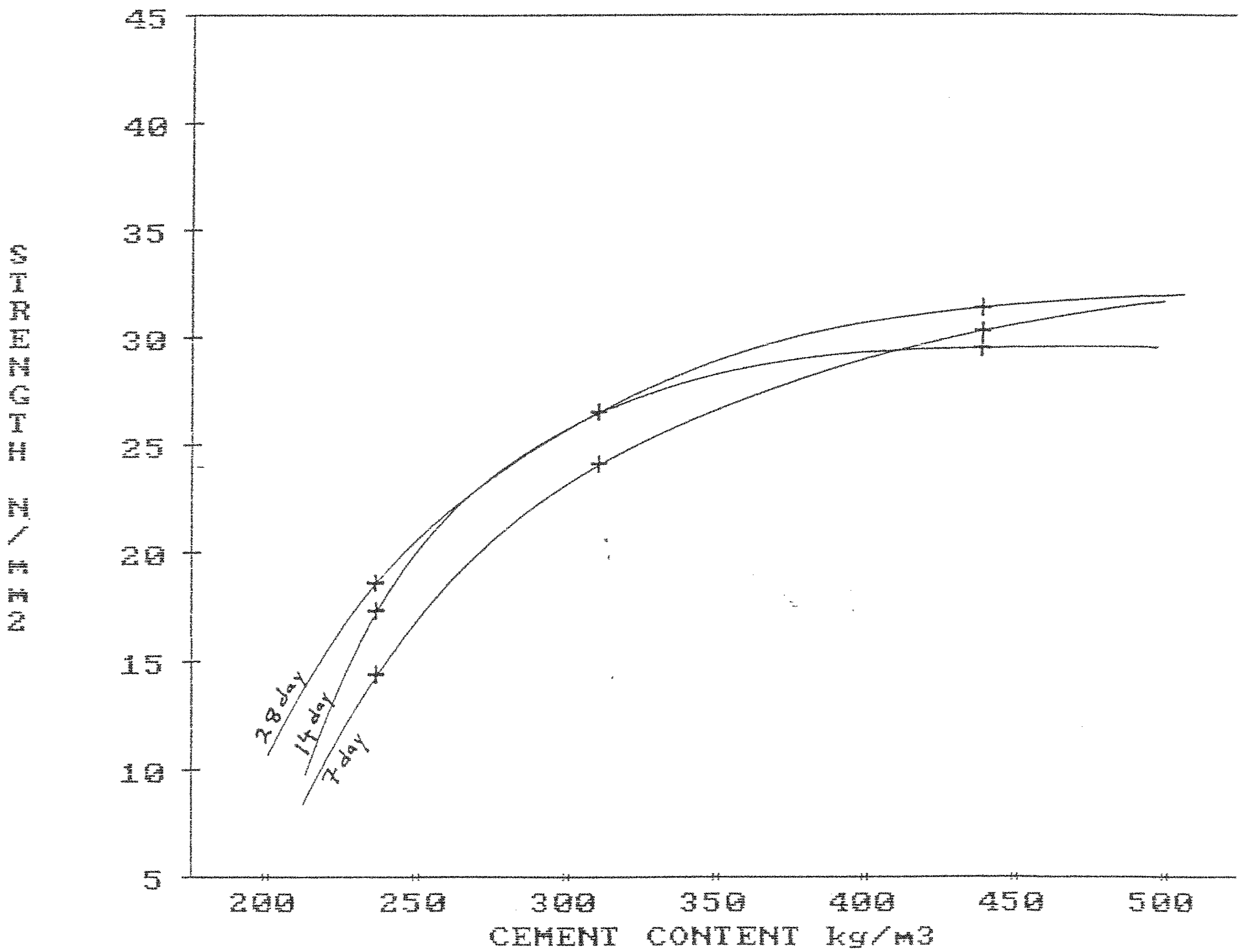


MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 2 FINES CONTENTS

RELATIONSHIP : COMPRESSIVE STRENGTH / UNIT CEMENT CONTENT



MATERIALS :

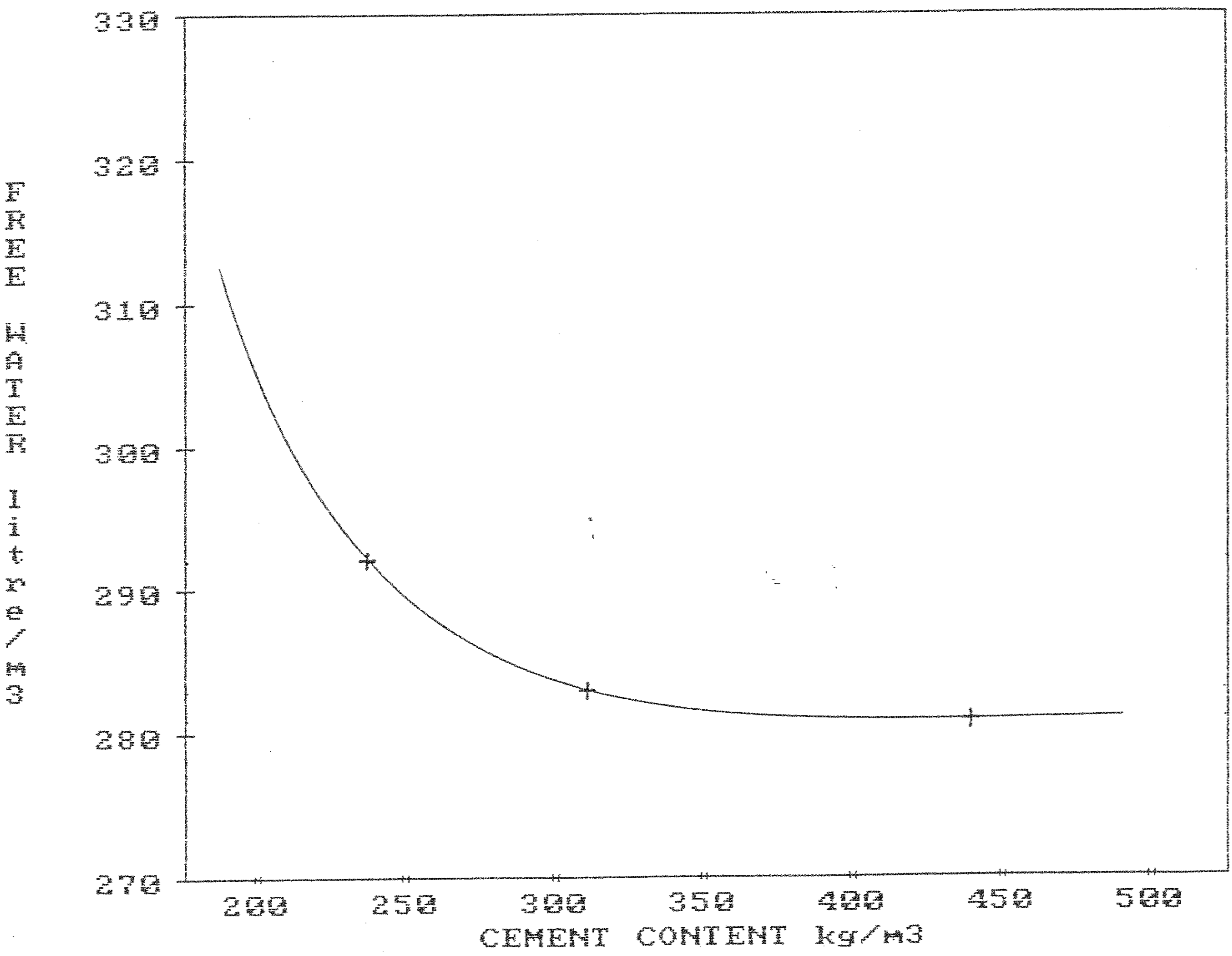
CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE

WORKABILITY RANGE : 35 - 50 mm SLUMP

89/3408E/3379

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 2 FINES CONTENTS

RELATIONSHIP : FREE WATER CONTENT / UNIT CEMENT CONTENT

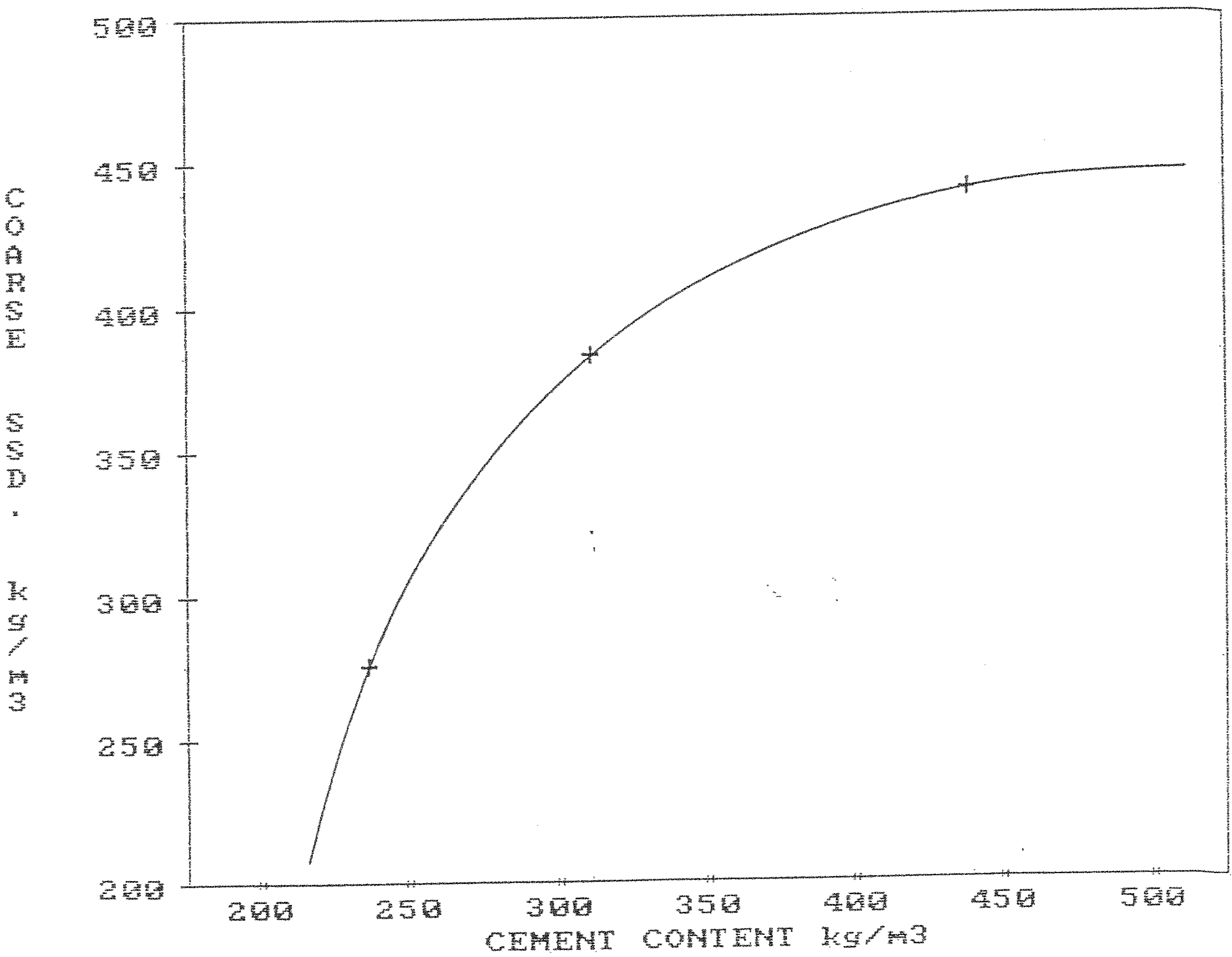


MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 2 FINES CONTENTS

RELATIONSHIP : UNIT COARSE AGGREGATE MASS / UNIT CEMENT CONTENT

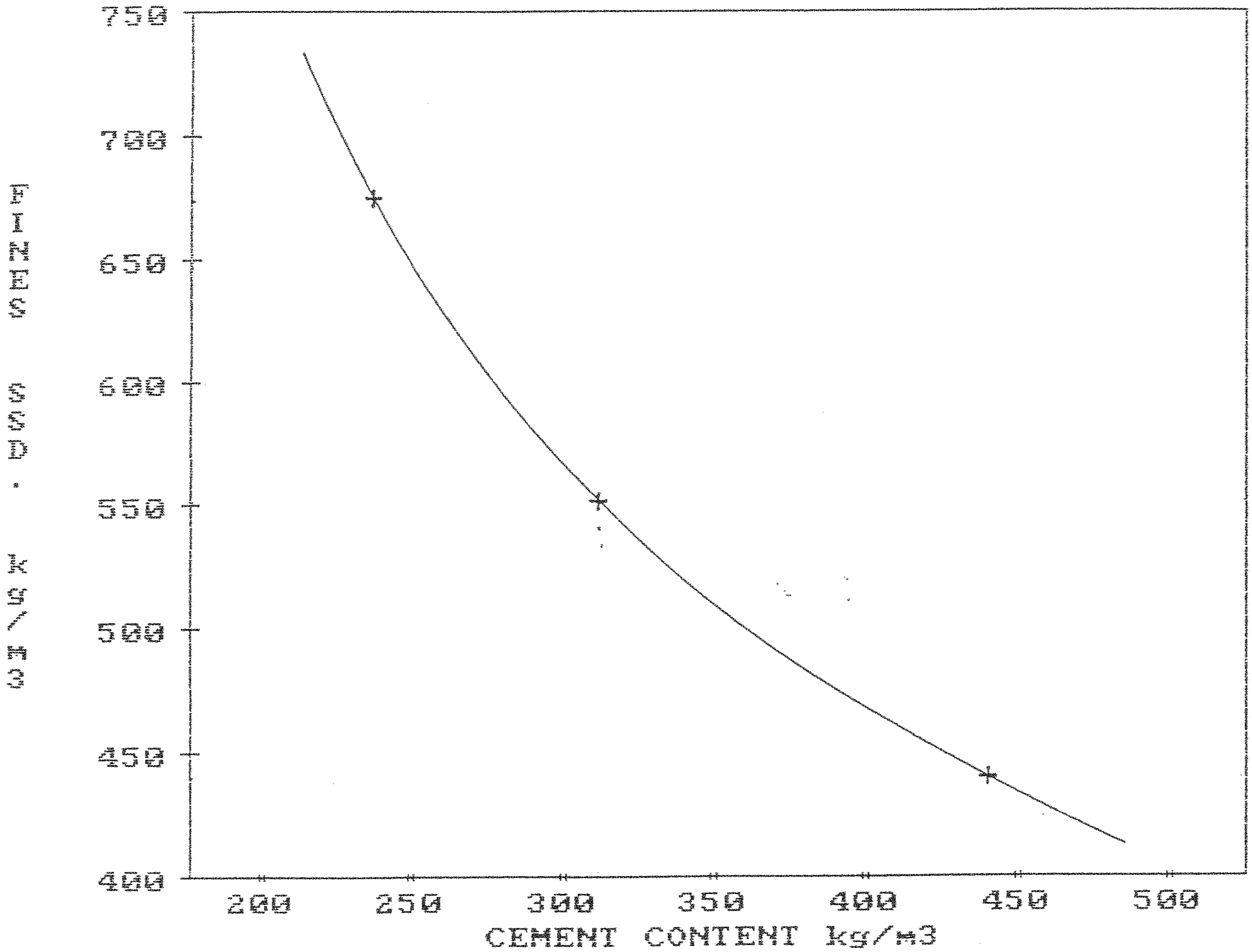


MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

LAVA PUMICE
STRUCTURAL CONCRETE MIX DESIGN
SERIES - 2 FINES CONTENTS

RELATIONSHIP : UNIT FINE AGGREGATE MASS / UNIT CEMENT CONTENT



MATERIALS :

CEMENT	: ORDINARY PORTLAND
FINE AGGREGATE	: PUMICE, BESSER 8-0mm
COARSE AGGREGATE	: PUMICE, GERMAN 18-0mm
ADMIXTURE / ADDITIVE	: NONE
WORKABILITY RANGE	: 35 - 50 mm SLUMP

PART TWO

PROPERTIES OF STRUCTURAL MIXES

3.0 PART TWO : PROPERTIES OF STRUCTURAL MIXES

3.1 Purpose of Assessment

Having carried out mix design trials to establish that structural grade concrete could be produced by pumice aggregates, the properties of such concretes were required.

As with the laboratory trials no admixtures other than pumice coarse and fine aggregates, BS 12 ordinary Portland cement and water were to be used for the manufacture of the concretes.

3.2 Test Specimens and Methods

Using the previously established relationships from the Series 2 laboratory trials, a set of test specimens were cast for each of 2/1, 3/1 and 4/1 aggregate/cement ratio mixes for laboratory testing, as follows:

TEST	METHOD	SPECIMEN
Compressive Strength and Density at 28 days	BS 1881: Parts 108, 111 and 114: 1983	3 no. 150mm cubes
Static Modulus of Elasticity	BS 1881: Part 121: 1983	1 no. 150x300mm cylinder
Drying Shrinkage and Wetting Expansion	BS 1881: Part 5 : 1970	4 no. 50x50x200mm prisms
Water Absorption (at 1/2 hour and thereafter at intermittent times to 17 days)	BS 340: 1979	2 no. 100mm cubes
Oven Dry Density cubes	BS 1881: Part 114: 1983	Water absorption cubes prior to water absorption test
Saturated Density cubes	BS 1881: Part 114: 1983	Water absorption after 17 days immersion
Saturated Coefficient of Thermal Expansion	R.D. Browne, Concrete, Nov. 1972, p51-53	1 no. 150x300mm of cylinder
Accelerated Depth of Carbonation	50% RH, 20°C, 4% CO_2 for 20 weeks after 2 weeks at 50% RH, 20°C at normal atmospheric CO_2; all specimens between 28 and 42 days old and moist cured prior to testing. Work carried out at Department of Civil Engineering University of Dundee.	12 no. 100mm cubes

3.3 Test Results

The results for all the tests are given in Tables 1, 2 and 3. Relationships between the various parameters and properties are given in Appendix 6.

3.4 Discussion and Conclusions

As expected various physical and mechanical test properties vary with aggregate:cement ratio or cement content. Properties which increase in value, indicating increasing quality with lower A/C ratios (high cement contents) are compressive strength, modulus of elasticity and density. Properties which decrease in value, indicating increasing quality, with lower A/C ratios are water absorption and accelerated carbonation. In all the above cases lowering the A/C ratio (higher cement content) increases quality.

Properties which do not show a straight forward relationship with A/C ratio are drying shrinkage wetting expansion and thermal expansion. The moisture movement values are much as expected for the high cement content (2/1 A/C ratio) mix having the highest value; however, the values for the 3/1 and 4/1 mixes are similar. The thermal expansion results do not follow any trend.

For the tests carried out at A/C ratios of 2/1, 3/1 and 4/1 (cement contents of 440, 320 and 245kg/m^3) the range of results is as follows:

compressive strength	19.0-31.5N/mm^2
saturated density	1570-1670kg/m^3
oven dry density	1240-1370kg/m^3
static modulus of elasticity	9,810-12,500N/mm^2
drying shrinkage	0.030-0.040%
wetting expansion	0.025-0.035%
water absorption	
at ½ hour	6.4-7.7%
at 17 days	17.3-19.0%
coefficient of thermal expansion	5.8-7.5 x10^{-6}/^{0}C
accelerated depth of carbonation	
at 20 weeks	39-50mm
estimated thermal conductivity (based on oven dry density)	0.40-0.49W/mK

89/3408E/3379

TABLE 1. SUMMARY OF RESULTS

MIX PROPORTION	2/1		
CEMENT CONTENT (kg/m^3)	440		
FINES CONTENT (%)	50		
COMPRESSIVE STRENGTH (N/mm^2) AT 28 DAYS	31.0/32.0/31.0		
mean	31.5		
SATURATED DENSITY (kg/m^3) AT 28 DAYS	1650/1660/1660		
mean	1660		
STATIC MODULUS OF ELASTICITY (N/mm^2)	12,500		
at COMPRESSIVE STRENGTH (N/mm^2)	31.0		
DRYING SHRINKAGE (%)	0.040/0.039/0.038		
mean	0.039		
to nearest 0.005	0.040		
WETTING EXPANSION (%)	0.036/0.035/0.037		
mean	0.036		
to nearest 0.005	0.035		
WATER ABSORPTION (%)	1.	2.	Mean
at ½ hour	6.2	6.8	6.5
3 hour	10.9	11.4	11.2
6 hour	12.1	12.4	12.3
24 hour	13.0	13.2	13.1
2 day	13.2	13.3	13.3
3 day	13.4	13.5	13.5
17 day	14.2	14.4	14.3
OVEN DRY DENSITY (kg/m^3) (before water immersion)	1370	1360	1370
SATURATED DENSITY (kg/m^3) (after 17 days immersion)	1670	1670	1670
COEFFICIENT OF THERMAL EXPANSION (SATURATED)/^0C	$7.1x10^{-6}$		
ACCELERATED DEPTH OF CARBONATION (mm)	1.	2.	Mean
carbonation period - 2½ weeks	10	12	11
5 weeks	12	13	12
7½ weeks	19	20	19
10 weeks	23	25	24
15 weeks	32	33	32
20 weeks	38	40	39
ESTIMATED THERMAL CONDUCTIVITY based on oven dried density and 3% moisture by volume (from CIBS Guide A3, 1980)	0.49 W/mK		

TABLE 2. SUMMARY OF RESULTS

MIX PROPORTION	3/1		
CEMENT CONTENT (kg/m^3)	320		
FINES CONTENT (%)	59		
COMPRESSIVE STRENGTH (N/mm^2) AT 28 DAYS	25.0/23.0/23.0		
mean	23.5		
SATURATED DENSITY (kg/m^3) AT 28 DAYS	1600/1610/1610		
mean	1610		
STATIC MODULUS OF ELASTICITY (N/mm^2)	11,070		
at COMPRESSIVE STRENGTH (N/mm^2)	18.5		
DRYING SHRINKAGE (%)	0.027/0.029/0.028		
mean	0.028		
to nearest 0.005	0.030		
WETTING EXPANSION (%)	0.024/0.025/0.025		
mean	0.025		
to nearest 0.005	0.025		
WATER ABSORPTION (%)	1.	2.	Mean
at ½ hour	6.3	6.5	6.4
3 hour	11.8	11.5	11.7
6 hour	13.4	13.0	13.2
24 hour	14.4	13.8	14.1
2 day	14.5	14.0	14.3
3 day	14.7	14.3	14.5
17 day	15.8	15.4	15.6
OVEN DRY DENSITY (kg/m^3) (before water immersion)	1330	1320	1330
SATURATED DENSITY (kg/m^3) (after 17 days immersion)	1630	1630	1630
COEFFICIENT OF THERMAL EXPANSION (SATURATED)/^0C	5.8×10^{-6}		
ACCELERATED DEPTH OF CARBONATION (mm)	1.	2.	Mean
carbonation period - 2½ weeks	12	14	13
5 weeks	15	20	17
7½ weeks	20	24	22
10 weeks	30	32	31
15 weeks	36	40	38
20 weeks	43	44	44
ESTIMATED THERMAL CONDUCTIVITY based on oven dried density and 3% moisture by volume (from CIBS Guide A3, 1980)	0.46 W/mK		

TABLE 3. SUMMARY OF RESULTS

MIX PROPORTION	4/1		
CEMENT CONTENT (kg/m^3)	245		
FINES CONTENT (%)	71		
COMPRESSIVE STRENGTH (N/mm^2)	19.5/18.0/19.5		
AT 28 DAYS mean	19.0		
SATURATED DENSITY (kg/m^3)	1580/1560/1580		
AT 28 DAYS mean	1570		
STATIC MODULUS OF ELASTICITY (N/mm^2)	9,810		
at COMPRESSIVE STRENGTH (N/mm^2)	19.0		
DRYING SHRINKAGE (%)	0.032/0.026/0.030		
mean	0.029		
to nearest 0.005	0.030		
WETTING EXPANSION (%)	0.029/0.026/0.025		
mean	0.027		
to nearest 0.005	0.025		
WATER ABSORPTION (%)	1.	2.	Mean
at ½ hour	7.4	8.0	7.7
3 hour	14.1	14.7	14.4
6 hour	16.5	16.7	16.6
24 hour	17.6	17.5	17.6
2 day	17.7	17.6	17.7
3 day	17.9	17.9	17.9
17 day	19.0	18.9	19.0
OVEN DRY DENSITY (kg/m^3) (before water immersion)	1260	1210	1240
SATURATED DENSITY (kg/m^3) (after 17 days immersion)	1610	1560	1590
COEFFICIENT OF THERMAL EXPANSION (SATURATED)/^{0}C	7.5×10^{-6}		
ACCELERATED DEPTH OF CARBONATION (mm)	1.	2.	Mean
carbonation period - 2½ weeks	17	22	20
5 weeks	25	25	25
7½ weeks	31	33	32
10 weeks	38	40	39
15 weeks	40	46	43
20 weeks	--complete (50+)--		
ESTIMATED THERMAL CONDUCTIVITY based on oven dried density and 3% moisture by volume (from CIBS Guide A3, 1980)	0.40 W/mK		

(from CIBS Guide A3, 1980)

RILEM classifies lightweight aggregate concrete into three types, I Structural, II Structural and insulating and III Insulating, based on density, compressive strength and thermal conductivity, as follows:-

RILEM functional classification of lightweight aggregate concrete

Class	I	II	III
Type of lightweight concrete	Structural	Structural and insulating	Insulating
Oven-dry density (kg/m^3)	<2000	not specified	not specified
Compressive strength (N/mm^2)	>15.0	>3.5	>0.5
Coefficient of thermal conductivity (W/m.k)	--	<0.75	<0.30

For the range of structural mixes examined, the pumice aggregate concrete can comply with type I Structural and type II Structural and Insulating. For type III Insulating mixes, higher A/C ratios will be required in the region of 15/1 or higher (see STATS Report on Concrete Mix Design for Lightweight Masonry Units, May 1990).

As outlined in section 2.4, a ceiling strength in the 30-35 N/mm^2 range applies for mixes in excess of $400kg/m^3$ cement content. Both the 2/1 and 3/1 A/C ratio (440 and $320kg/m^3$ cement content mixes) record strengths in excess of $20N/mm^2$ which is the lowest allowable under BS 8110 : Part 2 : 1985 for reinforced lightweight aggregate concrete, however, figures in the region of $340kg/m^3$ minimum cement content (maximum A/C ratio of 2.8/1) would be more likely to consistently achieve a grade 20 supply.

The static modulus of elasticity for the mixes examined is some 45% of that for equivalent normal weight concretes. BS 8110 : Part 2 : 1985, Section 7.2 gives values for normal weight concrete static modulus of elasticity and a conversion formula for lightweight concrete based on density. A comparison of the predicted values and actual values is very close using the measured saturated density values, as indicated below.

strength grade	28 day static modulus of elasticity ($N/mm^3 \times 10^3$) normal weight	lightweight*	actualØ
20	24	10.7	10.0
25	25	11.7	11.3
30	26	12.4	12.3

* from formula - normal weight static modulus x $(W/2400)^2$
where W = density (BS 8110 : Part 2 : 1985, Section 7)

Ø interpolated from graph of recorded values

Moisture movement is low at 0.030 to 0.040% drying shrinkage and 0.025 to 0.035% wetting expansion; the wetting expansion is some 85% of the drying shrinkage. These values are lower than stated in the technical literature on lightweight concrete (e.g. Neville 1981).

Coefficients of thermal expansion at circa 6 to 7 x $10^{-6}/^{0}C$ are lower than those published by Neville 1981 (9.4 to 10.8 x $10^{-6}/^{0}C$) although they are at the lower end of the range for lightweight concrete given by the Institute of Structural Engineers/Concrete Society 1987 at between 7 and 9 x $10^{-6}/^{0}C$. Normal weight concretes typically have values of 12 to 13 x $10^{-6}/^{0}C$.

For the mixes examined, dry densities vary between 1240 and 1370kg/m^3. Using the relationship between oven dry density and thermal conductivity given in the CIBS Guide A3, 1980, the range in thermal conductivities would be 0.40 to 0.49W/mK. This enables the structural pumice concrete to comply with RILEM Class II Structural and Insulating.

Water absorption values, as for all lightweight concretes, are high with greater values recorded for lower cement contents (increased A/C ratios). As with normal weight concretes, the pumice aggregate concrete increases in weight rapidly by capillary absorptivity and therafter increases only slowly. This change in water uptake is very apparent from the water absorption v. root of time relationship (figure 15). The interpolated changes in shape (nick points) for the 3 No. mixes all occur at circa 3½ hours after immersion. However, moisture uptake at this time is different for the 3 No. mixes, increasing with increasing A/C ratio, as follows:- 2/1 - 12.9%, 3/1 - 13.9% and 4/1 - 17.3%.

The accelerated carbonation results indicated an almost linear relationship with root time after the initial 2½ weeks. As expected the higher cement content mixes performed better with lower depths of carbonation than the lower cement mixes. As the accelerated testing is innovative for lightweight aggregate concrete there is, as yet, no correlation between it and real time carbonation.

Bond to any embedded reinforcement will be typical of that developed in lightweight aggregate concrete. High cement content mixes with relatively strong lightweight aggregates will have a bond behaviour similar to normal weight concrete but lower cement content mixes especially with relatively weak lightweight aggregates will have reduced bond behaviour. High water content mixes due to lightweight fines may be subject to settlement and bleeding with resultant air voids below horizontal steel which will reduce bond strength.

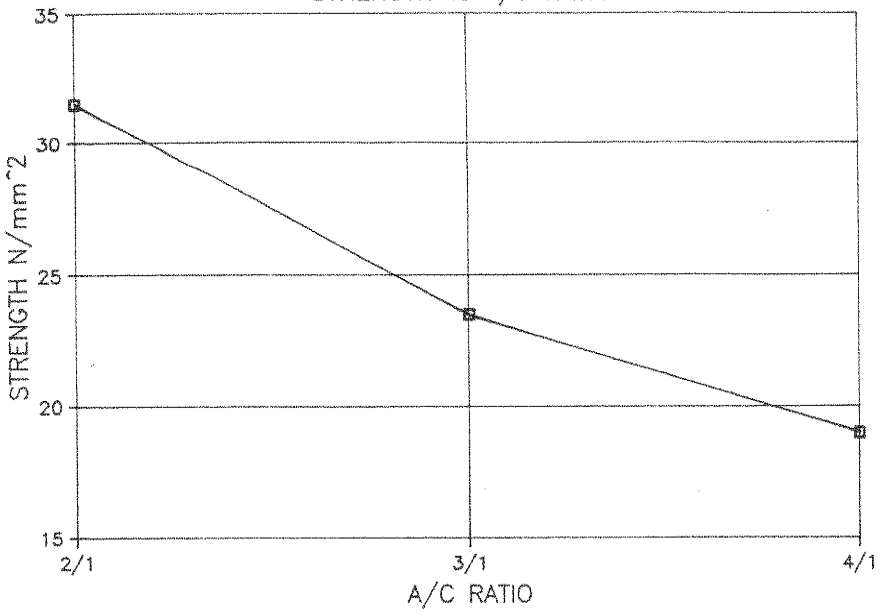
APPENDIX 6

MAIN RELATIONSHIPS

FIGURES 1 TO 16

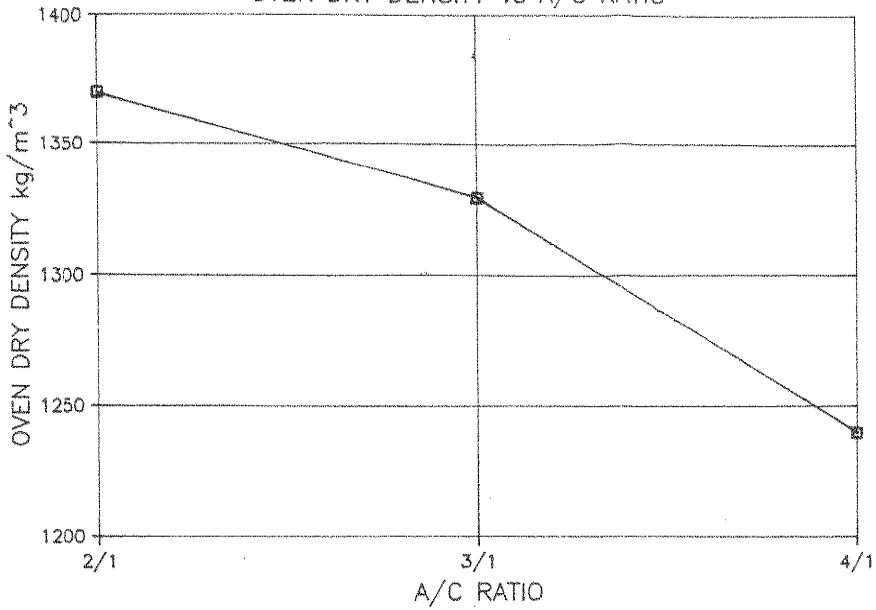
#3408 FIGURE 1

STRENGTH vs A/C RATIO



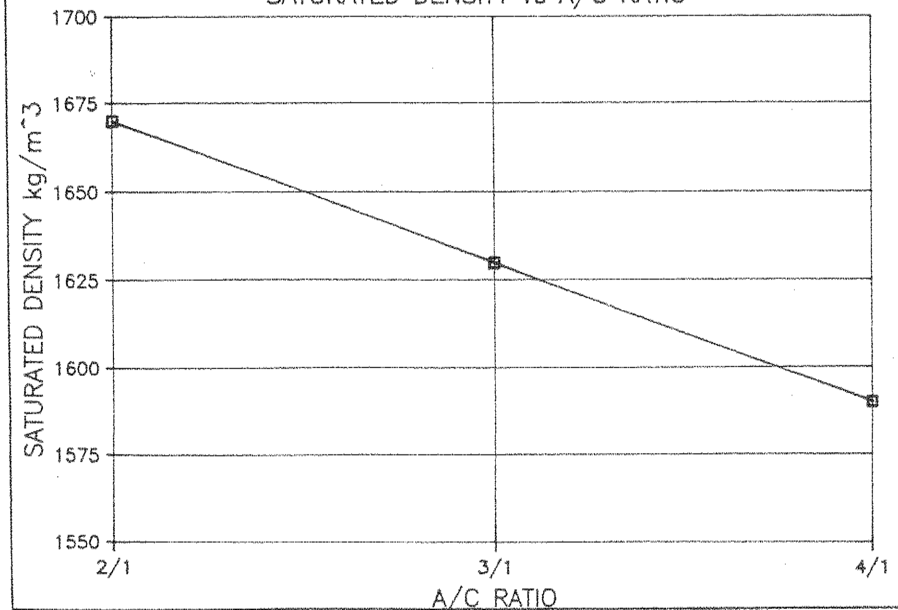
#3408 FIGURE 2

OVEN DRY DENSITY vs A/C RATIO



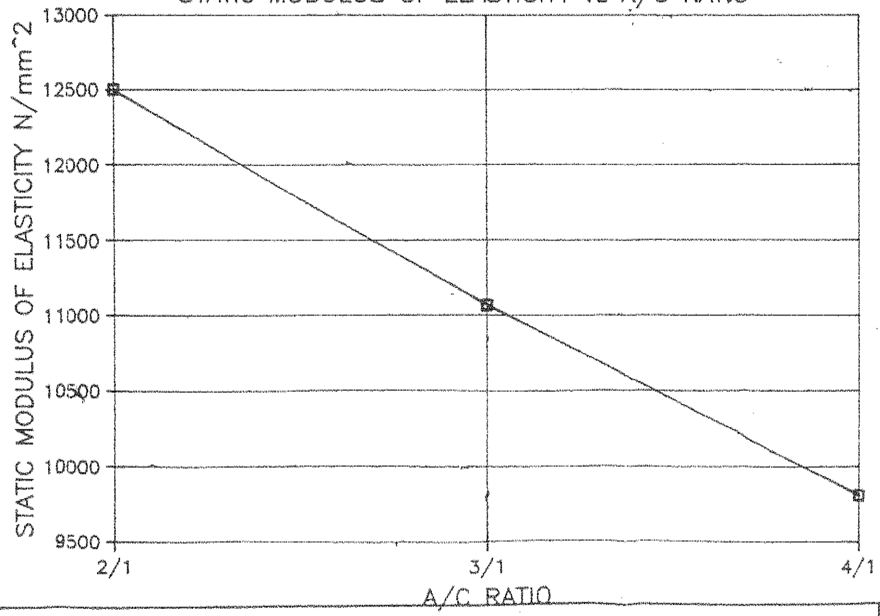
#3408 FIGURE 3

SATURATED DENSITY vs A/C RATIO



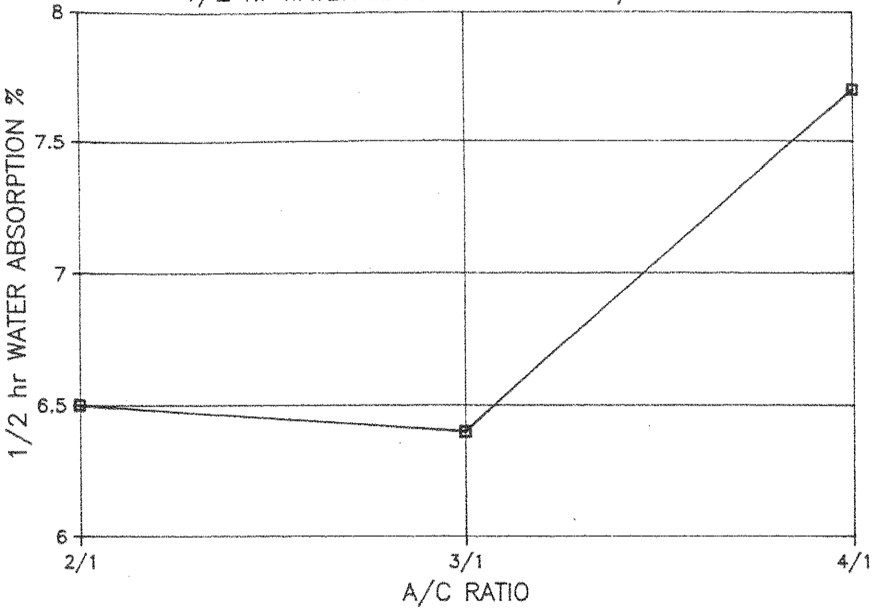
#3408 FIGURE 4

STATIC MODULUS OF ELASTICITY vs A/C RATIO

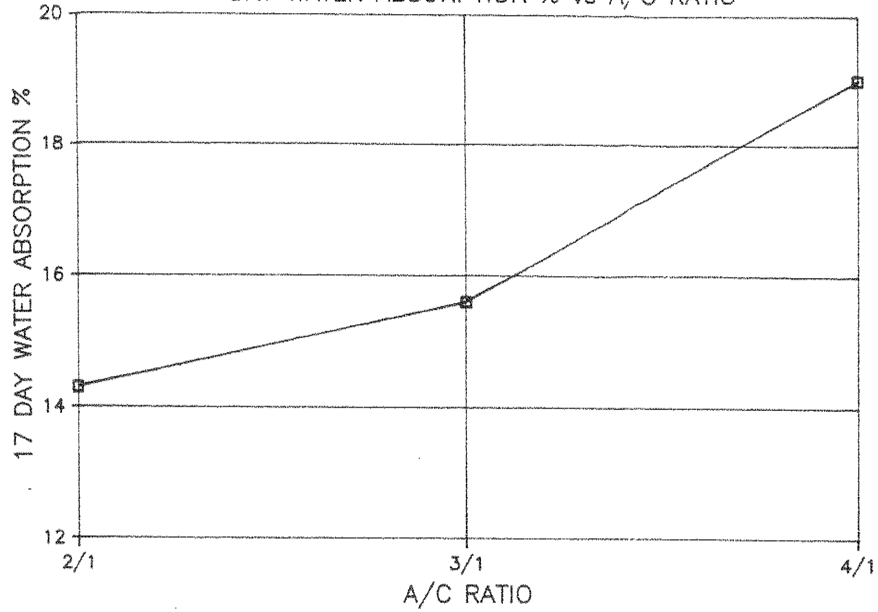


Job N° 3408E
Figure
STATS

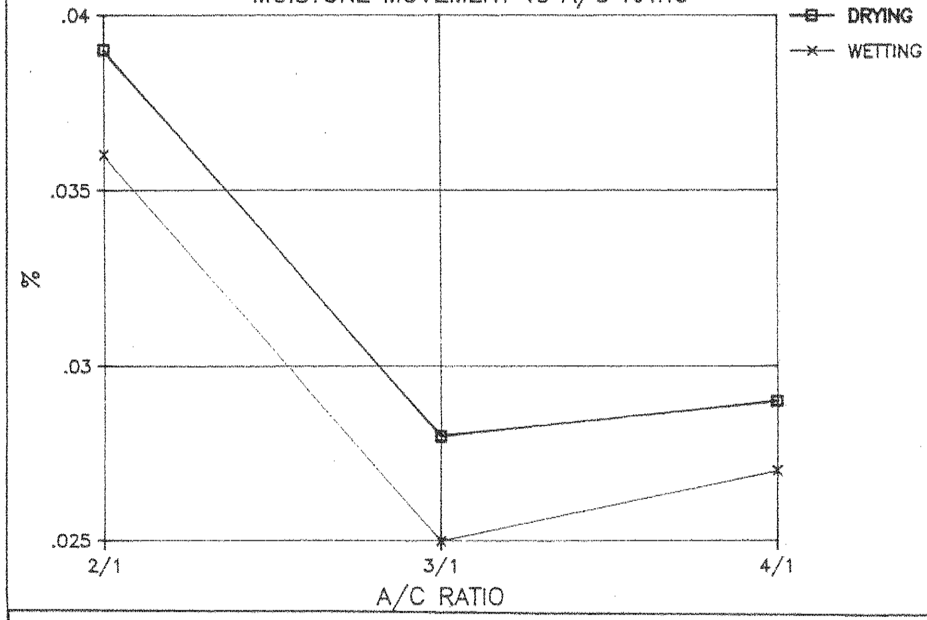
#3408 FIGURE 5
1/2 hr WATER ABSORPTION % vs A/C RATIO



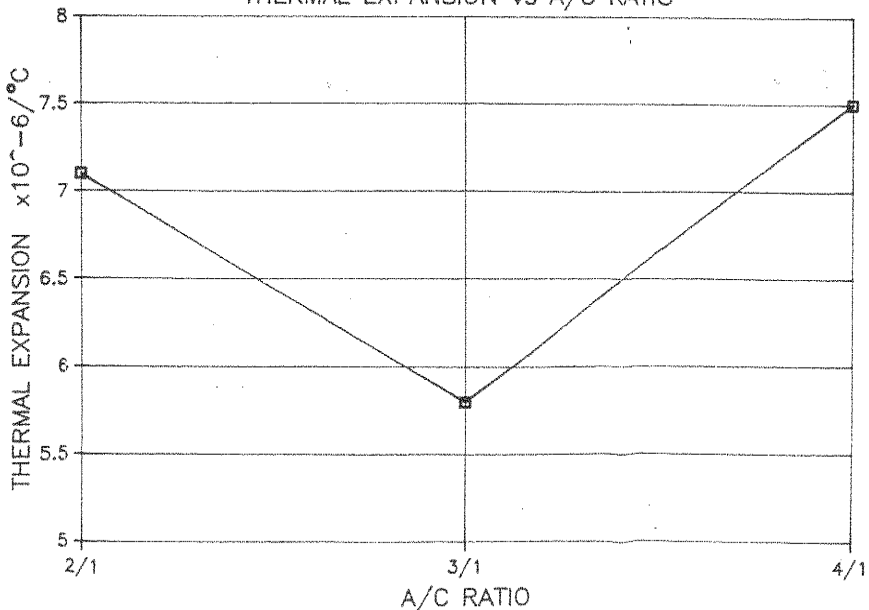
#3408 FIGURE 6
17 DAY WATER ABSORPTION % vs A/C RATIO



#3408 FIGURE 7
MOISTURE MOVEMENT vs A/C RATIO

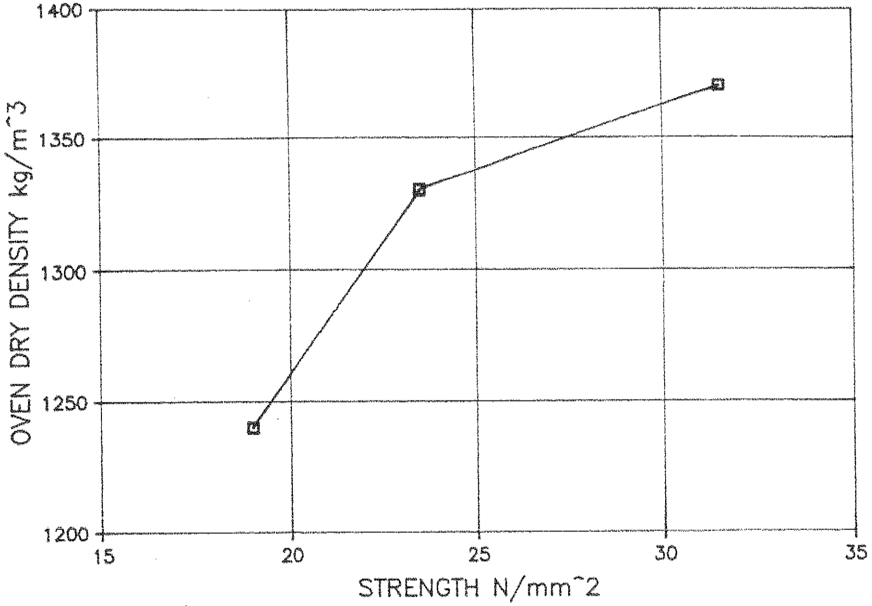


#3408 FIGURE 8
THERMAL EXPANSION vs A/C RATIO

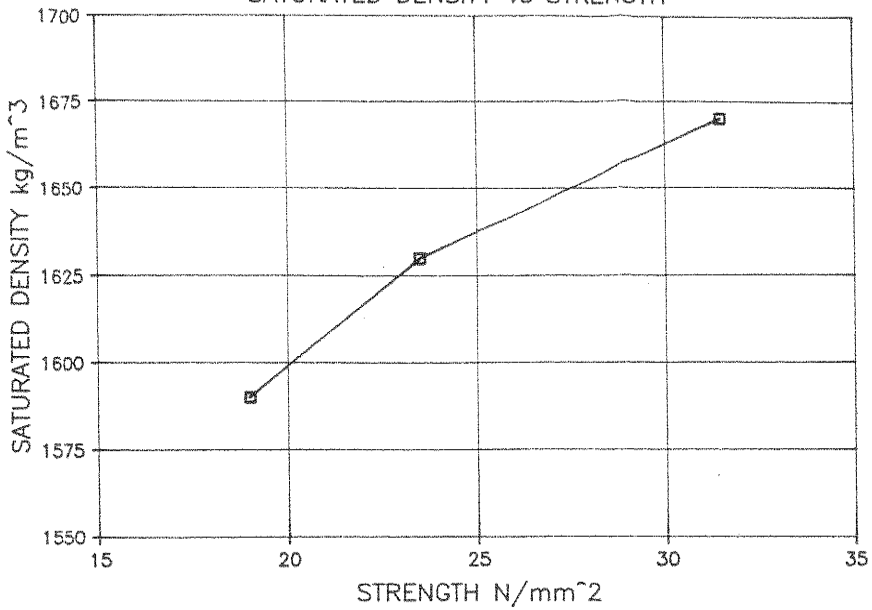


Job N° 3408E
Figure
STATS

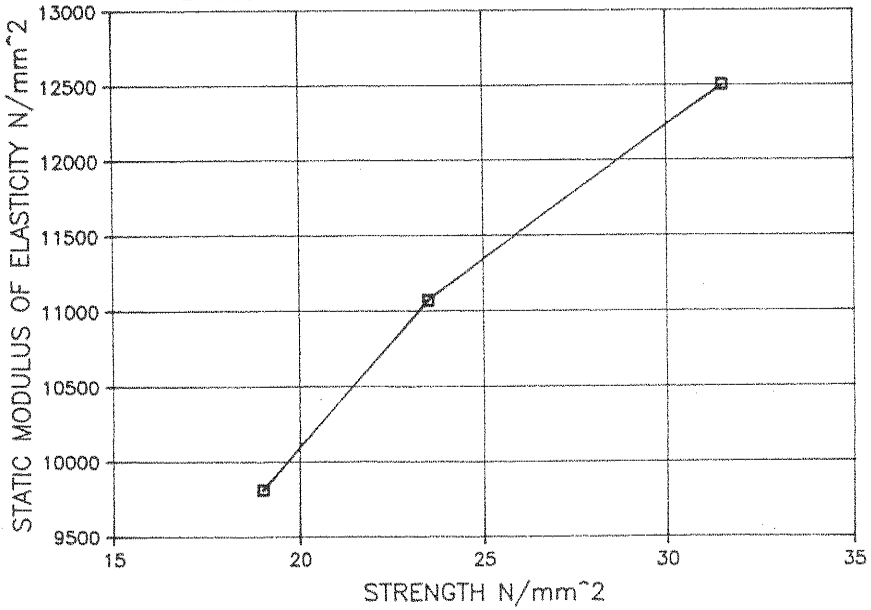
#3408 FIGURE 9
OVEN DRY DENSITY vs STRENGTH



#3408 FIGURE 10
SATURATED DENSITY vs STRENGTH



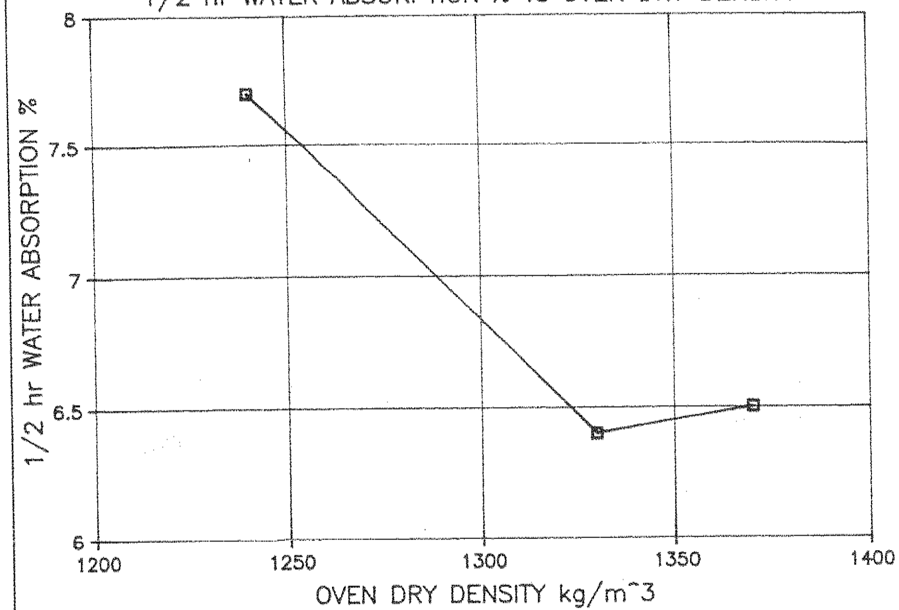
#3408 FIGURE 11
STATIC MODULUS OF ELASTICITY vs STRENGTH



Job N° 3408E
Figure
STATS

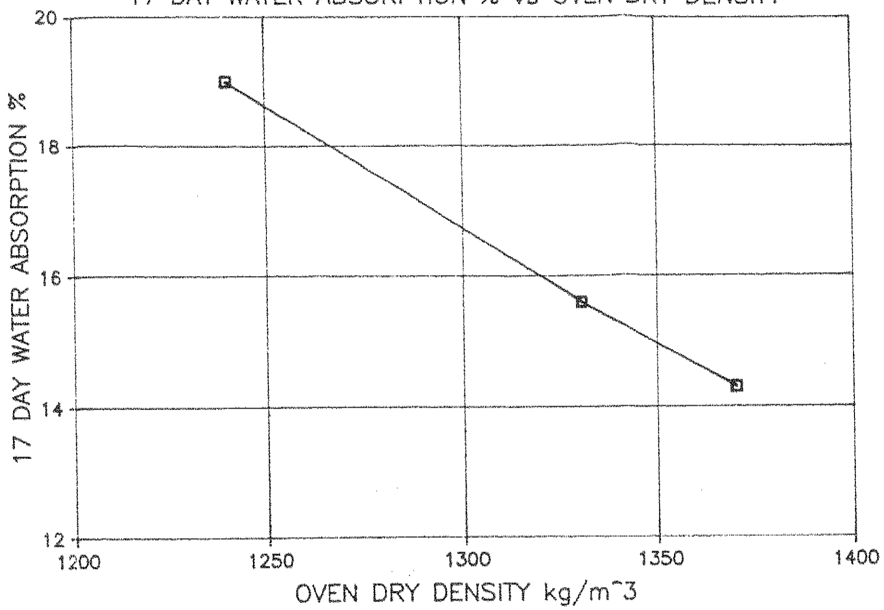
#3408 FIGURE 12

1/2 hr WATER ABSORPTION % vs OVEN DRY DENSITY



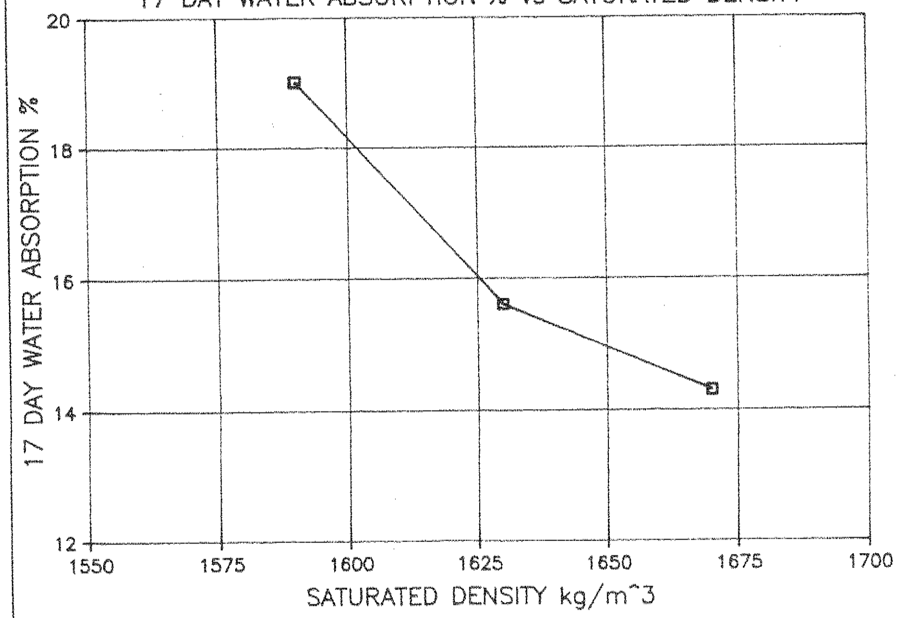
#3408 FIGURE 13

17 DAY WATER ABSORPTION % vs OVEN DRY DENSITY



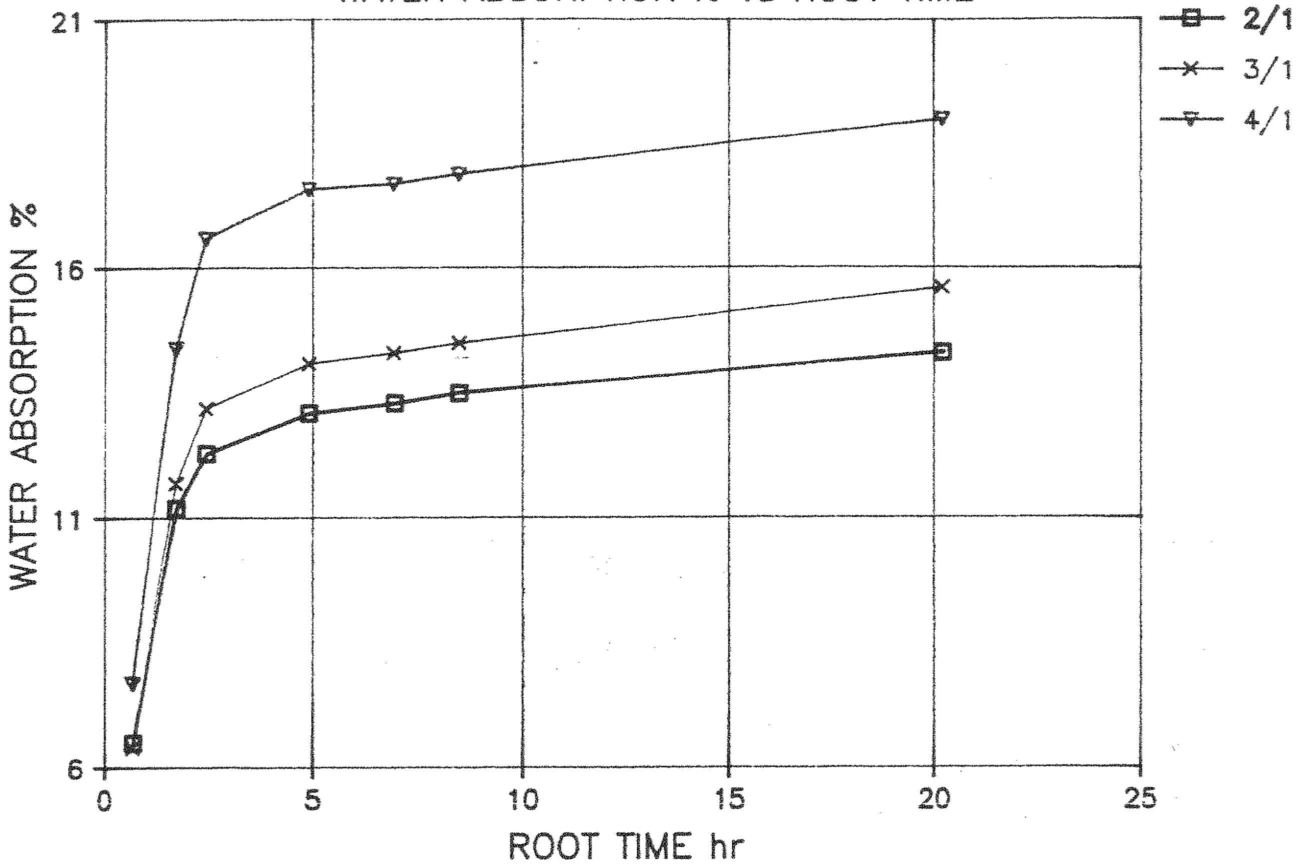
#3408 FIGURE 14

17 DAY WATER ABSORPTION % vs SATURATED DENSITY



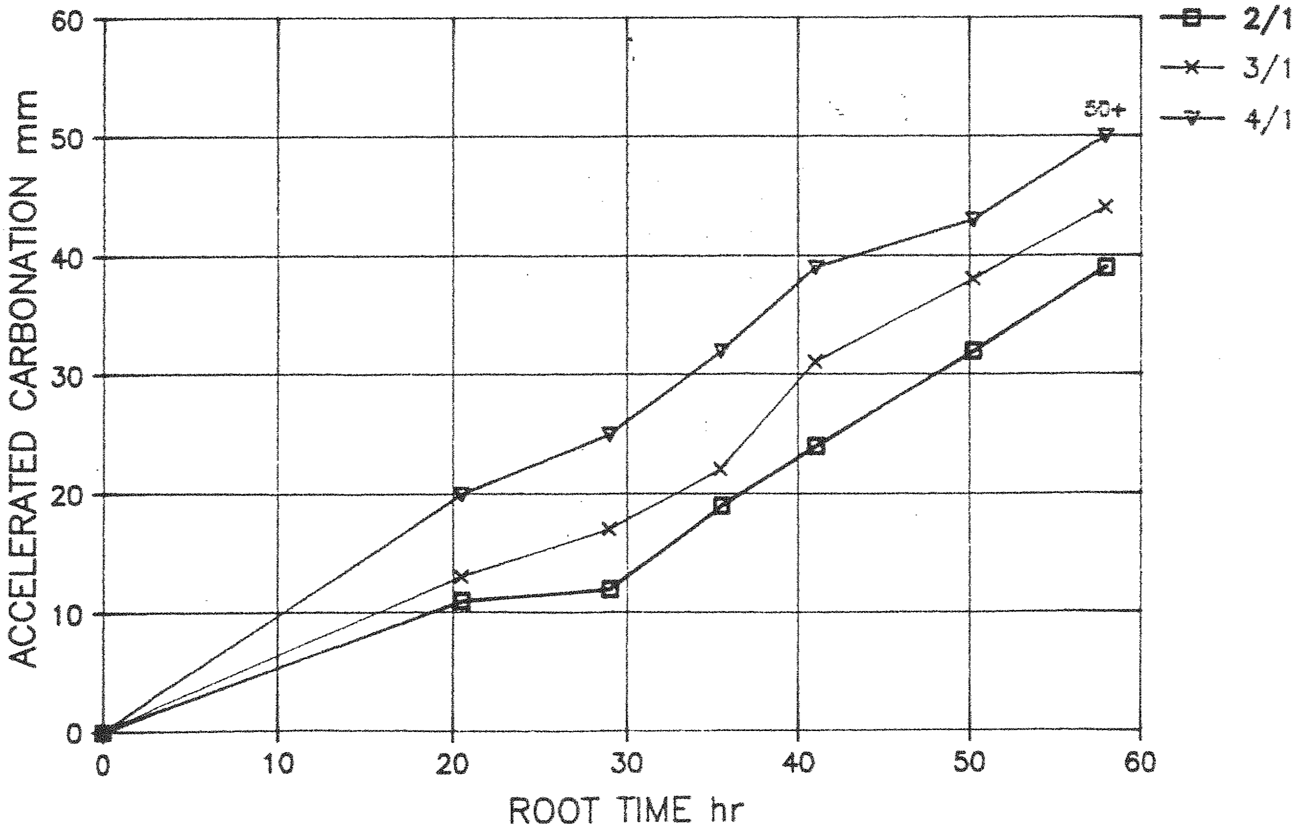
#3408 FIGURE 15

WATER ABSORPTION % vs ROOT TIME



#3408 FIGURE 16

ACCELERATED CARBONATION vs ROOT TIME



	Job N° 3408E	STATS
	Figure	

4.0 PART THREE

LABORATORY AND FIELD TRIALS OF PUMPABLE MIXES

4.0 PART THREE : LABORATORY AND FIELD TRIALS OF PUMPABLE MIXES

4.1 Purpose of Assessment

The assessment was carried out in order to determine the suitability of Yali pumice coarse and fine aggregates to produce pumpable structural grade concrete within normal cement content ranges and to produce mix design data for such concrete.

Various admixtures and pumping aids were to be used in the assessment together with pumice coarse and fine aggregates, cement and water. Only as a last resort was any natural sand fine aggregate to be used to ensure pumpability.

4.2 Mix Design Method

Using the mix designs previously established (see Part One) as starting points, laboratory trial mixes were carried out using various admixtures at varying dosages. The original mixes were also altered by varying the fines content to be more suitable for pump emplacement. Target slumps were 150+mm

The admixtures used in the test programme in the laboratory and for the pumping trials were as follows:-

product name	manufacturer	type	description	recommended dosage
CORMIX PA	Cormix Ltd, England	pumping aid	powder	0.15-0.25% of cement
CORMIX AE4		air entraining agent	liquid	200ml/50kg cement
TIAMAC II	MAC Mediterranea, Italy	superplasticiser	liquid	1.5-2.5 litres per 100kg cement
SIKAMENT T3	Sika Inertol, England	superplasticiser	powder	0.2-0.8% of cement
CONPLAST P509	Fosroc International Ltd	plasticiser	liquid	0.15-0.3 litres/100kg cement
CONPLAST AEA		air entraining agent	liquid	0.04-0.10 litres/100kg cement

Data sheets for the various products are reproduced in Appendix 7.

The initial trial mixes (5 No.) used the previously established mix designs at 4/1 and 3/1 aggregate:cement ratios and CORMIX PA pumping aid at standard (0.2% of cement) and double dosage (0.4% of cement), together with a control mix with no admixtures.

A second set of trial mixes (4 No.) at 4/1 aggregate/cement ratio were carried out. One trial with Tiamac II admixture using the previously established mix design, a second trial also using Tiamac II but with a reduction in fines content, a third trial with normal dosage of Sikament T3 using the previously established mix design and a fourth with a high dosage of Sikament T3.

The third set of trial mixes (4 No.) were carried out at a target 350kg/m^3 cement content (aggregate:cement ratio of 2.47/1). The first trial was with the previously established mix design and with Sikament T3 admixture. The second trial was as the first but increasing the fines content from 59.5 to 62.5%. The third trial increased the fines to 65% with Sikament T3 and Tiamac II admixtures. The fourth trial remained at the 65% fines content with Sikament T3 and Tiamac II admixtures but with half of the fines replaced by natural sand.

The fourth set of mix trials (3 No.) were carried out at 280, 300 and 400kg/m^3 cement contents (aggregate/cement ratios of 3.73/1, 3.5/1 and 2.5/1) with Sikament T3 admixture and with natural sand replacing half of the pumice fines content.

The last (fifth) set of laboratory trials (3 No.) were carried out at 400kg/m^3 cement content (aggregate:cement ratio of 2.15/1) with all pumice aggregates, Sikament T3 and Cormix AE4 admixtures and increased percentages of pumice fines. The first trial was at 13% above the previously established level with Sikament T3, the second trial with fines 17.4% above and also with Sikament T3, the third trial was at the +13% fines content but with Sikament T3 and Cormix AE4 admixtures.

A summary of the various laboratory trials is given in Table 4.

4.3 Results of Laboratory Trial Mixes

Full results of the various laboratory trials are given in Appendix 8.

Of the various admixtures used in the test programme, the most beneficial of the 3 No. chosen as pumping aids (i.e. Cormix PA, Tiamac II and Sikament T3) was the Sikament T3 in conjunction with an air-entraining agent. Increased percentages of pumice fines would also be required to ensure pumpability.

Replacement of pumice fines by 50% of natural sand significantly improved the cohesiveness, workability and appearance of the concrete and would ensure pumpability with the addition of Sikament T3.

TABLE 4

SUMMARY OF LABORATORY TRIALS FOR PUMPABLE MIXES

Set	Trial	Actual A/C Ratio	Nominal Cement Content (kg/m^3)	Fines Content (%)	Fines Type Pumice (%)	Fines Type Sand (%)	Admixture	Doseage
1	1	4/1	240	71.0	71.0	--	Cormix PA	0.2% cement
	2	3/1	310			--	Cormix PA	0.2% cement
	3	4/1	240	71.0	71.0	--	---	---
	4	4/1	240	71.0	71.0	--	Cormix PA	0.2% cement
	5	4/1	240	71.0	71.0	--	Cormix PA	0.4% cement
2	1	4/1	240	71.0	71.0	--	Tiamac II	1.21/100kg cement
	2	4/1	240	66.2	66.2	--	Tiamac II	1.21/100kg cement
	3	4/1	240	71.0	71.0	--	Sikament T3	0.5% cement
	4	4/1	240	71.0	71.0	--	Sikament T3	1.0% cement
3	1	2.47/1	350	59.5	59.5	--	Sikament T3	0.43% cement
	2	2.47/1	350	62.5	62.5	--	Sikament T3	0.43% cement
	3	2.47/1	350	65.0	65.0	--	Sikament T3 + Tiamac II	0.4% cement 1.51/100kg cement
	4	2.47/1	350	65.0	32.5	32.5	Sikament T3 + Tiamac II	0.4% cement 1.51/100kg cement
4	1	3.5/1	300	62.9	34.6	34.6	Sikament T3	0.4% cement
	2	2.5/1	400	64.8	32.4	32.4	Sikament T3	0.4% cement
	3	3.73/1	280	69.7	34.85	34.85	Sikament T3	0.4% cement
5	1	2.15/1	400	65.0	65.0	--	Sikament T3	0.51% cement
	2	2.15/1	400	69.4	69.4	--	Sikament T3	0.51% cement
	3	2.15/1	400	65.0	65.0	--	Sikament T3 +Cormix AE4	0.4% cement 200ml/50kg cement

4.4 Pumping Trials

Full scale pumping trials were undertaken on 24 June 1990 at the ready mix concrete plant of John Fyfe Ltd at Coatbridge, Scotland. 3 No. 1.0m^3 and 1 No. 1.5m^3 mixes were batched by the concrete plant, as follows:-

Batch No.	Volume (m^3)	Cement Content (kg/m^3)	Fines Content (%)	Admixture Sikament T3	Admixture Conplast P509	Admixture Conplast AEA
1	1.5	400	69.4	0.5	200	100
2	1.0	350	74.4	0.5	200	100
3	1.0	400	73.6	0.5	200	100
4	1.0	300	76.0	0.5	200	100
				%	ml/100kg cement	ml/100kg cement

All the mixes were successfully pumped by a POCHIN Concrete Pumping concrete pump with a 22m boom (see plates 1 to 5). The batch 1 mix was, however, harsh in appearance and the pump laboured slightly. This mix was repeated as batch no. 3 at an increased fines content. No addition of natural sand fine aggregate was necessary.

Compared with the original mix designs for structural concrete (see Part 1), the quantity of fines has been significantly increased to achieve pumpable structural concrete.

3 No. admixtures were also necessary to ensure pumpability - a powdered superplasticiser (Sikament T3) and a liquid air entraining agent (CONPLAST AEA) as dictated by the laboratory trials but also including a plasticiser (CONPLAST P509); all at recommended dosages.

Batch nos. 2, 3 and 4 were all of self levelling workability, easily pumped and with overall good, cohesive appearance (see plates 3, 4 and 5). Pumping pressures were as follows:-

Batch No.	Pumping Pressure (bars)
2	100
3	100 - 150
4	200 max

Full mix details are given in Appendix 9.

As the coarse and fine aggregate used had been stockpiled on-site prior to batching they were in a near saturated condition. The actual water content of the mixes was thus difficult to ascertain. Further laboratory mix trials were thus undertaken using the mix proportions used for the site trials to determine the free water:cement ratio of the mixes.

Full mix details are contained in Appendix 9.

For pumpable structural lightweight concrete with pumice aggregate in the 300 to 400kg/m^3 range of cement contents, the percentage of fines required is in the 76 to 74% range with free water:cement ratios of between 0.67 to 0.52/1. Upper compressive strength limit is circa 30N/mm^2.

Densities achieved by the field trials are higher than anticipated (in the 1600 to 1700kg/m^3 range) bearing in mind that the concretes are air entrained. It is possible that unintentional contamination by natural sand in the ready mix plant storage silos has occurred leading to higher densities. The supplementary laboratory mixes indicated plastic densities of circa 1400kg/m^3 which on the basis of the laboratory trial mixes would give 28 day saturated densities of circa 1450kg/m^3.

Relationships between the various parameters for pumpable structural pumice aggregate are given in Appendix 10.

APPENDIX 7

ADMIXTURE DATA SHEETS

CI/SfB | Yu2

cormix
Pumping aid

Date April, 1987

DESCRIPTION

*CORMIX P.A. is a pumping aid for use with lightweight aggregates. It is specifically formulated to overcome the tendency of these aggregates to exhibit high water absorbency under pump working pressures, thus offsetting 'dry pack' pipeline blockages. CORMIX P.A. is a homogeneous powdered mixture consisting of a blend of water reducing and workability retaining components. It is manufactured from carefully selected high grade raw materials.

ADVANTAGES

★ CORMIX P.A. reduces the water absorbency of lightweight aggregates, enabling mixes to be placed by pump.

★ Gives considerable savings in time and effort compared with other placing methods such as crane/hoist and skip.

★ Enables substantial water reductions to be made without loss of workability, thus producing more durable concrete.

★ Any tendency for the concrete to segregate is modified.

★ Increases the intrinsic workability of the concrete resulting in less effort being required for full compaction.

PROPERTIES

Appearance . Free-flowing dark brown powder

Bulk Density .... 615 kg/m³ (38.4 lb/ft³)

Storage Life .. Indefinite in air tight paper bags

Air Entrainment . . . Additional air entrainment is of the order of 3%

Chloride Content .... Nil

Solubility .... Readily soluble

Handling .... There is no health hazard associated with the handling of CORMIX P.A. However, if it is spilt the floor will be made slippery and should be washed down immediately with water. For further information see 'Cormix and Safety' instructions.

Compatibility With Cements . . . CORMIX P.A. can be used with all normal cements. Prior to use with special cements we recommend Cormix Limited be consulted.

Compatibility With Other Admixtures ...... Premixing with other chemical admixtures is not advised as the effectiveness of the admixture may be adversely affected. In such circumstances we recommend that Cormix Limited be consulted.

'Cormix' is a trade mark

METHOD OF USE

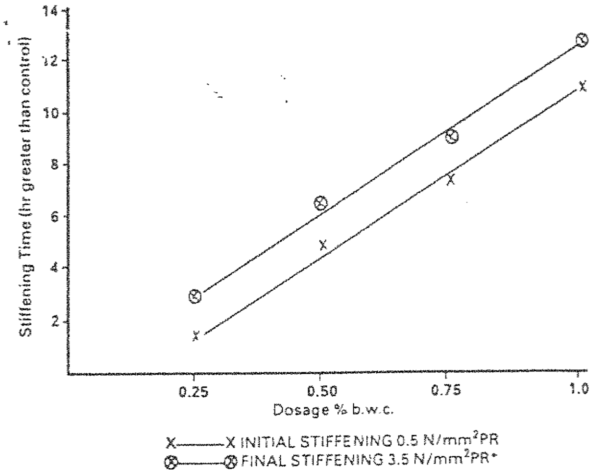
CORMIX P.A. is supplied ready for use. It should be added to the concrete or mortar mix during the mixing process by hand sprinkling or powder dispenser at the same time as the aggregates or cement. No extension of normal mixing time is necessary.

ADDITION RATE

The performance of CORMIX P.A. is best assessed after preliminary site tests. The final assessment of dosage level should be made after site evaluations with the actual materials and mix proportions to be used. As a guide to these trials an addition level of **0.15%—0.25% CORMIX P.A.** is recommended based on the weight of cement. For advice and assistance with your trials we recommend that Cormix Limited be consulted.

EFFECT OF OVER-DOSING

Over-dosing of 2 or 3 times the recommended level will generally result in increased workability with an increased setting time as shown below.



*TESTED IN ACCORDANCE WITH B.S.5075 Part 1: 1974, ADMIXTURES FOR CONCRETE.

APPLICATION No. 1:

Use of CORMIX P.A. to effect reduction in % bleed water.

Example:

Mix No. 1

Coarse Aggregate-Lightweight:
†Aglite (shape irregular) 12mm—5mm

Fine Aggregate:
Pit Sand (shape irregular) .. .. Zone 3

†'Aglite' is a proprietary brand name of Aglite 'Midlands' Limited.

Cement . . . . Ordinary Portland
Mix Proportions:
Cement:Sand:Aggregate
1:1.875:1.25

Aggregate/Cement
Ratio 3.125:1
Fine:Coarse Aggregate 60:40

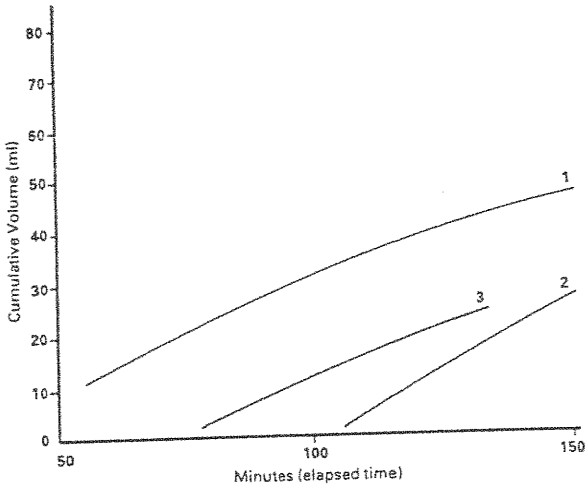
Water/Cement Ratio:
Control 1 . . . . . . 0.73
Mix 1A 0.70
Mix 1B 0.725

CORMIX P.A.—Level of Addition:
Control 1 . . . . . . Nil
Mix 1A . . . . . . 0.125% addition by weight of cement
Mix 1B . . . . . . 0.250% addition by weight of cement

Determined Properties of the Concrete

Mix	Flow* cm	Bleed Water ml x 10^{-2}/cm^2	Bleed Water %
Control 1	60	11.6	4.60
Mix 1A	60	3.3	2.53
Mix 1B	62	6.1	2.20

*GERMAN STANDARD DIN 1048



1. CONTROL
2. CORMIX P.A. 0.125% by weight of cement
3. CORMIX P.A. 0.250% by weight of cement

Example:
Mix No. 2

Coarse Aggregate-Lightweight:
‡Lytag (shape irregular/rounded) . . 12mm—5mm

Fine Aggregate:
Pit Sand (shape irregular) . . . . Zone 3
Cement . . . . Ordinary Portland
Mix Proportions:
Cement:Sand:Aggregate
1:1.875:1.25

Aggregate/Cement
Ratio 3.125:1
Fine:Coarse Aggregate 60:40

Water/Cement Ratio:
Control 2 . . . . . . 0.75
Mix 2 . . . . . . 0.675

CORMIX P.A.—Level of Addition:
Control 2 . . . . . . Nil
Mix 2 . . . . . . 0.25% addition by weight of cement

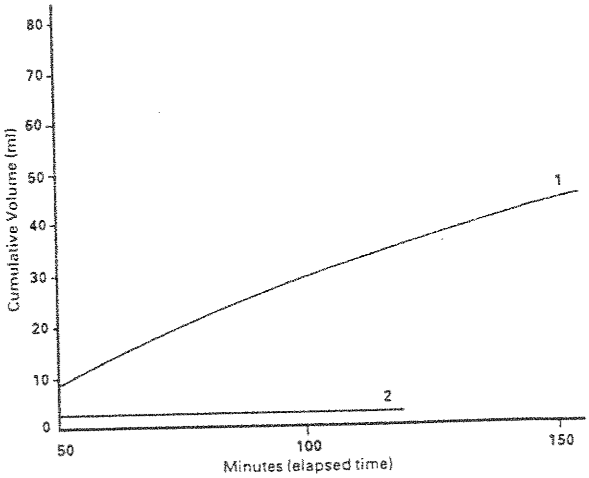
‡'Lytag' is a proprietary brand name of Lytag Limited.

Determined Properties of the Concrete

Mix	Flow* cm	Bleed Water ml x 10^{-2}/cm^2	Bleed Water %
Control 2	56	10.4	3.66
Mix 2	56	0.9	0.27

*GERMAN STANDARD DIN 1048

Note:
All bleed results quoted for Mixes 1 and 2 were calculated in accordance with ASTM C232-58.



1. CONTROL
2. CORMIX P.A. 0.25% by weight of cement

APPLICATION No. 2:
Use of CORMIX P.A. to place lightweight concrete by concrete placer.

CORMIX P.A. has been evaluated on site using a pneumatic placer, with a 33 metre length of 75 mm diameter flexible pipe placed so that the maximum vertical height was 15 metres above ground level. A Control (Mix 3) was produced and this was compared with a mix containing CORMIX P.A. (Mix 3A) and a further mix containing a proprietary pumping aid (Mix 3B).

Example:
Mix No. 3

Coarse Aggregate-Lightweight:
‡Lytag (shape irregular/rounded) . . 12mm—5mm

Fine Aggregate:
Pit Sand (shape irregular) . . . . Zone 3
Cement . . . . Ordinary Portland
Mix Proportions:
Cement:Sand:Aggregate
1:1.26:1.54

Aggregate/Cement
Ratio 2.80:1
Fine:Coarse Aggregate 45:55

Water/Cement Ratio:
Control 3 . . . . . . 0.73
Mix 3A 0.80
Mix 3B 0.80

Level of Addition:
Control 3 . . . . . . Nil
Mix 3A . . . . . . 0.25% CORMIX P.A. by weight of cement
Mix 3B . . . . . . 0.25% Proprietary pumping aid by weight of cement.

Determined Properties of the Concrete

Mix	Slump mm	Placed	Oven Dry Density kg/m^3	28 Day Compressive Strength N/mm^2
Control 3	100	Difficult	1530	45.50
Mix 3A	100	Yes	1510	39.75
Mix 3B	100	Yes	1485	36.50

APPLICATION No.3:

Comparison of CORMIX P.A. with Proprietary Pumping Aid to effect placing of lightweight aggregate concrete by concrete pump.

CORMIX P.A. was used to place lightweight concrete using a *Putzmeister BA1405D trailer pump powered by a 6 cylinder Deutz diesel engine. Internal diameter of pipe was 150mm and the length 50 metres with 4 bends of 90° and 1 bend of 45°.

Example:
Mix No. 4

Coarse Aggregate:
‡Lytag (shape irregular/rounded) .. 12mm—5mm

Fine Aggregate:
Pit Sand (shape irregular) .. .. Zone 2

Cement .. .. Ordinary Portland

Mix Proportions:
Cement:Sand:Aggregate 1:1.75:1.27

Aggregate/Cement Ratio 3.02:1

Fine:Coarse Aggregate 58:42

Water/Cement Ratio:
Mix 4A 0.60
Mix 4B 0.63

Level of Addition:
Mix 4A .. .. .. 0.25% CORMIX P.A. by weight of cement
Mix 4B .. .. .. 0.25% Proprietary pumping aid by weight of cement.

Determined Properties of the Concrete

Mix	Flow cm	Pumped	Density† kg/m^3		Average Compressive Strength N/mm^2	
			7 days	28 days	7 days	28 days
4A	60	Yes	1945	1960	21.0	38.0
4B	60	Yes	1975	1975	22.0	39.0

†Saturated densities

Note:
No Control concrete was produced for the above evaluation as the lightweight mix would certainly not withstand pumping pressures and would cause pump blockages.

**'Putzmeister' is a proprietary brand name of Putzmeister Limited who are a fully owned subsidiary of Putzmeister Werk Maschinen Fabrik GmbH.*

PACKAGING

CORMIX P.A. is supplied in disposable 5 ply weatherproof paper bags. Each bag contains 25 kilogrammes of powder.

For the convenience of ready mixed concrete suppliers, CORMIX P.A. is also available in 6kg packs, normally sufficient to dose a full 6 m^3 load of lightweight concrete.

STORAGE

CORMIX P.A.should be stored in dry conditions, similar to cement, in order to protect the pack.

AVAILABILITY

Prompt deliveries can be arranged by contacting Cormix Limited, P.O. Box 132, Warrington, Cheshire, WA5 1AG, Telephone 0925 51222, Telex 627562G. Local supplies are available for markets outside the UK.

TECHNICAL SERVICE

The Cormix Technical Service Department is available to assist you in the correct use of our products and its resources are at your disposal entirely without obligation.

The information given in this leaflet is based not only on work in our laboratories but also on practical experience obtained during field work. It is offered without guarantee and no patent liability is assumed.

Cormix Limited, P.O. Box 132, Warrington, Cheshire, England WA5 1AG

Issued and printed by Cormix Limited, Warrington (M32)

cormix
Air entraining agent 4

CI/SfB	
	Yu2

Date September, 1983

DESCRIPTION

*CORMIX A.E.4 is a liquid air entraining agent for use in all types of mortar and concrete mixes. It is particularly designed for use in the production of foamed concrete and for use with synthetic and naturally occurring lightweight aggregates (bulk densities 300 kg—1000 kg per cubic metre) where the density of the fine aggregate/cement paste is normally required to be similar to that of the aggregate.

CORMIX A.E.4 is formulated from carefully selected raw materials and is manufactured under controlled conditions to give a consistent product. It is a blend of anionic surfactants.

ADVANTAGES

★ CORMIX A.E.4 will entrain air into all types of concrete even those with highly angular crushed aggregates.

★ It can be used with all types of lightweight aggregates to produce very low density concrete mixes.

★ CORMIX A.E.4 can be employed to entrain air in mixes containing high proportions of pulverised fuel ash.

★ An aqueous solution of CORMIX A.E.4 can be prefoamed to give a very stable foam for use in the production of foamed concrete.

PROPERTIES

Appearance .... Pale straw coloured liquid
Specific Gravity .... 1.03 at 20°C
Viscosity .... 3.37 cP at 20°C
Chloride Content .... Nil
Solubility in Water .... Infinite
Freezing Point .... Less than 0°C
Storage Life in Manufacturers Drums ....
Indefinite. Information on bulk storage is available on request.
Corrosiveness to Mild Steel .... Nil
Handling .... CORMIX A.E.4 is formulated from chemicals which present no fire or health hazards. However, if it is spilt, the floor will be made slippery and should be washed down immediately with cold water. For further information see 'Cormix and Safety' instructions.

Compatibility With Cements .... CORMIX A.E.4 can be used with all types of Portland Cement including Sulphate Resisting Cements. For use with special cements we recommend that you consult Cormix Limited.

Compatibility With Other Admixtures .... CORMIX A.E.4 should not be pre-mixed with other admixtures. The performance of the material may be affected by the presence of other chemicals, and we would recommend that Cormix Limited be consulted in such circumstances.

METHOD OF USE

CORMIX A.E.4 is supplied ready for use. It should be added to concrete or mortar mixes during the mixing process at the same time as the water or the aggregates. It should not be added directly to the cement or mortar. No extension of normal mixing time is necessary.

ADDITION RATES

The performance of CORMIX A.E.4 is best assessed after preliminary tests on site using the actual mix and plant under consideration to determine the optimum dosage rate which will give the desired concrete properties.

For foamed concrete/mortar a **5%—7% solution of CORMIX A.E.4** is added usually via a foam tube. The quantity of foam added will determine the resultant density of the concrete/mortar produced. Hence the volume of aqueous solution added is proportional to the concrete/mortar density required. As a guide see graph in 'Application No. 1'.

For lightweight aggregates or low density concrete an addition level of **200 ml CORMIX A.E.4 per 50 kg cement** should be evaluated. For advice and assistance with your trials we would recommend that you consult Cormix Limited. The air content of air entrained concrete should be regularly checked, and because of the absorptive nature of most lightweight aggregates, a gravimetric determination is most suitable.

EFFECT OF OVER-DOSING

As with all air entraining agents, CORMIX A.E.4 in any given mix will proportionately reduce compressive strength as the level of entrained air is increased. Over-dosing with CORMIX A.E.4 will normally produce an increase in air content and workability, together with a loss in ultimate compressive strength.

'Cormix' is a trade mark

DISPENSING

It is preferable that liquid admixtures for concrete should be introduced into a mixer by means of automatic dispensing equipment. Such equipment is available from Cormix Limited.

For details see our leaflet 'Cormix Automatic Dispensing Equipment for Liquid Concrete Admixtures', or consult Cormix Limited.

TEST RESULTS

Numerous investigations have been carried out in our own Concrete Laboratory, and at various sites. The examples quoted below are intended to illustrate the applications of CORMIX A.E.4.

Tests were carried out with materials complying with and in the manner prescribed in the relevant British Standards.

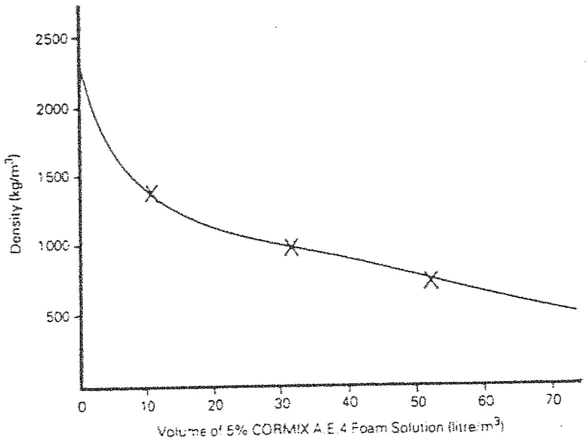
APPLICATION No. 1:
Use of CORMIX A.E.4 to produce foamed mortar.

Foamed mortar of varying density was produced by altering the volume of foam solution in a 1:1:0.45 Sand:Cement:Water mix. The mortar was prepared using a proprietary foamed mortar production rig.

Example:
Mix No. 1 kg

Cement (Ordinary Portland) 100
Zone 4 Sand 100
Water .. .. ..45 w/c=0.45

The densities obtained for a given dosage are shown graphically below:



APPLICATION No. 2:
Use of CORMIX A.E.4 in concrete using lightweight aggregates.

CORMIX A.E.4 can be added to lightweight aggregate concrete mixes to lower the density of the cementitious matrix to bring it nearer to that of the aggregates used. Shown below are test results obtained using CORMIX A.E.4 in lightweight concrete blocks.

Example:
Mix No. 2
Coarse Aggregate ..Lightweight
Fine Aggregate ..Furnace Bottom Ash
Cement .. .. ..Ordinary Portland
Mix Proportions:
Cement: Fine Aggregate: Coarse Aggregate
1:0.81:2.32

Aggregate/Cement
Ratio 3.13:1
CORMIX A.E.4—Level of Addition:
Control 2 .. ..Nil
Mix 2 .. .. ..200 ml per 50 kg cement

Determined Properties of the Concrete

Mix	7 Day Compressive Strength N/mm²	Test Block Density kg/m³	Oven Dried Density kg/m³
Control 2	2.94	1016	989
Mix 2	2.39	700	653

All the above results are the average of ten blocks.

PACKAGING

CORMIX A.E.4 is supplied in 210 litre (45 gallon approx.), free, non-returnable containers. Alternatively road tanker deliveries can be arranged.

STORAGE

CORMIX A.E.4 should preferably be stored protected from frost. If the product does become frozen, it should be carefully mixed after thawing out to restore it to its normal state.

AVAILABILITY

Prompt deliveries can be arranged by contacting Cormix Limited, P.O. Box 132, Warrington, Cheshire WA5 1AG, Telephone 0925 51222, Telex 627562G. Local supplies are available for markets outside the UK.

TECHNICAL SERVICE

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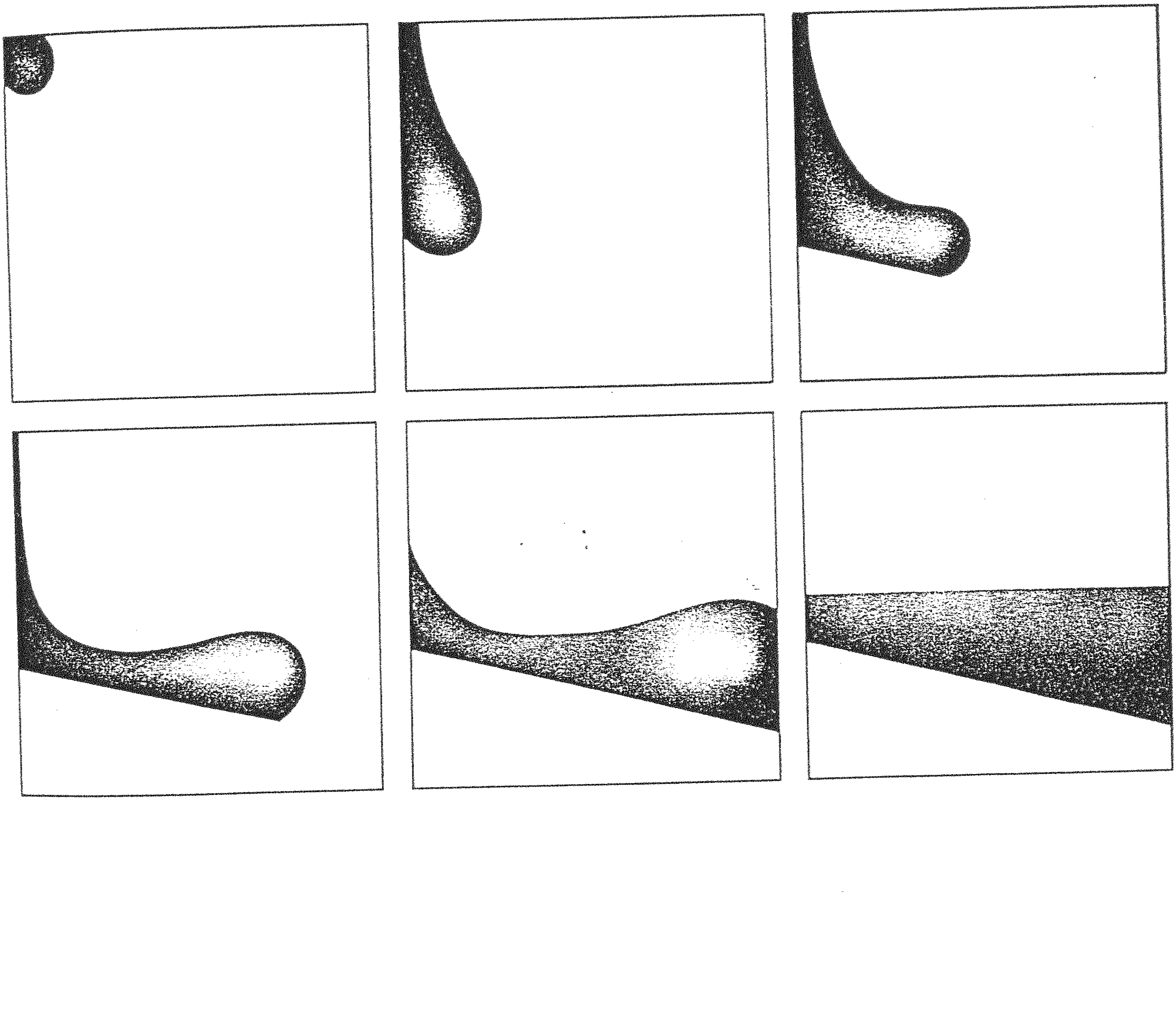
TIAMAC® 11

admixtures



Company policy and rheoplastic concrete

MAC MEDITERRANEA's policy is directed at research, production and sale of technologically advanced admixtures for cement, concrete and mortars, and also to provide assistance in the application of such products.
TIAMAC 11 admixture for rheoplastic lightweight concrete is one of the results of this policy.

As a matter of fact TIAMAC 11 admixture gives the opportunity of reducing water/cement ratios to very low levels, thus to produce a rheoplastic lightweight concrete with advanced technological qualities. A large number of scientific papers on this subject confirm that all rheoplastic lightweight concrete's properties (strength, modulus of elasticity, shrinkage, creep, durability, protection of reinforcement) are equivalent to the properties of a no-slump (1 inch or 25 mm) concrete without TIAMAC 11 admixture. Unlike the latter, however, rheoplastic lightweight concrete does not call for sophisficated and costly compacting systems, nor does it require skilled labor.

Rheoplasticity is more than a theoretical concept or a slogan.

It is a practical quality which enables the production on worksites and precast plants, of materials which previously could only be made in laboratory conditions.

Rheoplasticity meets customers and engineers' requirements to obtain a strong safe, durable and reliable structure, and also contractors' requirements to carry out their work in a host of difficult operating and economic conditions.

WARRANTY AND LIABILITY

The information given here is true and represents our best knowledge and is based not only on Laboratory work but also on field experience. However, because of numerous factors affecting results we offer this information without guarantee and no patent liability.

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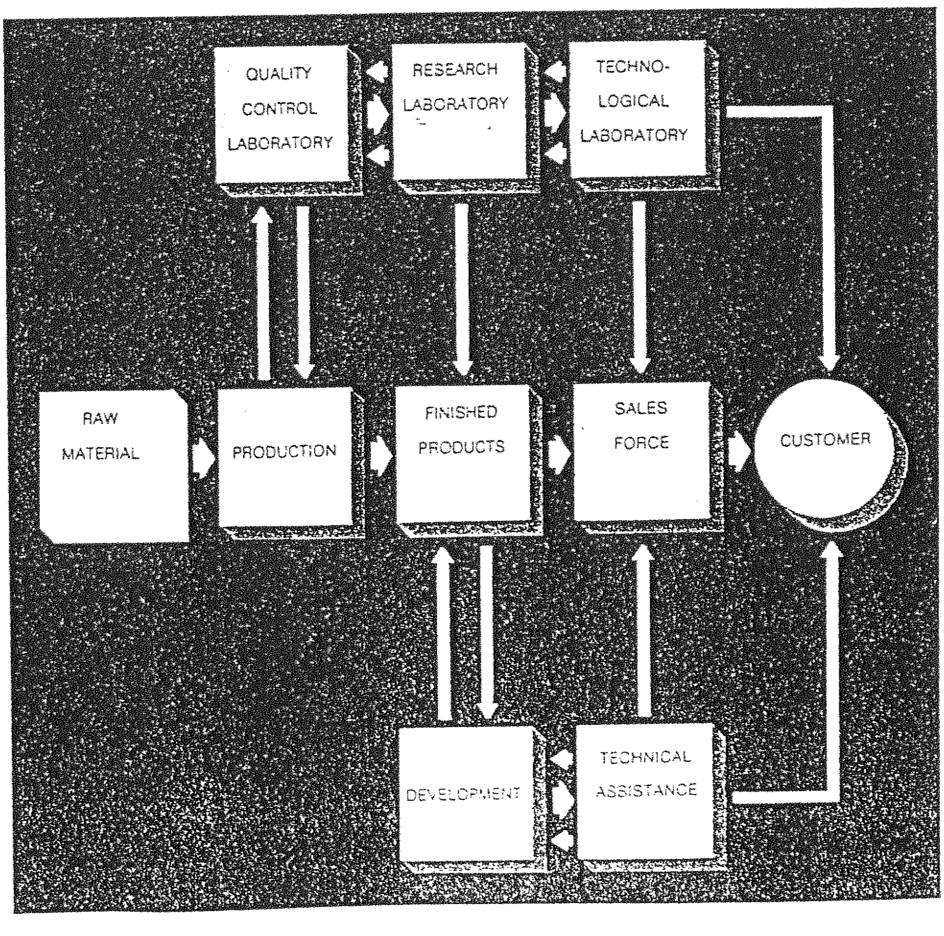


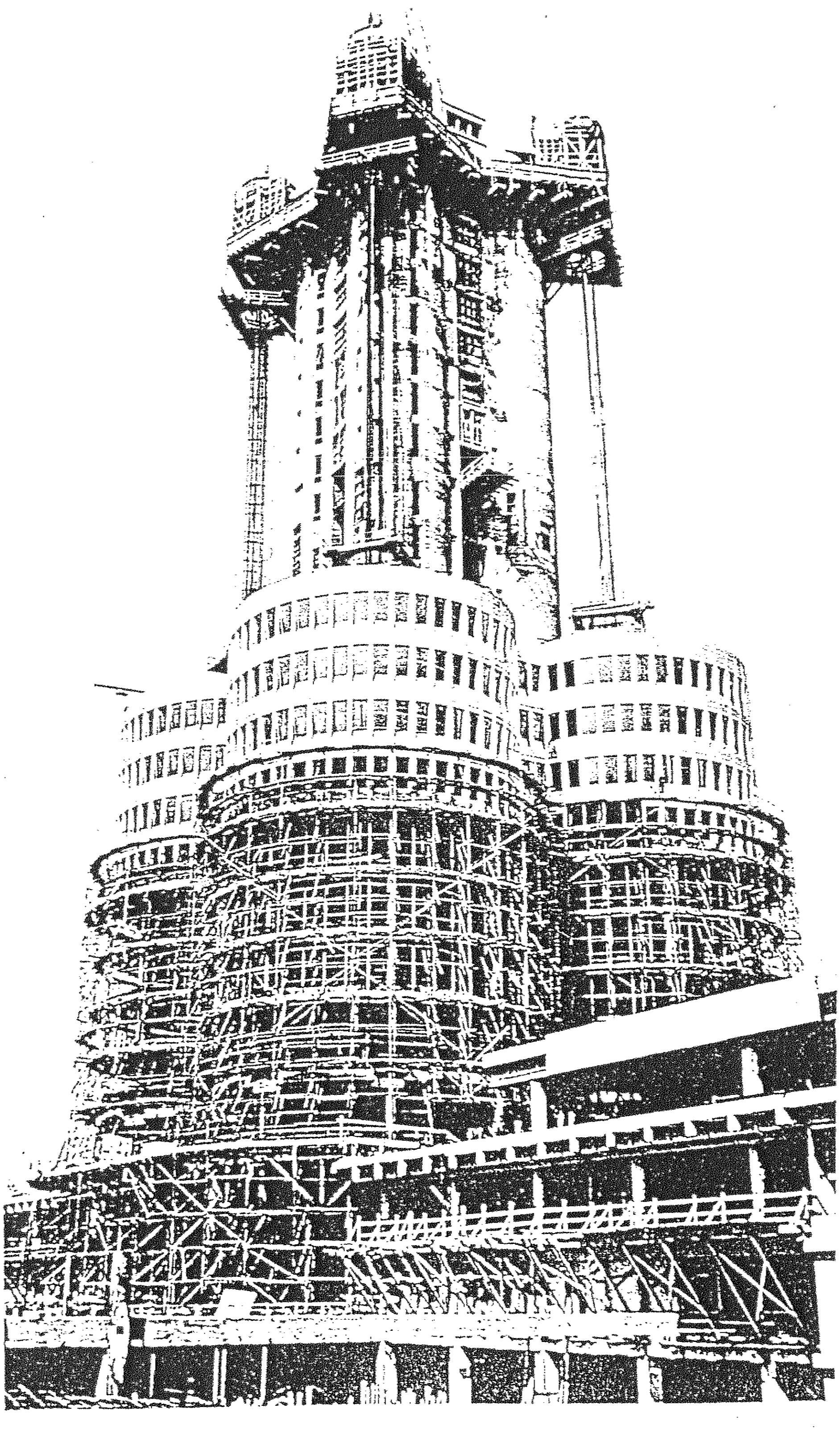
LIGHTWEIGHT CONCRETE

Lightweight concrete is generally a concrete with specific gravity 800 - 1,800 Kg/m³ (1,384/3,033 lbs/yd³). Specific gravity can be lowered either using porous, therefore light, aggregates instead of ordinary ones, or introducing air into the mortar, or removing the fine fractions of aggregate, and compacting concrete only partially. In all cases, the aim is to introduce voids into the aggregate, into the mortar or between mortar and aggregate. A combination of the three methods can also be made in order to reduce furtherly the weight of concrete.

The use of lightweight aggregates is by far the simplest and most commonly used method of making a lightweight concrete, and expanded clay is the most widely used lightweight aggregate especially for lightweight structural concretes (specific gravity: 1,400 - 1,800 Kg/m³ or 2,359 - 3,033 lbs/yd³).

The first patent concerning the use of expanded clay goes back to 1918 (Heydy), and concrete containing expanded clay was first produced on an industrial scale in 1929 in the United States. However, as long ago as the second century the Romans built the dome of the Pantheon (diameter 44 metres) with a lightweight conglomerate incorporating a naturally porous aggregate (pumicestone).

Obviously, a reduced specific gravity results in a lower strength but it is not difficult to obtain lightweight structural concretes which have a characteristic compressive strength of 200 Kg/cm² (2,845 psi) rising, in some cases, to 500 Kg/cm² (7,112 psi). The greatest advantages of lightweight concrete are its low weight (allowing construction on ground with only moderate



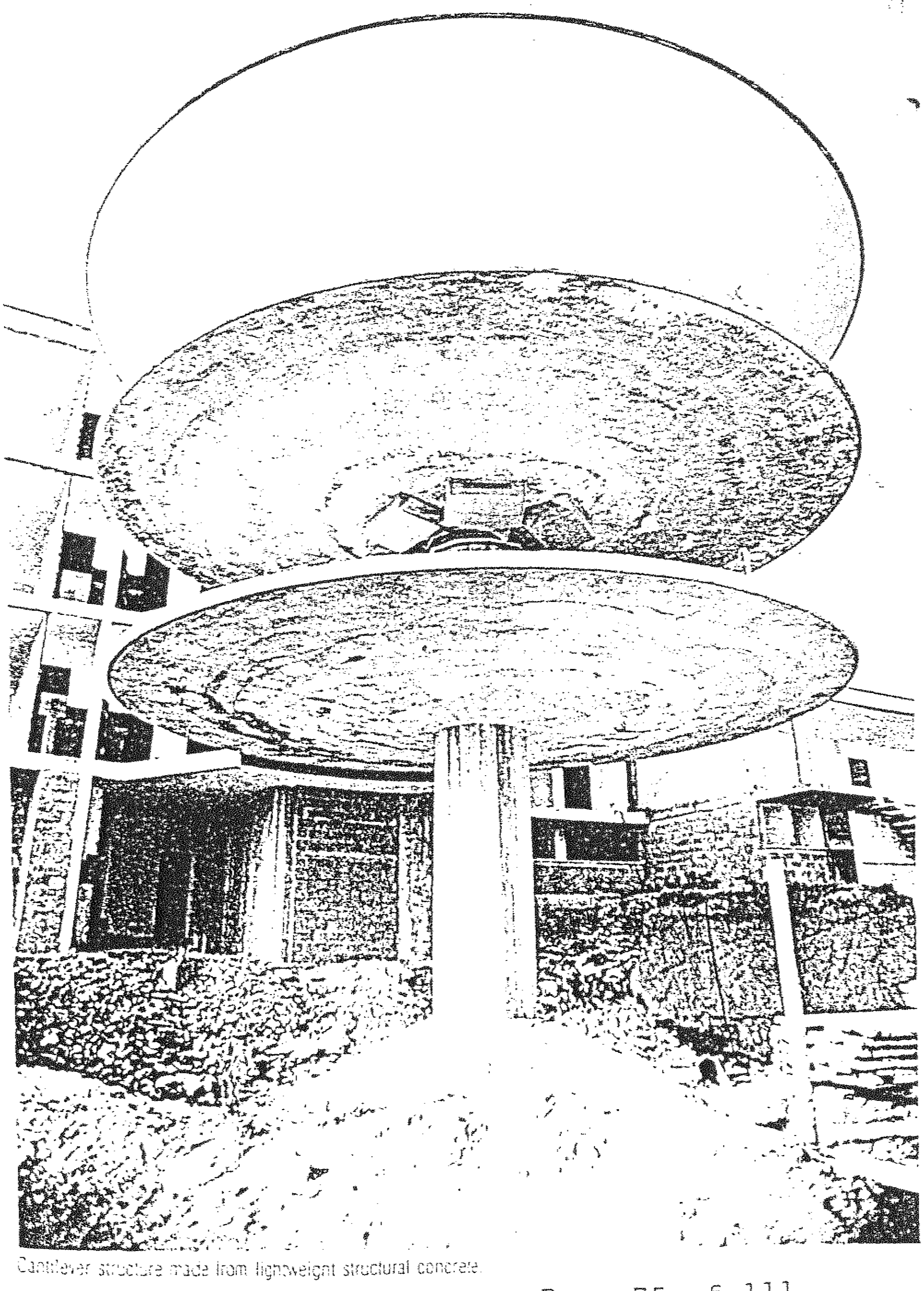
Construction in Munich, built during 1970-1972 [illegible] bearing capacity, the use of less reinforcement, higher structures, greater economy in lifting and transport etc.), and the lower thermal conductivity of the material.

The latter advantage has doubtless become the most attractive characteristic of lightweight concrete especially after the outbreak of the energy crisis in the 1970' s.

Although the cost of 1 m^3 of lightweight concrete is higher than that of an ordinary concrete, because of the increased cost of aggregates, the overall cost of a lightweight concrete building may prove more competitive than that of an ordinary concrete building; furthermore, the comparison is more favourable for the former when the structure is higher and the span greater [2].

If, in addition to building costs, account is also taken of operating costs, especially heating and air conditioning cost, the use of lightweight concrete for buildings offers still further economic advantages.

In antiseismic structures, lightweight concrete is even more attractive than ordinary concrete because of its lower modulus of elasticity and its lower specific gravity [3] [4].



Cantilever structure made from lightweight structural concrete.

TIAMAC® 11

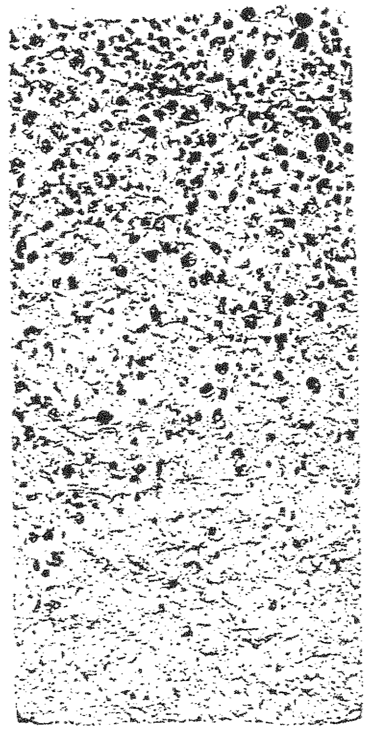
An essential component of lightweight rheoplastic concretes

A concrete containing lightweight aggregates is more difficult to mix and place than an ordinary concrete. Expanded clay aggregates tend to "float" because of their low specific gravity, especially in fluid concretes, in view of the reduced cohesion of the binding mortar.

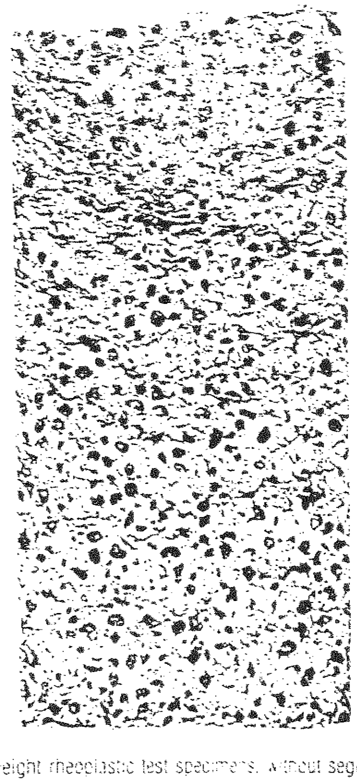
Segregation in concretes containing lightweight aggregates is the more evident the lower its specific gravity is. Consequently conglomerates with specific gravity lower than (1,300 Kg/m^3 - 2,190 lbs/yd^3) can mostly be used only for pressed blocks.

Because of segregation occurring in fresh lightweight concrete, the hardened conglomerate may display considerable irregularity in all of its properties: its strength, shrinkage, creep, permeability, durability, thermal conductivity etc., will consequently vary in different parts of the structure depending on the amount of lightweight aggregate locally present. In particular, its thermal insulation properties may be seriously affected by the presence of thermal bridges in those parts of the component where the lightweight aggregate is lacking.

By using TIAMAC 11 admixture in lightweight concretes, rheoplastic mixes can be obtained, i.e. fluid and non-segregating, yet with a low water/cement ratio. Furthermore, with TIAMAC 11 it is possible to obtain lightweight concretes of even lower specific gravities without any sign of segregation. In addition to overcoming the disad-

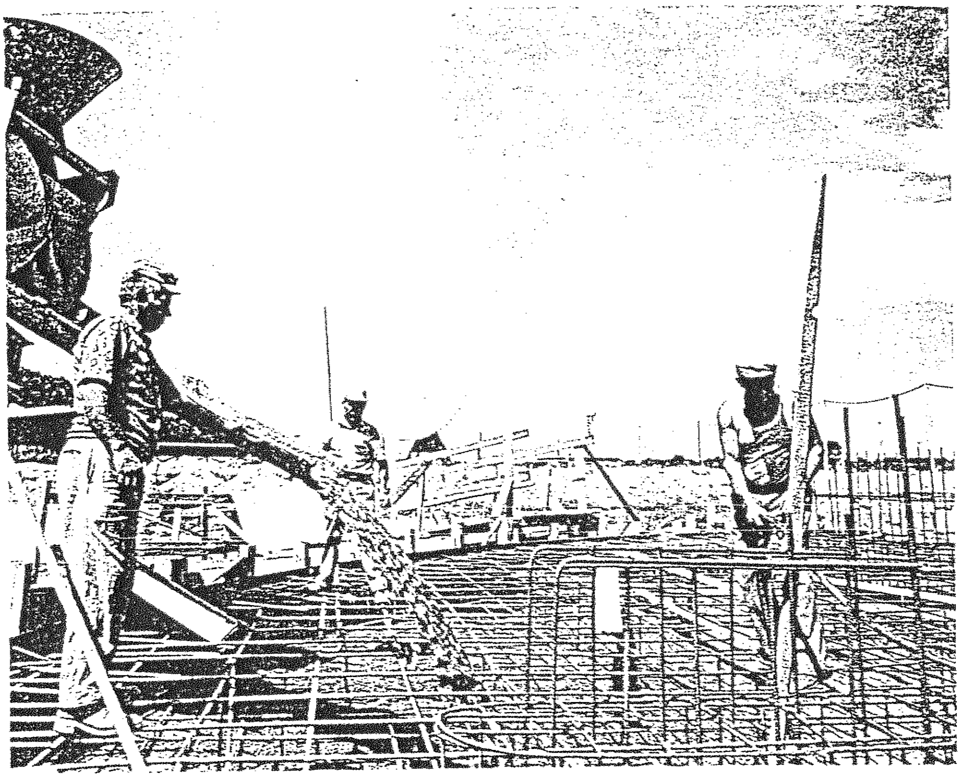


Lightweight concrete test specimens, with segregation.



Lightweight rheoplastic test specimens, without segregation.

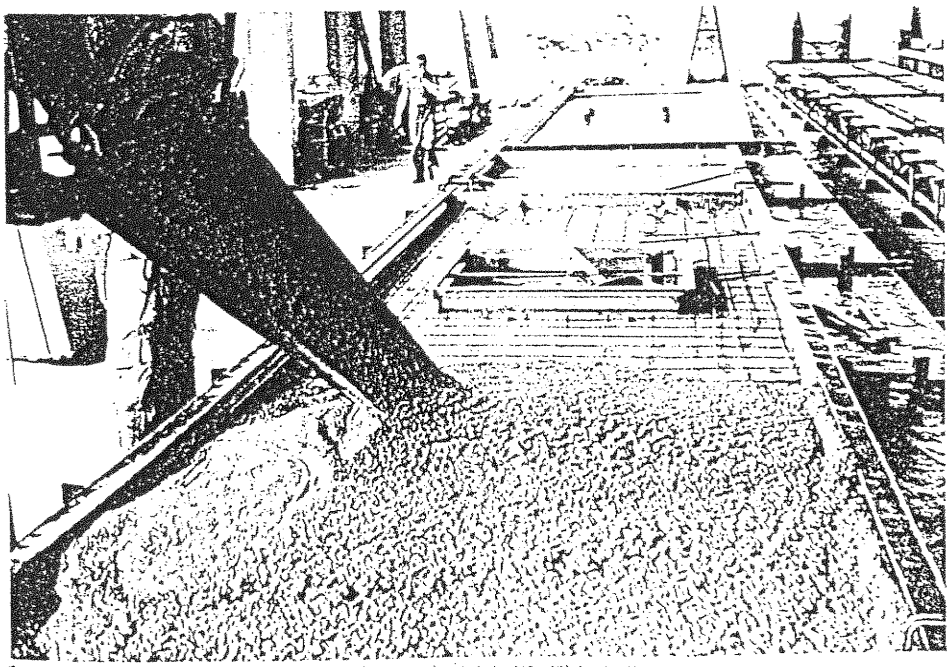
vantages due to segregation, rheoplastic lightweight concrete has all the advantages of very low water/cement ratio. In particular, rheoplastic lightweight concrete can be used to produce materials with better and more constant thermal insulation, its low permeability making thermal insulation not affected by humidity conditions of the environment. (see table 1).



Casting of lightweight rheoplastic concrete for a foundation structure [5].

Description of product

TIAMAC 11 admixture is composed of synthetic polymers specially designed to provide concrete with rheoplastic qualities. A rheoplastic lightweight concrete is fluid, a 200 mm (8 in.) slump, easily-flowing but at the same time free from any segregation of the lightweight aggregate.



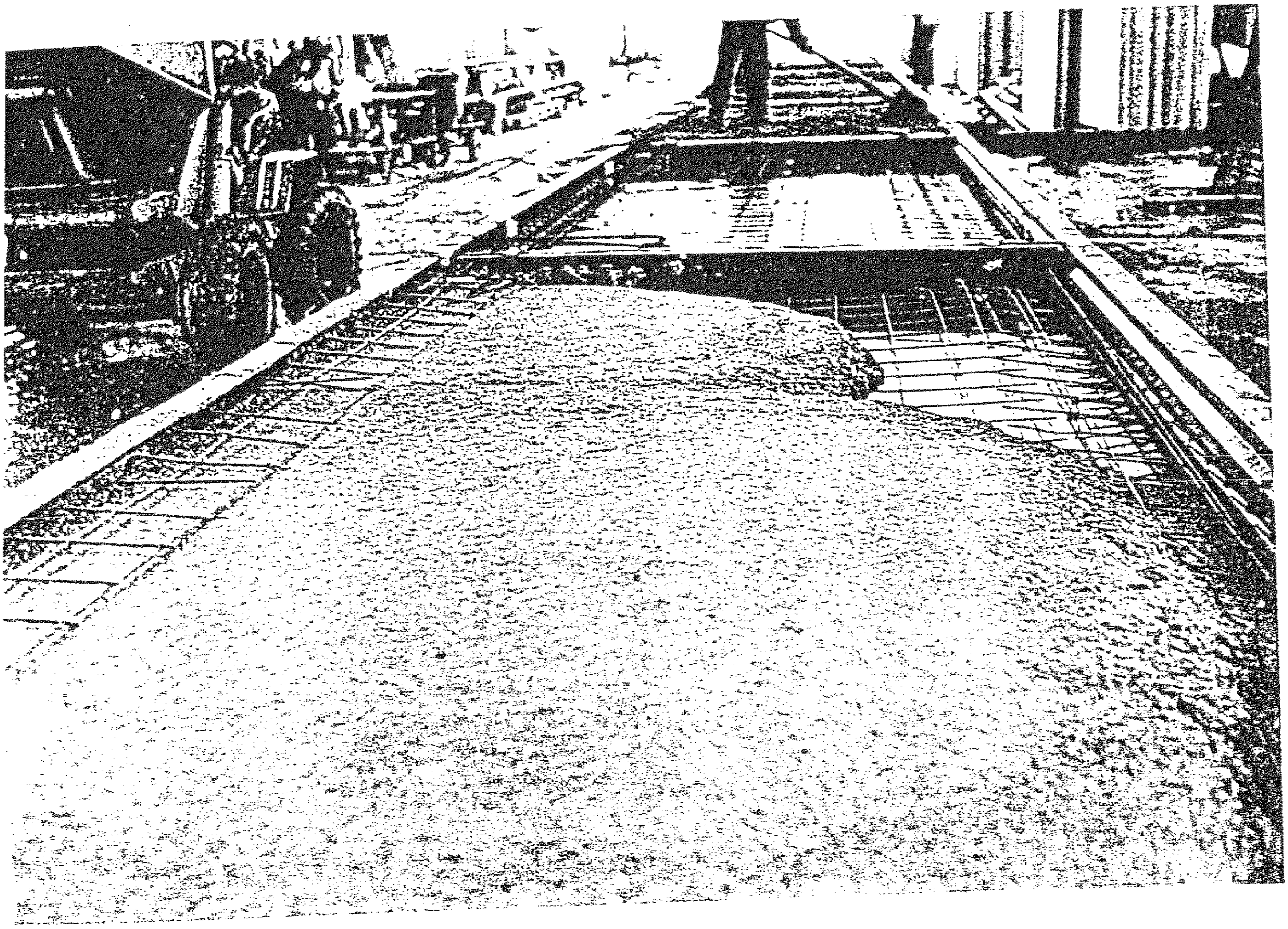
Casting of self-levelling lightweight rheoplastic concrete in a prefabrication plant

Advantages

TIAMAC 11 admixture considerably improves lightweight concrete properties in both fresh and hardened state. Advantages are the more evident, the lower the specific gravity of the desired concrete is.

Fresh concrete:

a) Workability. The addition of TIAMAC 11 admixture (1.5 ÷ 2.5 liters per 100 Kg of cement - 23-28 oz/100 lbs) increases concrete mix workability from rigid (10 ÷ 25 mm, 0.5 ÷ 1" slump) to very fluid or self-levelling (200 ÷ 240



Pouring lightweight rheoplastic concrete.

mm, 8 ÷ 10" slump). The period of workability depends on how much of the mixing water is absorbed by the lightweight nonsaturated aggregates.

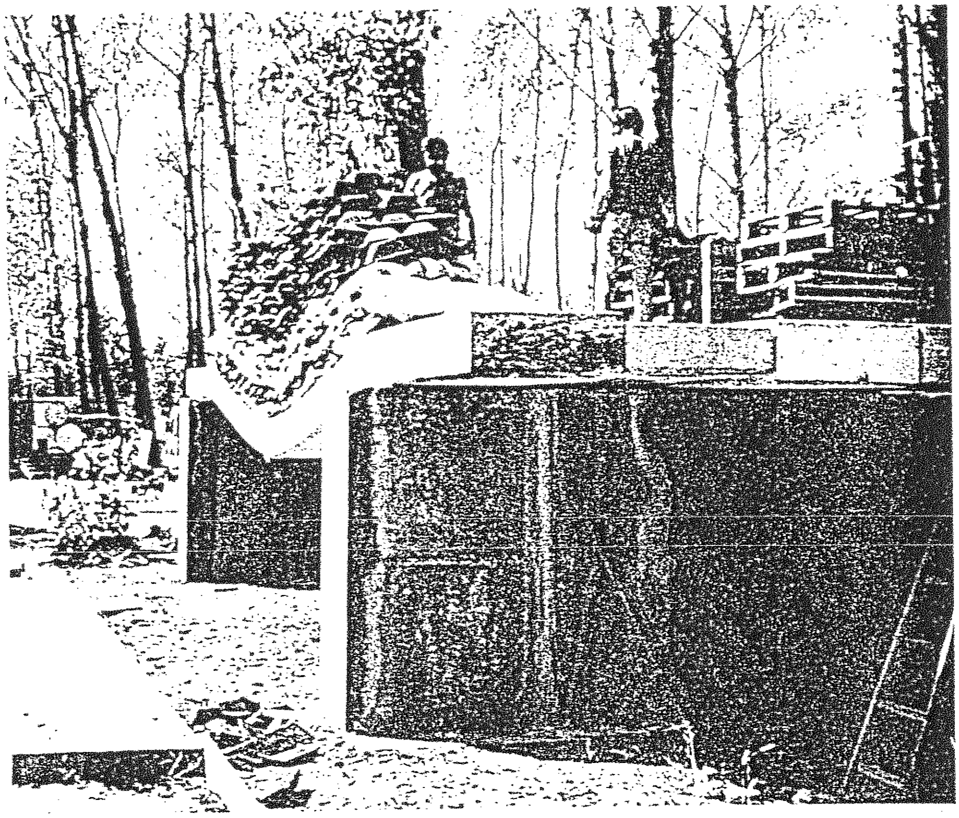
Rheoplastic lightweight concrete with TIAMAC 11 admixture can be rapidly and reliably placed without sophisticated compacting systems which cause segregation in ordinary lightweight concrete.

b) Water/cement ratio. A lightweight concrete containing TIAMAC 11 admixture requires 25 ÷ 30 % less water than a plain concrete of same workability.

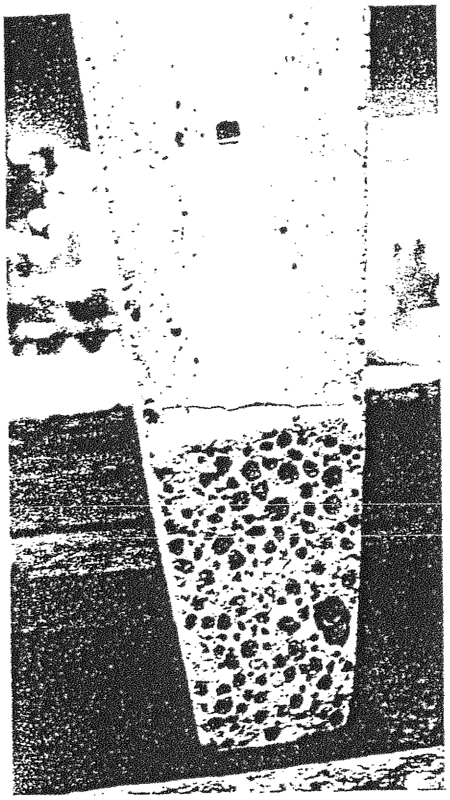
c) Cohesiveness. The cohesiveness of rheoplastic lightweight concrete with TIAMAC 11 admixture is so high to prevent lightweight aggregates to "float" to the surface, even in a concrete with specific gravity of 1.000 ÷ 1,200 Kg/m³ (1.685 ÷ 2.022 lbs/yd³.

In the hardened state

a) **Strengths.** The strengths of a rheoplastic lightweight concrete with TIAMAC 11 admixture are equal or greater than those of a no-slump light-weight concrete of same specific gravity.



Field tests on lightweight concrete with TIAMAC [6].



Cross-section of a beam: the even distribution of the expanded clay granules is clearly visible.

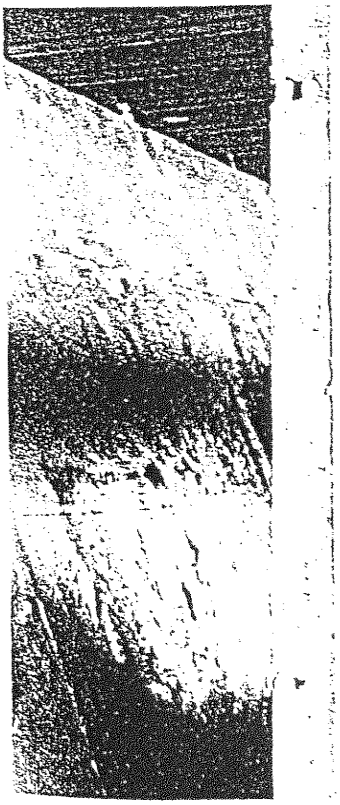
b) Homogeneity. TIAMAC 11 admixture enables to obtain homogeneous concrete structures as it makes the mix very cohesive and non-segregating. Consequently, heterogeneities in physical and mechanical characteristics (strength, modulus of elasticity, creep, shrinkage, thermal conductivity, etc.), very common in ordinary lightweight concrete, are eliminated (7).

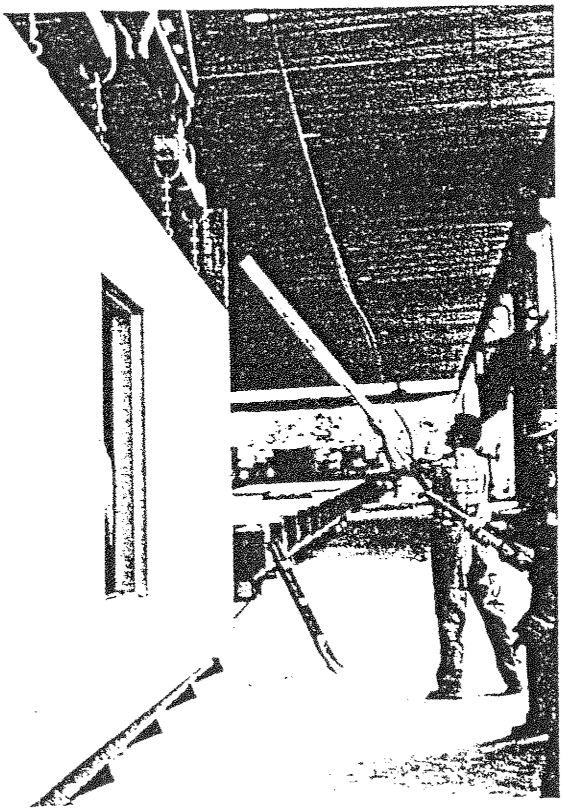
c) Permeability. The permeability of a rheoplastic lightweight concrete containing TIAMAC 11 admixture is much lower than that of a plain lightweight concrete without additive, the difference mostly depending on the low water/cement ratio.

d) Thermal Insulation. Thermal conductivity of rheoplastic lightweight concrete containing TIAMAC 11 admixture is the same of an identical plain concrete having same specific gravity and same humidity. However, as there is no segregation of the lightweight aggregate, self-levelling lightweight concretes with specific gravity up to 1,000 Kg/m^3 (1,685 lbs/yd^3) approx. can be made, thus greatly reducing thermal conductivity.

In addition, permeability being lower, thermal conductivity of lightweight concrete with TIAMAC 11 admixture does not modify when humidity conditions of the environment change; whilst, on the contrary, in a plain concrete, the real thermal insulation of the material decreases as its humidity increases.

Table 1 shows how thermal insulation rises as specific gravity and humidity of concrete drop. For example, at a given specific gravity a 5% increase in the humidity compared to a dry concrete results in a 75% increase in thermal conductivity.





[illegible] lightweight rheoplastic concrete with a specific gravity of 1,400 Kg/m^3

The table also shows the humidity factors which should be multiplied by the thermal conductivity of a dry concrete in order to obtain that of a wet concrete.

e) Shrinkage. The shrinkage of a rheoplastic lightweight concrete containing TIAMAC 11 admixture is less than that of a lightweight concrete without additive and having the same specific gravity, the difference being due to the reduction of the mixing water.

Where to use

The use of TIAMAC 11 admixture is recommended for all types of lightweight structural and/or heat-insulating concrete to obtain homogeneous, fluid and at the same time non-segregating mixes.

Dosage

Recommended dosage is 1.5 : 2.5 liters per 100 Kg of cement (23-38 oz/100 lbs).

How to use

TIAMAC 11 admixture is a ready-to-use liquid. It can be added to concrete at the same time as the water during the mixing process. It is recommended that at least 50% of the water is added to the mix before TIAMAC 11 is poured, so that the lightweight aggregate does not absorb part of the additive reducing its efficiency.

TABLE 1 - Influence of specific weight and humidity of the concrete on thermal conductivity (Cal/m h° C).

SPECIFIC WEIGHT	HUMIDITY (%)				HUMIDITY % VOLUME	HUMIDITY FACTOR
	0	3	5	20		
1.000	0,16	0,26	0,28	0,41	0	1,0
1.100	0,18	0,29	0,31	0,46		
1.200	0,21	0,33	0,37	0,54	1	1,3
1.300	0,24	0,38	0,42	0,61		
1.400	0,27	0,44	0,47	0,69	3	1,6
1.500	0,32	0,51	0,56	0,82		
1.600	0,36	0,57	0,63	0,92	5	1,75
1.700	0,41	0,66	0,72	1,05		
1.800	0,47	0,75	0,82	1,20	10	2,10
1.900	0,49	0,78	0,86	1,25		
2.000	0,61	0,98	1,07	1,56	15	2,35
2.100	0,69	1,11	1,21	1,76	20	2,55
2.200	0,78	1,25	1,36	1,99		
2.300	0,88	1,41	1,54	2,24	25	2,75
2.400	0,99	1,58	1,73	2.52		

EXAMPLE: On the basis of the thermal conductivity of dry concrete (0.36 Cal/m h° C, having a specific weight of 1,600 kg/m³), the thermal conductivity of a concrete having 5% humidity can be calculated by multiplying 0.36 by 1.75.

Packaging

TIAMAC 11 admixture is supplied in 55 and 210 liter (14 and 55 gall) drums or in bulk.

Precautions

TIAMAC 11 admixture must be stored in a place where temperature does not go below 2° C (35° F). If product has frozen, warm at 20° C (68° F) and agitate until completely reconstituted.

For further information, please apply to MAC Technical Service Department.

Suggested specification clause

All lightweight concrete (specifi gravity ......Kg/m³ or .....lbs/yd shall be rheoplastic, i.e. flui and flowable, and at the sam time cohesive and non-segrega ting, with at least a 200 mr (8") slump.

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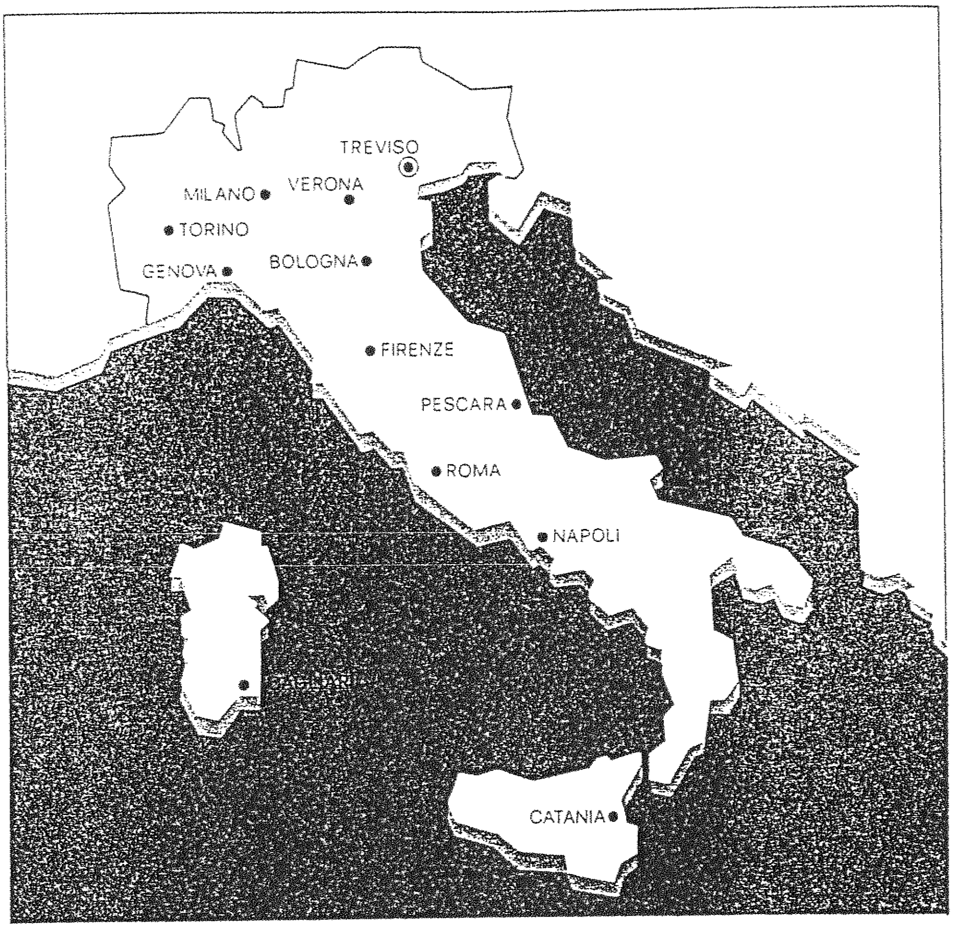

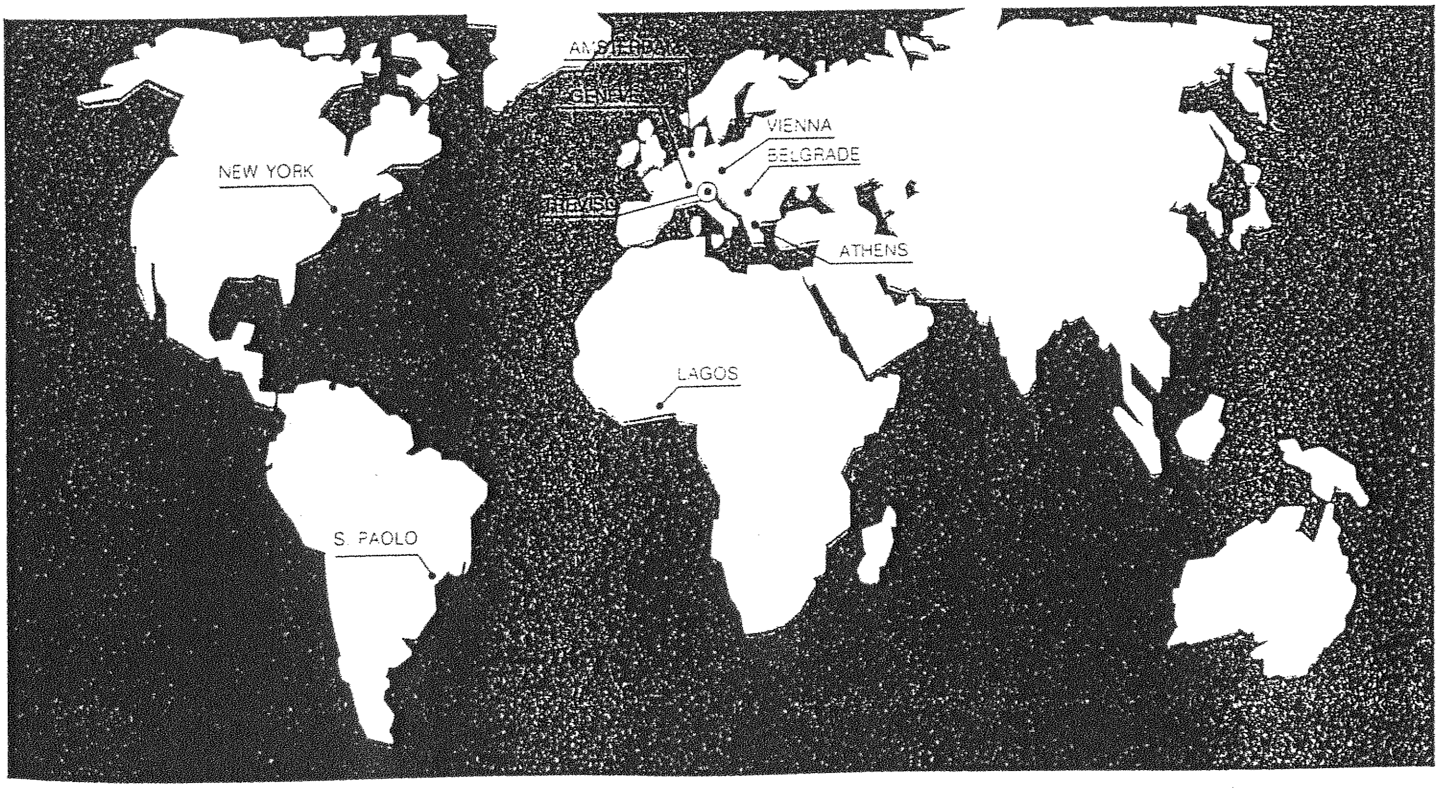

ITALIA

10143 Torino
Via G. Medici 23
Tel. 011/760777 - 766831

20123 Milano
Viale Papiniano 42
Tel. 02/8355731 - 2 - 3

37100 Verona
Via S. Eufemia 12
Tel. 045/26664

31100 Treviso
Vicolo Buranelli 33
Tel. 0422/40816 - 47370

16122 Genova
Via F. Romani 22/R
Tel. 010/882085

40122 Bologna
Via Delle Lame 118
Tel. 051/233312 - 228721

50129 Firenze
Via Di Barbano 6
Tel. 055/496609 - 486060

00199 Roma
Via Taro 3
Tel. 06/862114 - 855257 - 8441850

65100 Pescara
Via Tommaso Da Celano 8/10
Tel. 085/61752

80128 Napoli
Via Solario 14
Tel. 081/240136 - 248611

95027 Catania
Via Carrubbazza 46 (S. Gregorio)
Tel. 095/821895-6

09100 Cagliari
Via E. De Magistris 9
Tel. 070/664343

33100 Udine
Via Rialto 15
Tel. 0432/208037

ESTERO

SUISSE Genève
MAC PEM BETON S.A.
6 Rampe du Pont Rouge
1213 Petit Lancy 2
Tel. 022/422000 - Telex 22883

Zürich
Postfach 8953 Dietikon
Tel. 01/7405636

GREECE Athens 134
MAC BETON HELLAS S.A.
10 El. Venizelou Street
Tel. 3600740 - 3621204 - 3635245
Telex 215942

BRASIL Sao Paulo
MAC DO BRASIL
Avenida Paulista 1499
Tel. 2875652 - 2849606
Telex 011-23695

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Oficina 107
Tel. 723104/720352
Telex 23441 Edifica

USA New York City, N.Y. 10022
MAC USA Inc.
575 Madison Av. (Suite 1006)
Tel. (212) 486-0829
Telex 125864 WWBUS

Boca Raton Florida
Tel. 305 / 3680113

BENELUX 2396 AS Koudekerk
a/d Rijn (Netherlands)
SIGROMAC B.V. - Hoogewaard 214
Tel. 01714/4725
Telex 39172 METRO NL

ÖSTERREICH A 1190 Wien
EMBECON Spezialbaustoffe GmbH
Hutweidengasse 5/3
Tel. 0222/365148 - Telex 76316

JUGOSLAVIA Beograd
INDUSTRO INVEST
Licka 1-A
Tel. 680422 - Telex 12398

NIGERIA
c/o Treviso (Italy)

N 0142

SEDE E STABILIMENTO VIA VIC. DELLE CORTI 31100 TREVISO - C.P. 278 - TEL. 0422 [illegible] - TLX 410133 ADCEM

SIKAMENT T

Temporary Data Sheet
29 November 198

Thixotropic Super-plasticiser

Description

The **Sikament T** range of powdered admixtures is based upon combinations of high performance, water-reducing Sikament products, blended with balanced proportions of a long chain polymer thixotropic agent. Each product has a numbered suffix (e.g. Sikament T3) from 1-9, the higher the number the greater the thixotropy imparted to a concrete or mortar mix.

Advantages

* **Sikament T** combinations can eliminate segregation and bleeding in fluid and high workability mixes.
* Enable the pumping of concretes containing harsh or light-weight aggregates (Lytag).
* Control workability changes due to aggregate variations.
* Reduce water content and impart thixotropy to grouts and mortars.
* Avoid slumping of mortars in vertical applications.

Technical Data

Appearance:	Pale brown powder
Air Entraiment:	Nominal increase in fluid mixes. Significant increase in water-reduced highly thixotropic mixes. Chloride content: NIL (i.e.less than 0.1% w/w Cl-)
Storage life in sealed containers:	Minimum 12 months
Cement compatibility:	All portland Cements including SRPC
Effect on setting time:	Some retardation of set may occur at high dosages of some combinations and in particular with SRPC.
Effect of over dosage:	Enhanced water reduction, increased air content in highly thixotropic mixes, increased retardation where applicable.

Method of Use

In order to obtain optimum results Sikament T admixtures should be used only after carrying out trials. For maximum dispersion, Sikament T admixtures are best distributed onto the aggregates prior to mixing or distributed as evenly as possible into the mixer or truck before all the mixing water has been added. The addition of Sikament T admixtures into readymix trucks on site is often unavoidable. In such cases, the required dosage should be added to the mix and the drums rotated at maximum revolutions for a period of five minutes prior to discharge.

Dosage:
0.2-0.8% by weight of cementitious materials.

Trials are necessary to determine the dosage of particular blend to produce a desired effect. Our Admixture Division staff will be pleased to recommend products and dosages for initial trials.

For pumping lightweight structural concrete (Lytag), Sikament T3 at a dosage of 1kg/m3 has proved to be very effective. Pumping grade Lytag should always be used in mixes designed for pumping containing natural sand fines.

For pumping Lytag concrete under high pressure an increase in dosage of Sikament T3 or the use of a more thixotropic blend (e.g., Sikament T7) as determined by trials may prove necessary.

Lytag aggregates absorb water during pumping, and sampling for test purposes should take place after the concrete has passed through the pump.

Packaging
Sikament T products are supplied in pack sizes appropriate to specific applications. Our Admixture Division staff will be pleased to advise you.

Handling Precautions
Sika Products are generally quite harmless, providing certain precautions normally taken when handling chemicals are observed. Avoid contact with foodstuffs or food utensils. Avoid prolonged skin contact. Wear protective clothing, gloves, goggles, masks etc (barrier cream). In the event of contamination, wash thoroughly with water. If the eye or mouth are affected, wash with clean water immediately and obtain medical attention.

The 'Guide to the Safe Handling and Use of Sika Products' is available and we strongly advise that it is read prior to the use of Sika Products. Sika products should be stored in sealed containers away from the reach of children.

Important Notice
The information given in this data sheet is based on many years experience and is correct to the best of our knowledge. However, since the use of our products in accordance with the instructions given, and their success in application is dependent on a number of factors, we can only be responsible for the quality of our products at the time of despatch. Should any doubt arise about specification or application, our technical service department should be contacted immediately. As the information given herein is of a general nature, we cannot assume any responsibility. Success will always depend on the peculiarities of the individual case. We also refer to our standard conditions of sale.

Please consult our Admixture Division personnel for further information.

Fosroc®

CI/SfB Yu2

March 1988

CONPLAST® P509

Water reducing admixture

USES

CONPLAST P509 is a high performance plasticiser. Large water reductions can be made resulting in significantly increased early and ultimate strengths. Alternatively, greatly increased workability can be achieved without loss in strength.

Significant cement savings can be made, without reductions in either strength or workability.

Waterproofing of structural concrete may be achieved by reducing water permeability and penetration.

ADVANTAGES

Water reduction of up to 15% can be achieved.

High ultimate strengths.

Early strengths increased by up to 35%.

Greatly improves workability while maintaining strength.

Extends the time for concrete placement by retaining workability.

Improves durability by increasing density and lowering permeability.

DESCRIPTION

CONPLAST P509 is a formulated blend of polymeric materials based on hydrolysed carbohydrate derivatives. It is designed to give maximum cement particle dispersion without producing unwanted secondary side effects.

STANDARDS

CONPLAST P509 complies with the requirements of BS 5075: Part 1, and with ASTM C494, Types A and D.

PROPERTIES

Calcium chloride content: Nil to BS 5075.

Air entrainment: Less than 1% additional air is entrained.

Specific gravity: Typically 1.20 at 20°C.

Compatibility: CONPLAST P509 can be used with all types of Portland cement and with PFA, silica fume and ground slag.

CONPLAST P509 is compatible with all other FOSROC CONPLAST admixtures, but should be added separately to the mix.

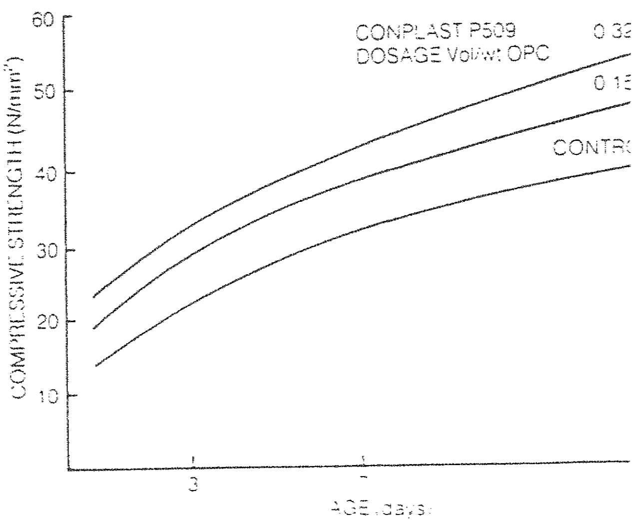
Water reduction: A reduction in mixing water of up to 15% can be achieved whilst maintaining workability.

Cement reduction: Cement content reductions of up to 15% can be achieved whilst maintaining original strengt and workability specifications.

Setting time: For Ordinary Portland Cement mixes, setting time is extended by less than 1 hour at normal dosage rates and equal workability. For sulphate resisting Portland Cement mixes a degree of retardation will occur. This may be best monitored by site mix design trials.

Workability: The addition of CONPLAST P509 without reduction in the water content, increases the slump and significantly improves concrete flow characteristics without decrease in concrete strength.

Compressive strength: Typical compressive strengths



Member of the Foseco Minsep Group
A Fosroc International Company

Certificate No. FM610
QAS 2514/209.

INSTRUCTIONS FOR USE

Dosage:
The optimum dosage is best determined by site trials with a specific concrete mix, which enables the effects on workability, strength gain and/or cement reduction to be measured. The rate of addition is typically between 160 and 420ml per 100kg of cement.

For waterproofing purposes the recommended dosage range is 400 to 500ml per 100kg of cement. At this dosage range, retardation of set will occur. This should be allowed for during construction.

Dispensing:
The correct quantity of CONPLAST P509 should be measured by means of a recommended dispenser, consult your local Fosroc Office or representative for advice regarding suitable equipment and its installation. The measured quantity of CONPLAST P509 should be added directly to the mixer preferably at the same time as the mixing water.

Curing:
Normal curing methods such as water spray, polythene sheeting, wet hessian or a curing membrane of the CONCURE* type should be used.

Cleaning:
Spillages of CONPLAST P509 can be removed with water.

Overdosing:
An overdose of double the recommended amount of CONPLAST P509 can result in significant retardation of the initial set of the concrete. The ultimate strength of the concrete will not be impaired and will, generally, be increased. A considerable increase in workability will be achieved.

PRECAUTIONS

Health & Safety:
CONPLAST P509 should not come in contact with skin and eyes or be swallowed.

Protective gloves and goggles should be used.

Splashes to skin should be washed with soap and water. Splashes to eyes should be washed with plenty of clean water and medical advice sought. If swallowed, seek medical attention immediately. DO NOT induce vomiting.

Fire:
CONPLAST P509 is non flammable.

STORAGE

CONPLAST P509 has a minimum shelf life of 12 months provided the temperature is kept within the range 2°C to 50°C. Should the material become frozen, it must be completely thawed and thoroughly mixed before use.

PACKAGING

CONPLAST P509: In 210 litre drums. Also in tanker loads. For larger users storage tanks and dispensing equipment can be supplied.

SUPPLY

Contact your local FOSROC Office or Representative.

TECHNICAL SERVICE

FOSROC provides a technical advisory service for on-site assistance and advice on evaluation trials and dispensing equipment.

*See separate data sheet

FOSROC CCD LIMITED
Vimy Road, LEIGHTON BUZZARD,
Beds LU7 7EW
Tel (0525) 852000 Telex 826156 FOSROC G Fax (0525) 852002

Fosroc Offices at
Telford 0952 618021
Manchester 061 873 7921
Spennymoor 0388 816529
Glasgow 041 771 0066

89/3408E/3379

Fosroc®

CI/SfB Yu2

January 1988

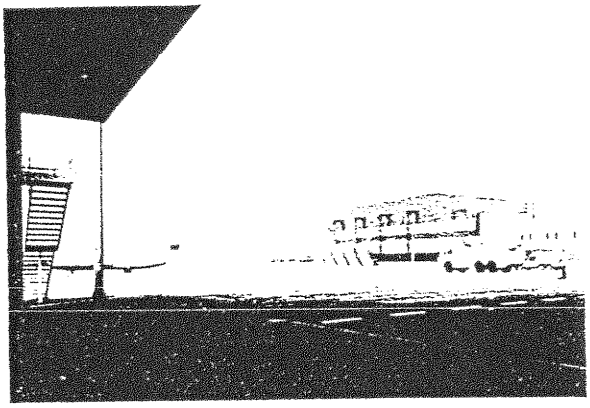
CONPLAST® AEA

Air entraining admixture

USES

To produce air entrained concrete for increased durability, resistant to damage by frost and de-icing salts, and to improve the cohesion and workability of concrete mixes where poorly graded aggregates must be used.

Typical applications include concrete roadways and bridge decks, airport runways and taxiways and other extensive areas of concrete exposed to potential frost damage. Also in any situation where bleeding, segregation or sand runs occur.



CONPLAST AEA in aprons and taxiways at Birmingham International Airport, England.

ADVANTAGES

Provides concrete with resistance to freezing and thawing.

Improves cohesion, reduces segregation and bleeding.

Gives dense, uniform, close textured surface to concrete.

Excellent air bubble stability.

Consistent performance, even with changes in aggregate quality and ambient temperature.

Effective in low workability concrete.

DESCRIPTION

CONPLAST AEA is a chloride-free admixture based on neutralised vinsol resin and is supplied as a dark brown solution. CONPLAST AEA acts on the interface of the cement/aggregate particles and mixing water to produce microscopic air bubbles evenly distributed throughout the concrete.

STANDARDS

CONPLAST AEA complies with BS 5075: Part 2, BS 4887, ASTM C260 and the DpT Specification for Highway Works 1986, Clause 1001 as an air entraining admixture.

PROPERTIES

Chloride content: Nil to BS 5075.

Specific gravity: Typically 1.02 at 20°C.

Air entrainment: Fig. 1 demonstrates the effect of CONPLAST AEA on typical concrete mixes.

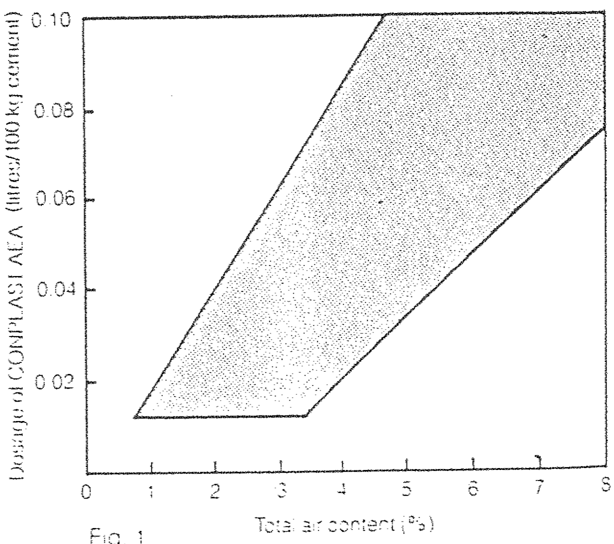


Fig. 1

Typical characteristics of representative mixes.

CONPLAST AEA (litres/100 kg cement)	Slump (mm)	Air entrainment (%)	Water/cement ratio	Compressive strength (N/mm²)		
				1 day	7 days	28 days
nil	50	nil	0.56	8	35	48
0.06	90	4.5	0.56	6	33	44
0.06	50	4.5	0.50	7	34	46

The degree of air entrainment will be affected by a number of factors:

Sand content: The quantity of air entrained will increase with increasing sand content – typically from 4.5 to 6.0% for a sand content increase from 35% to 45%.

Cement fineness and content: The amount of air entrained reduces with an increase in cement fineness. Air content decreases with increasing cement content. A 1% air loss may be typical for a cement content increase of 90 kg/m^3.

Organic impurities: Carbon can reduce the effectiveness of CONPLAST AEA. This does not normally create a problem, but care may have to be taken when using PFA, certain pigments or lignite bearing sands.

Concrete temperature: A temperature increase will reduce air content, eg: a rise from 10°C to 32°C may halve the amount of air entrained. In practice, daily fluctuations are much smaller and do not cause significant variations.

Mixing and pumping: Variations of mixer type and transit time will change the level of air entrainment. Small losses of air may occur during pumping. With long pipelines, air content in excess of 5% may seriously reduce the efficiency of the pump.

Compaction of concrete: Entrained air will not be lost by normal vibration, though prolonged vibration is best avoided.

Low workability concrete: ie: slumps of less than 25 mm or compacting factors between 0.80 to 0.85 may require an increased dosage of CONPLAST AEA in order to achieve the normal required air content.

Setting time: Negligible effect at normal dosage rates.

Compatibility: CONPLAST AEA is compatible with other FOSROC CONPLAST admixtures, but it is recommended that all admixtures be added to concrete separately.

CONPLAST AEA can be used with all types of Portland cements. For advice on special cements or cement replacement materials, consult the Fosroc Technical Sales Department.

INSTRUCTIONS FOR USE

Dosage

The optimum dosage must be determined by site trials with the particular concrete mix. As a guide, a dosage of 0.06 litres/100 kg cement will generally give an air content of 4½%±1½% with cement contents of 300-350 kg/m^3.

Once the dosage rate has been established care should be taken to ensure consistency of raw materials supplied and the mixing and delivery procedures. The air content should therefore be checked regularly by such means as the BS 1881 or ASTM C231 pressure methods.

Overdosing

An overdose of double the recommended amount of CONPLAST AEA can result in a slight increase in setting time and a reduction in compressive strength.

Dispensing

The correct quantity of CONPLAST AEA should be measured by means of a recommended dispenser. The Fosroc Technical Sales Department should be consulted regarding suitable equipment and its installation.

CONPLAST AEA should be added directly to the mixer and best results are obtained if added at the same time as the mixing water.

Curing

A CONCURE* curing membrane should be used, or alternative curing methods such as polythene, water spray or wet hessian.

Cleaning

Spillages of CONPLAST AEA can be removed with water.

PRECAUTIONS

Health and Safety

CONPLAST AEA is alkaline and should not come into contact with skin and eyes or be swallowed. Protective gloves and goggles should be worn. Splashes to skin should be washed with water, splashes to eyes should be flushed immediately with plenty of clean water and medical advice sought. If swallowed seek medical attention immediately – DO NOT induce vomiting.

Fire

CONPLAST AEA is non flammable.

STORAGE

CONPLAST AEA has a minimum shelf life of 12 months provided the temperature is kept within the range of 2°C to 50°C.

PACKAGING

CONPLAST AEA is supplied in 25 and 210 litre drums. Also in tanker loads. For larger users, storage tanks and dispensing equipment can be supplied.

SUPPLY

Contact your local FOSROC Office or representative.

TECHNICAL SERVICE

Fosroc provides a technical advisory service for on-site assistance and advice on evaluation trials and dispensing equipment.

ADDITIONAL INFORMATION

Technical data and guidance can be provided on a wide range of admixtures and concreting aids including accelerators, retarders, waterproofers, mould release agents, workability aids and materials

*See separate data sheet.

CONPLAST AEA

Fosroc

FOSROC CCD LIMITED
Vimy Road, LEIGHTON BUZZARD,
Beds LU7 7EW
Tel (0525) 852000 Telex 826156 FOSROC G Fax (0525) 852002

Fosroc Offices at
Telford 0952 618021
Manchester 061 873 7921
Spennymoor 0388 816529
Glasgow 041 771 0066

APPENDIX 8

LABORATORY TRIALS FOR PUMPABLE MIXES

LABORATORY TRIALS FOR PUMPABLE MIXES

SET	1				
TRIAL	1	2	3	4	5
A/C RATIO	4/1	3/1	4/1	4/1	4/1
CEMENT CONTENT (kg/m^3)	240	310	240	240	240
% FINES TOTAL	71.0	59.0	71.0	71.0	71.0
% PUMICE FINES	71.0	59.0	71.0	71.0	71.0
% SAND FINES	----	----	----	----	----
ADMIXTURE	CORMIX PA	CORMIX PA	NIL	CORMIX PA	CORMIX PA
DOSEAGE (% cement)	0.2	0.2		0.2	0.4
NOMINAL MIX PROPORTION					
CEMENT	1	1	1	1	1
FINES	2.84	1.77	2.84	2.84	2.84
COARSE	1.16	1.23	1.16	1.16	1.16
FREE WATER	1.23	0.91	1.23	1.23	1.23
NOMINAL BATCH WEIGHTS - ssd (kg)					
TOTAL	15.00	15.00	15.00	15.00	15.00
CEMENT	2.41	3.05	2.41	2.41	2.41
FINES	6.84	5.41	6.84	6.84	6.84
COARSE	2.79	3.75	2.79	2.79	2.79
WATER	2.96	2.78	2.96	2.96	2.96
ACTUAL BATCH WEIGHTS - wet (kg)					
TOTAL			14.61	14.33	14.33
CEMENT			2.41	2.41	2.41
FINES*			7.32	7.32	7.32
COARSE**			2.90	2.90	2.90
ADDED WATER			1.98	1.70	1.70
TOTAL FREE WATER			2.57	2.29	2.29
FREE WATER:CEMENT RATIO			1.07	0.95	0.95
SLUMP (mm)	150+	150+	150-collapse	150+	150+
APPEARANCE		improved workability and cohesiveness, less bleeding	bleeding heavily, segregating	reduced bleeding, but segregating	reduced bleeding, but segregatin
PLASTIC DENSITY (kg/m^3)			1550	1480	1460
STRENGTH (N/mm^2)					
AT 7 DAYS			11.0	11.0	11.5
AT 40 DAYS			18.5/18.5	17.5/18.0	17.5/18.5
SATURATED DENSITY (kg/m^3)					
AT 7 DAYS			1520	1460	1470
AT 40 DAYS			1540/1550	1510/1480	1490/1500

* moisture content of pumice 7.0% above s.s.d
** moisture content of pumice 4.0% above s.s.d

LABORATORY TRIALS FOR PUMPABLE MIXES

SET	2			
TRIAL	1	2	3	4
A/C RATIO	4/1	4/1	4/1	4/1
CEMENT CONTENT (kg/m^3)	240	240	240	240
% FINES TOTAL	71.0	66.2	71.0	71.0
% PUMICE FINES	71.0	66.2	71.0	71.0
% SAND FINES	----	----	----	----
ADMIXTURE	TIAMAC II	TIAMAC II	SIKAMENT T3	SIKAMENT T3
DOSEAGE (% cement)	1.21/100kg cement	1.21/100kg cement	0.5% cement	1.0% cement
NOMINAL MIX PROPORTION				
CEMENT	1.00	1.00	1.00	1.00
FINES	2.84	2.65	2.84	2.84
COARSE	1.16	1.35	1.16	1.16
FREE WATER	1.23	1.22	1.23	1.23
NOMINAL BATCH WEIGHTS - ssd (kg)				
TOTAL	9.96	9.95	9.96	9.96
CEMENT	1.60	1.60	1.60	1.60
FINES	4.54	4.24	4.54	4.54
COARSE	1.86	2.16	1.86	1.86
WATER	1.96	1.95	1.96	1.96
ACTUAL BATCH WEIGHTS - wet (kg)				
TOTAL	9.69	9.79	9.99	9.99
CEMENT	1.60	1.60	1.60	1.60
FINES*	4.95	4.62	1.97	1.97
COARSE**	1.97	2.29	1.97	1.97
ADDED WATER	1.17	1.28	1.47	1.47
TOTAL FREE WATER	1.69	1.79	1.99	1.99
FREE WATER:CEMENT RATIO	1.06/1	1.12/1	1.24/1	1.24/1
SLUMP (mm)	150+	150+	150+	150+
APPEARANCE	harsh, slight segregating	harsh, bleeding badly	harsh, bleeding	harsh, bleeding,
PLASTIC DENSITY (kg/m^3)	1425	1430	1455	
STRENGTH (N/mm^2) AT 7 DAYS	10.0/10.5	10.5/10.0	8.0/8.5	
SATURATED DENSITY (kg/m^3) AT 7 DAYS	1495/1515	1495/1485	1500/1500	

* moisture content of pumice 9% above s.s.d
** moisture content of pumice 6% above s.s.d

89/3408E/3379

LABORATORY TRIALS FOR PUMPABLE MIXES

SET	3			
TRIAL	1	2	3	4
A/C RATIO	2.47/1	2.47/1	2.47/1	2.47/1
CEMENT CONTENT (kg/m³)	350	350	350	350
% FINES TOTAL	59.5	62.5	65.0	65.0
% PUMICE FINES	59.5	62.5	65.0	32.5
% SAND FINES	----	----	----	32.5
ADMIXTURE	SIKAMENT T3	SIKAMENT T3	SIKAMENT TIAMAC T3 + II	SIKAMENT TIAMAC T3 + II
DOSEAGE (% cement)	0.43%	0.43%	0.40% 1.51/100kg	0.40% 1.51/100kg
NOMINAL MIX PROPORTION				
CEMENT	1.00	1.00	1.00	1.00
FINES	1.47	1.54	1.61	1.61
COARSE	1.00	0.93	0.86	0.86
FREE WATER	0.81	0.81	AS REQUIRED	AS REQUIRED
NOMINAL BATCH WEIGHTS - ssd (kg)				
TOTAL	10.00	10.00		
CEMENT	2.34	2.34	2.88	5.78
FINES	3.43	3.60	4.64	9.28
COARSE	2.34	2.17	2.48	5.00
WATER	1.89	1.89	AS REQUIRED	AS REQUIRED
ACTUAL BATCH WEIGHTS - wet (kg)				
TOTAL	10.00	10.00	12.17	22.30
CEMENT	2.34	2.34	2.88	5.78
FINES*ø	3.74	3.92	5.06	10.02
COARSE**	2.48	2.30	2.63	5.30
ADDED WATER	1.44	1.44	1.60	2.80
TOTAL FREE WATER	1.89	1.89	2.17	3.84
FREE WATER:CEMENT RATIO	0.81/1	0.81/1	0.75/1	0.66/1
APPEARANCE	POOR COHESION	POOR COHESION	BLEEDING BADLY	MORE COHESIVE PUMPABLE
PLASTIC DENSITY (kg/m³)			1555	1725
SATURATED DENSITY (kg/m³) AT DEMOULDING				1775

* moisture content of pumice 9.0% above s.s.d
** moisture content of pumice 6.0% above s.s.d
ø moisture content of sand 7.0% above s.s.d

89/3408E/3379

LABORATORY TRIALS FOR PUMPABLE MIXES

CT	4		
RIAL	1	2	3
/C RATIO	3.5/1	2.5/1	3.73/1
EMENT CONTENT (kg/m^3)	300	400	285
FINES TOTAL	69.2	64.8	69.7
PUMICE FINES	34.6	32.4	34.85
SAND FINES	34.6	32.4	34.85
DMIXTURE	SIKAMENT T3	SIKAMENT T3	SIKAMENT T3
OSEAGE (% cement)	0.4	0.4	0.4
NOMINAL MIX PROPORTION			
CEMENT	1.00	1.00	1.00
FINES	2.43	1.59	2.60
COARSE	1.09	0.92	1.13
FREE WATER	AS REQUIRED	AS REQUIRED	0.93
NOMINAL BATCH WEIGHTS - ssd (kg)			
TOTAL	10.00	16.43	10.01
CEMENT	1.85	4.00	1.77
FINES	4.50	6.36	4.60
COARSE	2.01	3.46	2.00
WATER	1.63	2.61	1.64
ACTUAL BATCH WEIGHTS - wet (kg)			
TOTAL	10.19	16.54	10.05
CEMENT	1.85	4.00	1.77
FINES*ø	4.86	6.87	4.96
COARSE**	2.13	3.67	2.12
ADDED WATER	1.35	2.00	1.20
TOTAL FREE WATER	1.83	2.72	1.69
FREE WATER:CEMENT RATIO	0.99/1	0.68/1	0.95/1
SLUMP (mm)	150+ Pumpable	150+ Pumpable	150+ Pumpable
PLASTIC DENSITY (kg/m^3)	1640	1650	1615

* moisture content of pumice 9.0% above s.s.d
** moisture content of pumice 6.0% above s.s.d
ø moisture content of sand 7.0% above s.s.d

89/3408E/3379

LABORATORY TRIALS FOR PUMPABLE MIXES

	5			
ET				
TRIAL	1	2	3	
A/C RATIO	2.15/1	2.15/1	2.15/1	
EMENT CONTENT (kg/m^3)	400	400	400	
FINES TOTAL	65.0	69.4	65.0	
% PUMICE FINES	65.0	69.4	65.0	
SAND FINES	----	----	----	
DMIXTURE	SIKAMENT T3	SIKAMENT T3	SIKAMENT T3 +	CORMIX AE4
DOSEAGE (% cement)	0.51%	0.51%	0.4%	200ml/50kg
NOMINAL MIX PROPORTION				
CEMENT	1.00	1.00	1.00	
FINES	1.47	1.50	1.40	
COARSE	0.78	0.66	0.75	
FREE WATER	0.68	0.56	0.68	
NOMINAL BATCH WEIGHTS - ssd (kg)				
TOTAL				
CEMENT	3.92	3.91	3.92	
FINES	5.49	5.86	5.49	
COARSE	2.94	2.59	2.94	
FREE WATER	2.65	2.64	2.65	
ACTUAL BATCH WEIGHTS - wet (kg)				
TOTAL				
CEMENT	3.92	3.91	3.92	
FINES*	5.76	6.15	5.76	
COARSE**	3.06	2.69	3.06	
ADDED WATER	2.10	2.20	2.00	
TOTAL FREE WATER	2.49	2.59	2.39	
FREE WATER:CEMENT RATIO	0.64/1	0.66/1	0.61/1	
SLUMP (mm)	150+	150+	150+	
APPEARANCE	SLIGHTLY HARSH	GOOD, COHESIVE PROBABLY PUMPABLE	GOOD, NO BLEEDING, COHESIVE, PROBABLY PUMPABLE	
PLASTIC DENSITY (kg/m^3)		1555	1340	

* moisture content of pumice 9.0% above s.s.d
** moisture content of pumice 6.0% above s.s.d
ø moisture content of sand 7.0% above s.s.d

APPENDIX 9

FIELD TRIAL OF PUMPABLE CONCRETE

FIELD TRIAL PUMPABLE CONCRETE

DATE :	24-6-90	24-6-90	24-6-90	24-6-90
BATCH :	1	2	3	4
VOLUME : (M^3)	1.5	1.0	1.0	1.0
MIX DESIGN (kg/m^3)				
cement	400	350	400	300
pumice fines	600	670	640	695
pumice coarse	265	230	230	220
ADMIXTURES				
Sikament T3 (%)	0.5	0.5	0.5	0.5
Conplast P509 (ml/100kg cement)	200	200	200	200
Conplast AEA (ml/100kg cement)	100	100	100	100
A/C RATIO	2.16/1	2.57/1	2.18/1	3.05/1
% FINES	69.4	74.4	73.6	76.0
WORKABILITY	self levelling	self levelling	self levelling	self levelling
APPEARANCE	harsh	good	good	good
PUMPING (pressure)	laboured	easy (100 bar)	easy (100-150 bar)	easy (200 bar max)
COMPRESSIVE STRENGTH (N/mm^2)				
at 3 days		20.0	25.0	21.0
at 7 days		24.0	29.0	25.5
at 28 days		28.5/29.0	28.0/32.0	27.5/24.5
28 days mean		29.0	30.0	26.0
SATURATED DENSITY (kg/m^3 to nearest $5kg/m^3$)				
at 3 days		1595	1670	1665
at 7 days		1610	1695	1650
at 28 days		1635/1615	1710/1715	1650/1665
28 days mean		1625	1715	1660
DEMOULDING DENSITY (kg/m^3) to nearest $5kg/m^3$ — 1		1580	1680	1622
2		1588	1680	1645
3		1576	1674	1610
4		1600	1654	1625
mean		1586	1672	1625

89/3408E/3379

SUPPLEMENTARY LABORATORY TRIALS FOR PUMPABLE CONCRETE

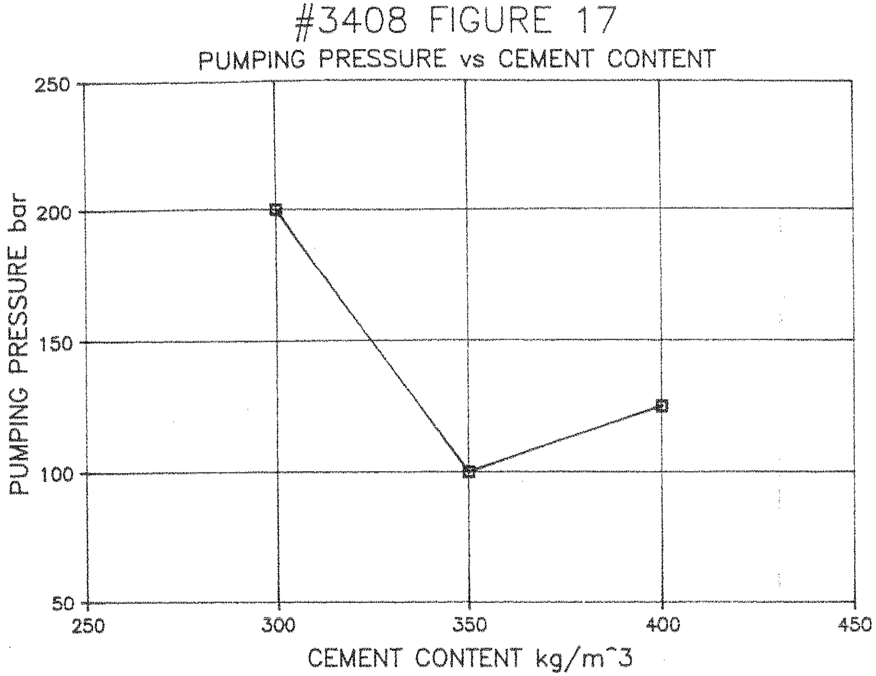
MIX	1	2	3
CEMENT CONTENT (kg/m^3)	400	350	300
AGGREGATE:CEMENT RATIO	2.18/1	2.57/1	3.05/1
% FINES	73.6	74.4	76.0
ADMIXTURES	T3/P509/AEA	T3/P509/AEA	T3/P509/AEA
BATCH WEIGHTS (ssd)(kg)			
TOTAL	15.0	12.0	12.0
CEMENT	4.73	3.36	2.96
FINES	7.56	6.42	6.84
COARSE	2.71	2.22	2.19
BATCH WEIGHTS (wet)(kg)			
TOTAL	15.49	12.41	12.43
CEMENT	4.73	3.36	2.96
FINES*	7.94	6.74	7.18
COARSE**	2.82	2.31	2.28
WATER ADDED (kg)	1.95	1.62	1.55
WATER-AGGREGATES (kg)	0.49	0.41	0.43
TOTAL FREE WATER (kg)	2.44	2.03	1.98
FREE W/C RATIO	0.52/1	0.61/1	0.67/1
SLUMP (mm)	200	200+	200+
APPEARANCE	Good, Cohesive	Good, Cohesive	Good, Cohesive
PLASTIC DENSITY (kg/m^3)	1415	1405	1395
BATCH WEIGHTS ($kg)/m^3$ (ssd) Ø			
CEMENT	384	336	295
FINES	613	642	683
COARSE	220	222	219
WATER	198	205	198
TOTAL	1415	1405	1395
ADMIXTURES			
SIKAMENT T3 (% cement)	0.5	0.5	0.5
CONPLAST P509 (ml/100kg cement)	200	200	200
CONPLAST AEA (ml/100kg cement)	100	100	100

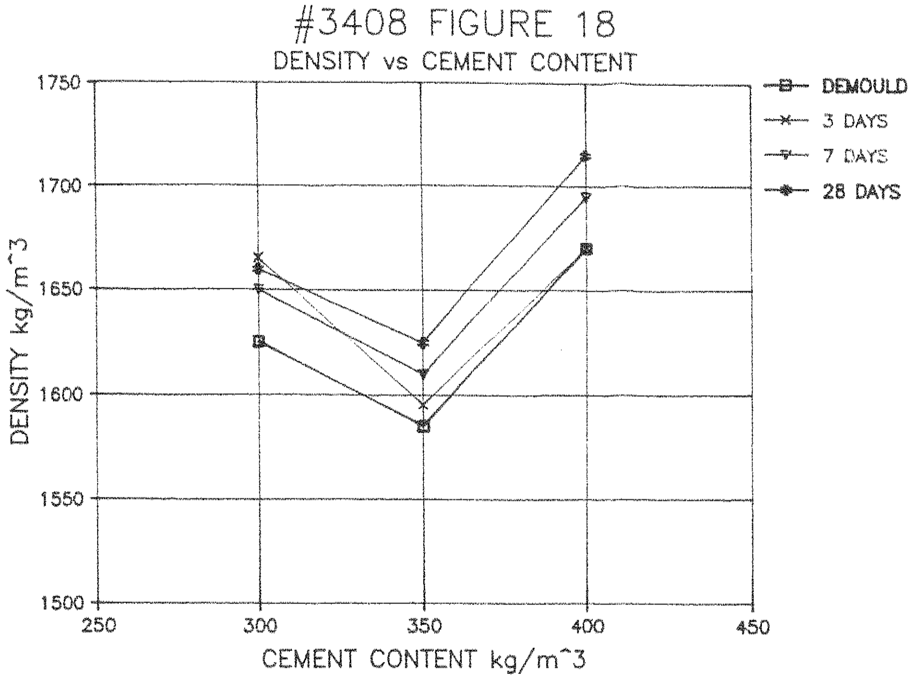
Ø based on plastic density
* moisture content 5% above ssd
** moisture content 4% above ssd

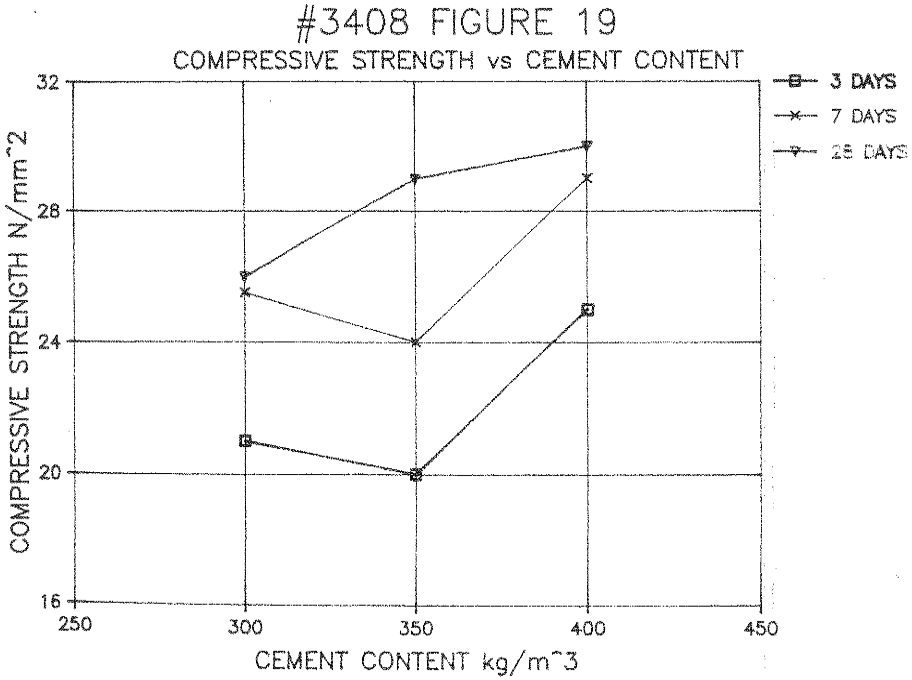
APPENDIX 10

MAIN RELATIONSHIPS
PUMPABLE STRUCTURAL CONCRETE

FIGURES 17 TO 25



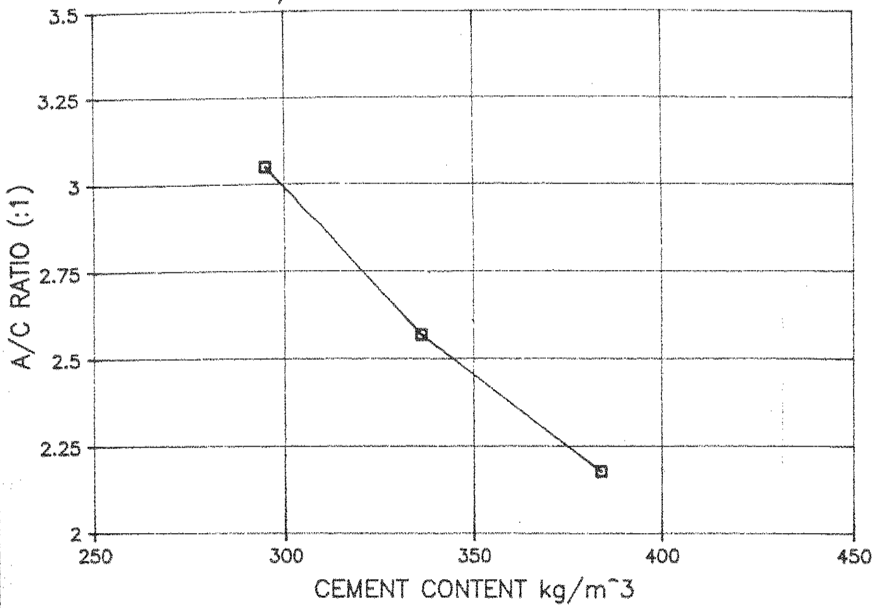




Job N° 3408E
Figure
STATS

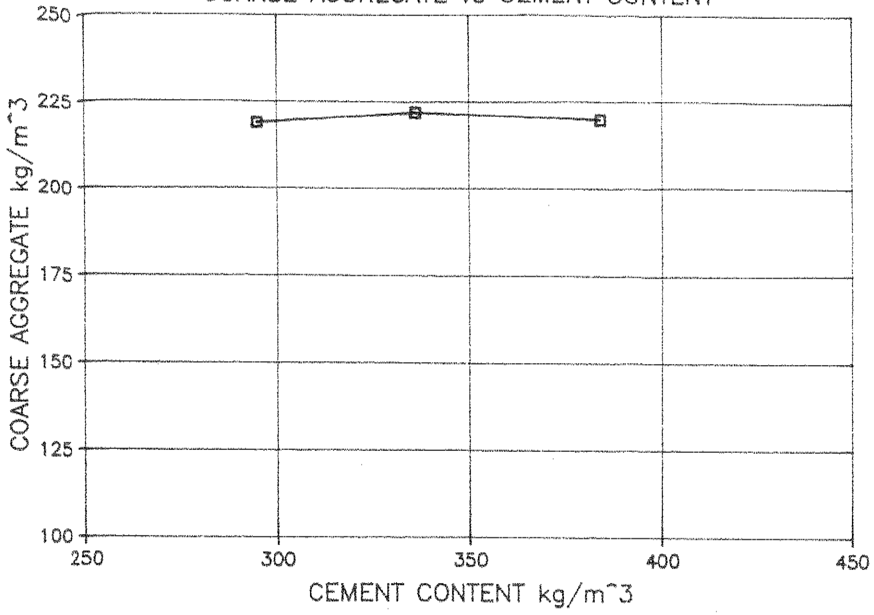
#3408 FIGURE 20

A/C RATIO vs CEMENT CONTENT



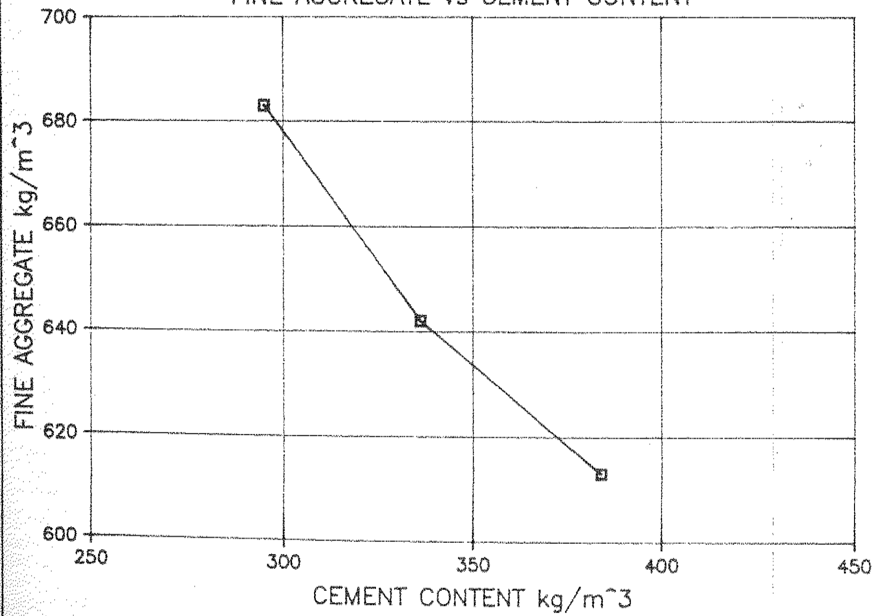
#3408 FIGURE 21

COARSE AGGREGATE vs CEMENT CONTENT



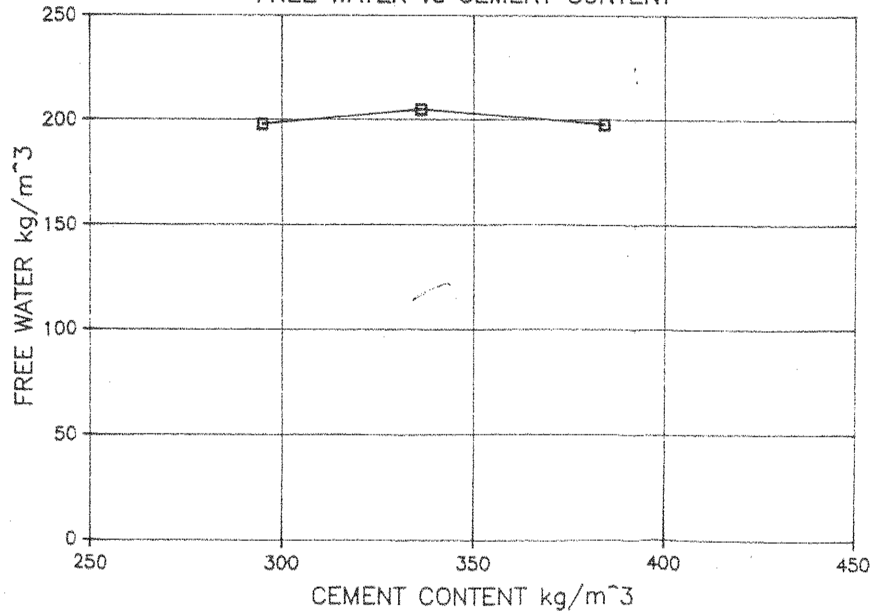
#3408 FIGURE 22

FINE AGGREGATE vs CEMENT CONTENT



#3408 FIGURE 23

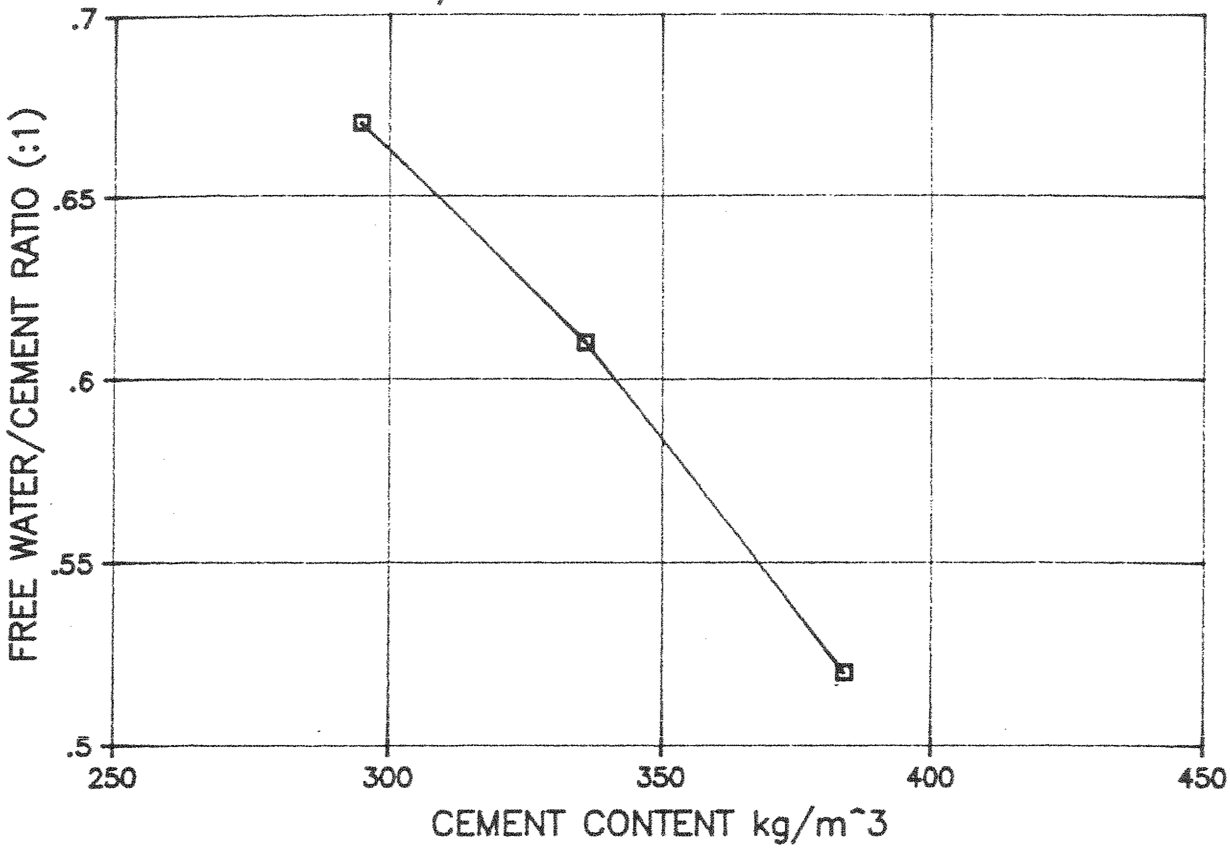
FREE WATER vs CEMENT CONTENT



Job N° 3408E	STATS
Figure	

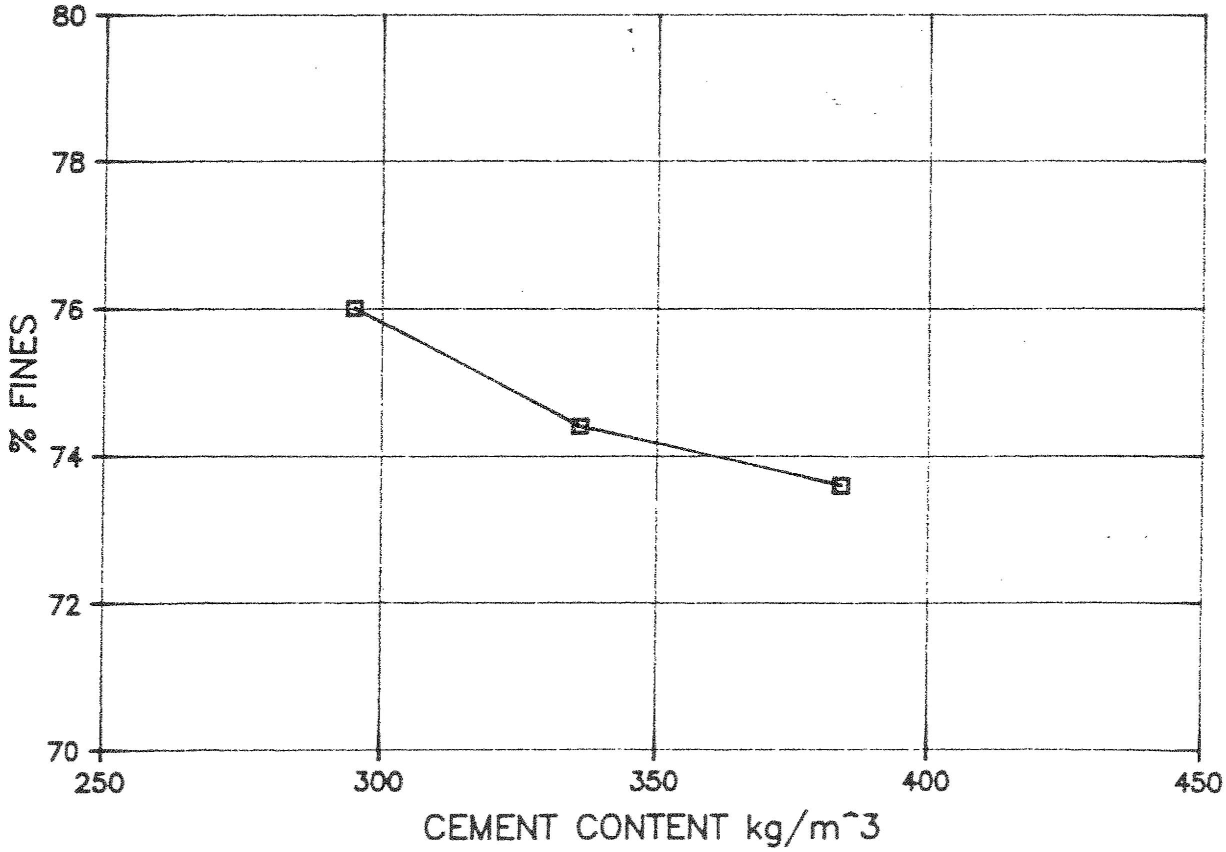
#3408 FIGURE 24

FREE WATER/CEMENT RATIO vs CEMENT CONTENT



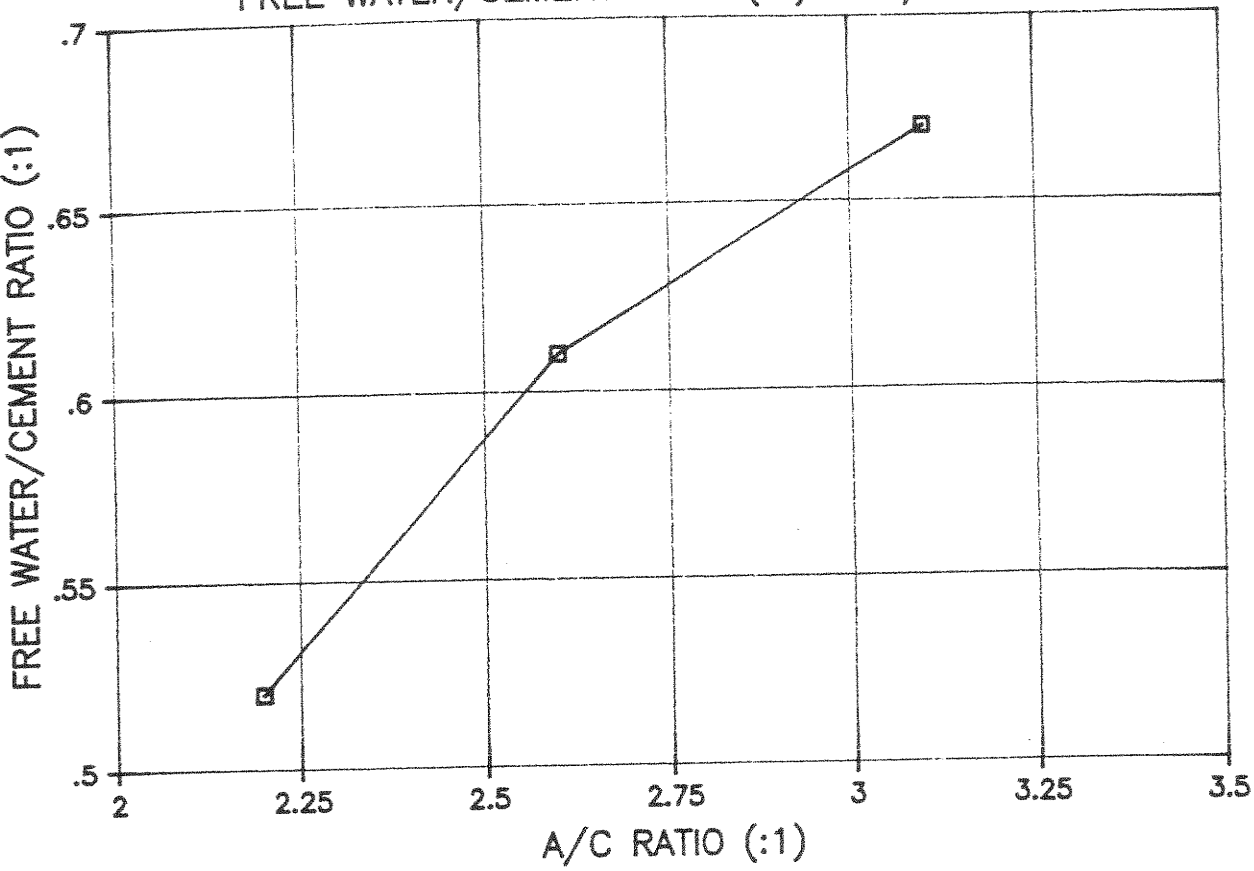
#3408 FIGURE 25

% FINES vs CEMENT CONTENT



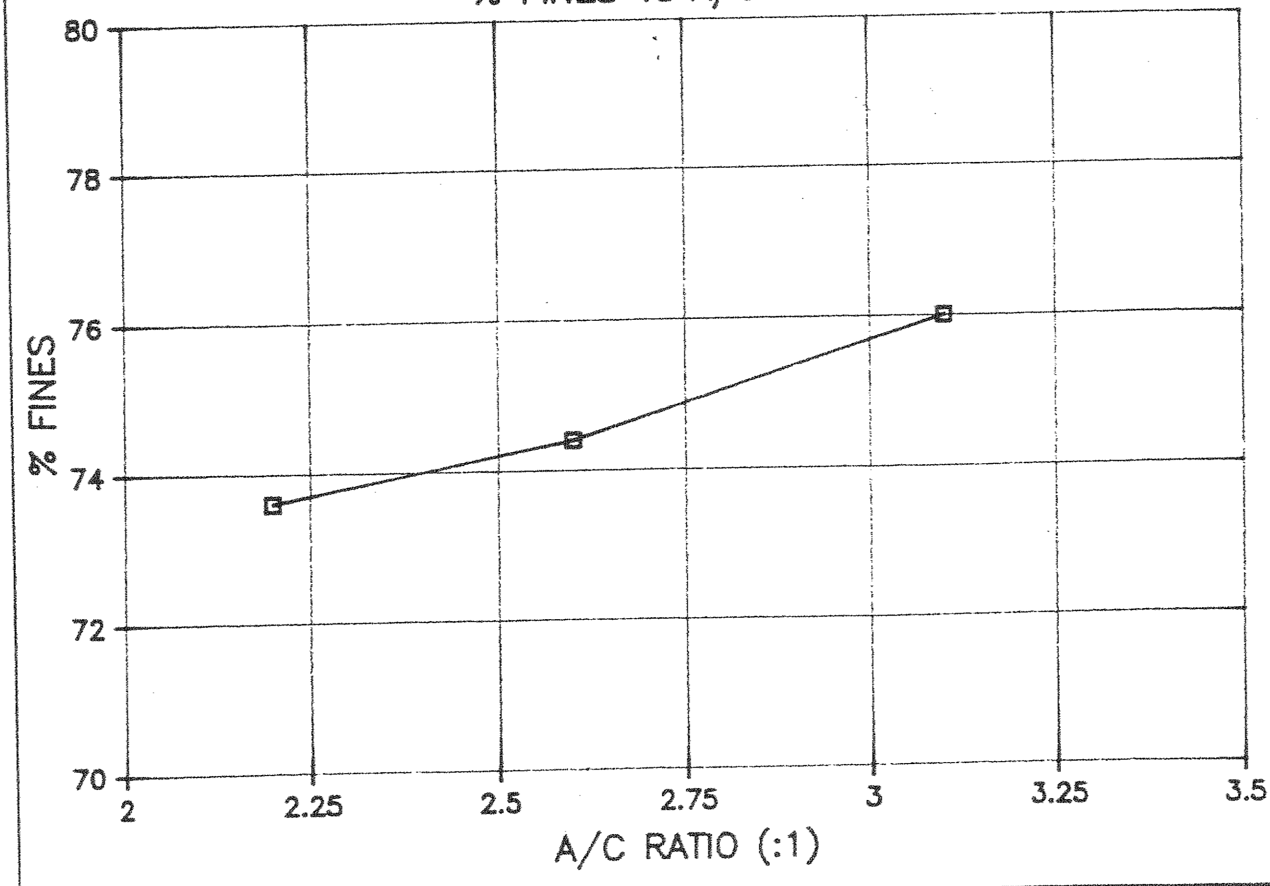
#3408 FIGURE 26

FREE WATER/CEMENT RATIO (:1) vs A/C RATIO



#3408 FIGURE 27

% FINES vs A/C RATIO



Job N° 3408E

Figure

STATS

APPENDIX 11

PLATES

PLATE 1 : POCHIN Concrete Pumping concrete pump

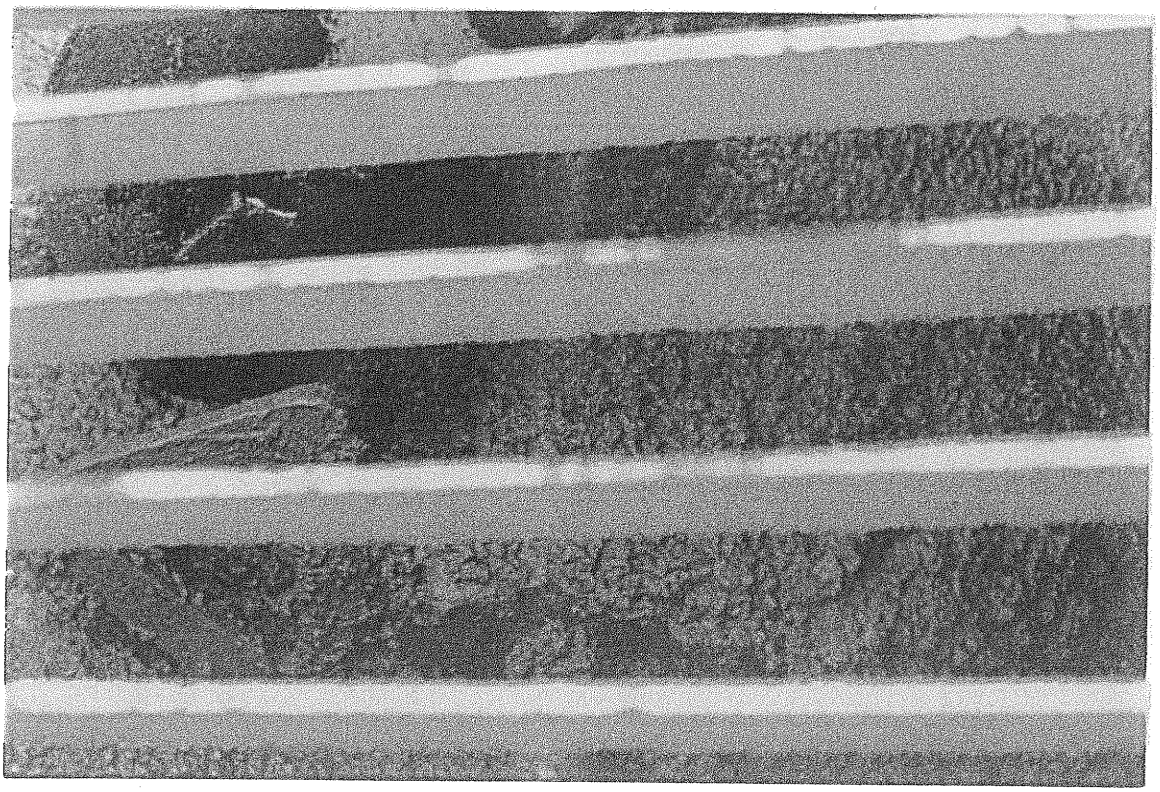


PLATE 2 : Pumice aggregate concrete in receiving hopper of pump, rotating agitator to LHS of plate

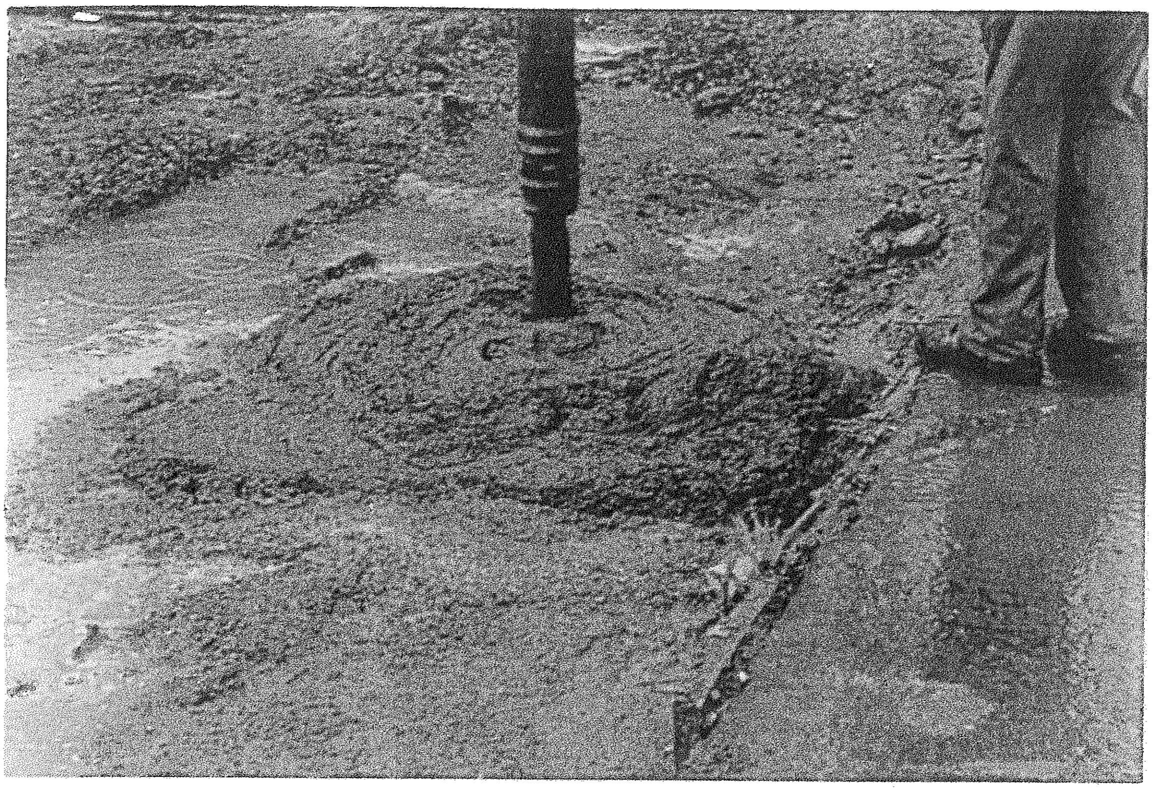


PLATE 3 : Batch 2,350kg/m^3 cement content, discharging from pump

PLATE 4 : Batch 3, 400kg/m^3 cement content, discharging from pump

PLATE 5 : Batch 4, 300kg/m^3 cement content, discharging from pump

5.0 PART FOUR
OVERALL CONCLUSIONS

5.0 PART FOUR : OVERALL CONCLUSIONS

Structural and Structural/Insulating concrete is able to be produced using pumice coarse and fine aggregate to meet the requirements of RILEM and BS 8110 subject to a strength ceiling in the 30-35N/mm^2 range for concretes in the normal range of cement contents (300 to 400kg/m^3).

For practical ready mix supply and pump emplacement the use of admixtures is necessary predominantly a pumping aid supplemented by a normal water-reducing plasticiser and an air-entraining agent. The pumpability is not thought to be sensitive to the generic type or manufacturer of the latter two but the correct choice of pumping aid is essential. From the trials undertaken a thixotropic, water reducing, super-plasticiser in powder form (Sikament T3) was found to give better workability, cohesiveness and appearance suitable for pumping than a powder water reducing, workability retaining pumping aid (Cormix PA) and a high range, water reducing superplasticiser liquid (Tiamac II).

If the supply of natural sand fine aggregate is not problematical, then replacement of pumice fines by natural sand may further improve pumpability.

As well as the addition of admixtures and/or natural sand, the percentage of pumice fines is increased for pumpable mixes compared with similar mixes of lesser workability or emplacement requirements.

6.0 PART FIVE

REFERENCES

4.0 PART FIVE : REFERENCES

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BS 1881: Part 108: 1983	Testing Concrete
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