

EVALUATION OF THE EFFECTS  
OF FORMTEX CPF ON THE  
SURFACE PROPERTIES OF  
CONCRETE

1304/98/10115

JUNE 1998

TAYWOOD " ENGINEERING " LIMITED

CONSULTANTS IN DESIGN AND TECHNOLOGY



**TEL**

# Technical Report

Report No. 1304/98/10115

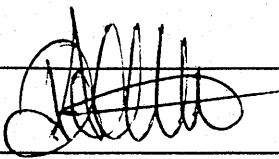
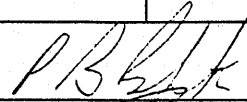
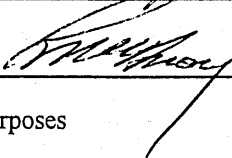
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Title

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Report Number  
& Date of Issue

1304/98/10115  
JUNE 1998

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Abstract	<p>The use of Formtex Formwork liner has been shown to greatly enhance the performance of the concrete surface in a series of durability related tests.</p>		
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**Taywood Engineering Ltd**  
**Technology Division**

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Issue 6 / 4482 / April 1997

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## 1. INTRODUCTION

The objective of the test program was to assess the use of Formtex controlled permeability formwork liner (CPF) to enhance durability of concrete in addition to improved surface appearance.

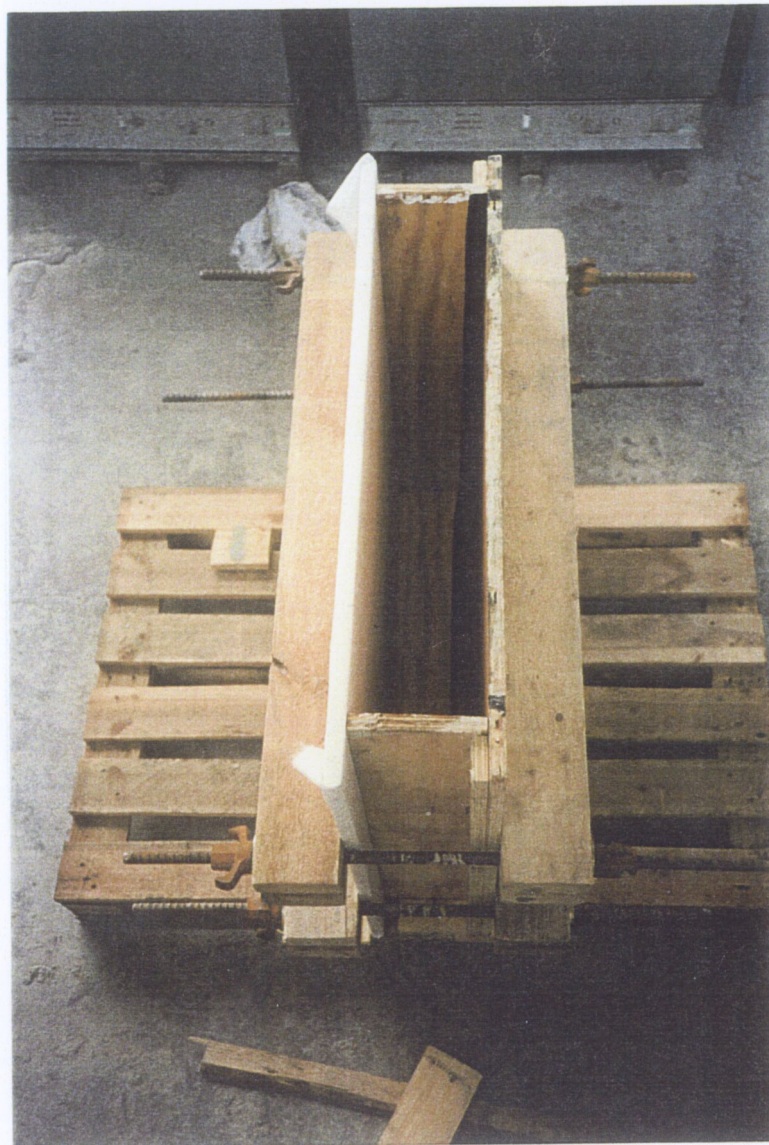


## 2. PRODUCTION OF TRIAL PANEL

Formwork for a trial panel of dimensions 750mm x 750mm x 150mm was produced in plywood. The large vertical faces were coated with a polyurethane varnish to represent resin coated ply or other impermeable formwork.

Immediately prior to production of the trial panel, and following detailed instruction from the representative (Charles Tuxford) of the supplier of the Formtex material (Euro Erosion Engineering), one of the 750mm x 750mm vertical faces was covered with Formtex CPF and tensioned in accordance with the manufacturers recommendations.

The assembled panel mould, with CPF in place, is shown in Photograph 1.



Photograph 1. Trial panel mould immediately before casting

A C35 concrete (0.1m<sup>3</sup> batch) was produced (see Table 1 for mix design details) in a 'Cumflow' type forced action pan mixer.



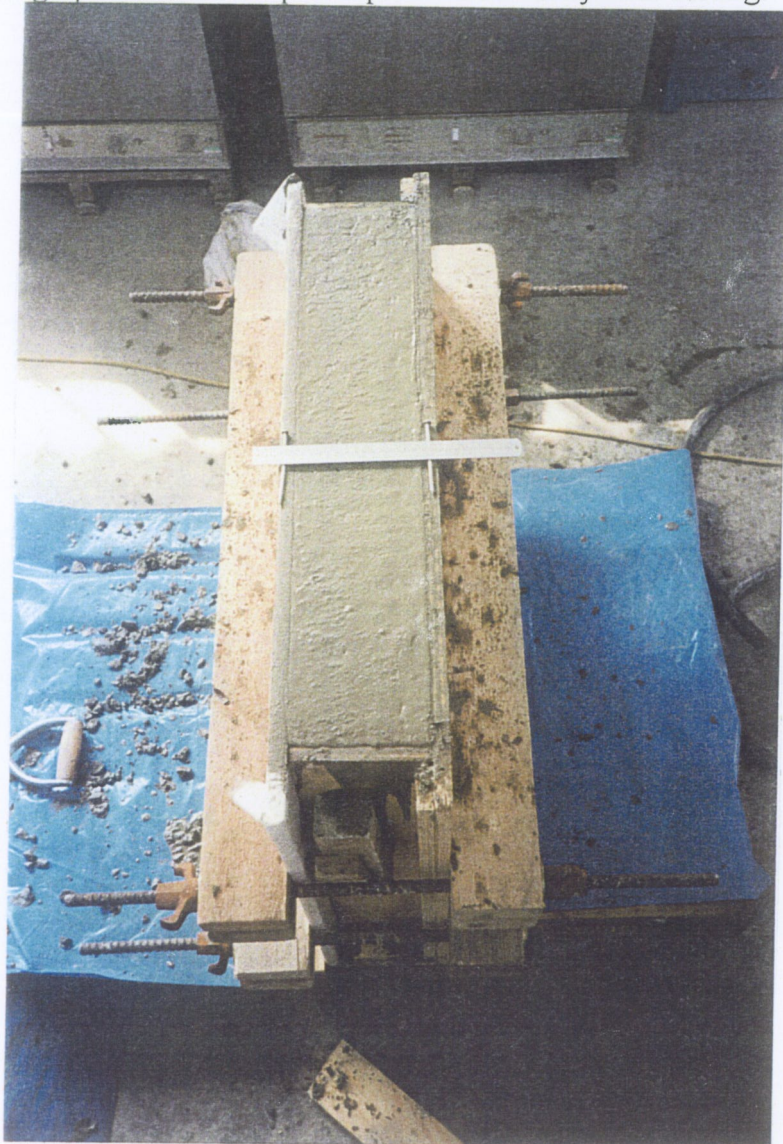
**Table 1 Concrete Mix Proportions (all at SSD condition)**

Cement (BCI Northfleet)	(kg/m <sup>3</sup> )	340
20mm (Thames Valley, Radlet Pit)	(kg/m <sup>3</sup> )	793
10mm (Thames Valley, Radlet Pit)	(kg/m <sup>3</sup> )	397
Sand (Thames Valley, Radlet Pit)	(kg/m <sup>3</sup> )	645
Water	(kg/m <sup>3</sup> )	180
Free Water/Cement Ratio		0.53

Concrete temperature of 25.7°C and initial slump (BS 1881 Part 102: 1983) of 75mm were recorded.

6 No. 100mm cubes were cast (BS 1881 Part 108: 1983). 3 each No. of these were tested for compressive strength (BS 1881 Part 116: 1983) at 7 and 28 days.

The concrete was placed in the trial panel in 3 equal layers, each compacted using an internal (poker) vibrator. Care was taken to ensure that the poker did not come into contact with the formwork liner. Photograph 2 shows completed panel immediately after casting.



Photograph 2. Trial panel at completion of casting

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The formwork was removed after 24 hours and the panel was subjected to a further three days site - simulated curing by wrapping the panel in wet hessian and polythene sheeting.

Following this the panel was stored in the laboratory until the start of testing at 28 days.

### 3. TEST PROCEDURE

The test programme was designed to provide a direct comparison between the properties of the concrete cast against the Formtex CPF and the impermeable form face.

#### 3.1 PANEL TESTING

The following tests were carried out within the middle two-thirds of the height of the panel and at the same height for each face in order to minimise the effects of vertical variations in concrete properties.

- Initial Surface Absorption (ISAT)      BS 1881 Part 208: 1983.
- Surface Hardness (Rebound Number)      BS 1881 Part 202: 1983
- Surface Tensile Strength (Pull Off)      BS 1881 Part 207: 1992

#### 3.2 CORE TESTING

Following completion of the test work on the panel faces, nominal 100mm diameter cores were drilled through the full thickness of the panel and the following tests were undertaken on both the CPF and non-CPF surfaces of the core:

- Sorptivity of Oven Dried Specimens to TEL in house test procedure.  
AG TM/95/01/issue 1 "Water Sorption Test".
- Accelerated Carbonation to pr EN 104-839 "Carbonation resistance".
- Chloride Diffusion to Test procedure 1 in accordance with TEL proforma. Ref: 1303S/MW001/JM issue 1.
- Resistance to Frost Attack to Rilem Recommendation CDC 2 : 1977.



## 4. RESULTS AND DISCUSSION

### 4.1 VISUAL APPEARANCE

Visual appearance of the CPF face is greatly improved with an almost complete elimination of blowholes, when compared with the face cast against the impermeable formwork.

### 4.2 CUBE TESTS

6 No. 100mm cubes were made, cured at  $20 \pm 2^\circ\text{C}$  in water, and tested for compressive strengths according to the requirements of the relevant parts of BS 1881.

Results are given in Table 2 below:

**Table 2 Results of Compressive Strength Tests**

	Strength (MPa)	
	Results	Mean
7d	36.5 38.5 39.0	38.0
28d	44.0 47.0 46.5	45.5

The mean hardened density of the concrete (BS 1881 Part 114: 1983) was  $2360 \text{ kg/m}^3$ .

### 4.3 PANEL TESTS

#### 4.3.1 ISAT

Results for the Initial Surface Absorption Test are listed in Table 3 below:

**Table 3 Results of Initial Surface Absorption Tests**

Form		ISAT ml/m <sup>2</sup> .s		
		10min	30min	60min
Formtex CPF	Test 1	0.023	*	*
	Test 2	0.028	*	*
	Test 3	0.033	*	*
	Mean	0.028	*	*
Non-CPF	Test 1	0.186	0.101	0.062
	Test 2	0.173	0.096	0.062
	Test 3	0.185	0.084	0.056
	Mean	0.181	0.094	0.060

\* No measurable absorption

#### 4.3.2 Surface Hardness (Schmidt Hammer)

20 No. vertical readings were taken on each face, contained in a 200 x 150mm grid. Each measurement was taken at 50 ± 5mm from the previous test, and no nearer than 50mm from any edge or sharp discontinuity of the panel. Results are given in Table 4 below. These results are quoted in terms of rebound number with no attempt to correlate this with compressive strength.

**Table 4 Results of Surface Hardness Tests**

CPF Face	Mean (of 20 No.)	48.875
	Sample Std. Dev.	2.533
	Range	44-53
Non-CPF Face	Mean (of 20 No.)	37.550
	Sample Std. Dev.	2.460
	Range	34-44

### 4.3.3 Surface Tensile Strength

6 No. pull off tests were also carried out on each face of the trial panel. This is reported in detail in Appendix A but a summary is presented in Table 5 below:

**Table 5 Results of Pull Off Tests**

Location	CPF Face Pull-off Strength (MPa)	Non-CPF Face Pull-off Strength (MPa)
1	2.95	1.53
2	2.84	1.74
3	2.62	1.63
4	3.51	1.63
5	3.29	1.42
6	3.18	1.63
Mean Pull-off Strength	3.1	1.6
Notes/Comments	Failures occurred well into the body of the concrete (approx. 15 to 25mm)	Failures occurred in layer of surface laitence (approx. 2mm) and up to 10mm into body of concrete

## 4.4 CORE TESTS

### 4.4.1 Sorptivity

Water sorption tests were carried out on the CPF and non-CPF faces of 1 No. core. The overall sorptivity of the CPF face was  $0.15 \text{ mm/min}^{1/2}$ , and the non-CPF face was  $0.31 \text{ mm/min}^{1/2}$ . Details of increments etc. are presented in Appendix B.

**4.4.2 Carbonation Resistance**

Carbonation resistance of the CPF and non-CPF faces was measured by an accelerated laboratory test in general accordance with pv EN 104-839:1997.

The results are given in tables 6.1 and 6.2 for CPF and non-CPF faces respectively.

Photograph 3 shows the non-CPF face and photograph 4 the CPF face, each at the time of carbonation measurement. Please note that the depth of carbonation, in each case, was measured from the exposed face, (i.e. the lower face as seen in the photographs).

**Table 6.2 NON CPF Face**

(S/N 123009/1)

READING	1	2	3	4	5	6	7	8
MEASUREMENT (mm)	14	14	12	13	16	14	15	13
MEAN (mm)	13.9							

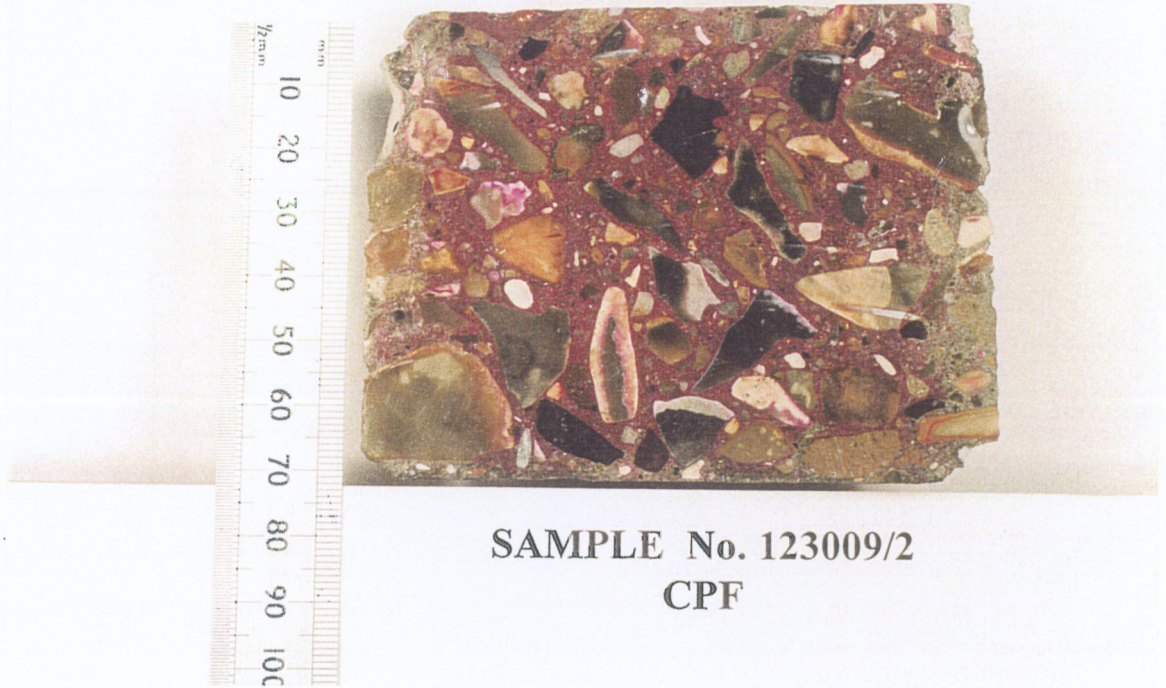


Photograph 3



**Table 6.1 CPF Face**

		(S/N 123009/2)							
READING		1	2	3	4	5	6	7	8
MEASUREMENT (mm)		5	3	2	5	3	6	5	2
MEAN	(mm)	3.9							



Photograph 4

**4.4.3 Chloride Diffusion**

Bulk chloride diffusion coefficients were determined on both faces in duplicate. Results are shown in Table 6 below.

**Table 7**

Chloride Diffusion Coefficient	CPF	Non-CPF
1 <sup>st</sup> Sample	$6.96 \times 10^{-13}$	$1.38 \times 10^{-12}$
2 <sup>nd</sup> Sample	$6.17 \times 10^{-13}$	$1.20 \times 10^{-12}$
<b>Mean</b>	$6.56 \times 10^{-13}$	$1.29 \times 10^{-12}$

For further details see Appendix C.

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#### 4.4.4 Resistance to Frost Attack

The formed CPF and non-CPF faces of 3 No. cores were subjected to 25 cycles of:

- 15-17 hrs @  $-20 \pm 2^{\circ}\text{C}$  (3% NaCl solution)
- 7-8 hrs @  $+20 \pm 2^{\circ}\text{C}$  (laboratory air)

Results are summarised in Table 7, and a full photographic record is given in Appendix D.

**TABLE 8****RILEM RECOMMENDATION: FREEZE / THAW - CDC2:1977****After 10 cycles**

CLIENT IDENTIFICATION	TEL SAMPLE NUMBER	CUMULATIVE SURFACE WEIGHT LOSS (mg/mm <sup>2</sup> )	DEPTH OF SCALING (mm)	% AREA SCALED	VISUAL ASSESSMENT AMERICAN / AUSTRIAN STANDARD	SUMMARY
2. 3. 1.	Non- CPF 123002/1 123003/1 123004/1	0.09 0.06 0.07	2.0 0.2 0.4	30 30 30	4 4 4	Considerable surface damage incurred.
2. 3. 1.	CPF 123002/2 123003/2 123004/2	0.00 0.00 0.00	0.0 0.0 0.0	0 0 0	0 0 0	No surface damage at all.

**After 20 cycles**

CLIENT IDENTIFICATION	TEL SAMPLE NUMBER	CUMULATIVE SURFACE WEIGHT LOSS (mg/mm <sup>2</sup> )	DEPTH OF SCALING (mm)	% AREA SCALED	VISUAL ASSESSMENT AMERICAN / AUSTRIAN STANDARD	SUMMARY
2. 3. 1.	Non- CPF 123002/1 123003/1 123004/1	1.22 1.14 1.86	3.6 3.0 3.2	99 90 90	5 5 5	Severe surface damage
2. 3. 1.	CPF 123002/2 123003/2 123004/2	0.01 0.01 0.00	0.4 0.2 0.4	0 0 0	1 0 1	No surface damage

**After 25 cycles**

CLIENT IDENTIFICATION	TEL SAMPLE NUMBER	CUMULATIVE SURFACE WEIGHT LOSS (mg/mm <sup>2</sup> )	DEPTH OF SCALING (mm)	% AREA SCALED	VISUAL ASSESSMENT AMERICAN / AUSTRIAN STANDARD	SUMMARY
2. 3. 1.	Non- CPF 123002/1 123003/1 123004/1	1.89 1.93 2.82	5.2 5.6 5.8	90 100 100	5 5 5	Very severe surface damage
2. 3. 1.	CPF 123002/2 123003/2 123004/2	0.02 0.01 0.01	0.6 0.8 0.6	0 0 0	1 0 1	Basically un-damaged

#### 4.5 SUMMARY OF RESULTS - FORMTEX CPF TRIAL PANEL

	Test	CPF Face	Non-CPF Face
P A N E L  T E S T S	ISAT (mean of 3 No.)	0.028 ml/(m <sup>2</sup> .s)	0.181 ml/(m <sup>2</sup> .s)
	10 mins	None	0.094 ml/(m <sup>2</sup> .s)
	30 mins 60 mins	None	0.060 ml/(m <sup>2</sup> .s)
	Rebound Number (mean of 20 No.)	49	37.5
	Surface Tensile (mean of 6 No.)	3.1 MPa	1.6 MPa
C O R E  T E S T S	Sorptivity	0.15 mm/min <sup>½</sup>	0.31 mm/min <sup>½</sup>
	Carbonation Resistance (Mean of 8No. readings)	Carbonation depth 3.9mm	Carbonation depth 13.9mm
	Chloride diffusion (mean of 2 No.)	6.56 x 10 <sup>-13</sup> m <sup>2</sup> /s@20°C	1.29 x 10 <sup>-12</sup> m <sup>2</sup> /s@20°C
	Freeze/thaw resistance (3 No. samples)	Summary - weight loss (mg/mm <sup>2</sup> ) No surface damage at all - 0.00 No surface damage - 0.01 Basically undamaged - 0.01	Summary - weight loss (mg/mm <sup>2</sup> ) Considerable surface damage - 0.07 Severe surface damage - 1.41 Very severe surface damage - 2.21



## 5. CONCLUSIONS

While only one concrete mix was tested, the results and observations described in this report show quite clearly that there are significant durability benefits to be gained from the use of Formtex CPF liner as opposed to impermeable formwork.

The range of test work was designed to assess the ability of a "typical" concrete to resist the most common mechanisms that lead to deterioration of concrete structures in the UK.

In all cases, the use of a Formtex CPF liner was found to significantly enhance surface properties of the concrete.

As it is widely accepted that it is these surface properties that affect concrete durability performance, it can be reasonably assumed that the use of this material would provide considerable advantages with respect to e.g.:

- Increased lifetime of structure

- Reduced repair costs

- Enhanced appearance

## **APPENDIX A**

### **Surface Tensile Strength Test**



# CONSTRUCTION MATERIALS MANAGEMENT

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**SUBJECT:** BOND-TESTING ON CONCRETE PANELS  
TO INVESTIGATE THE EFFICIENCY OF  
CONTROLLED PERMEABILITY FORMWORK.

**SITE:** TAYWOOD LABORATORIES, SOUTHALL

**CLIENT:** TAYWOOD ENGINEERING LIMITED

**CMM REF:** CTT005-97-1

**DATE:** 25th SEPTEMBER 1997

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## PART I

### INTRODUCTION

- 1.1 Taywood Engineering Ltd requested that a series of Bond-Tests be carried out by Construction Materials Management on a concrete trial panel in order to investigate the efficiency of controlled permeability formwork (CPF) when compared with conventional plywood. These tests form part of a more comprehensive study into CPF being undertaken by Taywood Engineering.

## PART 2

### BOND-TESTING

#### 2.1 TRIAL PANEL DETAILS

A concrete panel with the properties given below had been cast in the workshops of Taywood Engineering at Southall:

- Dimensions: 750 x 750 x 150mm.
- Concrete Mix: Nominally C35 with flint gravel and natural sand aggregates.
- Age at time of test: 28 days.
- Formwork:
  - i) Controlled permeability formwork (CPF) liner on one of the 750 x 750mm faces.
  - ii) Varnished plywood formwork on the other 750 x 750mm face.

#### 2.2 THE BOND-TEST SYSTEM

The Bond-Test is used to determine the direct tensile strength of concrete or the adhesion strength between two layers, e.g. concrete repairs. The concrete surface is prepared and wire brushed to ensure a plane and dust free surface. In this case, being under controlled conditions, only wire brushing was necessary. A 75mm diameter steel disc (in accordance with BS 1881: Part 207:1992) is glued to the concrete surface with rapid setting epoxy adhesive. In order to clearly define the area of test, the concrete is cored around the steel disc to the required depth. As the properties of the surface layer of the panel faces were to be compared, a coring depth of between 2 and 5mm was selected.

A pull-bolt is connected to the steel disc and a circular steel counterpressure unit is placed around the disc so that it bears on the concrete surface outside of the cored zone. The hydraulic pullmachine is connected to the pull-bolt and loading commenced. When the failure load is reached, the value on the dial gauge is noted and the bond strength calculated and reported.

Photographs showing the position of the steel discs and the Bond-Test equipment are included at Appendix A.

## 2.3 BOND-TESTING

The testing was carried out on 4th September 1997 at Southall. The positions of the steel discs for bond testing were arranged to accommodate 3 pairs of tests on each of the two test faces and to allow for any strength variation caused by casting height. The fact that other tests were to be carried out on the same face was also taken into account.

The steel disc positions were also arranged so that the tests on the CPF side and Non-CPF sides of the panel were back to back so that direct comparison for each test could be made thus minimising any effect that could occur due to positioning.

## 2.4 SUMMARY OF TEST RESULTS


A summary table of Bond-Test results is given below:

TEST NO.	PANEL FACE	BOND STRENGTH MPa	TEST NO.	PANEL FACE	BOND STRENGTH MPa
1	CPF	2.94	1	NON CPF	1.53
2		2.84	2		1.74
3		2.62	3		1.63
4		3.51	4		1.63
5		3.29	5		1.42
6		3.18	6		1.63
MEAN VALUE 3.1 MPa			MEAN VALUE 1.6 MPa		

The Bond-Test result sheets are included at Appendix B.

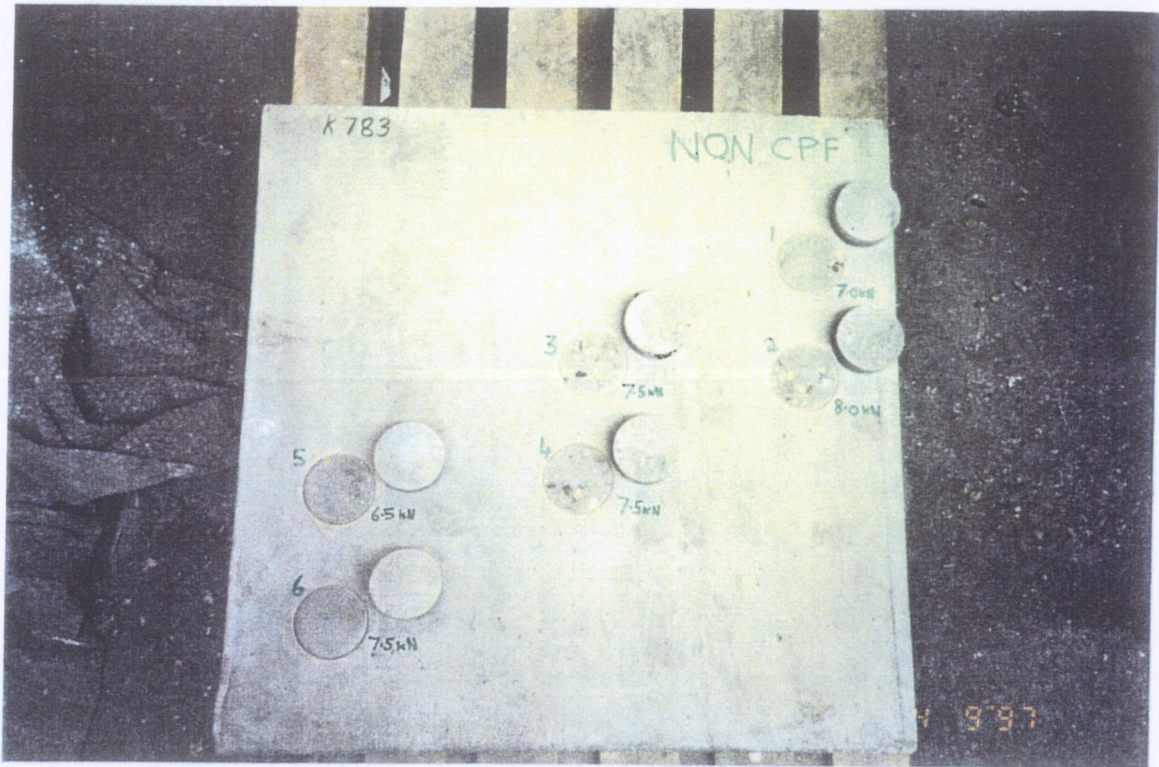
## 2.5 DISCUSSION OF RESULTS

- It can be seen from the summary table above that the CPF face has produced a surface layer with an average bond strength almost twice the value of the Non-CPF face.
- In addition the zone of failure in the concrete found during the bond tests was consistently much deeper, approx. 15mm, on the CPF face, compared with 2mm on the other face.
- This indicates that the water/cement ratio reducing effect of the CPF on the surface layer has been effective.

Signed:  .....

Date: ...25th SEPTEMBER 1997.....

**APPENDIX A**  
**PHOTOGRAPHS**

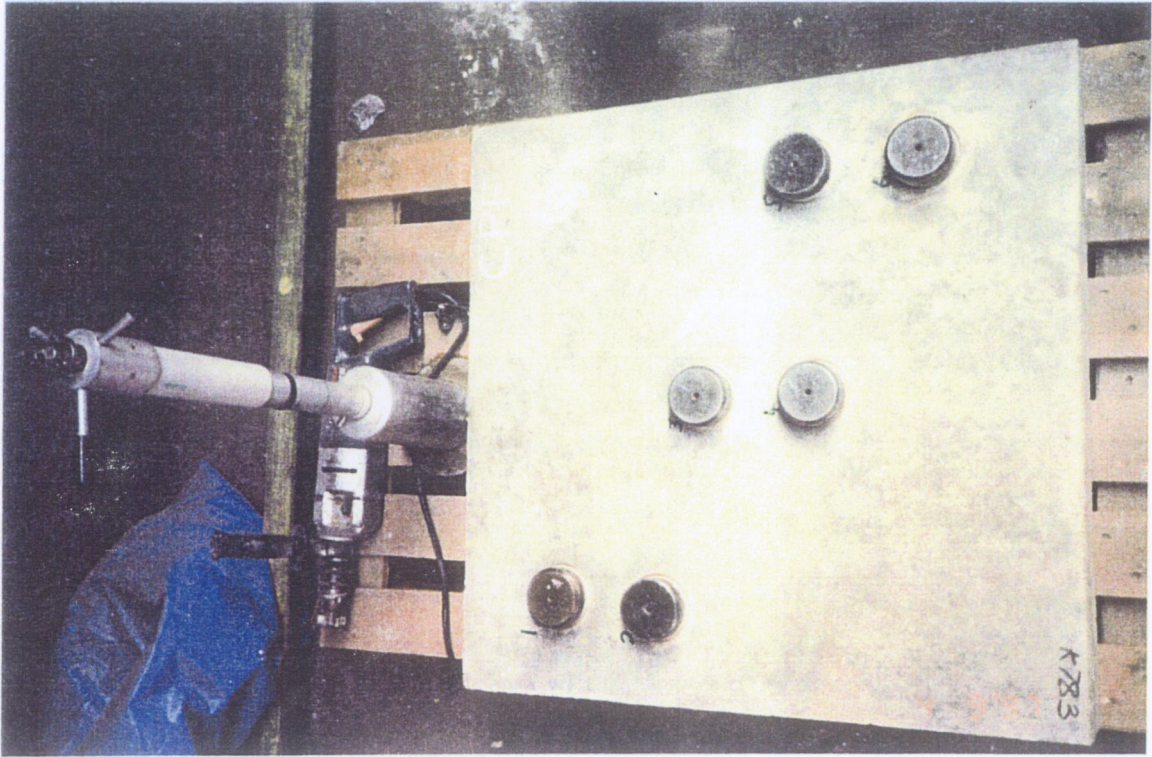


BOND-TEST: NON-CPF FACE OF PANEL AFTER TESTING

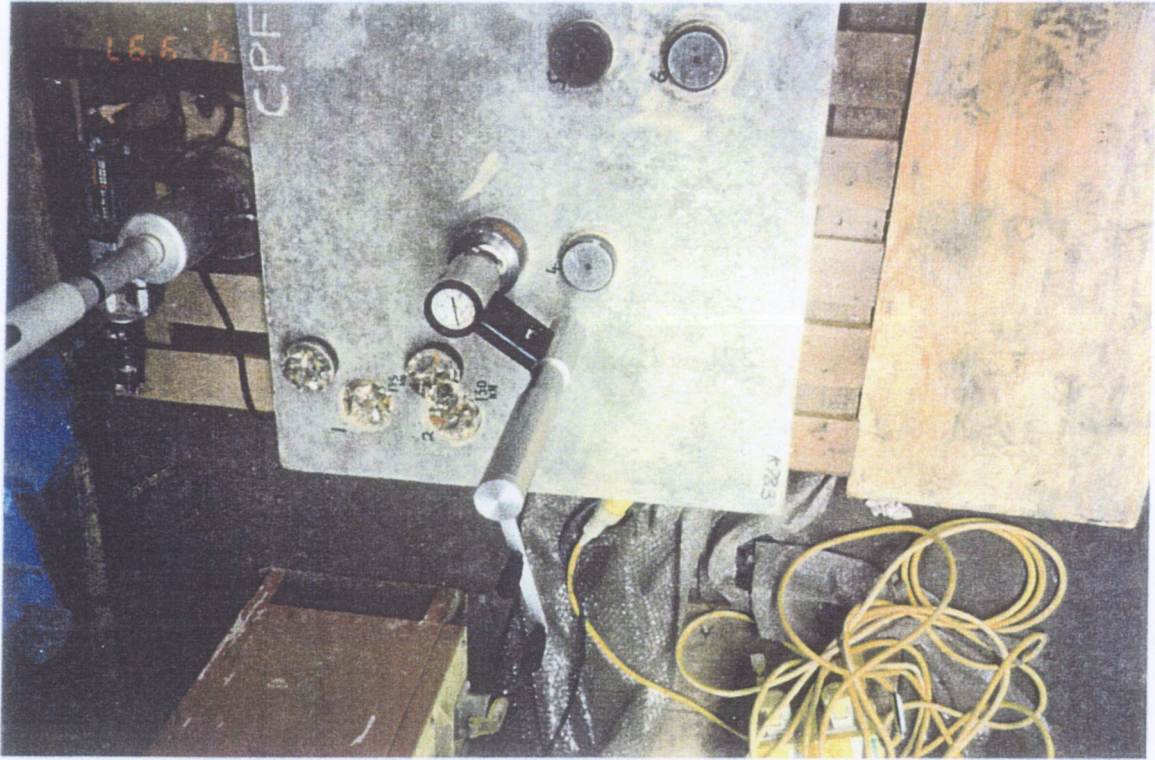


BOND-TEST: CPF FACE OF PANEL AFTER TESTING





BOND-TEST: STEEL DISCS FIXED & CORING COMPLETED



BOND-TEST: HYDRAULIC PULLMACHINE IN POSITION FOR TEST

**APPENDIX B**

- i) BOND-TEST RESULT SHEET - CPF FACE**
- ii) BOND-TEST RESULT SHEET - NON-CPF FACE**



**C**ONSTRUCTION  
**M**ATERIALS  
**M**ANAGEMENT

**IN-SITU CONCRETE PULL-OFF STRENGTH**  
**BOND-TEST REPORT**

CLIENT: Taywood Engineering Limited REF. No: CTT027-97-1/1  
 SITE: Taywood Laboratories, Southall  
 STRUCTURE: Controlled Permeability Formwork (CPF) Test Panel - CPF Side

DATE OF TEST:	4th September 1997
AGE OF CONCRETE:	28 days
CONCRETE TYPE:	C35. OPC. Aggregates: 20mm NS gravel & natural sand


TEST POSITIONS: CPF

Vertical/Horizontal Coring. x<sup>1</sup> x<sup>2</sup> x<sup>3</sup> x<sup>4</sup> x<sup>5</sup> x<sup>6</sup>

Test No.	Location	Dial Reading kN	Bond Strength MPa	Depth Drilled mm	Core Length mm	Comments
1	See diagram above	13.5	2.95	4	Approx	
2		13.0	2.84	3	15	
3		12.0	2.62	2	to	Less coarse aggregate
4		16.0	3.51	2	25	
5		15.0	3.29	2		
6		14.5	3.18	2		
<b>MEAN BOND STRENGTH MPa</b>			<b>3.1</b>			

Notes: Failures occurred well into body of concrete (approx. 15 to 25mm).

Instrument No: 11-2080 Calibration Date: 05.02.97

Operator Signature:  Operator Name: Worters Date: 4th Sept. 1997



**C**ONSTRUCTION  
**M**ATERIALS  
**M**ANAGEMENT

**IN-SITU CONCRETE PULL-OFF STRENGTH**  
**BOND-TEST REPORT**

CLIENT: Taywood Engineering Limited REF. No: CTT027-97-1/2  
 SITE: Taywood Laboratories, Southall.  
 STRUCTURE: Controlled Permeability Formwork (CPF) Test Panel - Non CPF Side


DATE OF TEST:	4th September 1997
AGE OF CONCRETE:	28 days
CONCRETE TYPE:	C35. OPC. Aggregates: 20mm NS gravel & natural sand

TEST POSITIONS: **NON-CPF**  
 Vertical/~~Horizontal~~ Coring. x<sup>3</sup> x<sup>1</sup>  
x<sup>5</sup> x<sup>4</sup> x<sup>2</sup>  
x<sup>6</sup>

Test No.	Location	Dial Reading kN	Bond Strength MPa	Depth Drilled mm	Core Length mm	Comments
1	See diagram above	7.0	1.53	3	Approx 2 to 10	
2		8.0	1.74	4		
3		7.5	1.63	3		
4		7.5	1.63	3		
5		6.5	1.42	3		
6		7.5	1.63	3		
<b>MEAN BOND STRENGTH MPa</b>			<b>1.6</b>			

Notes: Failures occurred between layer of surface laitence (approx.2mm) and up to 10mm into body of concrete.

Instrument No: 11-2080 Calibration Date: 05.02.97

Operator Signature:  Operator Name: Worters Date: 4th Sept.1997

## **APPENDIX B**

### **Water Sorption Tests**



**WATER SORPTION TEST**

Sample: 123007/1 (REPEAT)

Test Date: 10/10/97

Age at Test: Approximately 5 weeks

Tested By: Harjit Johal

Cross Sectional Area (A): 2371.09 mm<sup>2</sup>

Sample Weight (Wd): 378.24

Notes: Non-CPF

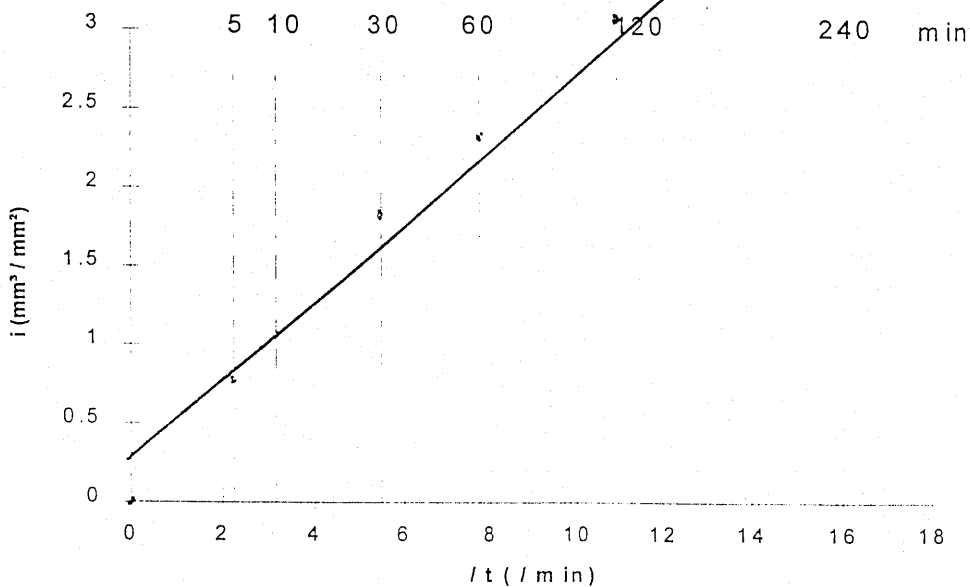
MEASUREMENTS

			TIME 'T' (mins)						
			0	5	10	30	60	120	240
WEIGHT Wt (g)			Wd	380.03	380.81	382.46	383.69	385.56	387.71
Wt - Wd (g)			0	1.79	2.57	4.22	5.45	7.32	9.47
i (mm <sup>3</sup> /mm <sup>2</sup> )			0	0.75	1.08	1.78	2.30	3.09	3.99
t (√min)			0	2.24	3.16	5.48	7.75	10.95	15.49
HEIGHT RISE at given distance from each face (mm)	FRONT FACE	0mm	0	3	3	7	11	11	11
		12mm	0	2	2	5	10.5	10.5	10.5
		24mm	0	2	2	5.5	5	5	5
		36mm	0	3	7	4	12	12	12
	BACK FACE	0mm	0	2	7	7	9.5	9.5	9.5
		12mm	0	3	3	5	8	8	8
		24mm	0	2	2	6	7	7	8
		36mm	0	4	4	9	12	12	13
	MEAN			2.63	3.75	6.06	9.38	9.38	9.63

NOTE:-  $i = \frac{W_t - W_d}{A} \times 10^3$  mm<sup>3</sup> / mm<sup>2</sup> for water sorption

RESULTS

SORPTIVITY = 0.31 mm/min<sup>1/2</sup>



**WATER SORPTION TEST**

Sample: 123007/2

Test Date: 10/10/97

Age at Test: Approximately 5 weeks

Tested By: Harjit Johal

Cross Sectional Area (A): 3947.51 mm<sup>2</sup> Sample Weight (Wd): 687.96

Notes: cPF

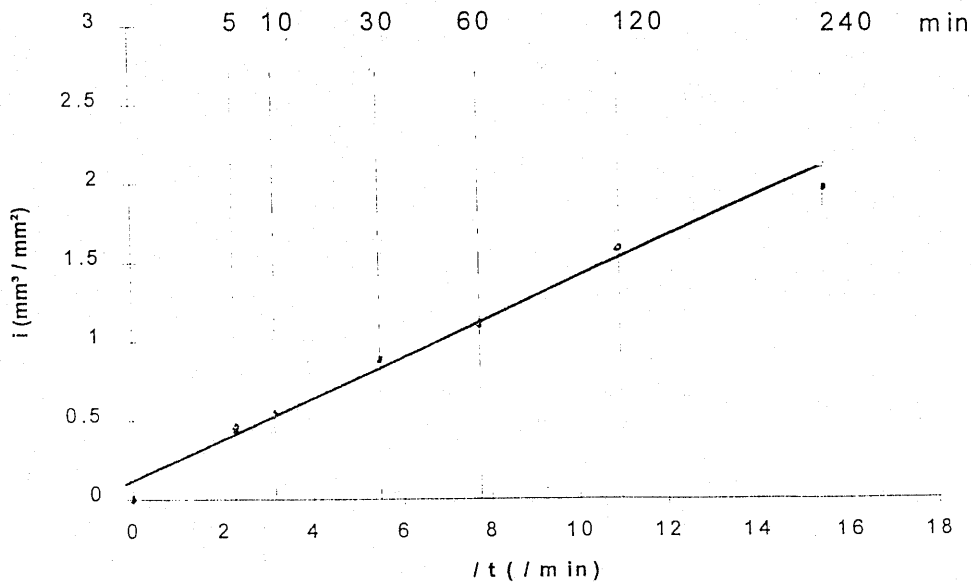
MEASUREMENTS

			TIME 'T' (mins)						
			0	5	10	30	60	120	240
WEIGHT Wt (g)			Wd	689.50	690.03	691.13	692.31	694.23	695.56
Wt - Wd (g)			0	1.54	2.07	3.17	4.35	6.27	7.60
i (mm <sup>3</sup> /mm <sup>2</sup> )			0	0.39	0.52	0.80	1.10	1.59	1.93
t (√min)			0	2.24	3.16	5.48	7.75	10.95	15.49
HEIGHT RISE at given distance from each face (mm)	FRONT FACE	0mm	0	5	5	5	5	5	5
		15mm	0	3	3.5	3.5	3.5	3.5	3.5
		30mm	0	2.5	2.5	4	4	4	4
		45mm	0	1	3	3	3	3	3
	BACK FACE	0mm	0	1.5	1.5	3	3	3	3
		15mm	0	2	2	3	3	3	3
		30mm	0	1.5	1.5	2	2	2	2
		45mm	0	2	3	3	3	3	3
	MEAN			2.31	2.38	3.31	3.31	3.31	3.31

NOTE:-  $i = \frac{W_t - W_d}{A} \times 10^3$  mm<sup>3</sup> / mm<sup>2</sup> for water sorption

RESULTS

SORPTIVITY = 0.15 mm/min<sup>1/2</sup>



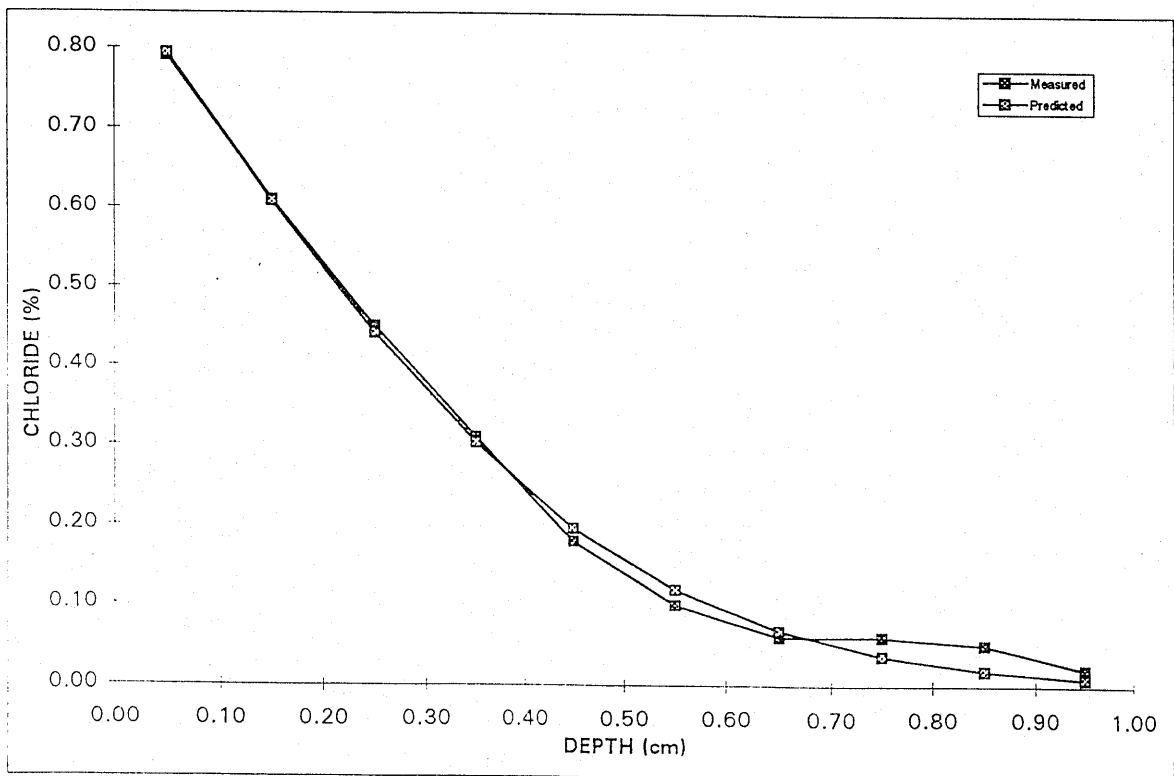
## **APPENDIX C**

### **Chloride Diffusion Tests**

**BEST FIT ANALYSIS OF CHLORIDE PROFILES**

Sample Number 123005/2 CPF 28 Day immersion

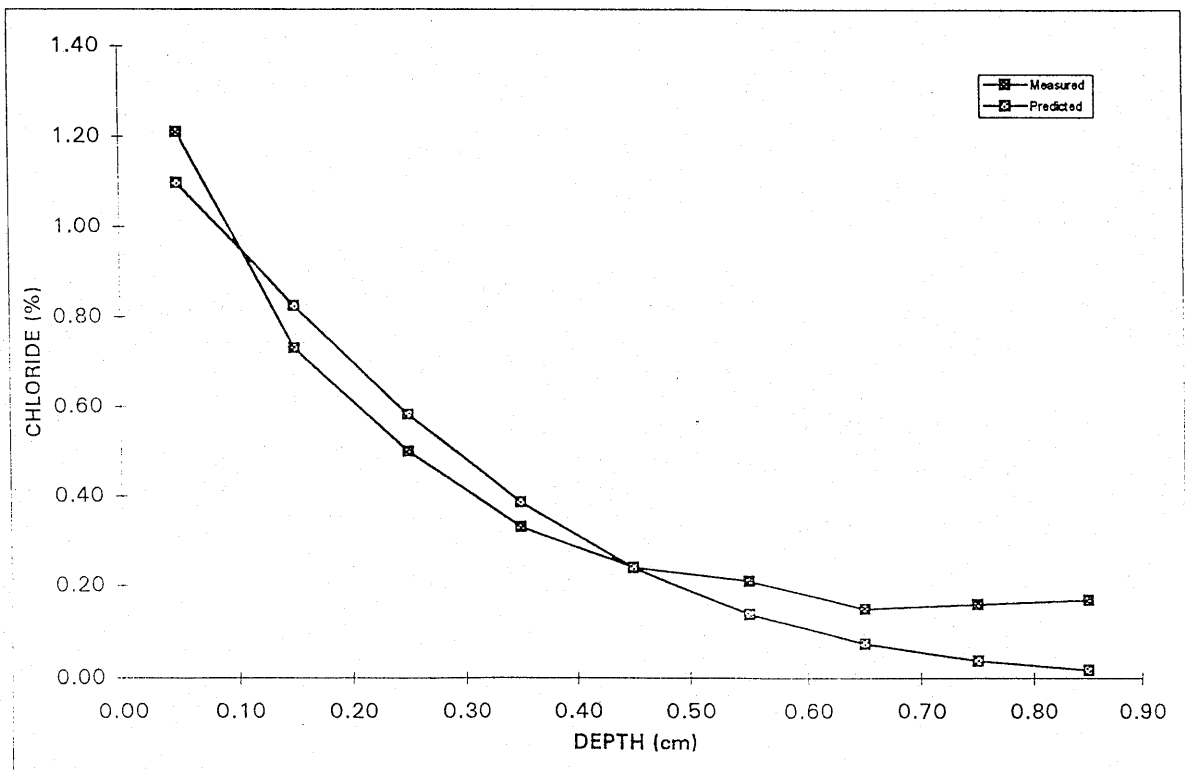
Depth cm	Cl(%conc)	Cl minus backgrnd	Est Cx	Squd diffs		
0			0.89		AGE (yrs)	0.0767
0.05	0.81	0.79	0.79	0.000	AGE (s)	2.42E+06
0.15	0.63	0.61	0.61	0.000	D (cm <sup>2</sup> /s)	2.78E-08
0.25	0.47	0.45	0.44	0.000	D(m <sup>2</sup> /s) @40°	2.78E-12
0.35	0.33	0.31	0.30	0.000	log D	-11.5556
0.45	0.20	0.18	0.20	0.000	Cs	0.880326
0.55	0.12	0.10	0.12	0.000	Background Cl	0.02
0.65	0.08	0.06	0.07	0.000	sum of squares =	0.002825
0.75	0.08	0.06	0.04	0.001		
0.85	0.07	0.05	0.02	0.001	D(m <sup>2</sup> /s) @20°	6.96E-13
0.95	0.04	0.02	0.01	0.000		
4.85						
4.95						



**BEST FIT ANALYSIS OF CHLORIDE PROFILES**

Sample Number: 123006/2 CPF 28 Day immersion

Depth cm	Cl(%conc)	Cl minus backgrnd	Est Cx	Soud diffs		
0			1.24		AGE (yrs)	0.0763
0.05	1.23	1.21	1.10	0.013	AGE (s)	2.42E+06
0.15	0.75	0.73	0.82	0.009	D (cm <sup>2</sup> /s)	2.47E-08
0.25	0.52	0.50	0.58	0.007	D(m <sup>2</sup> /s) @40°	2.47E-12
0.35	0.35	0.33	0.39	0.003	log D	-11.8076
0.45	0.26	0.24	0.24	0.000	Cs	1.240101
0.55	0.23	0.21	0.14	0.005	Background Cl	0.02
0.65	0.17	0.15	0.07	0.006	sum of squares =	0.080604
0.75	0.18	0.16	0.04	0.015	D(m <sup>2</sup> /s) @20°	6.17E-13
0.85	0.19	0.17	0.02	0.023		

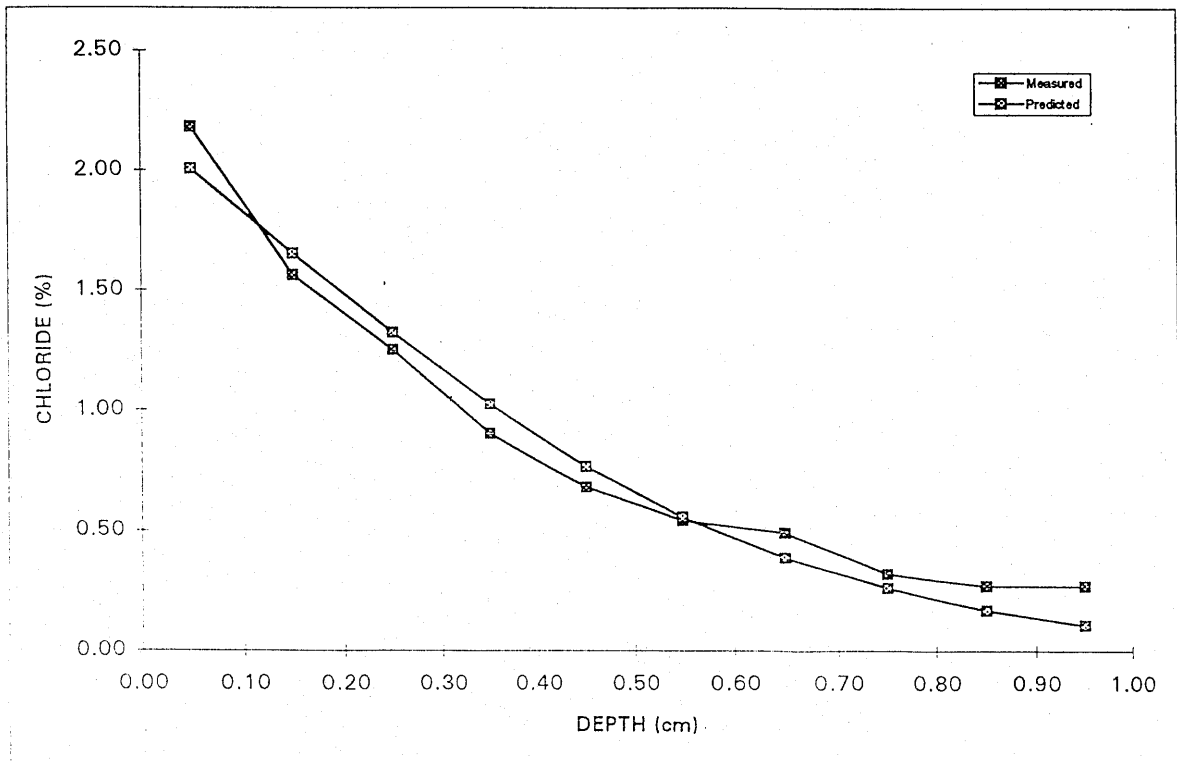




**BEST FIT ANALYSIS OF CHLORIDE PROFILES**

Sample Number 123005/1 Non-CPF 28 Day Immersion

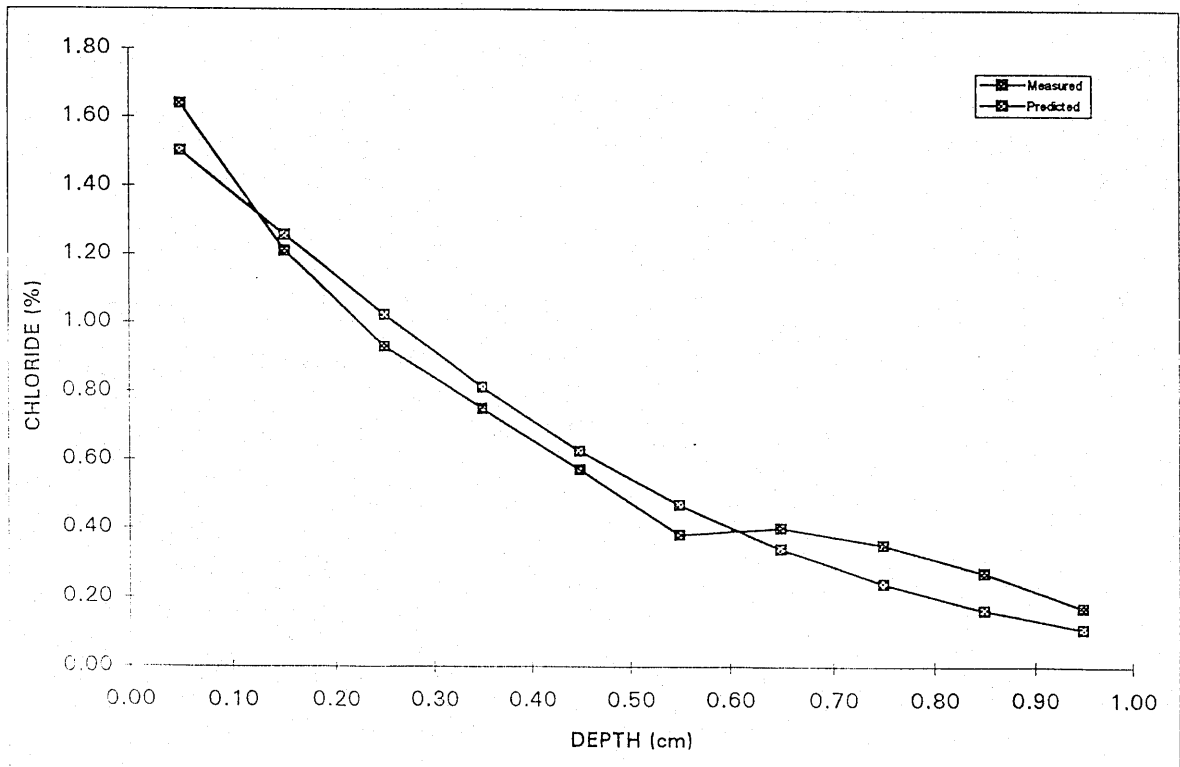
Depth cm	Cl(%conc)	Cl minus backgrnd	Est Cx	Squd diffs	
0			2.19		AGE (yrs) 0.0767
0.05	2.20	2.18	2.01	0.030	AGE (s) 2.42E+06
0.15	1.58	1.56	1.65	0.008	D (cm <sup>2</sup> /s) 4.78E-08
0.25	1.27	1.25	1.32	0.005	D(m <sup>2</sup> /s) @40° 4.78E-12
0.35	0.92	0.90	1.02	0.015	log D 11.3202
0.45	0.70	0.68	0.76	0.007	
0.55	0.56	0.54	0.55	0.000	Cs 2.187092
0.65	0.51	0.49	0.39	0.011	Background Cl 0.02
0.75	0.34	0.32	0.26	0.004	
0.85	0.29	0.27	0.17	0.010	sum of squares = 6.117630
0.95	0.29	0.27	0.11	0.027	D(m <sup>2</sup> /s) @20° 1.2E-12
4.85					
4.95					



**BEST FIT ANALYSIS OF CHLORIDE PROFILES**

Sample Number 123006/1 Non-CPF 28 Day immersion

Depth cm	Cl(%conc)	Cl minus backgrnd	Est Cx	Sqrd diffs	
0			1.63		AGE (yrs) 0.0767
0.05	1.66	1.64	1.50	0.019	AGE (s) 2.42E+06
0.15	1.23	1.21	1.26	0.002	D (cm <sup>2</sup> /s) 5.52E-08
0.25	0.95	0.93	1.02	0.009	D(m <sup>2</sup> /s) @40° 5.52E-12
0.35	0.77	0.75	0.81	0.004	log D -11.2583
0.45	0.59	0.57	0.62	0.003	
0.55	0.40	0.38	0.47	0.008	Cs 1.628178
0.65	0.42	0.40	0.34	0.004	Background Cl 0.02
0.75	0.37	0.35	0.24	0.012	
0.85	0.29	0.27	0.16	0.012	sum of squares = 0.075891
0.95	0.19	0.17	0.11	0.004	D(m <sup>2</sup> /s) @20° 1.38E-12
4.85					
4.95					

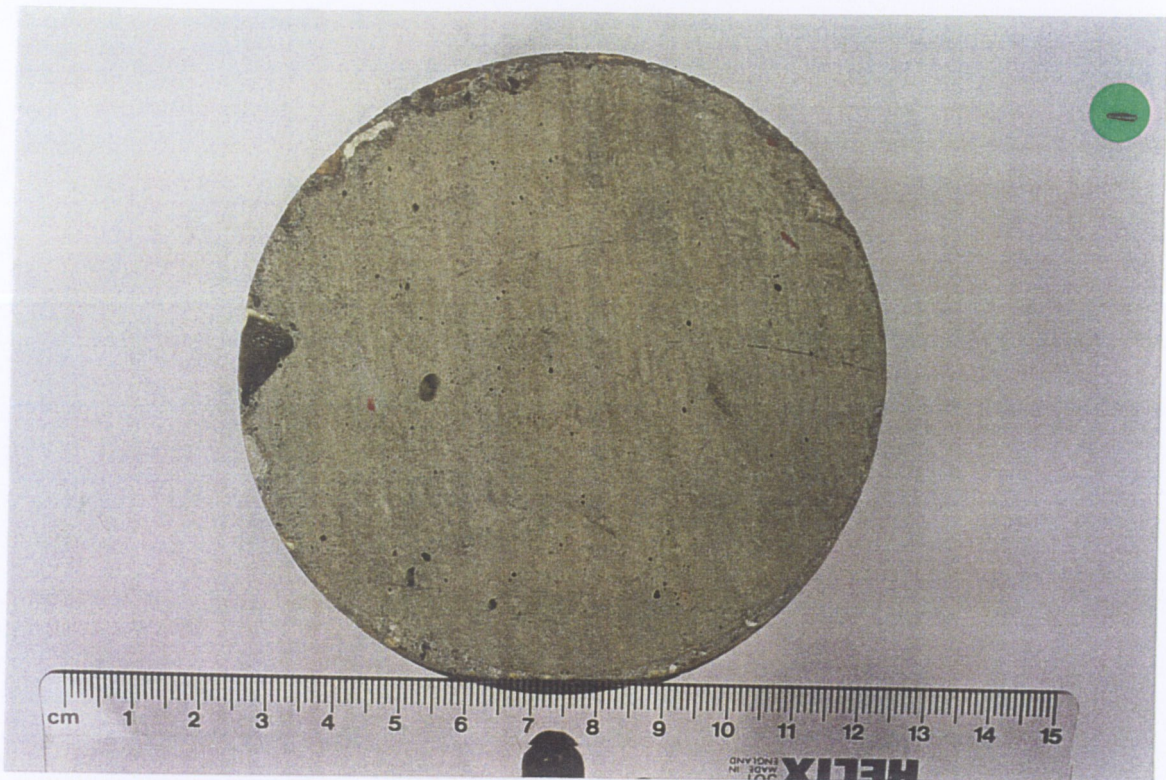


## **APPENDIX D**

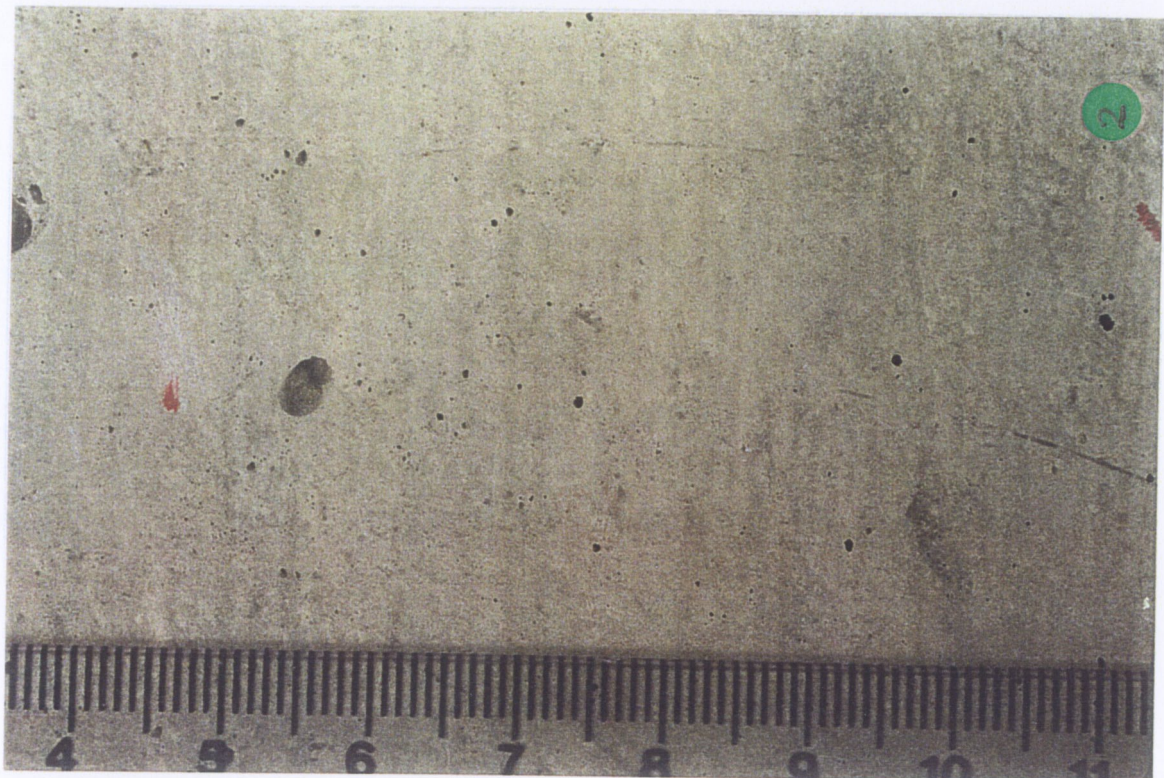
### **Freeze Thaw Tests**



PHOTOGRAPHS



No. 1 Non-CPF (123002/1): Before Test



No. 2 Non-CPF (123002/1): Before Test



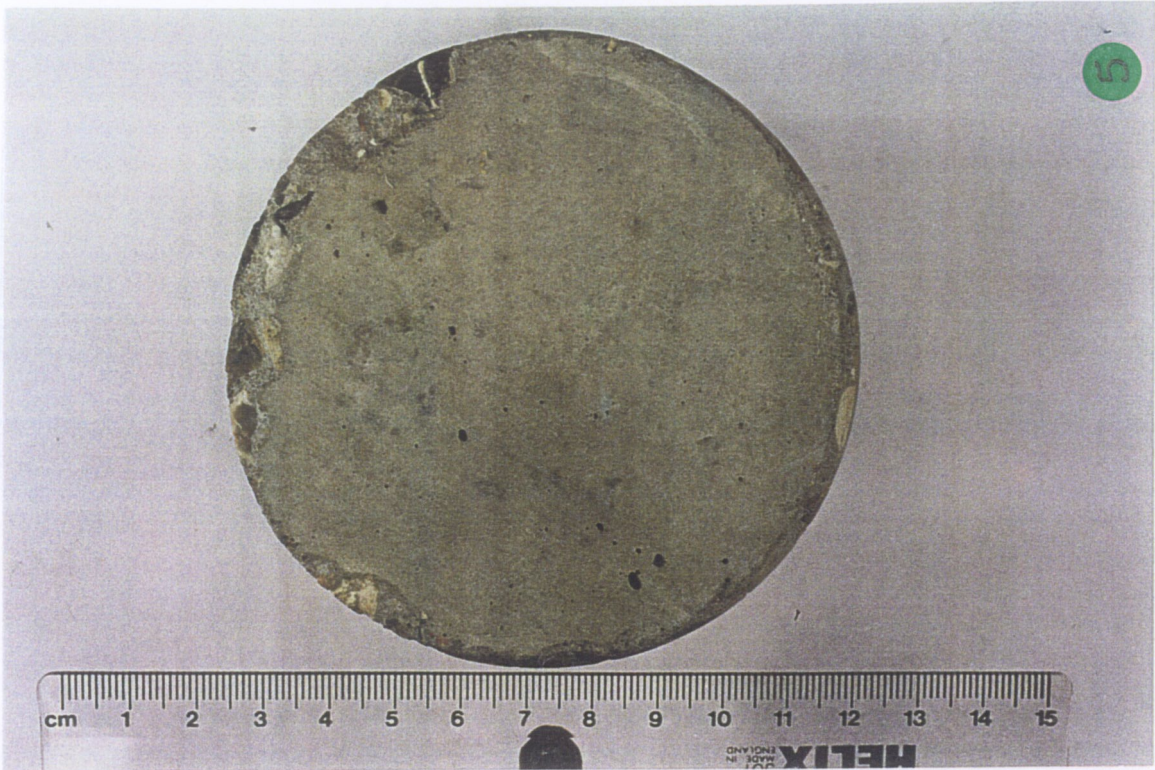


No. 3 Non-CPF (123002/1): After Test

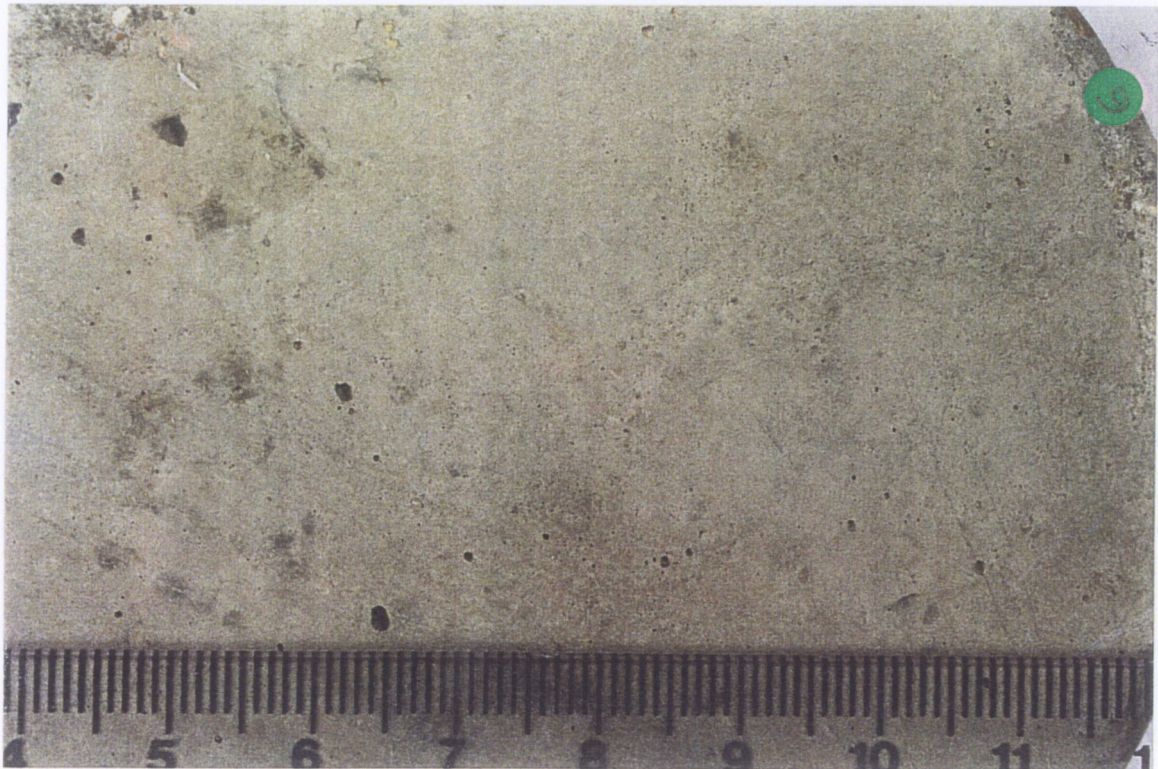


No. 4 Non-CPF (123002/1): After Test





No. 5 Non-CPF (123003/1): Before Test

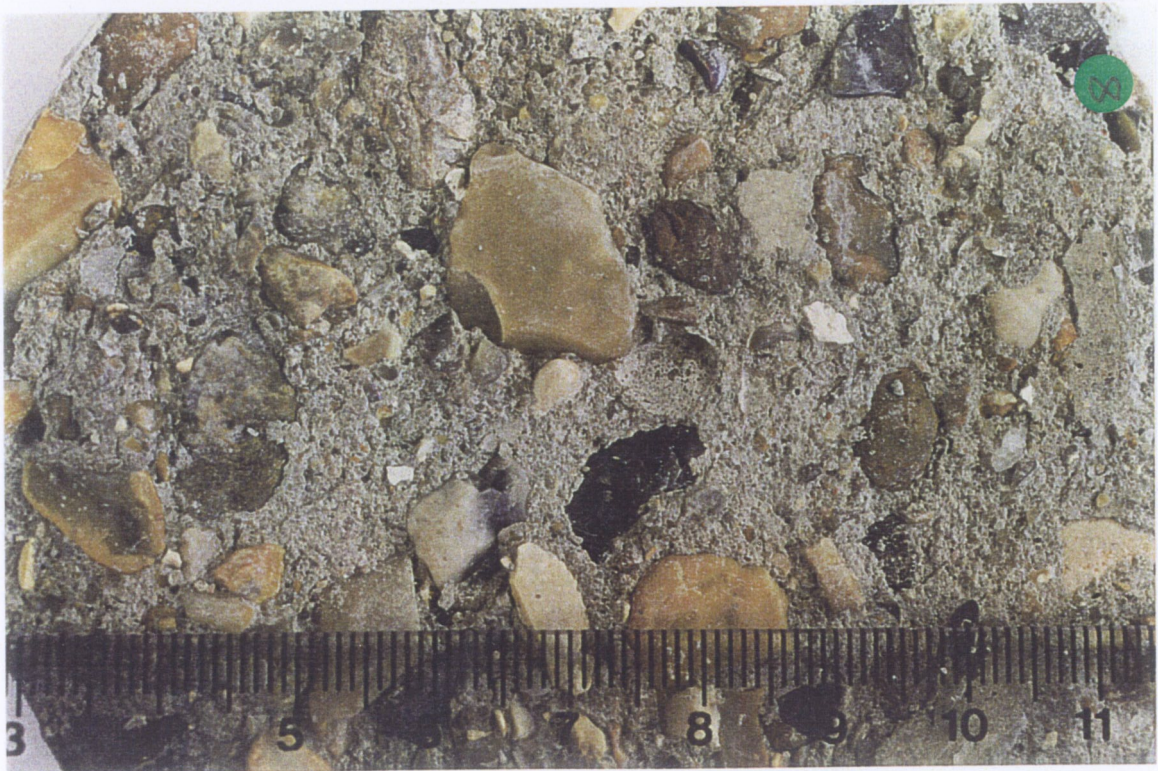


No. 6 Non-CPF (123003/1): Before Test



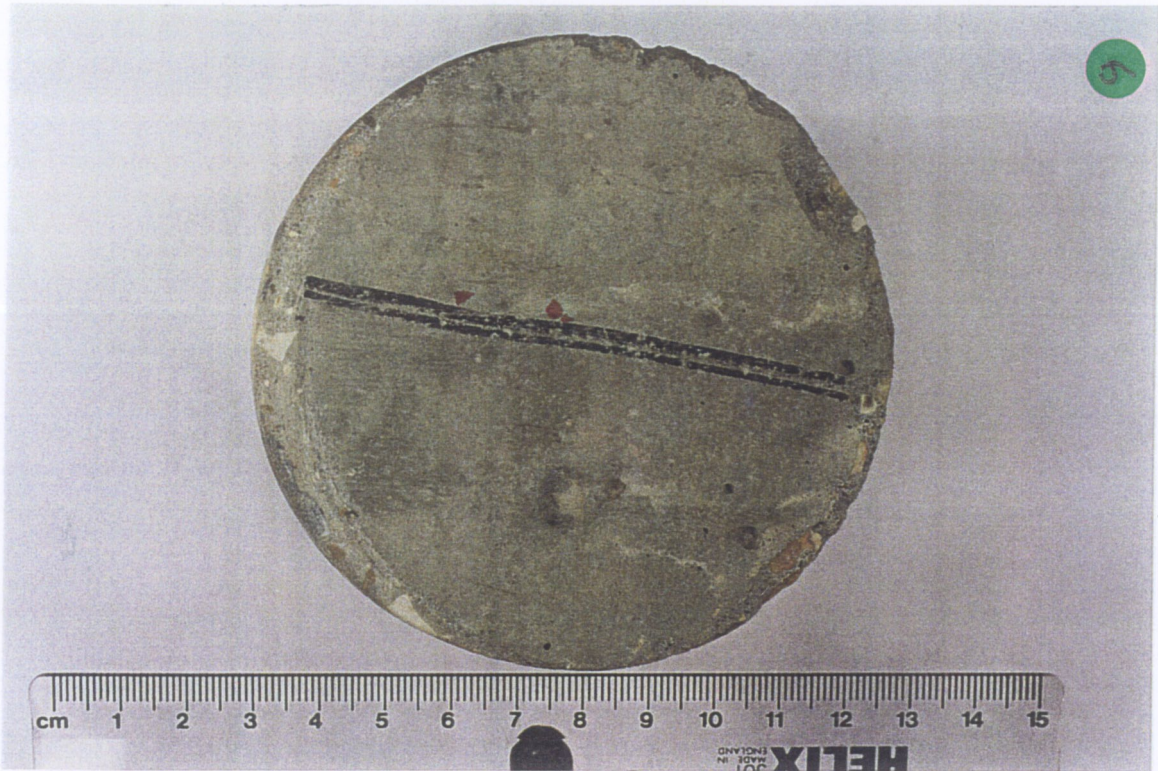


No. 7 Non-CPF (123003/1): After Test

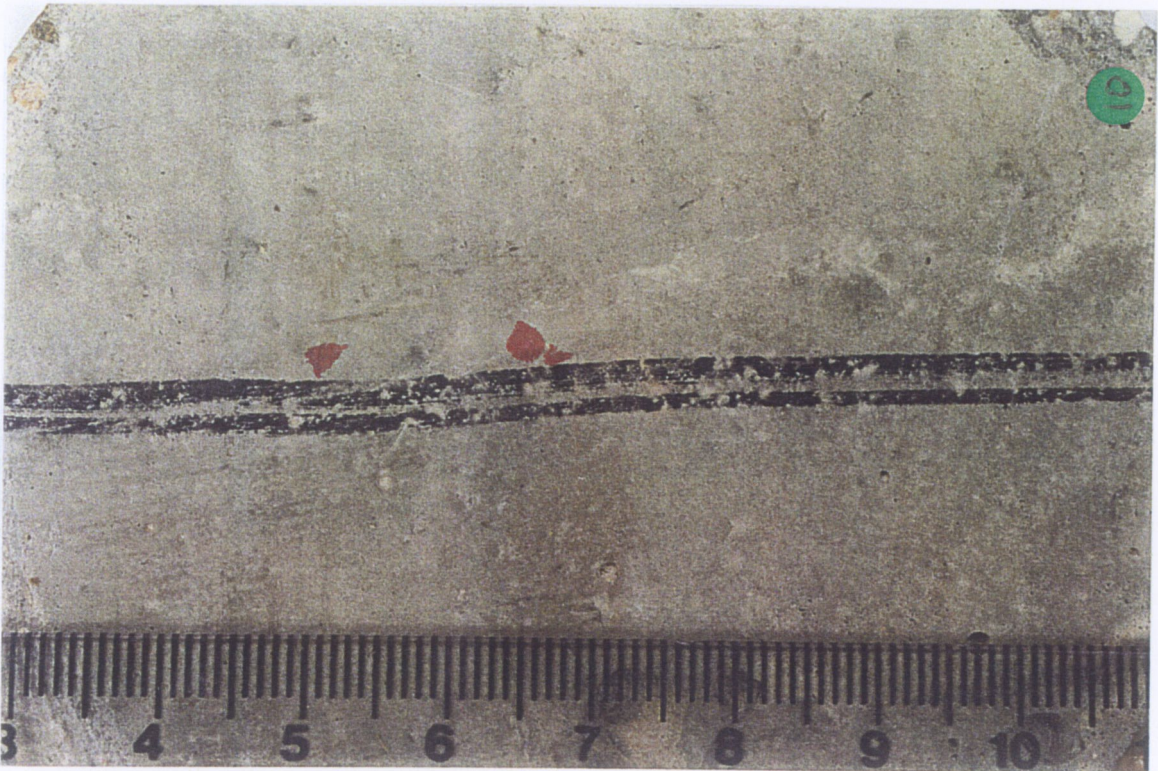


No. 8 Non-CPF (123003/1): After Test





No. 9 Non-CPF (123004/1): Before Test



No. 10 Non-CPF (123004/1): Before Test



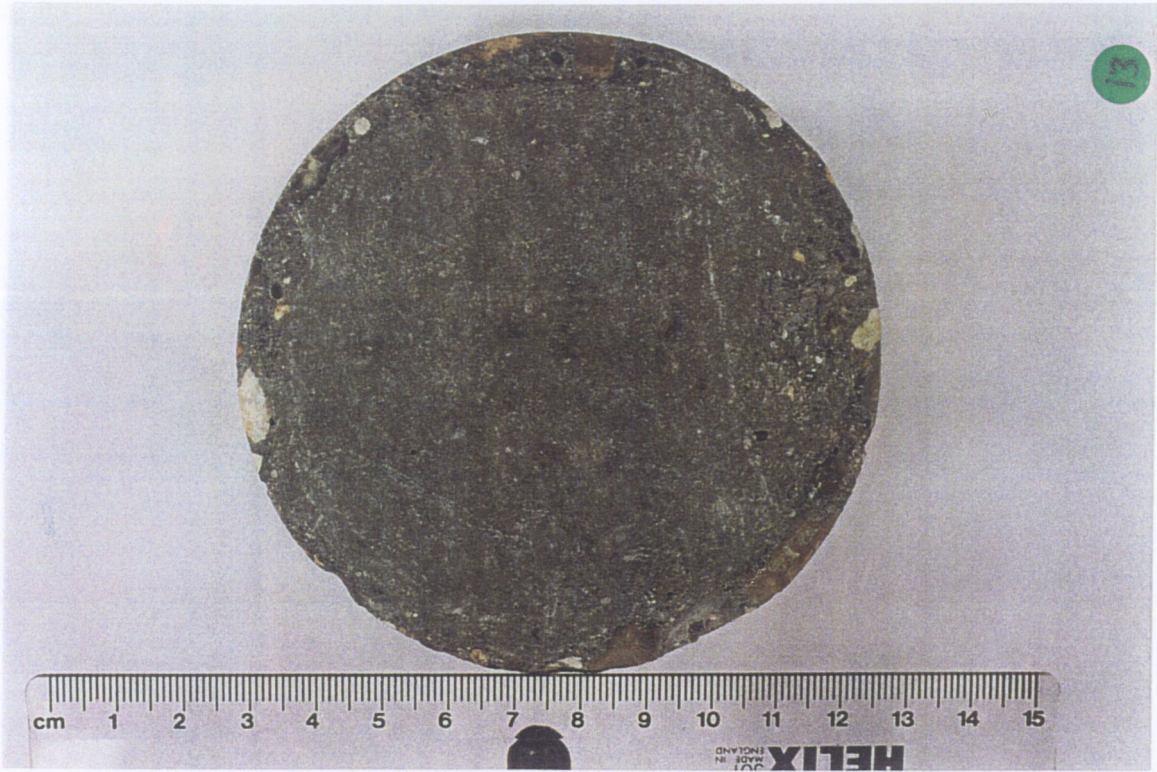


No. 11 Non-CPF (123004/1): After Test

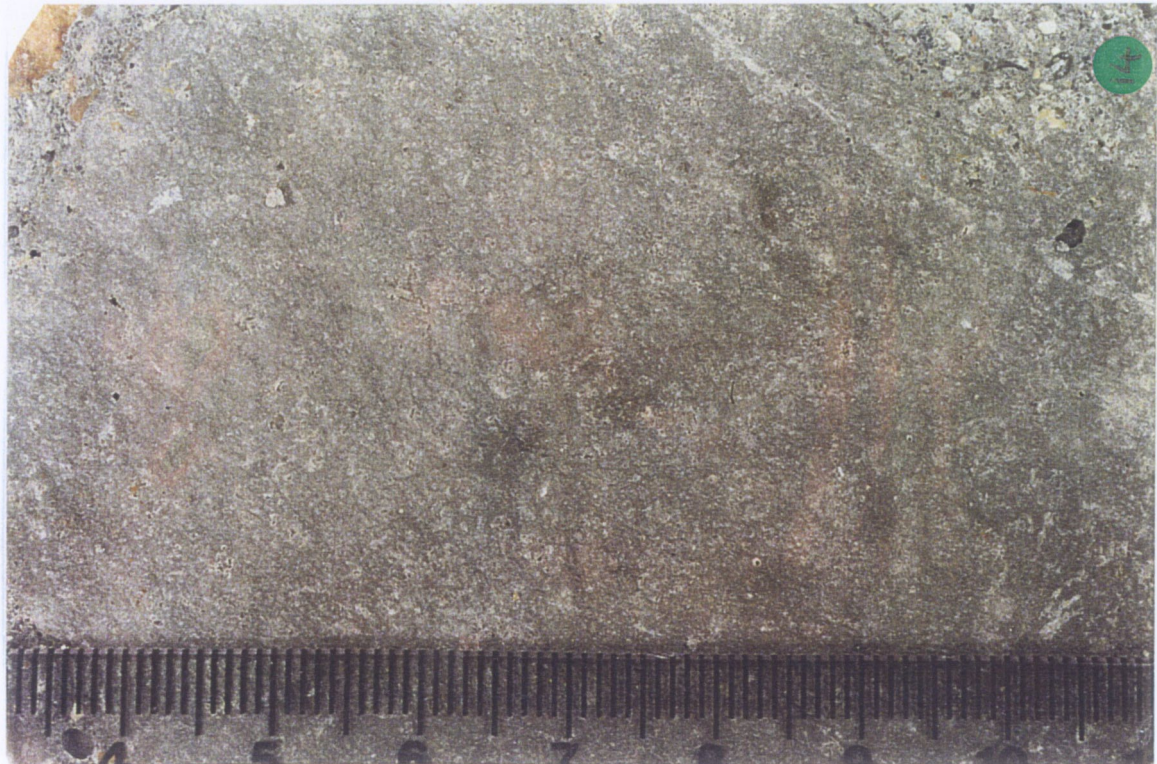


No. 12 Non-CPF (123004/1): After Test





No. 13 CPF (123002/2): Before Test

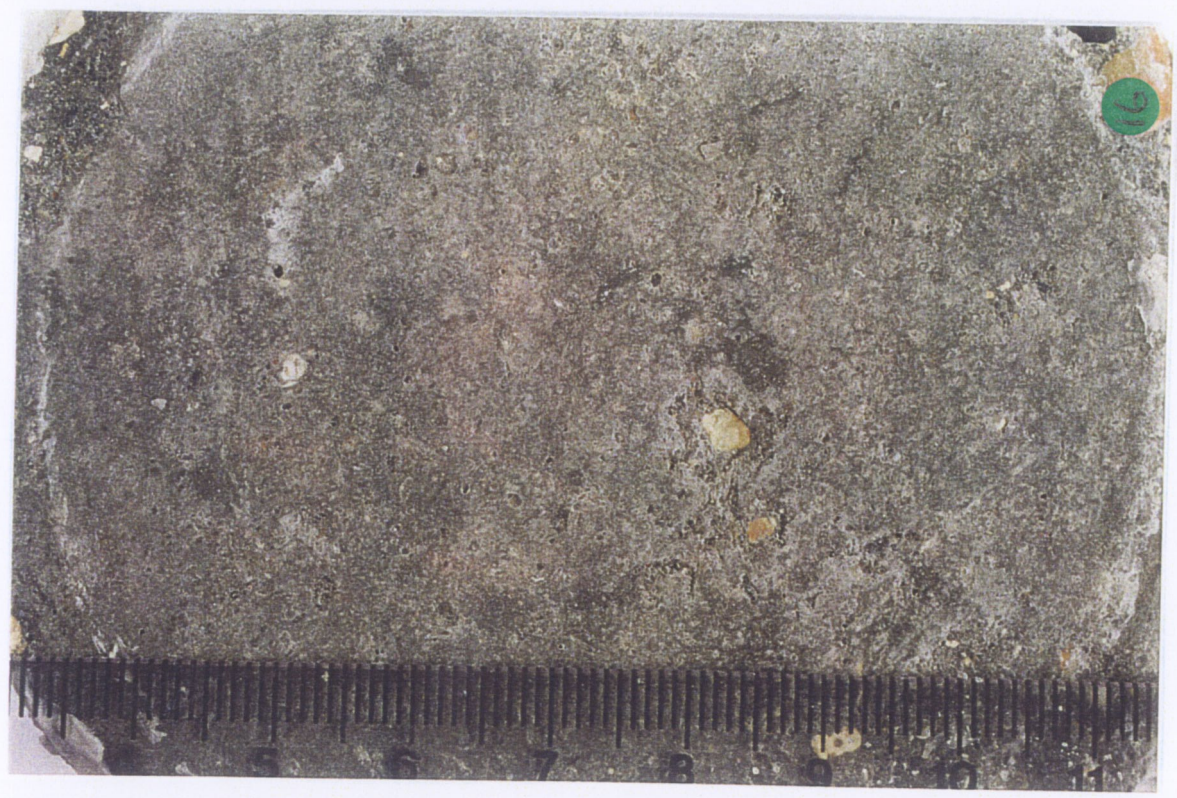


No. 14 CPF (123002/2): Before Test



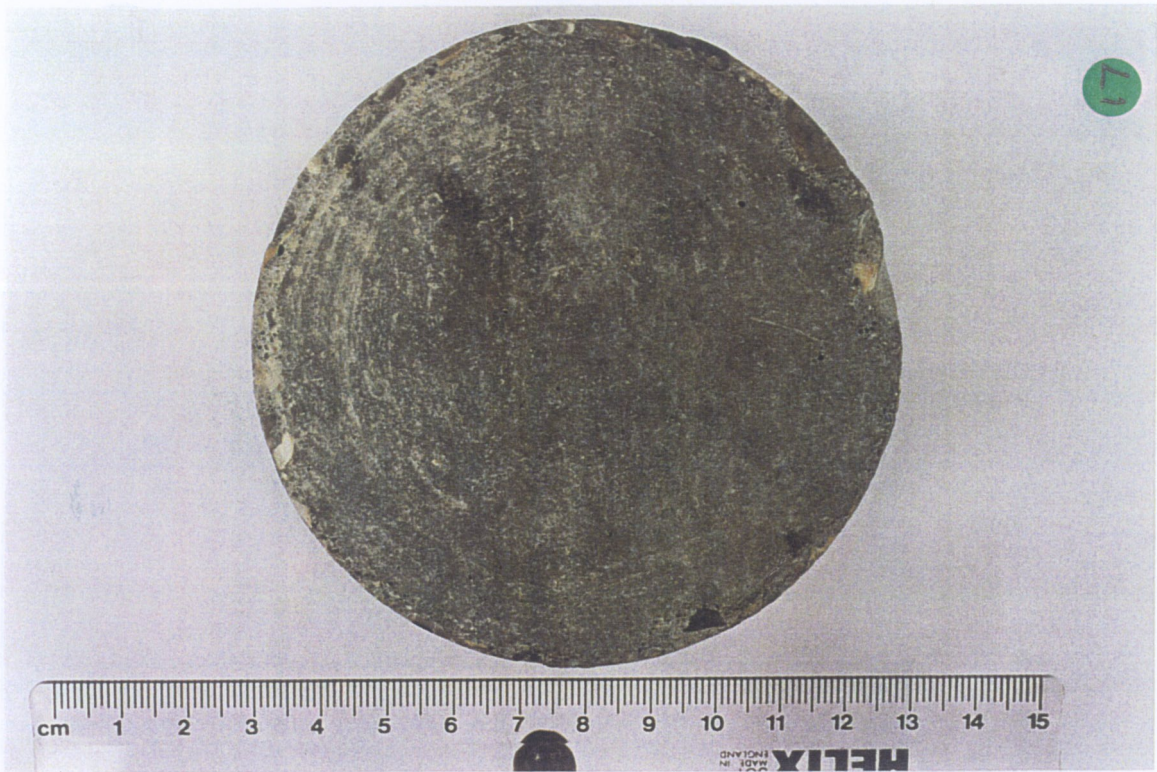


No. 15 CPF (123002/2): After Test

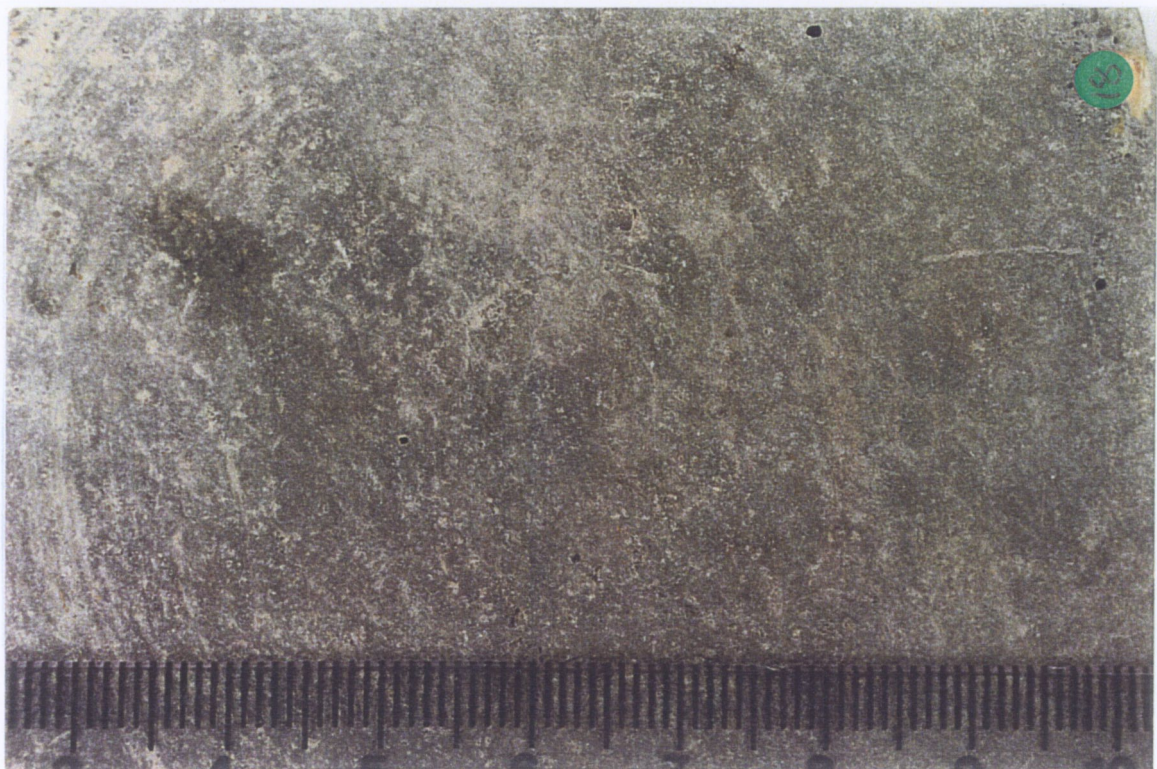


No. 16 CPF (123002/2): After Test





No. 17 CPF (123003/2): Before Test

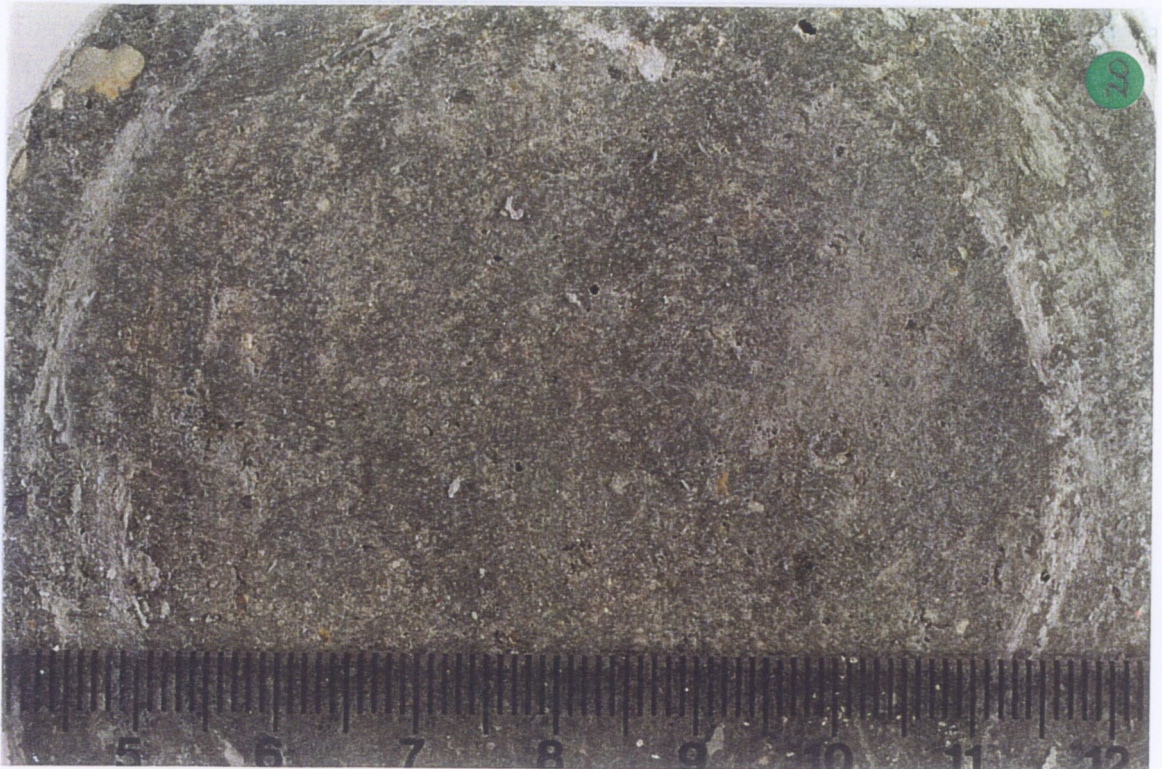


No. 18 CPF (123003/21): Before Test



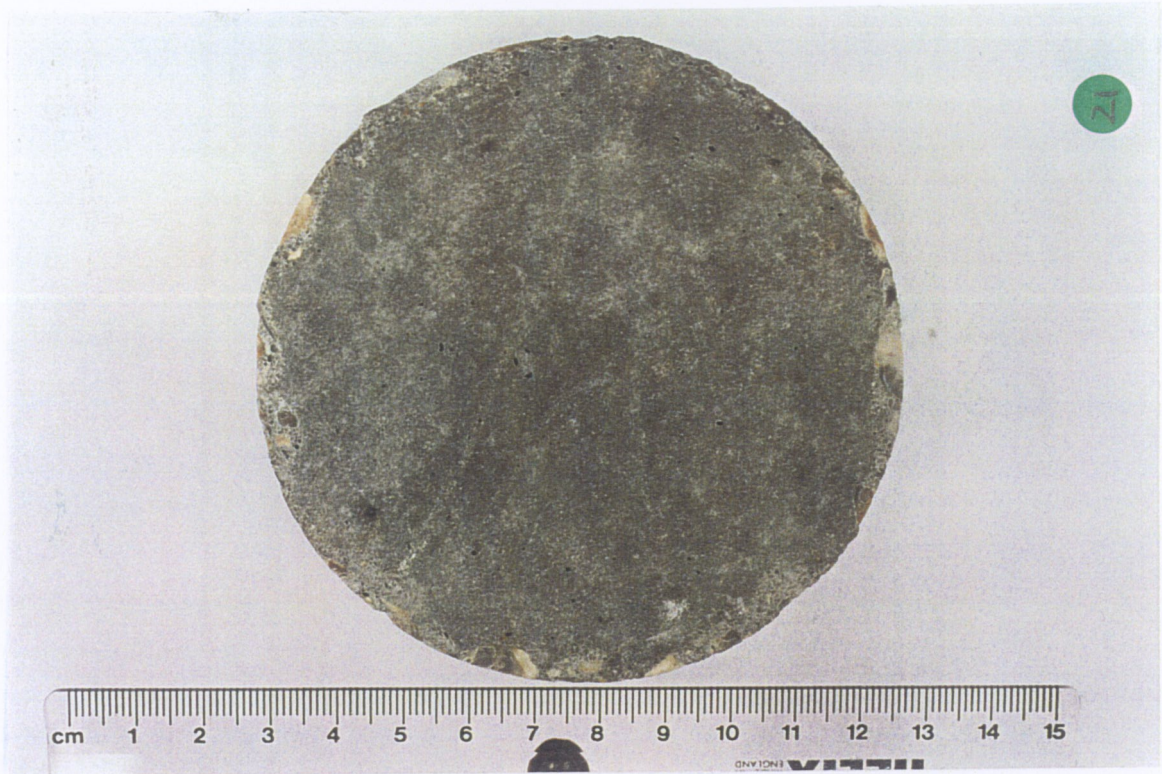


No. 19 CPF (123003/2): After Test

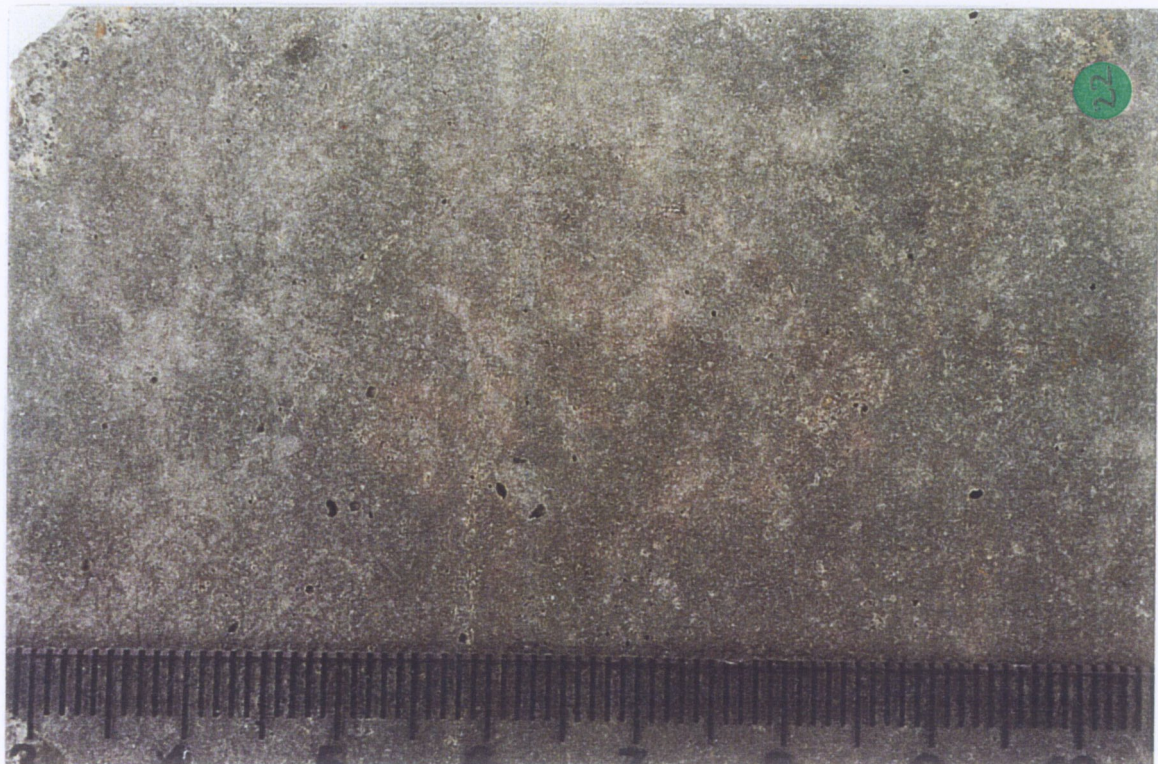


No. 20 CPF (123003/2): After Test





No. 21 CPF (123004/2): Before Test

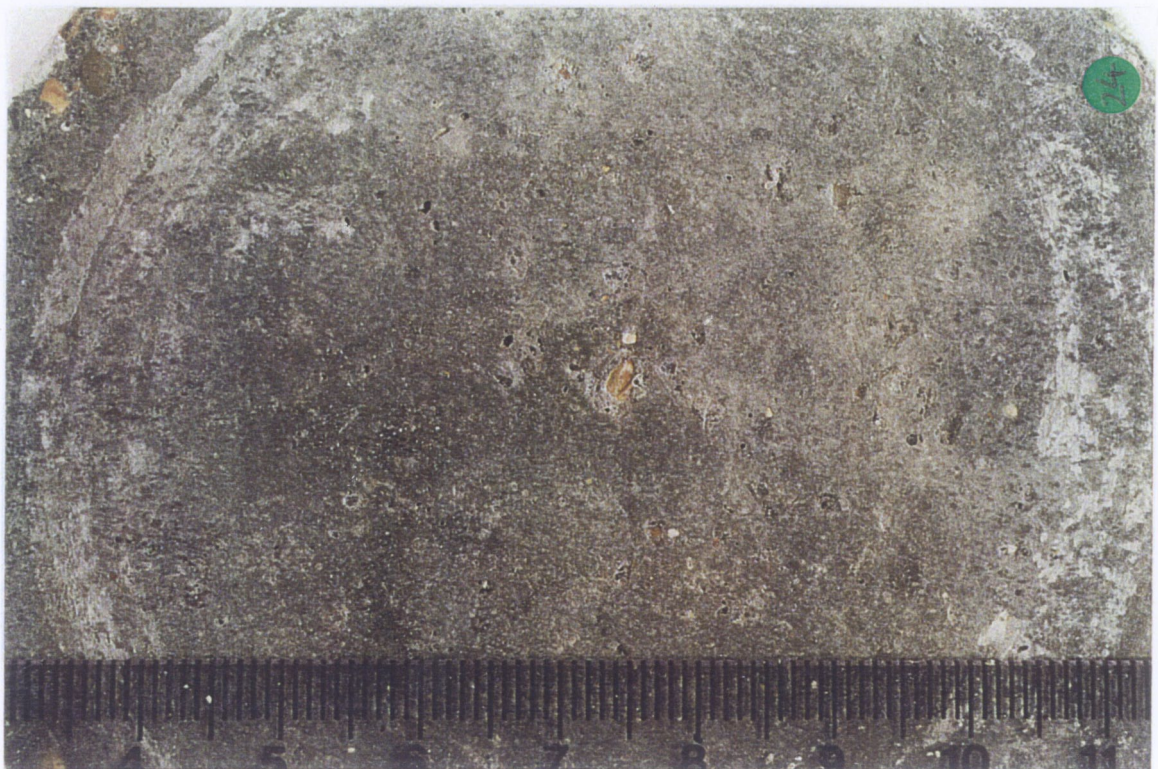


No. 22 CPF (123004/2): Before Test





No. 23 CPF (123004/2): After Test



No. 24 CPF (123004/2): After Test