STUDY ON FRESH AND HARDENED PROPERTIES OF CONCRETE WITH AND WITHOUT THE "XYPEX" ADMIXTURE

REPORT SUBMITTED TO

KAJIMA OVERSEAS ASIA PTE. LTD.

BY

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1. INTRODUCTION:

There have been some difficulties with workability and compressive strength in concrete containing the "Xypex" admixture at the Woodlands Checkpoint project. Following numerous plant trials and site production results, it has been suggested that there may be some incompatibility between the ""Xypex" and the "Cormix SP1" superplasticiser used.

The first stage of this study has involved five different mix designs tested in the laboratory. The materials used for the laboratory trials were supplied from the Woodlands Plant and thus would be representative of normal production conditions. The second stage involved plant trials on three of the mix designs. These trial mixes were witnessed by representatives from Kajima, Supermix and Jingslink Marketing. A summary of the mixes tested is given below:

Mark 8 : Grade 35P with a cement content of 360 kg/m^3, fine aggregate content of 43.1% and w/c ratio of 0.46 with "Xypex" and "Cormix SP1" added at 0.8% and 425mls per 100 kg of cement respectively. This mix is representative of the G35P "Xypex" concrete placed on site.

Mark 9 : Grade 45P with a cement content of 420 kg/m^3, fine aggregate content of 40.5% and w/c ratio of 0.45 with "Xypex" and "Cormix SP1" added at 0.8% and 425mls per 100 kg of cement respectively. This mix is representative of the G45P "Xypex" concrete placed on site.

Mark 10A: Grade 45P with a cement content of 420 kg/m^3, fine aggregate content of 36.5% and w/c ratio of 0.49 with "Xypex" added at 0.8%. This mix was proposed by Xypex Australia as an alternative to Mark 9 to eliminate the need for a superplasticiser while retaining the required strength and workability.

Mark 12A: Grade 35P with a cement content of 360 kg/m^3, fine aggregate content of 38.3% and w/c ratio of 0.49 with "Xypex" added at 0.8%. This mix was proposed by Xypex Australia as an alternative to Mark 8 to eliminate the need for a superplasticiser while retaining the required strength and workability.

SM 35P: Grade 35P with a cement content of 360 kg/m^3, fine aggregate content of 44.9% and w/c ratio of 0.43 with "Xypex" and "Cormix SP1" added at 0.8% and 900 mls per 100 kg of cement respectively. This mix was proposed by Supermix as an alternative to Mark 8 to improve the strength and workability of the Grade 35 concrete.

SM 45P: Grade 45P with a cement content of 420 kg/m^3, fine aggregate content of 40.8% and w/c ratio of 0.39 with "Xypex" and "Cormix SP1" added at 0.8% and 1000 mls per 100 kg of cement respectively. This mix was proposed by Supermix as an alternative to Mark 9 to improve the strength and workability of the Grade 45 concrete.

The mix proportions of the above trial mixes are given in Appendix I.

The laboratory trials were focused on investigating influence of "Cormix SP1" on the properties of "Xypex" modified concrete. They also provided an opportunity to objectively assess the viability of the various mix designs.

Following the laboratory trials, plant trials were conducted at the Woodlands plant using the Mark 12A, SM 35P and SM 45P mix designs together with some minor modifications.

This report provides results and comments on a range of tests that have been performed on selected mixes to determine;

- The effect of "Cormix SP1" on "Xypex" modified concrete,
- The effect of "Xypex" on "Cormix SP1"superplasticised concrete,
- The most suitable mixes to achieve the required strength and workability.

2. FRESH PROPERTIES OF THE CONCRETE:

2.1 Slump:

2.1.1 As shown in Appendix I, the mixes containing "Xypex" alone, namely, Marks 8(i), 9(i), 10A and 12A gave initial slumps of 27, 35-40, 149 and 36 mm respectively. Considering the specified slump requirement of 125 ± 25 mm, only Mark 10A could be considered for use without the addition of a superplasticiser.

2.1.2 The addition of "Cormix SP1" to the Mark 8(i), 9(i) and 12A mixes containing "Xypex" resulted in a significant increase in slump. However, Mark 8(ii) only had a slump of 52 mm and Marks 9(ii) and 12A(ii) had slumps of approximately 100 mm (i.e. at the lower end of the allowable slump range). Figures 1 (a) and (b) show slumps obtained from concrete with and without the superplasticiser.

2.1.3 SM 35P(ii) containing "Cormix SP1" and "Xypex" had a slump of 188 mm, in excess of the allowable slump range.

2.1.4 The plant trials were conducted on SM 35P, SM 45P and Mark 10A. The trials confirmed that dosages of 900 and 1000 mls of "Cormix SP1" per 100 kgs for SM 35P(WLCT 1) and SM 45P (WLCT 2) respectively gave slumps in excess of the specified requirements. Reducing the dosage of "Cormix SP1" by 100 mls for both grades gave compliant workability. The Mark 10A mix complied with the slump requirement without modification.

2.2 Air Content:

One possible cause of strength reduction as a result of admixture addition is air entrainment which would be indicated by an increased air content.

Comparison of the air content measurements made on Marks 8(i) and 9(i) which contained only "Xypex" with Marks 8(ii) and 9(ii) which also contained "Cormix SP1" showed the addition of the superplasticer actually reduced air content by 0.4 and 0.3% respectively.

Accordingly, air entrainment by "Cormix SP1" does not appear to be the cause of any observed strength reduction.

2.3 Retardation:

Another possible influence of an admixture which may indirectly cause a reduction in strength is if it were to produce significant retardation of set. This may result in early damage to the concrete during demoulding or in the event of improper curing.

A sieved sample of Mark 12A concrete with the addition of both "Xypex" and "Cormix SP1" reached final set within 8 hours of water addition. Other mixes did not suggest extended setting times.

Accordingly, excessive retardation caused by the addition of "Cormix SP1" in accordance with the proposed mix designs does not seem to be a factor in the observed strength reduction. Obviously, any accidental overdose of "Cormix SP1" may still produce such an effect.

3. MECHANICAL PROPERTIES OF THE CONCRETE:

3.1 Compressive Strength:

3.1.1 Compressive strength tests were conducted in accordance with BS 1881: Part 116: 1983 on nominal 100 mm cubes for the laboratory trials and nominal 150 mm cubes for the plant trials. Specimens were water cured at 28°C ± 2°C prior to test. The test equipment is shown in Figure 2. The data obtained are summarized in Appendix II.

3.1.2 Comparison of the compressive strengths of laboratory trial mixes, Marks 8(i), 9(i) and 12A(i) which contained "Xypex" alone with Marks 8(ii), 9(ii) and 12A(ii) which contained both "Xypex" as well as "Cormix SP1" showed no significant detrimental effect of the addition of the superplasticiser. The 28-day compressive strength results for companion mixes were all within one standard deviation of the other.

3.1.3 Comparison of SM 35P(i) which contained "Cormix SP1" only with SM 35(ii) which contained "Cormix SP1" and "Xypex" also showed no significant detrimental effect of the addition of the "Xypex" admixture. The 28-day compressive strength results for companion mixes were all within one standard deviation of the other.

3.1.4 All laboratory mixes achieved average 28-day compressive strengths in excess of the characteristic strength plus a design margin of 7.5 N/mm².

3.1.5 The concrete from the plant trials all achieved the required target strengths for their respective grades, even the unmodified SM 35P and 45P mixes (WLCT1 and 2) which were rejected by the Clerk of Works for excessive slump. The method of addition of the "Xypex" powder at the plant is shown in Figure 2.

3.1.6 The unmodified SM 35P and 45P mixes (WLCT1 and 2) differed from the modified mixes, WLCT 33 and 34 only in terms of the level of "Cormix SP1" added and the resultant workability. However, these mixes yielded 7- and 28-day strengths approximately 80 percent that of the mixes with slightly lower superplasticiser dosage and reduced workability suggesting that high workability may have a profound effect on these concretes. The strength results from the plant trial for SM 35P (WLCT 1) are comparable to those obtained from the laboratory trial with the same mix design and workability.

3.1.7 Another observation from the plant trial results is that the Mark 10A mix (WLCT 35), which had a designed w/c ratio of 0.49 and contained no superplasticiser, yielded 7- and 28-day strengths 75 and 78 percent of the modified SM 45P mix (WLCT 34). The modified SM 45P mix had the same cement content with the addition of "Cormix SP1" at a rate of 900 mls per 100 kg of cement which allowed the w/c ratio to be reduced to 0.39.

This suggests that the relative strength of these two mixes was determined by the w/c ratio differential with "Xypex" providing no additional strength enhancement.

3.2 Flexural Strength:

3.2.1 The modulus of rupture tests were conducted in accordance with BS 1881: Part 118: 1983 on 100 x 100 x 400 mm beams water cured for 28 days at 28°C ± 2°C. The test equipment is shown in Figure 4. The results are summarized in Appendices II and III.

3.2.2 The data suggest that there may be some nominal reduction in the flexural strength compared with the 28-day strength as a result of the addition of "Cormix SP1".

3.2.3 Any reduction may be associated with an effect of larger bleeding capacity due to the somewhat higher workability of the mixes containing the superplasticiser.

3.3 Tensile Strength:

3.3.1 The tensile strength tests were conducted on Mark 9(i) and (ii) mixes in accordance with BS 1881: Part 117: 1983 on 300 mm x 150 mm diameter cylinders. The specimens were water cured at 28°C ± 2°C until 28 days. The test procedure is shown in Figure 5. The splitting tensile strength data are also summarized in Appendices II and III.

3.3.2 While the average tensile strength of Mark 9(ii) is 11 percent lower than Mark 9(i), the standard deviation is very high. Therefore, it is not possible to conclude from these data that the tensile strength is lower.

3.4 Modulus of Elasticity:

3.4.1 Modulus of Elasticity was measured following the procedure outlined in BS 1881: Part 121: 1983 on 300 mm x 150 mm diameter cylinders. The specimens were water cured at 28°C ± 2°C until 28 days. The testing set up is shown in Figure 6. The Young's modulus data are also summarized in Appendices II and III.

3.4.2 The average results show Mark 9 (ii) to have a Young's Modulus 6 percent higher than that of the Mark 9(i) mix without "Cormix SP1" added.

4. PENETRABILITY PROPERTIES OF THE CONCRETE

4.1 Accelerated permeability

4.1.1 Most permeability information (using D'Arcy's equation) is based on steady state outflow through a concrete section subjected to a known pressure differential. Unfortunately, to establish such a steady state can take months. Accordingly, we have used two accelerated techniques to provide a more rapid comparison of concretes with and without either "Cormix SP1" or "Xypex" as well as giving a reasonable indication of the intrinsic permeability of the concretes. The first method is based penetration depth using Valenta's formula. The second is using a quasi-steady state inflow to calculate permeability. Stage 1 is deemed to cover the initial exposure period, Stage 2 covers where the flow first becomes linear, Stage 3 covers the later linear flow.

4.1.2 The test procedure involved subjecting tapered cylinders of approx. 100 mm diameter and 180 mm length to hydraulic pressure of 1000 psi, equivalent to 690 metres of water pressure for periods of up to 17 days. Details of the permeability testing equipment are given in Figures 7 (a) and (b). Depth of water penetration was measured after splitting in indirect tension. Water inflow was measured to an accuracy of approx. 14 microlitres. The specimens were water cured at 28°C ± 2°C until testing. The results are summarised in Appendix IV.

4.1.3 The Valenta permeability of the Mark 8(i) concrete which contained only "Xypex" was found to be 72 percent that of Mark 8(ii) concrete which also contained "Cormix SP1". With Coefficients of Permeability (k) less than 10 E-12 m/s, both concretes would be considered to be of low permeability according to the Concrete Society guidelines (Appendix VI).

4.1.4 The permeability results for SM 35P(i) and SM 35P(ii) provide a comparison of superplasticised concrete with and without "Xypex". Both Valenta and quasi steady- state results are given in Appendix IV and the inflow rates in Figure 8. Both show the addition of "Xypex" to have reduced permeability. The Valenta permeability gives an average over the entire test period and would be expected to be intermediate between the earlier Stage 2 and the later Stage 3 quasi steady-state results. Aside from the Stage 2 SM 35P(i) result, all values would be considered to be low according to the Concrete Society guidelines.

4.2 "Rapid chloride permeability" – Electrical Conductivity

4.2.1 Resistance to chloride ion penetration was also measured in accordance with ASTM C 1202-94. This test method covers the determination of the electrical conductance of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. The testing equipment is shown in Figure 9. The (51±3) mm x 100 mm diameter specimens were water cured at 28°C ± 2°C until 28 days and had their flat surfaces ground smooth. A summary of the average results are given in Appendix IV. The test reports of each individual specimen are shown in Appendix V.

4.2.2 The values would be considered high according to guideline given in Table 1 of ASTM C 1202-94 (as shown in Appendix VII), except in the case of Mark 8(ii) which would be considered moderate. Comparison of Mark 8(i) and 9(i) mixes with Mark 8(ii)

Comparison of Mark 8(i) and 9(i) mixes with Mark 8(ii) and 9(ii) mixes suggest that the addition of the "Cormix SP1" tend to reduce charge passed during test.

4.2.3 The significantly higher value for SM 35P(ii) at 5230 coulombs compared to SM 35P(i) at 4428 coulombs indicates that the addition of "Xypex" increased charge passed, i.e. electrical conductivity.

4.3 Absorption by Immersion

4.3.1 Absorption by immersion was measured using BS 1881: 122: 1983 on 75 mm diameter cores taken from 150 mm cubes water cured at 28°C ± 2°C until 28 days. The Standard involves measuring the weight gain after 30 minutes of immersion, correction to adjust for specimen dimensions and presenting the result as a percentage of dry weight. The specimens were left immersed for 72 hours to give an indication of total porosity as a percentage of dry weight. The summary of results are also given in Appendix IV.

4.3.2 The absorption results showed the addition of "Cormix SP1" to a "Xypex" modified mix reduced corrected 30 minute absorption by 20 and 15 percent for the Mark 8(ii) and 9(ii) mixes respectively. The addition of "Xypex" to SP 35P(i) mix was also found to reduce absorption by 7 percent.

4.3.3 Immersion for 72 hours showed the porosity of the concretes was reduced by approximately 10 percent by the addition of "Cormix SP1". The addition of "Xypex" did not reduce porosity. The porosity of the concretes tested ranged from 5.08 to 6.44 percent by weight which is equivalent to approximately 11.7 to 14.8 percent by volume.

4.4 Initial Surface Absorption Test

4.4.1 Absorption was also measured using the initial surface absorption test BS 1881: Part 5: 1970 (ISAT) on 100 x 100 x 400 mm beams stored at 20°C after water curing at 28°C ± 2°C until 28 days. The testing arrangement is shown in Figure 10. The cumulative absorption value gives an approximate integration over the 120 minute test to yield a single value for comparison.

4.4.2 ISAT data indicated no significant influence of the addition of "Cormix SP1" on surface absorption.

4.4.3 The addition of "Xypex" did appear to reduce cumulative absorption by 8.5 percent.

5. DISCUSSION

5.1 The laboratory trials showed the addition of the "Cormix SP1" superplasticiser to a "Xypex" modified concrete increased workability without any obvious detrimental effect on air content, retardation, compressive strength or density of the concrete. However, the plant trials showed higher workability mixes SM 35P and SM 45P (WLCT 1 & 2) containing 900 and 1000 mls of "Cormix SP1" per 100 kg of cement to have only 80 percent of the strength of lower workability mixes (WLCT 33 & 34) containing 100 mls less superplasticiser per 100 kg of cement but otherwise the same proportions.

While these mixes still achieved the required target strengths, a marked strength reduction would not be expected for such a nominal increase in superplasticiser dosage and slump. The SM 35P(ii) laboratory mix had the same mix proportions as WLCT 1 and gave similar 7- and 28-day strengths indicating that a sampling error during the plant trial could not be the reason. The fact that modified SM 45P mix (WLCT 34) had a dosage of 900 mls per 100 kg and exhibited higher strength does not support the hypothesis that there was a threshold level of "Cormix SP1" above which a detrimental effect became apparent. More likely the effect was associated with high workability.

Therefore the use of "Cormix SP1" to improve workability of mixes containing "Xypex" would appear not to be the cause of observed strength difficulties provided the specified slump was not exceeded.

5.2 The plant trials provide a comparison of Grade 45P concretes containing "Xypex" and "Cormix SP1" to give a w/c ratio of 0.39 (Modified SM 45P - WLCT 34) with Mark 10A (WLCT 35) containing "Xypex" alone and a w/c ratio of 0.49. The "Xypex" alone mix had 7- and 28-day strengths 75 and 78 percent of the lower w/c ratio mix containing superplasticiser. This suggests that the relative strengths were largely determined by their w/c ratios independent of the presence of either admixture. Both this result and the laboratory SM 35P(ii) suggest that "Xypex" does not have a significant strength enhancing effect under the test conditions.

5.3 Other mechanical properties appeared relatively unaffected by the addition of the "Cormix SP1". Flexural strength and tensile strength appear slightly lower as a proportion of the compressive strength in the superplasticised mixes. The Young's Modulus was slightly higher. These results could have been influenced by the higher workability of these concretes leading to a larger bleeding capacity.

5.4 The permeability results for Mark 8(i) and 8(ii) suggest a slightly higher permeability with the addition of the superplasticiser. Again, possibly due to the higher workability, however the scale of the increase may not be significant due to the accuracy of the experiment.

5.5 The addition of "Xypex" to a superplasticised mix (SM 35P(i)) did significantly reduce permeability to 47 to 38 percent that of the concrete containing "Cormix SP1" alone. The permeability of all "Xypex" modified concrete would be considered low according to the Concrete Society guidelines.

5.6 The so-called "Rapid Chloride Permeability" results showed "Cormix SP1" to reduce conductivity while "Xypex" tended to increase conductivity. The reduced conductivity of concretes to which superplasticiser was added may have been due to higher density as a result of better compaction. The higher conductivity when "Xypex" was added may have been due to slightly reduced density and possibly the chemical nature of the admixture increasing the concentration of negative ions available for transport. All values except for Mark 8(ii) would be considered high according to guideline given in Table 1 of ASTM 1 1202-94 (as shown in Appendix VII).

However, it should be noted that the test method specified in ASTM C 1202-94 is applicable to types of concrete where correlations have been established between the test procedure and long-term chloride ponding procedure. Based on the previous extensive study conducted in NUS, it is observed that the charge passed obtained by this test method has a relatively good linear relationship with the resistance to chloride ingress for 100% OPC concrete but not for the case of concrete containing mineral admixtures such as silica fume or ground granulated blast furnace slag. The charged passed cannot be used to assess and compare the resistance to chloride ingress without considering the type of cementitious materials used. Therefore, care should be taken in interpreting the charged passed obtained from concrete with and without "Xypex". In this study, the charged passed should be used as a reference but not as a reliable information on concrete's ability to resist chloride ion penetration.

5.7 The addition of "Cormix SP1"reduced absorption by immersion, presumably due to increased density. The rate of initial surface absorption was unchanged.

5.8 The addition of "Xypex" was found to slightly reduce both absorption by immersion and initial surface absorption. Therefore, the possible detrimental effect of early evaporation specifically on "waterproof" concrete mentioned in the interim report would not be expected to be a significant factor in "Xypex" modified concrete. The effect is based on evaporated water not being replaced upon subsequent immersion in water within a concrete of very low absorption and affecting later hydration.

6. CONCLUSIONS:

6.1 The use of "Cormix SP1" to improve workability of mixes containing "Xypex" did not appear to cause any significant detrimental effect on the fresh, mechanical or penetrability properties of the concrete.

6.2 The use of "Cormix SP1" and "Xypex" in high slump concretes resulted in a significant reduction in compressive strength compared with comparable lower slump concretes. This suggests care should be taken when using this concrete at high workability.

6.3 The Grade 35P mix using "Xypex" and "Cormix SP1" (Mark 8) was found to have a very low workability. This suggests that additional water or superplasticiser would have to be added to produce a pumpable concrete.

6.4 The Grade 45P mix using "Xypex" alone (Mark 10A) achieved a satisfactory mean strength. The comparable mix with superplasticiser and a lower w/c ratio achieved a much higher strength.

6.5 Modified SM 35P and SM 45P mix designs (WLCT 33 & 34) provide most satisfactory performance in terms of workability and strength. Therefore, we would recommend these mixes be considered for future casting.

6.6 The addition of "Xypex" was found to reduce permeability to one half to one third that of a reference Grade 35P (SM 35P) concrete. The permeability level would be considered to be low.

6.7 The addition of "Xypex" was found to have little effect on surface absorption, absorption by immersion and porosity.

6.8 The addition of "Xypex" was found to increase electrical conductivity when tested according to ASTM C1202.

6.9 To avoid the influence of sampling errors, the method for making test cubes from fresh concrete should be modified so that concrete specimens are protected from evaporation as soon as they are placed. Care should be taken to ensure they are not disturbed for at least 18 hours after casting.

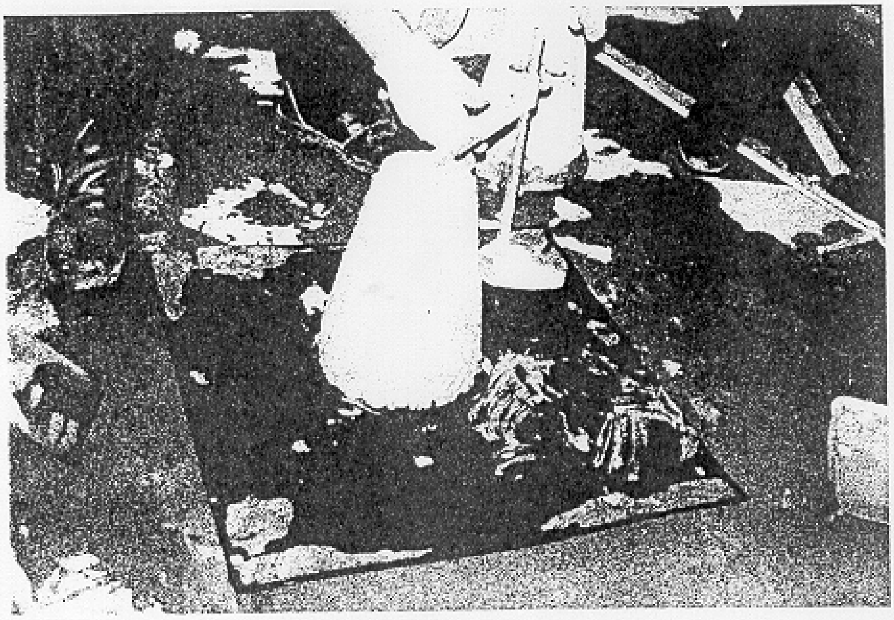


Figure 1a: Grade 45P concrete (Mark 9(i)) with "Xypex" only

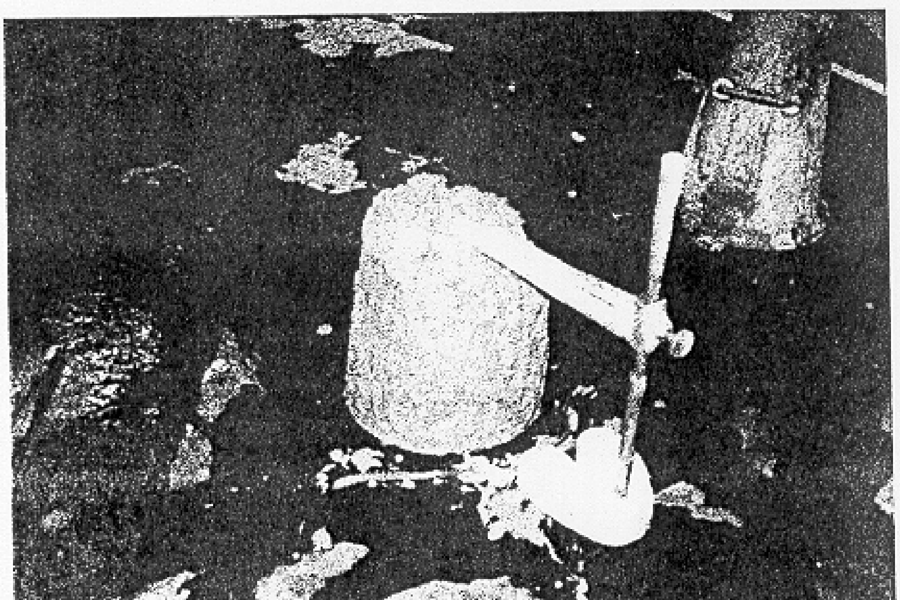


Figure 1b: Grade 45P concrete (Mark 9(ii)) with "Xypex" and "Cormix SP1"

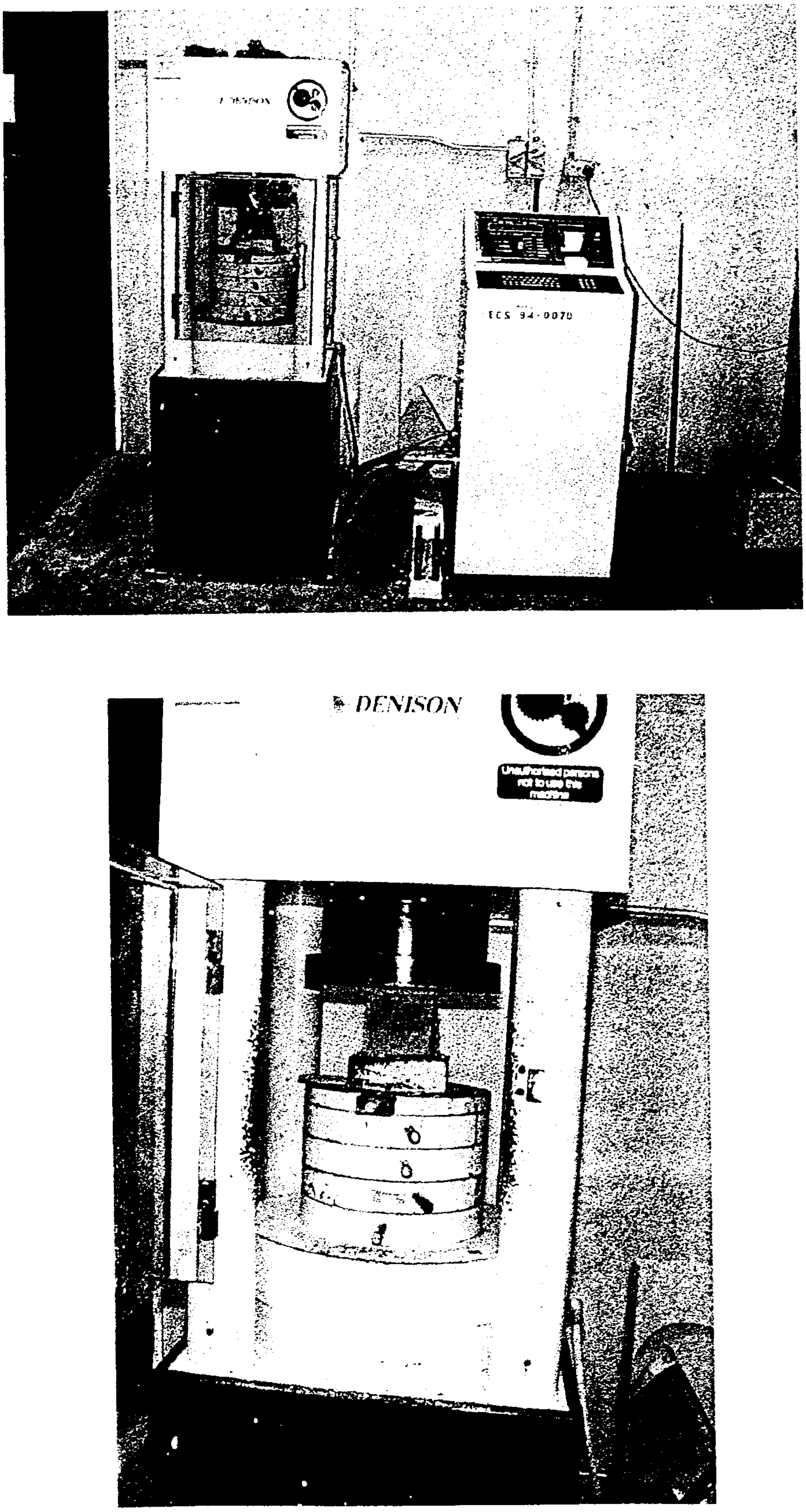


Figure 2: Cube Compressive Test Equipment

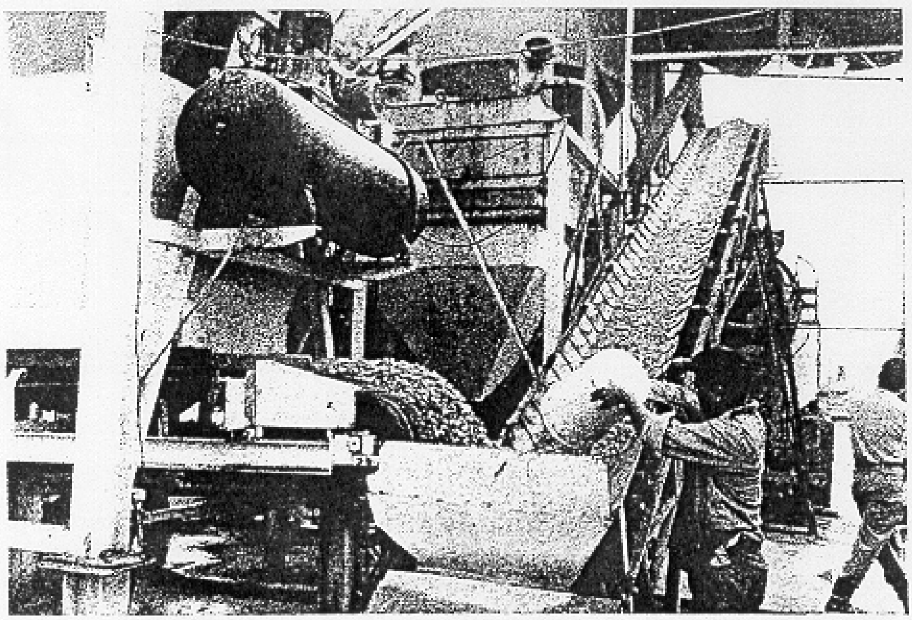
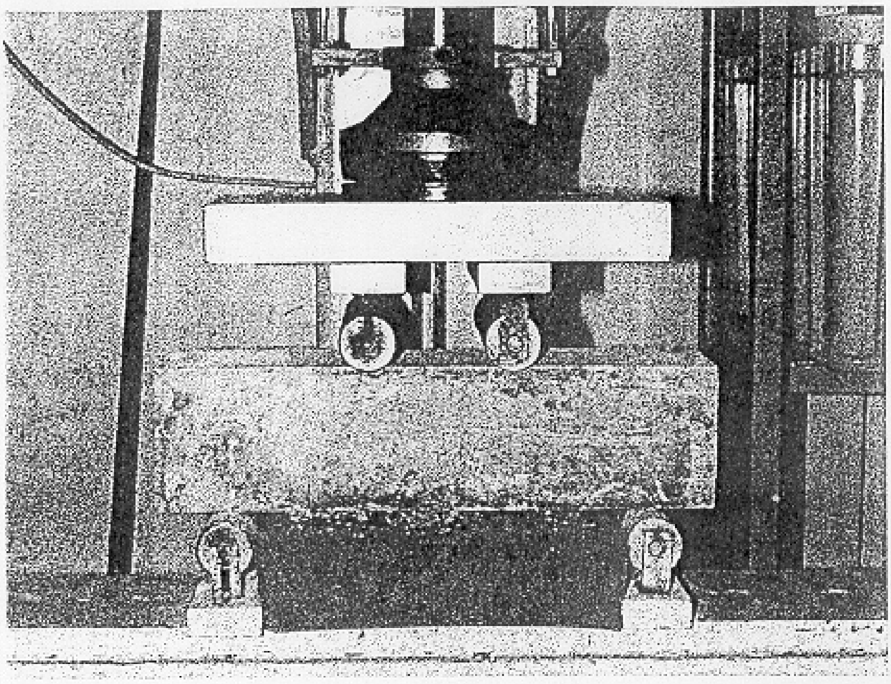


Figure 3: Addition of "Xypex" powdered admixture at batching plant



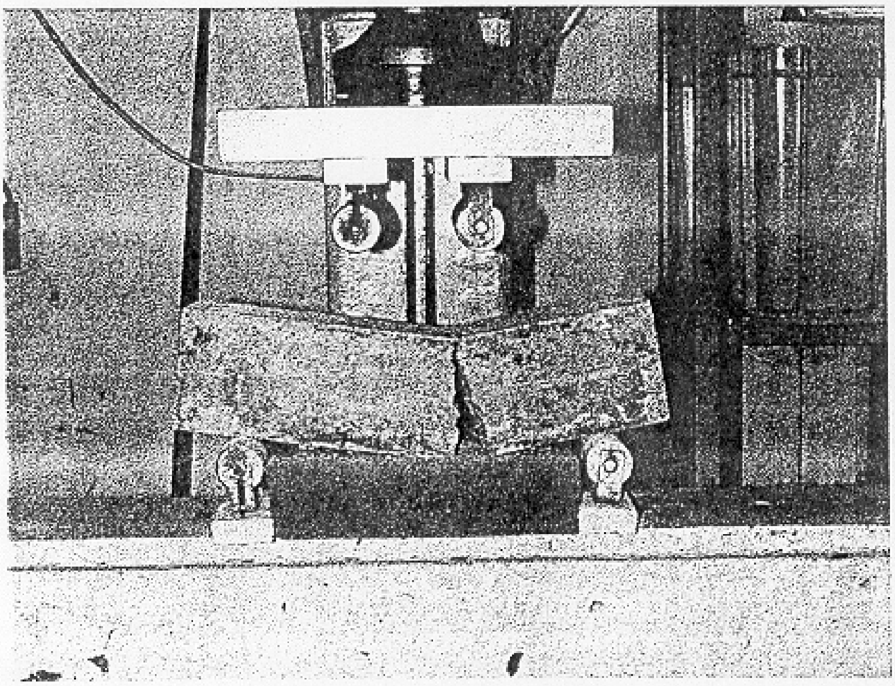
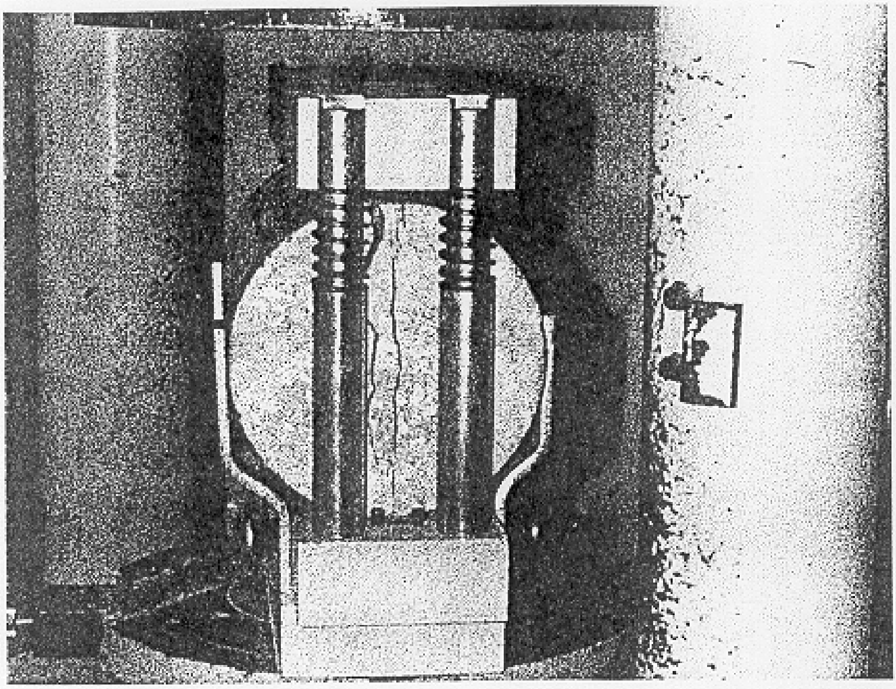


Figure 4 Flexural Test



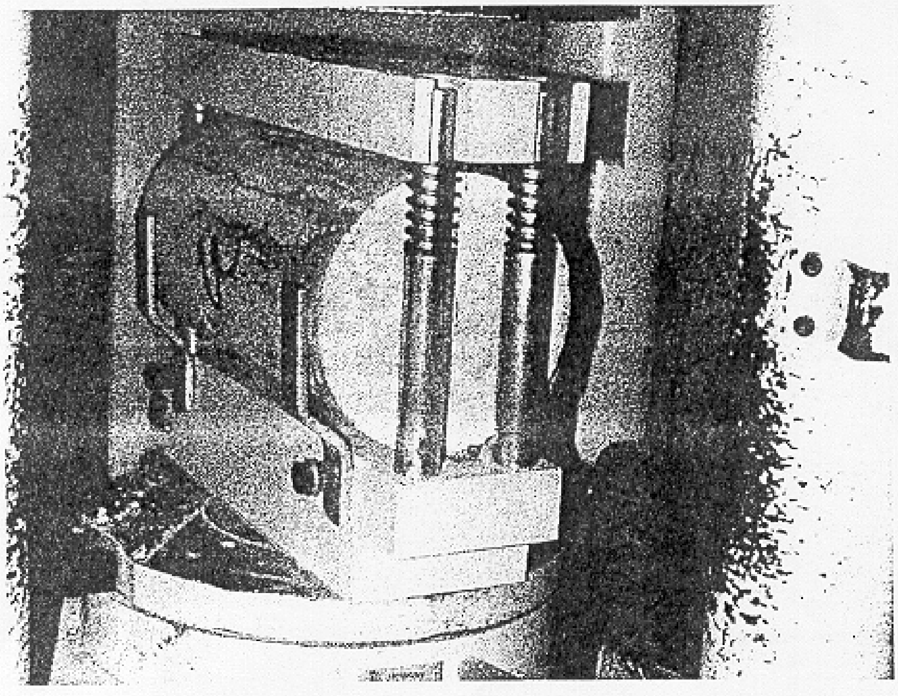


Figure 5: Cylinder Splitting Tensile Test

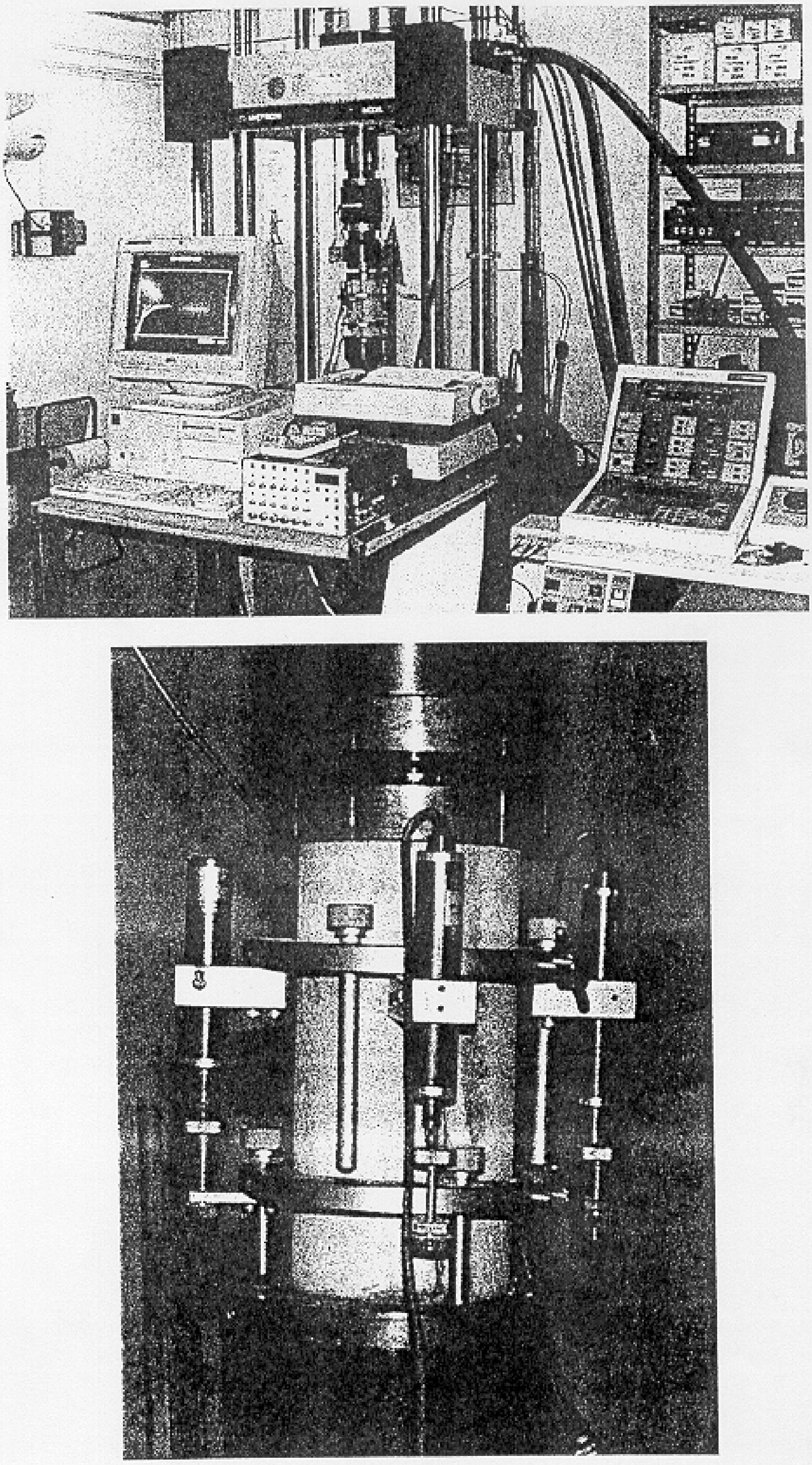


Figure 6: Young Modulus Test

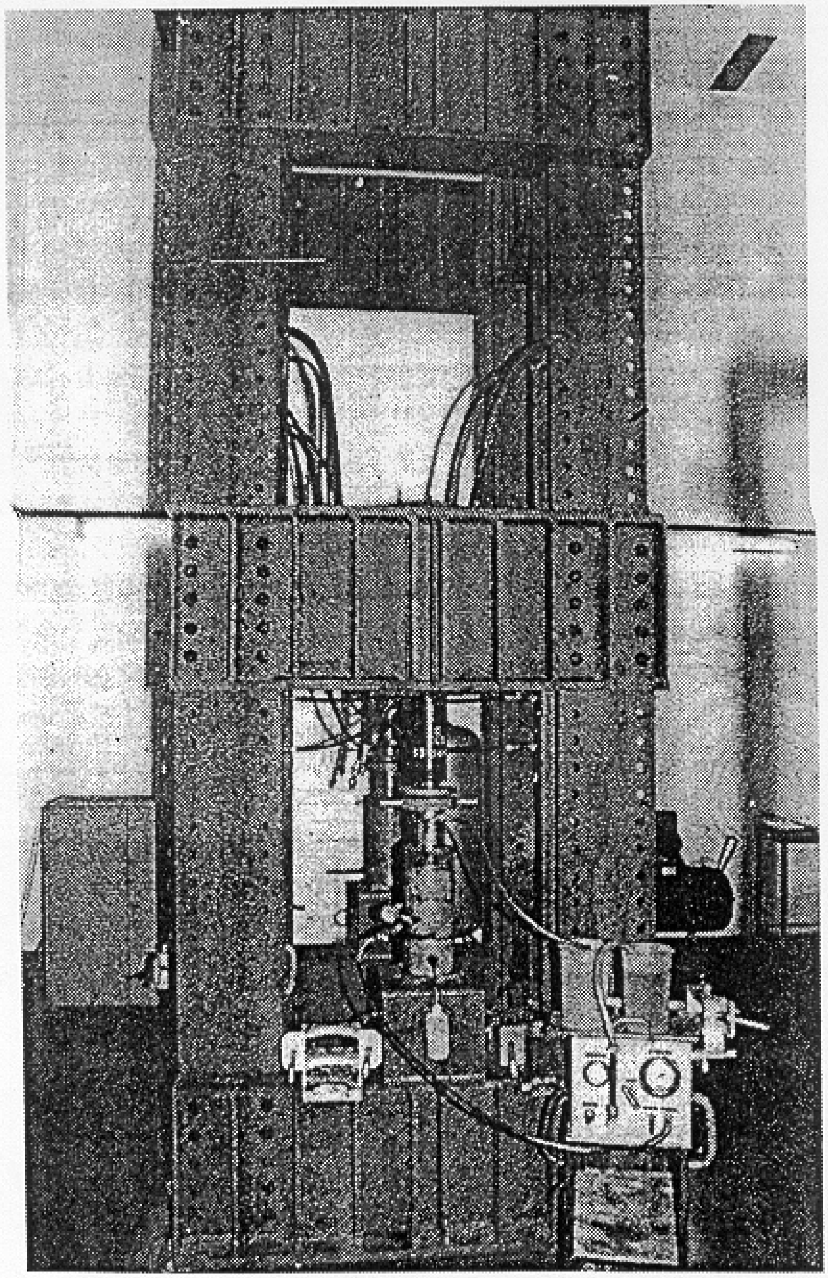


Figure 7a: Experimental set-up of accelerated water and chloride permeability tests showing the loading frame, hydraulic cylinders, permeability test cells and high-pressure refilling pump.

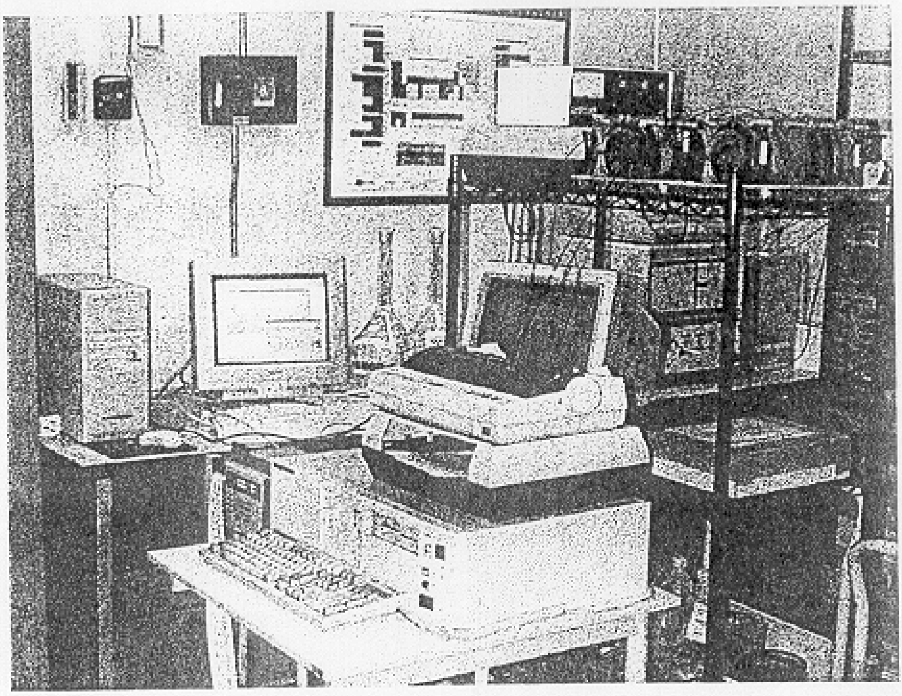


Figure 9(a): "Rapid Chloride Permeability" Test equipment

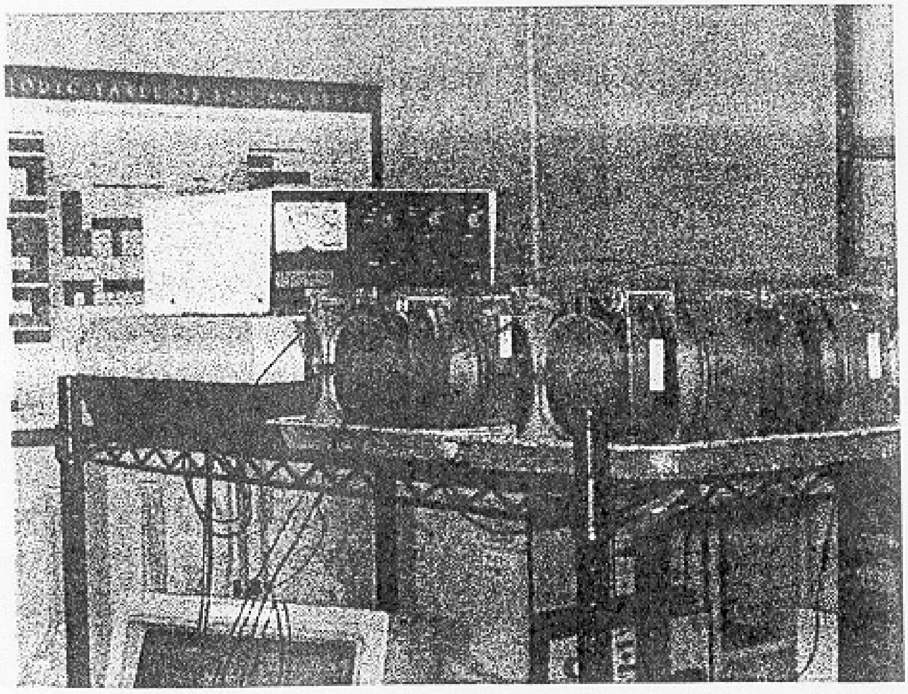
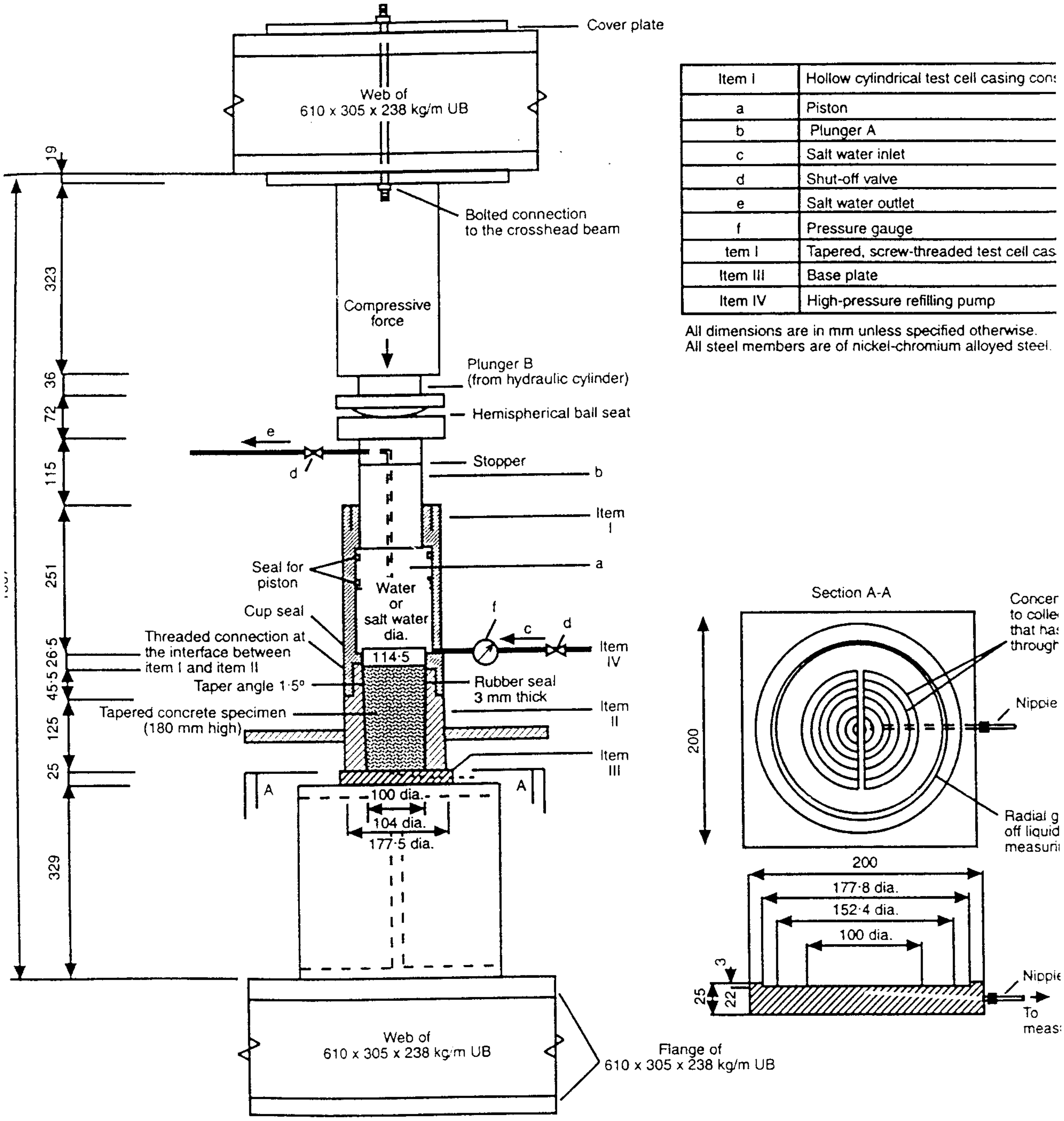


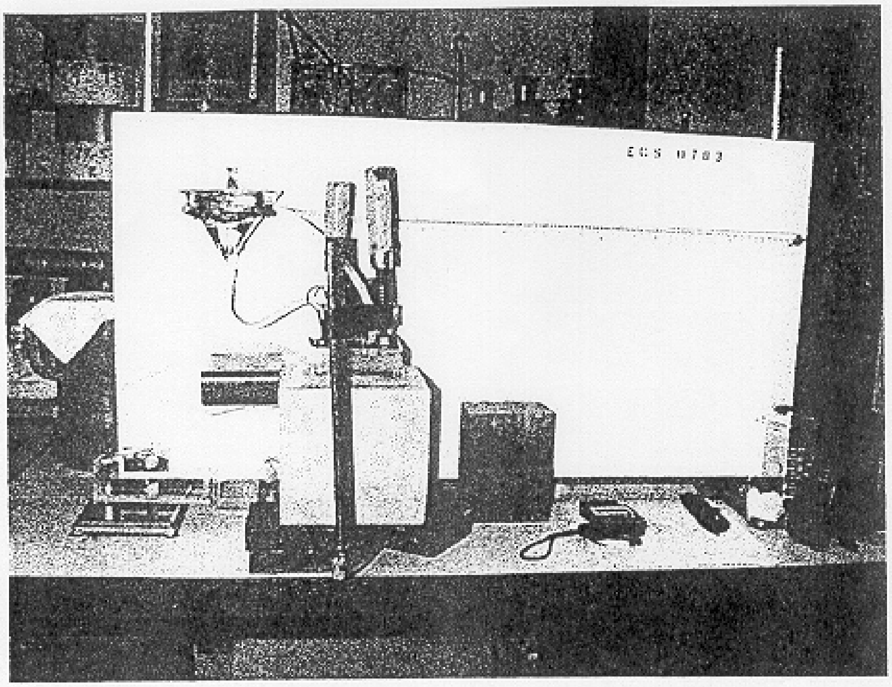
Figure 9(b): "Rapid Chloride Permeability " Test cells



Item I	Hollow cylindrical test cell casing con
a	Piston
b	Plunger A
c	Salt water inlet
d	Shut-off valve
e	Salt water outlet
f	Pressure gauge
tem I	Tapered, screw-threaded test cell cas
Item III	Base plate
Item IV	High-pressure refilling pump

All dimensions are in mm unless specified otherwise.
All steel members are of nickel-chromium alloyed steel.

Figure 7b: Cross-sectional view of permeability test cell.



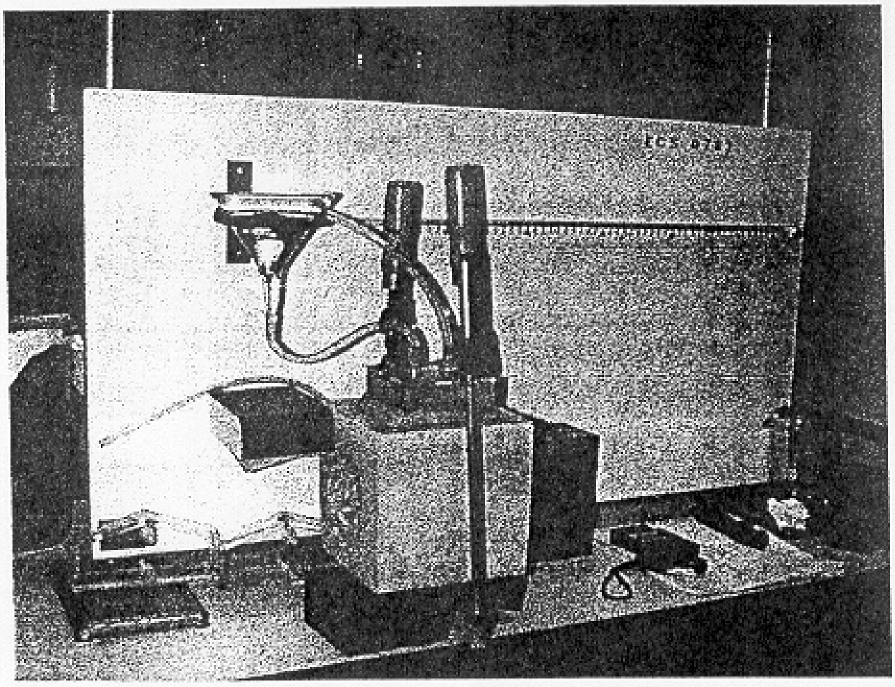


Figure 10: Initial Surface Absorption Test

SUMMARY OF MECHANICAL PROPERTIES

Mixes Grade	Mark 12A(i) 35P	Mark 12A(ii) 35P	Mark 10A 45P	Mark 8(i) 35P	Mark 8(ii) 35P	Mark 9(i) 45P	Mark 9(ii) 45P	SM 35P (I) 35P	SM 35P (ii) 35P
Date Cast	12-Aug-97	12-Aug-97	12-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97
Compressive Strength (N/mm2):									
3 day av.				32.0	41.1	41.6	40.5	25.6	28.5
SD				2.3	2.2	1.6	0.9	0.4	0.9
% of 28 day				62.0%	77.4%	75.8%	71.9%	59.3%	66.7%
7 day av.	44.1	42.3	37.9	42.2	46.7	47.8	48.1	33.7	36.1
SD	0.1	0.7	1.9	0.9	0.3	1.0	1.9	1.7	0.2
% of 28 day	84.0%	83.1%	82.5%	81.8%	88.0%	87.2%	85.5%	78.0%	84.5%
28 day av.	52.5	50.9	45.9	51.6	53.0	54.9	56.3	43.1	42.8
SD	2.1	1.8	1.0	1.7	1.4	1.0	2.7	0.8	1.6
Modulus of Rupture (N/mm2):									
28 day				5.87	5.73	5.85	5.43		
SD				0.04	0.17	0.23	0.3		
% of C.S.				11.4%	10.8%	10.7%	9.6%		
Tensile Splitting (N/mm2):									
28 day						3.99	3.55		
SD						0.44	1.31		
% of C.S.						7.3%	6.3%		
Young's Modulus (kN/mm2):									
28 day						30.82	32.65		
SD						1.35	0.92		

SUMMARY OF MECHANICAL PROPERTIES
PLANT TRIALS - Kajima

Mixes Grade	WLCT1 35P	WLCT2 45P	WLCT33 35P	WLCT34 45P	WLCT35 45P
Date Cast	28-Aug-97	28-Aug-97	28-Aug-97	28-Aug-97	28-Aug-97
Compressive Strength (N/mm2):					
7 day av.	36.0	45.9	45.8	57.3	43.0
SD	1.2	1.0	1.6	2.3	1.2
% of 28 day	80.6%	80.9%	87.7%	83.1%	79.6%
28 day av.	44.6	56.7	52.2	69.0	54.0
SD	1.3	1.6		0.5	2.7

MODULUS OF RUPTURE

TRIAL MIX REF: Kajima

Date	Sample Ref No.	Date Cast	Age (days)	Span (l) (mm)	Width (b) (mm)	Depth (d) (mm)	Wt. Air (kg)	Wt. Water (kg)	Density (kg/m^3)	Max. Load (kN)	Max. Stress (N/mm^2)	Rate (kN/min)	Notes:
10-Sep-97	81-19-13-8	13-Aug-97	28	300.0	100.0	100.0				19.68	5.90	12	
10-Sep-97	81-20-13-8	13-Aug-97	28	300.0	100.0	100.0				19.41	5.82	12	
10-Sep-97	81-21-13-8	13-Aug-97	28	300.0	100.0	100.0				19.64	5.89	12	
Average											**5.87**		
SD											**0.04**		
10-Sep-97	82-19-13-8	13-Aug-97	28	300.0	100.0	100.0				19.50	5.85	12	
10-Sep-97	82-20-13-8	13-Aug-97	28	300.0	100.0	100.0				18.47	5.54	12	
10-Sep-97	82-21-13-8	13-Aug-97	28	300.0	100.0	100.0				19.37	5.81	12	
Average											**5.73**		
SD											**0.17**		
10-Sep-97	91-19-13-8	13-Aug-97	28	300.0	100.0	100.0				20.40	6.12	12	
10-Sep-97	91-20-13-8	13-Aug-97	28	300.0	100.0	100.0				18.93	5.68	12	
10-Sep-97	91-21-13-8	13-Aug-97	28	300.0	100.0	100.0				19.20	5.76	12	
Average											**5.85**		
SD											**0.23**		
10-Sep-97	92-19-13-8	13-Aug-97	28	300.0	100.0	100.0				18.87	5.66	12	
10-Sep-97	92-20-13-8	13-Aug-97	28	300.0	100.0	100.0				16.96	5.09	12	
10-Sep-97	92-21-13-8	13-Aug-97	28	300.0	100.0	100.0				18.43	5.53	12	
Average											**5.43**		
SD											**0.30**		

SPLITTING TENSILE STRENGTH & YOUNG'S MODULUS

Mix Ref.	Mark 9(i)			Mark 9(ii)		
Sample Ref	91-16-13-8	91-17-13-8	91-18-13-8	92-16-13-8	92-17-13-8	92-18-13-8
Date Cast	13-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97
Date Tested	11-Sep-97	11-Sep-97	11-Sep-97	11-Sep-97	11-Sep-97	11-Sep-97
Age at test	29	29	29	29	29	29
Ultimate Load (kN)	269.5	259.9	317.7	174.1	354.3	225.7
Tensile Strength (N/mm2)	3.81	3.68	4.49	2.46	5.01	3.19
Average			**3.99**			**3.55**
SD			**0.44**			**1.31**
Young's Modulus (kN/mm2)	32.37	30.04	30.04	33.05	33.3	31.59
Average			**30.82**			**32.65**
SD			**1.35**			**0.92**

Laboratory Trial Mixes - Kajima
Cast on 12.8.97

Mixes	Mark 12A 35P	(i) (X)	(ii) (+ SP1)		Mark 10A 45P	(i) (X)
Cement	360	**18**			420	**21**
20 mm agg.	1110	**55.5**			1060	**53**
Sand	690	*34.5*			610	*30.5*
Free Moisture %	2.19				2.19	
Actual sand		**35.27**				**31.18**
Water	175	*8.75*			205	*10.25*
Adjusted water		**7.98**				**9.57**
Xypex (kg)	2.9	**0.145**			3.4	**0.17**
Cormix SP1 (lt)	1.53		**0.070**			
Air (%)	2	2			2	2
Actual air		**2.7**				**1.8**
Yield	998.74	49.94			998.30	49.91
Slump		36	103			149

Notes: Aggregates delivered in unwashed flour bags.
Asia cement used in lieu of PMC which was not delivered.
SP1 not added to Mark 10A because of potential for segregstion.

Appendix IV

SUMMARY OF PENETRABILITY DATA

	Mark 8(I) 35P	Mark 8(ii) 35P	Mark 9(I) 45P	Mark 9(ii) 45P	SM 35P (I) 35P	SM 35P (ii) 35P
Date Cast	13-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97	13-Aug-97
Accelerated Permeability:						
Valenta (m/s)	1.898E-13	2.622E-13			6.473E-13	2.949E-13
Stage 2 (m/s)					1.198E-12	5.653E-13
Stage 3 (m/s)					3.618E-13	1.379E-13
Rapid Chloride Permeability:						
Coulombs charge passed	4120.0	3406.0	4398.5	4051.0	4428.0	5230.5
Absorption:						
30 min corrected (%):	3.45	2.75	3.4	2.9	3.6	3.35
72 hour (%):	5.88	5.08	6.34	5.77	6.33	6.44
Initial Surface Aborption (ml/m2/sec):						
10 minute	0.180	0.192	0.311	0.319	0.445	0.430
30 minute	0.115	0.123	0.184	0.173	0.284	0.246
60 minute	0.077	0.088	0.111	0.107	0.177	0.161
120 minute	0.054	0.054	0.061	0.069	0.115	0.100
Cum. 2 hr Absorption (mls/m2)	703	767	1080	1078	1669	1527

Plant Trials - Kajima
Cast on 28.8.97

Mixes: **Code** **Grade**	**SM 35P** **WLCT1** **35P**	**Batch Vol.**	**SM 45P** **WLCT2** **45P**	**Batch Vol.**	**SM 35P(mod)** **WLCT33** **35P**	**Batch Vol.**	**SM 45P(mod)** **WLCT34** **45P**	**Batch Vol.**	**Mark 10A** **WLCT35** **45P**	**Batch Vol.**
Target Slump	125+25		125+25		125+25		125+25		125+25	
Time		13:30		14:05		14:20		14:40		15:15
Cement	360	1440	420	1680	360	1440	420	1680	420	1680
20 mm agg.	1020	4080	1050	4200	1020	4080	1050	4200	1060	4240
Sand	830	*3320*	725	*2900*	830	*3320*	725	*2900*	610	*2440*
Moist.%	5.5		5.5		5.5		5.5		5.5	
Act.sand		3500		3060		3500		3060		2580
Water	155	*620*	164	*656*	155	*620*	164	*656*	205	*820*
Adj.water		436		496		436		496		680
Xypex (kg)	2.9	11.6	3.40	13.6	2.9	11.6	3.40	13.6	3.40	13.6
P4 (kg)										
SP1 (lt)	3.24	12.96	4.20	16.80	2.88	11.52	3.78	15.12		
Air (Est.%)	2		2		2		2		2	
Actual air										
w/c	0.436	0.442	0.397	0.402	0.436	0.442	0.396	0.401	0.488	0.489
Yield	1001.32	4005.29	1001.81	4007.24	1000.06	4003.82	1001.38	4005.53	998.30	3993.18
Slump (mm) (a)		190		165		135		125		115
(b)		170		165						

Laboratory Trial Mixes - Kajima
Cast on 13.8.97

Mixes	Mark 8 35P	(I) (X)	(ii) (+ SP1)	Mark 9 45P	(I) (X)	(ii) (+ SP1)	SM 35P	(I) (SP1)	(ii) (+ X)
						Remix			
Cement	360	47.52	23.76	420	55.44	27.72	360	23.76	11.81
20 mm agg.	1020	134.64	67.32	1060	139.92	69.96	1020	67.32	33.46
Sand	774	*102.17*	*51.084*	720	*95.04*	*47.52*	830	*54.78*	27.22
Moist.%	6.56			6.56			6.56		
Act.sand		109.18			101.64	50.82		58.51	
Water	165	*21.78*	*10.89*	190	*25.08*	*12.54*	155	*10.23*	*5.08*
Adj.water		14.77			18.48	9.24		6.50	
Xypex (kg)	2.9	0.3828	0.191	3.4	0.4488	0.2244	2.9		0.0951
P4 (kg)									
SP1 (kg)	1.836		0.1212	2.142		0.1414	3.888	0.2566	0.1275
Air (%)	2			2			2		
Actual air		2.6	2.2		2.2	1.9			
w/c	0.458	0.462		0.452	0.454	0.454	0.431	0.435	
Yield	986.33	131.00	65.33	1026.00	135.71	67.77	998.02	65.99	32.84
Est. Wet Density		2.340			2.328			2.369	
Weight of Section		154.42			153.65				77.7
Volume									32.80
Slump (mm) (a)		27	52		35	100		226	188

Notes: Mixing sequence: Fine coarse agg., cement (X) + agg. (1 min), addition of water (3 mins on, 5 mins off, 2 mins on).
Mark 9 (ii) had to be remixed due to leakage of grout. Initial slump after Xypex addition 40 mm.

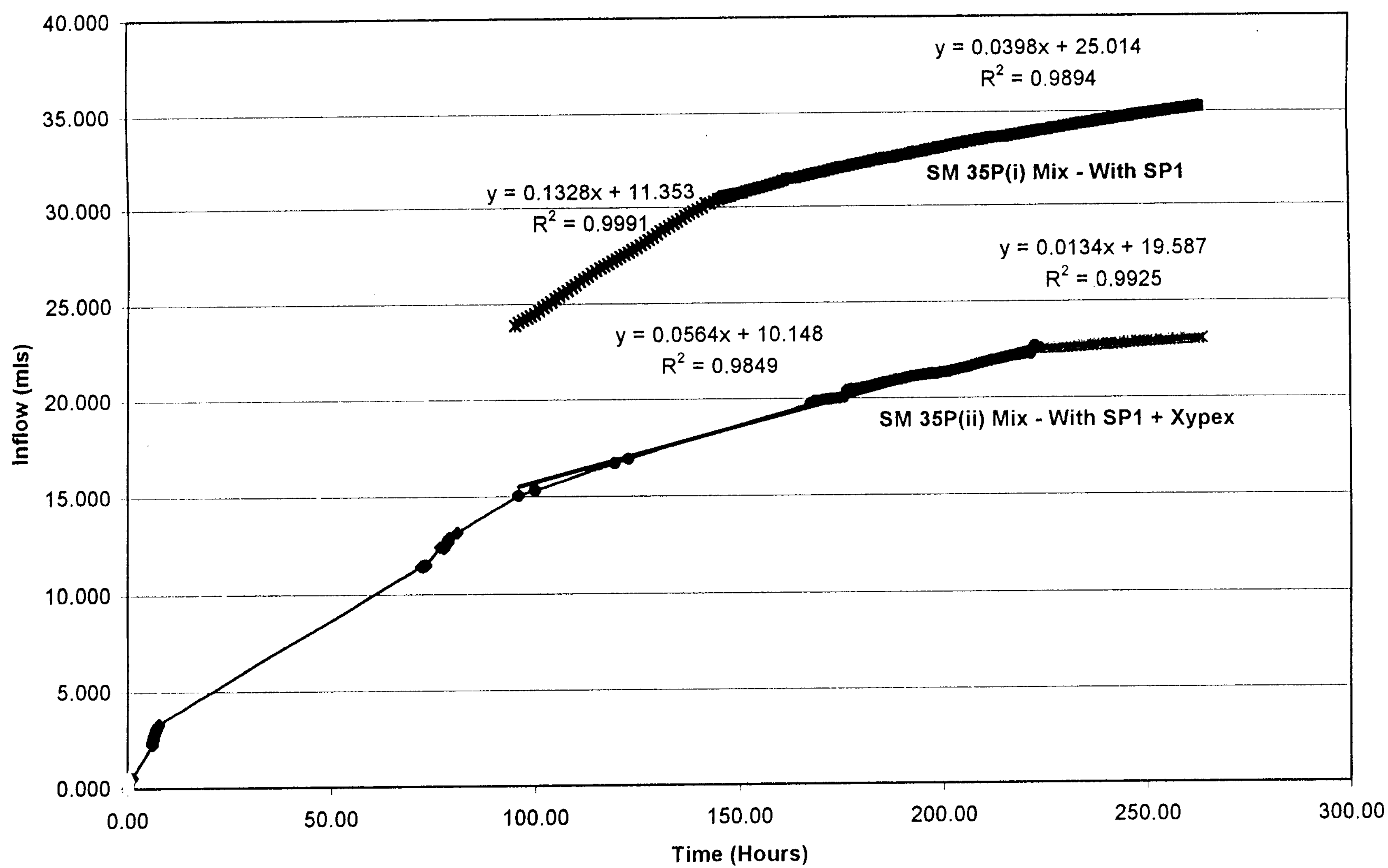
ACCELERATED PERMEABILITY

TRIAL MIX REF:	SM 35P(i)	Notes	SM 35P(ii)	Notes
Sample ref.	SM1-27-13-8		SM2-29-13-8	
Date Cast	13-Aug-97		13-Aug-97	
Moist Curing	24		21	
Ambient Curing.	6		5	
Test Temperature	30		30	
Thickness (mm)	180.0		195.0	
Diameter (mm) - Top	101.0		100.0	Epoxy taper
Bottom	109.0		100.0	
Start of Test	9/11/97 16:47	Salt water	9/8/97 10:18	Salt water
End of Test	9/25/97 11:00		9/25/97 11:00	
File Name	apc 4-77		apc 4-77	
Av. Input pressure	690		690	
Dry Weight (gms)				
Wet Weight (gms)				
Valenta Permeability:				
Average Penetration Depth (mm)	133		99.87	
k = a.x2/2.h.t (m/s)				
where a = porosity (est.)	0.06		0.06	
x = depth (m)	0.133		0.09987	
h = hydraulic head (m)	690		690	
t = time of action (s)	1188780		1471320	
k = Perm. Coeff. (m/s)	**6.473E-13**		**2.949E-13**	
Percentage of SM1	**100.00%**		**45.56%**	
Flow Rate	**Stage 2**	**Stage 3**	**Stage 2**	**Stage 3**
Slope	0.1328	0.0398	0.0564	0.0134
L (m)	0.1800	0.1800	0.1950	0.1950
A (m2)	0.0080	0.0080	0.0079	0.0079
Q (m3/s)	3.689E-11	1.106E-11	1.567E-11	3.722E-12
Estimated Coeff. Of Permeability	**1.202E-12**	**3.602E-13**	**5.640E-13**	**1.340E-13**
Percentage of SM1	**100.00%**	**100.00%**	**46.93%**	**37.21%**

ACCELERATED PERMEABILITY TEST

TRIAL MIX REF:	Mark 8(i)	Mark 8(ii)
Sample ref.	81-25-13-8	82-25-13-8
Date Cast	13-Aug-97	13-Aug-97
Age at Test	36 days	36 days
Test Temperature	30	30
Thickness (mm)	175.0	175.0
Diameter (mm) - Top	101.0	101.0
Bottom	109.0	109.0
Start of Test	9/18/97 12:57	9/18/97 12:57
End of Test	9/25/97 11:00	9/25/97 11:00
File Name	APC data SM1,SM2	APC data SM1,SM2
Av. Input pressure (m)	690	690
Valenta Permeability:		
Average Penetration Depth (mm)	54.9	64.6
k = a.x2/2.h.t (m/s)		
where a = porosity (est.)	0.06	0.06
x = depth (m)	0.055	0.065
h = hydraulic head (m)	690	690
t = time of action (s)	691200	691200
k = Perm. Coeff. (m/s)	**1.898E-13**	**2.622E-13**
Percentage of 82	**72.39%**	**100.00%**

Figure 8: Accelerated Permeability - Grade 35P concrete with and without Xypex.



Civil Engineering Department
James
NUS

OUR REF. : RCPT Series 81 DATE: 12-9-1997

YOUR REF.:

TEST REPORT

AASHTO T 277-891

RAPID CHLORIDE PERMEABILITY

SAMPLE IDENTIFICATION:

81-23) Mark 8(i)
81-24)

B C Ang
Structural/Concrete Laboratory
NUS

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: 81-23

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 49.5 mm

VOLTAGE: 10 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	32.9	185	31.9
10	32.9	190	31.9
15	32.9	195	31.9
20	32.9	200	31.9
25	32.9	205	31.9
30	32.9	210	31.9
35	32.9	215	31.9
40	32.9	220	31.8
45	32.9	225	31.9
50	32.9	230	31.9
55	32.9	235	31.8
60	32.9	240	31.8
65	32.9	245	31.8
70	32.9	250	31.5
75	32.9	255	31.7
80	32.8	260	31.1
85	32.9	265	31.0
90	32.9	270	31.1
95	32.8	275	31.2
100	32.8	280	31.8
105	32.7	285	31.2
110	32.2	290	31.7
115	32.2	295	30.9
120	31.9	300	31.5
125	31.9	305	30.9
130	31.9	310	30.9
135	31.9	315	30.9
140	31.9	320	30.9
145	31.9	325	30.9
150	31.9	330	30.9
155	31.9	335	30.9
160	31.9	340	29.0
165	31.9	345	30.9
170	31.9	350	30.9
175	31.9	355	30.9
180	31.9	360	30.9

MEASURED COULOMBS AT 10 VOLTS : 604 COULOMBS
ESTIMATED COULOMBS AT 60 VOLTS: > 3956 COULOMBS
PERMEABILITY CLASS: > 4000 : HIGH

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: 81-24

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 49.8 mm

VOLTAGE: 10 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	35.0	185	34.0
10	35.0	190	34.0
15	35.0	195	34.0
20	35.0	200	34.0
25	35.0	205	34.0
30	35.0	210	34.0
35	35.0	215	34.0
40	35.0	220	34.0
45	35.0	225	34.0
50	35.0	230	34.0
55	35.0	235	34.0
60	35.0	240	34.0
65	35.0	245	34.0
70	35.0	250	34.0
75	35.0	255	34.0
80	35.0	260	34.0
85	35.0	265	34.0
90	35.0	270	34.0
95	35.0	275	34.0
100	35.0	280	34.0
105	35.0	285	34.0
110	35.0	290	34.0
115	35.0	295	34.0
120	35.0	300	34.0
125	34.6	305	34.0
130	34.5	310	34.0
135	34.5	315	33.8
140	34.0	320	34.0
145	34.7	325	34.0
150	34.4	330	33.4
155	34.0	335	33.1
160	34.0	340	33.3
165	34.0	345	33.2
170	34.0	350	33.1
175	34.0	355	33.2
180	34.0	360	33.5

MEASURED COULOMBS AT 10 VOLTS : 654 COULOMBS
ESTIMATED COULOMBS AT 60 VOLTS: > 4284 COULOMBS
PERMEABILITY CLASS: > 4000 : HIGH

ivil Engineering Department
ames
US

UR REF. : RCPT Series 82 DATE: 13-9-1997

OUR REF.:

TEST REPORT

AASHTO T 277-891

RAPID CHLORIDE PERMEABILITY

SAMPLE IDENTIFICATION:

82-23) Mark 8(ii)
82-24)

O Ang
tructuraL/Concrete Laboratory
JS

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: 82-23

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 50.3 mm

VOLTAGE: 60 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	149.3	185	181.0
10	151.2	190	181.0
15	153.6	195	181.0
20	154.1	200	181.9
25	157.0	205	182.0
30	157.9	210	182.9
35	159.8	215	182.9
40	161.4	220	182.9
45	162.7	225	182.9
50	163.7	230	183.7
55	164.8	235	182.9
60	165.8	240	182.9
65	166.6	245	184.8
70	167.1	250	184.8
75	168.5	255	183.9
80	170.4	260	183.9
85	171.4	265	184.8
90	171.4	270	185.8
95	172.3	275	185.0
100	172.3	280	185.8
105	173.3	285	185.8
110	174.3	290	186.7
115	174.3	295	184.8
120	175.2	300	185.8
125	176.2	305	186.6
130	176.3	310	186.5
135	177.2	315	186.8
140	176.5	320	186.8
145	177.2	325	184.8
150	178.1	330	186.8
155	179.1	335	186.8
160	179.7	340	186.8
165	179.1	345	186.8
170	179.5	350	186.8
175	179.4	355	187.7
180	180.0	360	186.8

MEASURED COULOMBS AT 60 VOLTS : 3398 COULOMBS
PERMEABILITY CLASS: 2000-4000 : MODERATE

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: 82-24

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 50.9 mm

VOLTAGE: 60 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	145.8	185	178.9
10	148.8	190	178.9
15	150.6	195	178.9
20	151.7	200	179.9
25	153.6	205	179.9
30	154.6	210	180.8
35	155.6	215	180.9
40	157.6	220	181.8
45	158.5	225	181.8
50	159.4	230	182.8
55	160.5	235	183.7
60	162.0	240	183.8
65	163.0	245	183.8
70	164.3	250	184.2
75	165.1	255	184.7
80	166.3	260	184.7
85	167.2	265	184.7
90	167.2	270	185.7
95	168.2	275	186.4
100	169.2	280	186.7
105	170.1	285	186.7
110	171.1	290	186.7
115	171.6	295	187.6
120	172.1	300	187.6
125	173.1	305	187.6
130	173.3	310	188.6
135	174.0	315	188.6
140	175.0	320	188.6
145	175.0	325	189.6
150	175.0	330	189.6
155	176.0	335	189.6
160	176.0	340	190.6
165	176.9	345	190.6
170	176.9	350	190.6
175	177.9	355	191.3
180	178.1	360	191.5

MEASURED COULOMBS AT 60 VOLTS : 3414 COULOMBS
PERMEABILITY CLASS: 2000-4000 : MODERATE

Civil Engineering Department
James
NUS

OUR REF. : RCPT SERIES 91 & 92 DATE: 11-9-1997

YOUR REF.:

TEST REPORT

AASHTO T 277-891

RAPID CHLORIDE PERMEABILITY

SAMPLE IDENTIFICATION:

91-23) Mark 9(i)
91-24)
92-23) Mark 9(ii)
92-24)

B O ANG
Structural/Concrete Laboratory
Civil Engineering Department/NUS

Civil Engineering Department
James
NUS

OUR REF. : RCPT Series SM2

DATE: 18-9-1997

YOUR REF.:

TEST REPORT

AASHTO T 277-891

RAPID CHLORIDE PERMEABILITY

SAMPLE IDENTIFICATION:

sm2-23) ~~Mark~~ SM35P (ii)
sm2-24)

B O Ang
Structural/Concrete Laboratory
NUS

RCPT 2.3, G.M. Idorn Consult A/S, Denmark

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: sm2-23

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 52.3 mm

VOLTAGE: 10 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	43.4	185	37.7
10	43.4	190	38.6
15	43.4	195	40.2
20	43.4	200	37.7
25	40.5	205	38.6
30	39.6	210	39.6
35	39.6	215	37.7
40	39.8	220	37.7
45	39.6	225	39.6
50	40.3	230	40.4
55	41.5	235	40.5
60	40.5	240	39.6
65	39.6	245	38.6
70	39.6	250	38.8
75	39.6	255	39.6
80	38.6	260	40.5
85	37.7	265	39.6
90	39.6	270	38.6
95	40.4	275	40.5
100	41.5	280	39.6
105	40.5	285	37.7
110	40.6	290	37.7
115	41.5	295	38.6
120	40.5	300	38.8
125	40.5	305	36.7
130	40.5	310	39.6
135	40.1	315	37.2
140	39.6	320	40.5
145	39.6	325	39.6
150	39.6	330	38.8
155	40.4	335	38.6
160	39.6	340	38.5
165	39.6	345	38.6
170	37.7	350	38.6
175	38.6	355	39.7
180	39.6	360	38.6

ASURED COULOMBS AT 10 VOLTS : 792 COULOMBS
TIMATED COULOMBS AT 60 VOLTS: > 5188 COULOMBS
RMEABILITY CLASS: > 4000 : HIGH

RESULTS ACCORDING TO AASHTO T 277-891

RCPT 2.3, G.M. Idorn Consult A/S, Denmark

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: 91-23

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 52.5 mm

VOLTAGE: 10 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	36.7	185	35.7
10	36.7	190	35.7
15	36.7	195	35.7
20	36.7	200	35.7
25	36.7	205	35.7
30	36.7	210	35.7
35	36.7	215	35.7
40	36.7	220	35.7
45	36.7	225	35.7
50	36.7	230	35.7
55	36.7	235	35.7
60	36.7	240	35.7
65	36.7	245	35.7
70	36.7	250	35.7
75	36.7	255	35.7
80	36.7	260	35.7
85	36.7	265	35.7
90	36.7	270	35.7
95	36.5	275	35.7
100	36.3	280	35.7
105	35.9	285	35.7
110	35.8	290	35.7
115	36.2	295	35.7
120	35.8	300	35.7
125	35.7	305	35.7
130	35.7	310	35.7
135	35.7	315	35.7
140	35.7	320	35.7
145	35.7	325	35.7
150	35.7	330	35.7
155	35.7	335	35.7
160	35.7	340	35.7
165	35.7	345	35.7
170	35.7	350	35.7
175	35.7	355	35.7
180	35.7	360	35.7

ASURED COULOMBS AT 10 VOLTS : 722 COULOMBS
TIMATED COULOMBS AT 60 VOLTS: > 4729 COULOMBS
RMEABILITY CLASS: > 4000 : HIGH

SAMPLE IDENTIFICATION: sm2-24

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 53.1 mm

VOLTAGE: 10 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	40.8	185	39.5
10	40.8	190	39.3
15	40.8	195	38.9
20	40.8	200	38.9
25	40.8	205	38.9
30	40.8	210	38.9
35	40.8	215	38.9
40	40.8	220	38.9
45	40.8	225	38.9
50	40.8	230	38.9
55	40.8	235	38.9
60	40.8	240	38.9
65	40.8	245	38.9
70	40.8	250	38.9
75	40.8	255	38.9
80	40.8	260	38.9
85	40.8	265	38.9
90	40.8	270	38.9
95	40.8	275	38.9
100	40.8	280	38.9
105	40.8	285	38.9
110	40.1	290	38.9
115	39.9	295	38.9
120	39.9	300	38.9
125	39.9	305	38.9
130	39.9	310	38.9
135	39.9	315	38.8
140	39.9	320	38.9
145	39.9	325	38.8
150	39.9	330	38.9
155	39.9	335	38.5
160	39.9	340	38.9
165	39.9	345	38.0
170	39.9	350	38.7
175	39.9	355	38.8
180	39.6	360	37.9

ASURED COULOMBS AT 10 VOLTS : 805 COULOMBS
TIMATED COULOMBS AT 60 VOLTS: > 5273 COULOMBS
RMEABILITY CLASS: > 4000 : HIGH

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: 91-24

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 51.5 mm

VOLTAGE: 10 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	32.1	185	31.1
10	32.1	190	31.1
15	32.1	195	31.1
20	32.1	200	31.2
25	32.1	205	31.1
30	32.1	210	31.1
35	32.1	215	31.1
40	32.1	220	31.1
45	32.1	225	31.1
50	32.1	230	31.1
55	32.1	235	31.1
60	32.1	240	31.6
65	32.1	245	31.1
70	32.1	250	31.1
75	32.1	255	31.2
80	32.1	260	31.2
85	32.1	265	31.7
90	32.1	270	31.1
95	31.8	275	31.2
100	31.8	280	31.1
105	32.1	285	31.9
110	31.8	290	31.1
115	31.7	295	31.1
120	31.9	300	31.2
125	31.7	305	31.1
130	31.8	310	31.7
135	31.1	315	32.1
140	31.1	320	31.8
145	31.1	325	31.1
150	31.1	330	31.3
155	31.1	335	31.4
160	31.1	340	31.1
165	31.1	345	31.8
170	31.2	350	31.8
175	31.8	355	31.1
180	31.1	360	31.2

EASURED COULOMBS AT 10 VOLTS : 621 COULOMBS
STIMATED COULOMBS AT 60 VOLTS: > 4068 COULOMBS
ERMEABILITY CLASS: > 4000 : HIGH

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: 92-23

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 51.2 mm

VOLTAGE: 60 VOLTS

TIME [min]	A [mA]
5	171.2
10	173.1
15	173.3
20	173.1
25	175.0
30	175.3
35	177.0
40	177.8
45	177.9
50	178.9
55	180.8
60	181.8
65	181.8
70	183.7
75	184.7
80	185.7
85	187.6
90	187.6
95	189.5
100	190.3
105	191.5
110	191.5
115	193.4
120	195.3
125	196.3
130	197.0
135	198.2
140	199.2
145	200.2
150	201.1
155	202.1
160	204.0
165	204.0
170	205.0
175	206.0
180	206.9

TIME [min]	A [mA]
185	208.8
190	209.8
195	210.8
200	210.8
205	211.8
210	212.7
215	213.7
220	214.7
225	215.6
230	216.6
235	218.5
240	218.5
245	219.5
250	220.3
255	221.2
260	221.9
265	223.3
270	224.1
275	225.3
280	226.3
285	227.2
290	227.2
295	228.2
300	229.2
305	230.5
310	231.0
315	232.1
320	232.1
325	234.0
330	235.0
335	235.9
340	236.7
345	237.6
350	237.9
355	238.8
360	239.8

MEASURED COULOMBS AT 60 VOLTS : 4034 COULOMBS

PERMEABILITY CLASS: > 4000 : HIGH

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: 92-24

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 51.8 mm

VOLTAGE: 60 VOLTS

TIME [min]	A [mA]
5	168.1
10	171.0
15	169.0
20	171.0
25	172.9
30	174.9
35	174.9
40	176.8
45	172.9
50	175.8
55	177.6
60	180.7
65	176.8
70	179.7
75	182.6
80	184.2
85	186.5
90	184.6
95	186.5
100	187.5
105	189.4
110	190.4
115	193.3
120	190.4
125	191.8
130	192.3
135	198.2
140	193.3
145	195.6
150	198.6
155	200.1
160	202.0
165	199.8
170	202.0
175	203.0
180	205.9

TIME [min]	A [mA]
185	206.9
190	207.9
195	211.7
200	206.9
205	209.5
210	213.7
215	215.6
220	215.6
225	211.7
230	213.4
235	214.4
240	215.6
245	219.5
250	219.3
255	224.1
260	223.4
265	225.3
270	225.4
275	225.3
280	230.2
285	231.2
290	231.2
295	231.2
300	233.1
305	232.4
310	232.1
315	235.0
320	233.9
325	239.9
330	240.9
335	238.9
340	239.9
345	240.9
350	239.9
355	247.7
360	247.7

MEASURED COULOMBS AT 60 VOLTS : 4068 COULOMBS

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: sm1-24 SM35P(1)

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 48.0 mm

VOLTAGE: 10 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	42.7	185	42.8
10	42.7	190	42.8
15	42.8	195	42.8
20	42.7	200	42.8
25	42.8	205	42.8
30	42.8	210	42.8
35	42.8	215	42.8
40	42.7	220	42.8
45	42.8	225	42.8
50	42.8	230	42.8
55	42.8	235	42.8
60	42.8	240	42.8
65	42.8	245	42.8
70	42.8	250	42.8
75	42.8	255	42.8
80	42.8	260	42.8
85	42.8	265	42.8
90	42.8	270	42.8
95	42.8	275	42.8
100	42.8	280	42.8
105	42.8	285	42.8
110	42.8	290	42.8
115	42.8	295	42.8
120	42.8	300	42.8
125	42.8	305	42.8
130	42.8	310	42.8
135	42.8	315	42.8
140	42.8	320	42.8
145	42.8	325	42.8
150	42.8	330	42.8
155	42.8	335	42.8
160	42.8	340	42.8
165	42.8	345	42.8
170	42.8	350	42.8
175	42.8	355	42.8
180	42.8	360	42.8

MEASURED COULOMBS AT 10 VOLTS : 769 COULOMBS
ESTIMATED COULOMBS AT 60 VOLTS: > 5037 COULOMBS
PERMEABILITY CLASS: > 4000 : HIGH

RCPT 2.3, G.M. Idorn Consult A/S, Denmark

RESULTS ACCORDING TO AASHTO T 277-891

SAMPLE IDENTIFICATION: sm1-23 SM35P(i)

SAMPLE DIAMETER : 100.0 mm
SAMPLE THICKNESS: 48.0 mm

VOLTAGE: 10 VOLTS

TIME [min]	A [mA]	TIME [min]	A [mA]
5	30.0	185	33.8
10	32.9	190	33.8
15	32.9	195	33.8
20	32.9	200	33.8
25	32.8	205	33.8
30	32.9	210	33.8
35	32.9	215	33.8
40	32.9	220	33.8
45	32.5	225	33.8
50	32.9	230	33.8
55	31.6	235	33.8
60	32.9	240	31.8
65	31.9	245	32.7
70	31.9	250	30.9
75	32.9	255	30.9
80	31.9	260	30.9
85	32.9	265	30.9
90	32.3	270	32.9
95	31.9	275	31.8
100	31.9	280	31.9
105	31.7	285	31.8
110	31.9	290	31.9
115	31.8	295	31.9
120	32.6	300	31.9
125	31.9	305	32.9
130	31.9	310	32.6
135	32.9	315	33.8
140	31.2	320	33.8
145	31.9	325	31.9
150	31.8	330	30.9
155	31.8	335	30.9
160	31.9	340	32.9
165	33.8	345	31.9
170	33.8	350	31.9
175	33.8	355	31.8
180	33.8	360	30.9

ASURED COULOMBS AT 10 VOLTS : 583 COULOMBS
TIMATED COULOMBS AT 60 VOLTS: > 3819 COULOMBS
RMEABILITY CLASS: > 4000 : HIGH

ABSORPTION TEST- (Based on BS 1881: Part 122: 1983 except at 30 Celcius)

Trial Mix Ref. No: Kajima

Ref.No.	Date	Age	Av. Diam.	Length	Dry Wt.	30 mins	Abs. %	C.F.	Corr.Abs	24 hours	Abs. %	72 hours	Abs. %	14 day	Abs%	Notes
81-13-13-8	16-Sep-97	34	74.4	150.7	1423.90	1464.54	2.85	1.193	**3.4**	1506.55	**5.80**	1507.39	**5.86**	1510.39	**6.07**	13-Aug-97
81-14-13-8	16-Sep-97	34	74.4	148.7	1404.42	1445.30	2.91	1.190	**3.5**	1486.58	**5.85**	1487.35	**5.90**	1490.12	**6.10**	
82-13-13-8	16-Sep-97	34	74.5	152	1463.16	1497.26	2.33	1.196	**2.8**	1538.64	**5.16**	1539.36	**5.21**	1541.36	**5.34**	
82-14-13-8	16-Sep-97	34	74.6	149	1446.59	1479.09	2.25	1.193	**2.7**	1517.61	**4.91**	1518.22	**4.95**	1519.80	**5.06**	
91-13-13-8	16-Sep-97	34	74.4	151.4	1431.32	1469.91	2.70	1.194	**3.2**	1519.8	**6.18**	1520.66	**6.24**	1522.67	**6.38**	
91-14-13-8	16-Sep-97	34	74.4	150.9	1411.00	1453.48	3.01	1.194	**3.6**	1500.47	**6.34**	1501.3	**6.40**	1503.43	**6.55**	Less aggreg
92-13-13-8	16-Sep-97	34	74.5	153.5	1469.68	1505.22	2.42	1.198	**2.9**	1553	**5.67**	1553.74	**5.72**	1555.32	**5.83**	
92-14-13-8	16-Sep-97	34	74.3	153	1458.84	1494.35	2.43	1.196	**2.9**	1543.03	**5.77**	1543.7	**5.82**	1545.50	**5.94**	
SM1-13	16-Sep-97	34	74.5	153	1431.68	1476.73	3.15	1.198	**3.8**	1526.93	**6.65**	1527.78	**6.71**	1529.65	**6.84**	Less aggreg
SM1-14	16-Sep-97	34	74.6	150.5	1437.35	1478.42	2.86	1.195	**3.4**	1522.22	**5.90**	1522.96	**5.96**	1524.88	**6.09**	Piece fell of
										1521.77						
SM2-13	16-Sep-97	34	74.4	152	1424.58	1463.91	2.76	1.195	**3.3**	1515.45	**6.38**	1515.91	**6.41**	1517.57	**6.53**	
SM2-14	16-Sep-97	34	74.5	150.6	1408.94	1448.78	2.83	1.194	**3.4**	1499.31	**6.41**	1499.98	**6.46**	1501.56	**6.57**	
WLCT33-5	30-Sep-97	33	74.5	153.9	1501.41	1531.83	2.03	1.200	**2.4**	1574.94	**4.90**					28-Aug-97
WLCT33-6	30-Sep-97	33	74.5	154	1500.9	1531.63	2.05	1.199	**2.5**	1575.79	**4.99**					
WLCT34-5	30-Sep-97	33	74.5	153.7	1512.01	1539.24	1.80	1.199	**2.2**	1581.58	**4.60**					
WLCT34-6	30-Sep-97	33	74.5	152	1499.86	1526.46	1.77	1.196	**2.1**	1567.61	**4.52**					
WLCT35-4	30-Sep-97	33	74.5	151.9	1439.32	1480.24	2.84	1.196	**3.4**	1529.61	**6.27**					
WLCT35-6	30-Sep-97	33	74.5	151.1	1420.27	1463.55	3.05	1.195	**3.6**	1513.03	**6.53**					

INITIAL SURFACE ABSORPTION TEST

Sample ref.	81-22-13-8		82-22-13-8		91-22-13-8		92-22-13-8	
Date Cast	13-Aug-97		13-Aug-97		13-Aug-97		13-Aug-97	
Moist Curing	28		28		28		28	
Ambient / Oven	10		10		7		7	
Test Temperature	20		20		20		20	
Test Surface	Vertical cast		Vertical cast		Vertical cast		Vertical cast	
Date of Test	20-Sep-97		20-Sep-97		17-Sep-97		17-Sep-97	
Time	9:00		14:00		10:20		12:30	
Setup Time					140 sec		95sec	
Test Interval	2 minutes		2 minutes		1 minute		1 minute	
	Divisions	ml/m2/sec	Divisions	ml/m2/sec	Divisions	ml/m2/sec	Divisions	ml/m2/sec
10 minute	47	0.180	50	0.192	41	0.311	42	0.319
30 minute	30	0.115	32	0.123	24	0.184	23	0.173
60 minute	20	0.077	23	0.088	15	0.111	14	0.107
120 minute	14	0.054	15	0.058	8	0.061	9	0.069
Cum. 2 hr Absorption (mls/m2)		703		767		1080		1078
Equiv. Sorptivity (mm/min1/2)		0.064		0.070		0.099		0.098
Absorption Grade		Low		Low		Average		Average

Notes:

5 sec.travel

< 3 divisions	2 minutes
3 - 9 divisions	1 minute
10 -30 divisions	30 seconds
> 30 divisions	ISA > 3.60 mls/m2

Absorption Grade	Low	Average	High	Source
10 minute	< 0.25	0.25 - 0.50	> 0.50	T.R. No.31
30 minute	< 0.17	0.17 - 0.35	> 0.35	
60 minute	< 0.10	0.10 - 0.20	> 0.20	
120 minute	<0.07	0.07 - 0.15	> 0.15	
Cumulative 2 hr Absorption	< 1000	1000 - 2000	> 2000	T.E.L.
Sorptivity	< 0.12	0.12 - 0.23	> 0.23	T.E.L.

INITIAL SURFACE ABSORPTION TEST

Sample ref.	SM1-22-13-8		SM2-22-13-8		81-22-13-8		82-22-13-8	
Date Cast	13-Aug-97		13-Aug-97		13-Aug-97		13-Aug-97	
Moist Curing	28		28		28		28	
Ambient / Oven	10		10		7		7	
Test Temperature	20		20		20		20	
Test Surface	Vertical cast		Vertical cast		Top trowelled		Top trowelled	
Date of Test	20-Sep-97		20-Sep-97		17-Sep-97		17-Sep-97	
Time	9:00		14:00		10:20		12:30	
Setup Time					140 sec		95sec	
Test Interval	1 minute		1 minute		2 minutes		2 minutes	
	Divisions	ml/m2/sec	Divisions	ml/m2/sec	Divisions	ml/m2/sec	Divisions	ml/m2/sec
10 minute	58	0.445	56	0.430	36	0.138	44	0.169
30 minute	37	0.284	32	0.246	21	0.081	30	0.115
60 minute	23	0.177	21	0.161	15	0.058	19	0.073
120 minute	15	0.115	13	0.100	9	0.035	15	0.058
Cum. 2 hr Absorption (mls/m2)		1669		1527		513		684
Equiv. Sorptivity (mm/min1/2)		0.152		0.139		0.047		0.062
Absorption Grade		Average		Average		Low		Low

Notes:

5 sec.travel

< 3 divisions	2 minutes
3 - 9 divisions	1 minute
10 -30 division:	30 seconds
> 30 divisions	ISA > 3.60 mls/m2

Absorption Grade

	Low	Average	High	Source
10 minute	< 0.25	0.25 - 0.50	> 0.50	T.R. No.31
30 minute	< 0.17	0.17 - 0.35	> 0.35	
60 minute	< 0.10	0.10 - 0.20	> 0.20	
120 minute	<0.07	0.07 - 0.15	> 0.15	
Cumulative 2 hr Absorption	< 1000	1000 - 2000	> 2000	T.E.L.
Sorptivity	< 0.12	0.12 - 0.23	> 0.23	T.E.L.

INITIAL SURFACE ABSORPTION TEST

Sample ref.	WLCT33-KOA5		WLCT34-KOA5		WLCT35-KOA6			
Mix Ref.	SM 35P		SM 45P		Mark 10A			
Date Cast	28-Aug-97		28-Aug-97		28-Aug-97			
Moist Curing	28		28		28			
Ambient / Oven	4		5		4			
Test Temperature	20		20		20			
Test Surface	Vertical cast	(150mm3)	Vertical cast	(150mm3)	Vertical cast	(150mm3)		
Date of Test	29-Sep-97		30-Sep-97		29-Sep-97			
Time	14:30		9:20		9:30			
Setup Time								
Test Interval	2 minutes		2 minutes		2 minutes			
	Divisions	ml/m2/sec	Divisions	ml/m2/sec	Divisions	ml/m2/sec		
10 minute	43	0.165	38	0.146	34	0.131		
30 minute	31	0.119	28	0.107	25	0.096		
60 minute	20	0.077	17	0.065	15	0.058		
120 minute	11	0.042	10	0.036	9	0.035		
Cum. 2 hr Absorption (mls/m2)		667		584		523		
Equiv. Sorptivity (mm/min1/2)		0.061		0.053		0.048		
Absorption Grade		Low		Low		Low		

Notes:

5 sec.travel	
< 3 divisions	2 minutes
3 - 9 divisions	1 minute
10 -30 divisions	30 seconds
> 30 divisions	ISA > 3.60 mls/m2

Absorption Grade	Low	Average	High	Source
10 minute	< 0.25	0.25 - 0.50	> 0.50	T.R. No.31
30 minute	< 0.17	0.17 - 0.35	> 0.35	
60 minute	< 0.10	0.10 - 0.20	> 0.20	
120 minute	<0.07	0.07 - 0.15	> 0.15	
Cumulative 2 hr Absorption	< 1000	1000 - 2000	> 2000	T.E.L.
Sorptivity	< 0.12	0.12 - 0.23	> 0.23	T.E.L.

Appendix VI

Table 19. Typical values of concrete permeability and related properties.

Test Method	Units	Concrete Permeability/absorption/diffusion			Section
		Low	Average	High	
Permeability measured with liquids	m^2	$<10^{-19}$	$10^{-19} - 10^{-17}$	$>10^{-17}$	2.3
Permeability measured with gases	m^2	$<7 \times 10^{-18}$	$7 \times 10^{-18} - 7 \times 10^{-16}$	$>7 \times 10^{-16}$	2.5
Coefficient of permeability to water (Kw)	m/s	$<10^{-12}$	$10^{-12} - 10^{-10}$	$>10^{-10}$	2.3
ISAT 10 min 30 min 1 h 2 h	$mL/m^2/s$	<0.25 <0.17 <0.10 <0.07	0.25 - 0.50 0.17 - 0.35 0.10 - 0.20 0.07 - 0.15	>0.50 >0.35 >0.20 >0.15	3.2
Figg water absorption 50mm (Dry concrete)	s	>200	100 - 200	<100	3.3
Modified Figg air permeability index (Ove Arup) -55 to -50 kPA	s	>300	100 - 300	<100	3.3.2
Water absorption 30 min	%	<3	3-4	>4	4.2
Capillary rise in 4 hrs	mm	<10	10 - 20	>20	4.2.2
DIN 1048 depth of penetration (4 days)	mm	<30	30 - 60	>60	4.3.2
Oxygen diffusion coefficient 28 day	m^2/s	$<5 \times 10^{-8}$	$5 \times 10^{-8} - 5 \times 10^{-7}$	$>5 \times 10^{-7}$	4.5
Apparent chloride diffusion coefficient	m^2/s	$<1 \times 10^{-12}$	$1 \times 10^{-12} - 5 \times 10^{-12}$	$>5 \times 10^{-12}$	4.7

Note: Values shown are typical test values and should not be used for specification purposes (see text above).

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TABLE 1 * Chloride Ion Penetrability Based on Charge Passed (1)

Charge Passed (coulombs)	Chloride Ion Penetrability
>4,000	High
2,000–4,000	Moderate
1,000–2,000	Low
100–1,000	Very Low
<100	Negligible

* ASTM C1202-94