ƐCHNICAL REPORT

Title	JINGSLINK MARKETING PTE LTD XYPEX WATERPROOFING SINGAPORE ARTS CENTRE PROJECT
Reference No.	1303/97/8426

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Abstract

Jingslink Marketing Pte Ltd have engaged Taywood Engineering Limited (TEL) to act as an independent third body with expertise in materials consultancy to evaluate the effectiveness of the Xypex product used as an admixture.

This report contains the comments and views of the material.

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TEL

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1. INTRODUCTION

1.1 Background

Concrete Waterproofing Manufacturing Pty. Ltd. (CWMPL) trading as Xypex Australia have engaged Taywood Engineering Limited (TEL) to act as an independent third body with expertise in materials consultancy to comment on the effectiveness of the Xypex product. Key issues to address which are of interest to PWD are:

- the waterproofing capability of concrete when Xypex is used as an admixture
- heat reduction in concrete when Xypex is used
- increase in compressive strength in concrete when Xypex is used

CWMPL have given the proposed trial methodology (see Appendix A) for TEL to comment. A letter of TEL's comment is given in Appendix B.

Two concrete blocks of 2m by 2m by 0.9m were cast; one with the Xypex admixture and the other as a control. The Xypex treated concrete block was cast on 14 Jan 1997 and the Control mix concrete block was cast on 22 Jan 1997. Both concrete mix designs were given by the Client. The mix with Xypex admixture was designed by CWMPL and the control mix was designed by Supermix Concrete Pte. Ltd. to meet the requirements of Penta Ocean Construction Co., Ltd. in construction of the Singapore Art Centre.

Setsco Services Pte Ltd (SETSCO) carried out the site temperature monitoring and cores sampling for laboratory testing. This report contains TEL assessment of SETSCO's test results and available technical information in order to evaluate the Xypex product.

1.2 Scope of Work

TEL's scope of work included:

a. Review of available technical data sheets, test reports and methodology proposed for evaluating the product.

b. Comments based on item (a) above with particular reference to its effects on waterproofing, heat reduction and compressive strength.

c. Issuing of a report containing the results of the evaluation.

2. CONCLUSIONS

2.1 Setsco Services Pte Ltd (SETSCO) is a SINGLAS (Singapore Laboratory Accreditation Scheme) accreditated laboratory whose quality system is based on ISO/IEC Guide 25 and the test results are officially recognised in Singapore.

2.2 The following tests which were proposed by Xypex in their methodology were used to gauge the performance of Xypex

a. Reduction of temperature during the heat of hydration
b. Increase of concrete compressive strength
c. Improvement in the water permeability of concrete (i.e. less voidage in the concrete)

2.3 The concrete mix details proposed by Xypex are given in Table 5a whereas those of the control concrete mix are shown in Table 5b. Both mixes are Grade 40MPa concrete. The cement contents of the Xypex and control mixes are 355kg/m² and 410kg/m² respectively while the corresponding water / cement ratios are 0.45 and 0.41. The same source of cement was used in both pours.

2.4 The temperature monitoring results indicate that the measured peak and differential temperatures for the Xypex Mix are lower than the control mix. This is likely to be due to the lower cement content of the Xypex mix as compared to the control mix.

2.5 It is evident from the cube compressive strength results that the strength of the control mix is higher than the Xypex mix with the exception of the 1 day results. The strength gain with time was greater in the case of the control mix as compared with the Xypex mix. This is likely to be due to the higher cement content of the control mix.

2.6 Based on the results of the core compressive strength, it is apparent that the strength of the control mix was sightly lower than the Xypex mix. This trend is not consistent with the cube compressive strength results. The cube and core compressive strength of the Xypex mix appears to be consistent at 7 and 28 days. However, for the control mix, the core compressive strengths were lower than cube compressive strengths.

2.7 The magnification at which Scanning Electron Microscopy (SEM) was carried out showed a normal concrete matrix in the case of the control mix and evidence of Xypex crystals on the Xypex treated mix at 28 days. This would concur with Xypex's claim of the formation of crystalline structure in treated concrete. Information regarding the pore (void) and crystal size was not given in the SEM test results.

2.8 Based on the water permeability test results, the control mix showed no leakage from 1.4 to 4.2 bars, however, water leakage occurred at 7 bars. For the Xypex concrete mix, no leakage was observed from 1.4 to 7 bars. Water penetration was not recorded as was required in SETSCO's proposal. In this test, the permeability coefficient is not derived, however, the test does show an improvement in the water permeability when comparing the Xypex concrete mix to the control concrete mix. However, no acceptability criteria has been defined.

2.9 The assessment of the results are summarized as follows:

a) The Xypex mix appears to successfully restrict the water ingress under head pressures.

b) The Xypex mix shows comparable compressive strengths to the control mix, but with lower cement content.

c) Lower cement content has a beneficial effect on the thermal gradients in large pours.

d) Inclusion of Xypex in concrete does not appear to adversely affect the early age strength gain, stripping times etc. to any significant extent, based on the data presented herein.

3. REVIEW OF AVAILABLE TECHNICAL DATA SHEETS AND METHODOLOGY

3.1 No temperature monitoring data and core compressive strength results were available for TEL to review.

3.2 Permeability test reports from Pacific Testing Laboratory and Industrial Museum of Technology in Vienna are given in Appendix A and the review of which is as follow.

Pacific Testing Laboratory reported "The Xypex treated samples also exhibited leakage at each state of increased pressure, but consistently followed decreasing leakage patterns approaching zero. It can therefore be stated that the Xypex chemical treatment sealing effect eliminates all measurable leakage (refer to Appendix A, Permeability test of Xypex treated and untreated concrete samples, 1982, p.4)".

Industrial Museum of Technology in Vienna reported "The so far executed tests demonstrate that the concrete test specimens coated with Xypex have an impermeability to water quite superior to the uncoated ones (refer to Appendix A, Expert Opinion -re Concrete Sealing Material /1st Part ,1983, p.7)".

3.3 Australian Manufacturers of Xypex claims "The chemicals in Xypex are in the concrete, they are available to the by-products of cement hydration and water present. The chemical reaction takes place, a crystalline structure is formed and as the chemicals in Xypex continue to migrate through the water this crystalline growth will form behind this advancing front of chemicals. This reaction will continue until the chemicals in Xypex are either depleted or run out of water (refer to Appendix A., How does Xypex work? p.2)". Scanning electronic microscopic examination was conducted as part of this evaluation to conclusively assess the existence of crystalline growth.

4. RESULTS AND DISCUSSION

4.1 Survey Techniques / Laboratory Testing

4.1.1 Temperature Monitoring

Thermo-couples were placed in the positions assigned in the concrete blocks and connected to a data Logger before casting the concrete blocks. The temperature was recorded by the Data Logger. The test duration was 7 days. The temperature was taken every 30 minutes. Ambient temperature was recorded at half an hour intervals. Further details are given in SETSCO's test report in Appendix C.

4.1.2 Cube Compressive Strength

Fifteen 150 x 150 x 150mm concrete cubes were cast at the same time during the placement for each of the two test blocks. The compressive strength test was carried on the cubes at 1, 3, 7, 28 and 56 days in accordance to SS 78.

4.1.3 Core Sampling & Compressive Strength

Core samples of 100mm in diameter were taken to a depth of 900mm. The core sample locations and description were noted and tabulated in SETSCO's report given in Appendix C. The test specimens for compressive strength were cut from the top, middle and bottom of the core sample. Core samples were tested to BS 1881:Part 120:1983 to determine the compressive strength of the samples. The compressive strength test was carried out on the cores at 7 and 28 days.

4.1.4 Scanning Electron Miscroscopy

SETSCO had obtained 1 random core sample for scanning electron miscroscopy from the top of each of the Xypex treated and control concrete blocks. Scanning electronic microscopic examination was conducted to conclusively assess the existence of crystalline growth. Samples were taken after 28 days of curing. The magnification required was to be sufficient to permit the examination of the microscopic pores and capillaries in the matrix of the concrete sample for evidence of Xypex crystal.

4.1.5 Water Permeability

150mm diameter core samples were taken from each of the Xypex treated and control concrete blocks at 7 and 28 days and subjected to a water permeability test specified by the Client. According to the information provided, the test apparatus for the water permeability test is modeled after the test apparatus described in the Corps of Engineer's Test No CRD-C48-73 with several variations. The test specimens were cut from the top, middle and bottom of the core samples. The test details are as follow.

- 1.4 bars on the 1st and 2nd day
- 2.8 bars on the 3rd day
- 4.2 bars on the 4th day
- 7 bars on the 5th to 15th day

SETSCO's test report is given in Appendix C together with the details of the test procedure.

4.2 Results and Discussion

4.2.1 Temperature Monitoring

The temperature results obtained by SETSCO are given in Appendix C and summarised in Table 4.2. It is evident from these results that the peak and maximum differential temperatures for the control mix are 77°C and 23°C respectively whereas the corresponding values for the Xypex mix are 69°C and 18°C.
The temperature measured from the trial block with Xypex was lower compared to the control block. This is due to the lower cement content for the Xypex mix as compared to the control mix (see Tables 5a & 5b for the mix designs). Placement temperature as given by CWMPL for the Xypex treated concrete and control mix concrete was 26.2°C and 27.2°C respectively (see Appendix B). The cement content for the Xypex treated concrete and control concrete are 355 kg/m² and 410 kg/m² respectively. The same source of cement was used in both pours.

The Xypex mix reached its peak temperature slightly earlier than the control mix. This could be due to a slightly accelerating effect by Xypex or a slight retarding effect by the admixtures in the control mix. However, this is not particularly significant.

4.2.2 The Cube compressive strength results are summarised in Table 4.2. It can be seen from these results that the average cube compressive strength results for the control mix at 1,3,7,28 and 56 days are 18.5, 31.5, 41.5, 54.0 and 58.0 N/mm² respectively whereas the corresponding values for the Xypex mix are 20.5, 30.0, 37.0, 46.5 and 49.0 N/mm². The results show that the cube compressive strength of the control mix is higher than the Xypex mix.

4.2.3 Core Sampling & Compressive Strength

SETSCO's core compressive strength results are given in Appendix C and summarised in Table 4.2. The results indicate that the average core compressive strength results for the control mix at 7 and 28 days are 39.5 and 42.0 N/mm² respectively while the corresponding results for the Xypex mix are 38.5 and 45.0 N/mm². It can be seen from these results that the core compressive strength of the control mix is sightly lower than that of the Xypex mix.

4.2.4 Scanning Electron Miscroscopy (SEM)

The magnification at which Scanning Electron Microscopy was carried out showed a normal concrete matrix on the control mix and evidence of Xpyex crystals on the Xypex treated mix at 28 days. This would concur with Xypex's claim of the crystallization of crystals in treated concrete. Information regarding the pore (void) size and crystal size was not given with the SEM test results.

4.2.5 Water Permeability

The results are summarised in Table 4.2. They indicate that the Control mix showed no leakage from 1.4 to 4.2 bars. However water leakage occured at 7 bars. No leakage was observed from 1.4 to 7 bars for the Xypex concrete mix. The permeability coefficient of the concrete was not measured neither was the water penetration and therefore no acceptable criteria can be defined. These results do however indicate a qualitative improvement in the permeability of the Xypex mix over the control concrete mix.

TABLE 4.2 :

XYPEX PERFORMANCE TEST ON G40 CONCRETE

Type of Test	Control Mix Results	Xypex Mix Results
Water permeability at 7 days	No leakage occured from 1.4 bar to 4.2 bar Water leakage occured at 7 bar	No leakage occured from 1.4 bar to 7 bar
Average CUBE Compressive strength at 1 day at 3 days at 7 days at 28 days at 56 days	 18.5 N/mm² 31.5 N/mm² 41.5 N/mm² 54.0 N/mm² 58.0 N/mm²	 20.5 N/mm² 30.0 N/mm² 37.0 N/mm² 46.5 N/mm² 49.0N/mm²
Average CORE Compressive strength at 7 days at 28 days	 39.5 N/mm² 42.0 N/mm²	 38.5 N/mm² 45.0 N/mm²
Scanning Electron Microscopy (SEM) Test	Normal Concrete Matrix noted	Xypex crystals noted
Maximum Temperature Temperature difference	77°C 23°C	69°C 18°C

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Table 5A

Project: SINGAPORE ARTS CENTRE - PUMP MIX

Work: Construction of Main Basement works
Contractor : Penta Ocean Construction Co Ltd

1	1.1	Characteristic Strength	Specific 40N/mm² at 28 days below which 5% of test results may be expected to fall
	1.2	Cement Type	Ordinary Portland Cement
	1.3	Aggregrate Type : Coarse	Crushed Granite
		: Fine	Natural/Manufactured Sand
	1.4	Free Water/Cement Ratio Specified	
2	2.1	Slump for Concrete	95 + \ - 25mm
	2.2	Maximum Aggregate Size	20mm
	2.3	Free Water Content	Nominal Maximum Water 160kg / m³
3	3.1	Cement Content	355 kg / m³
	3.2	Total Aggregate Content	1775 kg / m³
	3.3	Proportion of Fine Aggregate	39.5%
	3.4	Fine Aggregate Content Grading to SS31, S.G. 2.61 (surface dry)	700 kg / m³
	3.5	Coarse Aggregate Content S.G. 2.62 (surface dry)	1075 kg / m³
4	4.1	XYPEX Admix C-2000	Dose Rate = 0.9% by weight of O.P.C. 3.2 kg / m³
5	5.1	Concrete Density	2293 kg / m³

6 MIX SUMMARY

Mix Mpa	Slump (mm)	Cement (Kg/m³)	20mm Graded (Kg/m³)	Sand (Kg/m³)	Nominal Max/Water (Kg/m³)	Max A/C Ratio	W/C Ratio	XYPEX Admin C-2000 (Kg/m³)
40	95+/-2	355	1075	700	160	3.00	0.45	3.2

SUPERMIX CONCRETE PTE LTD Table: 5B
CONCRETE MIX DESIGN

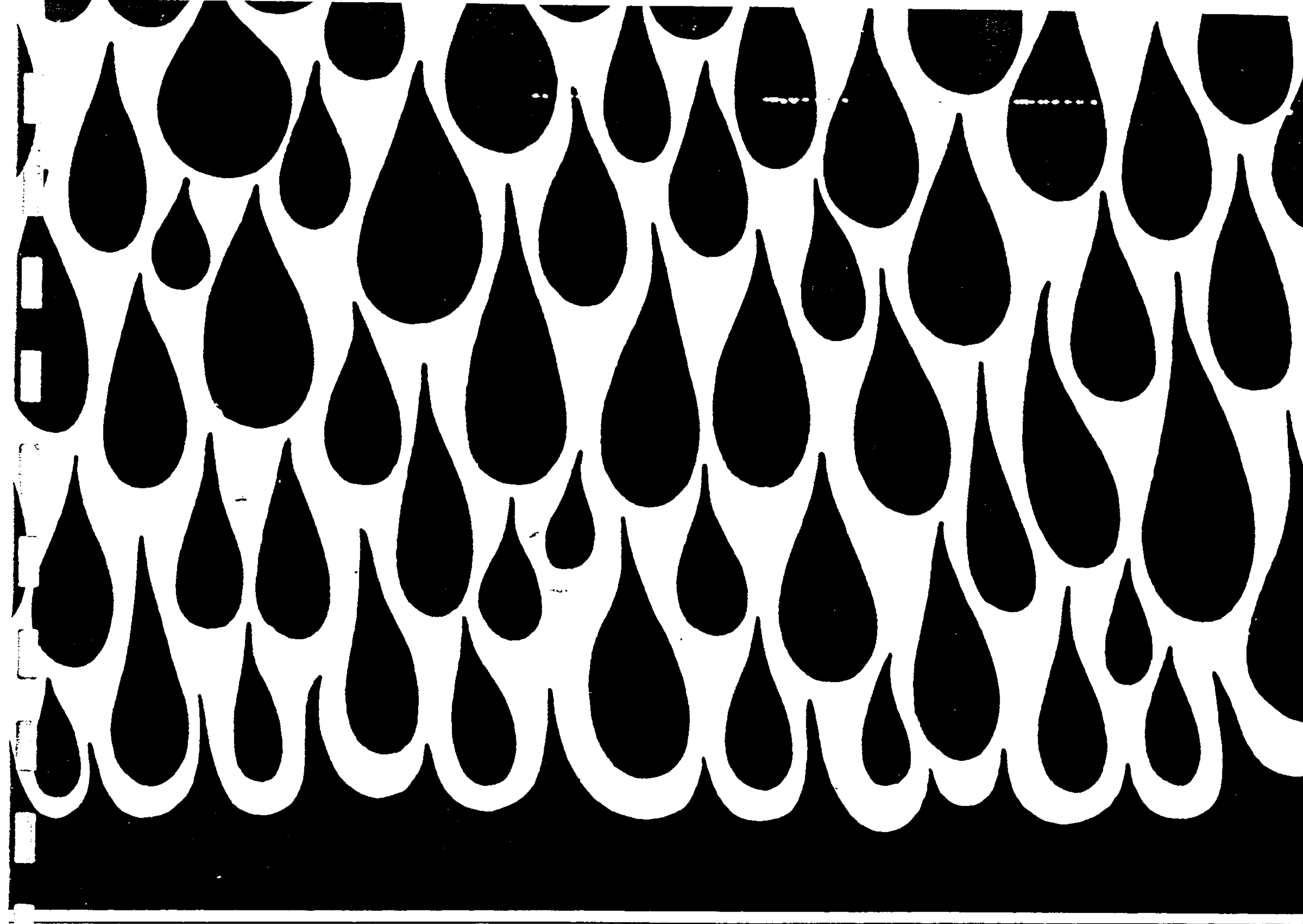
Project: Construction of Pile Foundation and Main Basement Works
Location: Singapore Arts Centre
Contractor: Penta Ocean Construction Co Ltd

1	1.1 Concrete Grade 1.2 Concrete Type 1.3 Slump for Concrete		40 N/mm² Pump Mix 125mm	
2	2.1 Characteristic Strength 2.2 Design Standard Deviation 2.3 Designed Margin 2.4 Target Mean Stength 2.5 Specified Water/Cement Ratio		40N/mm² at 28 days below which 5% of test results may be expected to fall. 4.57 N/mm² 1.64 x 4.57 N/mm² = 7.50 N/mm² 40 + 7.50 N/mm² = 47.50 N/mm² 0.41	
3	3.1 Cement	OPC	Brand:PMCW (S)	S.G.: 3.15
	3.2 Fine Aggregate	Natural	Size: Grading to SS31	S.G.: 2.61 (Surface Dry)
	3.3 Coarse Aggregate	Crushed	Size: 20mm	S.G.: 2.61 (Surface Dry)
	3.4 Water	PUB		
	3.5 Admixture	Cormix P4	650 ml/100kg of cement (Piasticizer & Retarder)	
	3.6 Reagent	Cormix SP1	400 ml/100kg of cement (Superplasticizer)	
4	4.1 Cement Content 4.2 Water Content 4.3 Concrete 4.4 Proporation of Fine Aggregate 4.5 Air Content		410kg/m³ 170 kg/³ 2353 kg/m³ 42.90% 2%	

5	5.1 Summary (kg/m³)			Coarse Aggregate	Admixture	Reagent
	Cement	Water	Fine Aggregate	1010	3.17	1.97
	410	170	758			
	Water/Cement Ratio		41%	Percentage of Fine Aggregate		42.90%
6	Remarks: The Characteristic strength shall conform to BS 5328 & SS289 This design mix is done under surface dry and saturated and conditions					

APPENDIX A

PROPOSED METHODOLOGY FOR XYPEX ADMIX C-2000



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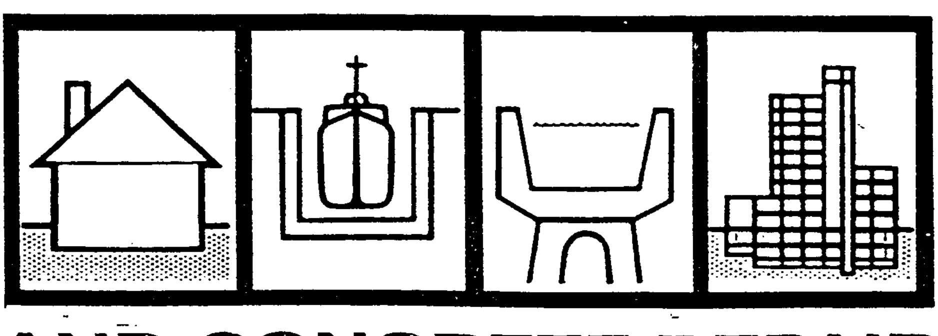

AND CONCRETE REPAIR

XYPEX
AUSTRALIA

PROPOSED METHODOLOGY FOR CONDUCT OF FIELD TEST
XYPEX Admix C-2000

TEST SITE

- To consist of formwork to dimensions of ; 2.0 m X 2.0 m X 0.9 m (deep).
- Formwork material to be 12 mm water resistant plywood.
- Reinforcement steel to comply with ART CENTRE design requirements in all regards.
- Site to be moistened prior to concrete placement.

CONCRETE

- As per mix design - ART CENTRE Design 1 Mark IV. (attachment 1)
- XYPEX Admix C-2000 to be dosed with regard to protocol (attachment 2) at the rate of 0.9 % cementitious content.
- "Slump" to conform to specified range per mix design.(attachment 1).
- Concrete is to be placed by pump, without the addition of any "pumping" admixtures.
- Normal minimum standard for compaction and finishing apply. (Refer to attachment 3.)
- Elapsed time from batching to commencement of placement not to exceed ninety (90) minutes. As per attachment 2 minimum elapsed interval between batching and placement is to be ten (10) minutes.

CURING

- Water - Wet covering (Permanently wet - material impregnation) for minimum three (3) days.
-

AUSTRALIAN MADE

Permeability

Objective

*The objective of this test is to measure the rate of outflow of water from the concrete test sample, **it is not** to measure the rate of inflow into the concrete sample.*

- Testing to be undertaken in accordance to the "spirit" of procedures employed by PACIFIC Testing Laboratory (attachment 6).
- Equipment for the conduct of the above is to be modelled upon "Industrial Museum of Technology in Vienna" (attachment 7).
- Permeability testing to be undertaken on core samples removed from test structure at seven (7) days and at twenty - eight (28) days. Cores are to be 200 mm diameter and test specimens are to be 50 mm thick and obtained from top, middle and bottom of core sample.
- Each of the above "slices" is to be subjected to testing.
- Each slice is to be accurately weighed prior to conduct of testing. Further each specimen should be assessed for moisture content by way of a moisture meter.
- Testing shall be to a minimum hydrostatic pressure of 7 Bars for 7 days.
- Pressure should be achieved by incremental increases as detailed ;

  1.4 bar on the 1st day,
  2.8 bar on the 4th day,
  4.2 bar on the 7th day, and
  7.0 bar on the 10th and subsequent days.

  Note: Pressure should be maintained until any "leakage" ceases.
  Note: In the event of outflows ceasing prior to the timings indicated above, the next incremental increase in water pressure should commence immediately. Optimum performance will permit 7 bars of pressure commencing at day one.

- It is anticipated that "leakage" may occur at time of pressure increases however leakage will dissipate as the XYPEX "activates", remembering that water is the catalyst for the reaction. (See attachments No's 8 and 9 for further information)
- Note: The samples should not be saturated prior to testing.
- The test is to monitor water permeability and the reduction of any measurable outflow from the test sample. To that end any water moving through the samples is to be measured and recorded by placement of a glass funnel, attached to the underside of the test sample, to collect outflow which shall be measured and recorded, at least, daily.

ATT. No 1

XYPEX AUSTRALIA

TRIAL MIX DESIGN 1 / MARK IV

Project: SINGAPORE ARTS CENTRE - PUMP MIX

Work: Construction of Main Basement works

Contractor: Penta Ocean Construction Co Ltd.

1.	1.1	Characteristic Strength	Specific 40 N/mm^2 at 28 days below which 5% of test results may be expected to fall.
	1.2	Cement Type	Ordinary Portland Cement
	1.3	Aggregate Type: : Coarse : Fine	Crushed Granite Natural/Manufactured Sand
	1.4	Free Water/Cement Ratio Specified	0.45 maximum
2.	2.1	Slump for Concrete	95 + \ - 25 mm
	2.2	Maximum Aggregate Size	20mm
	2.3	Free Water Content	Nominal Maximum Water 160 kg / m^3
3.	3.1	Cement Content	355 kg / m^3
	3.2	Total Aggregate Content	1775 kg / m^3
	3.3	Proportion of Fine Aggregate	39.5%
	3.4	Fine Aggregate Content Grading to SS31, S.G. 2.61 (surface dry)	700 kg / m^3
	3.5	Coarse Aggregate Content S.G. 2.62 (surface dry)	1075 kg / m^3
4.	4.1	XYPEX Admix C-2000	Dose Rate = 0.9% by weight of O.P.C. 3.2 kg / m^3
5.	5.1	Concrete Density	2293 kg / m^3

6. **MIX SUMMARY**

Mix (Mpa)	Slump (mm)	Cement (Kg/m^3)	20mm Graded (Kg/m^3)	Sand (Kg/m^3)	Nominal Max/Water (Kg/m^3)	Max A/c Ratio	W/C Ratio	XYPEX Admix C-2000 (kg/m^3)
40	95+/- 25	355	1075	700	160	3.00	0.45	3.2

AUSTRALIAN MADE

1 Compacting Concrete

1.1 PURPOSE

Compaction is the process which expels entrapped air from freshly placed concrete and packs the aggregate particles together so as to increase the density of the concrete. It increases significantly the ultimate strength of concrete and enhances the bond with reinforcement. It also increases the abrasion resistance and general durability of the concrete, decreases the permeability and helps to minimise its shrinkage and creep characteristics.

Proper compaction also ensures that the formwork is completely filled – ie there are no pockets of honeycombed material – and that the required surface finish is obtained on vertical surfaces.

AS 3600 specifies that concrete shall be compacted during placing so that:

- the entrapped air is expelled;
- the formwork is completely filled to the intended level;
- all reinforcement, tendons, ducts, anchorages and embedments are completely surrounded;
- the specified finish to the formed surfaces of the member is provided;
- the required properties of the concrete are achieved.

1.2 THE PROCESS

When first placed in the form, normal concretes (ie excluding those with very low or very high slumps) will contain between 5% and 20% by volume of entrapped air. The aggregate particles, although coated with mortar, will also tend to arch against one another and are prevented from slumping or consolidating by internal friction.

Compaction of concrete is, therefore, a two-stage process **Figure 8.1**. First, the aggregate particles are set in motion and consolidated to fill the form and give a level top surface. In the second stage, entrapped air is expelled. This description of the process is true whether compaction is carried out by rodding, tamping and similar manual methods, or when vibration is applied to the concrete. The latter, by temporarily 'liquefying' the concrete, is generally much more efficient than hand-tamping or rodding, and hence is almost universally applied on construction sites in Australia.

It is important to recognise the two stages in the compaction process because, with vibration, initial consolidation of the concrete can often be achieved relatively quickly. The concrete liquefies and the surface levels, giving the impression that the concrete is compacted. Entrapped air takes a little longer to rise to the surface. Compaction must therefore be prolonged until this is accomplished, ie until air bubbles no longer appear on the surface.

1.3 EFFECT ON FRESH CONCRETE

The effect of vibration on the properties of fresh concrete needs to be understood to ensure that the type and amount of vibration applied to the concrete are appropriate. Otherwise defects, such as excessive mortar loss and other forms of segregation, can be caused.

Concrete mixtures themselves need to be properly proportioned. Those lacking fines can be difficult to compact and, even when fully compacted, can have a high porosity. On the other hand, those with too high a fines content, particularly if they also have a high slump, may compact too readily and be prone to segregation and excessive bleeding. Properly proportioned mixtures are difficult to overcompact.

The stiffer mixes will require a greater energy input to compact them fully. This may be achieved by using a high energy vibrator or by vibrating the concrete for a longer time. In the latter case, the vibrator must have at least sufficient capacity to liquefy the concrete. Conversely, more-workable mixes will require less energy input.

The size and angularity of the coarse aggregate will also affect the effort required to fully compact concrete. The larger the aggregate, the greater the effort which will be required, while angular aggregates will require greater effort than smooth or rounded aggregates.

1.4 EFFECT ON HARDENED CONCRETE

Since compaction of concrete is designed to expel entrapped air and optimise the density of the concrete, it benefits most of the properties of hardened concrete. As may be seen from **Figure 8.2**, its effect on compressive strength is dramatic. For example, the strength of concrete containing 10% of entrapped air may be as little as 50% that of the concrete when fully compacted.

Permeability may be similarly affected since compaction, in addition to expelling entrapped air, promotes a more even distribution of pores within the concrete, causing them to become discontinuous.

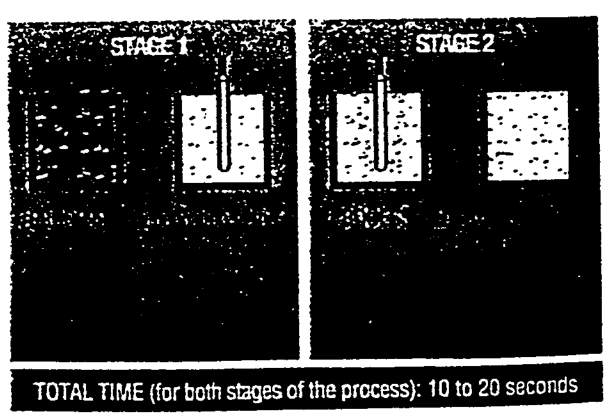

Figure 8.1 The process of compaction

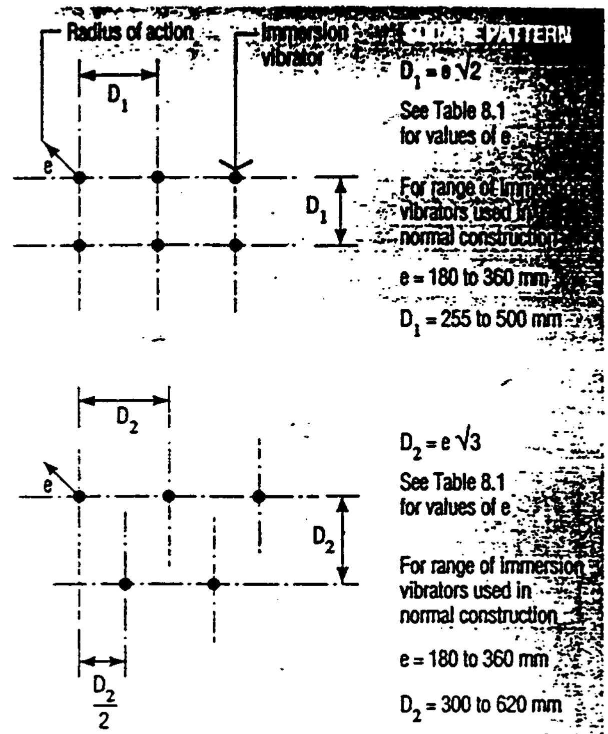

Figure 8.4 Alternative patterns for use of immersion vibrators

The *frequency* of a vibrator is the number of vibrations per second (Hz). In general, high-frequency vibrators are most suited to high-slump concrete and small maximum-sized aggregates; and low frequencies to low slumps and large maximum-sized aggregates. The *amplitude* is the maximum displacement of the head from its point of rest, measured in mm. It will be larger in air than in concrete which has a damping effect. As a general rule, high-amplitude vibrators are most suited to low-slump/large maximum-sized aggregate concrete and low amplitudes to high slumps and small maximum-sized aggregates. 8.5

Immersion vibrators should be inserted vertically into concrete, as quickly as possible, and then held stationary until air bubbles cease to rise to the surface, usually in about 15–20 seconds **Figure 8.3**. The vibrator should then be slowly withdrawn and reinserted in a fresh position adjacent to the first. These movements should be repeated in a regular pattern until all the concrete has been compacted **Figure 8.4**. Random insertions are likely to leave areas of the concrete uncompacted. The vibrator should not be used to cause concrete to flow horizontally in the forms, as this can lead to segregation.

In deep sections such as walls, foundations and larger columns, the concrete should be placed in layers about 300 mm thick. The vibrator should penetrate about 150 mm into the previous layer of fresh concrete

Table 8.1 Characteristics and applications of internal vibrators

Diameter of head (mm)	Recommended frequency (Hz)[1]	Average amplitude (mm)[2]	Radius of action (mm)[3,5]	Rate of concrete placement (m^3/h per vibrator)[4,5]	Application
20–40	150–250	0.4–0.8	80–150	0.8–4	High slump concrete in very thin members and confined places. May be used to supplement larger vibrators where reinforcement or ducts cause congestion in forms.
30–60	140–210	0.5–1.0	130–250	2.3–8	Concrete 100–150 mm slump in thin walls, columns, beams, precast piles, thin slabs, and along construction joints. May be used to supplement larger vibrators in confined areas.
50–90	130–200	0.6–1.3	180–360	4.6–15	Concrete (less than 80 mm slump) in normal construction, eg walls, floors, beams and columns in residential, commercial and industrial buildings.
80–150	120–180	0.8–1.5	300–500	11–31	Mass and structural concrete of 0 to 50 mm slump deposited in quantities up to 3 m^3 in relatively open forms of heavy construction.
130–180	90–140	1.0–2.0	400–600	19–38	Mass concrete in gravity dams, large piers, massive walls, etc.

Adapted from Table 5.15 ACI Committee Report: *Consolidation of Concrete* ACI Manual of Concrete Practice 1993 Part 2

1 *While vibrator is operating in concrete.*

2 *Computed or measured. This is peak amplitude (half the peak-to-peak value), operating in air. Reduced by 15–20% when operating in concrete.*

3 *Distance over which concrete is fully consolidated.*

4 *Assumes insertion spacing 1½ times the radius of action, and that vibrator operates two-thirds of time concrete is being placed.*

5 *Reflects not only the capability of the vibrator but also differences in workability of the mix, degree of de-aeration desired, and other conditions experienced in construction.*

compacted by both immersion and surface vibrators will have a denser, more abrasion-resistant surface than one compacted by immersion vibrators alone.

With centrally-mounted vibration units, the degree of compaction achieved may vary across the width of the beam. When they rest on edge forms, the latter may tend to damp the vibration at the extremities of the beam **Figure 8.8**. It is generally desirable, therefore, to supplement vibrating-beam compaction by using immersion vibrators alongside edge forms.

The effectiveness of vibration and, hence, degree of compaction increases with an increase in the beam weight, the amplitude and the frequency, and decreases with an increase in forward speed. Forward speed is critical in the correct use of vibrating-beam screeds and should be limited to between 0.5 and 1.0 m/min.

Generally speaking, vibrating-beam screeds are not suitable for concretes with slumps greater than about 75 mm, as an excessive amount of mortar may be brought to the surface. Ideally, they should be used only on concretes with slumps between 25 and 50 mm.

For the reasons given above, slabs 200 mm in thickness or over should be compacted initially with immersion vibrators. Slabs of less than 200 mm may also benefit from the use of immersion vibrators along their edges **Figure 8.9**. In using vibrating-beam screeds to compact concrete, the uncompacted concrete should first be roughly levelled to above the final level required, ie a surcharge should be provided to compensate for the reduction in slab thickness caused by the compaction of the concrete. The amount of surcharge should be such that, when the beam is moved forward, a consistent roll of concrete is maintained ahead of the beam. The surcharge may be provided evenly on slabs of up to about 4 m in width by the use of a 'surcharge-beam'. This is simply a straightedge (usually made of timber) with small packing pieces on the ends which ride on the edge forms **Figure 8.10**

The surcharge-beam is pulled over the uncompacted concrete without any attempt being made to compact or finish it. The sole purpose is to provide an even surcharge. The correct thickness for the packing pieces (and hence the surcharge) is soon found by observing the 'roll' of concrete. Providing an even surcharge has the advantage that one pass of the vibrating-beam screed is generally sufficient to compact, level and provide the initial finish. This is preferable to multiple passes, as a slower single pass is more effective than two faster passes.

The forward speed is most important and should be between 0.5 and 1.0 m/min. The lower speed should be used for thicker slabs and where reinforcement is close to the top face. A second, faster pass may be made as an aid to finishing.

1.5.4 Form Vibrators

Form vibrators are normally called 'external' vibrators and are useful with complicated members or where the reinforcement is highly congested. They are

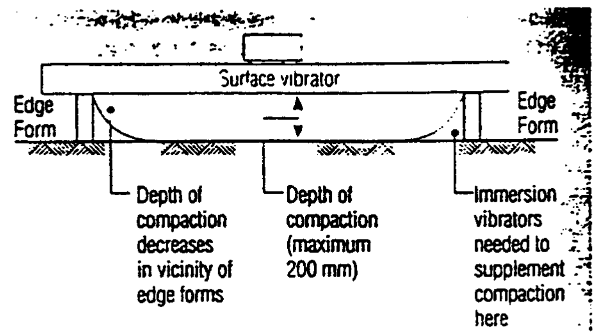

Figure 8.8 Degree of compaction varies across width when surface vibrators are used

Figure 8.9 Use of an immersion vibrator at a slab edge

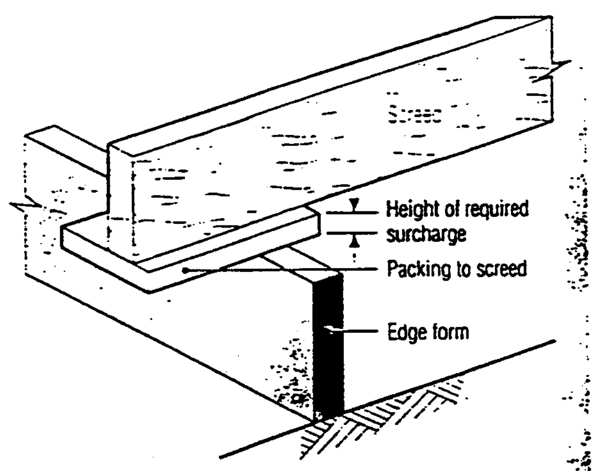

Figure 8.10 Method for providing a surcharge to the uncompacted concrete

2 Finishing Concrete Flatwork

2.1 GENERAL

'Flatwork' refers to any concrete floor or paving such as industrial floors, floors in buildings (both on ground and suspended), house floors, slabs, paths, patios, driveways, roads, etc.

The finishing of flatwork involves a combination of the following processes:

- Levelling
- Floating
- Trowelling
- Other treatments.

These are carried out while the concrete is still plastic. The purpose of finishing is to achieve the desired:

- level;
- flatness;
- surface density and texture.

2.2 LEVELLING (SCREEDING)

2.2.1 General

Levelling or screeding is the initial operation carried out on a concrete slab after the concrete has been placed in the forms and (if necessary) roughly levelled by shovel. Screeding is carried out by working a beam backwards and forwards across the concrete to achieve a level surface or by means of vibrating-beam screeds working off forms or guide rails.

Screeding should be done before bleed water rises to the surface.

2.2.2 Hand Screeding Off Forms or Screed Rails

Screeding off edge forms involves the use of a screed board to strike off the concrete to the height of the forms. Screed rails are temporary guides to support the screed board. They have to be removed after the surface is screeded, and the surface made good whilst the concrete is plastic.

The striking surface of a screed board should always be straight and true. Proprietary screed boards, such as hollow magnesium straightedges, should be used for major commercial work and for house slabs. Lengths of dressed timber are satisfactory in minor work.

To enable it to be worked backwards and forwards without losing its level, the straightedge should be between 300 and 600 mm longer than the greatest distance between the forms.

The surface is struck off by pulling the screed board forward, while moving it back and forth with a saw-like motion across the top of the edge forms. A small roll of concrete should always be kept ahead of the straightedge to fill in low spots and maintain a plane surface. Excessive amounts should be removed and placed ahead of the screed board.

2.2.3 Hand Screeding Off Wet-Screeds

'Wet-screeds' consist of pads or narrow strips of concrete (approximately 200 mm wide) placed to the correct level in advance of the main pour. The concrete finisher then uses the pads or strips as the control for levelling the slab.

This method allows large areas to be screeded without intermediate forms or guide rails and without the necessity to accurately level the edge forms. However, more skill is required and surveying equipment has to be available.

Generally proprietary aluminium or magnesium screed boards with a handle are preferred for this work.

2.2.4 Screeding Using Vibrating-Beam Screeds

Vibrating-beam screeds provide significant compaction in addition to their screeding capability. Their use and operation are described in Clause 1.5.3 of this Chapter.

The accuracy of the surface level achieved is dependent on the formwork on which the vibrating-beam rides. This formwork must therefore be accurately levelled and firmly fixed so that it will not distort under the weight of the vibrating-beam. Special care should be taken at joints of formwork boards.

The screed itself should not 'sag' or distort under the weight of the vibration unit and, for this reason, a 4-m width is about the limit for twin-beam, centrally-mounted vibration unit screeds. However, trussed vibrating-beam screeds can span 12 m with minimal 'sag' and can be used to provide floors with very tight surface tolerances **Figure 8.12**.

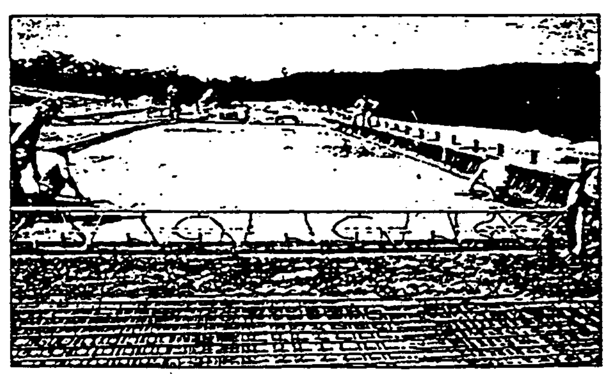

Figure 8.12 Typical trussed vibrating-beam screed

Well-worn magnesium floats should be discarded. They develop an edge almost as sharp as that of a steel trowel, and use of them risks closing the surface too soon.

Composition floats have resin-impregnated canvas surfaces. They are smoother than wooden floats but slightly rougher than magnesium floats. They also can be used after wood or power floating.

The hand float is held flat on the surface and moved in a sweeping arc to embed the aggregate, compact the concrete and remove minor imperfections and cracks. Sometimes the surface may be floated a second time, after some hardening has taken place, to impart the final desired texture to the concrete.

2.3.4 Floating by Machine

Machines for floating are usually trowelling machines with float shoes or, for use on low-slump concrete or toppings, disc-type machines (Kelly floats).

Float blades are wider than trowel blades and are turned up along the edges to prevent them digging into the surfaces whilst in the flat position. For this reason, floating with a trowelling machine equipped with normal trowel blades should not be attempted.

The power-float should be operated over the concrete in a regular pattern leaving a matt finish **Figure 8.15**. Concrete close to obstructions, or in slab corners, that cannot be reached with a power-float should be manually floated before power floating is begun.

The use of water sprays or other means of wetting the surface during finishing operations should not be permitted as such practices almost inevitably cause dusting of the slab at a later date

2.4 TROWELLING

2.4.1 General

Trowelling is carried out some time after floating. The delay is to allow some stiffening to take place so that aggregate particles are not torn out of the surface.

For a first trowelling, the trowel blade should be kept as flat against the surface as possible since tilting or pitching the trowel at too great an angle can create ripples in the concrete

Additional trowellings may be used to increase the smoothness, density, and wear resistance of the surface. Successive trowellings should be made with smaller trowels pitched progressively more. This increases the pressure at the bottom of the blade and helps compact the top surface.

Blisters forming on the surface during trowelling indicate that the angle of the trowel is too great. As soon as blisters are seen they should be pushed down immediately and reconded with a magnesium float or a flat trowel, depending on the stiffness of the concrete. The angle of the trowel should then be reduced to prevent more blisters forming at this stage.

A blistered surface will not be durable. Blisters can be broken out by traffic, and will show through any resilient tile placed over them.

2.4.2 Trowelling by Hand

A trowel for hand finishing has a flat, broad steel blade and is used in a sweeping arc motion with each pass overlapping the previous one.

The time for trowelling to be most effective calls for some experience and judgement, but, in general terms, when the trowel is moved across the surface it should give a ringing sound.

2.4.3 Trowelling by Machine

The trowelling machine (power trowel or 'helicopter') is a common tool in Australia for all classes of work and consists of several (generally four) steel trowel blades rotated by a motor and guided by a handle.

Trowelling by machine should be carried out systematically over the concrete in a regular pattern. Corner areas, areas closest to obstructions and small irregularities should then be 'touched-up' with a hand trowel.

Successive trowellings, with a break to allow further hardening, will 'densify' the surface, providing increased wear resistance. Successive trowellings should be at right angles to each other for maximum effectiveness.

2.5 EDGING

Edging provides a quarter-round arris along the edges of footpaths, patios, curbs and steps. It is achieved by running an edging trowel along the perimeter of the concrete. Edging trowels are steel and incorporate a quarter-round forming edge. They are available in a variety of widths and with various diameter quadrants.

Edging improves the appearance of many types of paving and makes the edges less vulnerable to chipping. However, edging should not be used at joints in industrial or warehouse floors or in floors which will be tiled or carpeted.

Joints in industrial floors should have a crisp right-angled corner. On formed edges this is achieved principally by the form boards which should have sharp, right-angled edges. Hand trowelling is generally used along such edges to ensure the sharpness of corners.

2.6 SURFACE TREATMENTS

2.6.1 General

Surface treatments should be chosen to suit the anticipated service conditions or to give the concrete a particular appearance.

The choice of finish will be influenced by the following considerations:

- The type of traffic and its frequency
- Whether the floor is subject to impact-loading
- Whether chemicals will come into contact with the slab.

Consideration should also be given to the operations to be carried out on the floor, which may determine how smooth it should be, and the necessity for hygiene and dust prevention.

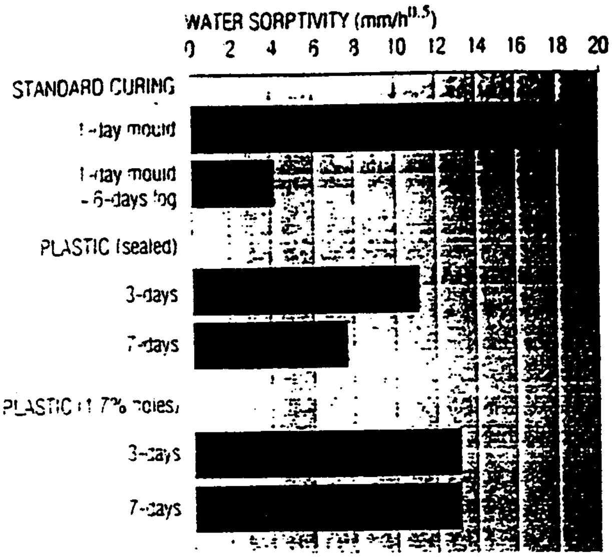

Figure 9.6 Effectiveness of plastic sheeting

For vertical work the member should be wrapped with sheeting and taped to limit moisture loss. Where colour of the finished surface is a consideration, the plastic sheeting should be kept clear of the surface to avoid hydration staining. This can be achieved with wooden battens or even scaffolding components, provided that a complete seal can be achieved and maintained.

Care must also be taken to prevent the sheeting being torn or otherwise damaged during use. A minimum thickness is required to ensure adequate strength in the sheet: ASTM C171 *Sheet Materials for Curing Concrete* specifies 0.10 mm. **Figure 9.6** illustrates the lack of effectiveness of plastic sheeting with holes representing only 1.7% of the sheet's surface area.

Plastic sheeting may be clear or coloured. Care must be taken that the colour is appropriate for the ambient conditions. For example, white or lightly coloured sheets reflect the rays of the sun and, hence, help to keep concrete relatively cool during hot weather. Black plastic, on the other hand, absorbs heat to a marked extent and may cause unacceptably high concrete temperatures. Its use should be avoided in hot weather, although in cold weather its use may be beneficial in accelerating the rate at which the concrete gains strength.

Clear plastic sheeting tends to be more neutral in its effect on temperature (except in hot weather, where it fails to shade the surface of the concrete) but tends to be less durable than the coloured sheets, thereby reducing its potential for re-use.

3.2.3 Curing Compounds

Curing compounds are liquids which can be brushed, sprayed, or squeegeed (usually sprayed) directly onto concrete surfaces and which then dry to form a relatively impermeable membrane which retards the loss of moisture from the concrete. Their properties and use are described in AS 3799.

They are an efficient and cost-effective means of curing concrete which may be applied to freshly placed concrete or that which has been partially cured by some other means. However, they may affect the bond between concrete and subsequent surface treatments. Special care in the choice of a suitable compound needs to be exercised in such circumstances.

Curing compounds are generally formulated from wax emulsions, chlorinated rubbers, synthetic and natural resins, and from PVA emulsions. Their effectiveness varies quite widely, depending on the material and strength of the emulsion, as is illustrated in **Figure 9.7**.

When used to cure fresh concrete, the timing of their application is critical for maximum effectiveness. They should be applied to the surface of the concrete after it has been finished, as soon as the free water on the surface has evaporated and there is no water sheen visible. Too early application dilutes the membrane; too late results in it being absorbed into the concrete with a consequent failure of the membrane to form.

They may also be used to reduce moisture loss from concrete after initial moist curing or the removal of formwork. In both cases the surface of the concrete should be thoroughly moistened before the application of the compound to prevent its absorption into the concrete.

Curing compounds can be applied by hand spray, power spray, brush or roller. The type or grade of curing compound should be matched to the type of equipment available and the manufacturer's directions followed. The rate of application should be uniform with coverage normally in the range 0.20 to 0.25 L/m². Where feasible two applications applied at right angles to each other will help ensure complete coverage.

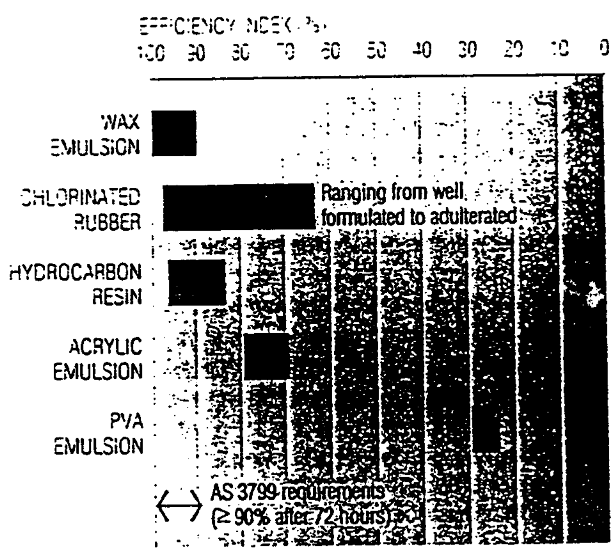

Figure 9.7 Comparative efficiency of curing compounds

Att No 5
1-3

SETSCO
SETSCO SERVICES PTE LTD
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Bukit Chermin Rd.
Singapore 098892.
Tel: 2700008
Telefax: 2700911
MAILING ADDRESS:
307 Telok Blangah Rd.
Singapore 098832.

Our Ref : *BTD/96/1009/XLP/gsr*
Date : *26/11/96*

Fax No : *299 - 5893*
Tel No : *299 - 5836*

TO : **Jingslink Marketing Pte Ltd**
Attn. : Mr Chan Ac Lam

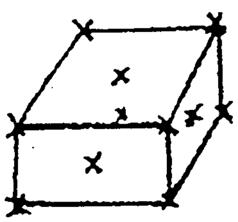
Subject : <u>XYPEX ADMIN C-2000 Waterproofing Field Test</u>

We refer to our discussion at Setsco on 25/11/96 regarding the field test of XYPEX ADMIN C-2000 waterproofing additive used for base of the Esplanade theatres on the bay. We are pleased to furnish the following test methods and the test fee for your kind reference.

1. <u>Monitor of the temperature of hydration on concrete block</u>

The concrete block should be 2000 x 2000 x 1000mm.
The concrete mix design will be given by client. The fresh concrete with waterproofing additive and all specimens will be given and prepared by client.

Before casting the concrete block, the thermo coupler will be placed in the position assigned in the concrete block and connected to Data Logger. The distribution of the thermo coupler is shown in the following Figure.



One point in the centre of the block
Eight points in the corner of the block
Six points in the centre of each surface of the block

The temperature will be determined and recorded by the Data Logger. The test duration should be 7 days. The temperature will be taken every 30 minutes during the first 3 days and then every 1 hour thereafter

Please do not hesitate to contact us if you require further information.

Best regards.

Xuliping
XU LIPING
MATERIAL ENGINEER
BUILDING TECHNOLOGY DEPT.

TEST METHODS AND PROCEDURES:

A. Description of Test Apparatus

The apparatus used for the permeability test was supplied by Xypex Chemical Company. It consisted of a panel to control air pressure and flow, four steel pressure vessels to hold the four samples to be used and the necessary hosed, gauges, valves, and fittings to carry out the test (see Photograph on Page 5). The gauges used for this test were calibrated by Pacific Testing Laboratories and are traceable to the National Bureau of Standards. Pressurized air was directed through the control panel to each of the four pressure vessels. Each vessel contained a gauge to monitor the pressure, and outlet hoses and flasks for collecting and measuring water output (as will be described in Procedure section). The major differences in the test apparatus and procedures are as listed below:

XYPEX TEST	CORPS. OF ENGINEER'S TEST
1. Steel cylinders were 6½ in. dia. × 6 in. high with samples approximately 6 in. dia. × 2 in. thick.	1. Steel cylinders were made to accommodate samples 14½ in. dia. × 15 in. high.
2. Apparatus was set up to measure water flow emitted from bottom side of concrete sample.	2. Apparatus set up with standpipe to measure flow of water into concrete samples.
3. Pressure was increased as described in data sheets, from 10 psig to 175 psig over duration of test.	3. Pressure started at 100 psig for five minutes, then increased to 200 psig and left for duration of test.
4. Polysulfide Sealant used to seal sample to cylinder.	4. Paraffin-rosin and asphalt mixtures used to seal sample to cylinder.
5. Cork ring used on bottom plate to set sample on.	5. Plaster ring used on bottom plate to set sample on.

(See Photograph and Diagram page)

B. Procedure

Per instructions supplied by Xypex, the four samples (two treated, two untreated) were placed in the four steel cylinders on 6/18/82. Each cylinder was equipped with several holes in the bottom plate.

These holes were surrounded by a cork ring, upon which the samples were placed. The treated samples were placed with the treated sides up. Sternson-Duoflex Self Leveling Two-Part Polysulfide Sealant (supplied by Xypex) was then poured in around the specimens until sealant ran up onto the top of the samples and up to the edge of a five inch diameter rubber "O" ring that had been placed on top of the cylinders, thus sealing off all voids around the samples. Specimens and sealant were then left to cure for seven days.

On 6 25 82 each cylinder was filled with water (at room temperature approx. 70°F) and each lid bolted down tightly. A cork gasket was placed between each lid and cylinder to assure that it was airtight. Pressurized air was then allowed into the cylinders and allowed to bear on the water contained in the cylinders. Pressure was set at 10 psig and the test begun. Water which was forced through the samples was trapped in flasks below, and measured as shown on the data sheets in the Data section of this report. Per instructions supplied by Mr. Mainwaring, the pressure was increased in all cylinders when the leakage approached zero for a twenty-four hour period for the treated samples. Pressures and water emitted for each cylinder sample is shown on the Data sheets. (Water measured after weekends, etc., was averaged over the days missed for the included graph.)

TEST RESULTS

The data gathered during the permeability test showed three concrete samples (two untreated and one treated) exhibiting leakage starting at ten psig, and the fourth sample exhibiting leakage starting at 30 psig. The untreated samples showed some decrease in leakage during each phase of increased pressure, but did not, at any time, approach zero. The Xypex treated samples also exhibited leakage at each state of increased pressure, but consistently followed decreasing leakage patterns approaching zero. *

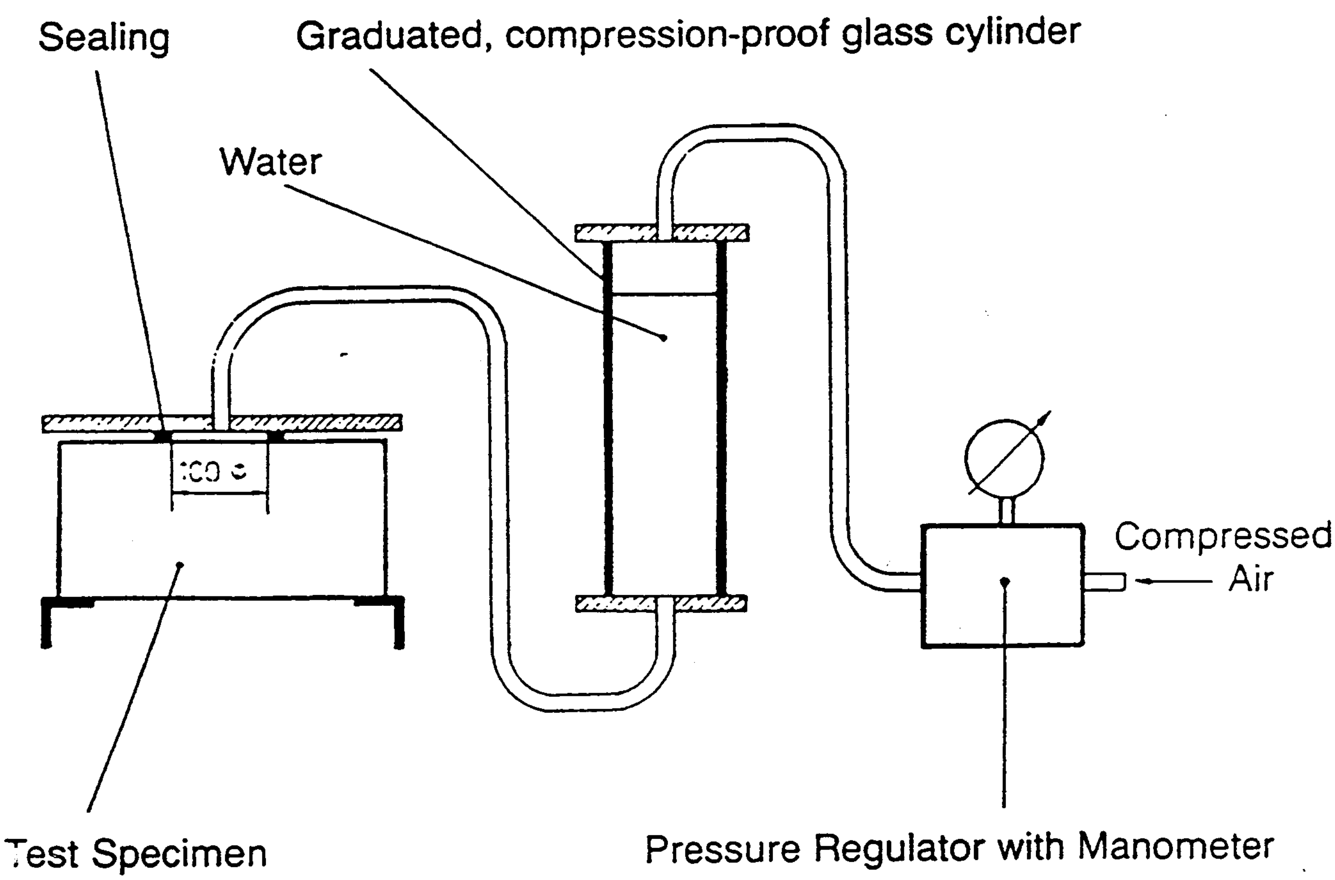
It can therefore be stated that the Xypex chemical treatment sealing effect eliminates all measurable leakage. *

END OF REPORT TEXT

4. DESCRIPTION OF EXPERIMENTAL PLANT FOR THE WATER LEAKAGE (IMPERMEABILITY) TEST

The experimental plant built in the Research Center is shown schematically in Picture 1.

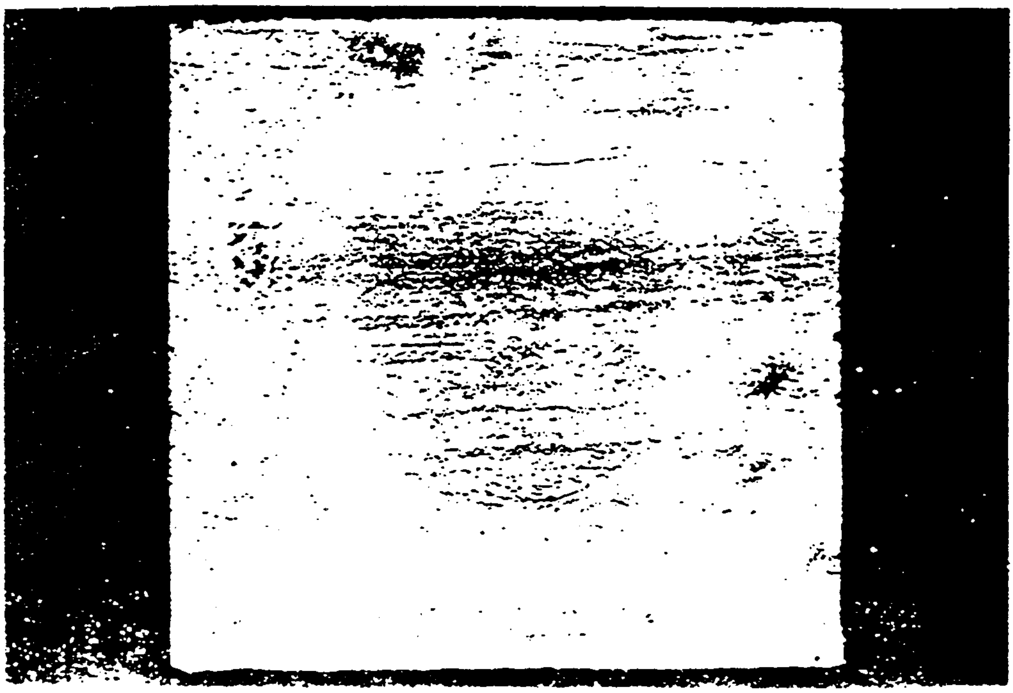
Schematic Design (Construction) of Testing Apparatus.



The water pressure amounted to 1.4 bar on the 1st and 2nd day
2.8 bar on the 3rd day
4.2 bar on the 4th day
7.0 bar on the 5th to 15th day.

5 EXECUTION OF COATING OF CONCRETE AREA

The coating was carried out on moist concrete surfaces by persons not connected with the Research Center, i.e. by technicians of the Applicant in the Research Center while being under observation by personnel of the said Research Center (Picture 4).



For the impermeability (to water) test according to ÖNORM B 3303 a concrete test area of the test specimen (= one side) was coated; for the capillary absorbency all concrete test areas (= all sides) of a test piece will be coated.

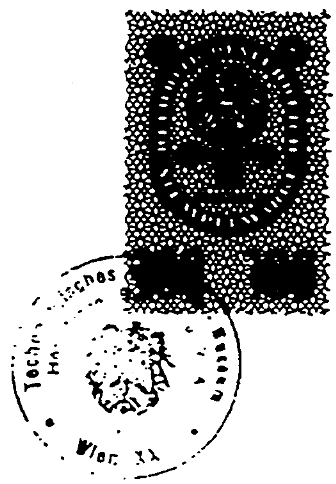
The first test slab was coated 36 hours after its production, the second test slab after 28 days.

The actual tests were started only after an additional 12 days of storage since according to the Applicant only after this period of time the effectiveness of the sealing material is assured.

6.2. **Compression Strength**

Cubes with a 100 mm long edge were cut from the broken-up test specimens and the compression areas polished 'plane-parallel' (or: 'with parallel faces').

	kN/cm²
Uncoated concrete test specimen (A)	6.6
Concrete test specimen coated 36 hours after its production (B)	7.7
Concrete test specimen coated 28 days after its production (C)	6.9



EXPERT OPINION

As requested by the Applicant, an Interim Report regarding the current tests is herewith given: The sofar executed tests demonstrate that the concrete test specimens coated with XYPEX have an impermeability to water quite superior to the uncoated ones.

* * * * * * * * * * * * * *

Att No 8
1-2

XYPEX
AUSTRALIA

Union Road, PO Box 255
ıvington NSW 2641 Australia

Concrete Waterproofing Manufacturing Pty. Ltd.
T/A XYPEX ACN 050 139 985

Telephone: (060) 40 244
Fax: (060) 40 241

HOW DOES XYPEX WORK?

The waterproofing effect of Xypex is based on two simple reactions, one chemical and one physical. We start with the basic fact that concrete is chemical in nature. When a cement particle hydrates there is a reaction between water and the cement which causes it to become a hard, solid mass but there are also chemical by-products given off which are lying dormant in the concrete.

With Xypex we have a second set of chemicals and if we can bring these two groups together (i.e. the by-products of cement hydration and the chemicals in Xypex) in the presence of moisture a chemical reaction takes place and the end product of this reaction is a non-soluble crystalline structure.

This crystalline structure can only take place where moisture is present and thus Xypex tends to form this crystalline material in the bleed water tracts, capillary tracts and shrinkage cracks in concrete. Wherever water goes, Xypex will form.

When Xypex is not being dosed to new concrete, and being used as a coating for remedial or existing concrete structures, in order to get the chemicals from the coating into the concrete we rely on a physical reaction which is called osmosis. The theory behind osmosis is that a solution of high density will migrate through a solution of lower density until the two equalise.

Thus when we saturate the concrete with water prior to applying the Xypex we are actually putting a solution of low density into place. When we apply Xypex to the concrete we create a solution of high chemical density at the surface and osmosis or osmotic pressure comes into play. The chemicals in Xypex must now migrate through the water (our solution of low density) until the two solutions equalise.

../2

ATT No 9

XYPEX

AUSTRALIA

45 Union Road,
Lavington, NSW, 2641

Concrete Waterproofing Manufacturing Pty Ltd
T/A XYPEX ACN 050 139 958

Telephone: (060) 402 444
Facsimile: (060) 402 411

FACSIMILE TRANSMISSION FORM

TO: JINGSLINK MARKETING PTE LTD
ATTENTION: CHAN A-LAM
FROM: LOCH JACKSON
RE: SINGAPORE ART CENTER TESTING
DATE: 10 / 12 / 96
FAX NO.: 0015 65 299 5893
PAGES: 1

(If this fax appears incomplete please contact us immediately)

Dear A Lam,

We have been talking to Dave Ross in Canada about our proposed testing for P.W.D. and Penta Ocean. Like all of us Dave is concerned that the testing is performed in a manner that is beneficial to us and that the authorities doing the testing understand exactly how we are working, thereby avoiding conducting tests we cannot pass.

As we are going to conduct a permeability test similar to U.S. Army Corp. Engineers Dave is very anxious that we have the testing authority and their " watch dog" understand that it should be a "water out" test and not a "water in" test. Xypex treated concrete will continue to suck some water for as long as it can be forced past the crystalline barrier at the surface and at depth. The real issue is not how much water goes into the concrete as what goes in is constantly being converted to crystals. The issue is how much is not converted and at what rate it flows through the concrete.

We are informed that the method of testing this should be to dry test the concrete straight out of the slab and not to let the test be done at saturation level as this will have no similarity to what will happen in reality. Obviously we are going to have to treat the control samples for permeability in the identical manner. This then should give us a clear rate of water flow for the two and determine conclusively that the water is being converted into crystal's. To further illustrate this conversion the test sample should be accurately weighed both before and after the testing. To remove any possible anomaly due to moisture, accurate water content should be measured with a moisture meter both before and after testing, when samples are superficially surface dry (SSD).

We are further informed that the method of detecting the water out was to attach a glass funnel to the bottom of the concrete specimen as pressure was applied and to measure the amount of water collected over given periods of time. Similar testing would be done on the control sample.

At all times it must be understood by those conducting the testing that the Xypex reaction is not instantaneous and that a lessening of leakage should be observed later into each pressure stabilisation period. We are not sure how long after we reach seven bars that it will take to control the head of pressure that the sample is subjected to. Therefore we should not undertake to commence to hold back the seven bars at three days after the final pressure is applied but rather from the point when no water flow is observed leaving the bottom of the test sample.

We would also like to think that the pressure test could be conducted until we have reached at least an equivalent water head as U.S. Army Corp. Engineers and hopefully greater. We do not see a necessity to carry this on to the control sample but it would obviously be beneficial to quantifying our results.

Whatever is decided it is important that our tests reflect life as the concrete will live it.

Yours sincerely,

L.W. Jackson
Manager International Division

APPENDIX B

RELEVANT CORRESPONDENCES

TAYWOOD ENGINEERING LIMITED

CONSULTANTS IN DESIGN AND TECHNOLOGY

5001 Beach Road
#09-82 Golden Mile Complex
Singapore 199588

Telephone: 65-392 2960 Facsimile: 65-392 2961
E-mail: telsing@singnet.com.sg

Our Ref: FWK/dg/97/001/7167-01

3 January 1997

Jingslink Marketing Pte Ltd *(via fax: 299 5893 & p.o. t)*
50 Jalan Sultan #10-08
Jalan Sultan Centre
Singapore 198974

Attention : Mr Chan A-Lam

Dear Mr Chan

TAYWOOD ENGINEERING LIMITED CONSULTANCY
XYPEX WATERPROOFING ADMIXTURE

Our meeting on 20 December 96 on the above refers.

The meeting was to review Xypex's proposed methodology and give comments where necessary enhance its relevance so that casting of a hot block/control block could be carried out. In this respect and with reference to its proposed methodology (Attached as Appendix A), please find TEL's comments as follow:

TEST SITE

- It is not the intention to establish the adiabatic temperature curve of the cement, therefore the trial block size of 2.0m x 2.0m x 0.9m is satisfactory.
- In order that heat loss through the sides of the trial block is minimised, 100mm thick polystyrene insulation is necessary.

CONCRETE

- Concrete mix shall be as per prescribed design indicated in the methodology.
- The control mix design should be made known for purposes of comparison and evaluation of the prescribed mix.
- No comments have been made by TEL with regards to placing, compacting and finishing concrete. These are workmanship specifications and have no bearing on this scope of study.

CURING

- The prescribed curing method shall be as per methodology document recommended by Xypex.

TEMPERATURE

- The ambient temperature should be recorded at more frequent intervals, preferably at least 3 hourly.

COMPRESSIVE STRENGTH (CUBES)

- Frequency of sampling of concrete shall be as per methodology document recommended by Xypex.

COMPRESSIVE STRENGTH (CORES)

- 100mm diameter cores preferably should be taken instead of 75mm diameter.

- Strength shall be tested as per methodology document on 7 days and 28 days. The contractor shall also sample and test cores at other periods to establish the strength gain, if this is desired for planning his works.

SCANNING ELECTRON MICROSCOPY (SEM) TEST

- 3 nos. of samples shall be taken as per methodology document. Review of the permeability test methods and relevance is still ongoing.

A control sample shall be cast subject to same procedures similar to the prescribed mix. All tests shall also apply to the control mix.

Yours sincerely

Fong Weng Khiong
Projects Manager

Encl. : Xypex Proposed Methodology (4 pages).

集利有限公司
JINGSLINK MARKETING PRIVATE LIMITED
50, Jalan Sultan, #10-08 Jalan Sultan Centre, Singapore 0719 Tel : 293 5836 Fax : 299 5893

FACSIMILE TRANSMITAL SHEET

To: TayWood Eng. Ltd.	Fax No: 392 2961 Date: 28.2.97
Attn: Mr. Fong	From: Chan A.L.
Please receive 6 page(s) inclusive of this page	

MESSAGE:

Dear Sir,

XYPEX PERFORMANCE TEST

As spoken, we fax. the following preliminary information for your attention.

1.) Records of Water permeability
2.) Compressive strength.
3.) Monitoring for heat of hydration
4.) Control mix mix design.

Regards

[signature]

TAYWOOD ENGINEERING LTD			
DATE	28/2/1997		
PERSON	NOTE	ACTION	INITIAL
PWK		✓	
DG		✓	
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FILE NO			

292 2961

SETSCO

SETSCO SERVICES PTE LTD

LOCATION:
Sukit Chermin Rd.
Singapore 0409
Tel: 2700568
Telex: RS 42760 SETSCO
Telefax: 2700911

MAILING ADDRESS:
277 Telok Blangah Rd.
Singapore 0409

FAX TRANSMITTAL SHEET

****

TO : Jingslink Marketing Pte Ltd

FROM : Xu Liping

DATE : 18/2/97

ATTN : Mr. CHAN A-LAM

NO. OF PAGES : 1 (including this page)

FAX NO. : 294-5893

SUBJECT : Some Test Results on concrete treated with XYPEX Waterproofing

(Please notify the sender if copy/copies is not well received)

MESSAGE :

The water permeability Test Results on control concrete (without XYPEX) are shown as follows:

Pressure & Age	Measurement on Control Concrete (ml/[illegible]) Sample 1	Sample 2	Sample 3
1.4 bar on the 1st day		No leakage	
2.8 bar on the 2nd day		No leakage	
4.2 bar on the 3th day		No leakage	
7.0 bar on the 4th day		No leakage	
7.0 bar on the 5th day	10	0	4
7.0 bar on the 6th day	30	20	25
7.0 bar on the 7th day	65	20	60
7.0 bar on the 8th day	70	30	60
7.0 bar on the 9th day	70	30	60
7.0 bar on the 10th day	70	30	60

The treated concrete with XYPEX was no leakage from 1.4 bar to 7 bar for 7 day. The above concrete were cured for 7 day.

Best Regards

Xuliping

Attn: Mr. Chan A-Lam.
Fax: 2995893.

SETSCO

SETSCO SERVICES PTE LTD

LOCATION:
Bukit Chermin Rd.
Singapore 0409.
Tel: 2700966
Telex: RS 42758 SETSCO
Telefax: 2700811

MAILING ADDRESS:
337 Telok Blangah Rd.
Singapore 0409.

85X

2/L1

FAX TRANSMITTAL SHEET

****

TO : Penta-Ocean Construction CO. Pte Ltd.

ATTN : Mr. H. TAGUCHI

FAX NO. : 3370-987

SUBJECT : XYPEX concrete waterproofing Test Results

FROM : Xu Liping

DATE : 18/2/97

NO. OF PAGES : 1 (including this page)

(Please notify the sender if copy/copies is not well received)

MESSAGE :

Please be informed that the some test results of control concrete & concrete treated with XYPEX waterproofing are shown as follows.

1 Water Permeability Test

a. Control concrete at 7days
No leakage occured from 1.4 bar to 4.2 bar. But water leakage occured at starting of 7 bar.

b. Treated concrete at 7days
No leakage occured from 1.4 bar to 7 bar.

2. Compressive Strength Test

a. compressive strength on control concrete cubes at 7 days.
average = 41.5 N/mm²

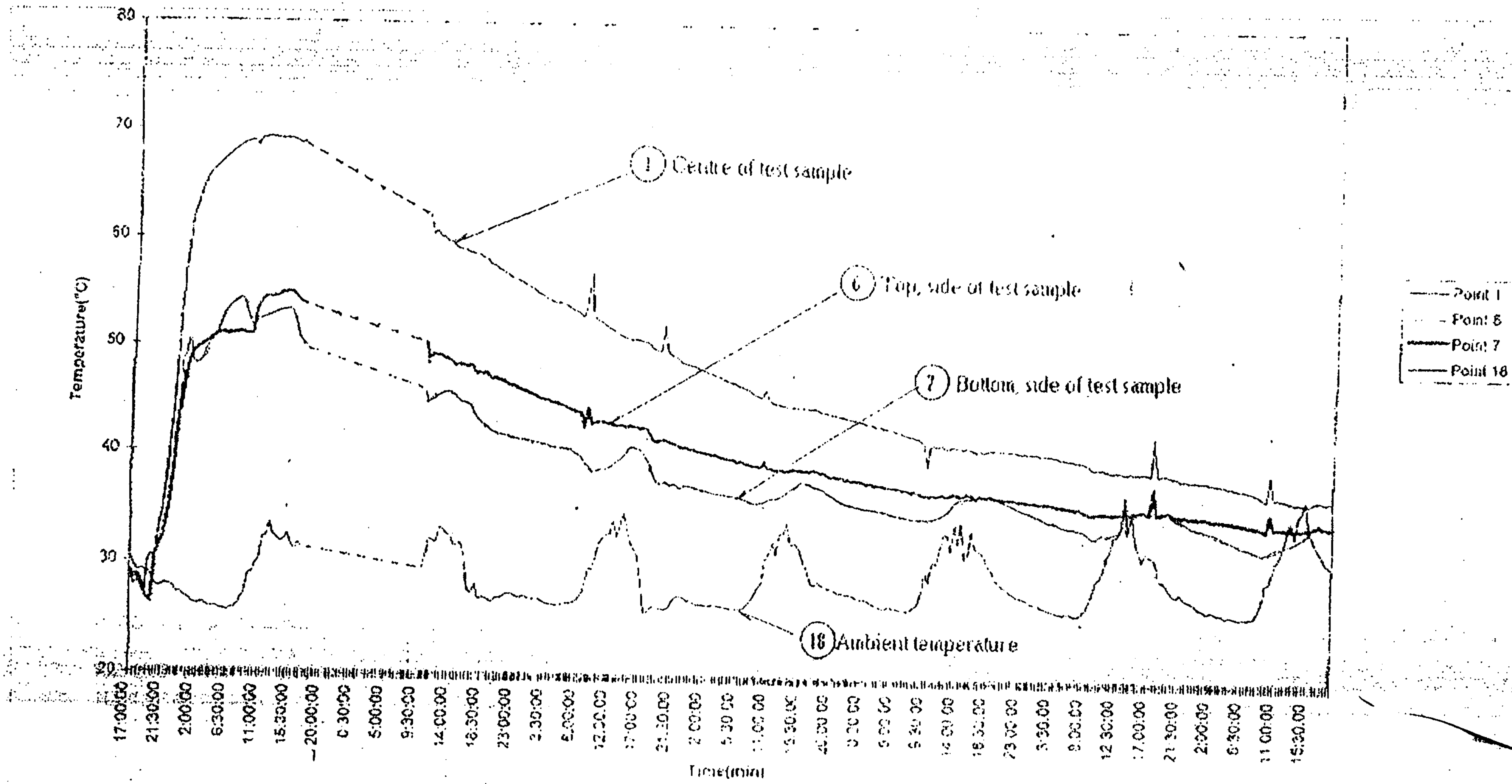
b. Compressive strength on treated concrete cubes at 7 days.
average = 37.0 N/mm².

Please do not hesitate to call us for clarification.

Best Regards,

Xuliping

Monitoring of Hydration Temperature for 7 Days on Xypex Admix Treated G40 Concrete Sample



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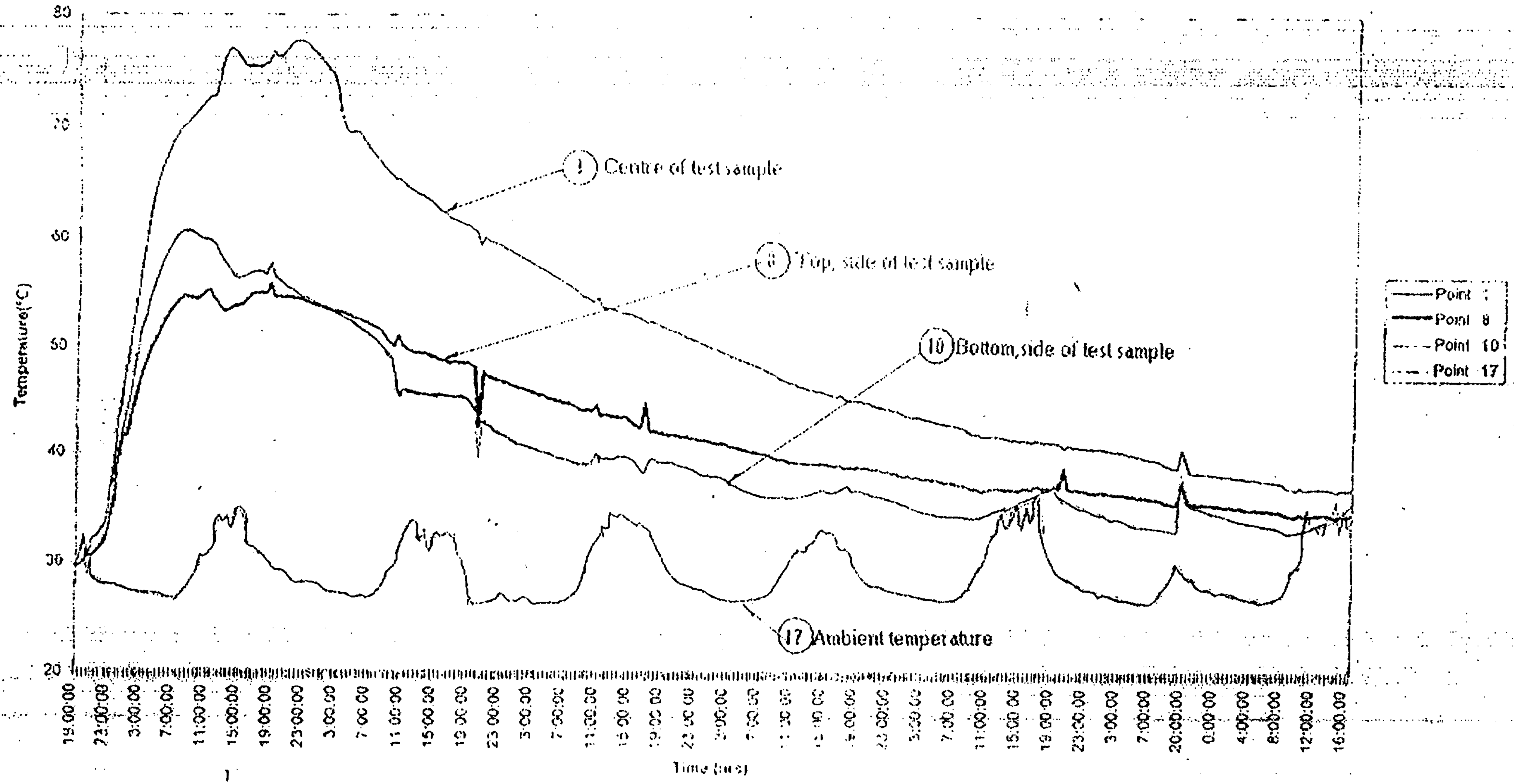
Monitoring of Hydration Temperature for 7 Days on G40 Concrete Control Sample



SUPERMIX CONCRETE PTE LTD

CONCRETE MIX DESIGN

Date : 13 Aug 1996

Project : Construction of Pile Foundation and Main Basement Works

Location : Singapore Arts Centre

Contractor : Penta Ocean Construction Co Ltd

1.	1.1 Concrete Grade		40 N/mm2	
	1.2 Concrete Type		Pump Mix	
	1.3 Slump for Concrete		125 mm	
2.	2.1 Characteristic Strength		40 N/mm2 at 28 days below which 5% of test results may be expected to fall.	
	2.2 Designed Standard Deviation		4.57 N/mm2	
	2.3 Designed Margin		1.64 x 4.57 N/mm2 = 7.50 N/mm2	
	2.4 Target Mean Strength		40 + 7.50 N/mm2 = 47.50 N/mm2	
	2.5 Specified Water/Cement Ratio		0.41	
3.	3.1 Cement	OPC	Brand :PMCW (S)	S.G. : 3.15
	3.2 Fine Aggregate	Natural	Size :Grading to SS 31	S.G. : 2.61 (Surface Dry)
	3.3 Coarse Aggregate	Crushed	Size :20 mm	S.G. : 2.62 (Surface Dry)
	3.4 Water	PUB		
	3.5 Admixture	Cormix P4	650 ml/100kg of cement (Plasticizer & Retarder)	
	3.6 Reagent	Cormix SP1	400 ml/100kg of cement (Superplasticizer)	
4.	4.1 Cement Content		410 kg/m3	
	4.2 Water Content		170 kg/m3	
	4.3 Concrete Density		2353 kg/m3	
	4.4 Proportion of Fine Aggregate		42.9 %	
	4.5 Air Content		2 %	

5. 5.1 Summary (kg/m3)

Cement	Water	Fine Aggregate	Coarse Aggregate	Admixture	Reagent
410	170	758	1010	3.17	1.97
Water/Cement Ratio		41%	Percentage of Fine Aggregate		42.9 %

6. Remarks : The characteristic strength shall conform to BS 5328 & SS 289
This design mix is done under surface dry and saturated conditions.

Xn 337

集利有限公司

JINGSLINK MARKETING PRIVATE LIMITED

50, Jalan Sultan, #10-08 Jalan Sultan Centre, Singapore 0719 Tel : 299 5836 Fax : 299 5893

FACSIMILE TRANSMITAL SHEET

To: TAYWOOD ENGINEERING LTD	Fax No: 392 2961 Date: 11.3.97
Attn: MR. FONG.	From: Chan A.L.
Please receive 7 page(s) inclusive of this page	

MESSAGE:

Dear Sir,

XYPEX WATERPROOFING ADMIXTURE PERFORMANCE TEST.

We forward herewith the results supplied by Setsco in connection with the above mentioned test.

The Xypex Treated concrete is as per Design mix mentioned in the Methodology.

The Control mix is as per Supermix design mix for G40 Concrete.

Regards

[signature]

TAYWOOD ENGINEERING LTD			
DATE	11/3/97.		
FWL			
PERSON			INITIAL
DG		✓	
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FILE NO	7167.		

David
Pls consolidate into tables and further discuss.
FWL
11/3/97

Table 1 : Compressive Strength Test on Control Concrete Cubes

Sample Reference	Control Concrete														
Specimen Reference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Size of Cube (mm)	150														
Date of Cast	22/01/97														
Date of Test	23/01/97			25/01/97			29/01/97			19/02/97			19/03/97		
Age at Test (days)	1			3			7			28			56		
Area (mm^2)	22,500														
Weight of Specimen (g)	8034.9	8010.9	8027.3	7955.9	8058.6	8014.9	8056.1	8042.0	8149.0	8068.2	8086.9	8091.3			
Compressive Strength (N/mm^2)	18.5	18.5	18.0	32.0	29.5	32.5	43.0	40.0	42.0	52.0	56.0	53.5			
Average Compressive Strength (N/mm^2)	18.5			31.5			41.5			54.0					

SETSCO

Table 2 : Compressive Strength Test on Concrete Cubes Treated with XYPEX Waterproofing

Sample Reference	Treated Concrete with XYPEX Waterproofing														
Specimen Reference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ize of Cube (mm)	150														
Date of Cast	14/01/97														
Date of Test	15/01/97			17/01/97			21/01/97			11/2/97			11/3/97		
ge at Test (days)	1			3			7			28			56		
rea (mm^2)	22,500														
eight of Specimen (g)	7952.4	7963.4	7914 7	7951.4	8006.4	7785.1	7963.7	8033.7	8055.6	7878.5	7875.7	7956.8			
ompressive Strength (N/mm^2)	21.0	20.5	20.0	29.5	31.0	31.5	38.5	34.5	38.0	46.5	46.5	46.0			
Average Compressive Strength (N/mm^2)	20.5			30.0			37.0			46.5					

TSCO

B20179/XLP

Table 3 : Visual Examination and Compressive Strength Test on Concrete Core

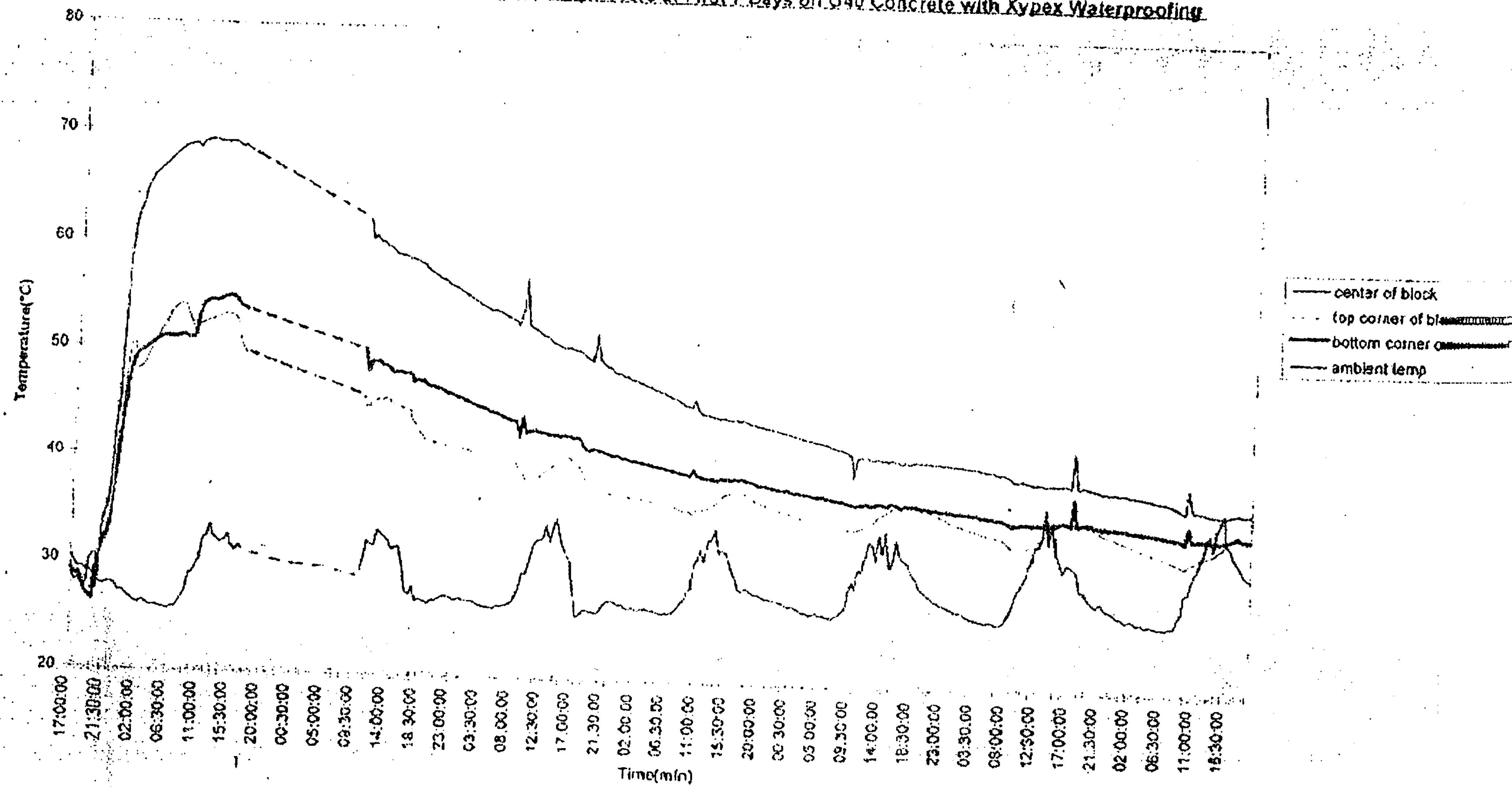
Sample Reference		Control Concrete						Treated Concrete with XYPEX Waterproofing					
Specimen Reference		1	2	3	4	5	6	1	2	3	4	5	6
Date of Cast		22/01/97						14/02/97					
Date of Coring		30/01/97			21/02/97			22/01/97			13/01/97		
Age at Test (days)		7			28			7			28		
Length of Core (mm)	Maximum	105.9	98.9	102.3	108.2	107.7	105.9	106.9	105.5	107.1	103.2	103.9	104.3
	Minimum	105.3	98.4	101.9	107.5	107.2	105.3	106.6	104.2	106.0	102.0	103.1	103.9
Excess Voidage(in accordance with BS 1881 : Part 120 : 1983 : Fig.1) %		0	0.5	0	1.5	0.5	0.5	0	0.5	1.5	0.5	0.5	0
Void Classification		Small	Large	Small	Large	Medium	Medium	Large	Large	Large	Large	Large	Large
Average Diameter (mm)		100.1	100.2	100.3	100.4	100.4	100.4	99.9	99.6	99.8	100.3	100.3	100.4
Average Length of Capped Specimen (mm)		108.8	102.5	105.3	110.9	110.4	109.5	109.9	107.7	110.0	107.2	106.6	107.1
Compressive Strength (N/mm^2)		38.5	42.0	37.5	42.5	40.5	42.5	41.5	35.0	38.5	44.0	44.0	47.0
Density (kg/m^3)		2300	2295	2300	2290	2300	2300	2325	2315	2300	2315	2305	2325

39.5 42.0 38.5 45.0

Table 4 : Water Permeability Test

Sample Reference	Control Concrete						Treated Concrete with XYPEX Waterproofing					
Specimen Reference	1	2	3	1	2	3	1	2	3	1	2	3
Date of Cast	22/01/97						14/01/97					
Date of Coring	30/01/97			20/02/97			22/01/97			12/02/97		
Age of Curing (days)	8			29			3			29		
Specimen Size (mm)	ϕ150 x 50											
Volume of water moving through the sample(mL) :												
At 1 bar on 1st day	0	0	0	0	0	0	0	0	0	0	0	0
At 2.4 bar on 2nd day	0	0	0	0	0	0	0	0	0	0	0	0
At 4.2 bar on 3rd day	0	0	0	0	0	0	0	0	0	0	0	0
At 7.0 bar on 4th day	0	0	0	0	0	0	0	0	0	0	0	0
5th day	10	0	4	10	0	0	0	0	0	0	0	0
6th day	30	20	25	74	13	0	0	0	0	0	0	0
7th day	65	20	60	78	20	0	0	0	0	0	0	0
8th day	70	30	60	45	10	0	0	0	0	0	0	0
9th day	70	30	60	35	10	0	0	0	0	0	0	0
10th day	70	30	60	46	10	0	0	0	0	0	0	0

Figure 2 :Monitoring of Temperature at First 7 Days on G40 Concrete with Xypex Waterproofing



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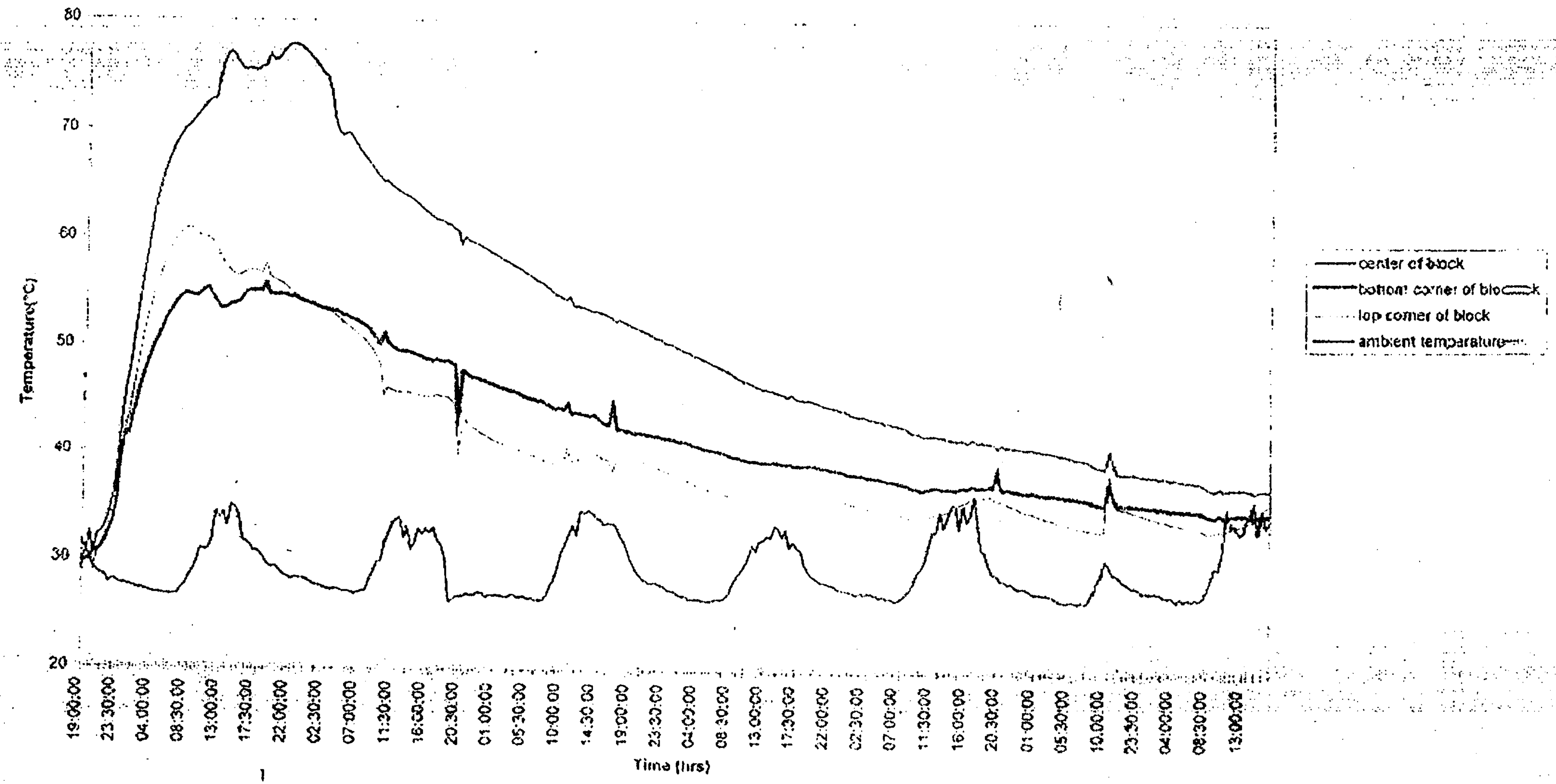
TSCO

Figure 1 : Monitoring of Temperature on G40 Concrete at First 7 Days



TAYWOOD ENGINEERING LIMITED
5001 BEACH ROAD #09-82
GOLDEN MILE COMPLEX
SINGAPORE 199588

Telephone : (65) 392 2960
Facsimile : (65) 392 2961
E-Mail : telsing@singnet.com.sg

FAX NO : 299 5893
COMPANY : Jingsing Marketing Pte Ltd
ATTENTION : Mr. Chan A-Lam.
COPY TO :

FROM : David Goh
DATE : 14 March 1997
JOB NO : 7167-01
TOTAL PAGES : 1

TAYWOOD ENGINEERING LTD			
DATE	17/3/97		
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FILE NO			

SUBJECT: XYPEX CONSULTANCY

Dear Mr. Chan,

We'll like to have the following information from the casting of trial blocks:

- all measured slump test
- workability observed during casting
- placement temperature of the concrete .

Thanks & Regards

Attn: Mr. David Goh.

Xypex Treated concrete casted on 14/1/97

	temp	Slump	
At plant	21.8°C	80 mm	Water lost due to melting of ice before batching.
At site	27.2°C	85 mm.	

Workability : on the low side.

Control mix concrete casted on 22/1/97

	temp	Slump
At plant	–	–
At site	26.2°C	120 mm

Workability : good.

[signature]

IF YOU DO NOT RECEIVE ALL PAGES PLEASE [illegible]

APPENDIX C

SETSCO SERVICES PTE LTD TEST REPORT

- TEMPERATURE MONITORING
- CUBE COMPRESSIVE STRENGTH
- CORE SAMPLING & COMPRESSIVE STRENGTH
- SCANNING ELECTRON MISCROSCOPY
- WATER PERMEABILITY

SETSCO
SETSCO SERVICES PTE LTD
LOCATION:
Bukit Chermin Rd,
Singapore 098832.
Tel: 2700988
Telefax: 2700911
MAILING ADDRESS:
337 Telok Blangah Rd,
Singapore 098832.

Your Ref: JM/SC/SAC/214/976 Our Ref: B 20179/XLP Date: 24/03/97

TEST REPORT

(This Report is issued subject to the conditions set out overleaf)

Subject : Temperature Monitoring, Compressive Strength Test, Water Permeability Test and Scanning Electronic Microscopic (SEM) Examination on the control and treated concrete with XYPEX Admix C-2000 Waterproofing were requested by Jingslink Marketing Pte Ltd on 10/01/97.

Tested for :

1. **Jingslink Marketing Pte Ltd**
   50 Jalan Sultan Road
   Jalan Sultan Centre
   Singapore 198974
   Attn.: Mr. Chan A-Lam

2. **XYPEX Australia**
   Concrete Waterproofing Manufacturing Pte Ltd
   45 Union Road
   Lavington NSW 2641
   Australia
   Attn.: Mr. Loch W. Jackson

Method of Test : Proposed methodology for conduct of field test of XYPEX Admix C-2000 by Australian Manufacturers of XYPEX.

Project Reference : Art Centre Project
The Esplande - Theatres on the Bay.

Description of Sample : One no. of 2.0 x 2.0 x 0.9m concrete block treated with XYPEX Admix C-2000 was cast on 14/01/97.

One no. of 2.0 x 2.0 x 0.9m control concrete block was cast on 22/01/97.

The above castings was done at Marina Square for Art Centre project and witnessed by Setsco & PWD officials.

B 20179/50/gsr

1. Temperature monitoring on Control and Treated Concrete with XYPEX Admixture C-2000 Waterproofing

The "K" type Thermo Couples were put into the position of the block prior to the concrete placement. The distribution of the thermo couples and marking numbers are given as follows:

Treated Concrete:		Marking No.:
Position of the thermo couplesr:		
One point in the centre of the block	-	1
Four points in the corner of the top surface of the block	-	2, 5, 6 8.
Four points in the corner of the bottom surface of the block	-	3, 4, 7, 9.
One point in the centre of the top surface of the block	-	15
Two points in the centre of the bottom surface of the block	-	14, 16
Four points in the centre of the four sides surface of the block	-	10, 11, 12, 13
Two points for shaded ambient temperature	-	17, 18

Control Concrete

Position of thermo couples:

One point in the centre of the block	-	1
Four points in the corner of the top surface of the block	-	4, 7, 10, 13
Four points in the corner of the bottom surface of the block	-	5, 8, 11, 14
One point in the centre of the top surface of the block	-	3
One point in the centre of the bottom surface of the block	-	2
Four points in the centre of the four sides surface of the block	-	6, 9, 12, 15
Two points for shaded ambient temperature	-	16, 17

The thermo couples were connected to a Data Logger and the temperature in the concrete blocks were recorded every 30 minutes during the first 7 days after concreting.

All the temperature readings against the time are shown in the Appendix 1.

Figures 1 and 2 show the change in temperature readings at different times for three measuring points including ambient temperature. The three measuring points presented in Figures 1 and 2 were selected from the points with the highest temperature (centre of block) and 2 points with the lowest temperature (corner of blocks). The temperature readings on the other points fall within the above limited points in Figures 1 and 2.

Xuwping

2. Compressive Strength Test

Cubes : 15 nos 150 x 150 x 150mm cubes of control and treated concrete each were received from Penta-Ocean Construction Co. Ltd. All the cubes were cured in water until the age of test. Compressive strength test on the cubes were determined in accordance with BS 1881 Pt : 116 : 1983. The compressive strength test results are shown in Tables 1 and 2.

Cores : 2 nos of ϕ 100 x 900mm cylinders of control and treated concrete each were cored near the centre of the block at 7 and 28 days at Marina Square by Setsco (please see photographs 1 and 2 attached). The compressive strength on the concrete cores were determined in accordance with BS 1881 : Pt 120 : 1983. The results of the compressive strength test are given in Table 3.

3. Water Permeability Test

According to the test method, the objective of this test was to measure the rate of outflow of water from the concrete test specimen.

2 nos of ϕ 150 x 900mm cylinders of control and treated concrete each were cored near the centre of the block at 7 and 28 days at Marina Square by Setsco, (please see photographs 3 and 4 attached).

1 no of ϕ 150 x 50mm test specimen each was cut from the top, middle and bottom of the control and treated core sample. The water pressure on the test specimen was applied by incremental increase as follows:

1.4 bar on the 1st day
2.8 bar on the 4th day
4.2 bar on the 7th day
7.0 bar on the 10th day and maintained for 7 days

The volume of water percolating through the samples were collected from the bottom of the test specimens daily. The results are shown in Table 4.

4. Scanning electronic microscopic examination

Scanning electronic microscopic examination was conducted on the cores taken from the upper portion of the control concrete and concrete treated with XYPEX Waterproofing at 28 days. (Please see photographs 5 and 6 attached for microscopic view of control concrete and photographs 7 and 8 attached for microscopic view of treated concrete).

JASBEER SINGH
TESTING OFFICER

XU LIPING
MATERIAL ENGINEER
BUILDING TECHNOLOGY DEPARTMENT

Figure 1 : Monitoring of Temperature on G40 Concrete at First 7 Days

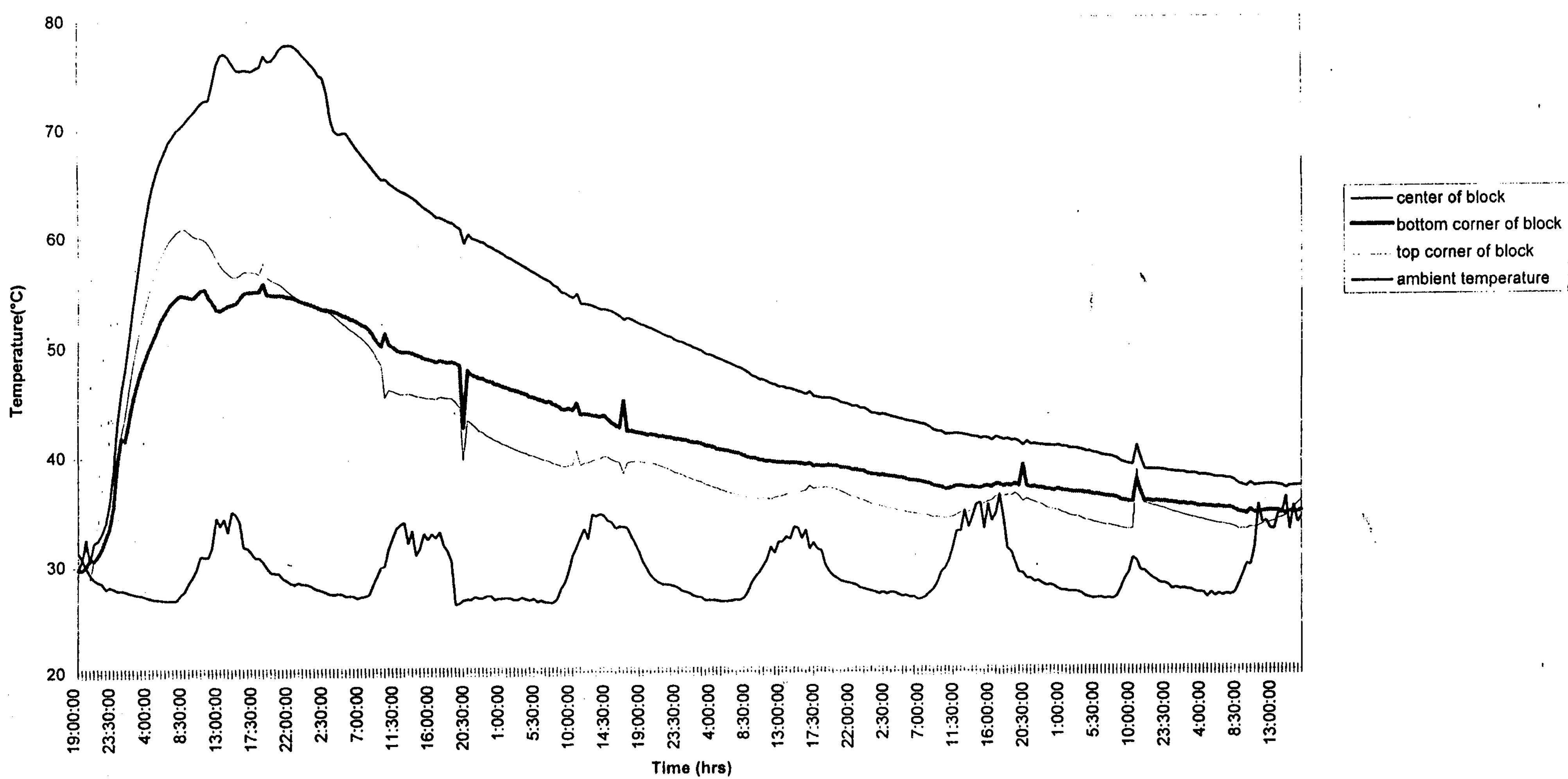

Figure 2 : Monitoring of Temperature at First 7 Days on G40 Concrete with Xypex Waterproofing

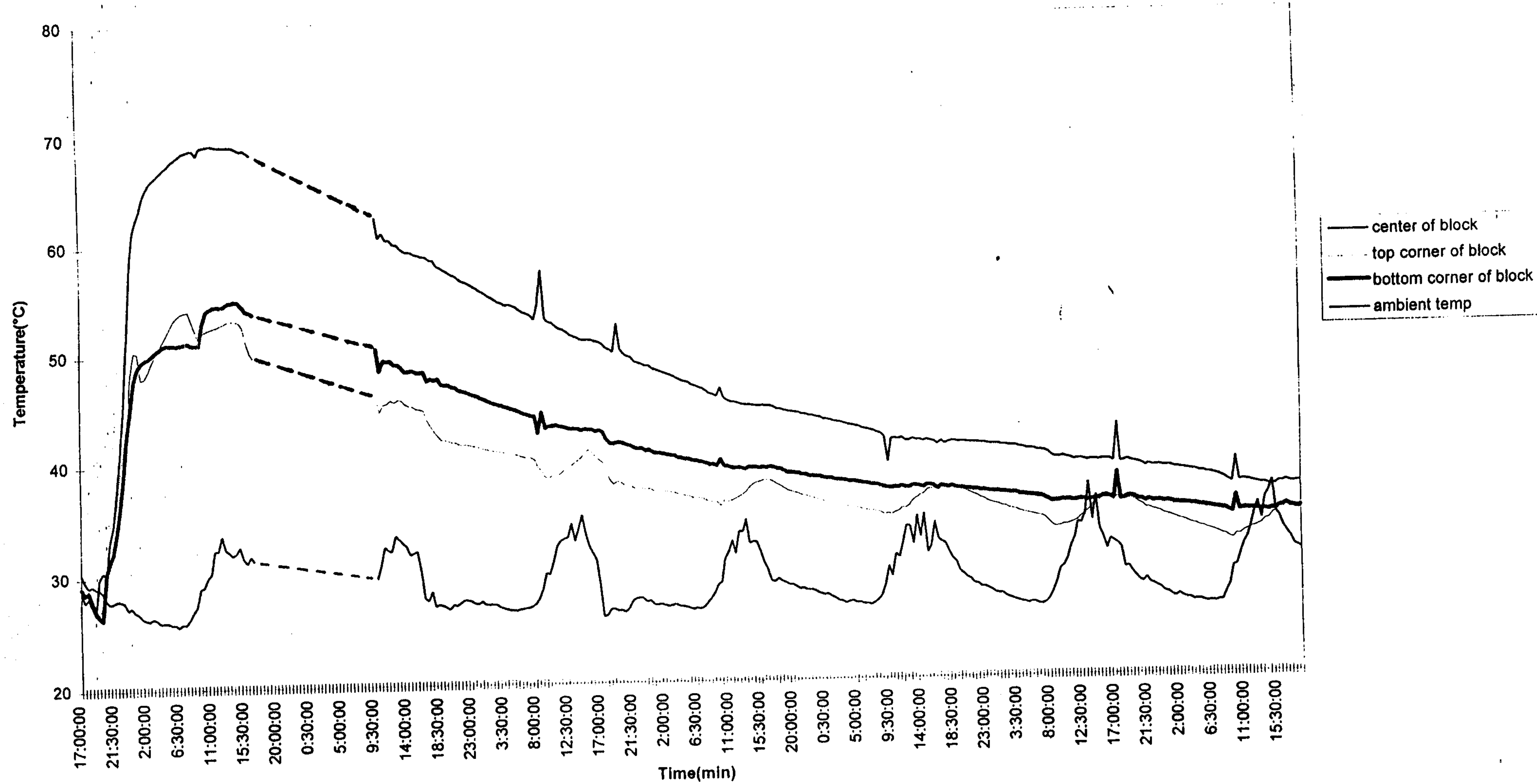

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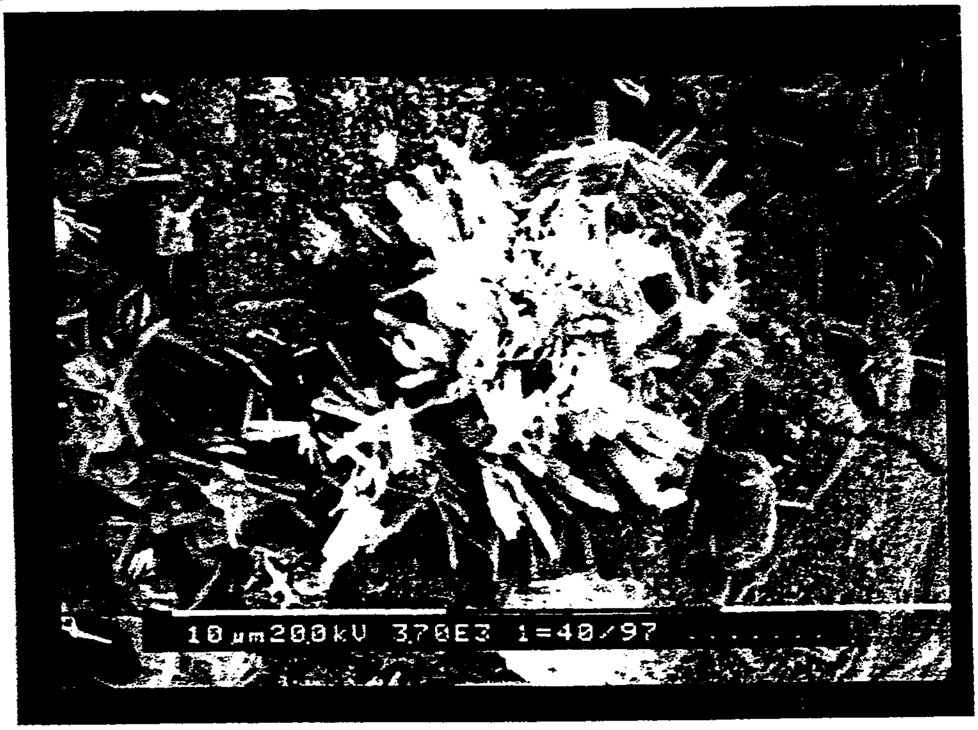
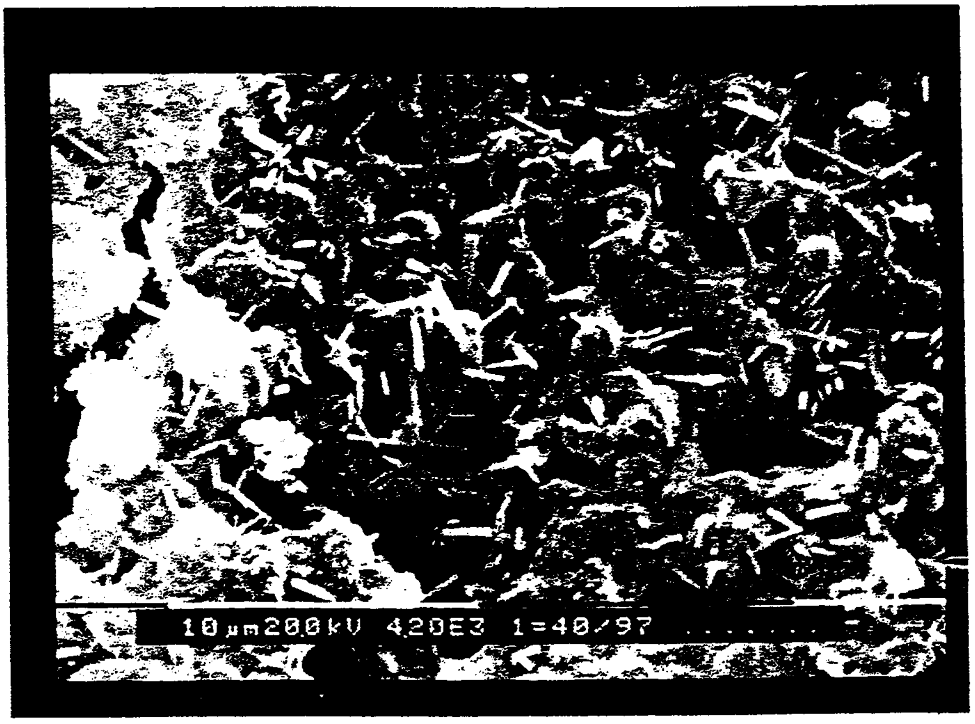
Table 1 : Compressive Strength Test on Control Concrete Cubes

Sample Reference	Control Concrete														
Specimen Reference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Size of Cube (mm)	150														
Date of Cast	22/01/97														
Date of Test	23/01/97			25/01/97			29/01/97			19/02/97			19/03/97		
Age at Test (days)	1			3			7			28			56		
Area (mm^2)	22,500														
Weight of Specimen (g)	8034.9	8010.9	8027.3	7955.9	8058.6	8014.9	8056.1	8042.0	8149.0	8068.2	8086.9	8091.3	7974.1	8102.4	8063.6
Compressive Strength (N/mm^2)	18.5	18.5	18.0	32.0	29.5	32.5	43.0	40.0	42.0	52.0	56.0	53.5	60.5	56.5	57.0
Average Compressive Strength (N/mm^2)	18.5			31.5			41.5			54.0			58.0		





Photographs 7 & 8 : SEM on treated concrete with XYPEX Admix C-2000 Waterproofing at 28 days.

Xuliping