RESEARCH REPORT

Anti-Carbonation Coatings for Use on Canadian Buildings

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ANTI-CARBONATION COATINGS FOR USE ON CANADIAN BUILDINGS

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NOTE: **DISPONIBLE AUSSI EN FRANÇAIS SOUS LE TITRE:**

REVÊTEMENTS ANTI-CARBONATATION POUR LES BÂTIMENTS CANADIENS

TABLE OF CONTENTS

Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part IX of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has a statutory responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

This publication is one of the many items of information published by CMHC with the assistance of federal funds. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those division of the Corporation that assisted in the study and its publication.

ABSTRACT

Carbonation is a process that reduces the natural alkalinity of concrete. Cement hydrates in the concrete react with atmospheric carbon dioxide to produce calcium carbonates. Advanced carbonation can induce corrosion of the reinforcing steel in a reinforced concrete structure which can in turn lead to fracture formation in concrete and structural distress.

Coatings and sealers have been found to slow or prevent the progress of carbonation in European laboratory tests. This field study initiated testing of certain coatings/sealers to determine their effect on the rate of carbonation and is monitoring their performance in a Canadian climate.

KEYWORDS

Carbonation, coatings, concrete, corrosion, reinforcing steel, sealers

EXECUTIVE SUMMARY

Introduction

Carbonation of concrete occurs when atmospheric carbon dioxide dissolves within the pore structure of concrete and reacts with various components in the cured concrete. This process reduces the natural alkalinity of concrete. When the carbonation front reaches the level of the reinforcing steel it causes the steel to lose its passivity (immunity to corrosion). Once the passivity is destroyed, reinforcing steel can corrode if sufficient water and oxygen are present.

The incidence of carbonation-related concrete deterioration in Europe has been widely reported. European experience with the carbonation phenomen has led to the development of remedial measures. Canada Mortgage and Housing Corporation has founded this study to evaluate the performance of "anti-carbonation" coatings when subjected to the Canadian climate.

This report presents preliminary findings from this study.

Objectives

a) To establish a test protocol for evaluating effectiveness of various anti-carbonation coatings in field applications.

b) To install "anti-carbonation" coatings in designated test panels and perform initial tests to establish existing carbonation conditions.

Methodology

The products to be tested were selected on the basis of technical data made available by the suppliers. The criteria for suitable products were carbon dioxide resistance, water vapour permeance, and water resistance.

The products were applied to cast-in-place shear walls on a 20 year old building with a significant depth of carbonation. The suppliers certified that the products were applied according to their specifications.

During surface preparation the concrete was found to have many "bug-holes". These "bug-holes" were not patched to prevent the patching material from influencing future carbonation depth readings.

Initial cores were taken from each of the test areas to determine the base levels of carbonation. Phenolphthalein testing was used to measure the carbonation depth.

Findings

Phenolphthalein testing indicates an average depth of carbonation of approximately 15mm. The readings were very uniform over the test areas, with a standard deviation of only 1.6mm. The projected change in carbonation depth over the next ten years is 4mm.

Conclusions

Future monitoring should include annual visual inspections of the test panels to assess the durability of the coatings in the Canadian climate. The concrete should also be monitored to assess any possible damage induced by the presence of the coatings.

Based upon the projected rate of carbonation during the test period, it is recommended that further testing for carbonation should be deferred until 4 and 10 year intervals. The uniformity in the existing depth of carbonation in these shear walls will facilitate comparison of the performance of the various coatings.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the following individuals and companies for their participation in this test program:

i) The Metro Toronto Housing Authority for allowing the testing to be performed on one of their buildings.

ii) John Bickley - John A. Bickley Associates Ltd.
Dr. Doug Hooton - University of Toronto
Neil Cumming - B. H. Levelton and Associates Ltd.
Sally Thompson - Robert Halsall and Associates Ltd.
John Kosednar - Robert Halsall and Associates Ltd.
For assisting in the development and review of the test protocols.

iii) DRE Industries Inc.
Fosroc Construction Chemicals a division of Foseco Canada Inc.
Master Builders Technologies Ltd.
Sika Canada Inc.
For applying their products to the shear walls for use in this study.

1. INTRODUCTION

1.1 Authorization

Testing took place on a building managed by the Metro Toronto Housing Authority. The Letter of Authorization for this testing is included in Appendix C.

1.2 Objectives

The purpose of this report is to document the initial phase of a long term study that will assess the performance of anti-carbonation coatings for use on concrete in a Canadian climate.

The scope of this initial phase of the study includes:

i) selecting a suitable candidate building;
ii) selecting the locations of test areas on the candidate building;
iii) selecting products to be tested;
iv) arranging application of the products; and
v) measuring baseline carbonation depths.

The purpose of the study of anti-carbonation coatings is to investigate their overall performance when exposed to typical Canadian climate conditions and not to reiterate the many laboratory programs which have already been undertaken.

Four products were selected for application to cast-in-place shear walls during this phase of the study. Further testing is required to monitor the rate of change of carbonation depth for coated versus uncoated concrete on the same building, and under similar exposure conditions.

1.3 Background

Carbonation is a form of environmentally induced degradation of concrete involving reactions between carbon dioxide in the atmosphere and the various components of the cured concrete. These reactions result in a drop in the pH of the concrete from approximately 12.5 to below 9; this results in a break down of the natural passive layer which initially forms on the surface of steel in concrete at a higher pH. Once the passive layer is destroyed, the reinforcing steel can corrode if sufficient water and oxygen are present. Carbonation is only detrimental to reinforced concrete if it reaches the level of the reinforcing steel. A building is more susceptible to carbonation induced damage if the steel is poorly placed with minimal cover, if the concrete is cracked, or if the concrete is very permeable to carbon dioxide.

The maximum rate of carbonation occurs when the pore structure of concrete has a relative humidity of 50 to 70%[8,11] (Roberts, 1981; Weirig, 1984). This occurs most often in concrete which is sheltered from direct rainfall. Interior concrete is more susceptible to carbonation, but since it is dry there is very little risk of corrosion, therefore exterior sheltered concrete elements are of interest.

2. PROCEDURE

2.1 Selection of Test Building and Test Areas

2.1.1 Building Selection

In accordance with the test protocol (see Appendix A), the selection of the building to be used for testing was based on results from a previous study by John Bickley[2] (Bickley, 1990). The building selected as the test site for the anti-carbonation coatings was found to have a high average depth of carbonation on cast-in-place elements, a high percentage permeable voids, high absorption, and on the basis of previous test results, a large projected change in carbonation depth.

The projected change in carbonation depth was determined by assuming that carbonation depth is a function of the square root of the age of the building: where

$$D_c = K\sqrt{A}$$

D_c is the depth of carbonation, A is the age of the building, and K is a "carbonation constant" based upon the historical rate of carbonation for a given sample of concrete.

The building selected for testing was constructed in about 1972. The average carbonation depth reported by John Bickley for vertical cast-in-place elements was 29mm. It was estimated that the projected average change in carbonation depth for vertical cast-in-place elements of the candidate building would be 8mm over a ten year period, from 29mm to 37mm.

All of the buildings in the Bickley study were at least fifteen years old. Because the rate of carbonation declines as a function of time, a younger building would have been preferable in order to have a greater change in depth of carbonation over the duration of this study. However, the selected building was chosen from those included in the previous CMHC study, where significant carbonation was known to exist.

2.1.2 Test Area Selection

A parallel CMHC-funded study[5] (Halsall, 1992) found that vertical concrete surfaces that are sheltered from direct rainfall exhibit a greater rate of carbonation than horizontal surfaces that may remain saturated for longer periods of time. Consequently the areas selected for application of the anti-carbonation coatings were second floor level shear walls which project from the face of the building (refer to Drawing No. SK-1, Appendix E). These shear walls are partially sheltered by third floor balconies above.

The test areas were selected in accordance with the test protocol (see Appendix A), to ensure that the only route for carbon dioxide to be absorbed into the coated concrete is through the coating, and not laterally through the concrete. The shear walls were coated on the end and both sides right up to the joint between the building and the shear wall for one full storey. There are no balconies on the second floor of the candidate building (see Photo #1, Appendix E), thus tenants do not have access to the coated areas. This should prevent vandalism or repainting of the test areas. The test areas are not subject to salt splash.

2.2 Selection of Products to be Tested

The protocol for the selection of suitable "anti-carbonation coatings" is included in Appendix B. This protocol outlines requirements for minimum resistance to carbon dioxide transfer, minimum water vapour transmission and maximum water penetration. These criteria were taken from European references which are listed at the end of the protocol.

Nineteen suppliers of concrete coating/sealer products reviewed by protocol; only two were able to meet all three criteria. These suppliers both have European counterparts and have access to laboratory test results from Europe. Five other suppliers could only meet 1 or 2 of the criteria; others did not respond. There was a general lack of knowledge amongst the suppliers in the area of carbonation. Their laboratories even had difficulty obtaining information about the test methods. In some cases there were subjective statements in the literature, such as 'resists carbon dioxide' which were not supported by laboratory results.

The two products which met all the criteria and one product which met two criteria were selected for testing. According to a BRE paper[4] (Davies, 1989), all three types of coatings performed well in laboratory tests of anti-carbonation coatings. The same report suggests that epoxy coatings have excellent anti-carbonation properties. Therefore, an epoxy coating was selected as the fourth test coating. The specific epoxy coating was chosen on the basis of a previous study of concrete sealers/coatings[1] (Aitken, 1989) rather than by reviewing literature from a variety of suppliers.

The four products included in this test program are:

i) A primer consisting of a reactive oligomeric silane/siloxane in an organic carrier, with a topcoat consisting of a resin solution of pigmented methacrylate in mineral spirits;
ii) A two component acrylic modified cementitious coating containing cement, silica sand, a reactive filler and acrylic copolymers;
iii) An aqueous based high solids acrylic primer and topcoat; and
iv) a pigmented polyamide epoxy coating.

Other criteria that will be considered when assessing the performance of these surface coatings for concrete include the ultraviolet light resistance, abrasion resistance, ease of application, time to first maintenance, ease of overcoating and aesthetic appearance[6] (Harwood, 1990).

Technical literature about the acrylic coating and the siloxane/methacrylate coating systems indicated that the products have excellent stability in ultraviolet light. The epoxy literature indicates that the coating will darken and discolour with exposure to ultraviolet light. The technical literature supplied for the cementitious coating does not discuss the effects of ultraviolet light.

The abrasion resistance and the other maintenance-related criteria of the four test products will be visually monitored over the test period. The coatings have been applied to areas that are partially shielded by balconies above, but will still have to withstand weathering.

2.3 Application of Coatings/Sealers

2.3.1 Surface Preparation

The four shear walls were sand-blasted on December 7, 1991 to provide a common surface preparation prior to application of the various coatings and sealer.

A light sandblasting of the surface of the reinforced concrete shear walls exposed numerous "bug-holes". The concrete generally appeared to be of inferior quality; poorly consolidated and improperly cured. Several reinforcing bars were exposed on the surfaces of the test areas.

The poor condition of the concrete is contributing to susceptibility to carbonation. It has been found that poor compaction and curing lead to generally poor concrete quality and increased carbonation susceptibility[(3)] (Currie, 1986).

The bug-holes were not repaired with a patch material prior to application of the coatings/sealers. The patch material would enhance the performance of the anti-carbonation coatings, or it could even locally realkalize (reduce the depth of carbonation) the concrete, thereby comprising the integrity of this study.

2.3.2 Environmental Conditions

Three products were applied to the shear walls on December 11, 1991 and the fourth was applied on December 12, 1991. The air temperature on December 11th was 9ºC with a relative humidity of 55%. The surface temperature of the test shear walls was a uniform 9º. On December 12th, the air temperature was 6º, and it was raining. The wall surface temperature was 6º. The rain did not affect the application because the wall is almost entirely sheltered, and because the cementitious coating that was applied on this date must be applied to a damp substrate.

2.3.3 Product Application

The siloxane primer with the methacrylate top coat was applied by the supplier's representative. The primer was applied by roller at a rate of 2.45 m^2/l (100 ft^2/U.S. gallon) and left to dry for approximately one hour. The topcoat was applied by roller at a rate of 4.91 m^2/l (200 ft^2/U.S. gallon). Application rates were as per manufacturers recommendations. The penetration depth of the primer was measured to range between 1 and 5mm.

Prior to application of the cementitious coating, the test panel was moistened with water. The coating was then brushed on in two coats. The first coat had dried for approximately 45 minutes before the second coat was applied. Subsequent thickness measurements indicated that the coating had been applied to an average of 0.85mm thick. The manufacturer recommends a thickness of 1mm. The application was performed by the supplier's representatives.

The high solids acrylic coating was applied by the supplier's representative in 3 coats. Two base coats were applied by brush and roller. The top coat was applied by roller, and then bug-holes were touched up by brush. Subsequent thickness measurements indicated a total average build of 0.6mm. The manufacturer recommends a thickness of 0.4mm in three coats for anti-carbonation applications.

The pigmented epoxy coating was applied by roller by the supplier's representative in one coat. The bug-holes and general surface defects were touched up by brush. The epoxy was applied at a rate of 2.35 m^2/l (96 ft^2/U.S. gallon). The manufacturers recommended application rate is 2.45 m^2/l to 3.67 m^2/l (100 to 150 ft^2/U.S. gallon).

The cementitious coating was the most difficult to apply; it needed to be brushed. The other three products were applied with approximately the same ease, although the epoxy was applied in one coat, and the acrylic in three coats. It is generally thought that anti-carbonation coatings should be applied in at least 2 coats with a thickness of 200 μm, to ensure a continuous layer without pinholes[(4)] (Davies, 1989).

The product literature for the test coatings/sealers did not indicate the life expectancy, nor recommended maintenance intervals for the products. This aspect will be monitored over the proposed 10 year study period.

Appendix C contains the Agreements for Special Services signed by the Suppliers indicating that their products would be applied according to their Specifications and that they agree to the terms of the testing.

2.4 Initial Testing

Five cores were taken from each of the four coated test areas, one month after the coatings were applied. The cores were stored in distilled water in the field, and then tightly wrapped in plastic to prevent exposure to atmospheric carbon dioxide.

The cores were split longitudinally and sprayed with a 1% phenolphthalein solution according to ISO Standard DOC N77E. The phenolphthalein solution turns purple when in contact with a pH of greater than 9, and remain colourless at a pH of less than 9. Thus, the depth of fully carbonated concrete can be determined. Partial carbonation (where the pH value still exceeds 9) will not be detected by the use of phenolphthalein. The depth to fully carbonated concrete will be referred to as the depth of carbonation for the purpose of this report.

The thickness of coatings and penetration depth of sealers was also determined from these cores.

3. OBSERVATIONS

3.1 Appearance

Aesthetically, the cementitious coating matches the concrete best in colour and finish. The other three products can be coloured to match the concrete, but tend to have a shiny finish. The colours of the products used for this testing were not well matched to the building, however, the suppliers indicated that the colour would be matched better for a large project. Aesthetic considerations should not be a factor if one or more of these coatings prove to be successful in preventing carbonation.

3.2 Carbonation Depths

The initial carbonation depths measured on the core samples were found to be high and uniform (see Table 1). The average carbonation depth for the south faces of the shear walls was found to be 14.9mm with a standard deviation of 1.8mm. The average carbonation depth for the north faces was 14.7mm with a standard deviation of 1.5mm.

Given the average measured depths of carbonation (14.8mm) and the age of the test building (17 years in 1991) it is possible to predict the average carbonation depth of untreated concrete in 4 and 10 years. If the depth of carbonation is assumed to vary directly with the square root of the age of the concrete then the projected carbonation depth would be 16.4mm in 1995, and 18.7mm in 2001 (refer to Appendix F).

While these changes in carbonation depths in the untreated areas are small and less than the previously predicted change, the uniformity of the readings over the test surfaces should allow small changes in the future to be detected.

TABLE 1

DEPTH OF CARBONATION

COATING	CORE LABEL	CARBONATION DEPTH (MM)	
		SOUTH END	NORTH END
A	A-1	15	12
	A-2	15	15
	A-3	15	14
	A-4	15	12
	A-5	15	16
B	B-1	15	15
	B-2	15	13
	B-3	17	15
	B-4	11	15
	B-5	15	15
C	C-1	14	18
	C-2	14	15
	C-3	12	16
	C-4	19	15
	C-5	16	15
D	D-1	13	13
	D-2	17	17
	D-3	16	15
	D-4	13	14
	D-5	15	14

4. CONCLUSIONS

4.1 Recommendations for Further Testing

The initial carbonation depth measurements on the four test areas in this study, it are fairly uniform. This will facilitate assessment of the relative performance of the four anti-carbonation coatings.

Since the projected change in carbonation depth based on measured carbonation depths is less than that originally estimated for this building, the test intervals should be longer than originally expected. We recommend that the visual examination of the test areas should take place after 1, 2, 4, 6 and 10 years. The coatings should be checked for evidence of UV damage (chalking, discolouring), evidence of damage from weathering and climate, and to determine whether or not the coatings need to be repaired or reapplied during the test period. The large number of bug-holes which existed, and were not repaired prior to coating application should be expected to cause some damage to the coatings which would not have occurred if the bug-holes had been repaired. The bug-holes may contain water that is trapped behind the coatings; this water could damage the coatings when it freezes and thaws. On the other hand, because the coatings were applied to shear walls that project from the exterior face of the building, they will not be subjected to transmission of moist air from the interior of the building which can induce freeze-thaw damage.

There is no value in taking carbonation depth measurements as often as the visual examinations due to the limitations of the phenolphthalein test to accurately measure slight changes in carbonation depth. Therefore it is recommended that carbonation depth measurements should be made after 4 and 10 years. These subsequent carbonation depth measurements should include (as outlined in the protocol) five cores from each of the test areas, and three cores from below the test areas in the uncoated areas, to act as controls for each shear wall. The cores must not be taken within 250mm of a previous core, because the patch material used to repair the previous cores may realkalize (decrease carbonation depth in) the concrete immediately adjacent to the previous core.

5. REFERENCES

1. Aitken, C.T. and Litvan, G.G. **Laboratory Investigation of Concrete Sealers**. National Research Council of Canada, IRC Report No. OR574, Volumes I and II, January, 1989.

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APPENDIX A

APPENDIX A

CARBONATION IN CANADIAN BUILDINGS
CMHC FILE NUMBER 6711-5

DRAFT TEST PROTOCOL

1. Objective

To determine the effectiveness of various coatings applied to concrete in preventing carbonation.

The emphasis of this study will be to monitor the change in depth of carbonation at a particular building with various coatings applied. The building to be used for testing was located in Toronto and was used for previous carbonation testing in CMHC study on the "Extent of Carbonation in Buildings in Toronto"[(1)].

The suitability of the coatings for use in the Canadian climate will be monitored visually to ensure that the coatings have good adhesion and do not induce freeze thaw damage of the concrete.

All aspects of this anti-carbonation study will be performed under the project management of Robert Halsall and Associates Limited.

2. Scope of Work

The work shall be limited to applying patches of the various coatings to be tested to vertical cast-in-place elements of the building and testing the change of depth of carbonation with time. The extent of carbonation will be determined using the phenolphthalein test method only.

3. Building Selection

The building to be used for this phase of the CMHC study of carbonation will be chosen from amongst the buildings used in the previous study.[(1)] The building will meet the following criteria:

.1 More than 50% of the cores taken from the building in the previous study had carbonation depths of greater than ten millimetres.

(1) Bickley, J.A. **Extent of carbonation in buildings in Toronto** Research Division, Policy Development and Research Sector, Canada Mortgage and Housing Corporation January 29, 1990.

.2 The carbonation depths were high for cores taken from vertical cast-in-place and balcony elements.

.3 The average percentage of permeable voids as found in the previous study for the building was above 13%.

.4 The average absorption found for the building was found in the previous study to be greater than 6%.

.5 The projected change in depth of carbonation over the subsequent five year period was greater than four millimetres.

4. Coating Application Location Selection

The selection of coating application locations will be based on the following criteria:

.1 The coatings will be applied to vertical cast-in-place shear walls over the height of a full storey.

.2 The configuration of the coating will be such that it does not allow carbon dioxide to travel laterally through the concrete to the location where cores will be taken. Thus, any carbonation will have been caused by carbon dioxide travelling through the coating, and not behind it.

i.e. For shear walls which project from the building adjacent to balconies, the coating will cover the exposed end and both sides of the shear wall right to the joint between the shear wall and the building face.

.3 The coatings will be applied to locations where the external surface of the concrete has not previously been repaired or damaged. A visual examination for the absence of patches, and sounding for the absence of delaminations will be sufficient to meet this criteria.

.4 The coatings will be applied at locations at or above the second storey which are therefore not subject to salt splash.

.5 No construction joints will cross the area to be coated with a particular coating.

5. Product Selection and Application

Coatings to be used for testing will be chosen by the project manager according to the "Draft Protocol for the Selection of Anti-Carbonation Coatings"(attached).

Suppliers who wish to have their coatings used for testing will provide their coating and application, free of charge to the project manager. The supplier will arrange for an experienced applicator to be available for the application of the coating to the subject building. The application will be performed according to the supplier's specifications and will include surface preparation, coating application and any required clean-up.

The application of the coating will be supervised by a representative of the project manager.

6. Coring Procedures

Five cores will be considered to constitute a scientific sample for the initial testing. The cores shall be obtained as follows:

.1 The cores will be 75mm diameter by nominally 200mm in length drilled using a water-cooled diamond drill. The core locations shall be repaired to the satisfaction of the building owner.

.2 The cores will be labelled and then immediately immersed in distilled water for transportation to the laboratory.

.3 The following information will be recorded for each core sample:

a) Date
b) Location - street address
- test area indicator
- exact location within test area
c) Coating Identifier
d) Exposure to Weather
e) Age of Structure

Each end of a core taken through a shear wall must be identified as a separate specimen.

.4 Five cores will be taken from each test area within one month of application of the coating. These five cores will be evenly spread across the test area.

.5 At times of future testing five cores will be taken from each test area. Three cores will be taken from the uncoated shearwall directly below each test area. The cores taken from below the coatings will act as controls for each shearwall.

.6 The minimum spacing between any two adjacent cores will 250mm. This holds for all twenty cores in a test area, and for the control cores.

7. Laboratory Procedures

All cores will be sent to Dr. D. Hooton at the University of Toronto for testing.

.1 The coating thickness or sealant depth will be measured for the first set of cores to ensure agreement with the manufacturer's specification.

.2 The samples will be split along the longitudinal axis and immediately submerged in distilled water to prevent further carbonation.

.3 The half cores from each location will be sprayed with standard phenolphthalein indicator solutions in accordance with the test procedure given in ISO Standard DOC N77E except that only four depth measurements will be made on each half cylinder.

.4 The measured carbonation depths will be recorded and averaged for each coating or control location.

.5 The carbonation depth will be plotted vs time over the five years to monitor its progress in both the coated and the control areas.

APPENDIX B

PROTOCOL FOR THE SELECTION OF

ANTI-CARBONATION COATINGS

OBJECTIVE.

On behalf of CMHC and its agents, the Consultant is proposing to make field trials to determine the performance of coatings which reduce the rate of carbonation of concrete exposed to weather.

REQUIREMENTS.

Interested suppliers will be given access to a public residential building in Toronto. An approved applicator nominated by the supplier will apply the selected coating to approximately 10 sq. meters of vertical concrete surface. The method of surface preparation, the quality and properties of the prepared surface, the method and rate of application, the number of coats and the final minimum thickness, and the post-application curing shall all be done in accordance with the suppliers recommendations. These recommendations shall be submitted in writing to the consultant for review prior to the field trial.

The coating applied will reduce the rate of carbon dioxide penetration into the concrete and will have a long service life before recoating. The expected service life will be stated by the supplier as will requirements for subsequent recoating.

The coating shall resist penetration by water and carbon dioxide but will have adequate water vapour transmission properties.

There are no national standards for such coatings, but the following criteria, or their equivalent, are to be met by the proposed coating.

Resistance to Carbon Dioxide Transfer

Equivalent air layer > 50m

or

Resistance $\geq$ 190 $MNsg^{-1}$

or

Flux < $5g/m^2/day$

or

BRE test after aging - very good carbonation resistance.

Water Vapour Transmission

Equivalent air layer	<	2m
or		
Resistance	<	11 $MNsg^{-1}$
or		
Flux	>	20/m^2/day

Water Penetration

Lower than the water vapour transmission rate
and
having an ISAT value < 35 g/m^2/ hr

Suppliers may provide test data to other test procedures and criteria but full details of the test procedure must be given together with adequate references to enable the Consultant to evaluate the alternative procedures.

REFERENCES:

The following references are recommended as background to these requirements:

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- Construction Industry Research and Information Association, "Technical Note 130 - Protection of Reinforced Concrete by Surface Treatments", 6 Storey's Gate, Westminster, London, England, SWIP 3AU.

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- BRE Information Paper IP 7/89, Dated May 1989, "The Effectiveness of Surface Coatings In Reducing Carbonation of Reinforced Concrete" Building Research Establishment, Garston, Watford, WD2 7JR.

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APPENDIX C

Ontario

Metropolitan
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M4W 3L4

365, rue Bloor est
Bureau 7000
Toronto (Ontario)
M4W 3L4

March 17, 1992

Robert Halsall and Associates Limited
188 Eglinton Avenue, 6th Floor
Toronto, Ontario
M4P 2X7

Attention: John Kosednar, P. Eng.
Project Engineer

Dear Sir:

Re: Anti-Carbonation Coatings

This is to confirm that Metropolitan Toronto Housing Authority (MTHA) has provided access for Robert Halsall and Associates Limited to 2063/2067 Islington Avenue (OH-144 Islington/St. Andrews) for the purpose of conducting required testing for Anti-Carbonation Coatings. The study was initiated by Ontario Ministry of Housing.

Yours truly,

D. Petrovic

D. Petrovic, P. Eng.
Senior Structural Engineer
Design Services

DP:cds

RECEIVED
MAR 18 1992
ROBERT HALSALL & ASSOC. LTD.
CONSULTING ENGINEERS

APPENDIX D

90x799B/a

AGREEMENT FOR SPECIAL SERVICES

This memorandum sets forth an understanding between Robert Halsall and Associates Limited, and the supplier of products to be used for testing.

The supplier agrees to provide services and materials according to the terms and conditions set forth in the attached letter dated November 12, 1991 and the test protocol dated August 1991.

Robert Halsall and Associates Limited is under no obligation to provide test results to the supplier. The results will be published for the Canada Mortgage and Housing Corporation. The participation of each of the suppliers will be acknowledged in this report.

Supplier	Supplier's Representative	Date
Robert Halsall and Associates	Project Supervisor	Date

ROBERT HALSALL AND ASSOCIATES LIMITED CONSULTING ENGINEERS

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DRE Industries Inc	Bill Dexwani	NOV 26 91
Supplier	Supplier's Representative	Date
	[signature]	Dec 6 91
Robert Halsall and Associates	Project Supervisor	Date

90x799B/a

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Sika Canada Inc.	Andrew Mitchell	11/18/91
Supplier	Supplier's Representative	Date
		Dec 6 91
Robert Halsall and Associates	Project Supervisor	Date

AGREEMENT FOR SPECIAL SERVICES

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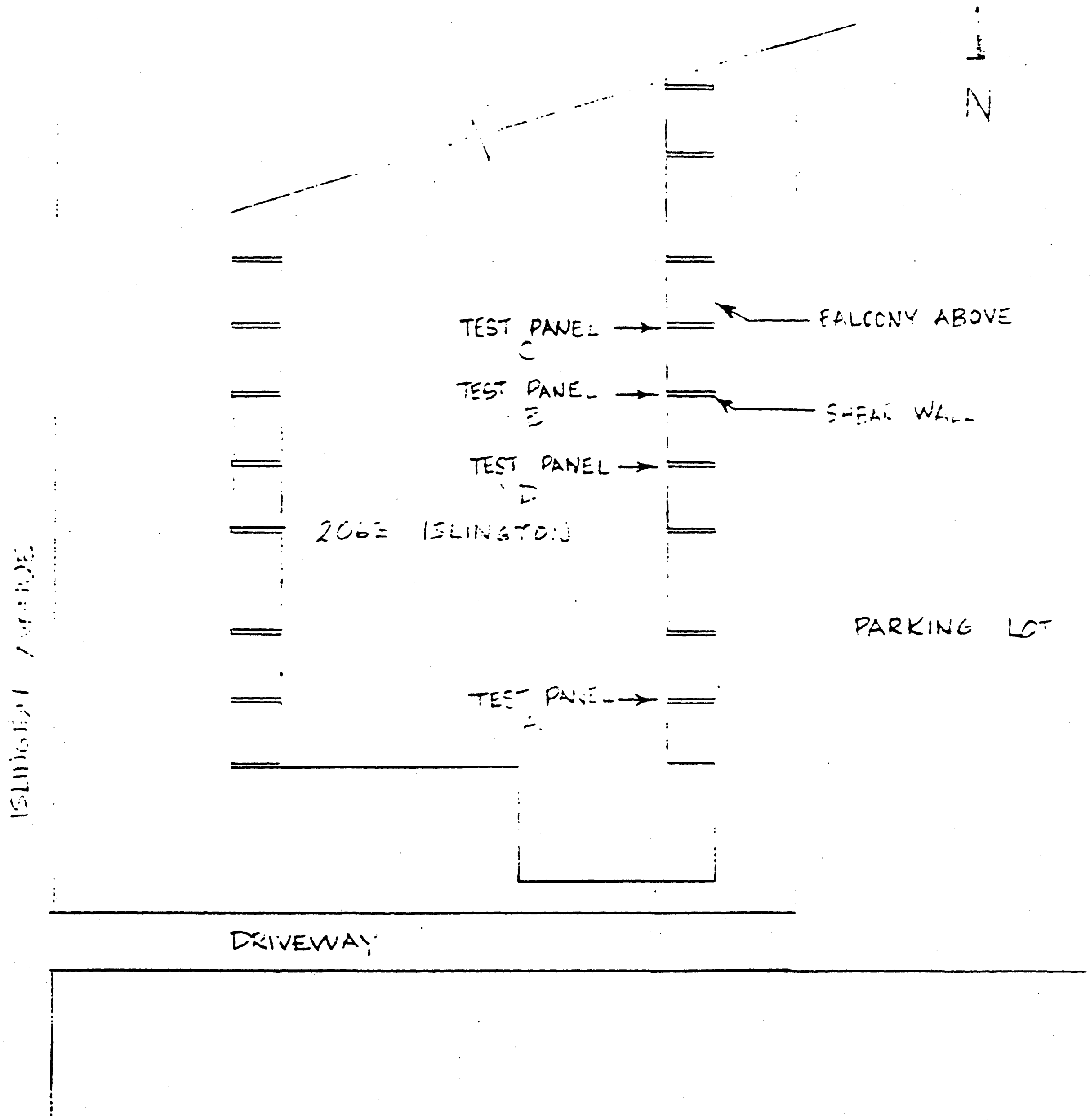
FOSROC	[signature]	11/12/91
Supplier	Supplier's Representative	Date
	[signature]	Dec 6 91
Robert Halsall and Associates	Project Supervisor	Date

APPENDIX E

Photo 1
Location of test panels

PANEL	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]



ANTI-CARBONATION COATINGS
2063 ISLINGTON AVE.

PLAN SHOWING LOCATION OF TEST PANELS

ROBERT HALSALL & ASSOCIATES LTD.
188 EGLINTON AVE. E., TORONTO, CANADA M4P 2X7 416-487-5256

Date:	Scale: NTS
Drawn by: SV	Checked by
Project No. 90x7	
Drawing No. SK-1	

APPENDIX F

APPENDIX F

CALCULATION OF PROJECTED CARBONATION DEPTHS

Assuming:

$$C_d = K\sqrt{A}$$

Where:	Cd	=	carbonation depth
	K	=	constant
	A	=	age of the building

Given: A = 17 years; and
Average carbonation depth = 14.8mm,

determine K for shearwalls at test building:

$$K = \frac{C_d}{\sqrt{A}} = \frac{14.8}{\sqrt{17}} = 3.59$$

Project carbonation depths for:

A = 21 years and
A = 27 years

<u>A = 21 (1995)</u>

$$C_d = K\sqrt{A} = 3.59\sqrt{21} = 16.4mm$$

<u>Age = 27 (2001)</u>

$$C_d = 3.59\sqrt{27} = 18.7mm$$

Therefore, the projected carbonation depth is 16.4mm IN 1995 and 18.7mm in 2001.

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