RESEARCH REPORT

Deterioration of Parking Structures Research Project

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DETERIORATION OF PARKING STRUCTURES RESEARCH PROJECT

DISCLAIMER

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The laboratory tests, and the relative humidity and temperature monitoring in the field were carried out competently by H. Schultz.

ABSTRACT

This report provides information aiming to assist engineers and owners to formulate the repair strategy and maintenance practices of existing garages built without adequate corrosion protection. The report is divided into nine sections. Section 1 is the main part of the report in which the problem of the deterioration of parking garages is described, the background of the present research and its objectives are stated, the methodology followed and the major cnclusions reached are presented. In Appendix A the data collected on the 62 garages in the sample are given. Case histories of 30 garages in the sample are presented in Appendix B. A novel method for the assessment of cable condition by gas flow is reported in Appendix C. In Appendix E the work on the determination of the alkali resistance of sealers is discussed. Lectures given on the results obtained in the course of the project, and papers published in journals and proceedings are listed in Appendix F. Participation of the Project Leader in standard writing committees are given in Appendix G, and in Appendix H the previously reported sub-projects are listed.

EXECUTIVE SUMMARY

Introduction

The "parking garage problem" emerged in the late 1970's. It was relaized that because the widespread deterioration of garages was caused by inadequacy of the then current design and construction practices, essentially all structures will have to be upgraded and periodically repaired to operate them in a safe and serviceable manner until the end of their design life.

The cost of the repair of the 5,000 garages estimated to be in existence was clearly very high, in excess of $2 billion.

The National Research Council commissioned a project in 1981 to document the information gained in field investigation and repair of deteriorated garages by a large consultant firm, Trow Ltd. (Project T2298-C, February 1981).

Canada Mortgage and Housing Corportion, as lead agency, National Research Coucnil of Canada, Public Works Canada, and Supply and Services Canada as co-sponsors provided financial and technical support to Project T4010-C, "Parking Structure Deterioration: "A Survey and Analysis of its Extent and Influencing Factors", the findings of which have been reported in 1984.

The present study was initiated by the private sector, The Canadian Institute of Public Real Estate Company, (CIPREC), in 1987 to collect information that will be useful to engineers and owners in the selection the repair strategy most appropriate for a given garage under consideration.

Canada Mortgage and Housing Corporation, Ministry of Housing of the Province of Ontario, National Research Council of Canada, Public Works Canada joined the project at the invitation of CIPREC and provided technical and financial assistance.

Gerard G. Litvan, Ph.D., Dipl. Chem. has been appointed as project manager, who has been the Scientific Authority of the previous two studies on parking garage deterioration.

OBJECTIVES

The primary objectives of the project were to:

1. Reduce life-cycle cost;
2. Reduce repair cost;
3. Increase longevity of repairs;
4. Reduce repair time;
5. Develop data base on the quality of components;
6. Establish requirements for the various types of structures;
7. Establish requirements for the various climatic environments.

Subsidiary Objectives: To be evaluated were:

1. The various repair methods;
2. The performance of membranes (generic types, products);
3. The performance of sealers;
4. The merits of membranes vs sealers;
5. The relative merits of repair strategies (at what stage and to what extent to repair);
6. The relative merits of the various structural designs;
7. The benefits of good housekeeping;
8. The benefits of proper maintenance;
9. The effects of the macro environment (climate, type of deicers);
10. The effects of the micro environment and means to improve (temperature, level of humidity, rate of ventilation, drainage, etc.);
11. The merits of cathodic protection (effectiveness of the various types of anodes, maintenance cost, cost effectiveness);
12. The value of the various types of surveys (delamination test, half-cell potential, chloride content);
13. The methodology of survey of garages after the installation of a waterproofing membrane;
14. The performance ramps;
15. The performance of various types of embedded heaters;
16. The corrosion resistance of drain-wells;
17. The performance of the various expansion joints (materials and design);
18. The feasibility of painting the soffit.

METHODOLOGY

The performance of 62 garages in the sample was monitored over a four year period. Standard condition survey protocols for conventionally reinforced, and post-tensioned garages have been developed for this purpose.

The structures were located in six provinces of Canada, and had various characteristics (age, state of repair, mode of rehabilitation, etc.). The features of the garages, and their repair history ware documented. The data are presented in Appendix A, and the case historics of selected structures are described in Appendix B.

Laboraotry evaluation of the concrete sealers was carried out according the test methods described previously in the Client Report No. 3, the effect of freeze-thaw resistance by standard test procedures ASTM C666 and C490.

Condition surveys following the standard protocol described in Client Report No. 3, were carried out by consulting firms. The results of non-standard surveys, made available to the project, were also utilized.

The technical details of monitoring of the relative humidity are given in Appendix D.

FINDINGS

Deteriorating parking structures designed and constructed without adequate protection against corrosion of the reinforcing steel can be kept in a serviceable condition, most probably until the end of their design life;

While no single repair method is superior to another, early repair is clearly the most effective from a technical and economic point of view;

The most common repair method, "Patch and Waterproof" works, on the whole, well. Care has to be exercised to achieve good bond between the existing and new concrete;

Though cathodic protection, (CP), does not arrest corrosion, it substantially reduces its rate and decreases the concentration of chlorides around the reinforcing steel. Proper installation and operation of the CP system can be a difficult task. Serviceability is a problem in seriously deteriorated structures unless a waterproofing membrane is installed. Regular monthly monitoring by qualified personnel is essential;

Garages even of the same structural type, do not deteriorate at the same rate. The deterioration rate of reinforced concrete decks in the sample expressed in terms of the delaminated area as determined by the chain drag test, varied between 5.8%/year and 0.06%/year;

The half-cell potential test (ASTM C876.80) results have poor reproducibility and are, under field conditions, not necessarily related to corrosion rate. The test is suitable mainly for obtaining specific information;

While the high chloride ion concentration in the concrete is the primary cause of corrosion, the rate of concrete deterioration depends also on other parameters such as its moisture content. Single chloride ion concentration threshold values cannot serve as a basis for prediction of performance;

The presence of a waterproofing membrane on the deck has been beneficial. There is no indication of moisture entrapment;

A major weakness of most of the existing waterproofing membrane system is the inadequacy of the wearing course;

The provisions of the CAN/CSA 413-87 Standard for new garages seem to be appropriate;

Durable, well performing garages can be built by complying with the requirements of the CAN/CSA 413-87 Standard;

Injection of grease into the dried ducts of an unbonded post-tensioned structure appears to significantly retard the corrosion of the steel tendons;

The results of the cable condition assessment by the gas flow method are encouraging;

Post-tensioned garages with unbonded tendons can perform well if designed, constructed, and maintained properly;

Monitoring the relative humidity, RH, prevailing in a garage deck can be a valuable tool in assessing the performance of protective systems;

The RH in the concrete deck of enclosed garages protected by a waterproofing membrane in good condition is so low, that only negligible corrosion of the reinforcing steel takes place in a great part of the year, (November to May);

The alkali resistance of concrete sealers should be determined by using substrates other than portland cement mortar cubes, like clay brick, which should be conditioned at 50% RH, rather than dried at 110°C before testing.

Recommendations

1. A policy of continuous maintenance should replace the present practice of carrying out little, or no, maintenance between major rehabilitations. The proposed policy will result in close to optimal garage performance at all times, less frequent major repairs, less disruption of parking services and lower life cycle cost. It will be necessary, however, to provide funds in the budget for the maintenance activity.

2. In order to facilitate continuous maintenance, every garage should have a log book containing:

   - the maintenance actions recommended by the design engineer;
   - the records of the maintenance actions performed;

- the condition survey test reports;
- the description of repairs;
- the recommendation of suppliers of installed protective systems, such as waterproofing or CP systems. Provision of a maintenance manual should be stipulated by the purchase contract.

3. Owners should retain on a long-term basis the services of a consulting engineer who, after familiarizing himself with the structure, will be in a good position to recommend to the owner the most appropriate course of action to eliminate defects discovered by visual or instrumental condition surveys.

4. Interdisciplienary reserarch aiming to identify solutions for a particular problem should be encouraged and supported, because the modes of corection of defects is often possible by borrowing techniques used in other disciplines (e.g. in the case of garages waterproofing was imported from roofing, cathodic protection from the pipeline and, epoxy coating from the chemical process technology).

RÉSUMÉ

Introduction

Les ouvrages de stationnement ont commencé à manifester des signes de problèmes vers la fin des années 1970. On s'est aperçu que puisque leur détérioration répandue résultait de la déficience des techniques de conception et d'exécution d'alors, essentiellement tous allaient devoir être modernisés et réparés périodiquement en vue d'assurer leur exploitation sécuritaire et leur bonne tenue en service jusqu'à la fin de leur durée utile.

Le coût de réparation de tels ouvrages qu'on estime à 5 000 est, de toute évidence, très élevé, se chiffrant à plus de 2 milliards de dollars.

Le Conseil national de recherches a commandé, en 1981, un étude dont l'objet consistait à documenter les informations obtenues lors de l'investigation sur place et de la réparation de garages détériorés, effectuées par l'importante maison de consultants Trow Ltd. (Recherche T2298-C, février 1981).

La Société canadienne d'hypothèques et de logement, à titre d'organisme prépondérant, le Conseil national de recherches du Canada, Travaux publics Canada, et Approvisionnements et Services Canada, en tant que coparrains, ont assuré le soutien financier et technique de la recherche T4010-C, «Parking Structure Deterioration : A Survey and Analysis of its Extent and Influencing Factors», dont les résultats ont été signalés en 1984.

La présente étude a été amorcée en 1987 par le secteur privé et l'Institut canadien des compagnies immobilières publiques dans le but de recueillir de l'information utile pour les ingénieurs et les propriétaires au moment d'envisager la stratégie de réparation tout indiquée pour un ouvrage donné.

La Société canadienne d'hypothèques et de logement, le Ministère du Logement de l'Ontario, le Conseil national de recherches du Canada, ainsi que Travaux publics Canada ont décidé d'unir leurs efforts sur l'invitation de l'Institut précité et de fournir un support technique et financier.

Gerard G. Litvan, détenteur d'un Ph.D. et d'un diplôme en chimie, a été nommé directeur de projet, ayant été l'autorité scientifique lors des deux études précédentes consacrées à la détérioration des ouvrages de stationnement.

OBJECTIFS

Les objectifs premiers de la recherche consistaient à :

1. Réduire le coût du cycle global.
2. Réduire le coût des réparations.
3. Allonger la durée utile des réparations.
4. Réduire le temps des réparations.
5. Élaborer une base de données sur la qualité des composants.
6. Fixer des exigences à l'égard des différents types d'ouvrages.
7. Fixer des exigences à l'égard des différents climats.

Les objectifs secondaires consistaient à évaluer :

1. Les diverses méthodes de réparation.
2. La performance des membranes (types génériques, produits).
3. La performance des produits de scellement.
4. Les mérites des membranes par rapport aux produits de scellement.
5. Les mérites respectifs des stratégies de réparation (à quel stade et dans quelle mesure effectuer les réparations).
6. Les mérites respectifs des différents designs structuraux.
7. Les avantages d'un entretien satisfaisant.
8. Les avantages d'une maintenance tout indiquée.
9. Les effets du macro-environnement (climat, type de produits de dégivrage).
10. Les effets du macro-environnement et les moyens d'amélioration (température, degré d'humidité, taux de ventilation, évacuation de l'eau, etc.).
11. Les mérites de la protection cathodique (efficacité des différents types d'anodes, coût d'entretien, efficience).
12. La valeur des différents types d'enquêtes (test de délaminage, potentiel par demi-piles, teneur en chlorure).
13. La méthode d'enquête des ouvrages après la mise en oeuvre d'une membrane d'imperméabilisation à l'eau.
14. La performance des rampes.
15. La performance de différents types d'éléments chauffants enrobés.
16. La résistance à la corrosion des puits d'évacuation d'eau.
17. La performance des différents joints de dilatation (matériaux et calcul).
18. La faisabilité de peindre le soffite.

MÉTHODE

La performance de 62 ouvrages de l'échantillon a fait l'objet d'un contrôle échelonné sur quatre ans. Des protocoles d'enquêtes standards sur l'état des garages à armature conventionnelle ou en béton précontraint par post-tension ont été mis au point à cette fin.

Les ouvrages étaient situés dans six provinces du Canada et affichaient différentes caractéristiques (âge, état, mode de réhabilitation, etc.). Les caractéristiques des ouvrages et leurs antécédents de réparation ont été documentés. La données sont présentées à l'Annexe A et les études de cas des ouvrages choisis figurent à l'Annexe B.

L'évaluation en laboratoire des produits de scellement du béton a été menée selon les méthodes d'essai déjà décrites dans le rapport client n° 3, l'effet de la résistance au cycle de gel et de dégel ayant été déterminé suivant les méthodes standards ASTM C666 et C490.

Les enquêtes sur l'état, à la suite du protocole standard décrit dans le rapport client n° 3, ont été menées par des maisons de consultants. Les résultats des enquêtes non standards, mis à la disposition des membres affectés à la recherche, ont également servi.

Les détails techniques du contrôle de l'humidité relative figurent à l'Annexe D.

RÉSULTATS

La tenue en service des ouvrages de stationnement en état de détérioration qui ont été réalisés sans protection suffisante contre la corrosion de l'acier d'armature peut problement être préservée jusqu'à la fin de leur durée utile.

Bien qu'aucune méthode ne soit supérieure à une autre, la solution vraiment la plus efficace tant sur le plan technique que financier consiste à effectuer les réparations tôt.

Les travaux de réparation les plus répandus, concernant le colmatage et l'imperméabilisation, donnent dans l'ensemble de bons résultats. Il faut cependant veiller à assurer une bonne adhérence entre la couche en place et la nouvelle couche de béton.

La protection cathodique ne met pas un terme à la corrosion, mais elle en réduit considérablement le rythme et diminue la concentration des chlorures autour de l'acier d'armature. L'installation et l'application appropriées de la protection cathodique peuvent toutefois se révéler difficiles. L'aptitude au service pose un problème pour les ouvrages sérieusement détériorés, à moins qu'une membrane d'imperméabilisation ne soit mise en oeuvre. Il est essentiel de confier à des experts le soin de procéder à un contrôle mensuel.

Les ouvrages appartenant au même type structural ne se détériorent pas tous au même rythme. Le rythme de détérioration des platelages en béton armé de l'échantillon, exprimé en fonction de la surface de délaminage déterminée par sondage à l'aide d'une chaîne, variait entre 5,8 % par année et 0,06 % par année.

Les résultats de l'essai de potentiel par demi-piles (ASTM C876.80) sont peu reproductibles et ne se rapportent pas nécessairement au taux de corrosion. L'essai convient surtout pour obtenir des renseignements précis.

Comme la cause principale de la corrosion tient à la forte concentration d'ions de chlorure dans le béton, le taux de détérioration de ce dernier dépend également d'autres paramètres comme sa teneur en eau. Les seuils de la concentration d'ions de chlorure ne peuvent pas à eux seuls servir de base pour prévoir la performance.

La présence d'une membrane d'imperméabilisation sur le platelage est certes bénéfique. Rien n'indique qu'elle emprisonne l'humidité.

La principale faiblesse de la plupart des membranes d'imperméabilisation tient à la médiocrité de leur surface d'usure.

Les dispositions de la norme CAN/CSA S413-87 visant les ouvrages de stationnement neufs semblent tout indiquées.

La conformité aux exigences de la norme CAN/CSA S413-87 permet de réaliser des ouvrages durables, affichant une tenue en service satisfaisante.

L'injection de graisse dans les gaines sèches non adhérentes d'un ouvrage en béton précontraint par post-tension semble retarder considérablement la corrosion de l'acier.

Les résultats de l'évaluation de l'état des câbles par la méthode du mouvement des gaz sont encourageants.

Les ouvrages précontraints par post-tension avec acier non adhérent peuvent afficher une bonne performance à condition d'être bien construits et entretenus.

Contrôler le degré d'humidité relative du platelage de l'ouvrage peut constituer un outil précieux pour évaluer la performance des sytèmes de protection.

L'humidité relative du platelage de béton d'ouvrages encloisonnés protégés par une membrane d'imperméabilisation en bon état est tellement faible que seulement une quantité négligeable de corrosion de l'acier d'armature se produit la majeure partie de l'année (de novembre à mai).

La résistance aux alkalis des produits de scellement du béton doit être déterminée en utilisant d'autres supports que des cubes de mortier de ciment Portland, comme la brique d'argile, qui devront être conditionnés à une humidité relative de 50 %, plutôt que séchés à 110 ° C avant la mise à l'essai.

Recommandations

1. Préconiser l'entretien continu plutôt que d'en effectuer peu ou pas du tout entre d'importants travaux de réhabilitation entraînera une performance presque optimale de l'ouvrage en tout temps, des réparations majeures moins fréquentes, une moindre interruption des services de stationnement et un coût global inférieur. Il sera cependant nécessaire d'affecter des fonds à l'entretien.

2. Pour favoriser un entretien continu, il est recommandé de tenir à l'égard de tous les ouvrages un registre faisant état :

   o de l'entretien prôné par l'ingénieur concepteur;
   o des travaux d'entretien effectués;
   o des rapports d'essai aux termes de l'enquête sur l'état des ouvrages;
   o de la description des réparations;
   o de la recommandations des fournisseurs de systèmes de protection, comme l'imperméabilisation ou la protection cathodique. Faire en sorte que le contrat d'achat prévoie un manuel d'entretien.

3. Les propriétaires doivent retenir à long terme les services d'un ingénieur consultant qui, après s'être familiarisé avec l'ouvrage, sera en mesure de leur recommander la marche à suivre tout indiquée pour corriger les défauts constatés lors d'une inspection visuelle ou à l'aide d'instruments.

4. La recherche interdisciplinaire visant à solutionner un problème particulier doit être encouragée et soutenue, puisque la correction de défauts est souvent possible en empruntant des techniques à d'autres disciplines (par exemple, l'imperméabilisation des ouvrages est empruntée à la technologie des couvertures, la protection cathodique à celle des pipelines et les revêtements d'époxy aux procédés chimiques).

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Half-cell test results in this report are all in negative volts measured against copper/copper sulfate electrode.

The negative signs have been , in most cases, omitted.

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DISCUSSION

INTRODUCTION

The parking garage problem deepened at a rapid rate when shortly after its emergence in the 1980's thousands of garages were found in need of repair and no proven method for their rehabilitation existed. The CMHC 1984 study showed that if not repaired rate of increase in delamination seems to escalate rapidly.

The Canadian Institute of Public Real Estate Companies, Canada Mortgage and Housing Corporation, the Ministry of Housing of the Province of Ontario, the National Research Council of Canada and Public Works Canada have decided to sponsor a project to provide information on the feasibility of rehabilitation and the merits of the various repair approaches.

A sample of garages was to be set up and the performance of the structures monitored in a uniform fashion and documented. The obtained data and conclusions derived by their analysis were to be made available to the engineering community, the industry and the owners enabling them to select a course of maintenance and repair most appropriate for a particular facility, as no single approach was expected to be suitable for all deteriorated structures.

An important objective was to achieve wide and rapid transfer of the obtained results through publication in the open literature, presentations and conferences and, by participating in the work of standards writing committees.

In addition other aspects of rehabilitation of deteriorated garages and the corrosion protection of new structures were to be examined.

This is the final report of the project.

1. Sample of Garages

To obtain data on the nature and severity of the parking garage problem, a sample of structures was set up. The intention was to gather the relevant characteristics of each parking facility and monitor its performance for at least a three year period.

Difficulties in acquiring the required data due to change of ownership or personnel, and the lack of records have been encountered in some cases. Consequently, enrolment of structures had to be actively pursued throughout the project period, while at the same time garages were removed from the sample if deemed not useful under the changed conditions. At the end 62 structures were in the sample.

The compiled data on the garages are given in Table 1 of Appendix A.

A brief summary of the characteristics is shown in Table 1 of this section.

It can be seen that a fairly good geographic distribution has been achieved; the garages are located in six provinces, and are exposed to the three major climates: those prevailing in Western, Central and Eastern Canada.

The sample well reflects the characteristics of the majority of garages in the field: The majority of structures were built in the 1970's, most of them are underground, and of reinforced concrete slab and column structural type. While the highest percentage of the total is located in Central Canada, the distinctly different group of post-tensioned garages typical of those in Alberta are also represented in significant numbers.

Of the 62 garages 40, or 65 percent, have been repaired at least once. The average age of the structures at the time of the rehabilitation was 13. years.

Table 1

Characteristics of Garages in the Sample

Number of garages in the sample	62
Geographic distribution of garage locations	
British Columbia	1
Alberta	12
Manitoba	1
South Western Ontario	15
South Eastern Ontario	19
Quebec	8
Nova Scotia	5
United States	1
Average age of garages	18 years
Oldest garage in the sample	64 years
Newest garage in the sample	3 years
Distribution by type of occupancy	
Office	23
Retail	2
Mixed, office/retail	15
Residential	22
Total area of garages	844,609 m^2
Average area per garage	13,622 m^2
Distribution by type of exposure	
Underground, enclosed	51
Freestanding, exposed	10
In the building, exposed	1

Table 1 (continued)

Characteristics of Garages in the Sample

Distribution by structural type	
Reinforced concrete slab and columns	36
Reinforced concrete slab and beams	10
Precast T beams	4
Post-tensioned	9
Steel frame	1
Waterproofing membrane	
In place	36
No membrane	21
No response	5
Concrete sealer	
In place	24
No sealer	28
No response	10
Repairs	
Repaired	40
Not repaired	10
No response	12
Average age at time of repairs	13.2 year
Total cost of first repairs	$11,507,174
Average cost of repairs per garage	$287,679
Total area repaired (suspended slab)	343,896 m^2
Average cost per m^2	$33.46

The cost of repairs was $11,507,174, or $287,679 per garage. Disregarding expenditures, if any, on the slab-on-grade and columns, the average cost per square metre of the structural slab was $33.46 or $3.11/ft^2.

2. Case Histories

Considering that the number of garages in Canada is estimated to be 5,000, the size of the sample does not permit a meaningful statistical analysis, particularly in view of the variability of the large number of parameters. Instead, a number of case histories of structures have been compiled, and the collected data analyzed where possible. These are presented in Appendix B.

3. Rate of Delamination

It would be of great value if expected performance of garages could be predicted. The data obtained in the present study were examined to explore the possibility.

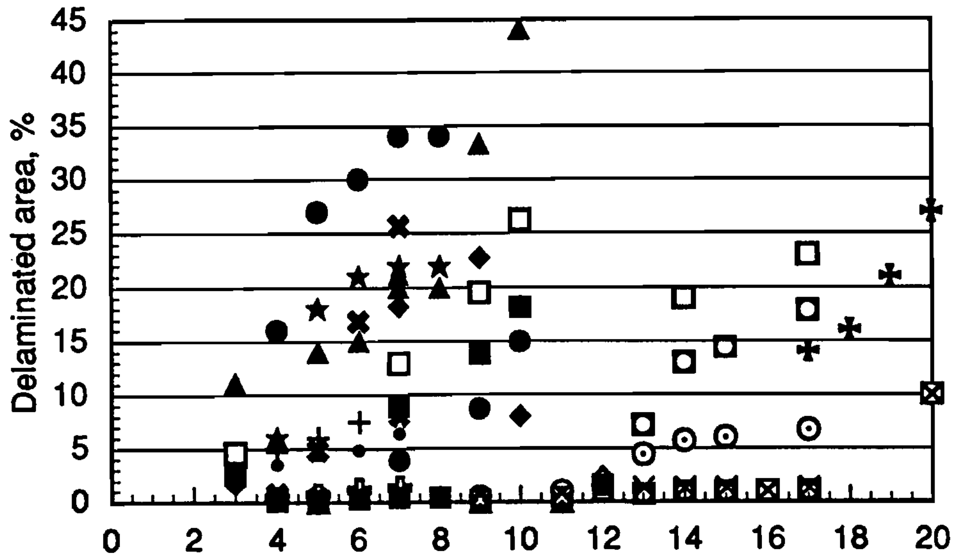
In Figure 1 the values of the delaminated area found in condition surveys carried out at various times after a major rehabilitation of garages are shown. Post-tensioned and cathodically protected structures were excluded.

Understandably, garages do not deteriorate at a single rate. Features, such as:

- the thickness of the cover over the reinforcing steel, the slope of the deck, the effectiveness of the waterproofing provided, etc;
- the quality of past repairs viz. thorough removal of delaminated concrete and where necessary below the reinforcing steel;
- good bonding between the patch and the old concrete;
- the type of usage, short vs long term parking;
- environmental conditions viz. temperature, relative humidity;

will affect or determine the rate of deterioration. The actual rate observed varied between 35% over 6 years (5.8%/yr) and 1% over 16 years (0.06%/yr).

Fig. 1
Rate of delamination of garages after major rehabilitation
(reinforced concrete decks)



It has to be emphasized that the inability of differentiating reliably between the soundings produced by delamination in the concrete and that by debonding of the waterproofing membrane from the concrete structure is also a major reason for the wide scatter of the results. Our efforts, partly funded by the Industrial Research Assistance Program, in the first year of the project to encourage Canadian instrument manufacturers to develop a reliable instrumental method for the accurate measurement of delaminations in concrete has not yielded useful results.

Even though no universal rate of deterioration exists, useful information can be extracted from the case histories of some of the garages.

Firstly it can be seen that if the chain drag tests are performed at periodic intervals the general trend can be ascertained with perhaps an acceptable degree of uncertainty. Please see in Appendix B Figures 18.1, 18.2 (p.6,7), 19.1, 19.2 (p.19), 20.1 (p.30), 29.1 (p.45), 30.1 (p.49), 53.1 (p.74), 55.2 (p.92), 56.1, 56.2 (p.97), 58.1 (p.111), 62.1 (p.132), 63.1 (p.138), and 64.1 (p.143). Because sudden rate increases can occur, the delamination test should be performed at a frequency of not more than at two or three year intervals. For example, in Garage No. 55 the upper ramp showed a sudden rate change in 1988, four years after repairs, that was not occurring in the other test sites. The rapid deterioration was detected by the yearly surveys (Fig. 55.2, p.92 Appendix B). Incidentally, this high rate of deterioration was most probably caused by frequent heavy traffic associated with short term parking while the rest of the garage is used for long term parking by residents and office employees.

Delamination increases with time in an exponential fashion (e.g. Fig. 18.2, p.7, Appendix B) but over a period of 4-5 years the rate can usually be described by a linear equation (Fig. 18.3, p.7 Appendix B).

Thus, it has to be concluded that the most important parameter, the rate of deterioration, can be determined by the chain drag test if performed at intervals of two-three years. This approach not only makes an assessment of the condition possible but also enables planning repairs in a safe fashion while harmonizing the rehabilitation with other non-technical considerations such as timing of garage closure for repairs, budgetary allocation, etc.

The results of an ongoing survey at 2-3 years intervals enables extrapolation of the rate of deterioration over a few years, usually with fairly good accuracy and minimal risk. The frequent survey minimizes the risk of the development of a safety problem.

4. Half Cell Potential

Determination of the electrical half cell potential of the reinforcing steel against a copper/copper sulfate standard electrode is normally carried out routinely as part of a detailed condition survey of garages. The methodology of the test is specified by American Society for Testing and Materials (ASTM) C876.80 Standard Test Method which suggests 1.2 m spacing between measurement points. In a large garage hundreds of determinations are performed. It is, therefore, of interest to examine the merit of the half cell potential test.

We have reported in the Progress Report of 15 December 1990 the results of the analysis of the data obtained in Garage No. 51. It was concluded that at least in this structure the repeatability was poor and this was probably due to changing resistivity of the concrete cover, caused by moisture content changes.

Opinions have been expressed that the poor results were possibly due to stray currents in this structural steel frame garage. The data collected in reinforced concrete structures provide an opportunity to check the validity of this assumption.

The agreement between the results of the chain drag and half cell potential tests in the case of Garage No. 53 is not very good (Please see "Half cell Potential" page 70, App. B).

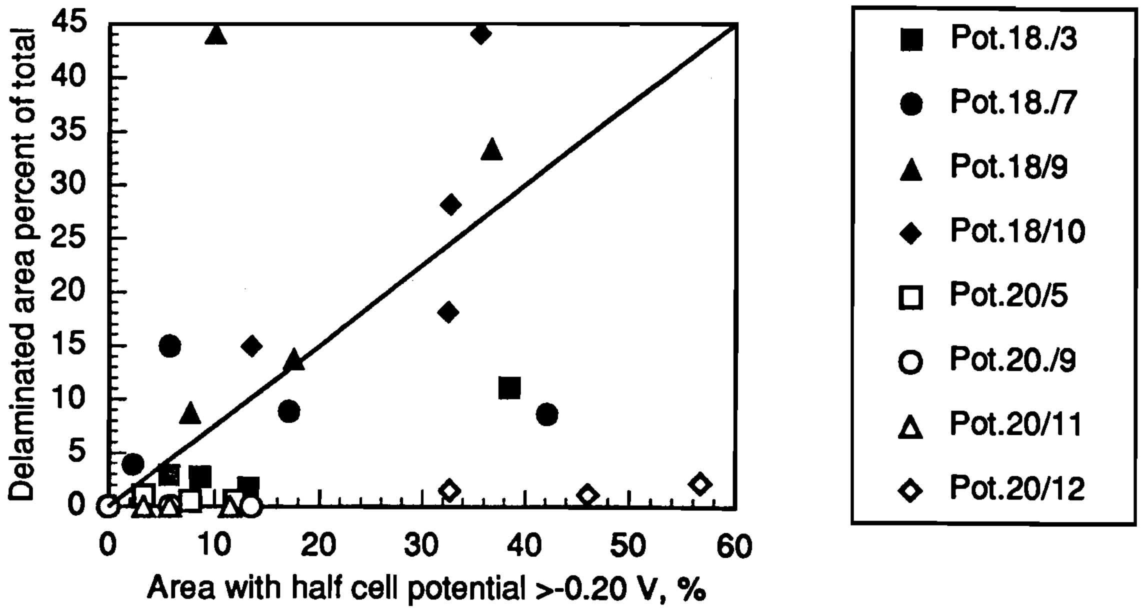
Garage No. 54, is in an excellent condition with 4.7 m^2, or 0.6%, hollow sounding area in 763.8 m^2 surveyed area (p.81, App. B). Half cell potential measurements indicated 0.6% area probably and 6.1% area possibly corroding. In this case the >-0.35 readings are in very good agreement with the chain drag test findings, though the hollow soundings were almost certainly caused by poor consolidation of the concrete at the time of placing it. The half cell potential of the steel in Garage No. 59 determined at approximately six months intervals since the completion of the construction show large variations. (Table 59.1, page 117, App. B).

The deterioration of Garage No. 64 progressed to such extent that repairs had to be undertaken 8 years after the previous rehabilitation in 1981, yet the half cell potential indicated decreasing corrosion activity (Figs. 64.7, 64.8 and 64.1, Appendix B, pp.146, 143).

The percent of the area in which the half cell potential was greater than -0.20 V plotted against the percent of the area in which hollow soundings were found by the chain drag test in Fig. 2. If both tests performed in

Garages No. 18 and 20 were in full agreement, the points would fall in the plot on the 45° line. No such tendency can be detected, in fact, there appears to be no relationship of any kind between the results of the two tests.

Fig. 2
Area with hollow soundings vs. area with half cell potential > -0.20 V



In the case of highway bridges in Switzerland, B. Elsener, S. Müller, M. Suter and H. Bohni concluded that "it is clearly shown that fixed potential value (as proposed in ASTM 876-80) for the identification and location of active corrosion of steel in concrete does not exist (corrosion monitoring steel in concrete-theory and practice in Corrosion of Reinforcement in Concrete, C.L. Page, K.W. J. Treadway, P.B. Banforth Eds, Society of Chemical Industry, Elsevier Applied Science, 1990. p.348).

Similar conclusions were reached by E. Escalente at the National Institute of Standards and Technology in the U.S.A. He writes: "The results in the laboratory reveal that corrosion potential measurements can serve as a good indicator of the corrosion performance of steel in concrete, showing that potential is inversely proportional to corrosion rate. However, similar field measurements on bridge decks reveal no such relationship between corrosion potential and corrosion rate measured by electrochemical means, suggesting that potential surveys of steel reinforcing in bridge decks may be misleading as an indicator of corrosion performance.

("Effectiveness of potential measurements for estimating corrosion of steel in concrete" in Corrosion of Reinforcement in Concrete, C.C. Page, K.W.J. Treadway, P.B. Bramforth, Eds. Society of Chemical Industry, Elsevier Applied Science, 1990, p. 281).

The results of the present project show that the potential measurements in garage decks also are of little value and should be carried out mainly for obtaining specific information.

5. Chloride Ion Threshold Value

As it is well known, concrete is highly alkaline (pH 12.5), and in this medium a corrosion resistant film develops on the surface of the steel protecting it from rusting. Chloride ions if present, however, destroy the protective layer and corrosion will take place provided moisture and oxygen are available.

Understandably, the threshold value of chloride ion concentration, above which deterioration will take place, is of great interest.

American Concrete Institute Committee 222, Corrosion of Metals in Concrete (ACI Journal, January/February 1985, p.3), summarizes the findings on the value of the threshold concentration up to 1985.

Work at the Federal Highway Administration Laboratories showed that corrosion of steel in hardened concrete will occur above 0.035 percent chloride, in terms of mass of concrete. This was confirmed by field studies of bridge decks in California and New York. More recently, B.B. Hope and A.K.C. Ip in laboratory investigation found corrosion to take place under various indoor and outdoor exposures to commence at concentrations between 0.014 and 0.022 percent soluble chloride ion by mass of concrete.

In the present study several garages were found to perform acceptably with chloride concentration of the concrete above 0.035 percent.

Garage No. 62 is one of the structures well performing after rehabilitation, yet the chloride ion content at the reinforcing steel level is 0.15%. (Figs. 62.2, 62.1 App. B. p.132).

The delaminated area in Garage No. 53, 17 years after construction, is 5 percent while the chloride ion content of the concrete is more than ten times of the threshold level (Fig. 53.9, Tbl. 53.1, Appendix B pp.79 and 72).

Garage No. 55 is, 15 years after construction, in a relatively good condition yet the chloride ion concentration of the concrete at the steel level is 0.3 percent (Fig. 55.3 App. B. p.93).

Garage No. 64 is in a poor condition and is now, in 1992, being repaired for the second time. The chloride concentration of the concrete of the steel horizon reached 0.6 percent. (Figs. 64.3, 64.4, 64.5, 64.6, App. B. p.144-145).

The findings suggests that:

- while the intensity of the corrosion activity is a direct function of the chloride concentration of the concrete,
- it is possible to achieve good performance despite high chloride concentrations if moisture is excluded from the deck.

6. Chloride Content of Aggregate

In fairly new structures located in South-Western Ontario, uniform chloride distribution were detected in the concrete to a depth of 50 mm (Garage No. 72, Garage No. 73, Appendix B p.149, p.151). As chloride based admixture has not been used, this result suggests that the chloride originates from the aggregate and not from external sources.

It is known that limestone in the Niagara Peninsula contains chlorides in relatively high concentration, typically 0.125 to 0.166 percent, but it is often not realized that a third of this amount or more, is water soluble.

It is recommended that for new post-tensioned garage construction aggregate with low chloride content be specified.

7. Waterproofing Membranes

The primary defense against water and chloride intrusion into the concrete deck is, in the majority of cases, a waterproofing membrane. On the whole, this approach works well.

There is no indication that installation of a membrane over a salt contaminated deck is ineffective, or even harmful as it has been feared.

The lifespan of the waterproofing membrane appears to be 10 years. (Garage No. 20)

The major weakness of the membrane is the wearing course. Turns, entry and exit ramps and other heavily travelled areas are usually the first locations in which the membrane fails. (Garage No. 20, Garage No. 59, Garage No. 24, Garage No. 74, Garage No. 55). The problem of the wearing course raises the question whether the much more substantial thick systems would not be preferable in some applications.

The efficiency of the membrane is well illustrated in Figs. 74.1 and 74.2 (Appendix B, p.156-157), where the areas marked "missing membrane" and "delaminated concrete" in most places coincide.

8. Concrete Sealers

Because they merely reduce rather than prevent water ingress into the deck, concrete sealers are used mainly in "crack free" post-tensioned and prestressed structures.

Tests performed show that the sealers used in Garages No. 68 and No. 72 on two hour exposure to water reduce absorption to approximately 10 percent of that of the same concrete with untreated surfaces . On longer exposure, such as 6 days, the benefit of sealer coating decreases to 50 percent absorption in terms of the untreated concrete. Thus, on garage decks with good slopes, on which no excessive ponding occurs, sealers seem to have merit.

There are several advantages in using sealers. They make early detection and repair of defects possible, and recoating the repaired concrete presents no difficulties. The cost of the sealers is a fraction of that of membranes. On the other hand, the inability to seal newly formed cracks once in place, the limited abrasion resistance and alkali sensitivity can in some cases be serious drawbacks.

Still, in the sample there are several examples of good performance shown by garages protected with sealers. Garage No. 31, a reinforced concrete structure, the deck of which has been protected with a polymethyl-methacrylate sealer from the time of construction in 1976, reapplied 16 years later, shows an estimated 10 percent delamination after 20 years of service.

Garage No. 32, no moisture barrier was installed at the time of construction in 1975, five years later a polymethyl-methacrylate sealer was applied on the deck, reapplied four years later, and now has an estimated delamination of the order of 3 to 5 percent.

These good performances could hardly be improved by using membranes. It seems that good quality sealers, properly applied and periodically renewed, have a lot to offer. The major impediment for the use of sealers is the lack of standards. This situation makes the selection of a sealer appropriate for a particular garage very difficult.

9. Cathodic Protection

Three garages, No.s 52, 57 and 63, in the sample are, at least partly, cathodically protected. The details of the case histories are described in Appendix B (p. 58, 100 and 134). In view of the small number of garages, only a few comments on the general aspects can be made.

- Cathodic protection (CP) very substantially reduces corrosion of the reinforcing steel. In garages in which CP was installed (Garage No. 57, Garage No. 63) in five years the delamination rate was 2 percent or less. It has to be mentioned that in Garage No. 63 a waterproofing membrane has also been installed;

- The chloride concentration around the reinforcing steel significantly decreases in CP protected garages , as it can be seen in Fig. 63.2 Appendix B. p.138).

The still problematic aspects of the method are:

- It can be a long-drawn tedious procedure to detect and eliminate all the electrical shorts which defeat the CP system;

- Due to the inaccuracy of the placement of the reinforcement in most existing structures it seems virtually impossible to achieve uniform current distribution and 100 percent protection;

- The accumulation of aggressive chemicals, produced by the electrolysis of the sodium chloride deicing salt at the anode, often causes debonding of the conductive anode layer, which then has to be repaired after it has been detected;

- In deteriorated garages leakage through the deck can create serious serviceability problem that can be solved only either by an extensive trough system or the application of an expensive waterproofing membrane;

- The operation of a CP system requires continuous monitoring by qualified personnel to make the necessary adjustments in the operating electrical conditions, and to perform repairs of the hardware; and

- Although no life cycle costing is available, in view of the capital cost and maintenance fee, the cost effectiveness of the CP based approach will have to be determined.

These tentative conclusions are in agreement with the findings published in the literature (R.P. Brown and J.P. Tinnea, "Cathodic Protection Design Problems for Reinforced Concrete", Materials Performance, 30, No. 8, p.28-31, 1991 and K. D. Bright "Testing Cathodic Protection Systems" Concrete International P.37-34, July 1991.)

As discussed in the case histories (Garage No. 52, App. B., p.58; Garage No. 57, App. B, p.102; Garage No. 63, App. B., p.136) the National Reinforced Concrete Cathodic Protection Association (NRCCPA) adopted a set of CP criteria that are very different and less stringent than those specified by the RP0290-90 standard of the National Association of Corrosion Engineers (NACE). The conflict between the views held by the large society and that of the Canadian industry association has to be resolved, and until this is accomplished the NRCCPA criteria will remain in doubt.

10. The Merits of The Provisions of the CSA 413-87 Standard

At the time of developing the CSA standard in the mid 1980's, the Committee established specifications for the design and construction of parking structures that were not yet proven by field experience. There are structures built before 1987, which were designed with a level of corrosion protection essentially conforming with the CSA S413 Standard making it possible to assess the value of the provisions of the Standard. These garages are:

Garage No. 54 (Appendix B, p.80), Garage No. 58 (Appendix B, p.110), Garage No. 59 (Appendix B, p.112) and Garage No. 60 (Appendix B, p.129).

The common features of these structures are good concrete cover (40 mm), good drainage, waterproofing membrane installed at the time of construction (except Garage No. 58) and relatively low water/cement ratio concrete, 0.45 in the case of Garage No. 54, 0.49 in that of Garage No. 59.

All the garages perform well, have very little delamination and low chloride concentration in the concrete deck. It seems reasonable to conclude that:

- durable garages can be built, and
- the provisions of CSA S413-87 seem to be, on the whole, appropriate.

11. Post-tensioned Garages

Posttensioned garages with unbonded tendons presents a major problem because corrosion of the strands can lead to cable eruption and to structural deficiency if not repaired.

The situation is made more serious by the lack of proven non-destructive test method for the assessment of the condition of the tendons.

In current practice, sections of cables are exposed and visually inspected, or pulled, examined and replaced. While the former method is based mainly on engineering judgment, the latter is very expensive, costing for a multi storey parkade $2-$4 million.

There are seven post-tensioned garages in the sample which can be divided into two broad groups: those of earlier vintage constructed without adequate safeguards and the more recent ones, designed with a conscious effort to provide adequate corrosion protection.

Garage No. 21 is a representative example of the first group. The maintenance objective in this case is to operate the facility in a safe manner to the end of its design life.

The case history of the East Parking Structure (Appendix B p.33) describes the repairs involving flushing the ducts with nitrogen gas followed by injection of grease under pressure. No cable eruption occurred since time of the administration of the above procedure in 1983.

A further development by Vanco Structural Services aims to minimize reliance on circumstantial evidence and engineering judgment in assessing the condition of post-tensioned garages. The results, of the trials obtained with our assistance, are described in Appendix C and are encouraging.

Other post-tensioned garages of early vintages are operated without much problem. Their performance is closely monitored, defects repaired if judged to be necessary, and the concrete sealer periodically reapplied. Garages No. 28 and 29 are examples for this approach (App. B, p. 41, 42).

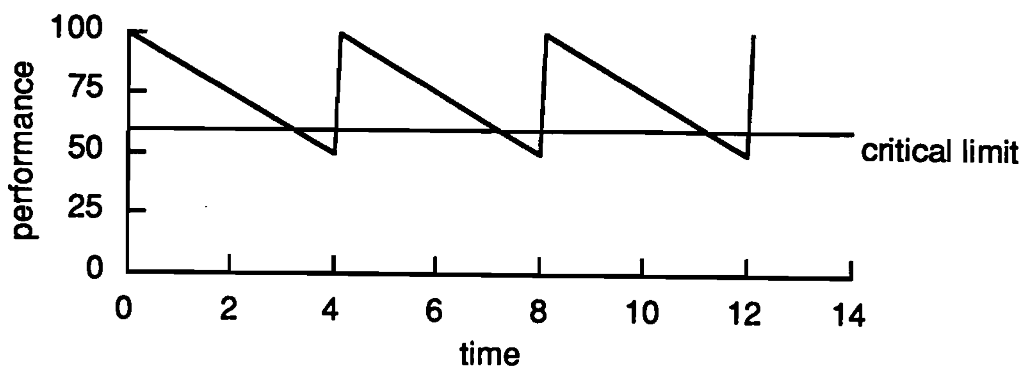
Garages No. 68, 69, 72 and 73 are representative of another class of post-tensioned garages. In the design of these relatively recently constructed structures protection of the post-tensioning steel from corrosion was assigned top priority. Beyond using cables with extruded plastic sheathing, ingress of water into the deck has been minimized by the application of a sealer and good drainage system. Most importantly, the performance of the garages is being monitored and the necessary repairs effected.

The case histories of the post-tensioned garages prove that durable structures can be constructed and older deteriorating garages can be repaired and operated in an apparently safe and satisfactory manner.

12. Repair of Deteriorated Garages

The typical performance of garages in time can be represented schematically as shown in Figure 3.

Fig. 3
Performance of a garage in time



Performance decreases rather rapidly below the critical limit at which time rehabilitation is needed to restore the level of performance, ideally to its design level. Because of the elevated chloride concentration of the concrete, deterioration reoccurs and eventually another repair will be necessary.

In practice, there are essentially two options in dealing with deteriorated conventionally reinforced parking structures: the "patch and waterproof" approach and cathodic protection (CP).

As also the case histories of garages in the sample show the patch and waterproof method is the most common and, on the whole, works well (e.g. Garage No. 62, 5 years after repairs shows less than 3 percent delamination). Apart from the problem caused by the high chloride concentration, most difficulties are related to debonding of the patch from the old existing concrete. (Garages No. 18, 64 and 57).

It is perhaps useful to point out that good bond between the original and repair concrete can be achieved if care is exercised. (All unsound concrete should be removed to a vertical face to avoid feather edging, the debris removed, the existing concrete moistened, a cement slurry bonding agent applied and the new concrete placed when the bonding coat is partially set). In an effort to cut cost and to save time, shortcuts are often taken that lead to unsatisfactory results. Hiring an independent supervising consultant experienced in garage rehabilitation is essential.

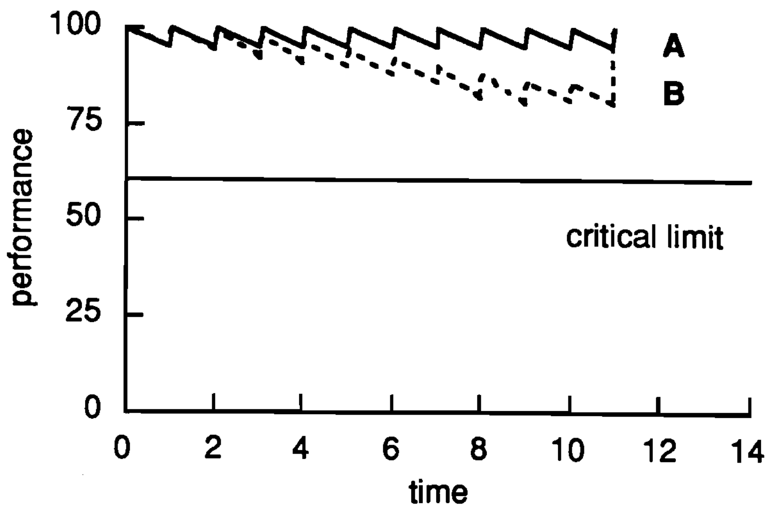
The merits and disadvantages of the other alternative repair method, CP, have been discussed above in Section 9, and need not be repeated. From a repair strategy point of view the case of Garage No. 57 is instructive inasmuch as it suggests that CP alone is not a viable option in dealing with seriously deteriorated structures; the leaking cracks have to be sealed or a waterproofing membrane installed, to assure good serviceability.

The timing of the rehabilitation with respect to the development of the defects seem to be of paramount importance.

In practice a garage is usually repaired when its performance is unacceptable to the users, or some time after that when funding is available. This practice although very understandable, is the least cost effective approach. This conclusion is based on numerous examples provided by the case histories, e.g. membrane defects that were left in a state of disrepair until the concrete deck required extensive restoration (e.g. Garage No. 74, App. B., p. 154).

The performance in time if repairs are carried out at frequent intervals is represented by curve A of Fig. 4. Even if full restoration is eventually becoming difficult or impractical (Curve B), the great benefits of on-going rehabilitation is continuous excellent performance at a fraction of the cost of the major renovation approach.

Fig. 4
Performance of a garage.
The effect of ongoing repairs



Why then is this strategy not adopted by more owners?

Firstly, many owners held the mistaken belief that a major rehabilitation not only corrects the deficiencies but also provides trouble free performance for a very long time. They are now realizing that to keep a garage operating in a safe and serviceable condition requires continuing attention.

Secondly, few owners, or their in-house staff, are sufficiently knowledgeable to handle the technical aspects of the repairs themselves without outside experts whom they call in only for major rehabilitations.

Thirdly, many consultants were not too eager to assume a custodian role of a garage structure and to perform yearly visual surveys and to recommend repairs when appropriate. Their reluctance was probably caused by the concern of encountering sudden gross deterioration, which some clients may claim should have been anticipated and avoided.

Gratifyingly, with the accumulation of field experiences major surprises are now less likely.

Thus it appears that the on-going repair approach is not only desirable but has now become feasible.

The cost of a yearly visual survey of a garage with 9,300 m^2 (100,000 ft^2) area is in the order of $1,000, (as of 1992), if drawings are available and the consultant is familiar with the repair history.

A full condition survey of a typical 9,300 m^2 garage costs about $10 to $12,000. This survey has to be carried out only at 2-3 yar intervals, or when the visual survey indicates a need for it.

13. Garage Log-Book

The lack of records on garage history, repairs and surveys causes inefficiency, added expenses, delays and other difficulties. Typically, the as built blue prints of the garage are not available, and uncertainties exist concerning most repair actions. Particular problems arise if change in property management personnel in large real estate companies or public housing authorities occurs.

It would be of great benefit to have a garage log-book in which all relevant information were entered.

In addition to the records, the book should also contain a maintenance schedule for the property manager on servicing and cleaning the garage. A short list includes:

- checking the proper functioning of the drains;
- sweeping and washing the floor at least once a year;
- inspection for water leakage and ponding; and
- checking for defects of the waterproofing system.

A detailed Maintenance Manual has been published in 1988, by the Canadian Parking Association 33 Queen St. East, Toronto, Ontario, M5C 1R5.

14. Epoxy Coated Reinforcing Steel

We have reported in 1989 that excessive cracking, not caused by corrosion, was observed in several garages constructed with epoxy coated reinforcing steel. While the great majority of structures constructed with epoxy coated steel perform very well, the discovered defects are of concern.

Several discussions with members of the Canadian Prestressed Concrete Institute resulted in an informal survey of recently constructed garages containing epoxy coated reinforcing steel by their committee.They reported that "definite correlation between excessive cracking and the use of epoxy rebar" could not be detected. The survey is continuing and the results will be updated periodically.

CPCI also contracted researchers of McGill and Waterloo Universities and the University of New Brunswick to investigate various aspects of the epoxy coated reinforcing steel construction of parking garages.

15. Monitoring of the Relative Humidity and Temperature in Garage 20

As reported earlier, the relative humidity and temperature prevailing in a suspended concrete deck has been monitored by Tekron Associates, as subcontractor, until sensors were removed in the course of garage rehabilitation.

In view of the usefulness of the obtained results it was decided to continue this activity in Garage No. 20.

The technical details of the installation, the numerical data collected, and the discussion of the results are given in Appendix D.

The conclusions reached are as follows:

1. Waterproofing membrane installed in Garage no. 20 was able to reduce moisture infiltration and consequently moisture content in the suspended deck to a very significant degree;

2. The relative humidity in the concrete protected by a membrane in good condition is so low, that in a great part of the year from November to May, little or no corrosion of the rebar occurs;

3. Concern over possible moisture condensation through the soffit, in quantities that may raise the RH values to near saturation level, proved to be groundless;

4. Notwithstanding its elastic nature, membrane can be torn by some cracks in the concrete compromising its waterproofing ability;

5. Conclusion No.4 underscores the importance of proper crack sealing before the installation of the membrane;

6. While the data prove the great merit of membranes, the benefit remains a potential rather than reality if not properly maintained and repaired;

7. These conclusions appear to be of general validity and are not the result of the unique features of Garage No. 20;

8. The used instrumental set-up proved to be simple to operate and reliable. Consideration should be given to utilizing it in condition surveys if deemed useful.

16. Alkali Resistance of Sealers

Several generic types of concrete sealers are known to react with alkalis and thus losing their waterproofing quality. Portland cement concrete being highly alkaline, there is a concern that alkali sensitive sealers applied onto concrete will lose their effectiveness.

A Task Group of the American Society for Testing and Materials was given the mandate to develop a standard that will ensure adequate alkali resistance of sealers. In order to accomplish this task, a test method for the assessment of alkali resistance is needed. IRC has taken part as member of the Task Group and carried out work, a summary of which is given in Appendix E.

17. Technology Transfer

Throughout the contract period it has been our practice to transfer information gained through our activities to the engineering community, owners and the interested public. It was felt that rapid communication was of benefit even if the work was not fully completed and the obtained results failed to explain all aspects of the problem. A list of the papers written and lectures presented is given in Appendix F.

18. Standard Writing Committees

The parking garage problem emerged in the early eighties without previous history and at a large scale. The enormity of the tasks viz. to repair an estimated 5,000 garages without any proven technology, and to develop specifications for new garages that will ensure lasting good performance created a crisis atmosphere. Consensus standards that summarize the existing knowledge on the various aspects of garage construction, repair and maintenance, was clearly the best option under the circumstances. For these reasons the Project Manager became a member and actively supported the relevant standard writing committees listed in Appendix G.

19. Previously Reported Sub-Projects

Several sub-projects were completed and reported previously. A list of these sub-projects appears in Appendix H.

20. Waterproofing Systems

Evaluation of the most frequently used waterproofing systems has been reported separately. "Evaluation of Elastomeric Membrane Systems used in Parking Garage Protection", 10 February, 1992.

21. Regional Differences

Although structures in the sample were located in six provinces, no useful conclusions could be arrived at concerning differences if the levels of protection required in the various climatic regions of the Canada. The in-homogeneity of the sample and the multiplicity of parameters affecting the performance prevented ascription of the observed differences in deterioration rates to regional effects. Generally speaking, parking garages seem to be subject to degradation in all major urban centres of Canada with the exception of Victoria B.C. While the conditions in Vancouver are far less harsh than in other parts of Canada, salt is still used and parking structures and bridges require protective measures.

22. The Influence of the Type of Structural Design on the Performance of Garages

The structural design types represented in the sample include
- reinforced concrete flat slab and supporting column structures;
- reinforce concrete beam and slab structures;
- post-tensioned structures;
- precast concrete structures;
- structural steel frame with reinforced or precast concrete floors.

Both, well and poorly performing garages of these structural types were encountered. In no case could the type of structural design identified as a dominant factor under all circumstances for the success, or the problems experienced with a garage. It has to be stressed that the above statement refers to the type of structural design and not the structural design itself. Improper design can lead to excessive cracking, water ingress, and other difficulties, and numerous examples of this have been reported in the case histories, Appendix B.

23. Expansion Joints

Leaking expansion joints are one of the most commonly observed defect in parking garages. It is very rare to see a well functioning expansion joint a few years after its installation. A failed expansion joint causes not only leakage through the slab but opens up a pathway through which salt containing water can penetrate the concrete deck. Measures to improve the performance and longevity of expansion joints is highly desirable.

24 Conclusions

24.1 Deteriorating parking structures designed and constructed without adequate protection against corrosion of the reinforcing steel can be kept in a serviceable condition, most probably until the end of their design life;

24.2 While no single repair method is superior to another, early repair is clearly the most effective from a technical and economic point of view;

24.3 The most common repair method, "Patch and Waterproof" works, on the whole, well. Care has to be exercised to achieve good bond between the existing and new concrete;

24.4 Though cathodic protection, (CP), does not arrest corrosion, it substantially reduces its rate and decreases the concentration of chlorides around the reinforcing steel. Proper installation and operation of the CP system can be a difficult task. Serviceability is a problem in seriously deteriorated structures unless a waterproofing membrane is installed. Regular monthly monitoring by qualified personnel is essential;

24.5 Garages even of the same structural type, do not deteriorate at the same rate. The deterioration rate of reinforced concrete decks in the sample, expressed in terms of the delaminated area as determined by the chain drag test, varied between 5.8%/year and 0.06%/year;

24.6 The half-cell potential test (ASTM C876.80) results have poor reproducibility and are, under field conditions, not necessarily related to corrosion rate. The test is suitable mainly for obtaining specific information;

24.7 While the high chloride ion concentration in the concrete is the primary cause of corrosion, the rate of concrete deterioration depends also on other parameters such as its moisture content. Single chloride ion concentration threshold values cannot serve as a basis for prediction of performance;

24.8 The presence of a waterproofing membrane on the deck has been beneficial. There is no indication of moisture entrapment;

24.9 A major weakness of most of the existing waterproofing membrane system is the inadequacy of the wearing course;

24.10 The provisions of the CAN/CSA 413-87 Standard for new garages seem to be appropriate;

24.11 Durable, well performing garages can be built by complying with the requirements of the CAN/CSA 413-87 Standard;

24.12 Injection of grease into the dried ducts of an unbonded Post-tensioned structure appears to significantly retard the corrosion of the steel tendons;

24.13 The results of the cable condition assessment by the gas flow method are encouraging;

24.14 Post-tensioned garages with unbonded tendons can perform well if designed, constructed, and maintained properly;

24.15 Monitoring the relative humidity, RH, prevailing in a garage deck can be a valuable tool in assessing the performance of protective systems;

24.16 The RH in the concrete deck of enclosed garages protected by a waterproofing membrane in good condition is so low, that only negligible corrosion of the reinforcing steel takes place in a great part of the year (November to May);

24.17 The alkali resistance of concrete sealers should be determined by using substrates other than portland cement mortar cubes, like clay brick, which should be conditioned at 50% RH, rather than dried at 110°C before testing.

25. Recommendations

25.1 A policy of continuous maintenance should replace the present practice of carrying out little, or no, maintenance between major rehabilitations. The proposed policy will result in close to optimal garage performance at all times, less frequent major repairs, less disruption of parking services and lower life cycle cost. It will be necessary, however, to provide funds in the budget for the maintenance activity.

25.2 In order to facilitate continuous maintenance, every garage should have a log book containing:

- the maintenance actions recommended by the design engineer;
- the records of the maintenance actions performed;
- the condition survey test reports;
- the description of repairs;
- the recommendation of suppliers of installed protective systems, such as waterproofing or CP systems. Provision of a maintenance manual should be stipulated by the purchase contract.

25.3 Owners should retain on a long-term basis the services of a consulting engineer who, after familiarizing himself with the structure, will be in a good position to recommend to the owner the most appropriate course of action to eliminate defects discovered by visual or instrumental condition surveys.

25.4 Interdisciplienary reserarch aiming to identify solutions for a particular problem should be encouraged and supported, because the modes of corection of defects is often possible by borrowing techniques used in other disciplines (e.g. in the case of garages waterproofing was imported from roofing, cathodic protection from the pipeline and, epoxy coating from the chemical process technology).

APPENDIX A

Table 1. Garage Sample

No	Property				Garage			
	Yr built	Yr. acqu'd	Type	Size,squ.m	Type	Size,sq.m	No.stalls	No.lev'ls
12	1976	1981	commer	13,011	free stand	6,552	220	3
13	1976	1981	commer	13,011	undergr	4,182	100	2
14	1976	1978	commer	14,498	undergr	8,364	-	2
15	1974	1976	commer	11,431	undergr	1,859	-	2
16	1981	1981	commer	65,056	undergr	12,546	160	2
17	1972	1972	commer	15,799	undergr	2,695	88	3
18	1970	1970	commer	61,059	undergr	19,194	647	2
19	1975	1975	mixed	-	undergr	12,600	532	3
20	1967	1967	commer	-	undergr	16,000	-	8
21	1973	1973	retail	74,814	free stand	74,814	1600	3
22	1960	1960	com.ret	300,000	undergr	25,093	700	2
23	1928	1974	com.ret	90,928	free stand	24,721	685	12
24	1975	1975	com.ret	83,643	undergr	4,926	148	4
25	1973	1973	com.ret	50,186	free stand	20,911	625	7
26	1980	-	resid	-	undergr	6,102	-	4
27	1981	-	resid	-	undergr	6,401	-	3
28	1965	1964	resid	-	undergr&exp	7,110	170	2
29	1969	1969	com.mix	36,245	free stand	18,587	600	5
30	1969	1969	com.mix	36,245	free stand	39,033	1000	6
31	1971	1971	resid	3,636	undergr	7,156	190	2
32	1975	1975	resid	3,253	undergr	4,647	110	2
33	1977	-	com.res	-	undergr	44,940	-	4
34	1978	-	resid	-	undergr	9,796	-	5
35	1978	1978	commer	-	undergr	4,786	135	2
36	1980	1980	commer	7,063	undergr	2,612	75	2
37	1968	1968	resid	-	undergr	5,409	170	2
38	1966	1966	resid	-	undergr	2,509	72	2
39	1970	1971	commer	-	undergr	5,548	160	3
40	1961	1965	mixed	-	open	2,230	64	1
41	1961	1965	mixed	-	undergr	2,667	50	1
43	1966	1966	resid	-	undergr	15,428	460	2
44	1975	1985	commer	-	undergr	8,086	209	3
45	1980	1981	commer	22,995	undergr	5,395	148	3
46	1982	1982	commer	86,405	undergr	20,820	500	3
47	1980	1980	commer	55,379	undergr	6,041	-	2
48	1977	1977	commer	22,291	undergr	6,306	216	4
49	1979	1979	commer	26,246	undergr	3,353	104	2
50	1987	1987	retail	-	free stand	29,368	500	2
51	1957	1957	commer	-	undergr	5,019	108	6
52	1971	1971	resid	15,829	undergr	5,916	156	2
53	1975	1975	mixed	-	undergr	11,894	324	3
54	1977	1977	commer	-	undergr	13,941	300	2
55	1977	1977	mixed	5,210	undergr	8,296	118	2
56	1971	1972	resid	20,000	undergr	7,203	228	4
57	1978	1983	resid	-	undergr	18,587	-	2
58	1979	1979	com.ret	4,024	undergr	4,540	132	2
59	1985	1985	commer	-	free stand	32,344	976	3
60	1983	1983	commer	78,178	undergr	13,071	304	4
61	1974	1974	commer	55,099	undergr	2,972	70	1
62	1975	1975	resid	-	undergr	2,792	-	2
63	1970	1970	resid	-	undergr	7,460	-	-
64	1970	1970	resid	-	undergr	13,462	-	3
65	1973	1973	resid	-	undergr	9,721	-	-
67	1986	1986	resid	-	undergr	8,445	-	2
68	1984	1984	resid	-	undergr	14,968	-	2
69	1983	1983	resid	-	undergr	13,748	-	2
70	1969	1969	resid	-	undergr	32,641	529	2
71	1976	1976	commercia	-	free stand	56,900	1400	7
72	1987	1987	resid	-	undergr	15,000	370	4
73	1989	1989	resid	-	undergr	10,000	250	2
74	1973	1973	ffice/reta	8919	undergr	18,876	-	1
75	1975	1975	ffice/reta	-	undergr	20125	463	3

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No	Slab on grade No.	Slab on grade Area m2	Slab on grade Thickn. mm	Suspended slab No.	Suspended slab Area m2	Suspended slab Thickn.mm	Roof slab No.	Roof slab Area,m2	Roof slab Thikn.mm	Environment Exposed	Environment Heated
12	1	2,184	310	1	2,184	219	1	2,184	219	Roof only	0
13	1	2,091	1238 raft	1	2,091	310	0	*	*	0	1
14	1	4,182	310	1	4,182	310	0	*	*	0	1
15	1	929	310	1	929	310	0	*	*	0	1
16	1	6,041	310	1	6,506	206	0	*	*	0	1
17	1	743	310	1	1,487	310	top 1	465	310	0	0
18	1	9,869	0	1	9,325	310	0	0	*	0	1
19	1	4,200	26	2	8,400	-	0	*	*	0	1
20	1	2,123	-	7	14,865	-	0	*	*	0	1
21	1	34,387	asphalt	2	40,428	-	0	*	*	1	0
22	0	*	*	2	25,093	206	0	*	*	0	1
23	1	93	*	11	24,628	181	0	*	*	1	1
24	1	1,200	103	3	3,800	258	0	*	*	0	0
25	1	1,673	129	6	19,238	258	0	*	*	0	0
26	1	-	77	2	-	-	1	-	-	0	0
27	1	2,102	-	2	4,300	-	1	-	-	0	0
28	1	3,680		1	3,429	206	1	2,551	206	grade 1	1, 0
29	1	2,974	155	5	15,613	155	1	-	258	1	0
30	1	3,717	155	5	35,316	258	1	8,922	258	upper levs	0
31	1	3,936	155	1	3,220	206	1	3,253	206	0	0
32	1	2,184	155	1	2,184	206	0	*	*	0	0
33	1	11,235	-	3	33,705	-	-	-	-	0	0
34	1	1,924	-	3	5,985	206	1	1,887	-	0	0
35	1	2,035	103	1	2,714	219	0	*	*	0	1
36	1	1,273	103	1	1,338	206	0	*	*	0	1
37	1	2,435	129	1	2,788	232	0	*	*	0	1
38	1	1,375	103	0	1,134	*	1	1,115	103	1	1
39	1	1,552	-	2	3,996	-	0	*	*	0	0
40	0	0	0	1	2,230	194	0	*	*	1	0
41	1	1,747	raft 30+42	0	9,920	*	0	*	*	0	1
43	1	8,457	52	0	8,921	*	1	6,970	206	1	1
44	1	2,695	-	2	5,390	155	0	*	*	0	1
45	1	1,798	-	2	3,597	-	0	*	*	0	0
46	1	6,940	-	2	13,880	-	0	*	*	0	0
47	1	2,788	103	1	3,253	181	0	*	*	0	1
48	1	1,200	-	3	1,200	181	0	*	*	0	1
49	1	889	-	1	2,463	-	*	*	*	-	-
50	1	14,684	75 asph	1	14,684	271	0	*	*	1	0
51	2	1,859	129	4	3,160	154+50	*	*	*	0	0
52	1	2,955	-	1	2,955	206	1	2,300	206	0	0
53	1	3,964	127	2	7,929	203	1	3,903	232	0	0
54	1	6,970	129	1	6,970	232	0	*	*	0	0
55	1	4,087	-	1	4,210	203	0	*	*	0	1
56	2	3,578	129	2	3,578	232	2	3,578	232	0	0
57	1	9,294	155	1	9,294	206	1	9,294	206	0	0
58	1	1,993	-	1	1,993	310	0	*	*	0	1
59	0	11,464	*	2	20,880	258	1	556	258	1	0
60	1	3,675	-	3	9,396	-	0	*	*	0	1
61	0	*	*	1	2,972	-	0	*	*	0	1
62	1	1,394	-	1	1,398	-	1	1,398	-	Roof only	-
63	-	3,724	-	-	3,736	-	-	-	-	-	-
64	1	4,487	-	2	8,975	-	1	4,487	-	Roof only	-
65	-	3,240	-	-	6,440	-					
67	1	4,223	-	1	4,223	160	1	-	-	Roof only	-
68	1	7,484	-	1	7,484	155	1	-	-	-	-
69	1	6,874	-	1	6,874	155	1	-	-	-	-
70	1	16,320	-	1	16,320	200	1	16,320	-	0	1
71	1	8,128	-	6	48,772	125	1	-	-	1	0
72	1	3,750	-	3	11,250	160	0	*	*	0	0
73	1	5,000	-	1	5,000	160	0	*	-	0	0
74	1	4484		3	14,392	240	1	-	-	0	1
75	1	7,323	150	2	12,802	160	-	-	-	0	0

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No	Environment			Reinforc'd	Flat slab	column	Pre cast			
	T contr'd	No hea	Fan		thickn mm	Beam sl	T beams	Columns	Slabs	Reinf.col
12	0	1	0	0	*	0	0	0	0	0
13	0	0	1	1	300	0	0	0	0	0
14	0	0	1	1	300	0	0	0	0	0
15	0	0	0	1	300	0	0	0	0	0
16	0	0	0	1	200	0	0	0	0	0
17	1	0	0	0	*	1	0	0	0	0
18	1	0	1	1	250	0	0	0	0	0
19	1	0	1	1	200	0	0	0	0	0
20	1	0	1	0	*	1	0	0	0	0
21	0	0	0	1	-	0	1	1	1	1
22	0	0	1	1	200	Steel col	0	0	0	0
23	0	0	0	0	*	1	0	0	0	0
24	0	1	1	1	250	0	0	0	0	0
25	0	1	1	1	250	0	0	0	0	0
26	0	1	-	1	*	-	*	*	*	*
27	0	1	0	1	*	*	*	*	*	*
28	1	0	1	0	*	0	0	0	0	0
29	0	0	0	0	*	0	0	0	0	0
30	0	low lev	w lev	1	250	0	0	0	0	0
31	0	1	1	1	*	0	0	0	0	0
32	0	1	1	1	200	0	0	0	0	0
33	0	1	-	1	*	0	0	0	0	0
34	0	1	0	-	*	-	-	-	-	-
35	-	-	-	1	212	0	0	0	0	0
36	0	0	0	0	*	1	0	0	0	0
37	0	0	0	1	225	0	0	0	0	0
38	0	0	0	0	*	1	0	0	0	0
39	0	1	0	0	*	1	0	0	0	0
40	0	0	0	1	185	0	0	0	0	0
41	0	0	0	raft1	750	ramp 1	0	0	0	0
43	0	0	0	1	200	0	0	0	0	0
44	0	0	0	1	150	0	0	0	0	0
45	1	0	1	0	*	1	0	0	1	1
46	1	0	1	0	*	0	0	0	1	0
47	0	0	0	0	*	1	0	0	0	0
48	1	0	1	0	*	0	0	0	1	1
49	-	-	-	-	-	-	-	-	-	-
50	0	0	0	1	225	0	0	0	0	0
51	0	1	0	0	*	0	0	0	0	0
52	0	1	1	1	200	0	0	0	0	0
53	0	1	1	1	200	0	0	0	0	0
54	0	1	1	1	-	0	0	0	0	0
55	0	0	0	0	*	1	0	0	0	0
56	0	1	1	1	225	0	0	0	0	0
57	0	1	0	1	200	0	0	0	0	0
58	1	0	1	1	300	0	0	0	0	0
59	0	0	0	0	*	1	0	0	0	0
60	1	0	1	1	-	0	0	0	0	0
61	1	0	1	1	-	0	0	0	0	0
62	-	-	-	1	-	0	0	0	0	0
63	-	-	-	-	-	-	-	-	-	-
64	-	-	-	1	0	0	0	1	0	0
65	-	-	-	-	-	-	-	-	-	-
67	-	-	-	0	*	0	0	0	0	0
68	-	-	-	0	*	0	0	0	0	0
69	-	-	-	0	*	0	0	0	0	0
70	-	0	1	1	-	0	0	0	0	0
71	*	*	0	0	*	0	1	1	1	0
72	*	1	1	0	*	0	0	0	0	0
73	*	1	1	0	-	0	0	0	0	0
74	1	0	1	1	240	0	0	0	0	0
75	0	1	1	1		0	0	0	0	0

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No	Pre cast				Strucure			Cement	Con crete		Entr'd
	T beams	Columns	Slabs	Reinf.col	Steel fr	Other	Post tens	Type	Fly ash%	Slag %	air,%
12	0	0	0	0	0	0	1	-	-	-	-
13	0	0	0	0	0	l.on gr.ra	0	-	-	-	-
14	0	0	0	0	0	0	0	-	-	-	-
15	0	0	0	0	0	0	0	-	-	-	-
16	0	0	0	0	0	0	0	-	-	-	-
17	0	0	0	0	0	0	0	-	-	-	-
18	0	0	0	0	0	0	0	10	0	0	6
19	0	0	0	0	0	0	0	10	0	0	6
20	0	0	0	0	0	0	0	10	0	0	6
21	1	1	1	1	0	0	1	-	-	-	-
22	0	0	0	0	1	0	0	10	0	0	0
23	0	0	0	0	1	0	0	10	0	0	-
24	0	0	0	0	0	0	0	10	0	0	0
25	0	0	0	0	0	0	0	10	0	0	0
26	*	*	*	*	*	*	*	-	-	-	-
27	*	*	*	*	*	*	*	-	-	-	-
28	0	0	0	0	0	0	1	-	-	-	-
29	0	0	0	0	0	0	1	-	0	0	-
30	0	0	0	0	0	0	0	-	0	0	-
31	0	0	0	0	0	0	0	-	0	0	0
32	0	0	0	0	0	0	0	-	-	-	-
33	0	0	0	0	0	0	0	-	-	-	-
34	-	-	-	-	-	-	-	*	-	-	-
35	0	0	0	0	0	0	0	10	0	0	4
36	0	0	0	0	0	0	0	-	0	0	0
37	0	0	0	0	0	0	0	-	-	-	-
38	0	0	0	0	0	0	0	-	-	-	-
39	0	0	0	0	0	0	0	-	-	-	-
40	0	0	0	0	0	0	0	-	-	-	-
41	0	0	0	0	0	0	0	-	-	-	-
43	0	0	0	0	0	0	0	-	-	-	-
44	0	0	0	0	0	0	0	-	-	-	-
45	0	0	1	1	0	0	0	-	-	6.5	-
46	0	0	1	0	1	0	0	50 & 10	0	0	6
47	0	0	0	0	0	0	0	-	-	-	-
48	0	0	1	1	0	0	0	-	-	1	-
49	-	-	-	-	-	-	-	-	-	-	-
50	0	0	0	0	0	0	0	10	0	0	5 to 8
51	0	0	0	0	1	0	0	10	0	0	6
52	0	0	0	0	0	0	0	-	-	-	-
53	0	0	0	0	0	0	0	-	-	-	-
54	0	0	0	0	0	0	0	10	0	0	6
55	0	0	0	0	0	0	0	-	-	-	-
56	0	0	0	0	0	0	0	-	-	-	6
57	0	0	0	0	0	0	0	10	-	-	6
58	0	0	0	0	0	0	0	-	-	-	-
59	0	0	0	0	0	0	0	10	0	25	8
60	0	0	0	0	0	0	0	10	0	0	8
61	0	0	0	0	0	0	0	-	-	-	-
62	0	0	0	0	0	0	0	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-	-
64	0	1	0	0	0	0	0	-	-	-	-
65	-	-	-	-	-	-	-	-	-	-	-
67	0	0	0	0	0	0	1	10	0	0	6
68	0	0	0	0	0	0	1	10	0	0	6
69	0	0	0	0	0	0	1	10	0	0	6
70	0	0	0	0	0	0	0	-	-	-	-
71	1	1	1	0	0	0	1	10	-	-	1
72	0	0	0	0	0	0	1	10	0	0	6
73	0	0	0	0	0	0	1	10	0	0	6
74	0	0	0	0	0	0	0	10	-	-	-
75	0	0	0	0	0	0	0	10	-	-	-

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

	Admix	Other	Aggregate			Concrete	Compr'ss	Reinforcement		Post-tens
No	CaCl2,%	admix.	Norm.wt	Lt.wt.	Size,mm	W/C	str.,MPa	Epoxy	Conc.cover	Bonded
12	-	-	0	1	-	-	31	0	25	0
13	-	-	1	0	-	-	28	0	50	*
14	-	-	1	0	-	-	28	0	25	*
15	-	-	-	-	-	-	-	0	37	*
16	-	-	1	0	-	-	34	0	37	*
17	-	-	-	-	-	-	-	0	37	*
18	0	0	1	0	19	-	21	0	18	*
19	0	0	1	0	19	-	21	0	18	*
20	0	0	1	0	19	-	21	0	18	*
21	-	-	1	0	19	-	50	0/1	-	0/1
22	0	0	1	0	19	-	28	0	-	*
23	-	-	1	0	19	-	45	0	-	*
24	0	0	1	0	19	-	26	0	20	*
25	0	0	1	0	19	-	28	0	18	*
26	-	-	-	-	-	-	20	0	-	*
27	-	-	-	-	-	-	-	0	-	*
28	-	-	-	-	-	-	-	0	18	0
29	0	-	1	0	19	-	21	0	18	0
30	0	0	1	0	19	-	19	0	25	*
31	0.3	-	1	0	19	-	21	0	18	*
32	1	-	1	0	19	-	19	0	18	*
33	-	-	-	-	-	-	-	-	-	0
34	-	-	-	-	-	-	-	-	-	*
35	0	0	1	0	-	-	24	0	25	*
36	0	0	1	0	-	-	24	0	25	*
37	-	-	1	0	-	-	21	0	18	*
38	-	-	1	0	-	-	24	0	-	*
39	-	-	1	-	-	-	28	0	25	*
40	-	-	1	0	-	-	-	0	18	*
41	-	-	1	0	-	-	21	0	18	*
43	-	-	1	0	-	-	-	0	18	*
44	-	-	1	-	-	-	-	0	-	*
45	0	uperplas	type 4	0	-	0.55	-	0	25	*
46	0	Darex AE	1	1	-	0.45	-	1	25	*
47	-	-	-	-	-	-	-	0	-	*
48	-	-	-	-	-	-	24	-	25	*
49	-	-	-	-	-	-	-	-	-	-
50	0	/RDA82&1	1	0	19	0.33	39	1	37	0
51	0	0	1	0	19	-	21	0	-	*
52	-	-	-	-	-	-	-	0	-	*
53	-	-	-	-	-	-	28	0	50	*
54	0	0	0	semi	19	0.45	28	0	-	*
55	-	-	-	-	-	-	-	0	-	*
56	-	-	1	0	19	-	21	0	37	*
57	-	-	1	0	-	-	34-62	0	-	*
58	-	-	-	-	-	-	-	0	-	0
59	0	RA Procre	1	0	19	0.48	30	0	50	*
60	0	WRA	1	0	-	-	-	0	-	0
61	-	-	-	-	-	-	-	-	-	*
62	-	-	-	-	-	-	-	0	-	*
63	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	-	0	50	*
65	-	-	-	-	-	-	-	-	-	-
67	0	0	1	0	-	-	29	0	37	0
68	-	-	1	0	-	-	27	0	25	0
69	0	0	1	0	-	-	21	0	25	0
70	-	-	-	-	-	-	-	0	-	0
71	0	0	1	0	-	-	28	0	38	1
72	0	0	1	0	19	-	30	1	38	0
73	0	0	1	0	19	-	28	1	38	0
74	-	-	-	-	-	-	39.6	0	64	0
75	-	-	-	-	-	-	-	0	40	*

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No	Post-tens Sheathing	Hardw're exposed	Floor Slope %	El.condu embedd	Floor drain Cast Iron	Alumin	Plastic	Epoxy	Expansion Type	joint Material
12	Plastic	1	-	0	1	0	0	0	-	-
13	*	*	-	0	1	0	0	0	*	*
14	*	*	-	1	1	0	0	0	-	-
15	*	*	-	1	1	0	0	0	0	*
16	*	*	-	1	1	0	0	0	-	-
17	*	*	-	1	1	0	0	0	*	*
18	*	*	2.0	1	1	0	0	0	liding plat	steel
19	*	*	-	-	1	0	0	0	liding plat	steel
20	*	*	-	1	1	0	0	0	0	*
21	paper/PE	-	1.0	1	1	0	0	0	T Seals	-
22	*	*	1.0	1	1	0	0	0	ecomp.rubb	-
23	*	*	-	1	1	0	0	0	-	-
24	*	0	0.0	1	1	0	0	0	0	*
25	*	*	1.0	1	1	0	0	0	one/level	-
26	*	*	-	1	-	-	-	-	*	-
27	*	*	-	-	-	-	-	-	*	*
28	Kraft paper	0	1.0	1	1	-	-	-	-	-
29	Kraft paper	0	1.0	1	1	0	0	0	*	*
30	*	*	1.0	1	1	0	0	0	late & angl	eopr.comp
31	*	*	1.0	1	1	0	0	0	-	eopr.comp
32	*	*	0.0	0	1	0	0	0	0	*
33	-	-	-	-	-	-	-	-	-	-
34	*	*	-	-	-	-	-	-	-	-
35	*	*	1.0	1	1	0	0	0	*	*
36	*	*	1.0	1	1	0	0	0	-	*
37	*	*	0.0	1	1	0	0	0	concr.nosin	erbord fil
38	*	*	2.0	0	1	0	0	0	traffic bea	olyurethan
39	*	*	0.0	0	1	0	0	0	0	NA
40	*	*	1.0	1	1	0	0	0	concr.nosin	filler c/w
41	*	*	0.0	-	1	0	0	0	*	*
43	*	*	0.5	1	1	0	0	0	concr.nosin	membrane
44	*	*	0.5	1	1	0	0	0	*	*
45	*	*	2.0	1	1	0	0	0	ncrete form	-
46	*	*	-	1	1	0	0	0	form toolec	r.& joint s
47	*	*	-	-	-	-	-	-	-	-
48	*	*	0.0	ramp 1	1	0	retrofit 1	0	-	-
49	-	-	-	-	-	-	-	-	-	-
50	*	*	1.5	0	0	0	0	1	pression s	pr.&galv.s
51	*	*	-	0	1	0	0	0	-	-
52	*	*	-	1	1	0	0	0	0	*
53	*	*	-	0	1	0	0	0	-	-
54	*	*	-	0	1	0	0	0	-	-
55	*	*	-	-	1	0	0	0	-	zote & Em
56	*	*	-	0	1	0	0	0	-	ph.fiberbo
57	*	*	1.0	1	1	0	1	O	me-Armour	oprene-st
58	*	*	-	0.5	1	0	0	0	0	*
59	*	*	2.3-3.4	1	1	0	0	1	onel 151 V.	eel-neopre
60	*	*	-	1	1	0	0	0	NA	*
61	*	*	-	-	1	0	0	0	0	*
62	*	*	-	-	-	-	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-
64	*	*	-	-	-	-	-	-	0	*
65	-	-	-	-	-	-	-	-	-	-
67	extrud.plas	0	-	1	-	-	-	-	-	-
68	extrud.plas	0	-	1	-	-	-	-	-	-
69	extrud.plas	0	-	1	-	-	-	-	-	-
70	*	*	-	1	1	0	0	0	-	-
71	stuffed	0	2.0	1	1	0	0	0	-	Elastometa
72	extruded	0	2.0	1	-	-	-	-	grouted	epoxy
73	extruded	0	2.0	1	-	-	-	-	grouted	epoxy
74	0	*	*	1	-	-	-	-	-	-
75	*	*	-	1	1	0	0	0	-	-

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No	Ramps					Membrane Number 1				
	Heated	Elecric	Glycol	Salted	Sand	Installed	At constr	Yr after	Generic type	Brand name
12	0	*	*	1	-	0	*	*	*	*
13	1	1	0	1	-	1	0	8	Mastic asphal	NR
14	0	-	-	-	-	1	0	7	Membr+coalta	NR
15	0	-	-	1	-	1	0	10	Polyurethane	yalflex Uniroy
16	1	1	0	1	-	1	0	-	Polyurethane	yalflex Uniroy
17	0	*	*	-	-	1	0	12	Polyurethane	yalflex Uniroy
18	ot working	0	1	1	0	1	0	10	Polyurethane	Kelmar
19	0	*	*	-	-	0	*	*	*	*
20	0	*	*	-	-	1	1	10	-	-
21	)	1	0	1	1	0	*	*	*	*
22	0	*	*	1	0	1	1	-	asphaltic	*
23	0	-	-	1	1	0	*	*	*	*
24	0	*	*	1	1	1	0	12	Polyurethane	Kelmar
25	0	*	*	1	1	1	0	11	-	Duochem
26	1	1	*	-	-	1	1	-	asphalt	-
27	1	1	*	-	-	1	1	*	asph+membr	-
28	interior	0	0	0	0	1	0	15	epoxy/ureth.	SternsonTDM
29	0	*	*	1	0	1	1	0	asphalt base	-
30	0	*	*	1	_	1	0	17	Rubber asph	Bemac
31	0	*	*	-	-	0	*	*	*	*
32	0	*	*	-	-	0	*	*	*	*
33	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	1	-	-	asphalt	-
35	1	1	0	-	-	0	*	*	*	*
36	1	-	-	-	-	0	*	*	*	*
37	1	1	0	-	-	1	0	19	polyurethane	Isoflex 750
38	1	1	0	-	-	1	0	21	polyurethane	Isoflex 750
39	0	*	*	-	-	0	*	*	*	*
40	0	*	*	-	-	1	0	24	bzd asph.shee	Bituthene shee
41	1	1	0	-	-	1	0	22	Polyurethane	375+9006 & ep
43	1	1	0	-	-	1	1	*	d asph c/w as	e Bituthene 5
44	1	-	-	-	-	1	0	11	ene copol.c/w	Kelmar
45	0	*	*	1	1	0	*	*	*	*
46	0	*	*	1	1	0	*	*	*	*
47	-	-	-	-	-	0	*	*	*	*
48	1	1	0	-	-	-	-	-	-	-
49	-	*	-	-	-	-	-	-	-	-
50	0	*	*	-	1	0	*	4	neoprene	Neoguard
51	0	*	*	1	0	1	0	45	neoprene	-
52	1	1	0	-	-	1	0	15	neoprene	Kelmar
53	0	*	*	1	0	0	*	*	*	*
54	1	1	0	1	0	1	1	0	-	-
55	0	*	*	-	-	1	0	7	neoprene	lmar expsure
56	1	1	0	0	0	1	0	14	ured rubberize	idrotech#612
57	0	*	*	1	0	0	*	*	*	*
58	0	*	*	0	0	1	0	6	coal tar epoxy	Kelmar
59	0&1	1	0	0	0	1	1	0	rathane,coal t	rnson TDM-1(
60	1	1	0	0	0	1	1	0	rene,epoxy co	Kelmar 350
61	1	1	0	0	0	1	1	0	mat,asphalt e	Braco C13HPC
62	-	-	-	-	-	1	0	10	rene,epoxy co	Kelmar
63	-	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	1	0	12	rene,epoxy co	lmar Full Syst
65	-	-	-	-	-	-	-	-	-	-
67	-					0	*	*	*	*
68	-	-	-	-	-	0	*	*	*	*
69	-	-	-	-	-	0	*	*	*	*
70	0	*	*	-	-	1	0	16	mastic asph	-
71	-	-	-	-	-	0	*	*	*	*
72	0	*	*	0	0	0	*	*	*	*
73	0	*	*	0	0	0	*	*	*	*
74	-	-	-	-	-	1	0	5	coal tar epxy	-
75	1	1	0	1	1	1	0	9		Permapol

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No	Membrane Number 1								
	Thickn.mm	Ground level	Level#1	Level#2	Level #3	Level #4	Roof level	Ramps	Area squ.m
12	*	*	*	*	*	*	*	*	*
13	75.00	0	1	*	*	*	*	1	2,183
14	75.00	0	1	*	*	*	*	0	232
15	1.00	0	1	0	0	0	0	1	929
16	1.00	0	1	0	0	0	*	1	6,503
17	1	0	1	*	*	*	1	1	1,950
18	3.80	0	1	*	*	*	*	1	9,320
19	*	*	*	*	*	*	*	*	*
20	-	0	1	1	1	1	*	-	-
21	*	*	*	*	*	*	*	*	*
22	12.00	0	Lev.92 area1+2	0	*	*	*	-	502
23	*	*	*	*	*	*	*	*	*
24	0.76	0	1	1	1	*	*	0	3,344
25	0.76	0	4AB/4CD 1	0	0	0	*	-	22,322
26	33.00	-	-	-	-	-	1	-	-
27	2.03	0	0	0	0	0	1	-	-
28	-	0	1	*	*	*	*	1	-
29	25.00	0	1	0	0	1	0	-	650
30	19.00	1	0	0	1	0	0	1	4,830
31	*	*	*	*	*	*	*	*	*
32	*	*	*	*	*	*	*	*	*
33	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-
35	*	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*	*
37	.5 1.0	0		0	0	0	0	0	93
38	0.5,0.5. 1.0	0	1	*	*	*	0	0	1,133
39	*	*	*	*	*	*	*	*	*
40	1.52	*	0	*	*	*	*	*	1,347
41	1.00	0	0	*	*	*	*	1	297
43	1.50	0	*	*	*	*	1	-	8,453
44	0.76	0	1	1	*	*	*	1	5,388
45	*	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	1	*
48	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-
50	*	*	1	*	*	*	*	*	14,678
51	0.5	-	-	-	-	-	-	-	-
52	0.5	0	1	*	*	*	*	*	2,958
53	*	*	*	*	*	*	*	*	*
54	-	-	-	*	*	*	*	*	-
55	-	0	1	*	*	*	*	-	4,394
56	0.5	0	0	0	*	*	1	0	3,576
57	*	*	*	*	*	*	*	*	*
58	-	0	1	*	*	*	*	1	2,308
59	1.52	0	1	*	*	*	1	1	20,950
60	0.76	-	1	1	1	*	*	1	-
61	-	*	1	*	*	*	*	-	-
62	2.5	0	1	*	*	*	asphalt	-	1,393
63	-	-	-	-	-	-	-	-	-
64	5.08	0	1	1	*	*	pvd,lndsc	-	8,971
65	-	-	-	-	*	*	-	-	-
67	*	*	*	*	*	*	*	*	*
68	*	*	*	*	*	*	*	*	*
69	*	*	*	*	*	*	*	*	*
70	-	0	1	*	*	*	*	0	4350
71	*	*	*	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*	*
74	2 - 3	0	1	1	1	0		*	11,410
75	1.2	0	1	0	0	0	*	1	3,245

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No	Membrane Number 2								
	Yr.aft.	Gen'c typ	Brand	Thickn.mm	Grd level	Level#1	Level#2	Level #3	Level #4
12	0	*	*	*	*	*	*	*	*
13	0	*	*	*	*	*	*	*	*
14	0	*	*	*	*	*	*	*	*
15	0	*	*	*	*	*	*	*	*
16	removed 2	-	-	-	-	-	-	-	-
17	removed 2	*	*	*	*	*	*	*	*
18	0	*	*	*	*	*	*	*	*
19	*	*	*	*	*	*	*	*	*
20	10	-	Permapol	NR	0	1	1	0	0
21	0	*	*	*	*	*	*	*	*
22	27	Elastomeric	Isoflex	1.20	0	Lev92area3	*	*	*
23	*	*	*	*	*	*	*	*	*
24	*	*	*	*	*	*	*	*	*
25	13	neoprene	Kelmar	0.51	0	0	3CD/6CD 1	0	0
26	mastic	-	-	-	-	-	-	-	-
27	*	*	*	*	*	*	*	*	*
28	-	-	-	-	-	-	*	*	*
29	17	rubber. asph	Bemac	25.00	0	1	0	0	1
30	*	*	*	*	*	*	*	*	*
31	*	*	*	*	*	*	*	*	*
32	*	*	*	*	*	*	*	*	*
33	-	-	-	-	-	-	*	-	-
34	-	-	-	-	-	-	*	-	-
35	*	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*	*
37	0	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*	*
41	0	*	*	*	*	*	*	*	*
43	20	-	-	-	0	*	*	*	*
44	*	*	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*	*
48	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-
50	*	*	*	*	*	*	*	*	*
51	49	rubber. asph	-	3.05	-	-	-	-	-
52	0	*	*	*	*	*	*	*	*
53	*	*	*	*	*	*	*	*	*
54	*	*	*	*	*	*	*	*	*
55	0	*	*	*	*	*	*	*	*
56	0	*	*	*	*	*	*	*	*
57	*	*	*	*	*	*	*	*	*
58	0	*	*	*	*	*	*	*	*
59	0	*	*	*	*	*	*	*	*
60	0	*	*	*	*	*	*	*	*
61	10	rub.asph	Hydrotech	20.30	*	1	*	*	*
62	*	*	*	*	*	*	*	*	*
63	-	-	350	-	-	-	-	-	-
64	0	*	*	*	*	*	*	*	*
65	-	-	-	-	-	-	-	-	-
67	*	*	*	*	*	*	*	*	*
68	*	*	*	*	*	*	*	*	*
69	*	*	*	*	*	*	*	*	*
70	0	*	*	*	*	*	*	*	*
71	*	*	*	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*	*
74	*	*	*	*	*	*	*	*	*
75	10	neoprene	Kelmar 350	3.00	0	0	1	*	*

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No				Sealer	Num ber 1				
No	Roof level	Ramps	Area sqm	Installed	At constr.	Yr after	Generic type	Brand name	Grd level
12	*	*	*	1	0	7	Silane	-	0
13	*	*	*	1	0	8	Silane	-	1
14	0	0	0	1	0	3	7%solid/epox	-	0
15	*	*	*	0	*	*	*	*	*
16	-	-	-	0	*	*	*	*	*
17	*	*	*	0	*	*	*	*	*
18	0	0	0	0	*	*	*	*	*
19	*	*	*	0	*	*	*	*	*
20	*	-	-	0	*	*	*	*	*
21	*	*	*	1	1	0	PMMA	Cndn Barrier	0
22	*	*	5,434	*	0	*	*	*	*
23	*	*	*	1	0	*	Epoxy	-	0
24	*	*	*	1	1	0	linseed oil	*	1
25	*	-	*	0	0	0	0	0	0
26	1	-	-	0	*	*	*	*	*
27	*	*	*	0	*	*	*	*	*
28	*	-	-	-	-	-	-	-	1
29	0	0	650	1	1	0	PMMA	Cndn Barrier	0
30	*	*	*	1	0	17,8,2y4	PMMA	Cndn Barrier	0
31	*	*	*	1	1	5	PMMA	Cndn Barrier	0
32	*	*	*	1	0	5	PMMA	Cndn Barrier	0
33	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-
35	*	*	*	1	0	6	alkoxysilane	Isoflex 618	0
36	*	*	*	1	0	4	kylalkoxysilar	Isoflex 618	0
37	*	*	*	1	0	19	kylalkoxysilar	ncressive 31	0
38	*	*	*	0	*	*	*	*	*
39	*	*	*	1	0	16	kylalkoxysilar	Isoflex 618	0
40	*	*	*	0	*	*	*	*	*
41	*	*	*	0	*	*	*	*	*
43	1	-	8,454	0	*	*	*	*	*
44	*	*	*	0	*	*	*	*	*
45	*	*	*	1	1	0	-	Hydrozo 30	1
46	*	*	*	1	1	0	-	or Seal Stern	1
47	*	*	*	0	*	*	*	*	*
48	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-
50	*	*	*	1	1	0	thylmethacryl	hdn Barr TRX1	*
51	-	-	-	0	*	*	*	*	*
52	*	*	*	0	*	*	*	*	*
53	*	*	*	-	-	-	-	-	-
54	*	*	*	0	*	*	*	*	*
55	*	*	*	0	*	*	*	*	*
56	*	*	*	0	*	*	*	*	*
57	*	*	*	0	*	*	*	*	*
58	*	*	*	1	1	6	-	ck Seal TRX1	1
59	*	*	*	0	*	*	*	*	*
60	*	*	*	1	1	0	acrylate	ck Seal TRX1	-
61	*	*	*	0	0	*	*	*	*
62	*	*	*	0	*	*	*	*	*
63	-	-	-	-	-	-	-	-	-
64	*	*	*	0	*	*	*	*	*
65	-	-	-	-	-	-	-	-	-
67	*	*	*	1	0	2	ysiloxane/me	bcote DeckGu	0
68	*	*	*	1	1	0	linseed oil		
69	*	*	*	1	1	0	linseed oil		0
70	*	*	*	0	*	*	*	*	*
71	*	*	*	0	*	*	*	*	*
72	*	*	*	1	1	*	lk.alkoxysilen	Burke	1
73	*	*	*	1	1	*	lk.alkoxysilen	Burke	1
74	*	*	*	0	*	*	*	*	*
75	*	1	8,318		*	*	*	*	*

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No	Sealer Number 1							Sealer No. 2	
	Level#1	Level#2	Level #3	Level #4	Roof level	Ramps	Area squm	Yr.after	Generic type
12	1	*	*	*	1	1	4,366	0	*
13	0	*	*	*	*	0	2,183	0	*
14	1	0	0	0	0	1	4,180	0	0
15	*	*	*	*	*	*	*	*	*
16	*	*	*	*	*	*	*	0	*
17	*	*	*	*	*	*	*	*	*
18	*	*	*	*	*	*	*	0	*
19	*	*	*	*	*	*	*	*	*
20	*	*	*	*	*	*	*	*	*
21	1	*	*	*	*	*	*	8	*
22	*	*	*	*	*	*	*	*	0
23	1	1	1	1	0	1	24,618	*	*
24	1	1	1	*	*	1	4,923	0	*
25	*	*	*	*	*	*	*	*	*
26	*	*	*	*	*	*	*	0	*
27	*	*	*	*	*	*	*	*	*
28	0	*	*	*	*	*	-	-	-
29	1	1	1	1	0	1	6,503	17	PMMA
30	1	1	1	1	1	1	34,094	0	PMMA
31	1	*	*	*	0	0	3,409	0	*
32	1	*	*	*	*	*	2,183	9	Silane
33	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-
35	1	*	*	*	*	0	2,712	*	*
36	1	0	0	0	0	1	1,337	*	*
37	1	*	*	*	*	*	2,694	*	*
38	*	*	*	*	*	*	*	*	*
39	1	1	*	*	*	*	3,994	*	*
40	*	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*	*
45	1	1	*	*	*	1	5,393	1&2&4	*
46	1	1	*	*	*	-	20,811	*	*
47	*	*	*	*	*	*	*	*	*
48	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-
50	1	*	*	*	*	*	13,935	0	*
51	*	*	*	*	*	*	*	*	*
52	*	*	*	*	*	*	*	0	*
53	-	-	-	-	-	-	*	-	-
54	*	*	*	*	*	*	*	0	*
55	*	*	*	*	*	*	*	0	*
56	*	*	*	*	*	*	*	*	*
57	*	*	*	*	*	*	*	*	*
58	1	*	*	*	*	1	2,308	0	*
59	*	*	*	*	*	*	*	*	*
60	-	*	-	-	-	-	-	0	*
61	*	*	*	*	*	*	*	*	*
62	*	*	*	*	*	*	*	*	*
63	-	-	-	-	*	-	-	-	-
64	*	*	*	*	*	*	*	*	*
65	-	-	-	-	*	-	-	-	-
67	1	*	*	*	*	1	4,221	0	*
68	1	*	*	*	*	1	7,480	4	alkalkoxysil
69	1	*	*	*	*	1	6,871	5	alkalkoxysil
70	*	*	*	*	*	*	*	*	*
71	*	*	*	*	*	*	*	*	*
72	1	1	1	*	*	1	15,000	0	*
73	1	*	*	*	*	1	10,000	0	*
74	*	*	*	*	*	*	*	*	*
75	*	*	*	*	*	*	*	*	*

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No	Brand name	Sealer Grd level	Number 2 Level#1	Level#2	Level #3	Level #4	Roof level	Ramps	Area,squ.m
12	*	*	*	*	*	*	*	*	*
13	*	*	*	*	*	*	*	*	*
14	0	0	0	0	0	0	0	0	0
15	*	*	*	*	*	*	*	*	*
16	*	*	*	*	*	*	*	*	*
17	*	*	*	*	*	*	*	*	*
18	*	*	*	*	*	*	*	*	*
19	*	*	*	*	*	*	*	*	*
20	*	*	*	*	*	*	*	*	*
21	n.Barrier TRX1	*	1	*	*	*	*	*	*
22	NA	*	*	*	*	*	*	*	*
23	*	*	*	*	*	*	*	*	*
24	*	*	*	*	*	*	*	*	*
25	*	*	*	*	*	*	*	*	*
26	*	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*	*
28	-	-	-	-	-	-	-	-	-
29	Can'ian Barrie	0	0	1	1	1	0	0	6,503
30	Can'ian Barrie	1	1	1	1	1	1	0	34094
31	*	*	*	*	*	*	*	*	*
32	Capseal X	0	1	*	*	*	*	*	2,183
33	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-
35	*	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*	*
37	*	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*	*
48	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-
50	*	*	*	*	*	*	*	*	*
51	*	*	*	*	*	*	*	*	*
52	*	*	*	*	*	*	*	*	*
53	-	-	-	-	-	-	-	-	-
54	*	*	*	*	*	*	*	*	*
55	*	*	*	*	*	*	*	*	*
56	*	*	*	*	*	*	*	*	*
57	*	*	*	*	*	*	*	*	*
58	*	*	*	*	*	*	*	*	*
59	*	*	*	*	*	*	*	*	*
60	*	*	*	*	*	*	*	*	*
61	*	*	*	*	*	*	*	*	*
62	*	*	*	*	*	*	*	*	*
63	-	-	-	-	-	-	-	-	-
64	*	*	*	*	*	*	*	*	*
65	-	-	-	-	-	-	-	-	-
67	*	*	*	*	*	*	*	*	*
68	hemtrete B5M	0	1	*	*	*	*	1	7,480
69	hemtrete B5M	0	1	*	*	*	*	1	6,871
70	*	*	*	*	*	*	*	*	*
71	*	*	*	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*	*
74	*	*	*	*	*	*	*	*	*
75	*	*	*	*	*	*	*	*	*

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No	Cathodic			Protection			Housekeeping		
	Installed	No.levels	Area,sqm	Area %	Type	Brand	Wk/sweep	Wk/wash	Wk/drain
12	0	*	*	*	*	*	4	13	13
13	0	*	*	*	*	*	13	26	26
14	0	*	*	*	*	*	13	8	16
15	0	*	*	*	*	*	4	4	8
16	0	*	*	*	*	*	1	4	-
17	0	*	*	*	*	*	4	8	-
18	0	*	*	*	*	*	1	1	1
19	0	*	*	*	*	*	1	1	1
20	0	*	*	*	*	*	1	1	1
21	0	*	*	*	*	*	-	-	-
22	0	*	*	*	*	*	-	-	-
23	0	*	*	*	*	*	52	52	52
24	0	*	*	*	*	*	52	26	52
25	0	*	*	*	*	*	-	-	-
26	0	*	*	*	*	*	-	-	-
27	0	*	*	*	*	*	-	-	-
28	0	*	*	*	*	*	-	-	-
29	0	*	*	*	*	*	26	26	26
30	0	*	*	*	*	*	26	26	26
31	0	*	*	*	*	*	1	52	52
32	0	*	*	*	*	*	1	52	1
33	0	-	-	-	-	-	-	-	-
34	0	-	-	-	-	-	4	-	-
35	0	*	*	*	*	*	17	26	26
36	0	*	*	*	*	*	17	26	26
37	0	*	*	*	*	*	26	26	26
38	0	*	*	*	*	*	26	26	26
39	0	*	*	*	*	*	52	-	52
40	0	*	*	*	*	*	52	-	52
41	0	*	*	*	*	*	52	-	52
43	*	0	*	*	*	*	52	-	52
44	0	*	*	*	*	*	26	26	26
45	0	*	*	*	*	*	13	13	26
46	0	*	*	*	*	*	13	13	26
47	0	*	*	*	*	*	-	-	-
48	-	-	-	-	-	-	13	13	13
49	-	-	-	-	-	-	13	13	3
50	0	*	*	*	*	*	-	-	-
51	0	*	*	*	*	*	1	1	1
52	1	1	278	9.4	paint	Passcor	-	-	-
53	0	-	-	-	-	-	-	52	52
54	0	*	*	*	*	*	26	26	26
55	0	*	*	*	*	*	1	1	52
56	0	*	*	*	*	*	0	0	0
57	1	1	9,290	50	paint	Corr.S	52	52	52
58	0	*	*	*	*	*	52	52	26
59	0	*	*	*	*	*	4	52	52
60	0	*	*	*	*	*	1	4	4
61	0	*	*	*	*	*	1	4	4
62	0	*	*	*	*	*	-	-	-
63	1	1	3730	50	paint	Passcor	-	-	-
64	0	*	*	*	*	*	-	-	-
65	-	-	-	-	-	-	-	-	-
67	0	0	0	0	0	0	-	-	-
68	0	*	*	*	*	*	-	-	-
69	0	*	*	*	*	*			
70	*	*	*	*	*	*	-	-	-
71	0	*	*	*	*	*	-	-	-
72	*	0	*	*	*	*	-	-	-
73	0	*	*	*	*	*	-	-	-
74	0	*	*	*	*	*	-	-	-
75	*	*	*	*	*	*	-	-	-

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No	Maintenance			Prior Repair Number 1						
	Insp/yr	As needed	Intervals	Delam. %	Leak/slab	Leak/roof	Exp.joint	Perim.	Ponding	Cracking
12	0.50	1	0	2.0	1	0	1	1	1	1
13	1.00	1	0	6.0	1	2	2	1	1	0
14	1.00	1	0	8.0	0	0	0	0	0	1
15	0.50	1	0	*	*	*	*	*	*	*
16	1.00	1	0	0.5	1	0	0	0	0	0
17	1.00	1	0	1.0	1	0	0	0	0	0
18	52.00	1	0	35.0	1	2	1	0	0	0
19	52.00	1	0	0.5	0	0	0	0	0	0
20	1.00	1	0	Small	1	*	*	0	0	0
21	-	1	1	-	1	*	1	0	0	0
22	-	1	0	ry extens	1	0	1	0	1	1
23	1.00	1	0	3.0	0	0	0	0	0	0
24	1.00	1	0	6.2	1	*	*	1	0	0
25	1.00	1	0	17.0	1	0	1	0	0	1
26	-	-	-	-	-	1	*	1	-	1
27	-	-	-	0.5	0	0	constr 1	1	0	0
28	-	-	-	1.0	0	0	1	1	-	-
29	1.00	1	1	0.3	1	0	0	0	1	0
30	1.00	1	0	13.0	1	0	1	0	1	0
31	3.00	1	0	1.0	1	0	1	0	0	0
32	3.00	1	0	1.0	1	1	0	0	1	0
33	-	-	-	-	-	-	-	-	-	-
34	-	-	-	20.0	1	0	1	0	0	1
35	1.00	1	0	0.0	0	0	0	0	1	1
36	1.00	1	0	0.0	0	0	0	0	1	1
37	1.00	1	0	8.2	0	0	1	0	1	1
38	1.00	1	0	1.0	0	0	1	0	0	1
39	1.00	1	0	0.3	0	0	0	0	1	1
40	1.00	1	0	5.6	1	0	0	1	0	0
41	1.00	1	0	60.0	0	0	0	0	1	0
43	1.00	1	0	2.2	0	0	1	0	1	0
44	1.00	1	0	37.0	0	0	0	1	1	1
45	26.00	1	0	2.0	1	0	0	0	0	1
46	13.00	1	1	2.0	1	*	0	1	0	1
47	-	-	-	6.0	1	*	1	0	1	1
48	-	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-	-
50	1	*	*	0.0	1	*	1	*	0	1
51	1	1	0	0.0	*	*	*	*	*	*
52	-	-	-	1.8	-	-	-	-	-	-
53	1	1	0	3.9	1	1	0	0	0	1
54	1	1	0	-	-	-	-	-	-	-
55	1	1	0	-	-	-	-	-	-	-
56	0	0	1	-	1	1	1	1	NR	1
57	1	1	0	8.0	0.5	0.5	0.5	0.5	0	0.5
58	1	1	0	1.1	1	*	*	0	0	1
59	-	-	-	0.0	0	0	0	0	0	0
60	26	1	0	0.0	1	0	0	0	0	0
61	26	1	0	some	1	*	*	1	0	*
62	-	-	-	-	-	*	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-
64	-	-	-	19.3	1	-	*	-	-	-
65	-	-	-	-	-	-	-	-	-	-
67	-	-	-	0.0	1(302m)	0	1(63m)	1(160m)	0	0
68	-	-	-	0.0	1(44m)	0	1(56m)	1(75m)		
69	-	-	-	0.0	1(9.5m)	0	1(185)	1(34m)		
70	-	-	-	29.0	1	1	1	1	0	0
71	-	-	-	0.1	1	0	1	*	1	1
72	-	1	-	0	1	0	1	1	1	1
73	-	1	-	0	0	0	0	0	0	0
74	-	-	-	-	1	-	1	-	1	1
75	-	-	-	18.0	1	*	1	1	1	1

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

				Prior	Repair	Number 1		
No	Spalling	Scaling	Effloresc	Cl %	Cell pot,%	Cover min,mm	Cover max,mm	Comp.psi
12	0	1	0	-	-	-	-	-
13	1	0	1	0.10	-	13	37	-
14	1	0	0	0.20	22	6	57	48
15	*	*	*	*	*	*	*	-
16	1	0	1	-	*	-	-	-
17	1	0	0	0	5	-	-	-
18	1	1	1	-	0	20	90	-
19	1	1	1	-	-	-	-	-
20	1	0	1	-	-	-	-	-
21	0	0	0	-	-	-	-	-
22	1	1	1	-	-	-	-	-
23	1	0	1	0.05	10	25	150	49
24	1	0	1	0.27	25	25	37	27
25	1	1	1	.011to 0.01	-	-	37	28
26	-	-	1	0.00	-	44	81	39
27	0	0	0	0.35	11.1	0	75	30
28	-	-	-	-	-	-	-	-
29	1	1	1	0.73	10	13	25	-
30	1	1	1	-	-	13	25	-
31	1	1	1	-	5	13	25	-
32	1	1	1	-	-	13	25	-
33	-	-	-	-	-	-	-	-
34	0	0	1	0.23	75	-	-	33
35	0	0	0	.02 to 0.18	0	-	-	26
36	0	0	0	0.01	0	-	-	20
37	1	0	1	0.18	25	25	37	28
38	0	0	1	0.10	4	38	44	26
39	0	0	1	0.01	0	50	50	26
40	0	0	0	0.05	5	25	89	28
41	1	1	0	raft 0.6	98	38	50	26
43	0	0	1	0.05	5	-	-	-
44	1	1	1	-	12	30	110	-
45	0	0	0	-	-	-	-	-
46	1	0	0	-	-	-	-	-
47	0	0	1	0.25	30	-	-	-
48	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-
50	1	0	1	-	-	-	-	-
51	*	*	*	*	*	*	*	*
52	-	-	-	0.27	-	13	44	-
53	1	1	1	0.456	20	17	100	29
54	-	-	-	-	-	-	-	-
55	-	-	-	-	-	-	-	-
56	1	1	1	-	-	3	50	31
57	0.5	0.5	0.5	-	-	6	19	48
58	1	0	1	0.07	7	6	64	-
59	0	0	0	-	-	2	64	30
60	0	0	0	-	-	-	-	-
61	*	*	1	-	-	-	-	-
62	-	-	-	-	-	-	-	-
63	-	-	-	-	-	-	-	-
64	-	-	-	-	0	-	-	-
65	-	-	-	-	-	-	-	-
67	1	0	0.00	0.01		-	-	-
68		0	0.00	0.340avg				
69		1		0.125avg				
70	1	1	1.00	0.34	45.00	6	68	
71	1	1	1.00	0.2 max	negligible	30	80	29
72	0	0	1.00	0.034	*	18	82	-
73	0	1	0.00	0.031	*	31	65	-
74	1	1	1.00	-	-	64	90	51
75	1	1	1	-	-	-	-	-

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No				Prior	Repair	Number 1			
	Entr.air%	Spacfactor	Memb.cracked	Memb.worn	Memb.satisf.	Column	Tendons	Date rpt	Rpt avail
12	-	*	*	*	*	-	1	1984	1
13	-	*	0	0	-	0	*	1980	*
14	3.00	0.03	0	0	1	0	0	1980	1
15	-	*	-	-	-	-	*	*	0
16	-	*	0	0	-	-	*	*	*
17	-	*	*	*	*	-	*	1987	1
18	-	-	*	*	*	0	*	1979	0
19	-	-	*	*	*	-	*	1983	1
20	-	-	1	0	-	-	*	-	0
21	-	-	*	*	*	bearings d	PC inserts	1982	1
22	*	*	*	*	*	1	*	*	0
23	-	-	*	*	*	-	-	1983+1987	1
24	0.00	*	*	*	*	1	*	1985	1
25	*	*	*	*	*	*	*	1984	0
26	2.40	0.69	-	-	1	-	*	1987	1
27	1.90	0.61	0	0	1	0	0	1987	1
28	-	-	*	*	*	1	slightly	1987	1
29	-	-	0	1	0	1	1	1985	1
30	-	-	-	-	-	1	*	1985	1
31	0.00	0.00	*	*	*	1	*	1987	0
32	-	-	*	*	*	-	*	*	0
33	-	-	-	-	-	-	*	-	-
34	-	-	-	-	-	-	*	1986	1
35	-	-	*	*	*	-	*	1983	1
36	-	-	*	*	*	-	*	1983	1
37	-	-	*	*	*	-	*	1985	1
38	-	-	-	-	-	0	0	1985	1
39	-	-	*	*	*	-	-	1985	1
40	-	-	0	0	1	1	0	1982+1984	1
41	-	-	-	-	-	1	*	1982	1
43	-	-	1	1	0	1	*	1983	1
44	-	-	*	*	*	0	0	1985	1
45	-	-	*	*	*	0	*	*	0
46	-	-	*	*	*	1	*	1985	1
47	-	-	*	*	*	0	*	1985	1
48	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-
50	6	0.18	*	*	*	*	*	1988/1989	1
51	*	*	*	*	*	*	*	01/1904	0
52	-	-	-	-	-	-	*	-	0
53	-	-	*	*	*	0	*	1988	1
54	-	-	-	-	-	-	-	-	1
55	-	-	-	-	-	-	-	-	0
56	-	-	-	-	-	-	*	1984	1
57	-	-	*	*	*	0	*	1985	1
58	-	-	*	*	*	0	*	1985	1
59	5	-	1	0	0	0	0	-	0
60	-	-	-	-	debonded	0	*	1988	1
61	-	-	1	0	0	0	*	1988	1
62	-	-	-	-	-	-	*	1988	-
63	-	-	-	-	-	-	-	-	-
64	-	-	-	-	-	-	*	1981	-
65	-	-	-	-	-	-	-	-	-
67	-	-	*	*	*	0	0	1988	1
68								1988	1
69						0		1988	1
70	31.80	-	-	-	-	-	*	1989	1
71	-	-	*	*	*	0	1	1986	1
72	-	-	*	*	*	0	0	1992	1
73	-	-	*	*	*	0	0	1992	1
74	3.00	0.76	-	-	-	-	*	1981	0
75	-	-	-	*	-		*	1983	0

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No	Repair Number 1							
	Jack ham	Blastrac	Hydrod.	Patching	Remov.mm	Patch%	Epoxy	Exp.joint
12	1	0	0	1	0	0	0	0
13	1	0	0	1	0	-	0	0
14	1	0	0	1	0	0	1	0
15	1	0	0	1	0	0	0	0
16	1	0	0	1	0	0	0	0
17	-	-	-	1	0	0	0	0
18	1	0	0	1	75 to 125	0	0	0
19	1	0	0	1	0	0.5	0	0
20	-	-	-	-	-	-	-	-
21	1	0	0	1	-	-	-	1
22	-	-	-	0	0	100	1	1
23	1	0	0	1	-	-	-	-
24	0	0	1	-	-	65	0	0
25	1	0	0	1	-	-	0	-
26	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*
28	1	0	0	1	-	-	*	1
29	1	0	0	1	50	-	0	0
30	0	1	1	1	75	0.7	0	1
31	0	0	0	0	0	0	1	0
32	1	0	0	1	75	-	0	0
33	-	-	-	-	-	-	-	-
34	*	*	*	*	*	*	*	*
35	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	rout & seal	0
37	1	0	0	0	0	0	rout & seal	1
38	1	0	0	1	-	-	0	1
39	1	0	0	1	-	-	rout & seal	0
40	1	0	0	0	0	0	0	1
41	1	1	0	0	75	-	0	0
43	1	0	0	1	0	-	0	1
44	1	1	0	1	*	15	0	0
45	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	1	0
47	*	*	*	*	*	*	*	*
48	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-
50	*	*	*	*	*	*	*	*
51	1	1	0	1	-	-	0	1
52	-	-	-	-	-	-	-	-
53	*	*	*	*	*	*	*	*
54	*	*	*	*	-	*	*	*
55	1	0	0	1	-	1	1	1
56	1	0	0	1	0	-	0	1
57	1	0	0	1	-	-	0	1
58	1	0	0	1	0	1.1	0	*
59	*	*	*	*	*	*	*	*
60	*	*	*	*	*	*	*	*
61	1	0	0	1	50	-	0	0
62	1	0	0	1	12	-	0	-
63	-	-	-	-	-	-	-	-
64	1	0	0	1	-	12	-	-
65	-	-	-	-	-	-	-	-
67	0	0	0	0	0	0	0	1
68	0	0	0	0	0	0	1Tremepoxy	1
69								1
70	1	0	0	0	200	0	0	1
71	0	*	*	*	*	*	*	*
72	0	0	0	0	0	0	0	0
73	0	*	*	*	*	*	*	*
74	-	-	-	-	-	-	1	1
75	1	-	-	1	-	18	1	1

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No	Repair Number 1									
	Add drain	Incr.slope	Add.mem	Sealer	CP	Rep.roof	Tendon	Other	Date	Cost
12	0	0	0	1	0	0	1	0	1984	$200,000
13	1	0	1	1	0	*	*	-	1984	$200,000
14	0	0	1	1	0	*	*	0	1980-1983	$300,000
15	0	0	1	0	0	*	*	-	1985	$63,000
16	1	0	1	0	0	*	*	-	1984	$175,000
17	0	0	0	0	0	*	*	-	-	$20,000
18	1	0	1	0	0	*	*	*	1980	$300,000
19	0	0	0	0	0	*	*	-	-	-
20	-	-	1	-	-	-	*	-	-	$100,000
21	-	-	-	-	-	*	-	-	1983	$1,300,000
22	1	1	1	0	0	*	*	Through slab	1980-1984	$500,000
23	1	0	1	0	0	0	*	*	1987	$500,000
24	1	0	1	0	0	*	*	soffit+through slab	1987	$750,000
25	1	-	1	0	0	*	*	soffit repair	1984	$226,131
26	*	*	*	*	0	*	*	*	*	*
27	*	*	*	*	*	*	*	*	*	*
28	0	0	1	1	0	*	0	repair column	1989	$170,000
29	1	0	1	1	0	1	0	Rout &seal cracks	1986	see #30
30	1	0	1	1	0	*	*	rout&seal crack	1986	$2,150,000
31	1	0	0	1	*	*	*	0	-	-
32	1	0	0	1	0	0	*	soffit,cracks	1984	$60,000
33	-	-	-	-	-	-	-	-	-	-
34	*	*	*	*	*	*	*	*	*	*
35	0	0	0	1	0	0	0	rout&seal crack	1984	$37,900
36	0	0	0	1	0	0	*	*	1984	$18,800
37	1	0	1	1	0	0	*	0	1987	$93,800
38	0	0	1	0	0	0	*	*	1987	$52,000
39	0	0	0	1	0	0	0	*	1987	$63,656
40	1	1	1	0	0	0	*	new wearing	1986	$215,000
41	0	1	1	0	0	0	*	top steel epoxy	1983	$220,000
43	1	1	1	0	0	1	*	0	1986	$662,000
44	1	1	1	0	0	*	*	0	1986	$651,300
45	0	0	0	1	0	0	*	cr.slurry to fill cr	1983	$5,000
46	0	0	0	0	0	*	*	*	-	-
47	*	*	*	*	*	*	*	*	*	*
48	-	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-	-
50	*	*	1	*	*	*	*	*	1991	$452,000
51	0	0	1	0	0	*	*	0	1978	$80,000
52	-	-	-	-	-	-	*	-		-
53	*	*	*	*	*	*	*	*	*	*
54	*	*	*	*	*	*	*	*	*	*
55	0	0	1	0	0	0	*	epoxysteel		-
56	1	0	1	0	0	1	*	0	1985	$505,539
57	1	-	0	0	1	0	*	*	1986	$300,000
58	0	0	1	0	0	*	*	0	1986	$88,000
59	*	*	*	*	*	*	*	*	*	*
60	*	*	rep'd	*	*	*	*	*	1989	*
61	0	1	1	0	0	*	*	0	1988	$260,000
62	-	-	1	0	0	*	-	-	1985	-
63	-	-	-					-	1982	$300,000
64	-	-	-	0	0	*	*	-	1982	$300,000
65	-	-	-	-	-	-	-	-	-	-
67	0	0	0	1	0	0	0	0	1988	$63,053
68	0	0	0	1	0	0	0	0	1988	≈ $70,000
69				1					1988	≈ $70,000
70	1	1	1	-	-	-	*	-	-	-
71	*	*	*	*	*	*	*	*	*	*
72	0	0	0	0	0	0	0	0	0	*
73	*	*	*	*	*	*	*	*	*	*
74	-	-	0	0	0	-	*	-	1981	-
75	-	-	1	0	0	*	*	-	1983	$124,995

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

	Prior Repair Number 2										
No	Delam. %	Leak/slab	Roof	Exp.join	Perim.w	Ponding	Cracking	Spalling	Scaling	Effiores	Cl %
12	2	0	0	0	1	0	0	0	0	0	-
13	3	iround water	*	0	0	0	0	0	0	0	-
14	6	1	*	0	0	0	0	1	0	0	-
15	0	0	0	0	0	0	0	0	0	0	0
16	0	1	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	exp.aggr 1	0	0	0
18	12.9	0	1	1	0	1	1	0	0	1	0.28
19	-	-	-	-	-	-	-	-	-	-	-
20	-	-	*	*	-	-	-	-	-	-	-
21	*	*	*	*	*	*	*	*	*	*	*
22	/.92sive ex	1	*	1	0	1	1	1	1	1	0.18
23	*	*	*	*	*	*	*	*	*	*	*
24	*	*	*	*	*	*	*	*	*	*	*
25	23	1	*	1	0	0	1	1	1	1	0.02
26	*	*	*	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*	*	*	*
28	*	*	*	*	*	*	*	*	*	*	*
29	2.2	*	*	*	*	*	*	*	*	*	*
30	-	1	-	1	-	-	-	-	-	-	-
31	10	1	0	1	1	0	0	1	1	1	-
32	0.5	0	1	0	1	0	0	0	1	0	-
33	5.5	0	0	1	0	0	1	0	0	0	-
34	*	*	*	*	*	*	*	*	*	*	*
35	*	*	*	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*	*	*	*
37	*	*	*	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*	*	*	*
48	-	-	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-	-	-
50	*	*	*	*	*	*	*	*	*	*	*
51	*	*	*	*	*	*	*	*	*	*	*
52	-	-	-	-	-	-	-	-	-	-	-
53	*	*	*	*	*	*	*	*	*	*	*
54	*	*	*	*	*	*	*	*	*	*	*
55	5	0	0	1	0	1	1	0	0	0	0.33
56	*	*	*	*	*	*	*	*	*	*	*
57	11	0.5	0.5	0.5	0.5	0	0	0.5	0.5	0.5	-
58	0.46	*	*	*	*	*	*	*	*	*	*
59	*	*	*	*	*	*	*	*	*	*	*
60	*	*	*	*	*	*	*	*	*	*	*
61	*	*	*	*	*	*	*	*	*	*	*
62	1.15	0	0	0	0	-	-	1	1	-	0
63	-	-	-	-	-	-	-	-	-	-	-
64	19.3	-	-	-	-	-	-	-	-	-	0.6
65	-	-	-	-	-	-	-	-	-	-	-
67	*	*	*	*	*	*	*	*	*	*	*
68	*	*	*	*	*	*	*	*	*	*	*
69						1					
70	*	*	*	*	*	*	*	*	*	*	*
71	*	*	*	*	*	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*	*	*	*
74	8	1	-	1	-	1	1	1	1	1	0.13
75		1	*	1	-	1	1	1	1	1	-

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No	Cell pot%	Cvr min	Cvr max	Prior Comp.MPa	Repair Ent.air%	Number Mem.crac	2 Memb.wor	Memb.sat	Column	Tendons	Rpt date
12	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	*	1986
14	40	-	-	-	-	0	0	1	-	*	1986
15	0	0	0	0	0	1	0	-	0	0	
16	0	0	0	0	0	1	1	0	-	-	1987
17	0	0	0	-	-	-	-	-	-	*	1987
18	3.1	-	-	-	-	0	1	1	0	*	1987
19	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	*	
21	*	*	*	*	*	*	*	*	*	*	*
22	10	0	38	28	*	*	*	*	1	*	1985
23	*	*	*	*	*	*	*	*	*	*	*
24	*	*	*	*	*	1	*	*	*	*	*
25	-	-	37	28	*	*	*	*	*	*	1984
26	*	*	*	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*	*	*	*
28	*	*	*	*	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*	*	*	*	1991
30	-	-	-	-	-	-	-	-	-	-	1985
31	-	-	-	-	-	*	*	*	1	*	1991
32	5	-	-	-	-	*	*	*	0	*	1984
33	14	-	-	-	-	*	*	1	-	-	-
34	*	*	*	*	*	*	*	*	*	*	*
35	*	*	*	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*	*	*	*
37	*	*	*	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*	*	*	*
48	-	-	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-	-	-
50	*	*	*	*	*	*	*	*	*	*	*
51	*	*	*	*	*	*	*	*	*	*	*
52	-	-	-	-	-	-	-	-	-	-	-
53	*	*	*	*	*	*	*	*	*	*	*
54	*	*	*	*	*	*	*	*	*	*	*
55	-	-	-	34	-	0	1	0	0	*	1988
56	*	*	*	*	*	*	*	*	*	*	*
57	-	0.25	1	48	*	*	*	*	0	*	1988
58	*	*	*	*	*	1	*	0	*	*	1986
59	*	*	*	*	*	*	*	*	*	*	*
60	*	*	*	*	*	1	*	0	*	*	1988
61	*	*	*	*	*	*	*	*	*	*	*
62	0.02	0	0	-	-	0	0	0	*	*	1990
63	-	-	-	-	-	-	-	-	-	-	-
64	0.4	-	-	-	-	0	0	1	*	*	1990
65	-	-	-	-	-	-	-	-	-	-	-
67	*	*	*	*	*	*	*	*	*	*	*
68	*	*	*	*	*	*	*	*	*	*	*
69											1991
70	*	*	*	*	*	*	*	*	*	*	*
71	*	*	*	*	*	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*	*	*	*
74	12	0	90	31	3	0.761	1	0	1		1991
75	-	-	-	-	-	*	*	*	-	*	1984

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No	Repair Number 2									
	Jack ham	Blastrac	Hydrode	Patching	Remov.in	Patch%	Epoxy Inj.	Exp.joint	Add drains	Incr.slope
12	*	*	*	*	*	*	*	*	*	*
13	-	-	-	-	-	-	-	-	-	-
14	*	*	*	*	*	*	*	*	*	*
15	-	-	-	-	-	-	-	-	-	-
16	0	0	0	0	membrane	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
18	*	*	*	*	*	*	*	*	*	*
19	-	-	-	-	-	-	-	-	-	-
20	*	*	*	*	*	*	*	*	*	*
21	*	*	*	*	*	*	*	*	*	*
22	-	-	-	-	-	100	0	1	1	1
23	*	*	*	*	*	*	*	*	*	*
24	*	*	*	*	*	*	*	*	*	*
25	0	0	1	1	-	-	-	1	1	-
26	*	*	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*	*	*
28	*	*	*	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*	*	*	*
30	-	-	-	-	-	-	-	-	-	-
31	*	*	*	*	*	*	*	*	*	*
32	*	*	*	*	*	*	*	*	*	*
33	-	-	-	-	-	-	-	-	-	-
34	*	*	*	*	*	*	*	*	*	*
35	*	*	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*	*	*
37	*	*	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*	*	*
48	-	-	-	-	-	-	-	-	-	-
49	-	-	-	-	-	-	-	-	-	-
50	*	*	*	*	*	*	*	*	*	*
51	*	*	*	*	*	*	*	*	*	*
52	-	-	-	-	-	-	-	-	-	-
53	*	*	*	*	*	*	*	*	*	*
54	*	*	*	*	*	*	*	*	*	*
55	*	*	*	*	*	*	*	*	*	*
56	*	*	*	*	*	*	*	*	*	*
57	0	*	*	*	*	*	*	*	*	*
58	0	*	*	*	*	*	*	*	*	*
59	*	*	*	*	*	*	*	*	*	*
60	*	*	*	*	*	*	*	*	*	*
61	*	*	*	*	*	*	*	*	*	*
62	*	*	*	*	*	*	*	*	*	*
63	-	-	-	-	-	-	-	-	-	-
64	*	*	*	*	*	*	*	*	*	*
65	-	-	-	-	-	-	-	-	-	-
67	*	*	*	*	*	*	*	*	*	*
68	*	*	*	*	*	*	*	*	*	*
69	-	-	-	-	-	-	-	-	1	1
70	*	*	*	*	*	*	*	*	*	*
71	0	*	*	*	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*	*	*
74	*	*	*	*	*	*	*	*	*	*
75	1	0	0	1	-	1	1	1	-	-

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No	Add CP	Repair Rpr.roof	Number 2 Repl.tend	Other	Date of rpr	Cost of rpr
12	*	*	*	*	*	*
13	-	-	-	-	-	-
14	*	*	*	*	*	*
15	*	*	*	Remove membr.	1987	$10,000
16	-	-	-	-	1986	$50,000
17	-	-	-	-	1987	$8,000
18	*	*	*	*	*	*
19	-	-	-	-	-	-
20	0	*	*	-	-	$300,000
21	*	*	*	*	*	*
22	0	*	*	*	1986	$1,543,000
23	*	*	*	*	*	*
24	*	*	*	*	*	*
25	-	-	-	soffit repair	1986	$532,000
26	*	*	*	*	*	*
27	*	*	*	*	*	*
28	*	*	*	*	*	*
29	*	*	*	*	*	*
30	-	-	-	SIKA patch	1986	$350,000
31	*	*	*	*	*	*
32	*	*	*	*	*	*
33	-	-	-	-	-	-
34	*	*	*	*	*	*
35	*	*	*	*	*	*
36	*	*	*	*	*	*
37	*	*	*	*	*	*
38	*	*	*	*	*	*
39	*	*	*	*	*	*
40	*	*	*	*	*	*
41	*	*	*	*	*	*
43	*	*	*	*	*	*
44	*	*	*	*	*	*
45	*	*	*	*	*	*
46	*	*	*	*	*	*
47	*	*	*	*	*	*
48	*	*	*	*	*	*
49	*	*	*	*	*	*
50	*	*	*	*	*	*
51	*	*	*	*	*	*
52	-	-	-	-	-	-
53	*	*	*	*	*	*
54	*	*	*	*	*	*
55	*	*	*	*	*	*
56	*	*	*	*	*	*
57	*	*	*	*	*	*
58	*	*	*	*	*	$20,000
59	*	*	*	*	*	*
60	*	*	*	rep.memb	*	$20,000
61	*	*	*	*	*	*
62	*	*	*	*	*	*
63	-	-	-	-	-	-
64	*	*	*	*	*	*
65	-	-	-	-	-	-
67	*	*	*	*	*	*
68	*	*	*	*	*	*
69						
70	*	*	*	*	*	*
71	*	*	*	0	*	*
72	*	*	*	*	*	*
73	*	*	*	*	*	*
74	*	*	*	*	*	*
75	0	*	*	-	1984	$306,871

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No	Rep sat'ry	Delam. %	Leak/slab	Leak/exp.j.	Ponding	Prior Repair 3 Cracking	Spalling	Scale/pitt	Effloresc
12	*	*	*	*	*	*	*	*	*
13	-	-	-	-	-	-	-	-	*
14	*	*	*	*	*	*	*	*	*
15	0	*	1	-	-	-	-	-	1
16	0	*	0	-	-	-	-	-	0
17	e	*	*	*	*	*	*	*	*
18	*	*	*	*	*	*	*	*	*
19	-	-	-	-	-	-	-	-	-
20	1	*	-	-	-	-	-	-	-
21	*	*	*	*	*	*	*	*	*
22	1	23	1	1	1	1	1	1	1
23	*	*	*	*	*	*	*	*	*
24	*	*	*	*	*	*	*	*	*
25	1	*	*	*	*	*	*	*	*
26	*	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*	*
28	*	*	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*	*	*
30	1	*	1	1	*	*	*	*	*
31	*	*	*	*	*	*	*	*	*
32	*	4	*	*	*	*	*	*	*
33	-	-	-	-	-	-	-	-	-
34	*	*	*	*	*	*	*	*	*
35	*	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*	*
37	*	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*	*
48	*	*	*	*	*	*	*	*	*
49	*	*	*	*	*	*	*	*	*
50	*	*	*	*	*	*	*	*	*
51	*	*	*	*	*	*	*	*	*
52	-	-	-	-	-	-	-	-	-
53	*	*	*	*	*	*	*	*	*
54	*	*	*	*	*	*	*	*	*
55	*	*	*	*	*	*	*	*	*
56	*	*	*	*	*	*	*	*	*
57	*	*	*	*	*	*	*	*	*
58	*	*	*	*	*	*	*	*	*
59	*	*	*	*	*	*	*	*	*
60	*	*	*	*	*	*	*	*	*
61	*	*	*	*	*	*	*	*	*
62	*	*	*	*	*	*	*	*	*
63	-	-	-	-	-	-	-	-	-
64	*	*	*	*	*	*	*	*	*
65	-	-	-	-	-	-	-	-	-
67	*	*	*	*	*	*	*	*	*
68	*	*	*	*	*	*	*	*	*
69									
70	*	*	*	*	*	*	*	*	*
71	*	*	*	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*	*
74	*	*	*	*	*	*	*	*	*
75		25	1	1	1	1	1	1	1

1=Yes, 0=No, * Not applicable, - No response

Table 1. (continued) Garage Sample

No				Prior Repair 3				
No	Cl conc,%	Cell pot,%	Cover min	Cover max	C'mpr.psi	Col'n spall	Duct water	Survey date
12	*	*	*	*	*	*	*	*
13	*	*	*	*	*	*	*	*
14	*	*	*	*	*	*	*	*
15	*	*	*	*	*	*	*	1987
16	*	*	*	*	*	*	*	1987
17	*	*	*	*	*	*	*	*
18	*	*	*	*	*	*	*	*
19	*	*	*	*	*	*	*	-
20	*	*	*	*	*	*	*	-
21	*	*	*	*	*	*	*	*
22	0.302	43	0	1.5	4000	1	1	1987
23	*	*	*	*	*	*	*	*
24	*	*	*	*	*	*	*	*
25	*	*	*	*	*	*	*	*
26	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*
28	*	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*	*
30	*	*	*	*	*	*	*	1990
31	*	*	*	*	*	*	*	*
32	*	*	*	*	*	*	*	1990
33	-	-	-	-	-	-	-	-
34	*	*	*	*	*	*	*	*
35	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*
37	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*
48	*	*	*	*	*	*	*	*
49	*	*	*	*	*	*	*	*
50	*	*	*	*	*	*	*	*
51	*	*	*	*	*	*	*	*
52	-	-	-	-	-	-	-	-
53	*	*	*	*	*	*	*	*
54	*	*	*	*	*	*	*	*
55	*	*	*	*	*	*	*	*
56	*	*	*	*	*	*	*	*
57	*	*	*	*	*	*	*	*
58	*	*	*	*	*	*	*	*
59	*	*	*	*	*	*	*	*
60	*	*	*	*	*	*	*	*
61	*	*	*	*	*	*	*	*
62	*	*	*	*	*	*	*	*
63	-	-	-	-	-	-	-	-
64	*	*	*	*	*	*	*	*
65	-	-	-	-	-	-	-	-
67	*	*	*	*	*	*	*	*
68	*	*	*	*	*	*	*	*
69								
70	*	*	*	*	*	*	*	*
71	*	*	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*
74	*	*	*	*	*	*	*	*
75	0.417	-	38	70		1	1	1991

1=Yes, 0=No, * Not applicable, - No response

Table 1.(continued) Garage Sample

No	Repair Number 3								
	Patch area%	Exp.joint	Add drain	Incr.slope	Inst.mem.	Sealer	Other	Date	Cost
12	*	*	*	*	*	*	*	*	*
13	*	*	*	*	*	*	*	*	*
14	*	*	*	*	*	*	*	*	*
15	*	*	*	*	*	xy floor c	*	1987	$6,500
16	*	*	*	*	*	Hydrozo	*	ongoing	$10,000
17	*	*	*	*	Sn502,latex,	Nitoflor	Fc130\epoxy	*	*
18	*	*	*	*	*	-	-	-	-
19	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-
21	*	*	*	*	*	*	*	*	*
22	100	1	1	1	1	0	Epoxy ctd stee	1988	$1,950,000
23	*	*	*	*	*	*	*	*	*
24	*	*	*	*	*	*	*	*	*
25	*	*	*	*	*	*	*	*	*
26	*	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*	*
28	*	*	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*	*	*
30	*	1	*	*	*	1	*	*	$100,000
31	*	*	*	*	*	*	*	*	*
32	*	*	*	*	*	*	*	*	*
33	-	-	-	-	-	-	-	-	-
34	*	*	*	*	*	*	*	*	*
35	*	*	*	*	*	*	*	*	*
36	*	*	*	*	*	*	*	*	*
37	*	*	*	*	*	*	*	*	*
38	*	*	*	*	*	*	*	*	*
39	*	*	*	*	*	*	*	*	*
40	*	*	*	*	*	*	*	*	*
41	*	*	*	*	*	*	*	*	*
43	*	*	*	*	*	*	*	*	*
44	*	*	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*	*	*
46	*	*	*	*	*	*	*	*	*
47	*	*	*	*	*	*	*	*	*
48	*	*	*	*	*	*	*	*	*
49	*	*	*	*	*	*	*	*	*
50	*	*	*	*	*	*	*	*	*
51	*	*	*	*	*	*	*	*	*
52	-	-	-	-	-	-	-	-	-
53	*	*	*	*	*	*	*	*	*
54	*	*	*	*	*	*	*	*	*
55	*	*	*	*	*	*	*	*	*
56	*	*	*	*	*	*	*	*	*
57	*	*	*	*	*	*	*	*	*
58	*	*	*	*	*	*	*	*	*
59	*	*	*	*	*	*	*	*	*
60	*	*	*	*	*	*	*	*	*
61	*	*	*	*	*	*	*	*	*
62	*	*	*	*	*	*	*	*	*
63	-	-	-	-	-	-	-	-	-
64	*	*	*	*	*	*	*	*	*
65	-	-	-	-	-	-	-	-	-
67	*	*	*	*	*	*	*	*	*
68	*	*	*	*	*	*	*	*	*
69									
70	*	*	*	*	*	*	*	*	*
71	*	*	*	*	*	*	*	*	*
72	*	*	*	*	*	*	*	*	*
73	*	*	*	*	*	*	*	*	*

1=Yes, 0=No, * Not applicable, - No response

APPENDIX B

Garage No. 18

An underground enclosed garage serving a large office building that was built in 1970.

The structure consists of one 300 mm thick suspended slab (11,148 m^2), one slab on grade approximately of the same size, and two interior ramps, each of approximately 70 m^2 in size.

Horizontal movement of the slab is facilitated by expansion joints the total measuring 263 metres.

The parking structure is of the flat slab design with drop panels. In addition, some of the columns have capitals.

Repair History and Protection System

Ten years after construction major rehabilitation was undertaken. It was necessitated by the detection of delamination in 35% of the area of the suspended slab. Spalling, scaling, efflorescence and leakage through the slab were evident.

The repair consisted of replacement of the delaminated concrete with sound concrete, and improvement of the drainage system. A waterproofing membrane (Kelmar) was installed. The cost of the repair was $300,000 (1980 $).

Rate of Delamination

The size of the delaminated areas, expressed as percentage of the total is given in Table 18.1 and Figures 18.1 and 18.2.

In a ten year period, from the time of rehabilitation in 1980, the overall extent of delamination grew 26.2%, but in Test Area 3 the size of delamination grew 44.1%. The lowest rate of delamination occurred in Area 2 (14.9% in 10 years) and Area 1 (18.1%).

Contrary to expectation, the rates of growth are still describable by a linear relationship as shown in Figures 18.3 through 18.7. Statistical analysis (Table 18.2) indicate that the considerable extent of deterioration can be fitted fairly well by linear regression. The standard error of estimate, the amount on average, we would expect to be off in predicting delaminations for a given year, varies between 1.9 and 4.6%. It should be emphasized that the results by no means imply constant rate of deterioration of this structure in the future. In fact almost certainly the contrary is true; delamination growth will take place at an accelerated, exponential rate. The value of the present results is the indication that in the case of Garage 18 up to approximately

30% delamination the data were on the initial, fairly linear portion of the experimental curve. Significantly, the linear regression line for Area 3 is the least accurate with the highest standard error of estimate (4.586). 1.7% (Area 1), 1.2% (Area 2), 4.0% (Area 3), 2.9% (Area 4) and 2.5% for the average.

Covermeter Readings

The thickness of the concrete cover in the four areas is listed in Table 18.3. Two comments can be made:

- The average cover, 1.8 in. or 46 mm, is actually more than required by the current CSA S413 standard (40 mm); and
- The cover in Area 3 is no different from that in other areas which perform significantly better.

These observations emphasize the importance of other defensive measures (concrete quality, drainage, waterproofing) as well as concrete cover, which in itself cannot prevent corrosion of the steel.

Half-Cell Potential

The half-cell potential readings obtained in the test areas are given in Table 18.4. The averages of all readings and the distribution in the four test areas of the readings according the ASTM threshold values are also presented in graphical form in Figs. 18.8 through 18.11.

It has to be noted that on the basis of the half-cell potential measurements the condition of the garage appears to be much better than it was found by the delamination survey. The proportion of readings less than 0.20 V is quite high (>60%) even in Area 3, though 44% of the area is delaminated. Corrosion is considered certain if the potential is greater than 0.35 V according to the ASTM C876 standard. In Area 3 20% of the readings fell in this category, while the chain-drag test indicated 44% delamination.

Comparing the delamination and half-cell potential values a very significant discrepancy is evident. In every case the half-cell potential indicates a lesser problem than the delamination test.

Chloride Content of Concrete

Two cores extracted from the deck in the last three surveys were analyzed for chloride content at three horizons (Table 18.5 and, Figs. 18.12 and 18.13).

It is interesting that after the repairs the chloride content has equalized leading to an elevated concentraton in the new patch.

Discussion

The delamination survey indicates that in some areas the corrosion activity is high and expected to accelerate in the future.

The reason for the unsatisfactory performance can be ascribed to several reasons: the repair by patching in 1980 failed in several places and are now sites of corrosion activity; in some areas the membrane debonded, is worn and cracked; and some of the expansion joints are in need of repair.

Since the major repair work in 1980 maintenance activity, if existed, failed to correct the emerging problems listed above.

Tablel18.1
Garage No.18.
Rate of delamination

Year	Area1, %	Area 2, %	Area 3, %	Arera 4, %	Total, %
1980	0	0	0	0	0
1983	2.7	2.9	11.1	1.7	4.6
1987	8.9	3.9	21.2	18.2	12.9
1989	13.8	8.7	33.3	22.8	19.5
1990	18.1	14.9	44.1	28.2	26.2

Tablel18.2
Garage No.18.
Regression analysis of rate delamination

```
Regression

Dep var:   AREA1      N:    5    Multiple R:  .975    Squared Multiple R:  .950

Adjusted Squared Multiple R:  .933     Standard Error of Estimate:        1.947

  Variable     Coefficient     Std Error      Std Coef Tolerance      T    P(2 tail)

CONSTANT        -3449.621       459.449         0.000  .           -7.508    0.005
    YEAR            1.742         0.231         0.975  .100E+01     7.527    0.005

                           Analysis of Variance

   Source   Sum-of-Squares    DF  Mean-Square      F-Ratio        P

 Regression        214.730     1      214.730       56.657      0.005
   Residual         11.370     3        3.790
```

Table 18.3
Garage No. 18
Covermeter Readings

Area	Range of Readings, mm	No. of Readings	Average, mm	Standard Deviation, mm
1	20 - 85	28	46	12
2	40 - 70	29	50	8
3	20 - 90	27	46	16
4	20 - 90	27	46	13
Total	20 - 90	111	46	13

Table 18.4
Garage No.18
Change of half-cell potential distribution with time

Per cent of readings of indicated voltage in the various test areas

C.S.E. Volt	1983	1987	1989	1990
Area 1, <.20	91.4	82.9	82.5	67.5
Area 1, .20-.35	8.6	14.3	15.0	30.0
Area 1, >.35	0.0	2.8	2.5	2.5
Area 2, <.20	94.3	97.7	92.3	86.5
Area 2., 20-.35	5.7	2.3	5.8	7.7
Area 2, >.35	0.0	0.0	1.9	5.8
Area 3, <.20	61.5	57.8	73.3	64.4
Area 3, .20-.35	38.5	33.3	15.5	15.6
Area 3, >.35	0.0	8.9	11.2	20.0
Area 4, <.20	86.8	94.2	90.0	68.3
Area 4, .20-.35	13.2	5.8	10.0	29.3
Area 4, >.35	0.0	0.0	0.0	2.4
Total, <.20	84.2	82.4	84.7	72.5
Total, .20-.35	15.8	14.5	11.3	19.7
Total, >.35	0.0	3.1	4.0	7.9

Table 18.5
Garage No. 18
Percentage of water soluble chloride content by mass of concrete

	Horizon			
Year	10-20 mm	20-30mm	50-60 mm	90-100 mm
1987		0.006*	0.083*	0.11
1987		0.283	0.021	0.016
1989		0.010*	0.056*	0.175
1989		0.339	0.132	0.013
1990	0.377		0.268	0.086
1990	0.227		0.075	0.011

* - denotes repair concrete

Fig.18. 1
Garage No.18.
Total extent of delaminations in test areas vs. time

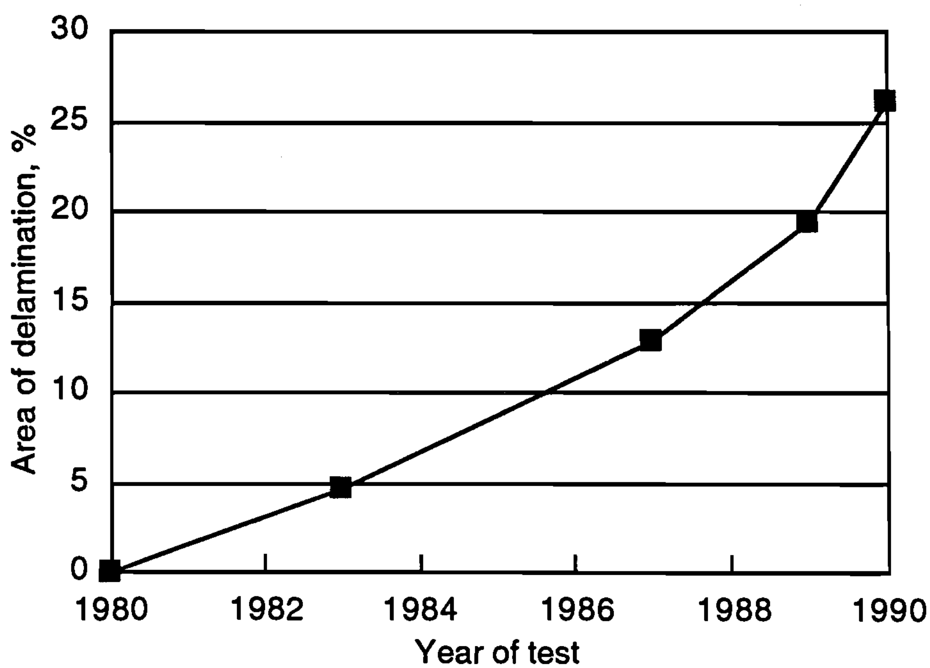


Fig.18.2
Garage No.18
Extent of delamination in test areas vs time

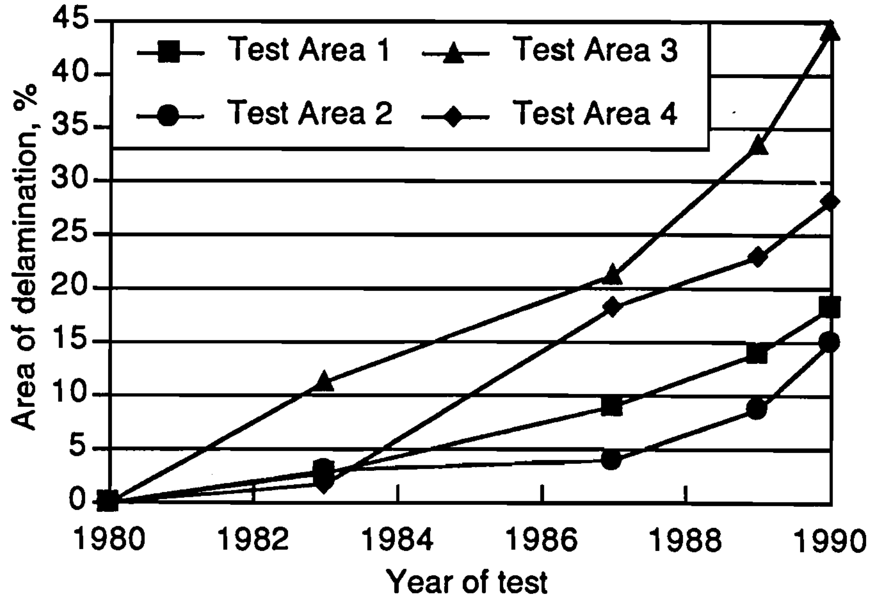
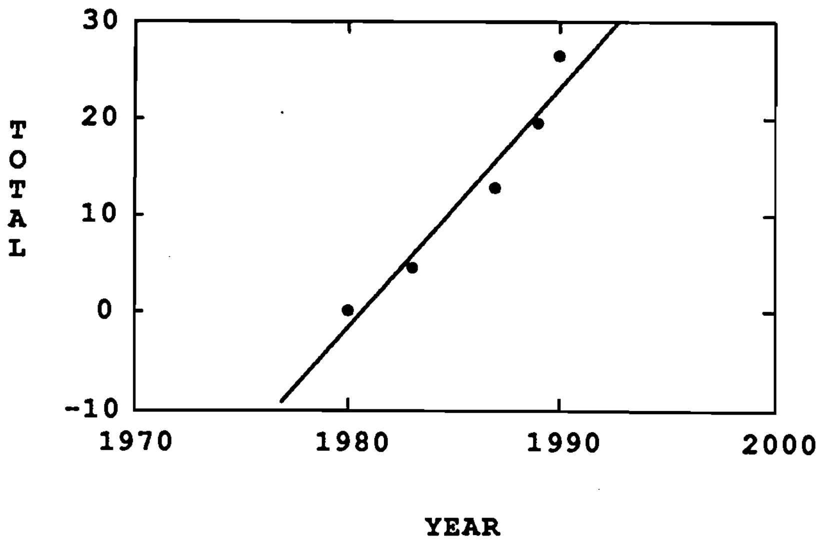
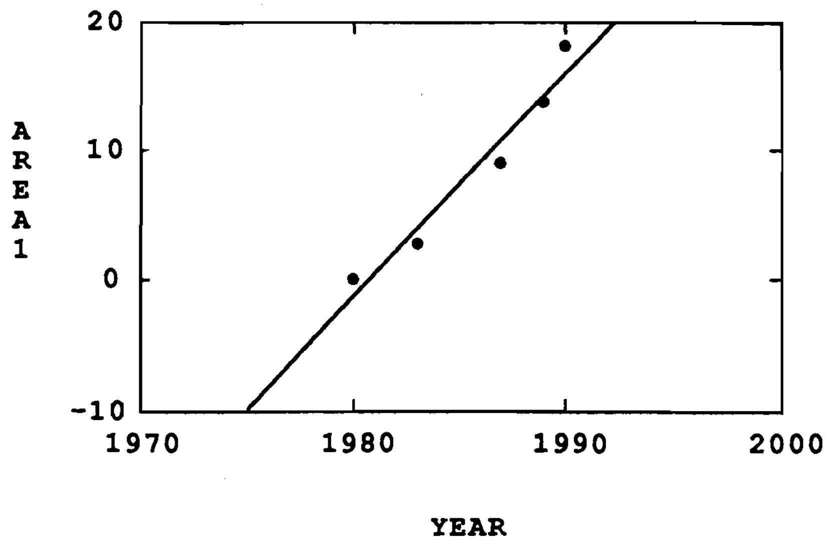


Figure 18.3
Garage No. 18
Regression line of extent of delaminations vs. time, all test areas



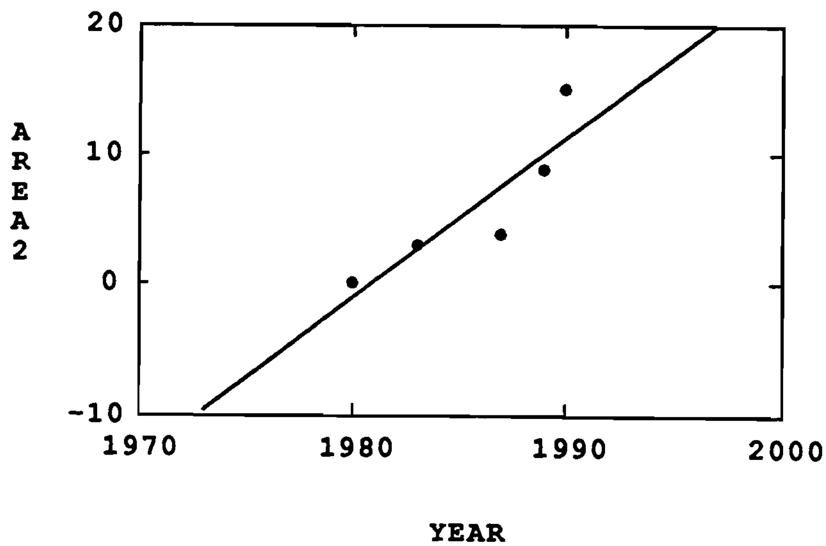
TOTAL=-4896.886+2.472*YEAR

Figure 18.4
Garage No. 18
Regression line of extent of delaminations vs. time in test area 1



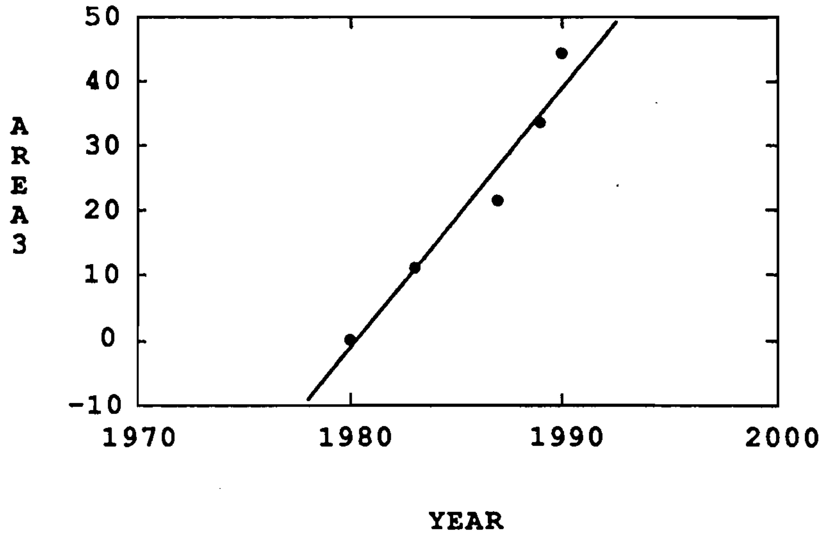
AREA1=-3449.621+1.742*YEAR

Figure 18.5
Garage No. 18
Regression line of extent of delaminations vs. time in test area 2



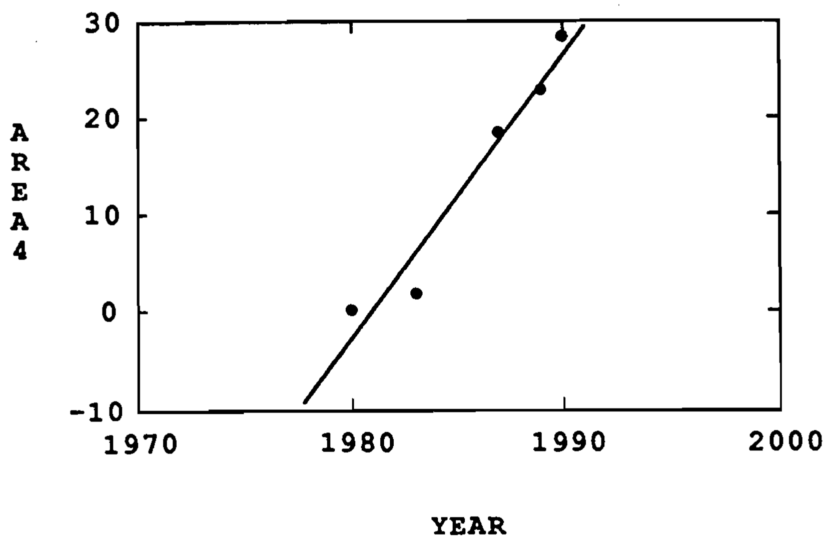
AREA2=-2433.537+1.229*YEAR

Figure 18.6
Garage No. 18
Regression line of extent of delaminations vs. time, in test area 3



AREA3=-8003.721+4.042*YEAR

Figure 18.7
Garage No. 18
Regression line of extent of delaminations vs. time, in test area 4



AREA4=-5833.272+2.945*YEAR

Fig.18.8
Garage No.18
Distribution of half-cell potential readings in the tested areas

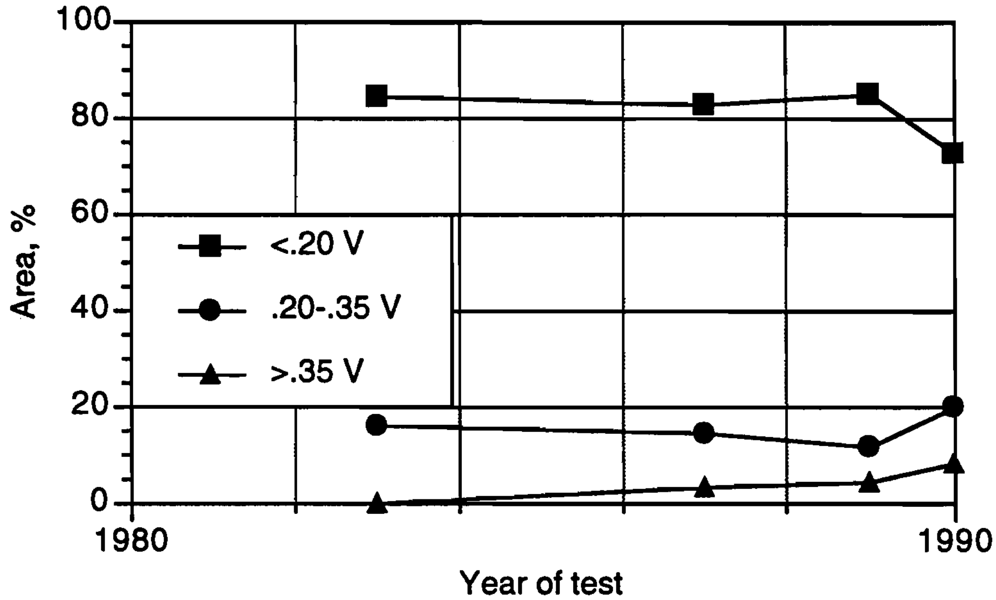


Fig.18.9
Garage No. 18
Per cent of area in which the half-cell potential is less than 0.20 V CSE

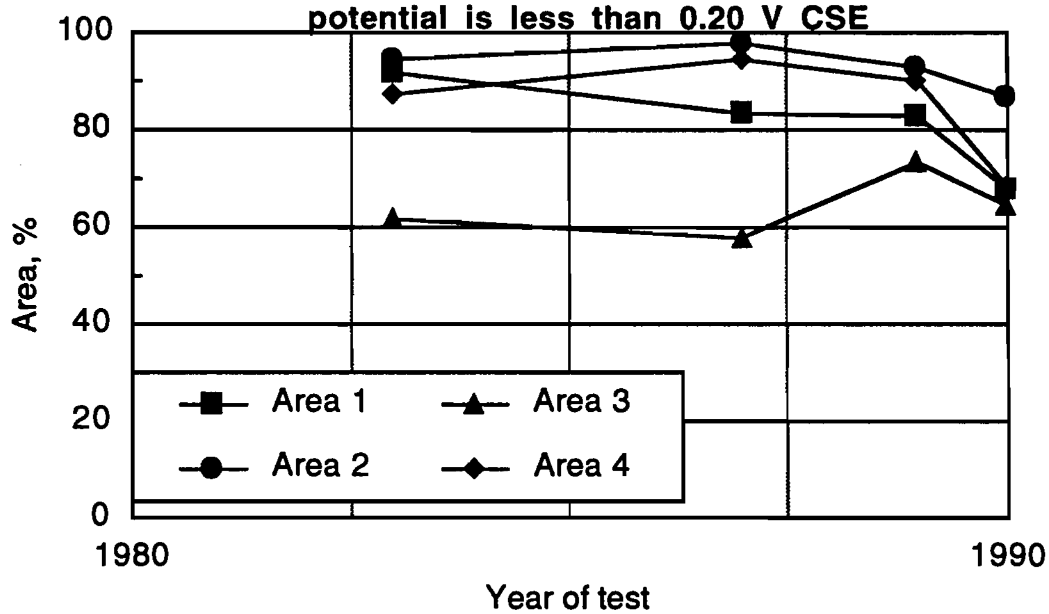


Fig. 18.10
Garage No.18
Per cent of area in which the half-cell potential is between 0.20 and 0.35 V

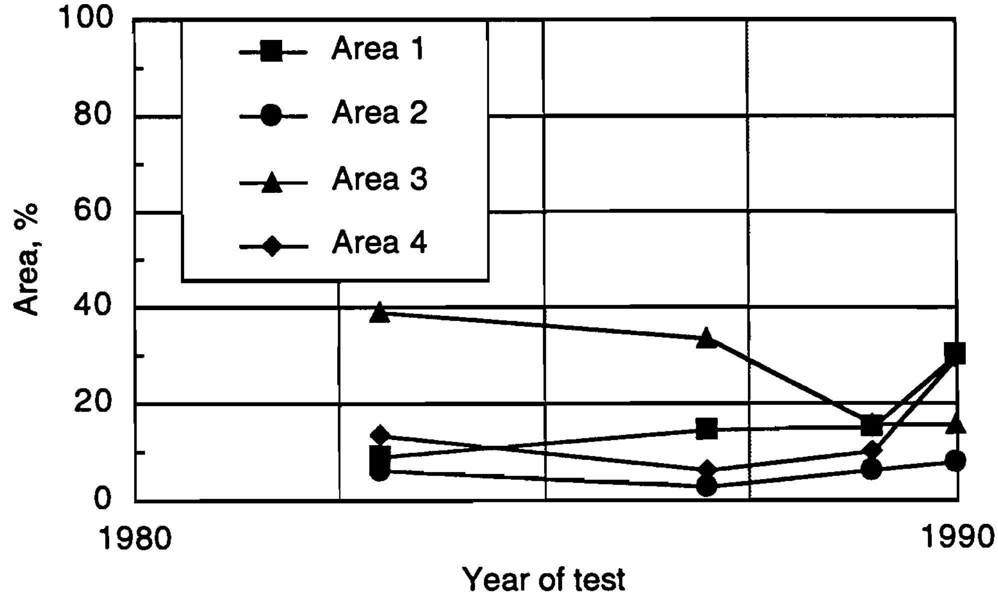


Fig. 18.11
Garage No.18
Per cent of area in which the half cell potential is greater than 0.35 V CSE

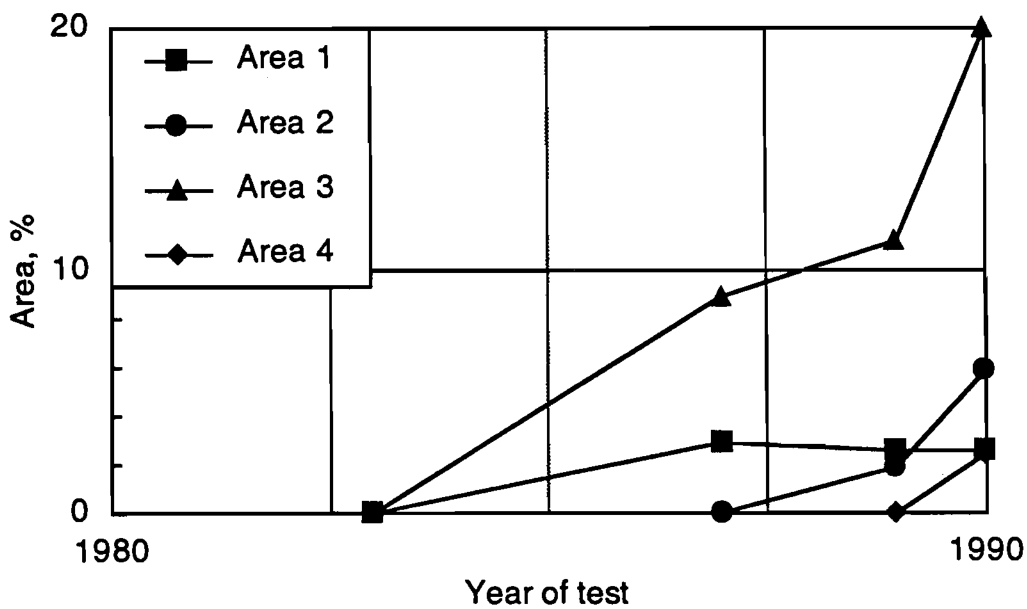


Fig. 18.12
Garage No.18
Chloride ion content, percent by mass of concrete, at horizons indicated

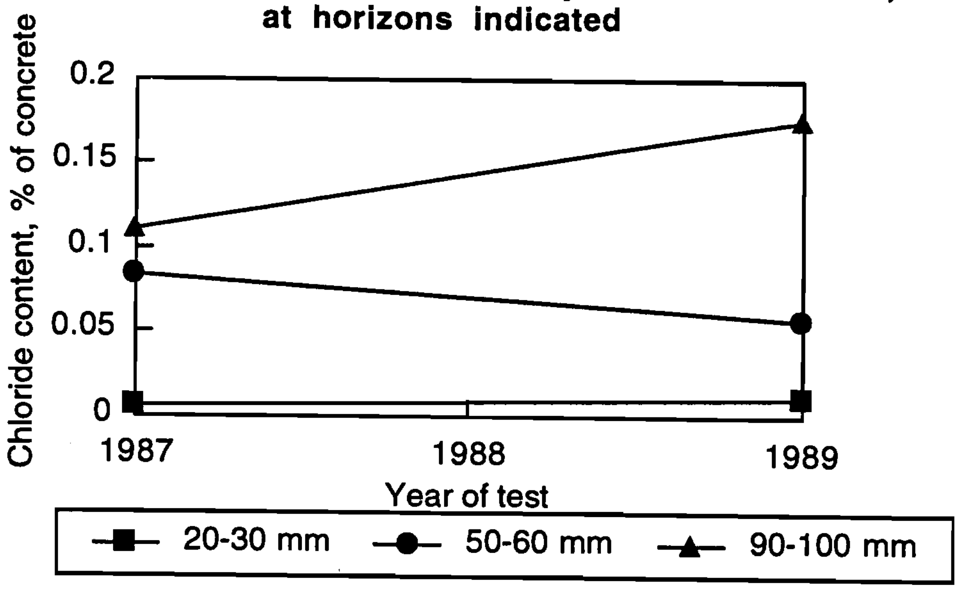
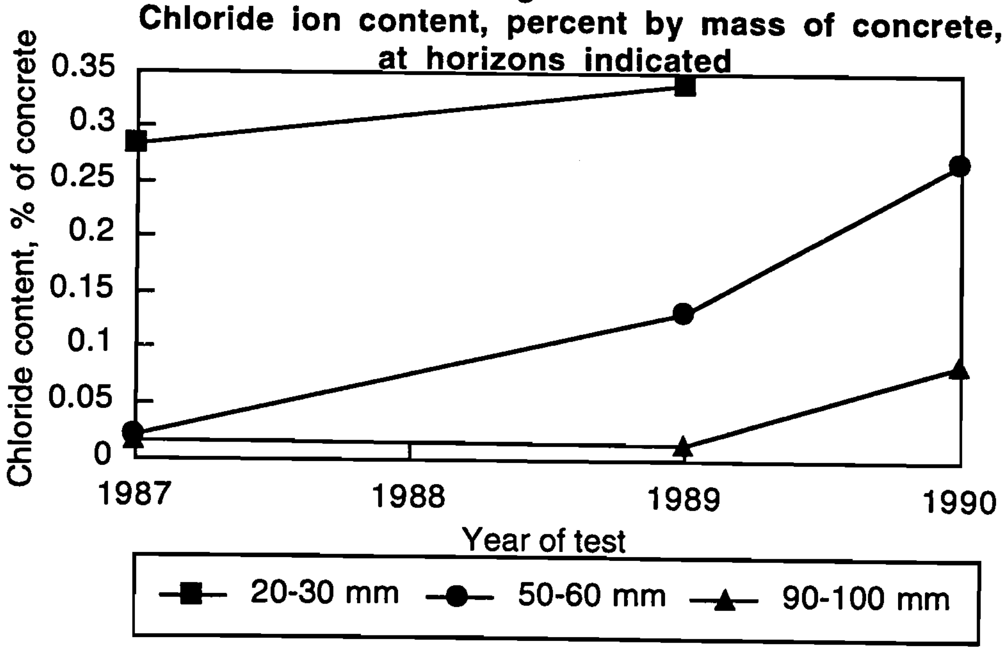


Fig. 18.13
Garage No.18
Chloride ion content, percent by mass of concrete, at horizons indicated



GARAGE NO. 19

Built in 1975, this underground parking garage serves a high-rise office and retail tower.

The structure is of flatslab design with drop panels, some columns have capitals.

In addition to the slab on grade there are two suspended concrete slabs that were topped with a concrete overlay at the time of construction.

The interior suspended slabs measure approximately 8,423 m^2, and the three interior ramps 786m^2.

Repair History

The first major rehabilitation of this garage took place in 1991 after 16 years of service. The worse cracks in the slabs have been epoxy injected from the underside. The drainage system has been greatly improved over the years.

Rate of Delamination

Condition surveys were made in 1983,1987,1989 and 1990. The results of the chain-drag test are given in Table 19.1 and in Figures 19.1 through 19.3.

In evaluating the results it has to be remembered that the extent of actual delamination is less than stated values because they include debonding of the topping from the substrate. Unfortunately these two quantities are cannot be differentiated by the chain drag test alone.

Almost certainly, the delamination indicated by the results in 1983 is to a large extent debonding. This is suggested by the pronounced plateau of the average (Fig. 19.1) and the results for several of the test areas. (Fig. 19.2 and Fig. 19.3).

After debonding, presumably soon after construction, the situation seems to have stabilized by 1983, and increases occurred only after 1989, when delamination probably due to steel rusting occurred.

Consistent with this assumption is the finding of the condition survey (1990) report that, " Despite the top surface of the overlay being very heavily scaled and pitted, the concrete of the suspended slab is generally in good condition."

Covermeter Readings

According to the values listed in Table 19.2 average thickness of the concrete cover over the reinforcing steel is 23mm. However, the range of the readings is 0 to 55mm. In three of the six test areas reinforcing steel was found totally exposed and the fourth area had only a shallow cover of 5mm. Since obtaining the results given in Table 19.2 cover was provided over the exposed steel as part of the maintenance activity.

Half-Cell Potential

Half-cell potential determined in 10 areas are given in Tables 19.3 and 19.4, and Figures 19.4 through 19.9. In plotting the results it was assumed that in 1975, after the completion of the construction, all readings were less than 0.20V.

If the assumed reading of 1975 are disregarded, the change between 1983 and 1990 is remarkably small, indicating a high degree of insensitivity of the half-cell potential to degradation or little deterioration in the last seven years.

Chloride Content of Concrete

The chloride content at the level of the top reinforcing steel was found in 1989 to range between 0.223 and 0.487 percent by mass of concrete. The chloride concentration was well above the 0.035 percent threshold value already in 1983, and changed relatively little since that time (Fig. 19.10).

Discussion

The tests carried out on this garage indicate delamination, or debonding, in a very large portion of the areas and the chloride content is very high. At the same time, These parameters have not changed dramatically since 1983. Normally, at 40 percent delamination level an exponential increase of deterioration is expected that would render the garage unusable within a few years.

This structure, however, remained functional with good serviceability needing a major rehabilitation only after 16 years, while usually garages of this vintage had to be repaired five to ten years after construction.

The explanation for the better than expected performance may be due to the combined effects of the presence of the concrete toppings and the substrate, and very importantly, repairs of defects at an early stage of deterioration.

Table 19.1
Garage No.19.
Extent of delamination vs time

Year	1975	1983	1987	1989	1990
Area 1,%	0.0	51.4	63.6	75.7	83.3
Area 2,%	0.0	46.4	66.0	69.4	88.5
Area 3,%	0.0	13.7	30.2	33.9	83.0
Area 4, %	0.0	95.6	95.6	95.8	96.9
Area 5, %	0.0	37.4	40.8	50.3	56.5
Area 6,%	0.0	14.2	20.4	34.3	41.9
Area 7, %	0.0	25.9	12.5	17.8	23.9
Area 8, %	0.0	49.1	51.9	65.4	68.6
Area 9,%	0.0	19.0	23.0	28.3	64.6
Area 10, %	0.0	57.6	33.3	43.0	84.6
Area 11,%	0.0	59.3	56.3	57.1	90.2
Total	0.0	41.6	43.5	49.6	70.3

Tbl. 19.2
Garage No. 19.
Covermeter Readings

Area	Range of Readings, mm	No of readings	Average, mm	Standard Deviaton, mm
1	10-45	23	31	8
3	0 -25	43	15	7
5	5-45	34	31	10
7	20-55	41	36	9
9	0-20	34	10	5
11	0-40	31	15	9
Total	0-55	206	23	13

Tbl. 19.3
Garage No.19
Change of half-cell potential distribution with time

C.S.E. Volt	1983, % of readings	1987, % of readings	1989, % of readings	1990, % of readings
Area 1, <.20	37.5	59.3	70.8	43.5
Area 1, .20-.35	41.7	33.3	29.2	56.5
Area 1, ,>.35	20.8	7.4	0.0	0.0
Area 2, <.20	43.4	22.0	26.9	22.0
Area 2, .20-.35	54.7	64.4	51.9	50.0
Area 2, >.35	1.9	13.6	21.2	28.0
Area 3, <.20	72.0	61.0	58.0	30.0
Area 3, .20-.35	26.0	28.8	34.0	50.0
Area 3, >.35	2.0	10.2	8.0	20.0
Area 5, <.20	44.4	30.6	46.2	18.4
Area 5, .20-.35	50.0	58.3	41.0	71.1
Area 5, >.35	5.6	11.1	12.8	10.5
Area 6, <.20	45.4	35.6	56.0	24.0
Area 6, .20-.35	54.6	62.2	44.0	70.0
Area 6, >.35	0.0	2.2	0.0	6.0
Area 7, <.20	6.8	4.5	16.0	4.0
Area 7, .20-.35	70.5	50.0	60.0	56.0
Area 7, >.35	22.7	45.5	54.0	40.0

Tbl. 19.4
Garage No.19
Change of half-cell potential distribution with time

C.S.E. Volt	1983, % of readings	1987, % of readings	1989, % of readings	1990, % of readings
Area 8, <.20	17.9	5.0	9.3	0.0
Area 8, .20-.35	76.9	80.0	74.4	62.8
Area 8, >.35	5.2	15.0	16.3	37.2
Area 9, <.20	61.1	38.9	60.0	12.5
Area 9, .20-.35	38.9	58.3	32.5	80.0
Area 9, >.35	0.0	2.8	7.5	7.5
Area 10, <.20	8.7	4.3	14.6	16.7
Area 10, .20-.35	73.9	78.3	72.9	56.3
Area 10, >.35	17.4	17.4	12.5	27.1
Area 11, <.20	0.0	5.6	2.5	17.5
Area 11, .20-.35	22.2	52.7	80.0	72.5
Area 11, >.35	77.8	41.7	17.5	10.0
Total, <.20	34.3	26.6	34.4	17.8
Total, 20-.35	51.7	56.8	53.0	62.0
Total, >.35	14.0	16.6	12.6	20.1

Figure 19.1
Garage No. 19
Total extent of delaminations in test areas vs. time

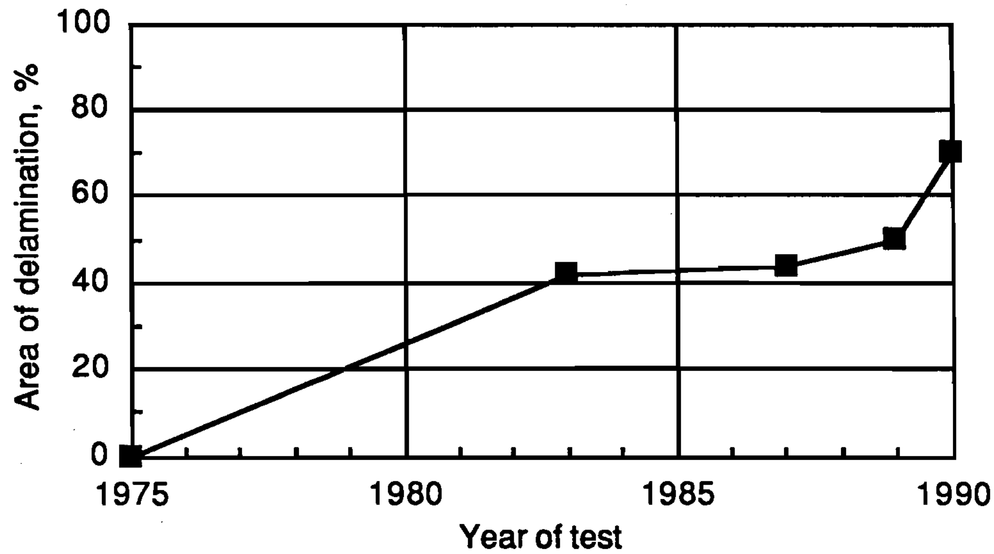


Fig. 19.2
Garage No.19.
Extent of delaminations vs. time in test areas 1 to 5

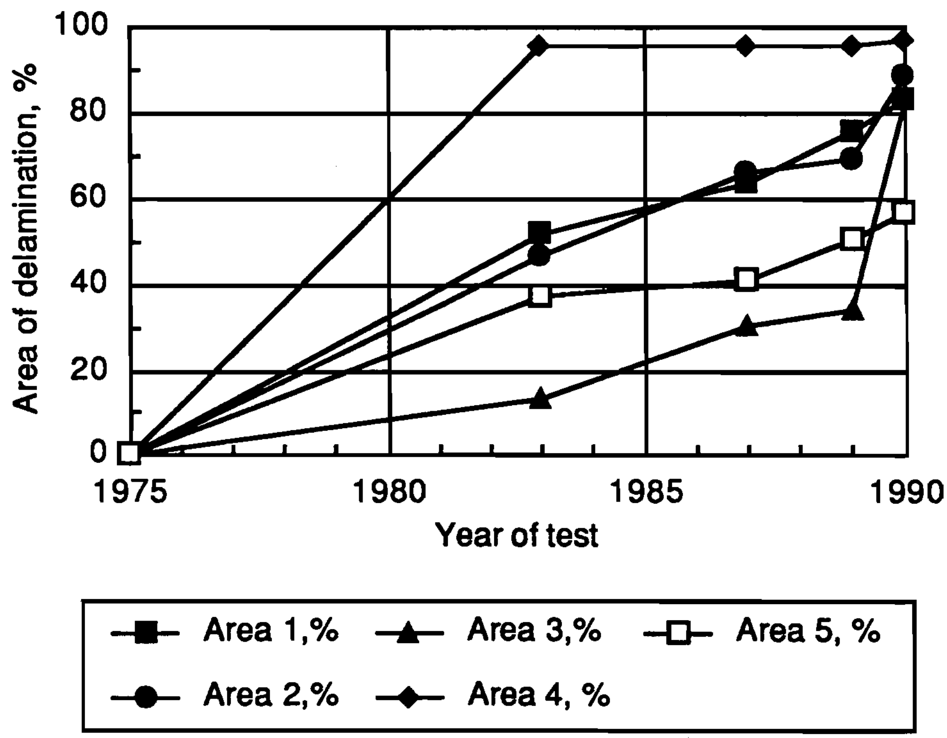


Fig. 19.3
Garage No.19.
Extent of delaminations vs. time in test areas 6 to 11

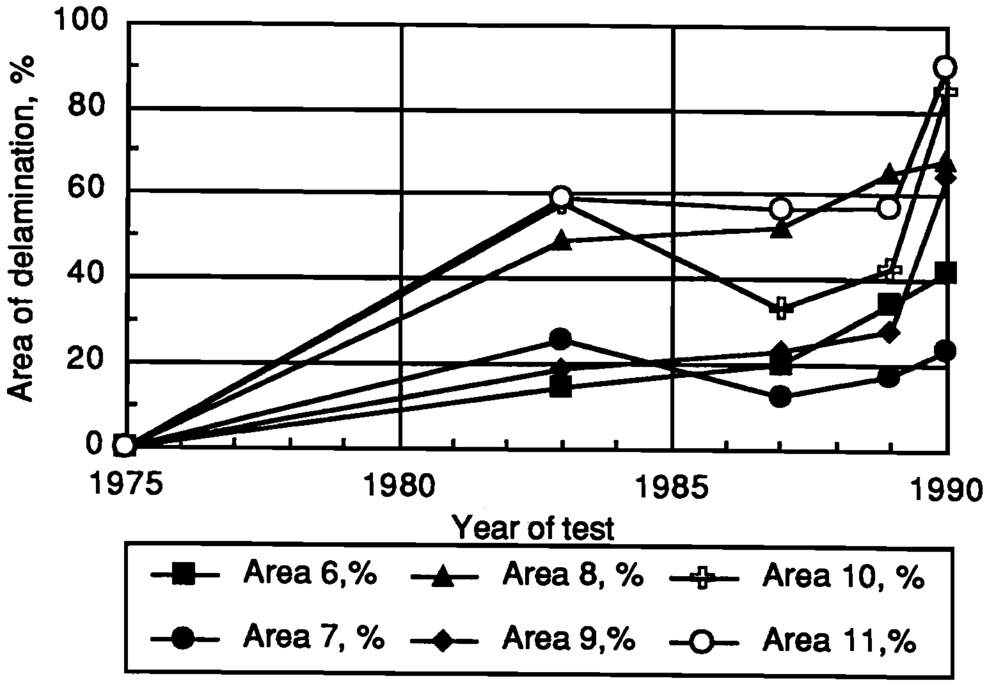


Fig. 19.4
Garage No 19
Percent of half-cell potential readings of less than 0.20 V in test areas

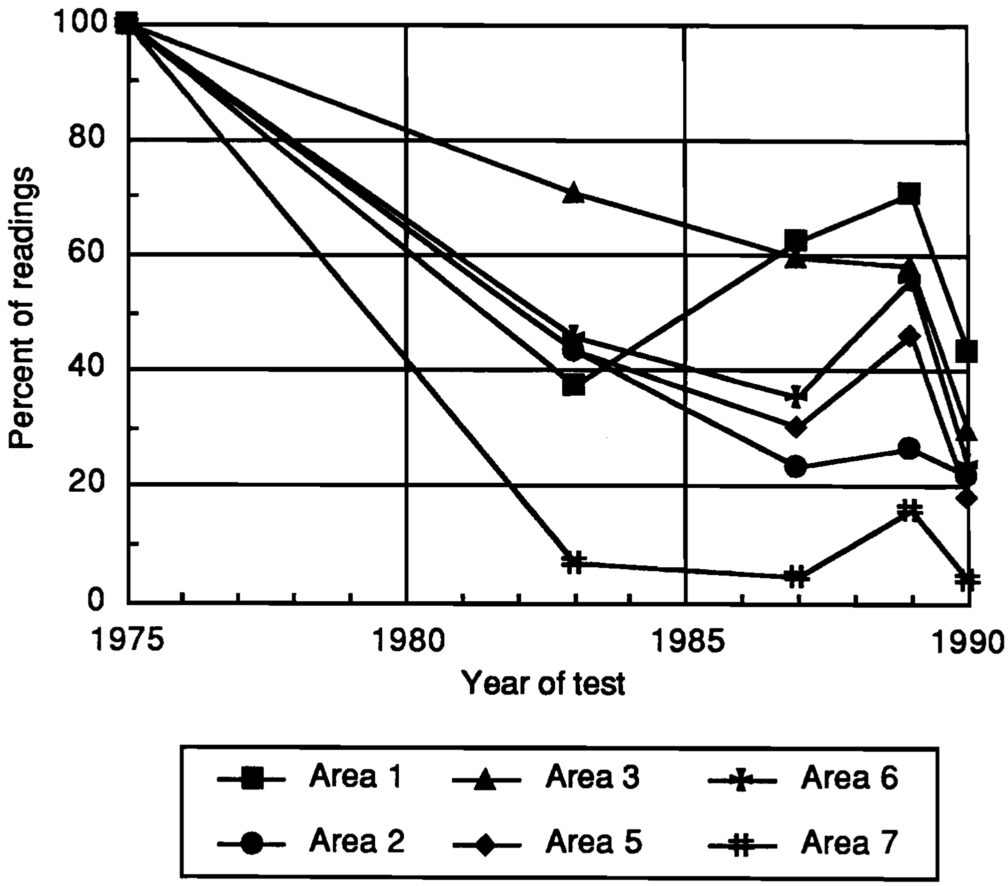


Fig. 19.5
Garage No.19.
Percent of half-cell potential readings of values 0.20-0.35V in test areas

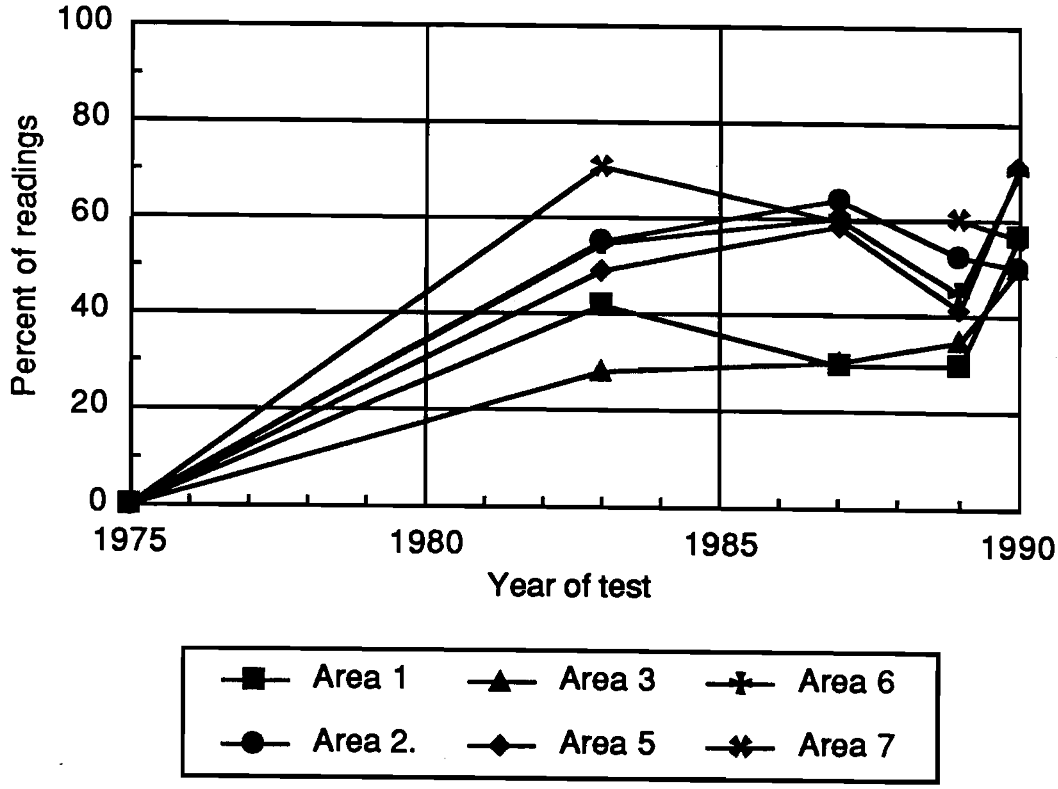


Fig. 19.6
Garage 19.
Percent of half-cell potential readings of values >0.35 V in test areas

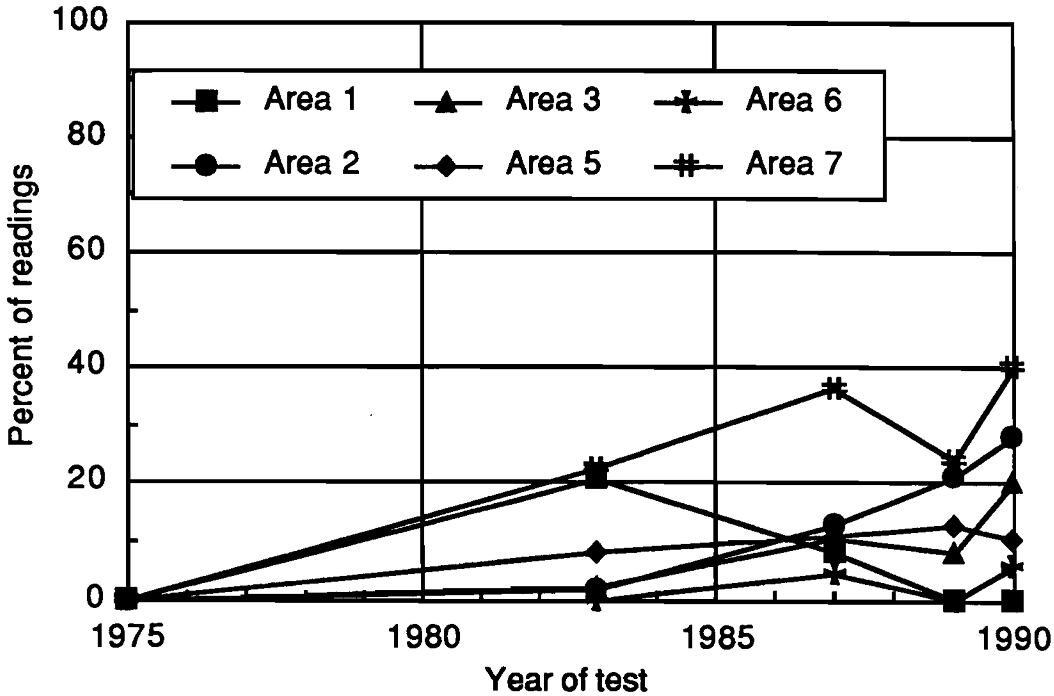


Fig. 19.7
Garage No.19
Percent of half-cell potential readings of less than 0.20 V in test areas

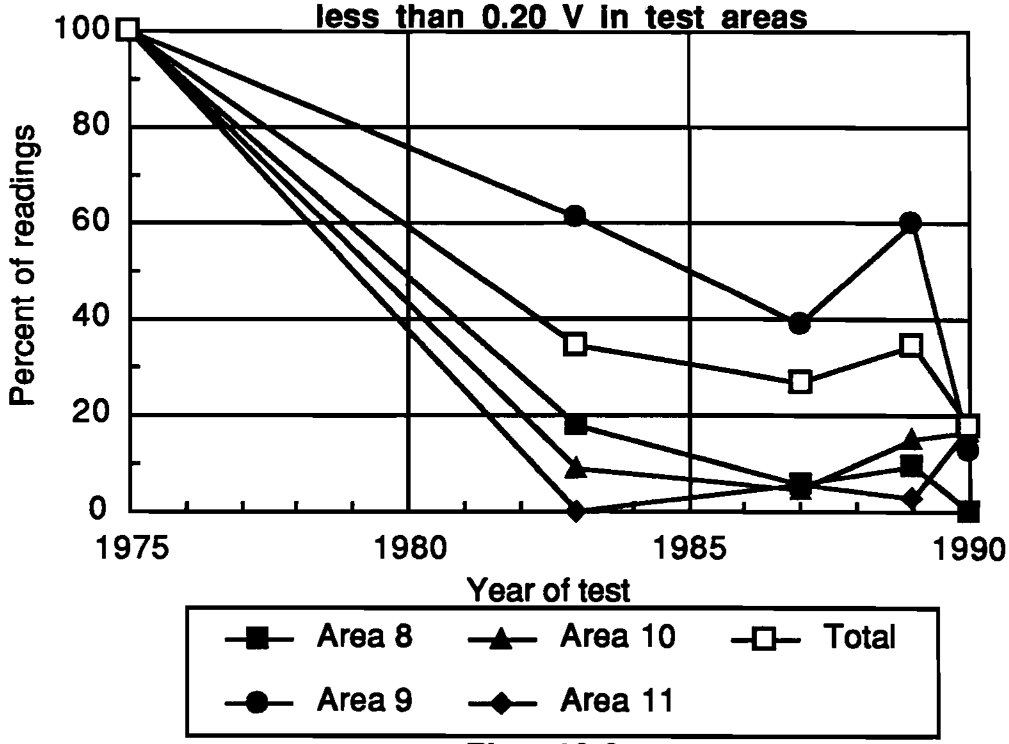


Fig. 19.8
Garage No.19
Percent of half-cell potential readings of values 0.20-0.35 V in test areas

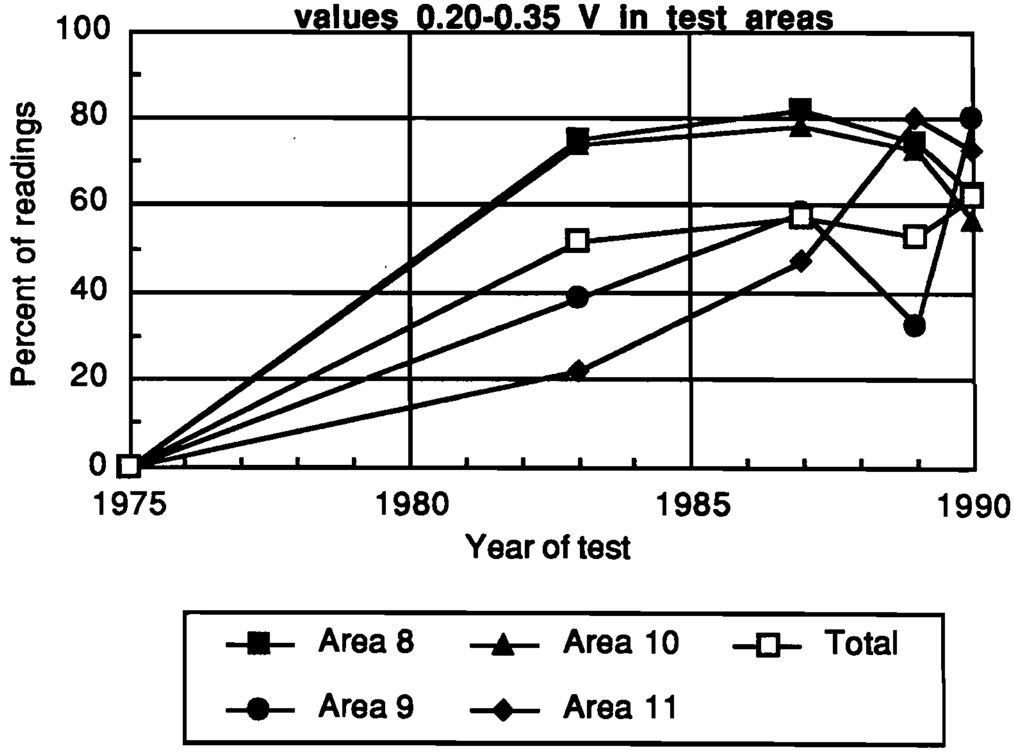


Fig. 19.9
Garage No.19.
Percent of half-cell potential readings of values >0.35 V in test areas

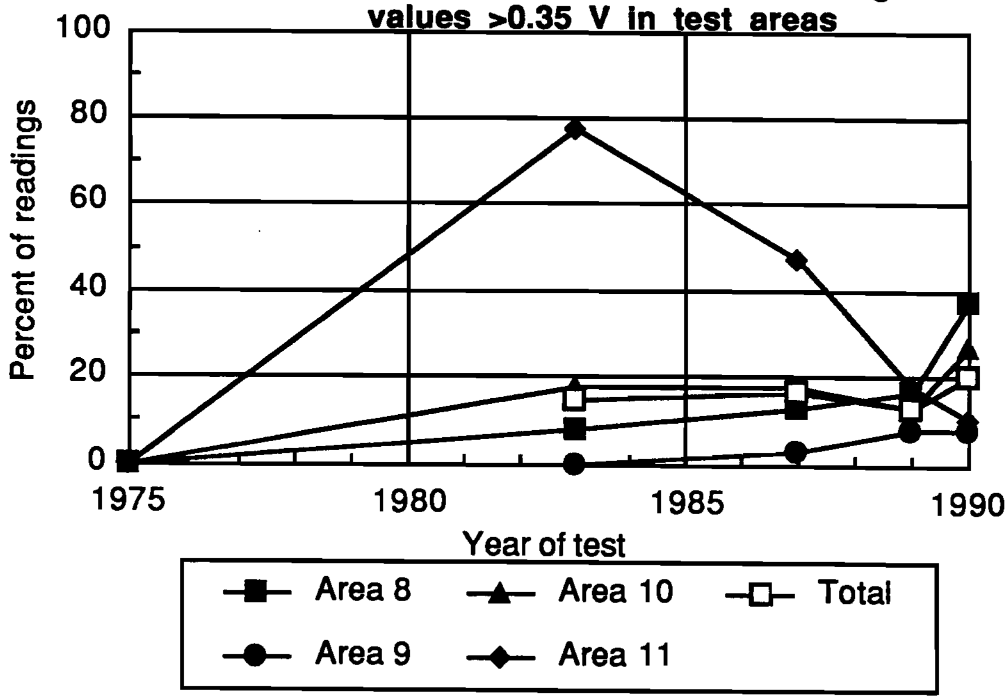
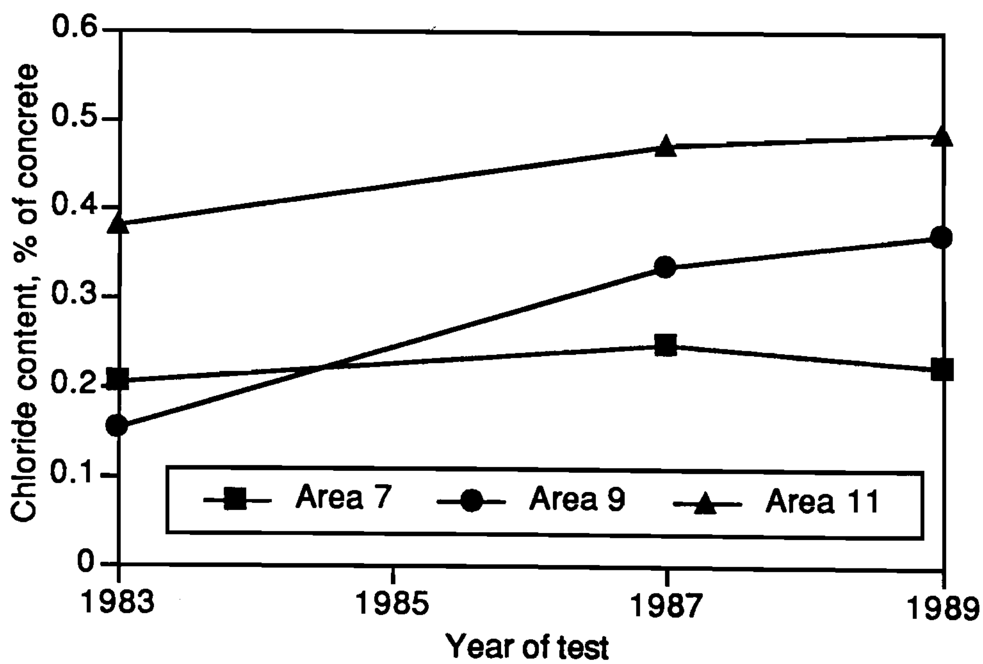


Fig. 19.10
Garage No.19
Chloride ion content at top steel level, expressed as percent of mass of concrete



Garage No. 20

Parking facility of a large office-commercial complex built in 1967. The total area of the seven suspended slabs and the slab on grade is approximately 16,000 m^2.

The structure is a one way slab with reinforced concrete beams.

Repair History

The suspended slabs were protected at the time of the construction in 1967 with a coal tar epoxy waterproofing system. Eleven years later, in 1978, the coal tar epoxy waterproofer was replaced on the upper two levels, in an area of approximately 4,255 m^2, with the Permapol Waterproofing System. Few repairs have been made since.

Visual Survey of Components

The waterproofing membrane is cracked and debonded from the slab in high traffic areas and turning routes.

Rate of Delamination

The increase of the area of concrete delamination between the years of 1983 and 1990 is shown in Table 20.1 and Figure 20.1.

The average total delamination 23 years after construction is 1.5%. The highest value, 2.2%, was found in Area 3.

Noteworthy is the sudden increase of delamination in 1990. In Areas 2 and 3 no delamination was found before that date, while in Area 1 a more gradual deterioration seems to have occurred. It is not clear whether the sudden increase is reflecting reality or is due to a change in survey personnel. The exponential rate of deterioration at this low level of delamination is in contrast to that observed in other structures, in which the increase in time could be described by a linear relationship up to at least 30% total delamination (eg. Garage 18).

In any case, the extent of delamination, 1.5% after 23 years of service, is very low.

Covermeter Readings

The thickness of the concrete cover over the top reinforcing steel is given in Table 20.2.

In three test areas a total of 88 readings were taken which ranged from 25 mm to 90 mm. This very wide span indicates poor workmanship in placing the steel. On the other hand, the minimum cover of 25 mm must be considered a good protective feature. The average cover is 50 mm, with a standard deviation of 14 mm.

Half-Cell Potential

In Table 20.3 the values of the half-cell potential in the three test areas, measured in the years of 1983, 1987, 1989 and 1990, are listed. The changes of the half-cell potentials are shown also in graphical form in Figs. 20.2 through 20.5.

On the whole the potentials are in broad agreement with the delamination results: potentials less than 0.20 V was found in the majority of the areas, indicating no corrosion activity. In Area 1, delamination is 1.5% and greater than 0.35 V potential (indicating definite corrosion activity) in 1.9% of the area. This agreement, however, is less impressive on noting that no corrosion was indicated in 1983 and 1987, and in 1989 3.8% area was deemed to corrode and then the value fell back in 1990 to 1.9%.

In the case of Area 2, only in 1990 had 3.8% of the area a potential greater than 0.35 V, but perhaps the increase of the readings in 0.20 V to 0.35 V range can be taken as a warning of the 1.1% delamination that was detected in 1990.

No indication of corrosion impending, or actual, was given by the half-cell potential readings for Area 3. None of the measurements was greater than 0.35 V and only in 1990 did the < 0.20 V group show a decrease.

Chloride Content of Concrete

The chloride content of the concrete given in Table 20.4 indicates low level of contamination at the reinforcing steel (40 - 50 mm) horizon or even above it (10 - 20 mm) although the data is very sparse. The threshold value above which corrosion is likely to occur is assumed to be between 0.025 and 0.035 percent chloride ion.

Discussion

This garage appears to be in excellent condition after 25 years of service, although in the last two years, since the condition survey taken in 1990, several defects became apparent at a fairly rapid rate.

The reason for the good service is undoubtedly the presence since construction of a waterproofing membrane that now has completely failed. The case of this garage proves the great value of waterproofing. It is hoped that repairs will be effected before further significant deterioration occurs.

Little value appears to be derivable from half-cell potential measurements.

Tbl.20.1
Garage No.20
Rate of delamination

Year	Area 1, %	Area 2, %	Area 3, %	Total, %
1983	0.5	0	0	0.2
1987	0.5	0	0	0.2
1989	1	0	0	0.4
1990	1.5	1.1	2.2	1.5

Tbl. 20.2
Garage No. 20
Covermeter Readings

Area	Range of Readings, mm	No. of Readings	Average, mm	Standard Deviation, mm
1	40-90	34	58	14
2	25-30	34	46	13
3	30-65	20	38	8
Total	25-90	88	50	14

Tbl. 20.3
Garage No. 20
Change of half-cell potential with time

Per cent of readings of indicated voltage in the various test areas

C.S.E. Volt	1983	1987	1989	1990
Area 1, <.20	92.3	86.5	88.5	67.3
Area 1, .20-.35	7.7	13.5	7.7	30.8
Area 1, >.35	0.0	0.0	3.8	1.9
Area 2, <.20	98.1	94.2	94.2	53.8
Area 2, .20-.35	1.9	5.8	5.8	42.3
Area 2, >.35	0.0	0.0	0.0	3.8
Area 3, <.20	96.7	100.0	96.7	43.3
Area 3, .20-.35	3.3	0.0	3.3	56.7
Area 3, >.35	0.0	0.0	0.0	0.0
Total, <.20	95.5	92.5	92.5	56.7
Total, .20-.35	4.5	7.5	6.0	41.0
Total, >.35	0.0	0.0	1.5	2.2

Tbl. 20. 4
Garage No. 20
Percentage of water soluble chloride content by mass of concrete

	10-20, mm	40-50, mm	50-60, mm	90-100, mm
1987		0.006		
1987		0.021		
1989		0.018		
1989		0.011		
1990	0.016		0.013	0.006

Fig. 20.1
Garage No.20
Extent of delamination in test areas vs. time

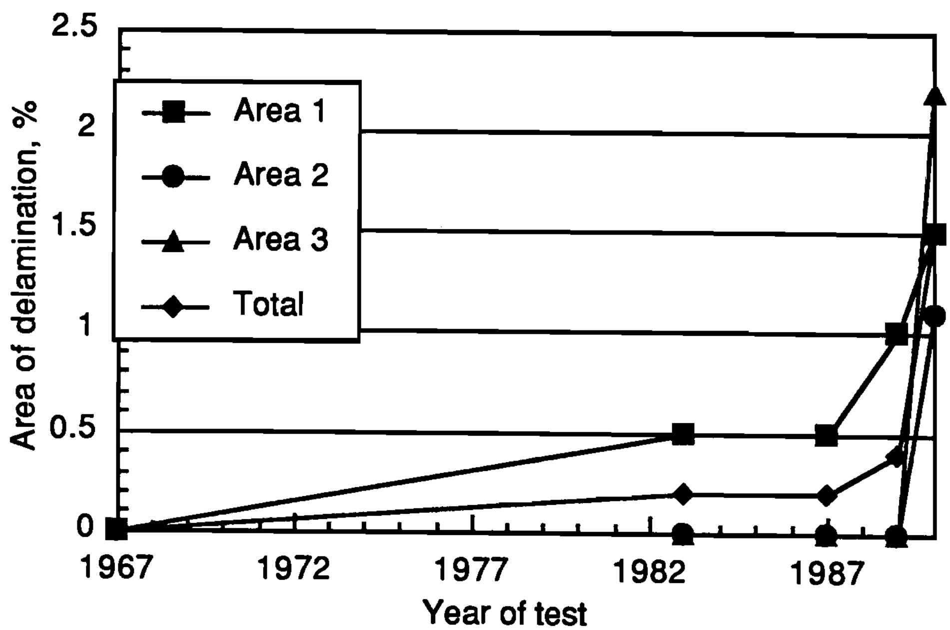


Fig. 20.2
Garage No.20
Distribution of half-cell potential readings in tested areas

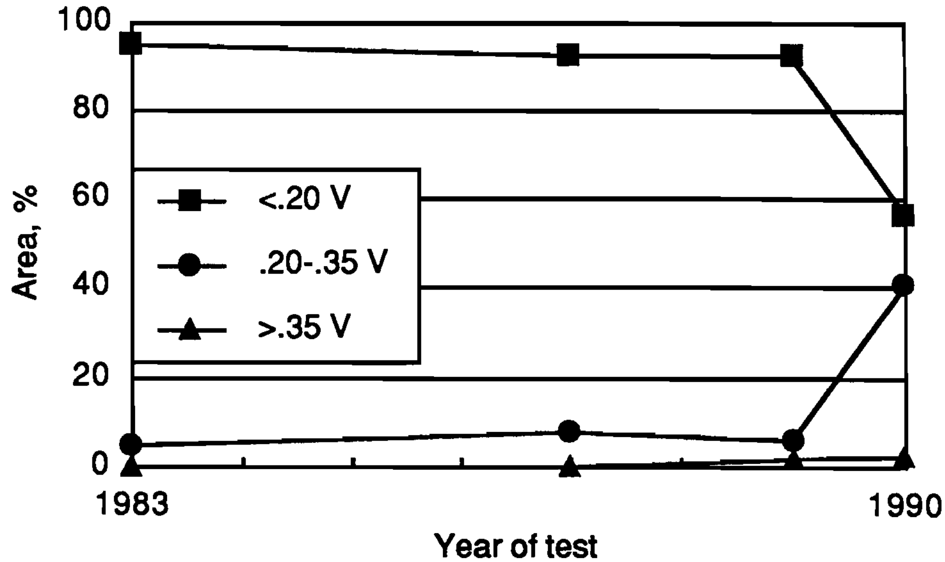


Fig. 20.3
Garage No.20
Per cent of area in which the half-cell potential is less than 0.20 V CSE

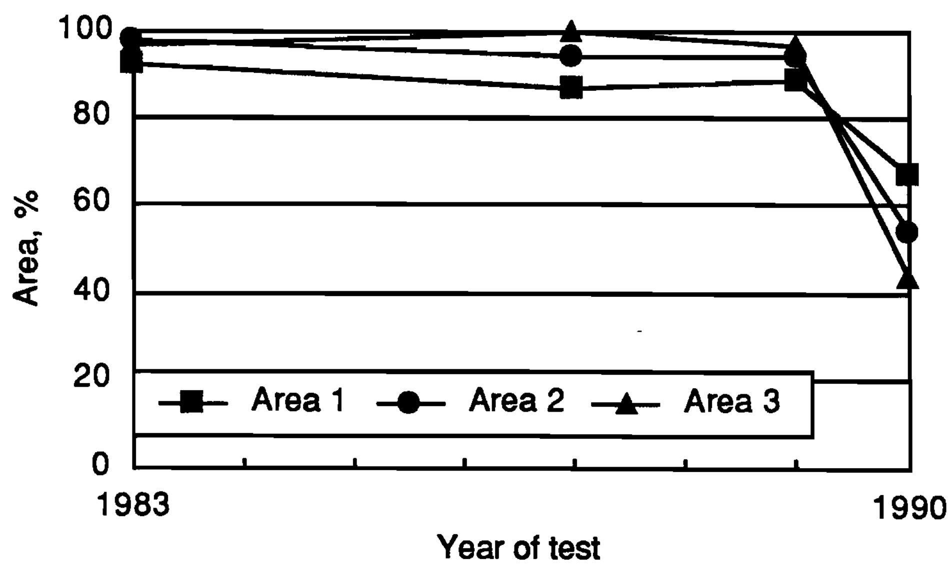


Fig. 20.4
Garage No. 20
Per cent of area in which the half-cell potential is >0.20 V - <0.35 V CSE

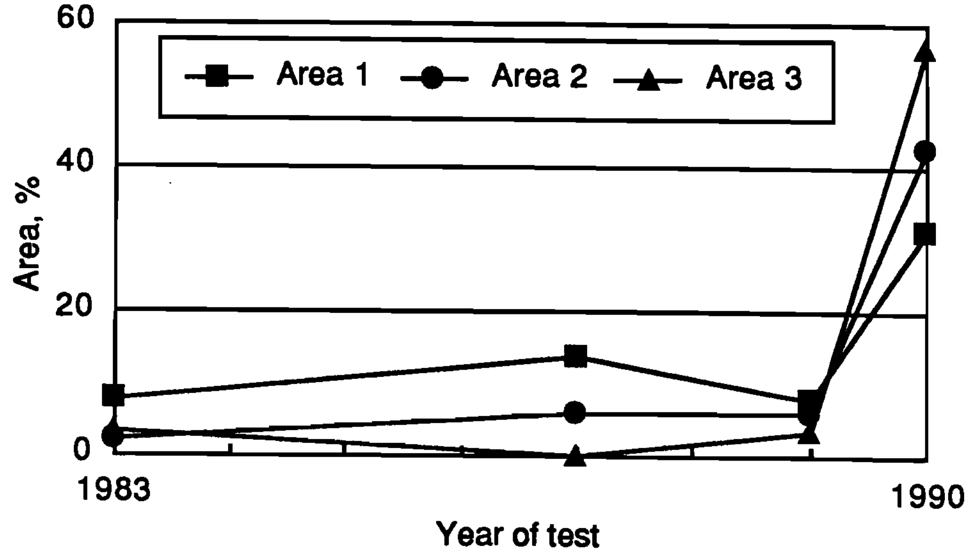
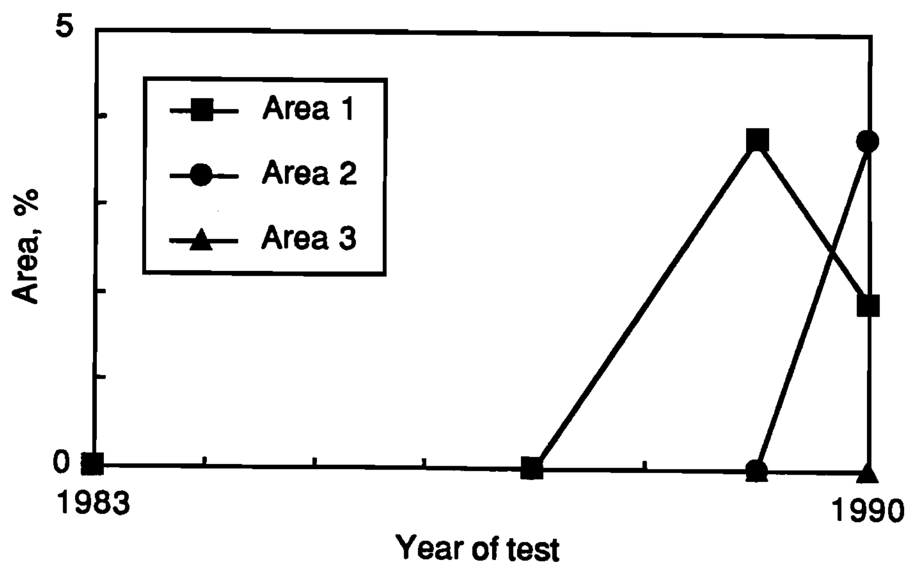


Fig. 20.5
Garage No.20
Per cent of area in which the half-cell potential is greater than 0.35 V CSE



Garage Number 21

Multilevel free standing parkade, exposed to the elements, serving a large shopping centre. The structure was built in 1972, but underwent expansion twice since that time.
The condition survey carried out in 1982 (at 10 years of age) noted the following:

Structure No.1
This parkade is of typical precast double tee construction with bonded concrete overlay. Expansion joints are spaced at 180' (54m) on centre.

Although shortly after construction the expansion joints failed and have been replaced, they were recommended to be replaced once again. Extensive leakage, spalling of concrete, and displacement of bearing pads were noted. Table 21.2 summarizes the repairs recommended and performed in the course of the rehabilitation.

1. Concrete topping repairs are required due to the corrosion of the mesh reinforcement. The major problem was caused by excessive leakage over the precast beams due to deterioration of the control joints. Over most beam lines a six foot wide strip of topping was replaced and cambered to direct the water flow away from the beam.
2. Expansion joints were a major source of the problems encountered in this parkade. The consultants opinion was that the main cause of joint failure was the incorrect assumption of the nominal movement. Consequently, the actual movements of each joint was measured over the range of -10°C to +30°C and extrapolated to -30°C to +30°C limits. The obtained values are shown in Table 21.3.

The extrapolated values ranged from 3.0 mm to 36.0 mm for the equally spaced joints. The joint movement capacity was then specified to be 50 mm. The so repaired joints have been performing well.
In addition, the control joints, the beam delaminations, column base damages, due to corrosion and freeze-thaw action, were repaired and the sliding bearings replaced.

East Parking Structure
This is a multi-level cast-in place post-tensioned (PT) parkade. In the beams the PT cables are fully bonded, and in the slabs unbonded. Several failures (three in 1982) resulted in break out of the tendons. The investigation of the cables consisted of the following:

- Removal of two percent of the panels to expose the end anchorages of the cables;
- Excavation of test pits to expose cables and anchorages;
- Removal of one of the failed cables;
- Covermeter survey to determine the cover over the cables at high points;
- Review of the cable layout drawings;
- Review of the structural drawings; and

- Review of the slab design.

The investigation revealed:
- The location of the most severe corrosion of the cable occured within 3 feet of the anchor; and
- Grease cover of the cable was not continuous.

A review of the structural design concluded that the load capacity was sufficient even if one quarter of the cables failed, provided they are equally spaced. Examination of the drawings showed that construction joints and intermediate anchors existed in all slabs. It was, therefore, decided to make an attempt to dry out the ducts and inject rust inhibiting grease in all cables using an innovative procedure developed by Vanco Structural Services. The overall repairs are listed in Table 21.4.

The procedure comprised the following steps:
1. Locating the cables on each end-anchor, and on each side of all intermediate anchors. Drilling a well and inserting grease injection ports.
2. Flushing the ducts with nitrogen to dry the ducts and cables;
3. Injection of grease through an end port until grease exuded at the next port 10 m away.

   For nine years, since 1983, no further eruption of the cables occured. End anchors exposed since the repairs show grease excudation that can be considered as proof for complete filling of the space.

North Parking Structure

In 1987, a one level free-standing post-tensioned structure was constructed over an existing deck. The choice of this structural type was based on the conclusion that post-tensioned structure can be made durable by providing adequate protection against water ingress.

The design incorporated cables with extruded sheath, grease and tight fitting sleeve over the bare cable in the anchor area, good detailing of the anchor cover, and epoxy coated reinforcing steel. The concrete cover was specified to be 40 mm and a penetrating sealer was applied onto the deck sealer was reapplied in 1991. The deck is now five years old and shows no sign of deterioration.

West Parking Structure

This garage was built in 1982. It is a multi-level cast-in- place reinforced parkade that is exposed to the elements. The steel in the upper mat is epoxy coated. The deck was protected with a sealer. Extensive delamination, in one slab 25 percent, occured 5-6 years after construction, which were repaired in 1992. Repairs of concrete, and expansion joint installation of traffic topping .

In 1989 the survey detected delaminations, and on examination of the exposed steel the epoxy coating was found to peel off. The steel itself is corroding.

In Table 21.1 some characteristics are given

Table 21.1
Garage No. 21
Structures of the shopping centre parkade

Structure #	Location	Type of Structure	Date constructed	Size m^2	No. of cars
1	North and west of centre	Precast double tees and concrete topping. Some hollow core slabs	1972	30,000 (1 level)	800
2	East of Centre	Poured in place post-tensioned slabs and beams. hollow core slabs at ramps.	1972	18,500 (multi-level)	525
3	East ramps and overpasses	Post-tensioned poured in place and precast girders.	1972	N/A	N/A
4	West of centre	Poured in place reinforced concrete	1982	9,300 (multi-level)	275
5	North of centre	Poured in place post-tensioned	1987	17,000 (1 level)	460

Table 21.2
Garage No. 21
Recommended repairs and costs.
North and West Structures built in 1972

Item	Description	Cost (1983)	Remarks
1.	Concrete topping repairs (1250 m^2)	$90,000 $50,000	Some delamination repairs Mostly repairs to debonded topping over beams to improve drainage.
2.	Expansion joint Repairs (1100 m)	$260,000	All existing expansion joints were replaced. Compression seals and concrete nosings were used in parking areas. Strip seals and steel nosings in heavy driving lanes.
3.	Control joint recaulking (18,000 m)	$82,000 $80,000	About 50% of the deck control joints have been recaulked. The remainder are still to be recaulked.
4.	Beam delamination repairs (220 m2)	$165,000	Extensive delamination repairs of the present beams were undertaken by gunite method.
5.	Replace bearing and beam hardware	$40,000	Numerous double tee bearings and beam bearings had shifted and were damaged. Some had previously fallen onto parked cars. There was also extensive corrosion related deterioration and separation of the bearing assembly components.
6.	Column base and pier repairs	$200,000 $ 50,000	Extensive freeze-thaw and corrosion damage to the piers have occurred. Excavation, repairs and regrading was required at all columns.
7.	Resurfacing of asphalt on grade	$180,000	Resurfacing of asphalt pavement was undertaken in 1987.
8.	Replace of electrical wiring		The original metal conduits had largely been replaced prior to 1982 due to extensive corrosion
9.	Miscellaneous	$110,000	Paint steel rails, stairs, inserts, etc. Repair concrete spalls, masonry walls etc.

Table 21.3
Garage No. 21
Expansion joint measurements (North parking Structure)

Location (Ref. DWG P1)	Measured movement (-10°C to +30°C) mm	Extrapolated movement (-30° to +30°C) mm
EM 1	17	25.5
EM 2	17	25.5
EM 3	22	33.0
EM 3A	15	22.5
EM 4	2	3.0
EM 5	21	31.5
EM 5A	24	36.0
EM 6	4	6.0
EM 7	12	18.0
EM 8	17	25.5
EM 8A	16	24.0

Table 21.4
Garage No. 21
Recommended and performed repairs East parking structure 1972

Item	Description	Cost	Remarks
1.	Top of slab delamination repairs (900 m^2)	$85,000	Black deformed reinforcing steel was used in the top of the slab
2.	Underside of deck and beam repairs	$18,000	Most underside repairs were required at leaking expansion joints. Repairs to the H.C. slabs were also required.
3.	Traffic topping	$106,000	Placed in anchorage zones, over construction joints and in areas of extensive top of slab repairs.
4.	Surface sealer	$40,000	Deck sealer was applied to all areas of deck not treated with traffic topping.
5.	Expansion joints	$44,000	All original expansion joints were replaced.
6.	Post-tension cable greasing	$150,000	All north-south slab cable casings were fully injected with a rust inhibiting grease. Temperature cables were not injected.
7.	Miscellaneous	$60,000	Painting steel rails, stairs, inserts, etc. Repair concrete spalls and masonry walls.

Garage No. 24

Underground enclosed garage in a high rise commercial and retail complex, built in 1975. Besides the slab on grade, the facility has three split level structural slabs, each with 1,200 m^2 area. The reinforced concrete slabs are 258 mm thick. The concrete cover over the black steel reinforcing steel is 20 mm.

Linseed oil surface sealer was applied at the time of construction.

Survey, 1985

In 1985 a condition survey detected delaminations in 6.2% of the area, leakage through the slab and perimeter walls, spalling of the concrete, and staining. In 25% of the area the half cell potential measured was greater than -350 mV. The actual concrete cover was greater than the specified 20 mm. It varied between 25 and 37 mm.

Repair, 1989

The rehabilitation carried out in 1987, comprised renewal of the concrete, that was removed with 17,000 psi water jet. Altogether 65% of the total area was replaced. In addition, repair of the concrete was carried out on the underside of the slab. In certain locations the slab in its entire thickness was replaced.

Waterproofing membrane (Kelmar) was installed, the drainage improved by the addition of new drains, and building up some slopes where new concrete was placed.

The cost of the repairs and improvements was $750,000.

Regular housekeeping consists of power sweeping the garage every week. Twice a year the floors are washed down with high pressure water (fire hose with 1.5 in diameter nozzle) In-house personnel carries out a visual and the chain drag test.

Survey, 1991

Four years after repairs (1991, spring) the survey noted the following:

- The water proofing membrane is worn in the driving aisles, particularly in the turns;
- In five areas ponding occurs; a condition that should be eliminated by the installation of additional floor drains.
- The waterproofing membrane is cracked:

  lower B3 level 16, +11, + 23 ft. total of 50 lineal ft.upper B4 level 19, + 13,+ 32,+ 55, + 5, + 15,+ 12 total of 106 ft. upper B3 and lower B4 level 3, + 2, + 6, + 16 +, 5 +,8 +,12 +, 15 +, 10 +, 20 +, 2 total of 133 ft ; a grand total of 289 lineal feet of cracks detected.

There is no evidence of through the slab leakage at the present time. Chain drag test identified small areas with hollow sonic response:

level B5 15 spots

level B4 12 spots

level B3 17 spots

These probably are due to poor adhesion of the membrane to the concrete.

Summary

This garage, four years after the repair, is in an excellent condition. Although the repair cost $14.10 per square foot was a multiple of the $5.62 average per square foot repair (including membrane) cost. The combination of thorough repair, and the excellent housekeeping and maintenance, is expected to provide uninterrupted good service with little additional expenditure. It will be interesting to see what the life cycle cost of this approach will be. In the evaluation, the impact of the absence of closures have to be also considered. This approach is very much valued by the tenants of the retail floor.

Garage No. 28

The garage of a 13 storey residential condominium tower built in 1964. The floor of the indoor underground garage is a slab-on-grade, while a post-tensioned slab above it on the ground level projects outside the building. Parking on this level is under the tower. The underground level is enclosed and heated, the grade level of the garage is exposed to the weather.

The structure was built using the "lift slab" method of construction. The floors of the building are 8 inches thick, post-tensioned, and supported by steel columns and the perimeter walls.

The post-tensioning cables are greased and wrapped in "Kraft paper". The cables are not bonded.

Condition Survey, 1987

Delamination was found in less than 1% of the 3,429 m^2 total area. Several tendons were inspected and noted that the grease was continuous and the paper wrapping intact. Only very slight surface rusting without pitting was observed. Some anchorages were found to be exposed. Spalling and delamination of 75% of the steel column footings was reported.

Repair, 1989

The columns were repaired, dykes built around them for protection, the expansion joint replaced, and installed membrane on the suspended deck and sealer on the slab-on-grade.

The membrane, epoxy-urethane, (Sternson TDM 1000), performed satisfactorily in the 3 years of service since the repairs.

Garage No. 29

Description of structure

Parking garage of a retail, and commercial complex built in 1969. The floor areas of the parking decks are as follows:

Level A	12,000 ft^2
Level B	38,000 ft^2
Level C	50,000 ft^2
Level D	30,000 ft^2
Level E	50,000 ft^2

Levels A and B are open at the east side levels C,D, and E are open all around. A multi-level office tower is located above the garage. The structure is cast in place post-tensioned concrete with 7" thick drop panels. The slab is 6" thick. The post-tensioning strand is a 1/4" diameter wire, arranged in circular clusters with paper sheathing. Stressing force is not known. The specified strength of the concrete is 4,000 psi. Original specifications called for a linseed oil/ kerosene surface sealer, application of which was commenced, but never completed.

Visual survey, 1985, (6 years after construction)

- No spalling of concrete
- Some through the slab cracks
- Four post-tensioning tendons exposed in the top surface of the slab
- Slab surface pitted and scaled
- Water ponding in some locations

Condition Survey, 1985

Delaminations were found only in two areas (B-5 and C-7). Areas in B-5 exhibited the greatest degree of half-cell potential activity. The delaminations detected were along a construction joint. Some through slab cracks were noted.

Column bases were found to show delaminations, probably a result of intrusion of water through the pour joints.

The exposed post-tensioning cables were examined over a 24 inch distance and detected only minor surface rust with the grease coating and the paper wrapping still intact.

The chloride content of the concrete in the majority of samples is in excess of the 0.035%.

In seven representative areas of levels B through E the half-cell potential of the suspended slabs was determined.

In summary, the results of this half-cell survey are as shown in Table 29.1.

Repairs, 1986

The repairs carried out consisted of removal of the delaminated concrete, patching, installation of additional drains, replacement of the waterproofing membrane on levels B and E (7,000 ft^2) and application of a surface sealer. (Canadian Barrier, TRX 166 Methacrylate) over the entire remaining area.

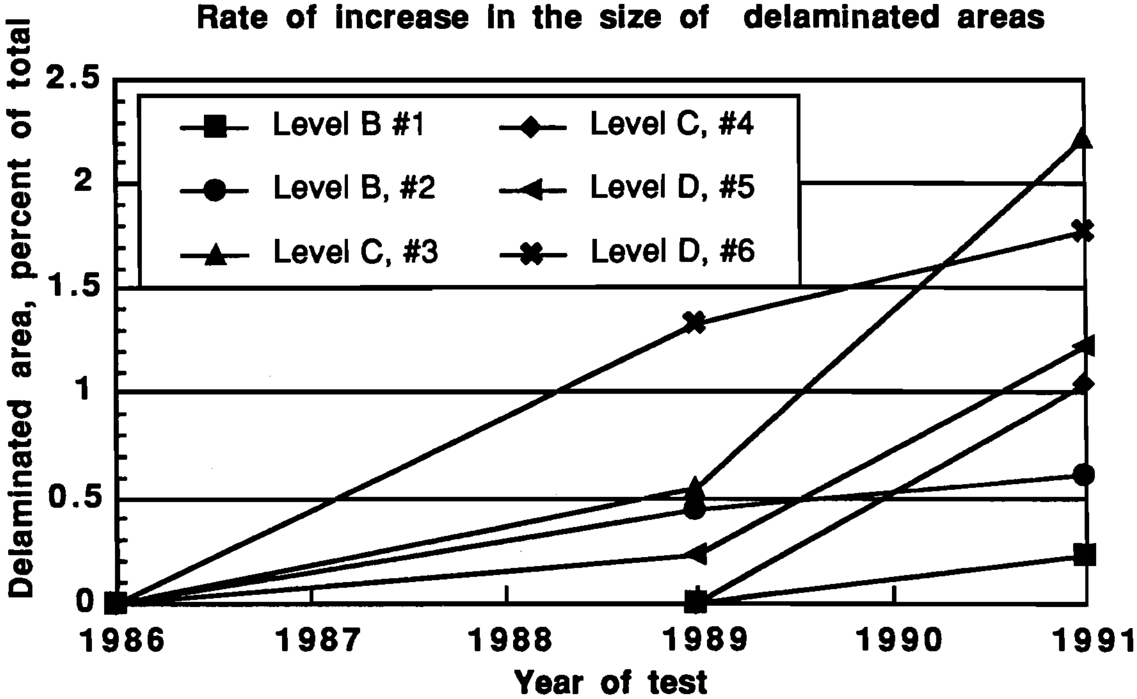
Condition Survey, 1991

No major defects were found, however, a thorough assessment of the condition of the post-tensioning cables, anchors, and the other components has not been carried out. A number of relatively minor deficiencies were identified and recommended to be repaired. The deterioration area is approximately between 0.2 and 2.2 % of the total. This good performance, if substantiated by more detailed investigation, is impressive.

Table 29.1
Garage No. 29
Half Cell Potential Survey of 1985

Area	Readings below .20 V	Readings between .20 & .35 V	Readings greater than .35 V
B-5	2%	60%	38%
C-8	40%	54%	6%
C-9	24%	74%	2%
D-9	45%	50%	5%
E-9	31%	65%	4%
E-10	20%	76%	4%
E-11	47%	50%	3%

Fig. 29.1
Garage No.29.
Rate of increase in the size of delaminated areas



Garage No. 30

Six level parking garage serving a commercial, retail and industrial complex built in 1969.

The size of the suspended slabs are as follows:

Level A	929 m^2
Level B	4,180 m^2
Level C	6,187 m^2
Level D	8,825 m^2
Level E	8,825 m2
Level F	8,640 m^2

Level A is slab-on-grade, levels B, and C are below grade and enclosed, levels D, E, and F are open to weather, level F is the roof deck. The structure is cast-in-place, reinforced concrete with 250 mm thick flat slabs, and drop panels on a 9.1 m by 9.1 m column grid. The slopes to drains vary between 2.2% and 1.1% in the north-south direction. No slope in the east-west direction has been called for.

The specified concrete strength was 27.6 MPa and the concrete cover over the reinforcing steel is 20 mm. There is one expansion joint in each of the suspended slabs.

The slab was coated with a surface sealer four years after construction. The application was renewed 8 and 12 years after construction.

Visual Survey, 1985

All suspended slabs were found to exhibit through the slab cracks, most extensively on levels B, C and D. The soffit of the slab showed rust staining while the top surface contained numerous spalls. The expansion joints were noted to leak. Surface pitting and scaling, presumably due to freezing and thawing, was present. Water ponding ocurred in a number of areas. Cracking at the base of some columns was reported.

Condition Survey 1985

The delaminations were most extensive on the lower levels which are enclosed.

The summary of the half cell potential readings are given in Table 30.1.

Repairs 1986

Altogether 13%, ranging between 1 and 56% of the total area, has been repaired. Spalling of the soffit made it necessary to repair 510 m^2 area on levels B,C and D. Drainage was improved by the installation of additional drains. Column spalls were repaired.

The entire surface of the slabs was coated with a methyl-methacrylate sealer.

The cost of the repair was $2,150.00.

After the repairs of 1986 a maintenance contract was given to a consulting firm that carried out visual and engineering surveys.

Repairs, 1989

Repairs recommended by the consultant was carried out. Some expansion joints were replaced and cracks routed and sealed. The sealer is renewed roughly every two years. The cost of the repairs was $100,000.

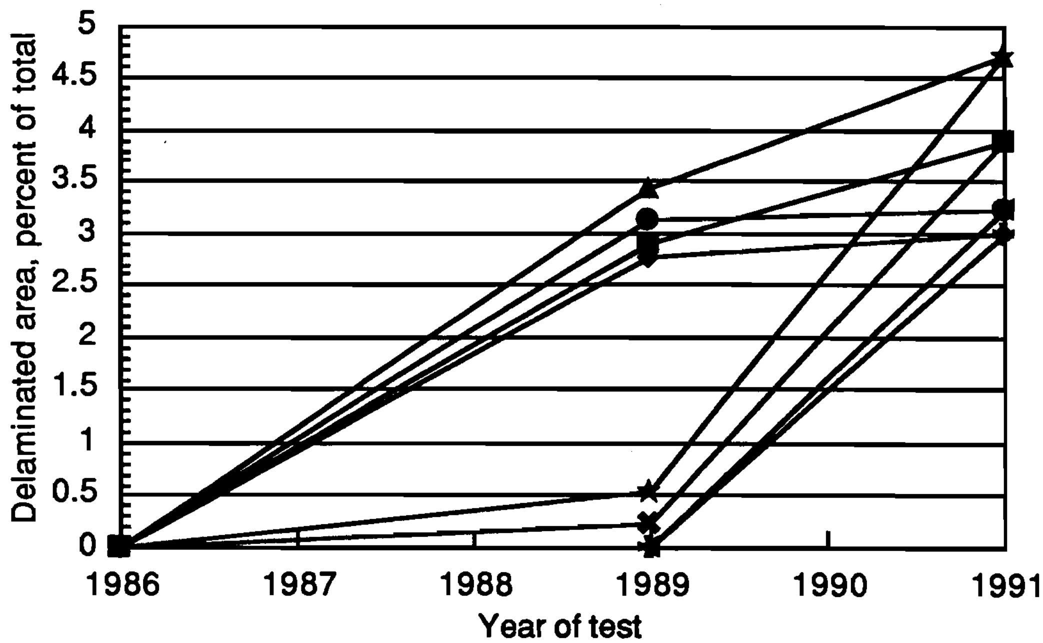
Condition Survey, 1991.

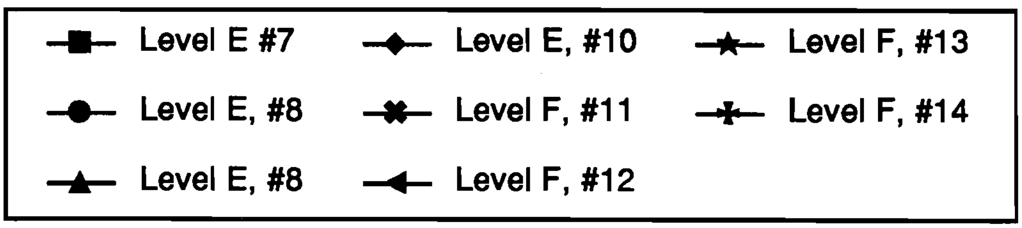
The survey identified a number of mainly minor defects which are in need of repair. One major problem is caused by a leaking water reservoir that caused the delamination on Level F (Figure 30.1) Repairs are now in progress. The size of the delamination area, five years after rehabilitation is approximately 4% of the total area. It seems that the repairs were well executed and the concrete sealer was of substantial benefit.

Table 30.1
Garage No. 30
Half Cell Potential Survey of 1985

Area	Readings below .20 V	Readings between .20 & .35 V	Readings greater than .35 V
A-1	36%	44%	20%
C-2	19%	37%	44%
C-3	32%	43%	25%
D-2	11%	54%	35%
D-6	75%	21%	4%
E-2	3%	78%	19%
E-5	0%	24%	76%
E-7	19%	67%	14%
F-5	62%	33%	5%
F-8	93%	7%	0%

Fig. 30.1
Garage No.30. 2
Rate of increase in the size of delaminated areas





Garage No. 31

Underground Parking garage of a medium rise apartment building constructed in 1971. The single suspended slab has a floor area of 3,220 m^2. The structure is of reinforced concrete columns and floor slabs type. There are two expansion joints with neoprene compression seal.

At the time of construction the slab was coated with a methyl methacylate (Canadian Barrier) surface sealer and the same sealer was reapplied five years later in 1976.

Survey in 1987, (16 years after construction)

Survey dectected delamination in less than 1% of the total area. Leakage was noted through the slab and the expansion joint. Concrete spalling, scaling, and pitting was evident. In approximately 5% of the area the half cell potential readings were greater than 350 mV.

Repairs, 1987

The cracks were sealed with injection of epoxy grout and the sealer was re-applied.

Survey, 1991

The area of the slab surface delamination is estimated to be in the order of 10%. A number of areas of slab soffit delaminations are in evidence in several locations, the total area of which is approximately 50 m^2. The expansion joints are leaking and in need of repair. Extensive water leakage was noted under the swimming pool area that is above the garage. Column base delamination is apparent in a number of cases. Approximately 18 m^2 of column base area is in need of repair.

Garage No. 32

A parking garage below a residential building, completed in 1975, with one suspended slab (2,184 m^2). The structure is of the reinforced concrete columns and flat slab type. The concrete cover over the black steel was specified to be 20 mm thick. The slab has zero slope. At the time of construction no waterproofing of any kind was installed but in 1980, five years after completion, a methyl methacylate sealer (Canadian Barrier) was applied on the suspended slab.

Repair History

In 1984 the less than 1% delamination was repaired, through-the-slab cracks grouted, the soffit repaired, additional drains installed and the sealer reapplied (silane type, Capseal X) the total cost of the repair was $60,000.

Visual Survey 1991

The building appears to be in a generally good state of repair. The area of surface delaminations is estimated to be in the order of 3 to 5%. The area of visible soffit delaminations is approximately 9.4 m^2. Despite the relatively high half-cell readings found in the 1986 inspection, only minor increase in observable deterioration appears to have occurred. The past repairs seem to be performing well.

Garage No. 50

Stand alone parkade structure in Central Canada serving a shopping centre. The garage, that is exposed to the elements, was built in the summer of 1987. It consists of one suspended deck, 14,684 m^2 in size, and a parking area of the same size on grade that is paved with 75 mm thick asphalt.

The structural slabs is 262 mm thick. The concrete used had a water/cement ratio of 0.33 and contained 20 mm aggregate. The entrained air content was between 5 and 8% and a high range water reducing admixture (superplasticizer) was also used. The specified compressive strength was 35MPa but was found in the tests to be 40 MPa.

The reinforced concrete structure comprises six sections each supported at the centre. The specified cover over the steel is 40mm. Construction was carried out mostly during a very hot summer and partly in the fall. Precautions appropriate for hot weather concreting were taken. The concrete was wet cured for seven days. The slope of the floors is 1.5%. The drains are epoxy coated and the drainage pipes are electrically heated. The expansion joint is of compression type, neoprene with galvanized steel nosings.

Because of concern that snowplows would damage the water proofing membrane, epoxy coated reinforcing steel was specified for the top mat and two coats of methyl methacrylate sealer was applied onto the surface. Two months after the last concrete pour, excessive cracking was noted. This defect was discussed previously along with other structures built with epoxy coated reinforcing steel. To protect the structure from deterioration and to improve the serviceability by eliminating leakage through the deck, it was decided in 1991 to install a water proofing membrane.

In the condition survey prior to placing the membrane no delaminations were found. Cracks were jointed and sealed. A total of 1,200 m had to be repaired. Over the columns additional 30 mil membrane was placed over the pattern cracking. The membrane chosen was the Neoguard/Autoguard system. The total cost of the waterproofing was $452,000.

Garage No. 51

Garage in an office building constructed in 1957. It has six levels, of which four are suspended. The structural slabs provide 3,207 m^2 parking and driving surface. The area of the slab on grade is 1,880 m^2.

The structural steel frame garage is partly below grade level and is not enclosed on all sides.

The suspended slabs are 152 mm thick and have a 50 mm concrete topping.

Repair History

A liquid neoprene waterproofing membrane was applied to the parking areas in 1972, fifteen years after construction.

In 1977, major cracks in the concrete casing of the structural steel columns, and damages of the deck were repaired, and a rubberized asphalt waterproofing membrane, with an asphaltic wearing course, installed at a cost of $80,000.

Condition Survey

Because of the concrete toping and waterproofing systems it was not possible to obtain a clear picture on the extent of delamination in the deck. The chain drag test indicated hollow soundings in 17.4 percent of the area in 1983, 21 percent in 1988, and 23.3 percent in 1989. Cores extracted from the deck have shown, however, that in most cases there was now no bond between the concrete topping and the structural slab, and the concrete surrounding the reinforcement was found to be sound.

Half-cell potentials were measured several times, after an unusual and unexplained decrease in their value in time was obtained, but the replicates did not clarify the question of the extent of corrosion. They only proved that, in view of the poor reproductivity, the results of the half-cell potential measurements must be interpreted with great caution. The data and analysis of the series of potential measurements taken in this garage have been reported earlier.

Of concern is the corrosion of steel connectors at the junctions of the beams and columns. For this reason, the concrete casing was removed at a location exposing the steel connections. (Originally at least two test sites were planned, but the concrete was so difficult to remove that the work was reduced). It was found, that at most 3 mm, or 15%, of the thickness of the flange of the exposed steel beam was lost due to corrosion.

Chloride ion content - The chloride ion content of the concrete slab determined in the survey carried out in 1988 and 1989 are shown in Table 51.1 and Figure 51.1. Considering that the background chloride content is 0.030 percent (90 to 100 mm horizon can be assumed to be indicating that), the chloride concentration at the level of the reinforcing steel is not higher than the critical threshold value.

No useful conclusions can be reached concerning the representative chloride content of the concrete slab, because of the small number of analyses performed, and the variability of the results obtained.

Repairs Carried out in 1992

A major rehabilitation was undertaken that included the removal of the rubberized asphalt and neoprene waterproofing systems, and the concrete topping.

On exposure, the concrete deck was found to be in a much worse condition than expected on the basis of the condition surveys. At least 30 percent of the area was found to be delaminated, with approximately 7 to 8 percent needing through the slab repairs.

The condition of the structural steel frame or its elements was good and required no repair or replacement.

A concrete topping was applied onto the patched concrete deck, and an elastomeric waterproofing membrane was also installed.

To improve drainage, slopes of the slabs have been increased and additional drains installed.

The cost of the repairs was approximately $600,000.

Comments

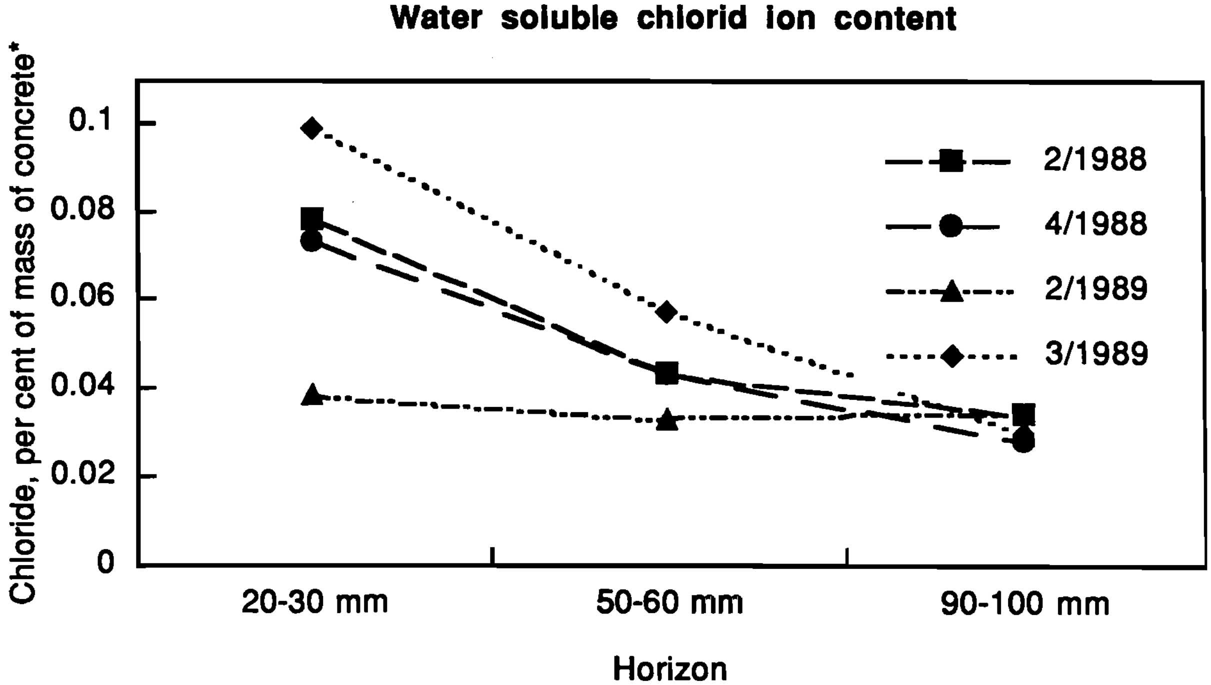
The case history of this garage well illustrates the difficulties in assessing the condition of a garage. The half-cell potentials proved to be unreliable means of evaluation, as did the chloride ion content, and the examination of concrete cores. While the latter two tests yield fairly reliable results, these are not necessarily representative of the entire deck because of the non-uniform conditions prevailing in most garages. Obviously, a larger number of tests have to be carried out to reduce the uncertainty.

Table 51.1
Garage No. 51
Water soluble chloride ion content, percent by mass of concrete

Core No.	2/1988	4/1988	2/1989	3/1989
20-30 mm	0.078	0.073	0.038	0.099
50-60 mm	0.043	0.043	0.033	0.057
90-100 mm	0.034	0.028	0.034	0.03

* Background chloride content is 0.030 %, an amount not available to act as a promoter of corrosion

Fig. 51.1
Garage No. 51
Water soluble chlorid ion content



* Background chloride content is 0.030 %, an amount not available to act as a promoter of corrosion

Garage No. 52

A two level underground enclosed parking garage in a highrise residential building, constructed in 1971.

The area of the two way reinforced concrete suspended slab is 2,958 m^2, and its thickness is 203 mm. The slab on grade is of the same size. The number of parking stalls is 156.

Repair History

In 1986 delaminations in the concrete deck were removed, and in one area cathodic protection installed in 1987. A waterproofing system consisting of a 0.5 mm thick neoprene membrane and a cold tar epoxy riding surface was also installed on the structural slab.

Cathodic Protection System

A cathodic protection (CP), system has been installed on the top surface of the concrete, that forms the upper parking level floor slab, the total area protected is approximately 279 m^2, representing 9.4% of the total slab. It is adjacent to the entrance/exit ramp and is exposed to heavier traffic than is typical for this garage.

The instant-off, and the decayed potential four hours after interruption of the DC power to the system, measured at yearly intervals, are shown in Fig. 52.1 through 52.4. In the site plan the polarization decay values at the various locations are also indicated.

It is not known what the design criteria for this particular CP system were, and therefore, before its effectiveness must be evaluated according to generally accepted criteria.

No standard for CP system used in parking garage application has been issued by the Canadian Standards Association. The National Reinforced Concrete Cathodic Protection Association, (NRCCPA), an industry association of the CP suppliers, adopted the following Guideline Specifications (1991 March): If the instant of potential is more electronegative than -350 mV, the minimum polarization decay is 50 mV, and if the instant-off potential is more electronegative than -200 mV but less than -350 mV, the minimum polarization decay is 1 mV. It must be noted that these criteria are less stringent than those of the Concrete Society/Corrosion Engineering Association Working Party (U.K.) recommendations, published in 1989.

Accepting the NRCCPA criteria, the CP systems can be deemed to have been well functioning in 1988, (Fig. 52.1) but partly failing to meet the criteria in the subsequent years. In 1989, at two grid locations D/2-6 and D/2-5, in 1990 at C/2-6, D/2-6, D/2-5, in 1991 at C-6, C/2-6, C/2-4/2, D/2-5 in 1991 the polarization decay is less than the minimum specified.

To be noted is the wide variation of the potentials, and of the polarization decay values in the deck. This is an indication of the difficulties experienced in controlling uniform current distribution in the system, and the consequent need for frequent adjustments that apparently have not been made.

Infra-red thermography detected four areas in which the wearing surface installed over the anode coating was more than 2°C warmer than the adjacent area of the floor. These hot spots ranged in size from 0.09 m^2 to 0.40 m^2. All four locations coincide with electric light fixtures on the soffit of the slab.

Delamination Test - The sizes of the areas in which the chain drag test produced hollow soundings are shown in Table 52.1

Several conditions can lead to the emission of hollow sounding:

- Wearing course separation from the waterproofing membrane or anode coating;

- Membrane or anode coating separated from the concrete substance;

- Delamination of the concrete, usually debonding between the reinforcing steel and the concrete; and

- Separation of the repair concrete from the original underlying concrete.

The values listed in the table may be the result of one, or combination of several of the above conditions. Inspection of extracted cores can give some indication of the nature of the cause at the particular location.

Condition of cores - The condition of cores, and their approximate location, is shown in Fig. 52.5. The CP protected area (C3 to E5) is outlined in the plan.

In the CP protected zone no concrete delamination was found in the cores. The hollow sound observed was apparently mainly due to debonding of the anode coating from the concrete surface. This condition should have been rectified, because uneven current distribution reduces the effectiveness of the system.

The membrane has debonded in a number of places; the largest area is at grid zone B5 to A9. A smaller area is around grid location E8.

The most significant delamination occured at grid points J4 to J7, and in the surrounding area.

At several locations, the new concrete placed in the course of the repairs has debonded from the old original concrete. This defect will most likely lead to failure.

Half-cell potential - The size of the area of deck in which the half cell potential of the reinforcing steel was found to be greater than -0.35V is shown in Table 52.2. Over the four years of monitoring the size of this area has decreased from 64 m^2 to 52 m^2. This result is most probably in error. Apart from the trend the absolute value is also suspect, as the chain drag survey indicated that hollow soundings in approximately 6 percent of the total area, while the half-cell potential showed corrosion activity in 26 percent of the surveyed area. It has to be also remembered, that only a fraction of the hollow soundings proved to be associated with concrete delamination, therefore, even the 6 percent figure is too high.

Survey of soffit - In 1991 approximately 4.8 percent of the soffit was found to be delaminated, and the length of the cracks that show evidence of water penetration is 459 m (Table 52.3). The area of delamination increased in four years by approximately 52 percent, and the length of cracks by 13 percent. The quantity of the former defect changed very little in the last three years, while the latter showed slow but steady increase.

Discussion

This garage is in an essentially good condition indicated by the slow rate of deterioration.

In the CP system protected area the rate of deterioration is less than in the rest of the deck. However, uneven current distribution, debonding of the anode coating, and "hot" spots were detected in the survey. CP system needs more maintenance than conventional garage protection systems, and this structure is not receiving the needed attention.

The entire garage would have benefited from yearly surveys and follow-up maintenance (concrete delaminations and the membrane).

Tbl. 52.1
Garage No. 52
Size of hollow sounding areas in and outside of the cathodically protected area of the slab

	CP protected, m^2	CP protected, %	No CP, m^2	No CP, %
1988	1.0	0.4	52.0	1.9
1989	2.3	0.8	84.8	3.2
1990	3.8	1.4	139.5	5.2
1991	6.0	2.1	184.2	6.9

Tbl. 52.2
Garage No.52
Area of deck in which the half-cell potential was found to be greater than -0.35V

	Area with half-cell potential > -0.35V	
	m^2	%
1988	64	33
1989	46	23
1990	46	23
1991	52	26

Tbl. 52.3
Garage No. 52
Area of delamination of concrete, and length of cracks in soffit that show evidence of water penetration

	Area of delamination of concrete , m^2	Length of leaking cracks, m
1988	1.9	406
1989	4.3	436
1990	4.8	441
1991	4.8	459

Fig. 52.1
Garage No 52
Instant-off and four hour decay potentials in mV, measured in 1988

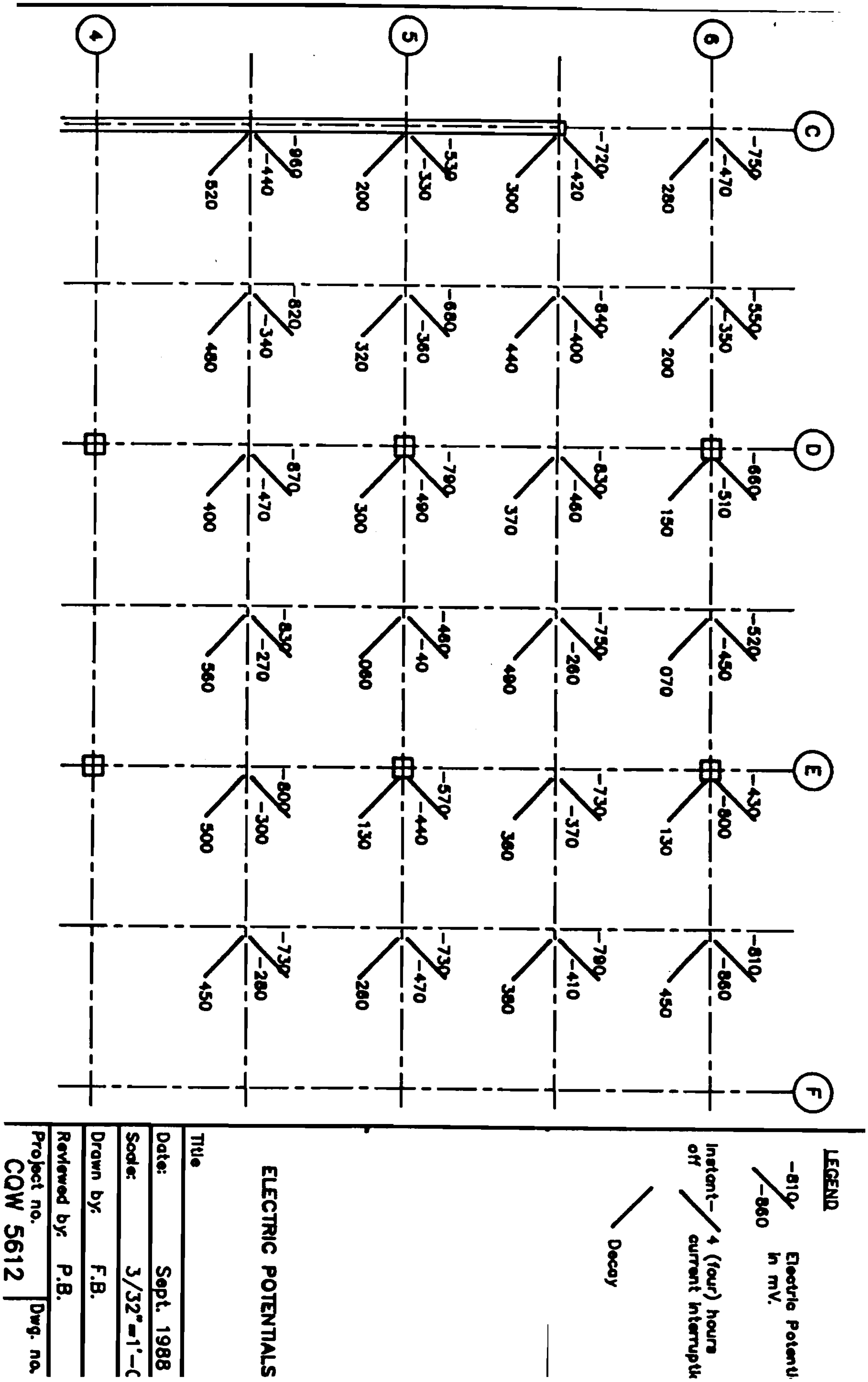


Fig. 52.2
Garage No 52
Instant-off and four hour decay potentials in mV, measured in 1989

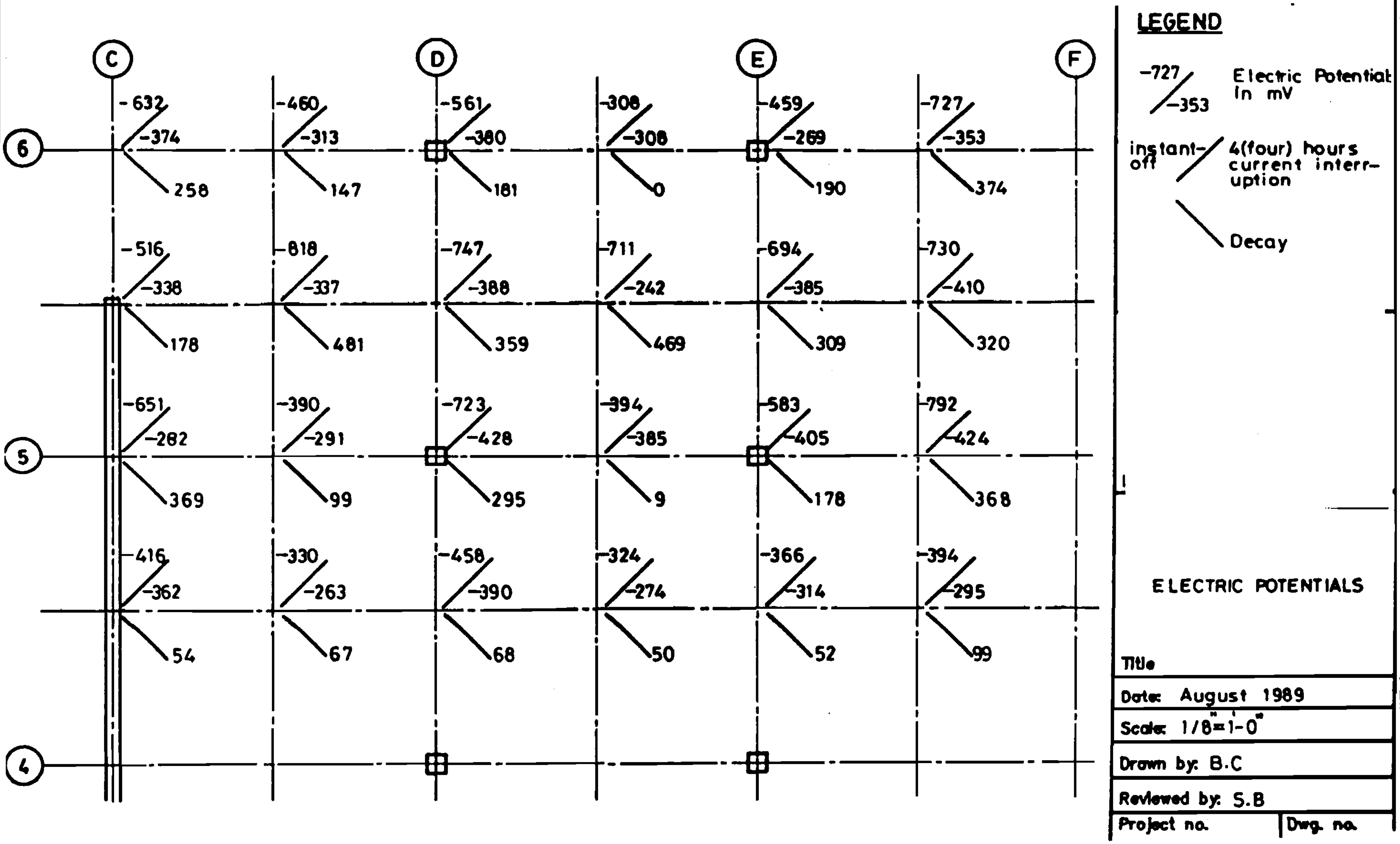


Fig. 52.3
Garage No 52
Instant-off, and four hour decay potentials in mV, measured in 1990

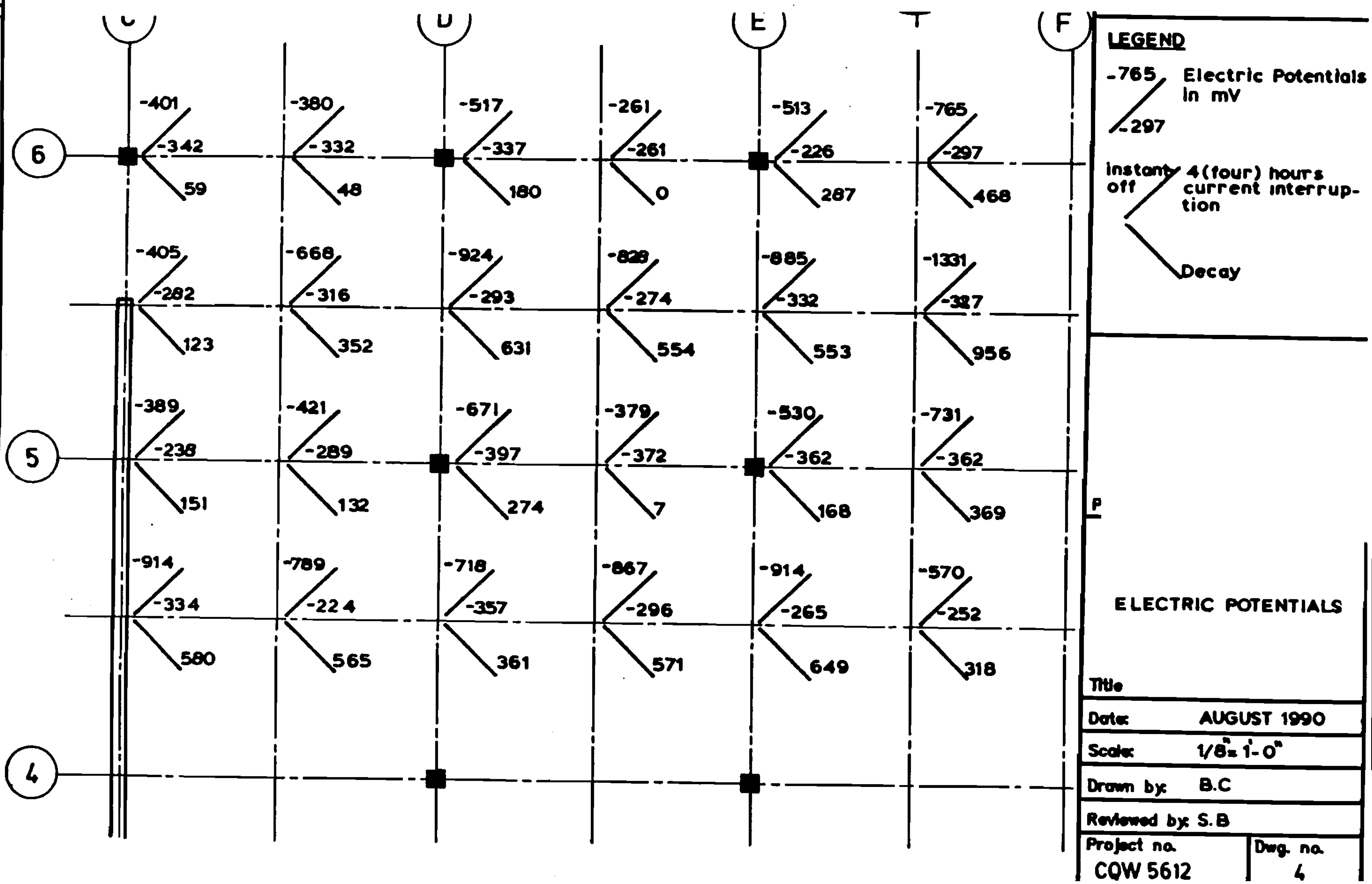


Fig. 52.4
Garage No 52
Instant-off, and four hour decay potentials in mV, measured in 1991

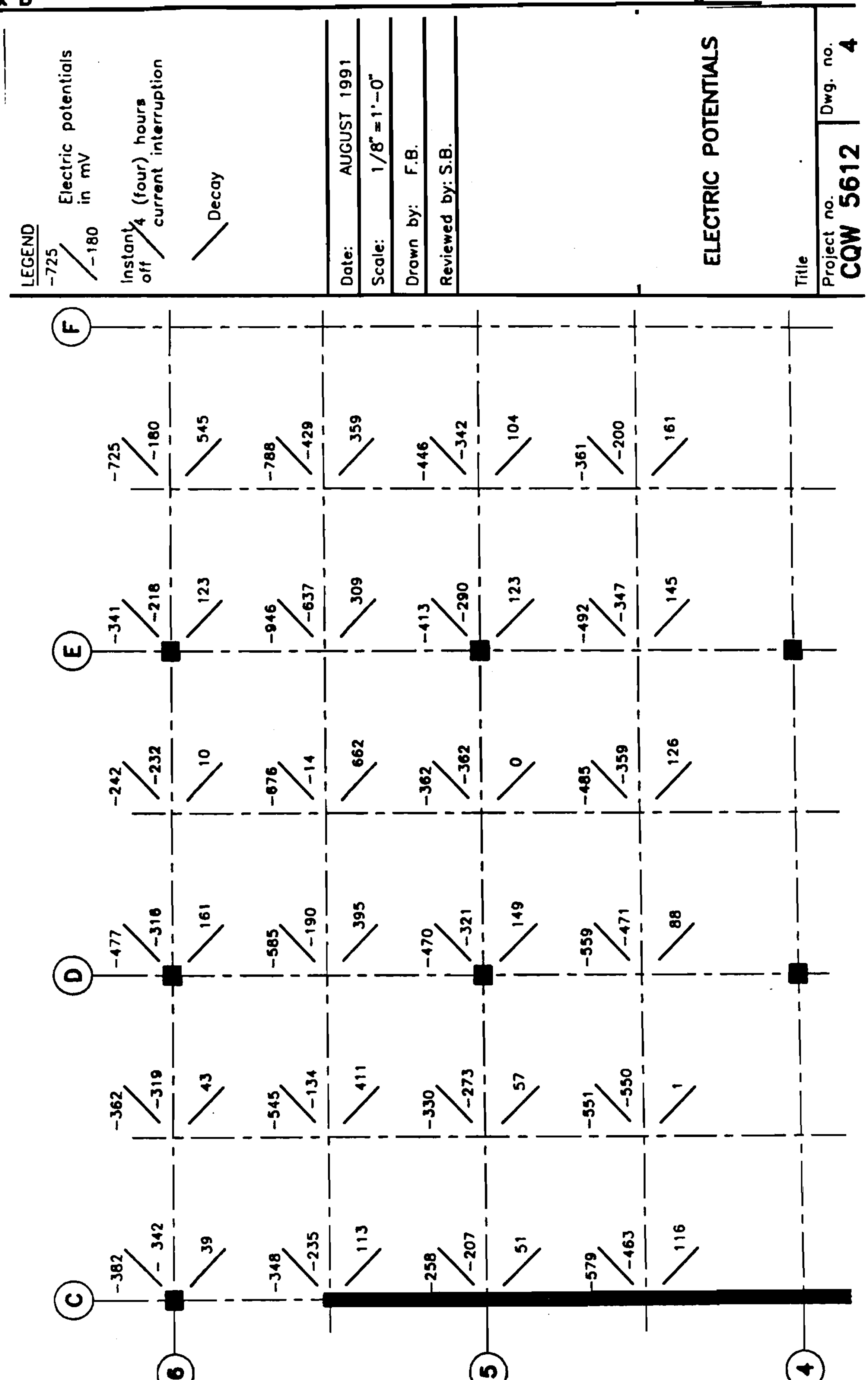


Fig. 52.5
Garage No. 52
Condition of cores and their approximate location

	1	2	3	4	5	6	7	8	9	10
A									11M	
B	17M; 35M				14 M	13M; 33M	1M; 6E	12M		
C	5M; 5M		8D(5); 9A; 18A	CP	31R; 32M					
D				10A	15A; 25M			21M; 34R		
E				16A			22M	23M	24R	
F				26D(10)			0	40D(3)		
H				38D(20)						
J	36D(5)			37D(25)	19D(15)	20D(10)	2D(10); 28D(30)			
K							29D(20)			
L			27D(30)						30R	3D(5)

NOTE: A = Anode coating debonded, D = Concrete delaminated (depth from top, mm), E = Exposed concrete, M = Membrane debonded from concrete, R = Repair concrete debonded from original concrete

Garage No. 53

An underground parking facility, constructed in 1975, has two suspended levels and one slab on grade. The two suspended levels are not interconnected by ramps and access to the parking decks is provided via different streets. A stairwell, however, is common to both slabs. A portion of the top suspended slab, Level A, has been designated for commercial parking.

The suspended levels are of a two-way reinforced concrete flat slab design supported by circular columns. The total area of the two structural slabs and slab on grade is 11,893 m^2.

No waterproofing membrane is present on either of the slabs, but there are signs that a sealer has been applied on some locations.

Repair History

No major repairs are know to have been performed on this structure.

Visual Survey

The top surface of the slab shows relatively few defects. The concrete has spalled in some places.

The underside of the slab, particularly that of the A level, is heavily stained as a result of leakage. More than a dozen plywood sheets and plastic troughs have been installed to protect the paint of the parked cars. Leakage is evident along the construction joints and major cracks.

Delamination Survey

The results of the four yearly surveys are summarized in Table 53.1 and Fig. 53.1.

The average delamination in the two structural decks in not very high, 5.2%, (31.9 m^2 / 610 m^2), relatively modest increase since 1988, when the average was 2.9% i.e. a yearly increase of 0.76 percentage points.

The situation is far less reassuring, when results obtained in Test Area A-2 are considered; delamination increased from 7.2 in 1988 to 17.8% in 1992 at an essentially linear rate. Corrosion activity seem to be very high in this area and delaminations will probably develop at an accelerated rate in the near future.

The results obtained on the lower level indicate little or no corrosion activity. It is expected, however, that deterioration in Area B-2 will accelerate, as it has already deviated from linearity in the last two years (Fig 53.1).

The soffit of slab B shows some scaling, in fact more than that of slab A (Table 53.2 and Fig. 53.2). This finding indicates that the corrosion activity in Area A-2 is still restricted mainly to the top mat of the reinforcing steel.

Half-cell Potential

The half-cell potential readings, are shown in Figs. 53.3 through 53.7.

Comparison of the rankings of the areas on the basis of the half-cell potential readings in excess of - 0.35 V and the extent of delamination indicate limited agreement.

Both parameters have extreme volume in Area A-2. On the basis of the half-cell potential Area A-1 is deteriorating the least, while the delamination survey found Area A-1 the second worst of the set. It is difficult to decide in which test result to place more credence. The fact that no condition, other than a discontinuity is known to produce a hollow sound on tapping on an uncovered concrete slab, favours the delamination test results. On the other hand, several variables, such as temperature, moisture content, junction potential affect the half-cell potential results.

The two sets of results are in general agreement, except for that for Area A-1, but the lack of confidence in the results of the half-cell potential measurement renders them of limited value.

The rate of deterioration in terms of the average potential readings is shown in Fig. 53.8. The number of the greater than -0.35 V readings steadily increased while those of less than 0.20 V decreased over the monitoring period.

Covermeter readings

The average thickness of the concrete cover over the reinforcing steel in the five test areas, as measured with a covermeter, are given in table 53.4. The values range from 19 mm to 100 mm, a span not unusual in this type of construction. Noteworthy is the rather thick cover that in fact exceeds the requirements of the current CSA S413 Standard.

Chloride contents

The water soluble chloride ion content of cores, one extracted from each level at yearly intervals, were determined and given in Fig. 53.9.

The absolute value of the concentration is an order of magnitude higher, than the values commonly considered as a critical concentration, above which corrosion almost certainly will occur in the presence of moisture, and oxygen.

The present case, together with others, raises question about the validity of the concept of critical concentration. This slab has no waterproofing system in place, contains chlorides in high concentration and, at least so far, has not deteriorated at a very high rate.

Tbl. 53.1
Garage No.53
Results of the delamination survey of the top surface of the suspended slabs

	Area tested	1988	1989	1990	1992
A1	209.0	9.1	11.9	12.6	14.6
A2	61.0	4.4	7.9	8.6	10.9
B1	207.0	1.5	1.8	1.9	2.0
B2	62.0	2.0	2.1	2.6	3.5
B3	71.0	0.9	0.9	0.9	0.9
Total	610.0	17.9	24.6	26.6	31.9

Note: Areas are in square metres

Tbl. 53.2
Garage No. 53
Size of the spalled areas of the soffits of the suspended slabs

	Area tested	1988	1989	1990	1992
Roof	2720	0.0	0.0	0.0	0.0
Level A	2570	0.0	0.3	2.2	4.7
Level B	3770	0.0	9.6	15.8	19.6
Total	9060	0.0	9.9	18.0	24.3

Note: Areas are in square metres

Tbl. 53.3
Garage No. 53
Ranking of the test areas, on the basis of the delamination and half-cell potential measurments, in descending order

	Rank in delamination test	Rank in half-cell potential test
1	A-2	A-2
2	A-1	B-2
3	B-2	B-3
4	B-3	B-1
5	B-1	A-1

Tbl. 53.4
Garage No. 53
Summary of the covermeter readings

Test area	Range of readings, mm	No. of readings	Average, mm	Standard deviation, mm
A-1	42-100	113	80	18
A-2	19-100	45	78	28
B-1	40-100	113	64	22
B-2	26-60	45	49	5
B-3	55-100	45	92	14
Total	19-100	361	73	

Fig. 53.1
Garage No. 53
Increase of Delaminated Areas of Surveyed Sections

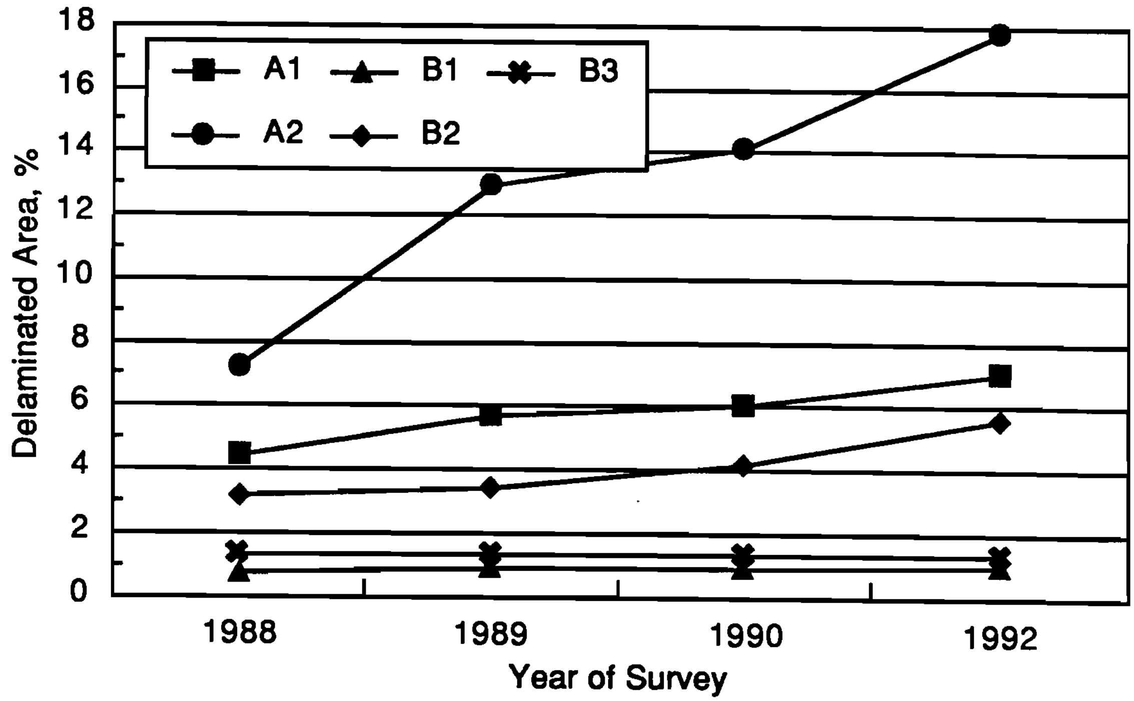


Fig. 53.2
Garage No. 53
Spalled areas of soffits of suspended slabs

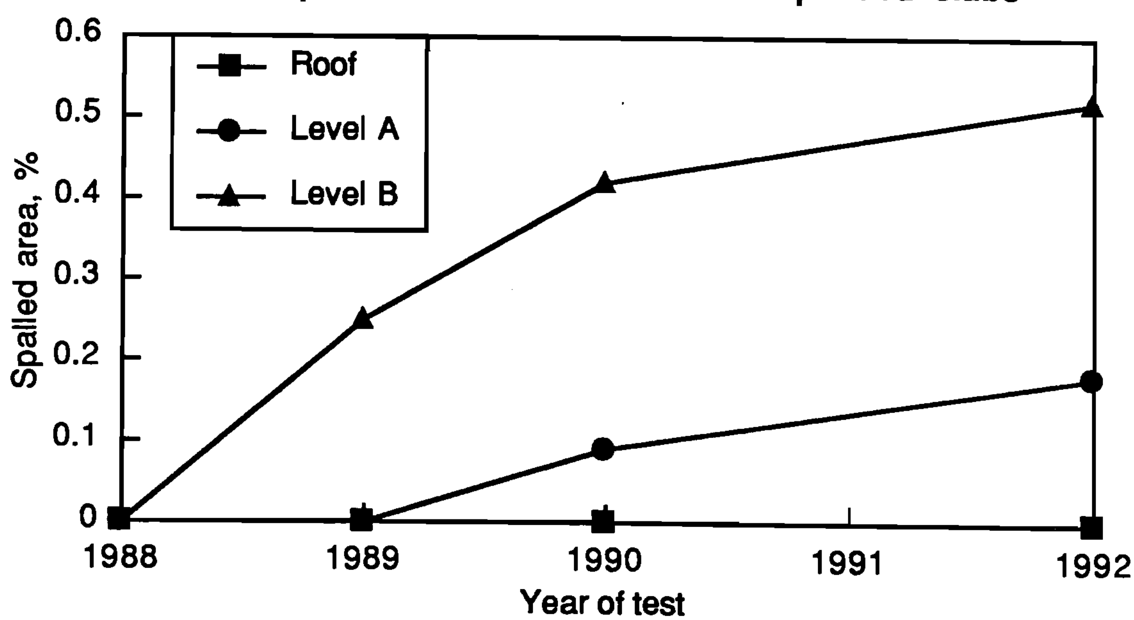


Fig. 53.3
Garage No. 53
Distribution of half-cell potential readings in Test Area A-1

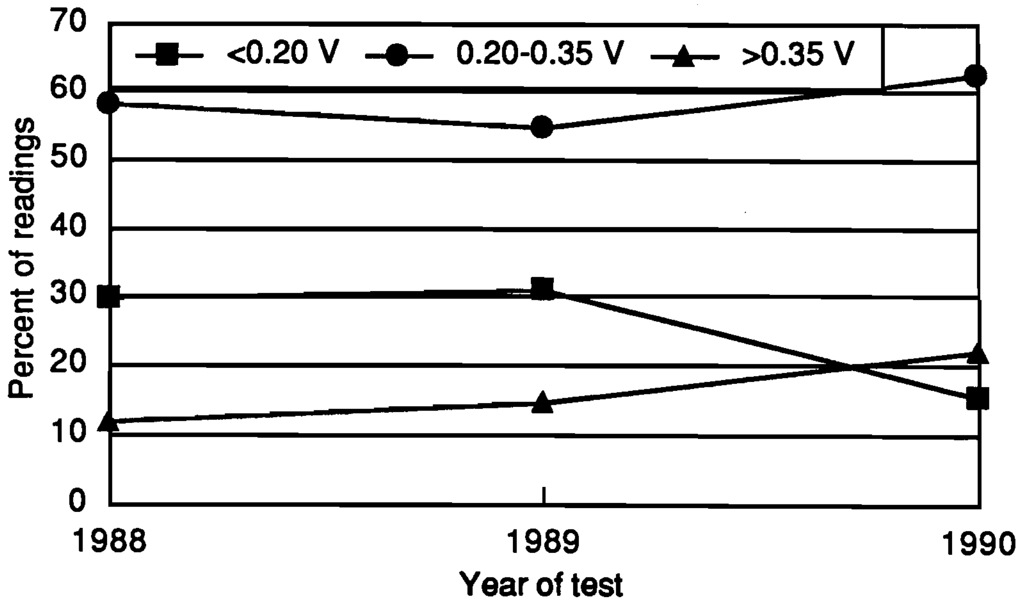


Fig. 53. 4
Garage No. 53 Distribution of half-cell potential readings in Test Area A-2

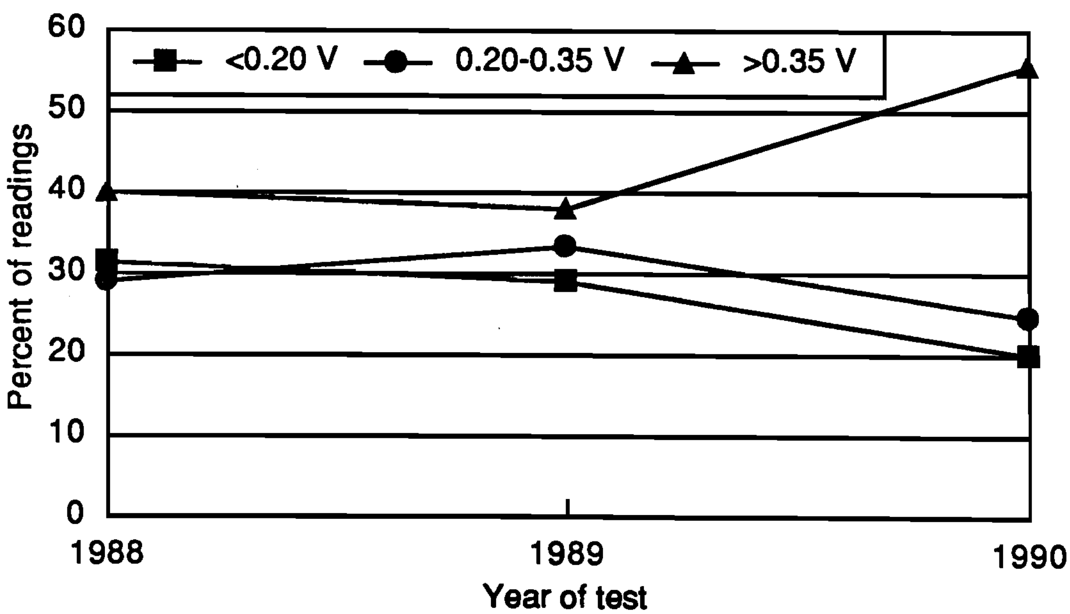


Fig. 53.5
Garage No. 53
Distribution of half-cell potential readings in Test Area B-1

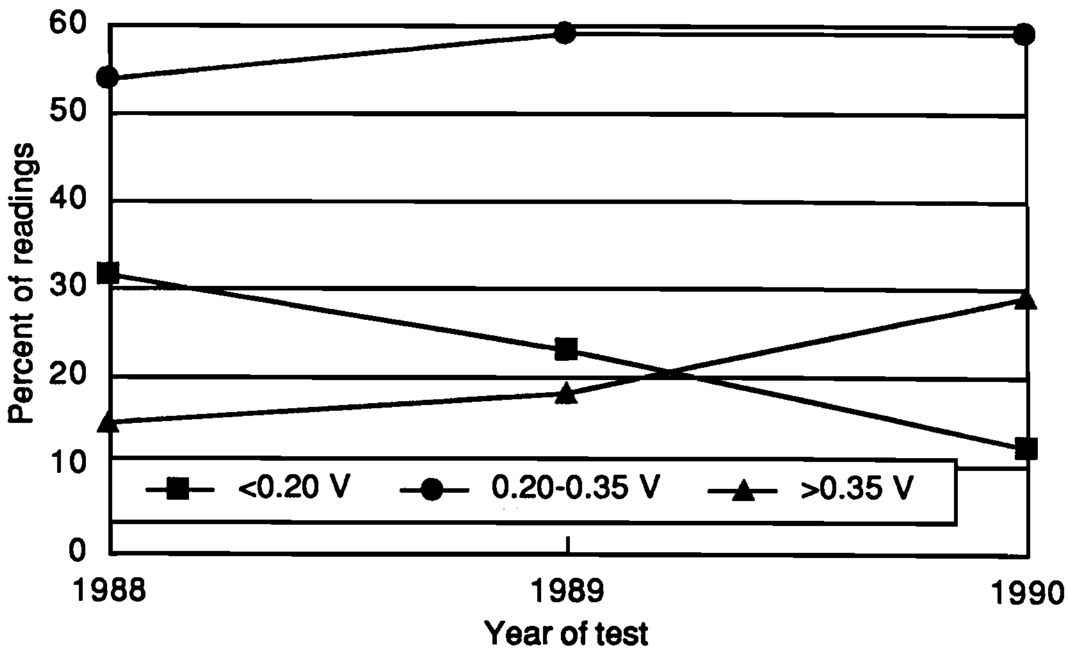


Fig. 53. 6
Garage No. 53.
Distribution of half-cell potential readings in Test Area B-2

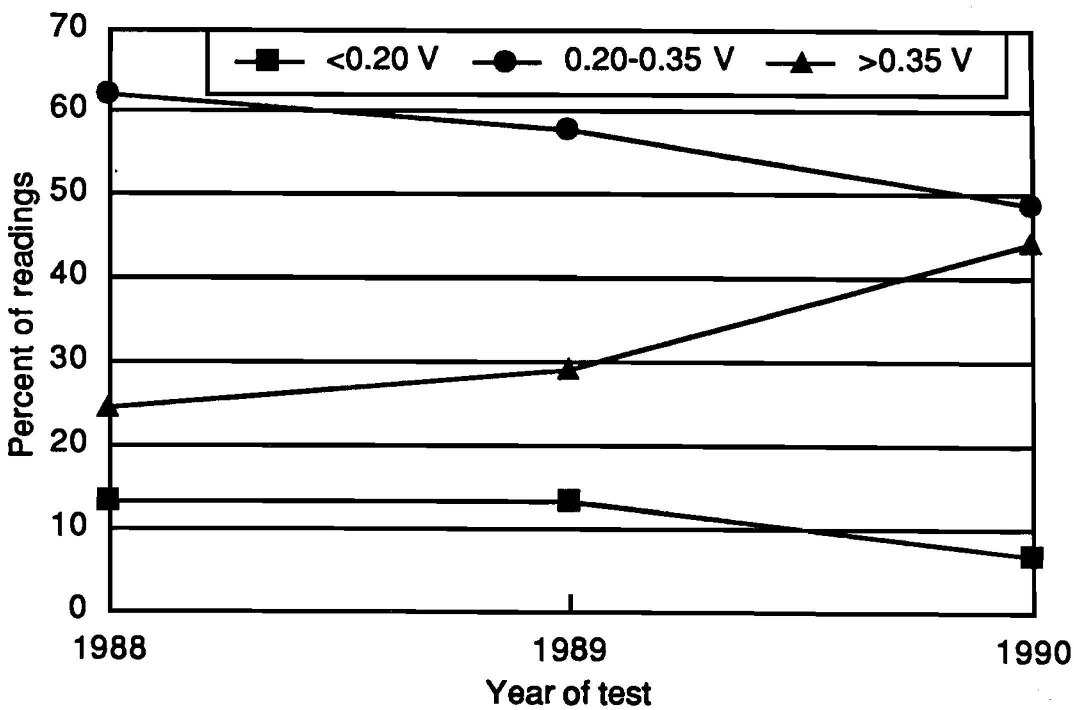


Fig. 53.7
Garage No. 53
Distribution of half-cell potential readings in Test Area B-3

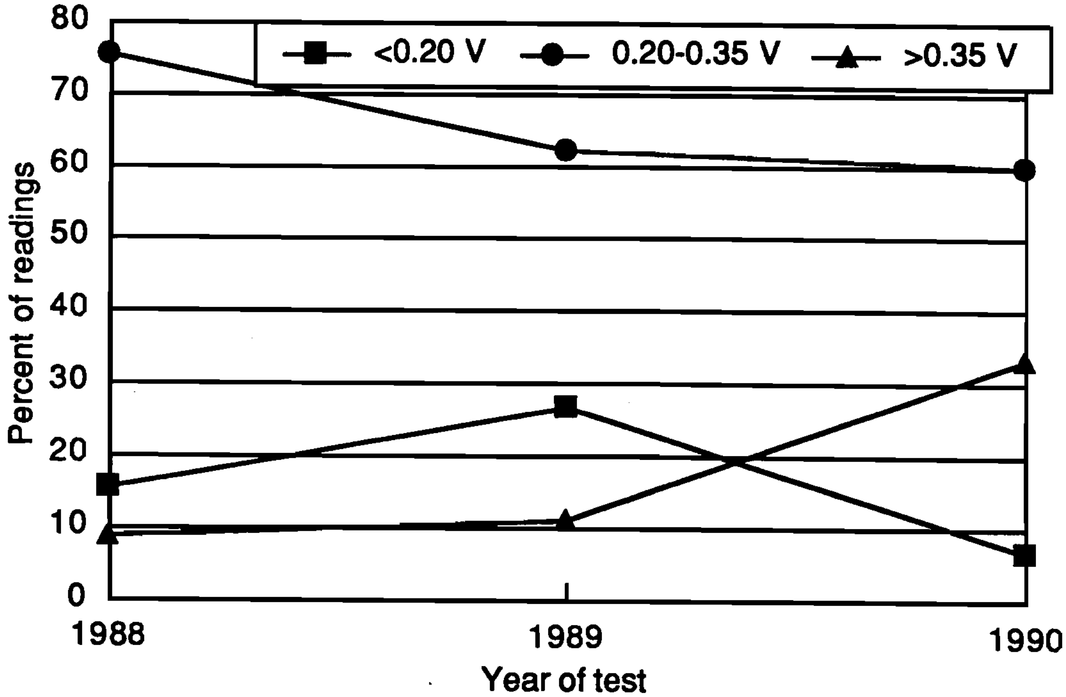


Fig. 53. 8
Garage No.53
Change of half-cell potential distribution with time (all areas)

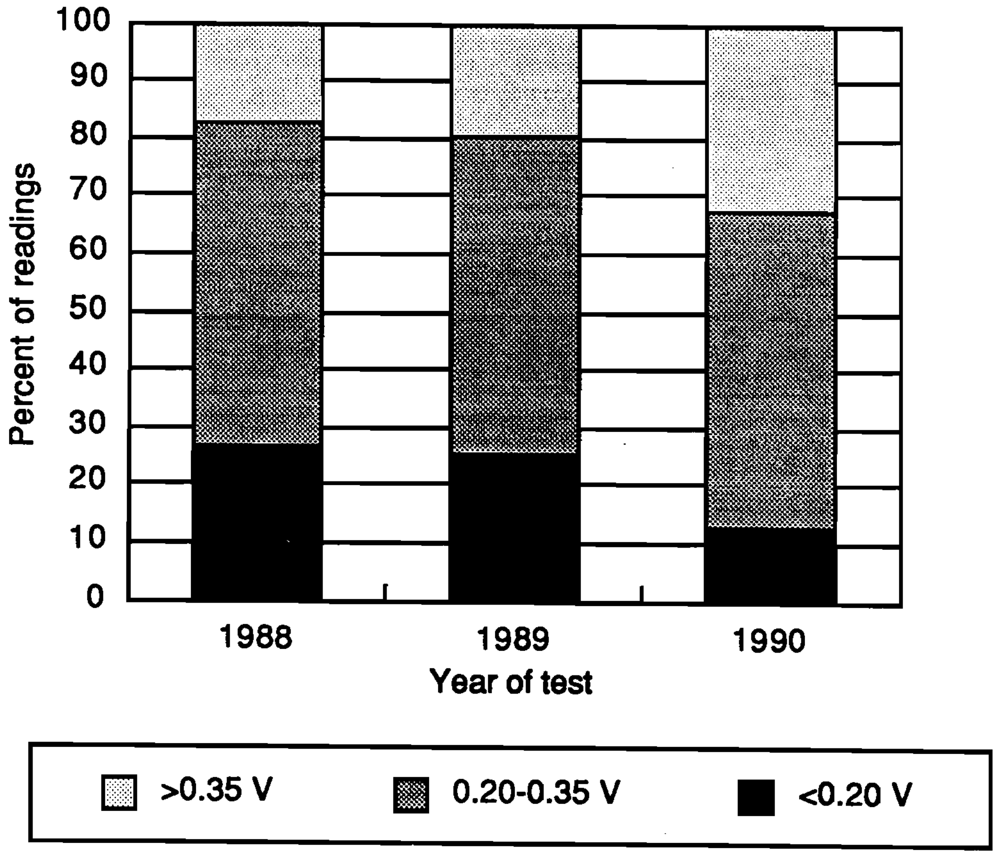
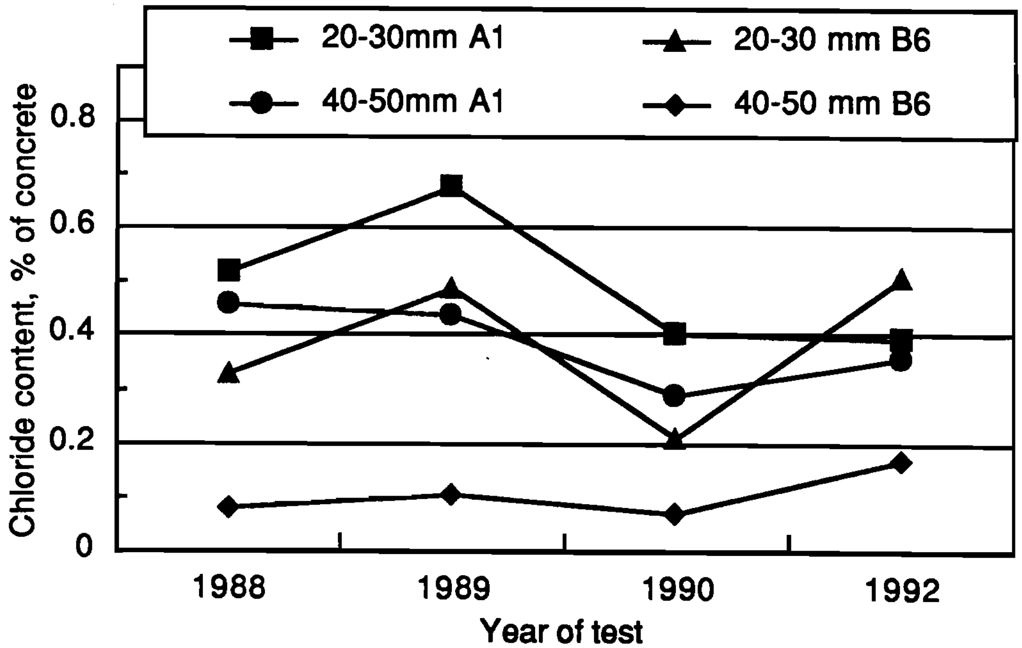


Fig. 53.9
Garage 53.
Chloride ion content (percent water soluble chloride ion by mass of concrete) of cored specimens



Garage No. 54

The parking facility beneath an office building consists of one interior suspended level, and a slab on grade.

The suspended level is of a two way reinforced concrete flat slab design, supported by circular columns with drop panels. Horizontal movement of the slab is accommodated by expansion joints.

The structural slab is protected with a Kelmar waterproofing membrane, that was installed at the time of construction in 1978.

The area of the suspended slab is 6982 m^2.

Repair History

There was little need for repair in this well maintained, and well performing garage. In the ten years of operation, the seals around the drain flanges, cracks in the membrane and discontinuities in the concrete due to poor compaction were repaired on a total cost of $5,000.

Condition Survey

Delamination test - The chain drag test, carried out in five test areas in 1988, identified 4.7 m^2 hollow sounding areas in a total of 763.8 m^2 area surveyed (Table. 54.1). Examination of the extracted cores revealed the existence of delaminations which probably are due to poor consolidation of the concrete at the time of construction. Some, but not all, of these defects were eliminated and the size of the delaminated area was reduced to 3.4 m^2 in the survey done in 1989.

It is quite possible that the defects observed were partly caused by debonding, or poor bonding, of the membrane from the concrete substrate. In any case, the average size of hollow sounding area was 0.44% with the maximum being 0.89% in Test Location No. 3.

Covermeter survey The average thickness of the concrete cover over the reinforcing steel was found to be 42 mm, (see Table 54.2) conforming with the requirements of the CSA S413 standard (40mm).

Half-cell Potential The distribution of the half-cell potential readings in the five test areas are presented in Fig. 54.1. Consistently with the delamination test results the overwhelming majority of the readings were less than -0.20 V (93.3%) and in the range of -0.20 V and -0.35 V (6.1%) indicating no, and little probability of corrosion, respectively. Only 0.6% of the readings had a value greater than -0.35 V, that signifies steel corrosion occuring at a greater than 90% probability. Considering the condition of this garage, the reliability of the finding that any corrosion is occuring must be questioned.

Visual Survey The components of the parking structure were found to show no defects, except that a) the interior entrance/exit ramp has some leaked cracks on the underside, and b) the perimeter wall/concrete slab interface is stained by leakage in a few locations.

Chloride ion content Two cores, each in 1988 and 1989, were extracted from the slab, and the chloride content determined at three horizons. The results are summarized in Table 54.3.

The concentrations are low, well below the generally accepted threshold values of 0.025 or 0.035 percent soluble chloride ion content by mass of concrete. The concentrations appear to be somewhat higher in 1989 than those obtained the year previous to that.

The significance of this increase is not clear and it would be worthwhile to carry out another determination now.

Conclusion

This structure at the age of 11 years was performing very well, and is expected to continue to do so till the end of its design life.

Tbl. 54.1
Garage No. 54
Hollow sounding areas in delamination test

Test location No.	Test location area, m^2	Hollow sounding area, 1988, m^2	Hollow sounding area, 1988, %	Hollow sounding area, 1989, m^2	Hollow sounding area, 1989, %
1	180.5	0.9	0.50	0.5	0.28
2	133.0	1.4	1.05	0.8	0.60
3	123.5	1.1	0.89	1.1	0.89
4	180.5	0.6	0.33	0.3	0.17
5	146.3	0.7	0.48	0.7	0.48
Total	763.8	4.7	0.61	3.4	0.44

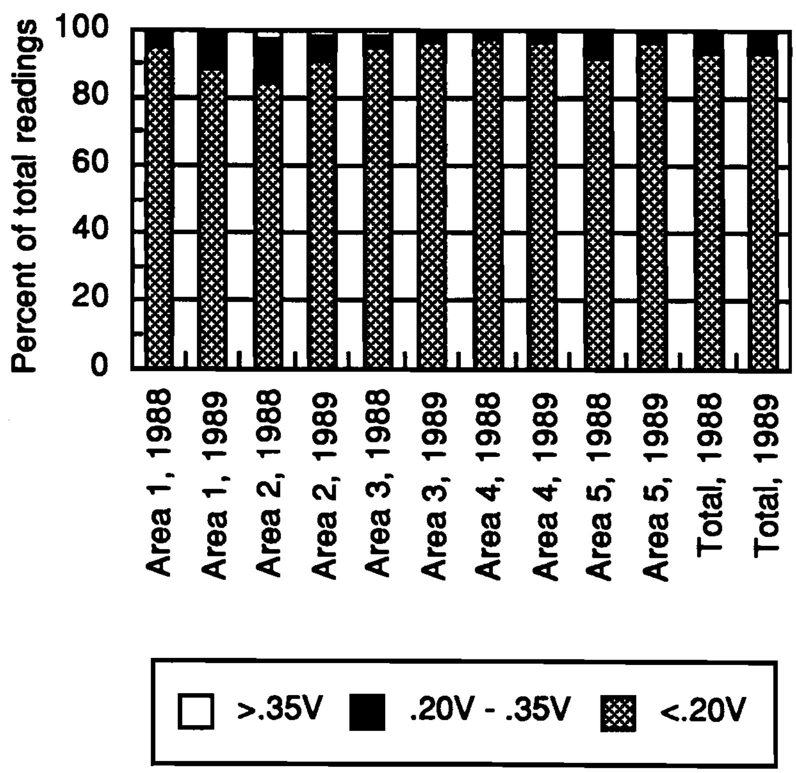
Tbl. 54.2
Garage No. 54
Covermeter readings on top of the interior suspended slab

Area	Range of readings, mm	No. of readings	Average, mm	standard deviation
1	29 to 74	62	44	10
2	20 to 55	62	36	9
3	20 to 65	50	45	10
4	17 to 75	66	44	13
5	23 to 75	56	40	9
Total	17 to 75	296	42	11

Tabl. 54.3
Garage no. 54
Chloride ion content, percent by mass of concrete at stated horizons

	20 - 30 mm	50 - 60 mm	90-100 mm
1988	0.011	0.011	0.010
	0.008	0.011	0.009
1989	0.017	0.026	0.019
	0.017	0.017	0.013

Fig. 54.1
Garage No. 54
Half-cell readings of stated ranges in test areas, percent



Garage No. 55

An underground parking garage of a building with mixed, office and residential, occupancy that has a total floor area of 8,296 m^2. The 118 parking stalls are located on one suspended slab and a slab on grade, which are approximately of equal size.

The structure, of reinforced concrete columns, beams and slab type, was built in 1977.

The 203 mm thick suspended slab, contains black steel reinforcement, and is protected with a waterproofing membrane (Kelmar).

Repair History

A major rehabilitation was undertaken seven years after construction. Delaminations, detected in 1% of the total area, were eliminated, 54 m long expansion joint was replaced and, a waterproofing membrane installed over the suspended deck.

In 1990, at 13 years of age and six years after rehabilitation, the surface of the interior entrance/exit ramp was repaired. Of the total 75 m leaking expansion joint, only 15 m was replaced.

Condition Survey

Visual surveys: Over the monitoring period a slow, but steady, deterioration of the garage was observable.

The waterproofing membrane developed cracks, ripples, and wear. The traffic topping suffered abrasion in the driveway lanes, particularly in turns, and in these places the bare membrane became exposed to the traffic.

The membrane was damaged at the ramp footing during repair work, and a new membrane in this area was installed only after a delay of a year.

The bond between the membrane and the expansion joint, and the floor drain flanges, respectively, failed in many places, resulting in leakage into and through the concrete slab. This was aggravated by poorly functioning drain seals.

The yearly increase of the total length of the cracks in the slab soffit levelled off at approximately 10%, after a yearly increase of 22% four years ago (Table 55.1 and Figure 55.1) . The majority of the cracks is concentrated in the area of the slab that is reserved for short term public parking.

No cracks were noted in the columns. The column footings are not protected by dykes.

The drains function satisfactorily, although the baskets contained some accumulated sand and dirt. Excessive ponding in several locations still occurs.

A severe defect in the garage is the leakage through the concrete slab of the loading dock above the garage, causing corrosion of the shelf angles in this area.

Of the total of 180 m expansion joint, 42% was found to be leaking due to bond failure, and deterioration of the sealant. The latter defect is most pronounced in areas of frequent exposure to water, such as ponding, water taps for washing, and run-off from ramps. Of the 75 m expansion joint that has to be replaced, to date only 15 m has been renewed.

Delamination: The growth of the delaminated areas is shown in Figure 55.2, and the numerical values given in Table 55.2.

In plotting the results, it was assumed that all delaminations were eliminated in the rehabilitation work carried out in 1984.

Since that time, a total of 8.5% delamination developed in the suspended deck at an essentially linear rate. The growth of delamination in the soffit and the lower ramp is also linear. The upper (entrance/exit) ramp, however, deteriorated at an exponential rate reaching a value of 25.6% in 1991, just prior to the repairs.

Concrete coring: Ten cores were extracted every year from the suspended slab as part of the field investigation. Five cores were taken through delaminated areas, to determine the plane of delamination, two cores in the vicinity of a new drain installed in 1988, and three cores were taken at locations selected randomly.

Examination of the cores showed that the waterproofing membrane was very well adhered to the concrete surface at all locations. However, the bond between the latex modified mortar repair patches and the concrete substrate was weak, as separation occurred at the interface in three of the cores extracted from the previously repaired areas. It is also evident that removal of concrete did not extend sufficiently low below the reinforcement.

Chloride content: The chloride content was determined in cores that were taken from the deck in the same general area as done previously during the test period.

The results, given in Table 55.3 and shown in Figure 55.3, indicate a peak chloride content in 1989. Variation in the proportions of the chloride containing paste and the uncontaminated aggregate, and non uniform salt distribution in the deck area would result in random scatter. The unexpected shape of the average and individual core chloride contents as a function of time (Figure 55.3 and Figure 55.4) must, therefore, be ascribed to systematic experimental error of the analysis.

Although no accurate information on the change of the chloride content with time is at hand, it is clear that the salt concentration is an order of magnitude higher than the accepted threshold value.

Conclusion

Garage 55 is in quite a good condition considering its age and the level of maintenance provided. The most serious defects are the delamination of the concrete of the entrance/exit ramp and the leakage through the loading dock.

The membrane, and the expansion joints have to be attended.

The high chloride content is seriously questioning the correctness of the generally accepted threshold value (0.035%). It appears that with more timely repairs this garage could be made well performing.

Tbl. 55.1
Garage No. 55
Total length of cracks, of stated width, in soffit

	0.3-1 mm, m	increase, %	1-2 mm, m	increase %
1988	347.4		28.7	
1989	426.7	22.8	30.4	23
1990	463.6	8.6	40.5	10.3
1991	493.8	6.5	64.4	10.5

Tbl. 55.2
Garage No. 55
Growth of the delaminated areas, expressed as percent of total, at locations indicated

	Deck	Soffit	Upper ramp	Lower ramp
1988	4.7	0.4	0.8	3.5
1989	6.0	0.7	4.8	4.4
1990	7.5	1.2	16.8	4.8
1991	8.5	1.4	25.6	6.4

Tbl.55
Garage 55
Chloride content of concrete, weight percent, at horizons indicated

	20-30mm	50-60mm	90-100mm
1988	0.377	0.366	0.219
	0.241	0.163	0.172
	0.376	0.319	0.243
Avg	***0.331***	***0.283***	***0.211***
1989	0.669	0.607	0.483
	0.534	0.463	0.484
	0.357	0.383	0.391
Avg	***0.520***	***0.484***	***0.453***
1990	0.636	0.530	0.322
	0.225	0.128	0.104
	0.467	0.344	0.224
Avg	***0.443***	***0.334***	***0.217***
1991	0.432	0.386	0.219
	0.296	0.188	0.141
	0.414	0.244	0.112
Avg	***0.381***	***0.273***	***0.157***

Fig. 55.1
Garage No. 55
Yearly increase of cracks, of stated sizes, in soffit

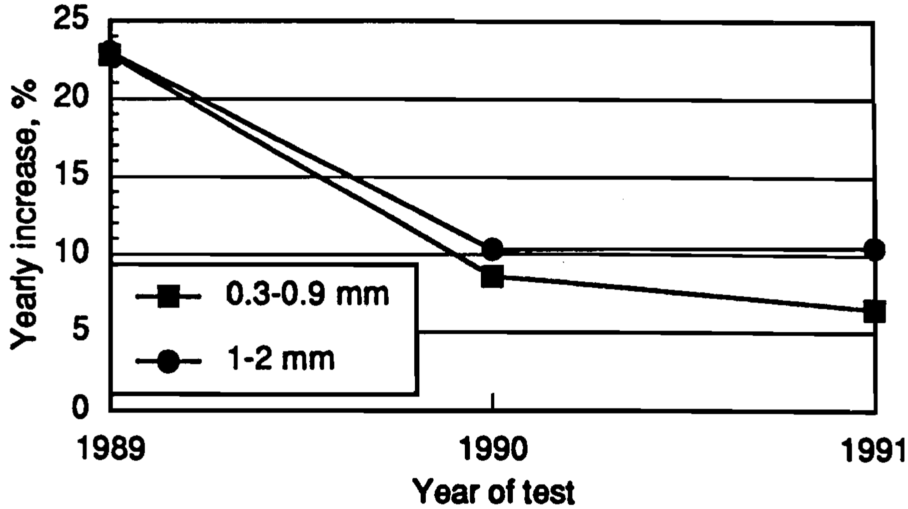


Fig. 55.2
Garage No. 55
Growth of the delaminated areas, expressed percent of total

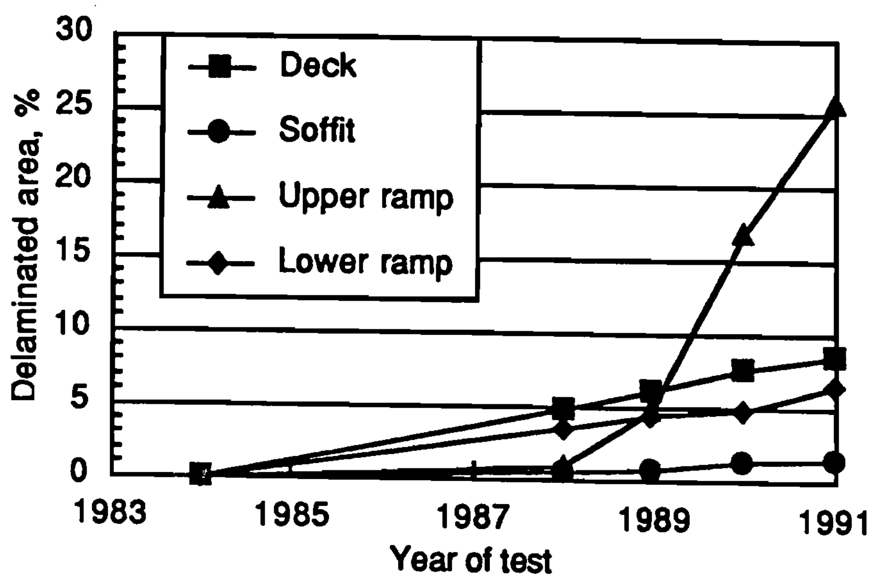


Fig. 55.3
Garage No. 55
Average chloride content, at horizons indicated, of the three concrete cores extracted from the deck

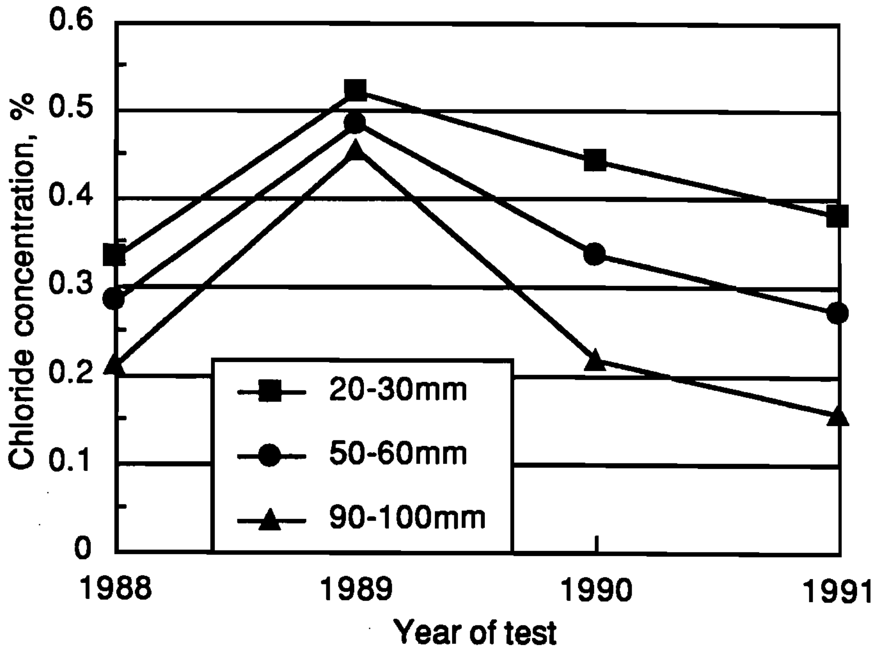
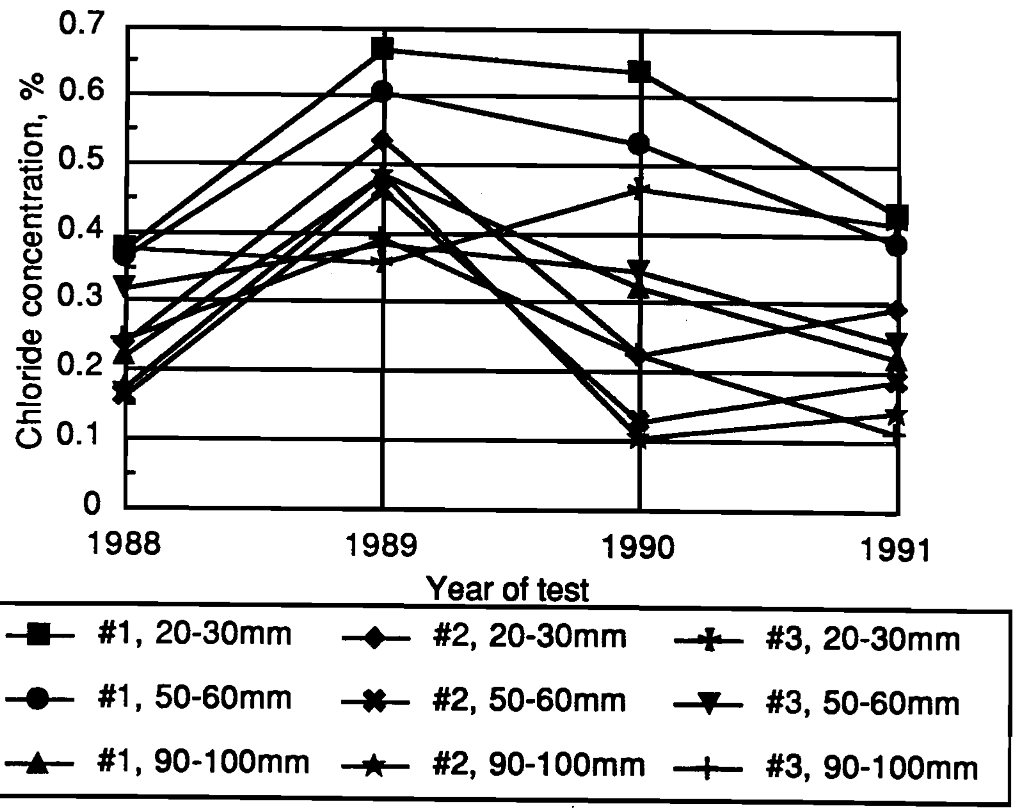


Fig. 55.4
Garage 55
Chloride content of concrete cores in weight percent, at horizons indicated



Garage No. 56

An underground parking facility in a 11 storey residential building, constructed in 1971. The garage consists of two suspended levels and two slabs-on-grade. There is a podium slab above grade and a roof level on grade. Vehicular traffic is allowed on a portion of the roof level.

The gross area of the garage is 7,200 m^2, the area of the suspended slab and the slab-on-grade is 3,574 m^2 each, and the area of the portion of the roof level which accommodates vehicular traffic is 915 m^2.

The 229 mm thick suspended flat slabs are supported by reinforced concrete columns.

Repair History

A condition survey was carried out in 1984 which revealed evidence of severe deterioration in the suspended slabs, as well in some walls and columns. Also, reinforcement deficiencies in the suspended slabs, amounting to 50 percent, were discovered in the original design. The columns supporting the garage slabs were also found deficient.

On the recommendation of the consultant the weather exposed roof and podium slabs were repaired, and waterproofed with a membrane. The interior slabs, however were not rehabilitated and had to be permanently shored. The lowest levels of the garage were sealed off. Steel columns were added beside the deficient structural columns to maintain safety.

The garage is used only to a limited extent. The only parking areas now available for use inside the garage are on the permanently shored slabs.

Condition Survey

Delamination test - A chain drag test was performed at yearly intervals to determine the extent of delamination in the suspended deck. The results indicate that the increase of the delaminations in time is exponential (Fig. 56.1). While in the first 17 years, 14 percent of the slab area became delaminated, in the subsequent three years the size of the deteriorated area doubled.

Chloride ion concentration - The chloride concentration of the concrete cores extracted from the suspended and roof deck was determined and the results are shown in Fig. 62.2 through Fig. 62.6. At the 20 to 30 mm horizon the concentrations seem to have increased rapidly during the monitoring period, reaching 0.92 percent in one case. There is no ready explanation for the unusually high absolute values and the apparent exponential rate of increase.

The chloride concentration in the original, and in the waterproofed repaired is higher than the accepted threshold value of 0.035 percent, but not by a large margin.

Discussion

The suspended slab of the garage is an example for accelerated deterioration that takes place in time if left unrepaired. It is expected that within a short period of time the suspended slab will have to be replaced.

Fig. 56.1
Garage No. 56
Percent of delaminated area in suspended deck

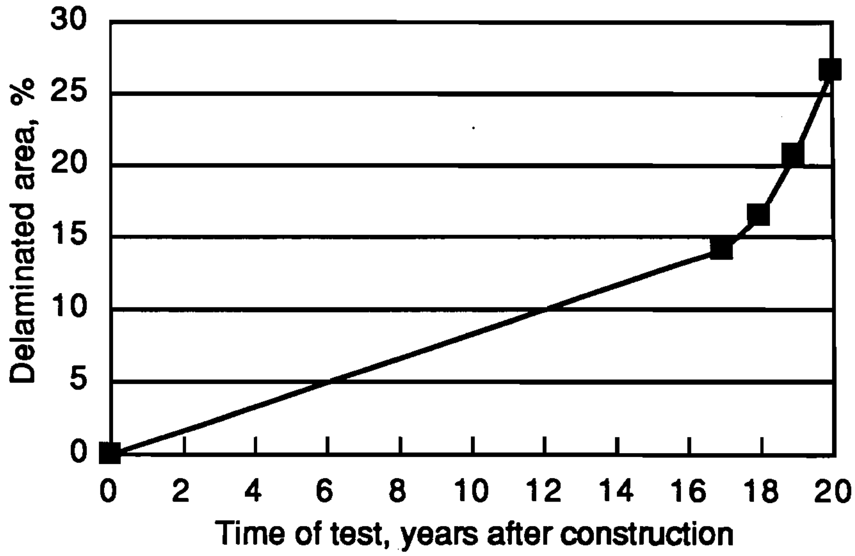


Fig. 56.2
Garage No. 56
Chloride ion concentration of concrete in the suspended deck at horizons stated, location No. 3

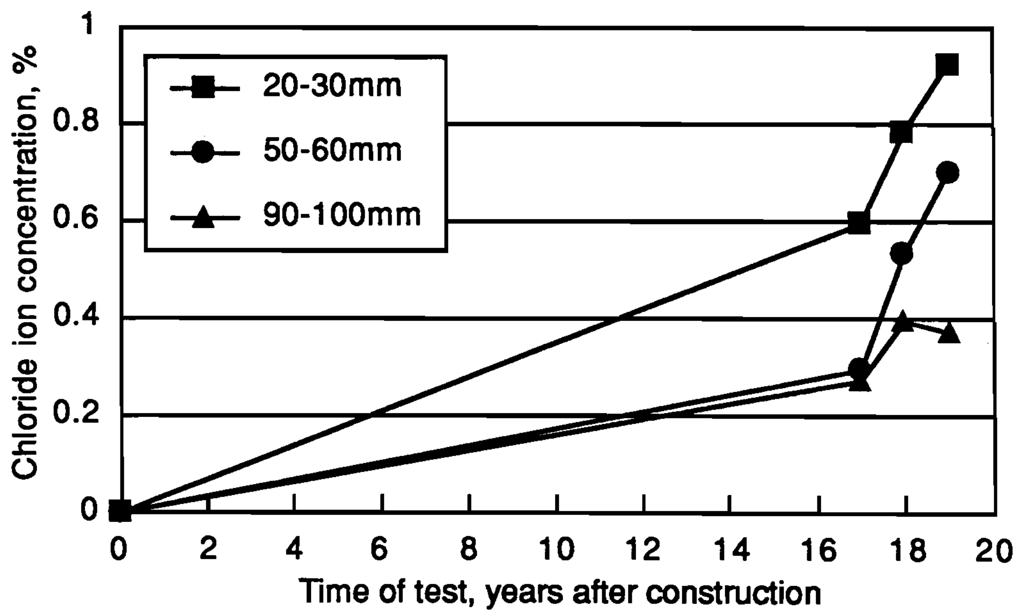


Fig. 56.3
Garage No. 56
Chloride ion concentration of concrete in the suspended deck at horizons stated, location No. 10

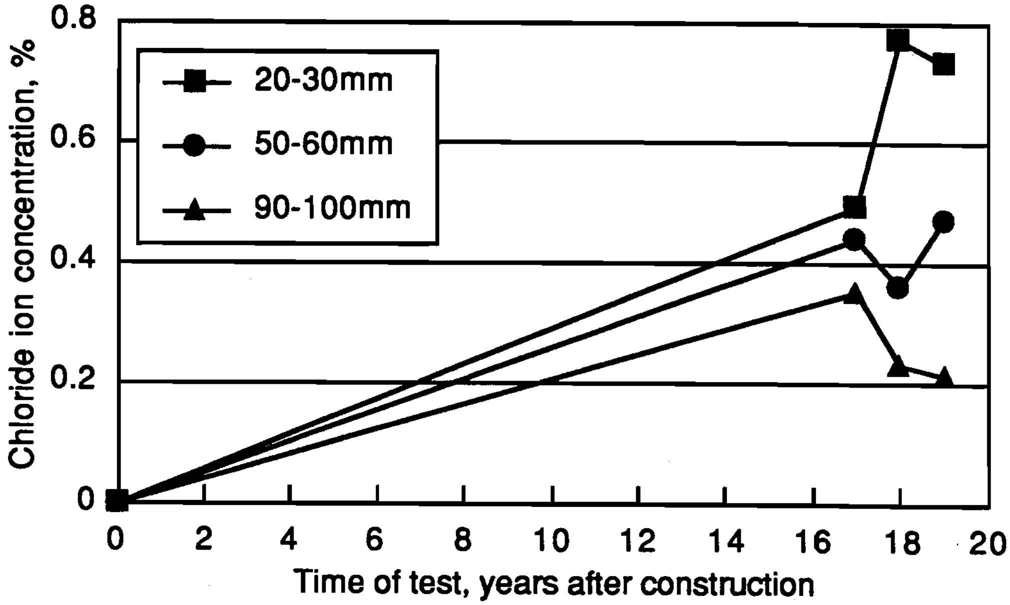


Fig. 56.4
Garage No. 56
Chloride ion concentration of concrete in roof slab, at horizons indicated, location No. 4 (original concrete)

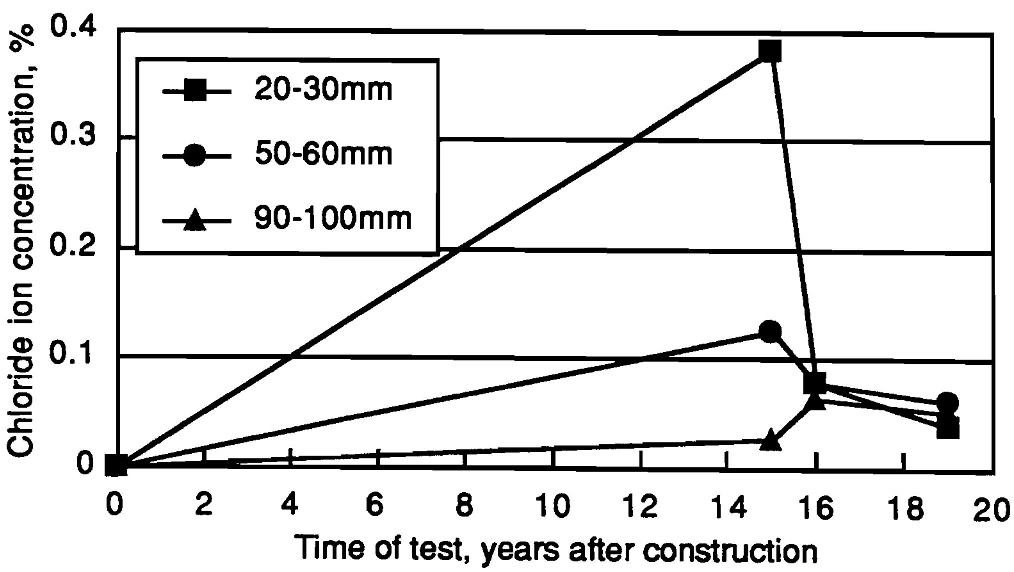
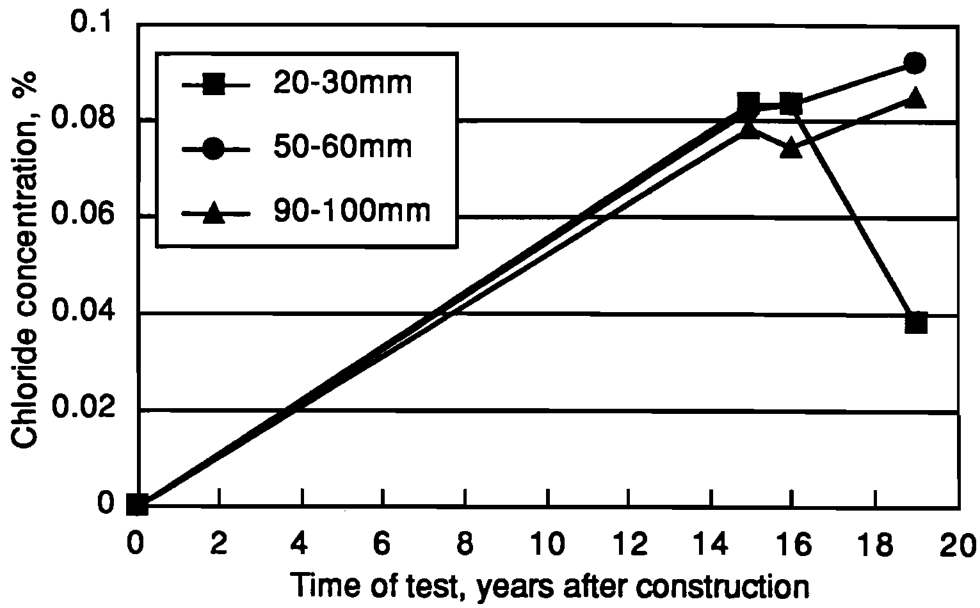


Fig. 56.5
Garage No. 56
Chloride ion concentration of concrete in roof slab, at horizons indicated, location No. 6
(repair concrete)



Garage No. 57

An enclosed underground garage constructed in 1978 of a residential highrise condominium building, comprising one slab-on-grade and one suspended slab level, each approximately 9,300 m^2 in size.

The reinforced concrete columns support 200 mm thick reinforced concrete flat slabs. The concrete mix was specified to contain 6 percent entrained air, and normal weight aggregate. The compressive strength is in excess of 35 MPa. Neither a membrane, nor a sealer has been applied on the surface.

Repair History

In a condition survey carried out seven years after construction, 8 percent delamination was detected. Small extent of leakage through the slab, and some spalling and scaling were also noted. The thickness of the concrete cover over the steel varied between 6 and 18 mm. The compressive strength ranged between 35 MPa and 63 MPa.

The repair strategy followed was to spend relatively little on repairs, and to install cathodic protection, (CP), to prevent further deterioration.

This plan was executed in 1986 at a cost of $350,000 or $400,000. (The exact amount cannot be ascertained). Approximately $50,000 was spent on the repair of spalls, and major cracks in the concrete, and the balance on the CP system.

By 1991 the serviceability of the garage deteriorated to such extent that the owners decided to undertake a major rehabilitation. The work was to include elimination of the delaminations, sealing the leaking cracks, and replacement of the expansion joints.

The work was stopped before completion of the repairs because of a dispute between the owner and the supervising engineer. Approximately 50 percent of the work has been completed.

Details of the Cathodic Protection Installation

The CP system was installed after repairs of the concrete slab. Continuity was tested and found satisfactory.

The number of zones is 21, each having its individual power supply. Platinum clad niobium wire serves as the primary, and a conductive coating (Porter DAC 85), as the secondary anode system. Monitoring of the power supply output, temperature, and humidity can be monitored from a remote location.

Condition Survey

Delamination test - The summary of the chain drag test is shown in Table 57.1.

The results of the test carried out in 1988 had to be omitted because the size of the delaminated area reported was very approximate, and was obviously seriously overestimated.

The sizes of the test areas are 413 m^2, 330 m^2, and 543 m^2, respectively.

The consultant carrying out the survey reported the area of delaminated concrete, and those of the bonded, and debonded patches separately. The extent of the repaired area is the sum of the bonded and unbonded areas. According to these figures in test area 4, 11, and 20 1.2%, 8.1% and 4.0%, of the area, respectively, was repaired in 1986. Three years later in 1989, 33%, 84% and 20%, respectively, of the patches have debonded. These values suggest that the overall deterioration was moderate, and the repair work was not of good quality. After the initial debonding, the situation remained stable in the subsequent three years.

In view of the constancy of the debonded values, it seems reasonable to ascribe only the "delaminated area" figures to be caused by corrosion activity. Assuming, as one has to, that no delamination existed after the repair in 1986 the incremental changes in the last three years appear to have taken place in a linear fashion. (Fig. 57.1).

Eight years after construction, the total delamination was 4.1%. Interestingly, the extrapolated total delamination six years after the repairs of 1986 is 3.8 percent.

Chloride content - The concentration of the soluble chloride ion content of the concrete, expressed as percent of the mass, is shown in Table 57.2. The listed values indicate the amount of chloride originating from external sources, as the background concentration (0.017%), determined at the 55-65 mm horizon, has been subtracted from the determined overall chloride content.

In the absence of any waterproofing system, the high, and increasing chloride concentration is not surprising, but nonetheless of concern. Particularly at core location No.5, the concentration is very high and is still increasing. Even at 100 mm depth the chloride content is 3 to 4 times higher than the generally accepted threshold value above which corrosion is expected to occur.

Cathodic Protection - The instant-off potential, and the four hour decayed potential were measured at yearly intervals in the past four years.

During the monitoring period the criteria for protection has been changed by the industry association of the CP suppliers, the National Reinforced Concrete Cathodic Protection Association (NRCCPA). The criteria, adopted by the Association in 1991, is that the minimum polarization decay must be 50 mV if the instant-off potential is more electronegative than -350mV; and 1mV if the instant-off potential is between -350 and -200 mV. There is no required polarization value if the instant-off potential is between 0 and -200 mV. Originally, the target was a minimum of 100 mV potential decay at all representative points within the area of the structure being protected, subject to a most negative limit of -1.150 V with respect to CU/$CuSO_4$ instantaneous off potential, to avoid hydrogen embrittlement.

In Table 57.3 the percent of the 160 grid points at which the NRCCPA criteria, and in Table 57.4 the British Concrete Society/National Association of Corrosion Engineers criteria were not met.

The plan view of the three sections, prepared in 1988 and in 1991, are shown in Figs. 57.2 through 57.4. The indicated defects were noted in a visual survey, and not by the chain drag, or other tests.

It is apparent, that over the four year period, cracks became more extensive, many to the point where drip trays had to be installed. Also, some deficiencies developed in the coating; blisters, discoloration and debonding occurred. In fact, the CP criteria adopted by the NRCCPA is the result of an attempt to reduce the quantity of chlorite, hypochlorite and other aggressive byproducts at the anode/substrate interface. Deterioration in the anode coating has greatly decreased in the later years of the monitoring period.

Discussion

Although the absolute value of deterioration, in terms of the size of delaminated area, is low, the performance of the CP system in this garage has been disappointing. Serviceability has been a major problem forcing the owners to commission a major repair project six years after the previous rehabilitation.

The source of the problem probably lies in the mistaken belief that:

1. CP can prevent corrosion; and
2. Only an incomplete restoration is needed before installing CP, if the extent of deterioration is acceptable from a structural and serviceability point of view.

As it turned out, corrosion could not be avoided, only retarded. Anode coating debonding made full protection impractical.

Under three circumstances the delaminations grew, and cracks propagated at a slow, but still sufficient rate to create an increasing serviceability program.

On balance, modest savings in the repairs of 1986, and a delamination rate much less than that would have occurred in a garage repaired in the conventional manner, has been traded for a serious serviceability problem, high chloride content, and high capital and maintenance cost.

Tbl. 57.1
Garage No. 57
Result of the delamination survey

	1989	1990	1991
Area 4			
Delaminated Area, %	1.3	1.5	2.4
Bonded Patches, %	0.8	0.8	0.8
Debonded patches, %	0.4	0.4	0.4
Area 11			
Delaminated Area, %	0.9	1.6	1.7
Bonded Patches, %	1.3	1.3	1.3
Debonded patches, %	6.8	6.8	6.8
Area 20			
Delaminated Area, %	1.5	2.1	2.1
Bonded Patches, %	3.2	3.2	3.2
Debonded patches, %	0.8	0.8	0.8
Total			
Delaminated Area, %	1.3	1.7	2.0
Bonded Patches, %	1.9	1.9	1.9
Debonded patches, %	2.2	2.2	2.2

Tbl. 57.2
Garage No. 57
Chloride ion content
Percent water soluble chloride by mass of concrete

Horizon, mm	1988	1989	1990	1991
Core location No.2				
20-30	0.142	0.097	0.121	0.144
50-60	0.010	0.019	0.039	0.028
90-100	0.013	0.003	0.022	0.002
Core location No.3				
55-65		0.000		
55-65		0.001		
Core location No.5				
10-20			0.347	
10-20			0.328	
20-30	0.007	0.323	0.249	0.460
50-60	0.01	0.105	0.155	0.233
90-100	0.009	0.004	0.034	0.105

Tbl. 57.3
Garage No. 57
Percent of test points at which the NRCCPA criterion for CP was no met

	1988	1989	1990	1991
Zone No. 4	7	15	15	11
Zone No. 11	9	6	8	0
Zone No. 20	9	4	5	5

Tbl. 57.4
Garage No. 57
Percent of test points at which the Concrete Society / NACE criterion was not met

	1988	1989	1990	1991
Zone No. 4	67	53	63	78
Zone No. 11	89	47	74	10
Zone No. 20	41	28	74	60

Fig. 57.1
Garage No. 57
Rate of concrete delamination

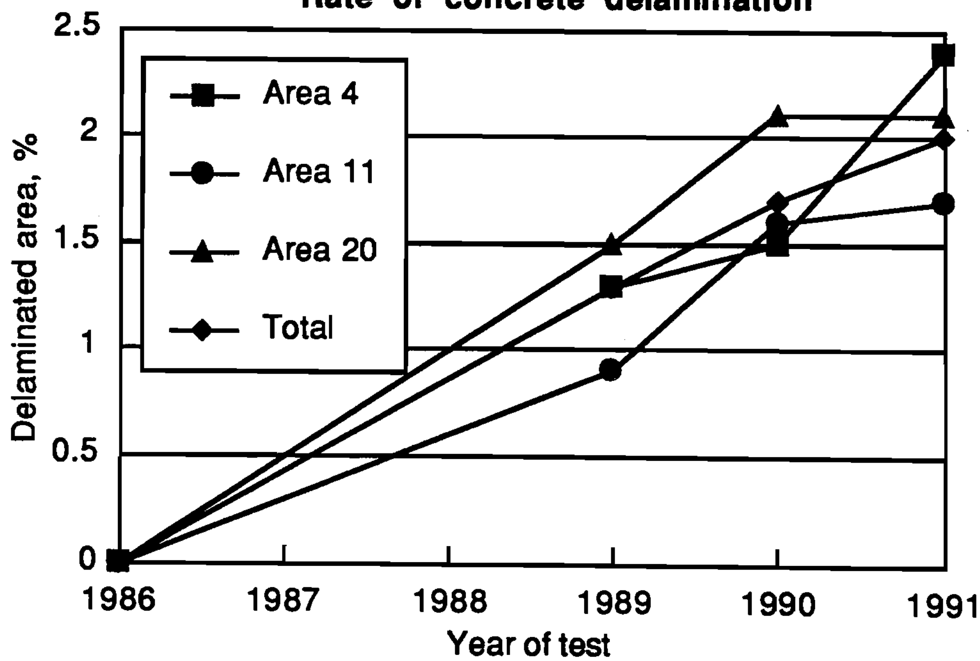


Fig. 57.2
Garage No. 57
Plan view of Section 4
in 1988 (top) and in 1991 (bottom)

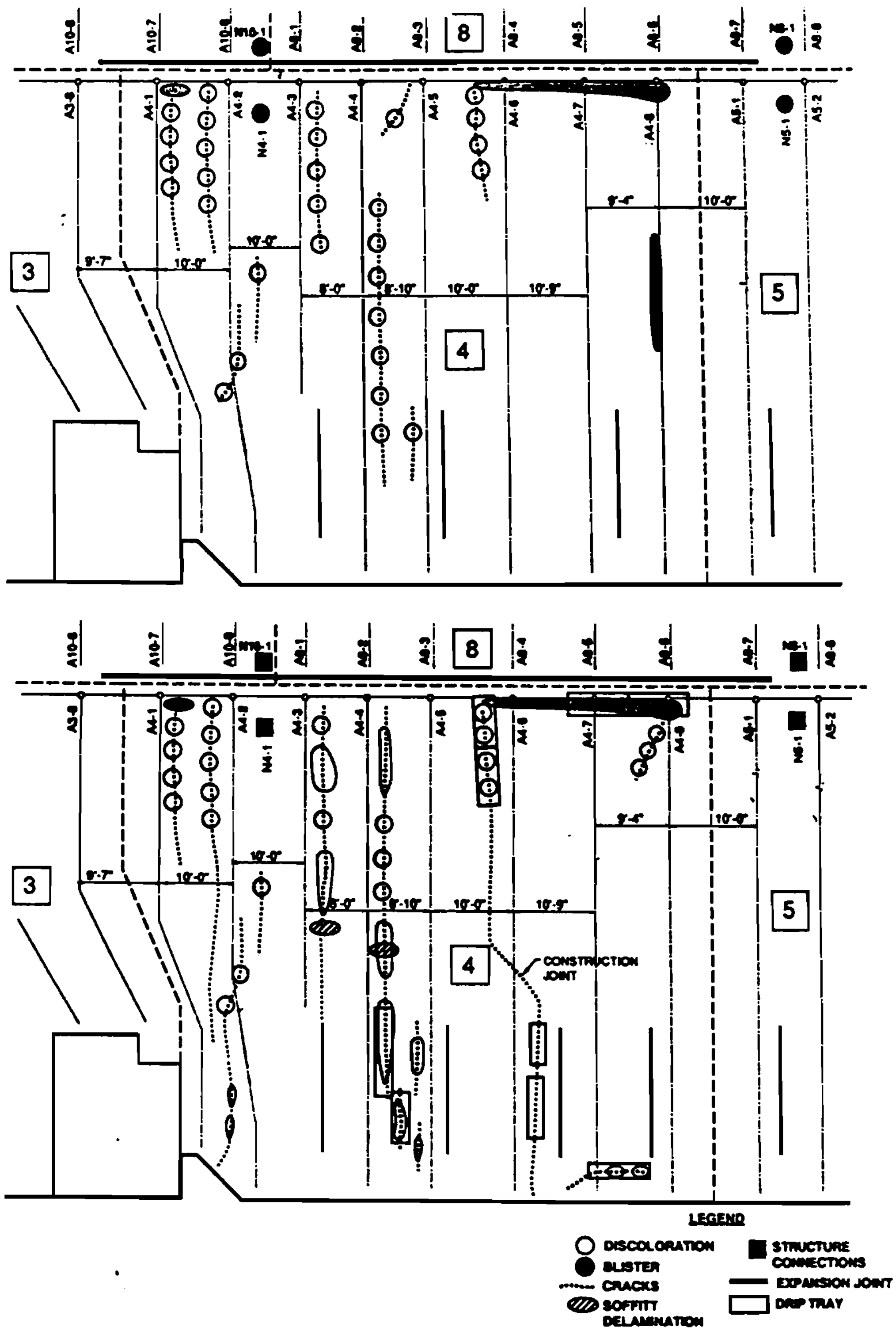
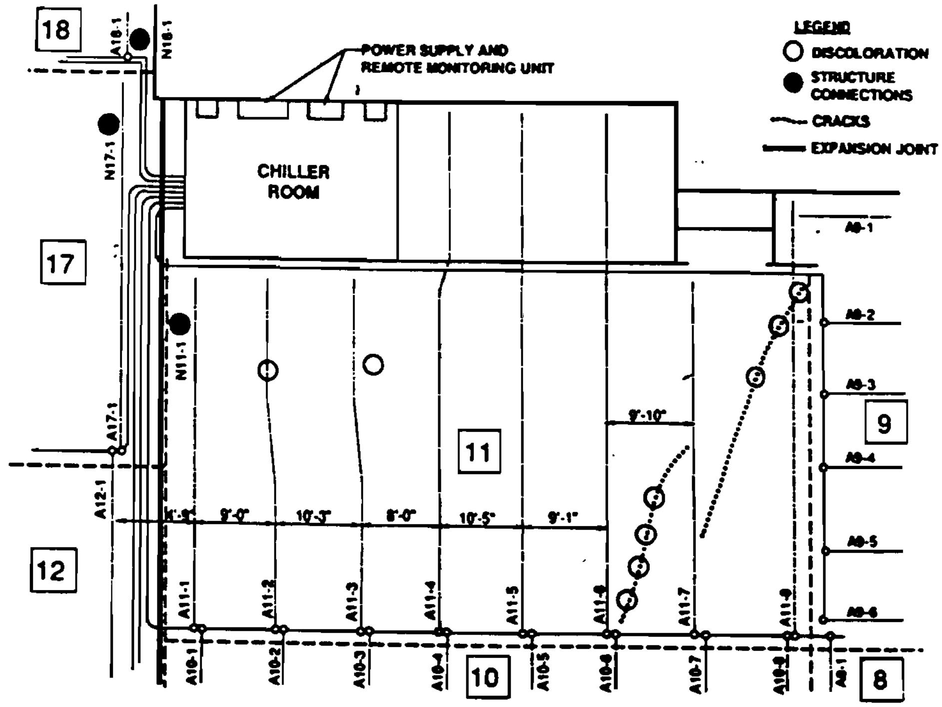


Fig. 57.3
Garage No. 57
Plan view of Section 11
in 1988 (top) and in 1991 (bottom)



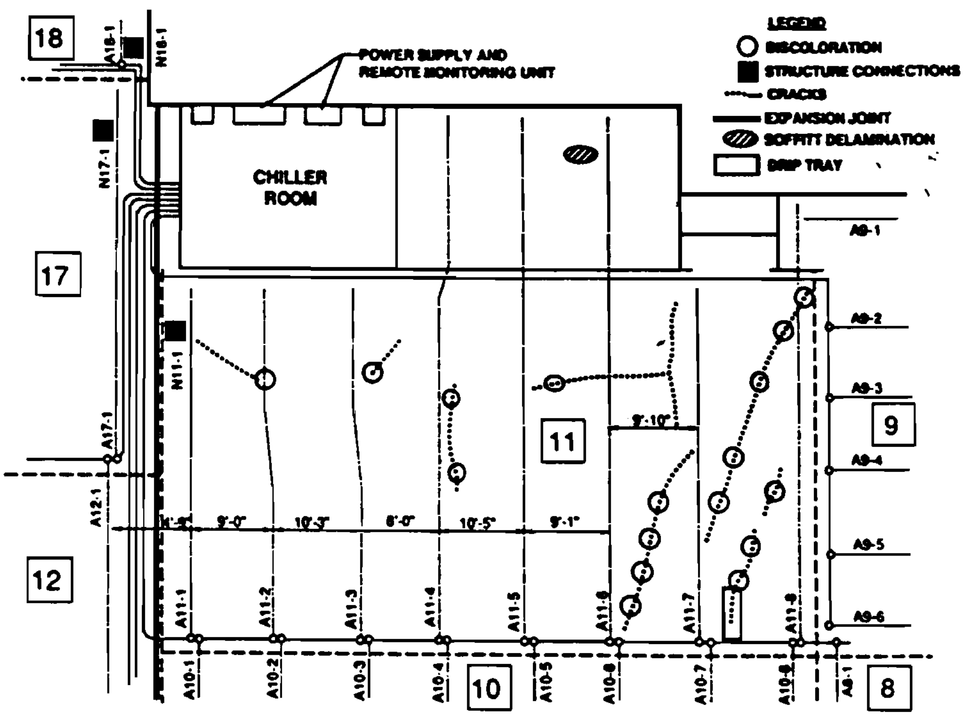
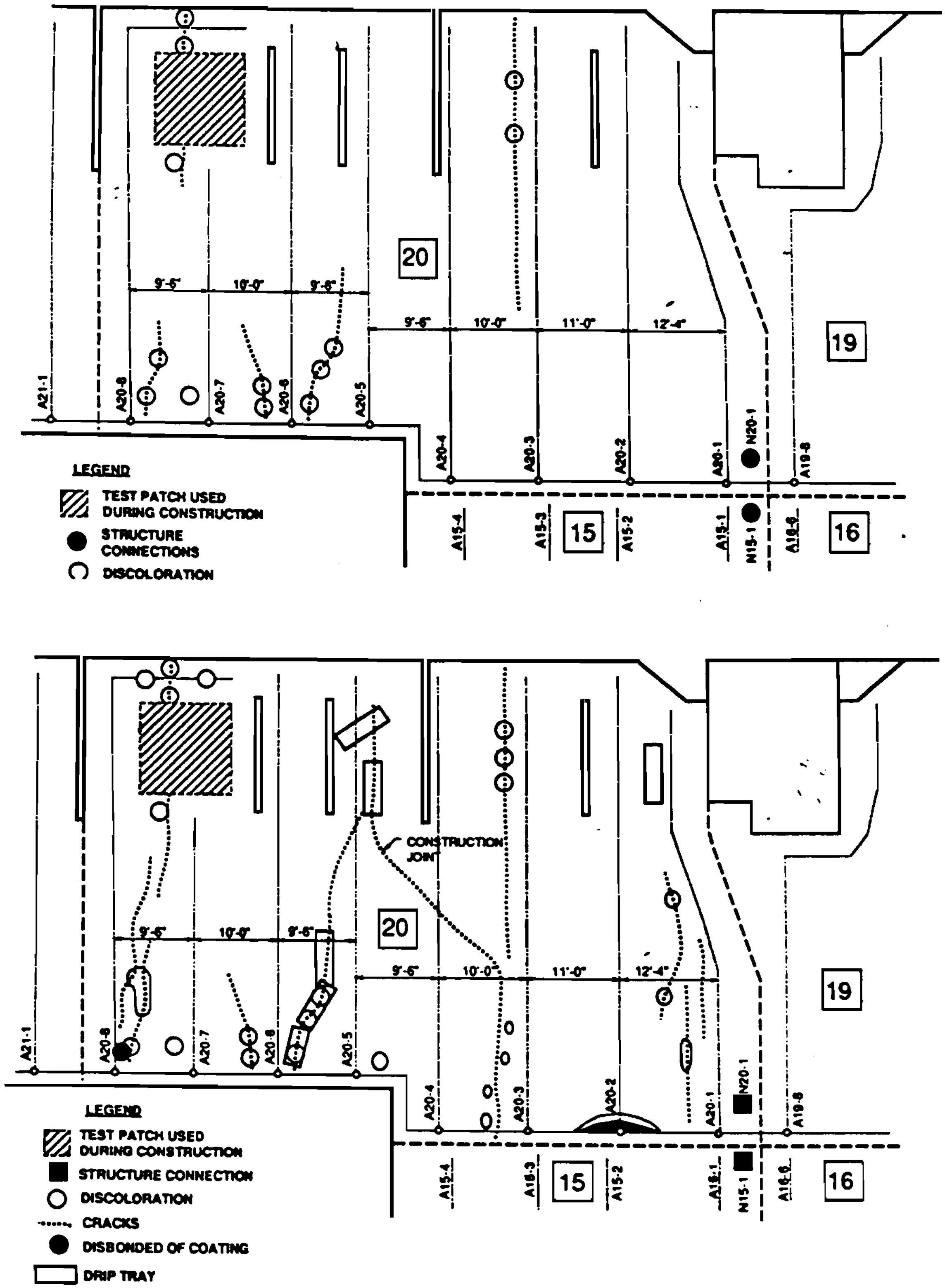


Fig. 57.4
Garage No. 57
Plan view of Section 20
in 1988 (top) and in 1991 (bottom)



Garage No. 58

Office building parking garage with one suspended slab (1,993 m^2) and loading dock, 315 m^2 built in 1979. The structure is of reinforced concrete columns and 300 mm thick flat slab. Black steel was used as reinforcement, the actual concrete cover is 25 mm. At the time of construction Canadian Barrier sealer was applied onto the concrete slab.

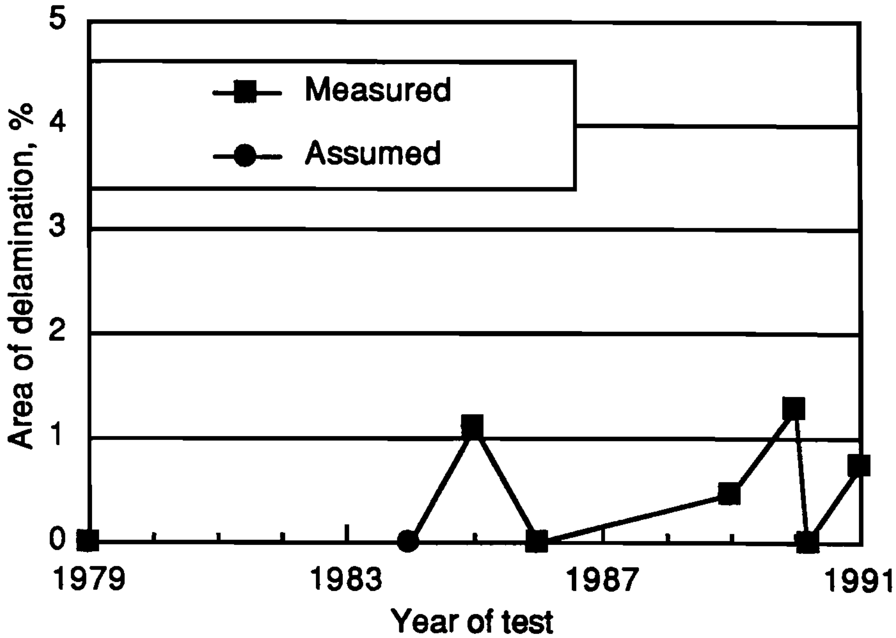
Six years after construction in 1985 condition survey detected 1.12% delamination and spalls in the deck of which 0.27% was in the soffit. The soluble salt contents at the level of the rebar were found to be 0.04, 0.02, 0.11, 0.11 per cent.

Repairs performed in 1986 (7 years old) comprised removal of the deteriorated concrete, patching and installation of waterproofing membrane (Kelmar) on the structural slab, renewal of the sealer on the slab-on-grade. Cost of the repairs was $18,000 and that of the membrane $70,000.

In 1989 (10 years old) survey detected 11.9 m^2 0.46% delamination. During subsequent repairs eventually 33 m^2 or 1.29% was replaced. In addition, 14 membrane defects have also been repaired. The cost was $20,000.

In 1991 (12 years old) 19 m^2 0.74% delaminations were detected, together with traffic topping defects. No repairs have yet been made.

Fig. 58.1
Garage No. 58
Area of delamination



Garage No. 59

A free standing parkade, exposed to the elements, serving a department store and other business establishments of the downtown area in a city with a population of 80,000.

At the time of the design of the structure in 1983 the City Engineering Department, being aware of the problems encountered with garages, specified durability as a top priority.

The parkade has three levels of approximately equal size, two suspended and one slab on grade, with a total area of 32,832 m^2, accommodating 976 cars.

Reinforced concrete columns and beams support the 250 mm thick slabs which have a slope between 2.3% and 4.5%.

The concrete contained type 10 cement, normal weight aggregate and air entraining admixture. The water/cement ratio was 0.45 and the specified compressive strength 35 MPa.

Black reinforcing steel was used throughout the structure. The minimum concrete cover over the top steel mat is 50 mm.

All horizontal surfaces were protected with an epoxy-urethane membrane with a modified epoxy wearsurface containing trap rock and silica sand aggregate (Sternson).

Beyond the conservative design, provisions for cathodic protection were made (should this become necessary in the future) by installing in each zone corrosion monitoring equipment consisting of a corrosion probe, a graphite reference electrode, and cables to the test panel.

A problem with the waterproofing membrane requiring remedial action developed during the construction phase. Most probably because the membrane installation was carried over in a very hot period of the summer, numerous bubbles formed soon after placement. As a corrective measure the bubbles were punctured with spiked rollers followed by an application of a second coat. This brought the thickness well over the specified 50 mil., resulting in cracking and other defects.

Eventually, it was decided to remove the membrane and install a new one. A great deal of difficulty was experienced with the various means of removal applied and, finally, the membrane had to be ground off.

The experience gained in this case shows that repairs over the existing epoxy-urethane membrane is seldom successful. The membrane in place has to be removed, and the new coat applied onto the clean bare concrete surface.

The waterproofing system is now considered to be satisfactory and accepted by the owner, except on the ramp at the toll booth the topping wears off and has to be renewed every year.

Repair History

No repairs have been performed in this garage since it was commissioned.

Present Condition

The potential of the reinforced steel with respect to a portable copper/copper sulfate reference electrode, as well as the imbedded graphite electrodes, have been measured twice a year since construction at 26 test locations. In addition, the corrosion rate was calculated from the corrosometer readings. The structure is unique because there are few, if any, structures in which potentials and corrosometer readings have been taken at few months' intervals since construction.

Suspended deck: The half-cell potentials with respect to a copper/copper electrode are listed in Table 59.1 and the corrosometer readings in Table 59.2. The half-cell potentials are also presented in graphical form in Figures 59.1 and 59.2.

1. The results well illustrate the merits of the half-cell potential readings in a real-life setting. While the relationship between corrosion and half-cell potential certainly exists, the values obtained in the field show large variability.

   For example, the results determined at location L2B2, L2B22 (Figure 59.1) and L3B22 shift to more negative values in time, indicating an increasing tendency for corrosion. However, in all three cases more positive values, of a magnitude that are generally considered to indicate the absence of corrosion, were measured occasionally. These results confirm our previous finding that a single set of measured potentials is an unreliable basis for reaching any conclusion.

   The cause for the early corrosion of the steel in the three locations is not clear. Test site L3B22 was observed to be near to a large crack, and probably the steel became exposed to water and oxygen.

   The relatively slow shift to negative values at L2B22 is consistent with a failure of the waterproofing membrane, and the potential shift occurred only after salt solution infiltrated the concrete and reached the steel.

2. The corrosometer readings (Table 59.2) seem to offer very little useful information.

   Initially, (21 January 1987) the calculated corrosion at all locations is very high, which considering the absence of salt and the age of the structure, is not likely.

   The readings obtained on a particular day tend to be all low or all high.

   Plotting the half-cell potentials vs. the calculated corrosion rate at the same location reveals very little agreement (Figures 59.3 and 59.4);

an increase of potential does not appear to be related to the increased corrosion rate.

Ramps: The half-cell potentials of the reinforcing steel with respect to a copper/copper sulfate electrode have been monitored at 13 locations. (Tables 59.3 to 59.5)

Immediately after construction, the potential values were negative and in the range that is considered indicative of corrosion. As it can be seen in Figures 59.5 to 59.8, no trend in time is apparent.

Occasionally, the potentials have extremely high values, e.g., East ramp location on 14 December 1988, -710 mV, or East ramp centre top, on 5 March 1990, -568 mV, which cannot be ascribed to corrosion of the steel and has been attributed by the consultant to the presence of some foreign metal in the soil, although the latter location is rather far from the ground.

The half-cell potential values obtained do not appear to make it possible to assess the level of corrosion activity in the ramp with a fair degree of confidence. On the one hand, the high potentials can be taken as an indication of corrosion, possibly precipitated by the rapid and frequent deterioration of the membrane at this location but, on the other, the significance of high potential values must be questioned because of the high values immediately after construction and the absence of a discernable trend over time.

The chloride content of the two concrete cores, extracted from the ramp in October 1990, was at the level of the top steel 0.016 and 0.015%, that is below the threshold level (0.035%) above which corrosion is to be expected. In the surface region, at 10 to 20 mm depth, however, in one case the chloride content exceeded the threshold level as it was 0.039%, while that of the other core was 0.018%.

General Remarks

The performance of the garage, although built before CSA S413 standard was developed, proves that durable garages can be built by following the present design and construction practices specified by the CSA S413 standard.

The history of the garage also shows that efforts have to be made continuously to obtain and maintain a well functioning, durable structure.

Six years after the completion of the construction there are a few areas that give rise to concem and are in need of attention. The condition of the ramps have to be fully evaluated and, if needed, corrective measure taken. Also, the high potential locations in the deck should be investigated. In general, a full commissioning condition survey should be undertaken and the detected defects repaired at an early stage before final acceptance by the owner.

Tbl. 591
Garage No. 59
Half-cell potential (CSE) of steel in the deck

	PWW	PWE	L2B2	L2B11	L2B22	L2B33	L3B5	L3B14	L2B18	L3B22	L3B27	L3B33	L3C21
14-Jul-86									-64.6				
21-Jan-87	-55	-76	-75	50	80	-20	51	60	32	-60	56	61	15
27-Oct-87	17	-40	-65	45	-25	-19	9	-14	-30	-296	54	28	-100
27-Jan-89	7	-30	-60	95	82	9	-30	0	-14	-242	27	13	-54
27-Jul-88	10	-67	-158	66	30	-6	25	38	80	-340	86	0	-58
14-Dec-	-26	58	-73	91	73	21	36	62	63	-223	73	51	48
24-Feb-	40	8	-9	39	10	-24	-57	30	48	-10	48	110	-12
15-Sep-	18	-89	-208	66	-20	-16	43	47	58	-405	68	-23	-62
23-Nov-	35	22	-176	105	55	34	58	56	49	-289	76	11	-25
5-Mar-90	-53	-45	-250	38	-112	60	87	6	3	-275	70	19	4
14-Jun-90	-57	-55	-240	36	-214	-55	-22	20	50	-299	40	-55	-52
7-Dec-90	-70	-65	-295	33	-205	-34	-34	-15	-10	-350	10	-45	-45
12-Apr-91	-80	-6	-310	83	-291	10	-29	56	86	-341	62	30	44
17-Sep-	-10	-10	-325	82	-308	9	22	61	74	-331	46	19	24
2-Dec-91	-15	-17	-290	68	-290	-22	28	12	25	-313	24	-15	-25

Tbl. 59.2
Garage No. 59
Corrosion rate in the deck calculated from corrosometer readings (mils per year)

	PWW	PWE	L2B2	L2B11	L2B22	L2B33	L3B5	L3B14	L2B18	L3B22	L3B27	L3B33	L3C21
14-Jul-86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21-Jan-87	0.340	0.240	0.190	0.210	0.170	0.270	0.310	0.190	0.230	0.240	0.170	0.000	0.240
27-Oct-87	0.026	0.018	0.028	0.026	0.044	0.008	0.023	0.021	0.034	0.021	0.047	0.000	0.015
27-Jan-89	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.000
27-Jul-88	0.000	0.000	0.012	0.000	0.000	0.012	0.012	0.000	0.008	0.016	0.004	0.000	0.012
14-Dec-88	-0.260	-0.015	-0.015	-0.160	-0.170	-0.190	-0.190	-0.160	-0.150	-0.180	-0.120	0.000	-0.150
24-Feb-89	0.430	0.090	0.220	0.190	0.390	0.270	0.270	0.27	0.220	0.310	0.220	0.000	0.260
15-Sep-89	0.021	0.035	-0.018	0.032	0.000	0.140	0.022	0.007	-0.046	0.000	0.007	0.000	0.000
23-Nov-89	-0.042	-0.053	-0.042	-0.042	-0.053	0.320	-0.011	0.042	-0.011	-0.053	-0.070	0.000	0.000
5-Mar-90	0.021	0.007	0.043	0.014	0.000	0.000	0.007	0.000	-0.007	0.021	0.050	0.000	0.007
14-Jun-90		0.000	0.031	0.031	0.008	0.000	0.047	-0.015	0.000	0.000		0.000	0.008
7-Dec-90		0.000	0.006	-0.012	-0.016	0.006	0.031	0.018	0.006	-0.006	0.006	0.000	0.000
12-Apr-91	-0.024	0.024	-0.016	-0.024	-0.016	-0.008	-0.016	-0.008	-0.008	0.008	-0.024	0.000	-0.008
17-Sep-91	-0.078	0.000	0.011	0.022	0.024	0.024	0.024	0.000	0.022	0.000	0.022	0.000	0.011
2-Dec-91	-0.024	0.024	-0.024	-0.024	0.024	0.024	-0.024	0.000	-0.024	-0.042	-0.024	0.000	-0.042

Tbl. 59.3
Garage 59
Half cell potential, (CSE) mV

	In-ramp, East	In-ramp, West	In-ramp, ctr	In-ramp bot'm
6	-380	-300	-208	-550
15	-454	-245	-212	-440
18	-72	-75	-262	-453
23	-78	-120	-160	-400
29	-237	-180	-457	
31	-220	-80	-511	
38	-294	-236	-194	-519
40	-216	-179	-112	-348
44	-519	-608	-338	-665
47	-527	-426	-328	-536
53	-377	-360	-260	-436
57	-303	-260	-172	-478
62	-247	-267	-173	-419
65	-299	-243	-222	-410

Tbl. 59.4
Garage 59
Half cell potential (CSE) mV

Date	Out-ramp East	Out-ramp, sensor	Out-ramp, asph.	Out-ramp, West	Out-ramp, sensor	Out-ramp, asphalt
21-Jan-87	-196	-181	-312	-188	-196	-330
27-Oct-87	-238	-185	-322	-213	-156	-344
27-Jan-89	-179	-78	-240	-128	-131	-294
27-Jul-88	-93	-60	-250	-97	-210	-290
14-Dec-88	-90	-90	-175	-84	-103	-255
24-Feb-89	-140	-112	-311	-40	-80	-350
15-Sep-89	-215	-150	-250	-150	-100	-390
23-Nov-89	-140	-120	-190	-170	-80	-266
5-Mar-90	-288	-318	-344	-154	-258	-350
14-Jun-90	-162	-240	-402	-100	-220	-305
7-Dec-90	-119	-205	-289	-95	-166	-305
12-Apr-91	-245	-238	-250	-235	-128	-291
17-Sep-91	-129	-109	-197	-119	-67	-295
2-Dec-91	-50	-180	-199	-90	-70	-255

Tbl. 59.5
Garage 59
Half cell potential (CSE) mV

Date	East ramp,ctr top	East ramp, mdl	East ramp, btm
21-Jan-87	-141	-378	-534
27-Oct-87	-141	-308	-484
27-Jan-89	-120	-459	-521
27-Jul-88	-276	-280	-485
14-Dec-88	-510	-700	-710
24-Feb-89	-430	-370	-525
15-Sep-89	-410	-318	-415
23-Nov-89	-312	-300	-430
5-Mar-90	-568	-518	-464
14-Jun-90	-388	-302	-405
7-Dec-90	-280	-260	-350
12-Apr-91	-259	-290	-416
17-Sep-91	-319	-322	-459
2-Dec-91	-410	-420	-475

Fig. 59.1
Garage No. 59
Half-cell potential of reinforcing steel in deck vs. time

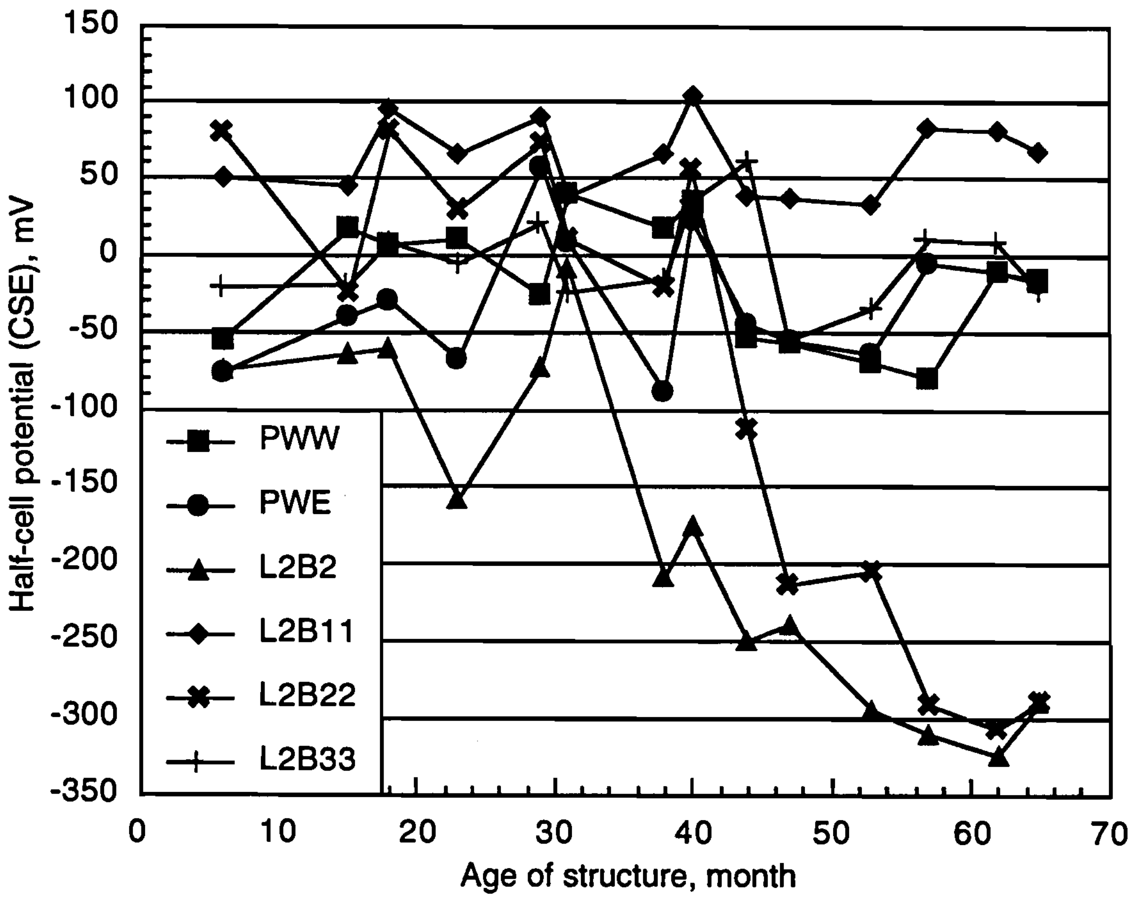


Fig. 59.2
Garage No. 59
Half-cell potential ofreinforcing steel in deck vs. time

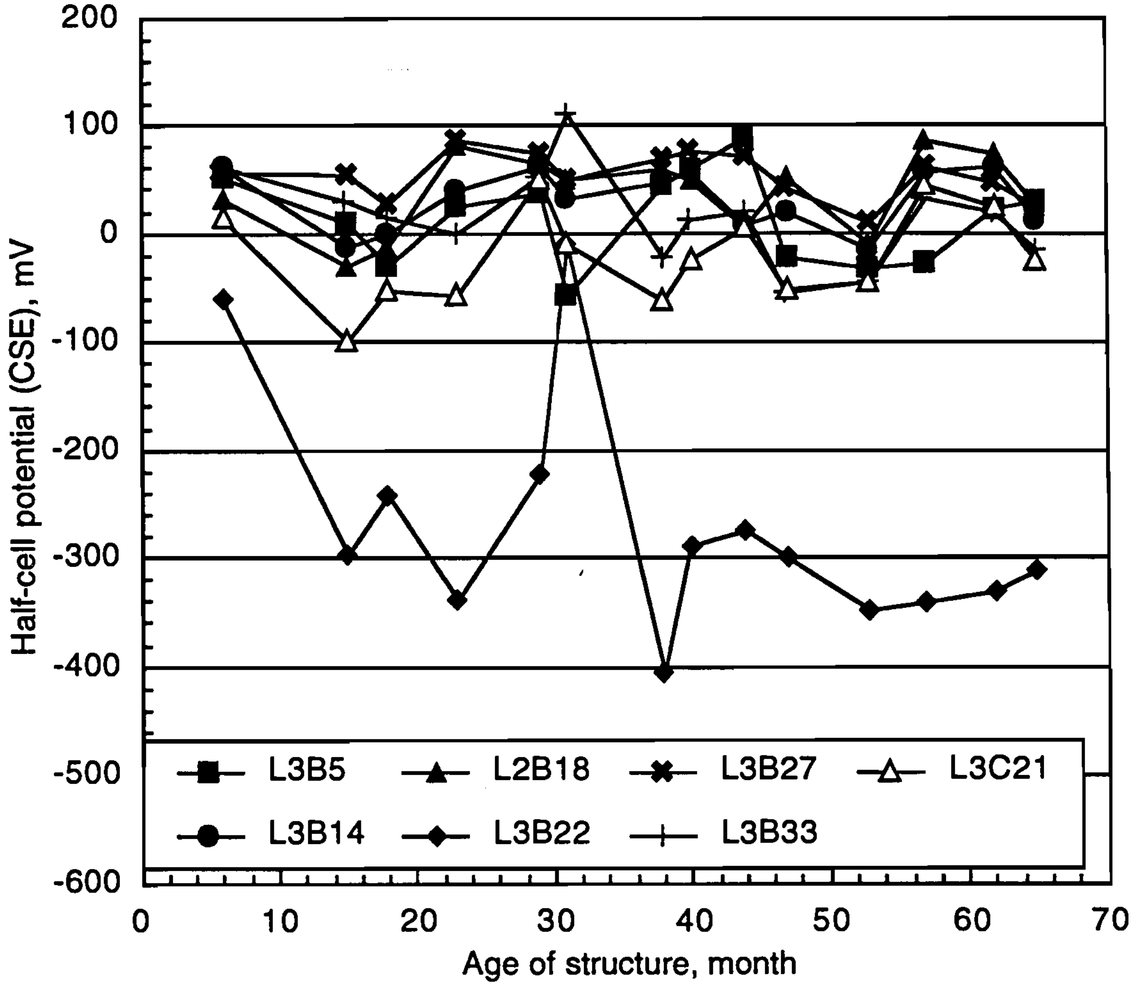


Fig. 59.3
Garage No. 59
Half-cell potential vs corrosion rate
at L3B22 test point

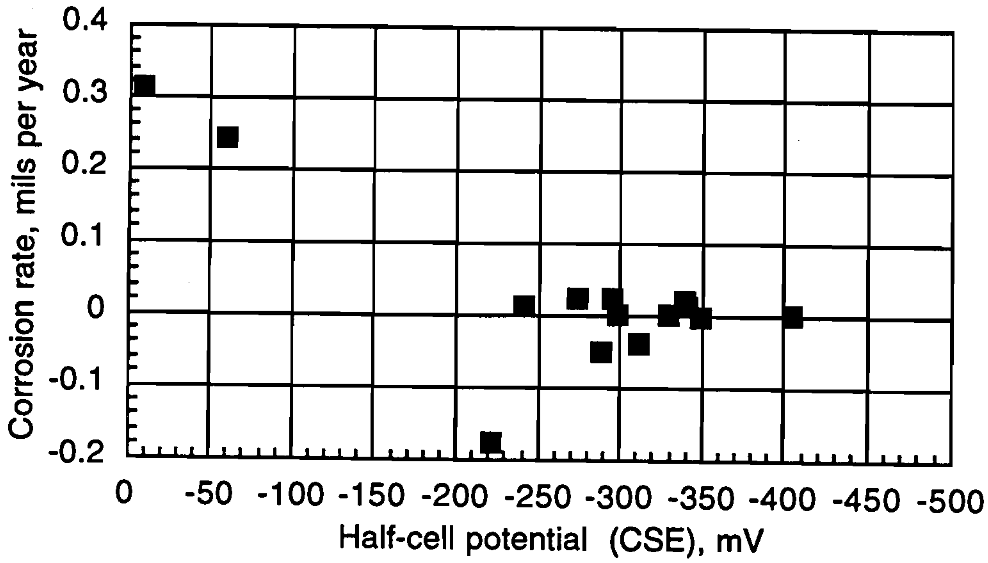


Fig. 59.4
Garage No. 59
Half-cell potential vs corrosion rate
at L2B2 test point

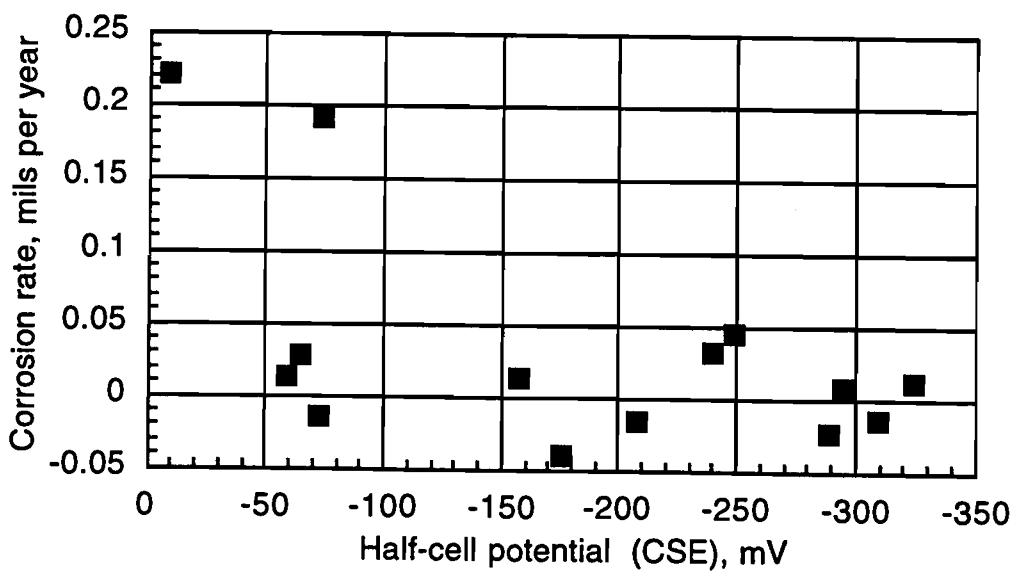


Fig. 59.5
Garage No. 59
Half-cell potential of steel in ramps vs. time

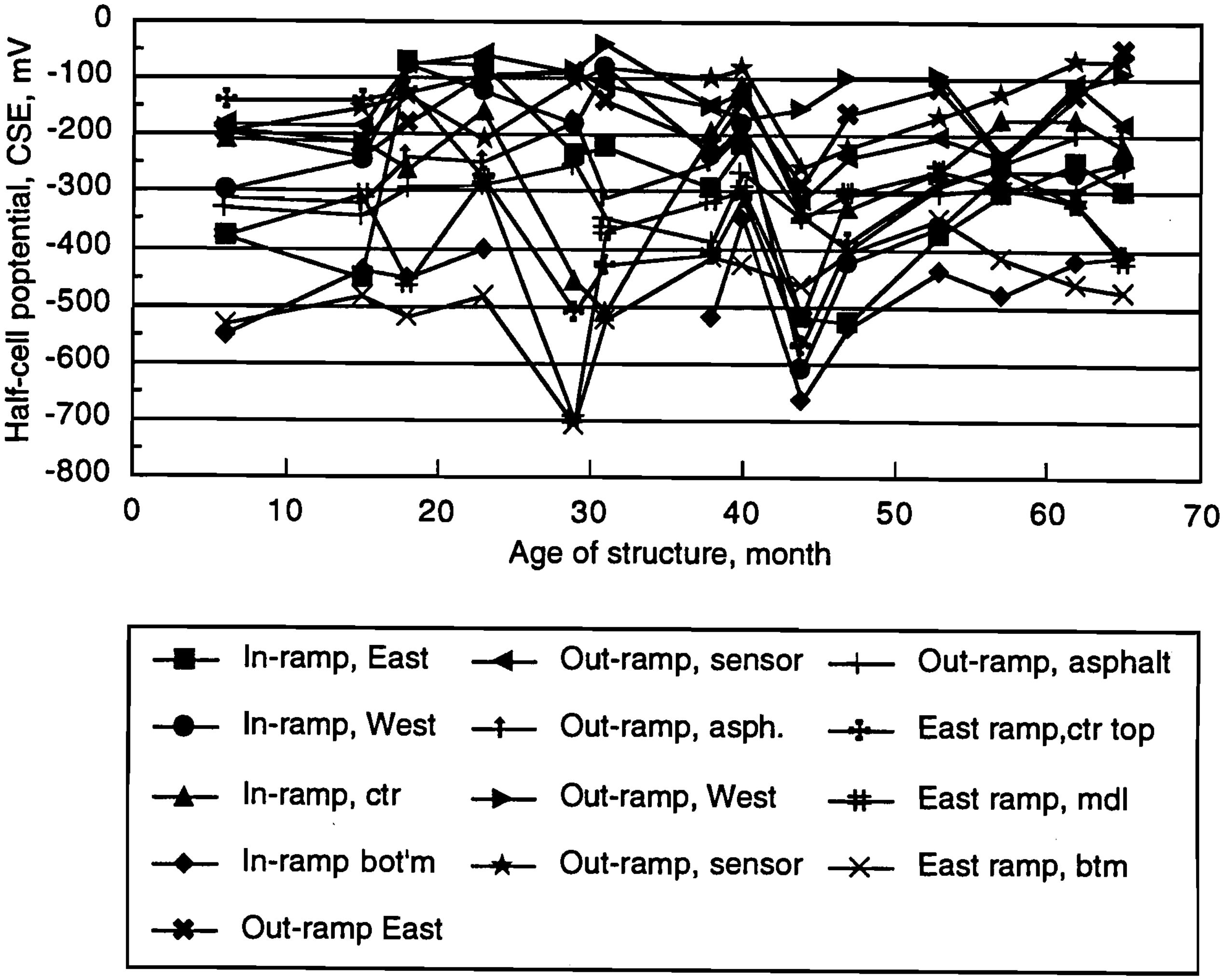


Fig. 59.6
Garage No. 59
Half-cell potential of steel in 'In-ramp' deck vs time

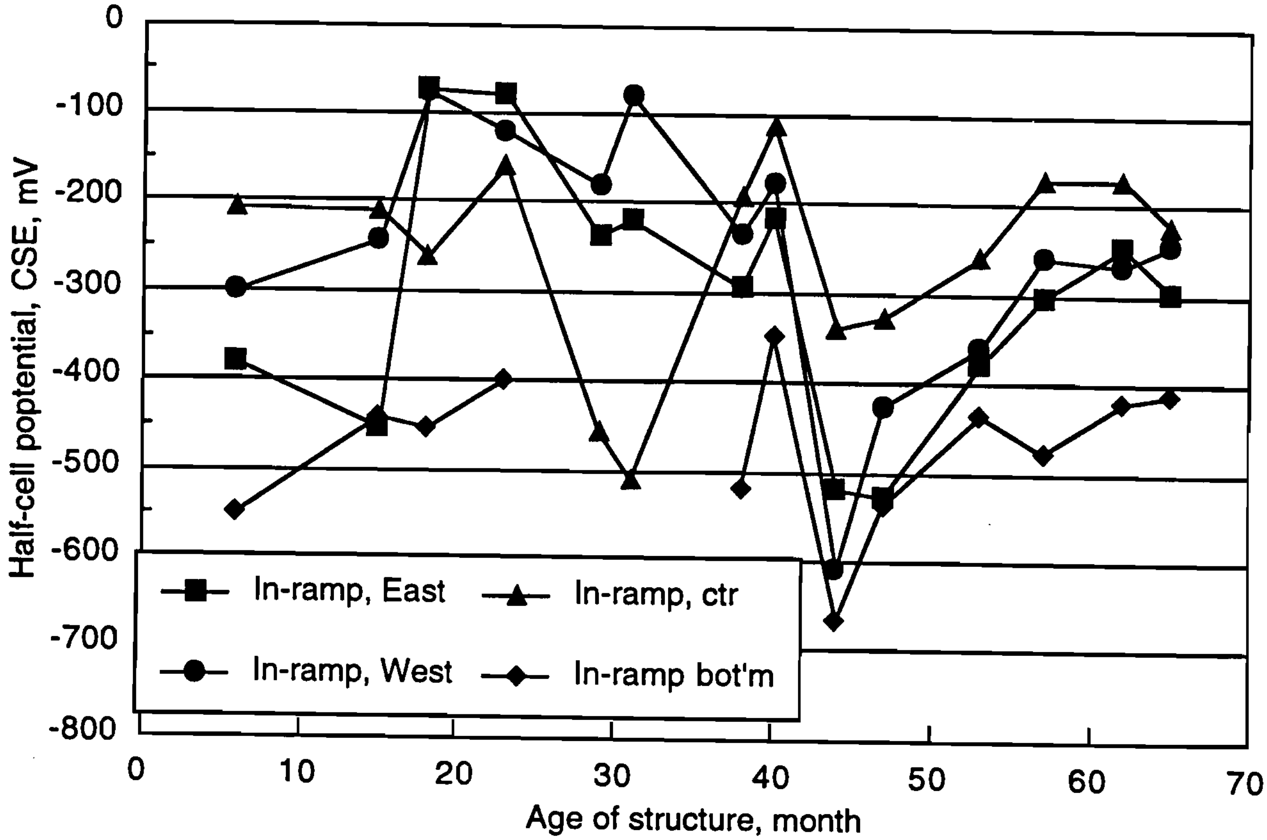


Fig. 59.7
Garage No. 59
Half-cell potential of steel in 'Out-ramp' vs time

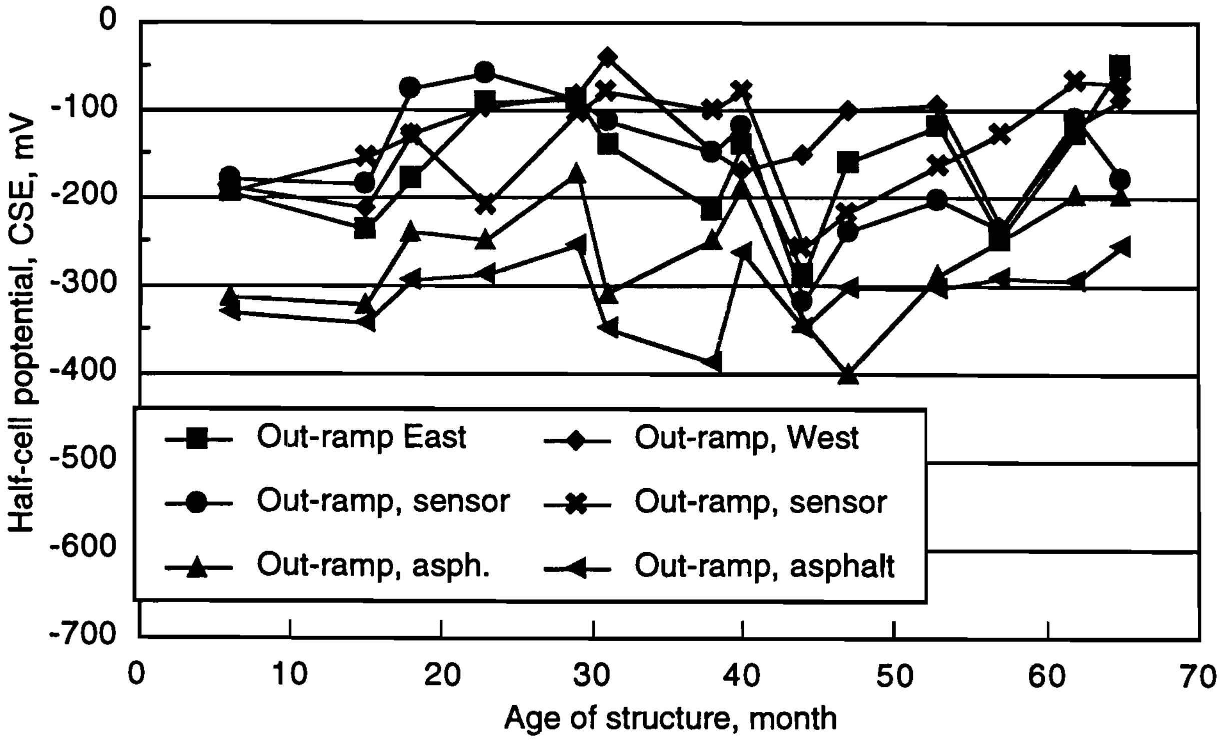
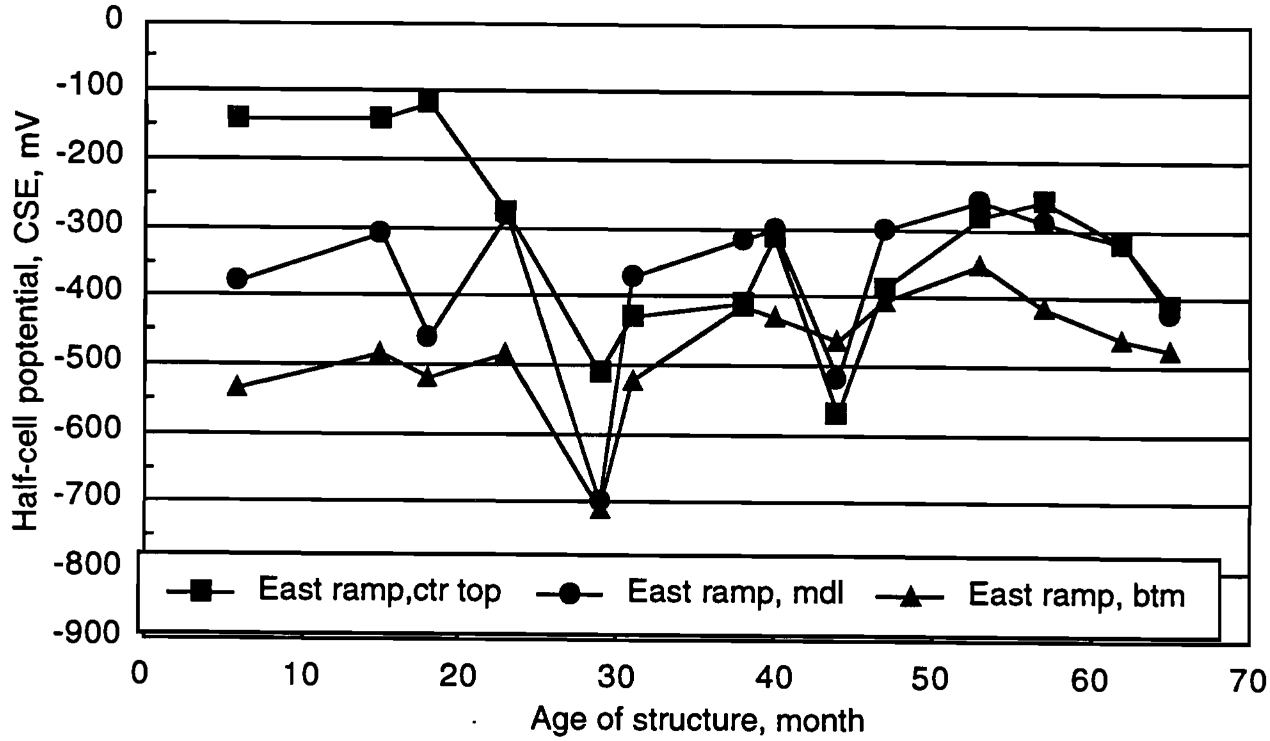


Fig. 59.8
Garage No. 59
Half-cell potential of steel in 'East-ramp' deck vs time



Garage No. 60

This garage that serves a high-rise office tower is of interest because, though built in 1982, the design and construction essentially conforms with the requirements of CSA S413 standard issued in 1987. The total area of the three suspended slabs is 9,396 m^2.

The structure is of the reinforced concrete columns and flat slab type. Black steel was used as reinforcement. At the time of construction a waterproofing membrane (Kelmar) was installed on the suspended slabs, and the slab on grade was coated with a sealer, TRX166 Deck seal.

On the whole the garage has performed well. Some debonding of the traffic topping occurred four years after installation that was repaired. In 1989, leaking cracks in the slab were repaired by epoxy injection ($40,000) and the membrane defects attended to in 1991 ($20,000). The results of the visual condition survey proves that durable garages can be built.

Garage No. 62

An underground unheated, enclosed parking facility consists of one suspended slab, a roof level, and a slab on grade. Part of the roof level is landscaped, the rest paved with asphalt. The suspended slab is two way reinforced and is supported by rectangular columns.

The area of the structural slab is approximately 1,400 m^2. There is an expansion joint between the parking garage and the residential building structure it serves. The parking facility was built in 1975.

Repair History - A condition survey was carried out in 1982, seven years after construction. The extent of delamination in the three test areas was 0.1, 30.0, and 7.9 percent, respectively. Rehabilitation took place in the second quarter of 1985.

Removal of delamination concrete was accomplished by the use of chipping hammers. Unsound concrete was removed to a minimum of 12 mm, where more than one half of the diameter of the reinforcing steel was exposed, the entire bar was exposed by chipping beneath the bar.

The repair material for shallow patches was polymer modified mortar. Before patching, the concrete was coated with an epoxy and a second coat was applied when the first became tacky.

The repair concrete for deep patches was 25 MPa. Defects in the soffit were repaired with shotcrete. The entire suspended slab was waterproofed with the Kelmar TE System.

Condition Survey - Delamination survey - The results of the yearly chain drag test are shown in Fig. 62.1. The results of the survey before the repairs are also indicated.

The total hollow sounding area is 2.4 percent, five years after repairs, and at 15 years of age of the building. Even if all hollow soundings are due to delamination, as opposed to debonding of the membrane from the concrete, this is a remarkably good performance.

The chain drag test results were supported by the findings with the extracted cores; the concrete was found to be generally sound, the steel not rusted with very few exceptions.

Chloride ion concentration - The water soluble chloride ion concentration of the original and repair concrete at three horizons are given in Fig. 62.2 and Fig. 62.3.

The chloride content of the parent concrete in the top surface horizon is 10 to 15 times, while at the level of the reinforcing steel it is four to five times higher than the accepted threshold value.

The repair concrete has low chloride content, except for one result which most probably due to experimental error. Interestingly, the chloride concentration of the original concrete at 90 mm depth, in the vicinity of the repair patches is decreasing, presumably because equalization of the concentrations takes place.

Half-cell potential - The percentages of the half-cell potentials indicating high, medium and low probability of corrosion of the reinforcing steel are shown in Fig. 62.4.

The greater than 0.35V potential is of the greatest importance because it indicates high probability of corrosion. Over the years, the percentage of these results has decreased indicating a long delay in response to the decreased corrosion activity following the repairs.

Discussion - At 15 years of age, and five years after rehabilitation this garage is in a very good condition. It can serve as an example for a well performing repaired garage. it should be noted that the traffic is light, as not every tenant in the apartment block owns a car.

The threshold chloride value, 0.035 percent by weight of concrete has been recently lowered by many consultants to 0.025 percent. The case of Garage 62 does not support this view.

Fig. 62.1
Garage no. 62
Percent of delaminated areas before and after repairs

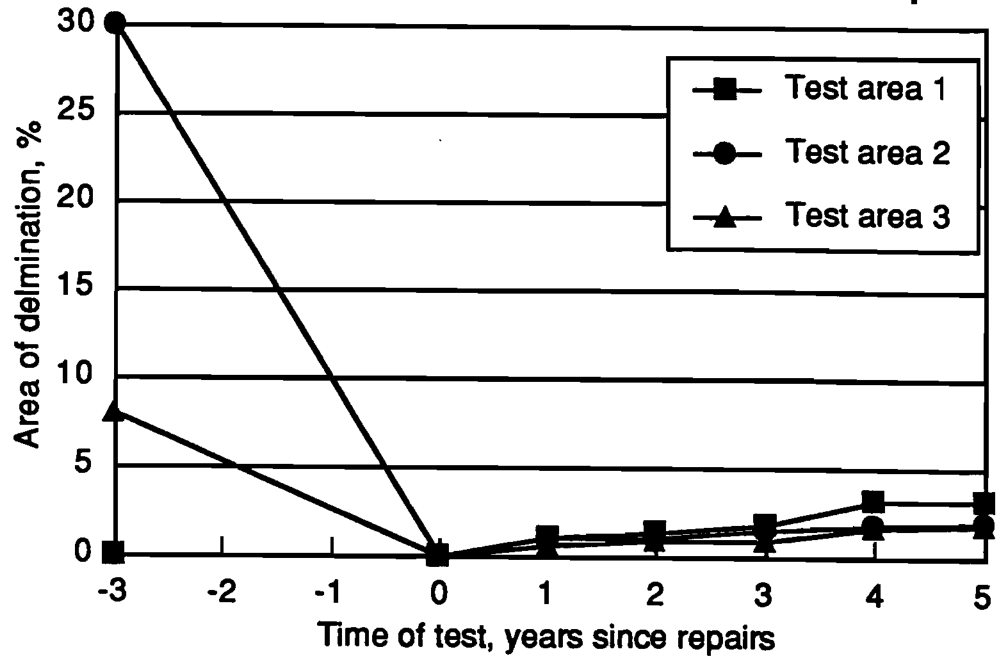


Fig. 62.2
Garage No. 62
Percent of chloride ion content of original concrete

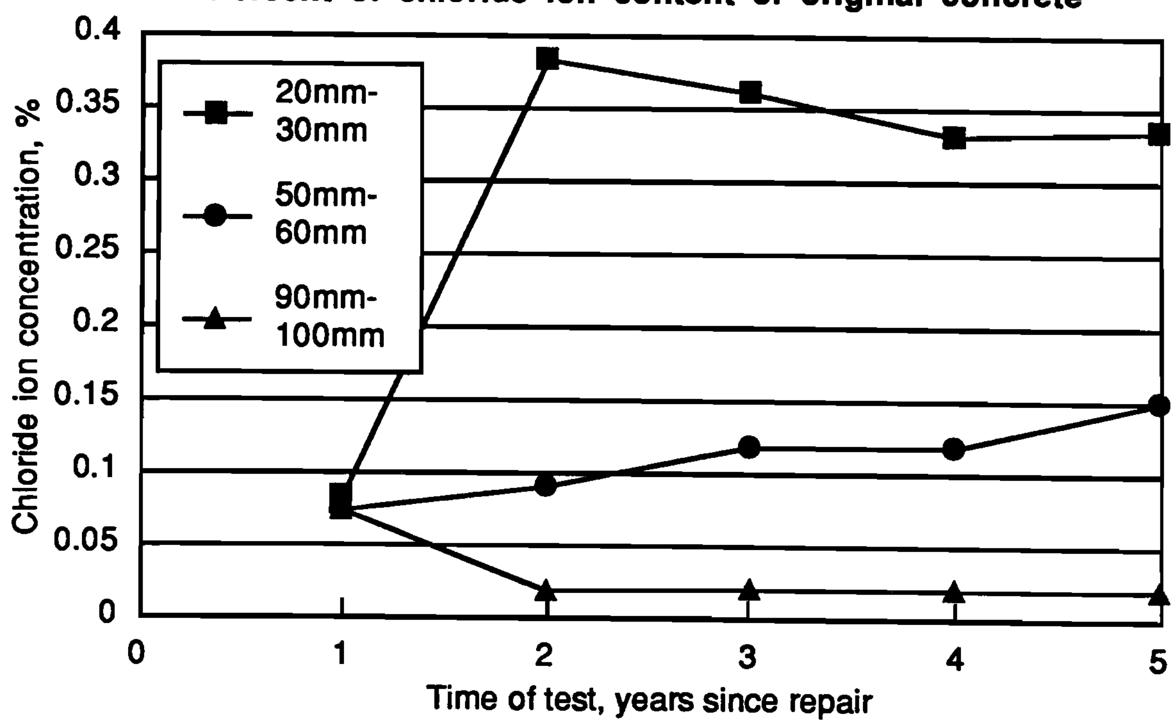


Fig. 62.3
Garage No. 62
Percent of chloride ion content of repair concrete

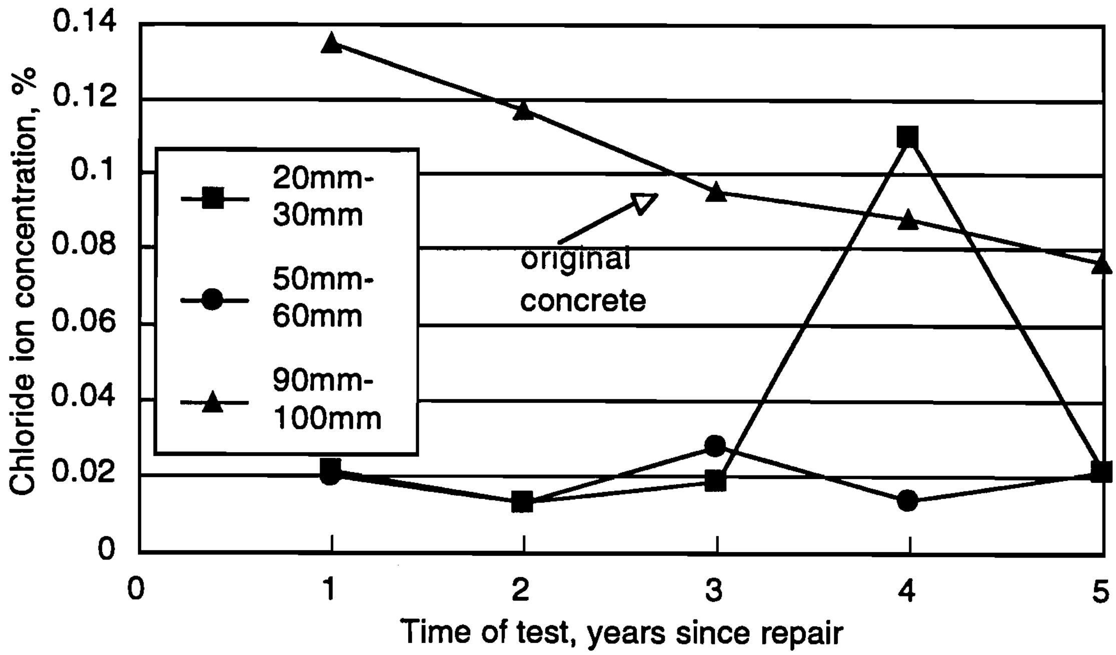
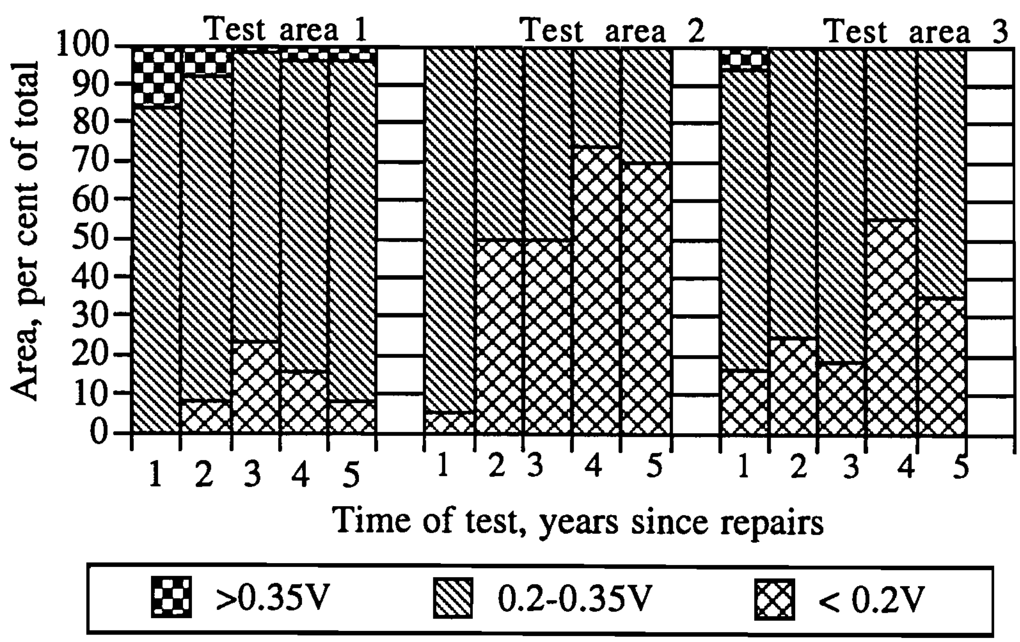


Fig.62.4
Garage No. 62
Percentage distribution of half cell potentials in test areas



Garage No. 63

Underground, enclosed, heated parking facility with one suspended slab, and one slab on grade.

The structural slab is of a two-way flat slab design, and is supported by rectangular and circular columns. The area of the suspended slab is 3,730 m^2.

The building was constructed in 1970.

Repair History

A condition survey carried out in 1981 detected 24.5 percent of the structural slab area delaminated. Rehabilitation of the garage undertaken in 1985, consisted of removal of the delaminated concrete by Hydro demolition, treatment of the concrete with a cement slurry, (to achieve good bonding between the old and the new concrete), and patching with 30 MPa concrete. Apparently, in 180 m^2 of the repaired area, the top reinforcement steel was coated with epoxy. On deciding to protect the repaired slab with cathodic protection (CP), the epoxy treatment was terminated. The suspended slab was waterproofed with the Kelmar TE system.

Immediately after the repairs at a cost of $116,000 a CP system (conductive coating on the soffit as anode) was installed, and was activated in May of 1986.

Condition Survey

Delamination test - The size of the areas of the deck in which hollow soundings were found on performing the chain drag test, is shown in Fig. 63.1. The absolute level of the extent of delamination is very low, although the rate appears to be increasing, particularly in Area 2.

With a waterproofing present, it is not possible to differentiate between soundings due to debonding of the membrane from the substrate, and those due to delamination in the concrete. One core, No. 2-89, was removed from the hollow-sounding Test Area 2, examination of which revealed the cause of the hollow soundings in this particular location to be a debonded concrete patch.

Chloride content - the water soluble chloride content of the original and repaired concrete, at three horizons, are shown in Fig. 63.2 and Fig. 63.3, respectively.

The concentration of chloride ions in the repair concrete is low, and no trend of increase is apparent. A single value, - one year after the repairs at the 50 mm to 60 mm horizon (Fig. 63.2), indicates increased concentration. This could be the result of either the migration of chloride ions from the original contaminated concrete or a decline effected by of CP which drives the negatively charged ions to the anode.

The results obtained with the original, old concrete can be explained by assuming that the general decrease of concentration over the test period in the 20 to 30 mm horizon is due to redistribution aiming to equalize the chloride content, and resulting in an increase of the chlorides at the 50 and 90 mm horizons. Consistent with this view is that, at the end of the monitoring period the concentrations at various levels of the original concrete are fairly similar and low.

It is interesting to note that the chloride concentration at the 90-100 mm horizon is higher in the repaired than in the non-repaired original area (Fig. 63.3 and Fig. 63.2). Accumulation of chlorides in certain areas necessitated repairs and even the unrepaired surrounding areas, although not delaminated, have a higher than average chloride concentration.

Cathodic protection monitoring - The CP system was commissioned in May 1986. Its functioning was reviewed on September 23, 24 and December 10, 1986, May 5, 1987, and January 24, 25 1990.

Considerable difficulties were experienced in the first years of operation mainly because of electrical shorts that existed between the reinforcing steel and the anode, and defects of the coated anode system.

Aiming to achieve 100 mV potential shift, high current densities and voltages had to be applied. The instant off potential at first was over 1.6V then 1.36V, and in 1987 0.34V. The potential shift criterion was changed subsequently to 50 mV.

No tests were carried out in 1988 and 1989.

The results of the test performed in 1990 are shown in Table 63.1. According to the guidelines of the Canadian National Reinforced Concrete Cathodic Protection Association, five locations of the 18 sites are not protected, a ratio equivalent to 28%. On the other hand, the more stringent National Association of Corrosion Engineers standard requires 100 mV shift and on this basis 89 percent of the area is unprotected.

No maintenance contract for the CP system appears to exist. The maintenance fee would have been $\$0.53/m^2$/year.

Conclusions

1. Seven years after a major rehabilitation this garage is in a good condition;

2. CP was almost certainly of benefit in avoiding corrosion of the steel, and in lowering the salt concentration. The presence of a waterproofing membrane obviously is also of great value;

3. Locating the electrical shorts was, in the initial years, a major effort; and

4. CP systems require close monitoring for maximum benefit and for avoiding the development of potentially harmful situations.

Tbl. 63.1
Garage No. 63
Summary of depolarization test of 1990

Test location	Rectifier On	Instant off	4 hour	Polarizat'n decay
A	357	319	285	34
B	277	267	229	38
C	258	256	219	17
D	330	276	258	18
E	341	288	271	17
B16	303	269	239	30
C1	470	464	472	**[8]**
D7	273	274	276	**[2]**
F2	398	377	327	50
F15	295	294	273	21
H3	412	393	394	**[1]**
J2	520	465	425	**40**
J14	338	321	244	77
K17	669	525	374	151
M1	590	570	555	**15**
M4	494	443	339	104
M12	349	333	248	85
N7	364	326	250	76

Half cell potentials with respect to copper/coppersulfate reference cell in negative mV.
Values in brackets shifted positively.
Bold faced values do not meet NRCCPA criteria

Fig. 63.1
Garage No. 63
Delamination of concrete deck, percent of slab area

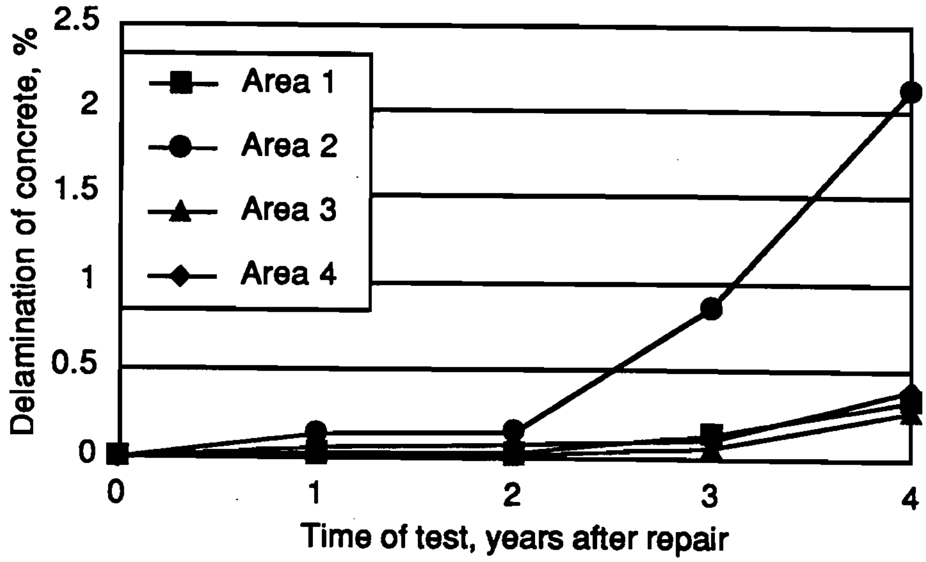


Fig. 63.2
Garage No. 63
Water soluble chloride content of original concrete at stated horizons, expressed as percent of mass

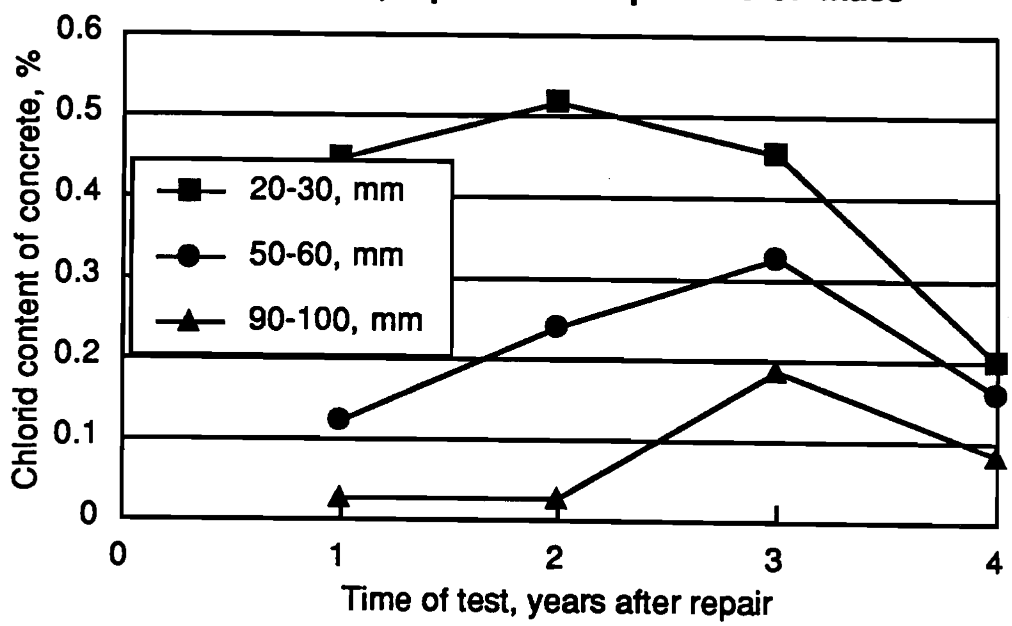
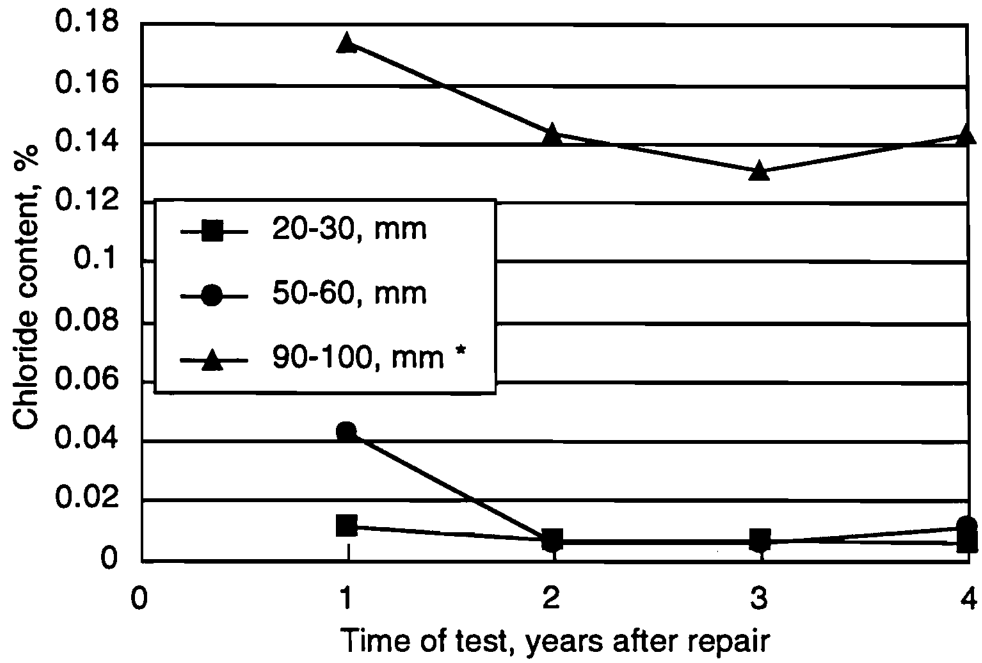


Fig. 63.3
Garage No. 63
Chloride content of repair concrete
expressed as percent of mass, at stated horizons



* original concrete

Garage No. 64

The below grade unheated, but enclosed, parking facility consists of two interior suspended levels, and a slab on grade. No vehicular traffic is permitted on the roof level which comprises paved and landscaped areas.

The interior suspended levels, of a two-way flat slab type, are supported by circular columns. The parking areas are accessed through one entrance, one exit ramp and two interior ramps.

There are no expansion joints in the slabs.

The garage, serving a residential building, was built in 1970.

The area of the suspended slabs is approximately 9,000 m^2.

Repair History

The garage was surveyed in 1981 and found considerable amount of delamination (see Fig. 64.1) which were repaired in 1982. The procedure consisted of saw cutting around delaminated concrete areas, and removal of the defective concrete by chipping, below the level of the reinforcing steel, using a hammer less than 5 kg in weight. After chipping the area was sandblasted and the exposed reinforcing bars were coated with epoxy, before the placement of the 30 MPa repair concrete.

The suspended slabs were waterproofed with a Kelmar Full System.

Condition Survey

Delamination survey - Chain drag test was performed five times since rehabilitation. The delaminated or debonded area, as percent of the total, is shown in Fig. 64.1.

Great differences exists in the performance of the four test areas; the delaminated/debonded area in Test Area C is ten times larger than that in Test Area B.

The distribution of defects due to delamination and debonding of patches in the extracted cores (Fig. 64.2) indicates that the repair concrete has not bonded well to the original concrete, and the high value of defects can be explained partly on that basis. There is, however no doubt about the poor condition of the deck.

Chloride content - The chloride ion concentration was determined at three horizons and four locations. The results, shown in Figs. 64.3 through 64.6, indicate generally high values even at 90 mm depth; the threshold concentration of 0.035 percent is exceeded, in most cases, by a margin of ten. Significantly, the chloride content of the repair concrete four years after placement is well above the initial value by a wide margin. It cannot be ascertained whether this is the result of diffusion of chloride ions from the adjacent contaminated old concrete, or infiltration from the exterior, or both.

Half-cell potential - The half-cell potential values obtained in the four test areas are shown in Fig. 64.7.

It is remarkable, that while the extent of delamination/debonding has exceeded that found before the rehabilitation, the fraction of areas with greater than -0.35 V is far less than it had been in 1981, in fact, has been decreasing in the last 5 years (Fig. 64.8). The area in which the potential was greater than -0.35 V decreased from 10.5 percent to 0.4 percent in the last five years. Before restoration, the percentage of < -0.35 V was 30 percent.

It could be argued that the high values of the delamination/debonding are mainly caused by debonding, which, of course, will not affect the half-cell potential. But no scenario, or theory, can explain the decrease of the potential with time, a result indicating decreasing corrosion as the garage ages.

The discrepancy between delamination and half-cell potential seriously questions the merit of the half-cell test in a parking garage setting.

Membrane - On the examination of the extracted cores the waterproofing membrane was found well-adhering to the concrete . Membrane thickness varied between 1.2 and 4.1 mm, with the average being 2.4 mm.

A visual survey of the top surface noted major defects in the Kelmar waterproofing system on Level 2 where it was missing and debonded in places.

Discussion

Eight years after rehabilitation this garage is in need of another repair. The delamination found in some areas require attention.

It is disappointing that deterioration was relatively rapid. It is not clear why the chloride ion concentration is so high; the possibility of the presence of calcium chloride exceleration or other chloride containing substance in the original concrete cannot be ruled out. Still, after the repairs in 1982, notwithstanding the chloride content, the garage was expected to perform better than it did. Clearly, the defects in the waterproofing system, the failure to repair the deficiencies must have substantially contributed to the problem. The relatively large extent of debonding of the concrete repair patches is another major cause of the poor performance.

This garage is now, in 1992, in the process of being repaired. This then indicates that the patch and waterproof approach even if done less than ideally can last for ten years, suggesting good quality repairs and maintenance will yield subtantially longer time between repairs.

Fig. 64.1
Garage No. 64
Hollow sounding areas in test areas detected by the chain drag test

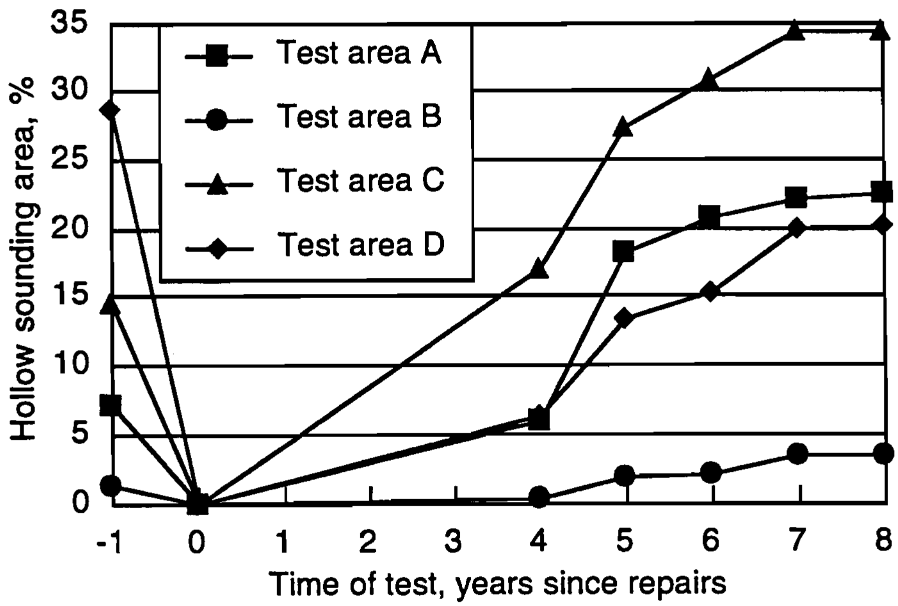


Fig. 64.2
Garage No. 64
Distribution of defects due to delamination and debonding in cores extracted in the four test areas

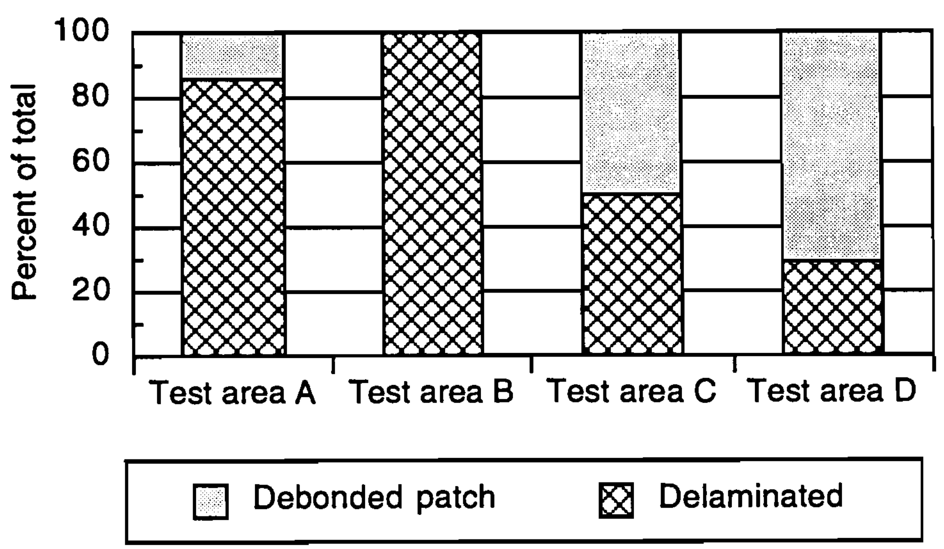


Fig.64.3
Garage 64
Chloride concentration of original concrete, at horizons stated

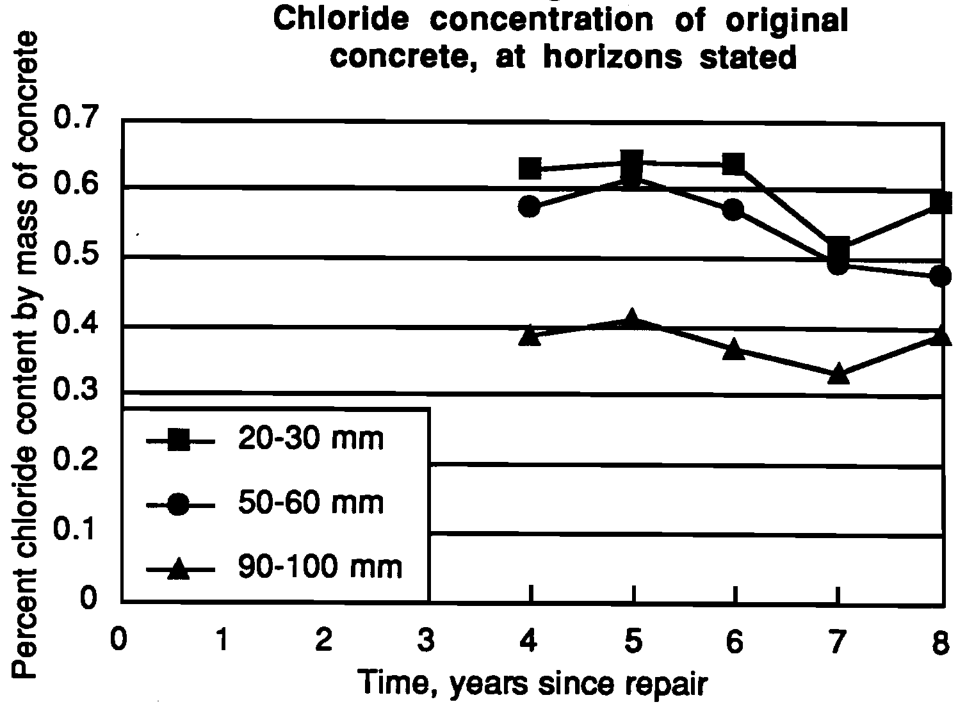


Fig.64.4
Garage 64
Chloride concentration of original concrete, at horizons stated

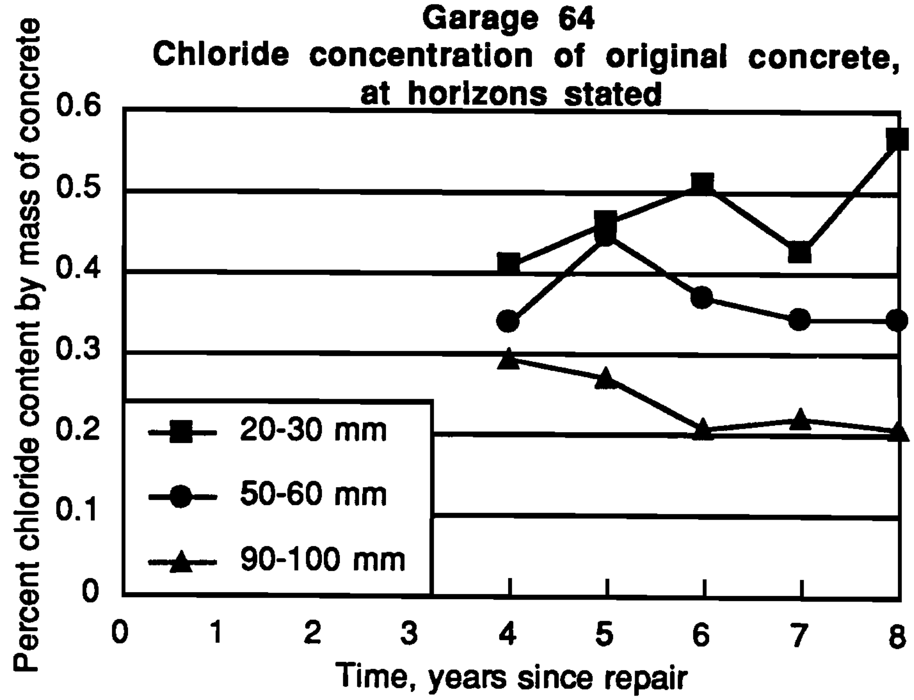


Fig.64.5
Garage 64
Chloride concentrations of original and repair concrete, at horizons stated

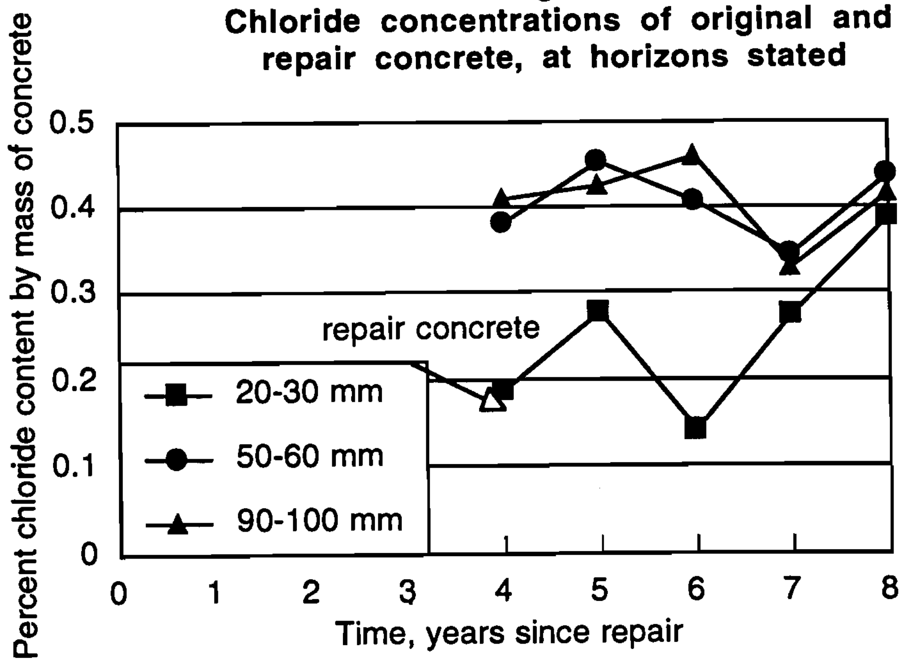


Fig.64.6
Garage No.64
Chloride concentrations of original and repair concrete, at horizons stated

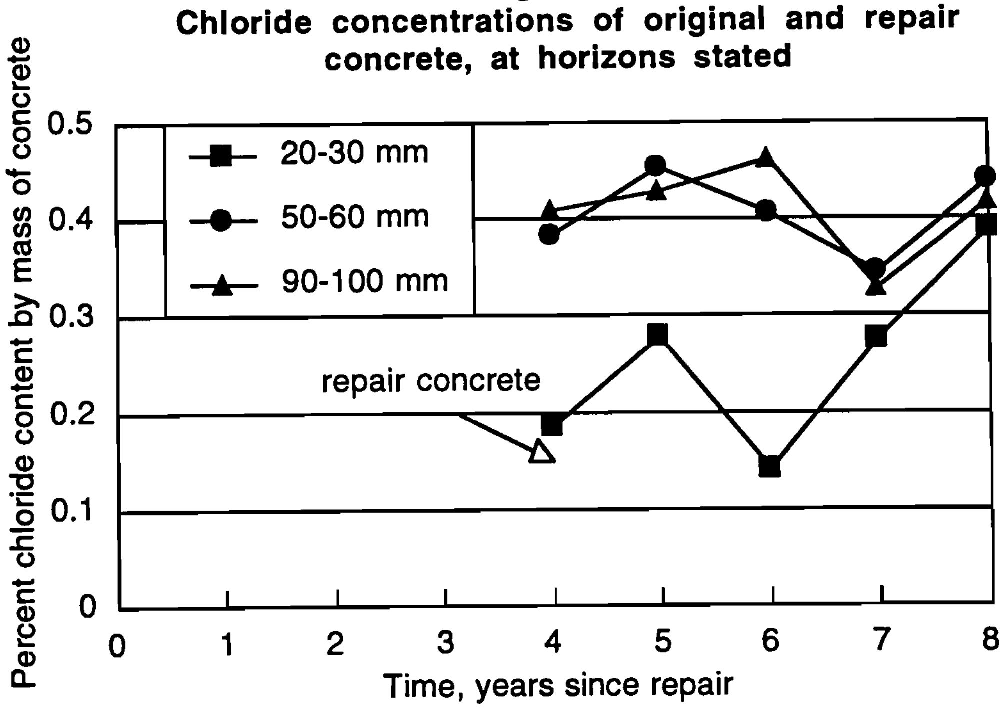


Fig.64.7
Garage No.64
Half cell potential of test areas beforeand after repair

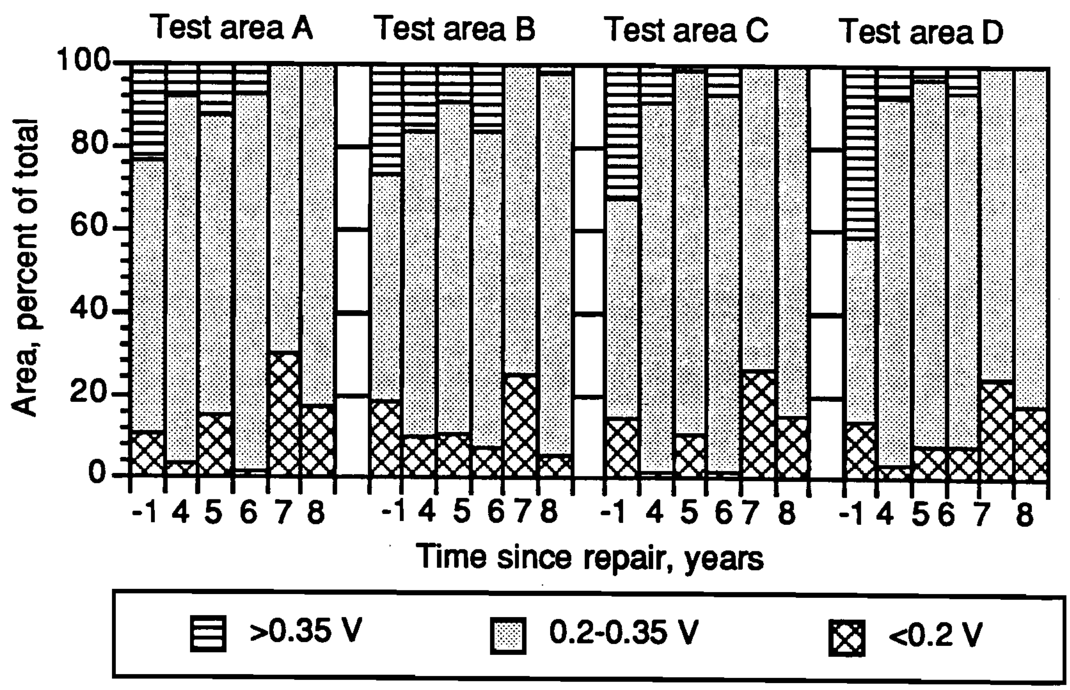
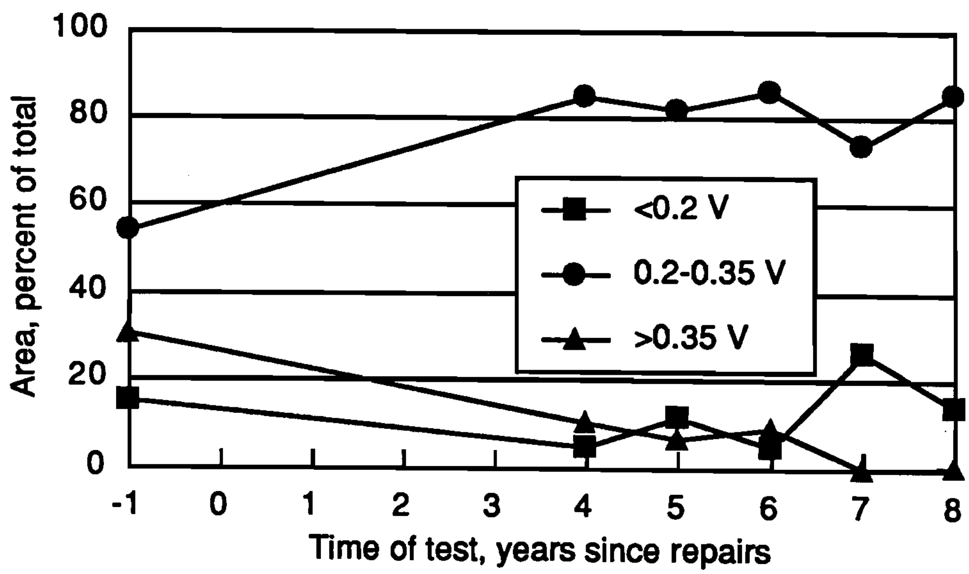


Fig.64.8
Garage No. 64
Half cell test results.
Totals of values obtained in the test areas



Garage No. 68

An underground, two level parking garage in a highrise residential building, constructed in 1984. The total number of parking stalls is 382, evenly divided between the slab-on-grade and the suspended level, the area of each measuring 7,632 m^2.

The 155 mm thick suspended slab is post-tensioned. The cables are protected with extruded plastic sheathing. The mild steel reinforcing bars in the top mat are epoxy coated. Fifty millimeter concrete cover was specified but in a condition survey the average cover was found to be 36 mm.

At the time of construction linseed oil was applied onto the top horizontal surfaces, and was recoated with alkoxy silane (Chemtrete) sealer four years later.

Repair History

A condition survey carried out at 4 years after construction noted 145 ft. leaking cracks and 185 feet leaking expansion joints in the deck. These cracks were repaired by routing followed by injection of an epoxy grout.

Condition survey carried out eight years after construction found again leaking cracks and expansion joints, although in a flood test only random ponding and small leakage was evident in the test areas.

The efficacy of the sealer was tested by measuring the water absorption through the coated surface of extracted cores. According to the results, the instantaneous water uptake was 10.6 percent of that absorbed by the untreated reference specimen. On longer exposure to ponding for six days, the absorption of the treated specimen increased to 40.8 percent.

The waterproofing quality of the sealer in place seems to be very satisfactory.

Garage No. 69

A parking facility of a highrise residential building consisting of a suspended slab and a slab-on-grade. The structure built in 1983 has a total area of approximately 13,955 m^2 with 340 parking stalls.

The structure is posttensioned. The unbonded tendons are protected with extruded plastic sheathing. The concrete cover over the reinforcing steel is 25 mm.

All the horizontal surfaces of the air entrained, 21 MPa concrete was given two coats of linseed oil at the time of construction, which was replaced five years later with an alkyl alkoxy silane sealer (Chemtrete BM 40).

A condition survey carried out at five years of age of the building, found 55 m leaking cracks in the suspended deck, 35 m in the perimeter walls, and 185 m leaking expansion joints. The chloride content at the level of the reinforcing steel was in the range of 0.013 to 0.085 percent.

In the subsequent repairs, at a cost of $70,000, the leaking expansion joints were replaced, the cracks sealed, additional drains installed, and the entire surface coated with a silane sealer.

Garage No. 72

A parking garage in a highrise residential building, constructed in 1987. The total area of the three suspended slabs and the slab-on-grade is approximately 15,000 m^2.

The structural slabs are 160 mm thick. The compressive strength of the concrete is 30 MPa. The specified concrete cover over the epoxy coated reinforcing steel is 38 mm.

The flat slabs are reinforced with posttensioning cables which are 7 wire unbonded strands, protected by a plastic sheath extruded over the strands as grease was applied. Grease filled plastic tubes and caps were also used at the epoxy coated cable anchors.

The structural slabs are supported by concrete ledges along the foundation wall.

Construction joints between slab pours, and cable anchor blockouts have been routed at the top, and sealed with gravity injected epoxy sealant. The entire horizontal surface is protected by a silane type sealer.

Condition Survey

A chain drag test, carried out as part of a comprehensive evaluation of the structure four years after construction found no delamination except some around the drains, construction joints and posttensioning cable blockouts.

Considerable random cracking in the deck, mainly due to restraints was noted.

On short term 2 (hours) exposure of extracted concrete cores, the water absorbed through the sealer (of unknown origin), treated surfaces was 10 percent of that absorbed through the untreated surface of the reference specimens. After six days, this percentage increased to 68.4 percent, and after

21 days of submersion the water uptake by the sealer treated concrete was 84 percent of that absorbed by the untreated concrete.

Chloride content is generally satisfactory. At the 25 mm horizon it is 0.034 percent, and is only slightly higher than at the 50 mm horizon (0.031 percent). The similarity of concentrations suggests that the chloride originates not from external sources but from the original concrete mix, most probably the aggregate. South Western Ontario limestones often have high chloride contents (typically 0.125, 0.166 percent) of which a considerable fraction is soluble, possibly 0.041 or even 0.091 percent.

Garage No. 73

Parking facility in a highrise residential building, constructred in 1989.

The underground posttensioned structure has, besides the slab-on-grade, one suspended slab of approximately 5,000 m^2 in area.

The thickness of the deck is 160 mm. The structural slab is supported by concrete ledges at the perimeter wall.

The postttensioning cables are protected with a 60 mil thick extruded plastic sheath. The steel reinforcing bars in the top mat are epoxy coated.

The horizontal surfaces of the garage are protected with a silane type concrete sealer.

Condition Survey

A survey was carried out in 1991, two years after construction. No evidence of ledge spalling was found. Above the ledge at the top of the slab the caulked joints appear to function well. No leakage through the slab was detected, and only very few cracks in the slab were noted. No delamination, only a very few pop-outs were found.

The concrete cover over the reinforcing steel ranged between 31 and 65 mm, with an average of 49 mm.

The chloride concentrations at the 10,25 and 50 mm horizon were 0.037, 0.031 and 0.034 percent. The uniform chloride distribution suggests that the chloride originates not from external sources but from a component of the original concrete mix, most probably the aggregate.

The sealer treated concrete of extracted cores absorbed, after two hours of exposure to water, 15.5 percent of the amount absorbed by the untreated specimens. The percentage increased to 68 percent after six, and 77.3 percent after 21 days.

This posttensioned garage is performing exceptionally well. Although only two years old, indications are that long term durability can be expected.

Garage No. 74

A four level underground garage of a large office complex. The minimum thickness of the two way reinforced slabs is 240 mm, and are supported by reinforced concrete columns with capitals, and by the concrete perimeter walls.

Repair History

The structure was built in 1973. A waterproofing membrane was applied in 1978, and major repairs were carried out in 1981. Most cracks in the soffit, and those on the top surface of the slab were epoxy injected.

Condition survey

In 1991, ten years after the repairs a condition survey found 8 percent of the area delaminated. A small fraction of this total is suspected to be due to debonding of the membrane from the concrete.

In the vicinity of the epoxy injected cracks new cracks, described as medium to narrow, developed. Approximately 8 percent of the cracks are leaking, resulting in efflorescence and stalactite deposits on the soffit.

The cover over the bottom mat of reinforcing steel has been removed in selected areas of heavy leakage, and rusting of the steel was observed in every case. In fact, the concrete cover was delaminated and was easily removed with a hammer.

The control joints in the middle of the slabs, have been sealed over their entire lengths with epoxy. This, of course, defeated the purpose of their existence. On the underside of the slabs along the joints, continuous cracks have formed.

Concrete cover

The concrete cover over the top mat of the reinforcing steel is fairly uniform throughout the slabs, averaging 64 mm. Readings less than 30 mm were obtained only in a few isolated locations. Very low readings of 5 to 10 mm were encountered in areas of extensive delamination, and spalls. The top reinforcing steel is exposed in eight locations.

Strength

The average compressive strength is 39.6 MPa. The lowest measurement is 31.1 MPa.

Chloride content

The water soluble chloride ion content of the delaminated concrete at the 0 to 10 mm horizon ranged from 0.084, to 0.184 percent by weight of concrete. At the 60 to 70 mm horizon, that is at the level of the reinforcement, the concentrations were 0.050, 0.054, 0.055 and 0.132 percent. Thus, the chloride ion concentration at all horizons exceeds the accepted threshold value of 0.035 to 0.025 percent by a large margin.

Half cell potentials

The potential measurements indicate that in approximately 12 percent of the area corrosion is taking place almost certainly (>-0.35V), and probably, in 42% of the area.

Waterproofing membrane

Two types of waterproofing membrane were installed in the garage: coal tar epoxy, 2-3 mm thick, and coal tar epoxy, 1-2 mm thick, with a roughened traffic wearing course. The condition of the membrane were found to range from fair to poor; in many locations the membrane is missing due to excessive wear and poor bond to the concrete.

Discussion

The major cause for the delaminations in this garage is the failure of the membrane to prevent water ingress into the deck at some locations.

The relationship between membrane defect and delamination is clearly shown in the survey drawings, in which "delaminated area" overlaps in most cases with a "missing membrane" designation Fig. 74.1 and Fig. 74.2. The conclusion has to be reached, that timely maintenance and repairs of the membrane would have prevented more serious damages of the concrete, and at great savings in the overall cost.

Epoxy injection into cracks does not appear to have great advantages; usually new cracks form in the vicinity of the sealed ones. This is consistent with the general experience. At present, epoxy injection is not being used in garage repairs. Elimination of the control joint was a mistake.

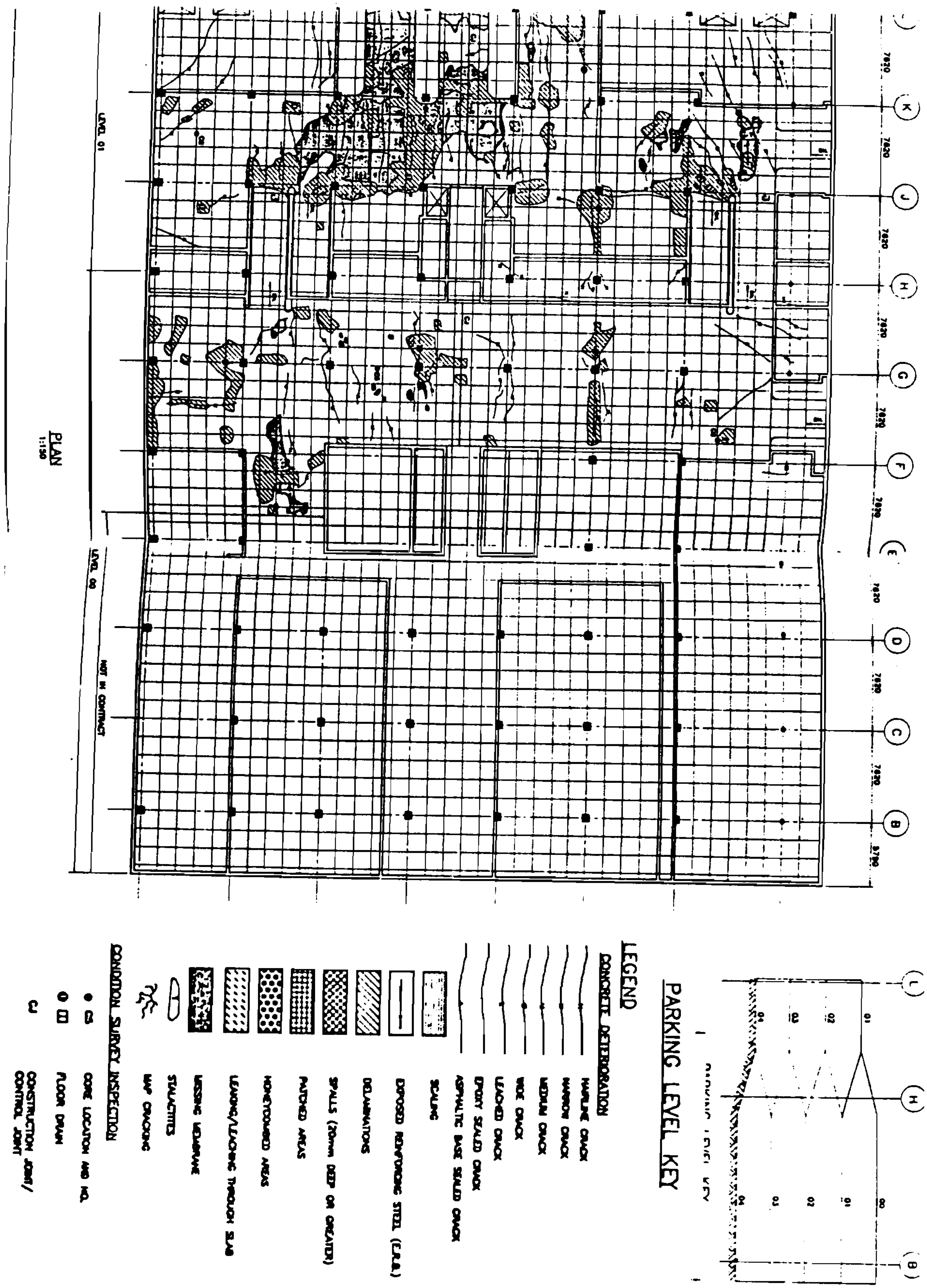


Fig. 74.1
Garage No. 74
Survey drawings, Level 01

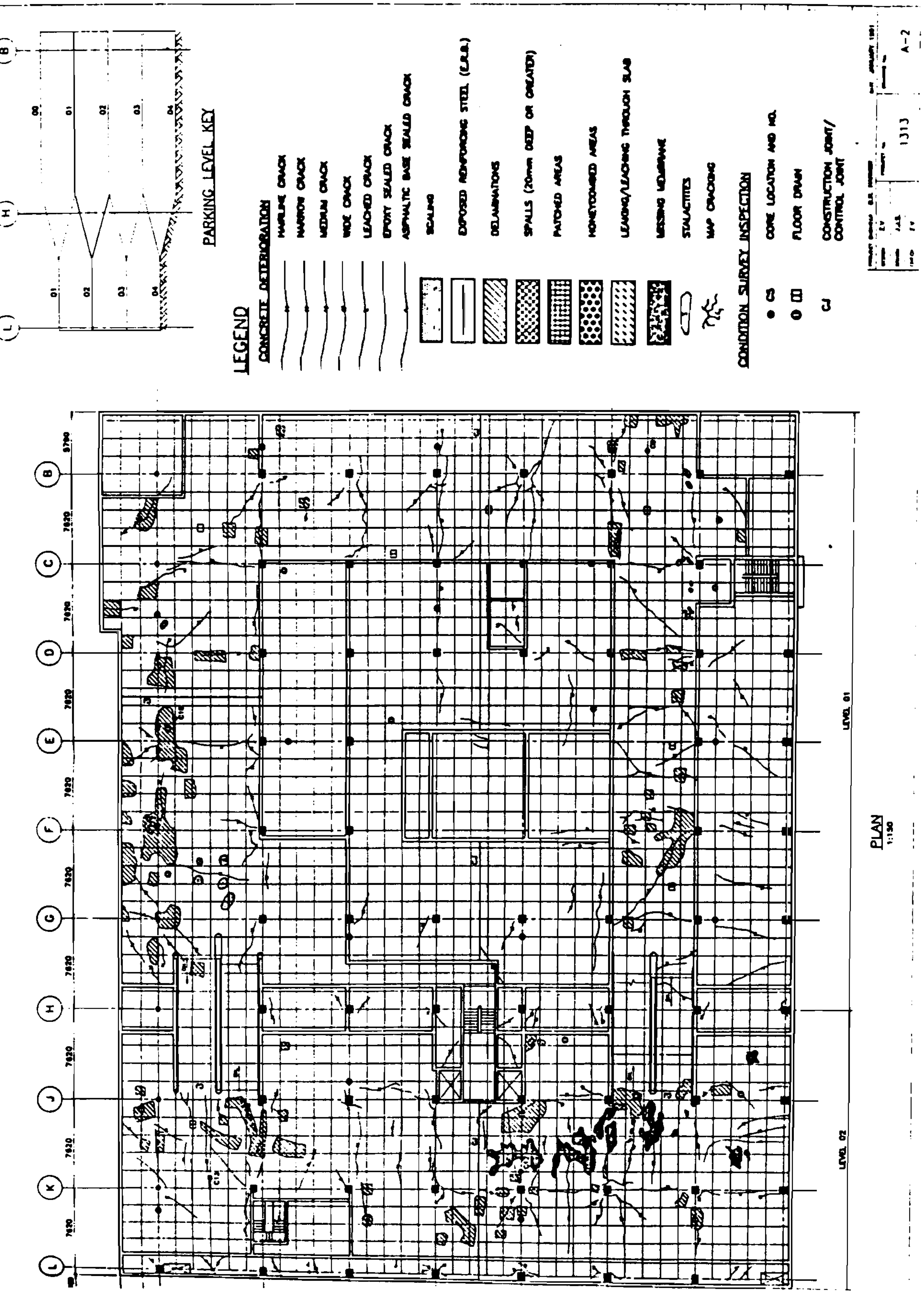


Fig. 74.2
Garage No. 74
Survey drawings. Levels 01 lower and 02 upper

Garage No. 75

An underground, three-level parking garage in an office building, built in 1975, housing commercial shopping areas at the lower three floors.

The parking facility consists of three public parking levels and a service level, which are denoted P1, P2, P3 and S1.

Parking levels P1 and P2 are two way flat-slabs supported by concrete columns with drop panels. Level P3 is a slab on grade.

The building consists of two symmetrical blocks, which are structurally independent. Horizontal movement is accommodated by one-inch expansion joints of approximately 68 m length.

The total parking area is 17,880m^2 (P1 3,245 m^2 , P2 7,312 m^2, and P3 7,323 m^2). In addition, the area of the three ramps, those of a truck ramp and loading dock bring the total to 20,125 m^2.

Repair History

Phase 1 of the repairs was carried out in 1983, eight years after construction. Approximately 600 m^2 concrete surface of level P1 was repaired, and Permapol 440 installed over an area of 4,050 m^2, at a cost of $124,995. Three months after the completion of the work, severe deterioration of the membrane, in turning lanes, and at the base of the car ramp, was reported. Despite of the five-year warranty on the waterproofing membrane in force, the owner has taken no action to demand repairs of the deficiencies.

Phase 2 (1984) consisted of repairing the concrete over an additional area of 1,500 m^2, and installation of Kelmar waterproofing membrane over the entire floor area of level P2. Cracks, of a total of 470 m length, were sealed as part of the preparation before applying the membrane. The cost was $306,871.

In Phase 3 (1986), the truck ramp, and the loading dock areas were repaired involving 1,176 m^2 of the area. On the truck ramps a coal tar epoxy wearing surface was installed to protect the Kelmar 350. The cost of the repairs was $109,283.

Condition Survey 1990

Delamination Survey - A total of 1,513 m^2 of delaminated area was identified by the chain drag test. The usual difficulties were encountered in differentiating between hollow soundings due to delamination in the concrete, and those due to debonding of the waterproofing membrane from the substrate.

On level P1 23%, on P2 West 59%, and P2 East 19% of the area was hollow sounding. Thus, on the average, 25 percent of the area of the two suspended levels is delaminated or debonded. Level P3, the slab on grade, is in good condition; only 2 percent of the area is delaminated.

Visual inspection - the membrane on level P1 is severely deteriorated; it is either minssng or abraded, particularly in the driving lanes. The membrane on level P2 is in a far better condition, notwithstanding defects due to wear. The very high delaminated/debonded area detected on this level raises the question whether the membrane is just wearing well but not waterproofing effectively.

Level P3, and the loading dock area are in relatively good condition with no major defects apparent.

Chloride ion content - the water soluble chloride ion content of the concrete cover extracted from the three levels of the garage is given in Table 75.1.

The analysis indicated in most areas chloride contents that are multiples of the threshold values above which corrosion is to be expected. Of particular concern is the high concentration even at the 50 mm to 60 mm horizon which is at the level of the reinforcing steel. It was noted, that at most locations at which the cores were extracted, the waterproofing membrane was in a fair to good condition.

Components inspection - Floor drains were found to be in good condition, but in most cases water leakage between the drain housing, and the surrounding concrete resulted in the accumulation of a white deposit in the soffit.

The structural walls, and columns are generally in a good condition.

The expansion joints are in need of attention.

Tbl.75.1
Garage No. 75
Water soluble chloride ion content at indicated horizo
percent by mass of concrete

	10-20 mm	50-60 mm	90-100 mm
P1-West (No.1)	0.005	0.017	0.004
P1-West (No.2)	0.480	0.206	0.026
P1-West (No.3)	0.417	0.058	0.023
P2-West (No.9)	0.518	0.027	0.006
P3-West (No,11)	0.780	0.683	0.415
P3-East (No.13)	0.596	0.445	0.157
S1 (No.14)	0.030	0.024	0.026

APPENDIX C

Cable Condition Assessment by the Gas Flow Method.

The method developed by Vanco Structural Services consists of passing low pressure dry nitrogen gas through the cable via nipples installed for this purpose, and monitoring the relative humidity of the exiting gas.

This simple, and relatively inexpensive, procedure seems to achieve several objectives:

1. Identifies the cables that contain water rendering the tendons vulnerable to corrosion;
2. Permits corrective action to make the concrete enclosure waterproof by providing means to locate the site of leakage, and to verify watertightness;
3. Permits to maintain a dry atmosphere in the cable (by bleeding dry nitrogen gas) and thus prevents further corrosion; and
4. By accomplishing and verifying the desired degree of dryness prepares the cable for grease filling, if that is the preferred preservative action.

The effects on flushing the cables with nitrogen gas, and maintaining a nitrogen atmosphere over the dried cable are shown in Figure 21.1 through 21.5.

It can be seen that

1. When the cables were opened up, the RH was over 80%, a level at which corrosion will certainly take place in the presence of oxygen;
2. Flushing with nitrogen gas reduced the RH significantly. The rate of the reduction depends on the amount of accumulated water, and the tightness of the concrete cover. The response observed in the case of Cable 1W indicates that not much water could have a accumulated in the cable, and the concrete cover is fairly tight; if it were perfect the initial RH would have been lower than 88%, but it is not leaking too badly because with modest efforts the RH was lowered to, and maintained at approximately 30%.
3. In contrast, it was not possible to lower the RH of Cable 5W below 50%. Either a larger amount of water has collected in the cable or the cover is leaking badly. There is some indication that the RH of the cable responds to changes in the atmosphere. The RH values of the cable and the atmosphere, shown in Fig.21.6, indicate that the cable RH is lower than that of the atmosphere - due to the drying effect of the injected gas - and that the two curves tend to change somewhat similarly - due to lack of a hermetic seal. The level of relationship can be judged fro from the regression plot (Fig.21.7).

Further trials are in progress.

Fig. 21.1
Garage 21
Relative humidity in Cable 1W and atmosphere during trial

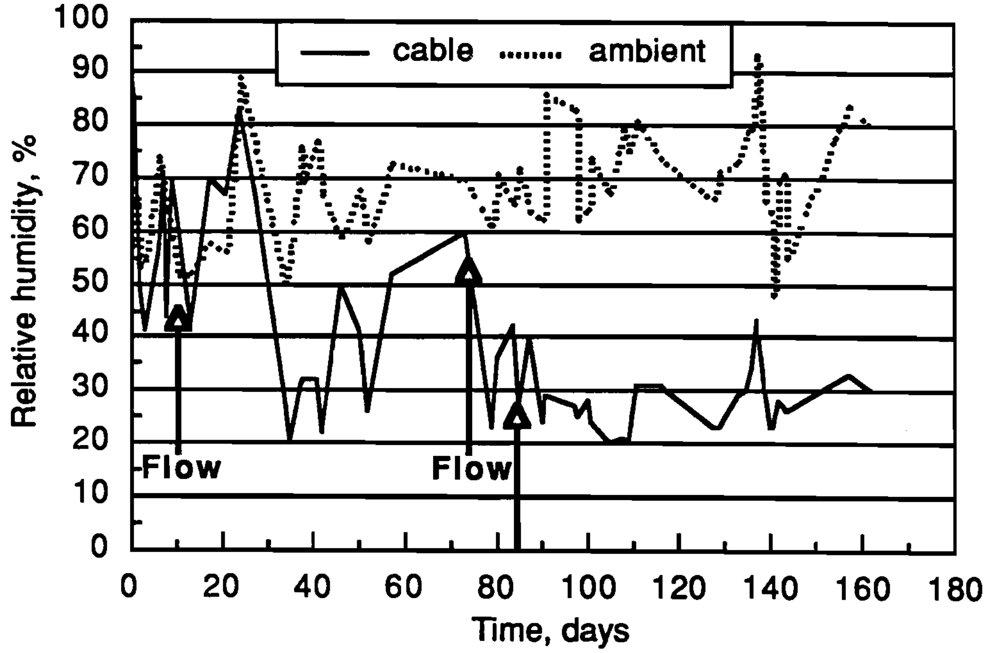


Fig. 21.2
Garage 21
Relative humidity in Cable 2W and atmosphere during trial

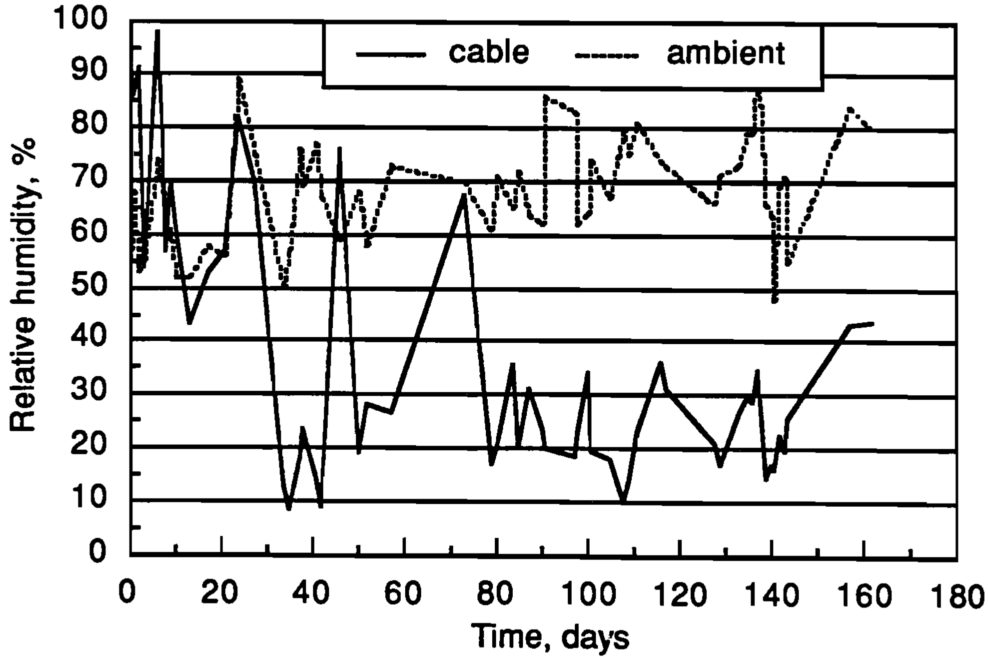


Fig. 21.3
Garage 21
Relative umidity in Cable 3W and atmosphere during trial

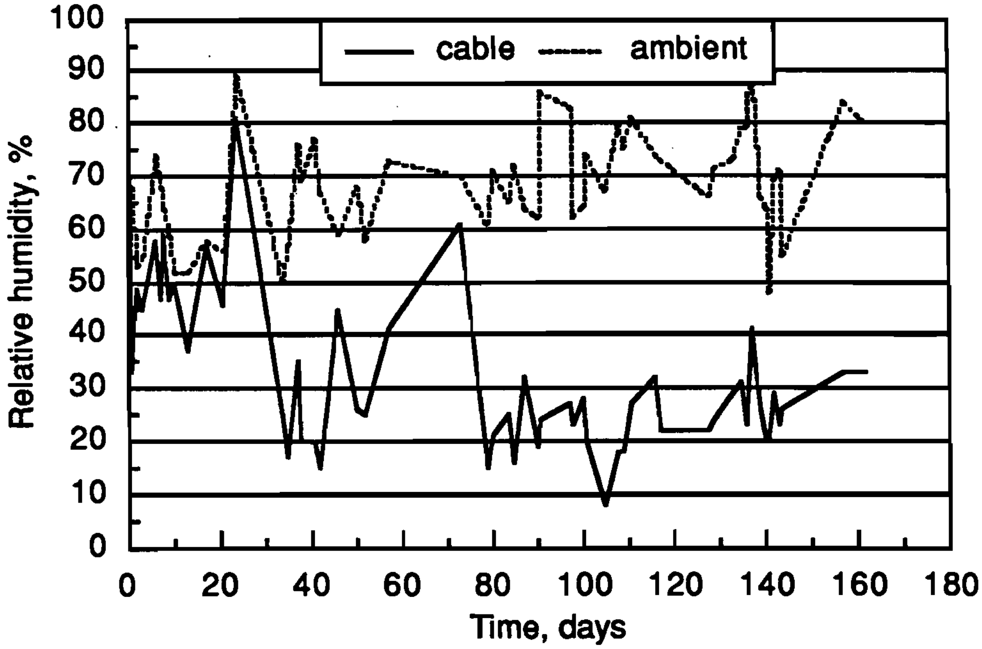


Fig. 21.4
Garage 21
Relative humidity in Cable 4W and atmosphere during trial

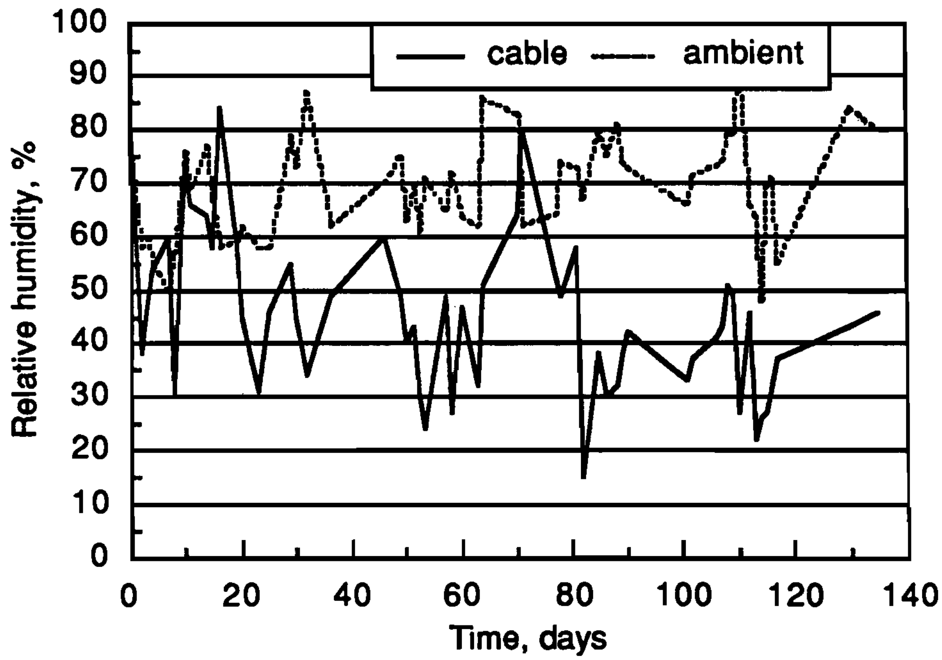
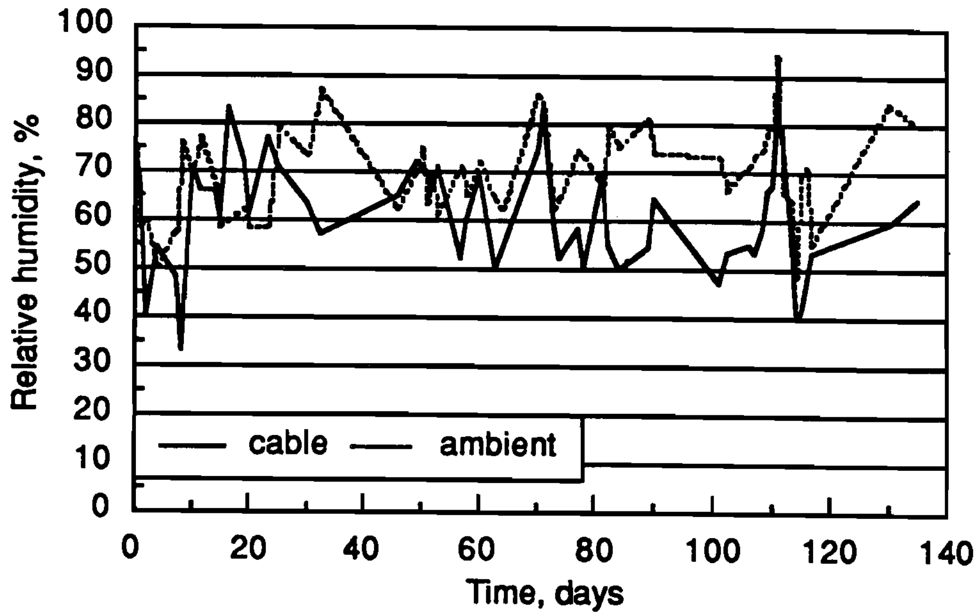
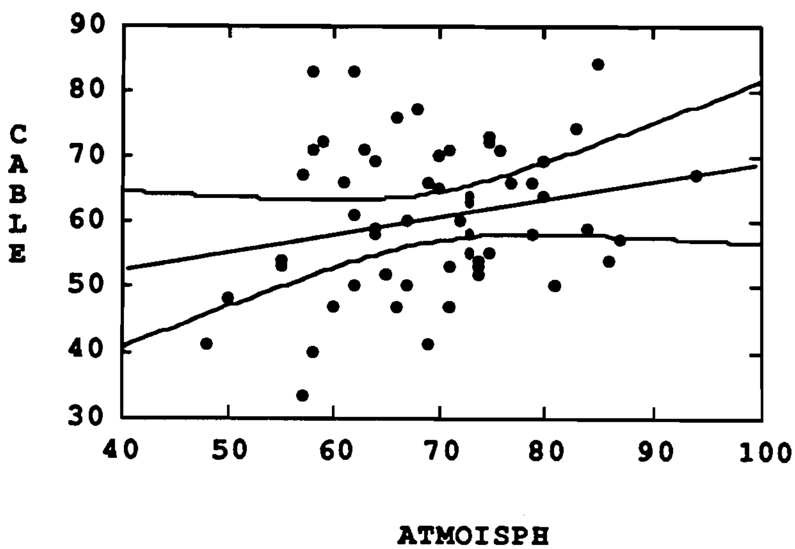


Fig.21.5
Garage 21
Relative humidity in Cable 5W and atmosphere during trial



Fig, 21.6
Garage No. 21
Relative humidites of Cable 5W vs. that of atmosphere



CABLE=41.664+0.274*ATMOISPH

APPENDIX D

Monitoring of the Relative Humidity and Temperature in Garage No. 20

On 8th February 1990 four 3-inch deep wells of 31.75 mm diameter were drilled in the soffit of the slab to accommodate the sensors. Provisions were made to place one probe in the beam for reference purposes. A schematic diagram of the site with the location of the sensors is shown in Fig. 20.6.

Technical details of the system were as follows:
Sensors: Vaisala Type HMP111A, Humidity and Temperature Probe.
Data logger: Data Electronics DT100 Data Logger.
Data transmission: Hayes Smartmodem 2400

The probes were affixed to the soffit of the concrete deck with the sensor tube positioned in the well and then the assembly was hermetically sealed from the outside atmosphere with a metal cover . The 12V power supply, the telephone modem and the data logger were mounted in a metal case.

The gauges were installed on February 15th. Data acquisition commenced on February 19th, 1990 at first manually and, after March 13th, automatically by a computer in IRC/NRC laboratory linked to the sensors by a modem. The readings have been taken every two hours without interruption since that time.

Results and Discussion

The large number of numerical data is now stored on computer disks. To save space, in Table 20.5 only two readings per day at 12 hour intervals are listed.

The results utilizing all the measured points are presented also in a graphical form in Figures 20.7 through 20.9.

The changes of the relative humidity (RH), in the concrete slab as indicated by sensors Nos. 1 through 4 are shown in Figure 20.7.

The following observations can be made:

1. Sensors 1 and 2 yielded very similar results;
2. The values obtained with sensor No. 3 are to a large extent similar to those of sensors No. 1 and No. 3 except for the episodes that occurred in early November, both in 1990 and 1991. From these dates onward the behaviour resembled

closely that of cell No. 4, but indicated lower RH values much sooner than cell No. 4.

3. The results obtained with sensor No. 4 are very different from those of cells No. 1 and 3, and are characterized by very high absolute values, often close to 100%, that slowly decrease in the summer months, but suddenly increase in November.
4. All curves indicate initially very high humidities, almost certainly due to wetting of the concrete in the coring operation. But while curves 1, 2 and 3 gradually decrease to 60% by July 1990, curve 4 remains above 95%.
5. Of great interest is the finding that, according to the readings by sensors Nos. 1 and 2, the RH at these locations was less than 50% in the winter months. In spring and summer the RH level increased, but only temporarily reached 60%.

   Since the corrosion process stops when the RH falls below 50% (Fig. 20.10), it can be concluded that waterproofing membrane can significantly reduce the rate of corrosion. In fact, sensors Nos. 1 and 2 indicated low values from the early fall and, thus perhaps, it is more correct to say that corrosion in these zones takes place only for a few months of the year.

   It would be interesting to see what the RH values will be in the next year when the initial disturbance of the conditions caused by the installation of the probes will be completely absent. Evidence may be obtained that intact, well functioning waterproofing membrane achieves what it is supposed to. The waterproofing quality of membranes in service has never been proven by instrumental methods, and concern was expressed to the effect, that condensation through the soffit side raises the humidity well over the threshold level above which corrosion occurs. The indications obtained in the present project do not support this view.

6. The unique results obtained with sensor No. 4 cannot be explained by assuming instrumental error, because on December 20th, 1990 the sensor was temporarily replaced with sensor No. 6, and the readings of the two transmitters were very similar (Fig. 20.11).

   When well No. 4 was opened up for the installation of sensor No. 6, it was noted that the surface of the concrete in the well was wet and, at places, bulk water was present.

7. On examination of the concrete floor above the sensor No. 4 location, with the Schupack Concrete Tightness Tester, the following results were obtained (please refer to site plan in Fig. 20.12):
   i) Sensor No. 4 location is close to construction joint, with the membrane cracked along the joint;
   ii) At test site approximately 4.5 m from sensor, marked No. 1 in Fig. 20.12, good vacuum was achieved;
   iii) In the test area along the construction joint, no vacuum could be obtained when evacuated with the tester (Test site No. 2) as was the case at test site No. 3. Along the construction joint the membrane is cracked in 75% of the total length;
   iv) In testing at sites 4 and 5, good vacuum was achieved, (though it decayed from 660 mm Hg to 558 mm Hg in two minutes), despite that these locations were directly over a major crack in the slab. This indicates that the leakage rate at the construction joint is much greater than at a visible large crack.

   This observation leaves little doubt that the high RH indicated by sensors No. 4 and No. 3 is due to leakage through the crack of the membrane, presumably over the construction joint.

8. The dramatic increases of the RH in test well No. 4 on December 15th, 1990 and November 22nd, 1991 when in 12 hours the RH increased from 75.5 to 95.5% and from 66.6 to 93.5%, respectively were most probably caused by infiltration of water. According to weather records no precipitation occurred on these particular dates, but it may be possible that water accumulated over a period of time on the floor or in crevices. The water may have originated from washing of the floor, that took place on the week-end of November 22.

9. The divergence of curve 3 from curves 1 and 2 after 15 December 1990 must have been caused by the event that affected curve 4 on the same day.

   Sensor 5 measures the RH in the beam. Curve 5 in Fig. 20.8 is a graphic representation of the obtained results.

   Over the period of monitoring the RH gradually decreased to less than 50% in January 1992. The high initial values must be ascribed to the core drilling operation in which water had to be used. Because of the large dimensions of the beam, changes take place at a slow rate and with relatively little fluctuation. It is conceivable that the RH will further decrease in the future.

Sensor No. 6 is exposed to the environment and the results, as shown in Fig. 20.8, represent the daily fluctuation.

The temperature readings made with all the sensors are shown in Fig. 20.9. According to the composite curves the temperature varies between 30°C and 5°C.

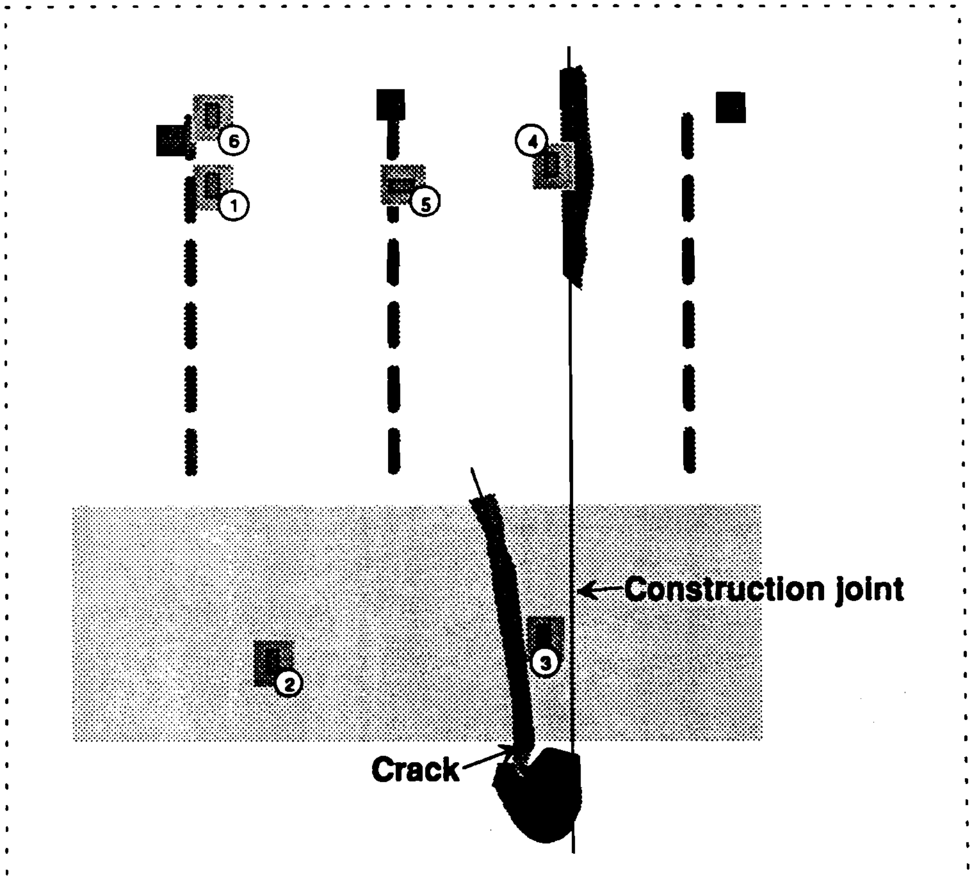
The outputs of sensors Nos. 1, 2, 3 and 4 over a one week and over a one day period are shown in Fig. 20.13 and in Fig. 20.14, respectively. Similarly, the variation of temperature over a one week, and over a one day period, are shown in Fig. 20.15, Fig. 20.16 and Fig. 20.17, respectively.

Conclusions

1. Waterproofing membrane installed in Garage No. 20 was able to reduce moisture infiltration and, consequently, moisture content in the suspended deck to a very significant degree.
2. The relative humidity in the concrete protected by the membrane in good condition is so low, that in a great part of the year no corrosion of the rebar takes place due to lack of moisture needed for the process.
3. Concern over condensation through the soffit ,in quantities that may raise the RH values to near saturation level, proved to be groundless.
4. Notwithstanding the elastic nature of the membrane, it can tear over some cracks in the concrete and loses its waterproofing ability.
5. Conclusion 4 underscores the importance of proper crack sealing before the installation of the membrane.
6. While the data proves the great merit of the membrane, the benefit remains a potential rather than reality if not properly maintained, and repaired.
7. There is no circumstance known that would render the above conclusions to be valid only for the monitored garage.
8. The used instrumental set-up proved to be simple to operate and reliable. Consideration should be given to utilize it in condition surveys to clarify some aspects of the performance.

Fig 20.6

Garage No. 20
Schematic diagram of the monitored area



Legend

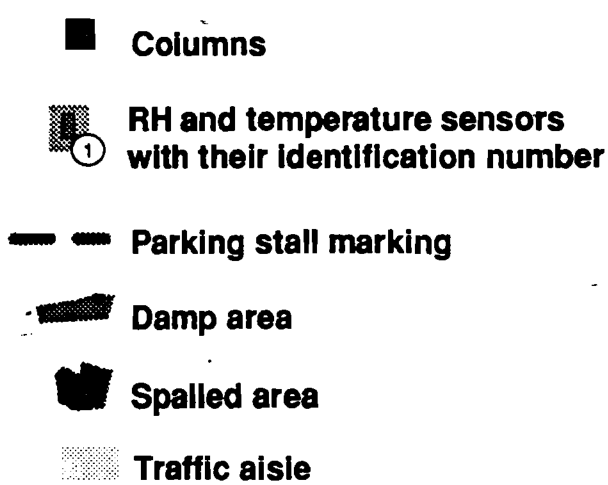


Fig. 20.7
Garage No. 20
Relative humidities indicated by sensors in floor slab

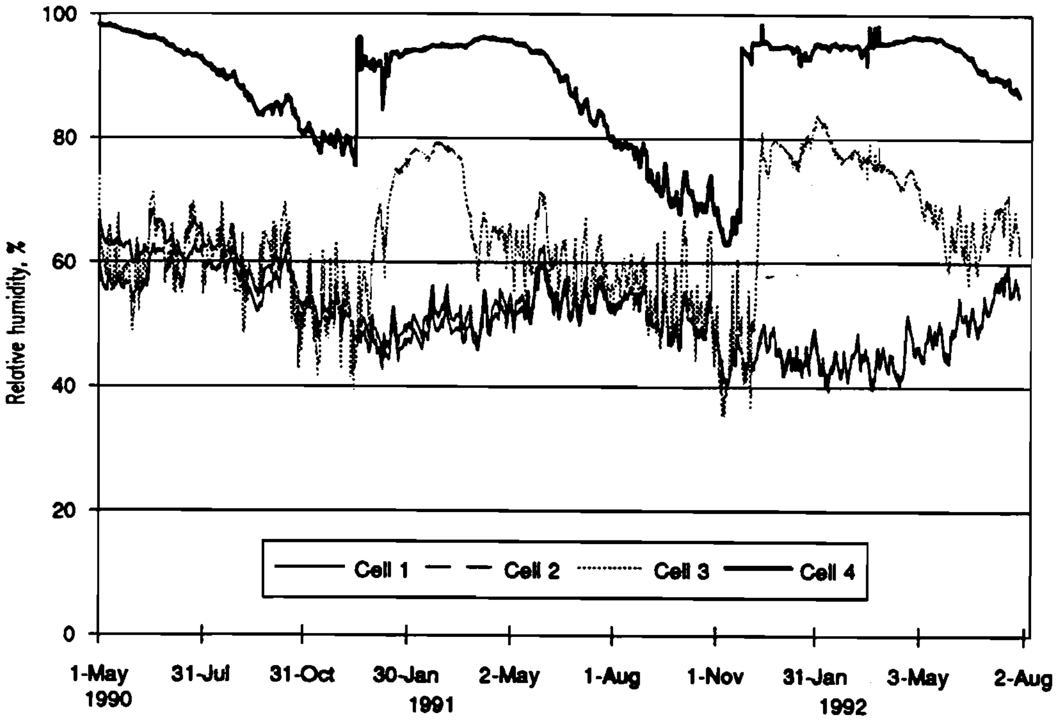


Fig. 20.8
Garage No. 20
Relative humidities indicated by sensors in beam and in air

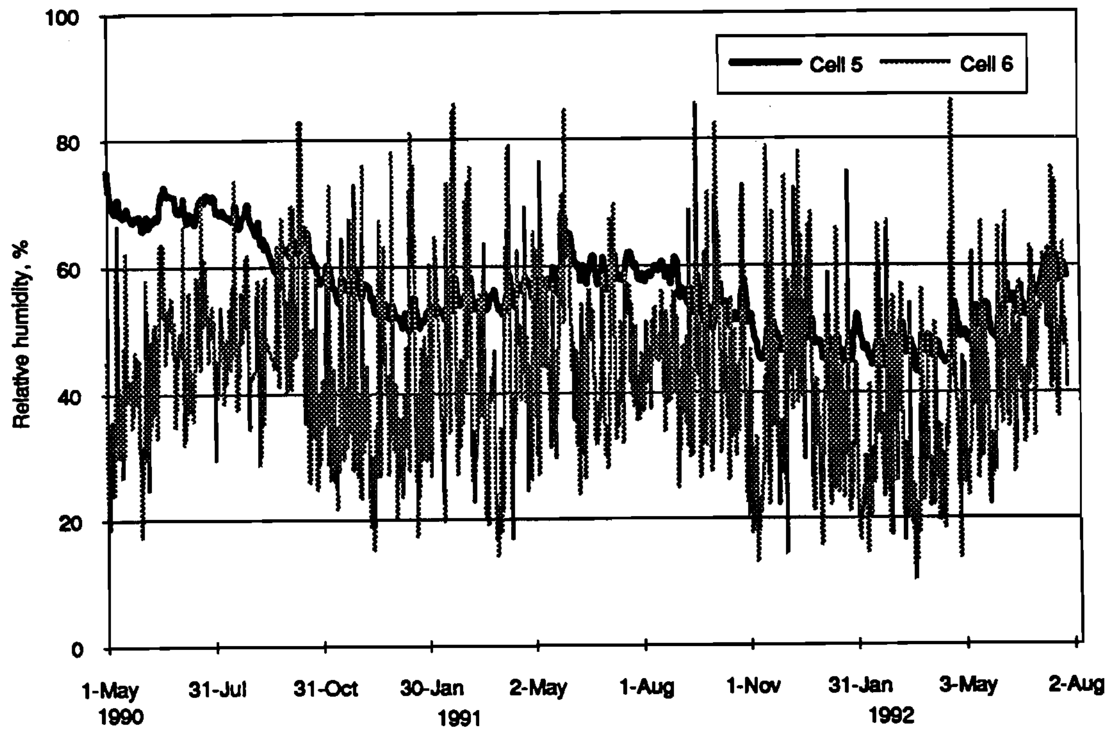


Fig. 20.9
Garage No. 20
Temperatures indicated by all six sensors

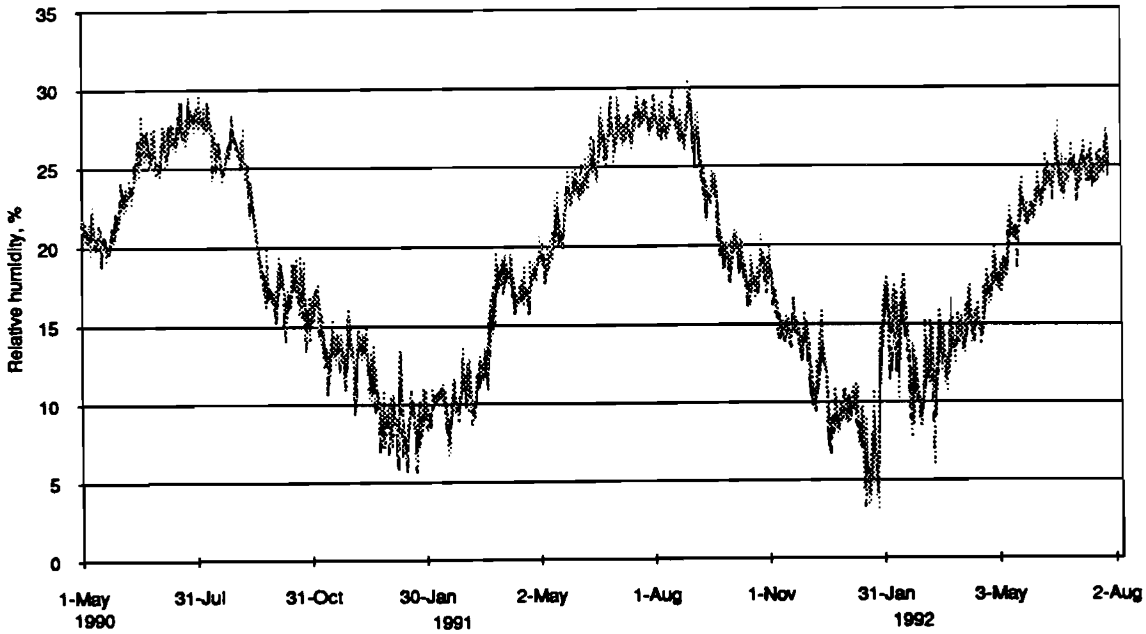
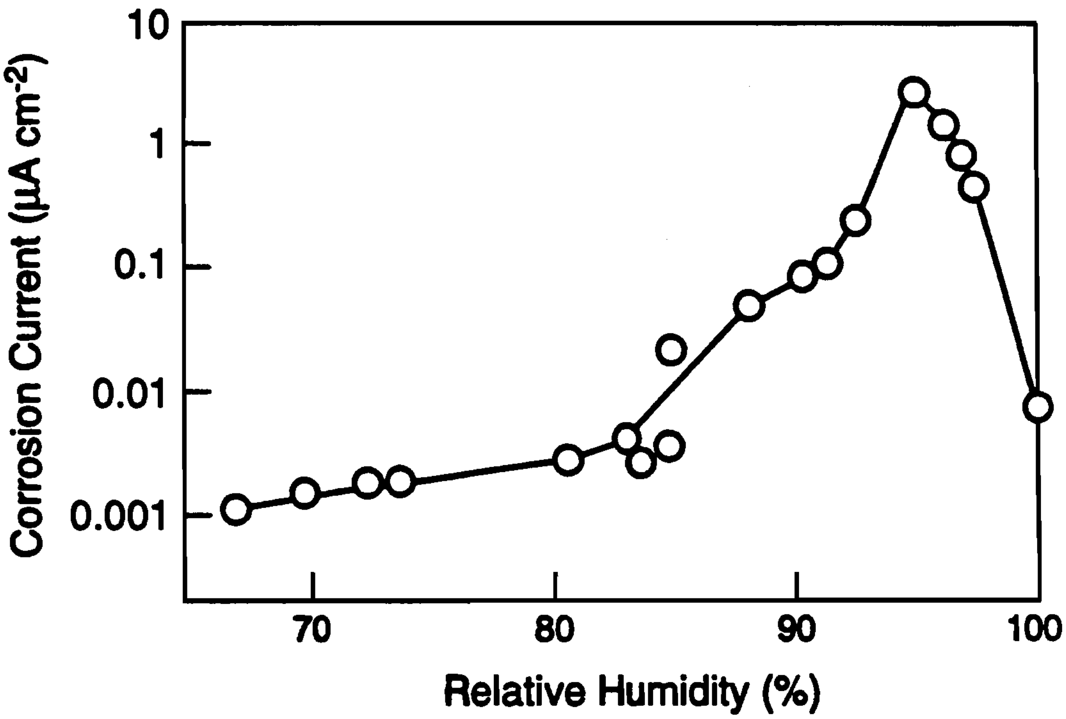


Fig. 20.10
Effect of the relative humidity on the corrosion rate of the reinforcing steel in concrete *



*(K. Tuutti, Corrosion of Steel in Concrete, Swedish Cement and Concrete Research Institute, Research Report No. 4, 1982)

Fig. 20.11
Garage No. 20
Check of readings indicated by exchange of sensors

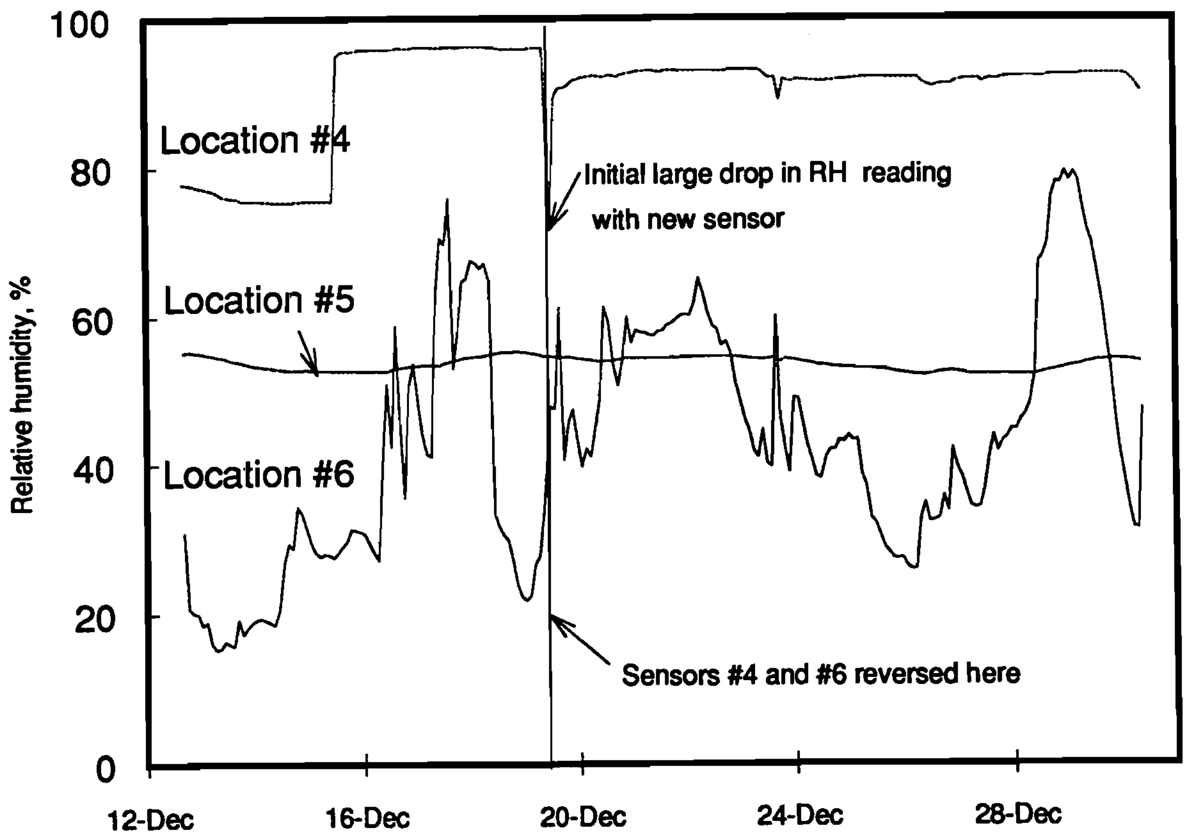
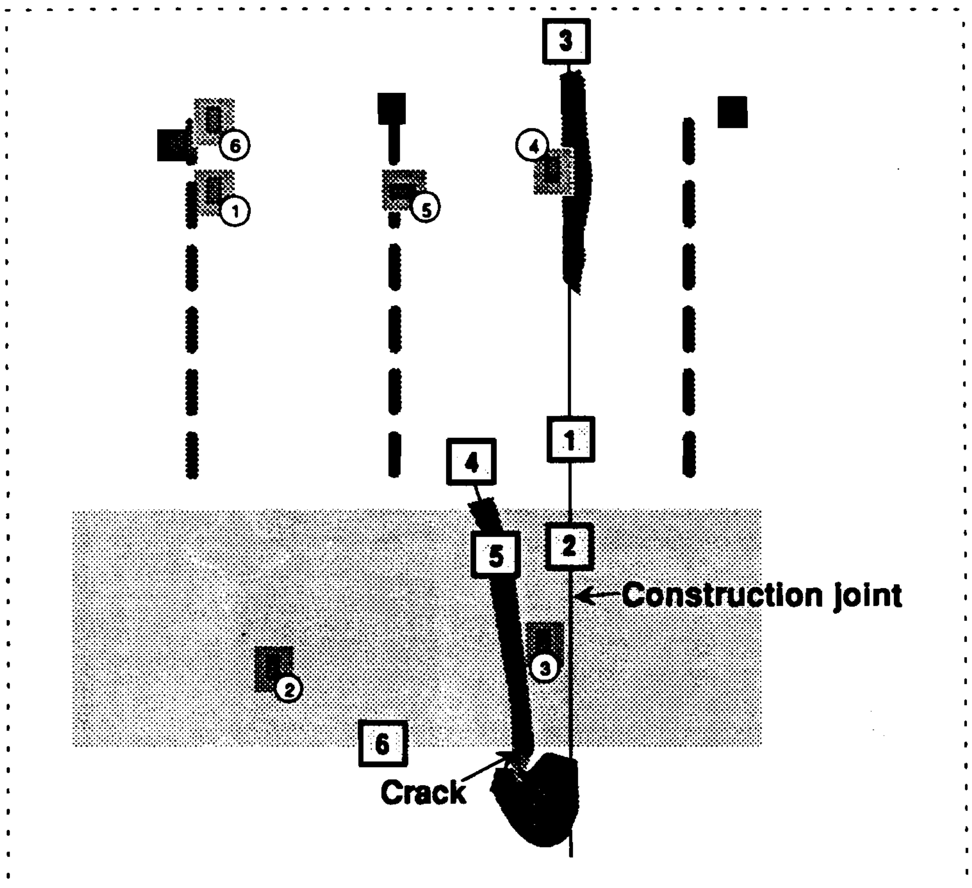


Fig 20.12

Garage No. 20

Schematic diagram of the monitored area



Legend

- Columns
- RH and temperature sensors with their identification number
- Parking stall marking
- Damp area
- Spalled area
- Traffic aisle
- 1 Tightness Tester test area

Fig. 20.13
Garage No. 20
Relative humidities recorded by sensors located in floor slab

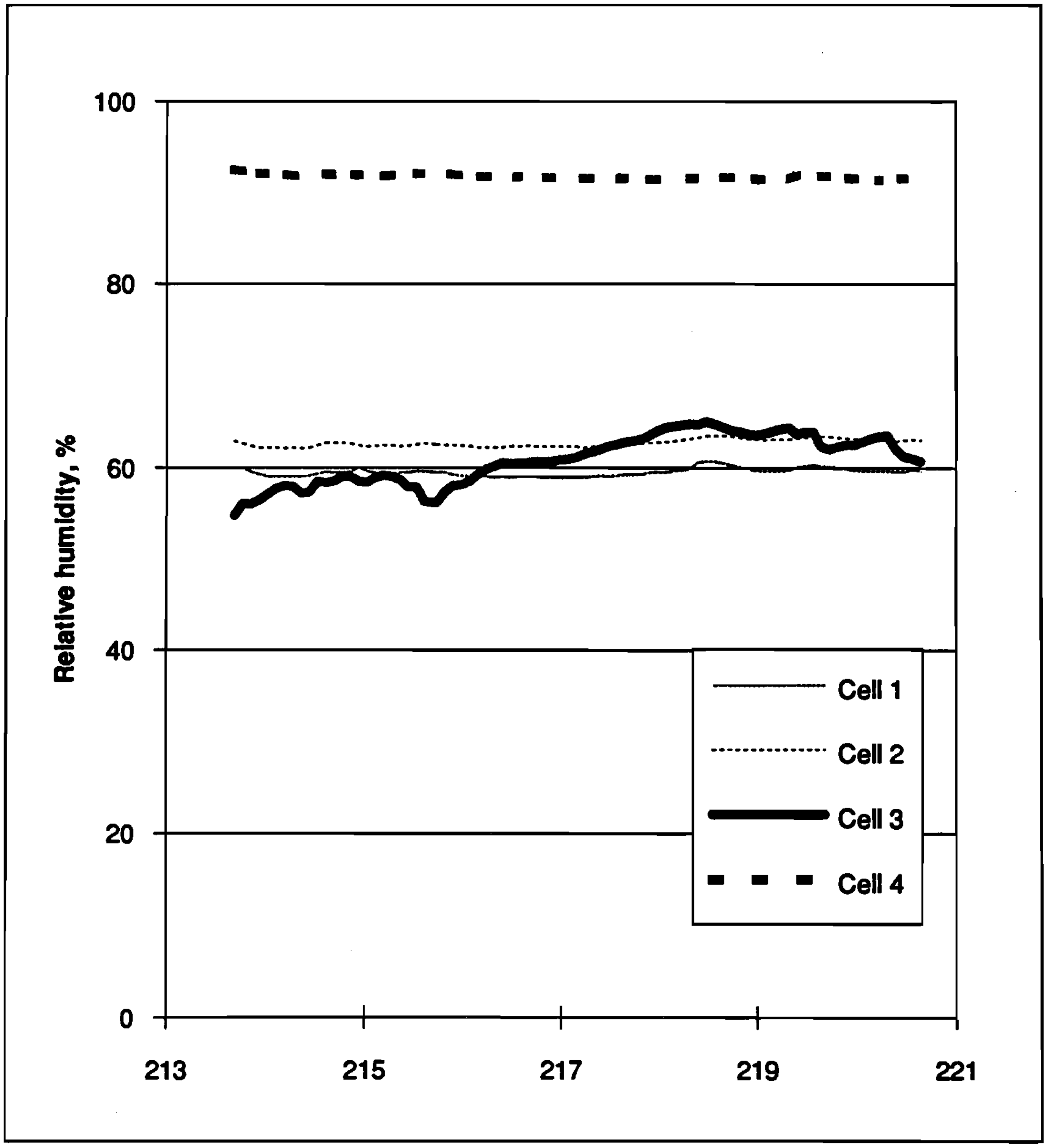


Fig. 20.14
Garage No. 20
Relative humidities recorded by sensors in beam and in air

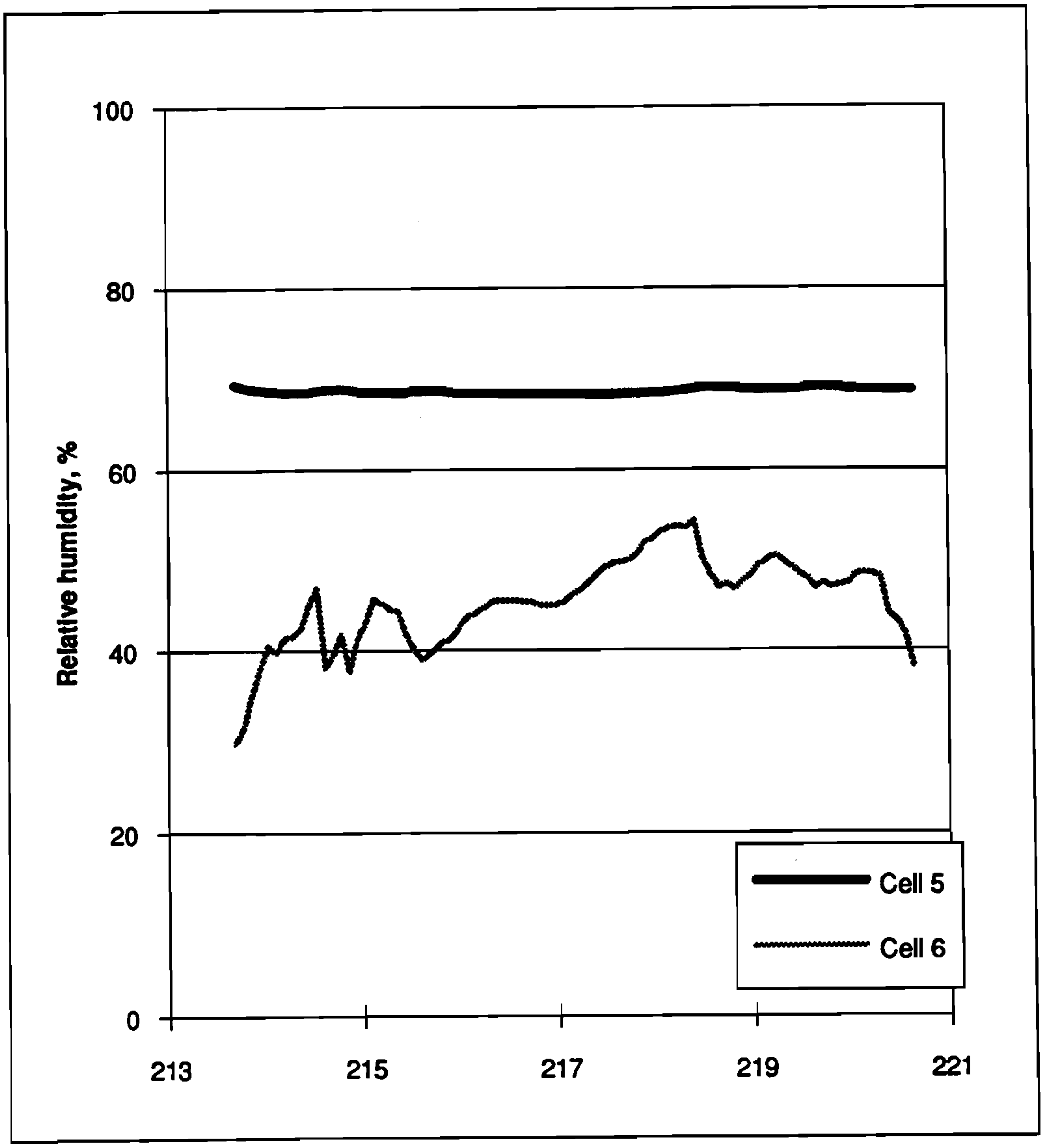


Fig. 20.15
Garage No. 20
Temperature values recorded during 1 week period, (1990)

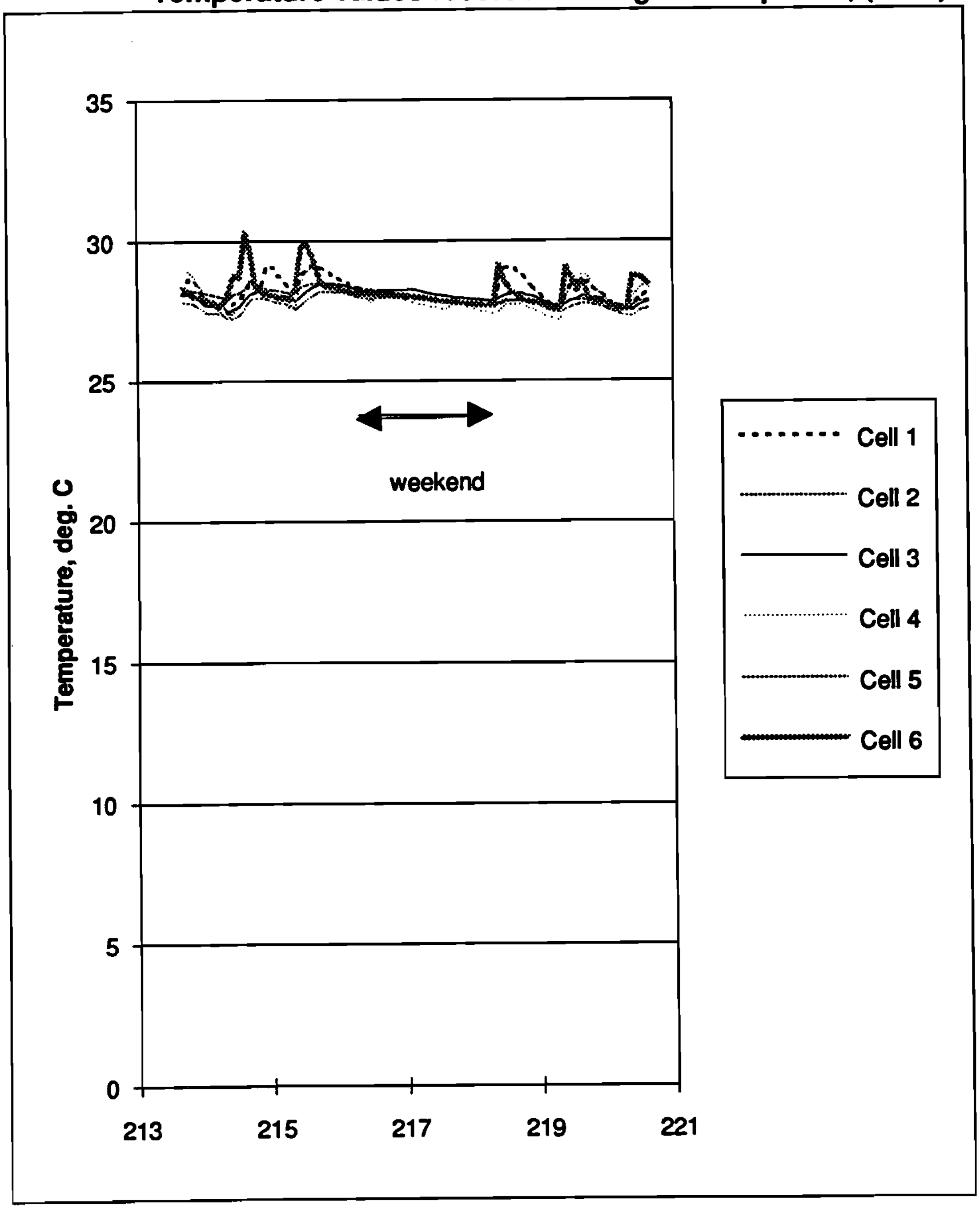


Fig. 20.16
Garage No. 20
Temperature comparison of air and floor sensors in 24 hr, period (summer)

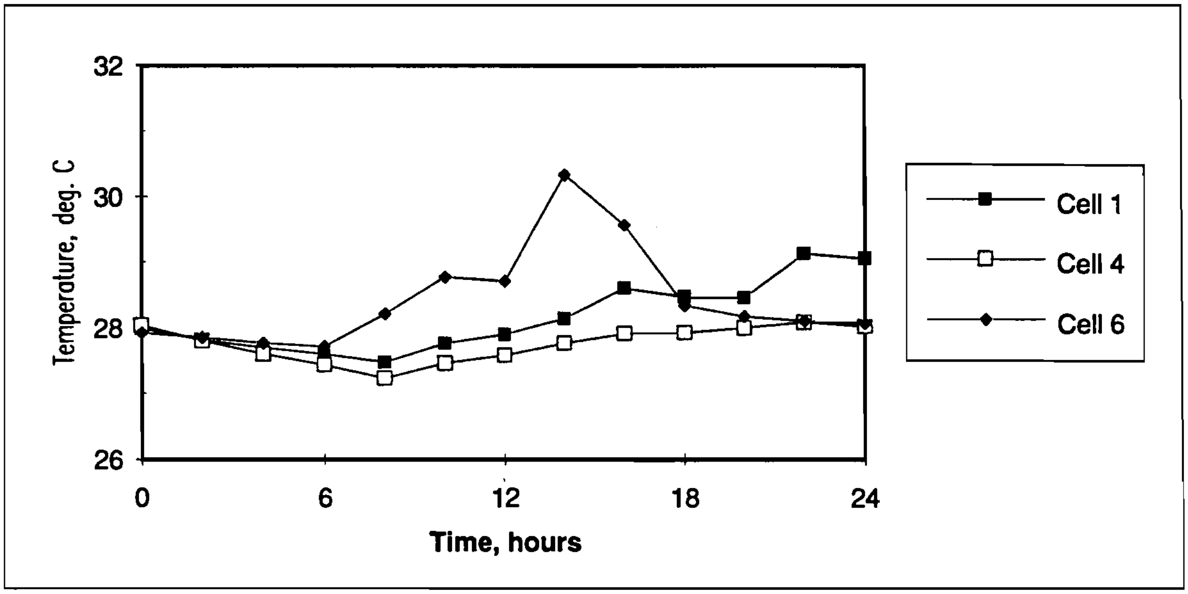


Fig. 20.17
Garage No. 20
Temperature comparison of air and floor sensors in 24 hr, period (winter)

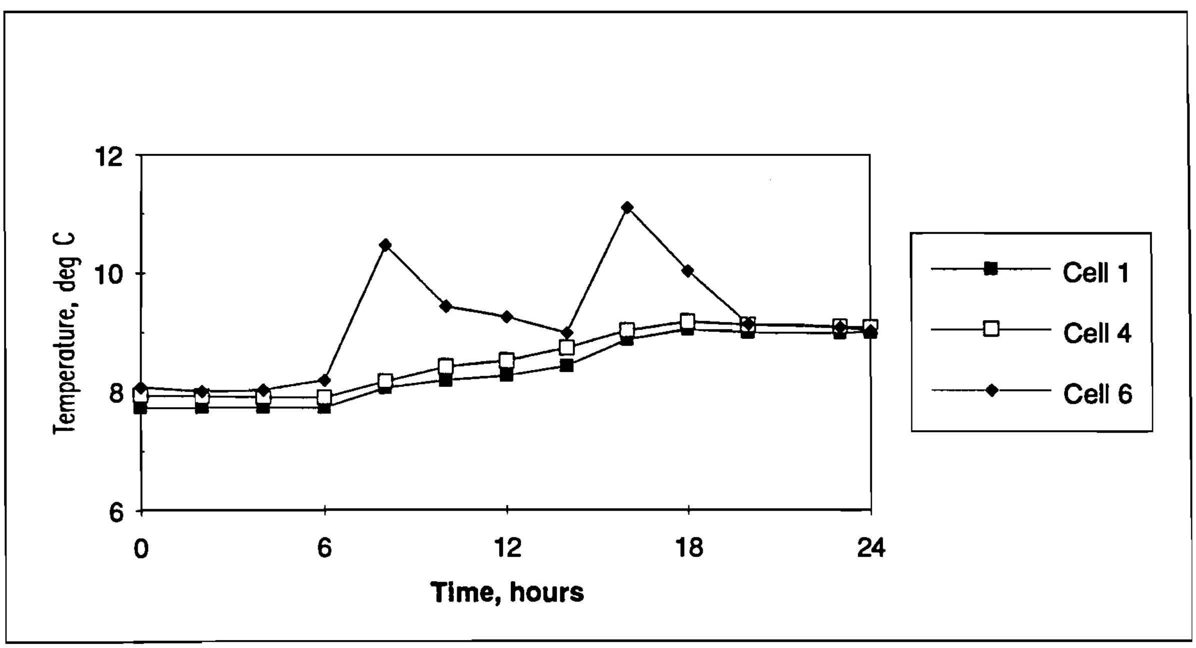


Table 20.5
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
30-Apr	22	21.6	21.9	22.3	21.4	22.4	63.04	71.52	73.92	98.32	75.04	45.12
1-May	20.9	21.2	21.4	21.1	21.1	21.2	60.72	69.20	69.84	98.16	73.84	28.40
1-May	21.0	21.0	21.2	20.7	21.2	21.4	59.84	67.76	65.60	98.08	72.96	23.04
2-May	20.7	20.6	20.9	20.2	20.9	20.8	58.64	66.32	63.36	98.16	71.84	23.84
2-May	21.4	21.0	21.2	20.9	21.2	21.7	58.32	65.76	62.40	98.00	71.28	18.56
3-May	20.9	20.9	21.1	20.5	20.9	20.9	57.44	65.04	61.68	98.16	70.72	26.88
3-May	21.4	21.1	21.3	20.8	21.3	21.6	57.28	64.88	62.72	98.16	70.56	23.52
4-May	20.9	21.0	21.2	20.5	20.9	20.9	56.40	64.08	60.40	98.08	69.84	26.32
4-May	20.4	20.7	21.0	20.2	20.7	20.8	56.16	63.84	61.28	98.08	69.60	35.12
5-May	20.2	20.7	20.8	20.0	20.5	20.5	56.08	63.84	61.60	98.08	69.44	35.68
5-May	20.1	20.6	20.6	19.9	20.3	20.4	56.00	63.60	60.08	98.08	69.20	31.20
6-May	19.9	20.4	20.6	19.8	20.2	20.3	55.68	63.28	59.92	98.08	68.88	34.40
6-May	21.4	20.9	21.0	20.8	20.7	21.4	56.16	63.28	58.72	98.08	68.96	24.16
7-May	20.6	20.7	20.8	20.2	20.4	20.5	55.36	62.80	57.84	98.00	68.56	32.24
7-May	20.5	20.3	20.5	19.9	20.5	20.3	55.60	62.80	60.80	97.92	68.80	39.36
8-May	20.0	20.2	20.4	19.6	20.2	20.3	55.44	62.88	58.16	97.92	68.56	38.96
8-May	22.2	21.2	21.3	21.1	20.8	21.1	57.28	64.24	63.20	98.16	69.20	59.84
9-May	21.1	21.0	21.3	20.8	20.7	20.9	57.36	64.96	65.36	98.08	69.76	54.16
9-May	22.3	21.4	21.7	22.6	21.5	21.5	58.56	65.76	65.76	98.40	70.64	66.56
10-May	21.4	21.0	21.2	21.3	21.3	21.2	58.24	65.84	64.80	98.08	70.72	41.36
10-May	20.2	20.4	20.6	20.9	21.0	20.7	57.52	65.36	64.88	98.16	70.48	30.24
11-May	20.1	20.4	20.6	20.4	20.7	20.6	56.56	64.16	57.20	98.00	69.44	30.56
11-May	20.4	20.6	20.8	20.7	20.5	20.5	56.24	63.52	55.84	98.08	68.80	31.04
12-May	20.0	20.3	20.5	19.9	20.3	20.3	55.60	62.72	55.20	97.92	68.16	36.08
12-May	20.1	20.1	20.2	19.5	20.1	20.2	55.76	62.72	56.96	97.84	68.08	38.80
13-May	19.7	20.1	20.3	19.4	19.9	20.0	55.60	62.72	57.68	97.84	68.00	40.16
13-May	20.5	20.6	20.8	21.0	20.3	20.7	56.08	63.04	58.56	98.08	68.24	26.88
14-May	20.6	20.6	20.8	20.6	20.3	20.5	55.60	62.48	55.84	97.84	67.84	37.84
14-May	21.4	20.5	20.7	21.1	20.8	20.8	56.64	63.20	61.76	97.92	68.64	47.28
15-May	20.8	20.8	21.0	20.5	20.7	20.8	56.48	63.60	60.64	97.76	68.56	46.00
15-May	21.0	20.8	21.1	21.3	21.0	21.0	56.56	63.52	60.32	97.92	68.72	30.32
16-May	20.7	20.9	21.1	20.5	20.8	20.9	55.76	62.64	55.68	97.68	68.00	39.84
16-May	19.9	18.8	19.0	20.0	20.6	20.5	56.88	63.28	65.04	97.60	68.80	62.32
17-May	19.9	19.9	20.1	19.8	20.4	20.4	57.36	64.64	66.72	97.60	68.96	51.44
17-May	20.3	19.8	20.1	20.8	20.4	20.5	58.00	65.20	67.76	97.68	69.36	39.36
18-May	20.2	20.3	20.5	20.1	20.3	20.4	57.36	64.56	61.52	97.60	68.88	38.72
18-May	20.6	20.5	20.7	20.1	20.2	20.4	57.28	64.00	58.40	97.60	68.40	39.68
19-May	20.4	20.4	20.6	19.8	20.1	20.3	56.80	63.60	57.76	97.52	68.16	40.56
19-May	20.1	20.3	20.6	19.9	20.0	20.2	56.40	63.28	57.44	97.52	67.92	41.52
20-May	19.7	20.1	20.3	19.5	19.9	20.0	56.24	62.96	58.32	97.44	67.76	42.24
20-May	19.3	19.7	19.9	19.1	19.7	19.8	55.84	62.56	56.96	97.28	67.52	40.72
21-May	19.3	19.8	20.0	19.0	19.5	19.7	55.84	62.48	57.12	97.28	67.28	40.24
21-May	20.2	19.8	20.0	20.0	19.7	19.8	56.32	62.64	58.96	97.36	67.52	34.88
22-May	19.5	19.7	20.0	19.5	19.6	19.8	55.68	62.16	55.60	97.20	67.12	39.28

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
22-May	19.5	19.7	19.9	19.6	19.8	19.9	55.60	62.08	58.24	97.20	67.20	36.88
23-May	19.4	19.8	20.0	19.4	19.6	19.8	55.76	62.24	57.92	97.12	67.12	43.76
23-May	20.4	20.4	20.6	20.3	20.0	20.5	56.40	62.72	59.52	97.20	67.44	39.28
24-May	20.3	20.4	20.6	19.9	20.0	20.3	56.40	62.80	59.36	97.12	67.44	46.64
24-May	21.2	20.8	21.1	20.8	20.6	20.9	57.12	63.12	59.12	97.28	67.92	38.40
25-May	21.1	20.9	21.2	20.9	20.6	20.8	56.64	62.96	58.64	97.20	67.68	45.76
25-May	20.8	21.0	21.2	20.9	20.6	20.8	56.64	63.04	60.00	97.20	67.76	43.76
26-May	20.7	21.0	21.2	20.5	20.5	20.7	56.40	62.88	59.28	97.04	67.68	43.28
26-May	20.6	21.0	21.2	20.3	20.5	20.8	56.56	62.88	59.12	97.04	67.60	44.00
27-May	20.6	21.0	21.2	20.3	20.5	20.8	56.56	62.80	59.52	96.96	67.52	45.44
27-May	22.1	21.9	22.1	21.6	21.1	21.8	57.36	63.44	58.72	97.20	68.08	38.16
28-May	21.5	21.7	21.8	21.1	21.1	21.4	56.48	62.56	56.72	96.96	67.68	32.00
28-May	22.0	21.5	21.8	21.1	21.4	21.6	56.08	61.92	54.80	96.96	67.52	31.20
29-May	21.3	21.5	21.7	20.8	21.3	21.4	55.12	61.28	53.04	96.88	66.88	28.88
29-May	21.8	21.7	21.9	21.9	21.6	21.8	54.72	60.64	50.88	96.96	66.64	17.36
30-May	21.4	21.6	21.8	21.2	21.5	21.6	53.76	59.76	48.96	96.80	65.92	25.52
30-May	22.2	22.2	22.4	21.9	22.0	22.2	54.00	59.92	51.36	96.96	66.00	27.52
31-May	22.0	22.2	22.4	21.7	21.9	22.0	53.76	59.68	50.96	96.80	65.84	32.00
31-May	24.1	23.0	23.2	23.5	22.7	22.9	54.72	60.08	51.68	97.12	66.32	30.16
1-Jun	23.0	22.9	23.0	22.5	22.6	22.7	54.00	59.92	53.12	96.80	66.08	35.68
1-Jun	23.8	23.0	23.2	22.4	22.6	22.7	55.28	60.24	56.24	96.80	66.08	42.64
2-Jun	23.4	23.1	23.3	22.5	22.7	22.8	55.60	61.44	60.56	96.80	66.88	57.84
2-Jun	23.1	23.1	23.3	22.5	22.7	22.8	56.40	62.56	63.20	96.80	67.68	53.36
3-Jun	22.8	23.0	23.2	22.3	22.7	22.8	56.64	62.96	63.76	96.80	68.00	51.76
3-Jun	23.1	23.0	23.2	23.0	22.9	23.0	56.40	62.48	59.28	96.88	68.00	29.76
4-Jun	22.5	22.7	22.9	22.3	22.7	22.7	55.20	61.12	55.28	96.64	67.12	31.76
4-Jun	23.7	22.9	23.1	22.6	23.0	23.1	55.04	60.40	52.56	96.56	66.72	24.96
5-Jun	22.7	22.7	22.9	22.3	22.8	22.8	54.08	59.84	52.16	96.48	66.16	32.48
5-Jun	22.9	22.6	22.8	23.3	22.9	22.9	54.80	60.56	57.68	96.80	66.56	44.56
6-Jun	22.6	22.7	22.9	22.6	22.7	22.8	55.12	61.12	59.20	96.40	66.64	48.16
6-Jun	23.6	23.4	23.5	23.9	23.3	23.4	55.60	61.44	57.20	96.64	67.12	35.12
7-Jun	23.2	23.2	23.4	23.2	23.3	23.3	55.20	61.04	56.16	96.40	66.88	40.40
7-Jun	24.2	23.8	24.0	24.4	23.7	23.8	55.92	61.28	56.64	96.64	67.12	36.88
8-Jun	23.8	23.7	23.9	23.6	23.7	23.7	55.52	61.28	56.88	96.32	67.04	43.52
8-Jun	23.6	23.7	23.9	23.4	23.6	23.6	55.68	61.52	58.96	96.48	67.12	48.32
9-Jun	23.4	23.6	23.8	23.5	23.5	23.5	56.16	62.08	60.88	96.24	67.44	50.64
9-Jun	23.3	23.4	23.6	23.3	23.4	23.4	56.80	62.48	61.92	96.24	67.68	50.88
10-Jun	23.2	23.4	23.6	22.8	23.2	23.3	56.72	62.64	62.08	96.16	67.68	49.12
10-Jun	23.9	23.8	24.0	24.9	23.6	23.8	57.04	62.64	60.24	96.48	68.00	37.12
11-Jun	23.6	23.7	23.9	23.5	23.6	23.7	56.56	62.08	58.24	96.16	67.60	40.40
11-Jun	25.3	24.4	24.6	24.3	24.2	24.4	56.72	61.76	56.80	96.08	67.60	33.28
12-Jun	24.5	24.3	24.4	24.0	24.2	24.3	56.00	61.44	57.28	96.08	67.28	39.84
12-Jun	25.1	24.7	24.8	24.9	24.7	24.8	56.72	62.08	59.44	96.16	67.84	43.76
13-Jun	24.7	24.6	24.8	24.3	24.6	24.9	56.96	62.32	60.08	96.00	67.84	48.64

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
13-Jun	26.2	25.6	25.8	26.0	25.3	25.5	58.64	64.16	64.48	96.32	69.20	63.12
14-Jun	25.5	25.4	25.6	25.3	25.3	25.6	59.28	65.04	66.48	96.16	69.84	61.60
14-Jun	26.7	26.0	26.2	26.3	26.0	26.0	60.64	66.48	68.56	96.40	71.04	63.60
15-Jun	26.0	25.8	26.1	25.6	25.9	25.8	60.88	67.04	69.44	96.24	71.36	63.28
15-Jun	25.7	25.8	25.3	24.8	25.7	25.7	61.12	67.20	69.36	96.00	71.52	59.28
16-Jun	25.5	25.7	25.4	24.5	25.5	25.6	61.44	67.44	70.16	96.08	71.60	60.24
16-Jun	25.5	25.7	25.7	24.7	25.3	25.5	61.68	67.60	70.40	96.08	71.68	63.28
17-Jun	25.8	25.9	26.0	25.7	25.5	28.3	62.56	68.24	71.12	96.40	72.08	57.20
17-Jun	26.8	26.4	26.6	26.5	25.9	26.3	62.88	68.56	70.96	96.48	72.64	52.32
18-Jun	26.6	26.4	26.5	26.3	26.0	27.5	62.64	68.08	69.52	96.48	72.40	51.68
18-Jun	26.7	26.2	26.4	26.3	26.1	26.3	61.84	67.28	67.92	96.32	72.08	44.96
19-Jun	26.3	26.1	26.3	25.9	26.1	27.4	61.60	66.72	64.88	96.24	71.68	46.64
19-Jun	26.2	25.8	26.1	25.9	26.0	26.0	61.04	66.16	64.24	96.00	71.28	47.92
20-Jun	26.2	25.8	26.1	25.6	26.0	27.2	61.28	66.16	63.52	96.00	71.12	52.64
20-Jun	26.7	25.2	25.5	25.2	25.9	25.8	61.90	66.24	66.00	95.84	71.20	53.12
21-Jun	26.3	25.7	26.0	25.8	25.9	27.1	61.75	66.64	65.20	96.00	71.20	51.04
21-Jun	27.4	26.2	26.4	26.4	26.1	26.2	62.06	66.80	65.76	96.00	71.44	50.00
22-Jun	26.4	26.1	26.3	25.8	26.1	26.1	61.58	66.72	65.52	95.92	71.36	53.12
22-Jun	26.7	26.1	26.3	26.2	26.0	26.0	61.98	66.64	66.08	95.92	71.28	52.48
23-Jun	26.0	25.9	26.1	25.7	25.9	25.8	61.58	66.64	66.00	95.76	71.28	54.16
23-Jun	25.4	25.6	25.8	25.1	25.7	25.6	61.58	66.64	66.48	95.68	71.28	55.20
24-Jun	25.4	25.6	25.8	25.0	25.6	25.5	61.82	66.72	66.40	95.60	71.28	54.00
24-Jun	25.3	25.5	25.7	24.8	25.4	25.5	61.73	66.56	65.92	95.60	71.12	50.00
25-Jun	25.8	25.6	25.7	25.4	25.4	27.4	61.92	66.40	64.96	95.60	70.96	46.72
25-Jun	26.3	26.0	26.1	26.3	25.8	25.9	61.82	66.32	64.64	95.92	71.12	51.44
26-Jun	26.6	26.0	26.1	25.9	25.9	27.0	62.15	66.24	64.88	95.60	71.04	45.76
26-Jun	26.5	25.9	26.1	25.9	26.1	26.1	61.34	65.76	63.28	95.52	70.96	43.04
27-Jun	25.8	25.7	25.9	25.9	26.0	27.6	60.32	64.72	58.64	95.52	70.24	34.96
27-Jun	26.1	25.6	25.8	25.9	26.0	26.3	59.42	63.52	56.56	95.28	69.44	39.84
28-Jun	25.7	25.6	25.8	26.0	25.9	26.4	59.03	63.12	56.40	95.44	68.96	37.76
28-Jun	24.6	24.8	25.0	25.0	25.7	25.3	58.16	62.72	58.56	94.96	68.80	44.56
29-Jun	24.7	25.0	25.3	24.6	25.3	25.1	58.48	63.04	59.04	94.96	68.64	44.80
29-Jun	24.8	25.1	25.2	25.4	25.1	25.1	58.56	63.04	59.44	95.04	68.48	47.20
30-Jun	24.7	25.0	25.1	24.7	24.9	25.0	58.64	63.12	60.56	94.80	68.48	48.80
30-Jun	25.3	25.1	25.3	25.2	24.8	25.0	59.28	63.36	61.52	94.80	68.56	49.52
1-Jul	24.9	25.0	25.2	24.6	24.8	24.9	59.12	63.52	61.92	94.72	68.72	49.04
1-Jul	24.8	25.0	25.2	24.5	24.7	24.9	58.96	63.28	61.20	94.64	68.64	46.48
2-Jul	26.5	25.3	25.6	25.2	25.1	26.4	59.92	63.60	60.40	94.64	68.72	46.08
2-Jul	26.3	25.6	25.8	25.4	25.4	25.6	59.84	63.92	62.40	94.72	69.28	49.92
3-Jul	26.5	26.0	26.3	26.5	26.0	27.2	60.00	64.32	62.32	94.96	69.52	47.04
3-Jul	26.6	26.3	26.5	26.6	26.2	26.2	61.12	65.68	66.32	94.96	70.48	66.48
4-Jul	27.2	26.4	26.6	26.6	26.5	27.6	61.68	66.16	65.84	94.88	70.88	47.36
4-Jul	26.7	26.2	26.4	26.2	26.5	26.4	59.76	64.08	59.60	94.56	69.84	32.24
5-Jul	26.7	26.2	26.4	26.7	26.5	27.4	58.96	63.04	56.96	94.56	68.96	34.72

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
6-Jul	26.1	25.9	26.1	25.9	26.2	26.2	57.92	62.00	55.04	94.24	68.24	33.20
6-Jul	25.8	25.9	26.1	25.4	26.0	26.0	57.36	61.44	55.04	94.16	67.68	35.04
7-Jul	25.6	25.8	25.4	25.1	25.8	25.8	56.96	60.96	55.04	94.00	67.20	35.60
7-Jul	25.5	25.8	25.8	25.0	25.6	25.7	56.96	60.88	56.80	94.00	67.04	39.20
8-Jul	25.5	25.8	25.9	25.0	25.5	25.7	57.12	61.04	58.80	93.92	67.04	51.68
8-Jul	27.5	26.3	26.4	25.8	25.8	26.7	59.28	62.72	63.68	94.08	68.00	55.92
9-Jul	26.6	26.3	26.5	25.8	25.9	26.1	58.56	62.72	62.00	94.00	68.32	47.28
9-Jul	27.6	26.6	26.8	26.5	26.2	27.2	59.20	62.96	59.76	94.08	68.48	43.92
10-Jul	26.8	26.5	26.7	26.3	26.4	26.5	58.00	62.00	57.60	93.92	68.24	37.28
10-Jul	27.0	26.7	26.9	27.5	26.7	27.5	58.00	61.84	57.36	94.08	68.00	39.92
11-Jul	27.0	26.6	26.8	26.7	26.6	26.7	57.20	61.04	55.60	93.76	67.60	37.52
11-Jul	27.0	26.8	27.0	26.7	26.8	27.9	57.36	61.44	57.20	93.68	67.60	42.32
12-Jul	26.6	26.5	26.7	26.8	26.7	26.7	57.20	61.28	57.28	93.68	67.60	39.76
12-Jul	27.5	26.8	26.9	26.8	26.9	27.7	57.44	61.12	56.40	93.60	67.44	35.92
13-Jul	27.1	26.8	27.0	26.5	26.7	26.8	56.80	60.64	55.12	93.44	67.04	38.40
13-Jul	26.6	26.7	26.9	26.1	26.5	26.6	56.56	60.48	55.84	93.36	66.88	38.80
14-Jul	26.5	26.7	26.9	26.1	26.5	26.5	56.48	60.40	57.36	93.20	66.72	43.76
14-Jul	26.5	26.7	26.9	26.0	26.5	26.5	57.04	60.96	59.68	93.28	67.12	51.36
15-Jul	26.5	26.7	27.0	26.1	26.4	26.5	57.92	61.84	62.24	93.28	67.68	58.24
15-Jul	27.6	27.1	27.4	27.2	26.6	27.2	59.44	63.28	65.12	93.60	68.56	57.52
16-Jul	27.1	27.0	27.2	26.8	26.6	26.7	59.12	63.20	64.08	93.52	68.80	52.80
16-Jul	28.3	27.2	27.4	27.4	27.0	27.8	60.24	63.84	64.32	93.68	69.28	51.12
17-Jul	27.6	27.2	27.4	27.1	27.1	27.1	59.92	64.00	64.72	93.52	69.52	54.40
17-Jul	27.9	27.6	27.8	28.8	27.5	29.2	60.56	64.80	65.28	94.08	70.00	47.92
18-Jul	27.9	27.6	27.8	28.1	27.5	27.6	60.56	64.72	65.60	93.68	70.08	55.92
18-Jul	28.4	27.9	28.1	28.2	27.9	29.2	60.88	65.12	64.16	93.60	70.40	44.96
19-Jul	29.2	28.0	28.2	28.2	27.9	28.0	60.56	64.24	62.88	93.52	70.00	43.84
19-Jul	28.6	26.9	27.1	27.8	28.0	28.3	61.28	64.80	67.76	93.52	70.48	70.80
20-Jul	27.6	26.8	27.0	27.1	27.7	27.6	61.44	66.00	69.04	93.36	70.88	59.68
20-Jul	27.3	27.2	27.4	26.9	27.4	27.4	61.44	66.16	68.24	93.44	70.88	50.72
21-Jul	27.2	27.1	27.3	26.8	27.2	27.2	61.12	65.60	67.04	93.28	70.48	53.52
21-Jul	27.0	27.0	27.2	26.6	27.1	27.1	61.04	65.52	67.12	93.12	70.32	51.84
22-Jul	26.9	27.0	27.2	26.5	26.9	27.0	61.04	65.36	66.80	93.12	70.16	55.20
22-Jul	27.4	26.6	27.0	26.8	27.2	28.2	62.24	66.40	69.76	93.28	70.96	61.12
23-Jul	27.0	26.7	26.9	26.4	26.9	26.9	62.16	66.48	69.28	93.12	71.04	58.40
23-Jul	27.4	27.2	27.3	27.2	27.3	29.0	62.56	67.04	69.04	93.36	71.36	54.08
24-Jul	27.2	27.1	27.3	26.9	27.1	27.1	62.40	66.64	68.24	93.20	71.20	55.68
24-Jul	29.5	27.7	27.8	28.1	27.6	28.2	63.68	66.96	66.00	93.52	71.44	50.72
25-Jul	27.9	27.3	27.5	27.2	27.4	27.4	61.84	65.92	65.76	93.12	70.88	47.92
25-Jul	28.7	27.9	28.2	28.3	28.0	28.7	62.08	66.00	62.72	93.36	71.04	45.20
26-Jul	28.0	27.7	28.0	27.7	27.8	27.7	61.44	65.36	64.32	93.04	70.64	50.72
26-Jul	28.7	28.1	28.4	28.4	28.2	28.5	61.84	65.68	63.12	93.12	70.80	49.36
27-Jul	28.3	28.1	28.4	28.0	28.1	28.1	61.44	65.36	64.32	92.96	70.64	52.32
27-Jul	28.0	28.0	28.3	28.1	27.9	27.9	61.52	65.52	64.72	93.04	70.64	50.32

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
28-Jul	27.8	28.0	28.2	27.7	27.8	27.8	61.52	65.36	65.12	92.80	70.48	52.80
28-Jul	27.8	27.9	28.2	27.4	27.7	27.8	61.76	65.52	65.84	92.80	70.64	53.52
29-Jul	27.7	27.8	28.1	27.3	27.7	27.7	61.76	65.44	66.24	92.64	70.64	53.76
29-Jul	29.1	28.4	28.8	29.1	28.3	28.6	62.64	66.08	63.44	93.12	71.20	48.96
30-Jul	28.5	28.4	28.7	28.3	28.3	28.2	61.84	65.44	64.64	92.72	70.80	51.52
30-Jul	28.9	28.4	28.7	28.5	28.5	28.6	62.08	65.44	64.16	92.72	70.96	44.96
31-Jul	27.9	27.9	28.2	27.7	28.2	28.0	60.64	64.16	61.68	92.32	70.00	41.28
31-Jul	28.1	27.8	28.1	28.9	28.3	28.3	60.00	62.96	54.80	92.48	69.36	29.84
1-Aug	27.7	27.4	27.7	27.6	28.1	27.8	59.04	62.16	58.08	91.92	68.56	41.36
1-Aug	28.6	27.9	28.1	27.9	28.6	29.6	59.44	62.72	58.56	91.92	68.80	39.52
2-Aug	28.5	27.8	28.0	27.8	28.2	28.0	59.36	62.48	59.20	91.84	68.56	45.28
2-Aug	29.1	28.2	28.5	29.0	28.5	28.5	59.44	62.56	56.24	92.08	68.64	40.08
3-Aug	28.4	28.0	28.3	28.1	28.3	28.2	59.04	62.24	59.84	91.76	68.40	44.72
3-Aug	28.1	28.0	28.2	28.1	28.2	28.1	59.04	62.32	60.64	91.76	68.40	45.44
4-Aug	27.9	27.9	28.2	27.7	28.0	28.0	58.96	62.24	61.44	91.60	68.24	46.72
4-Aug	27.8	27.8	28.0	27.7	27.9	27.8	59.28	62.56	62.96	91.60	68.40	50.00
5-Aug	27.7	27.6	27.9	27.4	27.7	27.7	59.76	63.04	64.64	91.52	68.64	53.76
5-Aug	28.8	27.9	28.1	27.7	27.8	27.9	60.32	63.44	64.16	91.68	68.96	47.36
6-Aug	27.7	27.5	27.7	27.2	27.7	27.6	59.68	63.12	64.24	91.44	68.80	50.56
6-Aug	28.5	27.8	28.1	28.7	27.9	28.0	60.16	63.44	62.08	91.84	69.04	47.52
7-Aug	27.6	27.4	27.6	27.4	27.7	27.5	59.68	63.12	63.44	91.36	68.80	48.48
7-Aug	28.1	27.6	27.8	28.2	27.8	27.9	59.60	62.80	60.40	91.44	68.64	38.56
8-Aug	27.5	27.3	27.5	27.2	27.6	27.5	58.64	61.84	60.32	90.96	68.00	41.52
8-Aug	29.2	28.0	28.1	28.1	28.1	28.4	59.28	62.16	59.84	91.12	68.16	43.68
9-Aug	28.1	27.6	27.8	28.2	27.9	27.8	58.64	61.84	60.96	91.04	67.92	44.00
9-Aug	29.0	28.0	28.2	29.0	28.3	28.3	59.20	62.16	60.56	91.12	68.16	41.92
10-Aug	28.3	27.7	27.9	27.8	28.1	27.9	58.72	62.00	61.76	90.72	68.00	48.56
10-Aug	27.8	27.6	27.5	27.4	27.9	27.8	58.80	62.16	61.76	90.64	68.08	46.24
11-Aug	27.6	27.6	27.6	27.1	27.8	27.7	58.72	62.16	62.48	90.56	68.00	48.48
11-Aug	27.3	27.4	27.6	27.1	27.6	27.5	58.80	62.24	62.40	90.56	68.00	45.52
12-Aug	27.0	27.1	27.3	26.7	27.4	27.2	58.40	61.68	61.92	90.40	67.60	44.24
12-Aug	25.1	24.3	24.8	25.3	26.8	26.4	58.40	61.68	65.04	90.00	67.76	53.44
13-Aug	25.5	25.6	25.9	25.3	26.4	26.2	58.96	62.64	65.12	90.16	67.68	52.88
13-Aug	26.8	26.4	26.8	27.0	26.5	26.7	59.36	62.72	62.32	90.72	67.68	43.92
14-Aug	26.5	26.3	26.6	26.3	26.4	26.5	58.80	62.08	61.92	90.24	67.36	45.28
14-Aug	27.4	26.2	26.6	27.5	26.7	26.5	59.36	62.24	62.72	90.48	67.68	56.56
15-Aug	25.4	24.7	25.2	25.4	26.0	25.3	58.80	62.24	64.40	89.92	67.68	55.52
15-Aug	25.9	25.2	25.6	25.5	25.9	25.8	59.68	63.28	65.68	90.16	68.00	57.20
16-Aug	25.6	25.1	25.3	25.2	25.6	25.6	59.84	63.52	66.40	90.16	68.08	58.00
16-Aug	26.4	26.3	26.6	26.2	26.0	26.4	61.20	65.12	69.28	90.64	68.88	73.60
17-Aug	26.2	26.3	26.6	26.0	26.0	26.2	61.76	65.76	69.52	90.72	69.52	65.20
17-Aug	26.1	26.2	26.5	25.9	26.0	26.2	61.84	65.76	68.24	90.80	69.76	57.12
18-Aug	25.6	25.7	26.0	25.1	25.9	25.9	61.36	64.96	66.80	90.40	69.52	46.40
18-Aug	25.2	25.3	25.6	24.8	25.6	25.7	60.00	63.36	59.12	90.08	68.48	37.84

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
19-Aug	25.0	25.2	25.4	24.7	25.4	25.4	59.20	62.32	58.96	89.76	67.60	39.60
19-Aug	25.3	24.6	24.9	24.5	25.1	25.2	58.56	61.12	56.72	89.52	66.80	37.60
20-Aug	24.6	24.5	24.8	24.1	24.9	25.0	58.00	60.88	56.72	89.28	66.32	42.64
20-Aug	25.0	24.4	24.8	24.3	24.8	25.0	57.84	60.56	56.40	89.20	66.08	42.88
21-Aug	24.4	24.4	24.7	24.1	24.7	24.7	57.92	60.96	60.16	89.20	66.24	48.32
21-Aug	25.3	24.8	25.2	25.3	24.9	25.1	58.48	61.20	59.60	89.52	66.32	48.48
22-Aug	25.0	24.9	25.2	24.9	24.9	25.0	58.72	61.84	62.24	89.36	66.64	55.84
22-Aug	25.4	25.5	25.8	26.0	25.4	25.7	59.28	62.48	62.24	89.84	67.28	50.72
23-Aug	25.4	25.4	25.7	25.4	25.5	25.5	59.36	62.48	63.20	89.60	67.44	53.68
23-Aug	25.9	25.7	26.0	26.1	25.8	26.0	59.60	62.64	61.20	89.76	67.60	48.32
24-Aug	26.1	25.9	26.2	25.9	25.8	25.9	59.92	63.04	62.88	89.68	67.84	55.68
24-Aug	26.0	26.0	26.3	25.7	25.8	25.9	60.24	63.28	63.20	89.68	68.00	52.72
25-Aug	25.9	26.1	26.4	25.9	25.8	26.0	60.40	63.52	63.84	89.68	68.16	57.12
25-Aug	26.0	26.2	26.5	25.7	25.8	26.0	60.72	63.84	64.48	89.68	68.40	57.12
26-Aug	26.0	26.2	26.6	25.7	25.9	26.1	61.28	64.40	65.84	89.76	68.88	61.20
26-Aug	27.3	26.8	27.1	26.6	26.4	26.8	62.16	65.12	66.16	90.16	69.60	50.72
27-Aug	26.8	26.7	27.0	26.5	26.4	26.7	61.84	64.96	65.84	90.16	69.60	56.24
27-Aug	28.4	27.3	27.6	27.7	27.0	27.2	62.56	65.28	65.52	90.48	69.92	61.92
28-Aug	27.3	27.0	27.4	26.9	27.0	27.0	62.00	65.28	65.52	90.16	69.84	57.20
28-Aug	26.8	26.9	27.3	27.2	27.0	26.9	60.88	64.00	59.44	90.00	69.28	35.04
29-Aug	26.8	26.9	27.2	26.8	26.9	26.9	60.16	62.96	57.60	89.52	68.40	42.08
29-Aug	26.6	26.5	27.0	27.1	26.9	26.9	59.28	61.92	55.12	89.36	67.84	34.56
30-Aug	26.6	26.6	27.0	26.7	26.8	26.8	58.88	61.44	55.44	88.96	67.20	42.24
3-Sep	25.5	25.4	25.7	25.2	25.5	25.6	56.72	59.04	55.04	87.68	65.12	43.76
4-Sep	25.5	24.8	25.1	25.4	25.6	26.7	57.20	59.28	59.68	87.76	65.28	55.52
4-Sep	25.3	25.0	25.4	25.4	25.6	25.7	57.84	60.48	61.12	88.00	65.92	53.60
5-Sep	25.5	25.3	25.7	25.3	25.6	26.8	58.32	61.04	60.72	88.00	66.32	49.52
5-Sep	25.7	25.4	25.8	25.4	25.7	26.0	58.96	61.76	63.20	88.16	66.80	57.84
6-Sep	26.0	25.7	26.1	25.7	25.9	27.5	59.52	62.56	64.48	88.40	67.20	50.56
6-Sep	25.2	25.0	25.4	25.2	25.7	25.5	57.52	60.16	52.64	87.68	66.08	28.80
7-Sep	24.7	24.9	25.2	24.6	25.3	25.3	56.32	58.80	49.44	87.04	64.88	30.24
7-Sep	24.2	24.5	24.8	24.2	25.0	24.9	55.36	57.84	48.48	86.64	64.24	30.40
8-Sep	24.2	24.5	24.8	24.1	24.7	24.8	55.12	57.44	48.96	86.64	63.60	33.44
8-Sep	24.6	24.7	25.1	24.4	24.7	25.2	55.28	57.60	51.28	86.48	63.60	41.12
9-Sep	24.8	24.6	24.9	25.3	24.8	25.4	55.68	57.92	54.56	86.88	63.84	46.64
9-Sep	24.5	24.1	24.5	25.2	24.7	24.7	56.56	58.96	59.68	87.20	64.64	56.80
10-Sep	24.1	23.2	23.6	24.2	24.4	24.3	56.24	58.40	55.60	86.72	64.40	35.52
10-Sep	23.2	22.8	23.2	23.2	24.1	23.6	54.72	57.12	53.20	85.92	63.52	38.56
11-Sep	22.1	21.9	22.3	22.6	23.5	23.2	54.08	56.56	53.60	85.76	62.88	37.44
11-Sep	22.9	23.0	23.4	23.3	23.3	23.4	55.28	57.92	58.88	86.16	63.12	58.32
12-Sep	23.2	23.1	23.5	24.2	23.8	24.2	55.92	58.80	59.68	86.72	63.92	48.80
19-Sep	18.7	18.2	18.8	18.4	18.5	18.5	51.84	54.32	54.64	83.52	59.52	44.08
20-Sep	18.9	18.1	18.5	18.5	18.4	18.7	52.40	54.56	55.92	83.68	59.60	46.88
20-Sep	18.6	18.0	18.4	18.7	18.2	18.2	52.08	54.48	55.12	83.84	59.60	49.20

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
21-Sep	17.8	18.0	18.5	17.9	18.0	18.1	52.48	55.36	59.68	83.68	59.92	63.28
21-Sep	17.5	17.8	18.2	17.6	17.8	17.8	53.28	56.48	62.80	83.92	60.72	57.20
22-Sep	17.2	17.5	18.0	17.2	17.5	17.5	53.44	56.40	60.64	83.84	60.72	53.92
22-Sep	17.0	17.1	17.6	17.0	17.3	17.2	53.44	56.32	59.44	83.92	60.72	43.76
23-Sep	16.9	16.7	17.2	17.1	17.1	17.3	52.72	55.20	54.72	83.76	60.08	41.36
24-Sep	16.1	16.1	16.7	16.4	16.6	16.6	52.72	55.36	57.84	83.36	59.92	52.64
24-Sep	17.3	16.9	19.6	18.8	17.3	19.9	53.68	56.40	65.12	84.24	60.64	56.80
25-Sep	17.0	17.2	18.2	17.7	17.3	17.4	54.08	56.96	60.32	84.40	61.04	56.96
25-Sep	17.5	16.6	17.1	17.5	17.3	18.3	54.96	57.36	62.64	84.40	61.52	64.72
26-Sep	17.1	17.0	17.5	17.2	17.3	17.3	55.60	58.64	64.88	84.56	62.08	67.76
30-Sep	16.7	16.4	16.8	16.9	16.8	16.8	56.64	59.44	62.16	85.04	63.04	40.40
30-Sep	15.9	16.0	16.5	16.4	16.5	16.4	56.00	58.88	61.52	84.72	62.56	54.72
1-Oct	16.5	15.9	16.3	16.7	16.6	17.3	56.40	59.28	63.28	84.72	62.64	47.12
1-Oct	16.0	15.3	15.8	15.7	16.2	16.2	55.76	58.48	59.20	84.32	62.24	43.60
2-Oct	15.1	15.2	15.4	15.8	16.2	16.7	54.96	58.16	59.84	83.60	61.92	50.48
2-Oct	16.2	15.9	16.2	16.2	16.2	16.6	56.16	59.04	62.40	84.08	62.16	56.64
3-Oct	17.4	16.9	17.1	17.0	17.0	18.5	57.20	60.00	65.84	84.56	62.72	69.68
3-Oct	17.3	16.7	17.0	17.2	17.0	17.2	57.92	61.04	66.40	85.12	63.68	57.84
4-Oct	17.6	17.2	17.4	17.9	17.5	19.4	58.00	60.96	64.64	85.36	63.76	40.88
4-Oct	18.2	17.8	18.2	17.9	17.5	18.0	57.20	60.16	59.36	85.20	63.36	44.40
5-Oct	17.8	17.8	18.1	17.6	17.6	17.9	57.04	60.08	62.00	85.12	63.28	60.24
5-Oct	19.0	18.4	18.7	18.0	17.7	18.2	58.48	61.28	65.68	85.52	63.84	69.36
6-Oct	18.3	18.2	18.4	17.8	17.8	18.1	58.32	61.60	65.60	85.52	64.40	54.88
6-Oct	17.7	18.1	18.3	17.9	17.8	18.0	57.84	61.04	61.60	85.60	64.16	48.88
7-Oct	17.5	17.7	18.0	17.4	17.7	17.9	57.44	60.48	60.88	85.20	63.92	47.20
7-Oct	17.1	17.6	17.9	17.0	17.5	17.8	56.96	60.00	58.32	84.96	63.52	45.84
8-Oct	16.5	15.1	15.4	16.3	17.3	16.9	56.40	58.56	60.64	84.40	63.36	53.76
9-Oct	15.5	15.6	15.9	15.6	16.8	16.6	56.24	59.28	60.72	84.16	62.88	47.44
9-Oct	15.0	14.4	14.6	15.3	16.4	16.0	55.68	58.64	61.04	83.92	62.64	47.20
10-Oct	14.0	14.6	14.8	14.4	15.7	15.6	55.76	59.12	63.52	83.52	62.32	59.92
10-Oct	15.8	15.6	15.9	15.7	15.9	16.8	57.68	60.64	65.44	84.40	62.88	82.88
11-Oct	15.5	15.7	16.0	16.1	15.8	16.2	58.40	61.76	66.48	84.80	63.60	74.56
11-Oct	16.7	16.3	16.7	16.2	16.3	17.3	59.44	62.48	66.88	85.12	64.32	62.96
12-Oct	16.2	16.4	16.7	16.0	16.3	16.7	59.12	62.56	67.12	85.20	64.48	65.68
12-Oct	16.6	16.6	17.0	16.2	16.4	16.9	59.84	62.96	67.60	85.36	64.72	82.80
13-Oct	16.3	16.5	16.9	16.4	16.3	16.8	60.32	63.76	68.40	85.68	65.36	77.76
13-Oct	16.2	16.8	16.9	16.4	16.3	16.8	60.64	64.24	69.04	85.76	65.68	70.96
14-Oct	16.4	17.0	17.2	16.7	16.4	16.9	60.88	64.32	69.52	86.08	65.84	65.20
14-Oct	18.8	17.7	18.0	18.0	17.2	18.9	61.92	64.56	69.60	86.64	66.32	51.36
15-Oct	17.8	17.6	17.9	17.6	17.4	17.7	60.56	63.60	67.36	86.48	66.08	47.84
15-Oct	18.9	18.1	18.4	18.6	18.0	18.3	59.76	62.40	63.92	86.72	65.52	35.60
16-Oct	17.8	17.9	18.2	17.8	17.9	18.2	58.40	61.28	62.56	86.00	64.72	42.32
16-Oct	17.6	17.2	17.6	18.0	18.0	18.1	58.40	61.28	64.32	85.92	64.72	57.28
17-Oct	17.3	17.4	17.7	17.4	17.8	18.3	58.64	61.44	64.32	85.84	64.64	54.88

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
17-Oct	18.3	17.7	18.0	18.4	18.2	18.3	59.84	62.56	66.64	86.32	65.36	66.16
18-Oct	18.0	17.9	18.2	17.9	18.2	19.3	59.84	62.56	64.64	86.24	65.28	47.60
18-Oct	17.1	16.8	17.1	17.4	18.1	17.9	57.76	60.72	58.48	85.60	64.56	27.52
19-Oct	16.7	16.9	17.1	16.8	17.7	17.5	56.56	59.36	56.16	84.88	63.36	26.08
19-Oct	16.3	16.7	16.9	16.2	17.3	17.1	55.52	58.16	50.32	84.08	62.40	27.52
20-Oct	15.9	16.2	16.4	15.7	16.8	16.8	54.80	57.28	52.08	83.68	61.52	30.56
20-Oct	16.0	16.5	16.7	16.2	16.6	16.8	54.80	57.20	52.40	83.84	61.12	42.16
21-Oct	16.7	16.9	17.2	16.5	16.6	19.4	55.92	57.92	57.44	83.92	61.36	50.32
21-Oct	17.9	17.5	17.8	17.6	17.2	17.7	56.24	58.40	56.48	84.48	61.92	41.92
22-Oct	16.9	16.9	17.2	16.9	17.2	18.6	55.28	57.60	53.84	84.00	61.76	34.96
22-Oct	15.6	15.9	16.2	15.9	17.0	16.8	54.00	56.48	50.56	83.12	61.20	35.20
23-Oct	16.1	16.6	17.0	16.1	16.8	18.1	54.24	56.64	51.04	83.12	60.72	36.56
23-Oct	16.8	17.2	17.5	16.8	17.0	17.4	54.24	56.40	49.28	83.20	60.64	33.52
24-Oct	17.5	17.1	17.4	17.0	17.2	19.2	54.32	55.68	50.00	82.96	60.40	38.64
24-Oct	15.4	15.4	15.7	16.6	17.0	16.1	53.36	55.68	55.60	82.80	60.64	58.96
25-Oct	14.6	14.7	15.1	15.2	16.5	16.1	52.80	55.28	50.40	82.00	60.32	25.36
25-Oct	13.5	14.3	14.7	14.0	15.8	15.5	51.76	54.24	44.72	81.20	59.20	24.96
26-Oct	14.3	15.2	15.5	14.5	15.4	15.5	51.68	53.84	42.88	81.12	58.40	25.44
26-Oct	14.9	15.7	16.0	14.9	15.3	15.8	51.60	53.52	43.12	81.04	57.92	28.40
27-Oct	15.0	15.6	15.8	15.0	15.3	15.7	51.44	53.28	48.08	80.96	57.84	36.56
27-Oct	15.0	15.4	15.6	15.0	15.3	15.6	51.76	53.60	51.44	81.04	58.00	40.40
28-Oct	14.9	14.9	15.1	14.7	15.2	16.9	51.68	53.04	48.72	80.80	57.92	37.12
28-Oct	14.1	14.4	14.7	14.4	15.2	15.3	50.80	52.72	45.84	80.40	57.84	29.36
29-Oct	14.2	14.6	14.8	14.3	15.1	16.9	50.40	52.40	47.60	80.08	57.44	34.08
29-Oct	14.5	14.7	15.0	14.4	15.4	15.5	51.12	52.88	50.80	80.32	57.76	40.88
30-Oct	15.8	15.4	15.7	15.7	15.6	16.6	52.00	53.44	52.40	80.96	57.92	42.32
30-Oct	15.3	15.5	15.8	15.6	15.6	15.9	51.68	53.68	49.68	81.04	58.24	36.72
31-Oct	15.8	15.4	15.7	15.7	15.9	16.9	51.68	53.28	49.68	80.80	58.08	35.04
31-Oct	15.4	15.7	15.9	15.5	15.9	16.1	51.52	53.44	49.04	80.80	58.24	35.92
1-Nov	15.5	15.9	16.2	16.4	16.1	17.0	51.36	53.36	50.56	81.12	58.08	39.04
1-Nov	16.4	16.8	17.1	16.8	16.3	17.0	52.56	54.56	54.80	81.52	58.72	50.00
2-Nov	16.4	16.9	17.2	16.4	16.4	16.9	53.04	55.12	56.56	81.52	59.12	53.52
2-Nov	16.6	17.0	17.4	17.3	16.6	17.0	53.68	55.84	59.28	82.16	59.68	59.12
3-Nov	16.6	17.0	17.2	16.8	16.6	17.0	54.32	56.48	60.32	82.24	60.24	57.76
3-Nov	16.4	16.6	16.8	16.6	16.6	16.9	54.24	56.40	59.44	82.24	60.40	40.00
4-Nov	16.2	16.0	16.3	16.4	16.8	17.7	53.12	55.04	53.52	81.44	59.92	29.04
4-Nov	14.8	14.4	14.7	14.9	16.3	16.1	52.48	54.16	56.16	80.72	59.44	64.00
5-Nov	15.6	14.7	15.0	15.4	16.1	16.7	54.08	55.60	61.20	81.28	59.84	72.72
5-Nov	14.6	14.4	14.7	14.6	15.6	15.6	53.84	56.08	59.44	81.20	60.00	46.40
6-Nov	14.8	14.3	14.6	14.4	15.5	15.8	53.12	55.28	54.88	80.72	59.52	26.48
6-Nov	13.9	14.0	14.4	13.9	15.1	15.1	52.16	54.40	50.08	80.32	58.72	34.24
7-Nov	14.4	14.2	14.5	14.4	14.9	15.7	52.08	54.00	52.00	80.24	58.24	29.04
7-Nov	13.3	13.4	13.8	13.3	14.4	14.6	51.12	53.28	47.60	79.68	57.84	30.48
8-Nov	13.5	13.4	13.7	13.4	14.2	15.3	50.88	52.88	48.08	79.36	57.28	31.20

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
8-Nov	12.5	12.4	12.9	12.6	13.8	13.9	50.08	52.08	47.20	78.96	56.88	37.68
9-Nov	12.8	13.3	13.6	12.8	13.5	13.8	50.56	52.72	51.12	79.12	56.72	43.92
9-Nov	13.7	13.4	13.8	13.0	13.4	13.7	51.28	52.88	50.80	79.36	56.80	40.88
10-Nov	12.8	13.2	13.5	12.8	13.3	13.5	50.32	52.40	45.36	79.12	56.64	26.08
10-Nov	12.5	13.0	13.4	12.6	13.1	13.3	49.84	51.76	46.24	78.72	56.16	29.44
11-Nov	12.3	12.5	12.5	12.6	12.9	13.1	49.12	50.88	44.40	78.56	55.68	25.28
11-Nov	10.7	12.3	12.4	11.9	12.6	12.7	47.84	50.24	41.52	77.76	55.12	21.92
12-Nov	11.0	11.8	11.8	12.2	12.5	13.3	47.60	49.60	43.92	77.84	54.72	34.72
12-Nov	12.1	11.9	12.1	11.8	12.2	12.5	48.56	49.84	43.52	77.68	54.72	27.36
13-Nov	12.6	12.0	12.2	11.8	12.4	13.4	48.48	49.52	43.68	77.36	54.48	27.68
13-Nov	11.9	12.0	12.4	11.8	12.3	12.6	48.08	49.52	43.92	77.44	54.48	33.84
14-Nov	12.6	12.5	12.8	12.9	12.8	14.0	48.64	50.08	50.96	77.92	54.80	47.44
15-Nov	13.6	13.5	13.7	14.1	13.4	13.8	50.40	52.08	57.20	79.52	56.16	57.68
15-Nov	14.7	14.1	14.4	15.1	14.3	15.4	51.84	53.44	60.32	80.80	57.20	64.64
16-Nov	14.6	14.4	14.7	14.8	14.5	14.8	52.56	54.64	61.92	80.80	58.24	58.24
16-Nov	13.6	13.8	14.0	13.8	14.4	14.8	52.00	54.24	60.16	80.32	58.32	64.08
17-Nov	12.8	13.5	13.5	13.0	14.0	14.0	52.08	54.40	60.48	80.16	58.32	47.20
17-Nov	12.8	13.3	13.5	12.6	13.6	13.7	51.60	53.52	54.08	79.76	57.84	30.72
18-Nov	12.8	13.3	13.6	12.6	13.4	13.5	50.96	52.80	49.12	79.52	57.12	29.84
18-Nov	12.9	12.9	13.3	12.9	13.4	14.2	50.64	52.16	50.24	79.36	56.80	37.04
19-Nov	13.4	13.3	13.6	13.2	13.3	13.7	50.64	52.08	47.92	79.44	56.56	33.60
19-Nov	13.8	13.9	14.1	14.3	13.6	14.6	50.72	52.32	51.36	79.84	56.64	41.20
20-Nov	13.6	13.8	14.1	13.7	13.7	14.1	50.72	52.40	50.08	79.68	56.80	36.72
20-Nov	13.9	13.4	13.6	14.0	14.0	14.6	50.48	51.92	49.04	79.52	56.80	31.76
21-Nov	13.0	13.1	13.4	13.1	13.7	13.9	49.92	51.60	47.76	78.96	56.48	33.84
21-Nov	12.4	12.1	12.3	12.8	13.6	13.9	49.92	51.44	55.04	78.88	56.48	53.20
22-Nov	12.5	12.7	12.9	12.6	13.4	13.6	50.64	52.56	56.64	78.96	56.72	54.00
22-Nov	13.6	13.1	13.4	14.0	13.7	14.5	52.16	53.84	60.48	80.40	57.52	67.60
23-Nov	13.6	13.6	13.8	13.9	13.8	14.1	52.56	54.64	60.32	80.40	58.08	53.12
23-Nov	13.0	13.3	13.5	13.2	13.6	13.9	51.92	54.24	54.88	80.00	58.08	34.16
24-Nov	12.4	12.9	13.1	12.5	13.3	13.5	51.28	53.52	52.80	79.44	57.44	38.40
25-Nov	11.9	12.1	12.0	11.7	12.6	12.9	50.80	52.72	53.76	78.72	56.72	35.60
25-Nov	12.0	11.9	12.1	11.8	12.6	13.2	50.32	52.24	49.44	78.56	56.48	28.08
26-Nov	11.0	11.6	11.5	11.6	12.4	12.5	49.84	51.92	51.20	78.32	56.16	39.92
26-Nov	11.4	11.4	11.6	11.3	12.3	13.1	50.72	52.64	58.16	78.40	56.40	72.88
27-Nov	11.6	11.6	11.8	11.6	12.1	12.6	51.84	53.92	60.96	79.04	57.04	67.12
27-Nov	13.6	13.1	13.3	13.1	12.8	15.6	53.84	55.84	62.72	80.16	58.16	70.16
28-Nov	13.6	13.8	13.9	13.5	13.2	14.0	54.32	56.88	63.36	80.80	59.12	55.12
28-Nov	14.7	14.2	14.4	14.1	13.9	16.2	54.64	56.88	61.76	81.12	59.52	42.80
29-Nov	14.1	13.7	13.9	14.0	13.9	14.4	53.36	55.52	58.48	80.96	58.96	32.48
29-Nov	14.7	13.9	14.1	13.8	14.1	15.5	52.88	54.80	53.20	80.56	58.48	27.04
30-Nov	14.0	13.9	14.2	14.0	14.0	14.4	52.00	54.16	52.32	80.40	58.00	30.32
30-Nov	13.4	13.6	13.2	13.4	13.9	14.2	51.36	53.52	51.12	79.84	57.52	39.44
1-Dec	13.6	13.4	13.1	13.2	13.6	13.9	51.52	53.44	53.36	79.68	57.36	39.44

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
1-Dec	12.8	13.0	13.1	12.6	13.4	13.6	50.72	52.80	46.48	79.04	57.04	23.52
2-Dec	12.1	12.5	12.6	12.1	13.0	13.2	49.68	51.76	46.48	78.32	56.16	23.60
2-Dec	11.2	11.3	11.5	11.3	12.7	12.4	48.40	50.40	42.96	77.44	55.60	23.52
3-Dec	9.5	11.0	11.2	10.5	12.1	12.0	47.84	50.48	48.24	77.12	55.12	35.04
3-Dec	9.4	10.4	10.8	10.1	11.5	12.2	49.04	51.28	57.04	77.12	55.28	65.28
4-Dec	10.3	11.0	11.3	10.6	11.1	11.5	50.72	52.96	60.56	78.00	56.00	75.92
4-Dec	10.3	10.8	11.0	11.0	11.2	12.8	51.44	53.84	60.16	78.56	56.72	38.88
5-Dec	10.7	11.6	11.4	11.3	11.7	13.0	50.80	53.52	56.32	78.40	56.72	30.80
5-Dec	12.8	12.8	12.7	12.5	12.5	14.5	51.92	53.84	57.36	79.20	56.96	39.92
6-Dec	13.7	14.3	13.7	13.6	13.2	14.6	52.00	54.16	53.76	79.76	57.20	32.88
6-Dec	14.4	14.2	14.0	14.8	13.9	15.1	52.00	53.76	52.16	80.32	57.44	34.56
7-Dec	14.0	14.2	14.3	13.9	13.8	14.4	51.60	53.44	53.60	79.68	57.20	35.92
7-Dec	13.1	13.5	13.6	13.0	13.7	14.4	51.28	53.28	56.24	79.20	57.20	44.48
8-Dec	13.3	13.6	13.7	13.0	13.5	13.9	51.44	53.28	56.64	79.20	57.12	38.72
8-Dec	13.2	13.6	13.8	13.0	13.4	13.9	51.12	52.96	52.40	79.04	56.80	38.72
9-Dec	13.2	13.5	13.6	12.9	13.3	13.8	51.04	52.80	55.12	78.88	56.72	40.16
9-Dec	14.4	14.1	14.2	14.8	13.9	14.6	51.36	53.04	50.56	80.00	56.96	23.68
10-Dec	13.6	13.9	14.0	13.6	13.7	14.0	50.24	51.92	51.12	78.72	56.40	20.80
10-Dec	13.2	13.6	13.8	13.4	13.6	14.1	49.20	50.96	41.52	78.08	55.76	19.04
11-Dec	13.0	13.6	13.8	12.9	13.4	13.7	48.80	50.40	47.12	77.52	55.12	21.92
11-Dec	13.6	13.7	13.8	13.3	13.6	14.5	48.56	50.08	41.76	77.20	54.96	24.32
12-Dec	13.2	13.6	13.4	13.0	13.4	13.8	48.32	49.84	47.44	77.04	54.72	30.16
12-Dec	14.1	13.7	13.8	14.0	14.0	14.8	49.12	50.40	47.76	77.76	55.36	20.80
13-Dec	12.9	13.1	13.2	12.8	13.7	13.6	47.76	49.28	45.20	76.80	54.72	15.20
13-Dec	11.0	11.4	11.6	11.1	12.9	12.6	46.08	47.84	39.44	75.52	53.84	17.28
14-Dec	11.3	11.8	12.1	11.3	12.4	12.6	46.08	47.68	43.60	75.44	53.12	18.80
14-Dec	11.4	12.0	12.3	11.3	12.2	12.5	46.08	47.68	43.20	75.44	52.80	34.32
15-Dec	11.6	12.1	12.3	11.4	12.0	12.4	46.32	47.76	46.40	75.52	52.80	27.92
15-Dec	10.8	12.0	11.5	10.3	11.8	12.3	45.76	47.68	43.36	95.52	52.72	31.28
16-Dec	10.8	11.8	11.0	10.2	11.7	12.2	45.76	47.60	44.72	95.84	52.64	27.12
16-Dec	11.3	10.9	10.9	10.8	11.9	13.3	46.64	47.84	51.60	95.92	53.12	35.52
17-Dec	10.9	11.3	11.5	10.8	11.5	11.9	47.12	48.80	53.92	96.08	53.44	41.04
17-Dec	12.0	10.6	10.7	10.6	11.7	12.9	48.88	49.60	58.64	96.00	54.08	58.24
18-Dec	10.9	10.8	11.0	10.5	11.3	11.8	48.96	50.88	60.16	96.16	54.72	67.20
18-Dec	11.6	10.9	10.8	10.7	12.0	13.8	48.96	50.80	53.84	95.84	55.20	27.04
19-Dec	11.0	11.9	11.7	11.0	12.0	12.5	48.00	50.56	49.68	96.00	54.88	27.60
19-Dec	10.2	10.5	10.5	10.8	11.7	11.5	47.20	49.60	48.08	90.88	54.48	45.60
20-Dec	9.5	10.5	10.3	10.1	11.1	10.9	46.96	49.52	52.24	92.24	53.92	44.88
20-Dec	11.3	11.0	10.9	10.7	11.4	12.4	48.40	50.32	55.84	92.32	54.24	54.08
21-Dec	10.4	10.5	10.4	10.3	11.1	11.1	48.32	50.40	57.36	92.96	54.32	57.52
21-Dec	10.0	10.3	9.8	10.0	10.8	10.8	48.40	50.56	58.16	92.96	54.32	59.52
22-Dec	10.2	10.6	10.3	10.0	10.7	10.8	48.88	51.04	59.20	92.96	54.48	63.12
22-Dec	9.5	9.6	9.5	9.5	10.3	10.1	48.64	50.72	58.56	93.04	54.48	54.96
23-Dec	9.1	9.2	9.1	9.1	9.9	10.2	48.08	50.24	57.04	93.04	54.16	40.96

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1990	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
23-Dec	8.0	7.0	7.0	8.1	10.1	10.3	47.20	49.12	55.04	91.68	54.16	42.16
24-Dec	7.7	8.1	8.0	7.6	9.3	9.2	47.36	49.92	56.72	91.52	53.60	40.56
24-Dec	7.9	8.4	8.3	7.8	8.8	9.1	47.28	49.76	56.88	91.60	53.04	43.12
25-Dec	8.5	9.0	8.9	8.4	8.7	9.1	47.52	49.84	56.88	91.92	52.88	36.80
25-Dec	7.7	8.3	8.4	7.8	8.5	8.6	46.48	48.88	52.56	91.92	52.48	27.28
26-Dec	7.3	7.9	7.9	7.4	8.2	9.0	45.68	48.00	50.88	91.92	52.00	32.72
26-Dec	7.3	7.5	7.4	7.7	9.3	11.0	45.36	47.84	50.00	91.04	52.48	33.60
27-Dec	7.2	7.9	7.7	7.4	8.5	8.5	45.84	48.24	53.20	91.76	52.00	34.00
27-Dec	7.8	8.0	7.9	8.1	8.7	9.0	46.32	48.56	54.00	91.84	52.16	43.04
28-Dec	8.2	8.6	8.1	8.2	8.6	8.9	46.72	48.96	55.44	92.16	52.08	48.08
28-Dec	8.9	9.4	9.1	8.9	8.8	9.4	47.92	50.16	58.72	92.40	52.72	78.00
29-Dec	9.1	9.6	9.3	9.0	9.0	9.7	48.88	51.20	60.40	92.48	53.52	74.48
29-Dec	9.2	9.6	9.1	9.0	9.2	9.5	49.28	51.60	61.92	92.56	54.08	52.88
30-Dec	8.6	9.0	7.8	8.3	9.1	9.1	48.24	50.48	61.68	91.12	53.76	31.20
30-Dec	7.5	7.2	6.8	7.8	9.0	9.8	47.20	49.28	60.32	90.64	53.52	34.00
31-Dec	7.3	7.4	7.2	7.2	8.3	8.3	47.12	49.44	62.56	91.36	52.96	31.04
31-Dec	7.4	8.0	7.8	7.4	7.9	8.2	46.72	49.20	63.60	91.68	52.32	30.96

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
1-Jan	8.1	8.8	8.8	8.0	7.9	8.4	46.96	49.28	65.12	91.92	52.08	40.88
1-Jan	9.0	8.7	8.9	8.6	8.5	10.5	47.52	49.36	66.56	91.76	52.48	41.76
2-Jan	8.5	8.8	8.9	8.2	8.6	8.7	46.72	48.96	66.96	91.92	52.40	20.24
2-Jan	7.3	8.1	8.2	7.8	8.7	9.8	45.20	47.84	66.64	91.44	52.00	29.36
3-Jan	8.5	9.5	9.5	8.6	9.0	10.0	46.16	48.64	67.60	91.76	52.08	30.80
3-Jan	8.9	9.8	9.8	9.0	9.5	10.6	46.16	48.56	67.04	91.76	52.24	30.00
4-Jan	9.1	9.9	9.9	9.5	9.4	9.7	46.16	48.32	68.64	92.24	52.08	26.96
4-Jan	8.8	9.4	9.4	8.9	9.3	9.4	45.60	47.60	68.88	92.16	51.68	29.20
5-Jan	8.7	9.3	9.4	8.7	9.1	9.3	45.52	47.44	69.20	92.24	51.52	36.32
5-Jan	8.3	8.8	8.8	8.2	8.9	9.0	45.12	47.04	68.72	92.16	51.36	33.60
6-Jan	7.4	8.6	7.8	8.8	8.6	8.6	44.40	46.80	67.84	88.80	51.04	26.16
6-Jan	6.2	6.5	6.4	6.8	8.6	9.1	43.28	45.44	64.88	84.40	50.80	28.00
7-Jan	6.2	7.2	7.0	6.5	8.1	7.4	43.60	45.92	65.76	86.56	50.64	23.76
7-Jan	5.9	6.9	6.7	6.9	8.5	10.7	42.72	45.44	61.44	86.40	50.40	24.64
8-Jan	8.4	9.8	9.6	8.5	9.3	11.5	44.88	47.52	64.32	89.84	51.28	28.40
8-Jan	9.2	9.5	9.3	9.2	10.1	12.6	44.96	46.96	60.16	87.12	51.52	39.76
9-Jan	10.9	11.5	11.2	10.5	11.1	13.4	46.48	48.56	59.92	89.76	52.32	33.76
9-Jan	10.7	9.9	9.8	10.5	11.7	13.4	46.16	47.44	57.12	89.84	52.80	35.84
10-Jan	9.4	9.1	9.0	9.5	11.1	10.6	46.40	48.00	65.60	93.28	52.88	47.44
10-Jan	7.4	6.7	6.8	7.6	10.0	10.0	44.72	46.24	62.64	89.84	51.92	31.84
11-Jan	7.2	7.5	7.5	7.3	9.2	8.6	44.88	46.88	65.44	90.24	51.36	40.08
11-Jan	7.1	7.7	7.6	7.1	8.5	8.3	44.64	46.80	67.28	90.16	50.80	37.12
12-Jan	7.4	8.0	8.0	7.3	8.2	8.1	45.04	47.28	69.20	89.76	50.72	36.00
12-Jan	7.3	7.8	7.4	7.2	7.9	7.9	44.64	46.80	69.36	92.08	50.32	29.28
13-Jan	7.2	7.8	7.0	6.5	7.7	7.8	44.32	46.40	69.76	92.32	50.00	28.00
13-Jan	6.7	6.7	6.6	6.6	7.6	7.7	44.24	46.08	70.24	92.08	50.00	72.08
14-Jan	5.7	6.1	6.0	6.2	7.2	6.8	44.48	46.56	70.72	92.08	50.40	60.88
14-Jan	6.2	6.6	6.7	7.1	7.1	8.7	45.60	47.68	71.20	93.52	50.88	81.12
15-Jan	7.7	8.3	8.5	7.9	7.6	8.0	47.36	49.68	72.32	93.68	51.92	75.44
15-Jan	8.4	8.4	8.6	8.7	8.2	9.0	48.32	50.48	72.00	93.52	52.80	75.60
16-Jan	9.0	9.3	9.4	9.1	8.5	9.0	49.20	51.68	72.88	93.60	53.60	73.12
16-Jan	9.6	9.6	9.8	10.6	9.2	10.0	50.16	52.56	73.04	93.76	54.48	75.92
17-Jan	9.7	9.9	9.8	9.8	9.4	9.6	50.24	52.88	73.60	93.60	54.80	60.48
17-Jan	10.9	9.7	9.8	10.6	9.7	10.4	50.96	52.88	73.60	93.68	55.20	64.72
18-Jan	9.9	10.1	10.1	10.1	9.8	10.0	49.60	52.40	74.48	93.60	54.96	32.32
18-Jan	9.5	10.0	10.1	9.5	9.6	9.7	48.56	51.36	74.72	93.52	54.16	27.28
19-Jan	9.3	10.0	10.2	9.3	9.5	9.6	48.00	50.56	75.12	93.44	53.52	39.52
19-Jan	9.4	9.9	9.3	9.6	9.4	9.5	47.84	50.24	74.40	93.84	53.28	25.92
20-Jan	8.8	9.3	8.1	8.0	9.2	9.1	46.80	49.12	74.24	93.52	52.64	17.36
20-Jan	7.1	7.3	7.2	6.9	8.6	8.8	45.52	47.60	74.08	93.28	51.92	28.56
21-Jan	7.0	7.7	7.8	6.8	8.1	7.8	45.20	47.60	74.80	93.28	51.44	23.60
21-Jan	6.0	7.2	7.2	6.2	7.7	8.2	44.00	46.80	73.92	92.80	50.88	25.20
22-Jan	5.6	7.0	7.0	6.0	7.3	7.8	43.92	46.64	74.00	92.80	50.48	27.20
22-Jan	6.9	8.0	8.0	6.9	7.4	9.6	44.88	47.20	74.40	92.88	50.40	42.08

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
23-Jan	8.1	8.9	8.9	7.9	7.6	8.3	46.24	48.32	75.36	93.20	51.04	47.04
23-Jan	7.8	8.0	8.1	8.1	8.1	10.2	46.08	48.24	74.32	93.04	51.60	32.80
24-Jan	7.3	7.9	8.0	7.8	7.6	8.1	46.08	48.40	75.04	93.28	51.60	41.60
24-Jan	7.6	8.3	8.2	8.5	8.3	10.4	45.84	48.40	74.32	92.96	51.76	29.60
25-Jan	7.8	8.8	8.7	8.1	7.9	8.3	46.16	48.56	75.76	93.36	51.60	32.88
25-Jan	8.1	8.9	9.0	8.0	7.9	8.3	46.00	48.32	75.76	93.36	51.28	48.88
26-Jan	8.5	9.2	9.2	8.3	8.0	8.5	46.64	48.72	76.00	93.44	51.52	47.68
26-Jan	8.8	9.4	9.1	8.1	8.2	8.7	46.80	48.88	75.76	93.68	51.76	43.84
27-Jan	8.7	9.6	9.1	8.1	8.4	9.3	46.64	48.96	75.84	93.84	51.92	45.92
27-Jan	9.6	9.9	9.8	10.1	9.0	11.2	47.68	49.68	75.68	94.00	52.64	42.40
28-Jan	9.3	10.0	10.0	9.5	9.0	9.5	47.68	50.00	76.56	94.00	52.88	41.12
28-Jan	9.4	9.8	9.8	9.9	9.6	10.8	46.88	49.12	75.20	93.60	52.96	29.44
29-Jan	8.5	9.1	9.1	8.6	9.0	9.2	46.48	48.64	76.24	93.68	52.40	30.08
29-Jan	9.5	9.6	9.5	9.6	9.6	11.0	47.28	49.36	75.68	93.76	52.88	46.48
30-Jan	8.7	8.9	8.9	8.8	9.1	9.3	47.60	49.76	76.40	94.00	53.04	60.32
30-Jan	8.7	8.7	8.7	9.2	9.5	10.0	47.52	50.00	75.44	93.68	53.52	45.68
31-Jan	8.2	8.7	8.4	8.3	9.0	9.0	47.68	50.32	76.56	93.84	53.36	46.80
31-Jan	9.0	9.0	8.9	9.1	9.3	10.0	47.76	50.32	76.32	93.68	53.36	27.04
1-Feb	8.5	9.0	8.9	8.3	8.8	8.8	47.20	49.76	77.28	93.84	52.88	28.80
1-Feb	8.5	9.1	9.2	8.4	8.6	8.8	46.80	49.28	77.44	93.92	52.32	36.64
2-Feb	8.6	9.1	9.1	8.4	8.6	8.8	46.88	49.20	77.60	93.84	52.24	45.36
2-Feb	8.8	9.3	9.4	9.2	8.6	9.0	47.20	49.44	77.68	94.16	52.32	53.12
3-Feb	8.9	9.3	9.3	9.2	8.6	9.0	47.52	49.68	77.68	94.00	52.56	54.24
3-Feb	10.4	10.5	10.5	11.0	9.7	10.9	48.96	51.20	77.60	94.08	53.68	53.92
4-Feb	10.2	10.4	10.4	10.3	9.7	10.0	49.28	51.60	78.24	94.16	54.16	64.56
11-Feb	10.5	10.9	11.1	10.3	10.9	11.0	46.32	48.32	77.60	93.92	52.32	19.84
12-Feb	10.3	10.8	10.9	10.2	10.6	10.4	45.84	47.68	77.28	94.08	51.84	36.24
12-Feb	10.6	10.8	10.8	11.5	10.9	11.1	46.88	48.88	77.52	94.24	52.56	50.24
13-Feb	10.0	10.4	10.4	10.5	10.6	10.9	46.96	49.04	77.36	94.32	52.80	63.52
13-Feb	10.6	10.3	10.3	11.0	10.8	10.9	48.24	50.16	77.52	94.24	53.52	59.36
14-Feb	10.3	10.0	9.9	10.1	10.5	10.8	48.72	50.64	77.12	94.16	53.84	73.28
14-Feb	8.7	8.8	8.7	9.2	10.3	10.1	48.16	50.80	76.72	94.08	54.32	60.08
15-Feb	8.2	8.6	8.3	8.6	9.6	9.4	48.32	51.12	76.96	94.08	54.08	58.08
15-Feb	8.4	8.9	8.5	8.4	9.2	9.2	48.64	51.28	76.88	94.24	54.00	45.68
16-Feb	8.7	9.0	8.4	8.1	8.9	9.1	48.56	51.20	76.96	94.40	53.76	48.00
16-Feb	8.7	8.9	8.3	6.7	8.7	8.9	48.16	50.80	76.96	94.40	53.44	33.92
17-Feb	8.3	8.3	7.5	6.6	8.5	8.4	47.28	49.68	76.16	94.48	52.88	43.44
17-Feb	8.1	8.3	8.2	7.2	8.6	8.8	47.44	50.24	76.72	94.48	53.04	54.32
18-Feb	8.0	8.4	8.3	7.7	8.3	9.1	47.84	50.64	76.64	94.56	53.04	73.20
18-Feb	8.8	8.6	8.6	8.6	8.9	9.2	49.12	51.84	76.72	94.48	54.08	74.00
19-Feb	8.6	8.6	8.7	8.4	8.7	10.6	49.76	52.56	77.04	94.64	54.48	84.40
19-Feb	9.8	9.8	9.9	9.9	9.6	10.2	50.96	54.16	76.96	94.64	55.84	76.88
20-Feb	9.5	9.7	9.8	9.6	9.6	11.5	51.44	54.40	77.28	94.88	56.00	81.92
20-Feb	11.0	10.8	10.9	11.0	10.6	11.2	52.72	55.76	77.52	94.80	57.20	76.48

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
21-Feb	10.5	10.6	10.6	10.4	10.5	11.6	53.04	56.08	78.24	94.88	57.44	85.68
21-Feb	11.1	10.3	10.2	10.9	11.1	11.2	53.44	56.32	77.68	94.80	58.24	60.32
22-Feb	9.8	10.0	9.9	9.5	10.6	10.4	52.24	55.52	78.72	94.72	57.52	36.64
22-Feb	9.7	10.2	10.2	9.4	10.3	10.2	51.28	54.56	78.96	94.72	56.56	29.52
23-Feb	9.5	10.0	9.9	9.2	10.0	10.0	50.40	53.36	79.12	94.72	55.68	27.36
23-Feb	9.5	9.9	10.1	9.7	9.8	9.9	49.84	52.64	79.12	94.80	55.04	34.88
24-Feb	9.2	9.5	9.6	9.0	9.6	9.7	49.28	51.76	78.80	94.64	54.56	43.36
24-Feb	9.3	9.8	9.7	9.8	9.8	10.0	49.20	52.24	79.04	94.72	54.64	34.80
25-Feb	8.9	9.6	9.6	9.1	9.5	10.0	48.88	51.68	79.12	94.72	54.24	38.72
25-Feb	9.9	10.5	10.6	9.8	9.9	10.1	49.28	51.92	79.36	94.64	54.32	31.68
26-Feb	9.7	10.1	10.1	9.5	9.7	10.2	48.80	51.04	78.88	94.64	53.92	45.36
26-Feb	10.6	10.7	10.7	10.7	10.3	10.7	49.36	51.68	79.12	94.72	54.32	35.28
27-Feb	10.3	10.6	10.7	10.2	10.2	10.6	48.88	51.20	79.12	94.80	54.08	44.24
27-Feb	11.1	11.6	11.6	11.7	11.0	12.9	49.20	51.68	78.88	94.80	54.40	35.36
28-Feb	11.0	11.5	11.5	11.0	10.9	11.1	49.28	51.52	79.36	94.88	54.40	39.84
28-Feb	11.9	12.0	11.9	12.3	11.8	13.6	50.00	52.32	78.48	94.80	55.04	43.60
1-Mar	11.7	12.0	12.0	12.4	11.6	11.8	50.24	52.48	79.28	95.12	55.20	48.96
1-Mar	11.7	11.9	12.0	11.7	11.5	11.7	50.64	52.88	79.12	94.96	55.36	70.16
2-Mar	11.4	11.6	11.7	11.4	11.5	11.4	50.96	53.28	79.12	94.88	55.84	52.72
2-Mar	10.4	11.4	11.4	11.7	11.3	11.3	49.92	52.80	78.72	94.96	55.60	40.24
3-Mar	9.8	11.2	11.2	11.0	11.1	11.1	49.44	52.32	78.72	94.80	55.12	45.60
3-Mar	10.7	10.8	10.9	10.7	11.2	12.5	50.72	53.04	78.00	94.64	55.68	52.88
4-Mar	10.1	10.5	10.5	10.2	10.6	10.8	51.20	53.84	78.56	94.80	56.00	73.20
4-Mar	10.7	10.7	10.7	10.8	11.0	12.5	51.76	54.48	77.84	94.64	56.64	51.12
5-Mar	9.6	10.4	10.1	9.7	10.5	10.7	51.84	54.96	78.56	94.72	56.72	67.84
5-Mar	11.3	11.1	11.0	10.9	11.2	12.9	52.96	55.60	77.84	94.72	57.28	56.64
6-Mar	11.3	11.1	11.2	10.7	10.9	11.2	53.52	56.24	79.04	94.96	57.60	75.60
6-Mar	12.1	10.7	10.7	11.9	11.6	11.9	54.00	56.40	77.60	94.96	58.40	55.60
7-Mar	9.9	10.2	10.3	9.9	11.1	10.8	52.08	55.28	78.56	94.80	57.60	30.16
7-Mar	9.0	9.5	9.5	9.4	10.7	10.8	50.64	53.92	77.76	94.56	56.64	26.40
8-Mar	8.5	9.2	9.3	8.6	9.9	9.6	50.16	53.12	78.40	94.56	55.52	29.60
8-Mar	9.2	9.9	9.6	9.0	9.6	9.7	50.08	52.72	78.08	94.64	54.80	34.24
9-Mar	9.4	9.9	9.2	9.1	9.5	9.6	49.76	52.24	78.00	94.64	54.48	29.12
9-Mar	9.3	9.9	9.8	9.8	9.5	9.7	49.04	51.52	78.08	94.72	54.00	22.96
10-Mar	9.2	9.7	9.8	9.5	9.4	9.5	48.40	50.72	78.00	94.72	53.44	23.52
10-Mar	10.1	10.5	10.6	10.0	9.8	10.2	48.72	50.88	78.00	94.72	53.52	29.84
11-Mar	10.3	10.5	10.6	10.1	10.1	11.9	48.64	50.72	77.84	94.64	53.44	32.24
11-Mar	10.8	11.0	11.1	10.5	10.4	10.8	48.80	50.80	77.84	94.72	53.60	29.76
12-Mar	11.3	11.1	11.2	11.4	10.8	12.0	48.80	50.56	77.68	94.72	53.60	43.60
12-Mar	11.5	11.2	11.3	11.6	11.4	11.7	48.88	50.72	77.44	94.80	54.00	34.96
13-Mar	11.8	11.3	11.4	12.1	11.7	12.5	48.96	50.64	76.96	94.80	54.08	52.80
13-Mar	11.5	11.1	11.2	12.3	12.0	12.0	49.20	51.12	77.12	94.88	54.64	44.00
14-Mar	11.9	11.7	11.9	12.9	12.3	13.0	49.44	51.60	77.04	94.96	54.80	55.52
14-Mar	11.7	11.4	11.4	12.5	12.5	12.4	49.52	51.68	76.88	94.88	55.04	42.08

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
15-Mar	11.8	11.9	11.6	11.8	12.5	12.4	49.12	51.44	76.48	94.72	54.72	43.28
15-Mar	11.5	11.7	11.5	11.4	12.2	12.1	49.36	51.76	77.04	94.80	54.72	46.48
16-Mar	11.5	11.7	11.7	11.6	12.0	12.0	49.28	51.60	77.12	94.96	54.56	37.60
16-Mar	11.5	11.9	12.0	11.5	11.8	11.9	48.96	51.28	77.12	94.80	54.24	36.72
17-Mar	12.0	12.0	12.2	12.7	12.2	12.7	49.04	51.20	76.40	94.88	54.32	49.76
17-Mar	11.7	12.1	12.3	12.0	12.4	12.4	49.68	52.08	76.88	94.80	55.04	58.24
18-Mar	12.5	12.6	12.8	12.8	12.7	13.5	50.64	52.88	76.48	94.88	55.52	63.52
18-Mar	13.1	12.6	12.8	13.0	13.1	13.2	50.88	53.12	76.64	94.80	55.92	41.04
19-Mar	12.1	12.5	12.6	13.0	13.2	13.3	49.60	52.24	76.00	94.80	55.60	27.76
19-Mar	11.7	12.2	12.4	12.7	13.0	12.8	48.64	51.04	75.68	94.88	54.80	20.64
20-Mar	11.7	12.0	12.1	12.6	13.1	13.6	47.68	50.00	74.72	94.72	54.08	20.00
20-Mar	11.0	11.7	11.8	11.5	12.8	12.3	47.20	49.44	74.16	94.64	53.44	23.68
21-Mar	12.1	12.6	12.8	13.0	13.4	15.3	46.88	49.28	72.08	94.64	53.28	21.28
21-Mar	12.6	13.3	13.7	13.0	14.0	15.2	47.12	49.44	71.20	94.48	53.44	19.36
22-Mar	13.9	14.9	14.8	14.0	14.6	15.9	47.36	49.76	70.56	94.64	53.52	34.40
22-Mar	13.1	14.7	13.6	13.6	15.2	16.2	47.60	50.40	69.68	94.48	54.16	39.36
23-Mar	14.9	16.0	15.1	14.9	15.7	16.8	49.04	51.12	69.76	94.88	54.72	38.56
23-Mar	14.5	15.1	14.9	14.5	15.9	16.6	49.12	51.12	70.08	94.96	54.96	38.88
24-Mar	14.8	14.6	14.6	14.5	16.2	17.1	49.04	50.88	68.32	94.96	55.20	42.72
24-Mar	14.4	15.0	15.2	14.3	16.2	16.8	49.36	51.52	69.28	94.96	55.36	40.32
25-Mar	15.1	16.0	16.0	15.4	16.5	17.7	49.52	52.00	68.08	95.04	55.60	39.84
26-Mar	15.0	16.3	16.5	15.3	17.0	17.6	49.76	52.08	67.04	95.12	55.84	45.84
27-Mar	16.8	17.5	17.5	16.3	17.3	19.6	51.52	53.12	68.08	95.28	56.40	46.72
27-Mar	16.8	17.5	17.5	16.5	17.6	18.3	50.48	52.24	64.08	95.36	56.16	24.32
28-Mar	17.1	17.9	17.8	16.8	17.7	18.3	50.24	51.76	63.76	95.44	55.60	20.88
28-Mar	17.8	18.6	18.5	17.4	17.9	18.7	49.60	50.96	64.16	95.60	55.04	17.04
29-Mar	17.6	18.3	18.2	17.3	18.0	18.3	48.64	49.92	64.48	95.60	54.48	17.52
29-Mar	17.6	18.4	18.3	17.4	18.1	18.6	47.92	49.20	64.00	95.68	54.00	14.16
30-Mar	17.4	18.1	18.0	17.3	18.0	18.3	47.36	48.64	63.20	95.76	53.60	21.84
30-Mar	17.9	18.7	18.6	17.9	18.2	18.8	47.12	48.40	61.92	95.76	53.28	17.12
31-Mar	18.0	18.6	18.5	17.9	18.3	18.7	46.96	48.16	62.48	95.76	53.20	22.16
31-Mar	18.1	18.9	18.8	18.0	18.5	19.0	47.28	48.56	62.72	95.84	53.44	34.56
1-Apr	18.3	18.9	18.8	18.3	18.7	19.3	47.44	48.64	61.52	95.92	53.76	33.20
1-Apr	17.1	17.8	18.0	17.4	18.7	18.9	46.40	47.84	59.60	95.68	53.60	23.20
2-Apr	17.4	18.0	18.0	17.4	18.4	19.1	46.08	47.44	57.60	95.68	53.04	18.16
2-Apr	17.6	18.4	18.4	18.1	18.5	19.2	45.84	47.20	58.64	95.76	52.72	22.24
3-Apr	17.9	18.7	18.7	18.4	18.6	19.5	45.76	47.12	56.64	95.84	52.56	21.28
3-Apr	18.6	19.0	19.1	18.9	18.8	18.8	46.00	46.96	57.84	96.00	52.48	23.68
4-Apr	19.0	17.7	17.8	18.6	18.9	18.9	46.80	46.96	62.00	96.08	52.72	48.32
4-Apr	18.0	17.9	18.0	18.4	18.6	18.3	47.52	48.72	63.76	96.08	53.84	51.36
5-Apr	17.9	18.1	18.2	17.8	18.4	18.1	48.00	49.44	64.48	96.08	54.16	53.92
5-Apr	17.8	18.2	18.3	17.8	18.3	18.0	49.04	50.72	66.08	96.08	54.96	62.96
6-Apr	17.9	18.1	18.2	17.6	18.1	17.9	49.60	51.12	66.24	96.16	55.36	54.16
6-Apr	18.0	18.3	18.4	17.8	18.1	17.9	50.16	51.84	66.80	96.16	55.76	65.76

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
7-Apr	19.2	18.5	18.6	19.4	18.8	19.5	51.84	53.20	67.68	96.24	56.96	77.68
7-Apr	19.3	18.6	18.7	19.2	18.9	18.7	53.20	55.04	68.40	96.32	58.24	78.48
8-Apr	19.1	17.8	18.0	18.6	18.9	18.7	53.84	55.60	67.60	96.24	58.96	75.92
8-Apr	17.7	16.9	17.1	17.7	18.4	18.0	52.96	55.36	66.88	96.08	58.88	52.32
9-Apr	18.0	16.8	17.0	17.7	18.2	18.1	53.36	55.44	66.88	96.08	58.64	78.96
9-Apr	16.9	16.6	16.8	17.1	17.9	17.5	52.40	54.96	66.56	96.08	58.32	40.00
10-Apr	16.6	16.6	16.9	17.4	17.7	17.6	51.28	53.76	64.88	96.08	57.44	28.80
10-Apr	15.7	16.0	16.2	16.7	17.2	16.8	49.92	52.32	63.12	96.00	56.32	21.68
11-Apr	15.9	16.1	16.4	16.7	17.0	17.2	49.04	51.04	60.96	95.92	55.20	17.04
12-Apr	15.9	16.2	16.5	16.2	16.7	16.4	48.40	50.32	61.52	95.92	54.48	26.96
12-Apr	16.3	16.7	16.9	16.4	16.6	16.5	48.48	50.32	60.56	95.92	54.08	39.36
13-Apr	16.5	16.7	16.9	16.9	16.6	16.5	48.64	50.32	62.08	96.08	54.16	37.92
13-Apr	16.5	16.6	16.8	16.4	16.5	16.4	48.48	50.00	62.96	96.00	54.08	32.88
14-Apr	16.5	16.6	16.7	16.3	16.5	16.4	48.16	49.60	62.88	95.92	53.76	36.72
14-Apr	16.8	16.7	16.9	17.3	16.9	17.6	49.12	50.64	64.16	95.92	54.64	49.44
15-Apr	16.5	16.6	16.8	16.5	16.8	16.6	49.60	51.36	64.80	95.92	55.12	54.80
15-Apr	17.1	16.7	16.8	17.4	17.2	17.6	51.20	52.80	65.84	96.16	56.32	62.56
16-Apr	16.7	16.5	16.7	17.4	17.0	16.8	50.64	52.64	65.60	96.08	56.24	48.00
16-Apr	17.2	16.8	17.1	17.9	17.3	17.6	51.20	52.96	64.88	95.92	56.56	49.92
17-Apr	17.1	16.7	17.0	17.2	17.2	17.0	51.20	53.20	65.76	96.00	56.64	51.20
17-Apr	16.9	16.7	17.1	18.2	17.4	17.8	51.36	53.52	64.96	96.08	56.96	47.84
18-Apr	16.3	16.6	16.8	16.5	17.2	16.7	51.28	53.68	65.92	95.84	56.96	50.64
18-Apr	17.1	17.0	17.2	17.8	17.4	18.7	51.84	54.00	64.72	95.92	57.12	39.12
19-Apr	17.0	17.1	17.3	17.1	17.3	17.1	51.60	53.76	65.28	95.84	56.96	45.76
19-Apr	17.1	17.1	17.3	17.0	17.2	17.1	51.68	53.52	64.96	95.92	56.72	46.40
20-Apr	17.0	17.1	17.3	16.8	17.0	16.9	51.28	53.28	64.80	95.84	56.56	44.72
20-Apr	16.8	17.0	17.2	16.6	16.9	16.8	50.96	52.96	63.12	95.84	56.32	43.44
21-Apr	16.6	16.8	16.9	16.4	16.7	16.6	50.72	52.64	63.92	95.76	56.08	45.12
21-Apr	16.6	15.8	15.9	16.6	17.0	17.5	52.24	53.92	65.36	95.76	57.28	57.84
22-Apr	15.9	15.8	15.9	15.9	16.6	16.2	52.72	54.88	65.84	95.76	57.76	69.20
22-Apr	17.3	15.6	15.7	16.8	16.8	17.3	54.16	55.84	64.96	95.76	58.48	38.96
23-Apr	16.8	16.3	16.4	16.6	16.7	16.6	52.80	55.12	65.52	95.68	57.92	45.76
23-Apr	17.9	17.0	17.3	18.1	17.3	19.1	53.20	55.20	64.56	95.76	58.00	40.16
24-Apr	17.4	17.1	17.3	17.6	17.3	17.1	52.64	54.96	65.84	95.76	57.76	49.36
24-Apr	18.3	17.7	17.9	18.3	17.9	18.0	52.88	55.04	64.00	95.84	58.00	24.56
25-Apr	17.9	17.8	18.0	17.9	17.9	17.6	51.84	54.00	64.32	95.76	57.20	37.76
25-Apr	18.7	18.5	18.8	19.2	18.6	18.5	51.84	53.92	62.00	95.92	57.36	33.12
26-Apr	18.6	18.4	18.6	18.8	18.6	18.2	51.68	53.60	64.64	95.84	57.04	44.32
26-Apr	18.9	18.7	18.9	18.9	18.6	18.3	51.84	53.60	64.48	95.84	57.04	38.64
27-Apr	18.5	18.4	18.6	18.4	18.5	18.1	50.96	52.72	63.84	95.76	56.56	30.40
27-Apr	18.2	18.2	18.5	18.1	18.3	18.0	50.00	51.68	59.04	95.60	55.76	26.40
28-Apr	18.0	18.1	18.4	17.9	18.2	17.9	49.36	50.96	60.00	95.60	55.20	31.20
28-Apr	18.9	18.9	19.3	19.4	18.7	18.6	50.16	51.68	61.20	95.76	55.60	46.72
29-Apr	18.8	18.9	19.2	19.0	18.7	18.5	50.40	52.00	63.36	95.68	55.92	47.04

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
29-Apr	19.4	19.0	19.3	19.4	19.3	19.2	51.92	53.60	65.76	95.60	57.12	65.36
30-Apr	19.1	19.0	19.3	19.0	19.1	18.8	52.00	53.92	66.16	95.68	57.36	50.16
30-Apr	19.9	19.8	20.1	20.6	19.7	19.7	52.64	54.48	64.88	95.84	58.00	56.40
1-May	19.6	19.5	19.8	19.7	19.6	19.3	52.56	54.48	65.84	95.76	58.00	52.24
1-May	19.9	19.6	19.9	20.3	19.7	20.0	53.20	55.04	66.48	95.76	58.40	62.56
2-May	19.2	19.1	19.5	19.5	19.6	19.2	52.32	54.32	63.28	95.60	58.08	36.48
2-May	19.5	19.4	19.7	20.3	19.6	19.7	52.08	53.92	62.00	95.68	57.76	40.24
3-May	19.1	18.9	19.3	20.2	19.4	19.0	51.20	52.88	59.60	95.60	57.04	30.72
3-May	18.9	19.0	19.3	19.1	19.2	18.8	50.40	52.08	58.64	95.44	56.24	30.24
4-May	19.0	19.1	19.5	18.9	19.0	18.7	50.00	51.52	57.76	95.36	55.68	30.40
4-May	18.7	18.8	19.1	18.6	18.9	18.6	49.36	50.72	56.40	95.28	55.20	27.28
5-May	18.6	18.7	19.1	18.6	18.7	18.5	48.72	50.08	55.12	95.20	54.64	28.32
5-May	18.5	17.7	18.0	18.7	18.8	18.8	49.60	50.48	61.52	95.12	55.12	76.32
6-May	18.1	17.8	18.2	18.2	18.5	18.2	51.04	52.80	65.04	95.04	56.32	69.52
6-May	19.0	18.7	19.0	19.4	18.9	19.4	52.00	53.92	65.28	95.20	57.20	55.92
7-May	18.6	18.5	18.9	18.8	18.7	18.4	51.60	53.44	62.56	95.12	57.04	45.68
7-May	19.2	18.9	19.3	20.0	19.0	19.5	52.00	53.68	63.68	95.28	57.20	63.84
8-May	18.8	18.3	18.7	19.1	18.8	18.6	51.76	53.44	61.76	95.12	57.28	44.40
8-May	19.0	18.6	18.9	19.2	19.1	19.6	51.84	53.60	61.84	94.96	57.28	50.08
9-May	18.9	18.7	19.1	19.1	19.0	18.7	51.76	53.52	61.60	95.04	57.20	50.16
9-May	19.9	19.5	19.9	20.6	19.4	19.9	52.56	54.32	61.20	95.12	57.68	47.76
10-May	19.7	19.4	19.8	19.9	19.4	19.3	52.00	53.68	61.76	95.04	57.36	47.20
10-May	19.5	19.4	19.7	19.5	19.4	19.8	52.08	53.92	62.08	94.96	57.36	44.08
11-May	20.9	19.7	20.0	20.8	19.4	19.3	52.88	54.24	63.68	95.12	57.60	58.32
11-May	20.0	19.7	19.9	20.0	19.4	19.3	52.96	54.88	65.12	94.96	58.08	46.00
12-May	19.8	19.6	19.8	20.0	19.4	19.3	52.32	54.24	64.08	94.88	57.76	44.32
12-May	21.5	20.4	20.6	22.0	20.1	20.8	53.04	54.48	58.88	95.20	58.08	42.56
13-May	21.0	20.6	20.9	21.7	20.2	20.1	52.08	53.84	61.28	95.04	57.68	41.36
13-May	21.7	21.0	21.2	22.9	20.9	21.1	52.00	53.60	56.80	95.28	57.76	32.56
14-May	20.9	20.6	20.9	22.0	20.7	20.3	50.80	52.40	58.40	94.88	56.80	31.68
14-May	21.9	21.2	21.5	22.7	21.0	21.3	50.96	52.24	54.72	94.88	56.72	34.48
15-May	21.5	21.1	21.0	22.6	21.1	20.8	50.96	52.48	59.52	94.80	56.80	48.56
15-May	22.7	21.9	22.0	23.4	21.6	22.0	52.16	53.68	60.16	94.72	57.60	48.56
16-May	22.6	22.2	22.5	23.0	21.9	21.7	52.56	54.40	62.96	94.64	58.16	57.76
16-May	22.1	20.1	20.2	22.2	22.1	20.9	54.00	55.52	66.08	94.56	59.84	55.04
17-May	21.1	20.6	20.6	21.2	21.5	20.7	53.28	55.44	66.08	94.40	59.20	41.36
17-May	20.9	20.9	21.1	21.0	21.1	20.7	52.24	54.40	62.48	94.32	58.24	32.80
18-May	20.6	20.6	20.8	20.6	20.8	20.3	51.28	53.20	61.04	94.16	57.36	33.52
18-May	20.3	20.5	20.7	20.3	20.5	20.2	50.48	52.32	58.24	93.92	56.56	29.92
19-May	20.2	20.3	20.5	20.1	20.3	20.0	50.08	51.68	59.20	93.84	56.08	36.80
19-May	20.1	20.4	20.6	20.1	20.1	19.9	50.08	51.68	58.00	93.68	55.92	38.72
20-May	20.2	20.4	20.5	20.2	20.0	19.9	50.16	51.68	59.92	93.68	56.00	42.88
20-May	22.1	21.4	21.6	21.9	21.1	21.8	51.36	52.80	58.00	93.76	56.80	46.88
21-May	21.6	21.4	21.6	21.9	21.1	20.9	51.68	53.28	61.92	93.68	57.28	55.52

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
21-May	23.2	22.5	22.7	23.2	22.1	22.5	52.88	54.40	60.40	93.92	58.40	49.04
22-May	22.7	22.4	22.6	22.6	22.2	21.8	52.80	54.56	63.28	93.76	58.56	54.40
22-May	23.8	23.1	23.3	23.2	22.7	22.9	53.76	55.44	62.88	93.76	59.20	68.00
23-May	23.3	23.0	23.2	23.1	22.8	22.5	54.32	56.32	65.60	93.76	60.00	64.40
23-May	24.7	24.0	24.3	25.0	23.8	24.2	55.76	57.76	66.40	94.16	61.20	69.04
24-May	24.8	23.9	24.1	24.6	23.8	23.4	56.40	58.56	67.76	94.00	61.92	71.28
24-May	24.0	23.8	24.1	24.0	23.7	23.3	56.72	59.28	68.64	94.00	62.48	66.72
25-May	23.7	23.6	23.1	23.6	23.6	23.0	56.72	59.20	68.64	93.92	62.56	54.00
25-May	23.1	23.0	22.7	23.2	23.3	22.8	55.60	57.92	67.52	93.76	61.68	51.12
26-May	22.7	22.6	22.6	22.6	23.0	22.5	55.68	57.92	67.84	93.60	61.44	60.88
26-May	23.5	22.7	22.8	23.6	23.2	23.4	57.76	60.00	70.08	93.84	62.80	84.64
27-May	23.3	23.0	23.2	23.3	23.1	22.7	58.72	61.44	70.80	93.76	63.68	78.08
27-May	25.0	23.9	24.1	25.0	23.6	23.7	59.68	62.16	71.36	94.16	64.48	62.96
28-May	24.2	23.8	24.0	24.3	23.6	23.4	59.12	61.84	71.28	93.92	64.40	67.84
28-May	25.0	23.9	24.2	25.1	24.0	23.6	59.60	62.00	70.96	94.08	64.72	65.12
29-May	24.2	23.7	24.0	24.4	23.9	23.3	59.12	61.84	71.04	93.84	64.56	63.84
29-May	24.5	23.8	24.1	24.8	24.0	23.6	59.12	61.76	69.28	93.84	64.56	61.92
30-May	23.9	23.6	23.9	23.9	23.9	23.4	59.04	61.84	70.16	93.60	64.48	64.24
30-May	24.6	24.2	24.5	24.5	24.2	24.0	60.08	62.88	70.96	93.76	65.20	64.32
31-May	24.2	23.9	24.2	24.2	24.1	23.7	59.44	62.00	70.64	93.52	64.80	53.28
31-May	23.9	23.7	23.9	23.9	23.9	23.4	58.80	61.20	70.24	93.44	64.16	50.72
1-Jun	23.7	23.5	23.7	23.9	23.7	23.2	57.92	60.08	69.28	93.36	63.36	43.84
1-Jun	23.5	23.3	23.5	23.6	23.5	23.1	57.12	59.04	68.00	93.20	62.56	47.12
2-Jun	23.4	23.2	23.4	23.4	23.3	23.0	56.96	58.80	67.92	93.04	62.24	47.92
2-Jun	24.7	23.8	24.1	24.5	23.8	23.5	57.04	58.64	63.60	93.04	62.24	35.84
3-Jun	23.9	23.6	23.9	23.9	23.7	23.3	55.76	57.44	63.68	92.72	61.36	41.52
3-Jun	25.1	23.8	24.1	24.6	23.9	23.6	55.92	57.12	61.04	92.72	61.20	36.40
4-Jun	23.9	23.6	23.8	23.8	23.8	23.3	54.80	56.32	62.08	92.40	60.64	40.88
4-Jun	24.3	23.7	24.0	24.5	24.1	23.6	54.96	56.40	59.60	92.32	60.80	43.52
5-Jun	23.6	23.4	23.7	23.7	23.8	23.2	54.64	56.32	60.64	92.08	60.48	46.64
5-Jun	24.5	24.1	24.4	24.6	24.0	23.8	54.72	56.24	56.72	92.16	60.48	31.92
6-Jun	24.7	23.9	24.2	24.5	24.1	23.7	54.24	55.44	60.00	91.92	59.92	41.84
6-Jun	25.3	24.8	25.0	25.6	24.7	24.4	54.64	56.00	58.96	92.00	60.40	39.52
7-Jun	24.9	24.6	24.8	25.0	24.6	24.2	54.16	55.60	61.60	91.68	60.08	45.20
7-Jun	24.5	24.5	24.8	24.6	24.4	24.1	53.28	54.72	58.88	91.44	59.52	24.16
8-Jun	24.2	24.1	24.3	24.2	24.2	23.8	52.16	53.28	58.56	91.12	58.40	31.92
8-Jun	24.0	24.0	24.2	24.3	24.0	23.6	51.68	52.72	58.80	90.88	57.92	33.68
9-Jun	24.0	24.0	24.1	24.1	23.9	23.6	51.60	52.64	59.68	90.72	57.76	37.52
9-Jun	25.5	25.0	25.2	25.8	24.6	24.5	52.96	54.00	60.32	91.04	58.72	52.48
10-Jun	25.1	24.9	25.1	25.2	24.6	24.4	53.44	54.80	62.96	90.88	59.28	54.00
10-Jun	26.4	25.7	25.9	26.2	25.2	25.0	54.16	55.44	59.60	91.04	60.08	41.28
11-Jun	25.6	25.4	25.5	25.6	25.2	24.8	53.84	55.20	62.56	90.80	59.92	49.12
11-Jun	26.9	25.5	25.6	26.7	25.7	25.2	54.16	55.12	59.60	90.88	60.16	30.56
12-Jun	25.2	24.7	24.9	25.2	25.3	24.6	52.16	53.36	58.32	90.16	58.80	31.60

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
12-Jun	25.5	25.2	25.4	25.5	25.3	24.8	51.68	52.80	54.88	89.92	58.16	26.64
13-Jun	25.0	24.9	25.1	25.0	25.0	24.5	50.88	52.00	56.80	89.52	57.52	32.72
13-Jun	26.7	25.4	25.7	25.7	25.5	25.1	51.36	52.00	53.76	89.44	57.52	33.52
14-Jun	25.7	25.2	25.4	25.4	25.4	24.8	50.88	51.84	57.52	89.12	57.28	37.28
14-Jun	25.3	25.2	25.4	25.9	25.2	24.8	51.28	52.48	59.44	89.28	57.60	52.64
15-Jun	25.1	25.0	25.2	25.5	25.0	24.5	52.24	53.52	62.00	89.36	58.48	52.64
15-Jun	25.0	24.5	24.7	24.8	24.7	24.3	52.64	53.84	60.96	89.20	58.80	54.48
16-Jun	24.4	24.4	24.6	24.6	24.5	24.0	53.04	54.56	62.96	89.28	59.20	56.40
16-Jun	25.4	25.0	25.3	25.6	24.9	24.6	54.00	55.60	63.28	89.60	59.92	51.60
17-Jun	25.4	25.0	25.2	25.3	24.9	26.6	54.48	55.84	63.92	89.52	60.16	54.00
17-Jun	26.8	26.0	26.3	27.2	25.7	25.5	54.88	56.40	62.08	90.16	60.80	48.48
18-Jun	26.7	25.9	26.2	26.8	25.8	28.2	55.36	56.48	62.80	89.92	60.88	49.76
18-Jun	27.5	26.6	26.9	27.4	26.4	26.2	55.44	57.04	62.72	89.92	61.44	53.04
19-Jun	27.1	26.4	26.7	27.0	26.4	27.5	55.92	57.36	63.68	89.92	61.60	52.88
19-Jun	28.0	27.1	27.3	28.8	26.9	26.6	55.60	57.12	60.40	90.08	61.68	43.44
20-Jun	27.4	26.8	27.0	27.6	26.9	27.8	55.12	56.40	60.48	89.44	61.12	42.64
20-Jun	27.5	27.0	27.3	27.9	27.1	26.6	53.92	55.28	56.96	88.96	60.40	32.96
21-Jun	26.9	26.7	26.9	27.1	26.9	26.2	52.88	54.24	57.84	88.40	59.52	34.16
21-Jun	27.1	26.5	25.5	25.7	26.7	26.1	52.72	53.52	55.20	87.84	58.96	33.20
22-Jun	26.6	26.1	26.0	25.9	26.3	25.7	51.84	52.80	57.60	87.60	58.40	35.44
22-Jun	26.1	25.9	26.0	25.9	26.0	25.5	51.20	52.16	57.36	87.28	57.76	32.00
23-Jun	25.8	25.8	25.9	25.8	25.7	25.3	50.96	51.92	57.76	87.04	57.36	37.68
23-Jun	25.8	25.8	25.2	25.7	25.5	25.2	50.56	51.60	54.80	86.80	57.12	33.44
24-Jun	26.9	26.2	26.0	26.6	25.9	27.2	51.12	51.76	55.04	86.80	57.20	38.56
24-Jun	27.0	26.6	26.8	27.4	26.1	26.0	50.88	51.68	55.12	86.88	57.20	35.60
25-Jun	27.6	26.9	27.0	27.8	26.7	28.2	51.28	52.00	52.80	86.80	57.68	36.80
25-Jun	27.5	27.2	27.4	27.6	26.8	26.5	51.36	52.24	55.76	86.64	57.76	41.68
26-Jun	28.8	27.4	27.6	28.0	27.1	28.2	52.64	52.96	58.00	86.72	58.24	45.84
26-Jun	28.7	27.9	28.1	28.2	27.5	27.3	53.60	54.80	62.24	87.36	59.68	56.40
27-Jun	29.4	28.1	28.3	29.2	27.9	28.8	54.80	55.92	62.32	88.00	60.72	52.96
28-Jun	28.8	28.3	28.4	28.9	27.9	27.6	55.12	56.72	64.32	88.00	61.36	58.80
28-Jun	27.8	27.5	27.7	27.9	27.7	27.2	54.16	55.68	60.88	87.28	60.88	38.16
29-Jun	27.1	27.1	27.3	26.1	27.3	26.7	53.20	54.56	58.96	86.00	59.92	42.32
29-Jun	26.9	26.8	26.9	25.3	27.0	26.4	52.88	54.16	59.60	85.68	59.44	35.20
30-Jun	26.6	26.6	26.7	26.1	26.7	26.2	51.68	52.72	54.72	85.52	58.32	30.48
30-Jun	26.4	26.5	25.9	26.1	26.4	26.0	50.96	51.92	55.68	85.12	57.60	30.56
1-Jul	26.8	26.9	27.0	27.1	26.4	26.0	50.56	51.36	53.84	84.88	56.96	30.56
1-Jul	27.3	26.7	26.8	26.9	26.7	28.2	50.48	51.04	51.28	84.64	56.88	30.64
1-Jul	27.1	26.8	27.0	27.0	26.7	26.3	49.84	50.40	50.40	84.16	56.40	28.32
2-Jul	27.9	26.9	27.1	27.4	27.0	29.5	50.16	50.56	51.12	84.16	56.48	31.44
2-Jul	27.9	27.2	27.4	27.4	27.0	26.8	50.00	50.56	53.76	83.92	56.40	35.12
3-Jul	28.1	27.3	27.5	27.9	27.3	28.2	50.48	51.04	54.00	84.24	56.88	43.20
3-Jul	28.0	27.6	27.8	29.0	27.4	27.1	51.44	52.40	58.40	85.12	57.76	51.68
4-Jul	28.2	27.4	27.6	28.1	27.6	28.3	52.64	53.68	62.64	84.96	58.88	67.28

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
4-Jul	27.6	27.2	27.4	27.8	27.4	27.0	53.44	54.88	62.80	85.44	59.76	57.76
5-Jul	27.2	27.0	27.2	27.3	27.2	26.8	53.84	55.36	63.44	85.44	60.16	56.48
5-Jul	27.3	27.0	27.2	27.7	27.0	26.6	54.48	56.00	64.24	85.92	60.64	60.56
6-Jul	27.1	26.9	27.1	27.3	26.9	26.5	55.04	56.64	65.04	85.92	61.12	60.64
6-Jul	26.9	26.8	26.9	27.1	26.8	26.4	55.36	56.96	65.28	86.00	61.36	58.16
7-Jul	27.6	26.5	26.6	27.4	27.0	27.5	56.40	57.52	67.12	86.16	61.84	69.76
7-Jul	27.2	26.8	27.0	27.3	26.9	26.5	56.08	57.76	65.60	86.24	61.92	48.80
8-Jul	27.5	26.8	27.0	27.5	27.0	27.7	55.44	56.64	60.24	85.52	61.12	40.32
8-Jul	27.5	27.0	27.2	27.4	27.0	26.6	54.00	55.12	56.96	84.64	60.00	32.96
9-Jul	27.5	27.0	27.2	27.4	27.1	27.8	53.36	54.40	55.44	84.08	59.36	37.28
9-Jul	27.4	27.1	27.3	27.4	27.1	26.8	52.80	53.76	55.44	83.60	58.96	35.68
10-Jul	28.1	27.1	27.2	27.6	27.4	28.3	52.88	53.44	54.00	83.28	58.64	36.08
10-Jul	28.3	27.3	27.5	27.7	27.3	27.0	52.24	52.88	53.76	82.96	58.32	34.96
11-Jul	28.2	27.3	27.4	27.8	27.6	28.2	52.08	52.72	53.36	82.88	58.24	38.80
11-Jul	27.9	27.5	27.7	27.9	27.5	27.1	51.84	52.72	54.80	82.72	58.08	38.56
12-Jul	27.4	27.1	27.3	27.4	27.3	26.9	51.76	52.64	57.04	82.48	58.00	42.48
12-Jul	26.9	26.9	27.1	26.9	27.1	26.7	51.92	52.96	57.84	82.40	58.16	51.36
13-Jul	26.6	26.5	26.6	26.6	26.8	26.4	52.32	53.36	59.36	82.64	58.56	46.16
13-Jul	26.5	26.4	26.5	26.4	26.6	26.2	52.32	53.28	59.28	82.56	58.48	44.00
14-Jul	27.3	26.7	26.8	27.0	26.8	27.8	52.64	53.44	57.28	82.48	58.40	42.72
14-Jul	27.2	27.0	27.2	27.2	26.9	26.6	51.76	52.56	54.32	82.08	57.92	32.16
15-Jul	27.6	27.2	27.3	27.7	27.2	28.3	51.92	52.40	52.88	81.92	57.76	37.76
15-Jul	28.2	27.5	27.7	27.8	27.4	27.1	51.92	52.56	55.28	82.00	57.92	42.64
16-Jul	28.4	27.6	27.8	28.1	27.6	28.3	52.40	53.04	56.80	82.24	58.32	45.12
16-Jul	28.3	27.8	28.0	28.6	27.8	27.4	53.28	54.32	60.48	82.96	59.20	59.04
17-Jul	28.8	28.0	28.2	28.6	28.1	28.7	54.72	55.68	62.56	83.52	60.40	57.36
17-Jul	28.7	28.4	28.6	28.6	28.3	27.9	54.96	56.24	62.00	83.84	60.88	52.72
18-Jul	29.6	28.6	28.8	29.4	28.7	29.6	55.68	56.80	61.84	84.16	61.36	52.96
18-Jul	29.3	28.7	28.9	29.2	28.7	28.2	56.00	57.36	63.12	84.40	61.76	56.40
19-Jul	28.7	28.4	28.6	28.7	28.5	28.0	56.16	57.68	64.08	84.40	62.08	57.36
19-Jul	28.6	28.3	27.5	28.3	28.3	27.8	56.32	57.68	63.84	84.32	62.00	54.16
20-Jul	28.2	28.0	27.9	28.1	28.0	27.7	56.32	57.68	64.24	84.24	62.08	55.84
20-Jul	28.3	28.0	28.2	27.9	27.9	27.5	56.64	58.00	64.48	84.24	62.16	56.88
21-Jul	28.5	28.0	28.1	28.4	28.0	28.6	56.40	57.68	61.60	84.16	62.16	41.92
21-Jul	28.3	27.9	28.2	28.2	28.1	27.7	55.44	56.56	59.52	83.52	61.36	42.16
22-Jul	28.9	28.1	28.3	28.9	28.2	28.7	56.00	56.88	61.60	83.84	61.36	53.92
22-Jul	28.9	28.3	28.4	28.8	28.1	27.8	55.44	56.40	59.04	83.20	61.12	39.68
23-Jul	29.1	28.2	28.4	28.8	28.2	28.7	55.12	55.76	57.60	82.64	60.64	40.16
23-Jul	28.7	28.3	28.5	28.7	28.2	27.9	54.32	55.04	56.48	82.00	60.08	38.48
24-Jul	29.2	28.3	28.5	29.5	28.4	29.1	54.00	54.64	54.80	82.08	59.76	38.16
24-Jul	29.3	28.3	28.5	29.1	28.5	28.1	54.32	55.12	58.24	81.92	60.16	48.88
25-Jul	29.0	28.4	28.5	29.0	28.5	29.0	54.72	55.68	59.84	82.16	60.48	50.56
25-Jul	28.6	28.4	28.6	29.0	28.4	28.0	54.32	55.28	57.76	81.76	60.32	39.76
26-Jul	28.2	28.0	28.2	28.3	28.2	27.8	53.52	54.32	57.44	81.04	59.60	39.68

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
26-Jul	27.9	27.7	27.9	28.0	28.0	27.5	52.96	53.52	55.60	80.48	58.96	35.92
27-Jul	27.5	27.3	27.4	27.6	27.7	27.2	52.48	52.96	56.56	80.08	58.48	39.28
27-Jul	27.7	27.3	27.4	27.3	27.5	27.1	52.48	52.80	56.56	79.92	58.24	39.76
28-Jul	28.1	27.4	27.5	27.8	27.6	27.9	52.88	53.20	56.48	80.16	58.40	42.56
29-Jul	27.8	27.6	27.7	27.7	27.6	27.2	52.08	52.48	55.28	79.68	57.92	36.00
29-Jul	28.4	27.8	28.0	29.0	27.9	28.2	52.24	52.56	52.16	80.08	58.00	39.04
30-Jul	28.1	27.8	28.1	28.4	27.9	27.5	51.92	52.32	55.36	79.52	57.84	44.88
30-Jul	28.5	28.1	28.3	28.8	28.1	28.3	52.80	53.28	56.08	80.24	58.56	46.24
31-Jul	28.2	28.1	28.3	28.7	28.0	27.6	52.56	53.04	56.72	79.92	58.48	43.04
31-Jul	29.5	28.4	28.6	29.1	28.4	28.8	53.44	53.52	55.92	80.24	58.88	45.36
1-Aug	28.9	28.4	28.6	29.5	28.4	27.9	52.48	52.88	55.44	79.76	58.32	37.44
1-Aug	29.4	28.5	28.7	29.2	28.6	28.8	52.56	52.64	52.48	79.36	58.24	37.36
2-Aug	28.9	28.3	28.6	28.8	28.5	28.0	51.84	52.08	54.32	78.72	57.76	38.00
2-Aug	28.3	28.1	28.3	28.3	28.2	27.8	51.68	52.00	55.20	78.56	57.68	40.56
3-Aug	28.2	28.0	28.2	28.1	28.0	27.7	51.68	52.00	56.00	78.48	57.52	42.24
3-Aug	27.8	27.6	27.8	27.8	27.9	27.4	52.00	52.40	58.00	78.56	57.92	51.28
4-Aug	27.2	27.0	27.2	27.2	27.6	27.1	52.56	53.04	59.52	78.96	58.48	51.28
4-Aug	27.8	27.3	27.5	27.9	27.5	27.6	53.44	53.60	59.04	79.44	58.72	44.24
5-Aug	27.6	27.1	27.3	27.5	27.3	27.0	52.48	52.96	56.80	78.72	58.24	41.92
5-Aug	28.4	27.4	27.7	29.1	27.6	27.8	53.20	53.44	56.80	79.68	58.56	45.20
6-Aug	27.6	27.2	27.4	28.0	27.4	27.0	52.80	53.36	58.08	78.88	58.48	47.28
6-Aug	28.0	27.7	27.9	28.7	28.0	28.1	53.28	53.92	57.92	79.44	59.04	46.48
7-Aug	27.6	27.4	26.7	27.8	27.6	27.2	52.88	53.36	57.60	78.64	58.56	44.24
7-Aug	28.9	27.9	27.6	29.1	28.2	29.0	53.36	53.68	53.44	79.04	58.88	37.76
8-Aug	28.1	27.7	27.8	28.2	27.9	27.5	52.64	53.04	56.72	78.16	58.32	44.32
8-Aug	28.3	27.9	28.1	29.0	28.2	28.1	53.12	53.60	57.52	78.72	58.72	51.20
9-Aug	27.5	27.2	27.4	27.7	27.9	27.4	53.36	53.92	59.04	78.48	59.04	50.00
9-Aug	27.4	27.3	27.5	27.4	27.6	27.2	53.68	54.32	59.68	78.64	59.12	50.24
10-Aug	27.1	27.0	27.3	27.1	27.5	27.0	53.84	54.48	59.92	78.64	59.28	51.52
10-Aug	26.8	26.8	27.0	26.9	27.3	26.8	54.00	54.64	60.00	78.80	59.44	51.12
11-Aug	26.8	26.8	27.0	26.8	27.0	26.6	54.32	54.96	60.72	78.88	59.44	53.52
11-Aug	27.4	27.2	27.4	28.2	27.3	27.5	55.04	55.68	59.92	79.76	60.00	49.36
12-Aug	27.3	27.2	27.4	27.6	27.3	26.9	54.24	54.72	58.88	78.88	59.44	45.52
12-Aug	27.9	27.7	27.9	28.8	27.8	27.9	54.64	55.04	55.76	79.36	59.76	45.92
13-Aug	27.8	27.6	27.8	28.1	27.7	27.3	54.16	54.48	57.92	78.64	59.36	46.24
13-Aug	28.5	28.1	28.3	29.1	28.0	28.0	54.64	54.88	56.16	79.04	59.60	45.28
14-Aug	28.1	27.9	28.2	28.5	28.0	27.6	54.08	54.40	57.68	78.32	59.28	45.60
14-Aug	29.5	28.6	28.8	29.3	28.6	28.9	54.80	54.88	56.08	78.72	59.76	45.20
15-Aug	28.9	28.4	28.6	29.0	28.5	28.1	54.72	55.04	59.04	78.72	59.92	49.60
15-Aug	30.0	28.8	29.0	29.6	29.0	29.2	55.28	55.36	56.80	79.04	60.24	46.80
16-Aug	28.9	28.4	28.7	28.9	28.8	28.2	55.04	55.60	60.00	78.88	60.32	52.48
16-Aug	28.4	28.2	28.5	28.5	28.5	28.0	55.20	55.76	60.56	79.04	60.40	51.84
17-Aug	28.4	27.9	28.1	28.2	28.3	27.8	55.52	56.08	61.52	78.96	60.56	56.16
17-Aug	27.8	27.6	27.9	27.8	28.1	27.6	55.52	56.24	61.28	78.96	60.72	50.64

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
18-Aug	27.6	27.6	27.8	27.6	27.8	27.4	55.20	55.84	60.16	78.64	60.32	46.08
18-Aug	28.0	27.5	27.8	27.8	28.0	27.9	54.88	55.20	54.64	78.32	60.08	40.00
19-Aug	27.5	27.3	27.5	27.5	27.7	27.2	54.08	54.32	56.56	77.52	59.28	39.44
19-Aug	28.0	27.4	27.7	28.2	28.0	28.1	53.76	53.84	52.48	77.36	58.96	34.08
20-Aug	27.4	27.2	27.4	27.5	27.6	27.1	53.04	53.12	54.72	76.64	58.24	39.20
20-Aug	26.9	26.8	27.1	27.4	27.6	27.4	53.36	53.60	57.84	76.96	58.56	52.80
21-Aug	26.6	26.7	27.0	26.9	27.2	26.7	53.92	54.32	59.04	77.28	58.96	51.52
21-Aug	27.7	27.4	27.6	28.8	27.4	27.7	54.72	55.04	56.88	78.64	59.52	46.88
22-Aug	27.3	27.2	27.4	28.0	27.4	27.0	54.88	55.20	59.68	78.00	59.68	49.84
22-Aug	28.0	27.3	27.6	28.3	27.5	27.9	54.96	55.04	56.88	77.92	59.68	41.76
23-Aug	27.3	26.9	27.2	27.5	27.3	26.9	53.92	53.92	56.24	76.88	58.96	38.88
23-Aug	27.3	26.8	27.0	26.9	27.1	26.7	53.28	53.20	54.56	76.24	58.32	38.80
24-Aug	26.6	26.4	26.7	26.7	26.9	26.4	52.56	52.56	54.64	75.84	57.92	38.80
24-Aug	26.2	26.3	26.3	26.3	26.7	26.2	52.16	52.16	53.20	75.36	57.36	39.12
25-Aug	26.3	26.3	26.3	26.3	26.5	26.1	52.32	52.32	55.84	75.52	57.28	47.12
25-Aug	27.8	27.1	27.2	27.8	27.1	27.5	53.60	53.60	57.44	76.80	58.24	49.20
26-Aug	27.2	27.0	27.1	27.3	27.0	26.7	53.92	54.08	59.36	76.96	58.72	53.92
26-Aug	28.5	27.7	28.0	28.9	27.6	27.9	54.96	55.04	59.12	78.40	59.60	50.32
27-Aug	28.0	27.6	27.8	28.4	27.6	27.4	55.12	55.44	60.88	78.00	59.92	56.08
27-Aug	29.1	28.4	28.5	30.5	28.4	28.8	56.08	56.40	60.00	79.28	60.72	50.40
28-Aug	28.6	28.2	28.4	29.2	28.3	28.0	56.00	56.40	61.52	78.56	60.80	54.72
28-Aug	29.6	28.8	29.0	29.3	28.9	28.8	56.56	56.88	58.96	78.72	61.36	40.00
29-Aug	29.2	28.7	28.9	29.0	28.8	28.4	55.20	55.36	57.84	77.60	60.16	43.52
29-Aug	29.5	29.1	29.3	30.1	29.3	29.7	55.36	55.68	56.88	78.16	60.48	46.08
30-Aug	29.4	29.2	29.4	29.9	29.3	28.8	55.84	56.08	59.60	78.16	60.80	52.24
30-Aug	28.7	28.4	28.6	29.2	29.0	28.4	55.52	55.92	59.76	77.92	60.72	37.76
31-Aug	26.9	26.9	27.1	27.5	28.4	27.4	52.80	52.96	54.48	75.36	58.64	25.12
31-Aug	26.5	26.6	26.8	26.8	27.8	26.9	51.60	51.52	53.12	74.40	57.20	25.68
1-Sep	25.9	26.2	26.3	26.4	27.3	26.5	50.48	50.24	52.40	73.60	56.08	27.76
1-Sep	26.2	26.5	26.7	26.4	26.9	26.3	50.32	49.92	50.24	73.36	55.44	30.88
2-Sep	26.2	26.5	25.1	26.3	26.7	26.3	50.00	49.52	48.48	73.04	55.12	31.84
2-Sep	26.8	26.7	26.4	27.4	26.8	27.2	50.24	49.76	49.60	73.44	55.12	36.48
3-Sep	27.0	27.1	27.2	27.3	26.9	26.7	50.88	50.48	53.84	73.68	55.68	43.68
3-Sep	27.6	27.2	27.4	28.4	27.3	27.5	51.92	51.52	55.68	74.88	56.64	47.60
4-Sep	27.4	27.0	27.2	27.5	27.4	26.9	51.36	50.96	53.28	73.92	56.40	38.72
4-Sep	27.8	27.2	27.4	28.5	27.6	27.6	51.52	51.04	52.96	74.32	56.40	38.16
5-Sep	26.6	26.1	26.3	27.4	27.3	26.6	50.40	50.08	51.52	73.20	55.92	37.20
5-Sep	25.7	25.2	25.5	26.8	27.0	26.4	49.92	49.76	50.88	72.88	55.52	37.60
6-Sep	25.4	25.3	25.6	26.3	26.5	25.7	49.84	49.68	52.08	72.56	55.12	44.32
6-Sep	25.1	25.0	25.3	25.7	26.1	25.4	50.00	49.92	52.16	72.72	55.20	35.44
7-Sep	24.5	24.4	24.6	25.0	25.6	25.0	49.68	49.68	52.64	72.32	54.88	42.96
7-Sep	24.1	24.2	24.4	24.4	25.1	24.7	50.00	50.08	54.72	72.48	54.88	48.80
8-Sep	24.4	24.4	24.6	24.6	24.9	24.5	50.16	50.24	53.84	72.64	54.88	42.16
8-Sep	24.1	23.5	23.7	24.0	24.6	24.7	49.28	49.20	48.56	71.68	54.24	31.84

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
9-Sep	23.2	23.1	23.4	23.6	24.2	23.7	49.04	49.04	50.56	71.60	54.08	39.60
9-Sep	24.0	23.6	23.9	24.5	24.3	24.8	50.88	50.80	62.32	73.04	54.96	68.80
10-Sep	23.8	23.5	23.8	24.1	24.2	23.8	52.40	52.80	63.20	74.40	56.64	52.72
10-Sep	22.7	22.2	22.5	22.9	24.0	23.5	50.56	50.88	52.64	72.88	55.60	30.08
11-Sep	21.6	21.6	21.9	22.6	23.3	22.6	49.28	49.52	50.08	71.76	54.24	33.92
11-Sep	22.7	22.4	22.8	22.9	23.3	23.8	49.44	49.44	49.60	71.52	53.92	31.92
12-Sep	22.8	22.9	23.2	23.3	23.2	22.9	48.96	48.88	47.28	71.20	53.28	32.96
12-Sep	22.8	22.7	23.0	23.2	23.3	22.8	48.56	48.40	46.16	70.88	53.20	30.48
13-Sep	22.8	22.8	23.2	23.0	23.2	22.8	48.48	48.24	48.32	70.72	52.88	36.48
13-Sep	23.5	23.0	23.3	23.3	23.2	22.9	48.96	48.40	49.60	71.04	52.96	39.20
14-Sep	23.2	23.2	23.5	23.9	23.2	23.0	48.96	48.80	51.04	71.36	53.20	43.84
14-Sep	22.9	23.0	23.2	23.2	23.2	22.9	49.28	49.12	53.28	71.36	53.60	50.00
15-Sep	22.7	22.7	22.9	23.1	23.0	22.8	50.24	50.24	56.56	72.08	54.40	58.32
15-Sep	23.7	23.4	23.7	24.1	23.4	23.8	52.24	52.24	64.08	73.68	55.76	81.84
16-Sep	24.2	23.9	24.2	24.8	23.7	23.6	54.56	55.20	65.20	75.52	58.00	85.52
16-Sep	24.7	23.9	24.2	25.2	24.1	24.6	54.64	55.12	59.20	75.92	58.56	47.68
17-Sep	24.0	23.5	23.8	24.2	24.0	23.4	53.12	53.44	58.24	74.72	57.52	43.04
17-Sep	23.8	23.2	23.5	23.7	24.1	24.2	52.64	52.88	56.64	73.92	56.96	45.36
18-Sep	23.8	23.7	24.0	23.8	23.9	23.5	52.88	53.36	58.24	74.16	56.96	50.96
18-Sep	23.9	23.9	24.2	24.4	24.1	24.5	52.40	52.72	51.36	73.92	56.72	36.48
19-Sep	23.6	23.5	23.8	23.9	24.0	23.6	51.12	51.12	49.04	72.56	55.68	28.48
19-Sep	22.7	22.5	22.8	23.0	23.8	23.2	49.68	49.52	46.24	71.20	54.72	26.80
20-Sep	20.5	20.7	20.9	21.2	23.0	21.7	48.24	48.24	47.20	70.00	53.52	29.76
20-Sep	20.8	21.0	21.3	21.0	22.2	21.4	48.08	47.84	48.24	69.76	52.64	31.84
21-Sep	20.8	20.9	21.3	21.2	21.7	21.0	47.68	47.36	48.40	69.60	52.08	32.96
21-Sep	19.6	19.5	19.8	20.1	21.1	20.2	46.96	46.64	49.44	69.04	51.60	35.76
22-Sep	19.4	19.4	19.6	19.8	20.6	20.1	47.04	46.64	50.08	69.12	51.28	38.56
22-Sep	20.2	19.7	20.0	20.3	20.6	20.8	48.24	47.76	55.04	70.00	51.92	62.08
23-Sep	20.5	19.9	20.3	20.2	20.4	20.0	48.48	48.24	51.52	70.24	52.24	37.92
23-Sep	20.1	19.7	20.0	20.1	20.3	20.5	47.60	47.44	47.68	69.60	51.76	31.92
24-Sep	19.9	19.8	20.1	19.9	20.1	20.0	47.20	46.96	46.96	69.12	51.28	33.76
24-Sep	19.4	18.5	18.9	19.7	20.0	19.5	47.76	47.44	55.36	69.68	51.76	54.24
25-Sep	18.9	18.8	19.2	19.3	19.6	19.4	48.08	48.24	54.00	69.84	52.08	47.20
25-Sep	19.4	18.6	18.9	19.5	19.7	20.0	49.28	49.28	59.20	70.72	52.88	71.60
26-Sep	19.3	19.1	19.4	19.9	19.7	19.5	49.84	50.24	58.32	71.52	53.60	47.92
26-Sep	20.0	19.7	19.9	20.3	19.8	20.2	49.76	50.00	55.20	71.36	53.52	40.64
27-Sep	19.7	19.5	19.8	19.9	19.8	19.7	48.96	49.20	50.24	70.64	52.96	37.04
27-Sep	19.6	19.7	19.9	19.8	19.7	19.6	48.64	48.72	51.52	70.32	52.56	35.92
28-Sep	19.5	19.6	19.8	20.0	19.6	19.5	48.00	48.00	50.72	69.84	52.08	30.16
28-Sep	18.8	18.7	19.0	19.2	19.4	18.9	47.20	47.04	48.88	68.88	51.52	27.76
29-Sep	17.8	17.9	18.1	18.1	18.9	18.5	46.24	46.08	48.56	68.00	50.72	29.12
29-Sep	18.5	18.0	18.3	18.6	18.7	18.6	46.40	45.92	46.48	68.08	50.40	32.16
30-Sep	17.6	17.9	18.2	18.1	18.4	18.2	45.84	45.76	45.76	67.76	50.08	32.64
30-Sep	18.5	18.1	18.5	18.8	18.7	20.3	47.04	46.72	54.48	68.72	50.72	52.88

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
1-Oct	18.6	18.8	19.1	18.8	18.7	18.8	47.84	47.76	53.84	69.36	51.44	51.68
1-Oct	20.1	19.0	19.4	20.2	19.2	20.0	49.76	49.28	60.24	70.96	52.72	70.88
2-Oct	19.6	19.3	19.6	19.9	19.3	19.4	50.88	51.20	62.96	71.84	54.08	72.64
2-Oct	20.4	19.7	20.0	20.8	19.8	20.7	52.64	53.12	65.20	73.20	55.60	82.56
3-Oct	20.2	19.5	19.8	20.4	19.9	19.9	53.52	54.40	66.00	73.84	56.72	73.84
3-Oct	20.8	20.2	20.5	20.8	20.7	20.9	54.40	55.44	67.12	74.56	57.84	68.56
4-Oct	19.9	19.8	20.1	20.2	20.4	20.0	53.52	54.56	63.44	74.16	57.28	52.16
4-Oct	19.9	20.0	20.3	20.3	20.2	20.0	53.44	54.40	62.80	74.00	56.88	60.72
5-Oct	20.0	20.2	20.5	21.0	20.2	20.0	54.08	55.04	64.16	74.64	57.28	65.12
5-Oct	19.6	19.9	20.2	20.3	20.1	19.8	53.68	54.56	60.32	74.40	57.28	46.96
6-Oct	19.4	19.9	20.1	20.0	19.9	19.6	53.04	53.68	57.60	73.52	56.56	40.96
6-Oct	18.8	19.2	19.4	20.0	19.8	19.7	51.84	52.32	52.32	72.64	55.84	30.72
7-Oct	18.3	18.6	18.2	18.7	19.4	19.0	50.88	51.04	51.12	71.36	54.72	32.64
7-Oct	19.0	18.8	18.7	19.7	19.3	19.5	51.04	50.96	54.56	71.76	54.40	43.44
8-Oct	18.8	19.0	19.2	19.1	19.1	19.0	50.72	50.72	52.32	71.12	54.08	40.64
8-Oct	19.7	19.7	19.9	20.2	19.5	20.4	50.96	50.88	52.72	71.52	54.16	40.88
9-Oct	19.6	19.7	20.0	20.0	19.6	19.6	51.04	50.96	53.92	71.36	54.24	42.24
9-Oct	19.6	18.8	19.3	20.3	19.9	20.2	50.96	50.56	55.68	71.28	54.48	54.16
10-Oct	18.5	18.5	18.8	18.9	19.5	19.2	50.80	50.96	56.00	70.88	54.48	46.16
10-Oct	18.6	18.8	19.1	20.3	19.5	19.6	50.80	51.04	55.12	71.60	54.40	44.08
11-Oct	17.9	18.3	18.6	18.7	19.1	18.7	50.24	50.32	52.24	70.40	53.84	39.76
11-Oct	18.3	18.6	18.9	18.6	18.8	18.6	50.00	50.00	50.56	70.00	53.44	36.00
12-Oct	18.3	18.6	18.8	18.4	18.6	18.4	50.24	50.08	53.76	70.16	53.44	38.56
12-Oct	17.5	17.6	17.8	17.5	18.2	17.8	49.12	48.80	50.96	69.12	52.72	28.08
13-Oct	17.1	17.3	17.5	17.1	17.8	17.5	48.24	47.92	49.44	68.40	51.76	28.08
13-Oct	16.8	17.1	17.3	16.9	17.5	17.3	47.44	47.04	44.24	67.84	51.12	26.40
14-Oct	16.7	17.2	16.2	16.8	17.3	17.1	47.20	46.72	45.84	67.60	50.64	31.68
14-Oct	17.5	17.2	17.2	17.7	17.5	17.7	48.00	47.28	52.88	68.48	51.04	48.72
15-Oct	16.6	16.8	17.0	16.8	17.2	17.1	48.64	48.40	56.64	68.80	51.76	55.04
15-Oct	17.1	16.8	17.2	17.5	17.3	17.2	49.28	49.04	55.04	69.60	52.48	33.04
16-Oct	16.2	16.5	16.7	16.6	17.0	16.9	48.32	48.16	50.32	68.64	51.76	37.52
16-Oct	16.9	16.5	16.7	16.8	17.1	19.3	48.40	48.00	50.40	68.64	51.68	33.92
17-Oct	16.8	17.0	17.2	17.0	17.0	17.1	48.48	48.32	51.68	68.80	51.68	44.32
17-Oct	18.0	17.5	17.9	18.0	17.7	18.8	49.36	48.88	53.44	69.44	52.32	45.76
18-Oct	18.1	17.8	18.1	18.0	17.8	17.8	49.44	49.20	52.80	69.68	52.56	41.76
18-Oct	17.6	17.8	18.1	17.7	17.7	17.6	49.12	48.96	53.12	69.28	52.40	49.92
19-Oct	17.4	17.7	17.9	17.4	17.6	17.4	49.36	49.28	53.84	69.44	52.64	42.96
19-Oct	16.9	17.1	17.3	16.8	17.4	17.2	48.56	48.40	48.08	68.80	52.24	30.32
20-Oct	16.7	17.1	17.3	16.6	17.1	17.0	48.00	47.76	47.76	68.24	51.52	33.60
20-Oct	17.4	17.2	17.5	17.2	17.5	18.0	48.24	47.68	48.48	68.40	51.68	38.00
21-Oct	17.0	17.1	17.4	17.0	17.3	17.2	48.40	48.00	50.96	68.56	51.76	42.72
21-Oct	17.4	17.6	17.8	18.0	17.5	18.7	48.80	48.56	52.72	69.36	52.08	44.48
22-Oct	17.0	17.2	17.4	17.3	17.5	17.3	48.32	48.00	49.04	68.64	51.92	34.16
22-Oct	17.1	17.3	17.6	17.3	17.6	18.1	48.00	47.68	48.08	68.24	51.60	38.08

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
23-Oct	17.5	17.7	18.0	17.7	17.7	17.7	48.64	48.32	51.76	68.88	51.92	45.12
23-Oct	18.7	18.4	18.6	18.8	18.3	19.2	49.68	49.12	54.40	69.68	52.56	50.16
24-Oct	18.6	18.6	18.9	18.7	18.4	18.5	50.80	50.56	58.88	70.56	53.68	65.28
24-Oct	20.3	19.1	19.4	20.8	19.2	20.3	52.72	52.32	64.32	72.40	55.20	69.12
25-Oct	19.6	19.3	19.6	19.9	19.3	19.2	53.12	53.44	63.60	72.64	56.08	70.80
25-Oct	19.3	19.4	19.6	19.7	19.3	19.2	53.76	54.32	64.64	73.12	56.72	72.64
26-Oct	19.2	19.4	19.6	19.5	19.3	19.2	54.40	55.12	65.20	73.52	57.36	72.56
26-Oct	18.9	19.1	19.3	19.2	19.2	18.8	54.80	55.44	65.20	74.00	57.84	60.32
27-Oct	17.7	17.7	17.8	18.0	18.7	18.2	53.36	53.92	61.76	72.64	56.88	41.44
27-Oct	18.4	18.2	18.5	18.7	18.9	19.1	52.72	53.04	55.68	72.24	56.16	34.96
28-Oct	18.0	17.9	18.2	18.0	18.6	18.2	51.68	51.76	52.16	71.04	55.12	29.12
28-Oct	18.2	17.6	17.9	17.8	18.6	18.7	50.56	50.40	47.44	70.00	54.16	24.00
29-Oct	17.0	17.1	17.4	17.2	18.1	17.6	49.20	49.04	48.24	69.04	52.88	23.84
29-Oct	17.5	17.4	17.7	17.5	18.1	19.4	48.56	48.32	44.64	68.40	52.24	20.80
30-Oct	17.5	17.4	17.7	17.5	17.9	17.7	47.92	47.44	43.36	67.84	51.44	23.44
30-Oct	18.5	17.9	18.2	18.4	18.1	19.4	48.00	47.20	45.20	68.00	51.12	29.76
31-Oct	18.1	18.0	18.3	18.1	18.1	18.1	48.16	47.68	48.32	67.92	51.36	40.40
31-Oct	18.9	18.4	18.6	18.7	18.5	20.0	48.64	48.16	50.40	68.40	51.84	40.72
31-Oct	18.8	18.5	18.7	18.7	18.6	18.7	48.88	48.48	51.60	68.64	52.00	46.96
1-Nov	18.2	18.2	18.5	18.3	18.4	18.3	48.96	48.64	52.32	68.72	52.24	45.04
1-Nov	18.1	18.2	18.4	18.4	18.3	18.2	49.12	48.96	53.36	68.96	52.40	45.28
2-Nov	17.9	18.1	18.2	18.0	18.1	18.0	48.64	48.40	51.52	68.32	52.16	31.44
2-Nov	16.3	16.2	16.4	16.6	17.6	16.8	46.80	46.32	47.92	66.88	51.04	17.84
3-Nov	16.4	16.7	16.9	16.5	17.2	16.9	46.16	45.68	47.04	66.24	50.00	21.20
3-Nov	16.8	16.7	16.9	16.2	17.2	17.1	45.68	45.12	40.48	65.84	49.52	19.52
4-Nov	16.0	16.2	16.4	15.9	16.8	16.5	44.80	44.24	42.56	65.36	48.72	19.68
4-Nov	15.9	16.3	16.6	16.1	16.7	16.6	44.40	43.92	39.04	65.12	48.48	21.20
5-Nov	15.7	16.2	16.4	15.8	16.5	16.3	44.24	43.68	42.72	65.04	48.16	22.48
5-Nov	16.5	16.6	16.9	17.2	16.7	16.8	44.32	43.60	42.24	65.52	48.00	33.20
6-Nov	15.8	16.1	16.3	16.1	16.4	16.3	43.92	43.28	42.88	64.88	47.84	20.88
6-Nov	15.0	15.5	15.7	15.6	16.3	16.1	42.80	42.40	35.28	64.24	47.36	13.20
7-Nov	14.6	15.1	15.4	14.9	15.8	15.5	42.16	41.60	38.32	63.52	46.56	14.48
7-Nov	14.5	15.1	15.4	14.6	15.7	15.8	41.60	41.28	35.68	63.20	46.24	18.88
8-Nov	14.1	14.7	14.9	14.4	15.3	15.1	41.44	40.80	38.72	62.96	45.84	18.00
8-Nov	14.7	15.4	15.6	14.9	15.2	15.3	41.44	40.88	35.44	63.04	45.60	22.72
9-Nov	14.0	15.1	14.4	14.4	15.1	15.0	41.12	40.88	39.60	62.80	45.60	23.36
9-Nov	14.3	15.0	15.1	14.6	15.0	15.0	41.28	40.64	40.08	62.96	45.44	20.80
10-Nov	14.6	15.0	15.2	14.8	14.9	15.0	41.28	40.48	40.48	62.96	45.28	22.72
10-Nov	14.7	15.0	15.2	15.3	14.9	14.9	41.20	40.40	38.32	63.28	45.36	25.52
11-Nov	14.6	15.0	15.2	14.8	14.8	15.0	41.28	40.56	40.96	63.04	45.36	25.84
11-Nov	14.5	14.7	15.0	14.5	15.2	15.0	41.28	40.56	40.56	63.04	45.60	28.80
12-Nov	14.0	14.5	14.7	14.2	14.9	14.8	41.20	40.56	41.28	62.96	45.44	29.52
12-Nov	13.9	14.4	14.6	14.5	14.9	14.7	41.76	41.20	45.92	63.76	46.00	40.24
13-Nov	13.9	14.4	14.7	14.2	14.7	14.7	42.24	41.68	46.64	63.84	46.16	41.12

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
13-Nov	14.9	15.1	15.4	15.4	15.0	15.2	43.44	42.96	49.68	65.20	47.04	42.48
14-Nov	14.3	14.8	15.1	14.7	14.9	14.9	43.20	42.80	47.04	64.72	47.12	41.60
14-Nov	14.7	14.6	15.0	15.3	15.1	15.4	45.44	45.04	56.72	66.40	48.56	78.72
15-Nov	14.6	14.7	14.9	14.9	15.0	15.0	46.48	46.48	58.32	67.04	49.76	59.36
15-Nov	14.7	15.1	15.3	15.3	15.0	14.9	46.48	46.56	56.16	67.36	49.92	51.84
16-Nov	14.3	14.7	14.9	14.4	14.8	14.7	45.68	45.68	51.36	66.40	49.44	27.36
16-Nov	13.7	14.1	14.3	13.9	14.5	14.3	44.48	44.32	43.60	65.44	48.56	22.40
17-Nov	13.7	14.3	14.4	13.9	14.3	14.3	44.00	43.76	45.52	64.88	47.84	25.84
17-Nov	13.6	13.8	14.1	13.7	14.4	14.3	43.76	43.44	44.64	64.80	47.76	31.52
18-Nov	13.5	14.0	14.2	13.7	14.2	14.1	43.68	43.36	46.16	64.64	47.36	35.76
18-Nov	15.6	14.5	14.9	14.6	14.6	14.9	45.12	44.24	50.40	65.60	48.00	48.32
19-Nov	14.6	14.6	14.9	14.5	14.6	14.8	45.52	45.20	53.44	66.24	48.64	60.40
19-Nov	16.6	15.3	15.6	15.9	15.6	15.6	48.16	47.68	60.64	68.24	50.72	68.40
20-Nov	15.4	15.2	15.4	15.5	15.5	15.4	48.16	48.40	60.00	68.48	51.36	57.44
20-Nov	14.7	14.4	14.8	15.3	15.4	15.1	46.72	47.04	51.12	67.76	50.80	35.20
21-Nov	14.4	14.5	14.8	14.7	15.2	15.0	46.48	46.48	50.24	66.96	50.08	37.92
21-Nov	14.9	14.7	15.0	15.4	15.4	15.1	46.32	46.40	48.48	67.20	50.08	35.28
22-Nov	14.4	14.6	14.9	14.9	15.1	14.9	45.92	45.92	49.76	66.56	49.52	35.20
22-Nov	14.6	15.2	15.0	14.7	15.0	15.0	46.00	46.08	48.64	93.52	49.36	42.48
23-Nov	14.8	15.1	14.8	14.5	14.9	14.9	46.32	46.24	51.60	94.48	49.44	47.92
23-Nov	13.8	14.0	14.2	14.2	14.6	14.4	45.60	45.60	46.24	94.64	49.36	32.16
24-Nov	13.7	14.1	14.3	13.9	14.4	15.2	45.36	45.20	45.60	94.48	48.80	29.76
24-Nov	13.6	13.4	13.7	14.0	14.4	14.1	44.64	44.40	42.00	94.24	48.48	22.64
25-Nov	13.2	13.4	13.6	13.5	14.0	14.0	44.00	43.76	42.72	94.24	47.76	28.64
25-Nov	13.0	12.9	13.2	13.9	14.1	13.6	43.60	43.28	40.56	94.08	47.60	22.32
26-Nov	12.7	13.0	13.2	13.1	13.6	13.5	43.20	42.88	41.44	93.92	46.88	27.04
26-Nov	13.3	13.4	13.7	13.5	13.8	13.7	43.36	43.04	40.64	93.76	46.96	27.60
27-Nov	13.2	13.5	13.8	13.6	13.6	14.6	43.44	43.04	43.68	93.76	46.72	35.68
27-Nov	14.4	14.4	14.6	14.7	14.3	14.4	44.00	43.68	42.56	93.76	47.36	30.08
28-Nov	13.8	14.0	14.3	14.2	14.2	15.7	43.52	43.20	42.88	93.60	47.04	30.88
28-Nov	14.2	14.4	14.7	15.4	14.5	14.6	43.60	43.36	40.80	93.52	47.20	27.52
29-Nov	14.2	14.5	14.7	14.7	14.5	14.5	43.44	43.04	44.00	93.28	46.96	29.20
29-Nov	14.5	14.9	15.1	14.8	14.7	14.8	44.96	44.64	55.84	93.20	47.92	74.16
30-Nov	14.0	14.6	14.1	14.6	14.6	14.6	45.44	45.28	54.24	93.20	48.72	48.64
30-Nov	12.6	13.7	13.7	13.8	14.3	14.1	44.48	44.72	47.28	92.88	48.56	35.52
1-Dec	12.9	13.5	13.6	13.5	14.1	14.9	44.48	44.08	45.60	92.56	48.08	26.32
1-Dec	13.0	13.3	13.5	13.0	14.0	13.8	43.60	43.12	36.72	92.16	47.44	14.32
2-Dec	12.7	12.7	12.9	12.8	13.5	13.3	42.40	41.60	39.36	92.08	46.32	38.48
2-Dec	11.2	11.1	11.4	11.6	13.2	12.9	42.96	42.40	50.16	94.88	46.80	57.68
3-Dec	11.1	11.1	11.4	11.6	12.6	12.5	43.20	42.56	49.28	94.96	46.80	51.36
3-Dec	10.6	10.5	10.5	11.3	12.3	11.8	43.76	43.28	50.88	95.44	47.20	52.24
4-Dec	10.7	11.0	10.9	11.0	11.8	11.7	44.08	43.36	49.12	95.36	46.96	43.28
4-Dec	10.0	10.0	9.9	10.6	11.4	11.3	43.52	43.20	49.20	95.28	46.88	46.56
5-Dec	10.0	9.9	9.8	10.3	11.0	10.8	43.44	42.80	49.20	95.28	46.56	49.44

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
5-Dec	10.4	10.7	10.7	10.5	11.0	11.2	44.24	44.00	52.88	95.36	47.04	55.60
6-Dec	10.2	10.8	10.2	9.9	10.7	10.9	44.40	44.16	53.44	95.36	47.12	37.52
6-Dec	9.6	10.6	10.4	9.7	10.4	10.6	44.64	44.56	58.88	95.36	47.36	58.16
7-Dec	9.6	10.2	10.1	9.7	10.2	10.4	44.96	44.72	59.28	95.36	47.60	45.44
7-Dec	9.4	10.0	9.9	9.9	10.0	10.3	44.80	44.56	59.52	95.36	47.52	43.84
8-Dec	10.2	10.3	10.3	10.3	10.1	12.7	45.52	44.72	62.96	95.36	47.52	72.24
8-Dec	11.4	11.2	11.3	11.0	10.9	11.8	46.64	46.32	67.68	95.12	48.88	54.56
9-Dec	11.0	11.0	11.0	11.0	10.8	12.3	46.96	46.32	71.60	95.36	49.20	58.40
9-Dec	11.6	11.4	11.4	11.5	11.2	11.5	47.28	46.88	75.20	95.28	49.60	52.24
10-Dec	11.9	11.8	11.9	12.1	11.3	13.6	47.52	46.96	76.88	95.52	49.60	56.00
10-Dec	13.2	12.3	12.3	14.0	12.4	14.3	48.40	47.92	77.84	95.60	50.72	38.40
11-Dec	12.8	12.5	12.6	13.0	12.3	14.2	48.16	47.92	78.40	95.52	50.64	55.76
11-Dec	13.5	13.1	13.3	13.7	13.1	15.0	48.80	48.72	81.04	98.32	51.52	43.12
12-Dec	13.7	13.6	13.8	13.9	13.4	15.8	49.20	49.12	80.56	98.32	51.68	78.00
12-Dec	13.9	12.8	12.9	14.6	13.8	14.3	49.52	49.28	76.80	95.60	52.24	45.92
13-Dec	13.3	13.0	13.0	13.7	13.6	13.5	49.12	49.20	77.20	95.52	52.00	46.08
13-Dec	13.1	13.0	12.7	13.1	13.4	13.4	49.44	49.76	76.80	95.36	52.16	65.04
14-Dec	12.8	12.9	12.3	12.5	13.1	13.1	49.68	50.08	76.48	95.36	52.32	50.08
14-Dec	12.4	12.8	12.4	12.1	12.8	12.8	49.04	49.44	76.48	95.44	51.84	39.92
15-Dec	11.6	11.8	11.6	11.6	12.3	12.3	47.92	47.84	75.52	95.60	51.12	39.44
15-Dec	10.5	10.6	10.6	10.6	12.0	11.7	47.68	47.76	75.36	95.76	50.96	54.48
16-Dec	9.6	9.9	9.3	9.5	11.2	10.2	47.12	46.80	74.32	95.68	50.48	32.16
16-Dec	8.3	8.2	8.1	8.3	10.5	10.2	46.40	46.32	74.40	95.44	49.84	29.68
17-Dec	8.6	8.2	7.9	8.7	9.7	9.9	46.48	45.52	73.76	95.60	49.12	54.56
17-Dec	7.2	7.1	7.2	7.8	8.9	9.1	45.92	45.92	74.56	95.36	48.80	57.84
18-Dec	7.1	7.4	7.2	7.6	8.2	8.3	46.08	46.00	74.64	95.36	48.56	49.20
18-Dec	6.8	6.8	6.9	7.5	7.8	8.0	46.16	46.16	75.68	95.04	48.56	49.04
19-Dec	6.7	7.2	7.3	7.2	7.5	8.5	46.56	46.64	76.32	94.56	48.56	61.12
19-Dec	8.3	8.9	8.9	8.4	8.2	8.8	47.84	48.08	77.76	94.56	49.44	61.20
20-Dec	8.2	8.9	8.9	8.6	8.1	8.7	48.16	48.40	78.64	94.72	49.68	66.48
20-Dec	8.2	9.0	9.1	8.6	8.2	8.8	48.56	48.88	78.88	94.64	50.16	59.68
21-Dec	7.9	8.9	8.7	8.4	8.2	8.7	48.48	48.72	79.12	94.64	50.32	54.64
21-Dec	8.1	8.9	8.5	8.4	8.2	8.7	48.64	48.72	79.28	94.64	50.40	52.40
22-Dec	8.8	9.3	9.1	9.0	8.5	10.8	48.96	48.80	79.12	94.56	50.56	68.32
22-Dec	9.2	9.6	9.5	9.8	9.2	9.7	49.76	49.76	79.44	94.72	51.68	44.88
23-Dec	8.8	9.0	8.7	8.9	9.1	10.3	48.80	48.64	79.36	94.56	51.12	26.96
23-Dec	8.6	9.4	9.3	8.7	8.9	9.2	48.08	47.84	79.84	94.64	50.48	24.72
24-Dec	8.4	9.1	9.0	8.3	8.7	8.9	47.12	46.72	79.84	94.56	49.52	21.44
24-Dec	8.2	8.9	8.7	8.0	8.5	8.7	46.32	45.76	79.76	94.64	48.72	21.52
25-Dec	8.0	8.8	8.6	7.8	8.3	8.6	45.68	45.04	79.44	94.56	48.08	21.92
25-Dec	8.4	9.3	9.1	8.2	8.2	8.8	45.68	45.12	79.36	94.64	47.76	38.56
26-Dec	8.6	9.2	8.7	8.4	8.4	9.6	45.84	45.12	78.96	94.56	47.84	41.36
26-Dec	8.8	9.6	9.2	9.1	8.8	9.5	45.92	45.44	78.88	94.56	48.24	31.76
27-Dec	8.9	9.6	9.4	8.8	8.7	10.0	45.76	45.04	78.96	94.64	47.92	42.40

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1991	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
27-Dec	9.3	10.0	9.4	9.3	8.9	9.4	46.40	45.68	78.96	94.80	48.32	40.08
28-Dec	9.1	9.8	9.6	9.1	8.9	9.4	46.08	45.28	79.28	94.80	48.24	35.36
28-Dec	9.1	9.7	9.6	9.0	8.9	9.3	45.92	45.04	79.28	94.80	48.08	36.00
29-Dec	9.2	9.8	9.8	9.2	9.0	10.4	45.68	44.80	78.88	94.72	47.92	34.24
29-Dec	10.1	10.8	10.8	10.2	9.7	10.4	45.84	45.04	78.96	94.72	48.24	23.12
30-Dec	9.4	10.1	10.0	9.3	9.5	10.2	44.88	44.00	78.96	94.64	47.60	23.12
30-Dec	9.5	10.2	10.1	9.5	9.5	10.9	44.88	44.00	78.80	94.64	47.52	24.72
31-Dec	9.3	10.1	10.0	9.4	9.5	9.6	44.40	43.44	79.04	94.80	47.12	17.60
31-Dec	8.9	9.6	9.4	8.7	9.2	9.2	43.60	42.56	78.72	94.72	46.48	15.84

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
1-Jan	8.6	9.3	9.2	8.5	9.0	9.0	43.04	41.84	78.56	94.72	45.84	17.28
1-Jan	8.8	9.6	9.6	9.2	8.9	9.5	42.80	41.68	78.16	94.80	45.52	25.84
2-Jan	9.1	9.9	10.0	9.4	9.1	9.3	43.20	42.08	78.48	94.88	45.76	30.16
2-Jan	9.7	10.3	10.4	10.0	9.3	10.2	43.60	42.32	78.24	94.80	45.84	38.56
3-Jan	9.7	10.3	10.4	9.8	9.4	9.7	43.92	42.72	78.40	94.80	46.24	38.96
3-Jan	9.5	10.0	10.1	9.5	9.4	9.6	43.92	42.72	78.32	94.88	46.40	40.56
4-Jan	9.4	9.8	9.4	8.8	9.3	9.6	44.16	42.96	77.76	95.04	46.56	47.84
4-Jan	9.3	9.7	9.2	9.0	9.2	9.5	44.56	43.44	77.60	95.04	46.88	52.24
5-Jan	9.2	9.6	9.4	8.8	9.1	9.4	44.96	44.00	77.76	94.96	47.28	52.32
5-Jan	10.1	9.7	9.7	10.2	9.7	10.7	45.84	44.64	77.04	94.88	48.08	58.72
6-Jan	9.6	9.6	9.7	9.5	9.6	9.8	45.92	45.12	77.52	94.80	48.40	44.64
6-Jan	10.2	10.0	10.2	10.6	9.9	11.1	46.24	45.44	77.12	94.88	48.64	52.24
7-Jan	9.7	9.8	10.0	9.7	9.8	10.0	45.68	45.12	77.44	94.80	48.56	26.64
7-Jan	9.5	9.6	9.7	9.6	9.8	10.5	44.56	43.84	76.64	94.72	47.84	23.28
8-Jan	8.9	9.6	9.7	9.0	9.5	9.5	44.00	43.36	77.20	94.72	47.12	22.32
8-Jan	9.1	8.6	8.7	9.3	9.8	11.3	43.76	42.72	75.52	94.24	47.04	35.60
9-Jan	8.6	9.2	9.0	8.7	9.2	9.4	44.08	43.44	76.72	94.32	46.96	37.76
9-Jan	8.6	8.1	8.0	8.8	9.5	10.9	44.40	43.60	75.52	93.84	47.44	40.56
10-Jan	7.9	8.6	8.2	8.1	8.9	8.8	44.72	44.24	76.48	94.08	47.52	48.64
10-Jan	7.9	8.6	8.3	7.9	8.6	8.6	44.80	44.16	76.48	94.16	47.44	44.32
11-Jan	7.6	8.5	7.4	7.0	8.2	8.2	44.48	43.84	76.00	94.32	47.12	27.60
11-Jan	7.5	8.6	7.9	7.0	7.9	8.2	43.92	43.28	76.40	94.48	46.56	24.88
12-Jan	7.5	8.4	8.1	7.2	7.7	8.0	43.44	42.64	76.48	94.48	46.08	26.72
12-Jan	7.1	7.2	7.1	7.4	7.9	9.6	43.76	42.88	75.20	94.40	46.48	51.44
13-Jan	7.5	8.2	8.1	7.6	7.6	8.0	45.28	44.48	76.48	94.80	47.20	65.84
13-Jan	8.9	8.4	8.4	8.7	8.6	9.9	46.64	45.76	75.44	94.72	48.56	52.00
14-Jan	7.6	7.7	7.3	7.3	8.0	8.0	46.24	45.68	76.56	94.88	48.64	43.76
14-Jan	5.5	4.6	5.1	5.1	7.6	9.1	44.48	44.00	74.56	94.48	48.32	41.44
15-Jan	4.2	4.8	4.7	3.7	6.2	5.6	43.84	44.00	76.72	94.64	47.36	24.32
15-Jan	3.2	3.3	3.3	3.6	5.9	6.8	42.72	42.72	75.44	94.24	46.80	31.92
16-Jan	4.4	5.5	5.0	4.7	6.0	7.8	43.28	43.76	76.96	92.64	46.56	27.12
16-Jan	5.4	5.7	5.4	5.4	6.7	8.9	43.84	43.68	76.48	91.76	46.88	31.52
17-Jan	5.5	6.2	5.6	5.3	6.0	6.2	44.64	44.32	78.56	92.40	46.56	40.08
17-Jan	5.2	5.9	5.5	5.1	5.7	5.9	44.32	43.84	78.72	93.20	46.24	44.56
18-Jan	4.7	5.5	5.3	4.5	5.2	5.2	43.92	43.52	79.36	93.52	46.00	30.32
18-Jan	4.1	5.0	4.7	4.2	4.7	4.8	43.20	42.80	78.96	93.60	45.44	30.80
19-Jan	3.0	3.8	2.6	2.7	4.1	4.3	42.08	41.68	77.68	93.20	44.96	23.52
19-Jan	5.1	5.3	5.0	4.5	5.4	6.8	43.52	42.80	78.08	93.20	45.76	34.64
20-Jan	4.4	5.1	4.8	4.2	4.7	5.0	43.44	43.04	79.04	93.60	45.44	39.84
20-Jan	5.4	5.7	5.6	5.6	5.6	7.9	43.92	43.52	78.64	93.44	46.08	34.48
21-Jan	6.2	6.9	6.0	5.7	5.8	7.6	44.16	43.92	79.04	93.52	46.16	31.76
21-Jan	6.3	6.2	6.0	6.1	6.4	6.9	44.48	43.92	79.52	94.08	46.80	37.92
22-Jan	6.0	6.7	5.5	4.8	6.2	8.2	43.68	43.52	78.88	92.64	46.16	30.48
22-Jan	7.8	8.2	7.9	6.9	7.2	10.7	45.28	44.96	79.36	92.72	46.88	57.36

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
23-Jan	7.9	8.3	8.2	7.3	7.0	7.8	46.56	46.16	80.72	93.20	47.76	74.64
23-Jan	7.2	7.0	6.7	6.2	7.4	8.4	46.40	46.16	79.76	92.80	48.72	27.44
24-Jan	6.2	6.8	6.4	5.2	6.8	6.6	45.20	45.20	80.56	92.88	47.84	21.92
24-Jan	4.9	5.6	5.1	4.3	6.2	6.6	43.52	43.68	79.68	92.96	46.88	21.20
25-Jan	4.1	5.4	4.1	3.6	5.5	6.0	42.80	43.12	79.52	93.12	46.08	24.88
25-Jan	4.7	6.0	5.2	4.0	5.3	6.8	42.96	43.04	80.08	93.20	45.52	22.96
26-Jan	3.9	5.0	4.2	3.2	4.7	5.3	42.16	42.00	79.76	93.20	45.04	25.68
26-Jan	6.7	7.2	6.8	6.0	7.1	11.8	43.36	43.36	78.32	92.64	46.16	32.08
27-Jan	9.3	10.2	9.5	9.2	9.1	13.0	45.04	45.04	79.36	93.36	47.60	26.08
27-Jan	10.2	11.2	10.9	10.7	11.1	13.9	45.60	45.60	79.52	93.52	48.72	31.36
28-Jan	12.2	12.9	12.6	11.8	12.0	14.8	46.88	46.32	80.64	93.92	49.12	36.08
28-Jan	13.2	12.4	12.2	12.6	12.6	14.0	47.84	46.48	80.88	94.24	49.84	43.44
29-Jan	13.4	13.5	13.4	12.9	12.8	14.1	48.16	47.20	81.92	94.48	50.08	42.88
29-Jan	14.2	14.1	13.9	14.2	14.0	15.8	48.64	48.00	81.28	94.40	51.12	44.88
30-Jan	14.2	15.1	14.8	14.0	14.6	16.4	49.20	49.12	82.08	94.80	51.92	44.24
30-Jan	15.0	14.9	14.7	15.1	15.4	16.6	49.44	48.80	81.92	95.04	52.32	37.12
31-Jan	15.7	16.1	15.9	15.3	15.7	16.9	49.20	48.48	83.12	95.12	51.92	22.72
31-Jan	16.2	16.8	15.8	15.6	16.1	17.4	48.48	47.68	83.04	95.20	51.28	20.64
1-Feb	16.3	16.8	16.0	16.0	16.4	17.4	47.76	46.72	83.44	95.28	50.80	18.08
1-Feb	16.7	17.2	17.0	16.3	16.8	17.9	47.20	46.00	83.84	95.36	50.24	18.80
2-Feb	16.9	17.4	17.2	16.6	17.1	18.1	46.64	45.36	83.76	95.36	49.84	16.64
2-Feb	15.2	15.5	15.5	15.1	16.7	17.2	45.28	44.16	83.20	95.12	49.20	18.72
3-Feb	15.5	16.2	16.0	15.2	16.6	17.4	45.20	44.08	83.52	95.20	48.80	20.16
3-Feb	13.6	13.3	12.6	12.7	15.7	15.8	44.16	42.80	82.72	95.20	48.24	21.84
4-Feb	12.2	12.1	11.4	12.0	14.7	14.5	42.88	41.92	82.48	95.28	47.36	22.24
4-Feb	12.5	13.3	12.8	12.6	14.5	15.7	43.36	42.64	82.64	94.72	47.12	24.00
5-Feb	13.0	13.0	12.3	13.2	14.4	15.6	43.28	42.24	82.08	94.72	46.96	25.20
5-Feb	12.0	13.4	12.5	12.7	14.5	15.7	42.80	42.56	82.32	94.72	46.88	22.24
6-Feb	13.4	13.5	13.4	13.6	14.7	16.6	43.36	42.08	81.84	94.88	46.88	30.08
6-Feb	14.0	14.2	13.8	13.9	15.1	16.5	44.16	42.96	82.40	94.96	47.28	29.52
7-Feb	15.4	15.7	15.3	15.0	15.5	17.1	44.88	43.68	82.80	95.04	47.44	25.20
7-Feb	15.4	16.4	15.5	15.5	16.0	17.4	44.08	43.52	82.24	95.04	47.52	19.92
8-Feb	14.4	15.7	14.1	14.7	15.8	16.6	43.20	42.40	82.08	95.04	46.96	14.56
8-Feb	14.0	15.3	15.0	14.0	15.7	16.6	42.48	41.68	82.56	94.80	46.40	14.56
9-Feb	12.6	12.1	11.9	13.2	14.9	14.4	41.36	39.76	80.96	95.04	45.76	21.60
9-Feb	13.0	13.6	13.3	12.9	14.8	15.7	41.92	40.80	81.92	94.72	45.60	23.36
10-Feb	13.7	13.6	13.7	13.5	14.8	17.1	42.24	40.88	81.28	94.72	45.68	41.44
10-Feb	12.7	12.5	12.4	12.2	14.7	15.4	42.08	40.80	81.04	94.56	45.84	21.52
11-Feb	12.0	11.5	11.5	11.3	14.1	14.5	41.44	39.84	80.16	94.56	45.28	26.88
11-Feb	11.8	11.7	11.6	11.0	13.8	14.5	41.28	40.24	80.56	94.48	45.04	22.24
12-Feb	10.7	10.8	10.6	9.9	13.2	14.1	40.40	39.28	79.28	94.16	44.56	20.64
12-Feb	11.6	12.6	12.4	10.7	13.2	14.8	41.20	40.56	80.32	94.40	44.48	27.76
12-Feb	13.3	13.2	13.0	12.2	13.8	16.2	42.24	40.96	79.44	94.48	45.04	31.44
13-Feb	13.8	14.1	14.0	13.0	14.3	16.2	42.64	41.68	80.00	94.72	45.52	26.40

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
13-Feb	14.5	15.5	15.1	13.9	14.8	16.6	42.88	42.08	79.92	94.88	45.76	25.60
14-Feb	15.2	16.1	15.9	14.6	15.4	17.2	43.20	42.40	79.76	95.12	46.08	30.08
14-Feb	15.6	16.3	16.2	15.2	16.0	17.5	43.52	42.48	79.28	95.12	46.56	27.92
15-Feb	16.0	16.9	16.6	15.7	16.6	18.0	43.60	42.72	78.88	95.12	46.88	26.40
15-Feb	15.3	15.8	15.6	15.7	17.0	18.3	43.04	42.24	77.68	95.12	47.04	36.08
16-Feb	15.0	15.3	15.1	15.1	16.8	17.6	44.08	43.04	78.16	95.12	47.52	33.44
16-Feb	15.3	14.3	14.2	15.1	16.5	16.3	44.64	42.88	77.52	95.36	47.60	58.48
17-Feb	15.1	15.1	15.0	14.8	16.2	16.0	45.28	44.40	78.64	95.36	48.16	45.68
17-Feb	15.0	14.7	14.7	15.0	15.9	15.9	45.76	44.80	78.16	95.44	48.32	66.40
18-Feb	14.0	13.6	13.7	14.0	15.2	14.8	45.92	45.12	78.08	95.20	48.64	47.04
18-Feb	13.5	12.7	12.8	12.9	14.8	14.5	45.60	44.80	77.60	94.96	48.40	59.52
19-Feb	13.3	13.3	13.3	12.8	14.3	14.0	45.52	45.20	78.24	95.12	48.32	33.52
19-Feb	11.4	10.9	11.0	11.6	13.6	13.2	44.08	43.68	76.80	94.96	47.68	54.64
20-Feb	10.3	10.7	10.4	10.6	12.8	12.0	44.00	43.92	77.44	94.96	47.44	36.40
20-Feb	8.9	9.9	10.1	9.4	11.8	11.1	42.96	43.04	77.28	94.88	46.48	29.20
21-Feb	9.2	9.9	9.4	9.1	10.7	10.0	42.96	42.64	77.12	94.96	45.52	36.48
21-Feb	8.8	9.3	9.3	8.5	9.8	9.4	42.64	42.16	77.44	94.88	44.96	28.72
22-Feb	8.3	8.8	7.8	8.0	9.0	9.0	41.84	41.36	76.48	94.80	44.24	26.48
22-Feb	9.4	10.3	9.7	9.3	10.1	13.7	41.60	41.84	75.68	94.40	44.56	23.68
23-Feb	8.5	10.9	10.9	9.7	10.1	10.5	41.36	41.84	76.96	94.80	44.64	25.36
23-Feb	9.8	10.9	10.7	10.3	10.8	13.4	41.92	41.52	75.52	94.56	44.64	29.76
24-Feb	11.2	12.1	11.7	11.6	11.3	12.2	43.28	42.64	76.64	95.04	45.36	36.88
24-Feb	11.3	11.2	10.9	11.2	11.3	12.2	43.68	42.56	76.56	94.96	45.52	65.76
25-Feb	11.3	11.8	11.5	11.4	11.5	11.9	44.56	44.00	77.04	95.04	46.48	56.96
25-Feb	12.3	12.2	11.9	12.1	11.9	12.7	45.92	45.12	76.88	95.12	47.44	67.04
26-Feb	11.8	12.1	11.2	11.1	11.9	12.0	45.52	45.12	76.88	95.20	47.68	36.08
26-Feb	10.4	10.6	10.1	10.4	11.5	11.5	44.40	43.92	76.64	95.12	47.28	49.36
27-Feb	10.2	11.2	10.9	10.4	11.3	11.4	44.16	44.08	77.44	95.12	46.96	24.64
27-Feb	9.8	10.7	10.6	9.6	10.8	10.9	43.20	43.04	77.36	95.04	46.08	19.68
28-Feb	9.5	10.5	10.2	9.2	10.4	10.4	42.40	42.16	77.44	94.96	45.20	17.60
28-Feb	9.2	10.2	9.9	8.8	10.0	10.1	41.76	41.36	77.28	94.96	44.48	24.24
1-Mar	9.1	10.1	9.9	8.8	9.7	9.8	41.44	41.04	77.28	94.96	44.08	17.36
1-Mar	8.5	9.0	8.9	9.0	9.4	10.0	41.36	40.72	76.80	95.04	44.00	54.40
2-Mar	8.5	9.2	8.8	8.5	9.2	9.4	41.92	41.52	77.04	94.80	44.32	44.96
2-Mar	9.0	9.2	9.0	9.1	9.3	10.2	42.88	42.24	76.88	94.56	44.80	55.28
3-Mar	9.9	10.3	10.1	9.5	9.7	10.2	43.28	42.88	77.60	94.64	45.36	39.12
3-Mar	10.7	10.9	10.7	10.2	10.4	12.4	43.60	43.20	76.60	94.40	45.70	37.80
4-Mar	10.7	11.3	11.1	10.4	10.4	10.9	44.40	44.20	78.00	94.80	46.40	49.10
4-Mar	11.9	12.0	11.8	11.8	11.3	15.4	45.40	45.10	77.10	94.70	47.30	37.50
5-Mar	11.4	11.9	11.8	11.2	11.1	11.6	45.40	45.30	78.20	95.00	47.50	35.00
5-Mar	12.2	12.2	12.1	12.0	11.8	14.0	45.10	45.00	77.40	94.80	47.60	26.00
6-Mar	11.8	12.4	12.2	11.6	11.7	12.0	44.90	44.70	78.30	95.00	47.40	37.40
6-Mar	12.0	12.6	12.5	11.7	12.0	13.5	45.30	45.30	78.20	95.00	47.70	48.00
7-Mar	11.7	12.3	12.2	11.5	11.8	12.1	45.70	45.50	78.40	95.00	48.00	49.60

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
7-Mar	11.6	12.1	11.9	11.3	11.6	11.9	45.90	45.70	78.20	95.00	48.20	51.20
8-Mar	11.4	11.8	11.7	11.1	11.5	11.8	46.00	45.80	78.20	95.00	48.30	47.30
8-Mar	13.2	12.7	12.5	12.6	12.3	15.4	47.40	47.00	77.40	95.00	49.30	50.40
9-Mar	12.8	12.9	12.8	12.5	12.5	12.8	47.70	47.70	78.30	95.20	49.90	52.60
9-Mar	13.5	13.1	13.0	13.3	13.1	14.8	48.70	48.60	77.50	95.10	50.90	57.10
10-Mar	12.3	12.3	12.2	12.2	12.7	12.8	48.40	48.60	78.20	95.10	51.00	37.10
10-Mar	11.4	10.4	10.4	11.3	13.0	14.8	46.80	47.00	75.80	94.60	50.60	29.00
11-Mar	9.8	10.5	9.9	10.1	12.1	11.4	45.70	46.40	77.40	94.80	49.40	20.90
11-Mar	7.7	8.2	8.2	8.6	11.7	12.4	43.68	44.64	75.36	93.76	48.64	23.76
12-Mar	6.1	7.7	7.6	7.0	10.0	8.8	43.04	44.08	76.72	93.84	47.20	16.56
12-Mar	6.4	6.9	6.6	6.2	9.5	11.5	42.72	43.36	74.72	93.20	46.24	32.08
13-Mar	8.7	9.9	9.0	8.0	9.7	11.4	44.32	44.96	76.56	93.76	46.48	28.40
13-Mar	10.5	12.0	11.2	10.0	10.6	12.9	44.96	45.44	76.72	94.00	46.80	24.16
14-Mar	11.2	12.5	12.0	11.0	11.4	13.1	44.96	45.04	77.28	94.16	46.96	22.48
14-Mar	12.1	13.1	12.5	11.9	12.2	14.2	44.88	44.56	76.48	94.24	47.04	20.56
15-Mar	12.4	13.6	11.9	12.2	12.7	14.0	44.56	44.32	76.40	94.40	46.96	20.56
15-Mar	13.5	14.4	13.6	12.7	13.5	15.5	44.72	44.24	76.40	94.16	46.96	27.28
16-Mar	14.1	15.2	14.8	13.5	14.1	15.9	45.28	44.72	77.04	94.56	47.36	33.04
16-Mar	13.9	14.0	13.9	13.6	14.3	15.0	46.16	45.44	76.24	94.64	48.40	54.00
17-Mar	12.6	13.3	13.0	12.5	13.5	13.6	45.76	45.28	77.36	94.96	48.16	29.44
17-Mar	12.8	12.8	12.5	12.0	13.4	15.2	45.20	44.80	73.60	91.76	47.84	22.00
18-Mar	12.1	12.8	12.5	11.9	13.0	13.0	44.80	44.40	77.20	94.96	47.44	19.52
18-Mar	13.2	13.0	12.9	12.4	13.3	14.8	44.96	44.00	76.32	94.80	47.20	20.96
19-Mar	12.3	13.0	12.8	12.2	13.0	13.1	43.76	43.44	76.88	95.04	46.56	18.16
19-Mar	13.6	14.0	13.9	13.1	13.6	14.9	44.16	43.52	76.16	94.88	46.64	25.52
20-Mar	13.4	13.9	13.8	13.1	13.7	13.8	44.08	43.36	79.52	97.92	46.72	14.80
20-Mar	12.4	12.9	12.7	11.8	13.0	13.1	42.64	41.76	76.56	95.04	45.44	12.72
21-Mar	11.8	12.3	12.1	11.4	12.6	12.7	41.68	40.80	76.16	94.96	44.64	10.24
21-Mar	11.6	12.3	12.2	11.0	12.3	12.4	41.04	40.24	76.08	94.88	44.00	13.04
22-Mar	11.3	11.9	11.8	10.9	11.9	12.0	40.48	39.60	75.92	94.96	43.44	12.96
22-Mar	12.4	12.6	12.5	12.0	12.3	13.0	41.04	40.00	75.12	94.80	43.60	22.40
23-Mar	11.5	12.0	11.1	10.5	11.8	11.9	40.56	39.60	74.96	94.80	43.36	18.24
23-Mar	12.1	12.8	12.6	11.7	12.3	14.4	41.12	40.32	75.04	94.88	43.76	22.56
24-Mar	11.9	12.6	12.4	11.6	12.1	12.4	40.96	40.00	75.52	95.12	43.68	17.84
24-Mar	13.6	14.2	14.1	13.2	13.2	15.1	42.00	41.20	77.76	97.92	44.48	29.44
25-Mar	13.2	13.8	13.7	12.8	12.9	13.4	42.00	41.04	75.68	95.28	44.48	38.08
25-Mar	14.4	14.1	14.0	14.0	13.9	16.6	43.84	42.72	74.88	95.20	46.00	48.24
26-Mar	14.1	14.4	14.2	13.8	13.9	14.1	44.72	43.92	76.00	95.36	47.04	55.84
26-Mar	14.9	13.9	13.9	14.5	14.5	15.5	46.16	45.44	74.80	95.12	48.56	56.24
27-Mar	14.0	13.9	13.8	13.7	14.2	14.2	46.32	46.08	76.08	95.36	48.96	49.60
27-Mar	13.7	14.1	14.0	13.0	14.0	14.1	45.84	45.76	76.16	95.20	48.72	37.44
28-Mar	13.5	14.0	13.8	13.1	14.1	14.0	45.36	45.12	78.88	98.16	48.48	22.88
28-Mar	13.0	13.5	13.4	12.7	13.5	13.5	44.08	43.68	76.08	95.28	47.12	24.08
29-Mar	12.8	13.2	13.0	12.6	13.2	13.3	43.52	43.04	75.92	95.28	46.56	25.84

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
29-Mar	14.5	14.0	13.8	14.3	14.0	14.9	44.40	43.52	74.72	95.20	47.04	35.36
30-Mar	13.9	14.0	13.9	13.5	13.8	14.1	44.48	43.92	75.92	95.28	47.12	37.60
30-Mar	15.6	14.5	14.3	15.2	14.8	15.5	45.68	44.64	74.72	95.28	48.16	38.64
31-Mar	14.3	14.4	14.2	14.2	14.4	14.5	45.12	44.72	75.92	95.44	47.92	40.32
31-Mar	15.2	14.1	13.9	14.5	14.8	15.2	46.48	45.92	75.12	95.20	49.12	49.28
1-Apr	13.9	14.0	13.8	13.6	14.3	14.2	45.84	45.84	76.00	95.28	48.88	34.00
1-Apr	14.8	14.3	14.2	14.3	14.6	15.2	46.08	45.84	75.60	95.36	49.04	29.52
2-Apr	13.9	14.0	14.0	13.7	14.3	14.2	45.04	44.96	75.68	95.36	48.24	29.92
2-Apr	15.0	14.5	14.4	14.3	14.8	15.5	45.20	44.88	75.28	95.20	48.24	22.00
3-Apr	14.1	14.0	13.8	13.8	14.4	14.4	44.16	43.92	75.20	95.28	47.44	22.72
3-Apr	13.8	14.1	13.7	13.5	14.2	14.2	43.52	43.28	74.88	95.28	46.72	24.48
4-Apr	13.5	13.8	13.7	13.2	13.9	14.0	43.04	42.80	75.12	95.28	46.24	25.36
4-Apr	13.4	14.0	13.8	13.2	13.7	13.8	42.96	42.64	75.20	95.28	46.00	28.16
5-Apr	13.4	13.7	13.5	13.0	13.5	14.4	43.12	42.32	75.04	95.28	45.76	29.60
5-Apr	14.8	14.5	14.4	14.1	14.1	15.5	43.28	42.72	74.56	95.20	46.16	22.32
6-Apr	14.1	14.2	14.1	14.1	14.0	16.3	43.04	42.32	74.56	95.44	45.92	51.04
6-Apr	14.9	14.5	14.4	15.1	14.8	16.2	44.64	44.24	74.56	95.36	47.52	49.12
7-Apr	15.1	14.8	14.8	15.2	14.7	15.7	45.36	44.88	74.96	95.36	47.92	47.84
7-Apr	15.6	15.8	15.7	15.7	15.2	15.6	45.04	44.96	74.96	95.36	48.16	27.92
8-Apr	16.4	15.7	15.6	15.7	15.4	17.2	45.04	44.24	74.48	95.36	47.68	28.56
9-Apr	16.0	16.1	16.0	15.7	15.7	15.8	44.72	44.40	74.88	95.52	47.84	35.44
9-Apr	17.2	16.3	16.3	16.3	16.1	17.4	45.12	44.32	74.40	95.36	47.92	26.64
10-Apr	15.9	16.0	15.9	15.6	16.0	15.9	43.52	43.12	74.32	95.44	47.12	19.68
10-Apr	14.8	15.6	15.0	14.7	15.7	15.5	42.56	42.48	73.76	95.84	46.56	29.84
11-Apr	13.9	15.1	14.3	13.9	15.2	14.9	42.56	42.48	73.92	95.68	46.32	34.80
11-Apr	14.2	15.0	14.7	14.1	14.9	14.8	42.88	42.48	74.08	95.76	46.32	25.92
12-Apr	13.9	14.5	14.3	13.9	14.5	14.7	42.16	41.60	73.76	95.76	45.60	28.32
12-Apr	14.5	15.0	14.8	14.5	14.5	14.7	42.40	41.84	73.28	95.76	45.68	20.88
13-Apr	14.6	14.9	13.9	14.2	14.6	15.8	42.00	41.28	72.80	95.60	45.28	30.72
13-Apr	15.3	15.3	15.1	15.0	15.0	15.3	42.32	41.52	72.88	95.76	45.52	22.24
14-Apr	15.8	15.2	15.1	15.3	15.1	15.9	42.24	41.04	72.48	95.92	45.20	18.48
15-Apr	15.4	15.4	15.3	15.4	15.2	15.3	41.36	40.56	72.48	95.92	44.80	19.84
15-Apr	15.4	15.2	15.1	15.2	15.6	16.5	41.20	40.32	71.76	95.76	44.80	24.40
16-Apr	15.1	15.4	15.3	15.0	15.4	15.4	41.60	40.88	72.24	95.84	45.04	34.24
16-Apr	14.8	15.3	15.2	14.7	15.2	15.2	41.76	41.20	72.48	95.84	45.20	35.44
17-Apr	14.6	15.0	15.0	14.4	15.0	14.9	41.84	41.28	72.48	95.84	45.28	32.00
17-Apr	14.4	14.9	14.8	14.3	14.8	14.8	41.92	41.36	72.40	95.76	45.36	37.68
18-Apr	14.3	14.7	13.8	13.8	14.5	14.6	42.24	41.76	71.84	95.76	45.60	40.16
18-Apr	14.4	14.9	14.2	14.1	14.4	14.7	42.80	42.40	72.40	95.76	45.92	49.44
19-Apr	14.3	14.7	14.5	14.1	14.3	14.6	43.44	43.04	72.72	95.76	46.56	50.56
19-Apr	14.4	14.9	14.4	14.3	14.3	14.6	44.32	44.16	72.72	95.76	47.28	64.96
20-Apr	15.5	15.7	15.5	16.1	15.0	17.3	46.24	46.08	73.12	95.84	48.88	63.68
21-Apr	15.9	16.2	16.1	16.1	15.6	15.8	48.16	48.32	73.84	96.00	50.80	82.32
21-Apr	17.0	17.1	17.2	17.7	16.4	17.5	50.16	50.48	74.16	96.16	52.56	85.92

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
22-Apr	16.8	16.9	16.8	16.7	16.5	16.6	50.56	51.04	74.64	96.24	53.44	70.40
22-Apr	17.6	17.0	17.0	17.6	17.1	18.6	51.36	51.68	74.48	96.16	54.32	42.80
23-Apr	17.1	17.0	17.0	17.2	16.9	16.9	50.48	50.96	75.04	96.24	53.68	50.64
23-Apr	17.7	17.4	17.6	17.9	17.6	17.6	50.24	50.64	74.96	96.32	53.68	41.60
24-Apr	17.1	17.2	17.3	17.3	17.3	17.1	49.52	49.92	75.12	96.24	52.96	40.56
24-Apr	17.0	17.4	16.6	16.3	17.2	17.1	49.12	49.44	74.56	96.24	52.40	40.64
25-Apr	16.9	17.3	16.8	16.1	16.9	16.9	48.80	48.88	75.04	96.24	51.92	38.88
25-Apr	16.9	17.1	17.0	16.5	16.8	16.8	48.48	48.40	75.04	96.32	51.52	35.76
26-Apr	16.8	16.9	16.9	16.5	16.7	16.8	47.84	47.68	74.80	96.40	51.04	33.28
26-Apr	18.1	17.7	17.8	17.8	17.3	17.5	47.92	47.44	74.32	96.40	50.96	25.36
27-Apr	17.3	17.3	17.4	17.1	17.2	17.2	46.64	46.32	74.24	96.48	50.00	26.72
27-Apr	17.8	18.0	18.1	18.9	17.6	19.3	46.24	45.92	73.36	96.64	49.68	13.76
28-Apr	17.6	17.9	18.0	18.1	17.5	17.6	45.60	45.04	73.44	96.48	48.96	27.36
28-Apr	18.8	18.8	18.8	18.6	18.3	20.1	45.92	45.20	72.56	96.40	49.12	25.84
29-Apr	18.3	18.4	18.5	18.2	18.2	18.2	45.68	44.96	72.72	96.48	48.96	45.68
29-Apr	17.5	17.5	17.6	17.4	18.0	17.7	46.48	46.08	73.12	96.40	49.92	34.32
30-Apr	17.8	17.6	17.8	17.6	18.1	19.3	46.30	45.90	72.50	96.20	49.80	29.90
30-Apr	17.8	17.9	18.1	17.7	18.0	17.8	46.10	45.70	71.90	96.40	49.40	37.70
1-May	17.6	17.8	18.0	17.6	17.8	17.6	46.20	45.80	72.30	96.40	49.40	43.30
1-May	17.6	18.0	18.2	17.7	17.6	17.6	46.60	46.30	72.00	96.40	49.80	44.60
2-May	17.4	17.7	17.9	17.4	17.5	17.4	46.60	46.40	72.20	96.40	49.90	40.00
2-May	17.3	17.8	17.9	17.5	17.4	17.4	46.50	46.20	71.80	96.40	49.80	38.00
2-May	17.6	17.7	17.9	17.4	17.5	18.2	46.40	46.00	71.28	96.24	49.68	38.88
2-May	17.2	17.4	17.6	17.2	17.4	17.3	45.84	45.36	70.72	96.24	49.36	25.76
3-May	17.6	17.6	17.7	17.4	17.6	18.8	45.52	44.96	70.16	96.16	48.96	30.08
3-May	17.0	17.2	17.4	17.1	17.4	17.2	45.12	44.56	69.52	96.16	48.72	30.96
4-May	17.9	17.4	17.6	17.1	17.6	18.9	45.28	44.48	68.88	96.08	48.56	28.16
4-May	17.5	17.5	17.7	18.0	17.4	17.4	44.64	44.00	68.24	96.32	48.16	23.76
5-May	18.1	17.8	18.0	18.2	17.9	19.2	44.88	44.00	67.60	96.08	48.16	30.32
5-May	18.3	18.2	18.4	18.2	17.9	17.9	44.80	44.00	67.68	96.24	48.08	30.40
6-May	18.7	18.4	18.5	18.5	18.4	19.4	44.88	44.08	67.44	96.16	48.24	31.76
6-May	18.9	18.9	19.1	18.8	18.5	18.5	44.88	44.08	67.04	96.32	48.24	33.12
7-May	18.4	18.5	18.6	18.4	18.4	18.3	44.80	44.16	67.76	96.24	48.32	60.96
7-May	18.2	18.6	18.6	17.9	18.2	18.2	46.48	46.32	69.52	96.24	49.68	62.16
8-May	18.1	18.5	18.6	17.8	18.1	18.1	47.28	47.20	70.16	96.24	50.56	50.32
8-May	18.4	18.9	19.0	18.7	18.1	18.3	47.28	47.20	70.08	96.40	50.64	46.40
9-May	19.2	19.1	19.2	19.0	18.6	20.2	47.52	47.36	68.96	96.08	51.04	37.92
9-May	20.3	20.0	20.2	19.9	19.0	19.3	48.16	47.76	68.80	96.32	51.28	45.28
10-May	21.4	20.5	20.5	20.6	20.0	21.7	48.96	48.40	68.96	96.24	52.08	47.52
10-May	21.3	20.9	21.1	21.3	20.2	20.3	49.28	49.12	69.76	96.40	52.64	52.72
11-May	22.1	21.3	21.5	21.6	20.7	22.4	50.08	49.76	69.28	96.40	53.28	47.52
12-May	21.4	20.9	21.1	21.5	20.8	20.7	49.80	49.80	69.70	96.40	53.70	39.20
12-May	21.7	20.9	21.1	21	21.0	21.7	49.50	49.40	68.90	96.20	53.30	34.20
13-May	20.9	20.6	20.9	20.7	20.8	20.5	48.20	48.00	68.30	96.30	52.30	26.40

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
13-May	21	20.7	20.9	20.9	20.9	21.4	47.60	47.40	67.30	96.20	51.60	29.30
14-May	20.9	20.9	21.1	21.5	20.8	20.6	47.00	46.60	66.60	96.30	51.00	29.30
14-May	20.6	20.7	20.9	20.8	20.6	20.4	46.70	46.30	67.20	96.20	50.60	38.60
15-May	20.6	20.9	20.4	20.7	20.5	20.5	47.40	47.00	67.40	96.20	51.00	49.20
15-May	20.6	20.8	20.9	20.6	20.5	20.4	48.10	47.80	68.50	96.20	51.50	52.90
16-May	20.8	21	21.2	20.6	20.5	20.5	49.00	48.90	69.10	96.20	52.30	66.90
16-May	20.3	20.5	20.6	20.2	20.4	20.2	49.20	49.20	69.40	96.20	53.00	36.10
17-May	19.9	20.3	18.6	19.1	20.1	20.0	48.00	47.70	65.90	96.00	51.80	30.10
17-May	20.7	20.6	19.9	20.2	20.5	21.2	47.80	47.30	65.70	95.80	51.50	31.50
18-May	20.8	20.7	20.2	20.6	20.4	20.4	47.50	46.90	65.80	96.10	51.10	39.80
18-May	21.4	21.1	21.1	21.5	21.0	22.0	48.30	47.80	67.00	96.10	51.80	49.20
19-May	21.7	21.7	21.9	21.6	21.1	21.1	49.00	48.70	67.50	96.10	52.50	53.80
19-May	22.8	22.3	22.5	22.7	21.8	23.7	50.00	49.60	67.20	96.00	53.40	46.60
20-May	22.9	22.8	23	22.8	22.1	22.1	50.20	50.00	68.70	96.20	53.80	48.60
20-May	23.7	23.1	23.3	23.5	22.8	24.0	50.60	50.30	68.70	96.20	54.20	43.60
21-May	23.7	23.5	23.6	24.2	23.1	22.9	49.80	49.50	68.60	96.20	53.80	38.10
21-May	23.2	23.2	23.3	23.3	23.0	22.7	49.60	49.30	69.20	96.20	53.40	45.90
22-May	22.2	22.4	22.5	22.3	22.8	22.4	49.70	49.50	68.60	96.10	53.80	41.00
22-May	21.9	22.3	22.4	21.8	22.4	21.9	48.70	48.40	67.70	96.00	52.80	25.80
23-May	21.8	22.2	22.3	21.7	22.0	21.8	47.60	47.00	66.20	95.90	51.60	23.40
23-May	21.6	22	22.1	21.6	22.0	22.3	46.60	46.10	64.70	95.70	50.80	22.30
24-May	21.3	21.5	21.7	21.2	21.6	21.4	45.60	44.80	63.40	95.70	49.80	22.30
24-May	21.9	21.9	22	21.8	21.9	22.7	45.70	44.70	63.40	95.50	49.60	26.30
25-May	21.3	21.3	21.6	21.2	21.6	21.3	45.20	44.30	62.10	95.50	49.30	30.50
25-May	21.9	21.7	22	21.4	21.8	21.9	45.70	44.60	61.70	95.40	49.40	31.20
26-May	21.3	21.4	21.7	21.1	21.5	21.2	45.30	44.40	61.20	95.40	49.20	33.60
26-May	21.7	21.9	22.1	21.9	21.7	22.1	45.52	44.64	60.08	95.36	49.36	28.88
27-May	21.8	21.9	22.1	22.4	21.7	21.6	44.96	44.00	59.12	95.36	48.88	27.36
27-May	22.3	22.4	22.6	22.5	22.2	22.6	45.12	44.16	59.68	95.20	49.04	29.60
28-May	22.3	22.4	22.7	22.6	22.1	21.9	44.88	43.84	58.48	95.28	48.80	27.60
28-May	22.1	22.3	22.6	22.2	22.0	21.8	44.72	43.76	59.44	95.20	48.72	33.52
29-May	21.9	22.3	22.5	22.1	21.9	21.8	45.04	44.16	59.68	95.12	48.96	38.80
29-May	21.9	22.3	22.5	22.0	21.8	21.7	45.76	44.96	61.68	95.04	49.52	48.96
30-May	21.8	22.2	22.4	21.8	21.8	21.6	46.80	46.16	63.60	95.04	50.40	55.20
30-May	22.5	21.9	22.2	22.3	22.1	22.7	48.48	47.76	65.36	94.96	51.76	65.92
31-May	22.1	22.2	22.5	22.1	22.0	21.8	48.88	48.56	66.32	94.96	52.48	53.76
31-May	23.0	22.6	22.9	23.4	22.5	23.3	49.36	48.88	64.32	95.04	52.96	43.04
1-Jun	22.8	22.8	23.0	23.0	22.5	22.3	48.48	48.08	62.72	94.88	52.32	41.12
1-Jun	23.6	23.3	23.4	23.4	23.1	24.0	48.64	48.16	61.92	94.88	52.56	37.28
2-Jun	23.5	23.4	23.6	24.7	23.1	23.0	48.88	48.40	63.12	94.96	52.56	47.92
2-Jun	23.6	23.6	23.8	24.4	23.6	24.3	49.28	49.04	63.76	94.72	53.20	43.84
3-Jun	23.2	23.3	23.5	23.8	23.5	23.0	49.04	48.72	62.40	94.64	53.12	35.20
3-Jun	23.7	23.4	23.7	23.9	23.7	24.0	49.04	48.48	61.84	94.48	52.96	45.28
4-Jun	23.3	22.9	23.3	23.2	23.5	23.0	49.76	49.44	64.80	94.56	53.52	55.20

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
4-Jun	22.9	22.9	23.1	22.9	23.2	22.8	50.32	50.24	66.00	94.48	53.92	58.80
5-Jun	22.5	22.8	23.0	22.8	22.9	22.5	51.12	51.36	67.44	94.56	54.72	64.88
5-Jun	22.5	22.8	23.0	22.6	22.7	22.4	52.08	52.32	68.32	94.40	55.36	66.08
6-Jun	22.5	22.9	23.1	22.5	22.6	22.4	52.88	53.28	68.96	94.40	56.08	68.40
6-Jun	23.9	23.6	23.8	23.7	23.0	23.5	54.24	54.48	69.60	94.80	57.20	59.92
7-Jun	23.6	23.2	23.4	23.9	23.1	22.9	53.60	53.84	69.12	94.56	56.96	53.04
7-Jun	24.6	23.7	23.8	24.4	23.6	24.3	53.92	53.84	67.92	94.56	57.12	36.72
8-Jun	23.8	23.3	23.6	23.9	23.6	23.3	52.00	52.00	64.56	94.32	55.76	36.80
8-Jun	24.1	23.8	24.1	24.4	23.8	25.8	51.84	51.76	61.76	94.24	55.44	34.80
9-Jun	23.8	23.6	23.9	24.2	23.7	23.4	50.80	50.64	61.20	94.16	54.56	36.08
9-Jun	24.2	24.0	24.2	24.5	24.0	24.8	51.04	50.80	61.44	94.08	54.56	43.44
10-Jun	24.2	24.1	24.4	24.7	24.0	23.7	50.88	50.64	62.88	94.00	54.40	48.80
10-Jun	24.7	24.4	24.6	25.3	24.2	24.8	51.20	50.88	60.24	93.92	54.64	39.76
11-Jun	24.8	24.7	25.0	24.6	24.4	24.2	51.20	50.88	62.96	93.76	54.72	47.52
11-Jun	24.4	24.4	24.1	23.6	24.3	24.0	51.36	51.20	65.04	93.60	55.04	52.40
12-Jun	24.1	24.2	23.8	23.8	24.1	23.8	51.84	51.68	66.32	93.68	55.36	53.44
12-Jun	23.9	24.1	24.1	23.8	23.9	23.8	51.84	51.76	66.56	93.60	55.52	46.88
13-Jun	23.6	23.8	24.0	23.5	23.8	23.5	50.96	50.80	63.36	93.52	54.88	35.36
13-Jun	24.3	24.1	24.2	24.4	24.0	24.9	50.40	49.92	59.76	93.44	54.24	27.44
14-Jun	23.4	23.3	22.9	23.8	23.7	23.4	49.04	48.40	58.00	93.12	52.96	30.32
14-Jun	24.3	24.1	24.3	24.7	24.0	24.5	49.28	48.56	56.48	93.04	52.88	31.84
15-Jun	24.2	24.2	24.4	24.3	23.9	23.7	49.12	48.48	60.48	92.88	52.64	42.24
15-Jun	25.2	24.6	24.9	25.4	24.5	24.9	49.92	49.04	59.68	92.96	53.20	42.72
16-Jun	26.0	25.2	25.4	26.0	24.7	24.5	50.40	49.76	62.72	92.88	53.76	50.96
16-Jun	26.8	25.8	26.1	26.7	25.4	25.9	51.36	50.80	62.88	93.04	54.80	49.04
17-Jun	26.1	25.8	26.0	26.3	25.5	25.3	51.68	51.52	65.20	92.96	55.44	57.68
17-Jun	26.8	26.3	26.5	28.0	26.1	26.8	52.72	52.64	65.92	93.28	56.48	53.28
18-Jun	26.0	25.6	25.9	27.5	26.0	25.5	52.96	53.04	67.20	93.04	56.96	54.24
18-Jun	25.1	24.8	24.5	25.6	25.6	25.0	52.24	52.32	65.92	92.56	56.48	41.60
19-Jun	23.9	24.0	24.1	24.3	25.1	24.4	51.12	51.20	63.28	92.24	55.44	39.60
19-Jun	23.9	24.0	24.2	23.9	24.6	24.0	50.80	50.72	63.28	92.16	54.80	38.88
20-Jun	23.5	23.8	24.0	23.5	24.2	23.8	50.48	50.32	62.08	92.00	54.24	41.36
20-Jun	24.6	24.1	24.3	24.9	24.2	24.3	51.04	50.48	62.08	92.08	54.32	44.08
21-Jun	23.3	23.2	23.4	23.7	23.8	23.4	49.68	49.36	59.92	91.60	53.60	36.88
21-Jun	24.4	23.8	24.0	24.4	24.0	25.7	49.92	49.36	58.72	91.52	53.44	32.24
22-Jun	24.0	23.8	24.0	24.0	23.9	23.7	48.96	48.32	58.08	91.28	52.64	32.16
22-Jun	23.4	23.5	23.7	23.4	23.7	23.4	48.48	48.00	58.48	91.04	52.32	36.16
23-Jun	22.8	23.0	23.2	22.8	23.4	23.1	48.64	48.24	60.64	90.88	52.40	43.60
23-Jun	23.7	23.8	24.0	24.4	23.6	23.9	49.44	49.12	59.92	91.12	52.96	35.36
24-Jun	24.5	23.8	24.1	23.9	23.6	23.5	49.60	49.04	61.04	90.80	52.96	44.32
24-Jun	24.6	24.4	24.6	25.4	24.2	25.2	50.24	49.92	61.20	91.20	53.84	45.04
25-Jun	24.5	24.3	24.6	25.2	24.4	24.1	49.92	49.60	61.76	90.80	53.60	41.76
25-Jun	24.5	24.4	24.6	24.6	24.3	24.1	50.32	50.00	63.28	90.64	53.76	54.08
26-Jun	24.4	24.3	24.5	25.2	24.3	24.0	50.00	49.84	62.40	90.64	53.76	41.44

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
26-Jun	24.2	24.3	24.5	24.4	24.2	24.0	50.00	49.84	63.12	90.48	53.68	52.72
27-Jun	24.1	24.4	24.6	24.2	24.1	24.0	51.28	51.44	65.76	90.56	54.88	62.96
27-Jun	25.2	25.0	25.2	25.1	24.5	24.9	52.72	52.80	66.72	90.96	56.16	59.68
28-Jun	24.8	25.0	25.2	24.9	24.6	24.5	52.96	53.28	67.28	90.80	56.48	62.48
28-Jun	25.0	24.9	25.2	25.8	25.0	25.8	54.32	54.80	68.96	91.20	57.92	56.40
29-Jun	25.2	25.1	25.4	26.4	25.0	24.8	53.36	53.52	65.92	91.04	56.96	43.84
29-Jun	25.0	25.0	25.3	25.6	24.9	24.6	53.36	53.52	66.80	90.80	56.88	58.48
30-Jun	24.9	25.0	25.3	25.6	25.0	24.6	52.88	53.04	64.72	90.64	56.80	33.28
30-Jun	25.3	25.1	25.4	25.4	25.2	25.2	52.48	52.40	62.08	90.32	56.24	38.24
1-Jul	25.2	24.9	25.3	25.3	25.1	24.7	51.84	51.68	62.48	90.00	55.52	40.08
1-Jul	25.6	24.9	25.3	25.1	25.4	25.2	52.08	51.76	62.24	89.84	55.84	40.80
2-Jul	24.5	24.2	24.6	24.3	25.0	24.4	51.68	51.68	62.72	89.68	55.52	48.80
2-Jul	24.1	24.0	24.4	24.1	24.6	24.5	52.08	52.16	63.92	89.68	55.76	46.80
3-Jul	22.8	23.8	23.0	23.2	24.2	23.7	51.84	52.32	64.56	89.52	55.76	53.84
3-Jul	22.9	23.4	23.6	23.3	23.9	23.5	52.40	52.48	64.56	89.60	55.92	51.12
4-Jul	23.0	23.2	23.5	23.1	23.6	23.2	52.64	52.56	65.04	89.52	55.84	53.84
4-Jul	24.8	23.8	24.1	24.4	23.9	24.0	53.76	53.44	65.60	89.92	56.56	54.80
5-Jul	23.8	23.6	24.0	24.4	23.8	23.5	53.36	53.52	65.76	89.68	56.56	56.48
5-Jul	24.7	24.2	24.6	24.4	24.3	25.3	54.32	54.48	66.24	89.76	57.28	53.12
6-Jul	24.5	24.2	24.6	24.5	24.2	24.0	53.92	54.00	65.84	89.68	57.12	53.12
6-Jul	25.6	24.8	25.1	25.0	24.8	25.4	54.72	54.80	66.08	89.76	57.84	54.08
7-Jul	24.6	24.1	24.4	24.6	24.6	24.3	54.48	54.72	66.72	89.60	57.76	58.96
7-Jul	25.6	24.9	25.2	25.0	25.0	25.6	55.84	56.24	68.40	89.92	58.88	59.52
8-Jul	25.2	24.8	25.1	24.9	24.9	24.7	55.68	56.16	68.48	89.84	58.88	61.76
8-Jul	26.7	25.5	25.7	25.7	25.3	26.7	56.80	57.20	68.72	90.08	59.68	54.48
9-Jul	25.6	25.0	25.4	25.4	25.2	25.1	56.16	56.80	68.64	90.00	59.52	61.52
9-Jul	25.2	24.9	25.3	25.1	25.0	24.9	56.24	56.96	69.04	89.92	59.68	58.16
10-Jul	24.8	24.7	25.0	24.8	24.9	24.7	56.00	56.64	68.48	89.76	59.52	50.88
10-Jul	24.4	24.4	24.7	24.4	24.7	24.4	55.52	56.00	67.36	89.52	59.04	50.32
11-Jul	23.9	24.0	24.4	23.9	24.5	24.1	55.60	56.16	67.68	89.44	58.96	57.20
11-Jul	25.6	24.6	24.9	25.3	24.7	25.0	57.04	57.28	69.04	89.92	59.68	62.80
12-Jul	24.7	24.4	24.8	24.7	24.6	24.3	56.32	56.88	68.56	89.68	59.60	54.96
12-Jul	24.8	24.4	24.8	25.4	24.8	24.8	56.88	57.60	69.28	89.84	60.16	61.52
13-Jul	24.4	24.2	24.0	24.2	24.6	24.2	56.96	57.60	69.04	89.52	60.08	60.32
13-Jul	26.0	24.8	24.8	25.2	25.0	25.4	57.76	58.00	69.20	89.68	60.48	52.88
14-Jul	25.2	24.6	24.8	25.0	24.9	24.6	56.24	56.64	68.00	89.36	59.44	45.12
14-Jul	25.9	25.0	25.2	25.8	25.4	26.3	55.92	56.08	64.48	89.20	59.12	40.80
15-Jul	25.3	25.0	25.2	25.3	25.2	25.0	54.96	55.20	64.88	88.80	58.32	41.68
15-Jul	25.2	23.7	23.9	24.7	25.2	25.0	56.00	56.08	67.76	88.88	59.04	75.36
16-Jul	24.4	24.1	24.3	24.3	24.9	24.5	56.88	57.84	69.44	89.04	59.92	67.60
16-Jul	24.5	24.3	24.4	24.6	24.7	24.4	57.60	58.56	70.08	89.44	60.48	67.44
17-Jul	24.3	24.3	24.5	24.6	24.6	24.3	57.68	58.72	70.24	89.44	60.64	62.88
17-Jul	24.0	24.0	24.2	24.1	24.4	24.1	57.44	58.24	70.08	89.28	60.48	57.76
18-Jul	24.0	24.2	24.4	24.1	24.3	24.0	57.84	58.56	70.16	89.28	60.64	64.56

Table 20.5 (continued)
Relative humidity and temperature readings in Garage No, 20 (12 hrs. intervals)

Date	Temperature, deg. C						Relative humidity, %					
1992	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
18-Jul	24.9	24.4	24.7	25.3	24.9	25.1	59.04	59.68	70.96	89.68	61.68	73.44
19-Jul	24.6	24.6	24.7	24.9	24.7	24.4	58.96	59.84	71.04	89.76	61.76	51.36
19-Jul	25.8	24.4	24.7	24.8	24.9	25.4	57.84	57.92	67.36	89.28	60.64	39.04
20-Jul	24.4	24.0	24.3	24.3	24.5	24.1	55.68	55.92	64.48	88.56	58.88	36.48
20-Jul	25.1	24.5	24.8	25.1	24.9	25.5	55.44	55.36	61.68	88.16	58.48	36.32
21-Jul	24.5	24.3	24.6	24.6	24.7	24.2	54.48	54.48	62.16	87.92	57.60	40.32
21-Jul	25.7	24.8	25.0	25.0	25.4	26.0	55.04	54.80	62.80	87.84	58.00	46.00
22-Jul	24.9	24.6	24.8	24.8	25.0	24.5	54.72	54.72	64.00	87.68	57.84	48.88
22-Jul	25.9	25.0	25.3	25.9	25.4	25.2	55.44	55.28	63.76	87.92	58.24	50.16
23-Jul	25.2	24.8	25.1	25.2	25.2	24.7	54.88	55.04	64.96	87.60	58.00	51.68
23-Jul	24.9	24.9	25.1	24.9	25.0	24.6	55.20	55.36	65.92	87.52	58.16	56.48
24-Jul	24.7	24.9	25.1	24.8	24.9	24.6	55.92	56.16	67.20	87.68	58.80	61.60
24-Jul	24.7	24.8	25.0	24.7	24.8	24.5	56.56	56.88	68.00	87.92	59.36	63.68
25-Jul	24.7	24.9	25.1	24.6	24.7	24.5	57.04	57.36	68.56	88.00	59.84	62.72
25-Jul	26.4	25.5	25.7	25.8	25.4	25.8	57.76	57.76	67.60	88.32	60.48	53.20
26-Jul	25.4	25.2	25.4	25.3	25.2	24.9	56.56	56.80	66.64	87.84	59.76	47.44
26-Jul	26.3	25.8	25.9	26.1	26.0	27.3	56.80	56.96	65.36	87.92	60.00	51.60
27-Jul	25.7	25.6	25.8	25.7	25.7	25.4	55.92	55.92	65.20	87.44	59.12	47.92
27-Jul	26.9	26.1	26.3	26.4	26.0	26.2	56.48	56.16	64.80	87.52	59.36	47.92
28-Jul	24.4	25.4	25.1	25.7	25.8	25.4	54.48	55.04	64.00	86.96	58.56	41.04
28-Jul	25.9	26.0	26.1	25.9	26.0	26.1	55.28	54.88	61.04	86.80	58.32	43.20

APPENDIX E

Alkali Resistance of Sealers

At present, there is no generally accepted test method to evaluate the alkali resistance of sealers. The aim of our efforts has been to develop a reliable method for the assessment of this property. The results of the work carried out at IRC were shared with other members of Task Group D01.47.07 "Alkali Resistance of Masonry Treatments" of the American Society for Testing and Materials.

Initially, the test procedure followed consisted of comparing the moisture absorption of mortar cubes coated with a sealer on immersion in 0.1 normal KOH solution with that if immersed in water. The weight recorded and the weight gain during a 140 day period of immersion are shown in Tables 1 and 2, Appendix E, while the average weight gains are listed in Table 3, Appendix E, and represented graphically in Figure 1, Appendix E.

The results indicate no significant difference in water absorption on exposure to 01N KOH. This may be a consequence of either excellent alkali resistance or the negligible effect of 0.1N KOH in the strongly alkaline environment of the mortar. Therefore, it was decided to carry out the test with specimens not containing alkalis.

In the second test series the water absorption of sealer treated burnt clay brick specimens on immersion in 0.1N KOH or water was determined. The weights recorded, and the percentage weight gained are given in Table 4 and Table 5, the average absorption of the specimens treated with one of three sealers is shown in Table 6 and Figure 2, Appendix E. Sealer treated brick specimens on exposure to alkaline solution show pronounced, in one case four fold, increase of absorption compared to that they do on immersion in water. This finding suggests that the absence of observable effect on exposure to alkali is not caused by alkali resistance of the sealer, but by the test conditions.

A further problem of the test is the wide variation in the results obtained by the laboratories participating in the round robin and it was decided to repeat the test series with the mortar cubes (Third series).

The treatment of the mortar cubes prior to the absorption test was changed in the third series. Originally the cubes were dried at 110°C for 24 hours, followed by conditioning for a 24 hour period at room temperature prior to coating them with the sealer. In the third series of tests the cubes were conditioned at 50 percent RH in the laboratory for seven days and then treated with the sealer.

The weight recorded on immersion in water or 0.1N KOH solution, and the percent weight gain of samples are given in Table 7 and Table 8, Appendix E. The average absorption values are listed in Table 9 and shown in Figure 3, Appendix E.

The weight gain of the immersed cubes was much less in the third than in the first series of tests. This almost certainly is due to the difference in conditioning of the specimens prior to testing. To verify this assumption two mortar cubes were dried at 110°C and the water absorption on exposure to 50 percent RH in the laboratory was monitored.

According to the results given in Table 10, the mortar cubes lost approximately 13g or 4.3% weight on drying and in 25 days regained approximately 6.6g, or a little more than 50% of the moisture lost when heated to 110°C.

It is clear then that the observed absorption in the first series of test was to a large extent due to conditioning, restoration of the moisture content at room condition. Under these circumstances the differences due to the alkalinity of the bath represents a very small percentage difference that may not even be detected. In the process of picking-up large amounts of water differences in the experimental conditions can cause wide scatter of the results. It seems that the effort to standardize the conditions by dying all the specimens at 110°C caused an inherent uncertainty in the test results. Furthermore, thorough drying created a condition that never occurs under field conditions and thus the results, at best, may be comparable to each other but have no relevance to field conditions.

Conclusions

1. Alkali sensitivity of sealers does not manifest itself on exposing sealer treated mortar cubes to 0.1N KOH because the effect of the additional alkalinity provided by the test is negligible to that of the hydrated portland cement;

2. Alkali sensitivity of sealers should probably be tested using porous substrates with PH of essentially 7, such as clay brick; and

3. The substrates should not be dried at 110°C prior to the test, rather be conditioned at 50% RH.

Table 1

Weights (g) of sealer treated mortar cubes on immersion in water or 0.1N KOH solution.

Sealer	Spec. No.	Sealed dry	Immersed in water (days) 1	7	14	21	28	42	56	70	91	140
D211	1	281.41	283.5	286.1	287.5	288.4	289.0	290.3	291.1	292.0	292.9	294.8
	33	295.58	297.7	300.4	301.7	302.5	303.3	305.4	306.1	306.9	307.8	309.7
	116	288.29	290.4	293.0	294.5	295.3	295.9	297.3	298.0	298.8	299.8	301.8
	148	309.61	311.7	314.5	315.9	316.9	317.7	318.9	319.8	320.6	321.7	323.8
	214	276.53	278.5	281.3	282.7	283.6	284.2	285.6	286.5	287.3	288.3	290.3
D212	10	319.95	322.5	348.6	349.8	350.6	351.2	352.0	352.3	352.5	352.8	353.1
	42	294.11	298.0	321.4	322.5	323.2	323.6	324.2	324.4	324.6	324.8	352.0
	125	296.39	299.4	323.7	324.8	325.5	325.9	326.6	326.7	327.0	327.3	327.5
	197	277.8	283.3	305.3	306.2	307.0	307.4	307.9	308.1	308.3	308.6	308.7
	217	285.35	293.7	313.3	314.4	315.2	315.5	316.0	316.2	316.4	316.6	316.8
D213	20	292.54	297.1	306.0	309.3	310.9	311.9	314.4	316.0	317.2	318.6	320.7
	75	294.92	298.6	308.3	311.8	313.4	314.4	317.5	319.0	320.1	321.3	323.0
	146	310.36	313.6	320.8	324.1	326.0	327.2	329.7	331.4	332.8	334.7	337.5
	208	269.2	278.2	296.7	297.9	298.4	298.7	299.3	299.6	299.7	300.1	300.4
	236	267.84	273.5	282.5	285.4	287.6	288.7	290.7	291.7	292.6	293.6	295.0

			Immersed in 0.1N KOH									
D211	4	287.41	289.8	292.4	293.9	294.7	295.6	296.6	297.4	298.2	299.5	301.5
	35	283.01	285.4	287.9	289.4	290.1	290.8	291.9	292.7	293.4	294.6	296.6
	123	277.27	279.4	282.0	283.4	284.2	284.9	285.9	286.7	287.4	288.6	290.5
	191	278.39	280.7	283.7	285.2	286.0	288.0	289.1	290.0	290.9	292.1	294.2
	216	277.28	279.7	282.7	284.0	284.8	285.8	286.9	287.8	288.6	289.8	291.9
D212	15	301.05	304.3	328.9	329.8	330.3	330.8	331.3	331.4	331.7	331.9	332.2
	46	283.38	287.7	309.8	310.6	311.2	311.7	312.2	312.3	312.5	312.7	313.1
	144	289.56	293.4	316.5	317.5	318.1	318.6	319.2	319.3	319.5	319.7	320.0
	199	282.51	289.8	309.7	310.6	311.1	311.5	311.9	312.1	312.2	312.4	312.7
	219	303.27	310.0	334.1	335.2	335.7	336.2	336.7	337.0	337.2	337.5	337.9
D213	32	308.23	314.2	320.0	322.1	323.5	327.3	329.2	330.8	332.4	334.6	336.6
	98	272.55	277.9	283.9	285.8	287.0	288.8	290.4	291.6	292.7	294.1	296.2
	147	310.98	317.9	325.2	327.5	328.8	332.2	334.0	336.1	337.2	338.6	340.2
	213	277.64	286.4	293.7	296.1	297.8	301.7	303.7	304.7	305.3	306.2	306.8
	243	303.48	316.3	328.6	330.7	331.8	333.9	334.9	335.2	335.5	336.0	336.4

Table 2
Percent weight gain of samples, during immersion in water or 0.1N KOH

Sealer No.	Spec. No.	Days immersed in water										
		1	7	14	21	28	42	56	70	91	119	140
D211	1	0.74	1.70	2.20	2.52	2.76	3.22	3.49	3.82	4.15	4.62	4.84
	33	0.71	1.66	2.09	2.39	2.64	3.37	3.62	3.91	4.19	4.60	4.85
	116	0.75	1.67	2.19	2.47	2.69	3.18	3.44	3.72	4.05	4.54	4.79
	148	0.67	1.60	2.07	2.39	2.64	3.05	3.35	3.62	3.98	4.41	4.67
	214	0.73	1.75	2.27	2.60	2.83	3.34	3.68	3.97	4.34	4.82	5.09
D212	10	0.81	9.14	9.50	9.77	9.96	10.21	10.29	10.38	10.46	10.53	10.57
	42	1.33	9.46	9.83	10.08	10.22	10.43	10.49	10.57	10.64	10.69	10.71
	125	1.02	9.39	9.77	10.01	10.14	10.37	10.41	10.51	10.61	10.66	10.69
	197	2.00	10.09	10.43	10.71	10.84	11.06	11.11	11.20	11.28	11.34	11.34
	217	2.97	9.97	10.36	10.66	10.75	10.95	11.01	11.10	11.15	11.23	11.22
D213	20	1.58	4.66	5.80	6.34	6.69	7.56	8.12	8.51	8.99	9.46	9.71
	75	1.28	4.58	5.79	6.32	6.69	7.74	8.27	8.63	9.03	9.42	9.61
	146	1.04	3.39	4.48	5.08	5.48	6.29	6.85	7.31	7.91	8.54	8.86
	208	3.37	10.34	10.78	10.98	11.09	11.31	11.40	11.47	11.61	11.70	11.74
	236	2.14	5.53	6.62	7.46	7.87	8.63	9.02	9.34	9.72	10.08	10.25

Sealer No.	Spec. No.	Days immersed in alkali										
		1	7	14	21	28	42	56	70	91	119	140
D211	4	0.84	1.75	2.29	2.58	2.90	3.24	3.54	3.83	4.28	4.78	4.99
	35	0.84	1.76	2.28	2.56	2.80	3.19	3.48	3.74	4.15	4.66	4.87
	123	0.80	1.74	2.25	2.55	2.78	3.18	3.44	3.72	4.14	4.63	4.86
	191	0.85	1.93	2.47	2.77	3.50	3.91	4.26	4.57	5.02	5.50	5.76
	216	0.89	1.98	2.48	2.77	3.12	3.54	3.84	4.15	4.59	5.09	5.35
D212	15	1.09	9.42	9.73	9.90	10.08	10.23	10.28	10.37	10.44	10.53	10.53
	46	1.56	9.50	9.81	10.00	10.19	10.37	10.43	10.51	10.57	10.68	10.69
	144	1.36	9.48	9.84	10.03	10.21	10.42	10.45	10.55	10.61	10.68	10.71
	199	2.63	9.83	10.15	10.35	10.49	10.64	10.68	10.75	10.82	10.87	10.91
	219	2.24	10.35	10.70	10.90	11.06	11.23	11.31	11.40	11.49	11.60	11.63
D213	32	1.95	3.86	4.56	5.02	6.26	6.88	7.42	7.94	8.66	9.11	9.32
	98	1.97	4.20	4.92	5.36	6.03	6.63	7.08	7.47	7.99	8.52	8.78
	147	2.26	4.62	5.37	5.79	6.90	7.47	8.16	8.54	8.98	9.33	9.50
	213	3.20	5.84	6.74	7.36	8.77	9.51	9.88	10.10	10.40	10.57	10.64
	243	4.28	8.38	9.08	9.44	10.15	10.47	10.57	10.68	10.85	10.93	10.99

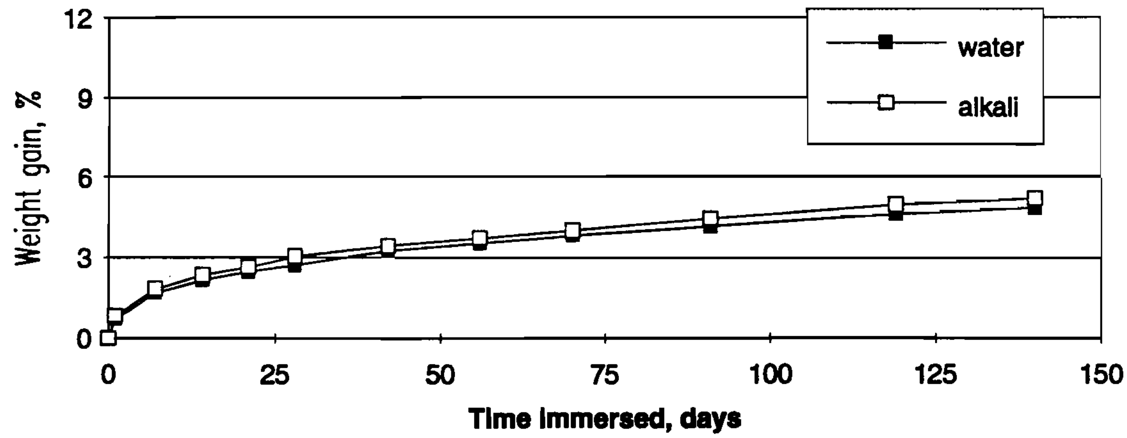
Table 3

Average percent weight gain of sealer treated mortar specimens immersed in water or alkali

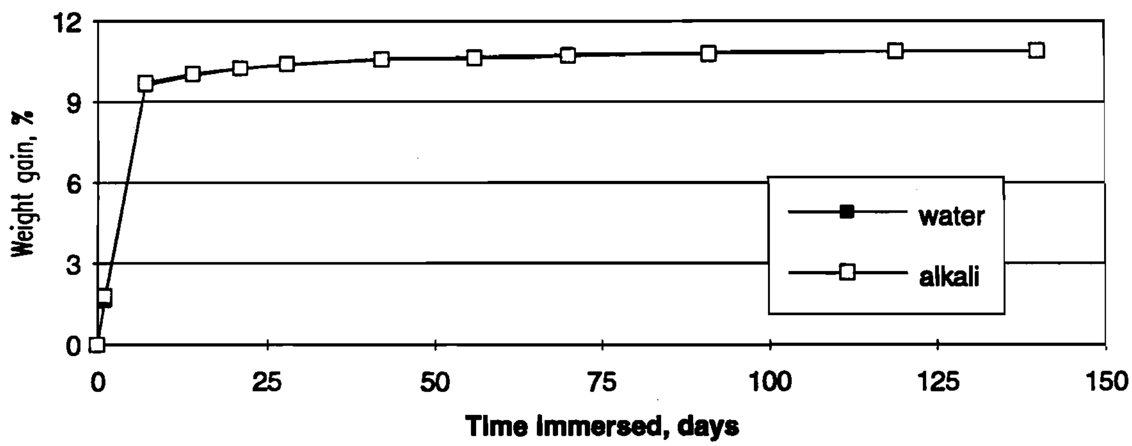
Sealer/Bath	Weight gain, %, at times indicated (days)										
	1	7	14	21	28	42	56	70	91	119	140
D211 / water	0.72	1.67	2.16	2.47	2.71	3.23	3.51	3.81	4.14	4.60	4.85
D211 / alkali	0.84	1.83	2.35	2.65	3.02	3.41	3.71	4.00	4.43	4.93	5.17
	1	7	14	21	28	42	56	70	91	119	140
D212 / water	1.62	9.61	9.98	10.25	10.38	10.60	10.66	10.76	10.83	10.89	10.91
D212 / alkali	1.78	9.71	10.05	10.24	10.40	10.58	10.63	10.71	10.79	10.88	10.89
	1	7	14	21	28	42	56	70	91	119	140
D213 / water	1.88	5.70	6.69	7.24	7.56	8.30	8.73	9.05	9.45	9.84	10.03
D213 / alkali	2.73	5.38	6.13	6.59	7.62	8.19	8.62	8.94	9.39	9.69	9.84

Fig. 1

Weight gain of mortar cubes treated with sealer D211



Weight gain of mortar cubes treared with sealer D212



Weight gain of mortar cubes treated with sealer D213

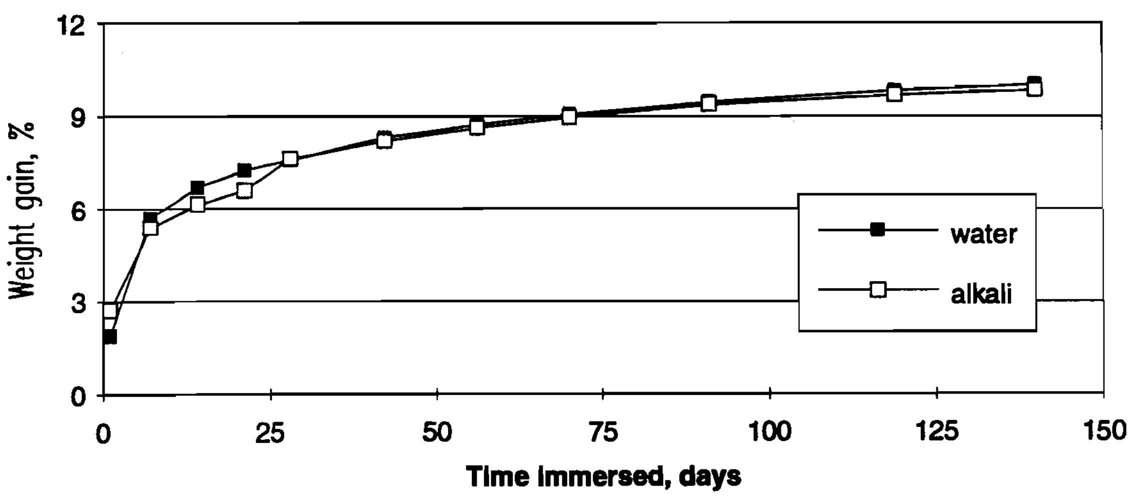


Table 4

Weights (g) recorded of sealer treated brick sections on immersion in water or 0.1N KOH

				Immersed for a period of:									
				Hrs. in water		Days in water							
Sealer No.	Spec. No.	Dry (orig.)	Dry (Sealed)	2	6	1	2	7	14	21	28	49	70
D211	1	333.8	337.0	337.8	338.0	339.1	339.9	343.2	345.3	346.5	347.4	349.3	350.7
	2	324.5	328.9	329.5	329.6	330.4	331.1	334.5	336.0	336.7	337.3	338.5	339.2
	3	323.8	329.4	329.9	330.0	330.6	331.2	335.1	337.0	337.9	338.5	339.6	340.3
	4	313.3	317.9	318.1	318.2	318.5	318.8	320.4	321.0	321.3	321.4	322.0	322.3
	5	338.1	342.0	342.8	343.0	343.9	344.7	348.7	350.7	351.8	352.6	354.5	355.6
D212	6	329.8	330.6	331.8	332.4	333.9	334.9	337.7	339.8	341.2	342.4	344.7	346.1
	7	309.5	310.6	311.9	312.5	314.1	315.1	318.3	320.5	321.9	323.2	325.5	326.8
	8	325.2	325.9	327.0	327.6	328.9	329.8	332.8	335.3	336.9	338.3	341.2	343.1
	9	330.2	331.1	332.2	332.8	334.2	335.1	337.8	339.9	341.2	342.3	344.6	346.0
	10	333.4	334.1	335.2	335.7	337.0	338.0	341.0	344.0	346.4	348.8	354.0	358.0
D213	11	327.0	328.9	333.0	347.5	362.7	366.4	377.0	380.8	382.2	383.2	385.4	387.0
	12	326.5	329.2	331.7	334.6	370.4	376.0	378.8	380.4	381.5	382.5	384.8	386.7
	13	329.6	331.4	331.9	332.8	357.1	364.2	374.9	378.0	379.3	380.3	382.7	384.5
	14	327.0	328.6	332.5	339.8	361.4	366.3	374.1	375.9	377.1	378.0	380.0	381.7
	15	325.0	326.6	327.7	332.7	354.9	361.1	370.2	372.3	373.4	374.1	376.0	377.4
				Immersed in 0.1N KOH									
D211	16	329.2	333.7	334.0	334.3	335.1	335.4	336.7	337.8	338.6	339.3	340.8	342.0
	17	324.2	327.4	327.6	327.9	328.4	328.6	329.7	330.8	331.6	332.3	333.7	334.8
	18	330.8	333.6	334.7	335.5	337.5	339.0	342.8	345.7	347.6	349.0	352.0	354.2
	19	325.8	328.7	329.2	329.6	330.5	331.2	333.7	335.7	337.3	338.5	341.1	343.0
	20	343.0	345.9	346.9	347.6	349.6	351.2	355.4	358.5	360.5	362.0	364.9	367.1
D212	21	337.6	338.3	339.8	340.9	347.2	365.6	383.3	386.7	387.1	387.4	388.1	388.5
	22	323.5	324.2	325.6	326.7	332.1	349.1	367.1	374.2	375.5	375.8	376.5	376.9
	23	333.9	335.4	336.8	338.0	341.1	345.3	359.5	369.2	378.3	386.7	391.2	392.6
	24	328.8	330.4	331.7	332.9	336.3	341.3	355.4	364.1	370.1	374.0	380.2	382.6
	25	327.3	328.9	330.2	331.3	334.8	339.2	352.4	363.5	374.1	382.3	386.8	387.8
D213	26	336.3	338.8	346.3	382.2	385.3	385.7	386.4	387.3	388.0	388.6	390.3	391.7
	27	332.4	334.9	344.7	376.3	379.4	379.6	380.3	381.3	381.9	382.5	384.2	385.5
	28	326.7	328.8	345.5	369.6	373.6	373.8	374.6	375.4	376.1	376.8	378.7	380.2
	29	336.8	338.2	362.9	375.5	378.9	379.3	380.0	380.9	381.6	382.1	383.5	384.6
	30	317.2	319.4	330.0	357.6	364.8	365.2	365.8	366.7	367.5	368.2	370.0	371.5

Table 5

Percent weight gain of sealer treated brick sections immersed in water or in 0.1N KOH solution

Spec. No.	Time immersed in water								
	Hours		Days						
	2	6	1	2	7	14	21	28	49
1	0.23	0.30	0.60	0.83	1.82	2.44	2.80	3.06	3.64
2	0.20	0.21	0.47	0.68	1.70	2.15	2.38	2.56	2.93
3	0.13	0.18	0.36	0.53	1.72	2.29	2.56	2.73	3.08
4	0.07	0.10	0.20	0.27	0.80	0.98	1.07	1.12	1.29
5	0.22	0.29	0.56	0.80	1.96	2.53	2.84	3.08	3.65
6	0.36	0.55	0.99	1.31	2.14	2.79	3.22	3.56	4.26
7	0.41	0.60	1.11	1.45	2.48	3.18	3.64	4.04	4.79
8	0.34	0.53	0.94	1.22	2.12	2.88	3.39	3.82	4.71
9	0.34	0.52	0.94	1.21	2.03	2.66	3.04	3.38	4.08
10	0.30	0.45	0.84	1.14	2.06	2.94	3.68	4.40	5.94
11	1.23	5.66	10.28	11.40	14.61	15.80	16.22	16.51	17.18
12	0.77	1.66	12.53	14.22	15.08	15.56	15.91	16.20	16.90
13	0.16	0.45	7.76	9.93	13.14	14.07	14.47	14.76	15.50
14	1.17	3.41	9.98	11.45	13.83	14.40	14.76	15.02	15.64
15	0.32	1.86	8.65	10.56	13.35	13.99	14.31	14.55	15.12
	Time immersed in alkali								
Spec. No.	Hours		Days						
	2	6	1	2	7	14	21	28	49
16	0.08	0.18	0.42	0.52	0.91	1.23	1.47	1.68	2.13
17	0.08	0.15	0.32	0.39	0.72	1.04	1.30	1.50	1.93
18	0.34	0.59	1.18	1.62	2.76	3.62	4.20	4.62	5.52
19	0.15	0.28	0.55	0.77	1.51	2.14	2.63	2.98	3.77
20	0.29	0.51	1.08	1.53	2.75	3.65	4.22	4.66	5.51
21	0.43	0.76	2.61	8.06	13.28	14.30	14.42	14.49	14.71
22	0.43	0.77	2.43	7.69	13.23	15.42	15.82	15.92	16.14
23	0.39	0.75	1.68	2.94	7.17	10.08	12.77	15.29	16.63
24	0.38	0.76	1.79	3.30	7.58	10.19	12.01	13.19	15.08
25	0.37	0.73	1.79	3.14	7.15	10.53	13.72	16.23	17.60
26	2.21	12.82	13.73	13.84	14.07	14.33	14.53	14.71	15.21
27	2.92	12.35	13.28	13.35	13.56	13.84	14.04	14.22	17.70
28	5.06	12.40	13.62	13.69	13.91	14.16	14.38	14.58	15.17
29	7.32	11.03	12.05	12.15	12.37	12.63	12.83	12.97	13.39
30	3.34	11.98	14.21	14.33	14.52	14.81	15.06	15.28	15.85

Table 6

Average percent weight gain of sealer treated brick specimens immersed in water or alkali

Sealer	Solution	Days immersed in water/alkali								
		0.1	0.25	1	2	7	14	21	28	49
D211	Water	0.17	0.21	0.44	0.62	1.60	2.08	2.33	2.51	2.92
	Alkali	0.19	0.34	0.71	0.97	1.73	2.34	2.76	3.09	3.77
D212	Water	0.35	0.53	0.97	1.27	2.16	2.89	3.39	3.84	4.76
	Alkali	0.40	0.75	2.06	5.03	9.68	12.10	13.75	15.02	16.03
D213	Water	0.73	2.61	9.84	11.51	14.00	14.76	15.13	15.41	16.07
	Alkali	4.17	12.12	13.38	13.47	13.69	13.95	14.17	14.35	14.96

Fig. 2

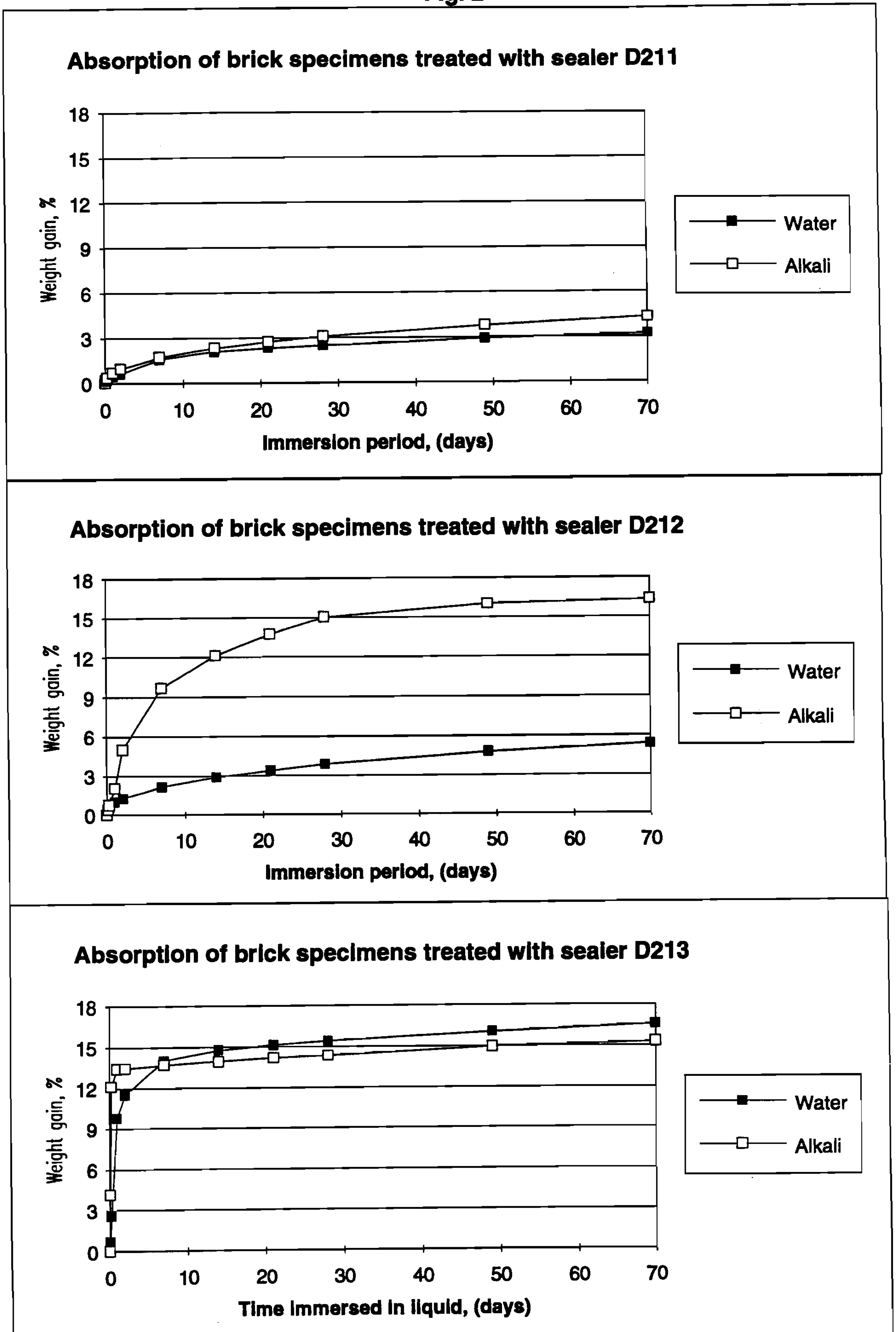

Absorption of brick specimens treated with sealer D211
Weight gain, %
18
15
12
9
6
3
0
0
10
20
30
40
50
60
70
Immersion period, (days)
Water
Alkali
Absorption of brick specimens treated with sealer D212
Weight gain, %
Immersion period, (days)
Water
Alkali
Absorption of brick specimens treated with sealer D213
Weight gain, %
Time immersed in liquid, (days)
Water
Alkali

Table 7
Weights (g) recorded of sealer treated mortar cubes on immersion in water (Spec. No.1 through 15), or 0.1 N KOH (Spec. No.16 through 30)

Sealer No.	Spec. No.	Original weight	Sealed (dry)	Immersed (days)				
				1	7	14	21	28
D211	1	292.8	294.3	295.3	296.4	297.4	298.1	298.7
	2	298.3	299.8	300.8	301.7	302.2	302.9	303.4
	3	294.6	296.1	297.0	298.1	298.9	299.6	300.2
	4	287.9	289.6	290.6	291.5	292.0	292.6	293.1
	5	283.2	284.8	285.8	286.7	287.3	287.8	288.3
D212	6	301.0	302.9	312.6	317.0	317.0	317.2	317.5
	7	295.5	297.6	300.1	313.4	313.7	314.0	314.4
	8	299.8	301.8	310.4	313.8	314.0	314.1	314.5
	9	301.1	303.2	305.9	318.8	319.2	319.3	319.8
	10	299.5	301.7	306.1	317.6	317.9	318.0	318.4
D213	11	291.2	292.5	294.3	297.2	298.5	299.5	300.5
	12	300.8	302.1	305.6	313.4	315.1	315.9	316.6
	13	299.8	301.1	302.5	305.6	307.1	308.2	309.3
	14	300.7	302.0	303.7	307.0	308.5	309.6	310.6
	15	293.1	294.5	296.5	300.9	302.5	303.5	304.5
D211	16	297.0	298.5	299.5	300.7	301.3	301.8	302.7
	17	298.4	299.9	300.8	301.9	302.4	303.0	303.8
	18	290.4	291.9	292.9	294.3	295.1	295.8	296.7
	19	303.5	305.0	306.1	307.8	308.5	309.3	310.3
	20	299.1	300.6	301.7	302.9	303.6	304.5	306.0
D212	21	286.9	288.7	301.0	301.8	301.9	302.0	302.3
	22	300.2	302.2	316.4	317.2	317.4	317.5	317.9
	23	288.3	290.3	303.7	304.7	304.8	305.0	305.2
	34	293.8	295.9	309.2	310.5	310.6	310.7	311.1
	25	295.7	297.7	311.6	312.7	312.9	313.0	313.3
D213	26	289.6	290.9	293.8	297.8	298.9	299.9	300.7
	27	300.2	301.4	305.1	310.2	311.6	312.6	313.5
	28	296.8	298.2	301.8	306.7	308.0	308.9	309.8
	29	297.0	298.3	302.1	307.3	308.9	309.9	310.9
	30	297.3	298.6	302.9	307.6	309.2	310.0	310.9

Table 8

Percent weight gain of sealer treated mortar specimens on immersion in water (Spec. No 1 through 15) or 0.1 N KOH (Spec. No 16 through 30) (Third Series)

Sealer No.	Spec. No.	Sealed (dry)	Immersed (days)				
			1	7	14	21	28
D211	1	294.34	0.34	0.70	1.05	1.26	1.46
	2	299.81	0.33	0.63	0.81	1.02	1.20
	3	296.08	0.32	0.68	0.95	1.19	1.39
	4	289.55	0.36	0.67	0.85	1.05	1.23
	5	284.84	0.33	0.65	0.86	1.02	1.23
D212	6	302.90	3.21	4.66	4.66	4.73	4.83
	7	297.62	0.83	5.30	5.40	5.51	5.63
	8	301.77	2.86	3.99	4.05	4.10	4.20
	9	303.16	0.90	5.16	5.29	5.33	5.48
	10	301.65	1.48	5.29	5.39	5.42	5.55
D213	11	292.54	0.59	1.60	2.04	2.38	2.73
	12	302.10	1.15	3.72	4.30	4.57	4.81
	13	301.10	0.47	1.49	1.99	2.36	2.73
	14	302.04	0.55	1.65	2.14	2.50	2.82
	15	294.50	0.69	2.16	2.72	3.06	3.40
D211	16	298.48	0.34	0.75	0.93	1.12	1.40
	17	299.85	0.30	0.68	0.85	1.04	1.31
	18	291.90	0.35	0.82	1.08	1.33	1.64
	19	304.96	0.38	0.93	1.16	1.43	1.75
	20	300.59	0.36	0.77	1.01	1.29	1.78
D212	21	288.73	4.24	4.51	4.55	4.60	4.69
	22	302.24	4.69	4.95	5.02	5.05	5.19
	23	290.33	4.61	4.95	5.00	5.04	5.13
	34	295.85	4.52	4.95	4.99	5.03	5.14
	25	297.70	4.66	5.04	5.10	5.13	5.25
D213	26	290.94	0.97	2.36	2.75	3.06	3.36
	27	301.42	1.21	2.91	3.38	3.71	3.99
	28	298.16	1.22	2.86	3.31	3.62	3.91
	29	298.33	1.25	3.01	3.54	3.88	4.20
	30	298.62	1.45	3.00	3.55	3.80	4.10

Table 9

Average percent weight gain of sealer treated mortar cubes on immersion in water or 0.1 N KOH (Third Series)

Days immersed		0	1	7	14	21	28
Sealer							
D211	Water	0	0.34	0.67	0.90	1.11	1.30
	Alkali	0	0.34	0.79	1.01	1.24	1.58
D212	Water	0	1.99	4.88	4.96	5.02	5.14
	Alkali	0	4.54	4.88	4.93	4.97	5.08
D213	Water	0	0.69	2.12	2.64	2.97	3.30
	Alkali	0	1.22	2.83	3.31	3.61	3.91

APPENDIX F

Technology Transfer

Lectures on the parking garage problem given during the contract period.

1. Workshop for the staff of CIPREC member companies, Toronto, June 25, 1987;

2. Parking Garages, Their Deterioration, Rehabilitation and Upgrading, Workshop of Technical University of Nova Scotia, Toronto, November 26, 1987;

3. Parking Garages, Their Deterioration, Rehabilitation and Upgrading, Workshop of the Technical University of Nova Scotia, Montreal, December 1-2, 1987;

4. Ottawa Chapter of BOMA, Parking Garage Problem, April 5, 1988;

5. Fifth Canadian Building and Construction Congress, Montreal, November 27, 1988, "Design for Durability";

6. Workshop for the staff of CIPREC member companies, Toronto, March 1989;

7. Workshop for the staff of CIPREC member companies, Montreal, March 1989;

8. Repair and Restoration of Concrete Structures, Science Council of British Columbia, Vancouver, B.C., March 2, 1990;

9. In-house seminar for Tridel Corporation, Toronto, September 12, 1990;

10. American Concrete Institute Annual Convention, Toronto, March 22, 1990, "Deterioration of Parking Structures Research Project";

11. Fifth International Conference on Durability of Building Materials and Components, November 8, 1990, Brighton, U.K. "Performance of Parking Garage Decks constructed with Epoxy Coated Reinforcing Steel";

12. Municipal Update Course, Ministry of Transportation of Ontario, Ottawa, February 12, 1991, "Concrete parking Structures";

13. Second CANMET/ACI International Conference on Durability of Concrete, Montreal, August 4-9, 1991, "Deterioration of Parking Structures";

14. Tohuku University, Sendai, Japan, "Corrosion of Reinforcing Steel in Concrete";

15. Premiere Conference: Materials Protection for the Nineties, National Application of Corrosion Engineers, Toronto, November 18, 1991, "Evaluation of Corrosion Control Methods - Membranes, Sealers, Epoxy Coatings";

16. Structural Engineering Workshop, Public Works Canada, Ottawa, May 27, 1992, "Update on Parking Garage Rehabilitation";

17. Canadian Parking Association Annual Convention, Edmonton, September 28, 1992, "Performance of Repaired and Protected Parking Structures".

Papers published on the parking garage problem during the contract period

1. **G.G. Litvan**, "Designing for Durability Proceedings, Fifth Canadian Building and Construction Congress, November 27-29, 1988, Montreal.

2. **C.T. Aitken and G.G. Litvan**, "Laboratory Investigation of Concrete Sealers", Concrete International: Design and Construction, Vol. II, No.11, November 1989, pp.37-42.

3. **G.G. Litvan**, "Performance of Parking Garage Decks Constructed with Epoxy Coated Reinforcing Steel", Proceedings of the 5th Int'l Conference on Durability of Building Materials and Components, Brighton, U.K., November 7-9, 12990, pp.421-432.

4. **G.G. Litvan**, "Deterioration of Parking Structures Research Project", Second CANMET/ACI International Conference of Durability of Concrete, August 4-9, 1991, Montreal, Proceedings, pp. 317-334.

5. **G.G. Litvan**, "Condition survey of parking structures" in Feedback from Practice of Durability Data, Appendix: Examples of Field Investigations, CIB International Council for Building Research Studies and Documentation, Report 128, 1990.

6. **G.G. Litvan**, "The effect of sealers on the freeze-thaw resistance of mortar", submitted to Cement and Concrete Research.

APPENDIX G

STANDARDS WRITING COMMITTEES

The Project Leader is a member of and actively supports the following committees in the area relevant to the parking garage problem:

Canadian Standards Association
Committee S413, Parking Garage Structures,
Chairman of Subcommittee on Moisture Barriers,
Task Group on Concrete Restoration,
Committee on Precast Concrete Paving Elements

American Concrete Institute
Committee 362, Parking Structures,
Committee 201, Durability of Concrete,
Committee 365, Service Life Prediction

American Society for Testing and Materials
Committee D-1 on Paint and Related coatings and Materials
Committee D01.47 Masonry Treatments

CIB Working Commission W80/RILEM Technical
Committee 100TSL, Prediction of Service Life of Building Materials and Components

APPENDIX H

LIST OF PREVIOUSLY REPORTED SUB-PROJECTS

Protocol for the condition survey of parking garages (reinforced concrete) Report No. 3

Protocol for the condition survey of parking garages (posttensioned) Report No. 3

Report on the examination of cathodic protection systems applied to deteriorated parking garages (C.L.Page) Report No. 2

Protocol for the condition survey of parking structures (cathodically protected reinforced concrete) Report No. 3

Responses to cathodic protection system suppliers to IRC questionnaire Report No. 3

Survey of concrete sealers Report No. 3

Concrete delamination detection by ultrasonic method (Pylon Electronic Development Ltd.) Report No. 3

Status of search for alternative deicing chemicals Report No. 4

Investigation of the performance of parking garage decks constructed with epoxy coated reinforcing steel Report No. 5

Monitoring and maintenance procedures for parking garages Report No. 6

Feasibility study on the use of ground probing radar for evaluating corrosion of rebars within the reinforced concrete floors of parking garages (Edgetech I.G Ltd) Report No. 6

Benefits of good maintenance and housekeeping practices Report No. 7