# A database tool to support building envelope failure diagnosis

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## ABSTRACT

### A database tool to support building envelope failure diagnosis

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In the past seven years, building envelope failures have had a share of 25% of the total of failures that occurred in Quebec's housing stock. More than half of the resources used by Canadians to repair and renovate their houses have been used for roofing rehabilitation and wall system repairs and replacement. If these expenditures are to be reduced, building envelope problems have to be detected at early stages and their causes understood clearly. Diagnosis of building envelope failures has been traditionally done by inspectors that learn mostly through practice, with few tools to support them.

This thesis' objective is to develop a tool to support the diagnostic process during a building envelope investigation. First, an extensive literature review gives a portrait of the state of the field of diagnostics. To this day, most of the knowledge acquired from the study of failures stays with experienced practitioners. Efforts to codify or extract such knowledge are still few. However, a general diagnostic method and approach was implemented into a proposed computer tool.

Access to the files of the Quebec Home Builder's Association (APCHQ) allowed information on residential building envelope failures in Quebec to be collected and organized into a computer database. Analysis of the database information pointed to water infiltration as the most frequent failure in the first 5 years of life of the houses. Inappropriate design accounted for 43% of the problems, 25% were due to deficient workmanship, and 11% to wrong detailing. The database built in this research could be a framework to collect and disseminate information about problems in the building

envelope in Quebec and Canada. Thus, with it, a portrait of the current building envelope problems can be made.

The prototype tool was designed and implemented to demonstrate how a tool integrating a database populated with well-documented and relevant cases of failure can be used in in-situ investigations. The tool works by supplying relevant similar cases of envelope failures. Developed using Microsoft Access, it allows delving into the 96 cases of the database and automates the production of reports.

An evaluation of the prototype tool finally led to the development of guidelines for the next generation of a diagnostic support tool. Such tool should combine retrieving of similar cases with interrogation of relevant general knowledge in order to make a diagnosis and propose remedial measures.

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# Chapter 1. Statement of the research problem

## 1.1 Introduction

The fast evolution of building materials and processes, together with the trend to build in shorter periods of time at minimum cost, is paralleled with an increase of reported building envelope failures. Even though failures and defects in buildings have existed for ages, the field of building pathology is relatively new and its knowledge organization presents gaps in the standardization, collection and recording of building envelope failures and defects. It seems evident that the study of failures and defects will lead to the improvement of buildings. Yet, such idea is still not altogether embraced by many practitioners. (Harris, 2001).

### 1.1.1 Current State of Knowledge

Traditionally, similar construction systems and materials were used and over time their behavior became known. With the energy crisis in the 1970s, new materials, systems and techniques were introduced to insulate buildings, and performance requirements evolved greatly. The increased complexity of current envelope assemblies makes their proper design and construction challenging. A lack of understanding of the envelope behavior and the interaction of its components explains in part the increase of recent buildings having failures.

The study of building envelope failures belongs to the rapidly evolving field of forensic engineering. Up till now, in general, this field has not reached the level of standardization of methods found in other fields. As mentioned by Audet-Lapointe (1999), building envelope pathology is still in its infancy. According to the Building

Research Board (1985) of the National Research Council in Washington, D. C., building diagnostic activity is developing without a coordinated focus and only responds to failures or imminent failures. As a result, the assessment often does not follow a logical sequence and may omit steps, resulting in a situation where the problem is partially understood. Typically, in the case of building envelope failures, knowledge generated by their analysis has been spread through the publication of case studies. There is yet no standard methodology to study building envelope failures. This can be explained by the fact that every building is different and is the product of a complex process involving designers, builders, owners, and materials, resources, interests, etc. Therefore, the development of standard methods to approach envelope failures will have to address a wide array of possible parameters involved in a case. Another reason for the lack of a common methodology comes from the fact that building defects are often subject to litigation and the study of such defects is constrained by judicial and financial interests.

So far, in practice, building failure diagnosis has relied on the knowledge and experience of investigators. However, some diagnostic aids have been developed to help in the diagnostic process, such as: checklists, charts, tables, matrices, fault trees and computer based tools. These diagnostic aids are used as a means to organize facts when problems are too complex and the causes of the problem are not obvious to building inspectors.

### 1.1.2 Problem

Typically, failures and defects do not have a single cause but result from the interaction of human action, environmental conditions and building components. This results in a failure investigation that seldom leads to absolute irrefutable answers but rather to the suggestion of a most probable cause of failure. Even though collection of information surrounding building envelope failures is case specific, expert opinions produced with the same set of information can be different. The best interpretation of the causes of the failure would be the one made by a qualified investigator presenting the scenario under which the failure was most likely produced (Greenspan *et al.*, 1989).

The investigator of building envelope failures and defects should ideally be best qualified in the discipline related to the problem. Also, a strong technical background and broad experience is required. However, access to reliable and organized information of past failure cases could help inexperienced inspectors to diagnose building envelope defects and failures.

Databases populated with cases of failure would be a valuable resource for building pathologists. A database of past investigations should aim at supporting inspectors in recognizing failure symptoms while not creating preconceptions that would narrow the investigator's search. Among the benefits of the use of databases, would be the dissemination of lessons learned from past mistakes. But, efforts of gathering and spreading information about building failures have often failed due to the lack of contributors, funding and interest. However, collections of failures exist in the files of warranty programs of builders and professionals. The development of guidelines and standards for the building industry would benefit given access to the knowledge that would be generated through the systematic study of failures. There is a need for databases in which building defects can be efficiently stored, classified, dissected, analyzed and understood (Audet-Lapointe, 1999).

To our knowledge there has been little joint effort of collecting the lessons taught by building envelope failures. In our view, such an effort could produce a database that could be used to support building inspectors, direct the attention of designers and builders to crucial aspects and lead to overall better performance of building systems in the future. Also, there has been little effort to provide tools for building inspectors to support the diagnostic process. Such tools could organize and simplify data collection on site, point to additional required information, provide similar failure cases for comparison and guideline purpose and standardize report production.

### 1.1.3 Proposed approach

A study by the Architecture and Engineering Performance Information Center in the United States done in 1987 indicated that leaky roofs and walls are probably the most insidious problems faced by building owners. While the literature is replete with cases of building envelope failures, there is a need for a well organized methodical approach to investigate this type of failures.

There is scarcity of tools to support the diagnostic process. Given the diversity of building construction and the complexity of failure processes, as a step towards a more complete tool, this thesis is based on the framework that the most effective diagnosis tools are those that provide relevant information to the building inspector, rather than those that attempt to substitute the reasoning process by which hypotheses are made when assessing the building envelope.

The tool proposed is composed of two elements. A computer database containing 96 cases that can be fed with an increasing number of building envelope defects and failures and an interface tool to interrogate the database on cases of building envelope failures. The database information is organized into a proposed methodical sequence. Such organization standardizes the collection of data and reporting of building envelope failures. The interface tool allows the user to build queries that provide information that relates symptoms to a particular building problem to assist building inspectors in the diagnosis of building envelope defects and failures.

## 1.2 Research Objectives

The scope of this thesis is to investigate the available means of supporting the diagnosis of building envelope failures and propose a tool that supports the investigation and resolving process of diagnosticians of the building envelope.

This project specifically aims to:

1. Provide a state of the art review of available diagnosis tools
2. Develop the conceptual functions and content of a tool to support the diagnosis process
3. Demonstrate the adequacy of such tool through a proof-of-concept tool based on a database of building failures
4. Structure and populate a database with building envelope failure cases, including symptoms, diagnosis and treatment while ensuring future expandability and use by practitioners and researchers
5. Produce statistics using the database on the vulnerable areas of design, construction or maintenance of envelope in Quebec and make recommendations to house builders.

### 1.3 Literature review

This literature review aims to describe the field of knowledge of building diagnosis by first introducing the subject of forensic engineering and building pathology. The process of defect diagnosis is presented, together with the available methods to diagnose building failures, followed by guidelines for building diagnosis and the requirements for building investigators. The actual description of failure mechanisms and the selection process of adequate remedial measures is not the object of this thesis. Such work would be system and climate specific and is outside the scope of this research.

#### 1.3.1 Forensic engineering

Forensic Engineering is the art and science practiced by professionals qualified to serve as experts in engineering matters subject of controversy before courts of law or in arbitration actions (Specter, 1987). It supports the investigation of failures in engineered objects, such as buildings.

Forensic engineers contribute significantly to the process of learning from failures by disseminating information to the design field of engineering. Forensic engineering as a profession is relatively new. It can be compared with medical pathology, that has played a major role in the development of science (Carper, 2001). A significant body of knowledge about building bridges, airplanes, structures and cars has been amassed by the traditional engineering professions. Major disasters have happened along the history of the usage of these artefacts, but their need has persisted, so lessons from failures have been incorporated into new designs. As a result, products were improved and there was an enhanced understanding of how to develop them. Developers improve their body of knowledge and professional wisdom by studying building failures and documenting the history of failures (Dalcher, 2000).

As Benjamin Franklin said, "Experience is a dear teacher, and only fools will learn from no other." Accumulated experience could be used as:

a. a historical baseline
b. feedback on the process and methods used
c. a risk management technique for observing risky patterns
d. data/knowledge resource used to train inexperienced people
e. a decision aiding tool
f. a tool for continuous process improvement
g. a motivation to record assumptions, decisions and rationale
h. a foundation for a comprehensive body of experience

As explained by Dalcher (2000), practitioners benefit from forensic practice by recomposing the body of knowledge. Identifying core problems and highlighting the state of the practice will lead to more pertinent research. The knowledge acquired can serve as a historical baseline within the organization that helps improve assessments and estimates. The result will be better tuned processes and enhanced confidence. Feedback from forensic practice can be used to improve methods and calibrate models by making them more relevant and ensuring that they point out the right problems.

Education benefits from forensic practice because it feeds back knowledge into the engineering schools. By highlighting failed approaches or the importance of central topic through the use of the case study method, educators transmit the resultant knowledge that comes from detailed analyses. It is through case studies that discussions and comments about the state of the practice are generated. They are very beneficial if comparisons are made of good and bad practices. Statistics about failures produce new knowledge that can be used to frame encountered problems and to suggest the measures to be followed. With a detailed analysis of failures, essential areas of future research can be identified. Forensic experience makes education more relevant because it injects a dose of reality into the classroom.

As explained by Dalcher (2000), case histories are the primary tool available to forensic engineers. They contain a historical description and analysis of actual processes. They are most valuable because they serve to trace decisions (recorded rationale) to their eventual results. Case histories help identify, define and assess persistent problems and their complexities. One can easily conclude that maintaining forensic case histories is a form of risk management and hopefully, mitigation of problems. Case histories identify and generate ideas about cause-effect chains and dynamic relationships related to the development effort. They also help identifying feedback requisites. But their main application is highlighting the complex dynamics involved in magnifying and developing small scale problems into fully fledged catastrophes. Case histories provide a tool that substitutes costly experience. They stimulate our thinking about potential solutions by identifying critical areas and patterns.

### 1.3.2 Building Pathology

Building pathology is the holistic approach to understanding building failures. It requires a detailed knowledge of building design, construction, usage and modification, as well as the various mechanisms that affect their material and environmental conditions. It is “an interdisciplinary approach and requires a wider recognition of the ways in which buildings and people respond and react to each other”(Watt, 1999). Forensic engineering is the parent discipline of Building Pathology. Building pathology studies building defects and failures in order to understand the causes of problems in building systems to propose remedial measures.

This thesis focuses on one system of the building, namely the envelope. The building envelope interacts with various building subsystems. It has implications on the durability and serviceability of the building as a whole, and consequently on the health, safety, comfort and productivity of its occupants. A preventive approach to building failures and defects is always desirable. Building envelope performance evaluations serve, among other purposes, to identify vulnerable areas of the building envelope and failures of the envelope to control heat flow, air flow, water entry and moisture (Institute for Research in Construction, 1993). When prevention of defects and failures through performance evaluations has not been implemented in a building, defects and failures then require an assessment that will find their cause(s) so that appropriate remedial measures are put into practice.

Since there is a wide array of defects and investigators, there is no standard methodology to diagnose building failures. Investigation methods depend on the point of view of the investigator, his/her expertise and the nature of the defect. The same defect could be approached differently by different investigators, sometimes having different results. That is why there is a need for a discipline like building pathology (Van den Beukel, 1993).

### 1.3.3 The process of building failure diagnosis

Defect diagnosis is "the logical way of proceeding from the evidence to the cause of a defect, after which remedies can be prescribed" (National Building Agency, 1979). A building defect investigation is aimed to detect all the defects that exist in a building as well as their causes. Defects are often visible and obvious, but sometimes they occur in such a form or location that simple detection is not possible (Watt, 1999). If this is the case, the investigator can make use of a diagnostic procedure that could vary in complexity depending on the nature of the defect and the given needs of the investigation. Precedents of the procedure that should be followed in the diagnosis of building defects can be found in crime detection, pathology or forensic medicine. Diagnosis of defects is comparable to crime detection because investigation produces evidence and hypotheses are generated and examined to assess which one best matches the facts (Department of the Environment, Property Services Agency, 1989). During a diagnosis, false trails in the investigation have to be identified as information gathered during the investigation is analyzed. Evidence of the specific agent that is causing the defect has to be found, analyzed and assessed, followed by the formulation and testing of hypotheses (Addleson, 1992).

According to Van den Beukel (1993), the diagnostic process starts with the acknowledgement of anomalies that reveal the presence of a defect or a condition of imminent failure or from the observation of a failure that already occurred. Then, the diagnosis aims to do a methodical analysis of all the possibilities of the causes of the failure.

To Addleson (1992), the diagnostic procedure starts by analyzing the first clues provided by the symptoms. Symptoms are understood as the way by which the cause of the defects has manifested itself. After analyzing the symptoms the investigator has a clue of what the scope and nature of the investigation will be. It is at the stage of symptom analysis when the investigator defines their cause and points out the most probable culprits of the problem. At this stage a first hypothesis is made to suggest the cause of the defect. Then the investigation has to be designed to test such hypothesis. It should be noted that, during the analysis of symptoms, all external factors that contribute to the existence of the problem should also be taken into account (Addleson, 1992).

As mentioned by Van den Beukel (1993), the investigation of building defects is a decision making process that might be influenced by factors like time of delivery, missing or unrecoverable information and unforeseen events. The investigator has to face uncertainties and handle them in some probabilistic way. The analysis of anomalies found in a building is an important stage in the diagnostic procedure. This is because if such anomalies are interpreted as symptoms, they will allow for a pre-acknowledgement of the defects that caused the failure. The pre-acknowledgement of defects involves the formulation of a first hypothesis called "prediagnostic conjectures". The "prediagnostic conjectures" should be verified through analytical and more accurate instrumental surveys. Surveys will allow the elimination of conjectures that cannot be supported with evidence found in the investigation, leading to a sub-group of definitive diagnoses. The definitive diagnoses at this point have a degree of certainty, so they have to be tested again in what Van den Beukel (1993) calls a "requalification stage". It is at this phase of diagnosis when a correct diagnosis supported by operative and methodological tools can optimize the requalification procedure. In order to determine the causes of defects, authors have proposed several ways to carry on a diagnosis, going step by step. Before starting with an investigation, its scope has to be determined. The scope of defect investigations depends on the amount of money that can be spent on them. It is related to:

1. The nature of the defect
2. The accuracy with which the cause(s) need(s) to be identified
3. The need to establish the reason why the defect occurred. (i.e. to determine liability or to decide the type of remedial work)

It is generally the case that the more uncommon the defect, the greater the accuracy required in the identification of the cause(s) and the wider the scope of the investigation. A simple investigation could consist of a thorough visual inspection and limited data collection. An exhaustive investigation could take months, need extensive destructive investigations, site and laboratory tests and intensive data collection. The scope of any investigation should be designed according to the case. (Addleson, 1992)

In his paper, Fisher (1986) lists the requirements of a complete building failure investigation. Though it was thought originally for catastrophic structural failures, it is applicable to building envelope failure investigations. The investigation should include: 1. The definition of the problem to be undertaken by the investigating team; 2. Acquisition of field and test data; 3. Generation of a failure theory; 4. Analysis and conclusions relating to the failure

Greenspan *et al.* (1989) point out that the fundamental stages of a failure investigation process are: a) data acquisition, b) analysis of data, and c) presentation of opinions and conclusions.

Fisher (1986) proposes the following recommended basic steps that guide inexperienced investigators in a building failure investigation:

1. Perform interviews to obtain detailed information about the failure
2. Develop failure hypotheses based on the original structure and conditions.
3. Test each failure hypothesis through critical observation
4. Prepare "failure element" sketches and compile a detailed photographic log.
5. Perform field testing as required.
6. Take samples under prescribed conditions and carefully identify exhibits for laboratory testing
7. Conduct interviews again
8. Retrieve and categorize systematically all documents relevant to the investigation
9. Review original design
10. Conduct independent structural analysis
11. Examine all data and develop final conclusions

On-site data collection, research, on and off-site testing, analysis, and documentation are common components of a full scope failure investigation. These steps may be expanded, altered, or omitted depending on the nature of the failure, but always without compromising the investigation findings (Greenspan *et al.*, 1989). Table 1.1 compares authors' methodology of investigation for building defects. It collects ideas from all the authors and proposes a detailed plan of action. It is recommended to adjust it to the size, needs and scope defined at the beginning of the investigation.

| MAIN TASKS IN A BUILDING INVESTIGATION | ACTIONS TAKEN IN A DIAGNOSTIC INVESTIGATION | Eldridge 1976 | Fisher 1986 | Greenspan et al 1989 | Addleson 1992 | Van den Beukel 1993 | P. for Bldg. Cond. Assessment 1993 | Carper 1999 | Watt 1999 | Beasley 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| DETECTION | 1. Detection and acknowledgement of anomalies | | | | | X | | | X | |
| COMMISION | 2. Commission of forensic engineer by client | | | | | | | X | | |
| INFORMATION ACQUISITION | 3. Data acquisition and collection | X | | X | X | | | | | |
| | 4. Background research and review of original project briefs, site surveys, design and as-built drawings and specifications | | | X | | | X | X | X | |
| | 5. Preliminary document review | | | | | | | X | | X |
| | 6. Initial reconnaissance site visit | | | | X | | | X | X | X |
| | 7. Interviews | | X | | | | X | X | | |
| PRELIMINARY ANALISIS | 8. Analysis of symptoms | | | | X | | | | | |
| | 9. Methodical analysis of possibilities of causes of failure | | | | | X | | | | |
| | 10. Formulation and development of first hypotheses | | X | | X | X | | X | | |
| | 11. Definition of objective, scope and nature of investigation | | | | X | | | X | | |
| | 12. Formulation of investigative plan | | | | | | | X | | |
| INVESTIGATION | 13. Detailed on site survey | | | | | | | | X | X |
| | 14. Measurement taking | X | | | | | | | | |
| | 15. Data recording, sketches and photos | X | X | | X | | | | | |
| | 16. Destructive investigations | | | | X | | | | | |
| | 17. Field testing, sample collection and custody | | X | | | | | X | | X |
| | 18. Site and laboratory tests | | | X | X | | | X | X | |
| | 19. Test and verification of hypotheses | | X | | X | X | | | | |
| ANALISIS OF EVIDENCE FOUND IN INVESTIGATION | 20. Analysis and interpretation of results | | | | | | | | X | |
| | 21. Elimination of hypotheses not supported with evidence | | | | | X | | | | |
| | 22. Develop a number of theories based on observations | | | | | | | | X | |
| | 23. Define set of questions to differentiate between theories | | | | | | | | X | |
| ITERATION OF INVESTIGATION | 24. Iteration of the survey to test hypotheses again, if needed | | | | | X | | | | |
| | 25. Repetition of interviews | | X | | | | | | | |
| | 26. Get feedback: redefine questions as required to support new information and prognosis | | | | | | | | X | |
| | 27. Retrieve and organize relevant documents | | X | | | | | | | |
| | 28. Review original design | | | | | | | | | |
| FINAL ANALYSIS AND FORMULATION OF DIAGNOSIS | 29. Conduct independent analysis, if needed | | X | | | | | X | | |
| | 30. Examination of data | | X | X | | | | X | | |
| | 31. Synthesis of information | | | | | | | X | | |
| | 32. Comparison of symptoms with failure conditions | | | | X | | | | | |
| | 33. Development of conclusions: match diagnosis to symptoms and results | | X | | | | | X | X | |
| | 34. Definition of the ultimate cause of failure | | | | X | | | X | | |
| | 35. Formulation of a diagnosis (supported by operative and methodological tools) | | | | | X | | | | |
| REMEDIAL MEASURES | 36. Action: develop appropriate course of action | | | | | | | | X | |
| DOCUMENTATION AND PRESENTATION OF CONCLUSIONS | 37. Organization and Communication of findings | | | X | | | | X | X | X |
| | 38. Presentation of opinions and conclusions | | | X | | | | | | |

Table 1.1 Comparison of diagnostic methodologies for building failures proposed by different authors

#### 1.3.3.1 Preliminary site visit

A preliminary site visit consists normally of a walkthrough of the building that serves the inspector to define the extent to which the survey is required. It allows the inspector to:

a. Make contact with occupants, neighbors and people related to the building
b. Get familiarized with the layout of the building
c. Confirm security arrangements
d. Ensure that facilities are available for safe access to all parts of the building
e. Establish the nature and extent of services
f. Agree nature and extent of the destructive investigation and clearing of investigation site
g. Establish physical boundaries for the investigation area as well as easements and rights of way, when needed
h. Assess the need for specialized survey services (e.g. non-destructive survey)
i. Assess the need for specialized investigative equipment
j. Take photographs and sketches as a record for a later survey

Beasley (2000), proposes that the investigation process should include a visual condition survey. This stage consists of a field observation of the manifestations of the problem, making annotations on drawings and photographs

#### 1.3.3.2 Background research

As mentioned by Eldridge (1976), the first step of a building investigation consists of collecting all the possible data. It is better to have too much information than not enough. During a building failure and defect investigation, there are many sources of information from which the diagnostician can obtain relevant information, being: records, oral testimonies, observations made by the inspector, publications and tests. The objective of the investigation is to provide the diagnostician with data about the materials and details used in the building, and the actual conditions under which the materials and elements were subjected before, during and after construction (Addleson, 1992).

According to Watt (1999), the purpose of background research is to inform the inspector about issues concerning location, site, construction, use and occupation of a building. Key issues might include the following:

a. Establishing the way the building was built
b. Establishing former uses of the building
c. Establishing site conditions
d. Establishing earlier programs of repair and/or maintenance
e. Establishing if the building has suffered any alteration from its original design

Addleson (1992) and Beasley (2000) coincide in recommending that the investigation should contain a document review supported with all the relevant information acquired from:

1. Drawings and specifications
2. Architect's Instructions
3. Site notes, minutes, reports
4. Weather conditions experienced during construction
5. Maintenance manuals and records
6. Repair records

7. Reports on the defects
8. Interviews with building occupants, managers and maintenance personnel
9. Meteorological records
10. Published information/research
11. Observations in the field
12. Detailed field investigation notes
13. In-situ testing results
14. Laboratory test data
15. Chemical analyses
16. Simulations

Depending on the scope of the investigation, the investigator should use the sources of information mentioned above. The diagnostician should collect information from all relevant sources to build the history of the failure. For this task, the time available varies. But the investigator has to keep in mind that if the information is incomplete, time will be required later to finish its collection. In the case of a building envelope evaluation, it could be useful to refer to Part 5 of the National Building Code. Given that there are similarities with audits and building investigations the Code provides criteria for the assessment that could be useful in a building envelope investigation as well. During collection of information, the diagnostician has to avoid jumping to conclusions and second-hand information should be analyzed with reserve, trying to confirm it with other sources.

### 1.3.3.3 On site procedures

Eldridge (1976) describes the procedures to be followed by a diagnostician on site. It is crucial to on-site investigations that everything considered relevant should be observed and recorded. Data should be recorded adequately by taking notes, using a tape recorder or a camera. All oral statements should be recorded for later confirmation if necessary, especially when a defect is subject of dispute. If the area of the failure is not accessible, the diagnostician should use any of the existing visual aids or any means possible to observe the defect closely, given that the defect could be a crack in the foundation or damaged tiles in the roof. The investigator has to take measurements of building elements to gauge the extent of the defect, parallel to data collection on site. Inaccuracies such as out of level, out of plumbness, out of squareness, etc., should be discriminated to only those that occurred subsequent to the erection of the building. When the investigator is measuring, it is necessary to have datum points. Surveys are always done to diagnose a building defect. In those cases in which a survey has to be done in only one visit, it is necessary to collect information that would later be redundant. As said by Van den Beukel (1993), redundancy is justified in this case because it is difficult to establish the difference between relevant and irrelevant information before all data has been analyzed. It is preferable to iterate the survey stage whenever possible. This way, later examinations can be used to test the developing diagnosis. Watt (1999) proposed a ten-stage on-site and three-stage off-site procedure that will direct the investigator through the assessment of defects. He suggests the following on-site procedure for the assessment of defects:

1. Inspect the defect closely

2. Record the defect by description, measurement, photograph, or sketch drawing
3. Inspect and examine the construction around the fault for other indications of the problem (or related defects), looking for hidden parts of the building that could be affected
4. Ascertain as accurately as possible the exact form of the construction
5. Examine construction drawings/specifications if available for detailed information on the fabric of the building
6. Test defect if applicable and take samples for analysis
7. Inspect hidden areas
8. Examine maintenance manuals if available
9. Open up the structure if required
10. Discuss the problem with the occupants of the building

An off-site procedure should include: a) reference to relevant published information, b) consultation with specialists, c) commissioning more detailed examination/testing by specialists. Beasley (2000), suggests that detailed inspections should be done to determine the state of the building at the time of construction and prior to the failure. Measurements, examination of building elements, connections etc. should be done in an inspection. In a case required by the investigation, sample collection and custody of the samples would involve a laboratory examination and material testing, checking that samples are kept intact and are representative of the defect.

#### 1.3.3.4 Establishing the diagnosis

After gathering all the evidence needed, the diagnostician then has to determine what are the most likely causes of defects, as well as those that contributed to their existence (Addleson, 1992). Authors coincide in the importance of collecting information in a failure investigation. Once the steps of a building investigation have been understood, it is pertinent to know how to define the causes and sources of defects and failures.

Nicastro (1997) says that the diagnostic process is consistent with the scientific method. Therefore, the general procedure to establish a diagnosis is:

1. Statement of the problem
2. Observations
3. Formulation of hypothesis
4. Perform test or experiment
5. Analysis of the outcome to develop conclusions
6. Iteration: form new hypothesis, test and analyze

According to Ransom (1987), the analysis of defects starts generally following a breakdown structure. When analyzing defects, two main steps are pointed out:

1. Classification of symptoms, for example, a damp ceiling as a symptom.
2. A deeper diagnosis is then performed to determine the cause of the symptom, for example, split roofing felt.

Still further analysis will be required to determine the cause of the splitting, such as a differential movement between felt and substrate. Finally, the ultimate cause of the differential movement should be found and it will lie in a specific physical, chemical, and biological agent that is the culprit of such problem.

Defects are varied in magnitude and nature. They often have more than one cause from which they originate. The investigator should try to find the ultimate cause of the problem, this is, the first event that harmed the integrity of the building or component and that is responsible for the defect. In some cases, there are defects that are not related among themselves. For example, a building with a crack that suffers from dampness. Not necessarily the crack is the means of ingress of water. It could be that both defects are not related though they appear to be. But both should be treated. Nothing should be taken for granted (Addleson, 1992).

Watt (1999) mentions that the various ways in which defects manifest themselves are:

1. Visual (e.g. staining, cracking)
2. Physical (e.g. structural failure)
3. Olfactory (e.g. odors)
4. Aural (e.g. water hammer)
5. Tactile (e.g. uneven surfaces)

It is important to distinguish from the cause(s) of a defect and the source of a defect. For Addleson, there are three basic causes of a defect: dampness, movements (i.e. physical change) and chemical/biological change. Table 1.2 gives details of this classification.

Table 1.2 Classification of the sources of problems according to Addleson (1992)

| Dampness/Moisture | Movement | Chemical/Biological changes |
|---|---|---|
| Rain<br>Ground water<br>Construction Process<br>Atmosphere (condensation)<br>Water Supply<br>Faulty Services<br>Maintenance and general usage | Externally applied loads (structural loading and movements in soils)<br>Changes in temperature<br>Changes in moisture (some of the sources for dampness relevant, but the atmosphere notably)<br>Vibrations<br>Other physical changes (such as ice or crystalline salt formation; loss of volatiles, as in asphalt and sealants)<br>Chemical changes (most of the sources for dampness are relevant; corrosion, sulphate attack and carbonation are most important changes) | Dampness (corrosion, sulphate attack, wood decay)<br>Temperature (wood burning)<br>Solar radiation (fading and/or decomposition of paints, plastics, sealants)<br>Presence of incompatible substances (setting of cement, adhesives and sealants) |

The above mentioned sources of causes of defects interact with the nature, behavior and transfer of the sources themselves; and the nature and behavior and resistance of materials (Addleson, 1992). Defects are sometimes caused by errors committed during design or construction. Defects can either manifest themselves by the action of external agents or remain latent. External agents and defects interact consequently having decay as a failure. Building component failures can be structural, (i.e. loss of physical, chemical and technological characteristics), or they can be the result of a performance failure. There are cases in which it can be both structural and performance failure. Normally it is the building occupant who first becomes aware of failures through the manifestations of the failures called anomalies. Decay is one of the causes of failures in buildings and it is a normal consequence of usage and aging. Decay is defined as "the evolution from a performance to a non-performance condition". There are two types of decay:

1) Natural decay: started by the aging of materials and components

2) Pathological decay: started by errors committed during the different stages of the building process.

The decay process needs time to develop. Components do not pass from a performance to a failure condition. Most of the time, anomalies manifest themselves before the final failure occurs, then, becoming a sort of symptoms that point to one or more possible defects. Acknowledgement and treatment of anomalies at an early stage is fundamental if failures are to be controlled or even avoided (Van den Beukel, 1993).

Van den Beukel (1993) mentions there are three types of cause descriptions. This classification applies if it is assumed that the analysis of the causes of a defect are determined by the use that will be given to the results of a given investigation:

1) Technique-oriented descriptions (what caused the defect?)

2) Liability-oriented descriptions (who caused the defect?)

3) System-oriented descriptions (how did the defect originate?)

Addleson (1992) and Carper (2001), propose a list of design, construction and usage aspects that could inherently be responsible for a defect either alone or in combination one with the others. Both authors' lists are shown in table 1.3

Table 1.3 Comparative classification of causes of building defects and failures

| **According to Addleson (1992), buildings defects occur because of these reasons individually or in combination:** | **According to Carper (2001), buildings fail because of:** |
|---|---|
| Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance | Fundamental errors at the outset of a project: flaws in the basic concept; Programming and project definition deficiencies; Pathology and teratology |
| Incorrect materials were specified and/or inappropriately detailed<br><br>Correct materials were specified, but inappropriately detailed | Errors during the design phase: Design challenge: anticipation of failure; Failure to meet applicable codes and standards; Engineering design errors: structural, mechanical/electrical, other technical disciplines; Material selection and detailing errors; Inadequate concern for durability and maintainability; Incomplete or inconsistent project documents |
| Correct materials were specified and appropriately detailed, but incorrectly ordered, handled and/or assembled on site | Errors during the construction phase: Communication, coordination and inspection; Improper sequencing of construction, Temporary weaknesses: material and connection vulnerabilities |
| | Operational Errors: Anticipating post-occupancy problems; Misuse and abuse; Operational problems with sophisticated equipment; Alterations, renovations and change in use; Deficient maintenance. |
| | Forces and destructive agents: natural and human-caused hazards: Buildings: static objects in a dynamic world; Gravity; Wind; Earthquake; Flood; Fire; Unusual loads: blast, vibration and collision; Time related deterioration; Other factors |

Defects manifestation does not necessarily coincide with their time of origin. According to statistics of 1987 presented at the 'ECE Consultation on Building Pathology and Prevention Disorders' (March 19-20, 1987) in nine countries such as Finland, France, Germany (East and West), Great Britain, Netherlands, Norway, U.S.A., failures were originated with the following pattern: design failure – 43%; execution failure – 38%; material failure– 14%. The remaining 5% corresponded mainly to "use" and a minimum share to "unknown". The same statistics in Czechoslovakia, Hungary and Poland, revealed a different pattern: design failure – 13%; execution failure – 57%; material failure– 30% (Van den Beukel, 1993).

In the investigation process, the investigator first attempts to determine the initiating location and mode of failure. When determining the causes of failure, the following should be established:

1. Mode and sequence of the failure: it could be done by simple observation
2. The demands acting on the facility at the time of failure: they could be static or dynamic loads, involving environmental factors such as temperature and humidity
3. The capacity of certain components to sustain loads or the entire facility at the time of failure: it could be done determining the as-designed, as-built state of the facility, as well as the load and environmental history of the facility. This can be done through analytical and physical testing techniques (Carper, 2001).

In his book, Building Pathology, Deterioration, Diagnostics and Intervention, Harris (2001), presents two generic theoretical approaches to building assessment followed by building investigators: a) the flaw detection approach, that "presumes performance until there is a problem manifestation"; b) the systems approach, that "presumes active deterioration until proven otherwise."

According to Harris, the flaw identification approach represents the conventional way of viewing buildings, where a single component may simultaneously provide functional contributions to more than one of these systems. There are two problems with this component approach to building inventories and assessments relative to building pathology. Once buildings are built, all the pieces form a whole that cannot be deconstructed to its original items. Also, many failures occur at the joints and seams of the building instead of occurring at the solid part of the components.

A pragmatic consequence of the flaw identification approach is that buildings are overdiagnosed for problems. Also, the component approach tends to emphasize those flaws that can be seen and minimize those that cannot be seen. On the other hand, the systems approach works by detecting the inability of the system to perform the necessary and essential function for which it was intended. A failure occurs according to the systems approach when the functionality of the system is compromised. This means that a component could already have entered a deterioration process but it is until the whole system fails to fulfill its intended function that a failure exists. The systems approach presumes that failures can occur and the fact that they cannot be detected does not mean that they do not exist. It presumes that materials and systems are subject to constant deterioration and by understanding their behavior it can be predicted where and when they are going to fail. It is unacceptable then, to respond to systemic deterioration on a reactive basis. Instead, the diagnostician must anticipate and predict failures in his assessments, because the consequences of a failure are too undesirable to wait for the mechanism of failure to appear. "Good pathologists are hunters, not trappers."

Knowledge of defects constantly evolves. New defects occur quite frequently as new materials and procedures are being tested (Department of the Environment, Property Services Agency, 1989). Considerable damage is caused by hidden defects which can remain undetected for years. During detection of latent defects the investigator needs to use all his skills to conduct a thorough investigation that includes non-destructive techniques, material testing, measurement, monitoring or destructive investigations (Watt, 1999).

Knowing the causes of building defects and their sources, we can reach a better understanding of the problem that is affecting our built environment. Once that the culprits of the building failure have been identified, it is possible to prescribe measures to remedy the problem. The success of any remedial measure is a function of the thoroughness and efficiency of the analysis that led to the identification of the causes of the failure.

### 1.3.3.5 Report writing

An important part of any building failure investigation is that of communicating the magnitude, the nature and the findings of such investigation. A diagnosis is often an opinion that should withstand criticism, especially if costly remedial measures are prescribed. People should be able to understand and follow the detailed argument that led to the conclusions and the reasons for rejecting other alternatives (Department of the Environment, Property Services Agency, 1989). One of the common mistakes to be avoided is to confuse assumptions with conclusions. If a report is subject to scrutiny, the forensic engineer should "be able to enumerate the assumptions made in arriving at his conclusions and to recognize that some assumptions are made in arriving at every conclusion" (Nicastro, 1997).

It is important to point out that expert opinions written in a report can be subject to meticulous scrutiny, but it does not mean that all investigators should arrive to the same conclusions. Therefore, when there is more than one report on a same building defect or failure written by different investigators, there can be differences and coincidences. However, it can be said that though the collection of facts and data surrounding a failure are specific, expert opinions generated from these data can differ widely. That is why the most accepted failure investigation findings are those employing a qualified investigation team that presents a report with the scenario under which the failure is most likely to occur (Greenspan *et al.*, 1989).

As stated by Beasley (2000), an investigation process should properly organize and communicate its findings. For this purpose, a report is written following a logical sequence from factual findings, to opinions and recommendations. Reports should contain:

a. Introduction and background

b. Observations and factual information

c. Analysis and discussion

d. Opinion/conclusions

e. Recommendations

If there are relevant assumptions and limitations due to incomplete information on which the report was based, it should be described (Beasley, 2000).

As suggested by Zickel (2000) and in the publication of the Institute for Research in Construction (1993), the following items are suggested to be included in a full report:

1. Description of the project

2. The problem encountered or a description of the failure

3. The investigation procedure

4. The findings

   a. Component condition summary:

      - Summary of building elements and their general condition

b. Key deficiencies and initial assessment of cause

- Location, severity, type, frequency and implications of defects and deficiencies
- Probable causes of deficiencies, where possible

5. Recommended repair and replacement

- For each of the key deficiencies, provide a recommended repair or replacement strategy, associated costing and timing for implementation

6. Lessons learned

- The adequacy of the envelope design for the building function
- An indication of the flexibility of the envelope design to respond to changing building-occupancy requirements

7. Attaching graphics, sketches and photographs

This section has covered the subject of report writing. The overall concept of building diagnosis having been discussed, the next part will cover the methods and tools actually available to support the diagnosis of building defects and failures.

### 1.3.4 Methods and tools to diagnose building failures

There are many tools available to support building investigators in the diagnosis of a failure or defect. Such tools can be as elementary as checklists or as complex as computer tools with reasoning mechanisms. In between there are charts, matrices, questionnaires, etc. However there is no absolute tool to suit all the needs of all given investigations. Some researchers have developed complex flow charts specially valuable for specialized and complex diagnoses. But it is impossible to draw process charts valid for all assignments (Carper, 2001). Some examples of tools found in the literature are presented in this section.

### 1.3.4.1 Tables mixed with questionnaires

Tables and questionnaires are one of the simplest tools that support the diagnostic process in a building failure investigation. Tables contain an arrangement of information in a brief space. They can be combined with a set of questions that could give hints of how to conduct an investigation. In medical pathology, questionnaires are used as a means of retrieving information from sick patients. In building pathology, questionnaires help diagnosticians collect information about the building and the defective element. The National Building Agency (1979), published a book that is organized in tables that contain questions that serve as a guide to the inquisitive thinking of inexperienced inspectors. The use of this book is simple. It proposes a structured questionnaire that direct the inspectors through the investigation in a general way. There is a generic list of defective components from which the inspector must choose the one that coincides with the actual case. The generic list refers the user to a section of the book with a table in which the defect is identified (from a list) as well as the exact location (from a list). An example of the above mentioned table can be found on table 1.4.

Table 1.4 Example of a table of the tool proposed by The National Building Agency (1979)

| **EXTERNAL WALLS AND CHIMNEYS** | | WHERE IS THE DEFECT? | | | **A** |
|---|---|---|---|---|---|
| The figures in the boxes on the opposite page are the reference numbers of the defect sheets which explain how to deal with the defects | WHAT IS THE DEFECT? | Brickwork of an external wall | Brickwork of a chimney | Render to brickwork or an external wall | Render to brickwork of a chimney |
| Questions to ask which will lead you to the correct defect sheet: | Cracking and splitting | A1, A3 | A2, A3 | A8, A7 | A7, A8 |
| WHAT IS THE DEFECT? | Bending, bulging and bowing | A1, A5 | A2 | | |
| IS IT IN EXTERNAL WALL BRICKWORK? | Crumbling mortar | A3 | A2, A3 | | |
| IS IT IN CHIMNEY BRICKWORK? | Crumbling bricks | A4 | A4 | | |
| IS IT IN RENDERING TO EXTERNAL BRICKWORK? | Movement of bricks at dpc | A1, A5 | A5 | | |
| IS IT IN RENDERING TO CHIMNEY BRICKWORK? | Flaking of rendering | | | A6 | A2, A6 |
| | Defective paint work | | | A9 | A9 |
| **A** | **EXTERNAL WALLS AND CHIMNEYS** | | | | |

The user then is directed to the "Defect Sheet", that is a table divided in two main sections. The first one contains the following information: type of defect, location, symptoms checks/questions, action.

A second section of the "Defect Sheet" contains the following information: type of defect, location, causes, remedies and cross references (to other defect sheets, to the British National Building Agency's maintenance training package on house construction and to the slides issued by the NBA). Table 1.5 illustrates the way defect sheets are presented.

Table 1.5 Example of the defect sheet of the tool proposed by The National Building Agency (1979)

| | | | | | | |
|---|---|---|---|---|---|---|
| Defect | **CRACKED BRICKWORK** | Defect | **CRACKED BRICKWORK** | | | **A1** |
| Location | **External walls** | Location | **External walls** | | | |
| Symptoms | Horizontal, vertical and diagonal cracks can be seen running along, down or across external walls and may be accompanied by overhanging of brickwork at dpc level and/or bowing of the wall | Causes | Cracks may be caused by any of the following:<br>* Subsoil movement (including change of water content)<br>* Foundation movement and failure<br>* Expansion of brickwork<br>* Chemical action on brickwork<br>* Failure of wall ties<br>* Spread of the roof structure (i.e. pushing out the walls) | | | |
| Checks/ questions | * Has the crack moved over a period of time; i.e. has it become wider or longer?<br>* Is there adjacent building development?<br>* Is mining carried out in the area?<br>* Has the weather been abnormally wet or dry?<br>* Is there a tree close to the wall, or has one recently been felled? | Remedies | Stable cracks: fill with a compressible filler which prevents water penetration and allows for further movement. The tenant can remain whilst repairs are carried out.<br>Unstable cracks: are structural defects and many involve excavation, underpinning and rebuilding parts of walls. This may involve temporary rehousing | | | |
| | | Cross references | Part I page no. | Part II other defect sheet references | Part III slide no. | |
| Action | Refer to surveyor | | 14 | A5, B3, D1, E1 | 1,2,3 | |

The structure of the tool facilitates access to expert knowledge about specific building failures, their diagnosis and treatment and supports the work of inexperienced inspectors on site. However, this tool does not go deep into technicalities and suggests remedial measures in a rather simplistic way. It also treats a limited number of problems. Therefore, it is possible that in very specific cases the user may not find information that applies to a particular defect. Moreover, the tool is suitable only for cases in which failures match with the problems listed in the generic index. Many of the defects covered by this tool apply only to British housing construction and its environmental conditions.

### 1.3.4.2 Decision Tree

A decision tree as shown in Department of the Environment, Property Services Agency (1989) is a diagram that represents the flow of the decision taking process in building defects investigation. A decision tree keeps track of the steps followed in an investigation. Decision trees are helpful when the investigation is designed and the scope and nature are defined. They serve to visualize and focus an investigation. However, they should not be regarded as a rigid plan of action or a diagnostic recipe because building failure investigations are seldom an immutable procedure. Even though the process of diagnosing building defects can be linear, it is not often the case. Different scenarios often occur in which a non-linear and cyclical process exists. It is important to note that the level of complexity of a building investigation can be such that its proper representation through a diagram like the one described above could become a tedious and time consuming task. Another limitation for this tool is that the diagnostic process is often full of uncertainty. Therefore, in those cases, representing the decisions that should be taken in advance to define a plan of action in the investigation of failures is impossible. Its use is advised at the early stages of the investigation as a general procedural representation to keep the investigation on track.

The book "Defects in Buildings"(Department of the Environment, Property Services Agency 1989), uses a decision tree to guide investigators through the diagnosis procedure of building defects. It supports the investigator by suggesting the actions to be followed according to the defects' nature and context. This is a tool that gives a general idea of an investigative process with different scenarios. There are a number of scenarios that are a combination of the different conditions represented in the above mentioned tree. But three main scenarios can be noted:

1. There is only one cause of the defect (see figure 1.1)
2. None of the causes correspond to the symptoms (see figure 1.2)
3. There is more than one cause of the defect (see figure 1.3)

The decision taking process in building diagnosis can follow many paths, and this particular example does not represent all the possible scenarios that could happen in building failure investigations.

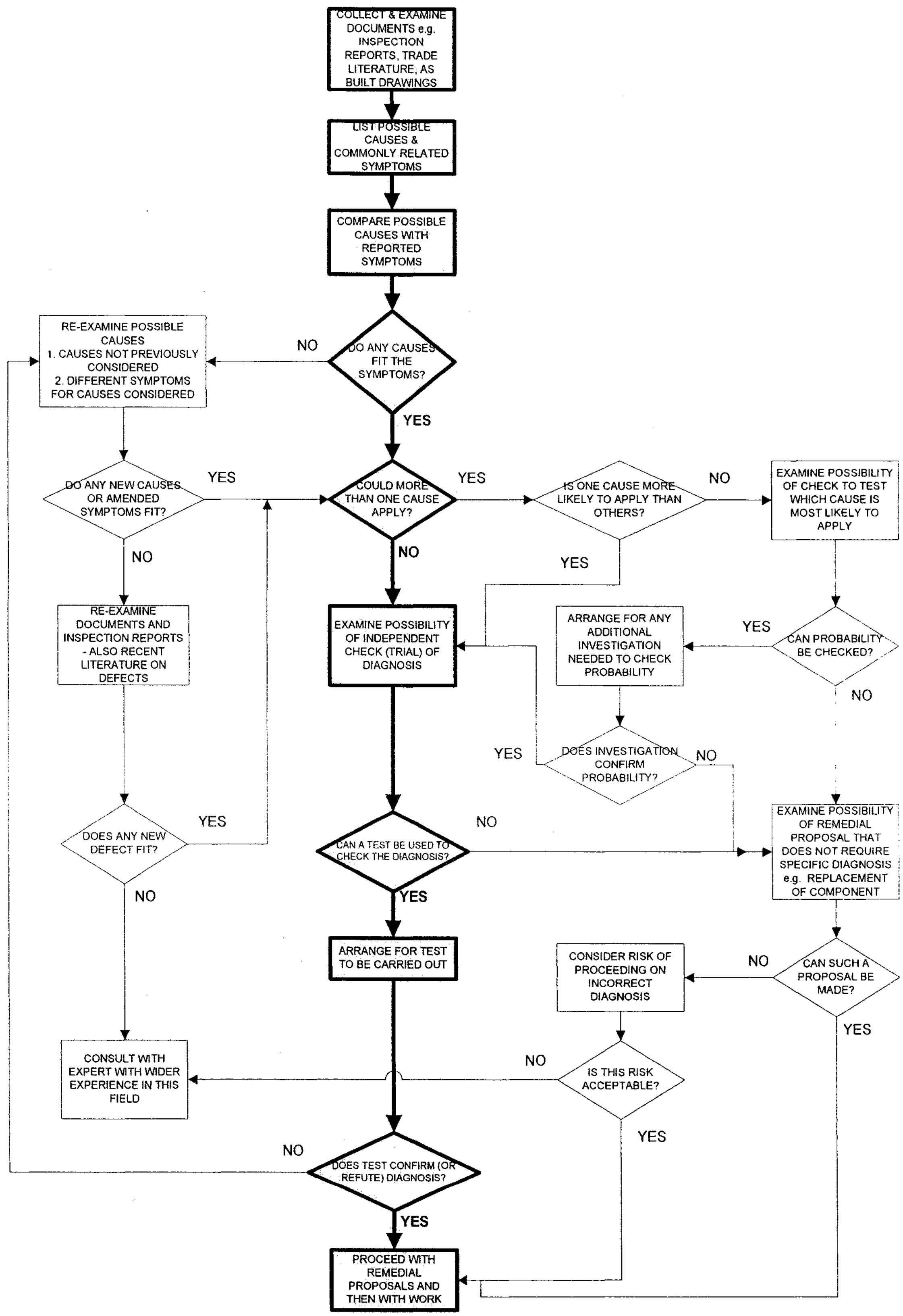


Figure 1.1 Failure investigation decision scenario in which there is only one cause of the defect, according to Department of the Environment, Property Services Agency (1989)

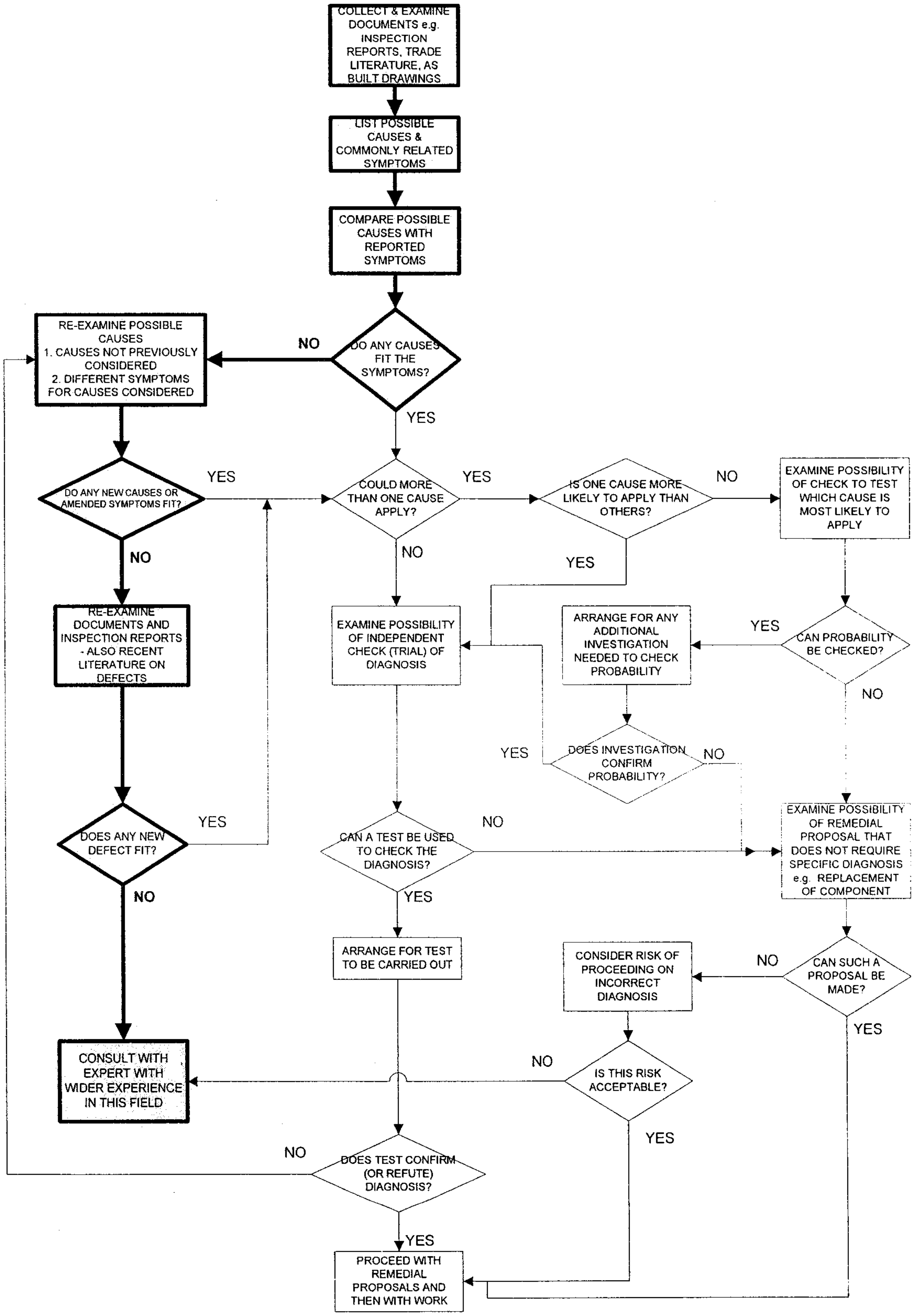


Figure 1.2 Failure investigation decision scenario in which none of the causes correspond to the symptoms, according to Department of the Environment, Property Services Agency (1989)

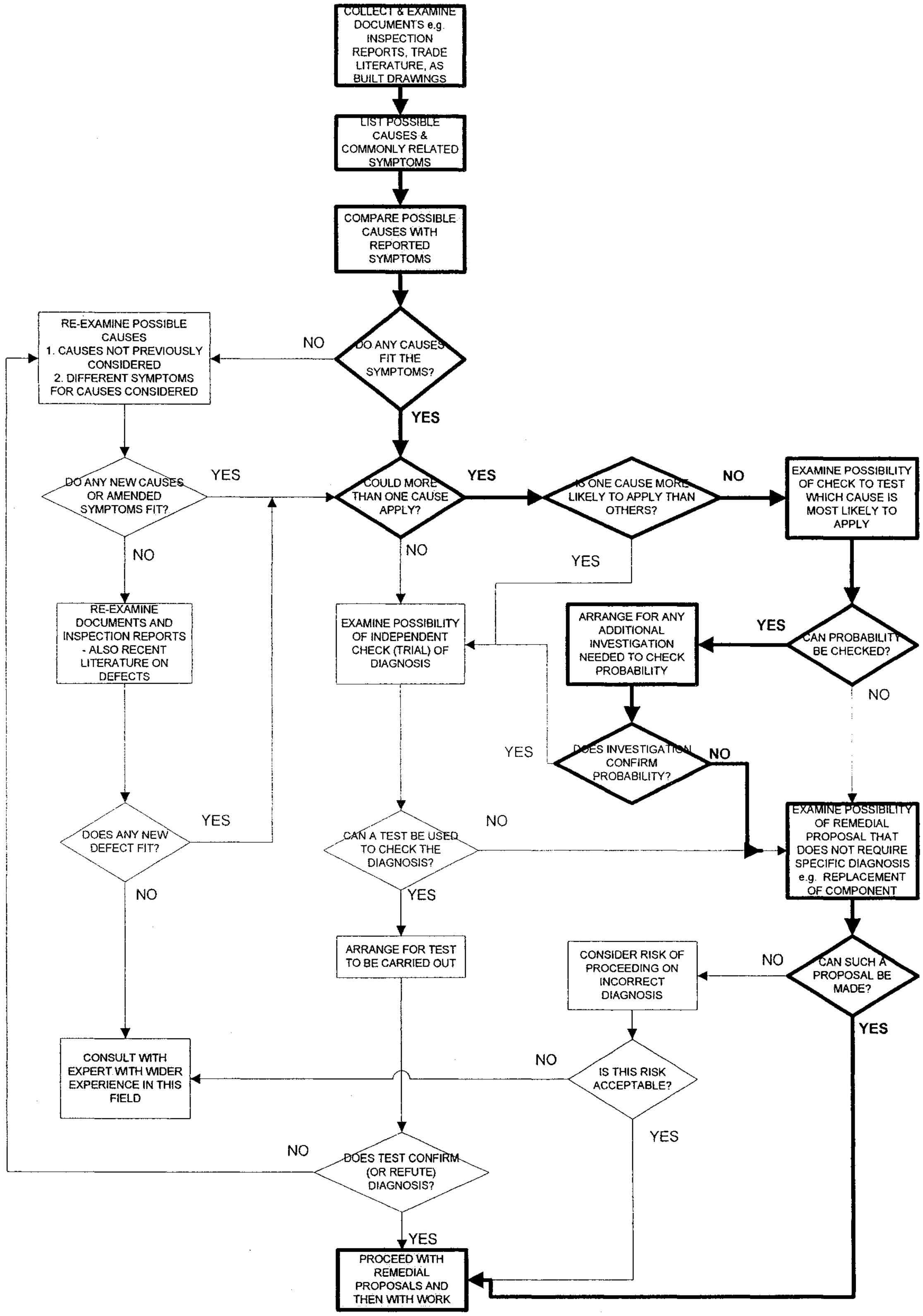


Figure 1.3 Failure investigation decision scenario in which there is more than one cause of the defect, according to Department of the Environment, Property Services Agency (1989)

#### 1.3.4.3 Checklist

An investigation is a decision making process in which a simple reminder of the things to be verified in a building can be very useful on site, where inspectors are influenced by factors like time pressure, missing information, and unforeseen events (Van den Beukel, 1993). Diagnostic aids can be as simple as a list of items to be checked on site. If the investigation is dealing with a specific defect or a problem that indicates a possible defect, a checklist can be very useful. A checklist calls the attention of the investigator to issues such as possible symptoms, a list of tests that can apply to a certain type of symptoms, etc.

As an example of a very elementary check list, the Institute for Research in Construction (1993) suggest a list of the building envelope components and their interconnections subject of evaluation:

Building Envelope Components:

1. Exterior walls
2. Windows and doors
3. Roofs
4. Foundation walls and slab

Characteristics to be assessed in the building envelope:

1. Heat gain/loss via conduction, convection and radiation through the envelope
2. Air flow in the form of infiltration, exfiltration and interstitial flows
3. Moisture in the form of excessive surface and interstitial condensation
4. Rain, snow, ice control

An example of a more elaborate check list is taken from Van den Beukel (1993). It is arranged in the chart:

| | AIR HUMIDITY | RISING DAMP | RAIN WATER PENETRATION |
|---|---|---|---|
| SOURCES | people<br>cooking<br>space under ground floor<br>gas water-heater<br>building moisture | ground water<br>rain water | rain water (direct)<br>rain water (indirect, leakage)<br>snow |
| INDICATIONS & ANOMALIES | mould on furniture<br>condensation (frequently showing on double glazing)<br>mould or wet spots on structure<br>mould in cupboards | distinct moisture front from below<br>timber rot (floor joists)<br>also at interior walls with foundation<br>efflorescence at moisture | distinct relation with rain (especially driving rain) |
| CAUSES OR STIMULATING CONDITIONS | poor functioning or poor design of ventilation system<br>filthy ventilation system<br>wrong use of ventilation system<br>gas water-heater without external outlet<br>wet space under ground floor with open connection to dwelling<br>thermal bridges (design, execution) | high ground water level<br>poor drainage<br>presence of salts<br>masonry foundation without moisture barrier (damp proof course)<br>lime mortar, used in masonry | solid walls (masonry)<br>poor pointing<br>wrongly placed cavity anchors<br>poorly executed or design details<br>cavity walls (fully filled) with imperfections of insulation material<br>cavity walls filled with insulation slabs (open joints) |

Figure 1.4 Checklist for moisture problems (as per Van den Beukel, 1993)

Checklists should be kept as simple as possible. Thus their main strength and limitation is their simplicity. A checklist is recommended as a mere reminder. The use of a complicated checklist on site, when the inspector often has to take pictures, draw sketches, interpret engineering drawings, handle equipment, and deal with building occupants can be impractical.

#### 1.3.4.4 Matrix

Building failure information can be organized and represented in a matrix. In a building investigation, a matrix is a two-dimensional array that links information horizontally and vertically by symbols that define the type of relationship existing between both pieces of information. Matrices are a means of representing relationships in order to visualize problems from a wider perspective by comparing different alternatives. For example, matrices are helpful to identify the causes of a failure from several possible options. Nicastro (1997) developed a matrix method of evaluation to help determine the actual cause of failure from several possible mechanisms.

| | **Subjective Information** (Hypotheses) | | |
|---|---|---|---|
| **Objective Information** | Brittle Fracture | Fatigue | Stress Corrosion Cracking |
| Failure occurred suddenly | X | | |
| Failure occurred during cold temperature | X | | |
| Member was under low, static tension | X | O | O |
| Member was under a thick plate | X | | |
| Structure was 10 years old | | X | X |
| Member had moderate corrosion | | | X |
| Fracture surface exhibited ductile & brittle zones | O | X | |

Figure 1.5 Example of matrix method of evaluation proposed by Nicastro (1997)

The method exemplified on figure 1.5 defines an array to assess the relationship between objective and subjective information. All relevant facts (objective information) are listed in a vertical axis. The potential failure mechanisms (subjective information) are listed along the horizontal axis. Intersections are filled in with symbols that indicate the degree of support in which "X" corresponds to probable cause and "O" to improbable cause, and if the space is "blank" there is no relationship. The limitations of this type of representation are that all knowledge cannot be embedded this way due to the complexity of failure events. A bidimensional array would be insufficient to represent the complex relationship often found in building envelope failures. Also, the format could be impractical if many pieces of information are used.

### 1.3.4.5 Questionnaire

During the survey, the investigator evaluates defects through a series of questions and answers. Such questions are aimed to verify hypotheses on the relationship of the defect with the structure, the fabric or environment within and around the building. The questions are also useful after research and further consideration of the causes of the defect. The following is an example of a set of questions proposed by Watt (1999):

Symptoms

- How does the defect manifest itself?
- Do the symptoms change (with weather conditions) or are they constant?
- Are the symptoms getting worse?

Investigation

- What is the extent of the defect and could it affect other parts of the building?
- Are the symptoms relevant to one or more possible defects?
- Could the cause of the defect be remote from the symptom?

Diagnosis

- What is the cause of the defect?

- Can the defect be attributed to two or more causes?
- Is the defect static or progressive?
- Is further action required to diagnose the defect?

Though questionnaires could be used as reminders that guide information acquisition, their main limitation is that they do not have any embedded knowledge.

### 1.3.4.6 Intelligent diagnosis systems

Intelligent systems are one of the relatively new available resources designed to support building diagnostics. The different approaches used in the design of intelligent diagnosis systems can be distinguished by the way in which the following questions are answered: "How will the system come to know of the relation between the observed symptoms and the consequent diagnosis? How will the system represent this relation? How will it use this representation for diagnosing faults?"(Balakrishnan, 1998)

In a diagnostic system, input that contains conditions of a failure obtained through measurements and observations of a problem are commonly encoded in a way that a machine can read and make use of it. An intelligent system identifies the probable cause of the problem and explains the nature of the observed symptoms. In order to do that task, the system needs to have sufficient knowledge of the domain. Expert systems or knowledge based systems are designed containing the necessary domain knowledge. But systems can also be engineered to acquire the necessary domain knowledge. This kind of systems automate knowledge acquisition through the use of machine learning techniques. There are other systems that make use of the domain knowledge that is implicit in rationale found in past cases stored in a memory. These systems are known as case-based systems.

The present research found examples of intelligent diagnosis systems that use case based and knowledge based techniques. Such systems are briefly described below following a chronological order.

Kalyanasundaram *et al* (1990), designed REPCON, an expert system for building repairs. It attempts to capture expert knowledge and transform it into heuristic patterns that link the nature of the building defect with the probable cause and the most appropriate repair method. REPCON uses a commercially available expert system development tool and Pascal as a programming language. It has 645 rules in the knowledge base, including meta-knowledge. The tool is intended to assist building repair consultants and township maintenance engineers in solving problems associated with the strengthening, modification, repair, and renovation of buildings. It allows users to supplement their own experience and judgment to arrive at decisions particularly suited to the circumstances of the problem faced. A system session helps the professional engineer to collect proper data on the problem and get a quick diagnosis and guidelines for repair measures. The categories of defects covered by the system are: concrete cracking, spalling and disintegration in concrete, cracking in brick masonry and dampness and leakage. Repair methods suggested by the system are simple and easily implemented with ordinary skill and material. Several graphic programs are incorporated in the system to allow exchange of information between the user and the system to arrive to a hypothetical crack pattern from the knowledge base that matches the actual crack pattern. The program is structured by knowledge nets that are the repository of domain knowledge and control information. The program uses an expert system development tool that supports backward chaining with a rule base and interface to procedures in a conventional programming language. There were no limitations reported in the reference for this system and there was lack of information to judge it properly.

Blankvoll and Horrigmoe (1991) designed Brutus, an expert system for repair of concrete structures in service. Its objective was to transfer knowledge and technology form experts to personnel responsible for planning and performing inspection, diagnostics, maintenance and repair of concrete structures. It can be used as a book of reference, a tool for inspection, a diagnostics tool and as a tool for maintenance and repair. It is a tool that supports decision makers in different phases of management and repair of concrete structures. Brutus was developed using the shell for expert systems "Nexpert Object". It is written in "C". It uses integrated forward and backward chaining. One limitation of Brutus is that it is restricted to concrete structures and only a limited number of damage mechanisms are included in the prototype.

Abdulhai *et al* (1993), designed Masonry Cladding, an expert system for masonry cladding failure analysis. It provides a heuristic procedure for diagnosing the most probable causes of cladding distresses and failure symptoms. A descriptive module in the program allows for problem definition and description of related wall components and surrounding environment. There is a diagnostic module that uses the collected information to generate the most probable cause of the observed symptoms. Masonry cladding is a knowledge based expert system in which knowledge bases, databases and algorithmic analysis modules are interconnected to form the two main modules: a descriptive module and a diagnostic module. The prototype tool was designed for future expansions. No limitations were reported in the paper.

Corte-Real Andrade *et al* (1998), designed a knowledge based system to diagnose and treat moisture pathologies in buildings. Developed for lay users with no more than basic knowledge of the problem, it gives details about the diagnosis of a moisture disorder through a graphic user interface, focusing on symptoms and diagnosis of a given element. The system has some non-automatic learning features, conceived to avoid conflict between learning and diagnosing. The system uses the same interface for data input. The main input data in the system is composed of those parameters that together can build the case of failure, such as: element that presented a problem, describing its characteristics; symptoms description; meteorological event that contributed to the symptoms; building characteristics; and hygro-thermal conditions. It provides a report with the explanation of every suggested diagnosis by defining characteristics of the problem, such as: color, position in the element, features of the problem, etc. The system provides a list of probable causes that were rejected in the diagnosis, so that the user knows the hypotheses that were ruled out. The program states the treatment for the problem and the procedure to be followed. The system uses MS Windows environment, with the shell Kappa-PC tool V. 2.3 by Intellicorp-1992 as a runtime environment. It is divided in the following modules: user interface, knowledge base (with 350 objects, 400 slots with an average of 3 optional values each, 50 rules, 60 methods and 30 functions), learning module, reporting and explanation modules. The method that compares the input data with pattern data, identifies which attributes confirm and which refute a given pathology. A backward chaining inference is then fired in order to attempt to prove two pre-defined goals: type of pathology and tendency type pathology. The limitation reported in the reference was that the development workbench was constrained by the tools available under the Kappa-PC shell.

Watson and Abdullah (1994), developed PAKAR, a case-based reasoning system that diagnoses building defects related to cracking of a building's superstructure, problems caused by damp, problems with windows, rooflights, and roofs. The cases in this system include case title, case description, and a set of questions that confirm the case. Intended for use by students or officers in a housing association or local authority it has a textual description of the problem that has to be entered as a set of matching cases is retrieved. Questions then focus on the nearest matching case amongst the set. If a defect is successfully diagnosed, further information can be obtained using a browse option, allowing MS Windows applications to be executed. PAKAR allows the use of AutoCAD drawings. It has a simple interface that uses questions with multiple options. The system was implemented using the shell produced by Inference: CBR-Express with CasePoint as a potential delivery medium. Inference's CBR products use nearest neighbor matching of cases. It uses MS Write to convey information along with AutoCAD drawings where relevant. PAKAR explains results by linking additional information to a case. It has problems handling numerical data due to the type of shell used. CBR Express is strong for textual information but weak for numerical information. A major limitation reported in the paper was the way that questions are weighted. Questions are used to focus on a particular case within a set of matching cases. Each question has a weight. Many cases share a question in common, but it is not possible for the same question to carry different weights in different cases. A previous version of

CBR Express allowed a question to carry different weights in different cases but this made the matching process very slow.

Shelbourn and Aouad (1999), designed an integrated virtual reality and case-based reasoning tool for training in building pathology. The tool uses a 3-dimensional environment showing a typical house. It is meant to be a software with a graphical interface as realistic as possible. Defects are taken from real life situations, photographed digitally, introduced into the environment and stored within the application. The virtual reality environment allows textures to be assigned to different components of the house, giving them the look of being affected by a defect. The system allows the user to fly around the environment of a typical house as if the user was on site. There are a number of defects in certain components (walls, floors, windows, etc.) that the user must identify. Once the defects are found, the user is given a score according to their performance. Failure scenarios can change thanks to the CBR system built in the program. The system combines the use of AutoCAD and DVReality (Virtual Reality software environment). A case-based reasoning system is supposed to handle the database of different defects in conjunction with the virtual reality application. This is to allow defects to be placed in a random order into the environment giving a new scenario every time the application is used. This is only a training tool that is not to be used on real cases of failure.

In the domain of preventive maintenance, which could be considered a cousin of building diagnostic, two projects are presented. The Construction Engineering Research Laboratory (2003) of the U.S. Army Corps of Engineers developed a ROOFER, an Engineered Management System (EMS). Micro-ROOFER is the software embodiment of ROOFER EMS that runs in Windows environment.

Micro-ROOFER is a roofing data collection and management system developed by the U.S. Army Corps of Engineers, designed to provide organizational facilities for the management of bituminous built-up, single ply and asphalt shingle roofing systems. Micro-ROOFER provides data and procedures that support the decision making for cost-effective maintenance and repair of building roofs. The capabilities of the system are: data storage and retrieval, database administration, windows ease of use and functionality, determination of membrane, flashing, insulation, and overall roof condition ratings, determination of optimal maintenance, repair and replacement strategies, report generation for network and project level management.

The system allows facility managers to rate their actual roof condition, prioritize projects and optimize budget allocation.

A second preventive maintenance project was devised by the Institute for Research in Construction in Canada. The project is called Building Envelope Life Cycle Asset Management (BELCAM). It is aimed at aiding facility managers and owners predict the service life of the building envelope. BELCAM project gathers experts in the field, building owners, researchers to investigate service life prediction tools, develop protocols and methods to define factors affecting premature failures, provide information about service life to integrate cost, performance, and reliability, and enable technology transfer to the industry through the implementation of information technology tools. BELCAM has developed (Institute for Research in Construction, 2000):

- a CD-ROM manual on how to conduct a condition-assessment survey for low slope-roofing
- preventive maintenance checklists

- an evaluation of available roofing software
- a roofing survey Canada-wide
- inspection protocols
- a guideline on how to improve roofing-service life and asset management
- service-life prediction and management tool for low-slope roofs with risk assessment techniques and an interactive graphic user interface.

All the above mentioned tools, either simple or complex, are resources that have been mostly developed by researchers. However, they are not used by practitioners as often as they should. Inspectors like to rely mostly on their experience and when they find a complicated tree or matrix or computer program, they get discouraged because they find it impractical. The tools described in this section are the most representative of the diagnosis aids. The following section consists of warnings and recommendations useful for diagnosticians when treating a building defect investigation.

### 1.3.5 Guidelines for building diagnosis

Authors agree in warning the diagnostician about dealing with a building defect or failure with an open and unbiased mind. This section gives some useful recommendations that the investigator should consider during a building defect and failure diagnosis. There are some hints that become relevant when there are doubts about the diagnosis and the effectiveness of the remedial measures. Such guidelines provide insight in the difficulties of building diagnosis and the need for supporting tools.

### 1.3.5.1 Guidelines at the early stage of building diagnosis

Different authors, such as Eldridge (1976), Greenspan *et al.* (1989), Addleson (1992) and Nicastro (1997), have useful warnings for the early stages of building diagnosis. Eldridge's recommendation to study a building defect was to first discard any preconceived ideas of the cause of the defect in the building subject of study. He warned about using the diagnosis as a means of confirming an already existing opinion. A correct diagnosis must assess impartially all the information (Eldridge, 1976).

Greenspan *et al.* (1989), warns about the error of relying on past experience too early in the investigation when trying to determine the failure cause. Investigators that conclude over the cause of a failure without exploring all hypotheses because they have seen this type of failure before, often have a preconceived judgment.

As said by Addleson (1992), the causes of a defect and the factors that affect it are determined by relating all the evidence found from various questions. So if the investigator has the right questions, consequently he will get adequate answers.

Nicastro (1997) says that it is common that investigators attempt to develop hypotheses too early. Also, in the book Defects in Buildings (Department of the Environment, Property Services Agency 1989), inspectors are warned about jumping to conclusions too early in the investigation, without supporting the hypothesis with evidence and tests. The most obvious causes of the problem should be regarded in a critical mood, even if all of the clues appear to point towards the same direction. Such warning is made because new and unprecedented defects occur from time to time. Hence, data from previous investigations can be unreliable or misleading. This reference suggests a case by case procedure while investigating a failure. Most of the steps in failure investigation are common sense. Greenspan *et al.* (1989) says that the investigator's aim should not always be to identify an absolute cause of failure. Often there are more cases in which there is a complex interaction of more than one component and force that cause a failure rather than those cases with a single cause. Therefore, a failure investigation seldom leads to absolute and irrefutable results. Instead, it can be said that it leads to the most probable cause of failure. Defects in buildings (Department of the Environment, Property Services Agency 1989), confirms the ideas brought by Greenspan *et al.*: defect diagnosis should not aim at discovering a single cause of a defect because this happens very rarely. Defects are often the result of a combination of factors that alone could be harmless to building integrity but together require a proper treatment and remedial work. Summarizing, the National Building Agency (1979), recommends to: avoid having preconceived ideas on causes, avoid jumping to conclusions and make a diagnosis based on commonsense and profound knowledge of building technology.

#### 1.3.5.2 Guidelines during diagnosis

Due to the complex nature of buildings caused by all the factors that intervene during construction and operation, the investigation will not be able to reproduce the exact conditions to which the building has been subjected (Department of the Environment, Property Services Agency, 1989). Defect investigation should be done systematically and thoroughly. Correct remedial measures depend on the proper identification of the causes of the defect. The deduction of the causes of a defect should not be influenced by liability of the cost of repair work, although, cost could determine the scale of the investigation required (Addleson, 1992). Inspectors should follow a procedure when doing a survey of a property. A recommendation is to begin inside the building at the top and finish outside at the bottom (Staveley, 1983). The diagnostic process should be methodical, step by step, but never entirely mechanical. It is useful to write a list of the potential causes of a defect because it provides a reference point to return to when unexplained symptoms are discovered. In the case of a liability dispute in a defect investigation, it is also useful to assemble facts to support the rejection of a potential cause, as well as those by which the diagnosis was made (Department of the Environment, Property Services Agency, 1989). Nicastro's (1997) recommendations to carry out a failure investigation are as follows:

- Determine if there are enough facts to render substantiated opinions.
- Define the problem by collecting information from a visit to the site and review of any available documents.
- Make a preliminary estimate of liability.
- Document the existing conditions at the time of failure with photographs, videotape and field notes.
- Record all relevant parameters, not just gross observations.
- Pay particular attention to temporal information. Because many failure mechanisms can be ruled out simply on the basis of the time occurrence or duration of a process, (i.e. concrete shrinkage over time diminishes after reaching a limit.)
- Perform laboratory testing.
- Perform research on industry standards, code requirements, design documents, possible failure mechanisms or material behavior.

- Formulate opinions that will withstand scrutiny by others based on all objective findings from fieldwork, laboratory tests and research.
- Use correlation of observations as a tool to discover defects.
- When recording opinions in a report, list alternative theories, explaining them.
- Do not confuse assumptions with conclusions.

It is vital that when a defect is uncovered, its cause be completely understood and correctly diagnosed prior to the application of remedial measures (Watt, 1999). Though this could seem obvious, Addleson (1992) recommends that to prescribe the appropriate remedial measures, an accurate diagnosis of the cause of the defect is needed. If incorrect remedial measures are appointed, there is a risk of not only having a short lived work but also one that could lead to other defects.

When the diagnostician decides on the type of remedial measures, he should evaluate if it is acceptable that such remedial measures alter the aspect of a building. There is a need to devise appropriate solutions that always ensure a respect for good practice principles, despite cost constraints and practical difficulties as well. If it is necessary to build additional layers of materials to an existing construction, the diagnostician in charge of devising remedial work should ensure that the new configuration does not cause a new defect (e.g., interstitial condensation, entrapment of moisture or other adverse thermal effects). In the case of a defect where interacting factors intervene in the production of the failure, Addleson (1992) suggests to carry out remedial work coping with such factors stage by stage on an experimental basis.

According to Department of the Environment, Property Services Agency (1989), if a diagnosis is complete and there are still doubts about it, it should be acknowledged that there is still uncertainty because an ineffective remedial measure can result from a wrong diagnosis. In such a case, a complete replacement would be justified to ensure successful remedy. The authors of Defects in Buildings make a warning about the lack of accuracy and unreliability of information gathered in the investigation as a common pitfall. It is always suggested to verify thoroughly all information on site because the "as built" drawings could not match the reality if repairs or renovations have been done after construction. Records that have information on how a defect started and how it evolved are very important for the diagnosis of causes. Sometimes they can be put together with information on the environment conditions and the usage of the building to determine the cause of a building defect. Note that the use given by building occupants is an important piece of information in the diagnosis of defects. Nonetheless, all information about building usage should be verified, for an incomplete or inaccurate report can be misleading. Remedial measures should cure the defect. If there is doubt about the effectiveness of a remedy, the recommendation is to go for a trial solution. In such case, it should be made clear that the remedy is for trial only and there is a possibility of recurrence of the defect. But recurrence of a defect should be avoided more than occurrence. Because building owners and occupants would not like to repeat the failure experience.

### 1.3.6 Requirements of a building investigator

A building failure and defect investigation requires knowledge, experience and wise judgment on the side of the diagnostician. The investigative process implies a set of rules to be followed in order to produce a complete and thorough analysis of the problem.

In this section of the literature review, the qualifications of a building investigator are presented.

Diagnosis requires, according to Watt (1999), the collection and assimilation of all relevant information on the defect and is highly dependable on the surveyor having:

1. Knowledge of the behavior of relevant building materials
2. Knowledge of the construction of the building
3. Knowledge of how the use (past, present and future) of the building affects the construction

Staveley (1983), suggests a more complete list of the qualifications of a surveyor, being:

1. Ability to communicate orally and in written form
2. A practical mind
3. Have an understanding of the working of services such as heating systems, etcetera
4. Ability to assimilate new ideas and building processes
5. Pleasant and tactful personality to deal with people involved in the investigation

Also, it is desirable if he/she can undertake simple building work, such as carpentry, brickwork, etcetera. Greenspan (1989), also describes the characteristics of an investigator, being:

1. Best qualification in the discipline related to the failure
2. Strong technical background
3. Broad experience in failure investigations when carrying out a major investigation

4. Open mind to accept all the pertinent data while recognizing the relevant information

The building diagnostician should be patient to avoid jumping to conclusions too soon. Also, he/she has to be inventive, inquisitive and must have a good knowledge of materials science and the factors that influence building performance. The diagnostician should learn to observe comprehensively through all the visual aids available. He/she has to devise techniques that prevent damage of evidence during destructive investigations and assess carefully the results of non-destructive tests (Addleson, 1992). For the case of building envelope investigations, investigators should have a good knowledge of envelope systems and the interactions of heat, air, water, and moisture flow to be able to evaluate the performance of the building envelope (Institute for Research in Construction, 1993).

In an effort to provide computer tools to building investigators, some of the above described knowledge should be integrated in the new tools meant to support the building failure diagnostic process.

## 1.4. Summary

There are different approaches to building diagnosis, and there is no general method to carry on a building defect and failure investigation that suits the needs of all investigations. Authors have produced classifications of the causes of building defects and failures according to the specific needs of the investigation that they are dealing with. Some tools that support the diagnostic process are available to investigators. But there is still a need for tools that help take better decisions when identifying a problem, its causes and appointing remedial measures. Therefore, the field of building diagnostics would benefit from the existence of a means to collect information about failures in buildings, their diagnosis and remedial measures.

Given the state of knowledge and the level of existing support tools for building envelope failure diagnosis, a research project was established to provide a first concept of supporting tool using a database populated with failure cases. Chapter 2 presents the conceptual design of a tool to support building failure investigations. Chapter 3 deals with the collection and systematization of the information in a computer database of building envelope failures and the production of statistics on typical failures on the first 5 years of life of the house. Chapter 4 discusses the issues of the development of a prototype computer tool to support building diagnosis using the database. Chapter 5 suggests some guidelines for the work needed to enhance the capabilities of the tool. The conclusions of this research as well as recommendations for future work are found in Chapter 6.

# Chapter 2. Concept of tool to support failure diagnosis

## 2.1 Context

One of the tasks in this research consisted of defining and producing a tool that would support building inspectors in the diagnosis of a building envelope problem. The requirement was specifically a tool that would provide information to inexperienced building inspectors about the characteristics of building envelope problems and could be used to define the envelope pathology of a building. The tool should be a means of collecting knowledge and transferring it to inexperienced investigators. This chapter gives more details on the design process of the tool.

## 2.2 Needs found in the literature review

### 2.2.1 The general need

As it has been previously said in the literature review, there is yet no standard methodology to study building envelope failures. Thus, it is vital for the development of building pathology to incorporate the knowledge generated through the study of failures faster and accurately (Audet Lapointe, 1999). It is necessary to come up with a procedure or approach to conduct building failure diagnosis based on the understanding of the interrelated impact of building performance parameters, including the effects of decisions made during the building delivery process. Such approach should guide the investigator to use appropriate application of specific diagnostic techniques in specific failure scenarios (Beznaczuk & Fazio, 1990). Investigators then, can benefit from a framework that guides towards accurate diagnoses in order to adopt the correct remedial measures (Addleson, 1992).

### 2.2.2 Specific needs of a tool that supports building investigators

In view of the fact that building diagnosis has commonly relied in knowledge accumulated through experience, and that databanks are a means to store knowledge, it has been said that there is a great need for databases to facilitate the study of failures (Audet Lapointe, 1999). Dalcher (2000) reinforced the idea, saying that it is necessary to generate joint efforts of collecting lessons taught by failed buildings in order to create a comprehensive "body of experience".

The field of building pathology is lacking a means to provide access to reliable and accurate information of lessons taught by failed buildings so that inexperienced building inspectors can learn from such lessons (Dalcher, 2000, Shelbourn *et al,* 1999). According to Dalcher (2000), there is a call to record a historical baseline of building pathology that acts as a decision aid tool and a tool for continuous process improvement. Building pathology investigators necessitate a means to record assumptions, decisions and rationale in the treatment of past building failures, as well as to keep track of the tendencies of building failures to detect risky patterns.

Tools that support the investigation process are needed, such as those that are specifically tailored by building pathologists based on the type of failures or their magnitude, and rely on the judgment of the investigator. The building envelope diagnostic process is now requiring a tool that provides information to building investigators and helps them recognize symptoms of failure in a building envelope.

Given that in building diagnosis, hypotheses of the cause of the problem are made at the stage of symptom analysis (Addleson, 1992), it is important to provide a tool that supports the formulation of such hypotheses. The tool should enable the best interpretation of the causes of a failure by presenting the scenario under which the failure will most likely occur (Greenspan *et al.*, 1989).

During a building investigation the inspector should be able to visualize the building perfectly to be able to prescribe adequate remedial measures (Watt, 1999). Therefore, it is essential to provide a tool that supports the diagnostician at this "visualization" stage.

The reasoning that leads to the creation of such a tool should be based on the fact that the most effective diagnosis tools are those that provide relevant information to the building inspector rather than those that attempt to substitute the reasoning process by which hypotheses are made when assessing the building envelope. By having access to stored cases of building envelope failures, the investigator should be able to study failures with similar characteristics under different scenarios. Therefore, he/she will have the possibility to formulate hypotheses of the causes of the building envelope problem in question.

### 2.3 Conceptual design of the tool

#### 2.3.1 General requirements of the Tool

The tool should use a generic data classification fine-tuned to suit the needs of building inspectors. It should provide a means to efficiently store, classify, dissect, and analyze the information and learn from past experiences of building envelope failures. The tool should also enable a further analysis of the information to understand the problem of building envelope failures.

Given that the tool should become a means to collect and retrieve information, it should facilitate generation of statistics to find repetitive patterns of failure in the building envelope.

The tool should ease access and use of information in order to give support in the decision taking process of diagnosis of building envelope failures. It should provide information to the investigator, letting him/her decide according to the facts found in the outcome of the queries ran in the tool.

The tool should be designed to support inspectors at the inference phase of an investigation and its use should imply a methodical approach to the diagnosis of building envelope failures. The main components required at the conceptual design phase of the computer tool are described next.

#### 2.3.1.1 Database

The tool should store information in a computer database to take advantage of its capabilities, such as fast and easy accessibility. The tool's database should be populated easily. This could be done by answering questions that are presented in a logical sequence and that are pertinent to any residential building envelope failure investigation.

The database of the tool should have information about the external factors that affect the behavior of the problem, as well as construction, design, or maintenance errors that made the building envelope vulnerable to natural elements or other environmental conditions. The database should contain, in summary, all relevant information found in the files. This is further explained in chapter 3.

#### 2.3.1.2 Interrogation of the database

The tool should allow the user to retrieve information from the database. This could be accomplished by means of a query builder. The query builder should give the user freedom to build complicated queries using several search criteria to find specific information from the database generated.

The user of the tool should be able to build queries to find files that contain any word, number or phrase from the database such as all of the symptom options as well as other type of information found in other fields of the database. This is meant to allow the user to compare a case on-site with those found in the database. Providing that the similarities of such comparison will give hints that the user could follow to take decisions. Examples of such decisions could be doing further testing or applying remedial measures that improve the performance of the building envelope or replace a component. Also, by revisiting cases that are similar to the one faced on site, the investigator should be able to see the rationale behind the decision taking process of past building envelope failures. This is intended to give support to building investigators in the formulation of hypotheses. However, it is important to remind the user to always keep in mind that all hypotheses should be tested to avoid falling in a preconceived attitude.

#### 2.3.1.3 Input/Output

The tool requires a way to input data into the database. The interface could be programmed to allow the user to populate the database by simply filling out a questionnaire. The questionnaire must have sufficient pieces of information needed for the diagnosis of common residential building envelope failures.

The questionnaire used to populate the database should guide users through the basic steps of a failure investigation and also allow them to review cases of building envelope failures that could be similar to the ones that are the subject of study.

The tool should allow the user to keep track, store, and visualize pictures in it. Photographs should be studied at the same time that information is stored and analyzed. The investigator should, in this way, be able to remember and mentally visualize the building perfectly in order to prescribe adequate remedial measures.

### 2.3.3 Proposed architecture of the tool

After analyzing the requirements, a model was designed to guide the construction of the new tool. The outcome was the following architecture:

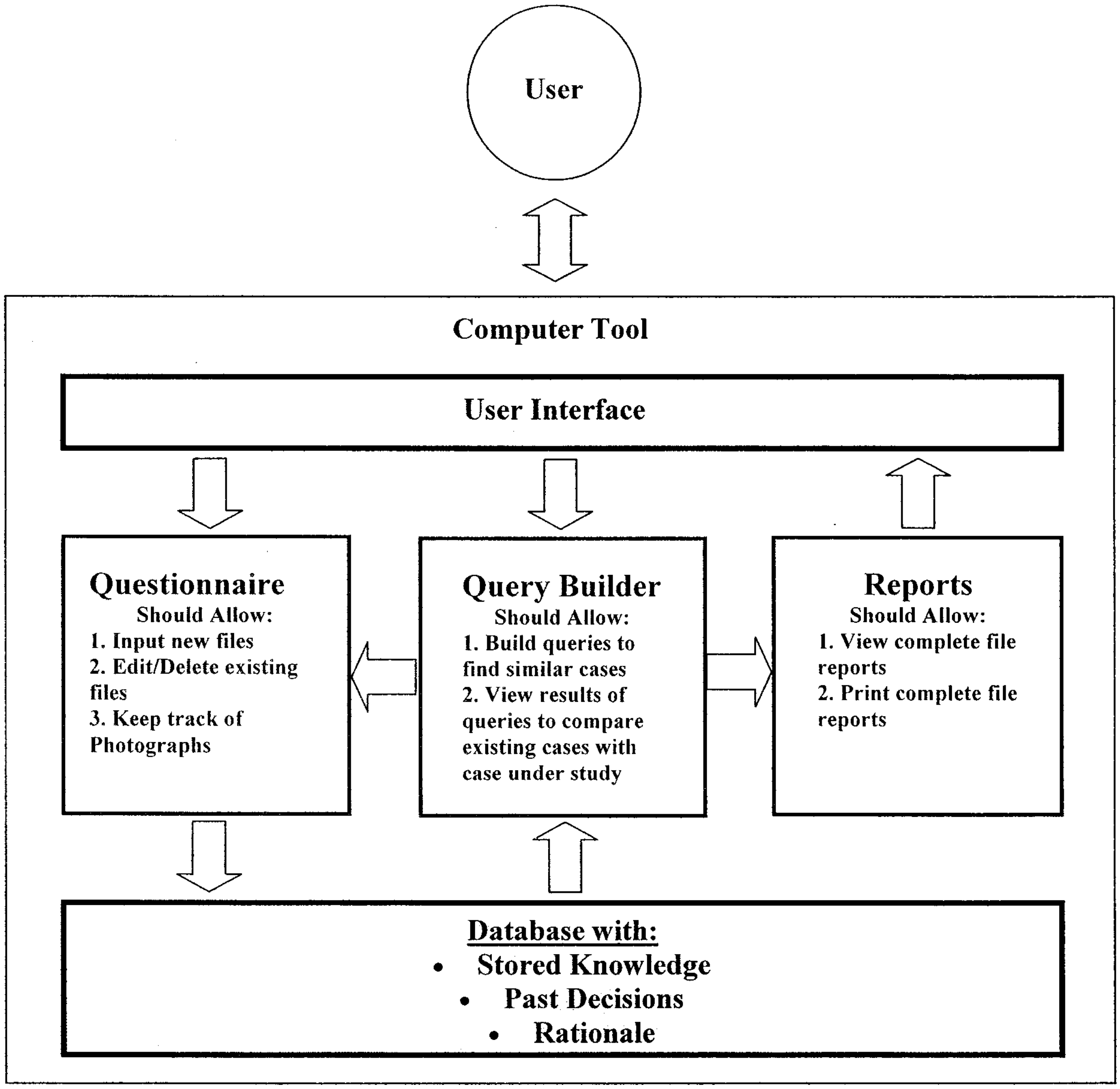


Figure 2.1 Architecture of the proposed tool

A proof-of-concept of such an approach is presented in the next chapters. In order to develop such a tool, the first step was to build a database that would provide the stored knowledge required. The development of such database is discussed in the following chapter.

# Chapter 3. A populated database of building envelope failures

## 3.1 Source of actual cases

The Quebec Association of House Contractors (Association Provinciale des Constructeurs d'Habitation du Québec, APCHQ), has a technical service department that gives expert advice on building failures and has a collection of 700 cases of failure. The APCHQ members build 80% of the new houses in Quebec. It can be said that the type of contractors and cases associated to the APCHQ for this database is representative of the province. Most of the cases reported at the APCHQ are in locations relatively close to urban locations. The main reason for this geographical concentration, according to the assessment of the APCHQ inspectors, is that the majority of the housing stock is concentrated in cities and competition among contractors in these areas is such that sometimes it results in low quality in the execution of construction jobs due to a lack of coordination among the subcontractors and a high demand of housing combined with a short time to build and deliver the dwellings. The situation in the minor urban areas is different because the market is smaller and a known problem may affect the reputation of a contractor. So these building companies normally take care of defects and failures until the client is satisfied without needing any other party to solve the problem.

It was the aim of this study to select the information from the APCHQ files that deals with the weak aspects of the residential envelope construction in Quebec in the first years of operation using a methodological approach to facilitate the assessment of failures in the building envelope. Using these files as the source of information, a survey was done to study the building envelope pathology by collecting symptoms, causes and the mechanisms of failure relating the failures to the characteristics of the building that make the envelope vulnerable and the factors that contribute to the problem. The information from this survey was used to build the database that is a main component of the tool developed.

This research project started with the discrimination, translation, acquisition, classification and storage of the knowledge found in the written reports of building envelope failures of the APCHQ technical service department. The files of the APCHQ are replete of all kinds of building failures, so the very first step consisted of finding out the cases that dealt with building envelope issues. The second stage consisted of analyzing all the cases (43 in total) of one year 2001 in order to identify the pieces of information that are collected by inspectors in terms of basic data, recording of the inspection and analysis and findings. Since the files contain information that is not solely technical, relevant information was discriminated after studying each file. This chore implied an analysis of the reports, photographs and sketches in order to understand the case. It is important to mention that the reports of the APCHQ did not present a standard format, due to the fact that each case is different, and that there were different inspectors producing such reports. Most of the reports were in the form a text, split into a form of Context, Mandate, Historic, Findings, Analysis, Recommendations, Conclusions, with no further break down or categorization of the information. So, after analyzing a representative number of cases, the pieces of information that would be required to build the database were selected. In order to extract the desired information and leave out the one that was not relevant to this study, an input form using a questionnaire was devised so that discrimination of information would also result in an orderly way of classifying and approaching the building envelope pathology of the houses in question. This part of the research was vital because it presented in an organized way, problems whose understanding was not straightforward. Two exhaustive lists of problems and symptoms were developed. Also, the building type was narrowed down to a list that could use generic combinations. The type of cladding, type of windows, material of windows, geometry of roof, covering of roof were narrowed down too. There were a set of questions that were devised to situate the user of the tool in the historic context of the problem, such as recurrence of the problem, appearance after extreme weather conditions, attempts to remedy the problem and diagnoses made by alternate specialists. Based on the literature review, the questionnaire made use of classifications proposed by different authors, such were the cases for the manifestations of distress, the failure mechanisms, the causes of the problem and the type of performance failure and the agents that caused the problem. Due to confidentiality restrictions, the APCHQ reports cannot be disclosed and no example can be presented here.

Since the APCHQ reports are written in French, everything had to be translated to English. After this, the database was built from the reported cases of failure found in the files of the technical service department of the APCHQ.

The technical department of the APCHQ gives expert advice to affiliated contractors that require the service and for the warranty program for new homes. This program covers among other issues:

- One year against existing defects and non visible defects when the building is occupied.
- Three years against hidden defects, after the building is occupied.
- Five years against major defects, following the end of construction.

- Conciliation, mediation and arbitration.

The main type of dwellings under the New Home Warranty Program of the APCHQ are:

- Detached
- Semi-detached
- Row
- Multifamily combustible and non combustible

In Quebec, 8 out of 10 new houses are protected by the New Home Warranty of APCHQ (APCHQ, 2002). The APCHQ warranties have been offered for 25 years. However, complete building envelope failure files are only available for the last seven years. This study's database collected the cases related to building envelope problems from year 1995 to 2001.

The failures reported at the APCHQ are of varied nature. They are mainly cases of new homes with problems and sometimes old houses that are inspected because of a request made by a contractor affiliated to the association. Since the New Home Warranty Program is comprehensive, there are failures that deal with floor finishes, acoustical performance, door/window installation, building envelope problems, poor execution of a construction job, hidden defects, etc. This study analyzed only the building pathology related to the building envelope and as such, it concentrated on moisture and water penetration.

This research involved the classification of building failures in a database so that an analysis of the performance of the residential envelope could be done. A major benefit of this database is that it facilitates the use of information to find out trends in building failures and to help the APCHQ members learn from their errors. As said by Van den Beukel (1993), databases can be used as diagnostic tools and as teaching tools.

## 3.2 Description of the database

### 3.2.1 How the database was done

The process of building the database started by studying the way the APCHQ inspectors reported failures. After analyzing the files that corresponded to a year of building failures of different types, the main variables were identified, such as: building type, problem, symptoms, recurrence of the problem, tests carried out by the inspector, etc. To organize the information found in the APCHQ files accordingly with this study's needs, a selection of issues were listed and put in the form of a questionnaire to facilitate the processing of information. Then, the procedure that followed consisted in studying the case of failure and answering the questionnaire. The problem with this type of data acquisition procedure is that many issues could have a lengthy answer. Therefore, to narrow the questions, they were put in multi-option form. However, every case was different from the previous one and this prevented the systematization of all the questions. Thus, many writing fields had to be kept.

Any database has to allow the retrieval of information in a way that it can be analyzed and compared. The database built for this purpose uses Microsoft Access. Access is a program versatile enough to handle these types of tasks. It is also a widely used program and since it comes together with Office it is an inexpensive solution. That was the main reason for the selection of this software.

### 3.2.2 The input form questionnaire

The database is built according to the available information in the reports done by the APCHQ inspectors. As it was mentioned previously, an input form with a questionnaire was used to extract the relevant information from to the building failure reports of the APCHQ inspectors and reorganize it in a way that its analysis would take less time than reading 8 or 10 full pages from a report. The questionnaire was structured using items such as the symptoms, mechanisms of failure, causes and remedial measures. The questionnaire was composed of nine sections. The first two described the context of the problem and defined the type of building. The next two sections related the history of the problem, such as the mandate of the experts' report and if there were attempts to remedy the problem, etc. The following sections listed the symptoms (as seen by the APCHQ inspector), defined their location and the findings of the inspector, focusing on the vulnerabilities of the building. Once this section was answered the questionnaire went through a list of items that helped analyze the problem, and defined the factors that affected the problem, the failure mechanisms and the causes. The questionnaire pointed out the weak aspects of the building envelope and the circumstances that contributed to the problem. The last component was the section of remedial measures and conclusions. This part had questions that served to evaluate the type of remedial measures proposed by the APCHQ inspector and classified the problem. A sample of the base questionnaire used for data collection at the APCHQ is shown in Appendix A. The building classification was refined and there were some minor changes to the base questionnaire. The final questionnaire was implemented in the prototype tool. The development of the tool is explained in chapter 4.

During the eight months of data collection at the APCHQ, inspectors were available to clarify doubts about the cases and their shortcomings. Further analysis of the information collected in the database allowed production of statistics about the residential building envelope cases reported at the APCHQ.

### 3.2.3 Total number of reported failures at the APCHQ

From 1995 to 2001, the number of failures reported at the APCHQ was 384. The number of building envelope failures was 96, approximately 25% of the total. However the percentage fluctuated according to the year. The year with less building envelope failures reported was 1999, with 15% and the year with more building envelope failures was 1996 with 33%. To demonstrate the richness of the database, a list of all its cases is provided in Appendix B. The major fields in this database are presented for each case. More information on each case can be found in the database.

## 3.4 Findings from the database analysis

### 3.4.1 Statistics

In terms of geographic distribution, table 3.1 shows that the percentage of cases of failure reported at the APCHQ in Montreal, with a population of 1 853 488 inhabitants in 2002 and the greater Montreal area with 3 548 775 inhabitants respectively. The center of Quebec region has 222 358 inhabitants Gatineau region 266 116 inhabitants, Saguenay region 281 675 inhabitants, Beauce 48 591 inhabitants and the rest of the province has

1 234 205 inhabitants (Institut de la statistique Quebec, 2004). Forty-one out of 96 houses had a problem that was recurrent. In 57 out of 96 cases, the contractors made an attempt to remedy the problem but failed to provide an adequate solution.

Table 3.1 Location of failures in Quebec and their share in terms of percentage of population and failures

**LOCATION OF ENVELOPE FAILURES IN QUEBEC**

| LOCATION | POPULATION | POPULATION % | FAILURE % |
|---|---|---|---|
| Montreal | 1 853 488 | 25% | 29% |
| Greater Montreal area (except Montreal) | 3 548 775 | 48% | 34% |
| Gatineau region | 266 116 | 4% | 3% |
| Center of Quebec | 222 358 | 3% | 13% |
| Saguenay | 281 675 | 4% | 2% |
| Beauce | 48 591 | 1% | 2% |
| Rest of the province | 1 234 205 | 17% | 17% |

Figure 3.1 shows the recurrence of moisture related problems according to the season of the year. Most of the problems occur in winter, when the differences between interior and exterior environments are greater. The harsh climate in this season makes evident many of the building envelope problems that under milder weather conditions would pass undetected. One frequent case happens in those periods of winter in which the temperature rises enough to melt snow that accumulates in roofs and due to the presence of ice dams leads to water infiltrations in the envelope.

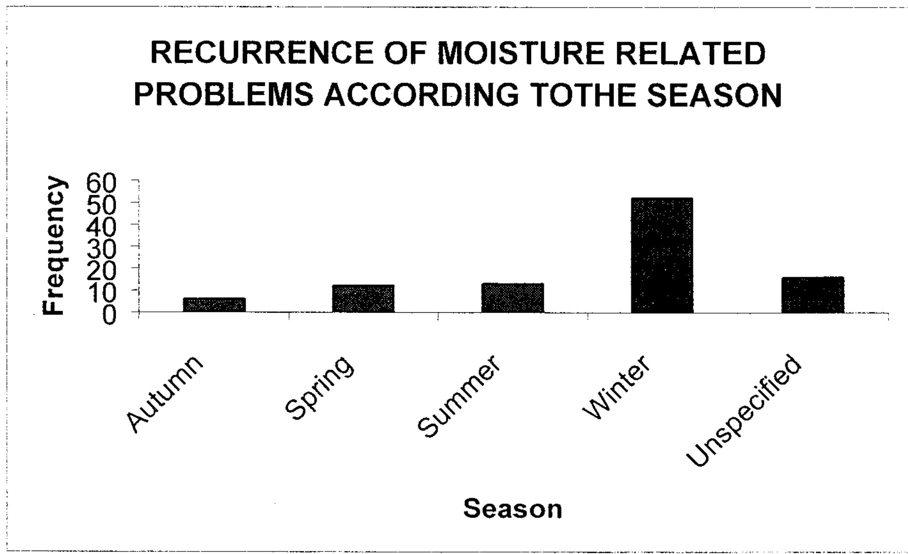


Figure 3.1: Recurrence of moisture related failures according to the season of the year

Table 3.2 presents the percentage of failures according to the type of houses. There are five types of houses in this classification: detached, semidetached, in row, multifamily and other type. Note that the largest percentages were held by the detached cottages with 23% of the failures, followed by the detached bungalows with 22%. Semidetached cottages presented 7%, cottages in row 5% and multifamily buildings of two to six stories high together accounted for 10%. The input form structure facilitated a classification of buildings by groups and allowed the production of this table. This confirms the value of a database like the one built for this research. The following figure and two tables also confirm the capacity of the database to retrieve statistical information.

Table 3.2: Percentage of failures according to type of houses

| Type of houses and recurrence of failure | | | |
|---|---|---|---|
| TYPE OF HOUSE | STOREYS | PERCENTAGE | |
| 1 Detached Bungalow | 1 | 17% | |
| 2 Detached Bungalow with attached garage | 1 | 2% | |
| 3 Detached Bungalow With a Dwelling at the basement | 1 | 1% | 22% |
| 4 Detached Prefabricated Bungalow | 1 | 2% | |
| 5 Detached Duplex (Vertical Condominium) | NA, 2 | 2% | |
| 6 Detached Residential Building Split Level Type | NA | 3% | |
| 7 Detached Cottage | 2 | 18% | |
| 8 Detached Cottage House with garage | 2 | 5% | 23% |
| 9 Coproperty of 6 detached dwellings | NA | 1% | |
| | | | **51%** |
| 10 Semidetached Bungalow | 1 | 2% | |
| 11 Semidetached Duplex | 2 | 2% | |
| 12 Semidetached Cottages | 2 | 7% | |
| 13 Semidetached Residential/Commercial Building | 2 | 1% | |
| 14 Semidetached Residential Building with 4 Units per Floor | 2 | 1% | |
| 15 Semidetached apartment house | 3 ½ | 1% | |
| 16 Semidetached, Multifamily Residential Building | NA | 1% | |
| 17 Semidetached Residential Building Held in Coproperty | 3 ½ | 1% | |
| | | | **17%** |
| 18 Cottage in Row | 2 | 5% | |
| 19 Row Duplex | 2 | 2% | |
| 20 Triplex in Row | 3 | 1% | |
| 21 Row House | 3 | 2% | |
| 22 Row House Condo style, with garage | 2, 3 | 1% | |
| | | | **11%** |
| 23 Residential Building | 7 | 1% | |
| 24 Rental Residential Building with 6 dwellings | 2 | 1% | |
| 25 Building in Co property | 3 | 1% | |
| 26 Residential Buildings held in divided Coproperty | 2&3,4,6 | 5% | |
| 27 Multifamily Condominium (15 dwellings) | 2 ½, 3, 3 ½ | 5% | |
| 28 Multiplex Condo | NA | 2% | |
| | | | **16%** |
| 29 Commercial Building | NA | 3% | |
| 30 Public Building (School) | 4 | 1% | |
| 31 Ancestral Cottage | 2 | 1% | |
| | | | **5%** |

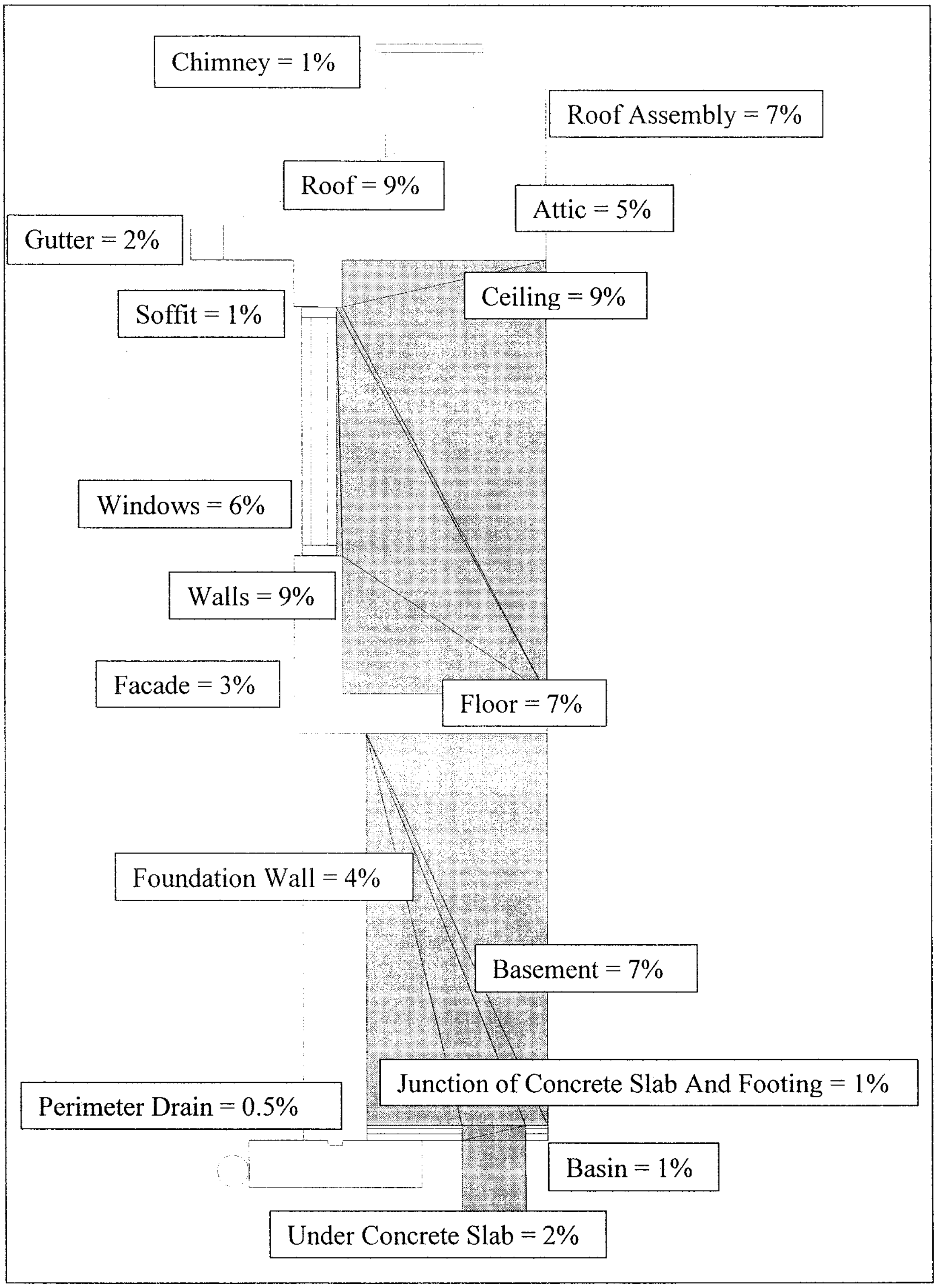


Figure 3.2 Some of the vulnerable spots of the buildings surveyed and their recurrence

Figure 3.2 reveals that many of the infiltration spots in the houses surveyed are close to the roof, notably, the roof assembly, the soffit, the attic, the ceiling, the gutter and the chimney.

Table 3.3 The most recurrent problems and their share of the percentage of building envelope cases that are reported

**Building envelope failures and their recurrence**

| PROBLEM | LOCATION | RECURRENCE | |
|---|---|---|---|
| **Air Infiltrations** | | | **6%** |
| **Air Exfiltrations** | | | **2%** |
| **Condensation in Surfaces** | Windows<br>Ceiling | | **6%** |
| **Condensation within an Assembly** | Attic<br>Behind the cladding | | |
| **Damages in Ceilings** | | | **2%** |
| **Diverse Deficiencies** | | | **2%** |
| **High Relative Humidity** | House<br>Basement | | **5%** |
| **Ice Accumulation** | Roof | | **6%** |
| **Ice Formation** | Roof Edge<br>Cladding | | **2%** |
| **Water Infiltrations - 68%of the houses had water infiltrations** | Basement | 16% | **57%** |
| | Ceiling | 13% | |
| | Windows | 6% | |
| | Roof | 7% | |
| | Garage | 2% | |
| | Unspecified | 10% | |
| | Under the balcony | 1% | |
| | Front Cornice | 1% | |
| | Cold Room | 1% | |
| **Other** | | | **13%** |

Table 3.3 shows that water infiltrations are by far, the most important problem that occurs in the envelope of the houses reported at the APCHQ.

In his book, Lyall Addleson (1992), summarizes some of the design, construction and usage aspects that could be the culprits for a defect either separately or in combination. One of the questions used this criteria to classify the causes of the problem. The following table shows a classification of the causes of the problems using Addleson's criteria and applying them to the database developed.

Table 3.4 Causes of problems and their recurrence

| Causes of problems and their recurrence | | |
|---|---|---|
| | PROBLEM | % |
| I. | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance (e.g. insufficient ventilation area for the roof attic) | 43% |
| II. | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site | 25% |
| III. | Correct materials were specified but inappropriately detailed | 9% |
| IV. | Poor maintenance | 5% |
| V. | Incorrect materials specified and/or inappropriately detailed | 2% |
| VI. | Unexpected Soil Conditions | 2% |
| VII. | Unexpected Climate Conditions | 2% |
| VIII. | Inadequate Use of the Building | 2% |
| IX. | Poor performance of an adapted old building envelope | 2% |
| X. | Normal Wear of Building elements and components | 2% |
| XI. | Other | 5% |

### 3.4.2 Recommendations to home builders at the APCHQ

It was the aim of this survey to make recommendations to the homebuilders at the APCHQ in order to reduce the number of building envelope failures. The following is a list made with the most common problems and mistakes to be avoided by building contractors and designers of the buildings surveyed.

1. Condensation problems in roof attic that were mainly due to:

- Unequal distribution of ventilation in the roof.
- Insufficient means of ventilation for the roof.
- Misplacement of insulation that obstructs ventilation and leaves some parts of the assembly without insulation or touching the deck forming a cold bridge.
- Installation of fan from bathroom or kitchen exhausting warm and humid air in the attic. Leaky ducts.

2. Water infiltration problems in the basement that were mainly due to:

- Overlooking the level of the water table and the type of soil as a source of water infiltrations in the basement.
- Lack of a defense for water that infiltrates from cold joints, namely the junction of slabs and walls.
- Slopes in the terrain that do not shed water away from the building.
- Downspouts or gutters that discharge water close to the building.
- Non provision for a gutter or any other means to channel water from the roof.

3. Water infiltration problems due to snow accumulation that were mainly caused by:

- complicated roof geometries (with crickets, gables, frontons, meeting points of different slopes) that have a difficult evacuation of snow or water, without taking appropriate measures to cope with this situation.

Note: A complicated roof geometry combined with heat losses and/or deficient ventilation favors snow accumulation especially at the valleys and roof edges, making them vulnerable spots to water infiltrations. Also, the orientation of the building is important to consider as solar radiation may cause the melting of built-up ice and snow.

4. Heat loss problems that were mainly due to:

- Insufficient insulation and misplacement of the insulation.
- Installation of insufficiently insulated sources of heat in places that should be kept cold in winter. (e.g. heating ducts or hot water pipes.)
- The use of skylights and embedded lights without considering that they are sources of heat.

5. High relative humidity problems that were mainly due to:

- Not considering the usage that the building will receive.

6. Difficult maintenance required like:

- Maintenance of roof ventilators to prevent them from obstruction with snow or ice.
- Maintenance of roof drains and gargoyles to prevent them from obstruction with snow or ice.

7. Air infiltrations problems that were mainly due to:

- Lack of tightness caused by poor workmanship in the construction of the air barrier.

### 3.5 Evaluation of database

The present database gathered information about failed residential building envelopes and defined a way in which this information could be easily stored and accessed. The main interest was to take advantage of the accumulated knowledge stored in the files of the APCHQ. For this purpose, the database in this study aimed firstly to develop a structure for the input of information to build a collection of cases of building envelope failures, their diagnoses and remedial measures. The database would then be used as a framework for building diagnostics, that would be applicable to train inexperienced surveyors in building pathology. It also became a means of generation of statistics and was used to draw a portrait of the residential construction industry from the point of view of failures occurring within the five year new home warranty period. It consists of the cases for which the contractor could not find the solution himself and requested the technical support of the association guardian of the warranty. Although not at all a complete portrait, the main findings are:

1. The type of failures commonly found are due to a lack of understanding of basic water management principles. For example, water should be shed away from the house and channeled efficiently.
2. More than half of the water infiltration problems occur in winter.
3. Almost 70% of the houses had water infiltrations due to one or more problems.
4. In this survey, wrong design was responsible for 43% of the problems, 25% were due to deficient workmanship, and 11% to wrong detailing.
5. The study pointed the need of increasing the knowledge of people who design and build houses and provide a supervisor or coordinator on site to ensure quality in the execution of the construction jobs.

The results of the analysis of information in the database can be used by the APCHQ to reorient, if needed, its training and information programs. Having developed the database and using it as a source of accumulated knowledge, a proof-of-concept prototype tool was designed to support building envelope diagnostics. Such tool is the object of the next chapter.

# Chapter 4. Implementation of a proof-of-concept prototype tool to support building envelope failures diagnosis

The model of the proposed tool found in Chapter 2, provided guidelines for the design and implementation of the prototype tool to demonstrate the appropriateness of the concept behind this research project. There were some decisions that had to be taken in order to carry out the implementation, such as the selection of: the computer paradigm, the database manager and the programming language. These issues are discussed in this section.

## 4.1 Selection of the computer paradigm

Software design theory says that previous to the elaboration of any software product, it is necessary to choose the paradigm that better suits the project that is to be done. A paradigm is a conceptual approach or a frame of reference that is used to understand or solve a problem. Some of the paradigms mostly used are: Classic life cycle, Prototypes, Spiral, Object oriented, etc. (Pressman, 2001).

The object oriented approach is a programming technique or way of structuring data based on an organization of fundamental entities named classes that incorporate attributes (such as dimensions, location, etc.), and methods (actions applied to change the attributes of the objects) that enable the linkage of objects to build complex programming systems.

The prototypes approach is a way to develop software that consists of producing prototypes and perfecting them until a final product is ready. It is an iterative process model suitable for cases in which a set of general objectives for the software are defined but there is detailed input, processing or output requirements that are not clearly identified. Also, this paradigm is used in cases in which the efficiency of the program's algorithm is uncertain. If the adaptability of the operating system or the form of interaction between the user and the computer is not clear, then, the prototyping paradigm is an appropriate approach.

The linear sequential approach, often referred as classic life cycle approach or waterfall model uses a sequential approach beginning at the system level, progressing through analysis, design, coding, testing and maintenance. This paradigm is the oldest and mostly used for software engineering. One of the problems with this model is that projects rarely follow the sequential order proposed by the model.

The spiral approach combines the iterative nature of prototyping with the systematic approach of the linear sequential model. It can be adapted to apply all over the service life of the computer software, as opposed to classical process models that conclude at the time that the software is delivered. But it requires considerable expertise in risk assessment, relying on such expertise for its success.The paradigm chosen for this project was Prototypes. Its sequence is as follows:

1. Analysis and fast design
2. Fast implementation
3. User evaluation (If the evaluation gives a satisfactory result, the final product is done then)
4. Evaluation of changes, if any

This process is repeated until the final product is released.

## 4.2 Program implementation divided by phases

In the current project, the analysis stage consisted of the following:

- Analysis of the data that is going to be used in the project
- Selection of the database manager
- Selection of the programming language
- Analysis of functions

The database manager selection and the programming language are chosen at the beginning of the process, while the rest of the tasks can have an indeterminate number of interactions within the life cycle of the project.

The fast design phase consists of the following:

- Design of the database
- Design of functions
- Algorithms

During the fast implementation stage the tasks were as follows:

- Menu Design
- Form Design
- Report Design
- Event Programming
- Algorithm Programming
- Functionality Test

The final product requires the following:

- Thorough evaluation of the product modules
- Production of installer disks

- User training

### 4.3 Analysis of the data

During the data analysis stage, the way of proceeding was:

- Identification of the data subject to storage obtained from real life.
- Definition of the type of data and their maximum length.

The available data types are:

- Text (0 to 255 characters)
- Number (Byte = 0 to 255; Integer = -32,768 to + 32,767; Long = -2,147,483,648 to 2,147,483,647; Single = Approximately –3.4E38 to 3.4E38, Double = Approximately –1.8E308 to 4.9E324)
- Memo (Text string with infinite length)
- Date (1/1/100 to 12/31/9999)
- Boolean (True or false values)

The maximum length of text is assigned in function of the length of the data. Those in which the length is more than 255 characters is Memo type, that allows text string with infinite length (Roman, 2002).

### 4.4 Selection of the data base manager and programming language

During the database manager selection, the use of the database was projected in function of the amount of records that it can store in a year. Given that the total number of cases of failure found in this research (96 in 7 years) did not overpass 10,000 records, the choice was Microsoft Access. If a larger database was needed, then the choice would have been Microsoft SQL Server. The 10,000 record criteria is a rule of thumb that serves as a reference point but should not be taken as an axiom since the selection of the database manager can be influenced by other factors, such as: the computer where the program will be executed, the network use capabilities of the application, experience with the manager, etc. In this project in particular, the factors that were decisive to the selection of Microsoft Access were:

a) its availability, a characteristic that makes it possible for many people familiarized with Microsoft Office to have access to such software
b) its interoperability among the products of the same family (Microsoft Office)
c) its easy operation in data management
d) its capacity to use Structured Query Language sentences, which the standard language to manipulate data in almost all database managers

The programming language selection was made in function with the familiarity of the programmer with the language. Also, the capacity of the language to manipulate the objects required by the system (database, reports, windows, hardware, etc.) was considered. For this project, the choice was Visual Basic 6.0, a popular language that is easy to understand. On the other hand, it is capable to manipulate almost any database manager, including Microsoft Access, the selected manager for this project.

The following step after all the concepts were defined and the conditions set, was to land all these ideas into a tool capable of coping with the requirements. The next section discusses the actual features of the tool to show that they respond to the needs found in the literature review.

## 4.5 Structure and components of the proposed tool

The tool was built according to the model proposed in the last section. It is composed of a:

a. database

b. questionnaire that serves as an input form

c. query builder

d. reporter

e. user interface

The tool is supported by a database that has all the stored knowledge, decisions and rationale used to solve previous cases of residential building envelope problems. The database is populated through an input form with a set of questions that are relevant to any building envelope failure investigation, as described previously in chapter 3. The tool has a module called "Query Builder" that allows the user build queries to get specific information from the database. The Reports module, allows the user to view the complete files that he/she selects. The user interface of the tool was kept as simple as possible so that the user did not have to take extensive training to be able to use the system.

### 4.5.1 Database

The main component of this research is the accumulated knowledge found in the database described in Chapter 3. For the implementation of the tool created in this project, the same database structure used in the questionnaire was kept with a number of minor additions. Some fields were added so that the tool could store information from questions that had an open answer. Table structure and fields were determined with the results from the data analysis, specifying the name of the table, the name of the fields, their type and their size. In this case in particular two tables were defined: one that contained the information and another that contained the controls used in the design of the forms. It is important to note that both tables do not have any direct relationship since one is used to store information and the other is part of the functionality of the program.

### 4.5.2 Modules of the Program, their function and capabilities

#### 4.5.2.1 Questionnaire

The tool was designed to use the computer version of the questionnaire as a means to input relevant information about the building, its pathology and remedial measures. In the same manner, the implemented questionnaire form allows modification or edition of the building data that was previously stored as well as its deletion (see table 4.1).

Table 4.1 Function and capabilities of questionnaire

| QUESTIONNAIRE | |
|---|---|
| Functions: | 1. Input a new file (with photographs included) |
| | 2. Edit and Delete an existing file (with photographs included) |
| Capabilities: | The questionnaire module allows the user to keep track of scanned pictures in "jpg" or "bmp" format so that the user can see them whenever he/she wants, together with the report. |

The Questionnaire module receives data from the user through a form that contains text boxes, check boxes and option buttons. Due to the great amount of information that has to be stored, it was divided in three forms with tab dividers to better organize the information by sections. To input a new file, the user must enter a file number and start filling out the questionnaire. As the user browses through the sections of the questionnaire, the system saves the current information in the database. To edit the data of a building previously stored, the user must select the desired file from a list that contains information that identifies the file. The user can load a file from this form and edit it. To delete a file, the user can select it from a list that pops out with a button in this same form and delete it. The file is deleted after the user has confirmed it.

The user interface is composed of a form created in Microsoft Visual Basic 6.0 that uses Scroll Menus, Grids, Buttons and Tab Controls for the general functions of the program. The Questionnaire (Input Form) uses Labels, Text Boxes, Check Boxes, Option Buttons and Image Controls. To keep the interface as simple as possible, the questionnaire and the query builder share similar forms to specify the criteria for the queries. The questionnaire has ten tab controls and screens that are alike, except for the one that contains the photograph section. The query builder uses a similar form to allow the user specification of search criteria, a form where the user can build queries and a form where the user can view and compare the results of the query. Figure 4.1 shows the input form that is used to populate the database.

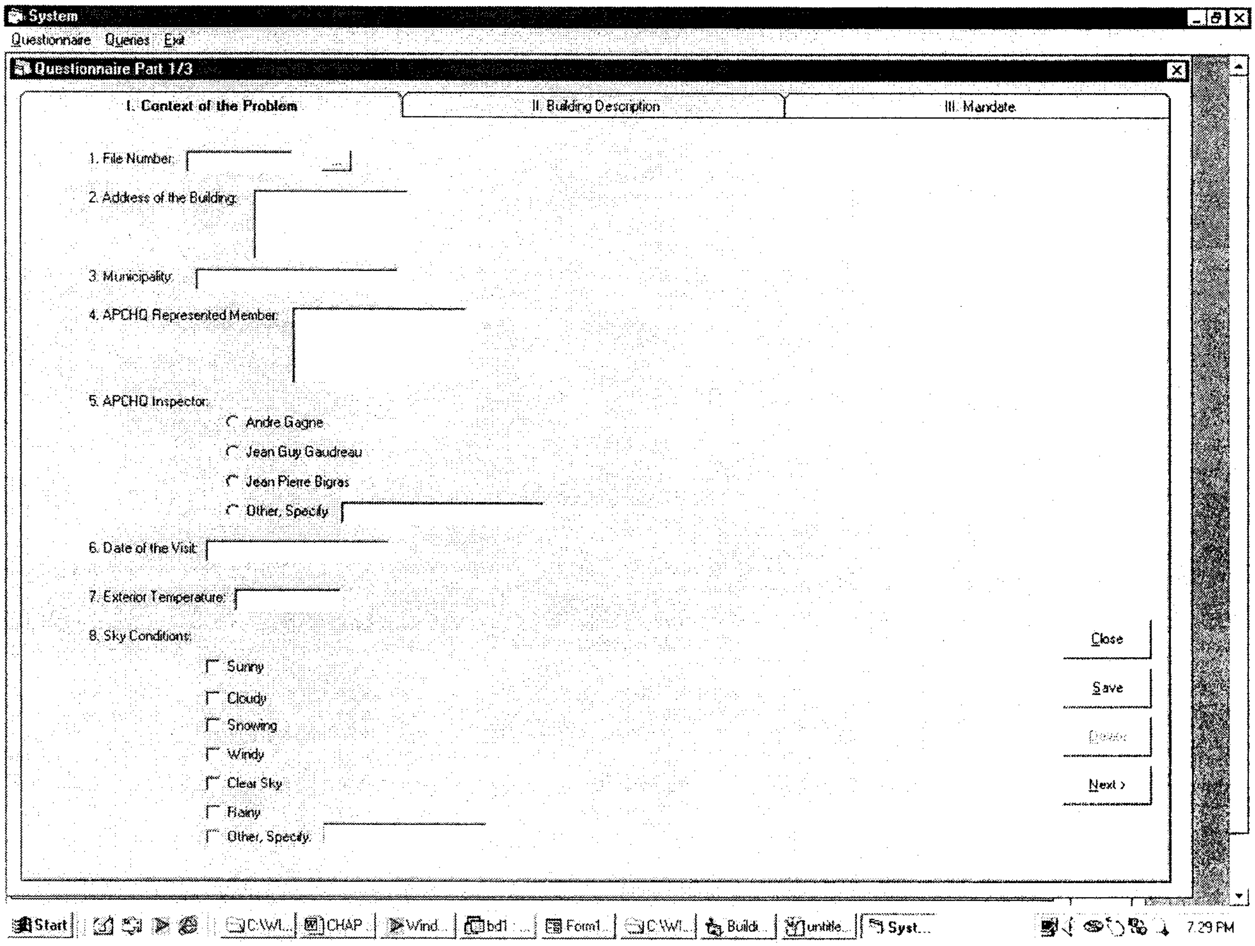


Figure 4.1 Part number one of the input form questionnaire

### 4.5.2.2 Query Builder

The query builder allows the user to extract the information from the data base building a query with search criteria in specific fields, including the operators “LIKE”, “=”, “<”, “>”, “<=”, “>=”, “AND” and “OR”. The tool shows the files that matched the search criteria and the user is able to consult them. (see table 4.2)

The user can define more than one search criteria and the system looks in all the records and verifies if there are words or phrases that match or not in each of the specified criteria, indicating the percentage of match from the total specified criteria versus the found criteria. Once the query is built, a list appears with the results obtained, indicating the file number and the percentage of match with the specified criterion of the query. The user has the option to see the report in the screen and print it or open it to be edited.

Table 4.2 Function and capabilities of the query builder

| **QUERY BUILDER** | |
|---|---|
| Functions: | 1. Build queries with unlimited number of different criterion |
| | 2. View results of queries |
| Capabilities: | The query builder allows the user to specify the fields that he/she wants to see after the query has been executed.<br>Also, the query builder module produces a table with the results of the query and with details of the query such as: number of files that matched the specified criteria, specified query criteria, fields that matched the criteria and fields that did not match.<br>The program allows the user to print the above mentioned window with the results of the query as well as the specified criteria, so that he/she can analyse them in hardcopy. This feature is most useful when there is a long list of files and results. The idea is to allow the user see only the information that he/she needs and avoid an overwhelming amount of information. |

The query builder uses a very similar form together with a main form that concentrates the SQL sentence stated for the purpose of getting specific information form the database, as shown in Figure 4.2:

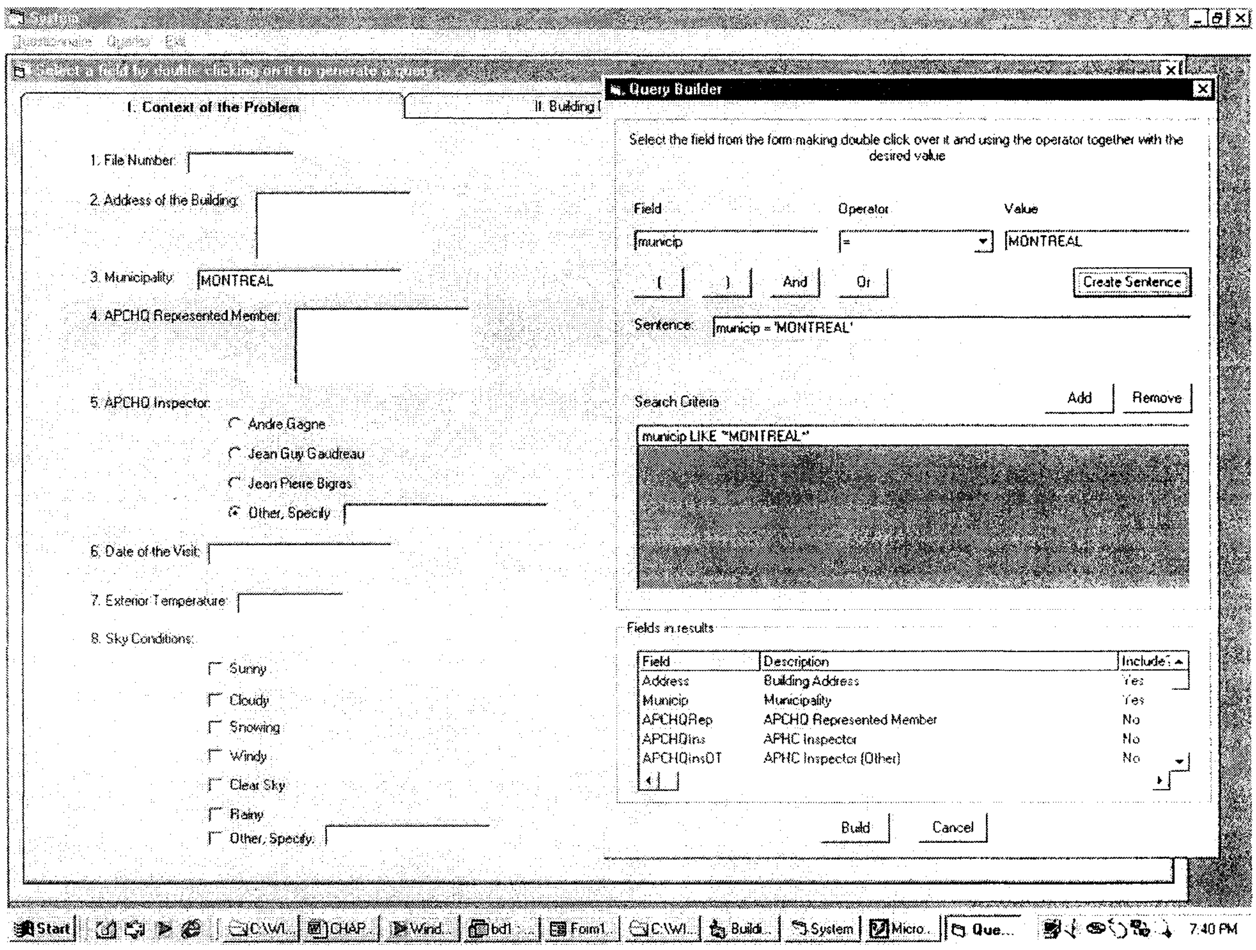


Figure 4.2 Query builder form of the tool

The system has also a form that shows the results of the query. Such form allows the user to compare the results of the query found in the files that matched the search criteria specified in the query builder form. Figure 4.3 shows both the main form of the query builder and the form that shows the query results. Match, corresponds to the percentage by which the cases listed in the results matched with the search criterion. If the case matched with all the criterion the percentage is 100% if it matched with half, the percentage is 50% and so on.

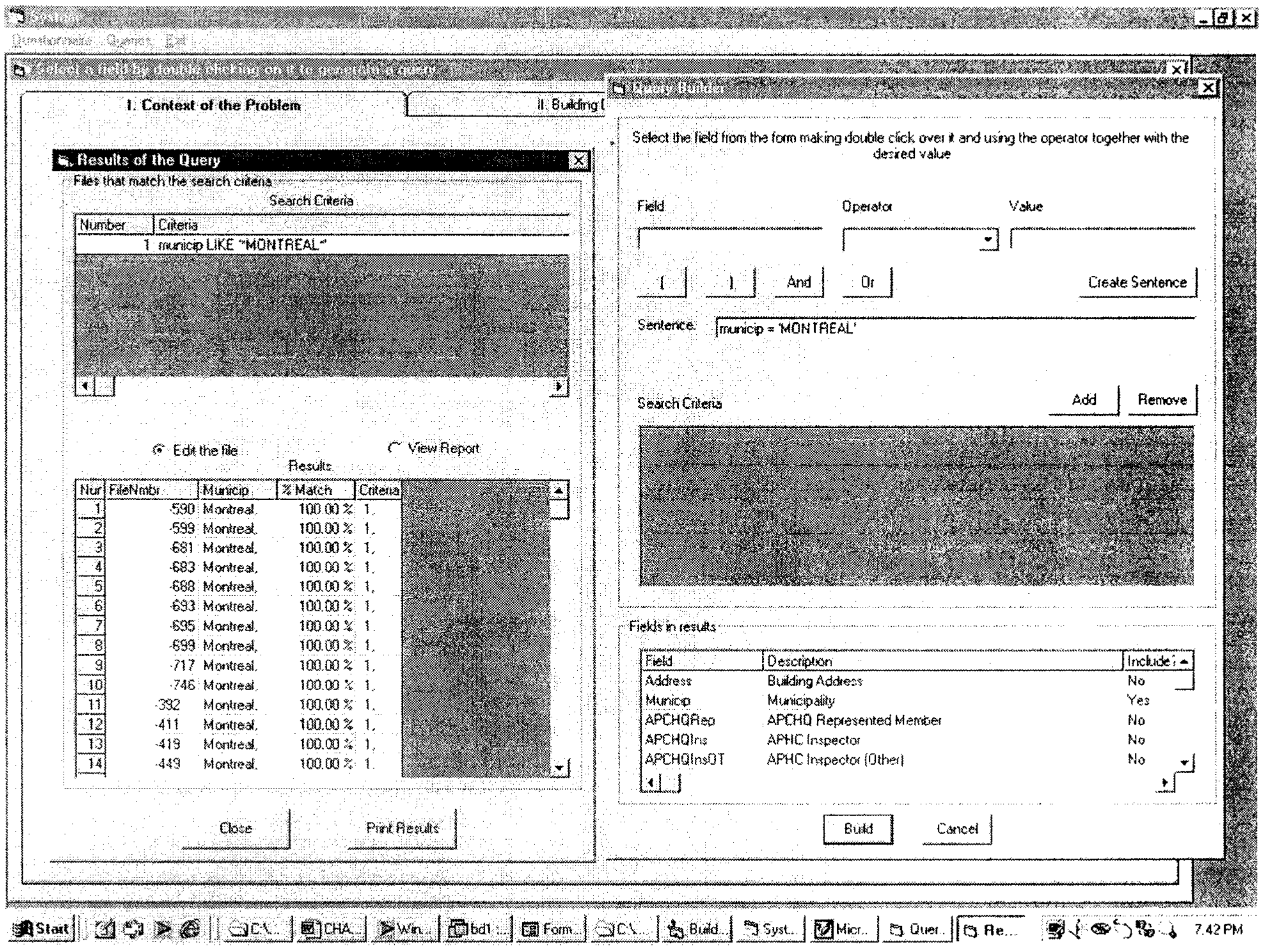


Figure 4.3 Form to display the results of a query

#### 4.5.2.3 Reporter

The reports produced by the system present all the information about the building based on the search criteria. This module can be activated through the query builder and shows the selected file on screen and allows such file to be printed. It is important to note that the reporter of Visual Basic 6.0 has limitations of space, therefore, it was necessary to create a report for each section of the questionnaire. And each report is composed of as many pages as the section has according to its size. Photographs can also be stored, queried by title, and printed.

Table 4.3 Function and capabilities of the reporter

| **REPORTER** | |
|---|---|
| Functions: | View and print complete file reports (with photographs included) |
| Capabilities: | The reporter module allows the user to print scanned pictures in "jpg" or "bmp" format whenever he/she wants, together with the report.<br>The reporter module allows the user to print an empty questionnaire so that he/she can fill it out by hand during an on site visit and have the information ready for input in the computer. |

In Figure 4.4 it can be seen that the Reports are presented in cascade form to allow browsing through the nine sections of the report. Each section of the questionnaire was put in a report alone, due to the limitations mentioned previously.

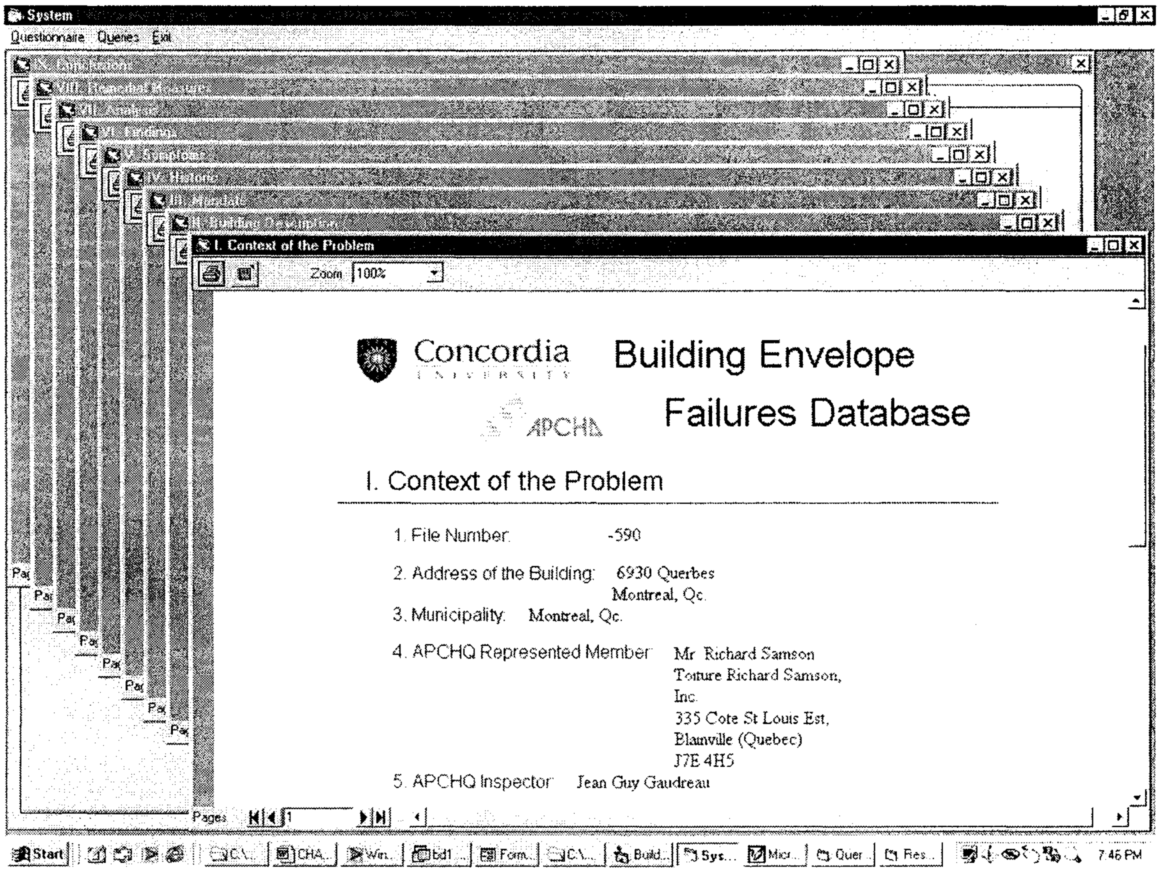


Figure 4.4 Reporter of the tool

### 4.6 Trial and evaluation of the tool

For the trial and evaluation of the tool, there was a meeting with Andre Gagne, director of the Technical Service Department of the APCHQ. The tool was presented showing each of its features. Queries were run in order to demonstrate the capabilities of the tool. The applications of the tool were explained as well. There was a positive reaction to the tool on the side of Mr. Gagne, who realized its use in organizing the reports of building envelope failures. Mr. Gagne commented that the time that the query builder used to retrieve information from the database was a bit long.

The intention of the evaluation and trial of the tool was to use the tool on several actual cases of failure. However, no cases of building envelope failure were reported to the technical department of the APCHQ in September and October, making it impossible to be tested on site. Therefore, validation of the tool was designed using a different approach taking random cases from the database and querying the database to find matching files. Four cases are presented here with increasing complexity of queries showing the diversity of matching that can result from the tool as programmed. For more detail on the cases, please refer to the appendix.

**CASE 1** - Taking file 684 randomly as a trial case

The building in file 684 is a row duplex, 2 stories high.

**Problem:** water infiltrations in the roof and ceilings.

**Symptoms:** Air exfiltration in the attic, damages caused by water in ceilings, ice dams, icicles, snow accumulation in the roof and water infiltrations in the attic.

Taking some of the symptoms that are representative of the problem in a general way:

- damages caused by water
- ice dams
- water infiltrations

**The query would be:**

(Symptoms LIKE *damages caused by water*) AND (Symptoms LIKE * ice dams *) AND (Symptoms LIKE * water infiltrations *)

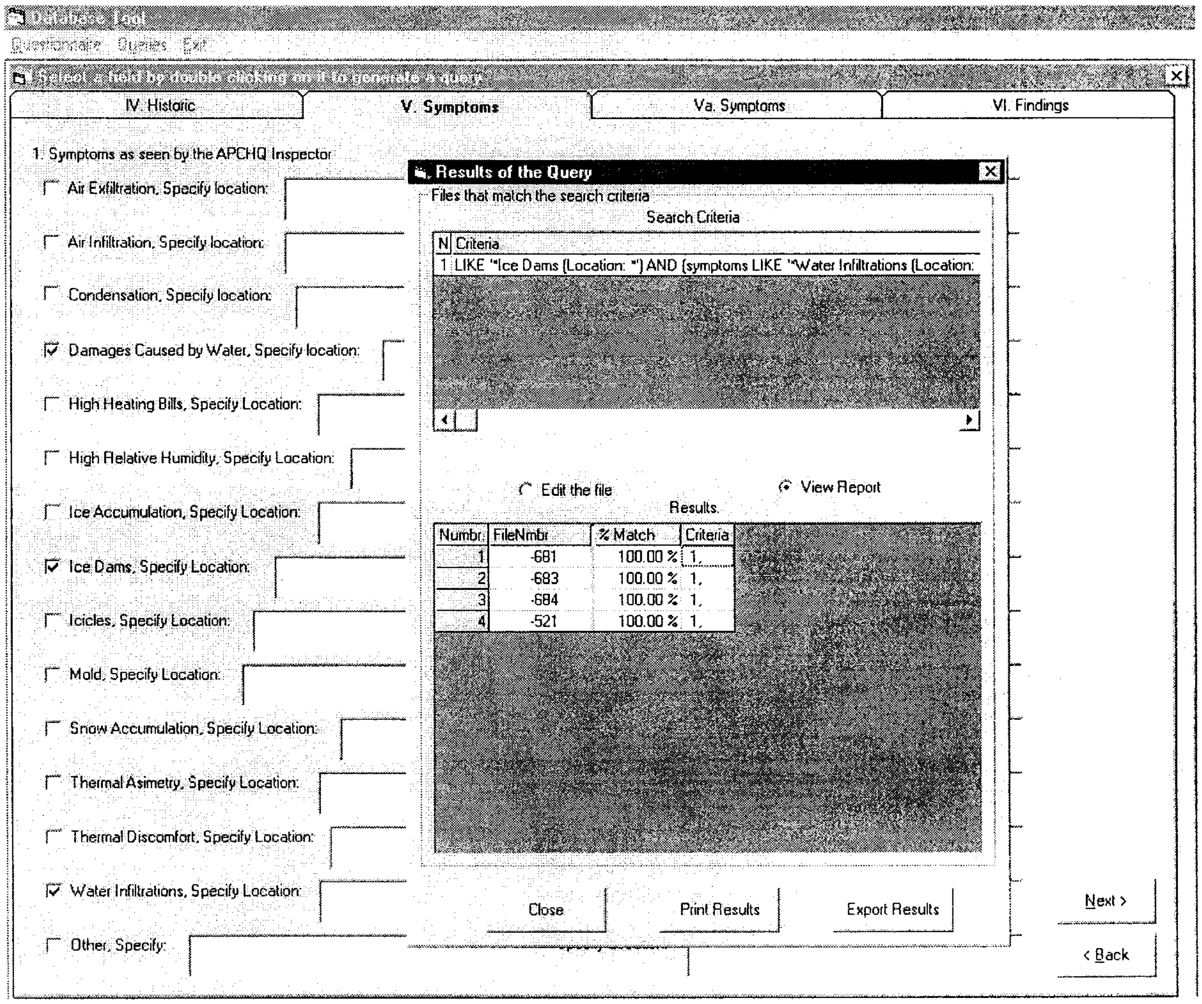


Figure 4.5 Results of query for case 1

**The resulting file numbers are:** 681, 683, 684, 521.

Comparing the cases it can be seen that there are two similar cases that match (681 and 683). File 521 has a different profile.

**CASE 2** - Taking file 499 randomly as a trial case

The building in file 499 is a detached bungalow, 1 story high.

**Problem:** Water infiltrations and cracks in the foundational walls. The problem location is the basement.

**Symptoms:** Water infiltrations in the basement and cracks in the foundational walls.

Taking some of the vulnerabilities that have an impact on the cause of the problem and that are representative of the problem in a general way:

- The slopes in the terrain are wrong
- The gutter downspout discharges close to the house

Combining these pieces of information with the type of problem,

**The query would be:**

(Problem LIKE *Water infiltrations in the basement*) AND (Vulnerabilities LIKE *slope*) AND (Vulnerabilities LIKE *gutter*)

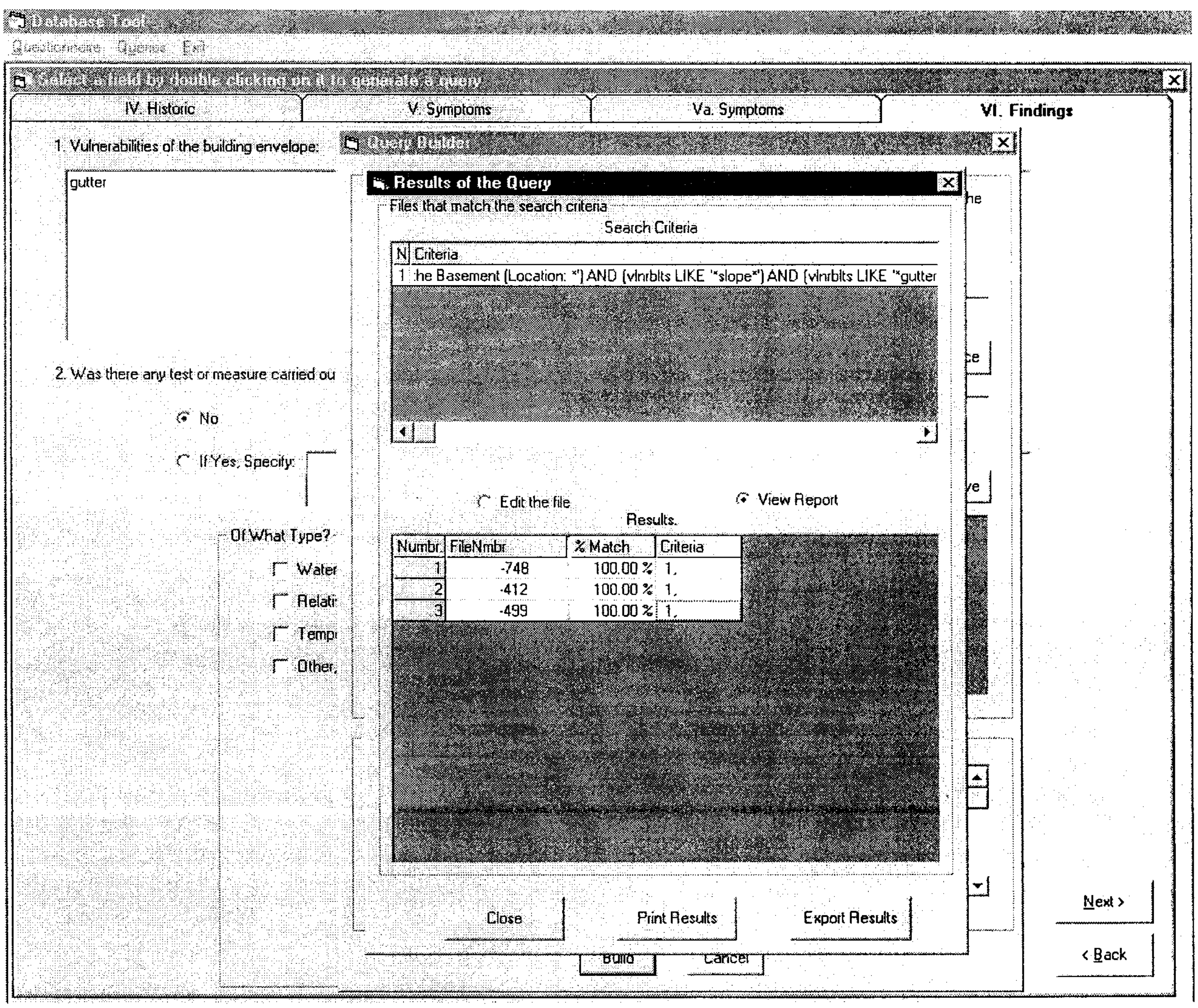

Figure 4.6 Results of query for case 2

**The resulting file numbers are:** 748, 412, 499

Comparing the cases it can be seen that the two similar cases match (412 and 748).

**CASE 3** - Taking file 575 randomly as a trial case.

The building in file 575 is a detached bungalow, 1 story high.

**Problem:** High relative humidity. The problem location is in the house.

**Symptoms:** Condensation in the windows of the house.

Knowing from this research that a high relative humidity is often due to the usage of occupants, and correlating this probable cause (usage) with the standard verification of the indoor environmental conditions in these cases (Relative Humidity Measurement) and the symptoms found in this case (condensation in windows).

**The query would be:**

(Test type LIKE *Relative Humidity*) OR (Causes LIKE *usage*) OR (Symptoms LIKE *Condensation*) OR (Symptom Location LIKE *Windows*)

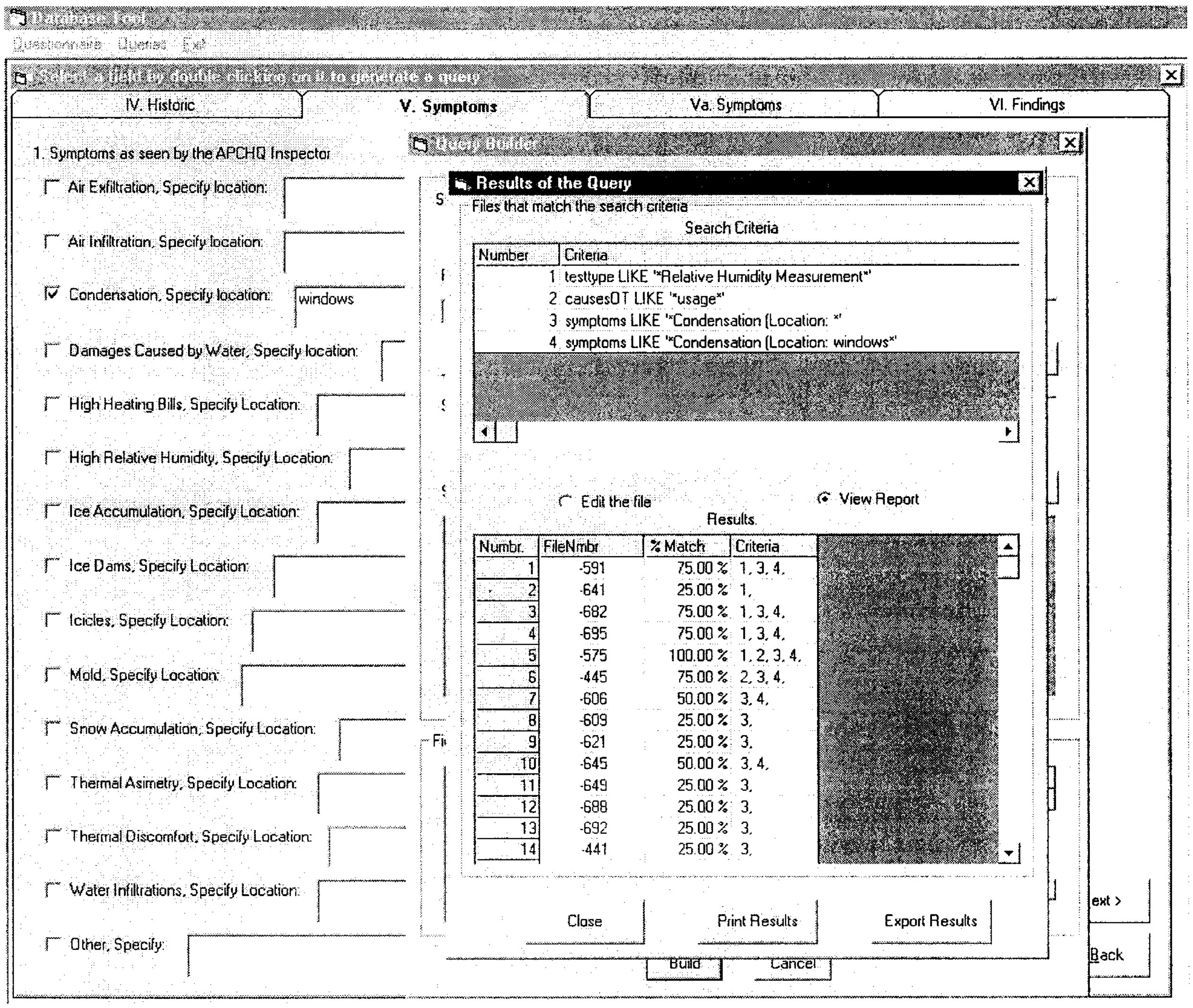

Figure 4.7 Results of query for case 3

The case that matches all the search criterion is 575 (because this is the sample case) and there are 4 cases that matched in 75% of the criterion. Such cases are 571, 682, 695 and 445.

There are other cases that matched with a less percentage, but since there are enough cases to compare that matched 75%, the lower matched cases will not be considered.

Case 445 outstands from the rest, because the criteria that did not match (Test type LIKE *Relative Humidity*) with the query is not as relevant as the second criteria

(Causes LIKE *usage*). Therefore, this case (445) was the first from the list to be analysed.

After analyzing and comparing the cases it can be seen that there is a similar case that matches file 575 (445). Files 571, 682 and 695 have less similarities.

**CASE 4** - Taking file 489 randomly as a trial case.

The building in file 489 is a semidetached cottage, 2 stories high.

**Problem:** Water infiltrations. The problem location is in the house.

**Symptoms:** Damages caused by water in the parquet floor covering, water infiltrations in the roof covering and traces of water infiltration in certain roof trusses.

Correlating the problem with the symptoms and key words that are related to the vulnerabilities found in the sample case,

**The query would be:**

(Problem LIKE *Water Infiltrations) OR (Symptoms LIKE *Damages Caused by Water*) OR (Symptoms LIKE *Water Infiltrations*) OR (Symptoms LIKE *Traces of water infiltration*) OR (Vulnerabilities LIKE *roof*) OR (Vulnerabilities LIKE *configuration*) OR (Vulnerabilities LIKE *accumu*)

The case that matches all the search criterion is 489 (because this is the sample case) and there are 5 cases that matched in 85.71% of the criterion. Such cases are 681, 683, 684, 693 and 527.

There are other cases that matched with a less percentage, but since there are enough cases to compare that matched 85.71%, the lower matched cases will not be considered.

Case 527 outstands from the rest, because the fourth criteria (Symptoms LIKE *Traces of water infiltration*) makes it unique with respect with the others and more similar to the sample case. Therefore, this case (527) was the first from the list to be analysed.

After analyzing and comparing the cases it can be seen that the case with most similarities matching file 489 is 527. Files 681, 683, 684 and 693 have less similarities but complement the ideas found in case 489. It can be said that the inspector would benefit in reading all these cases and learning from them in order to do the diagnosis of the sample case.

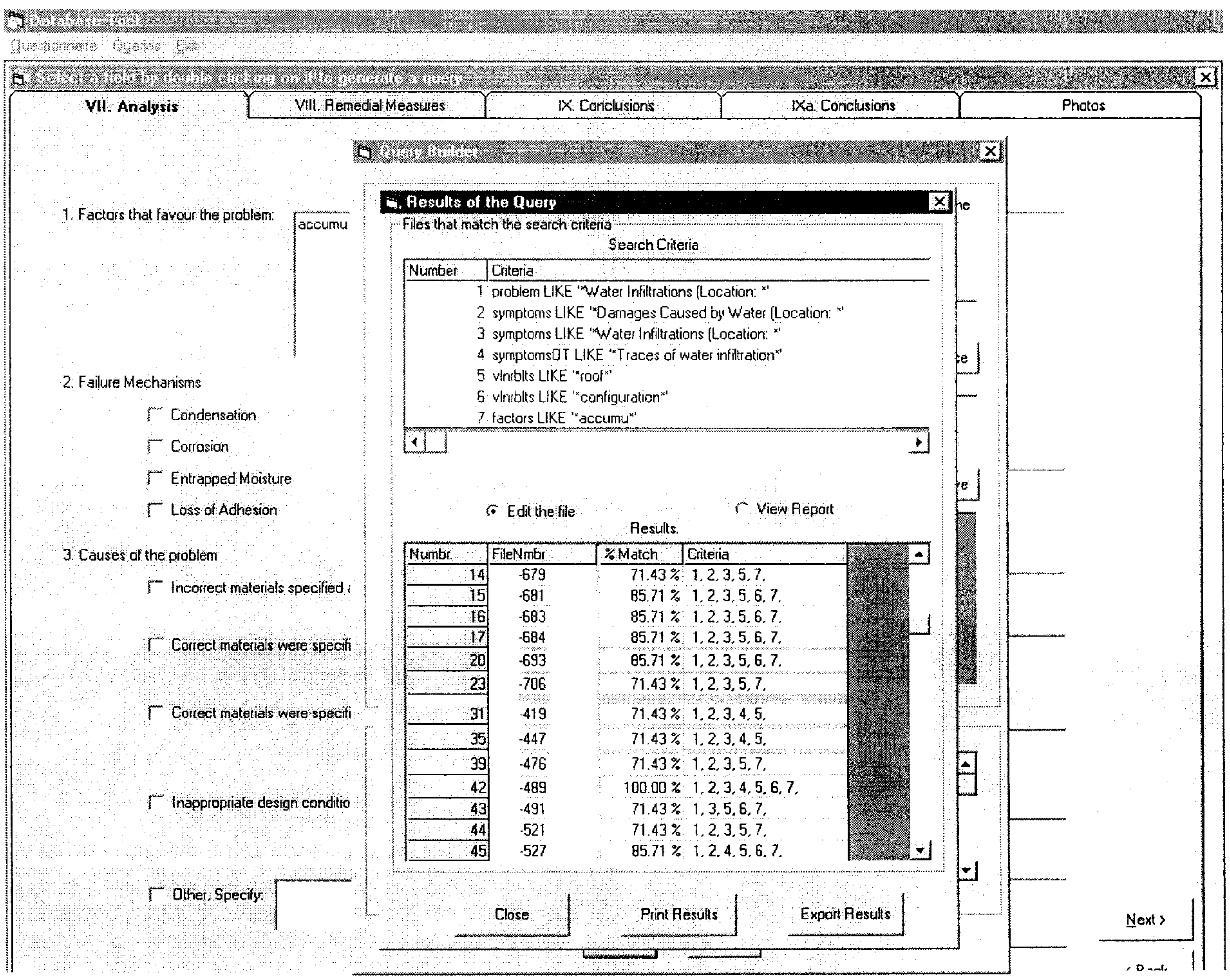


Figure 4.8 Results of query for case 4

The validation exercise demonstrates the capacity of the tool to retrieve appropriate similar cases.

From the meeting at APCHQ and the validation exercise, the strengths of the tool that can be pointed out are that it has a complete and extensive database with accumulated experience; it systematizes information about residential envelope pathology facilitating the generation of statistics and identification of patterns of failure; the retrieval of similar cases facilitates the decision making stage of building envelope diagnosis and remedy suggestion by providing relevant information to investigators based on previous cases solved with a similar pathology that are stored in the database. It is a means to analyze and compare building envelope failures because each failure is defined through the questionnaire and the database tool can enable comparison of cases according to the criteria specified by the user; the database can be used as a teaching tool resulting in recommendations to improve building envelope design, construction and maintenance. The tool can be useful to train inexperienced building inspectors by using it as a source of different cases of building envelope failure diagnosis. The user can browse through the database, reading different cases. The tool provides a library with cases that can be grouped by using the query builder. For example, the user can run a query to retrieve all the cases that dealt with water infiltrations in the roof. Then the user can read the pathology and remedial measures of each case, learning from past experiences.

# Chapter 5. Concept of a tool combining database and generic information

The prototype designed for this research project is a first attempt to develop a tool that gives support to building diagnosticians using a database with past experiences on diagnosis. For the reason that human diagnostic expertise could be expensive or not necessarily available and prone to errors, intelligent diagnosis systems have been implemented in many domains, including building pathology.

A further development to the proof-of-concept tool presented here would be to design and implement an intelligent diagnosis system that relies on case based reasoning. This chapter mentions the limitations of the current tool and proposes a way to add new capabilities of the tool using case based reasoning. This chapter will also mention in a general way some of the strengths of case based reasoning and will suggest the future work to be done in the design of the improved tool.

## 5.1 Limitations of the current tool

In order to propose a way in which the capabilities of a tool can be enhanced, it is necessary to identify its limitations. The current tool has the following limitations:

1. The current tool leaves adaptation or extrapolation of solutions found in the database to the new cases fully to the user. The tool does not suggest any remedial measures.
2. The retrieval of the information depends on the ability of the user to formulate the right queries with the right words. The user has to know how to query the system in order to get the case that is more alike. So, if the user does not do the right

query, he/she will not find the desired case. The current tool depends on the knowledge of the user of the building envelope vocabulary used in the cases to be able to retrieve the case that is alike.

3. Given that an important part of each case depends on textual descriptions, the current tool presents the problem that if the user makes a typographic mistake, there will be imprecision in the information retrieval and consequently the case matching.
4. The current tool does not index and relate the information in a way that facilitates its representation by a means different than text.

## 5.2 Characteristics of the enhanced tool

The tool with enhanced capabilities using case based reasoning should take advantage of the existing tool and also add functionalities that give better support to building diagnosticians. The tool should do the following:

1. Use the current tool to build a database with cases of building envelope failures
2. Define a way in which the information is stored in the database so that information is retrieved and compared efficiently
3. Receive input from the user about a particular failure scenario through an interface that narrows down the possibilities of building envelope anomalies, their characteristics and the environmental conditions under which they manifest themselves
4. Retrieve from the database the case that is most similar to the input given by the user
5. Compare the new input with the most similar case and find the differences

6. Modify the most similar case so that it is consistent with the new failure scenario that the user inputs
7. Propose a diagnosis of the problem and remedial measures according to the characteristics of the new input
8. Allow the user to verify the validity of the diagnosis and remedial measures
9. Allow the user to correct the diagnosis and remedial measures if needed
10. Store the new problem with its diagnosis and remedial measures in the database
11. Include generic cases as "text book perfect models" of each failure

The outcome of these requirements can be represented as follows:

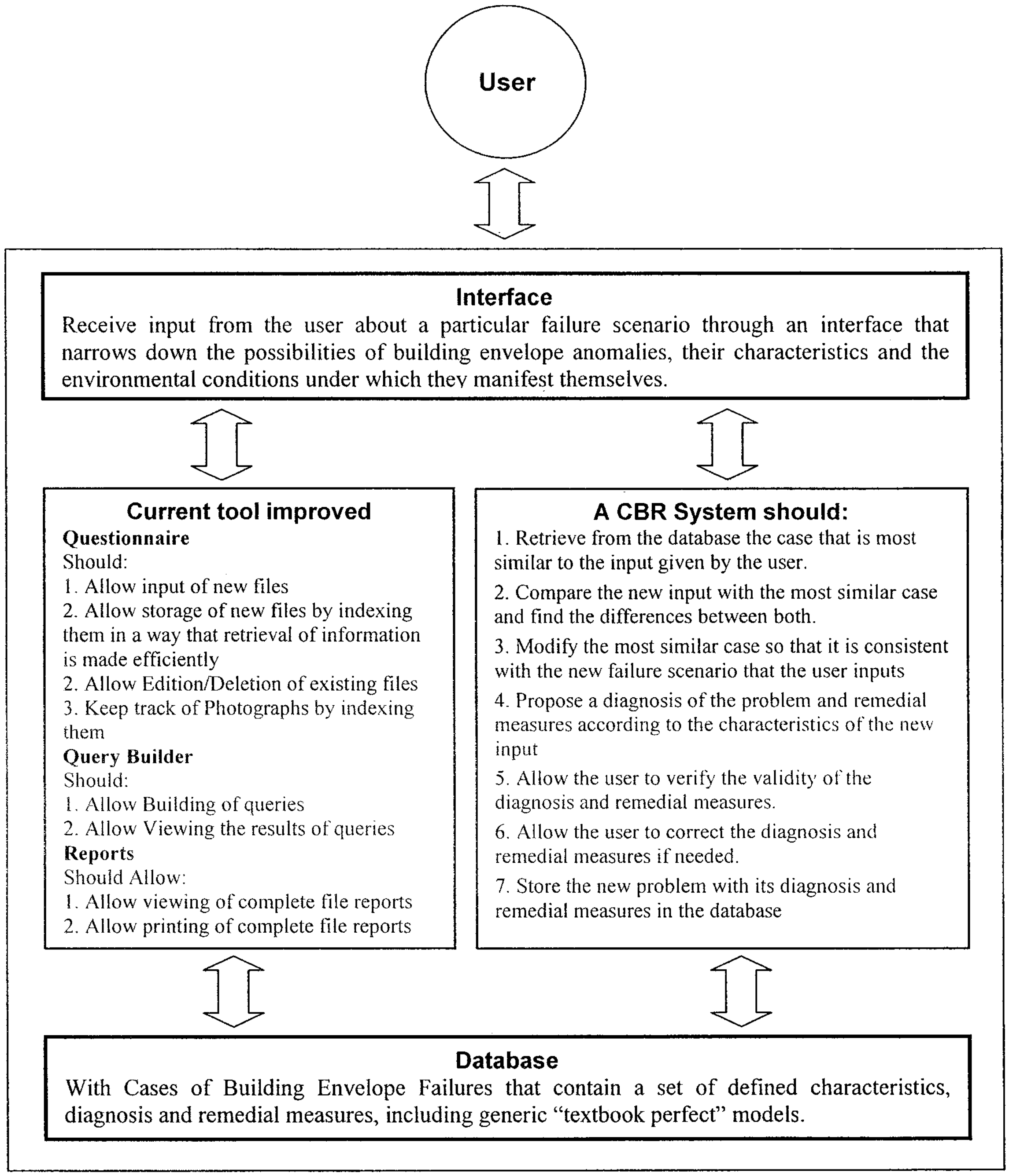


Figure 5.1 Architecture of the enhanced tool

## 5.3 Selecting case based reasoning systems

Case based systems belong to an approach that attempts to go around the task of extracting and codifying the experts' domain knowledge by relying on the use of implicit knowledge present in a collection of diagnostic cases (Kolodner, 1993). As opposed to model based systems and knowledge base systems, case based systems do not attempt to model the domain knowledge or the diagnostic reasoning of the expert. In a case based approach, the system attempts to make a diagnosis of the problem by reusing knowledge from a similar diagnostic case stored in memory and adapting it to the new conditions required by the problem. Case based systems depend on the adequacy and organization of the repository of cases to facilitate the retrieval of the most similar case with the most similar scenario. Case based reasoning diagnostic systems are one of the largest application areas of case based reasoning because such systems:

- do not require extensive specialist knowledge of any domain or task (Watson and Abdullah, 1994)
- are suitable for domains in which a model that suits all cases is not available, like in building envelope
- provide solutions when no algorithmic method is available (Hunt, 1999)

The current tool fits within the logic of case based reasoning. There are diagnostic cases stored in a database. The user queries the database in order to retrieve a case or cases that match a given failure scenario. The system shows the cases that match the desired criteria. The user adapts the retrieved case according to the new conditions and the system learns by adding a new case to the library.

Case based reasoning is suitable for residential building envelope diagnostics, a field in which typically professionals do not rely on theoretical models to determine the nature of problems. They use experience to diagnose the failures of the building envelope.

## 5.4 Implementation of case based reasoning for future tool development

There are many approaches and technologies to design an intelligent diagnosis system. Yet the most difficult and important task remains the same: assigning a given input to some category or class. The challenges presented by the proposed improvement are:

1. Interface design that narrows down the options used to define a case
2. Case representation and indexing
3. Case adaptation

The design of the interface is challenging too because it has to narrow down the options of receiving input from the user in the form of typed textual descriptions. Building envelopes are very varied and have many parameters because they are the result of a complex combination of materials, geometry, quality, economy and other interests. The interface of the system has to include the majority of the combinations possible yet be simple enough and user friendly. Therefore to come up with a generic way to address all these parameters would be a great accomplishment. In the new development scheme, the database used in the current tool should be reorganized. The database has textual information that could be represented and indexed according to the needs of the new tool.

There are shells that can handle textual information, an example is CBR-Express (Watson and Abdullah, 1994).

An important issue in the future development of this project will be the integration of new and past experiences in memory in a way that they can be retrieved efficiently and used by the case based system. It is important to remember that each case of building envelope failure has its own particularities.

The fact that the symptoms, the vulnerabilities, the factors affecting the problem, as well as the solutions are described in text presents a challenge for case representation and indexing because it will be necessary to establish a way in which the system can recognize each case according to its characteristics, diagnosis and remedial measures in order to retrieve the needed information, and be able to adapt the old solutions to the new scenarios.

Adaptation in case based systems can be achieved through heuristic rules, interaction with the user, first principles analysis and formulas. The choice of method depends on the application and the domain (Hunt, 1999). Case adaptation in some case based systems has been achieved using a knowledge based system. It works by adapting the case until it meets the current situation. Cases based reasoning may need a hybrid system for performance.

In conclusion, it can be said that a good system has to have a well organized case database that facilitates comparison of different case scenarios because case based reasoning is highly dependable on the way that information is stored and accessed in the memory. One of the advantages that it has is that it works with little domain theory available.

# Chapter 6. Conclusion and recommendations for further work

## 6.1 Contribution of this research

The present thesis on building envelope pathology diagnosis intends to facilitate the access to building envelope diagnostics rationale. Such knowledge is existent but disperse and has not been transferred efficiently to the people related to this field because there have been few attempts to collect and systematize information about building envelope failures.

At present there are no computer databases with cases of building envelope failures available to the public. There is currently only BELCAM-IRC project as an effort to create a comprehensive body of experience in terms of building envelope pathology in Canada (Institute for Research in Construction, 2000) and for now is focusing on roofs. Building envelope diagnosis relies mainly on the experience of the investigator. The AEPIC center in the United States dedicated to collect and disseminate building failures was closed because it lacked supporters (Kaminetzki, 1991 and Loss, 1987). It is important to mention that at the time when the AEPIC center was founded, computer databases were not as advanced and accessible as they are now.

In Quebec, the APCHQ contractors build the majority of the houses in the province, therefore the tool's database can grow year by year if used by the APCHQ inspectors, making it a feasible effort of collecting and accessing information about building envelope failures.

This research represents a viable effort to provide a means of dissecting building envelope failures and has advanced this field of study by proposing a way of organizing the information gathered in a building investigation; building a database capable of handling building information efficiently; equipping such database with a tool powerful enough to extract very specific information to be able to compare it with several cases of building envelope failures.

The database core of this research has many applications. Knowledge stored in the database can be used for training inexperienced building inspectors and many other purposes. The raw data collected in this research can also be processed, correlated and refined in order to produce statistics, find trends and failure patterns in the residential envelope of Quebec.

The proof-of-concept prototype tool developed demonstrated the feasibility of the proposed approach and the validation exercise demonstrates the capacity of a database tool to retrieve similar cases that might be required by inspectors during the course of an investigation

### 6.2 Recommendations for further work

A suitable project of further work to this research is the implementation of a diagnostic tool that uses case based reasoning, since a case-based reasoner solves new problems by adapting solutions used to solve old problems. In fact, the tool produced in this research followed some of the logic that case based reasoning uses. Case based reasoning models human reasoning and thinking. Case based reasoning programs store previous experience in memory in order to solve new problems by reusing experience about similar situations retrieved from the memory. Adaptation of the similar experience is used in the context of the new situation, either partially or completely. Learning of a case based reasoning system is achieved by storing the new experience in memory. It could be considered that the information be organized along the lines of the system proposed in the book "Common Building Defects, Diagnosis and Remedy", compiled by the U.K. National Building Agency and modified according to the existent defects in Quebec.

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# Appendix A – The input form questionnaire

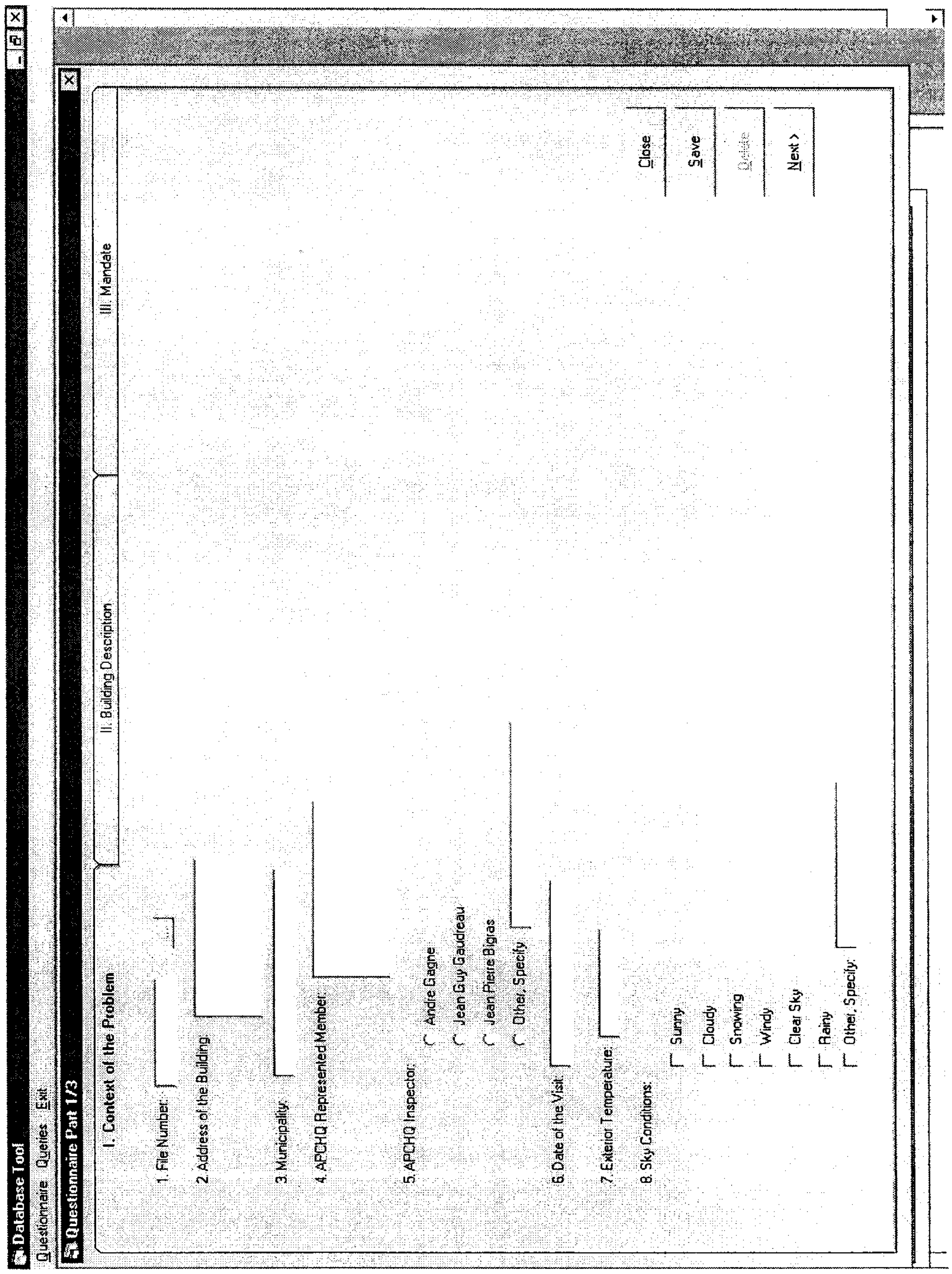


Figure A.1 Context of the problem

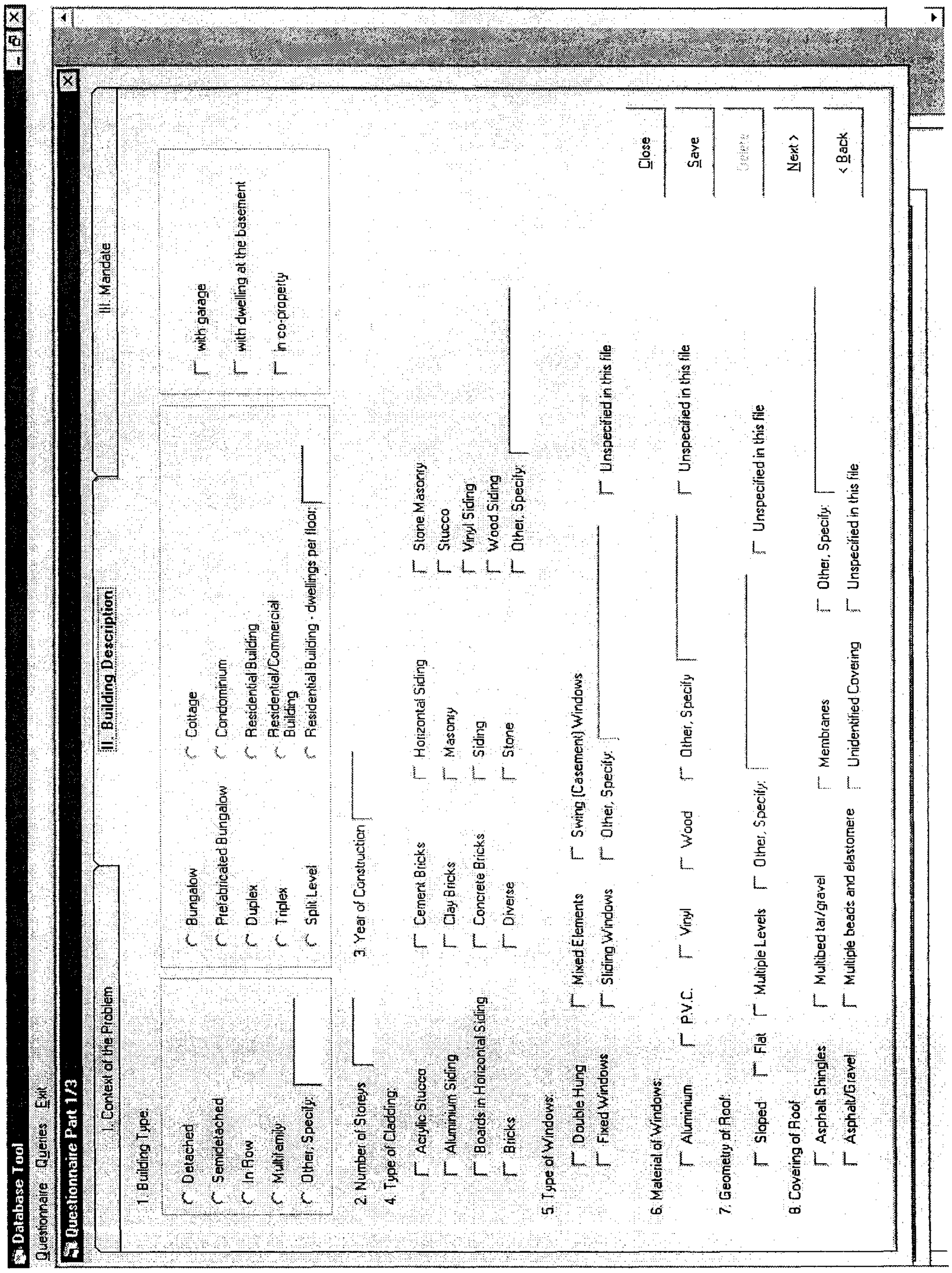


Figure A.2 Building description

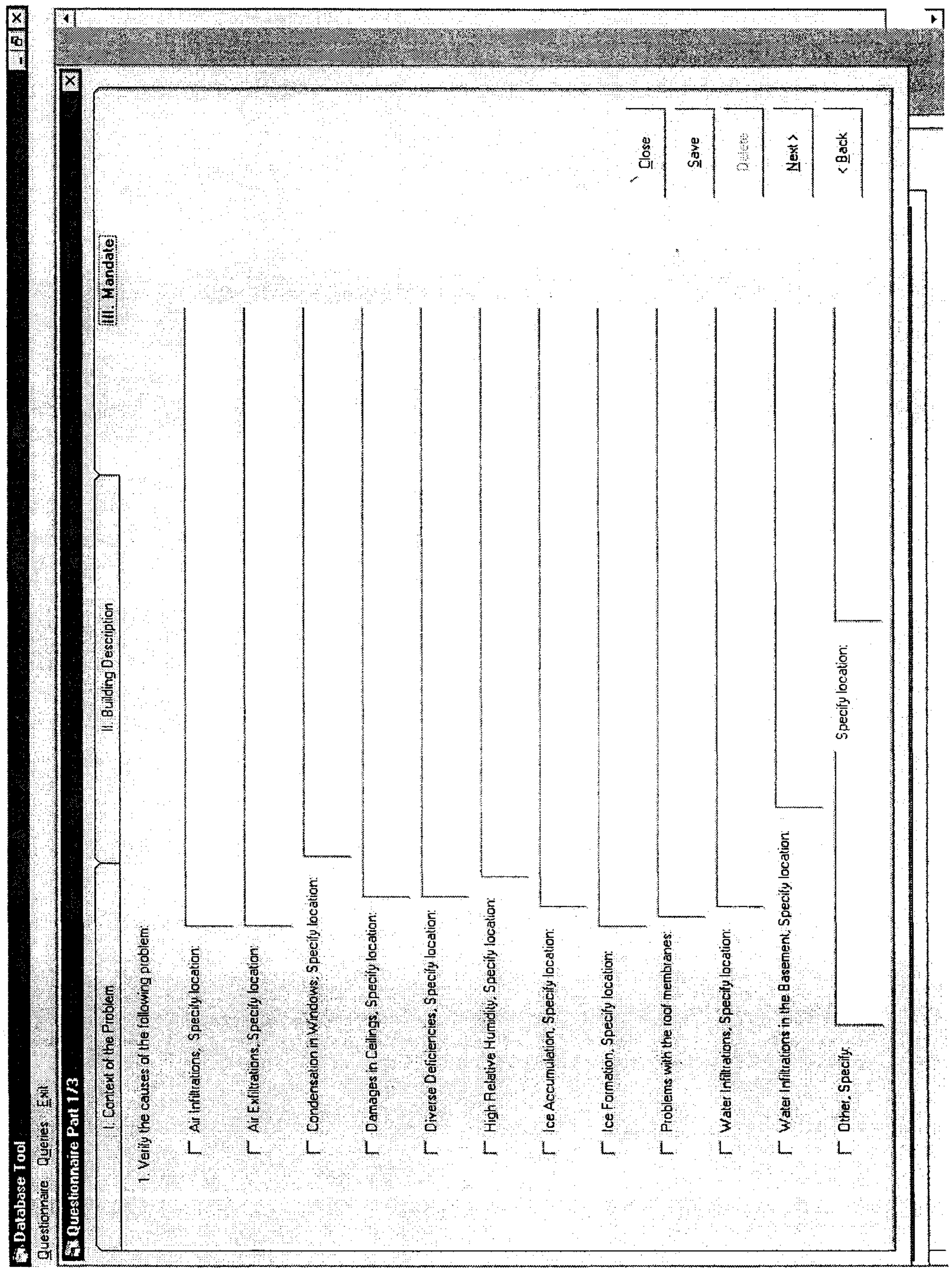


Figure A.3 Mandate

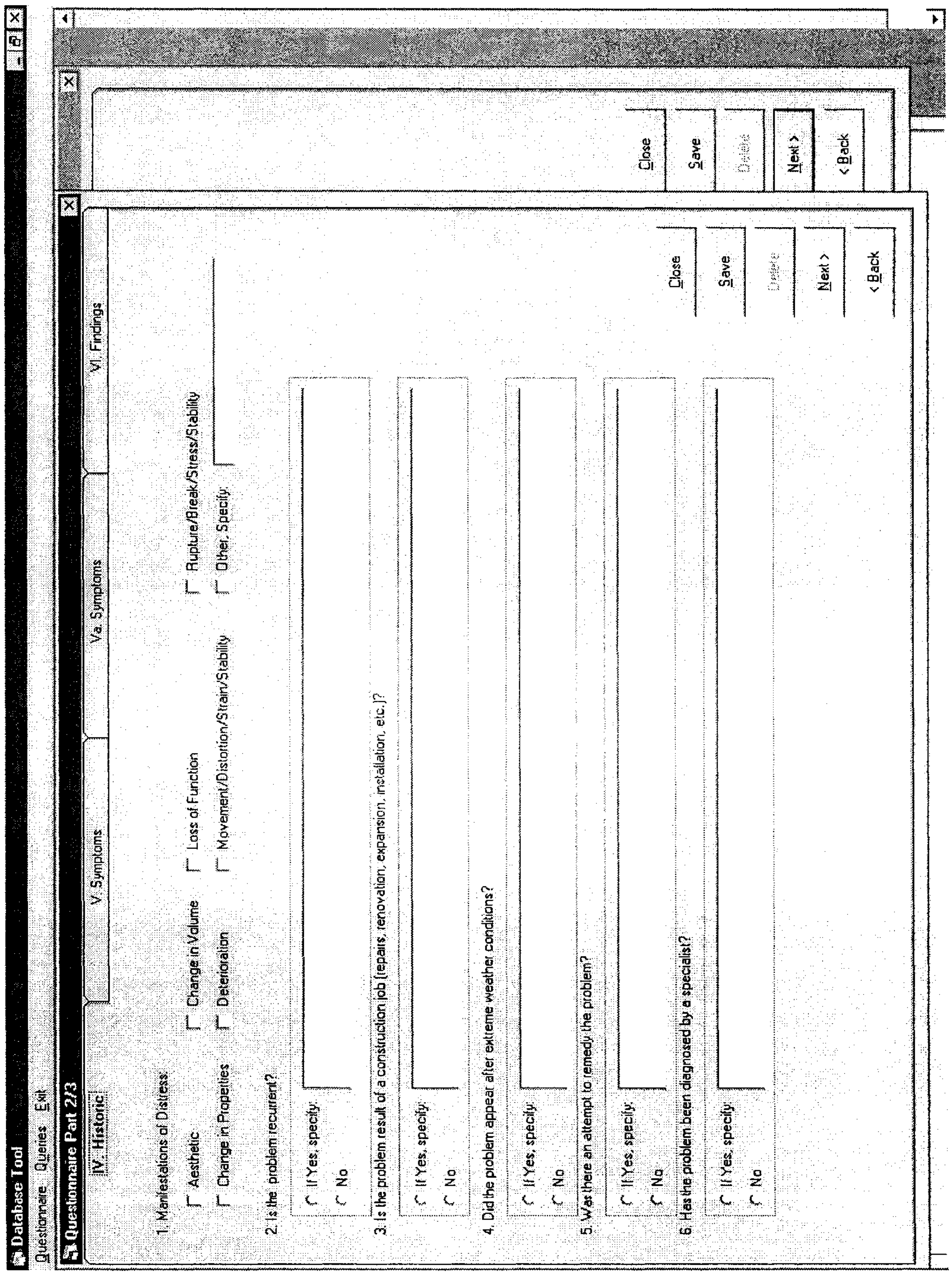


Figure A.4. Historic

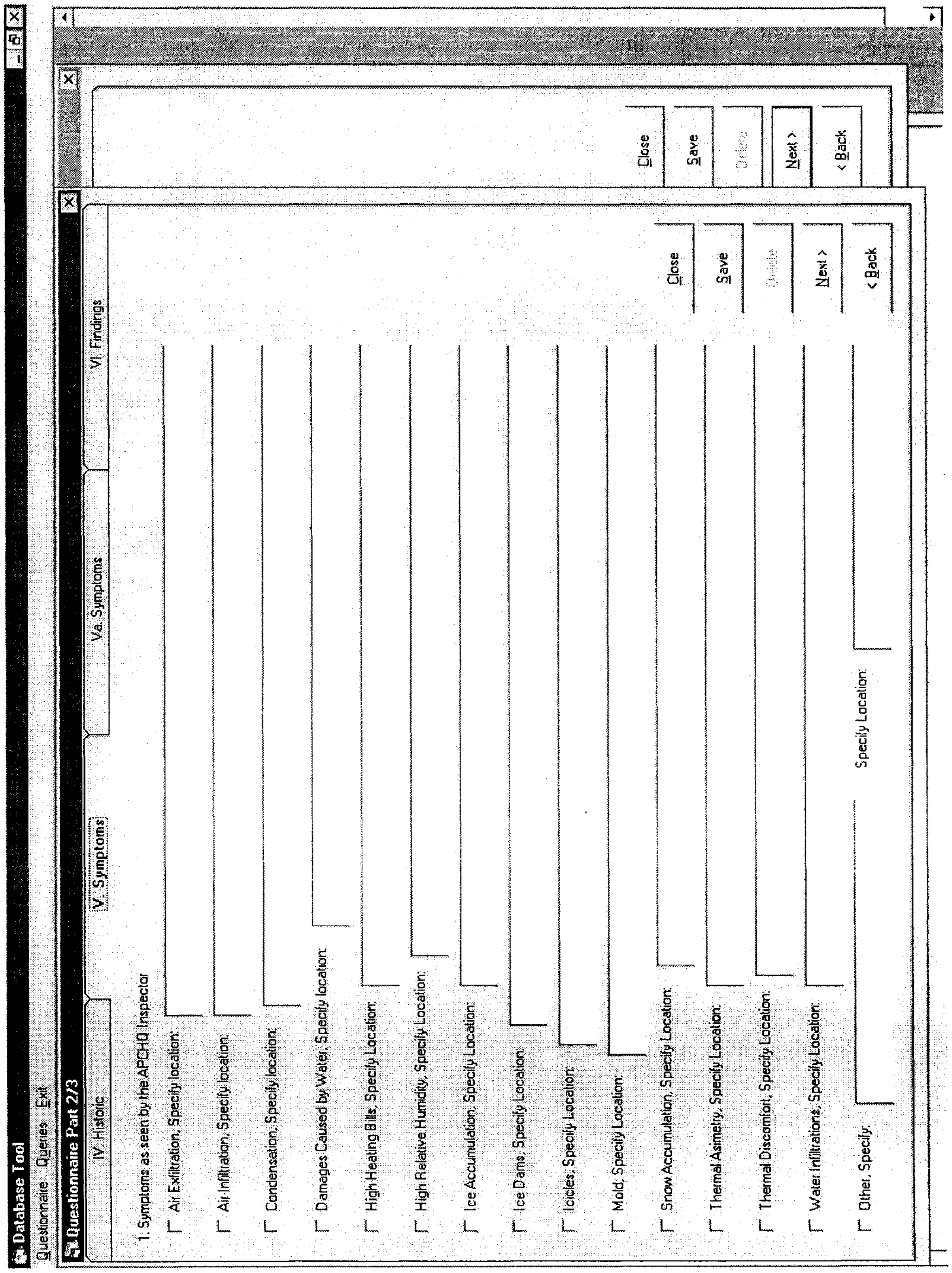


Figure A5. Symptoms

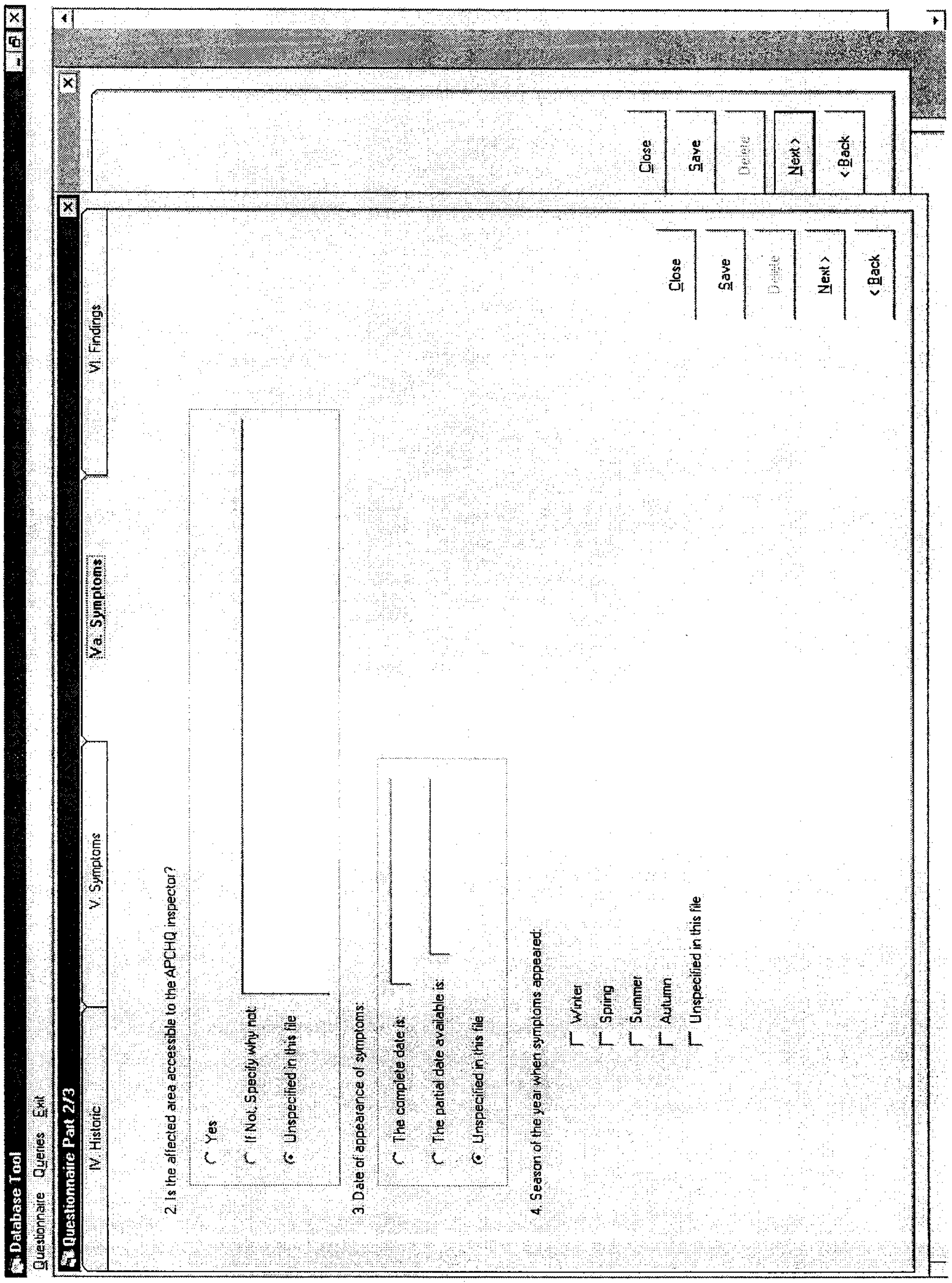


Figure A6. Symptoms (continued)

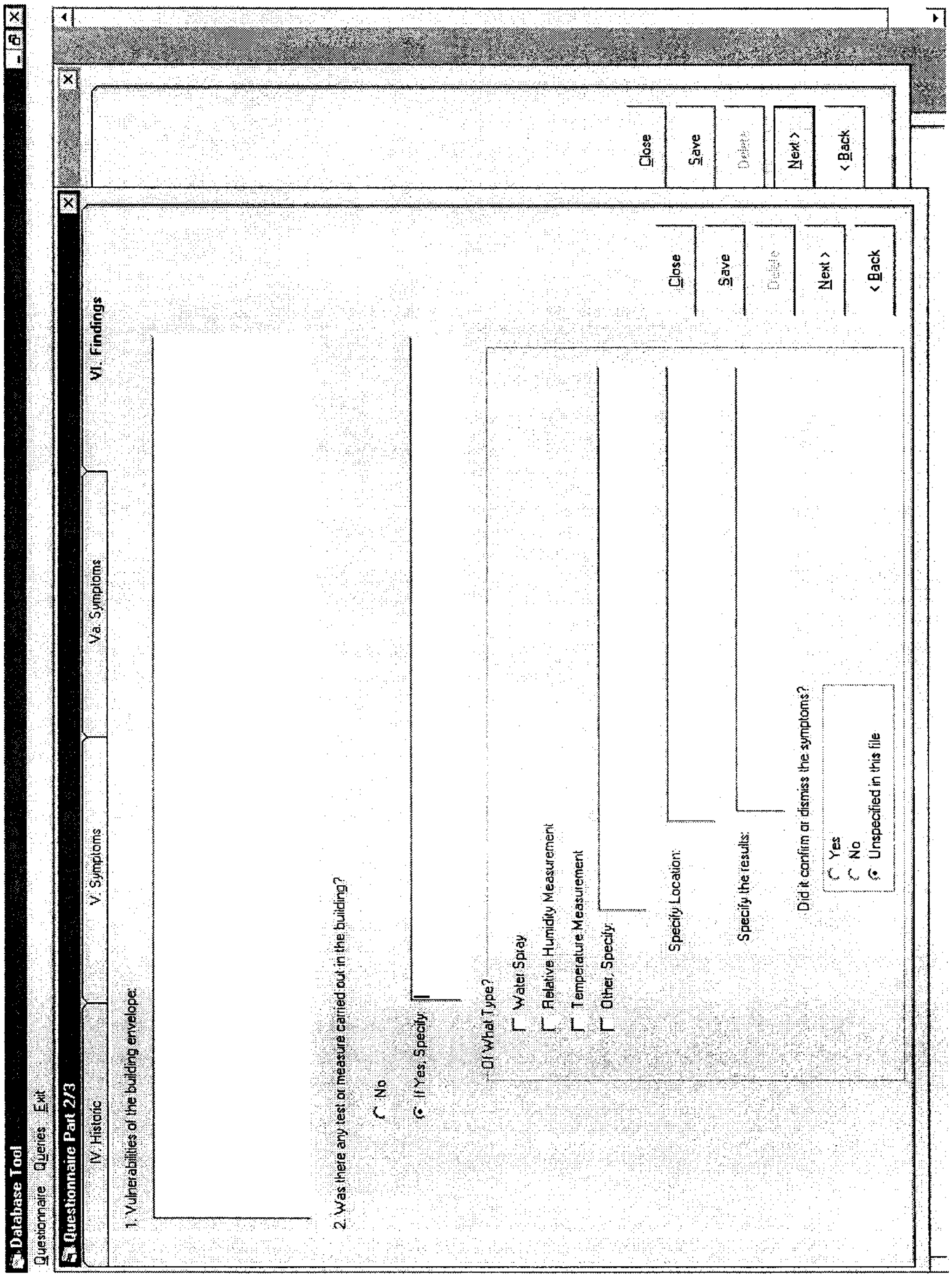


Figure A.7 Findings

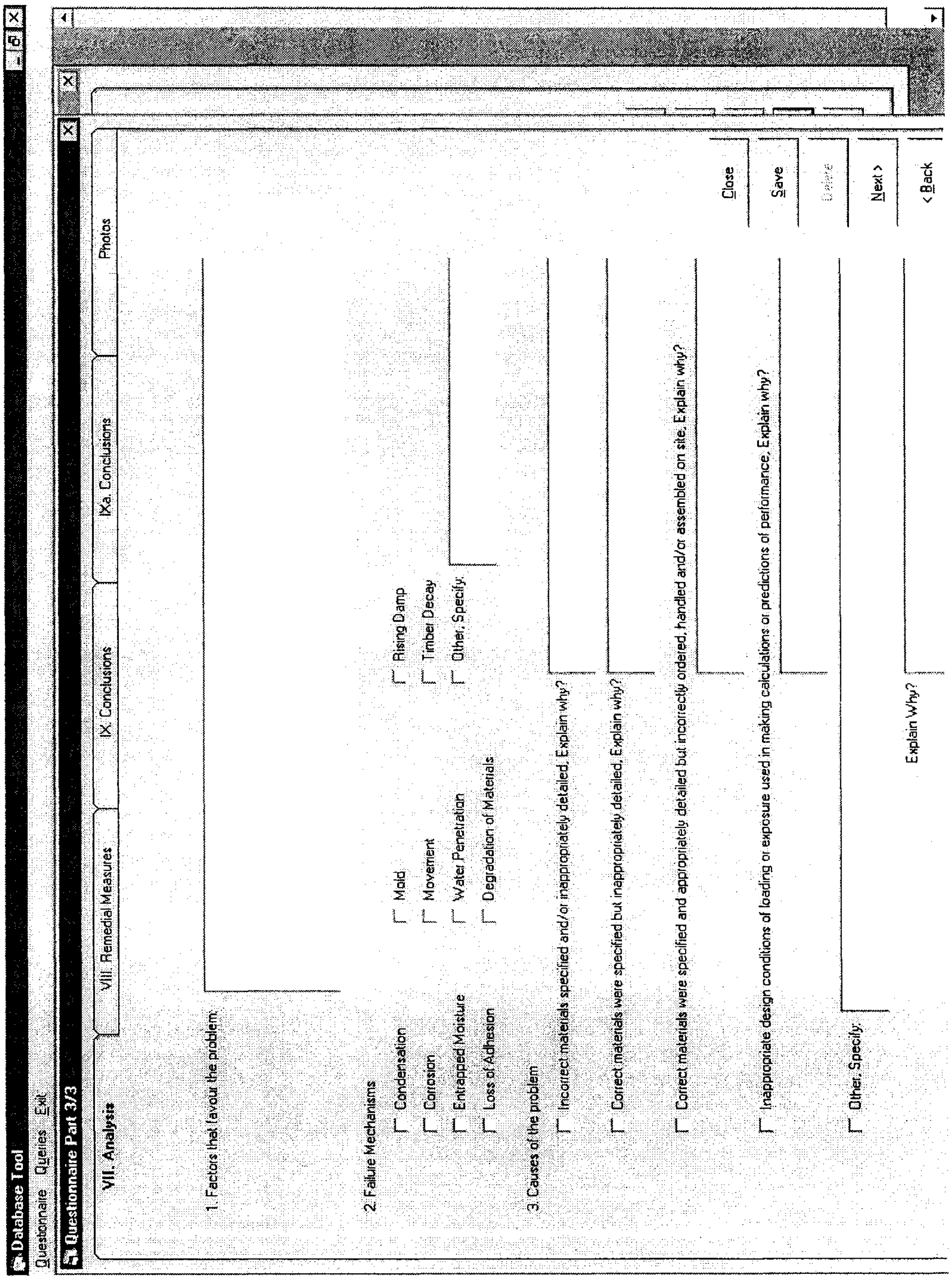


Figure A.8 Analysis

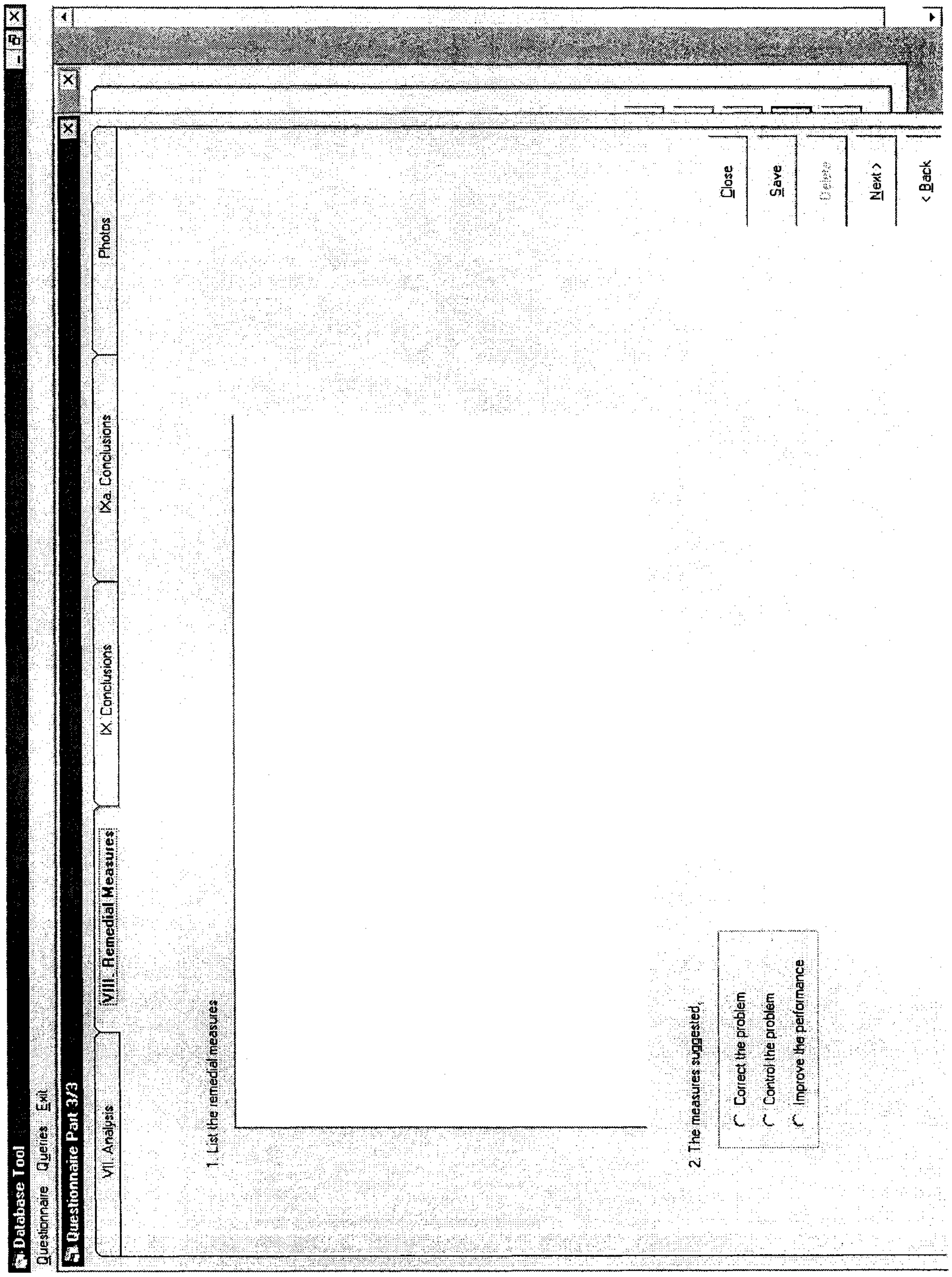


Figure A.9 Remedial Measures

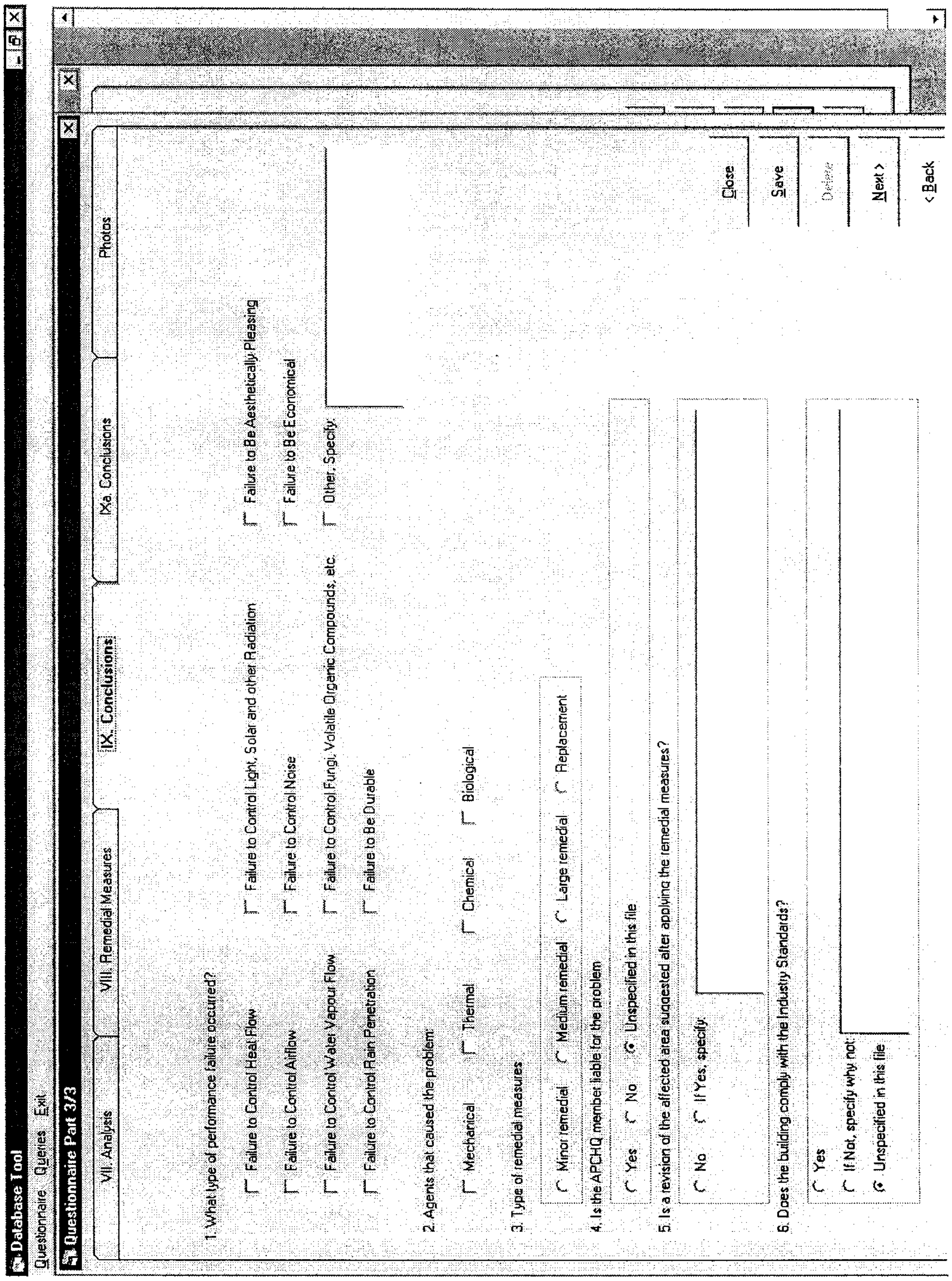


Figure A.10 Conclusions

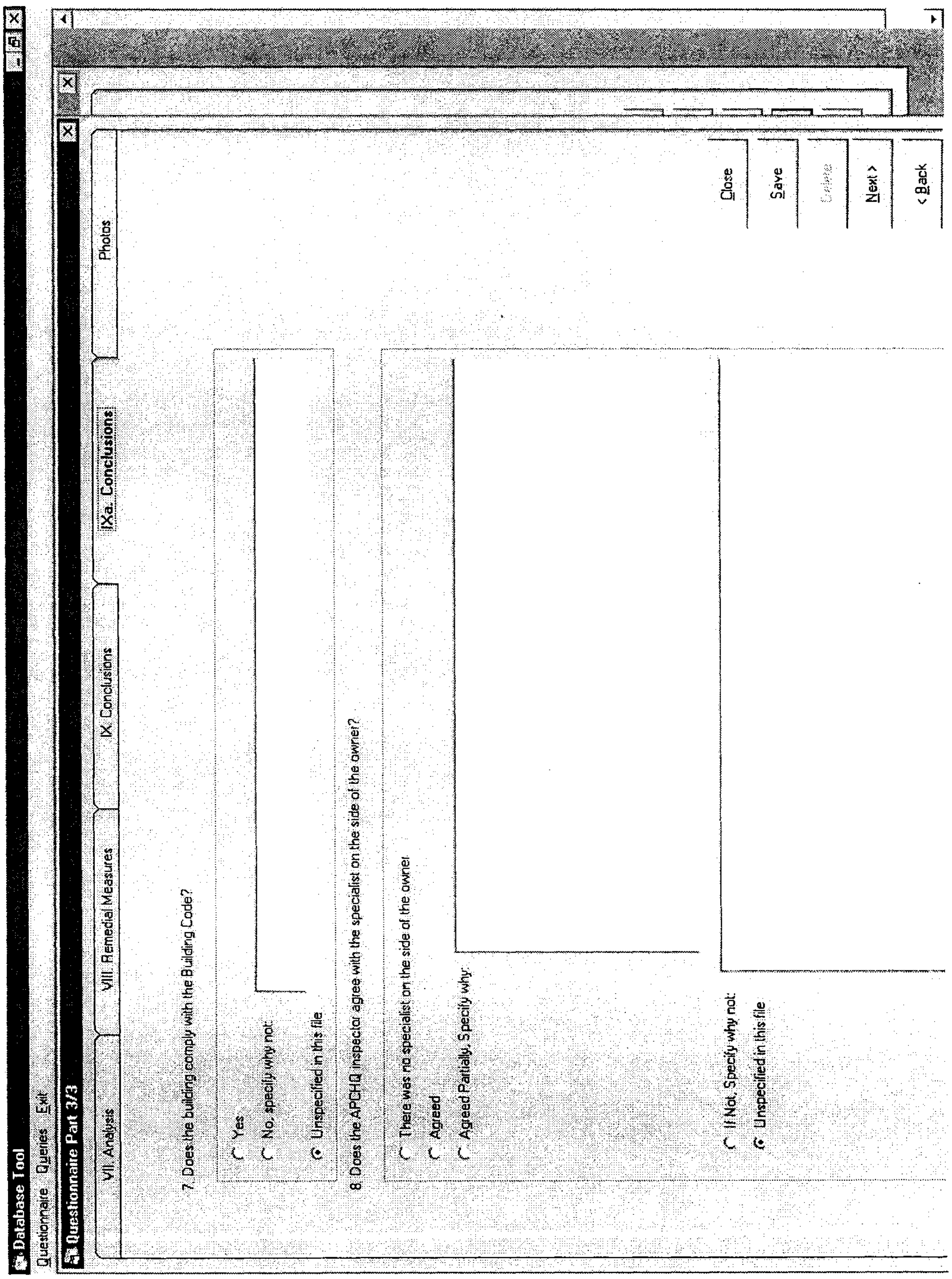


Figure A11. Conclusions (continued)

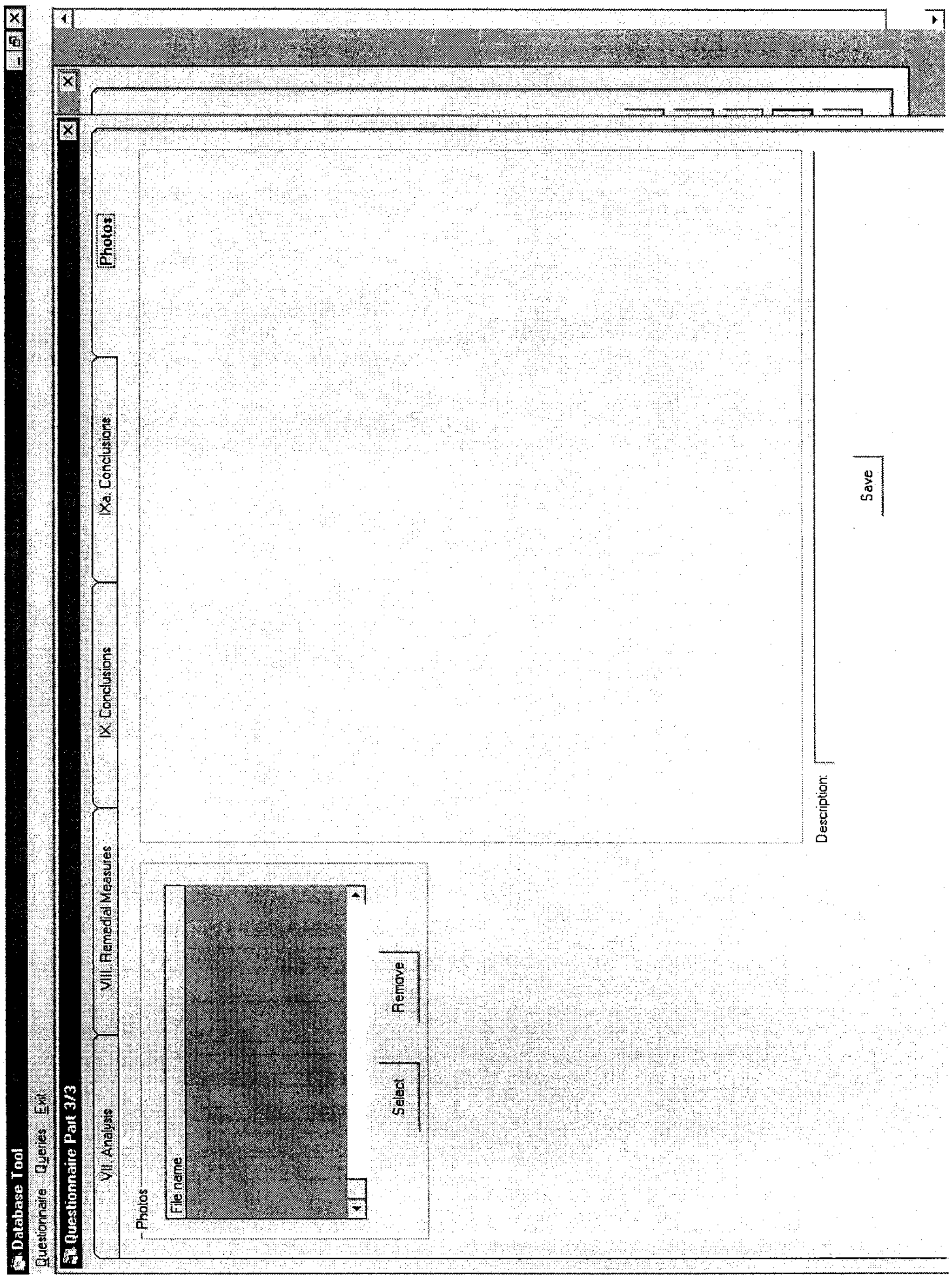


Figure A12. Photos

# Appendix B - List of cases sorted by location of symptoms

| Counter | Location | Symptom | File Number |
|---|---|---|---|
| 1 | **** | ***** | 753 |
| 2 | Attic | Air Exfiltration | 683 |
| 3 | Attic | Air Exfiltration | 684 |
| 4 | Attic | Air Infiltration | 682 |
| 5 | Attic | Air Infiltration | 692 |
| 6 | Attic | Stains (Black Stains) | 402 |
| 7 | Attic | Condensation | 649 |
| 8 | Attic | Damages Caused by Water | 742 |
| 9 | Attic | Icicles | 684 |
| 10 | Attic | Traces of Water Infiltrations | 706 |
| 11 | Attic | Water Infiltrations | 681 |
| 12 | Attic (Along the dividing wall) | Warm Air Leaks | 681 |
| 13 | Attic (Close to dividing wall) | Water Infiltrations | 683 |
| 14 | Attic (Close to gable) | Water Infiltrations | 684 |
| 15 | Attic (Insulation in Attic) | Wetness | 476 |
| 16 | Attic (Insulation in the Attic) | Wetness | 681 |
| 17 | Attic (Joist in the Attic) | Traces of Water Infiltrations | 433 |
| 18 | Attic (Plywood Deck) | Snow Accumulation | 759 |
| 19 | Attic (Through a damaged ventilator) | Water Infiltrations | 656 |
| 20 | Attic (Under Insulation) | Water Infiltrations | 649 |
| 21 | Balcony | Water Infiltrations | 761 |
| 22 | Balcony (Metallic Structure of balcony) | Air Infiltration | 532 |
| 23 | Basement | Damages Caused by Water | 609 |
| 24 | Basement | Smells (Humidity Smells) | 501 |
| 25 | Basement | Water Infiltrations | 609 |
| 26 | Basement | Water Infiltrations | 716 |
| 27 | Basement | Water Infiltrations | 746 |
| 28 | Basement | Water Infiltrations | 452 |
| 29 | Basement | Water Infiltrations | 499 |
| 30 | Basement | Water Infiltrations | 501 |
| 31 | Basement (Bathroom of dwelling in basement) | High Relative Humidity | 753 |
| 32 | Basement (Bedroom of dwelling in basement) | High Relative Humidity | 753 |
| 33 | Basement (Concrete slab at the exterior door) | Water Infiltrations | 645 |
| 34 | Basement (Family Room in Basement) | Water Infiltrations | 396 |
| 35 | Basement (Junction of Wall/Concrete Slab) | Water Infiltrations | 450 |
| 36 | Basement (Top part of foundational wall) | Water Infiltrations | 725 |
| 37 | Basement (Wall in the back) | Water Infiltrations | 412 |
| 38 | Basement (Wall Junctions) | Water Infiltrations | 642 |
| 39 | Basement Concrete Slab (Through Capillary Cracks) | Water Infiltrations | 441 |
| 40 | Basement Walls | Condensation | 501 |

| | | | |
|---|---|---|---|
| 41 | Basin | Water Infiltrations | 609 |
| 42 | Basin that Collects Rain Water | Presence of Ferrus Hydroxide in Large Amount | 452 |
| 43 | Building Elements Attached to House (Close to beam of Turret) | Traces of Water Infilrations | 527 |
| 44 | Building Elements Attached to House (Marquises d'Entrée) | Snow Accumulation | 681 |
| 45 | Carpet (Under carpet) | Traces of Condensation | 455 |
| 46 | Carpet of Bedroom | Wetness | 476 |
| 47 | Ceiling | Damages Caused by Water | 649 |
| 48 | Ceiling | Damages Caused by Water | 688 |
| 49 | Ceiling | Damages Caused by Water | 717 |
| 50 | Ceiling | Damages Caused by Water | 392 |
| 51 | Ceiling | Damages Caused by Water | 527 |
| 52 | Ceiling | Peeling of Paint | 590 |
| 53 | Ceiling | Water Infiltrations | 590 |
| 54 | Ceiling | Water Infiltrations | 688 |
| 55 | Ceiling | Water Infiltrations | 396 |
| 56 | Ceiling | Water Infiltrations | 431 |
| 57 | Ceiling | Water Infiltrations | 474 |
| 58 | Ceiling | Water Infiltrations | 483 |
| 59 | Ceiling (Access Hatch of Ceiling) | Traces of Condensation | 404 |
| 60 | Ceiling (Basement Ceiling) | Water Infiltrations | 495 |
| 61 | Ceiling (Bathroom Ceiling) | Water Infiltrations | 618 |
| 62 | Ceiling (Bathroom Ceiling) | Water Infiltrations | 693 |
| 63 | Ceiling (Ceiling Finishes) | Water Infiltrations | 681 |
| 64 | Ceiling (Ceiling of Basement) | Traces of Water Infiltrations | 495 |
| 65 | Ceiling (Ceiling of Bedroom) | Traces of Water Infiltrations | 419 |
| 66 | Ceiling (Ceiling of Living Rooms) | Cracks | 768 |
| 67 | Ceiling (Ceiling of Shower) | Mold | 649 |
| 68 | Ceiling (Close to beam) | Traces of Water Infiltration | 762 |
| 69 | Ceiling (Close to Chimney) | Water Infiltrations | 419 |
| 70 | Ceiling (Gypsum boards in Ceiling of Second Floor) | Swelling | 392 |
| 71 | Ceiling (Last Floor Ceilings) | Water Infiltrations | 696 |
| 72 | Ceiling (Second Floor Ceiling) | Water Infiltrations | 693 |
| 73 | Ceiling Assembly | Mold | 392 |
| 74 | Ceiling Assembly (Insulation in Ceiling of interior pool) | Wetness | 454 |
| 75 | Ceiling Assembly (Wood Deck) | Traces of Water Infiltrations | 449 |
| 76 | Chimney (Above Fireplace) | Water Infiltrations | 433 |
| 77 | Chimney (Brick Cladding of Chimney) | Water Infiltrations | 725 |
| 78 | Chimney (Fireplace) | Traces of Water Infiltrations | 433 |
| 79 | Chimney (Tile in Fireplace) | Loss of Adhesion | 433 |
| 80 | Cladding | Condensation | 621 |
| 81 | Cladding | Damages Caused by Water | 521 |
| 82 | Cladding | Efflorescence | 521 |
| 83 | Cladding | Water Infiltrations | 625 |

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| 84 | Cladding (Exterior Cladding) | Damages Caused by Water | 402 |
| 85 | Cladding (Mortar Joints of Brick Cladding) | Cracks | 449 |
| 86 | Cladding (Stone Cladding) | Stains (White Stains) | 521 |
| 87 | Cladding (Stones in Cladding) | Loss of Adhesion | 521 |
| 88 | Cold Room | Water Infiltrations | 396 |
| 89 | Deck | Mold | 433 |
| 90 | Deck (Floor Deck) | Wetness | 699 |
| 91 | Deck (Plywood deck in the front secion of the Attic) | Traces of Water Infiltrations | 481 |
| 92 | Deck (Plywood Roof Deck) | Mold | 390 |
| 93 | Deck (Plywood Roof Deck) | Undulation | 390 |
| 94 | Deck (Plywood Roof Deck) | Unwedging | 390 |
| 95 | Deck (Roof Deck in Façade close to Valley) | Wetness | 476 |
| 96 | Deck (Roof Deck under gutter downspout) | Deflection | 742 |
| 97 | Deck (Roof Deck) | Frost | 472 |
| 98 | Deck (Roof Deck) | Wetness | 699 |
| 99 | Deck (Roof Deck) | Wetness | 472 |
| 100 | Door | Condensation | 692 |
| 101 | Door (Front door) | Condensation | 695 |
| 102 | Doors (Around Door) | Air Infiltration | 682 |
| 103 | Drain on the perimeter of foundation | Presence of Ferrus Hydroxide in Large Amount | 452 |
| 104 | Electrical Room | Rot | 455 |
| 105 | Electrical Systems | Air Infiltration | 682 |
| 106 | Electrical Systems | Air Infiltration | 700 |
| 107 | Façade | Stains (Black Stains) | 402 |
| 108 | Façade | Traces of Water Infiltrations | 402 |
| 109 | Façade | Water Infiltrations | 700 |
| 110 | Façade (Between Drip and Wood Moldings) | Water Infiltrations | 528 |
| 111 | Façade (Junctions) | Water Infiltrations | 404 |
| 112 | False Floor in Basement | Damages Caused by Water | 762 |
| 113 | Finishes (Ceiling Finishes) | Damages Caused by Water | 681 |
| 114 | Finishes (Ceiling Finishes) | Damages Caused by Water | 683 |
| 115 | Finishes (Ceiling Finishes) | Damages Caused by Water | 684 |
| 116 | Finishes (Ceiling Finishes) | Damages Caused by Water | 693 |
| 117 | Finishes (Ceiling Finishes) | Damages Caused by Water | 696 |
| 118 | Finishes (Ceiling Finishes) | Damages Caused by Water | 699 |
| 119 | Finishes (Ceiling Finishes) | Damages Caused by Water | 706 |
| 120 | Finishes (Ceiling Finishes) | Damages Caused by Water | 524 |
| 121 | Finishes (Floor Finish) | Damages Caused by Water | 706 |
| 122 | Finishes (Floor Finishes) | Damages Caused by Water | 489 |
| 123 | Finishes (Floor Finishes) | Damages Caused by Water | 579 |
| 124 | Finishes (Floor Finishes) | Damages Caused by Water | 584 |
| 125 | Finishes (Gypsum Finishes) | Damages Caused by Water | 679 |
| 126 | Finishes (Interior of a Closet) | Damages Caused by Water | 759 |
| 127 | Finishes (Paint Finish) | Bubbles | 483 |
| 128 | Finishes (Plaster Covering of Ceiling) | Undulation | 483 |
| 129 | Finishes (Plaster Finish) | Cracks | 483 |

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| 130 | Finishes (Plaster Finish) | Undulation | 483 |
| 131 | Finishes (Wall Finishes) | Damages Caused by Water | 681 |
| 132 | Finishes (Wall Finishes) | Damages Caused by Water | 684 |
| 133 | Finishes (Wall Finishes) | Damages Caused by Water | 699 |
| 134 | Finishes (Wall Finishes) | Damages Caused by Water | 760 |
| 135 | Finishes (Wall Finishes) | Damages Caused by Water | 447 |
| 136 | Finishes (Wall Finishes) | Damages Caused by Water | 476 |
| 137 | Finishes (Wall Finishes) | Damages Caused by Water | 579 |
| 138 | Firewall | Cracks (Capillary Cracks) | 455 |
| 139 | Firewall | Settlement | 455 |
| 140 | Floor | Air Infiltration | 692 |
| 141 | Floor | Condensation | 609 |
| 142 | Floor | Damages Caused by Water | 679 |
| 143 | Floor | Damages Caused by Water | 684 |
| 144 | Floor | Traces of Water Infiltration | 760 |
| 145 | Floor | Water Infiltrations | 493 |
| 146 | Floor | Wetness | 691 |
| 147 | Floor (Floor at the access door) | Water Infiltrations | 645 |
| 148 | Floor (Kitchen Floor) | Thermal Discomfort | 633 |
| 149 | Floor (Parquet floor strips) | Loss of Adhesion | 584 |
| 150 | Floor (Parquet Floor strips) | Mold | 584 |
| 151 | Floor (Parquet floor) | Traces of Water Infiltrations | 584 |
| 152 | Foundational Wall | Cracks | 606 |
| 153 | Foundational Wall | Cracks | 609 |
| 154 | Foundational Wall | Crumbling | 746 |
| 155 | Foundational Wall | Damages Caused by Water | 762 |
| 156 | Foundational Wall | Sulphate Attack | 746 |
| 157 | Foundational Wall (Foundation in the back wall) | Cracks | 748 |
| 158 | Foundational Walls | Condensation | 441 |
| 159 | Foundational Walls | Cracks | 499 |
| 160 | Foundational Walls | Cracks | 501 |
| 161 | Foundational Walls | High Relative Humidity | 725 |
| 162 | Foundational Walls | Traces of Humidity | 501 |
| 163 | Foundational Walls (Back Foundation) | Water Infiltrations | 700 |
| 164 | Foundational Walls (Base of foundational wall) | Water Infiltrations | 746 |
| 165 | Foundational Walls (Bottom) | Water Infiltrations | 571 |
| 166 | Foundational Walls (Junction of slab and foundational wall) | Water Infiltrations | 761 |
| 167 | Foundational Walls (Perimeter of Foundation) | Water Infiltrations | 513 |
| 168 | Foundational Walls (Through cracks) | Water Infiltrations | 748 |
| 169 | Garage | Water Infiltrations | 606 |
| 170 | Gypsum Sheathing | Water Infiltrations | 691 |
| 171 | Gypsum Sheathing | Traces of Water Infiltrations | 584 |
| 172 | Heating System | Air Infiltration | 525 |
| 173 | House | Air Exfiltration | 423 |

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| 174 | House | Air Infiltration | 423 |
| 175 | House | High Heating Bills | 628 |
| 176 | House | High Heating Bills | 682 |
| 177 | House | High Heating Bills | 700 |
| 178 | House | High Heating Bills | 423 |
| 179 | House | Low Relative Humidity | 692 |
| 180 | House | Thermal Discomfort | 682 |
| 181 | House | Traces of Water Infiltrations | 481 |
| 182 | House | Water Infiltrations | 679 |
| 183 | House (Bathroom) | High Relative Humidity | 645 |
| 184 | House (Bedroom) | Damages Caused by Water | 419 |
| 185 | House (Certain rooms of the house) | Thermal Discomfort | 628 |
| 186 | House (Close to Pool) | Water Infiltrations | 558 |
| 187 | House (Dining Room) | Thermal Asimetry | 591 |
| 188 | House (Dwellings of the Building) | Damages Caused by Water | 483 |
| 189 | House (House in general) | High Relative Humidity | 645 |
| 190 | House (Kitchen and other rooms) | Cracks (Capillary Cracks) | 491 |
| 191 | House (Kitchen) | High Relative Humidity | 645 |
| 192 | House (Kitchen) | Water Infiltrations | 524 |
| 193 | House (Living Room) | Air Exfiltration | 684 |
| 194 | House (Living Room) | Thermal Asymmetry | 591 |
| 195 | House (Room above Kitchen) | Water Infiltrations | 521 |
| 196 | House (Stairs of House) | Air Infiltration | 633 |
| 197 | House (Storage Room under the dwelling) | Corrosion (Corrosion of Metallic Elements) | 609 |
| 198 | Insulation | Water Infiltrations | 691 |
| 199 | Junction of Vertical and Horizontal Panels | Water Infiltrations | 760 |
| 200 | Juncture of Ceiling and Wall | Cracks (Capillary Cracks) | 447 |
| 201 | Left and Right Elevations | Rot | 402 |
| 202 | Membrane (Finish Membrane) | Folds | 416 |
| 203 | Membrane (Roof Membrane) | Bubbles of Tar | 411 |
| 204 | Membrane (Roof Membrane) | Bulging | 691 |
| 205 | Membrane (Roof Membrane) | Degradation | 411 |
| 206 | Membrane (Roof Membrane) | Traces of Repairs | 416 |
| 207 | Membrane (Under Membrane of Roof) | Traces of Condensation | 483 |
| 208 | Parapet (Parapet Flashings) | Traces of Rust | 411 |
| 209 | Perimetral Drain (Flapper (Clappet de Retenu) of Discharge of drainage system on the perimeter of the foundation) | Presence of Ferrus Hydroxide in Large Amount | 452 |
| 210 | Projection of back wall of house | Traces of Water Infiltrations | 495 |
| 211 | Puisards | Water Infiltrations | 474 |
| 212 | Rive de Pourtour | Air Infiltration | 682 |
| 213 | Roof | Ice Accumulation | 476 |
| 214 | Roof | Ice Accumulation | 481 |
| 215 | Roof | Ice Dams | 681 |
| 216 | Roof | Ice Dams | 759 |
| 217 | Roof | Ice Dams | 491 |

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| 218 | Roof | Snow Accumulation | 681 |
| 219 | Roof | Deflection (Structural Deflection) | 411 |
| 220 | Roof | Water Infiltrations | 638 |
| 221 | Roof | Water Infiltrations | 641 |
| 222 | Roof | Water Infiltrations | 656 |
| 223 | Roof | Water Infiltrations | 768 |
| 224 | Roof | Water Infiltrations | 491 |
| 225 | Roof | Water Infiltrations | 558 |
| 226 | Roof (Aluminium Fascia) | Damages | 416 |
| 227 | Roof (Back face of the roof) | Ice Dams | 683 |
| 228 | Roof (Back face of the roof) | Snow Accumulation | 683 |
| 229 | Roof (Back Slope) | Water Infiltrations | 649 |
| 230 | Roof (Bordure de Toit) | Ice Accumulation | 754 |
| 231 | Roof (Cornice) | Ice Accumulation | 760 |
| 232 | Roof (Cornice) | Ice Accumulation | 476 |
| 233 | Roof (Cornices) | Ice Dams | 474 |
| 234 | Roof (Cornices) | Ice Dams | 481 |
| 235 | Roof (Cornices) | Icicles | 683 |
| 236 | Roof (Cornices) | Water Infiltrations | 474 |
| 237 | Roof (Edge of Roof) | Ice Dams | 599 |
| 238 | Roof (Edge of Roof) | Icicles | 628 |
| 239 | Roof (Front face of the roof) | Snow Accumulation | 684 |
| 240 | Roof (Front Roof) | Snow Accumulation | 481 |
| 241 | Roof (Front Section) | Ice Accumulation | 419 |
| 242 | Roof (Front Valley) | Water Infiltrations | 476 |
| 243 | Roof (Garage Roof) | Snow Accumulation | 706 |
| 244 | Roof (Gutters) | Ice Accumulation | 599 |
| 245 | Roof (Gutters) | Ice Accumulation | 481 |
| 246 | Roof (Gutters) | Ice Dams | 684 |
| 247 | Roof (Junction of 2 different roofs) | Ice Accumulation | 749 |
| 248 | Roof (Junction of 2 different roofs) | Icicles | 749 |
| 249 | Roof (Junction of 2 different roofs) | Water Infiltrations | 649 |
| 250 | Roof (Main basin of the roof) | Ice Accumulation | 558 |
| 251 | Roof (Metallic Roof Edge) | Damages | 416 |
| 252 | Roof (Middle of Roof Slope) | Water Infiltrations | 524 |
| 253 | Roof (South Valleys) | Water Infiltrations | 474 |
| 254 | Roof (Valleys on the back) | Water Infiltrations | 693 |
| 255 | Roof (Valleys on the front) | Snow Accumulation | 706 |
| 256 | Roof (Valleys) | Ice Dams | 474 |
| 257 | Roof (Valleys) | Ice Dams | 521 |
| 258 | Roof Assembly | Condensation | 688 |
| 259 | Roof Assembly | Mold | 433 |
| 260 | Roof Assembly | Water Infiltrations | 599 |
| 261 | Roof Assembly (Certain Roof Trusses) | Traces of Water Infiltrations | 489 |
| 262 | Roof Assembly (OSB Panel (Wood Shavings Panel) in roof) | Frost | 419 |
| 263 | Roof Assembly (Plywood of the roof) | Traces of Water Infiltrations | 447 |

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| 264 | Roof Assembly (Plywood Panels in Roof) | Undulation | 768 |
| 265 | Roof Assembly (Rafters of the Roof) | Traces of Water Infiltrations | 447 |
| 266 | Roof Assembly (Roof Joists) | Wetness | 691 |
| 267 | Roof Assembly (Roof Joists) | Wetness | 699 |
| 268 | Roof Assembly (Steel beam of Terrace Roof) | Corrosion (Rust) | 717 |
| 269 | Roof Assembly (Waferboard of Terrace Roof) | Rot | 717 |
| 270 | Roof Covering | Water Infiltrations | 489 |
| 271 | Roof Covering (Asphalt Shingles) | Damages Caused by De-Icing Procedure | 491 |
| 272 | Roof Covering (Asphalt Shingles) | Deformation | 407 |
| 273 | Roof Covering (Cedar Shingles) | Cracks | 449 |
| 274 | Roof Covering (Cedar Shingles) | Damages Caused by De-Icing Procedure | 491 |
| 275 | Roof Covering (Cedar Shingles) | Rupture | 449 |
| 276 | Roof Covering (Grains in Asphalt Shingles) | Loss of Adhesion | 407 |
| 277 | Sanitary Duct | Water Infiltrations | 609 |
| 278 | Sanitary Duct | Water Infiltrations | 396 |
| 279 | Sewage Discharge Pipe | Condensation | 455 |
| 280 | Shelves for storage | Spots (Black Spots) | 571 |
| 281 | Siding | Condensation | 692 |
| 282 | Slab (Concrete Slab) | Cracks | 450 |
| 283 | Slab (Concrete Slab) | Rupture | 450 |
| 284 | Slab (Concrete Slab) | Water Infiltrations | 396 |
| 285 | Slab (Floor Slab) | Water Infiltrations | 609 |
| 286 | Soffit | Ice Accumulation | 679 |
| 287 | Soffit | Traces of Water Infiltrations | 404 |
| 288 | Soffit | Water Infiltrations | 404 |
| 289 | Soffit (Aluminium Soffits) | Frost | 681 |
| 290 | Structure | Damages Caused by Water | 402 |
| 291 | Structure (Structure of Expansion) | Rot | 402 |
| 292 | Structure (Wood Structure) | Air Infiltration | 532 |
| 293 | Turret Covering | Damages Caused by De-Icing Procedure | 491 |
| 294 | Unspecified Location | Water Infiltrations | 447 |
| 295 | Vanite of Bathroom | Air Infiltration | 682 |
| 296 | Ventilation Systems | Air Infiltration | 682 |
| 297 | Ventilation Systems | Air Infiltration | 700 |
| 298 | Wall Assembly (Air barrier paper) | Water Infiltrations | 706 |
| 299 | Wall Assembly (Foam Insulation in Basement) | Spots (Black Spots) | 645 |
| 300 | Wall Assembly (OSB Close to Window Frame) | Rot | 625 |
| 301 | Wall Assembly (Wall Insulation) | Water Infiltrations | 599 |
| 302 | Wall Assembly (Wall Insulation) | Water Infiltrations | 625 |
| 303 | Wall Assembly (Wall Insulation) | Water Infiltrations | 641 |
| 304 | Wall Structure | Damages Caused by Water | 402 |

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| 305 Walls | Damages Caused by Water | 725 |
| 306 Walls | Damages Caused by Water | 455 |
| 307 Walls (Above Basement Window) | Water Infiltrations | 495 |
| 308 Walls (Along left side wall) | Dripping Water Noises | 501 |
| 309 Walls (Balcony Walls) | Mold | 495 |
| 310 Walls (Base of Walls) | Air Infiltration | 692 |
| 311 Walls (Basement Walls) | Efflorescence | 501 |
| 312 Walls (Basement Walls) | Traces of Humidity | 440 |
| 313 Walls (Basement Walls) | Traces of Humidity | 441 |
| 314 Walls (Closet Walls) | Mold | 441 |
| 315 Walls (Exterior Kitchen Wall) | Thermal Asymmetry | 682 |
| 316 Walls (Exterior Walls) | Air Infiltration | 621 |
| 317 Walls (Front Walls) | Water Infiltrations | 476 |
| 318 Walls (Laundry Room Walls) | Mold | 501 |
| 319 Walls (Wall around discharge pipe of sink) | Air Infiltration | 682 |
| 320 Walls (Wall that separates mechanical room from laundry) | Wetness | 501 |
| 321 Walls (Wall under landing of stairs) | Traces of Water Infiltrations | 513 |
| 322 Walls (Walls of Cold Room) | Cracks | 439 |
| 323 Walls (Walls of Office and Workshop) | Corrosion (Rust) | 455 |
| 324 Walls (Walls of Office and Workshop) | Traces of Humidity | 455 |
| 325 Walls (Walls of Office and Workshop) | Traces of Mud | 455 |
| 326 Water System (Water Conduits Access Hatch) | Water Infiltrations | 609 |
| 327 Water System (Water Pipes) | Frozen Water Pipes | 532 |
| 328 Windows | Air and Snow Infiltrations | 621 |
| 329 Windows | Air Infiltration | 621 |
| 330 Windows | Condensation | 591 |
| 331 Windows | Condensation | 606 |
| 332 Windows | Condensation | 692 |
| 333 Windows | Condensation | 695 |
| 334 Windows | Condensation | 445 |
| 335 Windows | Condensation | 575 |
| 336 Windows | Damages Caused by Water | 682 |
| 337 Windows | Dirt and Sand Intrusion | 621 |
| 338 Windows | Mold | 645 |
| 339 Windows | Mold | 445 |
| 340 Windows | Water Infiltrations | 625 |
| 341 Windows | Water Infiltrations | 768 |
| 342 Windows (Above Window) | Water Infiltrations | 584 |
| 343 Windows (Base of Glazing) | Water Infiltrations | 579 |
| 344 Windows (Base of Windows)**In Winter** | Frost (Frost Accumulation) | 445 |
| 345 Windows (Basement Window) | Water Infiltrations | 493 |
| 346 Windows (Bathroom Windows) | Condensation | 682 |
| 347 Windows (Head of Window-Door) | Water Infiltrations | 655 |
| 348 Windows (Kitchen Windows) | Air Infiltration | 682 |
| 349 Windows (Kitchen Windows) | Water Infiltrations | 521 |

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| 350 | Windows (Window Junctions) | Water Infiltrations | 625 |
| 351 | Windows (Window Junctions) | Water Infiltrations | 660 |
| 352 | Windows (Window Mullions of bathroom and kitchen) | Rot | 645 |
| 353 | Windows (Window Shutter) | Mold | 645 |
| 354 | Windows (Window Shutters) | Air Exfiltration | 660 |
| 355 | Windows (Window Shutters) | Air Infiltration | 660 |
| 356 | Windows (Window Wedges) | Water Infiltrations | 617 |
| 357 | Windows (Window-Door) | Water Infiltrations | 761 |
| 358 | Windows (Windows of Basement) | Condensation | 609 |
| 359 | Windows (Windows of Basement) | Condensation | 645 |
| 360 | Windows (Windows of ground floor) | Condensation | 645 |
| 361 | Windows (Windows of the Cold Room) | Mold | 439 |

# Appendix C

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| **File Number** | 590 |
| **Problem Location** | Ceiling of the last floor |
| **Building Type** | Triplex in Row |
| **Storeys** | 3 |
| **Problem** | Water Infiltrations (Specify location:_Ceiling of the last floor) |
| **Symptoms** | Water infiltrations – (Specify location: _Ceiling of the bedroom);<br><br>Other, Specify: _Peeling of Paint in the ceiling of the bedroom; |
| **Vulnerabilities** | - Excessive ventilation in the attic localized at the Maximum ventilator. This causes condensation of warm air in that area. |
| **Factors Affecting** | - The uneven distribution of the humid air evacuation<br><br>- The very slow extraction discharge |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design of the roof and its components favor Condensation |
| **Remedy** | - Change the Maximum ventilator and put a Goose Neck conventional type<br><br>- Augment the ventilation surface of the other Goose Neck ventilators to the maximum<br><br>-Install two new Goose Neck ventilators in the north section of the roof<br><br>- Dry the roof assembly by forcing fresh and dry air into it until the RH of the material reaches 19% |

*Information as extracted from APCHQ files*

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| **File Number** | 591 |
| **Problem Location** | Living and Dining Room; |
| **Building Type** | Other, Specify: _Semidetached apartment house |
| **Storeys** | 3 ½ |
| **Problem** | Condensation in Windows (Specify location:_Living and Dining Room);<br>Other, Specify: _Thermal asymmetry in the dwelling; |
| **Symptoms** | Condensation – (Specify location:_Windows);<br><br>Thermal Asymmetry – (Specify location:_Living Room and Dining Room are colder than rest of the house); |
| **Vulnerabilities** | - The window surface represents 35% of the room's exposed wall surface |
| **Factors Affecting** | - Stack effect localized at the chimney makes the air to circulate, cooling the room. This is due to the fact that the heating system installed of 2250 watts is to the limit.;<br><br>- The room is oriented to the North West; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_Building design causes stack effect |
| **Remedy** | - Ventilate the house adequately and maintain a R.H. in function of the exterior temperature. Ex. R.H.=35%, Interior Temp.=20°C, Ext. Temp.=-15°C;<br><br>- Adjust the balcony door to limit the possible air infiltrations;<br><br>- Limit the heat losses at the fireplace caused by air flux by installing doors in front of it.; |

*Information as extracted from APCHQ files*

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| **File Number** | 599 |
| **Problem Location** | Roof |
| **Building Type** | Other, Specify: _Row Houses |
| **Storeys** | 3 |
| **Problem** | Ice Accumulation (Specify location:_Edge of Roofs) |
| **Symptoms** | Ice Accumulation – (Specify location:_Gutters);<br><br>Ice Dams – (Specify location:_Edge of the roofs);<br><br>Water infiltrations – (Specify location:_Roof Assembly; Insulation at the Low wall of facade); |
| **Vulnerabilities** | - In the front section of the roof the cornice (corniche) is the means of ventilation of the attic and it is not continuous. The low walls in the façade limit water flow and air circulation.;<br><br>- In the back section of the roof, the configuration of the attic and the cathedral section slow down the air aspiration through the cornice (corniche).;<br><br>- Heat losses at the skylights; |
| **Factors Affecting** | - Ice accumulation at the gutters;<br><br>- Weak ventilation in the attic;<br><br>- Heat losses at the roof assembly;<br><br>- Solar Radiation that heats the wood deck or the shingles and melts the snow contributing to the formation of ice dams; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_Because the design favours the existence of ice dams and there are heat losses in the assembly |
| **Remedy** | - Ensure that under the plywood in the back of the attic the insulation is properly installed at the junction of the beam and wall;<br><br>- Increase the ventilation in the front and in the back by using grills in the actual soffit;<br><br>- Install grills in the front low walls to increase the air movement;<br><br>- Install an adequate membrane in the back of the aluminium siding to |

*Information as extracted from APCHQ files*

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| | diminish the risk of water infiltrations; |
| **File Number** | 606 |
| **Problem Location** | Windows; |
| **Building Type** | Other, Specify: _Detached Cottage House |
| **Storeys** | 2 |
| **Problem** | Condensation in Windows (Specify location:_Living Room, Bathroom, Bedroom);<br><br>Water Infiltrations (Specify location:_ Garage);<br><br>Water Infiltrations in the Basement;<br><br>Other, Specify _Deterioration of the windows "thermos" type; |
| **Symptoms** | Condensation – (Specify location: Windows "thermos" type, Wall assembly at the level of the construction paper);<br><br>Water infiltrations – (Specify location: _Garage);<br><br>Other, Specify: _Cracks at the foundational wall; |
| **Vulnerabilities** | There are cracks in the foundational wall |
| **Factors Affecting** | - The condensation at the windows "thermos"type is due to a premature failure of their seals that cause a lack of tightness.;<br>- The water infiltrations in the upper part of the foundational wall of the garage are due to a deficiency in the flashing at the base of the brick cladding.;<br>- The moisture migration problem at the basement wall assembly is due to the absence of a vapor retarder.; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_There are cracks in the foundational wall; |
| **Remedy** | - For the Foundational Wall, replace the defective flashing;<br><br>- For the windows, there is no remedial measure suggested;<br><br>- For the wet wall assembly, there are two possible solutions:<br>a)Dismount all the gypsum panels and the insulation, dry the walls and install a vapor retarder type #1, making sure that it is put adequately.<br>b)Dismantle the assembly of existing materials and spray the concrete walls with a polyurethane foam of no less than 2 inches thick |

*Information as extracted from APCHQ files*

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| **File Number** | 609 |
| **Problem Location** | Basement |
| **Building Type** | Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Condensation – (Specify location:_Underneath the floor tiles in the house and at the windows of the basement)<br><br>Damages Caused by water – (Specify location: _Basement)<br><br>Water infiltrations – (Specify location: _Basement; Water Conduits Access Hatch in front of the façade wall; At the back of the house in the sanitary duct between the bathroom and the dwelling; From underneath the floor slab in the technical room where the sump pump is located; From the sump);<br><br>Other, Specify: _Corrosion of Metallic elements at the storage room under the dwelling, Cracks at the foundational wall; |
| **Vulnerabilities** | - The French drain is not connected to the water basin.;<br><br>- The drainage system relies on the perforations done to the basin as a means of evacuating the water. These perforations after some time get clogged.;<br><br>- There are cracks in the foundational wall;<br><br>- At the basement, the position of the window in relation to the wall combined with the fact that the blinds remain closed, favour the cooling of the glazing and with this, condensation occurs.; |
| **Factors Affecting** | - During the period when snow melts, the amount of water in the drain increases dramatically, as opposed to summer period. This water accumulates under the slab until it reaches the top of it. Then it infiltrates to the interior of the house. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? This design is causes water infiltrations to the house |
| **Remedy** | - Connect the drain and the basin;<br><br>- Dry the empty space under the false deck;<br><br>- Inject or fill in the cracks in the foundational wall through the exterior; |

*Information as extracted from APCHQ files*

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| | - Install an air exchanger to control the R.H. at the house and reduce the condensation.; |
| **File Number** | 617 |
| **Problem Location** | Windows |
| **Building Type** | Other, Specify: _Residential Building held in divided Coproperty |
| **Storeys** | 4 |
| **Problem** | Water Infiltrations (Specify location:_Windows of the Bedrooms) |
| **Symptoms** | Water infiltrations – (Specify location: Window wedges of the bedrooms ) |
| **Vulnerabilities** | |
| **Factors Affecting** | |
| **Causes** | NA |
| **Remedy** | - There were no remedial measures recommended in this file |

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| **File Number** | 618 |
| **Problem Location** | Ceiling of the bathroom |
| **Building Type** | Residential Building (Detached Cottage House) |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location:_Ceiling of the bathroom) |
| **Symptoms** | Water infiltrations -- (Specify location: _Ceiling of the bathroom) |
| **Vulnerabilities** | - The junction of the bathroom roof to the principal section of the roof infiltrates water. |
| **Factors Affecting** | - The lack of ventilation in the affected area;<br><br>- The heat losses generated by the masonry structure of the house;<br><br>- The snow accumulations in that part of the roof that progressively turns into ice dams;<br><br>- The defrost water that cannot drip freely and makes the flashing system fail; |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_The problem was caused by the lack of tightness due to a poor detail at the junction of the bathroom roof and the principal roof section. |
| **Remedy** | - Sealing of the affected zone to correct the lack of tightness;<br><br>- Installation of new plywood to improve the roof condition;<br><br>- Installation of a double auto adhesive membrane to improve the roof condition; |

*Information as extracted from APCHQ files*

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| **File Number** | 621 |
| **Problem Location** | Windows; |
| **Building Type** | Other, Specify: _ Prefabricated Building (Detached Bungalow) |
| **Storeys** | 1 |
| **Problem** | Air Infiltrations (Specify location:_Through the windows, through the bottom of the exterior walls);<br><br>Other, Specify _Snow infiltrations around the sealed glass panels of the windows turret of the dining room;<br>Condensation behind the vinyl cladding; |
| **Symptoms** | Air Infiltration – (Specify location:_ Through the windows, through the base of the exterior walls);<br><br>Condensation – (Specify location:_Behind the Vinyl cladding);<br><br>Other, Specify: _ Snow infiltrations around the sealed glass panels of the window's turret of the dining room and at the window sill;<br><br>Dirt and sand intrusion through the windows; |
| **Vulnerabilities** | - Lack of tightness at the windows;<br>- Lack of tightness at the base of the exterior walls;<br>- Inadequate elimination of the humidity behind the siding caused by deficient ventilation inside the cavity that doesn't enable a good pressure equalization that would favour the drainage of the cavity.; |
| **Factors Affecting** | - Solar radiation that melts the frozen condensation behind the siding |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_The lack of tightness is a consequence of a poor assembly job as well as the lack of ventilation in the cavity. |
| **Remedy** | - In the case of condensation behind the siding, lift part of the cover of the siding in the bottom of the wall to allow ventilation and drainage of the cavity;<br><br>- In the case of air infiltration at the base of the wall, the use of a sealant in the affected area;<br><br>- In the case of air infiltration at the windows, the use of sealants in the affected area and execution of sealing according to details; |

*Information as extracted from APCHQ files*

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| **File Number** | 625 |
| **Problem Location** | Windows |
| **Building Type** | Other, Specify: _Residential Buildings held in divided Coproperty |
| **Storeys** | 2&3 |
| **Problem** | Water Infiltrations (Specify location:_Windows in the projections (saillies) of different buildings of the residential complex) |
| **Symptoms** | Water infiltrations – (Specify location: _ Windows in the projections (saillies) of different buildings of the residential complex, At the junction of the moulding and the window frame, At the insulation in the wall assembly close to the windows, Under the aluminium cladding);<br><br>Other, Specify: _Rot at the "plaque de copeaux" that meets the window frame in the projection (saillie); |
| **Vulnerabilities** | - Defective assembly of the flashing and the aluminium sheets in the 3-storey building;<br><br>- Empty spaces due to a settlement of the insulation at the window assembly that causes heat losses in the 2-storey building; |
| **Factors Affecting** | |
| **Causes** | Incorrect materials specified and/or inappropriately detailed, Explain why?_Voids in the insulation at the angles of are caused by the use of a type of insulation that settles, reducing its size. So a rigid insulation can be used instead to avoid the problem. Also, the fact that the molding lets the water pass through denotes that there was a deficient installation of the windows. |
| **Remedy** | - Welding and sealing each and every one of the moldings to ensure a permanent tightness;<br><br>- Replace the "panneaux de copeaux" that were affected by the water infiltrations;<br><br>- Replace the insulation at the angles of the windows with a rigid insulation that doesn't settle.; |

*Information as extracted from APCHQ files*

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| **File Number** | 628 |
| **Problem Location** | Roof Edge |
| **Building Type** | Semidetached Cottage |
| **Storeys** | 2 |
| **Problem** | Ice Formation (Specify location: Icicles in the edge of the roof (rive du toit) |
| **Symptoms** | High Heating Bills – (Specify location:_House);<br>Icicles – (Specify location:_Edge of the roof);<br>Thermal Discomfort – (Specify location:_Cold in certain rooms of the house ); |
| **Vulnerabilities** | - Lack of tightness in the crowning of the fire stopping wall with the under face of the roof.;<br><br>-The ventilation at the edge of the roof (rive du toit) of certain corridors formed by the roof trusses is obstructed by the insulation cushions;<br><br>-Heat losses that increase the temperature in the attic (entretoit) and melt the snow that accumulates in the roof, favouring the formation of ice dams and icicles. Such as: the chimney is exposed 20 ft. long and is in contact with the air in the attic.;<br><br>-The ventilation in the edge of the roof is not uniformly distributed.;<br><br>-The joints of the ventilation conduits situated in the attic are not sealed or air tight;<br><br>-The ventilation conduits situated in the attic are not insulated along their exposed length;<br><br>-For the room in the last floor, there is not an efficient air barrier for the parts of the exterior walls that are situated in the different attics (entretoits);<br><br>- At the dividing wall there is an air strip (lame d'air) behind the roof truss along the masonry wall that is closed in one of its ends, restricting air circulation and canalizing the heat to the attic;<br><br>-The top part of the chimney is directly in contact with the attic, this contributes largely to the increase of temperature in the attic and favours the melting of snow accumulated in the roof, causing ice dams. According to the APCHQ expertise this is the main cause of the problem.; |

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| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The inappropriate design that conceived a chimney that is directly in contact with the attic, contributing largely to the increase of temperature in the attic and favouring the melting of snow accumulated in the roof and causes ice dams |
| **Remedy** | - Fill up the air strip space at the dividing wall with rolls of fibre glass insulation;<br><br>- The voids between the plywood deck and the masonry elements must be filled up with insulation;<br><br>-In the attic, separate the chimney conduit in a more restricted and insulated space;<br><br>-Minimize the temperature differential of the air in the attic (entretoit) with the exterior air to reduce melting of snow accumulated in the roof by providing an effective ventilation along the perimeter of the roof edge by clearing the cornices that are blocked.;<br><br>-To eliminate the warm and humid air leaks from the joints of the ventilation conduits, provide tightness through the use of an adhesive tape and insulating the uninsulated section with an insulation of R-10 minimally.;<br><br>-In the last floor it is recommended to correct the walls to improve their air tightness; |

*Information as extracted from APCHQ files*

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| **File Number** | 633 |
| **Problem Location** | Stair case; |
| **Building Type** | Cottage in Row |
| **Storeys** | 2 |
| **Problem** | Air Infiltrations (Specify location:_ In the stairs that go to the mezzanine);<br><br>Other, Specify _Black Spots in the carpet of the stairs that go to the mezzanine; |
| **Symptoms** | Air Infiltration – (Specify location:_ In the stairs that go to the mezzanine and in the kitchen floor);<br><br>Thermal Discomfort – (Specify location:_In the kitchen floor); |
| **Vulnerabilities** | - There are visible spaces between the hardwood partitioning wall and the concrete blocks in each of the sides of the house;<br><br>- There are visible spaces between the hardwood partitioning wall and the stair structure;<br><br>- The gypsum panels of the basement are not perfectly tight at the level of the dividing walls. This can cause the infiltration of air with particles from the garage; |
| **Factors Affecting** | - The ascending movement of warm air from the lower floors to the upper floors causes the circulation of air that eventually infiltrates and carries dust, causing the appearance of black spots. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design is not tight |
| **Remedy** | - Seal the affected area with an acoustic sealant at the joints |

*Information as extracted from APCHQ files*

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| **File Number** | 638 |
| **Problem Location** | Ceiling of dwelling 769 |
| **Building Type** | Detached Duplex (Vertical Condominium) |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location:_Ceiling of dwelling 769) |
| **Symptoms** | Water infiltrations – (Specify location: _Joint of the membrane at the corner of the access hatch of the roof) |
| **Vulnerabilities** | - The drain of the roof was frozen at the time of the problem, this contributed to the accumulation of water under the ice and on top of it in the area;<br><br>- There is a weakness in the membrane at the corner of the access trap because the membrane at this point is displaced leaving a small area less protected.; |
| **Factors Affecting** | - The displacement of the membrane was due to a non cautious and continuous manipulation of the access hatch that excerpted pressure on the membrane, making it slide;<br><br>- There was a second bed of membrane to protect the corner at the access hatch but the excessive weather conditions that took place on February 23, 2000 were extreme and there was a weakness in that spot. So conditions combined and water could infiltrate by capillarity.;<br><br>- There was a large accumulation of water and snow that overpassed easily the level of the access hatch and that was the source of the infiltration.; |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_ There was a non cautious and continuous manipulation of the access hatch that excerpted pressure on the membrane, making it slide and move from its place |
| **Remedy** | - Use a sealant to fill in the joint at the corner of the access hatch |

*Information as extracted from APCHQ files*

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| **File Number** | 641 |
| **Problem Location** | Basement |
| **Building Type** | Other, Specify: _ Detached Bungalow with attached garage |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations;<br>Water Infiltrations in the Basement; |
| **Symptoms** | Water infiltrations – (Specify location: _Through the roof to the wall assembly at the level of the insulation and the "carton fibre" panels) |
| **Vulnerabilities** | - At the roof, there are nails at the level of the ventilators and vent holes that are not sealed.<br><br>- At the attic, at the level of the kitchen's evacuation exit, the wood deck is broken in two spots. This is due to the use of very dry wood.<br><br>- The shingle installation job at the valley (noue) is badly executed. |
| **Factors Affecting** | - There was a storm at the time of the construction job and since it was yet not finished infiltrations were most likely to happen |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_There were some deficiencies in the roof that caused the infiltrations |
| **Remedy** | - Seal the nails at the level of the roof ventilators, the plumbing vent hole and the kitchen vent hole;<br><br>- Install plywood supports screwed to the attic to prevent cracking of the decks while installing the shingles;<br><br>- Install the shingles at the valley of the roof in the correct sequence to ensure tightness:<br>1.Install membrane in the valley<br>2.Install a galvanized flashing<br>3.Install shingles at the level of the solarium and the eave (debordement sur le toit principal)<br>4.Install shingles at the main roof and cut at the level of the valley |

*Information as extracted from APCHQ files*

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| **File Number** | 642 |
| **Problem Location** | Basement |
| **Building Type** | Other, Specify: _ Multiplex Condo |
| **Storeys** | NA |
| **Problem** | Water Infiltrations in the Basement (Specify location:_Storage room ) |
| **Symptoms** | Water infiltrations – (Specify location: _At the junctions of the existing walls and the new foundations in the new construction.) |
| **Vulnerabilities** | - The roof gutter discharge pipes point to the corner where the infiltration took place;<br><br>- At the joint in front of the house at the ground level, there is a rubberized membrane over the liquid impermeable bed and a "carton fibre" saturated with asphalt meant to ensure tightness of the dry joint. Such membrane is wrinkled and doesn't have good adherence to the foundation.;<br><br>- At the moment of the concrete placing for the foundational wall, there was a segregation of the concrete aggregates along the dry joint that formed a "bee nest" type imperfection. This porous imperfection offers little resistance to humidity and water migration.; |
| **Factors Affecting** | - The rough grading (terrasement) is not finished so rain water is not canalized optimally |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site. Explain why?_The incorrect placement procedure of the concrete in the foundational wall made the envelope vulnerable to water penetration;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The location of the roof gutter discharge pipes is an inappropriate design; |
| **Remedy** | - Finish the rough grading (terrassement) in a way that water is not canalized towards the foundational wall;<br><br>- Relocate the discharge of the roof gutter far from the foundational wall;<br><br>-Fill in with a mastic sealant the top part of the existing rubberized membrane;<br><br>-Through the interior of the basement, inject polyurethane in the dry joints; |

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-Repair the “bee nests”by applying a mix of un part cement paste/two parts sand.;

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| **File Number** | 645 |
| **Problem Location** | House; |
| **Building Type** | Other, Specify: _Semidetached Bungalow |
| **Storeys** | 1 |
| **Problem** | High Relative Humidity;<br><br>Water Infiltrations;<br><br>Water Infiltrations in the Basement; |
| **Symptoms** | Condensation – (Specify location: Windows of the Ground Floor and the basement);<br><br>High Relative Humidity – (Specify location: At the bathroom and kitchen and in the house in general);<br><br>Mold – (Specify location: Window shutter of the living room, Window of the bedroom);<br><br>Water infiltrations – (Specify location: _In the floor at the access door, At the level of the basement concrete slab through the door that goes to the exterior);<br><br>Other, Specify: _Rot at the window mullions in the base of the windows of the kitchen and the bathroom.;<br><br>Black Spots at the end of the foam insulation in the basement; |
| **Vulnerabilities** | - There is a crack in the foundation at the level of the dividing wall;<br><br>- There are 3 cracks in the foundational wall that can infiltrate water to the interior.;<br><br>-There are cracks in the right side wall at the level of the access door in the upper right corner and at the window in the lower right corner.;<br><br>-The back wall has 2 cracks: One close to the dividing wall under the window and the other in the lower part of the second window.;<br><br>-The absence of a ventilator in the bathroom combined with the use of a whirlpool;<br><br>-The conduit of the air exchanger of the house is clogged with remains and lather close to the laundry machine and the dryer, therefore the |

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| | exchange or air is deficient and the excess of water vapour in the environment is not efficiently eliminated, favouring condensation.;<br><br>-The ground slope favours the conduction of water towards the house at the level of the right side and the back walls. Water can infiltrate through the cracks and stagnate behind the partitioning walls, creating an excess of humidity.;<br><br>-Since the walls have glass fibre insulation and plastic foam, the concrete zone that is directly in the limit of the foam is colder. This situation, together with the accumulation of water of the cracks are the causes of the black stains in the concrete.;<br><br>-Water infiltrates through the door sill of the basement that goes to the exterior in winter because the owners don't keep the stair cage area free of snow. This snow turns into ice and when it thaws, it infiltrates through the sill. This is the main source of humidity to the basement. There are important traces of water infiltration through the door sill that support this idea.;<br><br>- Also, the slopes of the ground that start at the street level and the patio are towards the stair cage of the basement.; |
| **Factors Affecting** | - The owners neglected the condensation in the windows by not keeping them dry and this combined with the high relative humidity and temperature favoured rot of the window mullions |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The absence of a ventilator in the bathroom combined with the use of a whirlpool. Water infiltrated through the stair cage because this design favors such infiltration. Also, there were cracks in the foundation. This was caused by poor performance of the concrete element. |
| **Remedy** | - Replace the 2 affected windows at the ground floor;<br><br>- Repair and clean up the walls at the basement; |

*Information as extracted from APCHQ files*

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| **File Number** | 649 |
| **Problem Location** | Ceiling; |
| **Building Type** | Other, Specify: _Detached Cottage with attached garage |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location:_ Ceiling of the main bedroom and bedroom 2; In the garage; In the attic);<br><br>Other, Specify: _Condensation in the attic at the plywood sheets; |
| **Symptoms** | Condensation – (Specify location:_In the attic at the plywood sheets);<br><br>Damages Caused by water -- (Specify location: _ Ceiling of the main bedroom and bedroom 2);<br><br>Mold – (Specify location: Ceiling of the shower at the junction of the wall and the ceiling);<br><br>Water infiltrations – (Specify location: In the interior of the garage at the level of the junction of the garage roof and the house roof; At the level of the back slope in the interior of the garage; Under the insulation in the attic at the "carton fibres" ); |
| **Vulnerabilities** | - There is a weak ventilation in the attic |
| **Factors Affecting** | - The roof is deteriorated by wear. In many spots the asphalt shingles are pierced and removed. There is a hole at the junction of the roof of the garage and the roof of the house that allows us to see the interior of the garage. This situation is repeated at the section in front and in the interior of the garage. The anomalies found between the shingle teeth demonstrate that they are worn out. The joints at the plumbing flashing are cracked.;<br><br>- The service life of the asphalt shingles of this house in particular is of 15 years. So they are expected to fail now.;<br><br>- There is a lack of maintenance of the shingles that is confirmed by their state of deterioration.;<br><br>- There is a lack tightness of the flashing due to a lack of maintenance;<br><br>- There are 2 visible holes in the cladding at the junction of the garage and the walls of the second floor that are facing the gutter downspout This holes were probably caused by the de-icing of the roof. There are marks of axe cuts that support this idea.; |

*Information as extracted from APCHQ files*

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| | - The house had a row of pine trees at the back and this favoured a poor ventilation of the attic because they served as a barrier for wind. Also, this tree barrier favoured the snow accumulation that is responsible of the damages to the plywood.;<br><br>- The continuous de-icing and cleaning of the roof caused damages to the asphalt shingles.;<br><br>- The ultraviolet rays also contributed to the wear out of the roof.;<br><br>- The owner's negligence to act promptly when the problem appeared;<br><br>- The person who sold the house to the owners didn't advise them that they were obliged to clean the snow of the roof during the winter because of the snow and ice accumulations.; |
| **Causes** | Other, Specify: End of service life and lack of maintenance |
| **Remedy** | - Repair the plywood at the spots that have holes;<br><br>- Redo the roof; |

*Information as extracted from APCHQ files*

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| **File Number** | 655 |
| **Problem Location** | Window-door on the back of the house |
| **Building Type** | Detached Cottage House |
| **Storeys** | NA |
| **Problem** | Water Infiltrations (Specify location:_At the head of the window-door on the back of the house) |
| **Symptoms** | Water infiltrations – (Specify location: _ At the head of the window-door at the back of the house |
| **Vulnerabilities** | - At the time of heavy rain from the East a portion of the water runoff that accumulates over the cladding overhanging the window-door is canalized under the metallic drip because of wind pressure. The water is pushed by the wind and contours the tightness system around the window door, causing the water infiltrations. |
| **Factors Affecting** | - Strong Winds combined with heavy rain the East push the water through the tightness system, causing water infiltrations |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The performance of the tightness system of the window-door is poor under harsh conditions |
| **Remedy** | - Fill in the under face of the drip at the sash frame of the window-door to re establish the tightness of the system. |

*Information as extracted from APCHQ files*

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| **File Number** | 656 |
| **Problem Location** | Ceiling of the house |
| **Building Type** | Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations (Specify location: _Ceiling of the house) |
| **Symptoms** | Water infiltrations – (Specify location: _ At the roof meant to protect the car from the elements; At the attic, through the cracks of one of the low ventilators that is damaged) |
| **Vulnerabilities** | - The metallic flashing at the bottom of the electric mast is not well sealed, allowing water to penetrate at the time of strong winds or ice dams.;<br><br>- The rubber counter flashing around the mast is cracked, allowing infiltrations between the mast and the flashing.;<br><br>- The goose neck of the hood extractor is not very tight. Its metal flashing is raised and is vulnerable to water infiltrations.;<br><br>-The base of the flashing of the "Maximum" ventilator isn't very tight. There is cracking in the sealant product.;<br><br>- The plastic low ventilator that is close to the ridge is cracked. This makes water easy to infiltrate.;<br><br>- The base of the other low ventilator isn't well sealed. The mastic sealant is dry and cracked.;<br><br>-Four pieces of shingles are missing or were pulled out. However there is a protection because the deck is not exposed.;<br><br>-The joint of the metallic flashing is open along the chimney. This can be a source of problems with time.;<br><br>- The ventilation space of the roof is obstructed by cushions of insulation.;<br><br>- Some support planks of the roof are broken and have settled. They don't offer an adequate support to the shingles. If this situation persists, the shingles can be damaged and infiltrations may appear.;<br><br>- The conduit of the exhaust of the kitchen hood is not insulated and it is disconnected from the goose neck. The lack of insulation contributes to |

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| | the increase of the air temperature at this spot which melts the snow accumulated over the roof that causes ice dams. The disconnection to the goose neck favours the air leaks that increase the Relative Humidity and eventually causing condensation problems that will end up being water leaks.;<br><br>- The flexible conduits of the air exchanger and the evacuator of the bath room are not insulated and this contributes to the increase of temperature of the air at this spot. Also, the conduit's slope is inverse and this harms the performance of the evacuation of exhaust air and the drainage of the moisture of the air that condenses at the interior of the conduits. If this conduits are perforated, water leaks are likely to happen.;<br><br>- The ceiling of the garage is without finish and it is not insulated. Since this garage occupies one of the sides of the roof, this side of the attic is not ventilated. This contributes to the increase of temperature at this area.;<br><br>- The garage roof is not tight and gases can be infiltrated to the house, compromising the occupants' health and safety.; |
| **Factors Affecting** | |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_The garage is not tight to gases and this is due to poor detailing. Also, the ventilation conduits have an inverted slope, which also can be due to a lack of details.;<br><br>Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_The insulation that is obstructing ventilation of the attic is due to poor craftsmanship.;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? There is a lack of tightness in the ventilation systems due to failed sealants; |
| **Remedy** | - Replacement of the missing or damaged shingles;<br><br>- Adequate fill up of the flashings and counter flashings;<br><br>- Replacement of the cracked ventilator;<br><br>- Clear up of the insulation that obstructs the ventilation in the border of the roof;<br><br>- The adequate reconnection of the hood conduits and the sealing of the |

*Information as extracted from APCHQ files*

joints with tape for conduits;

- The insulation of the hood conduits and the bathroom ventilator.;

- The stabilisation of the broken planks that support the roof. They have to be put again in their original position and be supported adequately by pieces of plywood sufficiently big.;

- The insulation of all the air exchanger conduits. Also, the reduction to their minimum lengths and their sloping towards the exterior to favour drainage of water in case of condensation.;

- Reestablishment of the fresh air intake at the border of the junction of the exterior wall of the house and the roof of the garage by building a ventilated false beam.;

*Information as extracted from APCHQ files*

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| **File Number** | 660 |
| **Problem Location** | House |
| **Building Type** | Multifamily Condominium |
| **Storeys** | 3 |
| **Problem** | Air Infiltrations;<br><br>Air Exfiltrations;<br><br>Water Infiltrations; |
| **Symptoms** | Air Exfiltration – (Specify location:_ Windows and garden doors of the houses.);<br><br>Air Infiltration – (Specify location:_ Windows and garden doors of the houses.);<br><br>Water infiltrations – (Specify location: _ Windows and exterior doors of the houses); |
| **Vulnerabilities** | - The shutters have interstices at the junction of the vertical and horizontal mouldings;<br><br>- Some mouldings were cut too long. So when they are exposed to the sun, they expand, opening the joints at the angles. This problem is found in all the windows and the entry door.;<br><br>- The mosquito screen rails of the garden doors are poorly installed and their functioning is not proper.;<br><br>- The windows are not according to norm AN/CSA-A-440 M; |
| **Factors Affecting** | - Sun causes the long mouldings to expand and widen the interstices at the joints of the shutters.; |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_The long mouldings were due to poor detailing or to poor craftsmanship of the manufacturer.;<br><br>o□Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_ The long mouldings were due to poor detailing or to poor craftsmanship of the manufacturer. Also, there was poor assembly of the mosquito screen of the garden door.; |
| **Remedy** | - Revise the windows and doors so that expansion of their components is allowed without producing deformations.; |

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- Ensure tightness and adequate service life of the windows and doors.;

- Correct the multiple manufacturing vices found in the windows and doors;

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| **File Number** | 679 |
| **Problem Location** | Border of the roofs |
| **Building Type** | Semidetached, Multifamily Residential Building |
| **Storeys** | |
| **Problem** | Ice Accumulation (Specify location: Border of the roofs)<br><br>Water Infiltrations |
| **Symptoms** | Damages Caused by water – (Specify location: _Gypsum; Wooden floors);<br><br>Ice Accumulation – (Specify location:_In the interior of the soffits located in the façade of the building);<br><br>Water infiltrations; |
| **Vulnerabilities** | - There is a fronton in each of the elevations of the slope that favours snow accumulation.<br><br>- There are heat losses at the junction of the top plate and the dividing wall due to a misplacement of insulating wool at the air conditioning conduits.<br><br>- The ventilation surface is limited by the frontons because the intermediate cladding is contiguous to the under face of the roof deck. Also, there is only one ventilator installed at the ridge. |
| **Factors Affecting** | - There was no wind in this season at the time of precipitations so the amount of snow over the roofs was an important one at the beginning of the season. This created important ice dams.<br><br>- Solar radiation contributes to the melting of snow in the roofs and causes ice dams. The thick beds of snow absorb heat and transfer it to the wood deck or the shingles and then snow melts. This action over the slopes that are exposed to the south favour the melting. The energy absorbed by the structure warms up the attic and causes melting of the snow over the non exposed slopes. The water that melts in milder days drips to the gutters and freezes when it touches the cold surface of the gutters. Progressively, ice accumulates over the edge of the roof, impeding the flow of snow or water. Then, ice and icicles start appearing in the soffits of the cornices.<br><br>- The habitable attic contributes to increase heat losses. |
| **Causes** | Correct materials were specified and appropriately detailed but |

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| | incorrectly ordered, handled and/or assembled on site, Explain why?_There are heat losses due to a misplacement of the insulation at the air conditioning conduits;<br>nappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The difference in temperature in the main attic and the attic of the fronton is due to poor ventilation caused by a poor design. |
| **Remedy** | - Install drips so that the auto adhesive membrane in the edge of the roof canalizes the water in front of the fascia.<br>- The auto adhesive membranes in the edge of the roof must be extended 12 to 39 inches minimum to the interior of the exterior wall<br>- Increase the ventilation surface of the attic to reach the requirements of the CNB90.<br>- The distribution of the ventilation must ensure air circulation to the frontons. |

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| **File Number** | 681 |
| **Problem Location** | Roof; |
| **Building Type** | Other, Specify: _Row Houses, Condo style, with garage |
| **Storeys** | 3 |
| **Problem** | Water Infiltrations (Specify location:_Roof and Ceiling of the ground floor of certain dwellings) |
| **Symptoms** | Damages Caused by water – (Specify location: _Ceiling finishes, wall finishes, and floors; Aluminium underfaces of the roof in front);<br><br>Ice Dams – (Specify location:_Roofs);<br><br>Snow Accumulation – (Specify location:_Roofs; Marquises d'Entree);<br><br>Water infiltrations – (Specify location: _Attic in the parts in front and at the back by the tall walls in the front façade; Ceiling finishes of the ground floor of #2416, 2414 and 2412 );<br><br>Other, Specify: _Wetness of the insulation at the attic;<br><br>Warm Air leaks at the attic along the dividing walls;<br><br>Frost of a good percentage of the aluminium soffits; |
| **Vulnerabilities** | - Some of the ventilation grills of the attic are not completely clear<br><br>- At #2424, the exit of the dryer air evacuator exhausts to the attic warm and humid air<br><br>-The fresh air intake of the air exchanger comes from the attic. And it is installed over the insulation.. When the exchanger is not operating, an ascending convection of warm air is produced inside the conduit from the dwelling towards the attic, creating a rise in the air temperature. Also, this type of installation of the intake favours the transport of a contaminant like the fibre glass to the house. This is unhealthy for the inhabitants.<br><br>-In the façade there are some masonry frontons that exceed the height of the eave. This favours snow accumulation.<br><br>-There is no air barrier over the pony wall (mur nain) on the side of the attic. This part of the attic is ventilated.<br><br>-The attics of the different houses are intercommunicated, so the sources |

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of problems are shared.

-The "roof in front" (toit avant) configuration of the roof of the building limits the possibility of meeting the ventilation surface through the cornices. On top of this, if such roof configuration is combined with a gable, this reduces the possibility of installing the ventilation surfaces in the eave and the gable will favour snow accumulation over the roof, particularly at the valleys. Considering that this gable directs all the melting water to a very localized and restricted place, this draws the over flooding of the gutters. The gutters are sources of ice accumulations in the eave.

- The exits of the mechanical ventilation conduits are placed on the aluminium "revetement" at the eave. This is very problematic because occasionally the warm and humid air that is exhausted hits the wall by the effect of the wind and is directed to the cornices where it condenses in the surface of the "revetement" and obstructs the ventilation orifices, contributing to a reduction of the ventilation surface.

- Some parts of the attic do not favour air circulation through the ventilation orifices, for example, the back (dos) of the fronton in façade and the gable in the back of the roof.

- The design of the roof makes it vulnerable because the configuration makes it difficult for snow to be evacuated naturally. A large amount of water in the roof converges to very constrained spaces. Such configuration consists of the following:
a) Large eaves
b) The crickets behind the frontons
c) The many valleys of the back crickets

- The building has "Marquises D'entrée" where snow accumulates.

- A large amount of water is eliminated through only one Rainwater Downspout of the gutter.

- The surfaces restricted for the installation of the ventilation orifices at the low borders of the roof aren't less than 25% of the total required.

- There is a possible lack of tightness at the penetration points of the structural elements of the roofs of the "marquise d'entrée" and the balconies to the envelope.

- There is a possible lack of tightness at the flashings at the junction of the stucco covering and the masonry

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| | - There is possible a canalization of water infiltrations through the soffits along the fire blocking wall<br><br>- The lower part of the windows is to close to the roofs and this constitutes a vulnerable point to water infiltrations<br><br>- There is possibly a lack of tightness at the aluminium flashing located at the junction of the stucco and the masonry or at the overlapping of the paper sheathing over the flashing.<br><br>- The soffits are covered with ice and they are adjacent to a fire stop wall. During mild weather, the water that is generated by the melt of this ice is canalized to the fire stop wall and the ceiling, causing infiltrations and damages to certain finishes. |
| **Factors Affecting** | - Solar radiation contributes to the melting of snow in the roofs and causes ice dams. The thick beds of snow absorb heat and transfer it to the wood deck or the shingles and then snow melts. This is the situation produced in the back slope of the roof.<br><br>- The water that melts in milder days drips to the gutters and freezes when it touches the cold surface of the gutters. Progressively, ice accumulates over the edge of the roof, impeding the flow of snow or water. Water infiltrates under the roof facing (revetement). Then, ice and icicles start appearing in the soffits of the cornices. After this, frost accumulation at the gutters cause ice dams and water is canalized under the shingles and the protection membrane infiltrating to the interior of the house.<br><br>- Heat losses, mainly due to convection of warm air circulation in the attic between the concrete block wall and the gypsum board. The air temperature at this place was excessively high. Another source of heat loss is the fire stop concrete block walls, where the temperature due to convection can reach more than 10°C.<br><br>- The habitable attic contributes to increase heat losses.<br><br>- Snow accumulation higher than the flashings at the junction of the wall and roof due to the turbulence of wind along the different roofs where their heights are different |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design has many conditions that do not allow an easy evacuation of snow and water. |

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| **Remedy** | - Ensure the tight sealing of the sheathing paper over the flashing of the junction of the wall and roof. There must be special attention to the flashing of the windows up to the upper part of the "marquises d'entrée" and the "marquises" of the balconies of the third floor .<br><br>- Verify the tightness at the penetration points of the structure of the "marquises" and the balconies. To accomplish this, remove a part of the aluminium sheathings of the underface of this structures.<br><br>-Verify the slopes of the balconies to ensure that they take away the water from the building.<br><br>- Improve the ventilation of the attic<br><br>- Eliminate or reduce significantly the heat losses to the attic, specifically the heat losses by convection at the dividing wall surface.<br><br>- Install an air barrier at the pony of the attic, over the face of the roof space<br><br>-Modify the evacuation of the ventilation systems so that their effect at the exit is not "contre"<br><br>-Ensure the efficiency of the protection membrane of the front roof (avant toit) and that of the valleys.<br><br>-Ensure the tightness of the structural elements at the points where they penetrate the envelope<br><br>-Ensure the efficiency of the sheathing paper and the flashings at the junction of the wall to the roof. |

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| **File Number** | 682 |
| **Problem Location** | House |
| **Building Type** | Detached Cottage House |
| **Storeys** | 2 |
| **Problem** | Air Infiltration – (Specify location:_House);<br>Other, Specify _Diverse Deficiencies; |
| **Symptoms** | Air Infiltration – (Specify location:_ Kitchen Windows; Kitchen Wall around the discharge pipe of the sink; Quadruple socket close to the window-door in the bedroom, Telephone socket close to the Quadruple socket; In the rails and the junction of the glasses of the 2 windows of the basement; In the closing system of the air intake in the cold chamber; In the perimeter of the door of the cold chamber; In the (Rive de pourtour); In the second floor, around the attic access hatch under the bathroom; In the (vanite) of the bathroom);<br><br>Condensation – (Specify location:_ Lower part of the bathroom window);<br><br>Damages Caused by water – (Specify location: _ Some of the mouldings that support the glass below the window);<br><br>High Heating Bills – (Specify location:_House);<br><br>Thermal Asimetry – (Specify location:_The exterior wall of the kitchen);<br><br>Thermal Discomfort – (Specify location:_House); |
| **Vulnerabilities** | |
| **Factors Affecting** | - The building is very exposed to the wind.;<br><br>- The main building is adjacent to a “garage de remisage”;<br><br>- The inappropriate installation of the blinds or curtains of the windows deviates or reduces the natural convection of warm air in front of the windows causing a low temperature of the interior face of the window and condensation in the glazing. The ultimate consequence is water accumulation at the bottom of the windows. If the excess of water is not eliminated quickly, it is absorbed by the more porous materials that can draw deterioration to certain components.; |
| **Causes** | Other, Specify: _Incompatible elements in the House, Explain why? Usage of blinds is not convenient and causes the problem |
| **Remedy** | - Replace certain support mouldings at the back of the glazing that are |

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damaged;

- Improve the tightness of the "rive de pourtour" at the patio sector by using foam insulation or a mastic sealant;

- Fill in the perimeter of the water pipe exit;

- Install an adequate weather stripping at the door of the cold room;

- Fill in the voids at the quadruple socket and the telephone socket with tightening cushions;

- Fill in the voids at the access trap of the attic under the bathroom;

- Improve the tightness of the envelope by the use of spraying a foam insulation at the wood works of the exterior windows and doors to build a barrier to air infiltrations.
-Re install the blinds and curtains at no less than 4 inches of the wall surface and keep them open as much as possible during cold the cold period.;

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| **File Number** | 683 |
| **Problem Location** | Roof; |
| **Building Type** | Other, Specify: _ Condominium House |
| **Storeys** | 3 |
| **Problem** | Water Infiltrations (Specify location:_Roof and ceilings) |
| **Symptoms** | Air Exfiltration – (Specify location:_At the attic along the dividing wall);<br><br>Damages Caused by water – (Specify location: _Ceiling finishes);<br><br>Ice Dams – (Specify location:_ On the main roof of the back face of the house; On the small part of the roof at the level of the 2nd floor in the back face of the house);<br><br>Icicles – (Specify location:_ At the aluminium sheathing of the cornices);<br><br>Snow Accumulation – (Specify location:_On the main roof of the back face of the house; On the small part of the roof at the level of the 2nd floor in the back face of the house);<br><br>Water infiltrations – (Specify location: _At the attic in the back part close to the dividing wall);<br><br>Other, Specify: _Frost at the aluminium sheathing of the under faces of the Roof front (avant-toit); |
| **Vulnerabilities** | - There is an inadequate ventilation of the attic;<br><br>- The architectural concept of the back roof (toit arriere), the fronton and the cricket reduce the possibility of installing the required ventilation surface on the eave. This limits the possibility of meeting the ventilation surface at the cornices in no less than 25% of the required surface. The effective surface of the ventilation orifices on the back is of more or less 6 squared inches. On top of this, when the ventilation orifices are obstructed by the ice, this contributes to reduce the ventilation surface.;<br><br>- There is a cricket of a fronton that does not favour air circulation through the ventilation orifices. The access to this part of the attic is done through a very insufficient area.;<br><br>- The back roof of the 2nd floor is ventilated only through the eave's orifices and there is no ventilator on the top part. This situation is inefficient to eliminate the accumulated heat losses at this part of the attic.; |

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| | - The roof has a fronton and a gable that favour snow accumulation on the roof and particularly on the south neighbouring valley (noue cote sud). The gable canalizes an important amount of water from snow melt to a very localized and restricted spot. This increases the problem. This small border of the roof of less than 2 feet is shared with the south neighbour and it has no gutter and drip, favouring water infiltrations through the roof facing (revetement de la toiture).;<br><br>- The design of the roof makes it vulnerable because the configuration makes it difficult for snow to be evacuated naturally. A large amount of water in the roof converges to very constrained spaces. Such configuration consists of the following:<br>a) Large eaves<br>b) The crickets behind the frontons<br>c) The valleys of the back gable<br><br>- There is a lack of tightness at the sheathing paper over the flashings at the junctions of walls and roof.; |
| **Factors Affecting** | - Solar Radiation;<br><br>- Heat losses mostly by convection of warm air along the face of the dividing wall and the access trap of the attic. Of less importance but non negligible, the voids around the ventilation conduits and the voids around the electric wires.;<br><br>- The formation of ice dams at the roof border that causes water infiltrations by the canalization of water under the shingles, beyond the protection membrane and the protections of the valley to finally infiltrate into the dwelling.;<br><br>- The snow accumulation in the roof due to wind turbulence.;<br><br>- The snow accumulation higher than the flashings at the junction of the wall and roof. This situation is more problematic for the part under the windows at the junction of the roof of the 2nd floor.; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The design favors snow accumulation and ice dams which are the ultimate cause of the water infiltrations |
| **Remedy** | - Improve the ventilation of the attic by installing a ventilation grill at the fronton of the main roof.; |

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- Improve the ventilation of the roof at the top part of the 2nd floor.;

-Enlarge the access to the gable to improve the air circulation at the attic and eliminate the spots where air is stagnant by cutting the plywood sheets that are useless and that impede a good circulation of air at this section.;

- Eliminate or reduce significantly the heat losses to the attic and specifically the losses through convection at the surface of the dividing walls.;

-Seal the penetration points of the electrical and ventilation elements at the roof.;

-Improve tightness at the access trap of the attic.;

-Modify the evacuation of the ventilation systems so that it is not necessary to use the "Maximum" ventilator.;

-Ensure the efficiency of the protection membrane of the front roof (avan-toit) and of the valleys.;

-Ensure the efficiency of the sheathing paper and the flashings at the junction of the wall and the roof, particularly at the low part of the windows that are on top of the roof of the 2nd floor.;

-Install a gutter at the back cornice close to the dividing wall so that water does not drip anymore from one roof to the other, because this is problematic and favours a premature deterioration of the shingle surfaces that are on the down slope section.;

- Install a drip at the fascia to favour the removal of the water of the fascia, reducing the risk of water infiltrations by capillarity under the shingles.;

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| **File Number** | 684 |
| **Problem Location** | Roof; |
| **Building Type** | Other, Specify: _Row Duplex |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Roof and Ceilings) |
| **Symptoms** | Air Exfiltration – (Specify location:_At the attic, along the dividing wall; Along the beam that overhangs in the living room);<br><br>Damages Caused by water – (Specify location: _Ceiling finishes; Wall finishes; Floor);<br><br>Ice Dams – (Specify location:_ At the roof on the front face; At the gutters);<br><br>Icicles – (Specify location:_At the attic very close to the gable in front);<br><br>Snow Accumulation – (Specify location:_At the roof on the front face);<br><br>Water infiltrations – (Specify location: _At the attic on the area close to the gable); |
| **Vulnerabilities** | - The “roof in front” (toit avant) configuration of the roof of the building limits the possibility of meeting the ventilation surface through the cornices. This being no less than 25% of the required surfaces.;<br><br>- The effective surface of the ventilation orifices for the section that goes from the corner of the valley up to the dividing wall is of 6 squared inches. This does not satisfy the minimum requirements of this sector. On top of this, when the ventilation orifices are obstructed by the ice, this contributes to reduce the ventilation surface.;<br><br>- There are heat losses at the attic that combined with an inadequate ventilation are the principal elements that contribute to the overheating of this attic.;<br><br>- The “roof in front” (toit avant) configuration of the roof of the building limits the possibility of installing the required ventilation surface at the eave . On top of this, if such roof configuration is combined with a gable, this will favour snow accumulation over the roof. Considering that this gable directs an important amount of the melting water to a very localized and restricted place, this worsens the problem. The small eave of less than 2 feet long is shared with the neighbour. The eave with gutter accumulates water that freezes and |

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| | forms ice dams. On top of this, if the fascia does not have a drip, it favours water infiltrations under the roof sheathing (revetement de la toiture). We can then see ice and icicles under the aluminium sheathing (revetement d'aluminium) of the cornices. Ice accumulation at the soffits reduces the ventilation of the attic and contributes to snow melt over the roof. The snow melt will cause ice dams and the risks of canalizing water under the shingles then beyond the protection membrane of the eave and the protections of the valley to infiltrate finally into the dwelling.;<br><br>- There is a valley of the gable on the back that is adjacent to an un levelled spot of the roof. Snow accumulates higher than the flashing at the junction between the unlevelled sections of the roof.;<br><br>- An important volume of water at the roof converges to a very constrained space.;<br><br>- There is no drip at the fascia of the roof.; |
| **Factors Affecting** | - There are ice dams at the gutter and the valleys;<br><br>- Solar Radiation in the façade;<br><br>- Solar radiation contributes to the melting of snow in the roofs and causes ice dams. The thick beds of snow absorb heat and transfer it to the wood deck or the shingles and then snow melts. This action happens at the slopes of the roof in front that are exposed to the south. When this situation is combined with an ice dam that is prolonged beyond the protection sheathing (revetement de protection) of the eave, infiltrations can be expected.;<br><br>- The convection of air along the face of the dividing wall;<br><br>- The heat losses along the beam on the ceiling of the living room.;<br><br>- There is snow accumulation between 2 gables that are close one to the other due to wind turbulence; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design of the roof favours snow accumulation and ice dams which ultimately cause water infiltrations |
| **Remedy** | - Improve the ventilation of the attic by installing a continuous grill through the eave close to the dividing wall.;<br><br>- Eliminate or reduce the heat losses to the attic, specifically the losses |

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by convection at the surface of the dividing wall of the right and around the beam overhanging the living room.;

- Ensure the efficiency of the protection membrane of the roof front (avan toit) and the valleys.;

-Install a drip at the fascia to remove the water from the fascia and reduce the risks of infiltrations by capillarity under the shingles.;

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| **File Number** | 688 |
| **Problem Location** | Ceiling of the commercial premise |
| **Building Type** | Other, Specify: _Semidetached Residential/Commercial Building |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Ceiling of the commercial premise) |
| **Symptoms** | Condensation – (Specify location: Roof assembly of the commercial premise);<br><br>Damages Caused by water – (Specify location: _Ceiling of the commercial premise);<br><br>Water infiltrations – (Specify location: _ Ceiling of the commercial premise); |
| **Vulnerabilities** | - There is a steel door installed by a third party that has a piece of polystyrene under the door sill. The space is not sealed and one piece of polyethylene serves as tightening element between the balcony and the door sill. This does not perform well.;<br><br>-There is no insulation nor vapour retarder in the structure of the ceiling of the commercial premise.;<br><br>-A section of the roof structure of the commercial premise exceeds the heated zone and part of the roof of such premise faces the exterior and at the same time it is connected to the interior. So there is warm air from the inside condensing because of the cold temperature of such part of the roof.;<br><br>- The poor insulation, together with the fact that part of the structure allows cold air infiltrations under the insulation are the causes of the water infiltration.;<br><br>- The heat losses due to the poor insulation, contribute to snow melting over the balcony. Ice is formed and with a temperature rise, water from the melt infiltrates under the door sill of the dwelling; |
| **Factors Affecting** | - With a temperature rise, water from the melt infiltrates under the door sill of the dwelling. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design of the commercial premise (if any), is wrong because it leaves a part of the roof exposed to the exterior temperature and leaves the interior of the premise connected. This resulted in condensation and water infiltrations. |

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| **Remedy** | - There were no remedial measures recommended in this file. |
| **File Number** | 691 |
| **Problem Location** | Ceilings |
| **Building Type** | Other, Specify: _ Rental Residential Building with 6 dwellings |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Ceilings) |
| **Symptoms** | Water infiltrations – (Specify location: _Gypsum sheathing; Insulation);<br><br>Other, Specify: _ Bulging of the membrane that is at the right edge of the roof;<br><br>Wetness of the roof joists and the floor; |
| **Vulnerabilities** | - The ventilator at the bathroom evacuates warm and humid air to the attic. This is the cause of the problem.;<br><br>- At the perimeter of the roof, the joists block the ventilation.;<br><br>- The owner modified the roof assembly by insulating the ceilings of the bedroom 2 and the living room with an R-20 insulation.;<br><br>- The space between the wood deck is reduced and restricts air movement, favouring condensation.; |
| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design of the ventilation system causes the problem |
| **Remedy** | - Close the space between the roof joists at the level of the ceiling of the bedroom 2.;<br><br>- Dry the deck;<br><br>- Replace the R-20 insulation for an R-12;<br><br>- Install a vapour retarder sealed at the level of the gypsum of the walls.;<br><br>-Dismantle the aluminium sheathing at the cornices.;<br><br>-Create the ventilation at the level of the rails.; |

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| **File Number** | 692 |
| **Problem Location** | Cladding |
| **Building Type** | Detached Cottage |
| **Storeys** | 2 |
| **Problem** | Ice Formation (Specify location: Vinyl Siding Cladding) |
| **Symptoms** | Air Infiltration – (Specify location:_Through the base of the walls; Through the space at the attic of the balcony and the house expansion; Through the interstices of the planks (planches));<br><br>Condensation – (Specify location: At the back of the horizontal siding; In the windows of the west side; At the door);<br><br>Other, Specify: _Low Relative Humidity at the house; |
| **Vulnerabilities** | - The installation of a wind barrier paper on the exterior side of the wall is ineffective because of the following reasons:<br>a) The insulation and the wind barrier paper are discontinuous at the level of the front gallery.<br>b) The paper is not sealed at the base of the walls.<br>c) At the level of the left side wall and at the back, we cannot verify if the tightness is achieved by the wind barrier and the system that the owner installed.<br>d) The space at the level of the roof of the gallery is not tight.<br>e) At the back, the expansion of the house is not yet complete and the wind barrier system has not been verified.<br>f) The level of tightness around the windows is according to the owners, inadequate. |
| **Factors Affecting** | - The strong winds infiltrate at the base of the walls or through the space at the attic of the balcony and the expansion, passing through the interstices of the planks. Since the fibre glass insulation does not fill completely the cavity, convection is produced. This movement of air is the most probable cause of the drying of the house. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The design of this renovation causes air infiltrations and condensation; |
| **Remedy** | - Install the siding and the insulation according to the standards.;<br><br>-Ensure the tightness of the sheathing paper at the base of the foundations.;<br><br>-Ensure the tightness of the paper at the window frames.; |

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- Ensure the continuity of the paper at the level of the attic under the front gallery. Also, at the level of the lateral walls and on the back.;

-Install a vapour retarder at the level of the interior walls to slow down the diffusion movement.;

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| **File Number** | 693 |
| **Problem Location** | Ceilings |
| **Building Type** | Residential Building (Detached Cottage) |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Ceilings); |
| **Symptoms** | Damages Caused by water – (Specify location: _Paint finish of the ceiling of the bathroom; Paint finish of the ceiling of the 2nd floor (l'etage);<br><br>Water infiltrations -- (Specify location: _Valleys of the back section of the building; Ceiling of the bathroom of the ground floor; Ceiling of the second floor (l'etage); |
| **Vulnerabilities** | - The expansion at the back of the house has a roof slope of 4/12 that joins the existing roof that has a slope of 12/12. A difference in height between the 2 levels creates an un evenness of 3 ft. This favours snow accumulation at the level of the 2 valleys of the expansion. At the time of milder weather, water cannot flow and goes under the membrane, the shingles and infiltrates to the roof structure.;<br><br>- There is possibly a poor insulation that favours snow accumulation;<br><br>- There is possibly an inadequate ventilation that favours snow accumulation;<br><br>- There are possibly voids between the insulation and the roof deck;<br><br>- The roof configuration favours snow accumulation;<br><br>- One of the roof ventilators exhausts warm air.;<br><br>- There is a possibility that the ventilators are blocked by snow accumulations. This diminishes their performance, and has as a consequence a warm attic.; |
| **Factors Affecting** | - Winds that come from the west and come from the façade, favour snow accumulation because of the way they hit the roof.;<br><br>- The accumulated snow melts if the ventilation is not efficient, favouring the warming up of the attic.; |
| **Causes** | Incorrect materials specified and/or inappropriately detailed, Explain why?_The use of flat type ventilators is incorrect because they don't work properly when the roof is full of snow; |

*Information as extracted from APCHQ files*

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| | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_There is possibly a poor insulation job that contributes to snow accumulation;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design of the roof expansion favours snow accumulation, which is the cause of the problem; |
| **Remedy** | - Replace the existing 2 flat ventilators for a Maximum type that can work even in the presence of snow.;<br><br>- Provide heating wires to the valleys because the roof configuration and the weak slope favour snow and ice accumulation.; |

*Information as extracted from APCHQ files*

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| **File Number** | 695 |
| **Problem Location** | Windows |
| **Building Type** | Other, Specify: _Residential Building Held in Coproperty |
| **Storeys** | 3 |
| **Problem** | Condensation in Windows |
| **Symptoms** | Condensation – (Specify location:_All the windows and front door) |
| **Vulnerabilities** | - The panels under the windows at the living room are not insulated properly;<br><br>- The air intake is situated in one of the house ends and the extraction ventilator is situated at the centre of the house. This makes difficult to move the exhaust and humid air of the front bedroom.;<br><br>- There is a poor overall ventilation in the house; |
| **Factors Affecting** | -There are 4 adults living in this house of 2 bedrooms. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The ventilation design favours stagnation of air in some parts of the house, which is the cause of the problem |
| **Remedy** | - Install extruded rigid insulation panels, seal the perimeter with an acoustic sealant and install a plywood finish in the surface. This will allow to maintain the base of the fixed windows less warm.;<br><br>- Install a fan (ventilateur a palles) at the ceiling of the dining room to mix the air at this zone. This will push the warm air over the glazing, diminishing condensation.;<br><br>- Leave the blinds open during the night and avoid lowering the temperature of the dwelling, since this contributes to the increase of the Relative Humidity.; |

*Information as extracted from APCHQ files*

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| **File Number** | 696 |
| **Problem Location** | Aesthetic; |
| **Building Type** | Other, Specify: _Public Building (School) |
| **Storeys** | 4 |
| **Problem** | Water Infiltrations (Specify location: Ceiling); |
| **Symptoms** | Damages Caused by water – (Specify location: _Plaster of walls and ceilings of the last floor and the inferior floors);<br><br>Water infiltrations – (Specify location: _Ceilings of the last floor where the offices are located); |
| **Vulnerabilities** | - The insulation is touching the wood deck or the masonry walls conducing the heat up to the deck and accentuating the heat loss.;<br><br>- The profiled deflectors of plastic foams leave the insulation in contact with the wood deck close to the cord members (membrures des fermes) of the roof. Heat loss transmitted by conduction accelerates the formation of ice dams.;<br><br>- There are heat losses caused by the fire stop concrete walls. Often when the cavity of the block cells is not filled, there is a heat loss through convection and conduction along the fire stop wall. This heat goes to the attic, warming up the wood deck and the cycle starts again.;<br><br>- There are skylights that are a non negligible source of heat loss. The glazing offers no resistance to heat transfer and the heat loss at the perimeter of the skylight causes snow melt. When water touches the cold surfaces close to the cornices, ice is formed.;<br><br>- The problem of ice accumulation is due mainly to heat losses caused by the masonry walls that heat the wood deck and the poor insulation of the attic.; |
| **Factors Affecting** | - Solar radiation contributes to the melting of snow in the roofs and causes ice dams. The thick beds of snow absorb heat and transfer it to the wood deck or the shingles and then snow melts. This action at the slopes that are exposed to the south favours snow melt. The energy absorbed by the structure warms up the attic and causes melt of snow in the slopes that are not exposed. |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_The insulation job is not done well because in some parts it touches the deck and walls. The poor insulation is one of the causes of |

*Information as extracted from APCHQ files*

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| | the problem |
| **Remedy** | - Seal the roof edge (pourtour du toit) with a membrane to impede water infiltrations at the time of milder weather. To do this, dismount the shingles in a band of 96 inches and install a membrane. The membrane must be sealed at the aluminium facia to ensure complete tightness.;<br><br>-Another option consists of installing heating wires around the roof controlled by a timer.; |

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| **File Number** | 699 |
| **Problem Location** | Ceilings; |
| **Building Type** | Other, Specify: _Semidetached Duplex |
| **Storeys** | 2 |
| **Problem** | Damages in Ceilings;<br><br>Other, Specify _Damages in walls; |
| **Symptoms** | Damages Caused by water – (Specify location: _Plaster finish of the bathroom, of the corridor and the closet in the dwelling of the 2nd floor; Plaster finish of the ceiling of the bathroom and the corridor in the dwelling of the ground floor);<br><br>Other, Specify: _Wetness of the roof joists and the roof deck;<br><br>Wetness of the floor deck; |
| **Vulnerabilities** | - There is a lack of tightness in the in the roof drain. There is steam leaking from it. Condensation of this steam can occur at the level of the roof deck. During mild weather, condensed water drips over the deck, the plaster and descends to the inferior floor.;<br><br>- There is a space between the roof drain and the combined sewer through which vapour can migrate when using hot water.; |
| **Factors Affecting** | |
| **Causes** | Other, Specify: _There is not enough information to define the cause of the problem |
| **Remedy** | - Seal adequately the space between the drain and the sewer. |

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| **File Number** | 700 |
| **Problem Location** | House |
| **Building Type** | Detached Cottage House |
| **Storeys** | 2 |
| **Problem** | Air Infiltrations;<br><br>Water Infiltrations; |
| **Symptoms** | Air Infiltration – (Specify location:_At the light switch of the master bedroom; Through the kitchen hood);<br><br>High Heating Bills – (Specify location: House);<br><br>Water infiltrations – (Specify location: _At the façade; At the back foundation); |
| **Vulnerabilities** | - There is a lack of tightness of the penetrations of the electric wires at the carpentry elements and at the ceiling covering in the attic.;<br><br>- There is a lack of tightness of the penetrations of the ventilation conduits at the carpentry elements and at the ceiling covering in the attic.;<br><br>- There is a lack of a button to control the extracting grill(grille de tire) of the air exchanger.;<br><br>- The sealant between the corner and the head of the door is defective.;<br><br>- There is a crack in the roughcast of the back window that is close to the ground. This is due to the quality or the reaction of the filling material used to fill up the excess of voids left by the opening of the window when installing it. In this case, water that had accumulated in front of the wall could have infiltrated to the dwelling.;<br><br>-The orientation of the opening of the goose neck is facing the dominant winds. Also, the small roof over the corner of the building favours the turbulence of wind that opens the damper (clapet) and pushes the air through the conduit to the filter of the hood.; |
| **Factors Affecting** | - The house has a double use: the basement is used as a business office. This is the reason for the high heating bills;<br><br>- The wind pushes water through the drainage joint (joint de coulee) between the foundation and the balcony. This was the source of the infiltrations in the façade.; |

*Information as extracted from APCHQ files*

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| | - The rough grading was not finished at the time of the basement infiltrations and there were water accumulations at this sector. The height of the final rough grading in relation to the window sill was less than six inches. This is inferior to the CNB norm and the situation became problematic because water could infiltrate between the low parts of the shutters and the window sill or the lower part of the sash (chassis) and the and the sash frame (dormant). There was no "margelle" in front of the basement window so snow would accumulate there and cause infiltrations.; |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_There are small details that are not correctly executed that cause the infiltrations |
| **Remedy** | - The contractor built a "margelle" to cope with the water infiltrations at the back foundation in the summer of 1999.;<br><br>- The contractor put a sealant at the main door sill to cope with the water infiltrations at the façade.;<br><br>- Make draught proof the penetration points at the level of the attic by sealing the junction of the ceiling covering (revetement de plafond) by using an adhesive band or sprayed foam insulation or a mastic sealant around the electric wires and the ventilation conduits.;<br><br>- Repair the button that controls the extracting grill(grille de tire) of the air exchanger. Because without the button, the occupants of the house cannot control the flow of air. This can cause an over consumption of energy for heating.;<br><br>-Dismount and increase the height of the swan tail ventilator and reinstall it orienting it to another direction;<br><br>-Build up a wind break screen in "U", facing the existing swan tail ventilator.;<br><br>-Ensure the proper functioning of the damper (clapet) of the hood.; |

*Information as extracted from APCHQ files*

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|---|---|
| **File Number** | 705 |
| **Problem Location** | House |
| **Building Type** | Other, Specify: _ Residential Building in Row (Row Cottage) |
| **Storeys** | 2 |
| **Problem** | High Relative Humidity (Specify location:_House) |
| **Symptoms** | High Relative Humidity – (Specify location:_House) |
| **Vulnerabilities** | - The mechanical system is composed of an extraction ventilator and a passive fresh air intake. There is a short circuit because of the proximity of the air intake in bedroom 2 with the extraction ventilator.;<br><br>- There is an unequal distribution of the fresh air pushed to the interior of the house.; |
| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The ventilation system was not designed properly and causes the problem |
| **Remedy** | - Respect the Building Code requirements;<br><br>- Install a ventilator in the ceiling of the dining room or the living room;<br><br>- Increase the extraction capacity of the ventilator of the bathroom;<br><br>- Install a fresh air intake at the play room; |

*Information as extracted from APCHQ files*

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| **File Number** | 706 |
| **Problem Location** | Roof; |
| **Building Type** | Detached Cottage House with double garage |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location:_Roof and Ceilings) |
| **Symptoms** | Damages Caused by water – (Specify location: _Ceiling and "retombee" finish of the dining room and the living room; Finish of the wood floors of the living and dining room; Finish of the wood floors of the 2nd floor.);<br><br>Snow Accumulation – (Specify location:_At the valleys of the front façade; Over the garage roof in the back along the house wall);<br><br>Water infiltrations – (Specify location: _Air barrier paper of the wall that divides the dwelling from the garage.);<br><br>Other, Specify: _Water infiltration traces at the attic; |
| **Vulnerabilities** | - There is an open joint between the stucco and the "J" moulding in the window.;<br><br>- There is a finishing difficult to accomplish at the junction of the stucco covering; (revetement de stuc), the asphalt shingle and the ventilated soffit;<br><br>-There is a crack at the top of the window in the stucco covering (revetement de stuc);<br><br>-Some shingles along the wall are not completely adhered among them. Also, the "J" moulding is raised because of some grains that got between it and the shingle.;<br><br>-The first roof truss of the garage is adjacent to the strapping (fourrures) of the wall of the dwelling. This complicates the installation of the roof covering panels. Possibly the flashing support of the base of the wall is not continuous.;<br><br>-The roof has no gutter.;<br><br>- The shingles at the valley are not properly installed and this can become a spot of infiltration when snow accumulates in the roof. However this is not a main source of infiltration in this case.; |

*Information as extracted from APCHQ files*

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| | - The dry joint between the window moulding and the stucco can be a penetration spot for water. However this is not a main source of infiltration in this case.;<br><br>- At the detail of the window base and the flashing of the base of the wall there is a major source of water infiltration. They are situated upstream of the water infiltration traces. The bottom corner on the left of the window is installed very close to the roof. It is no more than 1 ½ inches above the roof. This design makes necessary to cut the base flashing, making the spot very vulnerable to water infiltration to the slightest snow accumulation.;<br><br>-The architectural design of this roof at this sector favours the accumulation of snow due to wind turbulence. On top, the house is oriented to the south, where the solar radiation contributes to the melting of the snow accumulated. The thick layer of snow absorbs the heat and transmits it to the wood deck or the shingles and then snow melts. This is the situation that is produced in this roof.;<br><br>-Another important spot for water infiltrations is the detail at the junction of the base flashing. The least weakness in the construction of this will allow water infiltrations under a shingle that is not well adhered and raised by a stucco grain.;<br><br>-There are important amounts of water upstream of the roof that converge at the back slope of the garage roof because of the architectural design.; |
| **Factors Affecting** | - Solar Radiation melts the snow on the roof;<br><br>- Orientation of the vulnerable roof slopes contributes to the snow melt;<br><br>- Wind turbulence causes snow accumulation on the roof.; |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_The shingles that are not properly adhered to the roof are an important source of infiltrations. This is due to incorrect assembly;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design favours snow accumulations and at the same time has vulnerable spots to such accumulations.; |
| **Remedy** | - Ensure the efficiency of the air barrier membrane and the flashing around the window that overhangs the garage roof.; |

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| -Ensure the efficiency of the base flashing at the junction of the wall of the dwelling and the garage roof.;<br><br>-Install gutters at the main roof on the side of the garage.;<br><br>-Reduce the risks of infiltration by capillarity by ensuring a good adhesion of the shingles of the garage roof along the wall of the house.; |

*Information as extracted from APCHQ files*

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| **File Number** | 716 |
| **Problem Location** | Basement |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Water infiltrations – (Specify location: _Basement) |
| **Vulnerabilities** | - The crushed stone filling of the French drain is mixed with sand. This situation makes the lowering of the water table slower, favouring the increase of pressure under the slab. There is sand also in the bottom of the "basin de captation" |
| **Factors Affecting** | - The variation of the water table is the most probable cause of the water infiltration in this case. In the lots where the soil is mainly sand, the variations in the water table are frequent. This is controlled by the French drain on the exterior side of the foundation. Under the concrete slab the variation is the same but the time of reaction of the filling is slower, leaving the water level in suspension for some time and favouring water infiltrations through the junction of the foundational wall and the concrete slab. |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_The Crushed stone of the back filling of the French drain was mixed with sand. This affected the performance of the French drain system.<br><br>Other, Specify: _Variation of the water table. |
| **Remedy** | - Excavate along the left foundational wall, replace the actual drain with a non covered drain with a Texel geotextile membrane Model 7607/09 or similar.;<br><br>-Back fill with stone of ¾ inch;<br><br>-Install a model geotextile membrane and back fill the surfaces;<br><br>-Dismount the gutter downspout.;<br><br>-Keep the water level under the radius of the conduit that canalizes water of the drain to the basin.; |

*Information as extracted from APCHQ files*

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| **File Number** | 717 |
| **Problem Location** | Ceiling of the kitchen |
| **Building Type** | Semidetached Residential Building Held in Coproperty |
| **Storeys** | 3 ½ |
| **Problem** | Water Infiltrations (Specify location:_Ceiling of the kitchen) |
| **Symptoms** | Damages Caused by water – (Specify location: _Ceiling of the kitchen);<br><br>Other, Specify: _Rot of the waferboard of the roof assembly of the terrasse;<br><br>Rust of the steel beam at the roof assembly of the terrasse; |
| **Vulnerabilities** | - The detail at the junction of the gutter is the infiltration point in this case. The drip is right above the gutter and whenever ice accumulates at the gutter it forces the water to flow through the flashing system and infiltrate close to the steel beam. This is a detail that needs to be seen in drawing to visualize it better. |
| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design of the detail of the drip was wrong because it caused water infiltrations when the gutter had ice accumulations |
| **Remedy** | - Dismount a section of the wood terrasse, dismount the actual drip, Redo the drip but this time lowering below the inferior face of the gutter. Seal the membrane at the level of the new drip and re install the gutter;<br><br>- Open the ceiling in a surface of 48" x 96", take out the rot over the joists and the waferboards, treat the affected wood elements, spray the end of the steel beam with more or less 30 inches of polyurethane foam, insulate again the ceiling adequately, paint the kitchen ceiling with the aid of a vapour barrier paint.; |

*Information as extracted from APCHQ files*

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| **File Number** | 725 |
| **Problem Location** | Basement |
| **Building Type** | Other, Specify: _Detached Cottage House |
| **Storeys** | NA |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Damages Caused by water – (Specify location: Bottom of the closet wall.);<br><br>High Relative Humidity – (Specify location: At the bottom of the foundational walls);<br><br>Water infiltrations – (Specify location: _Basement at the top part of the foundational wall; Brick cladding of the chimney); |
| **Vulnerabilities** | - Water infiltrates through the top part of the wall, possibly through the formwork pins (broches de coffrage) or another spot not filled up.<br><br>- Water infiltrates through the foundation, accumulates around the concrete slab and contributes to the raise in the Relative Humidity at the low parts of the walls.<br><br>- Water infiltrates through the junction of the brick cladding at the chimney. It can easily find its way to the basement if there is a water infiltration through the mortar joints or the brick cladding |
| **Factors Affecting** | - The flashings of the chimney are worn out at the sealant joints. |
| **Causes** | Other, Specify: _Wear of the flashings at the chimney |
| **Remedy** | - For the infiltrations that take place at the brick cladding of the chimney, the repairs are the following:<br>a) Dismount the bottom part of the brick cladding and correct the flashing<br>b) Replace the bricks in the angles of the chimney with smooth stones without joints<br>c) Repair the flashings at the junction of the roof and the brick cladding<br><br>- For the infiltrations that take place at the basement, the repairs are the following:<br>a) Excavate the façade from the front balcony to the turret<br>b) Clean the concrete wall<br>c) Seal all the form pins (broches de coffrage)<br>d) Verify if there are cracks and fill them<br>e) Redo the bitumous coating<br>f) Place gravel to compensate the one taken out from the excavation |

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g) Fill up the foundations
h) Rearrange the terrain

- For the damages at the basement:
a) Cut the gypsum sheathing of the closet wall
b) Dry the components
c) Clean up the wall
d) Clean the carpet

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| **File Number** | 742 |
| **Problem Location** | |
| **Building Type** | Detached Cottage House With Garage Integrated |
| **Storeys** | NA |
| **Problem** | Other, Specify _Claim of an owner relative to the repairing of the roof. |
| **Symptoms** | Damages Caused by water – (Specify location: _Plywood at the attic at the level of the living room);<br><br>Other, Specify: _Deflection of the roof deck under the gutter downspout; |
| **Vulnerabilities** | - There is no flashing at the level of the chimney at the junction of the roof and the "toiture"?????????;<br><br>- There is a point of water infiltration at the gutter over the roof of the living room. There is a deflection of the roof deck at the gutter downspout.; |
| **Factors Affecting** | - The orientation of the house is South East and this favours snow melt that can cause ice accumulations with its ultimate consequence: water infiltrations.;<br><br>- The damages caused in the plywood at the roof are due, possibly to a large accumulation of ice or to an attempt to de ice the surface.; |
| **Causes** | Other, Specify: _The problem is possible due to a large accumulation of ice or an attempt to de ice the surface |
| **Remedy** | - There are no remedial measures specified in this file |

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| **File Number** | 746 |
| **Problem Location** | Basement |
| **Building Type** | Cottage in Row |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Water infiltrations – (Specify location: _Basement; Base of the foundational wall);<br><br>Other, Specify: _Crumbling of the foundational wall;<br><br>Sulphate attack at the foundational wall |
| **Vulnerabilities** | - The installation of a drain connected to a "puits perdu" is allowed by the Building Code. The water accumulated in the well (puits) must percolate through the soil or be evacuated to a sewer system or a ditch. If the water table rises and fills the well (puits), water can easily return to the drain and increase the hydrostatic pressure. In this case, the infiltrations are due to a backflow of the drainage system installed to the "puits perdu".;<br><br>- There is a gutter downspout goes along the foundation. This can contribute to the increase in water at that spot since the water that is canalized by this means has to be absorbed by the soil.; |
| **Factors Affecting** | - There is a variation in the water table that causes a backflow of water in the French drain that increases the hydrostatic pressure on the foundation, causing the water infiltrations. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The incorrect specification of a drainage system connected to a "puits perdu" is not suitable in a terrain where the water table is susceptible to changes in level._Also, the location of the gutter downspout contributes to the increase of water in the affected area |
| **Remedy** | - Eliminate the "puits perdu".;<br><br>- Excavate the corner of the foundation and connect the drain to the "bassin de captation" in the basement;<br><br>- Fill up the connection with crushed stone ¾ inch size;<br><br>- Canalize the gutter downspout to the back of the terrain.; |

*Information as extracted from APCHQ files*

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| **File Number** | 748 |
| **Problem Location** | Basement |
| **Building Type** | Detached Residential Building Split Level Type |
| **Storeys** | |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Water infiltrations – (Specify location: _At the cracks in the foundational wall);<br><br>Other, Specify: _Cracks in the foundations at the level of the back wall and two lateral corners |
| **Vulnerabilities** | - There is a gutter downspout close to one of the cracks that have infiltrations.<br><br>- The slope of the terrain is almost inexistent along the wall that has the cracks. This doesn't favour a fast elimination of the water that accumulates in the surface.<br><br>- The cracks occurred because the back filling of the foundation trench was done at a early age of the concrete, when it had not reached its ultimate strength.<br><br>- When the cracks appeared, they were repaired with epoxy injections. Probably the product was of a rigid type. This type of product does not allow any movement in the foundation therefore it is most likely to fail. |
| **Factors Affecting** | |
| **Causes** | Incorrect materials specified and/or inappropriately detailed, Explain why?_The possible cause of the problem is the use of an incorrect type of sealant for the cracks. Probably the one that they used at the beginning was of a rigid type that didn't allow movement of the foundation |
| **Remedy** | - Reparation of the cracks with an injection of a flexibly type.<br><br>- Reparation by putting a membrane at the cracked spots |

*Information as extracted from APCHQ files*

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| **File Number** | 749 |
| **Problem Location** | Roof of the garage |
| **Building Type** | Residential Building (Detached Cottage) With Garage Integrated |
| **Storeys** | 2 |
| **Problem** | Ice Accumulation (Specify location:_Roof of the garage) |
| **Symptoms** | Ice Accumulation – (Specify location:_Junction of the house and garage roofs);<br><br>Icicles – (Specify location:_ Junction of the house and garage roofs); |
| **Vulnerabilities** | - The configuration of the garage and house roof favour snow accumulation during winter. This accumulations are accentuated by the orientation of the building. Even though the contractor has built a cricket at the junction of the wall of the house, the valleys create a channel that finishes to the right of the brick cladding.;<br><br>- The construction of the cricket restricts the flow of water that comes from the top part of the main roof.;<br><br>- There are heat losses at the brick cladding of the side wall of the house that is continuous at the level of the garage. This happens even though the contractor injected polyurethane foam in the cavity and at the level of the garage ceiling, because now the heat losses are by conduction. Since bricks are a conductive material, they allow the warming of the attic located under the cricket. Conduction is increased if the interior temperature of the garage is maintained high; |
| **Factors Affecting** | - The angle of the sun in winter allows the warming up of the lateral face of the roof of the house, and doesn't allow, at the same time, the warming up of the slope of the garage. This situation favours ice formation and ice dams at the level of the garage roof. |
| **Causes** | Other, Specify: _Failure of Performance of the Building Envelope due to Heat Losses |
| **Remedy** | - Snow accumulations cannot be eliminated at the valley created at the junction of both roofs (garage and house). We can make easier the flow of water by modifying the valleys to enlarge the space at the junction of the garage roof and the wall of the house. (see drawing in file TEC 2001-749). By modifying the channel zone, water from snow melt will flow easier and will impede ice formation.;<br><br>- Install heating wires to keep the zone free of ice at the time of milder winter climate; |

*Information as extracted from APCHQ files*

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|---|---|
| **File Number** | 753 |
| **Problem Location** | Basement |
| **Building Type** | Residential Building (Detached Bungalow) With a Dwelling at the basem |
| **Storeys** | 1 |
| **Problem** | Other, Specify: _Excessive Humidity in the basement |
| **Symptoms** | Other, Specify: _ Excessive Humidity in the bathroom and the master bedroom of dwelling located in the basement |
| **Vulnerabilities** | |
| **Factors Affecting** | - The terrain is in a very accentuated slope. Very cold water trickles under the soil. This water is canalized to the drain and cools the footing of the foundation and the bottom of the foundational walls. This situation together with the conductivity of the concrete can favour the condensation in surfaces if the dew point is reached during warm periods.<br><br>- Another factor that can accentuate the problem is the moisture required for concrete placement. Only part of the water is used in hydration and the rest must evaporate progressively. In the first months the material is found to be more conductive and therefore can contribute to increase the problem. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The designer did not foresee the effect of the cold water runoff of the soil on the foundation |
| **Remedy** | - The problem is due to warm weather condensation accentuated by the drying process of the concrete so to improve the conditions the drainage at the base of the back walls and right side walls must be improved to allow water to be evacuated fast. In the next winter, the air exchanger will allow a quicker drying of the walls. |

*Information as extracted from APCHQ files*

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| **File Number** | 754 |
| **Problem Location** | Roof |
| **Building Type** | Other, Specify: _Residential Building held in Coproperty |
| **Storeys** | 6 |
| **Problem** | Ice Accumulation (Specify location:_Fascia Board (Bordure de toits) |
| **Symptoms** | Ice Accumulation – (Specify location:_Fascia Board (Bordure de Toit of the roofs that are above the terrace of the building |
| **Vulnerabilities** | - The roof has some "surbaissees" sections. In winter the "surbaissees" sections allow an important accumulation of snow. In the exposed faces, this accumulations can be swept out by the wind but it is not the case for the "surbaissees".;<br><br>- If the roof drainage system allows the flow of water from melt, there will not be any problem. But if the drain or the gargoyle that evacuates water is clogged with ice, water accumulation can make the protection membranes fail and cause water infiltrations along with damages.;<br><br>- The roof of the terrace is partly heated and partly ventilated. This worsens the problem of ice accumulation because the heat losses at the warm section causes snow melt and when the water reaches the ventilated section it freezes. This results in an inefficient gargoyle. The frozen water favours ice accumulation in the fascia board or the gargoyles and when temperature rises, the water accumulates over the terrace roof and causes failure in the protection membranes.; |
| **Factors Affecting** | - Solar Radiation can contribute to snow melt and water will be frozen in the colder zones of the roof. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The architectural design favors snow accumulations. This is inappropriate design |
| **Remedy** | - Install heating wires to keep the drainage zone free and in this way prevent the risks of water infiltrations in warmer periods of winter. |

*Information as extracted from APCHQ files*

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| **File Number** | 759 |
| **Problem Location** | Roof |
| **Building Type** | Residential Building (Detached Cottage) |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Roof) |
| **Symptoms** | Damages Caused by water – (Specify location: _Interior of a closet);<br><br>Ice Dams – (Specify location: Roof);<br><br>Snow Accumulation – (Specify location: Plywood deck at the attic); |
| **Vulnerabilities** | - There are water infiltrations caused by the melting of ice from ice dams at the time of milder periods in winter. Ice dams can be originated by water that freezes when entering in contact with the gutters. Progressively ice will accumulate in the roof edge impeding the flow of water.;<br><br>- A weak ventilation of the attic can favour ice dams because when poorly ventilated, the attic warms up causing snow melt and ice accumulation.;<br><br>- The most important cause for ice dams is the loss of heat towards the attic. Heat losses are mostly accentuated at the perimeter of the exterior walls because the insulation at the ceilings is difficult to install above the exterior walls. If the space between the insulation touches the wood deck, the heat loss is then increased. Also, the profiled deflectors of plastic foam leave the insulation in contact with the wood deck close to the truss members of the roof. In this case, the heat loss by conduction accelerates ice dam formation. Another sources of heat losses are: the access hatch of the attic, the embedded lamps (luminaires encastres), the beams supporting structural elements, etc.; |
| **Factors Affecting** | - Solar Radiation contributes to snow melt in the roofs and contributes to ice dam formation. The thick beds of snow absorb heat and transfer it to the wood deck or the shingles, then snow melts. This action over the slopes exposed to the south favour snow melt. The energy absorbed by the structure heats the attic and melts the snow over the non exposed slopes. The façade is oriented to the south;<br><br>- The house is located in a zone full of trees. The trees protect the house from the wind, favouring snow accumulation. Snow accumulation can block the ventilators in the roof.; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making |

*Information as extracted from APCHQ files*

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| | calculations or predictions of performance Explain why?_The design of the house and the orientation favour snow accumulation |
| **Remedy** | - Make the roof tight with the use of protection membranes<br><br>- Install heating wires to prevent ice dams. |

*Information as extracted from APCHQ files*

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|---|---|
| **File Number** | 760 |
| **Problem Location** | Ceiling of the Solarium |
| **Building Type** | Other, Specify: _Detached Residential Building (Bungalow) with attach |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations (Specify location: Ceiling of the solarium) |
| **Symptoms** | Damages Caused by water – (Specify location: _Gypsum under the window frame);<br><br>Ice Accumulation – (Specify location: Cornice);<br><br>Water infiltrations – (Specify location: _At the junction of the vertical and horizontal panels);<br><br>o☐Other, Specify: _Traces of water infiltration at the Floor; |
| **Vulnerabilities** | - The architectural concept of a "surbaisse" roof together with the orientation of the house favours snow accumulations.;<br><br>- The presence of the 2 skylights favours melt of the accumulated snow. This melted snow flows to the bottom and freezes when it touches the cold surfaces. Then an ice dam is produced. If there is an increase of temperature in winter, the water from the melted snow will be blocked by the ice.;<br><br>- There is a water infiltration at the junction of the vertical and horizontal panels because the end of the panels is not tight and water flows between the panels and drips through the aluminium extrusion.; |
| **Factors Affecting** | |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_The end of the vertical and horizontal panels is not tight and water infiltrates through this spot.;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The architectural concept of the "surbaisse" roof favours snow accumulation.; |
| **Remedy** | - Reduce heat losses through the skylights by installing a glazing in the inferior part of the areaway (puits de lumiere);<br><br>- Dismount the gutter and the fascia, seal completely the ends of the panels eliminating all sources of infiltration.(see detail on file TEC2001- |

*Information as extracted from APCHQ files*

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| | 760);<br><br>-Install heating wires to allow flow between the ice accumulation and the aluminium sheet.; |
| **File Number** | 761 |
| **Problem Location** | At the "cabanon" located under the balcony of the house |
| **Building Type** | Residential Building (Detached Cottage) |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location:_at the "cabanon" located under the balcony of the house) |
| **Symptoms** | Water infiltrations – (Specify location: _At the junction of the slab and the foundational wall; In front of the window door; at the right end of the balcony);<br><br>Other, Specify: _Cracks at the brick cladding and at the sealant joint on the left side of the window; |
| **Vulnerabilities** | - At the time of the construction of the house, the masonry job was done before the placing of the concrete slab of the balcony. This was done in a way that the wheepholes discharged the water inside the cabanon. (see drawing on file TEC2001-761);<br><br>- The contractor dismounted the masonry at the level of the slab and reinstalled a flashing to reject water at the level of the concrete slab but water infiltrations persisted because this job was not done at the level of the door window. On top of this, the flashing was not extended but to the exterior face of the left side wall of the house, leaving water trapped at the back of the cladding. When water accumulated in a sufficient amount, it flowed through the weak spots and infiltrated to the "cabanon".; |
| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The improper design caused water to be discharged by the wheepholes to the inside of the "cabanon" |
| **Remedy** | - Install a built in flashing in the concrete slab of the balcony. To do this, it is necessary to dismount the cladding over the balcony, insert the metallic flashing built in the slab and redo the brick cladding of the affected section. |

*Information as extracted from APCHQ files*

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| **File Number** | 762 |
| **Problem Location** | Floors of the basement |
| **Building Type** | Residential Building (Detached Cottage) |
| **Storeys** | 2 |
| **Problem** | Other, Specify _Deterioration of the floors of the basement |
| **Symptoms** | Damages Caused by water – (Specify location: _False Floor (Faux Plancher) of the basement);<br><br>Water infiltrations – (Specify location: _Junction of the concrete slab and the back foundational wall);<br><br>Other, Specify: _Traces of water infiltration at the ceiling close to one of the beams; |
| **Vulnerabilities** | - The conduit that connected the roof drain to the municipal sewer is blocked. The connection of this conduit was made to the main sanitary sewer. If this job was wrongly executed, the debris could obstruct the conduit. If the drain cannot evacuate the water from the perimeter of the foundation, it accumulates under the slab. This accumulation produces hydrostatic pressures and water ends up infiltrating through the shrinkage cracks of the slab or at the junction of the slab and the foundational walls. If the roof drain is connected to the same conduit, it can contribute to the accumulation of water under the slab if the connections are defective and not tight. The accumulation of water over the slab and the lack of ventilation in the "faux plancher" contributed to the deterioration of the "faux plancher" structure. |
| **Factors Affecting** | - The fact that in summer the water level in the soil is relatively low and the drain is less required made it difficult to detect that the drain was blocked. On top of that, the drain was repaired 6 years ago (according to the owner's sayings) which is a short time.;<br><br>- The infiltrations at the ceiling are due to normal wear of the roof. The roof is more than 10 years old.; |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why? Incorrect installation of the drain is the probable cause of it being clogged. |
| **Remedy** | - Unblock the blocked drain;<br><br>- Repair the damaged floors;<br><br>- Repair the damaged ceiling; |

*Information as extracted from APCHQ files*

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| | - The roof needs repairs because it has reached the end of its service life.; |
| **File Number** | 768 |
| **Problem Location** | In 12 different dwellings |
| **Building Type** | Residential Building with (8 dwellings) per Floor Held in Coproperty |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: In 12 different dwellings) |
| **Symptoms** | Water infiltrations – (Specify location: _Through the windows; Through the roof);<br><br>Other, Specify: _Cracks in Ceiling of the living rooms; Undulation of the plywood panels in the roof; |
| **Vulnerabilities** | -There is a lack of tightness at the windows;<br><br>- Water infiltrates through a valley that was broken with an axe when an amateur tried to de ice the roof. In general the roof has damages because of this type of deficient de icing job.;<br><br>-The evacuation conduits of the laundry dryer or the kitchen hood possibly lack a flapper (clapet de retenue) or have them inversed and do not close after usage. When these two machines are in use, warm and humid air heats the walls of the conduit. When they stop, fresh exterior air enters the conduits therefore condensation can happen in the conduit walls and when it is accumulated it infiltrates through the joints and drips in the ceilings. This explains that the symptoms occur only in winter.; |
| **Factors Affecting** | |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_There is a lack of tightness at the windows and this is probably due to an incorrect assembly;<br><br>Other, Specify: Poor maintenance (wrong de icing procedure); |
| **Remedy** | - Replace the shingles that were damaged by the de icing of amateurs.;<br><br>- If the hypothesis of condensation in the evacuation conduits is correct, then it is needed to carry some works at the level of the flappers (clapets) of the different evacuation systems at the ground floor.; |

*Information as extracted from APCHQ files*

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| **File Number** | 390 |
| **Problem Location** | Plywood deck of the roof |
| **Building Type** | Semidetached Residential Building with 4 Units per Floor |
| **Storeys** | 2 |
| **Problem** | Undulations in the plywood deck of the roof |
| **Symptoms** | Mold – (Specify location: Plywood roof deck facing the ventilation conduit in the attic);<br><br>Other, Specify: _Undulation of the plywood roof deck;<br><br>Unwedging of the plywood sheets of the plywood roof deck; |
| **Vulnerabilities** | - In the case of 153 rue Saint Georges, certain modifications in the ventilation conduits at the attic were done. This can be proved since there are tips of adhesive tape and a section of conduit over the insulation in the attic. The conduit leaks and it is the source of the problem. The leak results in a high relative humidity, causing expansion of the plywood and also mold. The plywood is damaged around this conduit.<br><br>- The flapper (clapet) of the ventilation conduit of 155 rue Saint Georges is blocked and there is a backflow of warm and humid air to the interior of the attic.<br><br>-The expansion of the wood fibres in the plywood deck of both houses is due to the increase of the humidity content of wood. This is accentuated by the leaks in the ventilation conduits. |
| **Factors Affecting** | -The undulations are apparently not recent. This means that they were either not noticed or neglected. |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_There is a leak in the ventilation conduit at the attic of 153 rue Saint Georges, due to poor workmanship<br><br>Other, Specify: There is a leak in the ventilation conduit at the attic of 155 rue Saint Georges, due to a lack of maintenance. |
| **Remedy** | - There are no remedial measures suggested in this case. |

*Information as extracted from APCHQ files*

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|---|---|
| **File Number** | 392 |
| **Problem Location** | Ceilings |
| **Building Type** | Semidetached Duplex |
| **Storeys** | 2 |
| **Problem** | Damages in Ceilings |
| **Symptoms** | Damages Caused by water – (Specify location: _Ceilings of the 2nd Floor Dwelling; Kitchen Ceiling of the 2nd Floor Dwelling);<br><br>Mold – (Specify location: Ceiling assembly of the 2nd Floor Dwelling);<br><br>Other, Specify: _Swelling of the gypsum boards in the ceiling of the 2nd Floor Dwelling;<br><br>Wetness of the gypsum boards in the ceiling of the 2nd Floor Dwelling;<br>Wetness of the gypsum boards in the walls of the 2nd Floor Dwelling;<br>Wetness of the batt insulation in the ceiling assembly of the 2nd Floor Dwelling;<br><br>Bubbles in the paint coat of the walls in the Bathroom;<br>Bubbles in the paint coat of the walls in the Hallway; |
| **Vulnerabilities** | - The house has a kind of soffit that overhangs in the façade put with the purpose of acting as a means of ventilation.. But it is not effective because the sense in which the joists and the sleepers are directed, does not favour air circulation through such overhang.<br><br>- The different norms of the National Building Code specify a ventilation surface of 1/150 of the insulated surface for flat roofs. In the present case, the roof has an insulated surface of 1102 ft2. Therefore the ventilation surface should be of 7.34 ft2. But the total surface offered by the goose neck ventilators is of 0.92 ft2. This is the main source of the problem because the building only has and effective 12.5% of the required ventilation surface.<br><br>- At the time of the repairs, the contractor did not remove the plaster from the walls, he installed a lower R-value insulation and a different vapour retarder because he had to follow the owner's consultant advice. The installation of a continuous vapour retarder in the ceiling was not possible due to the fact that the interior partitions remained in place untouched. This situation created many joints in each of the partitions. Therefore, air tightness of this assembly was very deficient. By increasing the thermal resistance of the ceilings, air tightness should be increased too. |

*Information as extracted from APCHQ files*

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| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The building does not have enough ventilation in the roof and also the design of the corrective measures did not consider the lack of air tightness due to the many joints generated at the partitions of the house. This is poor design. |
| **Remedy** | There are no remedial measures suggested for this case. |

*Information as extracted from APCHQ files*

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|---|---|
| **File Number** | 396 |
| **Problem Location** | Garage; |
| **Building Type** | Detached Cottage House, With Garage Integrated |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Garage, Basement and Cold Room of the house) |
| **Symptoms** | Water infiltrations – (Specify location: _Cold room; Family room in the Basement; Sanitary duct under the garage; Ceiling of the garage; Under the concrete slab) |
| **Vulnerabilities** | - The water infiltrations are due to weaknesses in the construction details.<br><br>- There is a cold joint generated by the pouring of the concrete in the balcony. The foundational walls were poured first and some time after, the balcony was poured. This situation favours the creation of cold joints. In the present case, this phenomenon is the cause of the water infiltrations in the right front part of the cold chamber.<br><br>- The perimeter of the window of the cold room is not tight. This window was installed after the pouring of the concrete. The perimeter was sealed with foam and parging. When the water spray test was done, water infiltrated through the frame and dripped over the floor.<br><br>- There is a spot of water infiltrations in the edges of the concrete slab of the terrace and the brick wall that is being carried by the slab. Probably, the flashing is defective at this spot.<br><br>- The flashing of the chimney is not adequate and water infiltrates behind the brick cladding and it trickles along the inner wall. If water cannot be channelled through the wheepholes, it flows above the foundations and drips to the basement. |
| **Factors Affecting** | - Heavy rain and strong winds favour the water infiltrations. |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_The water infiltrations are due to weaknesses in the construction details. |
| **Remedy** | - For the Cold joint generated at the balcony, inject the joint with epoxy or install an exterior membrane;<br><br>- For the infiltrations through the window of the cold room, correct the lack of tightness around the window frame; |

*Information as extracted from APCHQ files*

- For the infiltrations in the edges of the concrete slab and the brick walls of the terrace, install a metal flashing at this spots;

*Information as extracted from APCHQ files*

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| **File Number** | 402 |
| **Problem Location** | Expansion of the House (Agrandissement); |
| **Building Type** | Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Other, Specify _Damages Caused by Water;<br><br>Rot of the wood structure of the Expansion of the House (Agrandissement); |
| **Symptoms** | Damages Caused by water – (Specify location: _Exterior Stucco Cladding; Wall structure; Structural jambs (montants); Exterior and Interior Carton fibre, Wood strappings);<br><br>Other, Specify: _Rot of the structure of the Expansion of the House (Agrandissement);<br><br>Rot of the left side elevation;<br><br>Rot of the right side elevation;<br><br>Black stains and Traces of water infiltrations at the façade and the back façade;<br><br>Black stains in the attic; |
| **Vulnerabilities** | -The parapets are built with a wood frame covered with plywood. This "box" is covered with a metallic cladding. There is a metallic moulding in the bottom that fastens the metallic cladding of the parapets that has a "J" shape. At the time of rain fall, water is canalized through this moulding along the slope of the roof behind the metallic cladding in the vertical section along the walls. This "J" shape moulding was specified in the design of the architect and is the cause of infiltrations behind the cladding, despite the sealing at the junction of the stucco and the metallic cladding or the mouldings.<br><br>- The gutters are the mouldings proposed in the plans. They are working as gutters when their role is that of mouldings and their function is other than canalizing water. Therefore they are not effective doing this.<br><br>- At the design stage in 1980, the National Building Code required a (bande de depart) in the roof sealed over less than 200 mm and the (pureaux) should be fixed with mastic and the plans submitted by the architect do not meet this requirement. |

*Information as extracted from APCHQ files*

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| | - The main source of degradation is a design error. Not in the choice of cladding or the composition of the exterior envelope but in the details in the roof edges. The amount of water that trickles close to the windows and along the cladding have favoured the degradation of the walls. The two spots where the walls are more affected are those where the slopes of the roof collect and canalize water to. The fact that the contractor sealed such spots does not prevent water infiltrations. This design does not take into account the basic principle of keeping away water from the materials and components susceptible of deterioration. The designer canalized water of one part of the roof through a valley over the cladding where there is no gutter. These spots are the ones where the structure is very affected because the valleys pour a lot of water every time it rains. |
| **Factors Affecting** | - The sealing around the windows and openings must be maintained. The owner neglected the maintenance of such spots and it is very probable that they are already deteriorated after 15 years of being built. |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_There is a moulding that canalizes water behind the cladding and this is wrong detailing;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_There is a valley that collects water and pours it to the cladding. This is poor design;<br><br>Other, Specify: The sealants around windows and other openings have not been maintained by the owner; |
| **Remedy** | There are no remedial measures specified in this file |

*Information as extracted from APCHQ files*

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|---|---|
| **File Number** | 404 |
| **Problem Location** | Front Cornice |
| **Building Type** | Detached Residential Building Split Level Type |
| **Storeys** | NA |
| **Problem** | Water Infiltrations (Specify location: Front Cornice) |
| **Symptoms** | Water infiltrations – (Specify location: _Through the soffit of the cornice above the front gallery; Junction of the corner (corniere) under the façade flashing)<br><br>Other, Specify: _Traces of water infiltrations in the soffits;<br><br>Traces of condensation in the access hatch of the ceiling; |
| **Vulnerabilities** | - There is a spot of water infiltration at the junction of the corner (corniere) under the façade flashing. Water flows through the moulding and infiltrates at this spot;<br><br>- There is a lack of tightness at the access hatch of the ceiling due to the lack of a wind break around the access hatch; |
| **Factors Affecting** | -Heavy rain and strong wind favour the water infiltrations. |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_There are water infiltrations at the junction of the corner (corniere) under the façade flashing that are probably due to an incorrect overlap of the sheathing paper and the flashings on the façade and the side of the corner (corniere). This is poor workmanship |
| **Remedy** | - To eliminate the infiltrations at the junction of the corner (corniere) under the façade flashing, dismount the aluminium siding on the left side and overlap adequately the sheathing paper and the flashings in the façade and on the side of the corner (corniere);<br><br>- To eliminate the condensation problem in the access hatch of the ceiling, install a wind break in the access hatch; |

*Information as extracted from APCHQ files*

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|---|---|
| **File Number** | 407 |
| **Problem Location** | Asphalt Shingle Roof Cover |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Other, Specify _Deterioration of the Asphalt Shingle Roof Cover |
| **Symptoms** | Other, Specify: _Deformation in the corners of the asphalt shingles;<br><br>Loss of adhesion of the grains in the asphalt shingles; |
| **Vulnerabilities** | -The shingles present undulations due to a premature shrinkage |
| **Factors Affecting** | |
| **Causes** | Other, Specify: The shrinkage of the Asphalt shingles is probably due to a defective manufacturing process. |
| **Remedy** | Replace all the asphalt shingles on the roof |

*Information as extracted from APCHQ files*

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|---|---|
| **File Number** | 411 |
| **Problem Location** | Roof; |
| **Building Type** | Multifamily Condominium (15 dwellings) |
| **Storeys** | 3 ½ |
| **Problem** | Water Infiltrations (Specify location: Through the roof);<br><br>Other, Specify _Condensation in the attic;<br><br>Structural deflection;<br><br>Deterioration of the roof |
| **Symptoms** | Other, Specify: _Bubbles of tar in the roof membrane;<br><br>Traces of rust in the parapet flashings;<br><br>Degradation of the roof membrane;<br><br>Structural Deflection of the Roof of Building #2049; |
| **Vulnerabilities** | - The condensation problems can be due to the blocking of the evacuation grills by the fluff (charpie) from the driers. The grills were blocked, favouring the migration of exhaust air into the attic. Condensation created by this phenomenon is the source of water infiltrations<br><br>- The grills of the goose neck ventilators are blocked with fluff from the driers. This means that the owner is not giving maintenance to them;<br><br>-There is a roof deflection of 1 inch close to the left skylight of building #2049. This deflection can cause water ponding and it is probably the source of deterioration of the membrane at this spot. This amount of deflection is not admitted by the National Building Code;<br><br>-There is a lack of tightness at the goose necks of building #2039; |
| **Factors Affecting** | -Infiltrations happened during heavy rain. |
| **Causes** | Other, Specify: The evacuation grills are blocked with fluff from the driers, favouring condensation. This is due to a lack of maintenance. NOTE: STRUCTURAL DEFLECTION OF THE ROOF CAN HAVE MANY SOURCES AND THE FILE DOES NOT SPECIFY THEM. |
| **Remedy** | - Remove the wood deck to have access to the attic and correct the deflection problem according to Jaeger, the manufacturer of the trusses. |

*Information as extracted from APCHQ files*

- Verify the tightness of the goose necks in the roof of building # 2039

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|---|---|
| **File Number** | 412 |
| **Problem Location** | Basement |
| **Building Type** | Other, Specify: _Detached Prefabricated Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Water infiltrations – (Specify location: _Basement, along the wall in the back of the house); |
| **Vulnerabilities** | - The flapper (clapet de retenu) of the rain sewer has metallic deposits. This affects its performance.<br><br>- The drain of this house is connected directly to the rain sewer and is protected from backflow with a flapper (clapet de retenu). This type of connection is allowed by the National Building Code but the Quebec Provincial norms are different in this respect. The Provincial plumbing code applicable to this municipality requires to do the connection though a drainage basin (bassin de drainage). This basin allows drainage of water that accumulates under the concrete slab even if a pump is not installed. During heavy rain or spring snow melt, the water table fluctuates uniformly. Then, the drain lowered the water table around the footings but the center of the basement ground remains saturated with water. On top of this, circulation of water is slowed down by the existence of a footing running in the centre of the house. If a drainage basin is installed it will collect the water that accumulates under the slab.<br><br>- The depth of the excavation did not take into consideration the level of the water table. Apparently, the depth should have been less, so that it did not get close to the water table. At the time of the excavation, the identification of the soil should had a less deep excavation as a result.<br><br>- The gutters are close to the foundations. The rainwater downspout located on the left side of the house canalizes water directly along the foundations. At the time of heavy rain, this water supply can difficultly be taken by the drain. This situation contributes to the excess of water under the concrete slab.<br><br>- The slopes in the terrain are almost non existent this favours the accumulation of water close to the house. |
| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The depth of the excavation for the house did not consider the level of the water table. |

*Information as extracted from APCHQ files*

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| | Also, the gutter downspouts have their discharge close to the foundations and the slopes of the terrain are almost non existent. This is an error of design. |
| **Remedy** | There are no remedial measures suggested in this file |

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|---|---|
| **File Number** | 416 |
| **Problem Location** | Roof |
| **Building Type** | Multifamily Condominium |
| **Storeys** | 3 |
| **Problem** | Other, Specify _Damages in the roof of the building |
| **Symptoms** | Other, Specify: _Traces of repairs to the roof membrane done in January 1995;<br><br>Damages in the metallic edge (bordure metallique) of the roof;<br><br>Damages in the aluminium fascia;<br><br>Folds in the finish membrane in the damaged section;<br><br>Unattachement of a 25 ft wide band of the front fascia; |
| **Vulnerabilities** | - The under bed (sous-couche) used by the contractor was Soprema brand, type P.S. 90. It was nailed according to the plan found in the annex #1 of TEC 95-416. The type of nail used was other than the one recommended by the manufacturer of the membrane. |
| **Factors Affecting** | -The damages caused to the roof are the result of strong winds that hit the building at the time when the damages were produced. The National Building Code establishes the design parameters for wind loads and these loads are based in probabilities of 1/10, 1/30 and finally 1/100 that represent important winds. The probabilities of the Code are based on the factor of 1/30 and its this measure that is used in the structural design. Since the building of the present case is classified according to the IX section of the National Building Code, the design is based in the prescribed 1/30 median. In the present case, the measurements done in the airport of Quebec indicate winds with gusts of 106 km/hr. This speed in meters/second is equal to 29.44 m/s. The supplementary table of the National Building Code confirms that this speed is equal to a factor of 0.57 to 0.60 (See the table: Wind Pressure Conversion to Speed, provided on TEC 95-416). This factor is classified in the table "Design values of Canadian localities" under the 1/100 category where the probability of this type of winds can be produced. |
| **Causes** | Other, Specify: Unexpected climatological conditions |
| **Remedy** | - There are no remedial measures specified in this case. |

*Information as extracted from APCHQ files*

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| **File Number** | 419 |
| **Problem Location** | Attic |
| **Building Type** | Semidetached Cottage |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Attic) |
| **Symptoms** | Damages Caused by water – (Specify location: _Bedroom # 3, in back right corner);<br><br>Ice Accumulation – (Specify location: Front section of the roof);<br><br>Water infiltrations – (Specify location: _Ceiling of bedroom #2, close to the chimney);<br><br>Frost in the wood shavings panel in the back section of the roof;<br><br>Traces of water infiltration in the ceiling of bedroom #2; |
| **Vulnerabilities** | - The heating conduits are located in the attic and are covered with a weak insulation. This, combined with heat losses and insufficient ventilation of the attic contributes to the formation of ice dams when snow accumulates in the roof.<br><br>- The bathroom fan is incorrectly insulated and disengaged at some spots.<br><br>-There is a turbine ventilator that is close to two flat ventilators. The presence of frost in the back section of the wood deck reveals that there is a short circuit in the ventilation system The turbine pulls air not from the cornices but from the flat ventilators. This phenomenon contributes to air stagnation in the bottom part of the roof and the increase of temperature at this level.<br><br>- The architectural design of the building favours ice accumulation. Despite the fact that the presence of a membrane under the shingles contributes to diminish the damages, the least deficiency causes other infiltrations. The infiltrations in the back section are probably produced at the flashing of the chimney and under the shingles |
| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? Insufficient Ventilation and insulation, combined with an architectural design that favours snow accumulation caused the problem. This is poor design. |

*Information as extracted from APCHQ files*

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| **Remedy** | - The corrective measures done in the front section of the roof of the building are adequate.<br><br>- Regarding the back section of the roof of the building the installation of a membrane is needed to do with great care.<br><br>- Considering the heat losses in the heating conduits and the deficient ventilation, heating wires are necessary. A second alternative to this, would be the revision of the ventilation and the proper insulation of the heating and the bathroom fan conduits. |

*Information as extracted from APCHQ files*

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| **File Number** | 423 |
| **Problem Location** | House |
| **Building Type** | Other, Specify: _Commercial Building |
| **Storeys** | 2 |
| **Problem** | Air Infiltrations;<br><br>Air Exfiltrations; |
| **Symptoms** | Air Exfiltration;<br><br>Air Infiltration;<br><br>High Heating Bills; |
| **Vulnerabilities** | - The batt insulation is fixed to a vapour retarder that does not offer any resistance to air flow because of a very deficient installation;<br><br>- The joints between the insulation are not sealed;<br><br>- The insulation is compressed at the level of the bracings and the structural elements;<br><br>- There is no air tightness at the junction of the walls and the ceilings;<br><br>- According to the choice of envelope system, the steel sheet of the ceiling should act as an interior finish, vapour retarder, and air barrier. In this case, the steel sheet is only functioning as an interior finish. In this building, the vapour barrier was fixed to the insulation to act as an air barrier without caring for the tightness at the joints between the vapour retarder and the different elements of the building;<br><br>- Since the vapour retarder is fixed to the insulation, the exterior steel sheet compressed the insulation to a thickness of 1 ¾".The normal thickness for this insulation is 6". This is due to the fact that the compression excerpted over the insulation at the level of the structural elements is transmitted to the whole insulation assembly. This situation causes a reduction in the thermal resistance of the insulation at the spots where it is compressed. This poor installation reduces the overall thermal resistance of the building; |
| **Factors Affecting** | |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_The insulation and the vapour retarder in the envelope assembly is |

*Information as extracted from APCHQ files*

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| | poorly installed and this aggravated the problem of lack of tightness;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The lack of tightness was caused by a design that did not include an air barrier in the wall assembly. This caused the high heating bills; |
| **Remedy** | - Alternative 1: Dismantle the steel sheet of the exterior cladding and install an air barrier fixed over the framework. The batt insulation can then be different than an air barrier and will perform according to its purpose.<br><br>- Alternative 2: Use a sprayed material that will play the role of insulation and air tightness system. |

*Information as extracted from APCHQ files*

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| **File Number** | 431 |
| **Problem Location** | Ceilings of the House |
| **Building Type** | Detached Cottage House |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Ceilings of the House) |
| **Symptoms** | Water infiltrations – (Specify location: _Ceilings of the house) |
| **Vulnerabilities** | - In the valley located on the south east side the flashing has undulations due to the expansion of the material. The metal sheets of the valleys were installed in winter. Therefore, it is expected that an expansion would occur when exposed to warm weather. Some screws of the metal sheet covering of the roof are broken. However this situation does not cause the water infiltrations;<br><br>- The insulation placed in the valleys is damaged. Apparently the damages were done at the time of the installation of the roof covering;<br><br>-The distribution of the ventilation grills below the cornices is deficient. Specially on the side of the garage doors. This causes snow and ice accumulation in this part of the roof. The temperature under the metal sheet covering rises and melts the accumulated snow, and the cycle begins. At the time of a milder weather period, water from the top part of the roof cannot flow freely and infiltrates under the metal sheet covering;<br><br>- The ventilation system of the ridge is composed of wood planks and metal sheet sections built on site. (see pictures 4,5,6 on TEC 96-431). The metal sheets have perforations to allow ventilation of the ridge. This perforations are insufficient. Also, air movement is restrained at this spot by a mosquito mesh installed under the plank assembly; |
| **Factors Affecting** | - The orientation of the building favours snow accumulation in the valleys. Dominant winds from west favour snow accumulation in the roof sections opposite to them. This, combined with the fact that the metal sheet absorbs heat fast, favours snow melt, creating ice dams. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The problem is caused by ice dams that are due to a deficient distribution of the ventilation of the attic. This is a design problem. |
| **Remedy** | - Install heating wires along the exposed valleys;<br><br>- Duplicate the number of perforations in the ridge ventilation system to increase air flow; |

*Information as extracted from APCHQ files*

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| **File Number** | 433 |
| **Problem Location** | Chimney |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations (Specify location: Through the chimney) |
| **Symptoms** | Mold – (Specify location: Wood Shave Covering panel above the joist in the attic with traces of water infiltration; Wood Shave Deck in the attic; Edge of the roof truss; Top 2"x 4"member of the roof truss);<br><br>Water infiltrations – (Specify location: _Above the Fireplace through the chimney);<br><br>Other, Specify: _Traces of Water Infiltration in the "façade" of the Fireplace in the top corner;<br><br>Traces of Water Infiltration in a joist in the attic;<br><br>Loss of Adhesion of a tile in the bottom of the fireplace; |
| **Vulnerabilities** | - There is no vapour retarder in the section above the fireplace. This section is located in the interior of the wood box surrounding the metal fireplace. However, there was no visible condensation here. This situation is not correct but it did not cause the problem;<br><br>- The flashing of the chimney at the junction with the roof is allowing water infiltrations to the attic and the fireplace. The damages to the fireplace "façade" are, however, minimum and do not cause any problem to the building; |
| **Factors Affecting** | - The owner noticed that water was dripping in the fireplace but he thought that it was condensation and did nothing about it. This happened during many years, so the water infiltrations got worse with time until the owner realized that it was not condensation. |
| **Causes** | Other, Specify: Normal wear of building envelope components combined with negligence of the owner to remedy the problem. |
| **Remedy** | - Do a localized repair around the chimney without breaking the shingles previously removed. For this, the job should be done in autumn or during a cool day. If some shingles are broken, a mixture of the new and old shingles should be done during the general repair of the roof so that people cannot notice the difference between the newly repaired area and the old one. |

*Information as extracted from APCHQ files*

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| **File Number** | 439 |
| **Problem Location** | Cold room in the back of the house |
| **Building Type** | Detached Residential Building Split Level Type |
| **Storeys** | NA |
| **Problem** | Water Infiltrations (Specify location: Cold room in the back of the house) |
| **Symptoms** | Mold – (Specify location: Plywood used to fix the windows of the Cold Room);<br><br>Other, Specify: _Cracks in the walls of the cold room; |
| **Vulnerabilities** | - The space between the window frame and the concrete wall opening is not water tight. This is the source of the water infiltrations in the window.;<br><br>- The concrete slab that serves as a terrace is partially supported by the concrete wall of the main foundation. This generates a joint that infiltrates water to the interior of the cold room during mild weather periods in winter. Snow or ice that accumulates over the balcony (terrace) blocks the flow of water from snow melt.; |
| **Factors Affecting** | - The cold room is by definition a humid environment where the agriculture Ministry recommends a Relative Humidity around 80%. This is to keep the different types of food. In the present case, the owner changed the usage of the cold room to storage room. Therefore, the normal conditions of this room are not compatible any more with the usage given by the owner.;<br><br>- The owner keeps the windows of the cold room open. This situation increases the humidity in the room, given that warm and humid air comes in and condenses in the cooler surfaces of the concrete walls and floor. A high relative humidity implies a smelly room.; |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_The concrete slab that serves as a terrace is partially supported by the concrete wall of the main foundation. This generates a joint that infiltrates water to the interior of the cold room during mild weather periods in winter |
| **Remedy** | - For the infiltrations around the windows, the APCHQ inspector agreed to follow the same recommendations done by the expert Jean Corbeil. However, these recommendations are not found in TEC 96-439. Therefore, it is needed to consult the expert's report;<br><br>- For the infiltrations at the joint of the concrete slab and the back wall |

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| | of the house, install an aluminium flashing embedded in the concrete slab. The first step is to do a saw cut 1 ½ inches from the door sill. The second step is to insert an aluminium flashing under the exterior cladding as shown in drawing #1 of TEC 96-439. This is a method commonly used and effective. However, it is important to note that the snow and ice accumulations can increase the level of water over the balcony at the level of the sill of the window-door located 2 inches from the slab. This slab is not tight under the sill and this could cause infiltrations;<br><br>- To avoid vapour condensation behind the insulation of the cold room, install a vapour retarder over the insulation and seal the different joints; |
| **File Number** | 440 |
| **Problem Location** | Along the walls of the basement; |
| **Building Type** | Other, Specify: _Detached bungalow |
| **Storeys** | 1 |
| **Problem** | Other, Specify _Traces of humidity along the walls of the basement and certain spots in the floor |
| **Symptoms** | Other, Specify: _Humidity traces in the basement along the wall in the back of the house;<br><br>Humidity traces along the right side wall of the basement;<br><br>Humidity traces in the bottom of the walls of the basement; |
| **Vulnerabilities** | |
| **Factors Affecting** | - There is humidity generated by the drying process of concrete walls and slab. This is a new house and the water used for concrete placement and hydration is coming out of the concrete.;<br><br>- Another factor that contributes to a humid basement is the continuous ventilation in summer that brings hot and humid air into the basement that condenses when it finds a cool surface such as that of the bottom part of the basement walls and slab.; |
| **Causes** | Other, Specify: Normal drying process of the concrete walls and slab in the basement and misunderstanding of the owner of the relationship between ventilation the basement during warm days and condensation |
| **Remedy** | - To remedy the problem, the owner should keep an air temperature in the basement of at least 23°C during the warmest months. |

*Information as extracted from APCHQ files*

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| **File Number** | 441 |
| **Problem Location** | Basement |
| **Building Type** | Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Other, Specify _Traces of Humidity in the Basement |
| **Symptoms** | Condensation – (Specify location: Bottom of foundational walls);<br><br>Mold – (Specify location: Bottom of closet walls.);<br><br>Water infiltrations – (Specify location: _Through the capillary cracks in the concrete slab in the bathroom of the basement);<br><br>Other, Specify: _Traces of humidity along the back wall in the basement;<br>Traces of humidity along the left side wall in the basement |
| **Vulnerabilities** | - The floor of the drain pipe is located 8 ½" above the concrete slab. This favours stagnation of water in the drain. See drawing #1 in TEC 96-441. This explains the need of installing a drain under the slab in the bathroom of the basement.<br><br>- The closet is not heated and the doors are solid. This favours condensation because the walls of the closet are kept at a lower temperature than that of the rest of the house since the doors do not allow circulation of air in the closet. If the Relative Humidity in the house is high, condensation will appear. |
| **Factors Affecting** | - After foundations are poured, water from concrete mix is used in the hydration process. The excess of water evaporates. If the foundations were built in autumn (like in this case) the period of evaporation of water happens sporadically This situation favours a humid environment in the foundations. Since concrete is a conductor material, the base of the walls keeps the same temperature than the soil around it. So if the temperature of the soil is 12 degrees Celsius, the base of the walls will have the same temperature. Relative Humidity during summer is high. If the windows of the basement are kept open, or if a ventilation system forces warm and humid air to the basement, this air will condense at the touch of the cooler surfaces of the basement walls and slab. |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_The height of the drain was not the correct one. Therefore, it could not evacuate water properly causing water infiltrations and humidity. This is apparently a workmanship error. |

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| **Remedy** | - Correct the height of the drain in relation to the concrete slab so that water is evacuated and does not stay in the pipe, generating water infiltrations.;<br><br>- Replace the full solid doors of the closet with a type of door (persiennes) that allows circulation of air in the closet.;<br><br>- Dismount the baseboard heaters and the shoe mould and seal the bottom plate, reducing the potential air infiltrations.;<br><br>- Keep the air temperature at 23 degrees Celsius during the warmest months of the year.; |

*Information as extracted from APCHQ files*

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| **File Number** | 445 |
| **Problem Location** | Windows |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Condensation in Windows |
| **Symptoms** | Condensation – (Specify location: Low part of windows);<br><br>Mold – (Specify location:_ Low part of windows);<br><br>Other, Specify: _Frost accumulation at the base of the windows IN WINTER!!!; |
| **Vulnerabilities** | - The return grills (grilles de retour) of the ventilation system are installed in the ground floor and the grill with fresh air supply is located in the other side of the basement. This situation does not help control the humidity problem because cold air is heavier than warm air and the fact that fresh air is coming in to the basement, a closed room, makes it difficult to dilute the humid air of the ground floor. On top of this, the presence of lumber for the chimney in the basement short circuits the ventilation strategy;<br><br>- The ventilation conduit of the kitchen is not connected directly to the exterior. This situation restrains the evacuation of exhaust air.; |
| **Factors Affecting** | - The usage given by the owners is a source of humidity in buildings. The first symptom of condensation is the presence of frost at the base of the windows in winter. If water is not wiped immediately when condensation is produced in the base of the windows, it infiltrates under the varnish and will difficultly dry. This is the cause of the black spots (mold) in the windows. Also, the windows have blinds that favour stagnation of air. These type of screens prevent heating of the glazing unit. Therefore, the temperature difference between the room and the space between the glazing unit and the blinds, increases the condensation phenomenon. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The Ventilation system is not effective to lower the high relative humidity in the house. This is poor design.;<br><br>Other, Specify: Usage of the owner generates the humidity problem; |
| **Remedy** | - Correct the ventilation conduit of the kitchen so that it does not restrain the evacuation of exhaust air by increasing its diameter.; |

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- Apply two coats of vapour retarder paint in the walls and ceiling of the basement.;

- Wipe the condensation in the windows as soon as it is formed, before it goes under the varnish coat.;

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| **File Number** | 447 |
| **Problem Location** | House |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations |
| **Symptoms** | Damages Caused by water – (Specify location: _Gypsum covering (parement de gypse) of the back right bedroom);<br><br>Water infiltrations;<br><br>Other, Specify: _Traces of water infiltrations in the rafters of the roof;<br><br>Traces of water infiltrations in the plywood of the roof;<br><br>Capillary Cracks in the kitchen at the juncture of the ceiling and the wall in the back.; |
| **Vulnerabilities** | - Traces and stains along the rafters reveal that there is a condensation problem because ventilation of the attic is not effective. Also, the owner said that there were no ice dams at the time of the infiltrations and they happened in winter during milder weather periods. This and the existence of traces of water in the rafters of the cornices reinforces the hypothesis of condensation together. Code specifications for this type of roof are fixed in 1/150 of the insulated surface. In the present case, the rafter assembly and wall plates allow circulation of air but the air intakes at the bottom of the cornices are blocked with plywood. Also, there are static ventilators over the roof that do not favour a well distributed ventilation. Air passes from one ventilator to another and ventilation is only made superficially.;<br><br>-Heat losses can cause snow melt over the roof, provoking ice dams. They can be partly due to the presence of equipment or other installations over the roof. In this case, there is an exhaust grill that comes from the kitchen hood very close to the roof and an areaway (puits de lumiere); |
| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The ventilation system of the attic is not effective and causes condensation. This is poor design |
| **Remedy** | - Block the ventilator in the centre of the roof to allow the two other |

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| | ventilators work properly. |
| **File Number** | 449 |
| **Problem Location** | Window in Bay |
| **Building Type** | Semidetached Cottage |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Window in Bay) |
| **Symptoms** | Other, Specify: _Cracks in some cedar shingles;<br><br>Rupture of some cedar shingles;<br><br>Crack in the mortar joints of the brick cladding<br><br>Traces of water infiltrations in the deck of wood planks of the bay ceiling;<br><br>Traces of water infiltrations in the members of the wood plank ceiling of the bay window; |
| **Vulnerabilities** | - Between the 2 wood lintels, the sheathing paper in the back of the brick is not (entrecoupe) by a flashing. In other words, there is no flashing behind the brick cladding.;<br><br>- One of the shutters of the bay window is damaged and one of the window of the dining room too. This affects the tightness of the window.; |
| **Factors Affecting** | |
| **Causes** | Other, Specify: The Cause of the Problem is not defined in this expert's opinion |
| **Remedy** | - Consolidate the base of the bay without demolishing the whole assembly by installing 2"x 4"tie studs (tirants) in the top part of the low plate of the bay and cover it with ½"plywood. This method takes into account that the roof of the bay is independent and does not transmit any load to the base of the window.;<br><br>- Install new shutters in the windows with damaged ones.; |

*Information as extracted from APCHQ files*

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| **File Number** | 450 |
| **Problem Location** | Basement |
| **Building Type** | Detached Cottage House |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Water infiltrations – (Specify location: _Back right corner of the basement of 19 rue Madrid, through the wall/concrete slab junction.);<br><br>Other, Specify: _Crack in the left back corner of the concrete slab of 73 rue Madrid;<br><br>Rupture of the concrete slab in the back right corner of the basement of 19 rue Madrid; |
| **Vulnerabilities** | - In 19 rue Madrid, the gutter downspout of the neighbour flows directly to the zone of the foundations affected by the water infiltrations.;<br><br>- Infiltrations can happen if the perimetral drain was filled without the presence of crushed stone in a sufficient amount. In 73, rue Madrid, the crushed stone was put in place with a mechanic ram (belier mecanique). This method does not allow stone to be placed over the drain as in drawing #3 on TEC 96-450. If the back filling material (argyle) is put over the footing, water flows along the foundations cannot find the drain, so the least weakness in the junction of the footing and the wall can create water infiltrations.; |
| **Factors Affecting** | |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_The most probable cause of the problem is a wrong execution of the back filling of the perimetral drain of the foundations. This is wrong workmanship.; |
| **Remedy** | - A destructive investigation at the concrete slab is suggested by the APCHQ inspector to determine the level of water below the concrete slab. If the level of water is 11" below the concrete slab, it means that the drain is working well. If water infiltrates between the wall and the footing and excavation on the perimeter of the foundations is needed to locate the infiltration point .; |

*Information as extracted from APCHQ files*

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| **File Number** | 452 |
| **Problem Location** | Basement |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Water infiltrations – (Specify location: _Basement);<br><br>Other, Specify: _ Presence of Ferrus Hydroxide in large amount in the water on the perimeter of the foundation;<br><br>Presence of Ferrus Hydroxide in large amount in the Drain on the perimeter of the foundation;<br><br>Presence of Ferrus Hydroxide in large amount in the basin that collects rain water;<br><br>Presence of Ferrus Hydroxide in large amount at the flapper (clapet de retenu) in the discharge of the drainage system on the perimeter of the foundation; |
| **Vulnerabilities** | - There is no crushed stone over a section of the drain on the perimeter of the foundation. Therefore, water that comes from the surface of the terrain cannot by collected by the drain because the holes in the drain are blocked with soil.;<br><br>- The first owner of the house installed a basin to collect rain water. This way he eliminated the pressure under the slab. Water could then trickle through the crushed stone towards the basin. The owner then decided to connect the drain directly to the rain sewer and disconnect the basin pump. This method consisted of evacuating water by gravity but the least defect in the flapper (clapet de retenu) or in the rain drainage system could cause water infiltrations. In this case, the flapper (clapet de retenu) has deposits of ferrus hydroxide generated in the soil that do not allow a proper functioning of this device. In this case, if a section of the drainage system is defective or blocked, water can flow to the other direction towards the sewer system. However if the discharge is obstructed (with ferrus hydroxide), like in this case, water goes beyond the drain and infiltrate over the slab.;<br><br>- The perimetral drain is connected directly to the rain sewer. When the house was built, there was no basin to collect rain water. This method has the disadvantage of not being able to drain the crushed stone under the concrete slab. In the case in which water cannot trickle towards the |

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| | drain because of external clogging, a hydrostatic pressure will be generated under the slab. Water then infiltrates through all the interstices, capillary cracks in the perimeter of the concrete slab drain, etc.; |
| **Factors Affecting** | - The drainage system on the perimeter of the foundations is not working well because there is a high concentration of ferrus hydroxide in the soil around the house. This is caused by the bacteria present in the water table. Bacteria produce a filamentous substance of gelatinous consistence, clayey and of ochre colour. This bacterian gel is responsible for the decrease of the useful section of the drain and increase of the viscosity of the water that trickles in the drainage system. This phenomenon can block the drain in three ways: from the exterior, from the interior and by building deposits.;<br><br>- The soil under the footings is composed of clayey silt, which is a source of contamination of the soil.; |
| **Causes** | Other, Specify: Unexpected Soil Conditions |
| **Remedy** | - Replace the drain and the crushed stone in the perimeter of the house.;<br><br>- Use a geotextile membrane around the crushed stone in which the interstices are of the sufficient dimension to impede the proliferation of the colonies of bacteria.; |

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| **File Number** | 454 |
| **Problem Location** | Ceiling of the interior pool |
| **Building Type** | Detached Cottage |
| **Storeys** | 2 |
| **Problem** | Condensation in Ceiling of the interior pool |
| **Symptoms** | Condensation – (Specify location: Plywood deck of the ceiling of the interior pool);<br><br>Wetness of the Insulation of the ceiling of the interior pool; |
| **Vulnerabilities** | - The vapour retarder at the speaker in the ceiling of the interior pool is cut. This caused warm air to condense in the cold surface of the plywood deck.<br><br>- There is a lack of tightness in the access hatch of the ceiling that causes the condensation problem.<br><br>-The roof of the terrace that is above the interior pool, is composed of "I" shaped joists. This type of joist limits the ventilation of the roof assembly to one possibility. To create the slopes to canalize water to the roof drains, wood pieces of 1 inch thickness were placed perpendicular to the joists. This assembly should allow a crossed ventilation according to the National Code. But in this case, ventilation cannot be done but on the back side because the 2 sides are blocked by the low walls and the type of assembly. The ventilation in the roof assembly that is on top of the interior pool is insufficient.<br><br>-There is a backdraft of air despite the presence of an combustion air intake of 8 inches diameter.<br><br>- The chimney conduit of the boiler that heats the water has condensation when it is not working. This is caused by a depressurization of the mechanical room that creates a backdraft despite the fresh air intake. The reason for this problem is that the heating conduits and the joints at the spot where the chimney penetrates the slab of the ceiling are not tight.<br><br>- There is a pressurization of the room of the interior pool generated by the heating system that favours vapour migration in the ceiling assembly. |
| **Factors Affecting** | |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why? |

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The access hatch of the ceiling is not tight. Also, the vapour retarder is cut at the spot of the speaker in the ceiling of the pool. These situations caused the condensation problem. This is due to poor craftsmanship;

Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_There is a pressurization of the room of the interior pool generated by the heating system that favours vapour migration in the ceiling assembly. This is a result of an inefficient design of the HVAC system._The ventilation of the roof assembly of the interior pool is insufficient due to poor design of the envelope.

**Remedy**

-To solve the problem of insufficient ventilation of the roof assembly above the interior pool, there are 3 options:
a)Raise the terrace section to increase the ventilation through the low walls by dismounting the existing deck, install a girder (longeron) of 2x4 cut in an angle, make some holes in the low walls to allow a vertical ventilation, redo the deck and the membrane. This solution will allow ventilation on the 3 sides of the terrace.(see solution #1 in TEC 97-454)
b)Build the terrace roof section as a sealed roof by dismounting the vapour retarder, removing the existing insulation, dry the plywood, apply an R-40 polyurethane foam, install a sealed vapour retarder type 1 in the bottom of the joists, install the wood strapping and the wood covering. Note that it is very important to ensure tightness of in the perimeter of the terrace by sealing well the terrace section assembly at the wall of the house and at the double joists of the back section. The vapour retarder of the ceiling must be sealed at the foam. After this, the new section of the vapour retarder installed. (see solution #2 in TEC 97-454)
c)Eliminate the drainage basins and build slopes to canalize water to the back. The rest of the job should follow the same action applied to the vapour retarder and the ventilation holes in the low walls of the first solution.

- To correct the condensation in the chimney of the heating system due to the depressurization of the mechanical room, it is needed to seal all the heating system conduits and fill in the joints around the conduits that penetrates the concrete slab of the ceiling. Also, the heating system should be balanced to avoid pressurization of the room of the pool since it favours vapour migration.

- Replace the evacuation chimney of the heating system and install a mechanical extraction fan and some controls so that the water heating system cannot work unless the extraction fan is working first. Regarding the fresh air intake it can be of "Power Vent" type and it can be connected so that when the appliances get started it starts at the same

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time. This system has the advantage of diminishing cooling of the room and provide the needs of air for combustion.

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| **File Number** | 455 |
| **Problem Location** | Basement |
| **Building Type** | Multifamily Condominium |
| **Storeys** | 3 ½ |
| **Problem** | Other, Specify _Verify the state of the building after some repairs related to water infiltrations in the basement. |
| **Symptoms** | Condensation – (Specify location:_Sewage discharge pipe located on the side of the office and workshop);<br><br>Damages Caused by water – (Specify location: _Low plate (lisse basse) of the wall that holds the electric meters in the electrical room;<br><br>Other, Specify: _Rust in the bottom part of the walls of the office and workshop;<br><br>Traces of humidity along the wall of the office and workshop;<br><br>Traces of mud along the wall of the office and workshop;<br><br>Rot at certain poteaux (signposts) in the electrical room;<br><br>Condensation traces under the carpet of the corridor;<br><br>Settlement of ¾" in the firewall;<br><br>Capillary cracks on each side of the firewall; |
| **Vulnerabilities** | - The problems found in this building can be summarized in 2 points: poor performance of the exterior drainage and the presence of water under the basement slab.;<br><br>- If water is not evacuated from under the concrete slab and is kept close to it, as in the present case, condensation will appear in the surface of the floor during summer. It will also cause traces of mold in the bottom of the woodworks and in the floor covering. The water level cannot be less than the radius of the perimetral drain. In this case, the level should be 12 inches above the slab. Apparently the foundation walls that support the bearing walls of the corridor of the basement contribute to create a dam effect along the wall in the back. This is because this walls are lower than the exterior wall therefore, their footing is in a deeper location.;<br><br>-There is a berm (talus) that canalizes water to the building since it is |

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| | directed towards it.; |
| **Factors Affecting** | - The high level of water in the exterior of the building can create enough pressure to excerpt a hydrostatic pressure under the concrete slab of the basement so that at the time of heavy rain, water can infiltrate under the slab. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The water level in the ground was very high and the designer of the house did not foresee the problems that this would cause. This is poor design. |
| **Remedy** | - The water of the berm (talus) must be collected to reduce the water taken by the back drain. This can be done by building a drainage trench along the terrain, deep enough so that it reduces the pressure under the slab.;<br><br>- Repair the rotten elements in the structure of the building and in the corridor.;<br><br>- Repair the wall that separates the electrical room from the adjacent dwelling.; |

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| **File Number** | 472 |
| **Problem Location** | Roof Deck |
| **Building Type** | Detached Duplex (Vertical Condominium) |
| **Storeys** | NA |
| **Problem** | Other, Specify _Frost at the roof deck |
| **Symptoms** | Other, Specify: _ Frost at the roof deck;<br><br>Wetness of the roof deck in some spots;<br><br>Wetness of the members; |
| **Vulnerabilities** | - There are ventilation grills on the exterior walls and they are obstructed by a mosquito net folded many times and full of dust.;<br><br>- Access to the attic is by the dwelling on the 2nd floor, through tan access hatch in the corridor. The access hatch has no wind break around it. There is a lack of tightness at this spot.;<br><br>- The cellulose fibre insulation in the attic is displaced in many spots in front of the access hatch and around it. In the lowest part, the insulation is touching the deck at certain spots.;<br><br>- The ventilation surface is 4 ft2 and the minimum required for this building is 7 ft2. That is 1/150 of the insulated surface, that is more or less 1064 ft2 .; |
| **Factors Affecting** | - Condensation in old buildings is due to the poor insulation or absence of it. The insulation in the ceiling slows the passage of heat and cools the temperature in the attic and of all the components such as the deck, the members, the rafters etc. Since cold air cannot contain more water vapour than hot air, this can be very close to the dew point and deposit in the colder surfaces, wetting them at the moment in which it goes through the insulation. Such surfaces are the members and the deck. |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why? Something that contributed to the problem was the displaced insulation in the attic. This was due to a deficient craftsmanship.<br><br>Other, Specify: Poor Performance of an old building used according to today's needs |
| **Remedy** | - Increase the ventilation. The norms require a ventilation surface of 1/150 of the insulated surface. In the present case, with a surface of more or less 1064 ft2 it is needed 7 ft2 at least of ventilation surface. |

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The easiest solution is to install ventilation grills in the perimeter of the building at the top part of the walls. Special attention should be put to the location of the grills to allow the maximum performance of the goose neck fans.;

- Put in place the misplaced insulation;

- Put a wind break around the access hatch;

- Keep a space of at least 1 ½ " to 2"between the deck and the insulation surface.;

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| **File Number** | 474 |
| **Problem Location** | Roof |
| **Building Type** | Residential Building |
| **Storeys** | 7 |
| **Problem** | Water Infiltrations (Specify location: Roof) |
| **Symptoms** | Ice Dams – (Specify location: Cornices; Valleys on the south side of the roof);<br><br>Water infiltrations – (Specify location: _Cornices; Along different valleys in the roof; Ceiling of the 5th floor up to the main entrance hall; Around the conduits of the sumps (puisards) in the parking garage of the building.) |
| **Vulnerabilities** | - The fresh air intake has a mechanic shutter some inches close to the interior of the wall envelope. Despite it is insulated, condensation is produced in the interior of the conduit and water from condensation infiltrates through the joint of the conduit.<br><br>- There are some sumps (puisards) in the parking garage of the building that were installed to palliate the deflections that happened in the slab. These sumps (puisards) have infiltrations around the conduits due to a lack of tightness.<br><br>- The design of the building favours snow accumulation in the valleys. |
| **Factors Affecting** | - There is ice in the cornices and it blocks the drains in some spots.<br><br>- The rainwater downspout of the is full of ice and water from melted ice cannot flow freely, causing water infiltrations. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design of the building favours snow accumulation in the valleys |
| **Remedy** | - For the conduit that has infiltrations of condensed water, the control measure is to block it during winter with an insulated panel fixed in the conduit to eliminate the condensation of air.<br><br>- For the insulation needed in the main attics, lift the insulation and seal with an adhesive band the vapour barrier. The existing insulation can be reused if it is according to norms. |

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| **File Number** | 475 |
| **Problem Location** | Roof Edge; |
| **Building Type** | Other, Specify: _Residential Building in Row |
| **Storeys** | 3 |
| **Problem** | Ice Accumulation (Specify location:_Roof Edge)<br>Water Infiltrations |
| **Symptoms** | Ice Dams – (Specify location: Cornices of the roof)<br>Water infiltrations |
| **Vulnerabilities** | - The design favours ice accumulation;<br><br>-The plastic foam profiled deflectors (deflecteurs profiles) leave the insulation in contact with the wood deck close to the members of the roof trusses. In this case, the heat loss by conduction accelerates the formation of ice dams.;<br><br>- There are important heat losses in the skylights. The high temperatures in this zone are due to a deficient tightness at the junction of the wall and the floor and the insulation of the low walls of the skylights.;<br><br>- Another element to consider is the heating return conduit. It is not enough insulated and sealed at the junction of the walls. Opposite to the ventilator in the ridge (faitier), the air is stagnant and the chimney contributes to the warming up of the air in the attic.; |
| **Factors Affecting** | - Heat losses are the most important cause of ice dam formation because these losses increase the temperature of the attic. The wood deck is warmed up and causes snow melt. Water follows the same path to the gutter.<br>Heat losses are larger in the in the perimeter of the exterior walls because the insulation of the ceilings is more difficult to install above the exterior walls. If the space between the insulation touches the wood deck, the heat loss is increased and accelerates the formation of ice dams.<br>Another important element to consider is the heat loss at the concrete block fire walls. Often, builders forget to fill the cavity of the block cells. Then, there is heat loss by convection and conduction along the fire wall. This loss heats the air in the attic, warming up the wood deck and the cycle starts again.<br>Heat losses can happen too in the access hatch of the attic, in the embedded lamps, in the beams that support the structural elements, etc.;<br><br>- Skylights are a non negligible source of heat losses. Glazing offers little resistance to heat transfer. Heat losses in the perimeter of the skylight cause snow melt and ice is formed when water touches cold |

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| | surfaces such as those close to the cornices.;<br><br>- Solar radiation can contribute to snow melt over the roofs increasing the size of the ice dam. The thick beds of snow absorb heat and transmit it to the wood deck or to the shingles causing snow melt. This action over the slopes exposed to the south favour snow melt. The energy absorbed by the structure warms up the attic and causes snow melt in the non exposed slopes.;<br><br>- Gutters are the first source of ice accumulation in the roof edge. In sunny days or when the weather is mild, water generated from snow melt flows to the gutter and freezes at contact with it. The flow is slowed down by the successive formation of ice and little by little the gutter overflows. Progressively, ice accumulates in the roof edge, impeding any flow. Then, water makes it way and infiltrates under the roof covering. Ice and icicles appear in the soffits of the cornice.; |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why? There is a lack of tightness at the junction of the wall and the floor and the insulation of the low walls of the skylights due to poor craftsmanship; The plastic foam profiled deflectors (deflecteurs profiles) leave the insulation in contact with the wood deck close to the members of the roof trusses. This again is poor craftsmanship.;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_ The design favours ice accumulation. This is poor design.; |
| **Remedy** | - Make tight the junction of the wall and the floor;<br>- Install an adequate membrane around the skylights according to the drawing found in TEC 98-475;<br>- Insulate adequately the low walls of the skylights;<br>- Seal the access hatches;<br>- Install heating wires in the façade because the design favours ice accumulation;<br>- Insulate the heating conduit; |

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| **File Number** | 476 |
| **Problem Location** | Roof edge; |
| **Building Type** | Other, Specify: _Semidetached Residential Building (Cottage House) |
| **Storeys** | 2 |
| **Problem** | Ice Accumulation (Specify location: Roof edge);<br><br>Water Infiltrations; |
| **Symptoms** | Damages Caused by water – (Specify location: _Gypsum sheathing of the front bedroom of building 2443);<br><br>Ice Accumulation – (Specify location: Roof of buildings 2443 and 2445; Cornice in front of the gutter);<br><br>Water infiltrations – (Specify location: _Valley of the front section of the attic of building 2443; Walls of the front bedroom of building 2445);<br><br>Other, Specify: _Wetness of the Insulation in the attic of building 2443;<br><br>Wetness of the roof deck in the façade, close to the valley of building 2443;<br><br>Wetness of the carpet of the front bedroom of building 2443;<br><br>Frost at the roof deck in the façade, close to the valley of building 2443. |
| **Vulnerabilities** | - In building 2443, the firebreak separation has concrete blocks with open cells that favour heat losses.;<br><br>- In building 2443, the ventilation is partially blocked at the cornices by the insulation.;<br><br>- Poor ventilation of the attic can cause ice accumulation. The weak discharge of air at the level of the cornices in relation to the discharge in the top part of the roof favours the warming of this zone and contributes to snow melt.;<br><br>- The causes of ice accumulation are heat losses due to an unfilled open cell dividing wall and a deficient ventilation in the front section of the roof.;<br><br>-The plastic foam profiled deflectors (deflecteurs profiles) leave the insulation in contact with the wood deck close to the members of the roof trusses. In this case, the heat loss by conduction accelerates the |

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| | formation of ice dams.; |
| **Factors Affecting** | - Heat losses are the most important cause of ice dam formation because these losses increase the temperature of the attic. The wood deck is warmed up and causes snow melt. Water follows the same path to the gutter.<br>Heat losses are larger in the in the perimeter of the exterior walls because the insulation of the ceilings is more difficult to install above the exterior walls. If the space between the insulation touches the wood deck, the heat loss is increased and accelerates the formation of ice dams.<br>Another important element to consider is the heat loss at the concrete block fire walls. Often, builders forget to fill the cavity of the block cells. Then, there is heat loss by convection and conduction along the fire wall. This loss heats the air in the attic, warming up the wood deck and the cycle starts again.<br>Heat losses can happen too in the access hatch of the attic, in the embedded lamps, in the beams that support the structural elements, etc.;<br><br>- In building 2443, the flat ventilators are blocked by snow accumulation;<br><br>- Solar radiation can contribute to snow melt over the roofs increasing the size of the ice dam. The thick beds of snow absorb heat and transmit it to the wood deck or to the shingles causing snow melt. This action over the slopes exposed to the south favour snow melt. The energy absorbed by the structure warms up the attic and causes snow melt in the non exposed slopes.; |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_ In building 2443, the ventilation is partially blocked at the cornices by the insulation. This is poor craftsmanship.;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The ventilation in the attic is poor because the ventilators are deficient. This is poor design._The heat losses generated by the firebreak wall are due to poor design.; |
| **Remedy** | - For the heat losses at the dividing wall, seal the top part of the wall with a bed insulation or a polyurethane foam.;<br><br>- For the poor ventilation in the attic, clear the ice in the cornices, and replace the flat ventilators with a "Maximum" ventilator.;<br><br>- For the front part of the roof, increase the air intake of the soffits by installing a better performing grill. Also, install a flat ventilator over the |

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| firebreak box (caisson).;<br><br>- Install a self adhesive membrane in the zone identified in the drawing found in TEC 98-476.;<br><br>- Remove the gutter to allow a natural flow of water from.<br><br>- Install heating wires in case ice accumulations persist. |

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| **File Number** | 481 |
| **Problem Location** | Roof Edge; |
| **Building Type** | Other, Specify: _Semidetached Residential Buildings in Row (Cottage H |
| **Storeys** | 2 |
| **Problem** | Ice Accumulation (Specify location:_Roof Edge);<br><br>Water Infiltrations; |
| **Symptoms** | Ice Accumulation – (Specify location: Gutters of building 47; Roof building 50);<br><br>Ice Dams – (Specify location: Cornices of the roof);<br><br>Snow Accumulation – (Specify location: Front roof of building 47);<br><br>Other, Specify: _Traces of Water Infiltrations in the plywood deck in the front section of the attic of building 49;<br><br>Traces of Water Infiltrations in the interior of the house.; |
| **Vulnerabilities** | - In Building 49, the blown insulation is displaced in more or less important surfaces. Some deflectors are in a way that they form a thermal bridge.;<br><br>- The architectural design of Building 50 favours snow accumulation and the presence of gutters contributes to the formation of ice dams.;<br><br>- In the attic, the deflectors do not allow a clearance to break the thermal bridge.;<br><br>- Also, in the back section, close to the chimney, the evacuation conduit of the bathroom<br>fan in the 2nd floor draws exhaust air into the soffit of the cornice.;<br><br>- Ice accumulation in this case can be associated to a wrongly distributed ventilation of the attic.;<br><br>- The installation of a turbine type ventilator additional to the flat ventilators in the ridge of the roof short circuits the ventilation mechanism by pulling air from the nearby flat ventilators, instead of pulling air from the cornices. Stagnation of air in the bottom part of the attic favours the warming up of this zone and contributes to the appearance of ice dams from snow melt.; |
| **Factors Affecting** | - Heat losses are the most important cause of ice dam formation because |

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| | these losses increase the temperature of the attic. The wood deck is warmed up and causes snow melt. Water follows the same path to the gutter.<br>Heat losses are larger in the in the perimeter of the exterior walls because the insulation of the ceilings is more difficult to install above the exterior walls. If the space between the insulation touches the wood deck, the heat loss is increased and accelerates the formation of ice dams.<br>Another important element to consider is the heat loss at the concrete block fire walls. Often, builders forget to fill the cavity of the block cells. Then, there is heat loss by convection and conduction along the fire wall. This loss heats the air in the attic, warming up the wood deck and the cycle starts again.<br>Heat losses can happen too in the access hatch of the attic, in the embedded lamps, in the beams that support the structural elements, etc.;<br><br>- The ventilators in the roof are blocked by snow accumulations.;<br><br>- Solar radiation can contribute to snow melt over the roofs increasing the size of the ice dam. The thick beds of snow absorb heat and transmit it to the wood deck or to the shingles causing snow melt. This action over the slopes exposed to the south favour snow melt. The energy absorbed by the structure warms up the attic and causes snow melt in the non exposed slopes.;<br><br>- The façade of the building is oriented to the south/south-east. The orientation of the back section of the roof favours snow melt and ice accumulation close to the cornices and the crickets of the chimney.; |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_There is insulation in the attic that is displaced. This is deficient craftsmanship.;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The architectural design of Building 50 favours snow accumulation and the fan from the bathroom discharges exhaust air into the attic. This is poor design.; |
| **Remedy** | - For the deficient ventilation, clear the cornices of ice. Replace the polystyrene deflectors with cardboard fabricated for that effect. Verify the soffits to ensure that the insulation does not obstruct air flow. In case the attic does not have the minimum required ventilation surface, install grills in the existing soffits.;<br><br>- In the attics where turbines have been installed, the flat ventilators must be blocked to allow an adequate aspiration.; |

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- Taking into consideration the roof configuration of the buildings, take off the gutters of the back section of the roof and install heating wires.;

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| **File Number** | 483 |
| **Problem Location** | Dwellings 5 and 6 |
| **Building Type** | Multifamily Condominium |
| **Storeys** | 2 ½ |
| **Problem** | Damages in Ceilings (Specify location: Dwellings 5 and 6);<br><br>Water Infiltrations; |
| **Symptoms** | Damages Caused by water – (Specify location: _ Dwellings 5 and 6);<br><br>Water infiltrations – (Specify location: _Ceilings of dwellings 5 and 6);<br><br>Other, Specify: _ Bubbles in the paint finish of the living room;<br><br>Cracks in the plaster finish of the living room;<br><br>Undulation of the plaster finish of the living room;<br><br>Undulation of the plaster covering of the ceiling of the front corridor.;<br><br>Traces of Condensation under the protective membrane of the roof.;<br><br>Wetness of the blown insulation in the attic between the joists.; |
| **Vulnerabilities** | - During the insulation job, it is very important to fill all the cavities between the roof beams to avoid condensation problems due to lack of ventilation. This condition is was not observed in the building because there are voids of 1 ½ ft between the insulation and the deck.;<br><br>- In this building the polyethylene membrane has acted as a multibed membrane. It has not contributed to the increase of decrease of the condensation phenomenon. If the insulation job had not been foreseen, the membrane should have been removed to allow water migration in the attic. However the care with which the membrane was installed makes us question the role of the membrane as a vapour retarder. The damages to the ceilings of the dwellings are due to the presence of the membrane. It should have been covered with insulation. The membrane kept the existing conditions before the repairing of the roof. This conditions are the condensation due to the presence of voids under the wood deck. If the insulation job had been foreseen (it was not done), the problem is directly linked to the non execution of this job; |
| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making |

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| | calculations or predictions of performance Explain why?_The membrane in the roof was wrongly used due to a poor design of the roof. |
| **Remedy** | - There are no remedial measures in this file |

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| **File Number** | 489 |
| **Problem Location** | House |
| **Building Type** | Semidetached Cottage |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations |
| **Symptoms** | Damages Caused by water – (Specify location: _Parquet floor covering);<br><br>Water infiltrations – (Specify location: _roof covering);<br><br>Other, Specify: _Traces of water infiltration in certain roof trusses; |
| **Vulnerabilities** | - In the front cornice, there is a protection band made out of 15 lb. construction paper. This band is not sealed to the moulding of the roof edge or the drip. The protection of the roof edge, according to the National Code must be of two layers of paper #15 or one layer of paper 45 lb or an auto adhesive membrane. In this building the protection band is not according the National Code. However this is not the cause of the water infiltrations because the traces seen in the building are beyond the line that limits the membrane or protection band.;<br><br>- The configuration of the roof is favourable to ice dam formation. The accumulation of snow together with heat losses favour snow melt. When water reaches cold zones it freezes. This cycle favours the accumulation of ice and in mild weather, water from such melting process flows freely, infiltrating under the shingles.;<br><br>- Even though the ventilation of the building complies with the Code, it is possible that it is not enough for the requirements generated by the configuration of this building.; |
| **Factors Affecting** | - Since the water infiltrations are produced during mild winter weather, they can be due to condensation, black ice (verglas), or ice dams. In this case it is most probably that the cause of the water infiltrations is the accumulation of ice over the roof that favours the water infiltrations during mild weather.;<br><br>- Black ice (Verglas) can contribute to water infiltrations when the layer ice covers the bottom part of the roof. This layer of ice impedes the flow of water and the infiltrations happen in the same way as for ice dams.; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The roof configuration favours snow accumulation and this together with heat losses causes the water infiltrations. This is could be prevented with a |

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| | better design of the roof or a better design of the ventilation system of the attic for example. |
| **Remedy** | - There are no remedial measures recommended in this file |

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| **File Number** | 491 |
| **Problem Location** | Roof |
| **Building Type** | Other, Specify: _Ancestral Cottage |
| **Storeys** | 2 |
| **Problem** | Ice Accumulation;<br>Water Infiltrations (Specify location: Through the roof); |
| **Symptoms** | Ice Accumulation – (Specify location: Roof);<br><br>Ice Dams – (Specify location: Roof);<br><br>Water infiltrations – (Specify location: _Through the roof);<br><br>Other, Specify: _Damages caused by the de-icing procedure to the cedar shingles;<br><br>Damages caused by the de-icing procedure to the asphalt shingles in the roof of the front gallery;<br><br>Damages caused by the de-icing procedure to the turret covering;<br><br>Capillary Cracks in the kitchen and other rooms of the house; |
| **Vulnerabilities** | - Two of the heating conduits in the front turret of the house are facing directly to the zone where the ice accumulations are larger. Also, there is practically none insulation in the ceiling of this room and the fan of the bathroom evacuates exhaust air directly to the attic of the turret.;<br><br>- The absence of ventilation in the attic of the turret together with the warm and humid air of the bathroom fan contributes to snow melt.;<br><br>- Heat losses in the masonry wall are not to be neglected. The stone wall being heated on both sides has important heat losses by conduction.;<br><br>- Above the access door of the turret there is no insulation and this zone corresponds to the valley where there is ice accumulation. The ceiling of this hallway is not insulated and the heat losses are important.;<br><br>- The configuration of the roof allows important accumulations of snow. Particularly in the back of the turret and in the zone of the roof where the building addition meets the bedroom above the garage. In the roof on the back of the turret and close to the addition it is extremely difficult to control the snow accumulations.; |

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| | - The valley of the addition and the garage is very problematic. The cornice does not allow but a very poor intake of air worsening the heat losses generated by the heating conduits and the lack of insulation. It is practically impossible to ventilate this localized zone without installing ventilators directly above it. If this method is chosen, water infiltrations can happen if snow accumulation blocks the ventilators.;<br><br>-The main building has problems of ventilation. The ventilation is obstructed by the stone walls and the roof of the front gallery. The assembly makes it difficult ot correct the ventilation of the main building.;<br><br>-The ventilation of the attic of the gallery is inefficient and the asphalt shingles get damaged by the overheating effect in the attic.; |
| **Factors Affecting** | - In old buildings it is difficult to control ice accumulation in the roof because the structure and the techniques of old times make it difficult to apply modern ventilation and insulation techniques.;<br><br>- In spite of an adequate insulation and a proper ventilation solar radiation favours snow melt. Specially in the presence of iron or another conductive material. Water produced from the melt of snow trickles up to the cornices and freezes in cold zones. This cycle is repeated many times contributing to ice accumulation and ice dams.; |
| **Causes** | Other, Specify: Bad performance of an old building used with today's commodities. |
| **Remedy** | - Install heating wires in the roof on the back of the turret and close to the addition.;<br><br>- Insulate the ceiling of the turret and ventilate the zone appropriately.;<br><br>- Remove the gutters in the turret.;<br><br>-One section of the cedar covering of the turret must be replaced by copper.;<br><br>-To correct the damages to the cedar shingles, remove the shingles in the affected zones and replace at the same time the self adhesive membrane.;<br><br>- The damages to the covering of the turret are minor and can be repaired by welding.;<br><br>-To ventilate the back section of the main roof of the main building, follow the suggestions of the City of Quebec guide provided in TEC-98 |

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491. For the front section, the solution is to use the attic of the gallery in a way that air is conduced to the main attic. The installation of many ventilators is required to ventilate the attic of the gallery and the one of the main building.;

-For the turret, it is necessary to insulate the walls and ceiling. The attic of the turret can be ventilated through the installation of grilles in the top part of the back slope. The air intake in the bottom of the cornice can be achieved with small aesthetic grills. It is necessary to evaluate the effects of the ventilation of the bottom of the cornice in the section of the ceiling of the hallway. If this part is not insulated condensation can occur.;

- The repair of the roof of the gallery should be done with a membrane instead of the shingles because of the low slope and the difficulty of tightening the junction of the cedar covering.;

- For the uninsulated ceiling of the hallway, increase the ventilation and insulate the ceiling adequately.;

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| **File Number** | 493 |
| **Problem Location** | Basement |
| **Building Type** | Cottage in Row |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations in the Basement (Specify location: Window of the basement of the house situated in 874, rue D'Isere; Floor in front of the door-window of the house situated in 705, rue Namur) |
| **Symptoms** | Water infiltrations – (Specify location: _Above the window of the basement under the back terrace, between the window frame and the concrete lintel of the house situated in 874, rue D'Isere; In the floor that faces the door-window of the basement of the house situated in 705, rue Namur |
| **Vulnerabilities** | - In the house situated in 705, rue Namur, the exterior cladding in the back elevation is made out of brick up to the ground floor and aluminium siding to the 2nd floor. To ensure a good transition between the materials, an aluminium moulding covers the top part of the brick cladding. This transition moulding is made in a way that water that infiltrates under the "J" shape moulding cannot be evacuated freely. Water trickles behind the aluminium cladding and overflows above the flashing at the time of heavy rain. |
| **Factors Affecting** | - The problem appears with heavy rain combined with strong winds that push water inside the building. |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why? For the case of 705, rue Namur, there was a moulding that was incorrectly detailed and this caused the problem.;<br><br>Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why?_For the case of 874, rue D'Isere, there was a joint that was not tight and this caused the problem.; |
| **Remedy** | - For the house on 874, rue D'Isere, seal both interstices on the right side of the sill and the vertical members of the door-window. After this, a water spray test should be done to verify the tightness. If infiltrations persist, the groove of the door has to be dismounted and the joints under the groove must be sealed.;<br><br>- For the house on 705, rue Namur, the cause of the infiltrations is the "J" shape moulding installed in the roof of the projection (saillie) The first option consists of cutting the base of the moulding to eliminate the water accumulations that go behind the cladding. After this, a water spray test should be done at this spot. If the infiltrations persist, the transition |

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moulding must be revised and modified accordingly.;

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| **File Number** | 495 |
| **Problem Location** | Basement |
| **Building Type** | Semidetached Cottage |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Mold – (Specify location: Bottom of the wall in the back of the balcony);<br><br>Water infiltrations – (Specify location: _Above the basement window in the wall on the back of the balcony; Ceiling of the basement);<br><br>Other, Specify: Traces of Water Infiltration in the ceiling of the basement;<br><br>Traces of Water Infiltrations in the projection of the back wall of the house; |
| **Vulnerabilities** | - At the joint of the balcony slab there are infiltrations because the balcony slab is generally poured before the foundations. This situation results in a cold joint not very tight to water infiltrations. At the time of heavy or prolonged rain, water can infiltrate by capillarity to the interior side.;<br><br>- There are infiltrations at the junction of the slab and the cladding that are due to the type of assembly. At the time of heavy rain, water penetrates behind the brick cladding and trickles up to the level of the slab. Since water cannot flow freely over the exterior slab, it infiltrates between the slab and the floor structure. This flow of water is not caused directly by the polyurethane foam under the slab.; |
| **Factors Affecting** | Heavy rain pushed by strong winds contribute to the problem. |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_ There are infiltrations at the junction of the slab and the cladding that are due to the type of assembly. This is a detailing problem.;<br><br>Other, Specify: At the joint of the balcony slab there are infiltrations because the balcony slab is generally poured before the foundations. This situation results in a cold joint not very tight to water infiltrations. This is a standard process that causes a problem.; |
| **Remedy** | - For the balcony slab joint the infiltrations can be eliminated by injecting the joint from the interior in all its length with an epoxy paste. A second alternative is to create a drip on the exterior side covering the sensitive zone.; |

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- For the infiltrations at the junction of the slab and the cladding, the first solution consists in removing 3 rows of bricks above the exterior slab and insert a new metallic flashing under the sheathing paper (15 lb). This flashing should be embedded in the concrete slab and sealed according to the detail provided in TEC 98-495. It is needed to ensure that the sheathing paper is in place. For this, one or two bricks can be dismounted.;

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| **File Number** | 499 |
| **Problem Location** | Basement; |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations;<br><br>Other, Specify _Cracks in the Foundational Wall; |
| **Symptoms** | Water infiltrations – (Specify location: _Basement);<br><br>Other, Specify: _ Cracks in the Foundational Walls; |
| **Vulnerabilities** | - The slopes of the terrain are in the wrong direction and they are the direct cause of the cracks because they canalize water towards the building.;<br><br>- The gutter downspout is very close to the building so the water that comes out of it stays in the zone, increasing the amount of water and worsening the problem as a result.; |
| **Factors Affecting** | - Cracks in foundations can be due to shrinkage of material or to lateral push. Capillary cracks are generally vertical, and appear often in the bottom of basement windows or in the weaker spots of the foundational wall. In this case the cracks are very capillary, more of less horizontal. The most probable cause is adherence due to frost. The backfilling material is subject to water accumulation and during freezing winter temperatures it can adhere to the concrete of the foundations. When the soil is saturated with water, ice lenses form and they adhere to the foundational walls. Frozen ground swells and creates tensions in the concrete that is then subjected to tensions instead of the normal effects of compression. It is possible to reduce the effects of frost with an adequate drainage because if water remains close to the foundations, the soil saturates with water and the effects of frost are magnified. |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why? The slopes in the terrain are wrong. This is due to an incorrect or incomplete execution of the construction job.;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The gutter downspout discharges close to the house. This is a basic design error.; |
| **Remedy** | - Seal the exterior of the cracks with a plastic cement and a polyethylene membrane. A rigid insulation should be placed directly over the surfaces to prevent the adherence by an insulation.; |

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- Canalize the gutter downspout far from the building.;
- Correct the slope in the terrain to canalize water far from the building.;

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| **File Number** | 501 |
| **Problem Location** | Basement |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Other, Specify _Humidity Smells in the Basement |
| **Symptoms** | Condensation – (Specify location: Basement walls);<br><br>Water infiltrations – (Specify location: _Basement);<br><br>Other, Specify: _Humidity Smells in the left section of the basement;<br><br>Cracks in the left side foundational wall;<br><br>Humidity Traces in the lower part of the foundational wall;<br><br>Mold in the wood cladding of the wall in the laundry room behind the dryer;<br><br>Wetness along the wall that separates the mechanical room from the laundry room ;<br><br>Efflorescence in Basement walls;<br><br>Dripping water noises along the left side wall; |
| **Vulnerabilities** | - There is a non tight connection in the sink of the laundry room that leaks water to the wall of the mechanical room.;<br><br>- The left side wall of the house is completely covered with an ivy;<br><br>- Water coming from the roof is not canalized and it accumulates along the foundations.;<br><br>- The basement is ventilated to the exterior in summer, bringing hot and humid air inside and is cooled by an air conditioning system. This causes condensation in the walls.;<br><br>-There are cracks in the foundational wall that infiltrate water to the interior of the basement;<br><br>- There is an ivy along the left side wall that keeps the foundational wall humid; |
| **Factors Affecting** | - There is condensation in the basement due to the fact that the |

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| | foundational walls in contact with the ground are generally colder in the lower part than in the upper part. If warm and humid air from the exterior touches the surfaces, condensation will appear. A mechanical ventilation or air conditioning system favours cooling of the concrete walls and the phenomenon is magnified.;<br><br>- The presence of water infiltrations due to cracks in the wall and other sources worsen the problem because the higher the Relative Humidity, the greater the condensation.;<br><br>- The presence of an ivy in the left side wall keeps the foundational wall humid and when sun heats the wall vapour migrates to the interior because of the pressure difference of water vapour.; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The house has no gutter and because of this and water accumulates in the soil beside the house, causing the problem. This is an error of design. Also the use of a mechanical ventilation system in the basement is an error of design. |
| **Remedy** | - Do not open the windows of the basement in summer;<br><br>- Do not air condition the basement;<br><br>- Install gutters to control water runoff with downspouts that evacuate far from the foundations.;<br><br>- Correct the slopes in the terrain in a way that water is kept away from the building;<br><br>-Fill all the cracks in the foundational walls with an injection through the interior or with exterior membranes.;<br><br>-Eliminate the ivy along the left side wall.;<br><br>-Install a baseboard heating system independent from the current system, controlled with a thermostat in each room. Also it is needed to block the ventilation distribution grills and balance the system.;<br><br>-Before rearranging the opened walls of the basement, evacuate all the materials that could absorb humidity, such as cardboard boxes, tissues, lumber, etc. Once this is done, heat the basement to at least 25°C during 2 or 3 days with great ventilation and the windows slightly open. After this, rearrange the walls, keeping in mind that water vapour can get behind the existing materials so the insulation and the installation of the vapour retarder must be made before winter.; |

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| -Install a good fan in the laundry room;<br><br>-Repair the leaks in the discharge of the sink in the basement; |

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| **File Number** | 513 |
| **Problem Location** | Basement |
| **Building Type** | Other, Specify: _Semidetached Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Water infiltrations – (Specify location: _ Perimeter of the foundation);<br><br>Other, Specify: _Traces of Water Infiltrations at the bottom of the wall under the landing of the stairs;<br><br>Traces of Water Infiltrations at the bottom of the wall in the back of the basement;<br><br>Silt Accumulation in the basin of the drainage system; |
| **Vulnerabilities** | - The slope of the terrain around the house is negative, so rain water of snow melt cannot be evacuated far from the house.;<br><br>- The drain under the slab does not work properly. A section of the drain is blocked probably with silt so the water cannot be collected by the drain and evacuated. This causes hydrostatic pressures on the slab at the time of heavy rain or spring snow melt. That is why water appears in the perimeter of the foundation and explains why the contractor's measure of installing a membrane was not effective.; |
| **Factors Affecting** | - The terrain has silt and it has accumulated in the holes of the drain under de slab, impeding the collection of water by the drain.;<br><br>- Water infiltrations appear at the time of heavy rain along the right and back walls of the house due to hydrostatic pressures caused by the poor performance of the drain under the slab.;<br><br>- The drainage of the neighbouring lot in the back and in the right side is done over the terrain of the house. The neighbouring lot has clay with high content of silt.; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design of the drain was incorrect because it did not take into consideration the presence of silt in the terrain that could block a standard type drain. This is poor design. Also, the slopes of the terrain were negative and this is an error of the designer |
| **Remedy** | - Replace the standard type drain in the base of the foundations with a rigid 4"diameter drain. The same type used in purifying systems. Other |

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holes must be done around the drain so that it collects water. A backfilling of ¾"stone must be used to cover the drain. A geotextile membrane must be installed to coat wholly the backfilling stone. When backfilling, it is necessary to put in place a layer of impermeable clay to stop water from the surface from infiltrating in the stone backfilling.;

- Correct the slopes of the terrain, especially along the right side wall and in the back so that they evacuate water fast and efficiently.;

- Build a drain in the back section considering the conditions imposed by the neighbouring lot.;

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| **File Number** | 521 |
| **Problem Location** | Cladding |
| **Building Type** | Other, Specify: _Detached Cottage |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations;<br>Other, Specify _White stains in the stone cladding; |
| **Symptoms** | Damages Caused by water – (Specify location: _Stones in the cladding of the house);<br><br>Ice Dams – (Specify location: Valleys);<br><br>Water infiltrations – (Specify location: _Window of the kitchen; Room above the kitchen);<br><br>Other, Specify: _White Stains in the bottom of the stone cladding;<br><br>Loss of Adhesion of stones in the cladding of the house;<br><br>Efflorescence in the cladding; |
| **Vulnerabilities** | - The house has an addition that has a section of the roof that forms 2 valleys. The protrusion (decroche) in the wall is made in a way that it does not allow the flow of rain water freely to the exterior of the roof and favours the accumulation in the back of the cladding. If the masonry cladding remains saturated, leaching can happen over a long period. The evaporation of water implies the migration of salts entrained in the composition of the mortar, and that is the reason for the white stains.;<br><br>- The accumulation of ice in the valleys is due to the architecture of the roof. Due to its steep slopes, the roof favours snow accumulation. The orientation of the valleys is another factor that must not be neglected.;<br><br>- The ice accumulations are caused by a poorly distributed ventilation due to a lack of cornices.;<br><br>- The architectural design of the roof causes snow accumulation.;<br><br>-The construction methods used in the construction of the main section of the house do not allow the application of the base ventilation notions. The roof rafters are probably embedded in the masonry wall, impeding the application of the base principles.; |
| **Factors Affecting** | - Ice dams in the cornices of a roof can have many causes. One of them |

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is that even though the minimal ventilation Code requirements are observed, they are not enough for the particular case that has the problem. This situation combined with other factors, cause ice dams.;

- Gutters are the first source of ice accumulation in the roof edge. In sunny days or when the weather is mild, water generated from snow melt flows to the gutter and freezes at contact with it. The flow is slowed down by the successive formation of ice and little by little the gutter overflows. Progressively, ice accumulates in the roof edge, impeding any flow. Then, water makes it way and infiltrates under the roof covering. Ice and icicles appear in the soffits of the cornice.;

- Poor ventilation of the attic can cause ice accumulation. The weak discharge of air at the level of the cornices in relation to the discharge in the top part of the roof favours the warming of this zone and contributes to snow melt. Sometimes the ventilators in the ridge do not allow the evacuation of air because they are blocked by snow. To compensate this, some people install Maximum type ventilators. In this case if the flat ventilators are not obstructed, the added ventilator short circuits the strategy and instead of pulling air from the cornices, it pulls air from the flat ventilators near it. Stagnation of air in the bottom part favours the warming up of this zone and contributes to the appearance of ice dams due to snow melt.;

- Heat losses are the most important cause of ice dam formation because these losses increase the temperature of the attic. The wood deck is warmed up and causes snow melt. Water follows the same path to the gutter.
Heat losses are larger in the in the perimeter of the exterior walls because the insulation of the ceilings is more difficult to install above the exterior walls. If the space between the insulation touches the wood deck, the heat loss is increased and accelerates the formation of ice dams.
Another important element to consider is the heat loss at the concrete block fire walls. Often, builders forget to fill the cavity of the block cells. Then, there is heat loss by convection and conduction along the fire wall. This loss heats the air in the attic, warming up the wood deck and the cycle starts again.
Heat losses can happen too in the access hatch of the attic, in the embedded lamps, in the beams that support the structural elements, etc.;

- Solar radiation can contribute to snow melt over the roofs increasing the size of the ice dam. The thick beds of snow absorb heat and transmit it to the wood deck or to the shingles causing snow melt. This action over the slopes exposed to the south favour snow melt. The energy absorbed by the structure warms up the attic and causes snow melt in the

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| | non exposed slopes.; |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The design of the roof favours snow accumulation and this, together with a poorly distributed ventilation is an important cause of the problem. This is poor design. |
| **Remedy** | - In both valleys of the roof a band (bande de depart) of at least 6'is proposed. Starting from the edge of the cornice. This band must extend from each side of the valley to offer a better protection.;<br><br>- Install heating wires to keep the valleys free of ice. Also install heating wires in the gutter downspouts to allow the flow of water in winter.;<br><br>- For the water infiltrations in the left side section, two methods are suggested: lift the roof section to retreat the plan of the valleys, or cut the top of the low walls so that the roof covering can be extended beyond the wall cladding.; |

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| **File Number** | 524 |
| **Problem Location** | Roof Covering |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Other, Specify _Undulations in the roof covering |
| **Symptoms** | Damages Caused by water – (Specify location: _Gypsum covering of the ceiling of the living room; _ Gypsum covering of the ceiling of the kitchen;);<br><br>Water infiltrations – (Specify location: _Kitchen; Middle of the roof slope, 12' from the edge of the cornice); |
| **Vulnerabilities** | - There is lack of a protection band in the roof front (avant toit) in façade and in the back slope. |
| **Factors Affecting** | - The roof covering is 7 years old. Some shingles have their tips slightly lifted. In some spots, the grains are lost probably due to the de icing procedure.;<br><br>- The Ice Storm of 1998 caused many roof damages because of the accumulation of ice adhered to the roof covering. Such accumulation in the period of more or less 3 weeks caused water infiltrations. The ice melt water generated by the heat losses of the building could not flow freely. This situation contributed to the accumulation of ice under the shingles. Freezing water swells and tends to lift the tips of the shingles. Since they are adhered by a band of bitumen, shingles lift where there is an absence of such band.; |
| **Causes** | Other, Specify: Unexpected Load due to Unexpected Climatic Conditions |
| **Remedy** | - The contractor sealed the roof spots that infiltrated water. This solved the problem. |

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| **File Number** | 525 |
| **Problem Location** | Fireplace of the living room through the heating system grills |
| **Building Type** | Cottage in Row |
| **Storeys** | 2 |
| **Problem** | Air Infiltrations (Specify location: Fireplace of the living room through the heating system grills) |
| **Symptoms** | Air Infiltration – (Specify location:_ Fireplace of the living room through the heating system grills) |
| **Vulnerabilities** | - The living room is located directly above the garage. The ceiling of the garage is insulated and covered with gypsum. Since the structure of the floor of the living room is composed of hemstitched girders of 12 inches high, a space of 7 inches is left above the insulation of the ceiling of the garage. (see drawing in TEC 98-525) At the time when the air conditioning and heating system were done, this space was used to create return plenums for the HVAC system. This situation left the grill of the living room communicated directly with the empty space above the insulation. Due to the fact that there is a closed space without a direct heating source between the floor of the ground floor and the ceiling of the garage, a natural convection phenomenon favours the air movements. However this air movement is not the cooling source of the floor, because the air is limited to the space above the insulation. The cooling source of the floor is probably a cold air infiltration along the header.;<br><br>- The section of the header in the back of the track of the garage door was not corrected. The same as the section under the door.;<br><br>- Another possible source of cold air is the contour of the cold air intake of the fireplace. It is possible that the space around the conduit allows free circulation of air between the air space behind the brick cladding and the one above the insulation.; |
| **Factors Affecting** | |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why? There is a lack of tightness along the header and the fireplace. This is due to poor craftsmanship.;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_There is a connection between the air space above the insulation of the ceiling of the garage and the grills of the salon. This is one of the causes of the |

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| | problem and it is poor design; |
| **Remedy** | - The application of foam over the header assembly or the use of cellulose fibre blown insulation above the insulation in the garage ceiling in a band of more or less 3 ft in the perimeter of the garage. By filling all the cavity above the insulation of the garage ceiling, convection is eliminated.;<br><br>- Regarding the problem in the fireplace a light insulation is only possible because of the dimensions of the fireplace 2"x 4" over the plate. The level of tightness and insulation in the horizontal structure above the fireplace should be checked. Taking into account the height of the chimney, the effect of convection is important and the batt insulation is letting cold air in.; |

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| **File Number** | 527 |
| **Problem Location** | Ceiling of the living room |
| **Building Type** | Coproperty of 6 detached "logements" |
| **Storeys** | |
| **Problem** | Water Infiltrations (Specify location:_Ceiling of the living room); |
| **Symptoms** | Damages Caused by water – (Specify location: _ Close to the beam supporting the trusses of the turret;<br><br>Traces of water infiltration close to the beam supporting the trusses of the turret; |
| **Vulnerabilities** | - The configuration of the roof leaves little space for the installation of ventilation grills to allow a better circulation of air.<br><br>- The section of the cathedral roof has little natural ventilation. Along the cornice that is close to the terrace there is no ventilation grill. The soffit of the cornices of the turret are not communicated with the attic of the cathedral ceiling.<br><br>- The space restriction caused by the trusses in the attic make extraction of air less easy in the front section than in the back section for the fan placed in the back slope. This favours stagnation of air in the front attic.<br><br>- The configuration of the roof combined with the type of attic of the affected zone and the orientation of the building makes it inevitable for snow to accumulate. |
| **Factors Affecting** | - In this type of ceiling (cathedral type), air circulation is reduced by the friction of air over the insulation.<br><br>- The inevitable heat losses favour the increase of the temperature in the attic.<br><br>- Heat melts snow that accumulates close to the deck and favours the formation of ice dams. In milder weather, water cannot flow freely and infiltrates under the shingles, trickling to the interior of the house. |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The roof configuration, combined with the type of attic of the affected zone and the orientation of the building makes it inevitable for snow to accumulate. This is a design failure. |
| **Remedy** | - Install ventilation grills along the cornice of the terrace to accelerate the air circulation and diminish the effects of heat losses. |

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| | - Remove the existing shingles over the front section of the roof and install a self adhering membrane with a height of more or less 10 ft. above the turret. This will allow to cope with snow that melts because of solar radiation that contributes to the formation of ice dams. |
| **File Number** | 528 |
| **Problem Location** | Cornice of the Building |
| **Building Type** | Other, Specify: _Commercial Building |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations (Specify location:_ in the deflections of the back cornice of the building);<br><br>Other, Specify _Determine if the deflections in the back cornice of the building are due to an incorrect design or poor craftsmanship; |
| **Symptoms** | Water infiltrations – (Specify location: _between the drip and the wood moldings); |
| **Vulnerabilities** | - There is a deflection in the decorative cornice of the building that puts the drip not elevated enough and causing water to go above it, infiltrating between the drip and the wood moldings.;<br><br>- The drawing details of the cornice are imprecise in the fixation method of the cornice to the structural elements. They show light members of the cornice sliding under the plywood of the roof deck.;<br><br>- The cornice was subjected to loads of snow and ice without being properly connected to the structure, therefore it acted independently from the structure and deflected. Such deflection caused the water infiltrations.; |
| **Factors Affecting** | |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_The drawing details were ambiguous, lacked information and are the main cause of the problem.;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_The design didn't take into consideration the loads that the cornice would be subjected to during its service life. This caused the deflection of the cornice that ultimately resulted in water infiltrations.; |
| **Remedy** | - There are no remedial measures recommended |

*Information as extracted from APCHQ files*

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| **File Number** | 532 |
| **Problem Location** | Wall in the back of the house |
| **Building Type** | Other, Specify: _Row Duplex |
| **Storeys** | 2 |
| **Problem** | Air Infiltrations (Specify location:_wall in the back of the house); |
| **Symptoms** | Air Infiltration – (Specify location: Wood structure around the metal jambs of the foundational wall; Metallic girders (longerons) that support the balcony of the 2nd floor);<br><br>Other, Specify: _Frozen water pipes.; |
| **Vulnerabilities** | - In the basement, the water supply conduits are close to the foundational wall. Also, the two metal jambs (montants) are located in the places where the water conduits pass. It is possible to see that the wood structure around the metal jambs is not air tight.;<br><br>- To supply water to the kitchen sink the water pipes must go along the metallic girders (longerons) that support the balcony of the 2nd floor. It is possible that the tightness of the metal girders (longerons) was affected and during extreme conditions air infiltrates around them.; |
| **Factors Affecting** | - The air infiltrations are most likely to happen with extreme weather conditions.; |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why? The construction job affected the tightness of the metal side frames on the 2nd floor, causing the problem. This incorrect handling of construction elements. |
| **Remedy** | - Installation of insulation over the wall structure;<br><br>- For the 2nd floor, dismount the wood jambs that rest over the brick cladding and dismount some bricks. Then, seal around the metal girders (longerons) by injecting polyurethane foam.; |

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| **File Number** | 558 |
| **Problem Location** | Roof |
| **Building Type** | Other, Specify: _Commercial Building (hostel) |
| **Storeys** | NA |
| **Problem** | Water Infiltrations (Specify location: in the roof of the building); |
| **Symptoms** | Ice Accumulation – (Specify location:_Main basin of the roof);<br><br>Water infiltrations – (Specify location: _Through the roof; In the hall that accesses the pool; In the dining room; In the bar); |
| **Vulnerabilities** | - The roof membrane has some non-critical spots where there is lack of adherence.;<br><br>- The roof configuration is complicated and favours accumulation of large amounts of snow. It is made out of numerous basins formed at the valleys of the roof where water accumulates before being drained. Also, the main basin is directed to a drain that goes along the wall situated directly above one of the zones with water infiltrations.;<br><br>- The weak insulation of the roof favours melting accumulated snow, turning it into ice. If ice accumulates it ends up blocking the drain and causes important water accumulations at the time of milder weather, when ice melts. If the accumulations are enough, they can pass beyond the protection of the flashings and water infiltrates to the roof structure.;<br><br>-The identified points of water infiltration are: The flashing under the wood cladding at the section of the two floors and the zone above the hall that accesses the exterior pool.; |
| **Factors Affecting** | |
| **Causes** | Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why?_<br>The complicated configuration of the roof combined with a weak insulation caused the problem and this is poor design. |
| **Remedy** | - Repair the flashings under the existing cladding and correct the drainage system of the main basin. To accomplish this, it is recommended to build a thin wall (bati) along the wall of the 2nd floor up to a height of 15"and ensure that the flashing goes up enough behind the cladding. The latter should be repaired ensuring that the membrane remains unaffected. Also, a heating wire should be installed permanently at the drain of the main basin to prevent its obstruction in case of ice accumulation. A complete verification of the membrane must be done including the resealing of some joints.; |

*Information as extracted from APCHQ files*

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| | - A maintenance program during the winter must be done.; |
| **File Number** | 564 |
| **Problem Location** | Basement |
| **Building Type** | Detached Cottage House |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations in the Basement |
| **Symptoms** | Water infiltrations – (Specify location: _Mechanical room located in the basement); |
| **Vulnerabilities** | - There is a crack in the gypsum board in the stairs.;<br>- There is a horizontal crack in the stair case in the ceiling of the ground floor.; |
| **Factors Affecting** | - The cracks in the gypsum board are due to a lifting of the roof trusses caused by their long span and the expansion and contraction caused by seasonal temperatures. In winter cracks appear because the truss contracts and in summer they close due to an expansion of the truss.; |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why? The hole in the concrete slab that caused the problem was due to a soil pocket that got trapped in the concrete. This was due to an incorrect placement of the concrete on site. |
| **Remedy** | - For the water infiltration point in the concrete slab, inject the hole with epoxy and clean up the wall finishes and floor.;<br><br>- For the cracks in the gypsum board, it is necessary to put a control joint in the gypsum board in the bottom part of the member of the roof truss according to the expansion joint drawings provided in TEC 99-564.; |

*Information as extracted from APCHQ files*

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| **File Number** | 571 |
| **Problem Location** | Bottom of the foundational Walls |
| **Building Type** | Other, Specify: _Building in Coproperty |
| **Storeys** | 3 |
| **Problem** | Water infiltrations – (Specify location: _In the bottom of the foundational walls at the zones where shelves for storage are designed);<br><br>Other, Specify _Comment the expert opinion submitted by the firm "Les consultants techniques inc."; |
| **Symptoms** | Water infiltrations – (Specify location: _In the bottom of the foundational walls at the zones where shelves for storage are designed);<br><br>Other, Specify: _Spots in the shelves for storage.; |
| **Vulnerabilities** | - The French drain is connected to the central basin through the drainage conduit facing the garage door. It is the same case for the all the gutters. It is very probable that water runoff from the roof could backflow up to the drain, cooling the concrete surfaces, allowing condensation during summer period. |
| **Factors Affecting** | - The problem can be caused by either the condensation normal in summer period or the moisture migration through capillarity.;<br><br>- Condensation could be due to a high Relative Humidity during summer caused by leaving the garage door open. If the bottom of the foundations is kept more or less at 12°C and the Relative Humidity higher than 75%, condensation will appear in the cold surfaces.; |
| **Causes** | Other, Specify: Normal weather exposure of the building. |
| **Remedy** | - Disconnect the gutter downspouts from the sewage system and canalize them to the surface, so that the "puits perdu" system doesn't receive but the water from the gutters above the garage. This will help eliminate the hydrostatic pressure under the concrete slab since the water from the roof does not go to the French drain. |

*Information as extracted from APCHQ files*

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| **File Number** | 575 |
| **Problem Location** | House |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | High Relative Humidity (Specify location: In the house) |
| **Symptoms** | Condensation – (Specify location: Windows of the House) |
| **Vulnerabilities** | |
| **Factors Affecting** | - The usage of the house by the owners is the most probable source of humidity in the windows. |
| **Causes** | Other, Specify: The usage of the house by the owners is the source of humidity that causes the condensation problem. |
| **Remedy** | - Ventilate the house adequately and keep a Relative Humidity that will vary according to the exterior temperature.;<br><br>- Calibrate the ventilation system so that there is distribution of fresh air in the places where water vapour is mostly present.; |

*Information as extracted from APCHQ files*

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| **File Number** | 579 |
| **Problem Location** | House |
| **Building Type** | Other, Specify: _Detached Bungalow |
| **Storeys** | 1 |
| **Problem** | Water Infiltrations<br><br>Other, Specify _Verify the defects transmitted to the contractor –WATER INFILTRATIONS |
| **Symptoms** | Damages Caused by water – (Specify location: _Gypsum sheathing of the interior side; Parquet of the main bedroom);<br><br>Water infiltrations – (Specify location: At the window of the living room); |
| **Vulnerabilities** | - There is a failure in the flashing above the window where the infiltrations happen. The configuration of the window makes it difficult to install it adequately.; |
| **Factors Affecting** | - Strong winds that push rain through the problematic window contribute to the water infiltrations. |
| **Causes** | Correct materials were specified and appropriately detailed but incorrectly ordered, handled and/or assembled on site, Explain why? The flashing in the window that presented water infiltrations was incorrectly installed.;<br><br>Inappropriate design conditions of loading or exposure used in making calculations or predictions of performance Explain why? The configuration of the window that presented water infiltrations makes it difficult to install it adequately.; |
| **Remedy** | -For the infiltrations above the window of the living room, the cladding should be dismantled in the top part of the window and the flashing should be verified. |

*Information as extracted from APCHQ files*

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|---|---|
| **File Number** | 584 |
| **Problem Location** | Window |
| **Building Type** | Detached Cottage House |
| **Storeys** | 2 |
| **Problem** | Water Infiltrations (Specify location: Window in the back of the house) |
| **Symptoms** | Damages Caused by water – (Specify location: _Parquet floor);<br><br>Mold – (Specify location:_Parquet floor strips);<br><br>Water infiltrations – (Specify location: _Above the window of the living room);<br><br>Other, Specify: _Loss of Adhesion of parquet floor strips;<br><br>Traces of water infiltrations in the parquet floor;<br><br>Traces of water infiltrations in the gypsum sheathing; |
| **Vulnerabilities** | - It is possible that water infiltrates at the junction of the exterior corner of the window and the horizontal flashing. |
| **Factors Affecting** | - According to the owner, water infiltrated when there was a strong wind or heavy rain. |
| **Causes** | Correct materials were specified but inappropriately detailed, Explain why?_Water infiltrates through a weak spot in the junction of the exterior corner of the window and the flashing. This is an inappropriate detail. |
| **Remedy** | - Dismount the first aluminium sheet above the decorative band in the floor of the second floor to intercept the water that infiltrates with heavy rain. If the hidden part of the decorative band under the siding is not folded, this situation must be corrected according to the drawing provided in TEC 99-584 |

*Information as extracted from APCHQ files*

# **Appendix D** Related Literature


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