AN EXPERT SYSTEM APPROACH TO ESTABLISH DESIGN SNOW AND WIND LOADS

by

Karla Marie Embleton

A thesis
presented to the University of Manitoba
in partial fulfillment of the
requirements for the degree of
Master of Science
in
Agricultural Engineering

Winnipeg, Manitoba

(c) Karla Marie Embleton, 1990

National Library of Canada
Bibliothèque nationale du Canada

Canadian Theses Service
Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-63306-9

Canada

AN EXPERT SYSTEM APPROACH TO ESTABLISH DESIGN SNOW AND WIND LOADS

BY

KARLA MARIE EMBLETON

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF SCIENCE

© 1990

Permission has been granted to the LIBRARY OF THE UNIVERSITY OF MANITOBA to lend or sell copies of this thesis, to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film, and UNIVERSITY MICROFILMS to publish an abstract of this thesis.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

ABSTRACT

Expert systems (ES) appear capable of handling judgemental decisions required in the engineering design process which are not easily incorporated in computer software developed with traditional programming methods. To evaluate the potential of ES, the determination of design snow loads and design wind loads on user-defined structures were isolated for ES program development.

The expertise embodied in each ES program was extracted from the 1983 Canadian Farm Building Code, the 1985 National Building Code of Canada, and the Supplement to the 1985 National Building Code of Canada. Both programs were developed using the expert system shell 'Personal Consultant Plus' (PCPLUS). PCPLUS was operated on a UNiSYS 800 work station having a hard drive, EGA graphics, 72 MB RAM, and 4.9 MB extended RAM. AutoCAD10, dBASE3+, and GWBASIC were also used. During consultations, both ES programs interact with the user and with external programs and data files stored on the work station.

Both ES programs produce results in accordance with the national codes. Minor revisions, additions, and further testing are required if the ES programs are to evolve from the prototype stage to the point of commercial software. Strengths, weaknesses, and anomalies relating to this specific application of PCPLUS were discovered. These shell characteristics must be carefully reviewed as they limit the programs which can be developed with PCPLUS. Overall, the ES approach worked well in solving judgemental design decisions in the snow and wind program. This approach appears to hold much promise for the development of larger design environments.

ACKNOWLEDGEMENTS

There are several people I would like to recognize for their support and assistance in this project.

First, I wish to thank Dr. M.G. Britton, my major professor, for giving me the opportunity to work on this project.

Second, I am grateful to the National Research Council of Canada for allowing me to reproduce several figures from the Supplement to the 1985 National Building Code of Canada. These reproductions appear in Appendices A and C.

Third, I thank Debby and Bruce who have given me encouragement, support, and best of all, friendship.

Finally, I wish to thank my family - my dad for his shoulder, and my mom for her funny letters. Without both these things, this thesis would not have been possible.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

A - surface area (ft^2)

Ca - accumulation factor

Cb - basic snow load factor

Ce - exposure factor

Cg - gust factor

Ch - height factor

Cp - external pressure coefficient

Cpi - internal pressure coefficient

Cs - basic snow load coefficient

Cw - wind exposure factor

F - specified wind load (lb)

g - ground snow load (psf)

p - external pressure (psf)

Pi - internal design pressure (kPa)

q - basic design pressure (psf)

q - reference wind velocity pressure (psf, kPa)

S - specified roof snow load (psf, kPa)

So - ground snow load (kPa)

1. INTRODUCTION

Engineering design is a unique process whereby applied science and human judgement are combined to arrive at an optimum solution to a specific problem. Many people have attempted to define the design process by breaking it into a series of formal steps or stages which are worked through to attain a problem solution. However, such lists tend to be unrealistically rigid, incomplete, and inadequate with respect to actual practice (Koen, 1985). The most likely reason for this is that the lists underemphasize or negate the human aspect of design. Currently available computer software to aid design appears to be based on the assumption that the design step lists are accurate representations of the design process. Consequently, software aids for design concentrate on the applied science aspects of design.

In structural engineering, many software packages are available to perform mathematical analyses of structural components (Britton, 1989b) . Normally, each component must be identified for analysis and thoroughly defined by the user. The computer program then generates values such as stress, strain, and bending moment for the component which are output to hard copy. These numerical results must be interpreted by the software user for the design problem at hand. Such programs give little or no guidance towards the development of optimum solutions. It is the responsibility of the human to consider the effects of building site, use, and shape, as well as any local building codes, resource constraints, or general rules-of-thumb that could potentially affect the design solution. Rules-of-thumb have become known as 'heuristics'. Heuristics describe situation- specific cause/effect relationships between facts along with guidelines for decision making.

The job of the designer would be made easier if a computer aid was available that could help guide the designer from the initial conceptualization of the problem through to the attainment of an optimum solution. Such an aid would combine mathematical and non-mathematical problem solving skills. The mathematical tasks can be accomplished using software currently available. What is needed is a tool which aids in judgemental decision making.

Expert systems (ES) are a recently created branch of computer programming which appear to have the potential to perform judgemental decision making. This project explores the use of ES in the creation of two programs meant to aid in the design of wood, light-frame, low-rise structures in Canada. The objective of these programs is to establish snow and wind design loads for a user-defined structure in accordance with the 1983 Canadian Farm Building Code, the 1985 National Building Code of Canada, and the Supplement to the 1985 National Building Code. It is intended that the user will supply information relating to the structure and building site. The programs interpret this input information, using heuristics and numeric information from the building codes, to establish the design loads. The intent of this project is not only to solve the specific goals of each expert system program but also to give insight into the strengths and weaknesses of an ES approach to computer aided design.

2. ENGINEERING DESIGN

To create a useful computer aid for engineering design it is first necessary to understand the design process. In essence, engineering design is a strategy for causing change (Koen, 1985). Design is often viewed as an ill-defined problem which escapes typical problem solving approaches (Britton, 1989a). This view is based on the fact that at the beginning of the design process the end result is not well defined. However, this view is rather unsophisticated since most design problems contain both well and ill defined sub-problems. Also, engineers have developed a unique method for tackling design.

Koen (1985) describes the engineering method as a strategy for causing the best change in a poorly understood or uncertain situation within the available resources. Initially the engineer must identify the problem and select a transition strategy that will hopefully lead to a problem solution. Many transition strategies exist but each is limited by different constraints. The solution eventually arrived at is "best" with respect to the engineer's perception of the problem and the resources available. It is a subjective optimum which may not be appropriate if either the problem definition or available resources change. Typically, the perceived goal will evolve as the design progresses. Therefore, design is a forward action from an initial known situation towards a less well defined final position.

Koen (1985) states that several authors have attempted to define design in terms of algorithms. An algorithm is a fixed sequence of steps to follow to solve a problem. Such lists are inappropriate definitions of engineering design for several reasons. First, the steps defined in each list are perceptions of the author of the list. Second, there is no allowance for iteration, trial-and-error procedures, backtracking or skipping of steps - all of which are common in "normal" design. Lastly, the lists are incomplete and too general to be applied to every design problem.

Instead of algorithms, engineers make use of heuristics (Koen, 1985). Heuristics are guidelines, rules-of-thumb, and hints which provide plausible aid or direction in the solution of a problem. Heuristics are often problem specific, can be contradictory, and may be fallible. Their use improves the efficiency of the design process by reducing the time needed to solve the problem and by supplying the engineer with a method to follow in approaching the problem.

Algorithms could be very useful if they were viewed as heuristics. Used in this manner, algorithms could supply guidance without curtailing the engineer's freedom to move around within the design plan. Conventional software design aids make use of strict algorithms. Such programs are inflexible and cannot be adapted to specific problems. Expert systems make use of heuristics - many of which have algorithm-like functions. The heuristics divide the problem into sub-problems, or tasks, and direct the designer through each task. Unlike an algorithm, expert system heuristics can display flexibility in adapting to different problem definitions and allow for "normal" design practices. They will not stall or fail completely if one task cannot be completed.

2.1 DESIGN PROJECT

This thesis has evolved from a proposal which suggests that Canadian engineering creativity and productivity could be increased 100% by the development of artificial intelligence (AI) based software for use in design (Britton, 1989a). The

Department of Agricultural Engineering at the University of Manitoba is one of the participants in the proposal group. The department has set out to examine the use of the expert system (ES) branch of AI with respect to structural design. The project targeted for initial work was the design of wooden, low-rise, light-weight buildings in Canada. By selecting this specific project, it was possible to identify a design approach and the expertise required for the project before the job of programming began.

Eight design steps were identified for this project. These steps range from initial conceptualization of the problem to the calculation of building cost. These steps do not represent a strict algorithm as iteration, backtracking, and the like are expected. Instead, the steps heuristically define the tasks which are normally carried out during the course of design. The steps are :

1. Sketch building
2. Clarify design problem
3. Determine external loads
4. Select members
5. Prepare initial drawing of structure
6. Prepare final set of drawings and material selection
7. Compile materials list
8. Calculate building price

The third step - the determination of external loads - was chosen as the subject of this thesis. It therefore serves as a testing ground for the development of expert system programs to aid design. This step was selected due to the need to combine both mathematical and heuristic knowledge to reach a solution. Two external loads, snow and wind, were selected for this study. An expert system program for the determination of each type of design load on a user-defined structure was to be created. The expertise embodied in the expert system programs was to be extracted from the 1983 Canadian Farm Building Code, the 1985 National Building Code of Canada, and the Supplement to the 1985 National Building Code. This information would be further supplemented and interpreted by the resident expert in structural design in the Department of Agricultural Engineering at the Univeristy of Manitoba, Dr. M.G.Britton.

3. EXPERT SYSTEMS

When designing a structure, a human expert combines mathematical analysis techniques with judgemental decisions to reach a solution. The decisions are based on past experience and practical considerations such as construction practices, building codes, and site details. Graphical aids are employed to assist in the visualization and validation of decisions as design proceeds.

Several programs created with highly structured mathematical languages, including FORTRAN and COBOL, are commercially available for structural analysis. These programs determine structural properties in members of user-defined structures or trusses. The role of such programs is strictly one of analysis. The programs will not suggest alternate member layouts, where problems exist, or how these problems could be corrected. The designer must therefore interpret the output from the analysis keeping in mind any constraints peculiar to the problem at hand as well as more general guidelines governing the design.

These practical considerations, or guidelines, form a body of design rules that are nonmathematical and difficult to accommodate with conventional programming languages. Expert systems (ES) however, are computer programs meant to handle just this sort of knowledge.

ES mimic the decision making process of a human expert (Holt, 1989). An ES is composed of a body of facts relating to a specific problem, a set of inferences or rules that describe relationships between the facts, and a reasoning strategy that dictates which facts are examined and which rules are considered during the solution of a problem. The method by which facts, rules, and reasoning are handled varies with the ES used and the problem being solved. Like human experts, ES can operate with uncertainty, incomplete data, and can supply explanations of how decisions are arrived at. To date, ES have proven most effective when the problem area is clearly defined and bounded, the decisions to be made are judgemental in nature, and the problem would take a human expert no more than a few hours to solve (Whittaker et al., 1987).

3.1 Mimicking human decision making

Humans use symbolic reasoning to make decisions (Barrett and Castore, 1989). Symbols are chosen to represent objects which may be either physical or conceptual entities. These symbols are then manipulated using a variety of strategies and heuristics. In order to reach a decision, four stages of thought are worked through :

1. definition of the problem,
2. generation of a list of alternate actions or choices,
3. evaluation of the options, and
4. selection of, and action on, the option considered "best".

These thought processes are carried out simultaneously and reviewed as new information becomes available. Humans normally commit to an action by increments, especially when information concerning the problem is uncertain or incomplete.

Experts carry out the same thought processes but have more experience and knowledge about the problem than non-experts (Barrett and Castore, 1989). Experts systematically combine knowledge that has been gained through experience with information that is sensed and observed. They have methods of reaching a problem decision which allows them to "plough through" irrelevancies to reach a workable solution efficiently.

The aim of ES programming is to simulate the expert's approach to problem solving. This requires a computer environment that operates on symbolic logic, contains knowledge of a specific problem area, and a reasoning strategy that can manipulate the knowledge effectively.

The development of an expert system program parallels the thought process an expert travels through. The first operative is that the program must address the user's needs. This involves answering or solving the user's dilemma in a way that the user will accept. Problem solution begins with the definition and formulation of the problem. This requires a description of the specific situation by the user, as well as more generalized knowledge of the problem area acquired from a source of expertise. This information is stored in the ES program.

The next step is to process the information using the computer. Processing makes use of the heuristics and reasoning strategies of the human expert as they are embodied in the program. Heuristics are rules that describe relationships between data. These rules are most often expressed using cause/effect relationships. This step produces a ranked list of alternate actions or options. From this list, the user selects the option to be followed and traced in the rest of the program.

3.2 COMPONENTS OF AN EXPERT SYSTEM

Martin and Oxman (1988) describe four attributes a program must possess to be considered an expert system. These are:

1. the program must perform at an expert's level of competence in a particular problem domain,
2. the program must have inference mechanisms that can reason judgementally and justify their deductions,
3. the program must have databases of expert knowledge codified and stored for use by the system's inference mechanism, and
4. the programming involves describing and presenting knowledge to the system, NOT programming that describes how the knowledge is to be used.

In order to meet these qualifications, an expert system has several distinct components. Three components hinted at in the above list of ES attributes are a domain of factual information on the specific problem being examined, a set of rules that relate these facts to one another, and a reasoning strategy to solve the problem. These three components are referred to as the knowledge base and the inference engine (Martin and Oxman, 1988). In addition to the knowledge base and inference engine, an expert system contains an user-system interface, an explanation facility, and a knowledge acquisition facility (Martin and Oxman, 1988).

The knowledge base consists of the database and the decision rules used in the program. A list of objects symbolizing physical entities, concepts, conditions, and their attributes is stored in the database. This collection of facts forms the informational basis which the ES manipulates. Domain data is dynamic since the information in the system evolves and expands as the program executes.

The second component of the knowledge base is a set of rules that define static relationships between objects in the database. These rules represent the heuristic knowledge of the ES. By manipulation of these rules, the problem is broken down to a series of condition and consequence actions that are traced to a decision or goal.

The inference engine is the control structure of the ES. This mechanism determines what information will be used and how it will be used. By acting as a rule sequencer and interpreter the inference engine accesses rules and facts in the knowledge base, executes the program, and determines when the software has produced the best or most complete solution, given the limits of the system's knowledge.

The user-system interface has possibly the greatest influence on the user's acceptance of the ES program (Martin and Oxman, 1988). This facility consists of such items as menu generators, natural language modules, and graphics presentation modules. These items determine the ease with which a user can learn and use a program as well as the ease of program development.

Explanation facilities exist in order to explain or justify to the user the inferences and decisions made during program execution. This capability is normally associated only with human experts. Inclusion of this feature facilitates program development and debugging as well as lending credibility to the system in the eyes of the user.

The last basic component of ES is a knowledge acquisition facility. This facility consists of a knowledge editor and an induction tool. The editor ensures that knowledge data are properly configured to the form required by the inference mechanisms of the system. Syntax and consistency are checked by tracing objects and rules through the program. Induction tools facilitate data transfer to the ES program from external information sources. By allowing knowledge transfer from external sources, such as databases and analytical programs, the time spent building the knowledge base of the ES program is reduced and redundancies in the total system are lessened.

The six components which have been described are fundamental to all ES. Of the six components, only the knowledge base components are problem specific. The first expert system programs were developed from symbolic languages such as LISP and PROLOG. Development of all six components was required. Today, expert system programs are typically created using an expert system shell.

3.3 EXPERT SYSTEM SHELLS

Expert system shells facilitate the development of expert system programs by providing a programming environment that supports the inputting of knowledge into an otherwise complete expert system. The reasoning strategies incorporated in the inference engine are separate from the knowledge base and come complete with the shell. The development of ES programs with a shell differs from development using a symbolic language. With a shell, small prototype programs (approximately 300 rules) can be developed within 3 or 4 months, rather than several years as is likely with a language (Martin and Oxman, 1988).

A shell consists of all the basic components needed to support an ES program, other than the problem specific knowledge. Shells vary from one another with respect to knowledge base capacity, inference mechanisms used, facilities to make use of external information sources, graphics capabilities, and explanation facilities. A shell should therefore be selected specifically for the problem to be solved, the abilities of the developer, and the needs of the user.

3.4 PERSONAL CONSULTANT PLUS

The expert system shell selected for use in this project was 'Personal Consultant Plus' (PCPLUS). PCPLUS was created by Texas Instruments to facilitate the development of ES programs that run on personal computers. PCPLUS was created on the premise that the combination of simple control and inference techniques with sufficient domain knowledge could exhibit sophistication and expertise comparable to human expert performance (Martin and Oxman, 1988).

Several features of PCPLUS make it a potentially useful tool for the development of structural design programs. PCPLUS allows for a large knowledge base - the size of which varies with the complexity of the knowledge base and the amount of RAM memory that can be addressed. The shell comes with a very versatile graphics adapter that allows for inclusion of drawings into the expert system being developed. These drawings can be imported from almost any other personal computer graphics generation program. PCPLUS has its own higher level language called 'Abbreviated Rule Language' (ARL). This langauge facilitates knowledge base entry and program development. Also, several knowledge representation and reasoning techniques can be combined within a single program to improve program efficiency, ease of development, and management.

PCPLUS makes use of the three most popular forms of knowledge representation in ES : parameters, rules, and frames. A parameter is a structure which contains a piece of information. A parameter can have a variety of properties that define and limit its use in the program and the knowledge it stores. Only one property must be defined. The required property is called TYPE. TYPE indicates what sort of value the parameter can assume. Four choices for TYPE exist. These are a truth statement (yes/no, true/false), a single value with absolute certainty, and two different choices of multiple values with varying and absolute certainty. Optional properties that can be added to parameters, and which show up repeatedly in PCPLUS, include (Texas Instruments Incorporated, 1988):

1. TRANSLATION - definition of parameter,
2. PROMPT - specific phrase used to query user for parameter value,
3. EXPECT - lists of possible values user must chose from to answer PROMPT,
4. HELP - text supplied at user's request for additional information about a prompt,
5. GPROMPT - displays a pictorial PROMPT. This pictorial prompt can be combined with PROMPT,
6. DEFAULT - provides default value for parameter value,
7. METHOD - procedural statement for determining parameter value. May be a mathematical equation or a function call.

The second type of knowledge representation used in PCPLUS is rules. Rule based systems contain sets of 'IF...THEN' statements that represent heuristic relationships between parameters in the knowledge domain. The IF portion of the rules is referred to as the predicate clause (Engel et al., 1989). This clause describes a possible condition of one or more parameters. Boolean logic is used to combine parameters in the statement. If the clause is found to be true, the rule is instantiated. Instantiation consists of carrying out the actions described in the THEN portion of the rule, called the consequence clause (Engel et al., 1989). The action carried out might consist of supplying new information to the knowledge base, updating a parameter value, performing a procedure or communicating with the user.

Should the predicate clause be examined and found false, the rule is considered tried and failed. The rule is essentially used-up and not retried until factual information described in the predicate clause has changed.

If the predicate clause is indeterminate, due to a lack of information currently in the knowledge domain, the rule remains viable for retesting. The program will attempt to supply the missing data by querying the user, examining other rules in the system, and examining the attributes of parameters in the database.

The third knowledge representation scheme used in PCPLUS is the concept of 'frames'. A frame is a structure that provides for the grouping of rules and parametric data. Often a large problem can be broken into several smaller subproblems. The objective of the entire expert system program is to solve the large problem. The objective of each frame in the program is to solve an individual subproblem.

Every program in PCPLUS must have a least one frame - referred to as a ROOT frame (Texas Instruments, 1988). Additional frames can be added to represent subgoals, carry out procedures, and perform communication tasks. Frames are linked to one another to form decision trees. Linkage allows for information to be used repeatedly in different program frames via an inheritance facility associated with PCPLUS. Inheritance allows any given frame access to parametric information in frames above it on the decision tree (parent frames) and access to rules in frames below it on the decision tree (child frames).

Each frame has certain properties that ensure the proper progression of a program consultation. The most important properties are a list of goals, rule groups, and parameter groups associated with the frame. It is essential that at least one goal parameter be set per frame. The search to set a value for the goal parameter is what drives the expert system.

Two other frame properties available in PCPLUS are the INITIALDATA and PREMISE/PROMPT properties. INITIALDATA is used to store a listing of parameters whose values must be established prior to the solution of any frame goal. Initial data are information required for every consultation of the expert system program. The PREMISE/PROMPT property is common to all frames. This property actually consists of many possible combinations of PROMPT and PREMISE features, but for convenience it will be referred to as a single concept. The property is used to establish knowledge criteria that must be met before a frame can be entered. Entry criteria can be made as strict or as loose as is necessary to ensure proper program flow.

Two inferencing schemes can be used in PCPLUS programs to solve program and frame goals. These schemes are common in rule-based systems and are called forward chaining and backward chaining. Backward chaining concentrates on proving a specific goal value (Engel et al., 1989). If the goal value is not currently available through reference to the parametric facts in the knowledge domain, rules that set the goal value in their consequence clauses are examined. Once these rules are identified, the predicate clauses of each are tested to determine which can be instantiated to set the goal value. If data are missing in the predicate clauses, the system seeks other rules that will supply the missing information by assigning the appropriate parameter a value in their THEN clauses. This process continues until either a goal has been proven or the knowledge base is exhausted. Backward chaining logic can be combined with the inheritance facility to move the program down the decision tree.

With forward chaining, the reasoning process starts by considering all the data known about a specific problem (Engel et al., 1989). Rules are tested to see which can be instantiated given the current knowledge level. As rules are instantiated, new information is added to the knowledge base due to actions performed in the consequence clauses of the rules acted upon. The additional information in the knowledge base can cause other rules to instantiate. This process continues until the goal has been reached or the system can reason no further. Forward chaining can also be used to move the program from frame to frame.

In PCPLUS, backward and forward chaining can be combined to reach decisions more efficiently. The shell PCPLUS therefore supports hybrid ES programs. Programs can be developed that make use of more than one knowledge representation technique and more than one reasoning scheme.

4. KNOWLEDGE BASE EXPERTISE

A crucial component to the development of any expert system program is a ready source of reliable expertise. Typically this source will be an individual with both an academic and work history in the subject area. However, many other sources are available which have been under utilized to date.

The National Building Code of Canada with its various commentaries and supplements is such a source. The Code is intended as a guide of minimum safety provisions for buildings with respect to public health, fire protection, and structural sufficiency in Canada (ACNBC, 1985a). It has been used to establish municipal bylaws, and more recently provincial building codes. To date, nine editions of the Code have been published. The tenth is due for release in 1990.

The 1985 National Building Code and Supplement are the primary knowledge sources used in this project. Part 4 of the Code outlines basic requirements for structural design. Section 4.1.7 describes design load calculations for roof snow loads and Section 4.1.8 describes design wind load calculations. Chapter 4 in the 1985 Supplement contains explanatory material and technical information useful in the application of the Code's design requirements.

Prior to examining the details of the current Code as it applies to snow and wind load determination, a brief overview of the history and evolution of the National Building Code is in order. This overview will aid in the comprehension of current Code details. The Code is a dynamic entity based on human judgement and measurements taken during several Canada-wide environmental surveys. Therefore, as the design approach evolves and more factual information becomes available, code revisions can be expected.

4.1 HISTORY AND EVOLUTION OF CANADIAN SNOW CODES

The determination of design snow loads for roofs has undergone many changes since the first publication of the National Building Code of Canada in 1943. These changes reflect an ever greater appreciation of snow accumulation, drifting, creep and sliding on a variety of structures based on an ever increasing database of recorded measurements and model tests.

Prior to the 1960 National Building Code, specified roof snow loads were considered equal to the ground snow load expected at the site with only a step-wise reduction for sloped roofs allowed (ACNBC, 1965b). This resulted in many improperly designed structures, several of which were under designed with respect to drift loads. A Canada wide survey of actual roof loads was then carried out to provide information for a more refined assessment of the relationship between ground and roof snow loads.

Based on the findings of this survey, the 1960 National Building Code introduced a basic snow load coefficient equal to 0.8 to convert ground snow loads to roof snow loads (ACNBC, 1965b). The specified roof snow load, S, was calculated as:

$$S = g * Cs \quad \{psf\} \qquad \text{equ.4.1(1)}$$

where : g = ground snow load {psf}
Cs = basic snow load coefficient

Ground snow depths were established using an extreme value method of analysis with a thirty year return period. Ground load values were then calculated by converting snow depths to load values and adjusting the loads to allow for absorbtion of the maximum one day rainfall that could be expected when ground snow depths were deepest. The conversion of snow depths to loads was carried out using an average specific gravity of snow of 0.192. Design was to proceed on the consideration of the worst case application of the design load across the roof surface. Two scenarios were defined for consideration : 1) full loading with the specified roof load across the roof and 2) full loading using the specified roof load on any one section of the roof and half the specified load on the remaining roof surface. The sections receiving each load were to be chosen so as to maximize load on the member being designed. This process of load assessment was referred to as 'full and partial' loading.

The 1965 National Building Code introduced several further refinements (ACNBC, 1965a; ACNBC, 1965b). While the basic snow load coefficient retained the value of 0.8, adjustments for roof exposure and shape were defined. Also, the step-wise reduction of roof load was converted to a linear function for slopes between 30° and 70°.

An exposed roof was vaguely defined as being fully open to wind on all sides, not having any projections that could prevent snow from being blown off, and not being located in a mountainous area subject to heavy snow loads and low winter wind speeds. If all three of these criteria were met, a 25% reduction in Cs was allowed, taking Cs from a value of 0.8 to 0.6.

Schematics of several simple roof shapes were introduced. These drawings showed values of Cs and calculations of Cs for flat and shed roofs, gable and hip roofs, simple arch and curved roofs, two multi-level roof situations and the roof area next to a projection. The schematics also introduced multiple design criteria, or cases, that each roof had to meet. The cases that had to be considered for any given building depended on roof shape, geometry, and proximity to higher objects.

The 1970 Code included no major changes from the 1965 Code, though several refinements to clarify application were introduced (ACNBC, 1970a; ACNBC, 1970b). Two refinements affecting roof snow load were a more precise definition of exposure to wind, and a change from full and partial loading to full and zero loading.

The first refinement consisted of expanding the definition of a fully exposed roof to include a certain minimum clearance on all sides. The minimum clearance distance was set equal to ten times the height difference between the roof and the nearest taller object.

The second refinement consisted of replacing the consideration of full loading on any one portion of the roof and half loading on the remainder with full loading on any one portion and no load on the remainder. This revision required structures be designed for much greater load imbalances and was referred to as 'full and zero' loading.

In the 1975 National Building Code, a minimum design load of 20 psf was introduced for roofs with slopes less than or equal to 30° (ACNBC, 1975a; ACNBC, 1975b). Prior to this introduction, no minimum load other than the calculated specified roof load had existed for any roof surface. The reference to exposure was further refined by the inclusion of a definition of a "significant" roof projection as one capable of causing drift accumulation. Such a projection was defined as having a height above the roof, in feet, greater than the magnitude of the ground snow load (psf) divided by 30. Also, the change in the 1970 Code from 'full and partial' loading to 'full and zero' loading was judged to be too conservative and the former clause was readopted.

Apart from these changes the only alteration in roof snow load specifications occurred on the schematic describing the basic load coefficient to be used in the design of gable and hip roofed structures. For these structures the unbalanced load case was introduced for design consideration at a lower roof slope. This change resulted in slightly higher design loads for structures with roof slopes between 15° and 20°.

The 1977 and 1980 Codes included new provisions for arched roofs and a number of rationalizations to aid understanding of snow loads on roofs (ACNBC, 1977; ACNBC, 1980). The 1977 Code liberalized wind exposure requirements slightly by increasing non-obstructing roof projection heights to a height (feet) equal to the magnitude of the ground snow load (psf) divided by 25. The 1980 Code maintained this basic relationship though some change resulted from the conversion to whole metric units from Imperial units used in the earlier Code.

Because the 1980 Code was produced using the metric system of units, several small changes in coefficient values resulted. For the most part the 1980 Code adopted earlier design constraints and provisions. Significant changes included the adoption of a new specific gravity for snow on roofs. Previously, roof snow was assumed to have the same density as ground snow (192 kg/m^3). However, in light of new data taken from across the country and the assumption that maximum roof load likely occurs just after a snowstorm deposits relatively light fresh snow on top of old dense snow, roof snow was assigned an average density of 240 kg/m^3 (ACNBC, 1980).

The minimum design roof load was increased by approximately five percent to 1 kPa for roof slopes less than or equal to 30°. The basic snow load coefficient remained essentially the same for all roofs other than arches, though the minimum width needed on a projection to cause drifting was increased and the worst case loading on valley areas was introduced at a lower slope. The design of arch roofs changed dramatically. Four design cases describing one fairly uniform loading and three unbalanced loadings replaced the two more simplistic loadings described in earlier codes. These new cases were thought to be more representative of actual snow accumulation, drifting, and sliding on simple arched roofs.

4.1.1 1985 CANADIAN SNOW CODES

The snow codes in current use for determining design snow loads are set out and described in the 1985 National Building Code and Supplement. In 1985, the Code was completely rewritten to clarify the effects of site, building shape, and roof type on the specified roof load. This involved replacing the single snow load coefficient used in all previous Codes with four new factors. These new factors individually represent ground-to-roof snow load conversion, wind effects, slope effects, and accumulation effects on a given roof. The specified snow load at a particular point on a roof is the product of these factors for that roof position and the ground snow load.

Four technical changes to the Code were also introduced in 1985. First, the minimum uniform roof load of 1 kPa used in the 1980 Code was changed to a minimum concentrated load of 1.3 kN, which applied regardless of roof slope. Second, based on an increased database of measurements, the density of roof snow reported in the 1980 Code was replaced by a new unit weight of 2.4 kN/m^3. Third, the consideration of full and partial loading was restricted to the design of flat, shed, gable and arch roofs for uniform loads only. Last, the determination of unbalanced snow loads on arches was simplified.

The 1985 approach to roof snow load determination isolates and individually determines five factors that affect roof loads, including ground snow load. Due to a lack of data, factor values are not based on rigorous statistical analysis. However, they are thought to result in acceptable and conservative designs (ACNBC, 1985b). The specified roof snow load, S, is expressed as a product of these factors.

$$S = So * Cb * Cw * Cs * Ca \quad \{kPa\} \qquad \text{equ. 4.1.1(1)}$$

where : So = ground snow load {kPa}
Cb = basic snow load factor
Cw = wind exposure factor
Cs = roof slope factor
Ca = accumulation factor

As in all previous Canadian National Building codes, the basis for determining roof snow loads is ground snow load. In the Supplement to the 1985 Code, design weather data are listed for over 600 locations across Canada (ACNBC, 1985b). The tabulated design ground snow loads are based on an extreme value analysis of measured snow depths using a thirty year return period. The resulting snow depths were converted to loads using a Canada wide mean specific gravity of 0.2 for the entire ground snow cover. These loads were then adjusted to account for load increases due to the absorbtion of the maximum one day rainfall at each site during the period of the winter when snow depths were greatest.

The second term in the specified snow load equation is the basic snow load factor, Cb. This factor converts ground snow loads to roof snow loads and has a value of 0.8. This factor equates to the basic roof load coefficient Cs found in earlier codes when no adjustment for site or roof slope was made.

The wind exposure term, Cw, can be used to reduce design roof snow load if the structure is situated in a well exposed site. According to the 1985 Code, a well exposed site is one that meets three specific criteria (ACNBC, 1985a; ACNBC, 1985b). The first criterion is that the building must be located such that no obstructions higher than the roof are within a specific minimum distance from the roof. The minimum distance equals ten times the height difference of the obstruction over the roof. Secondly, the height of any roof projection, in metres, must not be greater than one quarter the magnitude of the ground snow load, in kilopascals. Thirdly, the loading case under consideration must not involve accumulation of snow due to drifting from an adjacent or nearby surface (a nearby surface is later defined as being not more than 5 m away). If all three criteria are met, Cw is set to 0.75, otherwise Cw is set to 1.0.

The slope factor, Cs, performs the same function as slope adjustments did in earlier Codes. The slope factor accounts for the fact that less snow accumulates on steeper roofs. The value of Cs is reduced linearly from 1.0 at a roof slope of 30°, to zero at a roof slope of 70°. When a slippery roofing material is used and snow sliding is unimpeded, the Code allows for the reduction of Cs starting at a 15° roof slope. However, the commentary cautions against the use of this earlier level of factor reduction due to a lack of substantiating research data.

The last term in the specified snow load equation is the accumulation factor, Ca. This factor adjusts the design load on the basis of the shape of the roof and the roof's proximity to other elevated surfaces that could potentially serve as a source of additional load due to drifting and/or sliding of snow.

Roof shape affects distribution and magnitude of snow drifting, creep, and slide. Much attention and research has recently been aimed at understanding and quantifying these effects on roof load. Drifting is caused when wind hits an obstruction. This results in regions of accelerated and retarded air flow around the object. Snow can be scoured from a windward slope, transported, and deposited on a leeward slope (O'Rourke et al., 1985). This action can cause large unbalanced loads on gable and arch roofs, triangular drift loads on lower roofs and triangular drift loads next to projections. There is also the potential for drift accumulations to occur in valley trough areas due to snow being carried from the upper slopes and deposited in the roof depressions.

The difficulty in determining a suitable accumulation factor is compounded by creep and sliding of snow. Roofs composed of a series of gable or curved spans can experience snow creep from upper slope surfaces down into the valley trough areas. Therefore, the accumulation factor will vary with distance from the center of the valley trough.

A complete listing of the 1985 National Building Code snow load factor values for simple structures is given in Appendix A. This listing has been reproduced from the Supplement to the 1985 National Building Code with the permission of the National Research Council (ACNBC, 1985b). This listing includes equations to calculate factor values as a function of roof geometry as well as minimum and maximum values the factors can assume. These values were combined with the heuristic knowledge presented in the Code and Supplement to create the knowledge base used in the snow load expert system.

4.2 HISTORY AND EVOLUTION OF CANADIAN WIND CODES

The determination of design wind loads has also undergone significant change since the first edition of the National Building Code in 1943. Stathopoulos (1984) has documented the history and evolution of wind load testing and code specification for low rise structures. He points out that wind loads vary with both wind and building characteristics. Wind characteristics include wind direction, speed, velocity profile, and turbulence. Building characteristics include size, roof shape, roof slope, porosity, and the size and distribution of openings in the exterior surfaces of the structure. An understanding and awareness of these influences on wind loading has not always been present and is still incomplete. Consequently, the incorporation of the effects of these wind and building characteristics into building standards for wind design has been a gradual process.

No simple relationship has been found to relate wind velocity pressure with the actual pressure experienced by a surface (Stathopoulos, 1984; ACNBC, 1985b). Therefore, wind load codes and standards are based on empirical pressure coefficients derived from wind tunnel tests. These empirical constants equate measured wind velocity pressures to actual surface pressures recorded on scale models. Much of the research data used to establish these constants were obtained before the importance of accurately simulating atmospheric boundary layer air flow was appreciated (Holmes, 1988; Stathopoulos, 1984; ACNBC, 1985b). Testing was performed using uniform steady flow air profiles. The resulting empirical constants tended to be conservative (Holmes, 1988; Stathopoulos, 1984). Also, their use is limited to buildings which share site and geometry features present in the model tests (ACNBC, 1985b). These features include such items as the orientation of the building in the air flow, roof slope, and ratio of building length to height to width.

National Building Codes released in Canada prior to 1960 combined these flawed empirical pressure coefficients with wind velocity pressures and a height factor to produce design loads on simple structures. In the 1961 Supplement to the National Building Code a new set of pressure coefficients was introduced to replace values used in the earlier codes (ACNBC, 1965b). The new values were adopted from standards put forward by the Swiss Association of Engineers and Architects in 1956. The Swiss standards included provisions for wind direction and variable building size ratios. They were also based on a more thorough examination of internal pressures than any other code (ACNBC, 1965b; Stathopoulos 1984). The new pressure coefficients for gable structures differed substantially from the values in the 1953 Canadian Code, but were in better agreement with test results of the time and the values found in the American Standards Association Code (ACNBC, 1965b).

The 1965 National Building Code and Supplement were based on the previous

Code but included corrections and rearrangements, and introduced additional pressure coefficient tables (ACNBC,1965a; ACNBC, 1965b). The new tables provided pressure coefficients for a variety of gable structures with typical size ratios and roof slopes between 0° and 60°. New provisions for flat topped high-rise structures were also included.

Wind loads for a given structure were calculated as the difference between internal and external pressures on the building's surfaces. The following force equation was used in these calculations:

$$F = q * Ch * Cp * A \qquad \{lb\} \qquad \text{equ 4.2(1)}$$

where : q = basic design pressure {psf}
Ch = height factor
Cp = pressure coefficient
A = surface area $\{ft^2\}$

The design pressure, q, represented the velocity pressure of the wind due to the kinetic energy of the moving air. It was calculated using wind speeds having a thirty year return period (ACNBC, 1965b).

The height factor, Ch, took into account the fact that wind velocity increases with height above ground. The Code assumed that wind velocity varied as the 1/10 power of height and wind gust pressure varied as the 1/5 power of height. The reference height used depended on the structure being analyzed but was generally equal to either the eave height or the mid-height of the roof.

The pressure coefficient, Cp, to be used in design wind load determination was essentially a shape factor related to building geometry. Shape factors were based on wind tunnel test data and represented mean peak pressures that had been averaged both spatially over the surface and over time. Some pressure coefficient figures included localized maximum and minimum values to be considered in the design of connections and anchorages. These local values were not to be considered in the determination of net wind pressures on the building (ACNBC, 1965b).

A more detailed approach to wind load determination was introduced in the 1970 National Building Code and Supplement (ACNBC, 1970a; ACNBC, 1970b). Three approaches to wind load determination were specified. The first was referred to as the "Simple procedure". This approach was similar to the method set forward in the 1960 and 1965 Codes and gave similar results. It was intended for the majority of buildings for which wind loading did not have a major effect on structural design (ACNBC, 1970b). Since low rise structures are not susceptible to the dynamic effects of wind, their analysis fell under this approach (Mehta, 1984; Stathopoulos, 1984). Because this thesis considers only this type of structure, only the simple approach will be discussed in detail.

The remaining two approaches consisted of an experimental approach and a "detailed procedure". The experimental approach consisted of special wind tunnel testing and was suggested only for those structures in unusual sites, having nontypical geometries, or when cost and safety warranted the expense of testing. The detailed procedure was offered as an intermediate analysis method for structures that fell between the guidelines set forward for the other two analysis methods. It consisted of a series of calculations involving building, wind, and site properties to establish static design pressures equivalent to actual surface pressures assumed to act on the building as a result of turbulent wind (ACNBC, 1970b).

The 1970 Code also introduced new pressure equations having factors whose values varied with the building component being designed. The value of the factors varied depending on whether the building as a whole was being examined or a secondary component, such as cladding, was being analyzed. The external design pressure equation for use in all analyses was :

$$p = q * Ce * Cg * Cp \qquad \{psf\} \qquad \text{equ 4.2(2)}$$

where : q = reference wind velocity pressure {psf}
Ce = exposure factor
Cg = gust factor
Cp = external pressure coefficient or shape factor

The reference velocity pressure used was a function of wind velocity. The return period used depended on the type of design being considered. Cladding and other secondary members were analyzed with reference to wind velocities having a 10 year return period. Whole buildings were analyzed with reference to a 30 year return period of wind speeds. Buildings being designed for post-disaster service required a wind speed return period of 100 years. By making reference to different return periods, a variable safety factor was introduced into design.

The exposure factor, Ce, used in the simple procedure was identical to the height factor used in earlier editions of the Code. Ce was based on a 1/10 power law relating wind gust velocity to surface height in open terrain (ACNBC, 1970b).

The gust factor, Cg, introduced for use with the simple procedure, had a value of 2 for design of the building as a whole, and a value of 2.5 for secondary members and cladding. The gust factor accounted for the fact that smaller surfaces experience greater average gust pressures than larger areas (Stathopoulos, 1984; ACNBC, 1970b). However, when gust factors were combined with the newly introduced reference velocity pressures, the smaller members and the building as a whole were often designed for approximately the same design pressures (ACNBC, 1970b).

The pressure coefficient used in equation 4.2(2) also depended on whether the whole structure, or a component member, was being examined. If the whole building was being considered, Cp was set to the value of the algebraic difference between windward and leeward surface external pressure coefficients given in Figure C1-6 of the Supplement to the National Building Code (ACNBC, 1970a). If a component was being considered, Cp was set to the external pressure coefficient given in Figure C1-6 based on the component's location on the building. A second equation was then used to determine internal pressure acting on the inner surface of the component. By considering both external and internal pressures, a net load on the component was established.

The equation used to calculate internal design pressure depended on the porosity of the building and the location of openings with respect to wind direction. If no large openings existed, external wind gust effects were assumed to have negligible affect on internal pressure. In such cases, internal design pressure, Pi, was calculated as :

$$Pi = q * Ce * Cpi \quad \{psf\} \qquad \text{equ 4.2(3)}$$

where : q = reference wind velocity pressure {psf}
Ce = exposure factor
Cpi = internal pressure coefficient

However, if large openings existed, wind gusts would be transmitted to the internal air space, and the equation for design internal pressure became :

$$Pi = q * Ce * Cg * Cpi \quad \{psf\} \qquad \text{equ 4.2(4)}$$

where : Cg = gust factor

The pressure coefficients to be used with equations 4.2(2) through 4.2(4) for low rise gable structures were presented in two new figures in the Supplement (Figure C1-6 and C1-8). Many of the figures used in earlier codes, based on uniform flow testing, were also included in the Supplement. These were to provide reference only and were not meant as a source of definitive design information.

One final noteworthy addition to the 1970 National Building Code was the new requirement of "full and partial" load distribution. This clause required structures to be designed to carry two distributions of the calculated design loads. The first distribution was the full design load over the entire surface. The second required a surface to carry 75% of the full design load on any one portion of the area and no load on the remaining surface area. No minimum design load was set forward other than the load value determined from the pressure equations.

The next two editions of the Code and Supplement were released in 1975 and 1977 (ACNBC, 1975a; ACNBC, 1975b; ACNBC, 1977). Both retained all of the clauses and equations set forward in the 1970 Code for low rise gable structures except that the definition of 'full and partial loading' was changed. The new Codes still required the consideration of the full loading case. However, the partial loading case was redefined to mean the consideration of 75% of the design load over any portion of the surface and full loading over the remainder (ACNBC, 1975a; ACNBC, 1977).

As noted earlier, the 1980 edition of the National Building Code and Supplement introduced the metric measurement system (ACNBC, 1980a; ACNBC, 1985b). In addition to this change, many revisions and additions were included in the simple procedure approach for low rise gable structures. These changes highlighted the growing appreciation of the importance of localized regions of high pressure and suction acting on building surfaces. These regions occur at building corners, roof eaves, gable roof edges and along ridges. Research has since shown that much of the wind damage reported originates at these points (Mehta, 1984; Robertson, 1988; Sparks et al., 1988).

The 1980 Code incorporated four new external pressure coefficient figures to replace the single figure used in the prior three editions of the Code. These new figures gave combined gust factor and pressure coefficient values, CpCg, for external pressure calculations based on the component being designed, roof slope, wind direction, and the tributary area over which the pressure acted.

The first new figure in the 1980 National Building Code, Figure B-6, listed combined values to be used on all the external surfaces during design of primary (load bearing) structural members (ACNBC, 1980). Both edge values and average values were given. Up to three design cases were specified for a gable structure, based on wind direction and roof slope. Any design was required to meet all the loading cases applicable to it.

The second new figure in the 1980 National Building Code, Figure B-7, gave

CpCg values for wall surfaces. These values were to be considered when designing secondary structural members (non-load bearing) and cladding. Maximum and minimum edge values were given, along with average values for central wall regions. Coefficient values decreased in magnitude as tributary area increased.

New figures B-8 and B-9 gave CpCg values for roof surfaces in the design of secondary members and cladding. Figure B-8 applied to roofs with slopes which did not exceed 10°. Figure B-9 applied to roofs with slopes between 10° and 45°. Both figures defined areas of extreme pressure values along eave and gable edges of the roof. Figure B-9 also defined extreme pressure regions along the roof ridge. CpCg values decreased as the size of the tributary area increased and as roof angle increased. These relationships have been reported , substantiated, and discussed in several recent publications (Blackmore, 1988; Holmes, 1988; Robertson, 1988; Stathopoulos, 1984).

Net surface pressures were calculated as the algebraic difference between external and internal pressures. Internal pressures were calculated for both primary and secondary structural component design using Figure B-11 (ACNBC, 1980). Figure B-11 was used to determine internal pressure coefficient values, Cpi, for use in equations 4.2(3) and 4.2(4). This figure was adopted from earlier codes and modified only to the extent that local extreme values along roof/wall edges were reduced slightly. These internal local pressure values were intended only for the design of anchorages and were not to be used to calculate total surface uplift.

4.2.1 1985 CANADIAN WIND CODE

The 1985 National Building Code and Supplement were the principle sources of

&design expertise used in the development of the wind load expert system program (ACNBC, 1985a; ACNBC,1985b). The 1985 Code uses the same procedures, equations and factor values to determine wind loads on low rise gable structures as were set forward in the 1980 Code. A complete listing of the factors used in the 1985 Code is given in Appendix C. The only 1985 addition was a more detailed explanation of internal pressure calculations.

Past editions of the National Building Code underemphasized the importance of internal pressure. Recent research shows that internal pressure can have a significant influence on building performance. This pressure varies with interior layout, wind direction, and the presence and distribution of openings in the exterior walls (Sparks et al., 1988; Stathopoulos, 1984). Stathopoulos (1984) states that internal pressures generally do not vary spatially within the building except near dominant openings. Internal pressure acts perpendicularly to surfaces, causing either an outward force (+), or an inward suction (-). Since this sign convention is opposite to that used in describing external pressures, net pressures are calculated as the algebraic difference between external and internal pressures acting on a surface.

To clarify the use of the internal pressure coefficient values presented in Figure B-11 of the 1985 Supplement, structures have been grouped into three categories based on building type and the distribution of external openings (ACNBC, 1985b). The first category is for structures having a large dominant opening. This group includes shed structures having an open side, buildings with shipping doors, and structures with large glass panels that could inadvertently break, thereby forming a large opening. Structures in this category are designed for the full range of possible internal pressure values listed in Figure B-11 (Cpi = -0.7 to Cpi = 0.7). They must also be designed for wind gust effects. Therefore, equation 4.2(4) is used for internal pressure calculations with a suggested gust factor value of 2 (ACNBC, 1985b).

The second category is for buildings with small openings that are non-uniformly distributed in the exterior surfaces of the structure. Most low rise buildings fall into this category (ACNBC, 1985b). These buildings tend to be fairly uniformly sealed but have doors and windows that allow for uneven air leakage. These structures are designed for the full range of pressure values given in Figure B-11 but do not require the consideration of gust effects. Therefore, equation 4.2(3) is used to determine internal pressure.

The last category is for structures having small, uniformly distributed openings only. These buildings are typically well sealed and therefore not subject to gust effects or imbalances in air leakage. Sealed, mechanically ventilated highrises, and lowrise structures without windows and having storm proof doors fall into this group. They are designed according to internal pressure equation 4.2(3) and are assigned an internal pressure coefficient of -0.3. However, if this internal coefficient value leads to a zero net load on the structure, an internal pressure coefficient value of 0 is used instead.

5. ENVIRONMENTAL PROGRAMS

To evaluate an artificial intelligence approach to structural design, two expert system programs were created using the shell PCPLUS. The first program determines roof snow load on structures having simple roof shapes according to provisions set forward in the 1985 National Building Code and Supplement (ACNBC,1985a; ACNBC, 1985b). The second program determines windloads on a gable shaped building according to the same Code and Supplement. Both programs have been developed to the stage of advanced prototypes.

5.1 HARDWARE AND SOFTWARE REQUIREMENTS

Both expert system programs were developed on a UNiSYS 800 work station having a hard drive speed of 28ms, EGA graphics, 72 MB of RAM, and 4.9 MB extended RAM memory. During execution, both expert system programs actively link with the software program dBASE3+ and a database file of weather data. The database file and software program are stored on the computer hard drive. The wind load program also accesses a small program written in GWBASIC which is stored in the computer. The GWBASIC program performs mathematical operations that cannot be handled in the shell environment. Both programs make extensive use of drawings created in AutoCAD10. These drawings appear throughout consultations with either program. In addition, both programs are extremely interactive with the user.

5.2 SNOW LOAD EXPERT SYSTEM PROGRAM

The primary goal of the snow load expert system program is to determine design snow loads across a user defined roof surface in accordance with the provisions and design requirements set forward in the 1985 National Building Code (ACNBC, 1985a).

Program use is limited to the simple structures presented in the Code, excluding any form of curved or arched roof. No special allowance is made in the prototype program for intended use or occupancy level of the user's structure.

The knowledge base of the snow load program consists of approximately 300 rules and 160 parameters. Each rule is considered a backward chaining rule unless a special ANTECEDENT tag has been placed on it, in which case the rule is valid for forward chaining only. Parameters have a variety of properties. Each parameter having a user prompt also has a HELP message attached to it. Therefore, every time the user is asked a question there is an explanatory message available should it be required.

5.2.1 STRUCTURE OF THE SNOW LOAD PROGRAM

The structure of the snow load program reflects the form of the specified snow load equation given in sentence 4.1.7.1.(1) of the 1985 National Building Code of Canada (ACNBC, 1985a). The equation is reproduced herein as equation 4.1.1(1). It states that roof load is a product of five factors, including ground snow load. Four of these factors - ground snow load So, wind exposure factor Cw, roof slope factor Cs, and accumulation factor Ca - vary with building site and shape. The fifth factor, the basic roof load factor Cb, has been set to a value of 0.8 and cannot assume any other value.

The solution of the primary goal is therefore broken into a series of subproblems. Each subproblem requires the solution of one of the variable factors in the snow load equation. Once these subgoals have been established, the design roof snow load, S, can be calculated. This solution method defines the basic tasks required in snow load determination. These tasks are shown in the skeletal outline of the snow load program in

Figure 5.2.1(1).

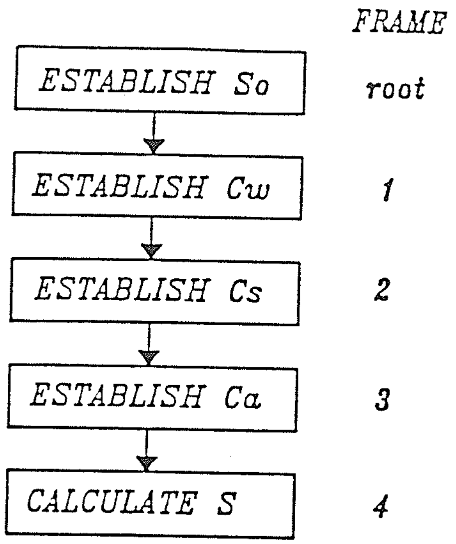


FIGURE 5.2.1(1) : SKELETAL STRUCTURE OF SNOW LOAD PROGRAM

Each of the tasks outlined in Figure 5.2.1(1) is embodied in a separate frame in the snow load program. Each frame goal must be successfully quantified before the program proceeds to the next frame.

The first frame establishes the ground load factor. This goal can be determined without any knowledge of the geometry of the user's building. The ground load frame therefore serves as the root frame for the program. The following four steps assign factor values and calculate roof load based on roof shape and geometry. This requires a branching of the program after the root frame to form paths that reflect the user's choice of structure. A more complicated program structure is therefore required, such as is shown in Figure 5.2.1(2).

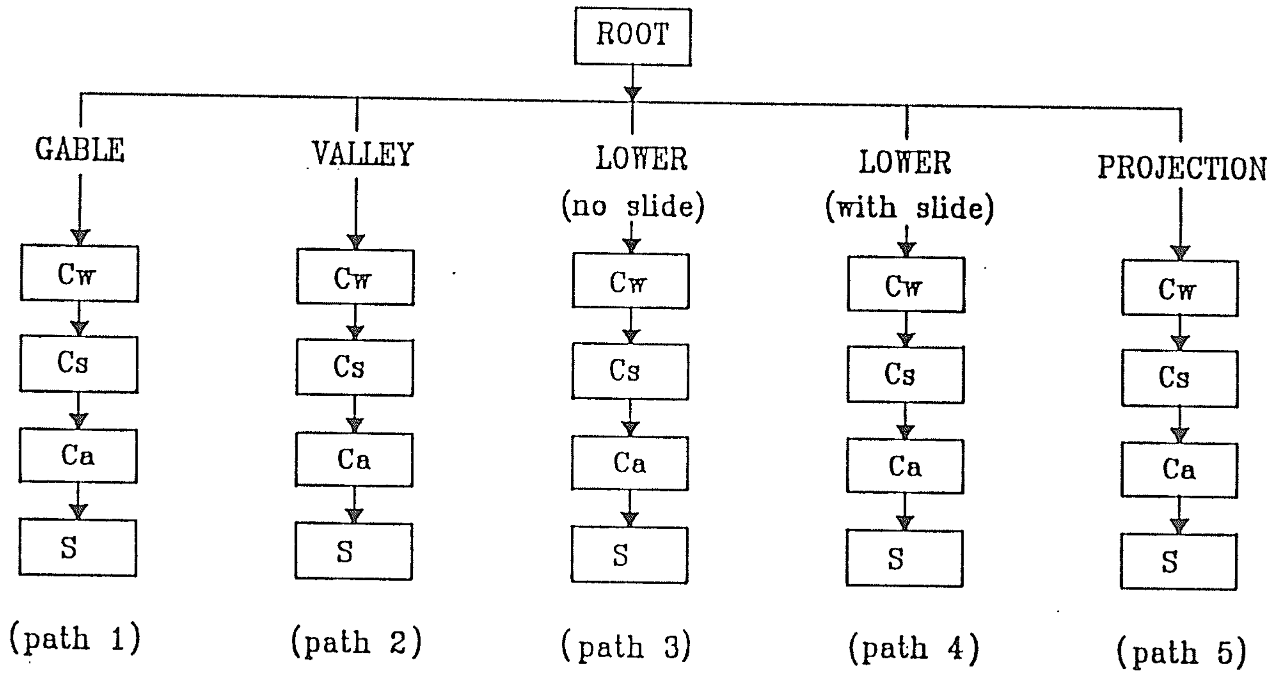


FIGURE 5.2.1(2) : CONCEPTUAL STRUCTURE OF SNOW LOAD PROGRAM

In Figure 5.2.1(2), five basic program paths are shown. The first path is taken if the user wishes to examine a flat, shed, or gable roofed structure. Path two is followed if a valley roof is to be analyzed. A valley roof occurs when two sloped plane roof surfaces meet at their eaves. An example of this occurs in greenhouses that consist of several spans of gable roofs joined at their eaves. Path three is followed when a lower roof in a multilevel roof system is indicated. This path applies only to lower roofs that do not experience additional loads due to the sliding of snow from the upper roof. Path four considers a lower roof in a multilevel roof system that does experience an extra load due to sliding snow. The fifth path is traced when the area next to a roof projection is examined.

The structure of the snow load program is very similar to the outline shown in Figure 5.2.1(2), however three revisions were required. First, a frame was added to the top of each program path for gathering geometric information about the building that would be needed in the remainder of the path. Secondly, a final summary frame was appended to each path. The summary frames communicate the consultation results to the user. Lastly, path 4 - used to determine load on a lower roof that experiences a slide load - was found to duplicate large portions of knowledge found in the gable path (path 1), and the simpler lower roof path (path 3). By passing through each of these other two paths prior to entering path 4, all the information necessary for calculating path 4 results could be obtained. Therefore, path 4 was reduced to a calculation frame and a summary frame. Logic was added to the root frame to insure proper program flow should this type of roof structure be selected for analysis. The final program structure in shown in Figure 5.2.1(3).

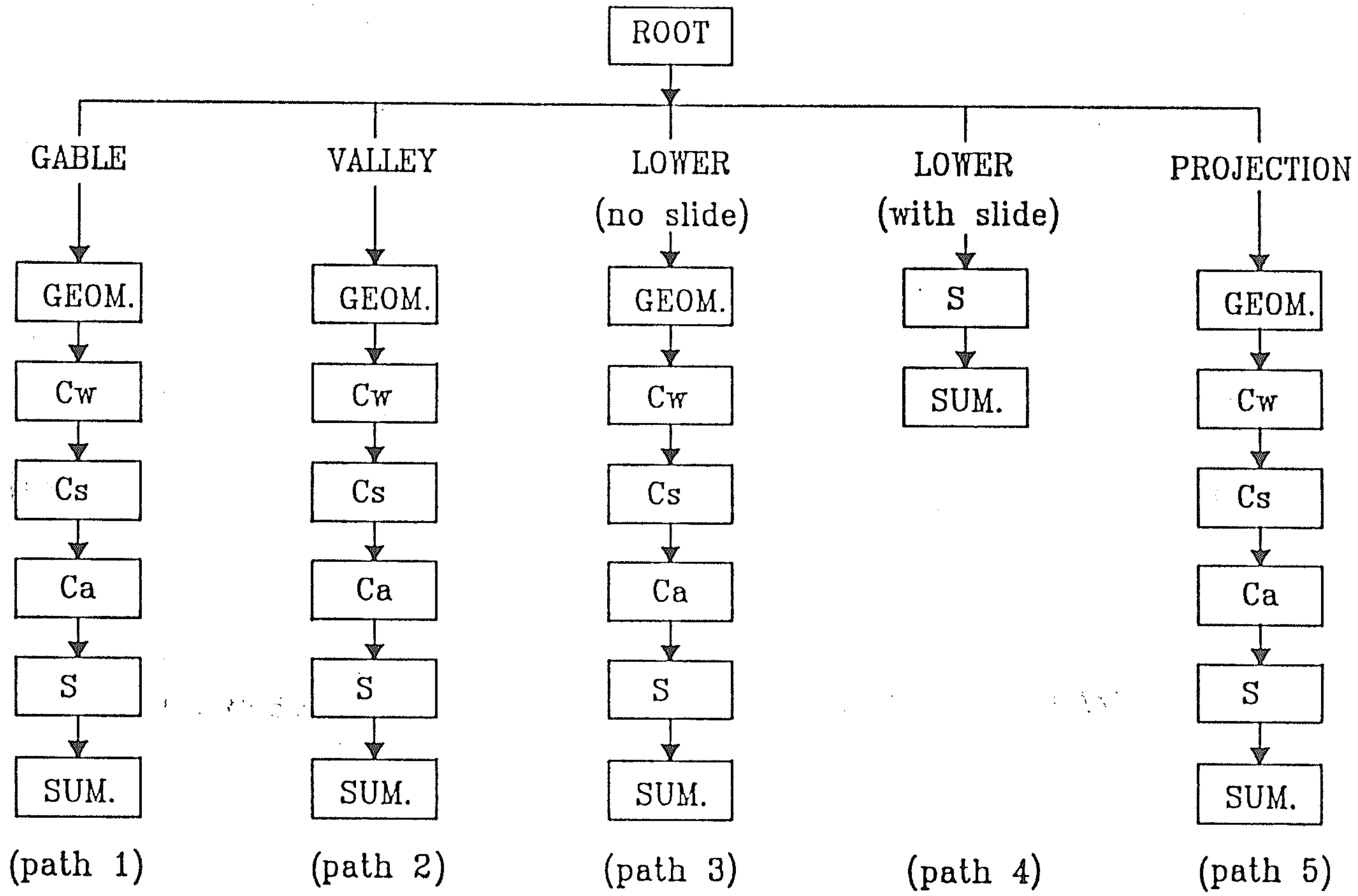


FIGURE 5.2.1(3) : FINAL STRUCTURE OF SNOW LOAD PROGRAM

5.2.2 DISCUSSION OF PROGRAM PATHS

Based on the type of structure the user wishes to investigate, one of the five paths shown in Figure 5.2.1(3) will be traced through the snow load expert system program. Each path begins in the frame *ROOT*. (This lettering convention will be used throughout the following text to indicate frame names. Parameter names are indicated by bold, capitalized script - ie **PARAMETER**). The *ROOT* frame has both a rule group and a parameter group associated with it. While a few of these parameters and rules are used specifically in the search for *ROOT* frame goal values, most are present to supply information to child frames and give logic flow guidance.

The *ROOT* frame has two goal parameters. Values must be established for both goals in the order in which they are listed before the program can pass to any other frame. The first goal to be determined is the ground snow load value. This value is stored in the goal parameter **GRND-SNOW**. The second goal value to be determined is the type of structure to be analyzed in the consultation. This value is stored in the goal parameter **ROOF-TYPE**. The program path followed will depend on the value of **ROOF-TYPE**.

To establish the **GRND-SNOW** value, two initial data parameters were introduced. The first is the province the user wishes to build in (**PROVINCE**), and the second is the exact site within the province (**LOCAL**). Both parameter values are set by supplying the user with a list of alternatives from which s/he must select an answer. These answer lists are stored as either declarative or procedural statements in the parameter's EXPECT property. The **PROVINCE** expect list is declarative since it contains an answer list which is shown to the user. The list includes the abbreviated names of all ten provinces and two territories in Canada. Once the **PROVINCE** value has been selected by the user, the program attempts to establish the **LOCAL** value.

The expect property of **LOCAL** is a procedural statement. This statement tells the program how to arrive at a list of acceptable answers to be presented to the user who will choose from them. In this case, the statement directs PCPLUS to activate dBASE3+ (which is stored on the computer's hard drive), and search a specific weather database file for the names of weather station sites listed in the user's chosen province. Information for the database file was extracted from tables of climatic information given in the Supplement to the 1985 National Building Code (ACNBC, 1985b). The list of sites is presented to the user. The user may either select a listed site or indicate that the intended building site is "Not listed". If a specific site is chosen, the premise clause in rule 1 turns true causing the rule to instantiate. This in turn results in the database file being re-entered. **GRND-SNOW** is assigned the ground snow load value listed in the database file for the user's province and site. The translation of rule 1 from PCPLUS's 'Abbreviated Rule Language' form to english is :

RULE 1

IF : 1) **PROVINCE** is known, and
2) **LOCAL** is known, and
3) **LOCAL** is not equal to "Not listed"

THEN : **GRND-SNOW** equals the ground snow load listed for **PROVINCE** and **LOCAL** in the weather database file.

If the user indicates that his/her site is "Not listed", rule one is deemed false and is abandoned. Three other rules that establish **GRND-SNOW** remain in the rulegroup. Each requires more information from the user before it can be considered either true or false.

To test the remaining **GRND-SNOW** rules, the user is asked to select one or two names from the **LOCAL** list that are close to his/her intended building site. The user is then presented with the ground snow load value(s) for the near-by site(s) and asked to chose one of the values or input his/her own. The rule that is eventually fired to set **GRND-SNOW** depends on whether the user examines one or two near-by sites and whether the user inputs his/her own snow data or selects one of the listed site values.

After establishing the **GRND-SNOW** goal, the program moves to the **ROOF-TYPE** goal. This goal is solved by a simple prompt to the user. A schematic of the five roof shapes that can be analyzed by the snow load program is presented to the user. The user indicates the type of roof to be analyzed by typing an integer between 1 and 5. The number entered corresponds to the path number labels shown in Figure 5.2.1(3). Antecedent (forward chaining) rules are used to move the consultation from the root frame to the geometry frame on the appropriate path.

5.2.2.1 PATH 1

Path 1 is taken when the user indicates that the structures to be examined has a flat, shed, or gable shaped roof. Path one is also entered to gather initial data for certain multilevel roof analyses. This second use of path 1 is discussed in more detail in Section 5.2.2.4.

Path 1 serves as the basic model of the program. The order of establishing factual information and the logic used to deduce relationships between facts used in path 1 are mimicked in each of the other paths. The flowchart in Figure 5.2.1(3) indicates that there are 6 frames to be worked through in path 1. The first is used to establish geometric information about the building. The next three use this information along with knowledge extracted from the National Building Code to set snow load coefficient values. The fifth frame calculates the specified snow load value to be used for the roof design. The last frame communicates the results of the consultation to the user. Each frame has a rulegroup associated with it, and some have a parameter group. A separate parameter group for each frame is not required due to inheritance between frames.

The first frame in path 1 is called *GABLE-GEOM*. This frame has both a rulegroup and a parameter group associated with it. The parameter group includes all the parameters needed for the logic in the rest of the path, excluding those already included in the *ROOT* frame parameter group.

GABLE-GEOM has four goal parameters : **GSHAPE, SLOPE, G-ANGLE** and **CASE2. GSHAPE** is used to store the user's choice of roof shape. The user is asked to select either a shed or gable roof style. If the user wishes to analyze a flat roofed structure, either shape may be selected and a roof slope of 0° is later indicated.

The **SLOPE** parameter stores information about the method of roof angle entry. The user is asked whether s/he wishes to enter roof slope in degrees or as a ratio of roof rise to roof run. If the degree method is selected, the user can enter roof angles from 0° to 90°. If the ratio method is chosen, roof slopes are restricted to ratios of 3:12, 4:12 and 5:12. The ratio to be used is selected from an expect list. The list is limited to these ratios since they are the ones most commonly used in light frame buildings (Britton, 1989b).

The third goal is **G-ANGLE**. The user is shown a schematic of the roof and asked to specify the angle of the roof. Gable structures are assumed to be balanced. The prompt used depends on the value of **SLOPE**. User answers given in degrees are stored directly into **G-ANGLE**. User answers entered as ratios are converted to degree form then stored in **G-ANGLE**. This conversion is necessary since the National Building Code calculates roof coefficient values based on roof angle in degrees.

The last goal parameter, **CASE2**, is used to indicate the number of loading cases that apply to the user defined structure. **CASE2** is a logic or truth parameter and can only assume values of true or false (yes or no). According to the National Building Code, all flat, shed, and gable roofs must be designed for a uniform snow load. This type of loading is referred to as 'case 1 loading'. Certain gable structures must also be designed for an unbalanced load due to snow drifting and sliding. This type of loading is referred to as 'case two loading'. If the user's structure has a gable roof with roof angle greater than 15° and less than or equal to 70°, the second loading case must be considered. Therefore, **CASE2** is set to 'True'. If the user has selected either a shed or gable structure, with roof angles less than or equal to 15°, **CASE2** is set to 'False'. The same occurs if roof angle is greater than 70°. When more than one loading case must be considered, a full set of roof snow load coefficients for each case must be established.

After establishing the value of the last goal in frame *GABLE-GEOM*, the program proceeds to the next frame on path one, *G-WIND*. The objective of this frame is to determine wind exposure factors for each of the possible loading cases. The goal parameters are therefore called **C-WIND1** and **C-WIND2**. If **CASE2** is false, **C-WIND2** is set to zero. If **CASE2** is true, **C-WIND2** is set to one. The value of **C-WIND1** depends on whether the roof structure is exposed. To meet the exposure criteria, a roof must be exposed to wind from all directions, not have any significant projections, and not be subject to drift loading. Since the second loading inherently implies drifting, no reduction for wind is allowed for case two loading. To determine whether a wind reduction is allowable for the uniform load case, the user is asked a series of questions concerning building site and roof projections. Heuristic rules interpret the user's information and determine whether the roof is exposed. If the reduction in roof load is warranted, **C-WIND1** is set to 0.75. If the exposure criteria are not met, **C-WIND1** is set to one.

The program then proceeds to the *G-SLOPE* frame. The objective of this frame is to establish slope factors for each of the possible loading cases. There are three goal parameters in *G-SLOPE* : **SLIPPERY**, **C-SLOPE1**, and **C-SLOPE2**. According to the National Building Code, the design roof snow load can be linearly reduced as a function of roof slope. The exact angle at which reductions can be made depends on whether the roofing material used on the building is slippery or not. The user is therefore asked to select a roofing material for use on his/her structure from a list of commonly used materials. Based on his/her selection, the goal **SLIPPERY** is set to either true or false. For example, if the user indicates that the roof is glass, **SLIPPERY** is set to true. If the user selects asphalt shingles as the roofing material, **SLIPPERY** is set to false.

The values of **C-SLOPE1** and **C-SLOPE2** are then determined according to the equations listed in Table 5.2.2.1(1). After the value of **C-SLOPE2** has been established, the program moves to the accumulation coefficient determination frame, *G-ACCUM*.

TABLE 5.2.2.1(1) : SLOPE COEFFICIENT EQUATIONS

DESIGN CASE	ROOF ANGLE (a°)	SLOPE COEFFICIENT, Cs not slippery	 slippery
1	a <= 15	1	1
	15 < a <= 30	1	1- (a-30) / 40
	30 < a <= 70	1- (a-15) /55	1- (a-30) / 40
	70 < a	0	0
2	a <= 30	1	1
	30 < a <= 70	1- (a-15) /55	1 - (a-30) / 40
	70 < a	0	0

There are two goal parameters in *G-ACCUM* : **C-ACCUM1** and **C-ACCUM2**. In case one loading there are no accumulation effects due to drifting and sliding so **C-ACCUM1** is set to one. If case two loading is not required, **C-ACCUM2** is set to zero. However, if the user's structure must be designed for the unbalanced loading case, an increase in specified roof load due to drifting must be considered. The amount of increase is a function of roof slope. **C-ACCUM2** is set to 1.0 for slopes less than or equal to 15°. As roofs become steeper they create a greater obstacle to wind. Wind can scour snow from the windward roof surface and deposit it on the leeward surface, thereby forming drifts on the leeward surface. The specified roof load must be increased to account for this extra drift load. This is done by linearly increasing **C-ACCUM2** from a value of 1.0 at roof slopes of 15° to a value of 1.25 for roof slopes of 20°. The drifting effect is thought to reach its maximum at a roof angle of 20° so no further increase in **C-ACCUM** is considered for steeper slopes.

Once the accumulation goal parameters have been set, all the data needed to calculate specified roof snow load for the user's structure are known. The program moves to frame ***G-GOAL*** and calculates values for goals **SNOW1** and **SNOW2**. These goal values are determined as follows :

SNOW1 = GRND-SNOW * Cb * C-WIND1 * C-SLOPE1 * C-ACCUM1
equ. 5.2.2.1(1)

if **CASE2** = **TRUE** :
SNOW2 = GRND-SNOW * Cb * C-WIND1 * C-SLOPE1 * C-ACCUM2
equ. 5.2.2.1(2)

if **CASE2** = **FALSE** :
SNOW2 = 0
equ. 5.2.2.1(3)

Having established the specified roof snow load values, the last frame in path one is entered. This frame conveys the results of the consultation to the user. In order to fire the rules needed to format and display information screens to the user, a dummy goal parameter, **DIM-TYPE**, is used. The frame's rule group is composed of both backward and forward chaining rules. The backward chaining rules are used to format screens that summarize the user's inputs from the consultation. When one of these rule is fired, the user is shown an appropriate input summary list. The consequence clause of the fired rule sets **DIM-TYPE** equal to **SLOPE**. Now only forward chaining rules can be used. For each combination of **SHAPE** and **DIM-TYPE** there is a forward chaining rule that will fire. When a forward chaining rule instantiates, the user is shown a schematic drawing of his/her structure and the loading cases that apply to it. The user is also presented with the specified snow load values and equations for each applicable loading case. Examples of the load schematic screens shown during the execution of this frame are presented in Appendix B.

Once the results screens are shown, the consultation is complete. The user may at this time chose to carry out another consultation, have the program explain some aspect of the logic used to arrive at the newly finished consultation, or quit.

The other program paths shown in Figure 5.2.1(3) deal with roof snow load calculation in a similar method to path one. However, the number and type of loading cases considered and the values of roof load coefficients are roof-type, and therefore path, dependent.

5.2.2.2 PATH TWO

If the user chooses to analyze a valley area between two sloped plane roof surfaces, the program proceeds from the root frame to path two. Path two has six frames to be worked through. They correspond directly to those used in path one. However, valley areas must be designed for up to three loading cases. The first case represents a uniform snow load. The second and third describe worst case load situations due to drifting and slope effects.

The first frame entered on path two is *VALLEY-GEOM*. This frame has eight goal parameters : **V-ANGLE1**, **V-ANGLE2**, **VB1**, **VB2**, **SLOPE**, **CASE1**, **CASE2**, and **CASE3**. The first question the user is asked is the method by which s/he wishes to enter roof slopes, The user's reply is stored in goal parameter **SLOPE**. This is the same parameter as was used in path one for this task. This is possible because **SLOPE** is associated with the root frame's parameter list and not a path frame. Therefore, **SLOPE** is available to all the child frames (ie. the rest of the program).

Next, the user is shown a schematic of a valley roof and asked to quantify roof slopes and runs for both roof surfaces forming the valley trough. This schematic is shown in Figure 5.2.2.2(1). The user prompts are worded according to the value stored in **SLOPE**. The left roof surface shown in Figure 5.2.2.2(1) is referred to as surface one. The angle and run of this surface are stored in goals **V-ANGLE1** and **VB1**, respectively. Similarly, **V-ANGLE2** and **VB2** store angle and run information for the second or right roof surface shown in Figure 5.2.2.2(1).

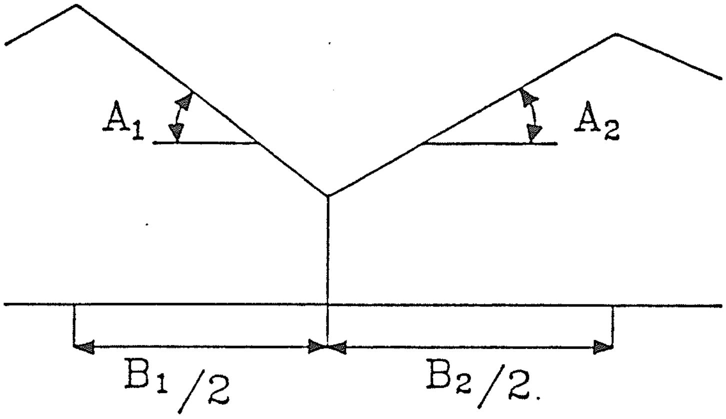


FIGURE 5.2.2.2(1) : VALLEY ROOF GEOMETRY

Since all valley roofs must be designed for the uniform load case, **CASE1** is set to true. If both **V-ANGLE1** and **V-ANGLE2** are less than 10°, design cases two and three need not be considered so **CASE2** and **CASE3** are set to false. However, if either angle is greater than 10°, the extra loading cases must be considered and both **CASE2** and **CASE3** are set to true.

Once all the goal values in frame 1 are determined, the program proceeds to the second frame in path 2, *V-WIND*. The objective of this frame is to establish wind coefficients for each of the possible loading cases. The coefficient values are stored in goal parameters **C-WIND1**, **C-WIND2**, and **C-WIND3**.

Only the uniform loading case is eligible for reductions due to wind (ACNBC, 1985b). The user is asked a series of questions concerning the building site and the presence of roof projections. Heuristic knowledge stored in the program is used to determine whether the roof meets the exposure criteria necessary for the reduction. If the criteria are met, **C-WIND1** is set to 0.75. If not, **C-WIND1** is set to 1.0.

If the second and third design load cases are being considered, (ie. **CASE2** and **CASE3** are true), **C-WIND2** and **C-WIND3** are each set to 1.0. If these cases are not being considered, **C-WIND2** and **C-WIND3** are set to zero.

The program then enters the frame *V-SLOPE*. This frame is used to establish slope reduction coefficients for each of the loading cases. According to the National Building Code, slope reductions are only allowed under uniform loading. Therefore, the goal parameters **C-SLOPE2** and **C-SLOPE3** are set to either 1.0 or 0, depending on whether these design cases are required or not.

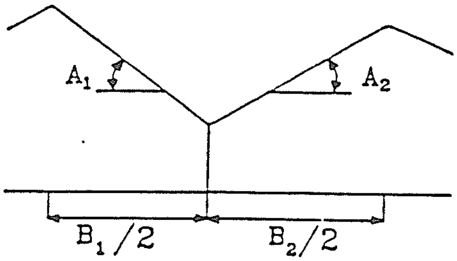
Since the slope reduction coefficient is a function of roof angle, the two roof surfaces forming the valley are assigned individual values. Unlike the gable roof considered in path 1, which was assumed to be balanced, the roof surfaces forming the valley can be assigned unique slope values. The slope coefficients for case one valley loading are stored in the goal parameters **C-LEFTSLOPE** and **C-RIGHTSLOPE**, where **C-LEFTSLOPE** corresponds to roof surface 1 in Figure 5.2.2.2(1).

The assignment of slope coefficients is also dependent on whether the roofing material is slippery or not. Therefore the user is asked to select the material to be used from a list of options. Based on the user's answer, the goal parameter **SLIPPERY** is set to either true or false. Slope coefficients for **C-LEFTSLOPE** and **C-RIGHTSLOPE** are assigned according to the equations given for case one loading in Table 5.2.2.1(1).

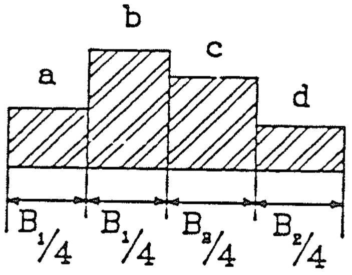
After establishing slope coefficients, the program proceeds to the fourth frame in path 2, ***V-ACCUM***, to determine accumulation coefficients. Accumulation coefficients account for reductions and increases in roof snow load due to drifting, slide, and creep of snow. Since uniform loading implies that there is no accumulation effect, goal parameters for accumulation coefficients associated with case one loading are set to 1.0.

However, **CASE2** and **CASE3** loading do take accumulation into account. Accumulation effects vary with horizontal distance from the valley trough. The National Building Code simulates accumulation effects on valley areas with step functions that divide each roof surface into two regions, each having its own coefficient value. The net effect of the assigned accumulation coefficient values are to specify valley roof loads, S, that are either 0.5, 1.0, or 1.5 times the ground snow load value, So, of the site. This is shown more clearly in Figure 5.2.2.2(2).

Accumulation coefficients for case two loading are stored in goal parameters **C-ACCUM2A**, **C-ACCUM2B**, **C-ACCUM2C**, and **C-ACCUM2D**. The last letter in each



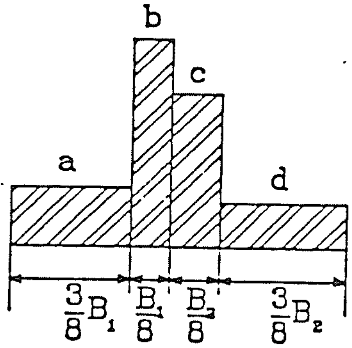
CASE 2



CASE 2

SECTION	Ca	S
a	0.625	0.5 So
b	1.25	So
c	1.25	So
d	0.625	0.5 So

CASE 3



CASE 3

SECTION	Ca	S
a	0.625	0.5 So
b	1.875	1.5 So
c	1.875	1.5 So
d	0.625	0.5 So

FIGURE 5.2.2.2(2) : ACCUMULATION COEFFICIENTS FOR CASE TWO AND CASE THREE LOADING ON VALLEY AREAS

goal name indicates the roof area the coefficient applies to. Similarly, case three accumulation coefficients are stored in goal parameters **C-ACCUM3A**, **C-ACCUM3B**, **C-ACCUM3C**, and **C-ACCUM3D.**

Once the accumulation goal parameters have been determined, all the information needed to calculate specified snow load values across the valley area for each design case are known. The load calculations are carried out in the fifth frame of path 2, *V-GOAL*. If **CASE2** and **CASE3** are true, roof snow loads for all three design cases are calculated for regions a,b,c, and d, according to the specified roof snow load equation 4.1.1.1(1). These calculations are summarized in Table 5.2.2.2(1). If **CASE2** and **CASE3** are false, only case 1 snow loads need be calculated. Case one loads would be calculated as shown in Table 5.2.2.2(1) while snow loads for case two and three would be set to zero.

TABLE 5.2.2.2(1) : SPECIFIED ROOF SNOW LOAD EQUATIONS FOR VALLEY ROOFS

DESIGN CASE	REGION	SPECIFIED ROOF SNOW LOAD, S (kPa)
1	a, b	So * Cb * C-WIND1 * C-EXPOSURE * C-LEFTSLOPE * C-ACCUM1A
	c, d	So * Cb * C-WIND1 * C-EXPOSURE * C-RIGHTSLOPE * C-ACCUM1C
2	a	So * Cb * C-WIND2 * C-EXPOSURE * C-SLOPE2 * C-ACCUM2A
	b	So * Cb * C-WIND2 * C-EXPOSURE * C-SLOPE2 * C-ACCUM2B
	c	So * Cb * C-WIND2 * C-EXPOSURE * C-SLOPE2 * C-ACCUM2C
	d	So * Cb * C-WIND2 * C-EXPOSURE * C-SLOPE2 * C-ACCUM2D
3	a	So * Cb * C-WIND3 * C-EXPOSURE * C-SLOPE3 * C-ACCUM3A
	b	So * Cb * C-WIND3 * C-EXPOSURE * C-SLOPE3 * C-ACCUM3B
	c	So * Cb * C-WIND3 * C-EXPOSURE * C-SLOPE3 * C-ACCUM3C
	d	So * Cb * C-WIND3 * C-EXPOSURE * C-SLOPE3 * C-ACCUM3D

The last frame in path 2, ***V-SUMMARY***, is used to format and display three types of screens to the user. These screens summarize the events and results of the consultation. The first screen shown to the user is a compilation of the information the user has supplied during the consultation. The second screen is a schematic of the valley roof. The schematic includes snow load distributions for each of the cases applicable to the user's structure. The last screen displays the calculated snow loads for each design case and each roof region along with the coefficient values used to arrive at the load values.

5.2.2.3 PATH 3

Path 3 is initiated whenever a user chooses to analyze a lower roof in a multilevel roof situation. The multilevel situations allowed for in the program consists of an upper roof which may be either flat, shed, or gable shaped, and a lower roof that is either flat or shed shaped. The lower roof is orientated such that it slopes away from the upper surface. The two roofs may be either adjoined or separated by a distance of up to 9 m. Within a 9 m distance of the upper roof, drift effects due to the roof will be felt. A lower roof situated more than 9 m from an upper roof feels no drift effect and can be analyzed as an independent structure (ie. path 1).

If the upper roof is flat or a shed that slopes away from the lower roof, snow will not be able to slide from the upper to lower roof surface. Therefore, the lower roof need only be designed for a uniform snow load and a snow load due to drifting. These are the loads determined in path 3.

If the upper roof has a surface which slopes down towards the lower roof, there is a possibility of snow sliding from the upper to lower roof. This causes an extra load on the lower roof. Since slide load is dependent on the uniform snow load on the upper roof, the program must travel path 1 to determine the magnitude of the slide load. Therefore, when slide loads need be considered, the program travels paths 3 and 1 prior to entering the first frame of path 4.

Path 3 is modelled after path 1. There are six frames in path 3 and each has a rule group associated with it. Only the first frame has a parameter group. With multilevel roofs, only one design case need be considered though the case may consist of several types of snow loads superimposed on the roof.

As in path 1, the first frame entered establishes geometric information about the roof structure. Goal parameters include the angle of both the lower and upper roof (**A1** and **A2** respectively), the run of both the lower and upper roof (**B1** and **B2**), and the height difference between the roofs (**H**). These dimensions are shown on Figure 5.2.2.3(1)

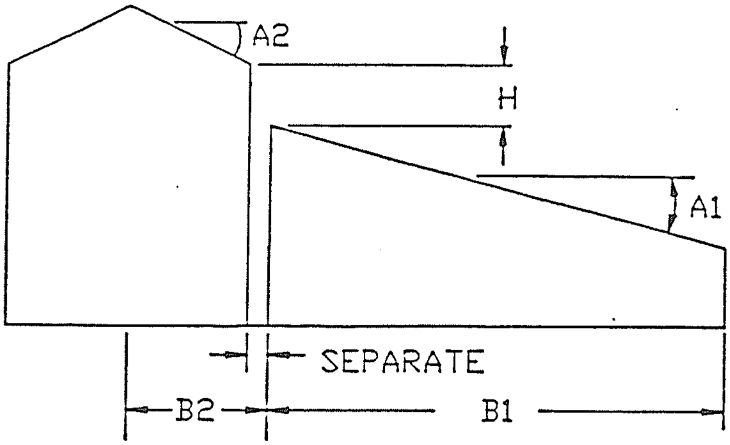


FIGURE 5.2.2.3(1) : MULTI-LEVEL ROOF GEOMETRY

For multilevel roof situations it is also necessary to establish critical benchmark distances measured from the upper roof edge that define regions of varying snow load and the position of the lower roof. The goal parameters that store benchmark distance information are : **PT-0**, **PT-XD**, **PT-10H**, **SEPARATE**, and **PT-B1**. These distances and the snow load regions are shown in Figure 5.2.2.3(2).

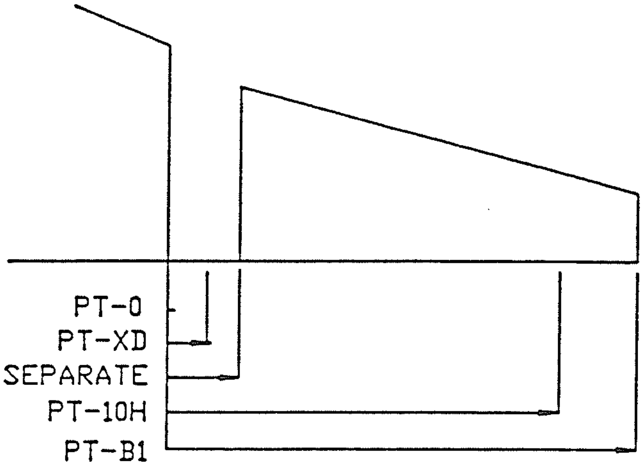


FIGURE 5.2.2.3(2) : BENCHMARK DISTANCES FOR MULTI-LEVEL ROOF

PT-0 represents the edge of the upper roof. The remaining benchmarks represent horizontal distances measured from this edge. Drift load is a maximum at **PT-0** and decreases linearly to a value of zero at **PT-XD**. Based on the Supplement to the National Building Code (ACNBC, 1985b), **PT-XD** is set to a value of **2*H**, with a minimum of 3 m, and a maximum of 9 m. **PT-XD** is the boundary between region 1 which experiences a drift load, and region 2 which has no drift load but does not qualify for wind exposure reductions. Region 2 is bounded on its other side by the benchmark **PT-10H**. **PT-10H** is set to a value of 10*H. Any point at a horizontal distance greater or equal to **PT-10H** from the upper roof is analyzed as if the upper roof were not present. Therefore, only a uniform load is considered in region 3 and the load may be reduced for wind exposure if the criteria for the reduction are met.

The remaining two benchmark goal parameters represent the edges of the lower roof. The user is asked to supply information about the distance separating the two roofs. This value is stored in benchmark **SEPARATE**. The edge of the lower roof furthest from the upper roof is at position **PT-B1**. If **SEPARATE** equals zero, **PT-B1** equals the value of **B1**. If **SEPARATE** is greater than zero, **PT-B1** equals the value of **SEPARATE** plus **B1**.

Once the geometric information has been determined and the benchmarks calculated, the program proceeds to frame *L-WIND* to establish wind coefficients for each benchmark position. The frame goals corresponding to the benchmarks are **C-WIND0**, **C-WINDXD**, **C-WIND10H**, **C-WINDSEP**, and **C-WINDB1**. The wind coefficient used to calculate total roof load can be set to either 1.0 or 0.75. Before the lower value can be used, the roof must meet the exposure criteria set out in the National Building Code. According to this Code, only region 3 in Figure 5.2.2.3(2) is eligible for wind reductions consideration.

Therefore, **C-WIND0** and **C-WINDXD** are both set to a value of 1.0. If region 3 meets the exposure criteria, **C-WIND10H** is set to 0.75. Otherwise, **C-WIND10H** is set to 1.0. The values of **C-WINDSEP** and **C-WINDB1** depend on where the edges of the lower roof lie with respect to point **PT-10H** and the wind load value assigned to regions 2 and 3.

The next frame considered is *L-ACCUM*. Here the accumulation coefficients to be used with each benchmark position are calculated. The goal parameters used to store the coefficient values are **C-ACCUM0**, **C-ACCUMXD**, **C-ACCUM10H**, **C-ACCUMSEP**, and **C-ACCUMB1**. The coefficient values quantify the extra drift load on the structure as a function of distance from the edge of the upper roof. The greatest drift load occurs at the edge of the upper roof and is calculated as a function of the height difference between the roofs. This function linearly reduces the accumulation coefficient value to 1.0 at the benchmark distance **PT-XD**. The exact function used is presented in Appendix A. From **PT-XD** outward, the accumulation coefficient is kept at a value of 1 to show uniform loading. The coefficients to be used at either end of the lower roof depend on where the roof edges lie with respect to benchmark **PT-XD**.

Once all the goal values have been determined, the program proceeds to frame *L-GOAL* to calculate specified roof snow load values for the lower roof. The load values represent both drift and uniform loads as shown in Figure 5.2.2.3(3). They are stored in goal parameters **SNOW0**, **SNOWXD**, **SNOW10H**, **SNOWSEP**, and **SNOWB1** and are calculated as follows :

SNOW0 = GRND-SNOW * Cb * C-WIND0 * C-SLOPE * C-ACCUM0
SNOWXD = GRND-SNOW * Cb * C-WINDXD * C-SLOPE * C-ACCUMXD
SNOW10H = GRND-SNOW * Cb * C-WIND10H * C-SLOPE * C-ACCUM10H
SNOWSEP = GRND-SNOW * CB * C-WINDSEP * C-SLOPE * C-ACCUMSEP
SNOWB1 = GRND-SNOW * Cb * C-WINDB1 * C-SLOPE * C-ACCUMB1

If the roof surfaces are adjoined (**SEPARATE** equals zero), **SNOWSEP** is set to equal

SNOW0.

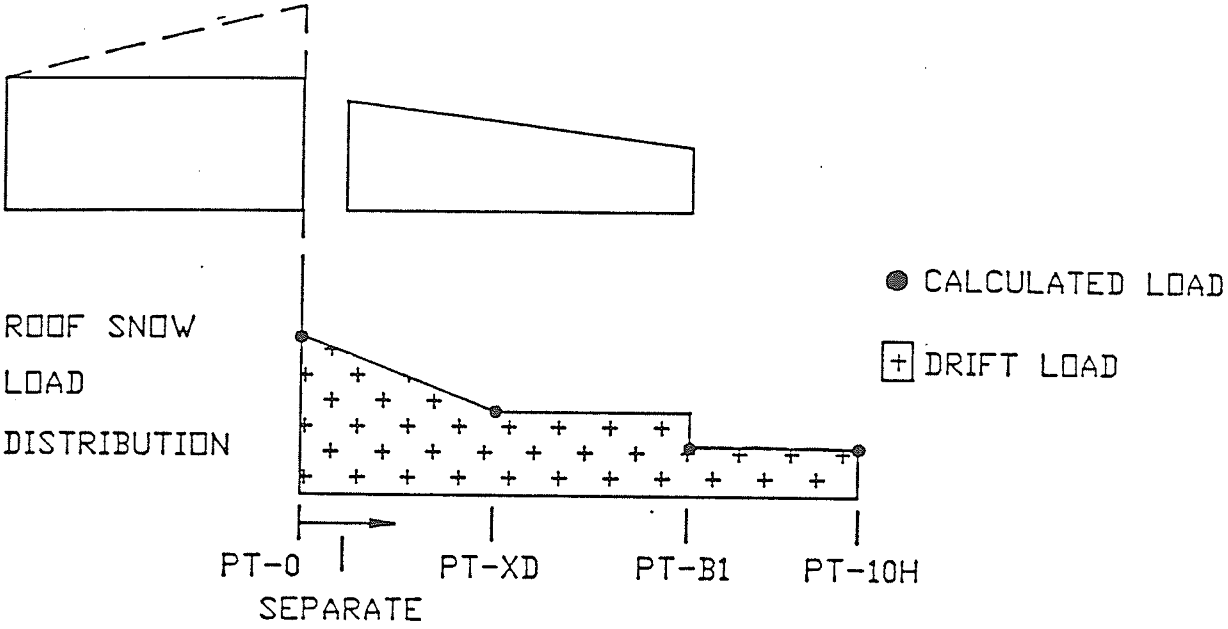


FIGURE 5.2.2.3(3) : SNOW LOAD DISTRIBUTION ON MULTI-LEVEL ROOF

The consultation concludes with the frame *L-SUMMARY* which provides the user with the results of the consultation. The user is shown three screens. The first summarizes the information s/he has supplied during the consultation. The second is a schematic of the structure the user has defined. The schematic includes a diagram showing snow load distribution with respect to the benchmark positions. This screen is shown in Appendix B. The last screen displays the calculated snow load results for the lower roof.

5.2.2.4 PATH 4

Path 4 is followed when the user wishes to analyze a lower roof in a multilevel roof situation in which snow can slide from the upper to lower roof. This occurs if the user selects either a gable or shed upper roof where the shed surface slopes down towards the lower roof. The total load on the lower roof therefore consists of a uniform load, a drift load, and a slide load.

All the information needed to calculate the total load on the lower roof can be gathered by travelling through paths already discussed. Path 3 supplies the uniform and drift load on the lower roof. Path 1 supplies information that can be used to determine the slide load. Both these paths are therefore traced to gather initial information prior to starting on the first frame in path 4.

According to the National Building Code, the total design slide load is equal to one half the uniform snow load on the upper roof surface that slopes towards the lower roof. For an upper shed roof, the total slide load is therefore equal to half the uniform shed load. For a gable upper roof, the total slide load is equal to half the uniform load on one face of the gable. The slide load is distributed over the region immediately adjacent to the upper roof. The distribution pattern is shown in Figure 5.2.2.4(1). Slide load is a maximum at the edge of the upper roof, and reduces linearly to a zero value at benchmark **PT-XD.**

The objective of the first frame in path 4, ***LOWSLOPE-SNOW***, is to combine the slide load with the loads predicted from path 3. The total specified snow load values for each of the benchmark distances, including both edges of the lower roof, are stored in goal parameters **SNOWL-0, SNOWL-XD, SNOWL-10H, SNOWL-SEP,** and **SNOWL-B1.** Since slide load only increases total load values between the edge of the

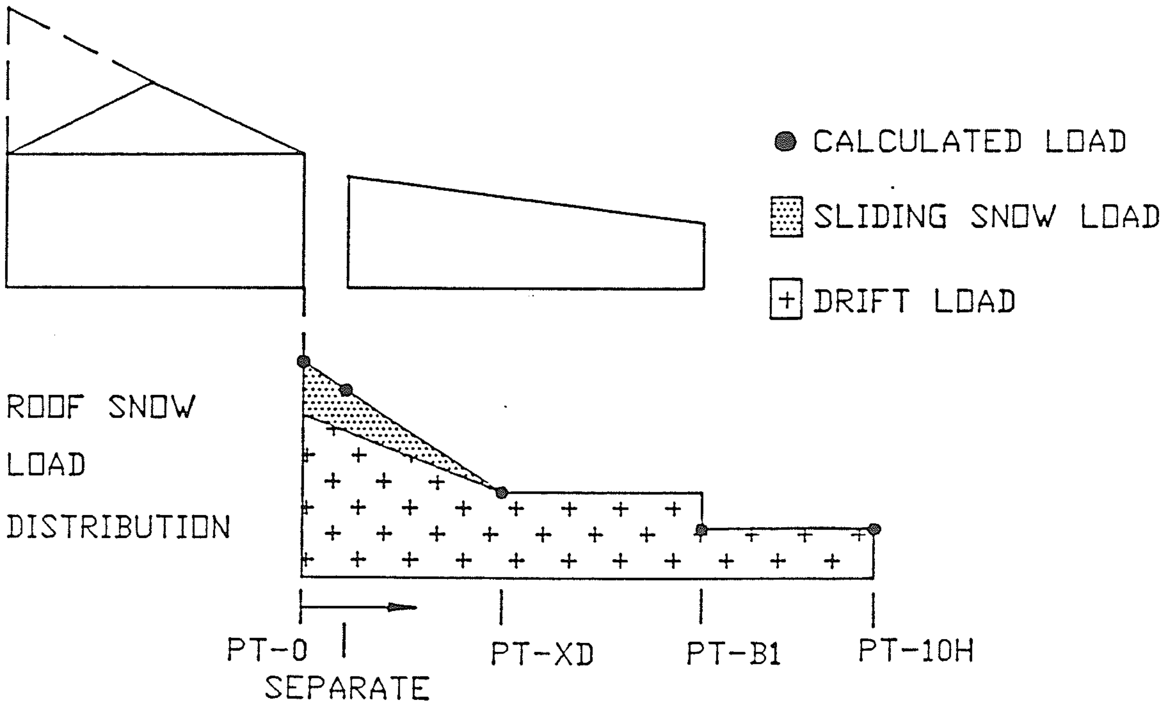


FIGURE 5.2.2.4(1) : SLIDE LOAD DISTRIBUTION ON MULTILEVEL ROOF

upper roof and benchmark **PT-XD**, values for goals **SNOWL-XD** and **SNOWL-10H** areset equal to the loads **SNOWXD** and **SNOW10H** calculated in path 3.

The value of **SNOWL-0** is calculated by distributing the slide load between the edge of the upper roof and benchmark **PT-XD**. The slide load is stored in parameter **SLIDE** and equals one half the uniform load on the upper roof surface experiencing snow slide. **SNOWL-0** is calculated as :

$$\text{SNOWL-0} = \{[(\text{SNOW0-SNOWXD}) * (\text{PT-XD}) - (2*\text{SLIDE})] / \text{PT-XD}\} + \text{SNOWXD} \qquad \text{equ. 5.2.2.4(1)}$$

The values of **SNOWL-SEP** and **SNOWL-B1** are determined by interpolation from the other goal parameter values. The interpolation is a matter of simple geometry based on the placement of the lower roof edges with respect to the distribution pattern shown in Figure 5.2.2.4(1).

After establishing the snow loads for the lower roof, the program enters the frame ***SLIDE-SUMMARY***. This frame formats and displays the standard output screens for a consultation. These screens summarize the user's inputs, display a schematic of the structure defined by the user, display the snow load distribution for the user's structure, and list the calculated specified snow loads to be used for design purposes.

5.2.2.5 PATH 5

The fifth program path is followed should the user wish to analyze snow load on a roof area adjacent to a roof projection. Typical roof projections include wide chimneys, penthouses, and parapet walls. The distribution of snow next to a roof projection is very similar to the load pattern found next to upper level roofs which do not cause snow slide loads. The distribution consists of a drift load, a uniform load not subject to wind reductions, and a uniform load that may be eligible for wind reductions. The distribution next to a roof projection is shown in Figure 5.2.2.5(1). Note that the distance marker '0' is immediately adjacent to the edge of the projection.

The first frame entered in path 5 is called ***PROJ-GEOM***. This frame objective is

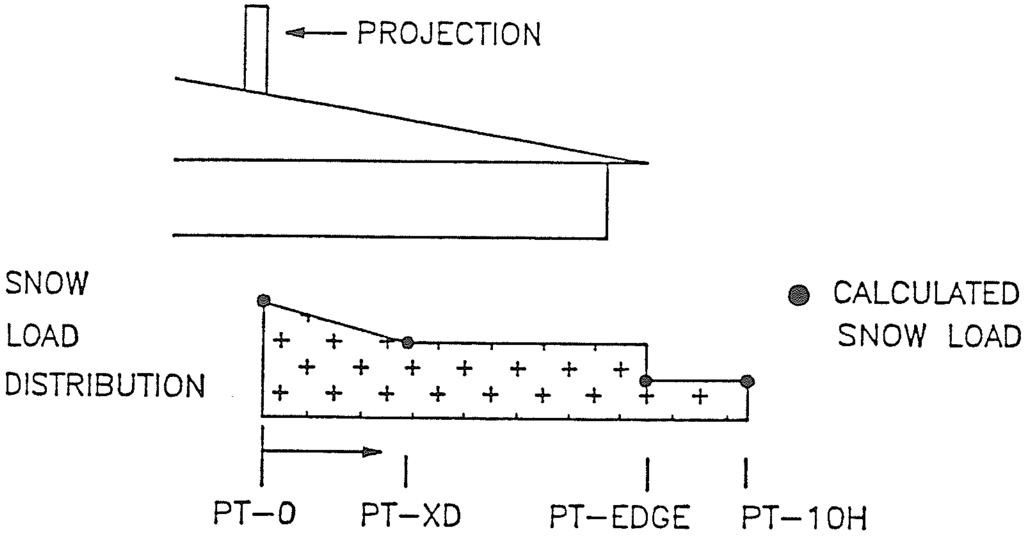


FIGURE 5.2.2.5(1): SNOW LOAD DISTRIBUTION NEAR A ROOF PROJECTION

to determine geometric information about the roof structure and use this information to establish benchmark distances **XD** and **10H-PROJ**. There are five user-defined goal parameters and one calculated goal parameter to be determined : **SLOPE, B-PROJ, H-PROJ, L-PROJ, A-PROJ,** and **XD. SLOPE** stores information about the method of user roof angle entry. **B-PROJ** stores the width of the projection. **H-PROJ** is the height of the projection above the roof surface. **L-PROJ** is the distance from the edge of the projection to the edge of the roof. **A-PROJ** is the angle of the roof from which the projection rises. These dimensions are shown in Figure 5.2.2.5(2). **XD** is a critical distance benchmark that is used to separate the roof region that experiences drift load from regions not experiencing drift load. **XD** is set equal to twice the projection height, H-PROJ, and has a minimum allowable value of 3 m and a maximum value of 9 m. Benchmark **10H-PROJ** is equal to ten times **H-PROJ**. It is not specifically defined as a goal parameter but is referred to later in the program.

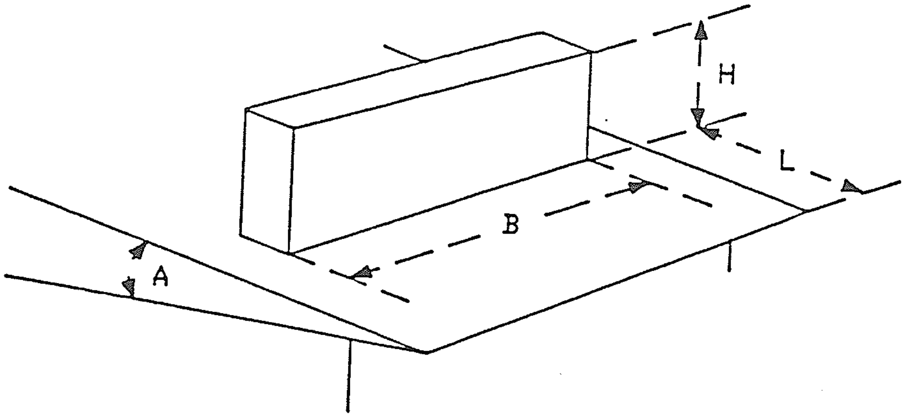


FIGURE 5.2.2.5(2) : PROJECTION GEOMETRY

The next frame, ***P-WIND***, establishes wind coefficient values at the benchmark distances and at the edge of the roof. These values are stored in goal parameters **C-WIND0**, **C-WINDXD**, **C-WIND10H**, and **C-WINDEDGE**. The value of the assigned coefficient depends on the width of the projection and distance from the projection.

If the projection width, in metres, is less than or equal to the magnitude of the ground snow load, in kilopascals, the projection creates negligible obstruction to wind. Under these circumstances, the goal parameters will all be set to either 0.75 or 1.0, depending on whether wind exposure criteria are met or not.

If the projection width, in metres, is greater than the magnitude of the ground snow load, in kilopascals, wind coefficient values will vary with distance from the projection and exposure. All benchmarks occurring within the **10H-PROJ** distance are assigned a wind coefficient value of 1.0. Wind coefficient values at benchmark **10H-**

PROJ and further from the projection depend on whether the exposure criteria are met. If the criteria are met, the goal values will be set to 0.75. Otherwise, the goal values will be set at 1.0.

The next frame considered assigns a single slope coefficient to be used across the entire roof area next to the projection. This slope coefficient value is stored in goal parameter **C-SLOPE** and is calculated as a function of roof slope and on the basis of whether the roofing material is slippery. The equations used to set **C-SLOPE** can be found in Table 5.2.2.1(1) under case one loading.

The fourth frame in path 5 assigns accumulation coefficient values to each of the benchmark positions, including the edge of the roof. These values are stored in goal parameters **C-ACCUM0, C-ACCUMXD, C-ACCUM10H,** and **C-ACCUMEDGE.**

If the width of the projection, in metres, is less than the magnitude of the ground snow load,in kilopascals, all goal parameters are set to 1.0. This implies that the projection is not wide enough for drift formation to occur. Therefore, the area next to the projection is subject only to a uniform snow load.

If the projection width, in metres, is greater than the magnitude of the ground snow load, in kilopascals, accumulation coefficient values are assigned for each benchmark using the same equations that were used in path 3 for the multilevel roof. These equations are given in Appendix A. Drift load is a maximum at the edge of the projection and decreases to zero at point **XD**. This is reflected by a high accumulation factor value at the edge of the projection, which is reduced linearly to a value of 1.0 at point **XD**. From point **XD** outward, accumulation coefficients are set equal to 1.0, implying a uniform snow load.

The value stored in **C-ACCUMEDGE** will depend on where the edge of the roof is with respect to benchmark **XD**. If the roof edge is further from the projection than **XD**, **C-ACCUMEDGE** will equal 1.0. If the roof edge is nearer the projection than XD, the value of **C-ACCUMEDGE** is interpolated from values **C-ACCUM0** and **C-ACCUMXD**.

The fifth frame in path 5 calculates the specified snow load at each of the benchmark positions. The load values are stored in goal parameters **SNOWP-0**, SNOWP-XD, **SNOWP-10H**, and SNOWEDGE. These goals are calculated as follows :

SNOWP-0 = GRND-SNOW * Cb * C-WIND0 * C-SLOPE * C-ACCUM0
SNOWP-XD = GRND-SNOW * Cb * C-WINDXD * C-SLOPE * C-ACCUMXD
SNOWP-10H = GRND-SNOW * Cb * C-WIND10H * C-SLOPE * C-ACCUM10H
SNOWEDGE = GRND-SNOW * Cb * C-WINDEDGE * C-SLOPE * C-ACCUMEDGE

After calculating the specified load values for the user defined roof, the program proceeds to the last frame in path 5, *P-SUMMARY*. This frame formats and displays to the user a summary of the information supplied by the user during the consultation, a schematic of the roof defined, a snow load distribution pattern appropriate to the defined roof, and a list of the calculated roof snow loads.

5.3 WIND LOAD EXPERT SYSTEM PROGRAM

The objective of the wind load expert system program is to calculate wind pressure values needed for the design of low-rise gable structures. The program makes use of the "simple procedure" and factor values set forward in the Supplement to the 1985 National Building Code (ACNBC, 1985b). Wind values for four design situations can be analyzed. These situations are : 1) design of the building as a whole, 2) design of primary members for strength, 3) design of primary members for deflection or vibration, and 4) design of secondary members including cladding. If the design situation requires the consideration of more than one loading case, pressure values for each case are determined. Provisions for building use and level of occupancy have been incorporated into the wind program. These provisions were extracted from the 1983 Canadian Farm Building Code, and the 1985 National Building Code (ACNBC, 1983; ACNBC, 1985a).

The wind program has a modular format consisting of 14 frames. These frames comprise approximately 290 rules and 240 parameters. Two types of rules are used. The first type are associated with individual frames and are stored in frame related name groups. These rules are either forward or backward chaining. They are used to establish frame goal values, to provide output to the user, and to move the program from frame to frame. The second type are called meta-rules and they are global in nature. Meta-rules are therefore available for use with any frame. Meta-rules are used in the wind program to alter frame goal parameters based on information supplied by the user. PCPLUS requires that meta-rules be defined in the first frame of a program. Two such rules have been included in the wind program.

The program path traced through the frames depends on the design situation being considered and on the geometry of the gable structure. As in the Section on snow loads, frame names are indicated by bold, capitalized, italicized text (ie. ***FRAME***), and parameter names are indicated with bold, capitalized, upright text (ie. **PARAMETER**).

5.3.1 STRUCTURE OF THE WIND LOAD PROGRAM

The structure of the wind load program reflects both the format of the pressure equations given in the 1985 National Building Code and the "normal" approach to problem solving (ACNBC, 1985a). The pressure equations consist of several factors that are determined individually, then multiplied to obtain either external or internal pressure values. These factors are loosely represented by individual frames in the wind program. In the "normal" approach to design, data pertaining to building site and structure are gathered before the majority of the required calculations are undertaken. This information is then drawn upon as needed during the course of the calculations. These two approaches were combined in the development of the wind program to produce a program which has a highly user interactive beginning followed by a calculation section. The program has also been designed to minimize program redundancies.

The determination of net design wind pressure loads on a structure or a structural component can be broken down into 5 sequential subproblems or steps. These steps are listed in Figure 5.3.1(1). Each step is represented by one or more frames in the program. The first step is to determine data concerning building site, intended use, occupancy level, and to identify the design situation to be analyzed. The second step involves the establishment of building geometry, including the type and distribution of openings to the external environment. Step three is the calculation of internal pressure values based on the information gathered in steps 1 and 2. Step four is the calculation of external pressure values. The determination of these values is also based on information gathered during the first two steps, but it is independent of step three results. The final step is the calculation of net design pressures for the user-defined structure and the displaying of these results to the user in a logical fashion.

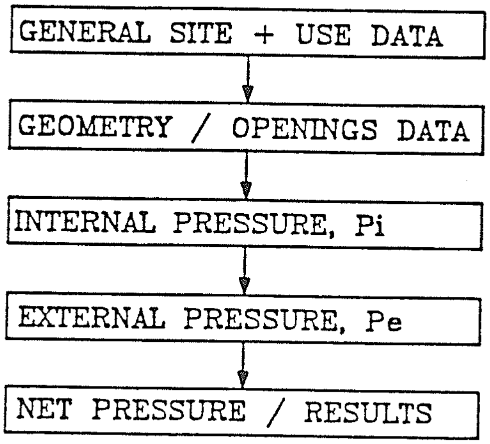


FIG 5.3.1(1) : FIVE WIND DESIGN STEPS

These five steps are worked through regardless of the design situation being considered. However, factor values used in the external pressure equations vary with design situation. Therefore, separate frames for use in steps four and five have been developed for each design situation. The program must therefore branch after the completion of step three. The wind program structure is shown in Figure 5.3.1(2). This figure shows the relationship between program frames and the five subproblems to be worked through to solve the problem.

Four program paths are shown in Figure 5.3.1(2). Each passes through the frames *WINDROOT*, *GEOMETRY*, and *INTERNAL*. Step one is performed in the frame

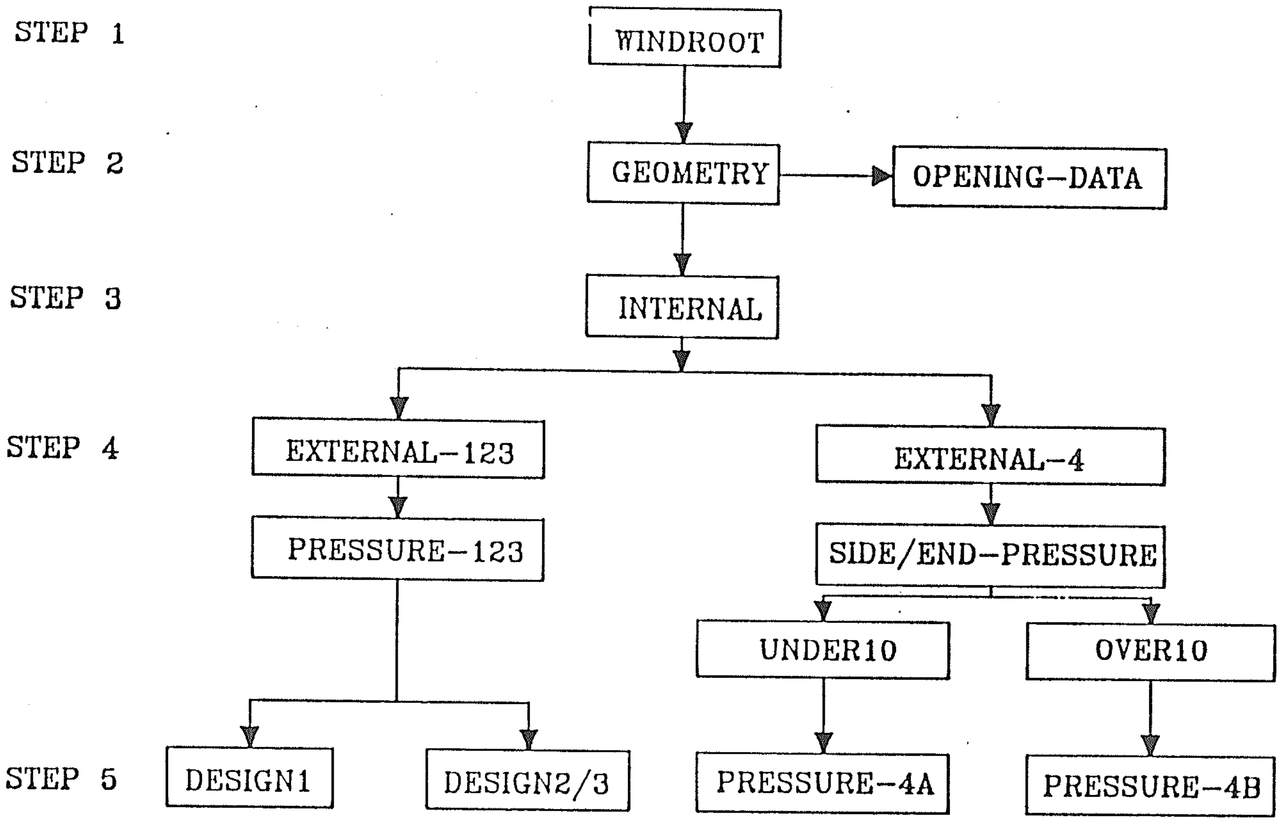


FIGURE 5.3.1(2) : FINAL STRUCTURE OF WIND LOAD PROGRAM

WINDROOT. Step two is performed using the frame *GEOMETRY*, and possibly frame *OPENING-DATA*. The frame *OPENING-DATA* is consulted only if certain types of external opening are specified by the user. This possibility exists with all four design situations. *OPENING-DATA* represents a program loop off of the *GEOMETRY* frame. If it is needed, the consultation passes from the frame *GEOMETRY*, to *OPENING-DATA*, then back to *GEOMETRY*. Step 3 is performed using frame *INTERNAL*.

The first branching of the program occurs after step 3 has been completed. If the whole building is being analyzed (DESIGN-CASE = 1), or a primary member is being analyzed (DESIGN-CASE = 2 or 3), the program follows the left branch. Step 4 is then performed using frames *EXTERNAL-123* and *PRESSURE-123*.

After the completion of step four, the program again splits, forming paths 1 and 2. If the entire building is being examined, the program follows path 1. If a primary structural component is being examined, the program follows path 2. The final step of the consultation consists of calculating design pressures and displaying these results to the user. This is done in frames unique to either path 1 or path 2.

If a secondary member is being analyzed (DESIGN-CASE = 4), the program follows the right branch of the first program branching shown in Figure 5.3.1(2). This branch traces frames *EXTERNAL-4* and *SIDE/END-PRESSURE*, then splits to form paths 3 and 4. *EXTERNAL-4* and *SIDE/END-PRESSURE* are used along with the first frame on each branch following the next split to perform step 4 duties. If the building has a roof slope of 10° or less, path 3 is followed. If the roof slope is greater than 10°, path 4 is followed. The last frame on both paths 3 and 4 is used to perform step five duties.

5.3.2 COMMON FRAMES

Regardless of the design situation being examined, every wind pressure analysis requires that certain pieces of information be established and certain calculations be performed. This work is done in the initial frames traced in a consultation of the wind program. There are four such frames : ***WINDROOT***, ***GEOMETRY***, ***OPENING-DATA***, and ***INTERNAL***.

WINDROOT

Every consultation of the wind load expert system program begins in the ***WINDROOT*** frame. This frame has 3 information groups associated with it : 1) a parameter group, 2) a local rule group, and 3) a meta-rule group. The parameter group defines pieces of data required in the ***WINDROOT*** frame as well as in many of the following frames. The transfer of parametric information down the program paths is possible due to the property of inheritance. The local rule group associated with ***WINDROOT*** is used to establish frame goal parameter values. The only influence these rules have on the rest of the program is to transfer the consultation from the ***WINDROOT*** frame to the ***GEOMETRY*** frame after all the ***WINDROOT*** goals are known. The meta-rules differ from frame rules in that meta-rules can be accessed from any frame in the program. Two meta-rules have been included in the wind program to set frame goals for ***OPENING-DATA*** on the basis of user-supplied information. Due to the structure of the shell PC-PLUS, meta-rules must be defined in the root frame of a program, regardless of where they will be used in the program.

WINDROOT has two initial data parameters and eight goal parameters. The initial data parameters are **PROVINCE** and **LOCAL.** These parameters must be established prior to the examination of the frame's goal parameters. **PROVINCE** is used to store the name of the province or territory the user wishes to build in. Once this parameter is known, the program accesses a database file of weather data. A list of sites having recorded weather data falling under the user's **PROVINCE** heading is compiled and brought back to the wind load program. The user is shown the list and asked to select a site. The selected site is stored in **LOCAL.** If the user desires a site not on the list, a value of "Not listed" is stored in **LOCAL.** The user is then asked to select listed sites which are in close proximity to his/her desired location in a manner similar to that employed in the snow load program.

After establishing values for both initial data parameters, the program begins analyzing goal parameters. The eight goal parameters associated with *WINDROOT* are : **Q10, Q30, Q100, DESIGN-CASE, L.H.O., H.H.O., AIR-TIGHT,** and **Q.** The first three are used to store reference wind velocity pressures for the user's site for return periods of 10 years, 30 years, and 100 years. These values are determined by re-entering the database file and retrieving the reference pressures stored under the appropriate **PROVINCE** and **LOCAL** headings. If **LOCAL** equals "Not listed", weather data from the nearby sites are presented to the user. The user may elect to use data from one of the nearby sites or enter his/her own. In either case, values for **Q10, Q30,** and **Q100** will be assigned.

The next goal parameter value to be established is **DESIGN-CASE.** This parameter can assume an integer value between one and four. The value assigned depends on the user's choice of design situation to be considered. A value of one indicates that the building is to be analyzed as a whole. A value of two indicates that the consultation will deal with the design of primary members for strength. Three indicates that primary members will be examined with respect to deflection and vibration. Four indicates that secondary components, including cladding and windows, will be examined. The user selects the value to be assigned to **DESIGN-CASE** from a displayed list of the four options mentioned above.

The next two goal parameters refer to the expected occupancy level in the user's structure. Both parameters are logic parameters and can have a value of either true or false. The first parameter, **L.H.O.**, stands for 'low human occupancy'. If the user indicates that the expected level of occupancy of the building during normal use is less than 1 person per 40 m^2 of floor space, **L.H.O.** is set to true (ACNBC, 1983). If a greater occupancy level is expected, **L.H.O.** is set to false. The parameter **H.H.O.** stands for 'high human occupancy'. It is assigned the opposite value of **L.H.O.**.

The seventh goal parameter, **AIR-TIGHT**, is also a logic parameter. The user is asked whether the building is to be designed to be air-tight. His/her answer is stored in the parameter **AIR-TIGHT**. **AIR-TIGHT** is normally set to true if the building is a greenhouse, residence, or similar structure which must be essentially impervious to wind gust transmittal. Animal housing, because of ventilation openings, and storage buildings are normally designed with **AIR-TIGHT** equal to false (Britton, 1989b).

The last goal parameter in *WINDROOT* is **Q**. **Q** stores the value of the reference wind velocity pressure to be used in the current consultation. **Q** is set equal to either

Q10 or **Q30** on the basis of the design case being considered and the expected occupancy level of the building (ACNBC, 1985b). If **DESIGN-CASE** equates to 1, 3, or 4, **Q** is set equal to **Q10**. If **DESIGN-CASE** equals 2, occupancy level must be examined. If the structure will have a low human occupancy (**L.H.O.** is true) **Q** is set equal to **Q10** (ACNBC, 1983). If the structure is to have a high human occupancy (**H.H.O.** is true) **Q** is set equal to **Q30**. The use of different reference velocity wind pressures allows for a higher factor of safety for more heavily populated buildings.

GEOMETRY

The frame *GEOMETRY* has both a rule group and a parameter group associated with it. It has five initial data parameters and four goal parameters. The initial data parameters store values for building width, **B**, length, **L**, wall height, **HW**, ridge to eave height, **HR**, and roof slope, **A**. These parameters are shown in Figure 5.3.2(1). Height and length values are stored in metres. Angles are stored in degrees. **B**, **L**, and **HW** are determined by presenting a schematic of the structure to the user and directly querying the user for values. **HR** and **A** are determined by first asking the user to define the roof rise-to-run ratio, then accessing a small GWBASIC program stored on the computer hard drive. The GWBASIC program calculates **HR** and **A** on the basis of roof rise to run and the width of the building. The goal parameter values are then transmitted back to the wind load program.

The goal parameters associated with frame *GEOMETRY* are : **OPENINGS**, **H-MIDROOF**, **Z**, and **H-REFERENCE**. The parameter **OPENINGS** is used to store information about the type and distribution of openings from the internal to external environment. Based on the discussion presented in the Supplement to the 1985 National

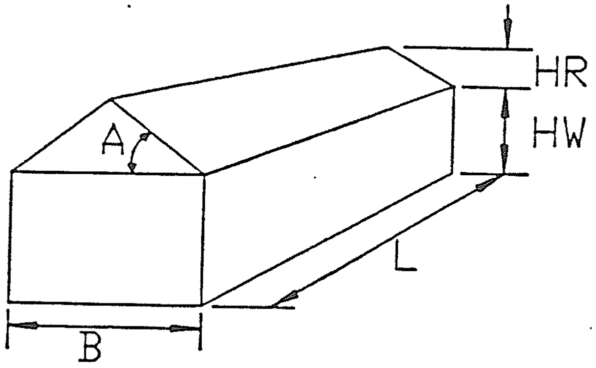


FIGURE 5.3.2(1) : BUILDING GEOMETRY FOR WIND PROGRAM

Building Code, three possibilities have been incorporated into the wind program (ACNBC, 1985b). They are : 1) a dominant large opening, 2) uniformly distributed small openings, and 3) nonuniformly distributed small openings. The user indicates the type of opening by entering a number between 1 and 3. This number is then stored in **OPENINGS.** If the user has indicated a uniform distribution of openings (**OPENINGS** = 2), the program proceeds directly to the next goal parameter. However, if an openings distribution that could cause air leakage imbalances has been chosen, (**OPENINGS** = 1 or 3), the program moves to frame *OPENING-DATA* before proceeding with *GEOMETRY* goal parameters.

OPENING-DATA

The purpose of *OPENING-DATA* is to gather information about the placement of nonuniformly distributed openings on the user's structure. Two goal parameters are associated with the frame : **OPENSIDE-LARGE** and **OPENSIDE-NONUNIFORM.** If the user indicated that a large opening is present, the placement of the opening is stored in the frame goal parameter **OPENSIDE-LARGE.** If small openings have been indicated, the distribution of the openings is stored in goal parameter **OPENSIDE-NONUNIFORM.**

Since only one of these situations can exist at a time, there is no need to trace both goal parameters. The meta-rules defined in ***WINDROOT*** examine the value of **OPENINGS** and cause only the appropriate goal parameter to be traced. This is accomplished by adjusting a priority flag on the goal parameters. If **OPENINGS** equals 1, the flag on parameter **OPENSIDE-LARGE** is set to 100. This causes it to be traced. The flag on **OPENSIDE-NONUNIFORM** is given a value of -100, ensuring that it will not be traced. When **OPENINGS** equals 3, the flag values are reversed.

Both goal parameters were created to store integer values that correspond to different placement of openings. When **OPENINGS** equates to 1, the user is shown the building schematic shown in Figure 5.3.2(2). The surfaces on the building have been assigned values from 1 to 6. The user indicates the surface containing the large opening by entering the surface number. This value is then stored in **OPENSIDE-LARGE.** The program would then return to the *GEOMETRY* frame.

When **OPENINGS** equates to 3, the user is shown the schematic in Figure 5.3.2(2) and asked to select the opening distribution from a list

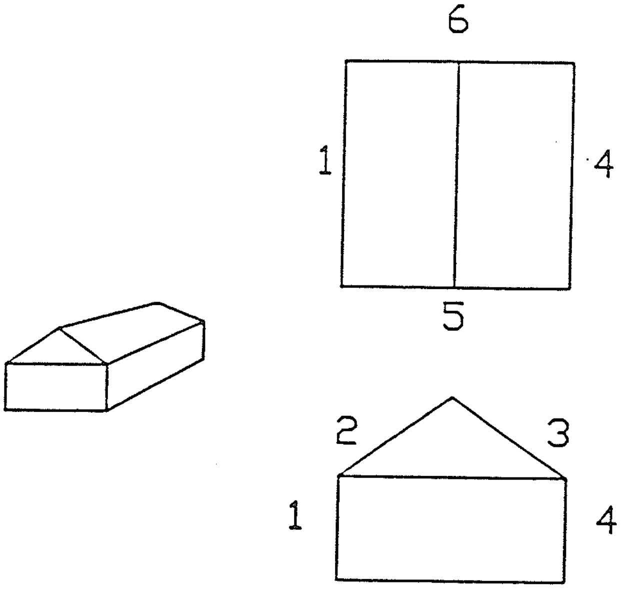


FIGURE 5.3.2(2) : GABLE BUILDING WALL DESIGNATIONS FOR WIND PROGRAM

of possibilities. The relationship between the value stored in **OPENSIDE-NONUNIFORM** and the placement of openings is given in Table 5.3.2(1). The program returns to frame *GEOMETRY* after establishing the goal parameter value.

The next goal parameter established in *GEOMETRY* is **H-MIDROOF**. This parameter stores the value of the mid-height of the roof in metres. Since both wall height and eave to ridge height are known, the calculation of **H-MIDROOF** requires no new information. The calculation proceeds via a simple mathematical equation stored in the parameter's method property.

The goal parameter **Z** stores information concerning the width of regions of higher than average pressures and suction along wall corners, roof eaves, and ridges. **Z**

TABLE 5.3.2(1) : RELATIONSHIP BETWEEN THE VALUE STORED IN PARAMETER OPENSIDE-NONUNIFORM AND THE PLACEMENT ON NONUNIFORM OPENINGS

OPENSIDE-NONUNIFORM VALUE	SURFACES CONTAINING MAJORITY OF OPENINGS
1	1
2	4
3	5
4	6
5	1,4
6	5,6
7	4,5,6
8	1,4,6
9	1,4,5
10	1,5,6

is dependent on building width, length, and total height. The determination of **Z** is complicated by the fact that several maximum and minimum criteria need to be considered. These criteria have been incorporated into the frame's rule group. The criteria can be found in the Supplement to the 1985 National Building Code which has been reproduced in Appendix C with the permission of the National Research Council (ACNBC, 1985b).

The last goal parameter to be resolved in this frame is **H-REFERENCE**. This parameter stores a reference height value for the building which will later be used to calculate an appropriate exposure factor. The criteria used to establish **H-REFERENCE** vary with the design case being examined and roof angle. These criteria can be found in Appendix C. They are summarized in Table 5.3.2(2).

If either a primary structural component or the whole building is being examined, the minimum value of **H-REFERENCE** is 6m. If the roof angle is greater than 10°,

TABLE 5.3.2(2) : ASSIGNMENT OF H-REFERENCE VALUES

DESIGN-CASE	ROOF-ANGLE (°)	CRITERIA	H-REFERENCE
1,2,3	>= 10°	midroof height >= 6m	midroof height
1,2,3	>= 10°	midroof height < 6m	6m
1,2,3	< 10°	wall height >= 6m	wall height
1,2,3	< 10°	wall height < 6m	6m
4	>= 10°	midroof height	midroof height
4	< 10°	wall height	wall height

H-REFERENCE is set equal to either the mid-height of the roof or 6m, whichever is greater. If the roof slope is less than 10°, **H-REFERENCE** is set equal to either the wall height or 6m, whichever is greater.

When a secondary component is being considered, no minimum value is set for **H-REFERENCE.** If the roof slope is greater than or equal to 10°, **H-REFERENCE** equates to the mid-height of the roof. If roof slope is less than 10°, **H-REFERENCE** equates to the height of the building walls.

INTERNAL

INTERNAL is the last frame common to all paths traced through the wind load program. *INTERNAL* has a rule group associated with it but no parameter group. The rule group contains the logic needed to assign internal pressure coefficient and gust factor values to the user's structure. Parametric information needed for use in the frame's rules are available from earlier frames through the property of inheritance.

There are five goal parameters in *INTERNAL* : **C-GUST**, **CPI-EAST**, **CPI-WEST**, **CPI-NORTH** and **CPI-SOUTH**. The internal gust factor to be used with the user's structure is stored in parameter **C-GUST**. The value stored is dependent upon the design situation being considered and on whether the building is to be air-tight (ACNBC, 1985a). Any analysis of an air-tight structure (**AIR-TIGHT** is true) receives a gust factor value of 1. If **AIR-TIGHT** is false, internal design pressures must be adjusted to account for gust transmittal. Therefore, when secondary members are analyzed, **C-GUST** is set to 2.5. When primary members or the building as a whole are examined, **C-GUST** is set to 2.

The building must be designed for winds coming from any direction. Since internal pressure varies with the placement of external openings with respect to wind direction, four goal parameters are required to store internal pressure coefficient values. These values correspond to east, west, north, and south winds. The range of possible coefficient values is listed and described in Figure B-11 in the Supplement to the 1985 National Building Code (ACNBC, 1985b). This figure is given in Appendix C and is summarized in Table 5.3.2(3). These pressure coefficient values are independent of the design case being examined.

TABLE 5.3.2(3) : INTERIOR PRESSURE COEFFICIENT VALUES FOR VARIOUS TYPES AND PLACEMENTS OF BUILDING OPENINGS

DESCRIPTION / CRITERIA	Cpi
openings mainly in windward wall	0.7
openings mainly in leeward wall	-0.5
openings mainly in walls parallel to wind flow	-0.7
openings uniformly distributed in all 4 walls	-0.3

Table 5.3.2(3) criteria are combined with the data stored in parameters **OPENINGS, OPENSIDE-LARGE,** and **OPENSIDE-NONUNIFORM** to establish internal pressure coefficient goal values. For uniformly distributed openings (**OPENINGS** = 2) each of the four pressure goal parameters receives a value of -0.3. When a large openings is present (**OPENINGS** = 1) internal pressure varies with wind direction with respect to the surface containing the opening. The goal parameters therefore receive the full range of coefficient values. The relationship between goal values and the placement of the large opening is shown in Table 5.3.2(4). If the building has small nonuniformly distributed openings (**OPENINGS** = 3), the full range of coefficient values are also considered. Goal values are assigned according to the relationships shown in Table 5.3.2(5).

TABLE 5.3.2(4) : INTERNAL PRESSURE COEFFICIENTS FOR A GABLE BUILDING WITH A DOMINANT LARGE OPENING

SURFACE WITH OPENING	Cpi-EAST	Cpi-WEST	Cpi-NORTH	Cpi-SOUTH
1	-0.5	0.7	-0.7	-0.7
2	-0.5	0.7	-0.7	-0.7
3	0.7	-0.5	-0.7	-0.7
4	0.7	-0.5	-0.7	-0.7
5	-0.7	-0.7	-0.5	0.7
6	-0.7	-0.7	0.7	0.5

Two forward chaining rules are tested after the last frame goal parameter has been assigned. The program branches after this frame and the forward chaining rules direct the consultation to the appropriate branch to be followed. The path choice is made on the basis of the design situation being considered. If a primary member or the building as a whole are being analyzed, the program proceeds down the left branch which begins with frame ***EXTERNAL-123.*** This branch later splits forming paths 1 and

TABLE 5.3.2(5) : INTERNAL PRESSURE COEFFICIENTS FOR A GABLE BUILDING WITH SMALL, NONUNIFORMLY DISTRIBUTED OPENINGS

SURFACES WITH OPENINGS	Cpi-EAST	Cpi-WEST	Cpi-NORTH	Cpi-SOUTH
1	-0.5	0.7	-0.7	-0.7
4	0.7	-0.5	-0.7	-0.7
5	-0.7	-0.7	-0.5	0.7
6	-0.7	-0.7	0.7	0.5
1,4	-0.3	-0.3	-0.7	-0.7
5,6	-0.7	-0.7	-0.3	-0.3
4,5,6	0.7	-0.7	-0.3	-0.3
1,4,5	-0.3	-0.3	-0.7	0.7
1,5,6	-0.7	0.7	-0.3	-0.3
1,4,6	-0.3	-0.3	0.7	-0.7

2. If a secondary member is being analyzed the program follows the right branch which begins with frame ***EXTERNAL-4***. This branch later splits to form paths 3 and 4.

5.3.3 FRAMES UNIQUE TO PATHS 1 AND 2

EXTERNAL-123

The first frame entered after paths 1 and 2 split from the remainder of the program is ***EXTERNAL-123***. The primary purpose of this frame is to establish external coefficient values needed in the calculation of external pressures on each surface. The values to be established are a combination of gust factor and external pressure coefficient, CpCg, for each surface on the building. They are assigned in accordance with Figure B-6 in the Supplement to the 1985 National Building Code (ACNBC, 1985b).

Three loading cases are considered. The first is called 'A' and refers to wind flow perpendicular to the roof ridge. The second case is called 'B1' and applies to wind flow parallel to the roof ridge. The third case is 'B2'. It also refers to wind flow parallel to the roof ridge but need be considered only if the building has a roof slope equal to or greater than 20°. In ***EXTERNAL-123***, CpCg values are established for all surfaces under all three load cases. If the slope criterion for B2 loading is not met, parameters used to store the combined factor values for B2 loading are set equal to 0.

The combined CpCg values in Figure B-6 of the Supplement are listed with respect to specific roof slopes and individual building surfaces. When CpCg values are required for non-listed slopes, the factors are interpolated linearly from listed values.

Figure B-6 of the Supplement to the 1985 National Building Code supplies both average and peak CpCg values for each surface (ACNBC, 1985b). The surfaces are referred to with integer designations. The average values apply to the majority of the surface area and are used in the determination of net surface pressures. Average factor values are listed under the surface's integer designation. The peak values apply to localized regions next to building corners and roof edges. Peak values are indicated by including the letter 'E' after the surface designation number. Both pressure regions and surface designations are shown in Figure 5.3.3(1).

The widths of the peak pressure regions are defined by parameters Y and Z. Z is the width of the corner strip on the gable end walls. Y is the width of peak regions on the sidewall, next to wall corners, and along the edge of the roof, next to the end walls. Both Y and Z are shown in Figure 5.3.3(1). Width Z was calculated in frame

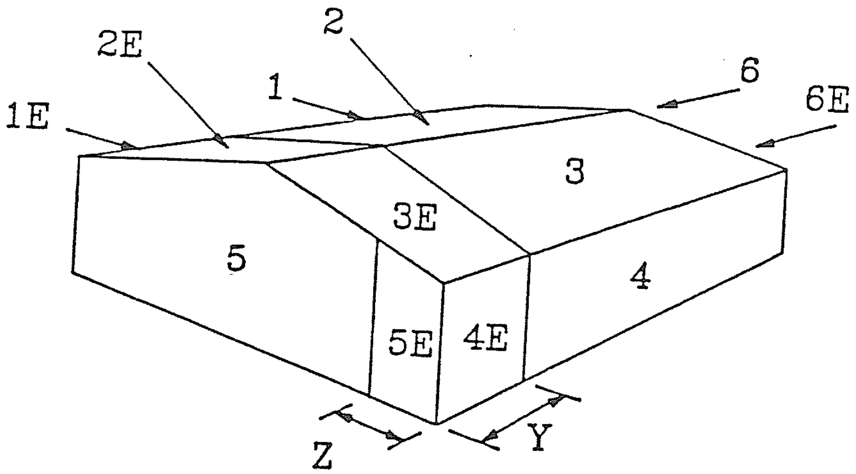


FIGURE 5.3.3(1) : REGIONS OF PEAK AND AVERAGE WIND PRESSURE FOR DESIGN OF PRIMARY STRUCTURAL MEMBERS AND THE BUILDING AS A WHOLE

GEOMETRY. Width Y is based on the value of Z and various maxima and minima criteria. The calculation of Y is given in Appendix C.

An important point to note is that the CpCg values listed in Figure B-6 of the Supplement to the 1985 National Building Code only apply to wind from two directions (ACNBC, 1985b). In the wind load program these directions are assumed to be west for case A, and south for cases B1 and B2. When net pressures are calculated for each surface on the building, all wind directions will be accounted for. This is discussed in detail in the section *DESIGN1*.

EXTERNAL-123 has seven goal parameters. The first is the width parameter Y. The determination of Y is given in Appendix C. The second goal parameter is C-EXPOSURE. This parameter stores the value of the exposure factor which will later be used in external pressure calculations for all six gable surfaces. C-EXPOSURE is calculated according to equation 5.3.3(1) and has a minimum value of 0.9.

$$\text{C-EXPOSURE} = (\text{H-REFERENCE} / 10)^{0.2} \qquad \text{equ. 5.3.3(1)}$$

The next five goal parameters are **CPCG-A-4E, CPCG-A-5, CPCG-A-6, CPCG-B1-6E**, and **CPCG-B2-6E.** These parameters store CpCg values for the edge region of wall 4 under case A loading, the average values for walls 5 and 6 under case A loading, and the values for edge regions on wall 6 under case B1 and B2 loading, respectively. Due to the composition of the rules used to evaluate these five parameters, average and peak CpCg values for all the surfaces under all three loading cases are established by the time the goal parameters are determined.

The first set of CpCg values established apply to case A loading. Coefficient values vary with roof slope and range from 1.15 to -2.0. A positive value indicates a pressure acting towards the surface. A negative value indicates a suction force on the surface. This suction is also referred to as uplift. In case A loading, surfaces 1 and 2 are windward, 3 and 4 are leeward, and walls 5 and 6 are parallel to wind flow.

The regions on windward wall 1 are assigned positive values. The regions on the leeward surfaces are assigned negative values. The values assigned to windward roof surface 2 are negative for roof slopes less than approximately 28° and positive for steeper slopes. Values for the gable end walls - surfaces 5 and 6 - are drawn from Figure B-11 in the Supplement to the 1985 National Building Code (ACNBC, 1985b). This figure indicates that the external pressure factor to be used for walls parallel to wind flow is -0.7. To make this value comparable to the ones drawn from Figure B-6 in the Supplement, it must be multiplied by a gust factor. The Supplement recommends a gust factor of 2 for design cases 1 through 3. Therefore, a CpCg value of -1.4 is stored in parameters referring to regions on walls 5 and 6. The full set of CpCg values for case A loading is listed in Appendix C.

The next set of CpCg values determined apply to case B1 loading. In this loading case, wall 5 is the windward wall, wall 6 is leeward, and sidewalls 1 and 4 are parallel to wind flow. Coefficient values are assigned independent of roof slope. Regions on wall 5 are assigned positive values while regions on all other surfaces receive negative values. The greatest value assigned is 1.15. This value applies to the edge regions on wall 5. The minimum value assigned is -2.0. This value applies to the edge regions on roof surface 2. The full set of CpCg values assigned for case B1 loading is shown in Appendix C.

The last set of CpCg factors to be established relate to case B2 loading. The wind direction in case B2 is identical to that in case B1. However, case B2 accounts for specific wind flow patterns which occur on buildings with steeper roof slopes. If the user defined structure has a roof slope of less than 20°, parameters for storing CpCg values for case B2 are set to zero. If the user's structure has a slope equal to or greater than 20°, CpCg values for case B2 parameters are set according to the values listed in Figure B-6 in the Supplement to the 1985 National Building Code (ACNBC, 1985b).

The principle effect of the steeper roof on flow is a reduction in the suction experienced by the walls parallel to wind flow. Roof regions receive the same CpCg values as in case B1. Windward and leeward walls are ignored since the values assigned in case B1 for walls 5 and 6 will govern design decisions. The CpCg values used in conjunction with case B2 loading are listed in Appendix C.

PRESSURE-123

The objective of frame ***PRESSURE-123*** is to calculate net pressure values for each surface on the user defined gable structure. This process is broken down into three stages. The first stage consists of determining internal pressures corresponding to north, south, east and west winds. In the second stage, external pressures on each surface are calculated for cases A, B1, and B2 using only the wind directions shown in the supplement. In the last stage, net pressures are established for each surface for loading cases A, B1, and B2 with respect to both the wind directions shown in the supplement and reversed wind flows.

Frame ***PRESSURE-123*** has both a rule group and a parameter group associated with it. The rule group is small and serves the sole purpose of directing the program to the next frame to be traced after the ***PRESSURE-123*** goal parameters have been set. The frame chosen depends on the design situation being considered. If the building is being examined as a whole, the program is directed to frame ***DESIGN1*** on path 1. If a primary structural member is being analyzed, the user is asked to specify the building surface in which the member appears. The program is then directed to frame ***DESIGN2/3*** on path 2.

The parameter group associated with ***PRESSURE-123*** contains parameters to store external and net pressure values. Internal pressure parameters are defined in the parameter group associated with the ***WINDROOT*** frame in order that they may be accessed by all program paths. External and net pressure parameter values are unique to specific design cases and are therefore not as readily shared. All of these pressure parameters contain a method property. This property details how the value of each parameter is to be established. For the pressure parameters, the method properties consist of mathematical equations based on the pressure equations found in the Supplement to the 1985 National Building Code (ACNBC, 1985b).

All internal pressure values are calculated according to internal pressure equation 4.2(4). This equation contains a gust factor. When the building is air-tight, the gust factor equals 1 and the method statement reduces to internal pressure equation 4.2(3).

External pressures are calculated according to equation 5.3.3(2). Only average pressures are calculated. Peak pressure values associated with corner, edge, and ridge regions are not included in the determination of design pressures when either the entire building or primary structural members are being examined (ACNBC, 1985b).

PE-(i)-(n) = **Q** * **C-EXPOSURE** * CPCG-(i)-(n) {kPa} equ 5.3.3(2)

where: PE = external pressure (kPa)
(i) = loading case (A, B1, or B2)
(n) = surface number as shown in Figure 5.3.2(2)
Q = reference wind velocity pressure (kPa)
C-EXPOSURE = exposure factor
CPCG = combined gust factor and external pressure coefficient value

Net pressures for all four wind directions are calculated using equation 5.3.3(3). Net pressure values are calculated as the algebraic difference between external and internal pressures on a given surface. It is necessary to take the difference and not the sum since opposite sign conventions are used for either value. The sign convention used with net pressures is the same as used with external pressures. A positive net pressure acts on a surface, towards the inside of the structure. A negative net pressure acts as a suction away from the surface. This is normally referred to as uplift.

F(n)-(wind)-(i) = [PE-(i)-(n)] - [PI-(wind)] {kPa} equ 5.3.3(3)

where: F = net pressure (kPa)
(n) = surface number as shown in Figure 5.3.2(2)
(wind) = wind direction
(i) = loading case (A, B1, or B2)
PE = external pressure (kPa)
PI = internal pressure (kPa)

When determining a net value for one of the wind directions shown in Figure B-6 of the Supplement to the National Building Code, the terms (wind), (i), and (n) are consistent in equation 5.3.3(3). This is not the case when a net pressure is calculated for a wind direction opposite to that shown in the Supplement. This is best illustrated by an example. When the net pressure on walls 1 and 4 are calculated according to the wind direction shown in case A in Figure B-6 of the Supplement, wall 1 is windward and wall 4 is leeward. The net pressure on each wall for case A would be calculates as :

F1-WEST-A = [PE-A-1] - [PI-WEST]

F4-WEST-A = [PE-A-4] - [PI-WEST]

When the wind direction is reversed, wall 1 is leeward and wall 4 is windward. Therefore, the external pressure experienced by both walls is reversed from the original wind case. The net pressures for walls 1 and 4 with reversed case A wind direction equals :

F1-EAST-A = [PE-A-4] - [PI-EAST]

F4-EAST-A = [PE-A-1] - [PI-EAST]

Similar substitutions are used as necessary to calculate net pressure values on all 6 building surfaces for all four wind directions.

DESIGN1

If the building is being analyzed as a whole, the program proceeds from frame ***PRESSURE-123*** to frame ***DESIGN1***. ***DESIGN1*** is used to perform duties associated with step 5, as described in Section 5.3.1. These duties include the formatting and displaying of consultation results to the user. For whole building design purposes the required results are the net pressures related to wind loading cases A, B1, and B2. The user's structure must be able to withstand 6 separate loadings - 3 from cases A, B1, and B2 with their proper wind directions, and 3 using reversed wind directions.

A dummy parameter is defined in this frame to cause rule instantiation. Two rules are available. One is used when roof slope is less than 20°. The other is used with steeper slopes. The antecedent portion of either rule causes a schematic of the building to be displayed, followed by the numeric results of the consultation. The schematic indicates the sign convention to be used in interpreting pressure values. If roof slope is less than 20°, the schematic is followed by a listing of net pressures for each surface for loading cases A and B1 with both proper and reversed wind directions. Four loading criteria are therefore set forward which the user's building must meet. A message is displayed explaining that case B2 loadings need not be considered on shallow roofed structures.

If roof slope is equal to or greater than 20°, net pressures for each surface under all three loading cases are shown. Both proper and reversed wind directions are considered. Therefore, the user is shown six separate loadings which the building must meet. Once the results have been displayed, path 1 is fully traced and the consultation is complete.

DESIGN2/3

DESIGN2/3 is entered after the completion of frame ***PRESSURE-123*** if a primary structural member is to be analyzed - ie. if **DESIGN-CASE** equals either 2 or 3. The objective of ***DESIGN2/3*** is to establish maximum and minimum design pressures for the surface containing the primary members and to display these results to the user. This objective is carried out in three steps.

The first step is to determine maximum and minimum pressures for loading cases A, B1, and B2 shown in Figure B-6 of the Supplement to the National Building Code (ACNBC, 1985b). Since the user has already identified the type of surface to be examined - side wall, end wall or roof surface - only net pressure values relating to the specified surface are considered. Maximum and minimum net pressures for each case are established by comparing net pressures values for the surface with wind direction as used in the database and with reversed wind directions. Maximum pressure values are stored in goal parameters **MAX-A, MAX-B1,** and **MAX-B2.** Minimum pressures are stored in goal parameters **MIN-A, MIN-B1,** and **MIN-B2.**

The second step is the determination of the overall maximum and minimum pressures for use in the design of the primary component. The maximum design pressure value is stored in goal parameter **DESIGN2/3-MAX.** It is selected from the maximum goal parameter values established in the first step. Similarly, the minimum design pressure value is stored in goal parameter DESIGN2/3-MIN and is selected from the minimum goal parameters calculated in the first step.

The final step consists of communicating the results of the consultation to the user. This is done in two stages. First, a schematic of the building is displayed showing the sign convention to be used when interpreting program pressures. Second, the maximum and minimum design pressures are shown along with the building surface to which they apply. These pressures are to be used in the deign of the primary structural members in the listed surface. Once these results are displayed, path 2 is fully traced and the consultation is complete.

5.3.4 FRAMES UNIQUE TO PATHS 3 AND 4

If the user wishes to analyze a secondary structural member, the program traces the initial common frames, described in Section 5.3.2, then follows the program branch which eventually splits into paths 3 and 4. This branch consists of six frames. The first two frames - ***EXTERNAL-4*** and ***SIDE/END PRESSURE*** - are traced during every secondary member consultation. After these frames, the program splits forming paths 3 and 4. Each of these paths contains two frames. Path 3 contains frames ***UNDER10*** and ***PRESSURE-4A***. Path 4 contains frames ***OVER10*** and ***PRESSURE-4B***

EXTERNAL-4

When a secondary member is being analyzed, the program enters frame *EXTERNAL-4* after completing frame *INTERNAL*. The objective of *EXTERNAL-4* is to establish the exposure factor value, and combined gust factor and external pressure coefficient values, needed in the determination of secondary member design pressures.

The exposure factor value is stored in goal parameter **C-EXPOSURE**. This factor will be used in pressure determinations for all surfaces on the building. **C-EXPOSURE** is calculated using equation 5.3.3(1) and has a minimum value of 0.9.

The combined gust and external pressure coefficient (CpCg) values are stored in goal parameters which have the prefix 'CPCG'. The remaining portion of each parameter name indicates the wall region over which the value is to be applied. When secondary members are designed it is necessary to consider both average and peak pressure regions on the building (ACNBC, 1985b). These regions are shown in Figure 5.3.4(1). Sidewall regions subject to average pressure are labelled **W14**. End wall regions subject to average pressures are labelled **W56**. The peak pressure regions are labelled **E14** on the sidewalls and **E56** on the end walls. Peak pressures act on the edge regions of each wall. The width of the peak pressure regions is defined by the value stored in parameter **Z**. This parameter value was established earlier in frame *GEOMETRY*.

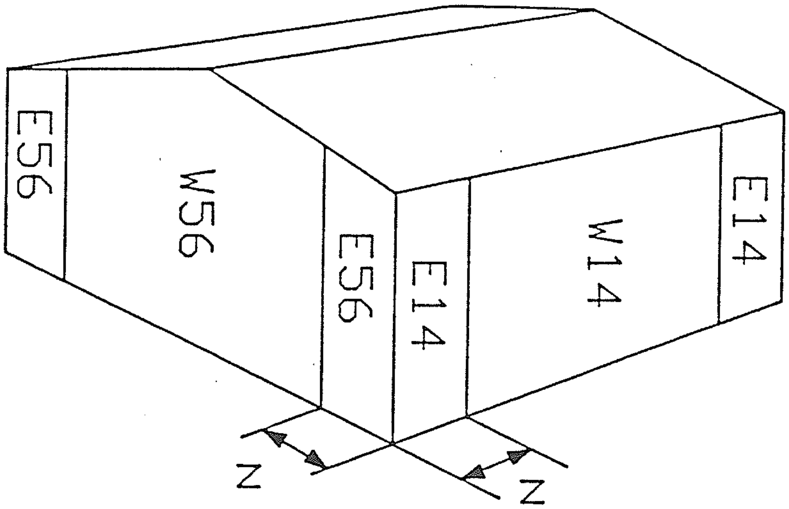


FIGURE 5.3.4(1) : WALL REGIONS OF PEAK AND AVERAGE WIND PRESSURE FOR USE IN THE DESIGN OF SECONDARY MEMBERS

Peak and average CpCg values are assigned to the user defined building in accordance with the graph included in Figure B-7 in the Supplement to the 1985 National Building Code (ACNBC, 1985b). This figure has been reproduced in Appendix C. The values assigned are dependent upon the size of the tributary area over which they are assumed to apply. As the tributary area increases, the magnitude of the CpCg values assigned decreases. Figure B-7 provides both maximum and minimum values for each wall region. Both values must be considered in the design of secondary members to account for varying wind directions. The CpCg value assigned for each wall region in the wind program is summarized in Table 5.3.4(1).

TABLE 5.3.4(1) : CpCg VALUES FOR GABLE WALL REGIONS FOR USE IN THE DESIGN OF SECONDARY STRUCTURAL COMPONENTS

SURFACE		AREA $<= 2m^2$	AREA $>= 50m^2$	$2m^2 < \text{AREA} < 50m^2$
E14	min	-2.1	-1.5	(0.6 / 48) * E14 - 2.125
	max	1.8	1.3	(-0.5 / 48) * E14 + 1.8208
W14	min	-1.8	-1.5	(0.3 / 48) * W14 - 1.8125
	max	1.8	1.3	(-0.5 / 48) * W14 + 1.8208
E56	min	-2.1	-1.5	(0.6 / 48) * E56 - 2.125
	max	1.8	1.3	(-0.5 / 48) * E56 + 1.8208
W56	min	-1.8	-1.5	(0.3 / 48) * W56 - 1.8125
	max	1.8	1.3	(-0.5 / 48) * W56 + 1.8208

SIDE/END-PRESSURE

After establishing external pressure coefficient values for all wall regions on the user's structure, the program leaves frame ***EXTERNAL-4*** and enters frame ***SIDE/END-PRESSURE***. The objective of this frame is to establish maximum and minimum net pressure values for each of the defined wall regions. To do so, the program must first calculate internal and external maximum and minimum pressures. These values are combined to establish the required net pressures.

All the information needed to calculate internal pressures is available to the frame through the inheritance facility. Internal pressures for each wind direction are calculated according to equation 4.2(4). These values are stored in parameters **PI-NORTH, PI-SOUTH, PI-EAST,** and **PI-WEST**. The goal parameter **PI-MAX** is set equal to the largest of these four values. The goal parameter **PI-MIN** is set equal to the smallest value.

External pressure values for the edge and central regions of both the end and side walls are calculated according to the following two equations :

PE-(i)-MAX = **Q** * **C-EXPOSURE** * CPCG-(i)-MAX {kPa} equ 5.3.4(1)

PE-(i)-MIN = **Q** * **C-EXPOSURE** * CPCG-(i)-MIN {kPa} equ 5.3.4(2)

where : (i) = wall region, designated as shown in Figure 5.3.4(1)

The values of CPCG-(i)-MAX and CPCG-(i)-MIN were established in the last frame. These calculations are carried out via method property statements attached to parameters used to store the pressure values.

Net pressures for each wall region are determined by taking the algebraic difference of external and internal pressures acting over the region. Again, it is necessary to take the difference and not the sum of these surface pressures since opposite sign conventions are used to determine each value. The net pressures are given with respect to the external pressure sign convention. A positive net pressure therefore acts from the outside towards the inside of the building. A negative net pressure has a suction effect. The net pressures, F, are calculated as follows :

F(i)-MAX = [PE-(i)-MAX] - [PI-MIN] {kPa} equ 5.3.4(3)

F(i)-MIN = [PE-(i)-MIN] - [PI-MAX] {kPa} equ 5.3.4(4)

where : i = wall region, designated as shown in Figure 5.3.4(1)

After establishing maximum and minimum net pressures for each region on the end and side walls, the program is ready to proceed to the next frame. Two antecedent rules are used to direct the program along either path 3 or path 4 (see Figure 5.3.1(2)). If the slope of the roof is less than or equal to 10°, the program is sent to frame *UNDER10* on path 3. If the slope is greater than 10°, the program enters frame *OVER10* on path 4.

UNDER10

UNDER10 is the first frame entered on path 3 after it splits from path 4. The objective of this frame is to establish combined gust and external pressure coefficient values (CpCg) for gable roofs having roof slopes less than or equal to 10°. This is accomplished by dividing the roof surface into regions of varying pressure. Each region is assigned maximum and minimum CpCg values in accordance with the graph shown in Figure B-8 in the Supplement to the 1985 National Building Code (ACNBC, 1985b). This figure is reproduced in Appendix C.

Each slope of the roof is divided into 6 regions. These regions are shown in Figure 5.3.4(2). The regions are corners, edge strips along the sidewalls and end walls, and a central region. When considered in plan view, the two corner regions are square and have side lengths equal to the value stored in parameter **Z**. This parametric value was established in frame ***GEOMETRY***. The area of each corner is stored in parameter **C**. The sidewall edge strip has width **Z** and its area is stored in parameter **SL-10**. The end wall edge strips have width **Z** when considered in plan view. The area of each is stored in parameter **SB-10**. The central region area is calculated by subtracting the edge and corner areas from the total area of the roof slope. The central area is stored in parameter **R10**.

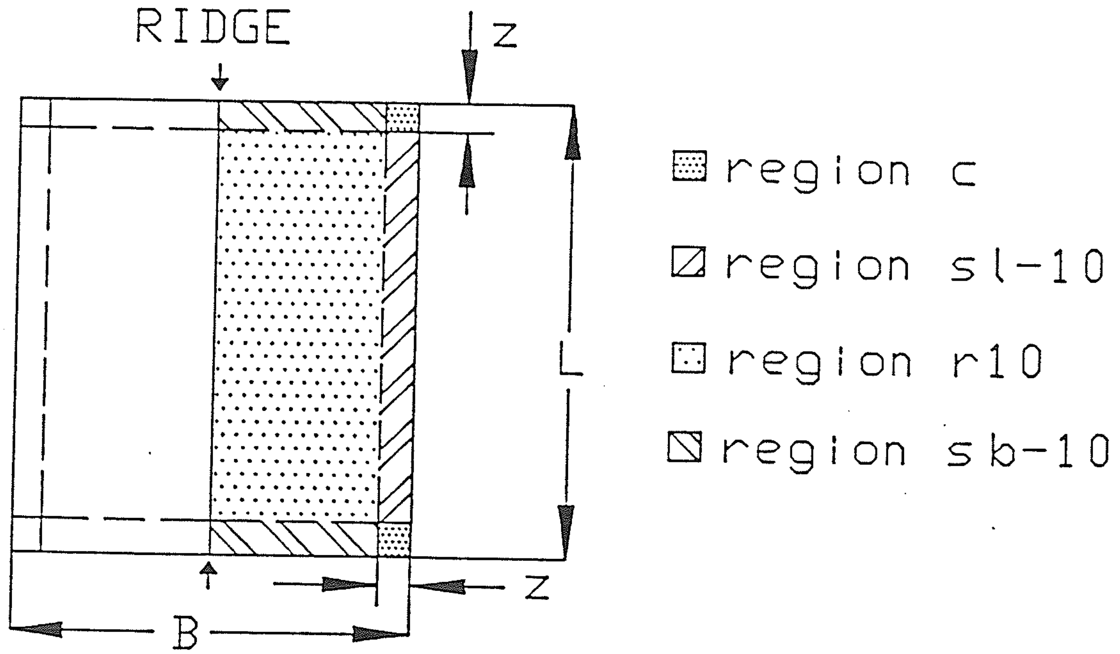


FIGURE 5.3.4(2): ROOF REGIONS OF PEAK AND AVERAGE WIND PRESSURE ON BUILDINGS WITH ROOF SLOPES LESS THAN 10°, FOR USE IN THE DESIGN OF SECONDARY MEMBERS

The combined CpCg values assigned to each region are dependent on the size of the region. The smaller the area, the greater the uplift design pressure. Only minimum or negative CpCg values are shown in Figure B-8. Because these roofs are shallow, wind causes a suction or uplift over the entire region. The wind program uses equations derived from Figure B-8 in the Supplement to assign minimum CpCg values to each roof region. Corner and central region equations are shown in Table 5.3.4(2). Edge region equations are shown in Table 5.3.4(3). Maximum CpCg values are set equal to 0 for each region.

TABLE 5.3.4(2) : MINIMUM CpCg VALUES FOR CORNER AND CENTRAL ROOF REGIONS ON A GABLE STRUCTURE WITH ROOF SLOPE <= 10°

REGION	AREA <= $1m^2$	AREA >= $10m^2$	$1m^2$ < AREA < $10m^2$
C	-4.4	-2	[(2.4 / 9) * C] - 4.6667
R10	-1.8	-1.5	[(0.3 / 90 * R10] - 1.8333

TABLE 5.3.4(3) : MINIMUM CpCg VALUES FOR EDGE ROOF REGIONS ON A GABLE STRUCTURE WITH ROOF SLOPE <= 10°

REGION	AREA <= $5m^2$	AREA >= $10m^2$	$1m^2$ < AREA < $10m^2$
SL-10	-2.5	-2	(0.1 * SL-10) - 3
SB-10	-2.5	-2	(0.1 * SB-10) - 3

PRESSURE-4A

Frame ***PRESSURE-4A*** is the last frame on path 3. Therefore, the purpose of this frame is to display the results of the consultation to the user. The results to be displayed are the minimum and maximum net wind pressures needed for the design of secondary structural members, including cladding and windows. The net pressures for side and end wall areas were determined in frame ***SIDE/END-PRESSURE***. Net pressures for the roof regions must be determined. All the data needed to calculate roof net pressures are available to the frame via the inheritance facility.

Net roof pressure values are calculated by taking the algebraic difference of external and internal pressures acting on the roof region. Internal maximum and minimum values are available from frame ***SIDE/END-PRESSURE***. External maximum and minimum pressures for each region are calculated according to equations 5.3.4(1) and 5.3.4(2) using the roof region designation shown in Figure 5.3.4(2). These calculations are performed using parameter method statements.

Net roof pressures for design are calculated using equations 5.3.4(3) and 5.3.4(4). Since opposite sign conventions are used internally and externally, net pressures are based on the difference of the surface pressures. Net pressures are stated in terms of the external pressure sign convention.

After establishing net pressure values for each roof region, the program begins displaying the results of the consultation to the user. First, the user is shown a schematic of the building on which the wall regions are labelled. This is followed by a list showing the size of each wall region. Next, a labelled schematic of the roof is displayed, followed by a list of the sizes of each roof region. The final screen lists the maximum and minimum net pressures for each region of the building as calculated during the consultation. These pressures are for use in the design of secondary members for the user defined building. This completes the frame and path 3.

OVER10

OVER10 is the first frame entered on path four after this path separates from path 3. The purpose of ***OVER10*** is to establish combined gust and external pressure coefficient values (CpCg) for gable roofs when roof slopes are greater than 10°. These values are assigned in accordance with information in Figure B-9 of the Supplement to the 1985 National Building Code (ACNBC, 1985b). This figure has been reproduced in Appendix C.

To assign CpCg roof values, each roof surface on either side of the roof ridge is divided into 11 localized pressure regions. The area of each region is stored in parameter names describing the region designation. These designations are shown in Figure 5.3.4(3). The four corner regions on each roof surface are labelled **C**. In plan view, each has side lengths equal to the value stored in parameter **Z**. The parametric value of **Z** was established in frame ***GEOMETRY***. The region along the sidewall is labelled **SE**. The two regions running along the end wall edges are labelled **SB**. In plan view, both **SE** and **SB** have width **Z**. **S'** regions have the same dimensions as **C** and are located next to the roof corners, along the ridge. The remaining roof area on each surface is labelled **R**.

Combined gust and external pressure coefficient values for use with each roof region are shown in two graphs in Figure B-9 of the Supplement to the 1985 National Building Code (ACNBC, 1985). The first graph shows the relationship between CpCg values and tributary area for roofs having angles between 10° and 30°. The second graph shows the same relationship for roofs having angles equal to or greater than 30° and less than or equal to 45°. In either graph the magnitude of the assigned CpCg values decreases as size of the region increases.

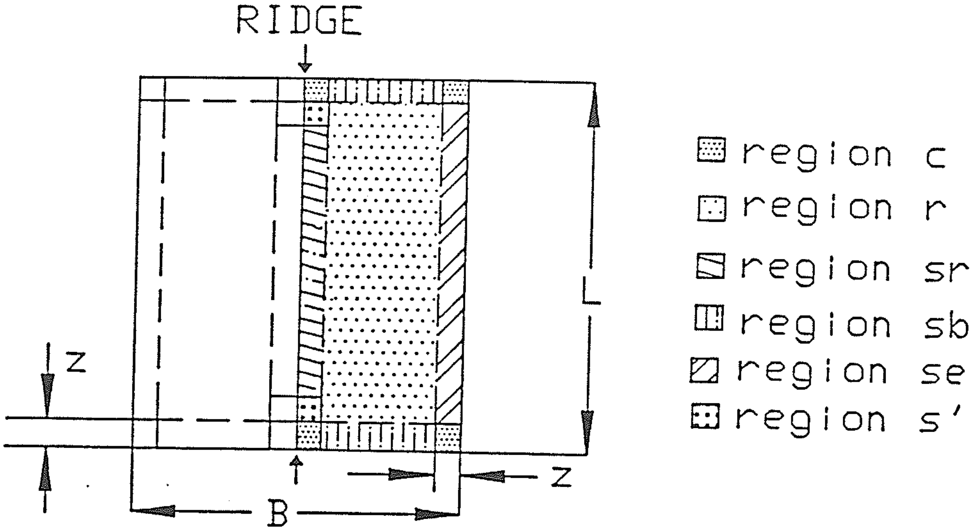


FIGURE 5.3.4(3) : ROOF REGIONS OF PEAK AND AVERAGE WIND PRESSURE ON BUILDINGS WITH ROOF SLOPES GREATER THAN OR EQUAL TO 10°, FOR USE IN THE DESIGN OF SECONDARY MEMBERS

Only minimum CpCg values are shown in the first graph. With shallower roofs, wind causes suction over the entire roof region. The first graph was used to derive the CpCg equations listed in Table 5.3.4(4). Maximum CpCg values are set to 0 for roofs with angles less than 10°.

TABLE 5.3.4(4) : COMBINED GUST AND EXTERNAL PRESSURE COEFFICIENT EQUATIONS FOR GABLE ROOFS WITH SLOPES LESS 30°

REGION	MINIMUM COMBINED GUST AND EXTERNAL PRESSURE VALUE, CpCg		
	AREA<=1m^2	AREA>=10m^2	1m^2<AREA<10m^2
C	-4.1	-2.6	(1.5 / 9) * C - 4.2667
R	-1.6	-1.5	(0.1 / 9) * R - 1.6111
SE	-2	-1.6	(0.4 / 9) * SE - 2.0444
SB	-2	-1.6	(0.4 / 9) * SB - 2.0444
	AREA<=5m^2	AREA>=10m^2	5m^2<AREA<10m^2
S'	-3.1	-2.6	(0.1 * S') - 3.6
SB	-3.1	-2.6	(0.1 * SB) - 3.6

The second graph shows both maximum and minimum CpCg values for each roof region. Equations derived from this graph are listed in Table 5.3.4(5). Positive pressures result from the steeper roof angles which allow wind to push on the roof. Since no information is listed for the design of secondary members on roofs with angles steeper than 45°, such roofs cannot be analyzed by the wind expert system program.

TABLE 5.3.4(5) : COMBINED GUST AND EXTERNAL PRESSURE COEFFICIENT EQUATIONS FOR GABLE ROOFS WITH SLOPES GREATER THAN 30° AND LESS THAN OR EQUAL TO 45°

REGION	MAXIMUM COMBINED GUST AND EXTERNAL PRESSURE VALUE, CpCg		
	AREA<=1m^2	AREA>=10m^2	1m^2<AREA<10m^2
C	1.6	1.5	(-0.3 / 9) * C - 1.6111
R	1.6	1.5	(-0.3 / 9) * R - 1.6111
SE	1.6	1.5	(-0.3 / 9) * SE - 1.6111
SR	1.6	1.5	(-0.3 / 9) * SR - 1.6111
S'	1.6	1.5	(-0.3 / 9) * S' - 1.6111
SB	1.6	1.5	(-0.3 / 9) * SB - 1.6111
	MINIMUM COMBINED GUST AND EXTERNAL PRESSURE VALUE, CpCg		
	AREA<=1m^2	AREA>=10m^2	1m^2<AREA<10m^2
C	-1.8	-1.5	(0.3 / 9) * C - 1.8333
R	-2.1	-1.8	(0.3 / 9) * R - 2.1333
SE	-2.1	-1.8	(0.3 / 9) * SE - 2.1333
SR	-2.1	-1.8	(0.3 / 9) * SR - 2.1333
S'	-2.1	-1.8	(0.3 / 9) * S' - 2.1333
SB	-2.1	-1.8	(0.3 / 9) * SB - 2.1333

PRESSURE-4B

Frame ***PRESSURE-4B*** is the last frame traced on path 4. It is entered after all the CpCg values for the roof have been established in frame ***OVER10***. The objective of ***PRESSURE-4B*** is to display to the user maximum and minimum net pressures needed for the design of secondary members on each region of the user's structure. The design pressures for side and end walls are available from frame ***SIDE/END-PRESSURE***. The net pressure values for roof regions must be calculated. All the data needed to calculate roof net pressures are available through inheritance.

Net roof pressures are calculated using method properties associated with the parameters that store the pressure values. The net pressure values for each roof region are calculated as they were in ***PRESSURE-4A***. Internal maximum and minimum values are available from frame ***SIDE/END-PRESSURE***. External maximum and minimum pressures for each region are calculated according to equations 5.3.4(1) and 5.3.4(2) with the region designations shown in Figure 5.3.4(3). Net maximum and minimum pressures for each region are then determined using equations 5.3.4(3) and 5.3.4(4). If a net pressure is positive, it acts perpendicularly to the surface, towards the inside of the building. Positive design pressures therefore "push" on the outside of the building. If the net pressure is negative, it acts perpendicular to the surface, away from the building. Negative design pressures therefore cause a suction or uplift action.

After establishing net pressure values for each roof region, the program begins displaying the results of the consultation to the user. First the user is shown a schematic of the building on which the wall regions are labelled and a list of sizes of each wall region. Next, a labelled schematic of the roof is displayed, followed by a list of the sizes of each roof region. The final screen lists the calculated maximum and minimum net pressures for each region of the building. This completes the frame and path 4.

6. SAMPLE CONSULTATIONS

During consultations with both the snow and wind design load expert system programs, the subtasks and reasoning operations described in the preceding chapter are not immediately visible to the user. These tasks are performed by the knowledge embodied in the programs and in the expert system shell. The role of the user is to supply information needed to describe the problem to be solved.

This chapter traces one simple consultation with either program from the point of view of the user. Each consultation can be replicated by following the steps described below and by entering the same input information. If alternate inputs are made, different screens will be displayed and different questions will be presented. Screens displayed to the user are shown in boxes. User inputs are typed in **BOLD** and may be followed by instructions to depress the ENTER key, shown as <ENTER>.

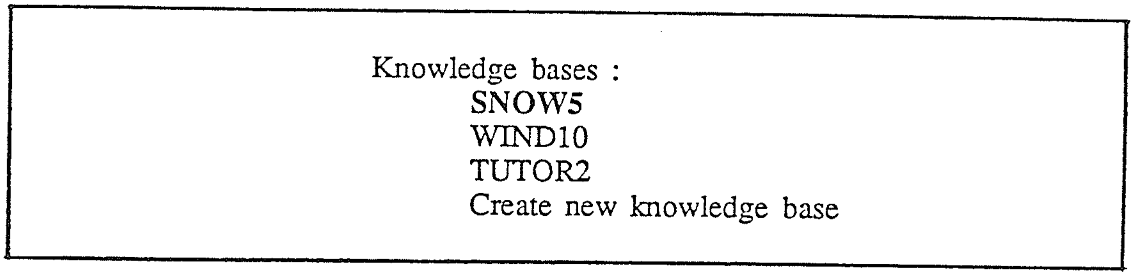
6.1 Sample Snow Load Consultation

This consultation examines a gable roofed building located in Winnipeg, Manitoba. The building has a roof slope of 14° and a roof covering of asphalt shingles. The building is located in a sheltered location and therefore does not meet the first wind exposure factor criterion.

The user initiates a consultation with the snow load program by loading the shell PCPLUS into the active memory of the computer.

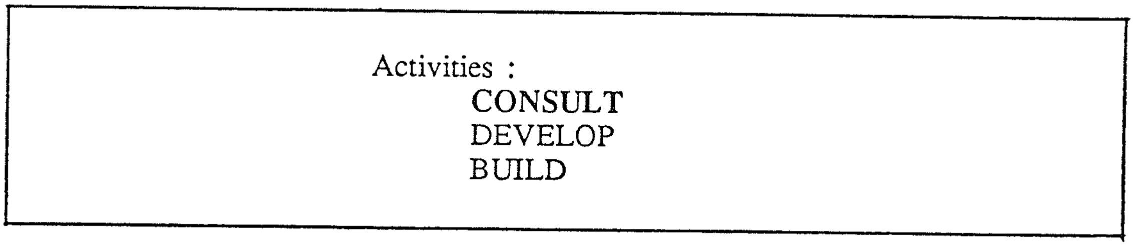
```
C: cd PCPLUS <ENTER>
C:\PCPLUS> PC EXT <ENTER>
```

The user will then be shown a list of the expert programs that can be accessed. The user selects the snow load program by moving the cursor to SNOW5 and pressing <ENTER>.



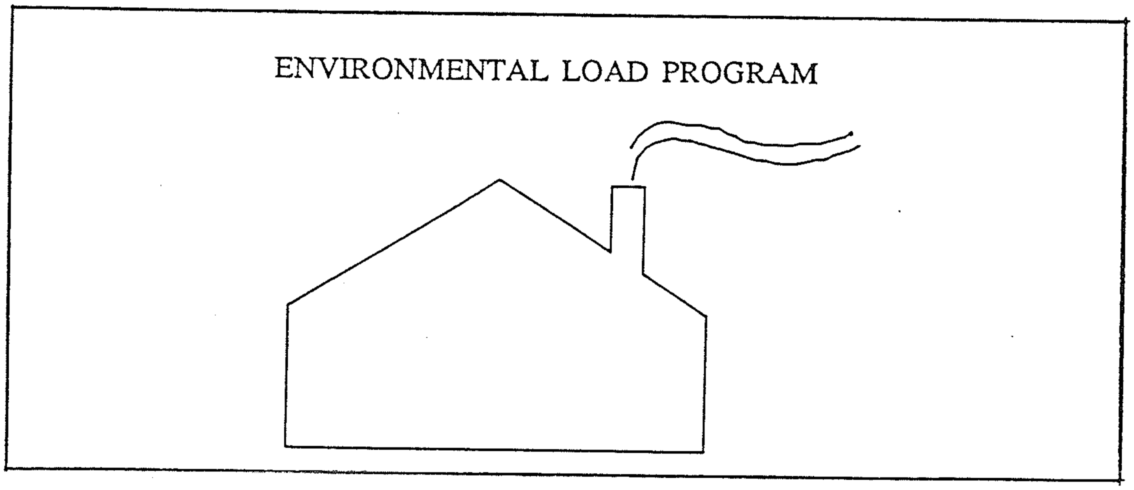
Knowledge bases :
- **SNOW5**
- WIND10
- TUTOR2
- Create new knowledge base

The snow load program is then loaded for use. The user is shown an 'ACTIVITIES SCREEN'. The user places the cursor over CONSULT and presses <ENTER>.



Activities :
- **CONSULT**
- DEVELOP
- BUILD

The consultation then begins. First, the user is shown a title screen. The user presses <ENTER> to continue.



ENVIRONMENTAL LOAD PROGRAM

The user is then asked to select the province in which the building is situated. The user places the cursor over MB and presses <ENTER>.

```
          In which province/territory will you be building ?

                 BC           ON           PEI
                 ALTA         PQ           NS
                 SASK         NFL          NWT
                 MB           NB           YK
```

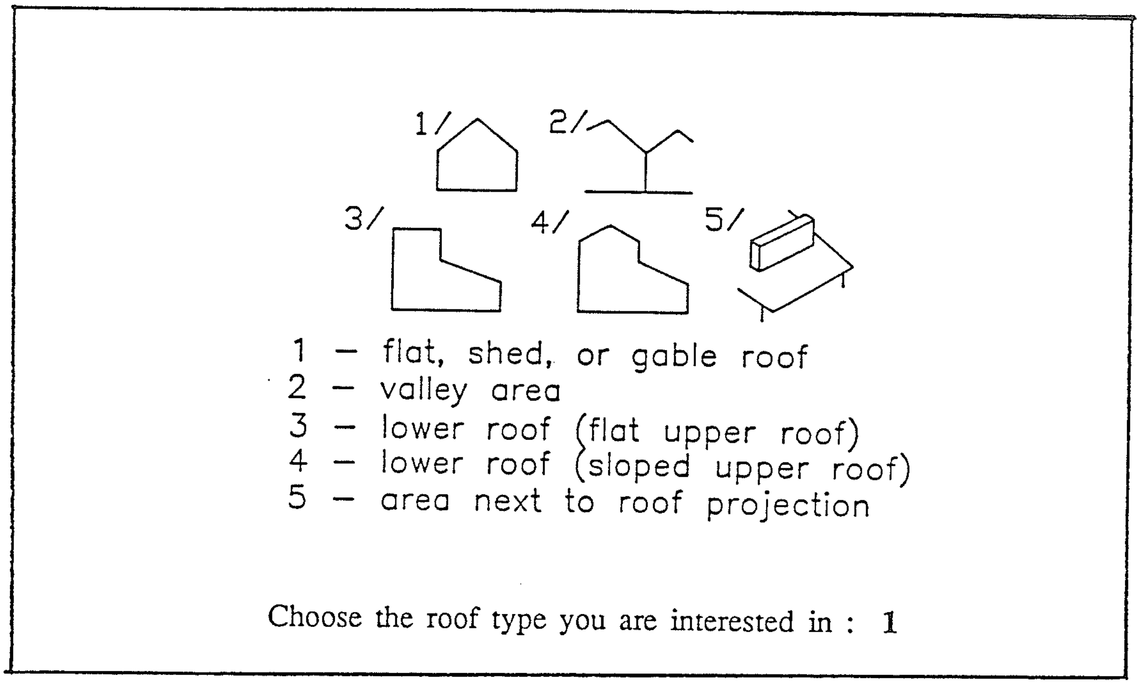
The program then accesses the dBASE3+ file of weather data stored on the computer. In doing so, the user is shown the license agreement for dBASE3+. The user may either wait for the consultation to continue (a short pause) or press <ENTER>, which will eliminate the pause.

The user is then asked to identify the location of the building within the chosen province. The user places the cursor over WINNIPEG and presses <ENTER>.

```
       Indicate the intended site of the building -

       BRANDON          GIMLI            THE PAS
       CHURCHILL        MORDEN           THOMSON
       DUAPHIN          NEEPAWA          WHITESHELL
       FLINFLON         STEINBACH        WINNIPEG
```

Once again, the dBASE3+ file is entered. The user is shown the license agreement and can either wait for the consultation to proceed or press <ENTER>.

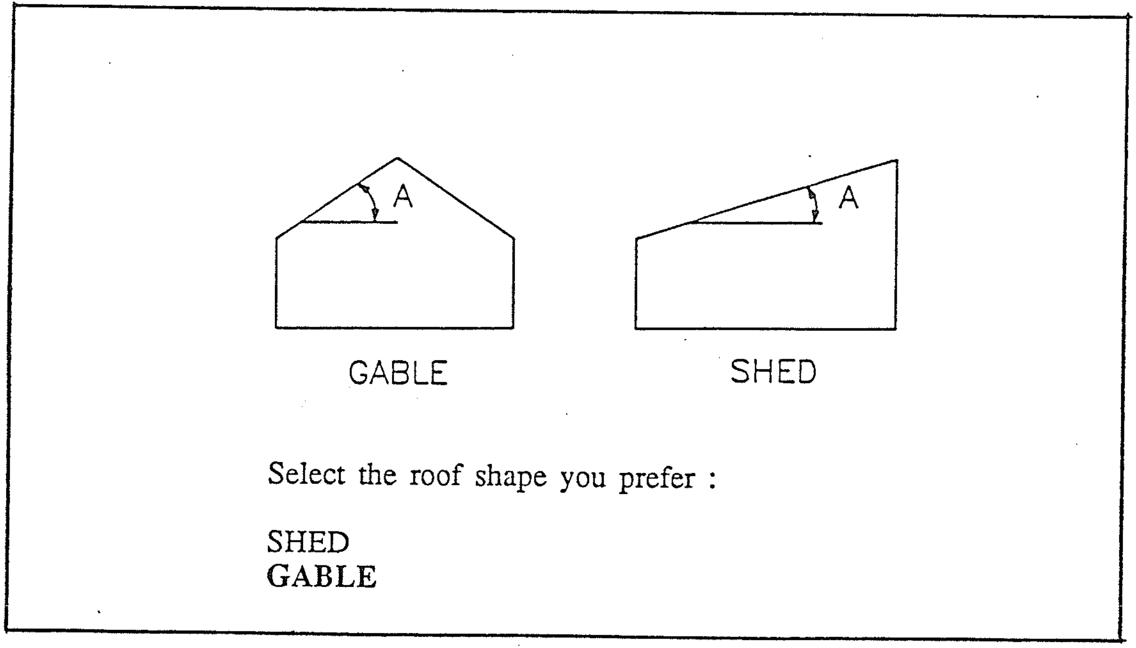
A schematic of the five roof types that can be analyzed by the program is displayed. The user indicates the analysis of a gable building by typing : **1** <ENTER>.



1 – flat, shed, or gable roof
2 – valley area
3 – lower roof (flat upper roof)
4 – lower roof (sloped upper roof)
5 – area next to roof projection

Choose the roof type you are interested in : **1**

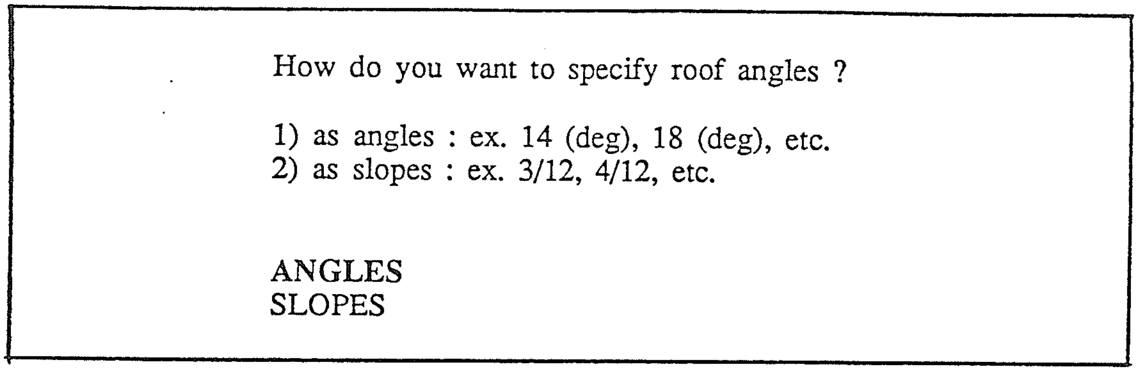
Next, the user is asked to select the roof shape to be examined. The user places the cursor over GABLE and presses <ENTER>.



Select the roof shape you prefer :

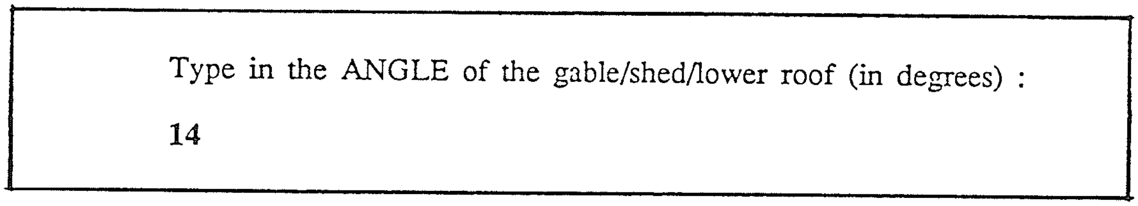
SHED
GABLE

The user then chooses the method by which the roof angle will be entered. In this example, the user elects to enter roof angle in degrees.



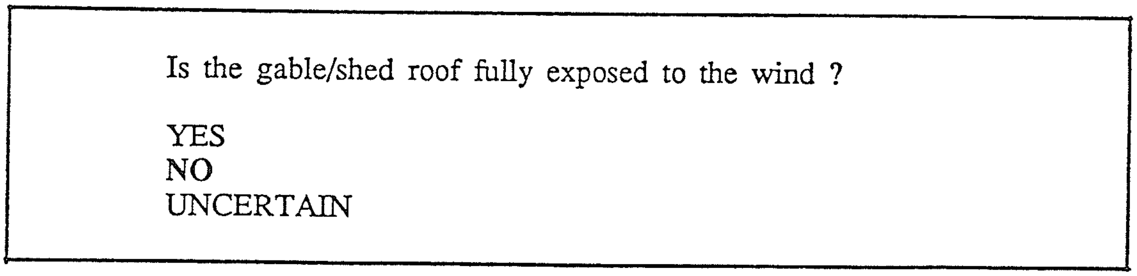
```
How do you want to specify roof angles ?

1) as angles : ex. 14 (deg), 18 (deg), etc.
2) as slopes : ex. 3/12, 4/12, etc.


ANGLES
SLOPES
```

The user is then asked to type in the roof angle in degrees. The user types 14 <ENTER>.



```
Type in the ANGLE of the gable/shed/lower roof (in degrees) :

14
```

Next, the user is asked to indicate whether the roof meets the first wind exposure requirement. The user places the cursor over NO and presses <ENTER>.



```
Is the gable/shed roof fully exposed to the wind ?

YES
NO
UNCERTAIN
```

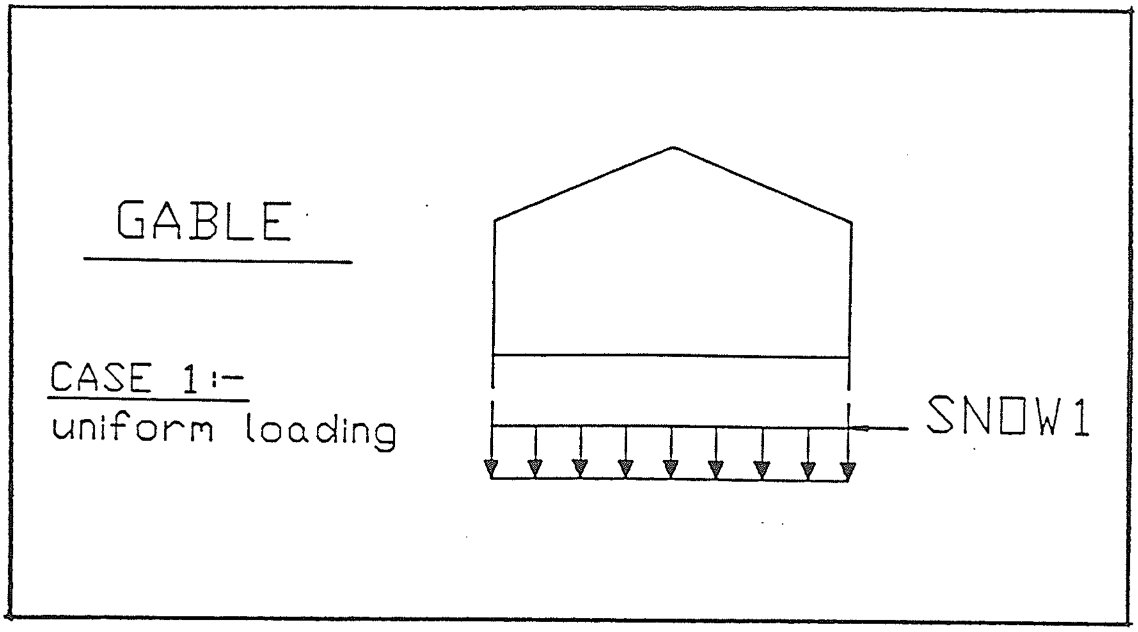
Lastly, the user is asked to choose a roofing material. The user selects asphalt shingles.

```
Which construction material is on the outside of the gable / shed roof ?

        ASPHALT-SHINGLES                METAL-NEW
        WOOD-SHINGLES                   METAL-OLD
        WOOD-PLANKS                     GLASS
```

A blue message will start flashing in the lower right hand portion of the screen. The message states that the computer is attempting to solve the snow load problem defined by the user. When the program has arrived at a solution, a green message appears on the lower left portion of the screen, prompting the user to press <ENTER>. When the user does so, the screen scrolls up to reveal the following input summary screen.

```
SUMMARY OF INPUTS

PROVINCE    :  MB                EXPOSED        : NO
LOCATION    :  WINNIPEG          OBSTRUCTION    : not required
ROOF TYPE   :  GABLE             ROOF MATERIAL  : asphalt shingles
DIMENSIONS
            angle of roof :  14 degrees
```

The user presses <ENTER> to proceed. The next screen displays a schematic of the user defined building along with the snow load cases for which it must be designed The user presses <ENTER> to continue. The last output screen shows the results of the consultation.



```
CONSULTATION RESULTS

for roof shape  =   GABLE
                                          Snow load (kPa)

Case 1 - uniform load                     1.68
Case 2 - nonuniform load                      0

        General Form : S = So * Cb * Cw * Cs * Ca

Case 1 : 1.68 = 2.1 * 0.8 * 1 * 1 * 1
```

A prompt appears on the lower left screen directing the user to press <ENTER> to continue. When this is done, a list of options is presented to the user. The user selects QUIT by moving the cursor over this command and pressing <ENTER>.

```
COMMANDS :
        CONTINUE
        HOW
        PRINT CONCLUSIONS
        REVIEW
        QUIT
```

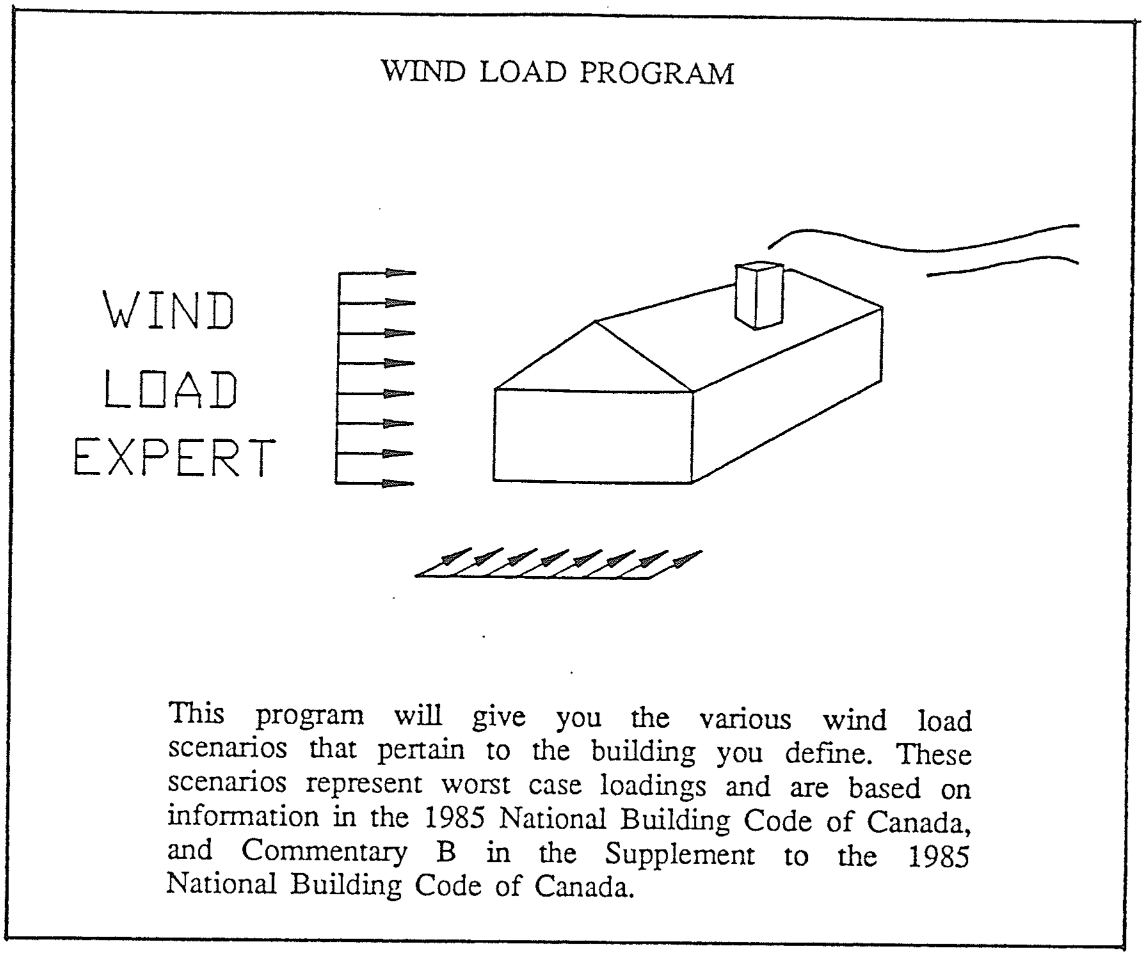
This takes the user back to the Activities screen. To exit from PCPLUS, the user presses the function key F2, and selects QUIT from the list of options. This takes the user back to the DOS prompt C:\PCPLUS>.

6.2 Sample Wind Load Consultation

The wind load problem to be solved consists of determining wind loads for the design of main (primary) member for strength. The members are on the side walls of a low rise gable building located in Winnipeg, Manitoba. The building is intended for low human occupancy and is not being designed to be airtight. Openings are located on the sidewalls of the building. The building will not have a frame construction. The dimensions of the building are as follows:

width	: 8 m
length	: 12 m
wall height	: 2.5 m
roof rise	: 3
roof run	: 12

The user loads PCPLUS in the same manner as described in the preceding example. When the knowledge base screen appears, the user places the cursor over WIND10 and presses <ENTER>. The user then selects CONSULT <ENTER> from the list of options displayed on the activities screen. The next screen is the title screen for the wind load program. The user presses <ENTER> to continue.



WIND LOAD PROGRAM

This program will give you the various wind load scenarios that pertain to the building you define. These scenarios represent worst case loadings and are based on information in the 1985 National Building Code of Canada, and Commentary B in the Supplement to the 1985 National Building Code of Canada.

The user is then asked to identify the province and site of the building within the province. This process is the same as is followed in the snow load program. Identical screens are displayed and the user's inputs are the same. Note that the program will again access the dBASE3+ program which causes the license agreement to be displayed.

Once the building location has been established, the user is asked to select the design case to be considered during the consultation. The user types **2** <ENTER>.

```
Select the design case you wish to consider :

1 - design of building as a whole
2 - design of main structural members for strength
3 - design of main structural members for deflection or
    vibration
4 - design of secondary structural members, cladding or windows

2
```

The user is then asked to identify the expected human occupancy level of the building. The user indicates a low level by placing the cursor over NO and pressing <ENTER>.

```
Will the structure have a human occupancy level of over 1
person / 40 m² during normal use ?

YES
NO
```

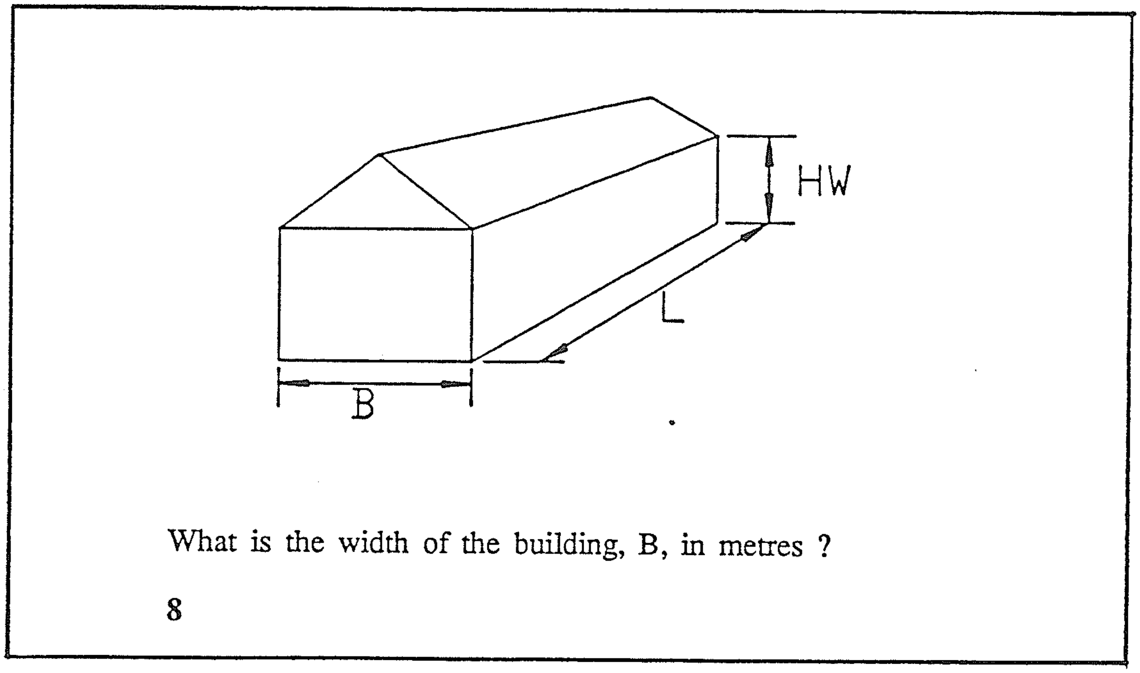
Next, the user is asked whether the building is to be airtight. The user selects NO <ENTER>.

```
Is the building designed to be airtight ?
(ex. residence, certain greenhouses)

YES
NO
```

The user is then presented with a screen which indicates the return period which will be used in the current wind load analysis. The user presses <ENTER> to continue.

```
In structures rated for low human occupancy, the design of
main members for strength requires the use of wind
reference velocities that have a one chance in 10 years
likelihood of being exceeded. The appropriate velocity
pressure for your site will be retrieved from the database
file.
```

The user is then asked to define the geometry of the building. The following graphic is shown and the user is prompted to enter each dimension individually. The user enters dimension values by typing in the appropriate number and pressing <ENTER>.



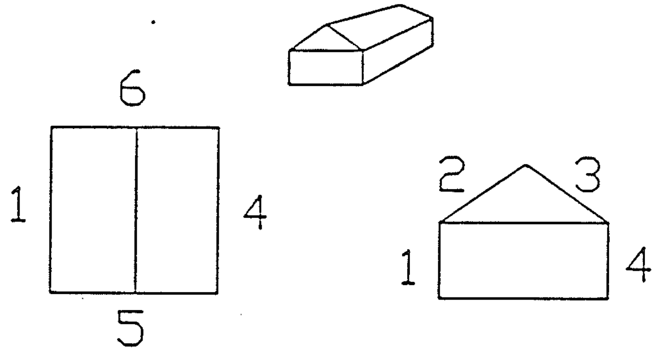
What is the width of the building, B, in metres ?

8

Once both the roof rise and run have been entered, the program accesses a mathematics routine stored on the workstation to calculate roof angle. This causes the screen to momentarily turn white. The next question the user is asked deals with the type of openings that will be present on the building. The user indicates that openings will be nonuniformly distributed on the building by typing 3 <ENTER>.

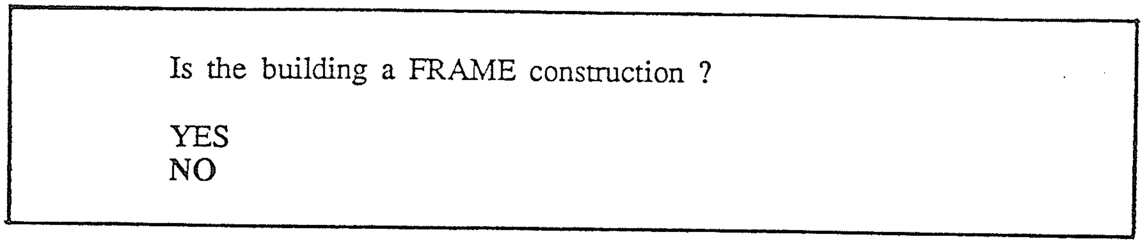
```
Which case best describes the number and size of locations on your
building (type in the number) :

1 - a large dominant opening on one wall
2 - several small openings distributed uniformly around the building
3 - several small openings distributed nonuniformly on several, but not
    all, walls of the building
4 - uncertain, require more information to make judgement
```

The user is then asked to identify which walls contain openings. The user types 5 <ENTER> to indicate openings on the side walls of the structure.



```
Given the wall labelling above, which wall/walls contain
the majority of the openings ? (type in the applicable
number)

1 - wall 1          3 - wall 5          5 - walls 1 and 4
2 - wall 4          4 - wall 6          6 - walls 5 and 6
              7 - group of three walls
```

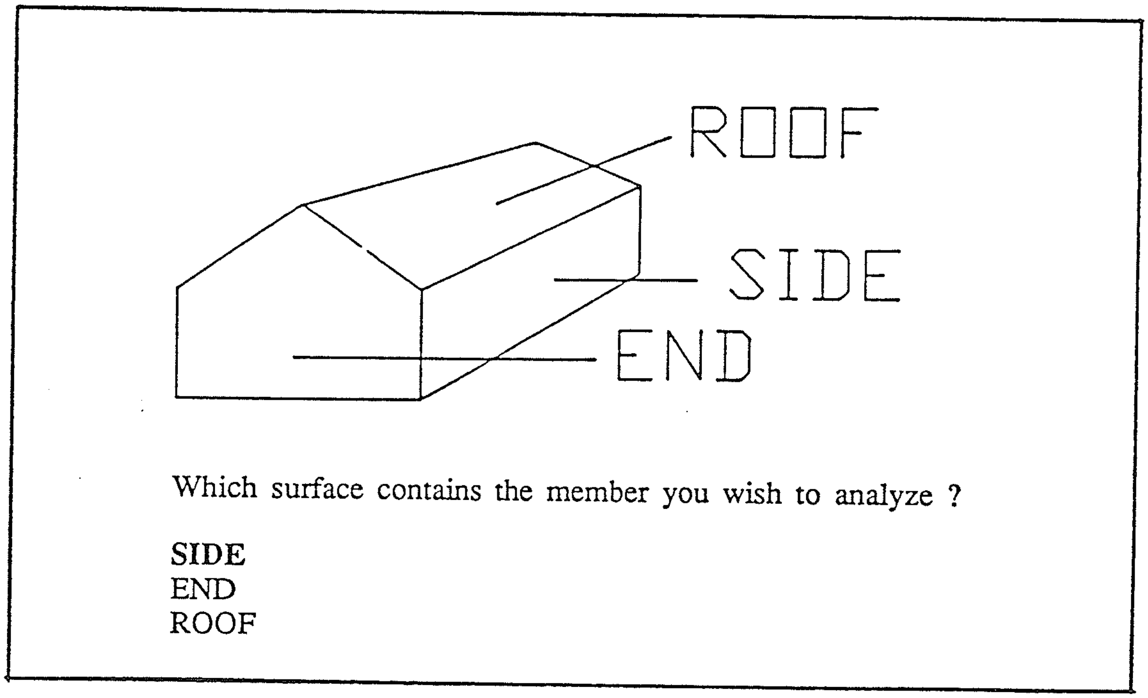
The user is asked whether the building is of a frame construction. The user moves the cursor to NO and presses <ENTER>.



Is the building a FRAME construction ?

YES
NO

The user is then asked to identify which building surface contains the main member being analyzed. The user selects SIDE from the list of options and presses <ENTER>. This is the last question of this consultation.



Which surface contains the member you wish to analyze ?

SIDE
END
ROOF

There is a slight pause in the consultation at this point while the program attempts to determine the wind design loads for the user defined structure. When the results have been established, the following screen is displayed.

```
RESULTS OF CONSULTATION

surface containing member          : SIDE

maximum design pressure (kPa)      : 0.47
minimum design pressure (kPa)      : -0.04
```

The user completes the consultation by pressing <ENTER>. This causes the list of commands to appear which appeared at the end of the snow load program consultation. To end the consultation, the user moves the cursor to QUIT and presses <ENTER>.

7. EVALUATION AND DISCUSSION

7.1 EVALUATION OF SNOW AND WIND PROGRAMS

Both the snow and wind expert system programs produce design load results in accordance with the 1985 National Building Code of Canada. However, both programs should be viewed as advanced prototypes and not finished software ready for commercial use. Each performs satisfactorily with respect to its own developmental premises, but requires further validation, revision, and additions before the final commercial stage is reached.

The development of any expert system (ES) program requires significant input from both the program developer (knowledge engineer) and a human expert in the problem area. Three stages must be worked through. In the first stage, the knowledge engineer and expert define the problem and establish an initial solution approach. During the second stage, the knowledge engineer attempts to build a working program prototype. The third stage is a review of the prototype by the expert. This validation process is more important in the development of ES programs than in traditional mathematical programs since much of the logic in the ES programs is of a judgemental nature. The human expert's validation is necessary to lend credibility to the program.

While many trial runs have been performed on both programs, the final validation stage has not taken place. However, since the objective of this project was to establish the feasibility of an ES approach to design, it is more critical that the developed programs perform in accordance with the premises on which they are based than that these premises are completely accurate. In this light, the snow and wind program are correct.

Forty-nine trial runs are included in Appendix D. The first 31 were performed using the snow program, the remaining were performed with the wind program. Each trial is accompanied by a hand-worked solution using the Canadian Farm Building Code, the National Building Code, and the Supplement to the National Building Code (ACNBC, 1983; ACNBC, 1985a; ACNBC, 1985b). In all trials, the program results agree with the hand calculations.

Three aspects of the snow load program should be reviewed. The first deals with how metal roofing materials are dealt with. The program classifies "new" metal as a slippery material and "old" metal as a non-slippery material. Slippery material can result in lower design loads for the roof possessing the slippery covering. Since, in time, a "new" slippery metal roof will become "old" and non-slippery, the lower roof design load is likely inappropriate. This problem cannot be resolved by simply classifying all metal roofs as non-slippery since roof slipperiness also affects the magnitude of sliding snow loads. When designing a lower roof in a multi-level roof situation, it is more conservative to consider an upper metal roof slippery. This can result in a larger slide load on the lower roof - which is the appropriate design load when the upper roof is still "new".

The second aspect warranting further attention in the snow load program is the method by which the roof exposure factor is established. According to the 1985 National Building Code, a 25% reduction in design snow load can be made for certain types and region of roofs if three criteria are met (ACNBC, 1985a). These criteria are listed as : 1) a minimum clearance distance around the building, 2) a maximum allowable roof projection height, and 3) a roof shape which does not promote snow drifting. These criteria are used in the same order in the snow load program to establish whether the exposure reduction is warranted. However, many roofs are ineligible for the reduction solely on the basis of roof shape. Therefore, the efficiency of the program would be improved if the last criterion were examined first. This change would require extensive reformation of the output screens which summarize consultation inputs. This would require considerable time and effort on the part of someone very familiar with the logic and details of the snow load program.

Lastly, the snow program is based solely on the 1985 National Building Code (ACNBC, 1985a). This Code makes no provisions for building use or occupancy level in the determination of design roof snow load values. To be complete, the program should include use and occupancy considerations. These considerations can be found in the 1983 Canadian Farm Building Code (ACNBC, 1983).

The wind program would be improved by two additions - both of which are already present in the snow program. First, the wind load program does not summarize the user's inputs prior to displaying consultation results. The inclusion of input summary screens would help the user interpret the program results and spot any input errors. Secondly, the addition of HELP message is recommended. These messages would be available to the user every time the user is asked a question during a consultation. They could be used to supply information concerning the question being asked and suggest appropriate responses. This would make the program easier to use, especially by users who are less familiar with wind load determination.

7.2 EVALUATION OF PCPLUS

PCPLUS has many features intended to facilitate the development of expert system programs on personal computers (PC). Most, but not all, were used in the development of the snow and wind programs. During the development of these programs, several strengths, weaknesses, and anomalies were detected in PCPLUS.

The strengths of PCPLUS can be grouped into two categories. These categories deal with user acceptance of the developed programs and ease of linkage between the expert system programs and external programs stored on the PC. PCPLUS allows the knowledge engineer to combine colour, text, and graphics to form screens the user will see and possibly interact with. This can result in aesthetically pleasing user interfaces which are highly informative. Graphics can be used to make questions the user is asked more understandable and as an aid in presenting program results. Graphics are easily incorporated into PCPLUS programs from AutoCAD and other software programs. Along with the screen formation features, PCPLUS facilitates the composition and display of HELP messages. These messages are programmed into the ES by the knowledge engineer and appear when requested by the user. While useful in ES programs that aid designers, the true strength of this feature would be most apparent in educational software.

PCPLUS programs can be made to access many types of external programs stored on the computer hard disk. The documentation which accompanies PCPLUS includes specific commands for use in accessing dBASE programs. This documentation is coherent and easy to follow. PCPLUS will access dBASE2, dBASE3, and dBASE3+ files but will not communicate properly with dBASE4. Both the snow and wind programs retrieve information from a dBASE3+ file. The ability to communicate with the database file tremendously reduces the number of rules needed in the knowledge base of either program. However, the access process is rather disruptive to a consultation due to the entry requirements of the database program. This is not a failing of PCPLUS.

A PCPLUS program can also be made to communicate with DOS. If the program requires trigonometric operations, the DOS link is more than convenient - it is a necessity. PCPLUS can not perform trigonometry. The DOS access allows the knowledge engineer to write an external mathematics program, store this program on the computer, and access it from the expert system. The wind program makes use of a mathematics program written in GWBASIC. The connection which takes place during a consultation between the wind program and the GWBASIC program is smooth and quick. The only indication the user has of the connection is that the screen momentarily turns from black to white.

Unfortunately, several disadvantages can also be found in PCPLUS. To the end user of the expert system the most annoying aspects are the relatively slow speed of program execution and the inability to reproduce screen graphics on the printer. PCPLUS was developed using a LISP dialect. LISP languages run very slowly on personal computers (Martin and Oxman, 1989). The snow and wind programs are further slowed by the need to access external programs and retrieve graphics files. Consequently, consultations with either program can take approximately 4 to 15 minutes. The time factor could become a hinderance in programs with larger knowledge bases, more graphic displays, or more external program links.

Graphics could be printed by installing specially formatted graphics files on the computer. These files would then be sent to the printer via a program stored on the computer and accessed through a DOS link to the expert system. Such a process would require considerable work to make it operational and is not really part of the problem solution.

The remaining weaknesses of PCPLUS are related to program development. PCPLUS requires more RAM than is normally available on personal computers. Consequently, a typical PC must be expanded for PCPLUS program development. The computer used in this project contained twice the recommended RAM for PCPLUS. Even with this extra memory, problems due to a lack of memory were common during program development. These problems generally occurred after two hours of uninterrupted programming and resulted in an inability to save the work done during that time. These difficulties were avoided when the program being developed was saved every 60 to 90 minutes and the PCPLUS environment was then exited. This process appears to free the RAM for further use. Compiled versions of ES programs developed in PCPLUS do not require extra RAM.

Other problems arise due to limitations in PCPLUS features. The first such problem is a lack of certain mathematical skills. PCPLUS can perform basic algebraic and exponential operations but cannot perform trigonometry. This is a fairly serious limitation when developing engineering software. The lack can be circumvented by creating mathematical programs which are accessed through the PCPLUS-DOS link. However, this results in extra work for the program developer and slows the speed of consultations.

A second limitation occurs in the facility that allows multiple frames to share a parameter group. This feature was used in the snow load program. Certain parameters shared in this manner were not actually available to all the frames sharing the parameter group. It is believed that the parameters which cannot be shared are ones which are goal parameters for the frames involved. The goal parameters must therefore be moved from the shared parameter group to a frame common to all the frames sharing the parameter group - such as the ROOT frame. This point is not made in the documentation accompanying PCPLUS.

A third limitation occurs with META rules. Misuse of this feature is catastrophic. If a META rule is not properly formatted PCPLUS erases the knowledge base of any frame affected by the META rule. This destroys the expert system program. Unfortunately, the proper formation of META rules is not clearly documented and no warning is given of the possible consequences of misuse. In the wind program, two META rules were incorporated successfully. However, when a third having the same format was added, the program was destroyed. It is not known why this occurred. It is strongly recommended that META rules be used very cautiously and only when a back-up version of the program is available.

The last PCPLUS facility found to require amendments is the REVIEW feature. This feature allows the user of the expert system program to alter any previously entered input to the program and rerun the program with this change. It is also a very useful testing aid during program development. However, PCPLUS cannot be relied upon to trace the effects of the changed input through the remaining portion of the expert system program. Therefore, the person initiating the review must indicate not only the desired input to be changed but also a change in every input and goal parameter which could be affected by the initial change. If the program developer is aware of this requirement, the REVIEW feature can be used successfully. Since the end user of the program is unlikely to be aware of the necessary changes, it is recommended that the user not call up this feature. Misuse of the REVIEW process produces results which are misleading and incorrect.

While limitations in existing PCPLUS facilities can be disruptive, misleading, and even catastrophic, the most hindering aspects to program development using PCPLUS are the lack of certain features. The features missing deal with the ease of program editing and development. Possibly the greatest hinderance is the lack of an 'undo' command. The same key strokes performed at different levels in the editing environment result in very different actions. Consequently, it is easy to accidentally erase a rule or frame when one is attempting to exit it. There are only two courses of action should this accident occur : 1) the lost material can be reprogrammed, or 2) the program can be exited without saving any of the additions or revisions which have been made since it was loaded. The first option normally requires that a hard copy of the program be available. The second option can result in considerable reprogramming.

The second editing feature missing is a truly global change command. If several rules exist in which parameter 'A' is set equal to 1, and the developer wishes to change each rule so that 'A' is set to 2, each rule will have to be entered and individually edited. This is time consuming and error prone. If the developer wishes to change the name of the parameter from 'A' to 'B', PCPLUS will partially facilitate the change. PCPLUS will revise the parameter name in knowledge base rules so long as the name

'B' is not currently defined in the expert system. Also, PCPLUS will only make the revision in the IF and THEN properties of rules. PCPLUS will not revise the parameter name in METHOD statements, PREMISE statements, or any other parameter or program property. The programmer must make these additional changes individually. Failure to do so leads to program errors or failure.

If a frame name is changed, PCPLUS will not make the revision in either the rules or in the memory spaces which define parent-child frame relationships. Once again, the developer must edit the rules individually. The frame revision required is more subtle. If the developer saves the program containing the new frame name under the old program name, the continuity of the program will be disrupted. The next time the program is executed, it will attempt to find the old frame name. Not being able to do so, the program will assume the frame does not exist. This typically results in the termination of a consultation. To avoid this error, the programmer must save the program containing the new frame name under a new program name. For example, if a frame name was altered in a program called SNOW, the program should be saved under a new name, such as SNOW2. This error is particularly hard to discover as it cannot be detected during the editing process. It can only be spotted in printouts of the program. Also, it is an easy error to overlook in the printouts unless one knows what to search for.

The last editing feature missing is a feature that would allow large portions of the program to be copied. PCPLUS facilitates the copying of rule properties from one rule to another. However, the properties can only be copied one at a time. Each property must therefore be copied, edited, and saved individually before the next is retrieved.

Program development would be much faster if entire rules could be copied and if several rules could be copied at a time.

7.3 EVALUATION OF THE EXPERT SYSTEM APPROACH

When selecting a program approach it is crucial that the approach be tailored to the problem at hand. If the problem consists mainly of mathematical analyses, a traditional programming approach is warranted. However, if the problem requires considerable manipulation of concepts and ideas in order to make judgemental decisions, an expert system approach is likely appropriate. Since engineering design problems consist of both problem types, a combination of ES and traditional programming would seem to be most effective. This was attempted in both the snow and wind load programs and appears to be a successful method of solving design problems. The expert system programs govern the design solution. The traditional software components are called upon by the expert system as needed in the solution process.

There are two major advantages to ES governance and hybrid programs. First, the ES component handles the judgemental decisions and keeps track of the criteria which affect each mathematical decision. When a person solves a problem by hand - with or without the use of a traditional computer analysis program - it is up to the person to remember the criteria and make the judgement decisions. This can often be difficult and confusing. When the computer is used to store the criteria and judgement relationships, the chances of error are significantly reduced.

Secondly, the structure of an ES program can be tailored to fit the problem being solved. This gives the ES program flexibility which is missing in traditional programs.

This flexibility supports ES governance of hybrid programs by allowing program execution to vary based on user input information. Also, the ES program can be created with as loose or rigid a structure as is needed by the problem to be solved. If the problem can be broken down into a well ordered series of steps, the expert system program can be made fairly rigid. This can be seen in the snow load program. However, if the solution method varies considerably with the details of the particular problem being examined, the expert system program structure can be made more loose. This can be seen in the wind load program.

Two key points should be reviewed if an expert system approach to programming is being considered. These apply regardless of whether the ES approach is being contemplated by itself or as a hybrid with more traditional programming methods. First, the problem to be solved must be defined, potential solution methods must be identified, and the expertise required to create the program's knowledge base must be sought. This generally means that a human expert in the problem domain be found. This expert will be involved in problem definition and analysis as well as in validating the developed program.

Next, an appropriate design environment must be selected. This means that either a suitable expert system shell must be found or a programming language must be selected. If a shell is used, the shell must possess graphic features, external linkage abilities, and knowledge base development features which are appropriate for the problem, the knowledge engineer, and the end user. If a program is to be developed using a language, the knowledge engineer's work will be tremendously increased. The developer will be required to produce not only a knowledge base, but also inference mechanisms, screen generators, and other features which are contained in expert system shells. This approach is therefore considerably more time consuming and difficult, but it provides a means by which shell limitations can be avoided.

8. CONCLUSIONS

The following conclusions were reached during the development of the snow and wind design load programs discussed herein.

1) ES can perform judgemental decisions required in engineering design problems.

2) ES can be developed to work independently or as hybrids which communicate with external programs and data files.

3) ES shells facilitate program development but have limitations which restrict their range of application. Restrictions can result from the lack of shell features, speed of program execution, or unusual hardware requirements.

4) An ES shell should be selected on the basis of the problem to be solved, the skills of the knowledge engineer, and the needs of the end user. Four key shell characteristics should be reviewed :

- the ease of graphics incorporation,
- the screen formation features,
- the ease of knowledge base entry and management, and
- the ease of external access to other programs and data files.

BIBLIOGRAPHY

ACNBC, 1965a, National Building Code of Canada 1965, Part 4, 3rd Printing, National Research Council, Ottawa, ON, Canada

ACNBC, 1965b, Supplement No. 3 to the National Building Code of Canada 1965, National Research Council of Canada, Ottawa, ON, Canada

ACNBC, 1970a, National Building Code of Canada 1970, 2nd Printing, National Research Council, Ottawa, ON, Canada

ACNBC, 1970b, Supplement No. 4 to the National Building Code of Canada 1970, National Research Council of Canada, Ottawa, ON, Canada

ACNBC, 1975a, National Building Code of Canada 1975, National Research Council, Ottawa, ON, Canada

ACNBC, 1975b, Supplement No. 4 to the National Building Code of Canada 1975, National Research Council of Canada, Ottawa, ON, Canada

ACNBC, 1977, National Building Code of Canada 1975, National Research Council, Ottawa, ON, Canada

ACNBC, 1980, The Supplement to the National Building Code of Canada 1980, National Research Council, Ottawa, ON, Canada

ACNBC, 1983, Canadian Farm Building Code 1983, National Research Council, Ottawa, ON, Canada

ACNBC, 1985a, National Building Code of Canada 1985, National Research Council, Ottawa, ON, Canada

ACNBC, 1985b, Supplement No. 4 to the National Building Code of Canada 1985, National Research Council of Canada, Ottawa, ON, Canada

Barrett, J.R. and C.H. Castore, 1989, "Decision making and decision support", in Knowledge Engineering in Agriculture, eds. J.R. Barrett and D.D. Jones, ASAE, Michigan, USA, p. 13-19

Bennett, Richard M., 1988, "Snow load factors for LRFD", Journal of Structural Engineering, ASCE, Vol. 114, No. 2, p. 2371-2383

Blackmore, P.A., 1988, "Load reduction on flat roofs - the effect of edge profile", Journal of Wind Engineering and Industrial Aerodynamics, Vol. 29, p. 89-90

Britton, M.G., 1989a, Knowledge Aided Design - A feasibility study report on the application of artificial intelligence to Engineering, submitted to PRECARN Associates by Spar Aerospace Limited, Canadian Marconi Company, Bristol Aerospace Limited, University of Toronto, University of Manitoba, Ecole Polytechnique of Montreal, and the University of Calgary, section 3.7, p. 68-74

Britton, M.G.,1989b, Personal correspondence

Engel, B.A., R.H. Thieme, and A.D. Whittaker, 1989, "Representation and reasoning", in Knowledge Engineering in Agriculture, eds. J.R. Barrett and D.D. Jones, ASAE, Michigan, USA, p. 47-76

Holmes, J.D., 1988, "Distribution of peak wind loads on a low-rise building", Journal of Wind Engineering and Industrial Aerodynamics, Vol. 29, p. 59-67

Holt, D.A., 1989, "The growing potential of expert systems in agriculture", in Knowledge Engineering in Agriculture, eds. J.R. Barrett and D.D. Jones, ASAE, Michigan, USA, p. 1-11

Jones, D.D. and J.R. Barrett, 1989, "Building Expert Systems", in Knowledge Engineering in Agriculture, eds. J.R. Barrett and D.D. Jones, ASAE, Michigan, USA, p. 21-31

Koen, Billy Vaughn, 1985, Definition of the Engineering Method, American Society for Engineering Education, Washington, D.C., USA

Martin, James and Steven Oxman, 1988, Building Expert Systems - A Tutorial, Prentice Hall, New Jersey, USA

Mehta, Kishor C., 1984, "Wind induced damage observations and their implications for design practice", Engineering Structures, Vol. 6, No. 4, p. 242-247

O'Rourke, Michael, 1989 "Roof collapse under snowdrift loading and snowdrift design criteria (a discussion)", Journal of the Performance of Constructed Facilities, ASCE, Vol. 3, No. 4, p. 266-268

O'Rourke, Michael, Robert Redfield, and Peter von Bradsky, 1982, "Uniform snow loads on structures", Journal of the Structural Division, Proceedings of the American Society of Civil Engineers, ASCE, Vol. 108, No. ST12, p. 2781-2798

O'Rourke, Michael, Robert S. Speck Jr., and Ulrich Stiefel, 1985, "Drift snow loads on multilevel roofs", Journal of Structural Engineering, ASCE, Vol. 111, No. 2, p.290-306

O'Rourke, Michael, Wayne Tobiasson, and Evelyn Wood, 1986, "Proposed code provisions for drift snow loads", Journal of Structural Engineering, ASCE, Vol. 112, No. 9, p. 2080-2092

O'Rourke, Michael and Evelyn Wood, 1986, "Improved relationship for drift loads on buildings", Canadian Journal of Civil Engineering, NRC, Vol. 13, p. 647-652

Robertson, A.P., 1988, "Codification of local pressure coefficients for low-rise structures", Journal of Wind Engineering and Industrial Aerodynamics, Vol. 30, p. 143-152

Sack, R.L., 1988, "Snow loads on sloped roofs", Journal of Structural Engineering, ASCE, Vol. 114, No. 3, p. 501-517

Sack, Ronald L., 1989, "Designing structures for snow loads", Journal of Structural Engineering, ASCE, Vol. 155, No. 2, p. 303-315

Sparks, P.R., M.L. Hessig, J.A. Murden, and B.L. Sill, 1988, "On the failure of single-story wood-framed houses in severe storms", Journal of Wind Engineering and Industrial Aerodynamics, Vol. 29, p. 245-252

Stathopoulos, Theodore, 1984, "Wind loads on low-rise buildings : a review of the state of the art", Engineering Structures, Vol. 6, p. 119-135

Taylor, D.A., 1985, "Snow loads on sloping roofs : two pilot studies in the Ottawa area", Canadian Journal of Civil Engineering, NRC, Vol. 12, p. 334-343

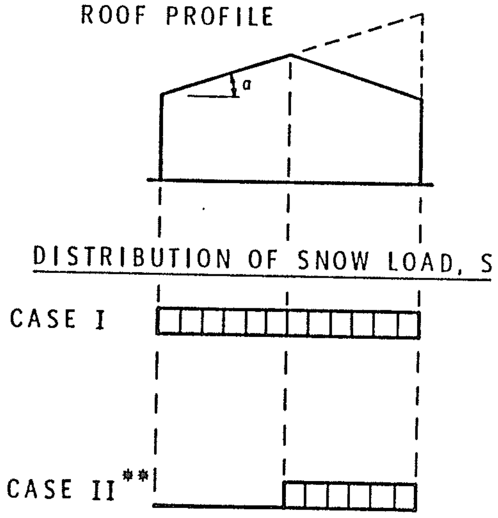
Templin, J.T. and W.R. Schriever, 1981, "Loads due to drifted snow", Journal of the Structural Division, Proceedings of the American Society of Civil Engineering, ASCE, Vol. 12, No. ST8, p. 1916-1925

Texas Instruments Incorporated, 1988, <u>Personal Consultant Plus - Reference Guide, Site License Version</u>, Publishing Center Texas Instruments Incorporated Data Systems Group, Austin, Texas, USA

Whittaker, A.D., D.D. Jones, R.H. Thieme, and J.R. Barrett, 1987, "Guidelines for getting started with expert systems", Agricultural Engineering, July/August, p. 24-27

APPENDIX A

NATIONAL BUILDING CODE FIGURES AND TABLES FOR USE IN DETERMINING DESIGN ROOF SNOW LOAD VALUES FOR FIVE SIMPLE STRUCTURES



LOAD CASE	ROOF SLOPE α	FACTORS		
		C_w	C_s	C_a
I	$0° \le \alpha \le 90°$	0.75 OR 1.0	$f(\alpha)$*	1.0
II	$\le 15°$ $15° < \alpha \le 20°$ $20° < \alpha \le 30°$ $30° < \alpha \le 90°$	1.0 1.0 1.0 1.0	1.0 1.0 1.0 $f(\alpha)$*	0 $0.25 + \alpha/20$ 1.25 1.25

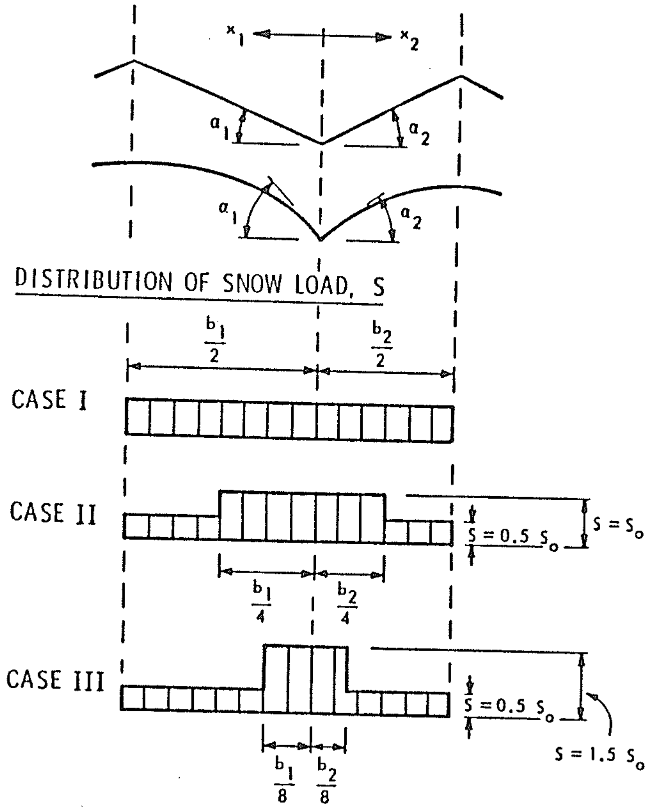
BR 6470-5

Figure H-1 Snow distributions and snow loading factors for gable, flat and shed roofs

Notes to Figure H-1:

*Varies as a function of slope α as defined in NBC Sentence 4.1.7.1.(4).

**The Case II loading does not apply to single-sloped (shed) roofs.

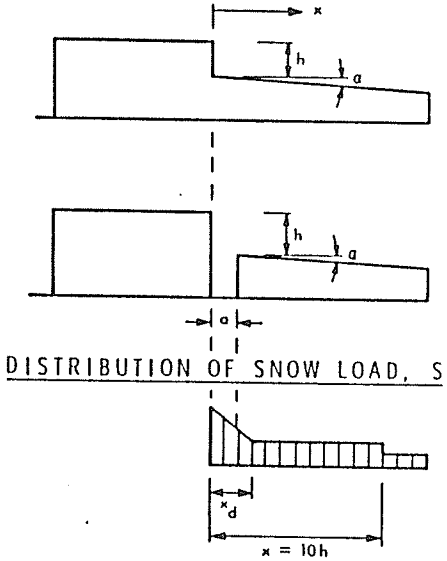


LOAD CASE	ROOF SLOPE α	FACTORS		
		C_w	C_s	C_a
I	$\alpha \leq 90°$	0.75 OR 1.0	$f(\alpha)$*	1.0
II	$10° < \alpha \leq 90°$	1.0	1.0	For $0 < x \leq b/4$: $C_a = 1.25$ For $b/4 < x \leq b/2$: $C_a = 0.625$
III	$10° < \alpha \leq 90°$	1.0	1.0	For $0 < x \leq b/8$: $C_a = 1.875$ For $b/8 < x \leq b/2$: $C_a' = 0.625$

BR 6470-7

Figure II-3 Snow distributions and snow loading factors for valley areas of roofs

Note to Figure II-3:
*Varies as a function of slope α as defined in NBC Sentence 4.1.7.1.(4).



Value of x_d:

$x_d = 2\,h$ but $3\ m \le x_d \le 9\ m$

Value of C_{ao}:

$$C_{ao} = \frac{1.25\,\gamma h}{S_o}$$

when $C_{ao} < 1.0$ use 1.0, when $C_{ao} > 3.75$ use 3.75

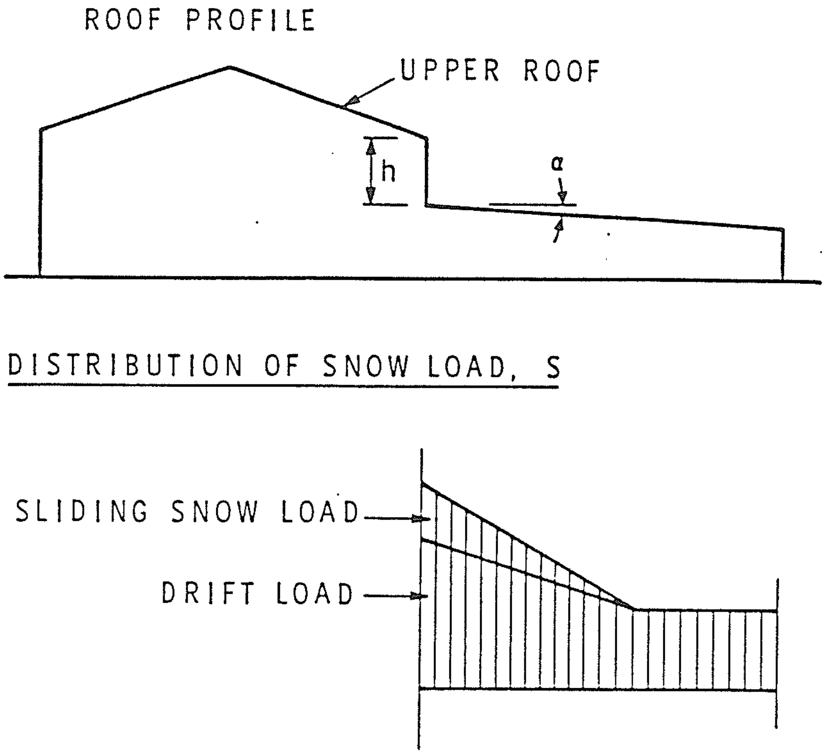
x	FACTORS		
	C_w	C_s	C_a **
0	1.0	$f(\alpha)$*	C_{ao}
$0 < x \le x_d$	1.0	$f(\alpha)$*	$C_{ao} - \frac{(C_{ao} - 1)x}{x_d}$
$x_d < x \le 10h$	1.0	$f(\alpha)$*	1.0
> 10h	0.75 OR 1.0	$f(\alpha)$*	1.0

BR 6470-8

Figure H-4 Snow distributions and snow loading factors for lower levels of adjacent roofs

Note to Figure H-4:

*Varies as a function of slope α as defined in NBC Sentence 4.1.7.1.(4).



LOWER ROOF is designed for drift load (See Figures H-3 and H-4) + sliding snow load (See text of this Commentary) UPPER ROOF is designed in accordance with NBC Subsection 4.1.7. (See Figures H-1 and H-2)

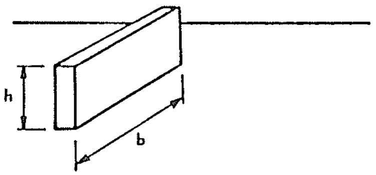
BR 6470-9

Figure H-5 Snow distributions on lower roof with sloping upper roof

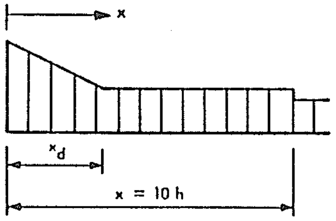
Notes to Figure H-5:

Lower roof is designed for drift load (see Figures H-3 and H-4) + sliding snow load (see text of this Commentary).
Upper roof is designed in accordance with NBC Subsection 4.1.7. (See Figures H-1 and H-2.)

ROOF PROJECTION



DISTRIBUTION OF SNOW LOAD, S



b, metres	x	FACTORS		
		C_w	C_s	C_a
$\leq S_o$ IN kPa**	ALL	0.75 OR 1.0	f(α)*	1.0
$> S_o$ IN kPa	0	0.75 OR 1.0	f(α)*	C_{ao}
$> S_o$ IN kPa	$0 < x \leq x_d$	1.0	f(α)*	$C_{ao} - \frac{(C_{ao} - 1)x}{x_d}$
$> S_o$ IN kPa	$x_d < x \leq 10\,h$	1.0	f(α)*	1.0
	$> 10\,h$	0.75 OR 1.0	f(α)*	1.0

BR 6470-10

Value of x_d:

$x_d = 2\,h$ but $3\text{ m} \leq x_d \leq 9\text{ m}$

Value of C_{ao}:

$$C_{ao} = \frac{0.8\,\gamma\,h}{S_o}$$

when $C_{ao} < 1.0$ use 1.0, when $C_{ao} > 2.5$ use 2.5

Figure II-6 Snow distribution and snow loading factors for areas adjacent to roof projections

Notes to Figure II-6:

*Varies as a function of slope α as defined in NBC Sentence 4.1.7.1 (4)

**If b is less than S_o, metres the effect of the obstruction on the snow loading can be ignored.

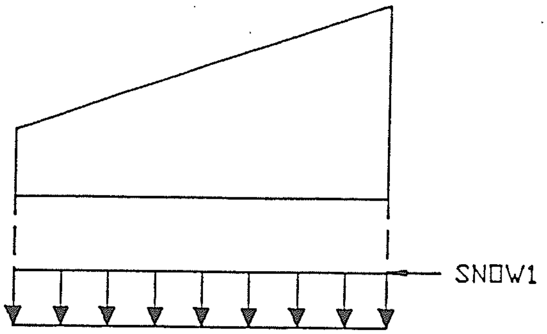
APPENDIX B

EXAMPLES OF OUTPUT SCREENS USED IN THE SNOW LOAD EXPERT SYSTEM PROGRAM

SHED

CASE 1:-

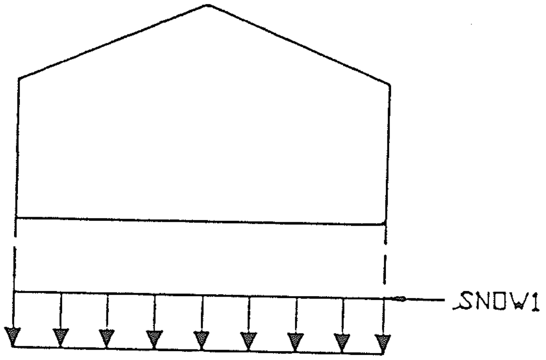
uniform loading



GABLE

CASE 1:-

uniform loading



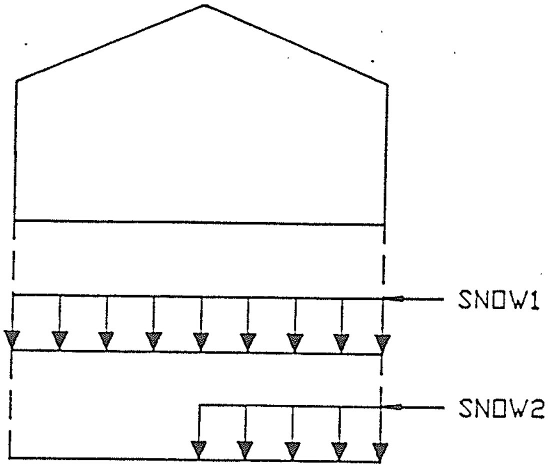
GABLE

CASE 1:-

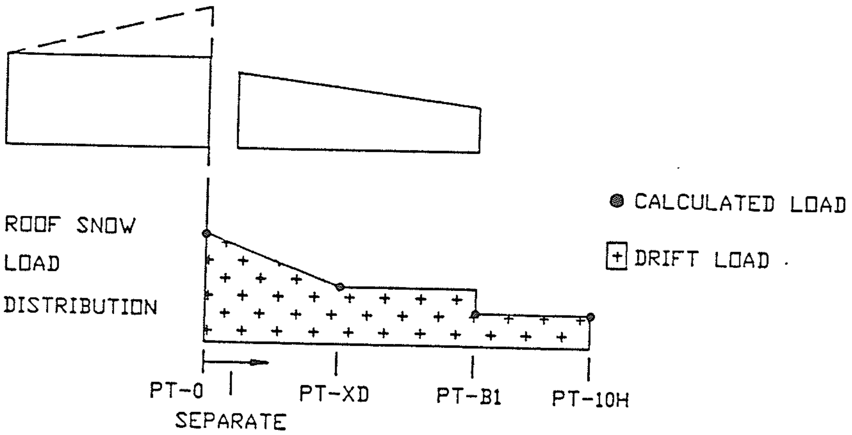
uniform loading

CASE 2 :-

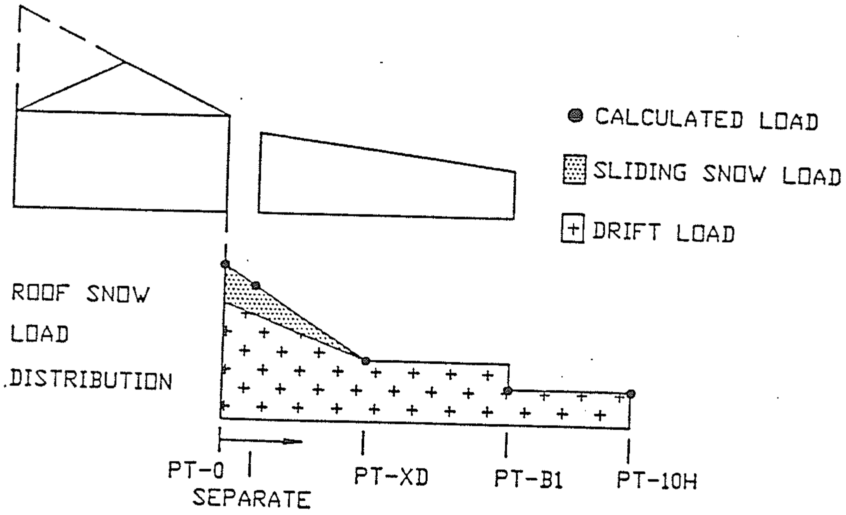
partial loading



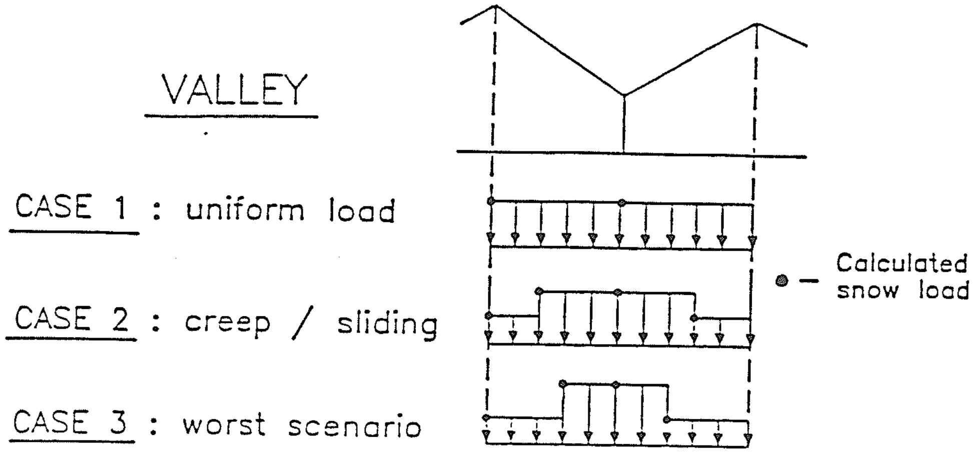
LOWER ROOF NEXT TO FLAT BLD OR RIGHT OPENING SHED



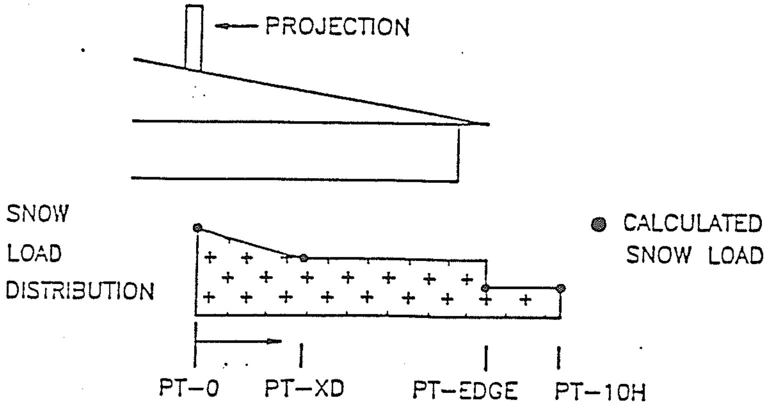
LOWER ROOF NEXT TO GABLE OR LEFT OPENING SHED



VALLEY



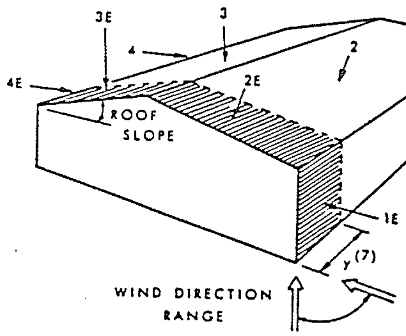
SNOW LOAD NEXT TO PROJECTION



APPENDIX C

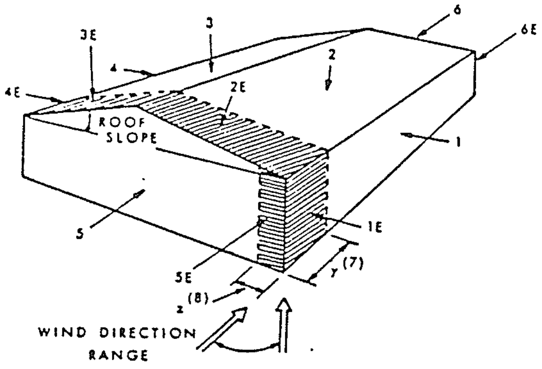
NATIONAL BUILDING CODE FIGURES AND TABLES FOR USE IN DETERMINING DESIGN WIND LOAD VALUES FOR LOW-RISE GABLE STRUCTURES

LOAD CASE A: WINDS GENERALLY PERPENDICULAR TO RIDGE



ROOF SLOPE	BUILDING SURFACES							
	1	1E	2	2E	3	3E	4	4E
0 TO 5°	0.75	1.15	-1.3	-2.0	-0.7	-1.0	-0.55	-0.8
20°	1.0	1.5	-1.3	-2.0	-0.9	-1.3	-0.8	-1.2
30 TO 45°	1.05	1.3	0.4	0.5	-0.8	-1.0	-0.7	-0.9
90°	1.05	1.3	1.05	1.3	-0.7	-0.9	-0.7	-0.9

LOAD CASES B: WINDS GENERALLY PARALLEL TO RIDGE



CASE	ROOF SLOPE	BUILDING SURFACES											
		1	1E	2	2E	3	3E	4	4E	5	5E	6	6E
B1	0 TO 90°	0	0	-1.3	-2.0	-0.7	-1.0	0	0	0.75	1.15	-0.55	-0.8
B2	≥ 20°	-0.85	-0.9	-1.3	-2.0	-0.7	-1.0	-0.85	-0.9	0	0	0	0

BR 5911-17

Figure B-6

External peak pressure coefficients, C_pC_g, for primary structural actions arising from wind loads acting simultaneously on all surfaces

Notes to Figure B-6

(1) The building must be designed for *all* wind directions. Each corner must be considered in turn as the windward corner shown in the sketches. For all roof slopes, Case A and Case B1 are required as 2 separate loading conditions to generate the wind actions, including torsion, to be resisted by the structural system. If the roof slope is 20° or more, a third loading condition B2 is also required as provided for by the second line of Case B.

(2) For values of roof slope not shown, the coefficient (C_pC_g) may be interpolated linearly.

(3) Positive coefficients denote forces toward the surface whereas negative coefficients denote forces away from the suface.

(4) Interior pressure coefficients C_{pi} are given in Figure B-11.

(5) The reference height H for pressures is mid-height of the roof or 6 m, whichever is larger. The eave height may be substituted for the mean height if he slope of the roof is less than 10°.

(6) For the design of foundations, but exclusive of anchorages to the frame, only 70 per cent of the effective load is to be considered.

(7) End zone width "y" should be the greater of 6 m or 2 z where "z" is the gable wall end zone defined for Case B below. Alternatively, for buildings with frames, the end zone "y" may be the distance between the end and the first interior frame.

(8) End zone width "z" is the lesser of 10 per cent of the least horizontal dimension or 40 per cent of height H, except that "z" must be at least 4 per cent of the horizontal dimension and at least 1 m.

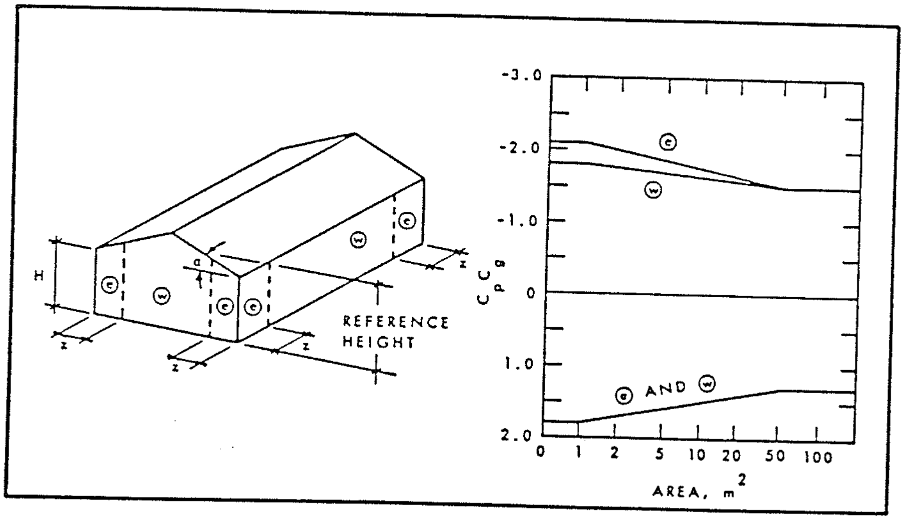


Figure B-7

BR 5911-19

External peak pressure coefficients, C_pC_g, on individual walls and for the design of cladding and secondary structural members

Notes to Figure B-7:

(1) These coefficients apply for any roof slope, α.

(2) The abscissa area in the graph is the design tributary area within the specified zone.

(3) z = 10 per cent of least horizontal dimension or 40 per cent of height, H, whichever is less. Also $z \geqq 1$ m, $z \geqq 4$ per cent of least horizontal dimension.

(4) Interior pressure coefficients C_{pi} are given in Figure B-11.

(5) The eave height may be substituted for the reference height (mean height) if the angle of the roof is less than 10°.

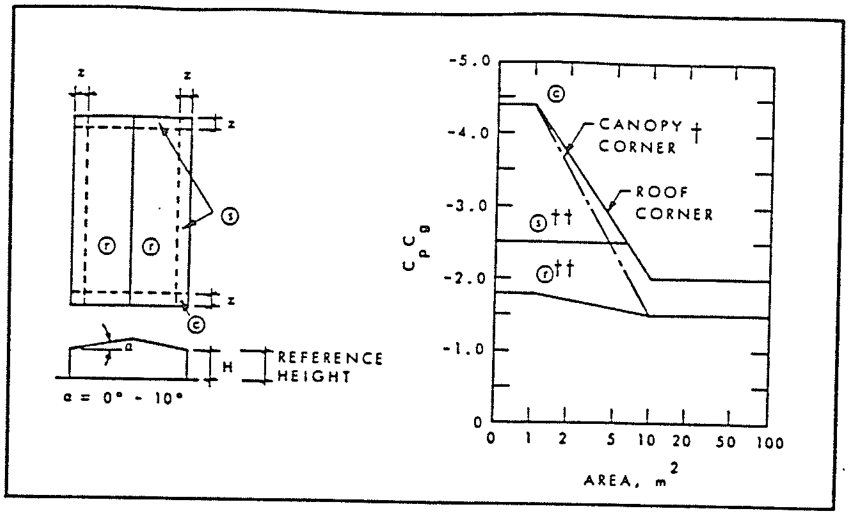


Figure B-8

BR 5911-20

External peak pressure coefficients, C_pC_g, on roofs of 10° slope or less for design of cladding and secondary structural members

Notes to Figure B-8:

(1) † canopy coefficients include contributions from both upper and lower surfaces.

(2) †† s and r are applicable to both roofs and canopies.

(3) The abscissa area in the graph is the design tributary area within the specified zone.

(4) $z = 10$ per cent of least horizontal dimension or 40 per cent of height, H, whichever is less. Also $z \geqq 1$ m, $z \geqq 4$ per cent of least horizontal dimension.

(5) Interior pressure coefficients C_{pi} are given in Figure B-11.

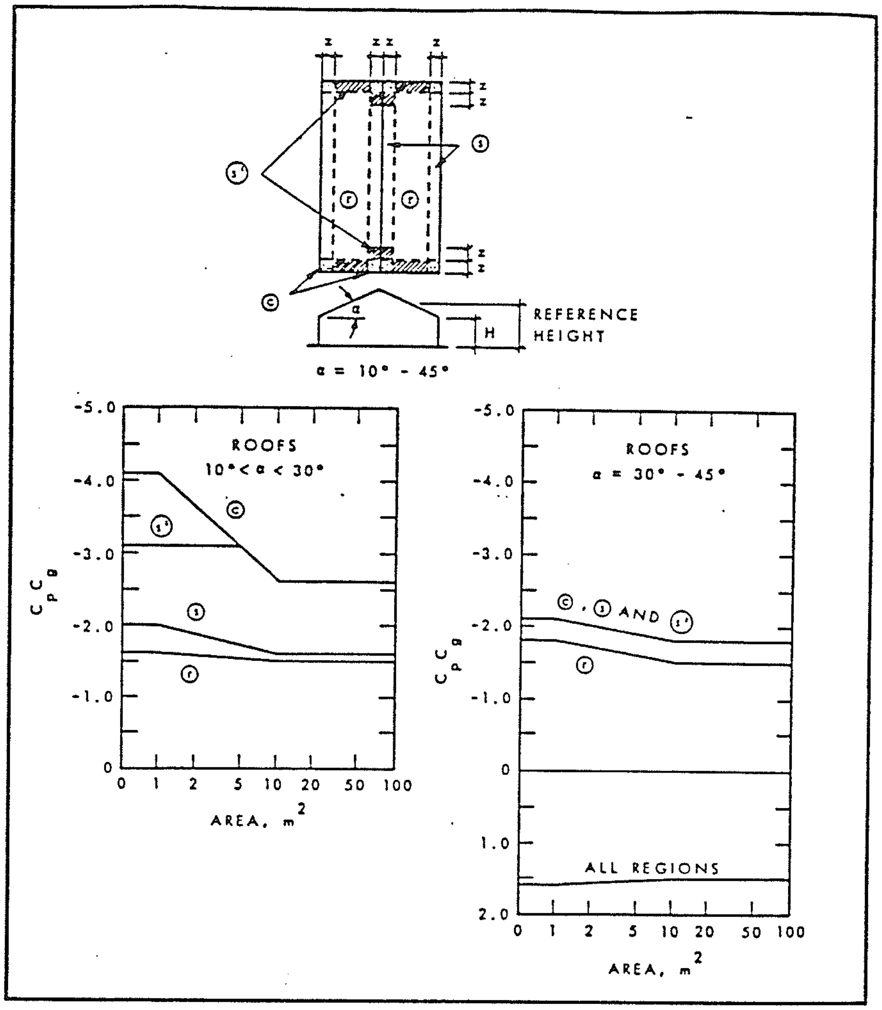


Figure B-9

BR 5911-18

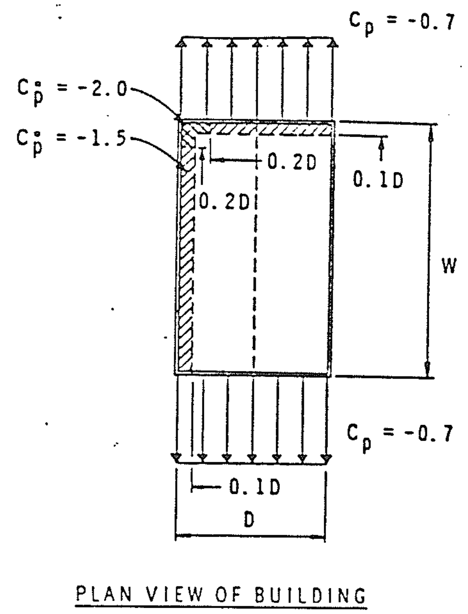
External peak pressure coefficients C_pC_g, on roofs of greater than 10° slope for design of cladding and secondary structural members

Notes to Figure B-9:

(1) The abscissa area in the graph is the design tributary area within the specified zone.

(2) z = 10 per cent of least horizontal dimension or 40 per cent of height, H, whichever is less. Also z ≧ 1 m, z ≧ 4 per cent of least horizontal dimension.

(3) Interior pressure coefficients C_{pi} are given in Figure B-11.



INTERIOR PRESSURES	C_{pi}
1. Openings mainly in windward wall.	+0.7
2. Openings mainly in leeward wall.	-0.5
3. Openings mainly in walls parallel to wind direction.	-0.7
4. Openings uniformly distributed in all 4 walls.	-0.3

Figure B-11 BR 4314-6

End wall pressure coefficients, local suction maxima on the roof and interior pressures for use with Figures B-6 to B-10

Notes to Figure B-11:

(1) Local maximum suctions: the coefficients C_p^* for the roof surface occur for wind at an angle to one corner, and are used in the design of the roofing itself and its anchorage to the structure. C_p^* are not to be added to the C_p for determining total uplift on the roof.

(2) End walls: the end walls are the ones parallel to the wind direction and have a uniform pressure distribution over the whole building height, except for local maximum suction as indicated in Figure B-10.

(3) Reference height for exposure factor: for the calculation of external pressures on end walls use H, the total height of the building. For the calculation of internal pressures, use ½ H unless there are dominant openings in the windward wall, in which case use Z, the height to the highest such opening.

APPENDIX D

VALIDATION RUNS OF SNOW LOAD AND WIND LOAD EXPERT SYSTEM PROGRAMS

TEST	LOCATION	ROOF	ANGLE	EXPOSED	PROJECTION	ROOFING
1	Revelstoke, BC	shed	3:12	no	/	asphalt shingles
2	Winnipeg, MB	shed	3:12	no	/	asphalt shingles
3	Winnipeg, MB	shed	14.04°	no	/	asphalt shingles
4	Winnipeg, MB	shed	20°	no	/	asphalt shingles
5	Winnipeg, MB	shed	20°	yes	no	asphalt shingles
6	Winnipeg, MB	shed	20°	yes	0.5 m	asphalt shingles
7	Winnipeg, MB	shed	20°	yes	1.0 m	asphalt shingles
8	Winnipeg, MB	gable	14.04°	yes	no	asphalt shingles
9	Winnipeg, MB	gable	20°	yes	no	asphalt shingles
10	Winnipeg, MB	gable	45°	yes	no	asphalt shingles
11	Winnipeg, MB	gable	20°	yes	0.5 m	asphalt shingles
12	Winnipeg, MB	gable	20°	yes	1.0 m	asphalt shingles
13	Winnipeg, MB	gable	20°	no		asphalt shingles
14	Winnipeg, MB	gable	20°	no		glass

Test 1:

Shed in Revelstoke, BC. Roof rise:run = 3:12.
Sheltered location, asphalt-shingle roof

$S_o = 4.6$ KPa
$C_B = 0.8$
not exposed → $C_w = 1.0$
roof non-slippery, $a < 30°$ → $C_s = 1.0$
case 1 → $C_a = 1.0$
case 2 → not applicable

case 1: $S_1 = 4.6(0.8)(1.0)(1.0)(1.0)$ $\underline{S_1 = 3.68 \text{ KPa}}$

case 2: not applicable to sheds

Test 2:

Shed in Winnipeg, MB. Roof rise:run = 3:12, sheltered location, asphalt-shingle roof

$S_o = 2.1$ KPa
$C_B = 0.8$
not exposed → $C_w = 1.0$
roof non-slippery, $a < 30°$ → $C_s = 1.0$
case 1 → $C_a = 1.0$
case 2 → not applicable to sheds

case 1 : $S_1 = (2.1)(0.8)(1)(1)(1)$ $\underline{S_1 = 1.68 \text{ KPa}}$

case 2 : not applicable

Test 3:

Shed in Winnipeg; Roof angle = 14.04°, Sheltered location, asphalt shingle roof.

$S_o = 2.1$ KPa, $C_B = 0.8$
not exposed → $C_w = 1.0$
non slippery → $C_s = 1.0$
case 1 → $C_a = 1.0$
case 2 → not applicable to sheds

case 1 : $S_1 = (2.1)(0.8)(1)(1)(1)$ $\underline{S_1 = 1.68 \text{ KPa}}$

TEST 4:

Shed in Winnipeg, MB Angle = 20°, Non-exposed site, asphalt-shingle roof

$S_o = 2.1$ KPa , $C_B = 0.8$
non-exposed → $C_w = 1.0$
non-slippery → $C_s = 1.0$
case 1 → $C_a = 1.0$
case 2 → not applicable to sheds

$S_1 = 2.1(0.8)(1)(1)(1)$ $\underline{S_1 = 1.68 \text{ KPa}}$

TEST 5:

Shed in Winnipeg, MB. Roof angle = 20°, Exposed site, no roof projection, asphalt-shingle roof

$S_o = 2.1$ KPa , $C_B = 0.8$

case 1 - exposed, no projection → $C_w = 0.75$
non-slippery, $a < 30°$ → $C_s = 1.0$
$C_a = 1.0$

case 2 - not applicable

$S_1 = 2.1(0.8)(0.75)(1)(1)$ $\underline{S_1 = 1.26 \text{ KPa}}$

TEST 6:

Shed in Winnipeg, MB. Angle = 20°, exposed, roof projection height = 0.5 m, asphalt shingle roof

$S_o = 2.1$ KPa , $C_B = 0.8$

case 1 - exposed, proj. ht $< \frac{S_o}{4}$ → $C_w = 0.75$
non slippery, $a < 30°$ → $C_s = 1.0$
$C_a = 1.0$

case 2 - not applicable to sheds

$S_1 = 2.1(0.8)(0.75)(1)(1)$ $\underline{S_1 = 1.26 \text{ KPa}}$

TEST 7:

Shed in Winnipeg MB. Angle = 20°, exposed site, projection height = 1.0 m, asphalt shingle roof

So = 2.1 KPa, CB = 0.8

case 1 - proj. ht > $\frac{So}{4}$ → Cw = 1.0

non-slippery, a < 30° → Cs = 1.0
Ca = 1.0

case 2 - not applicable.

S_1 = 2.1 (0.8)(1)(1)(1) $\underline{S_1 = 1.68 \text{ KPa}}$

TEST 8

Gable in Winnipeg MB, Angle = 14.04°, exposed site, no projections, asphalt shingle roof

So = 2.1 KPa, CB = 0.8

shape ⇒ drifting → Cw = 1.0
non-slippery, a < 30° → Cs = 1.0
case 1 → Ca = 1.0
case 2 - not applicable since a < 15°

S_1 = 2.1 (0.8)(1.0)(1.0)(1.0) $\underline{S_1 = 1.68 \text{ KPa}}$

TEST 9

Gable in Winnipeg, Angle = 20°, exposed site, no roof projections, asphalt-shingle roof.

So = 2.1 KPa, CB = 0.8

case 1 → drifting → Cw = 1.0
nonslippery → Cs = 1.0
Ca = 1.0 $\underline{S_1 = 1.68 \text{ KPa}}$

case 2 → Cw = 1.0
Cs = 1.0
Ca = 1.25 $\underline{S_2 = 2.1 \text{ KPa}}$

TEST 10:

Gable in Winnipeg, Angle = 45°, exposed site, no roof projections, asphalt shingle roof

$S_o = 2.1$ KPa , $C_B = 0.8$

case 1 : drifting → $C_w = 1.0$
non slippery , $a > 30°$ → $C_s = 1 - \left(\frac{a-30}{40}\right)$
$C_s = 0.625$
$C_a = 1.0$

$S_1 = 2.1(0.8)(1.0)(0.625)(1.0)$ $\underline{S_1 = 1.05 \text{ KPa}}$

case 2 : $C_w = 1.0$
$C_s = 0.625$
$C_a = 1.25$

$S_2 = 2.1(0.8)(1.0)(0.625)(1.25)$ $\underline{S_2 = 1.3125 \text{ KPa}}$

TEST 11

Gable in Winnipeg, Angle = 20°, exposed site, roof projection height = 0.5 m, asphalt shingle roof

$S_o = 2.1$ KPa
$C_B = 0.8$

case 1 : drifting → $C_w = 1.0$
nonslippery, $a < 30°$ → $C_s = 1.0$
$C_a = 1.0$

$S_1 = 2.1(0.8)(1.0)(1.0)(1.0)$ $\underline{S_1 = 1.68 \text{ KPa}}$

case 2 : $C_w = 1.0$
non-slippery , $a < 30$ → $C_s = 1.0$
$C_a = 1.25$

$S_2 = 2.1(0.8)(1.0)(1.0)(1.25)$ $\underline{S_2 = 2.1 \text{ KPa}}$

TEST 12

Gable in Winnipeg, Angle = 20°, exposed, roof projection height = 1.0 m, asphalt shingle roof

$S_o = 2.1$ KPa
$C_B = 0.8$

case 1 : proj. ht > $\frac{S_o}{4}$ → $C_w = 1.0$
nonslippery, $a < 30°$ → $C_s = 1.0$
$C_a = 1.0$

$S_1 = 2.1(0.8)(1)(1)(1)$ $\underline{S_1 = 1.68 \text{ KPa}}$

case 2 : $C_w = 1.0$
$C_s = 1.0$
$C_a = 1.25$

$S_2 = 2.1(0.8)(1)(1)(1.25)$ $\underline{S_2 = 2.1 \text{ KPa}}$

TEST 13

Gable in Winnipeg, Angle = 20°, non-exposed site, asphalt shingle roof

$S_o = 2.1$ KPa
$C_B = 0.8$

case 1 – non-exposed → $C_w = 1.0$
non-slippery, $a < 30°$ → $C_s = 1.0$
$C_a = 1.0$

$S_1 = (2.1)(0.8)(1)(1)(1)$ $\underline{S_1 = 1.68 \text{ KPa}}$

case 2 – $C_w = 1.0$
$C_s = 1.0$
$C_a = 1.25$

$S_2 = (2.1)(0.8)(1)(1)(1.25)$ $\underline{S_2 = 2.1 \text{ KPa}}$

TEST 14.

Gable in Winnipeg, Roof angle = 20°, non-exposed site, glass roof

$S_o = 2.1$ KPa
$C_3 = 0.8$

case 1 – non-exposed → $C_w = 1.0$
slippery, → $C_s = 1.0 - \left(\frac{a-15}{55}\right)$
$C_s = 0.9091$
$C_a = 1.0$

$S_1 = 2.1(0.8)(1.0)(.9091)(1.0)$ $\underline{S_1 = 1.527 \text{ KPa}}$

case 2 . $C_w = 1.0$
$C_s = 1.0$
$C_a = 1.25$

$S_2 = 2.1(0.8)(1)(1)(1.25)$ $\underline{S_2 = 2.1 \text{ KPa}}$

TEST	LOCATION	ROOF	A_1	A_2	B_1	B_2	EXPOSED	ROOFING
15	Winnipeg, MB	valley	8°	5°	20m	30m	yes	asphalt shingles
16	Winnipeg, MB	valley	20°	5°	20m	30m	yes	asphalt shingles
17	Winnipeg, MB	valley	20°	10°	20m	30m	yes	asphalt shingles

TEST 15

Valley roof in Winnipeg, MB A1 = 8°, A2 = 5°, B1 = 20 m, B2 = 30 m
exposed site, no roof projections, asphalt shingles

$S_o = 2.1$ KPa
$C_B = 0.8$
case 2 + 3 not applicable due to shallowness of roofs

case 1 : left side $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.0$

$S_L = 2.1\,(0.8)(0.75)(1)(1)$ $\underline{S_L = 1.26 \text{ KPa}}$

right side $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.0$ $\underline{S_R = 1.26 \text{ KPa}}$

TEST 16

Valley in Winnipeg, A1 = 20°, A2 = 5°, B1 = 20 m, B2 = 30 m
exposed site, no roof projections, asphalt-shingles.

$S_o = 2.1$ KPa
$C_B = 0.8$

case 1 - left side $C_w = 0.75$, $C_s = 1.0$, $C_a = 1.0$ $\underline{S_L = 1.26 \text{ KPa}}$

- right side $C_w = 0.75$, $C_s = 1.0$, $C_a = 1.0$ $\underline{S_R = 1.26 \text{ KPa}}$

case 2 - a : $C_w = 0.75$
$C_s = 1.0$
$C_a = 0.625$ $\underline{S_a = 1.05 \text{ KPa}}$

b : $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.25$ $\underline{S_b = 2.1 \text{ KPa}}$

c : $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.25$ $\underline{S_c = 2.1 \text{ KPa}}$

d : $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.25$ $\underline{S_d = 1.05 \text{ KPa}}$

case 3 - a $C_w = 0.75$
$C_s = 1.0$
$C_a = 0.625$ <u>$S_a = 1.05$ kPa</u>

b $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.875$ <u>$S_b = 3.15$ kPa</u>

c $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.875$ <u>$S_c = 3.15$ kPa</u>

d $C_w = 0.75$
$C_s = 1.0$
$C_a = 0.625$ <u>$S_d = 1.05$ kPa</u>

<u>TEST 17</u>

Valley in Winnipeg, $A1 = 20°$, $A2 = 40°$, $B1 = 20$ m, $B2 = 30$ m, exposed site, no roof projections, asphalt shingle roof

$S_o = 2.1$ kPa
$C_B = 0.8$

case 1 - left $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.0$ <u>$S_L = 1.26$ kPa.</u>

right $C_w = 0.75$
$C_s = 1 - \left(\frac{40-30}{40}\right) = 0.75$
$C_a = 1.0$. <u>$S_R = 0.945$ kPa</u>

case 2 - a $C_w = 0.75$
$C_s = 1.0$
$C_a = 0.625$ <u>$S_a = 1.05$ kPa</u>

b $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.25$ <u>$S_b = 2.1$ kPa</u>

c $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.25$ <u>$S_c = 2.1$ kPa</u>

d $C_w = 0.75$
$C_s = 1.0$
$C_a = 0.625$ <u>$S_d = 1.05$ kPa</u>

case 3 - a Cw = 0.75
Cs = 1.0
Ca = 0.625
Sa = 1.05 KPa

b Cw = 0.75
Cs = 1.0
Ca = 1.875
Sb = 3.15 KPa

c Cw = 0.75
Cs = 1.0
Ca = 1.875
Sc = 3.15 KPa

d Cw = 0.75
Cs = 1.0
Ca = 0.625
Sd = 1.05 KPa

MULTI-LEVEL ROOF TESTS - NO SLIDING FROM UPPER TO LOWER ROOF

- ALL TESTS FOR WINNIPEG LOCATION

TEST	UPPER ROOF	A1 (°)	B1 (m)	H (m)	SEPARATION (m)	EXPOSED	PROJECTION	ROOFING
18	flat	20	25	2	0	yes	no	asphalt
19	flat	20	25	2	0	yes	no	glass
20	flat	20	24	2	1	yes	no	glass
21	flat	20	17	2	8	yes	no	glass
22	right shed	20	25	2	0	yes	no	asphalt
23	right shed	20	25	2	0	no		asphalt

TEST 18

Multilevel roof, flat upper roof, $A1 = 20°$, $B1 = 25$ m, $H = 2$m
separation $= 0$ m, lower roof exposed w/ no projections
asphalt shingles on lower roof

$S_o = 2.1$ KPa
$C_B = 0.8$

Pt-0 $C_w = 1.0$
$C_s = 1.0$
$C_a = \frac{1.25(2.4)(2)}{2.1} = 2.8571$ $\underline{S_0 = 4.8 \text{ KPa}}$

Pt-XD $C_w = 1.0$
$C_s = 1.0$
$C_a = 2.8571 - \left(\frac{2.8571-1}{4}\right)4 = 1.0$ $\underline{S_{XD} = 1.68 \text{ KPa}}$

Pt-10H $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.0$ $\underline{S_{10H} = 1.26 \text{ KPa}}$

Separation $Sep = 0 \rightarrow S_{SEP} = S_0$ $\underline{S_{SEP} = 4.8 \text{ KPa}}$

Lower edge $(Sep + B1) > 10H \rightarrow S_{EDGE} = S_{10H}$ $\underline{S_{EDGE} = 1.26 \text{ KPa}}$

TEST 19

Multi-level roof, flat upper roof, $A1 = 20°$, $B1 = 25$m, $H = 2$m
separation $= 0$ m, exposed site, no lower roof projections,
lower roof is glass

$S_o = 2.1$ KPa, $C_B = 0.8$

Pt-0 $C_w = 1.0$
$C_s = 1 - \left(\frac{20-15}{55}\right) = 0.9091$
$C_a = \frac{1.25(2.4)(2)}{2.1} = 2.8571$ $\underline{S_0 = 4.3676 \text{ KPa}}$

Pt-XD $C_w = 1.0$
$C_s = 0.9091$
$C_a = 1$ $\underline{S_{XD} = 1.5273 \text{ KPa}}$

Pt-10H $C_w = 0.75$
$C_s = 0.9091$
$C_a = 1.0$
$\underline{S_{10H} = 1.1455 \text{ KPa}}$

Separation $= 0 \rightarrow S_{SEP} = S_0$ $\underline{S_{SEP} = 4.3636 \text{ KPa}}$

Lower edge $(\text{sep.} + b1) > 10H$ $\underline{S_{EDGE} = 1.1455 \text{ KPa}}$

TEST 20

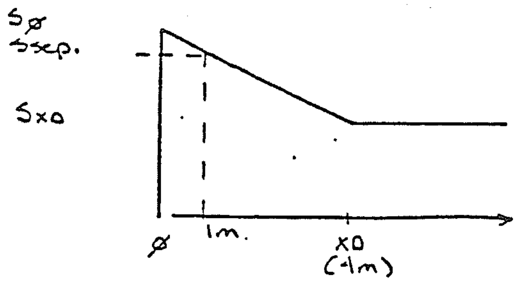
Multilevel roof, flat upper roof, A1 = 20°, B1 = 24 m, H = 2 m, separation = 1 m, lower roof exposed w/ no projections, lower roof is glass.

$S_o = 2.1$ KPa, $C_B = 0.8$

Pt-0 $C_w = 1.0$
$C_s = 1 - \left(\frac{20-15}{55}\right) = 0.9091$
$C_a = \frac{1.25(2.4)(2)}{2.1} = 2.8571$
$\underline{S_0 = 4.3636 \text{ KPa}}$

Pt-XD $C_w = 1.0$
$C_s = 0.9091$
$C_a = 1.0$
$\underline{S_{XD} = 1.5273 \text{ KPa}}$

Pt-10H $C_w = 0.75$
$C_s = 0.9091$
$C_a = 1.0$
$\underline{S_{10H} = 1.1455 \text{ KPa}}$



$$\left(\frac{S_0 - S_{XD}}{4}\right) = \left(\frac{S_{SEP} - S_{XD}}{3}\right)$$

$\underline{S_{SEP} = 3.6545 \text{ KPa}}$

Lower edge : $(\text{Sep} + B1) > 10H$ $\underline{S_{EDGE} = 1.1455 \text{ KPa}}$

TEST 21

Multi-level roof, flat upper roof, A1 = 20°, B1 = 17°, H = 2m, separation = 8m, lower roof exposed w/ no projections, lower roof is glass

$S_O = 2.1$ KPa
$C_B = 0.8$

Pt-0
$C_w = 1.0$
$C_s = 1 - \left(\frac{20-15}{55}\right) = 0.9091$
$C_a = \frac{1.25(2.4)(2)}{2.1} = 2.8571$
$\underline{S_0 = 4.3636 \text{ KPa}}$

Pt-XD
$C_w = 1.0$
$C_s = 0.9091$
$C_a = 1.0$
$\underline{S_{XD} = 1.5275 \text{ KPa}}$

Pt-10H
$C_w = 0.75$
$C_s = 0.9091$
$C_a = 1.0$
$\underline{S_{10H} = 1.1455 \text{ KPa}}$

Separation: Sep > XD, Sep < 10H — $\underline{S_{SEP} = 1.5275 \text{ KPa}}$

Lower edge: (Sep + B1) > 10H — $\underline{S_{EDGE} = 1.1455 \text{ KPa}}$

TEST 22

Multi-level roof, shed w/ right end high, A1 = 20°, B1 = 25m, H = 2m, separation = 0 m, lower roof exposed w/ no projections, asphalt shingles on lower roof.

$S_O = 2.1$ KPa
$C_B = 0.8$

Pt-0
$C_w = 1.0$
$C_s = 1.0$
$C_a = \frac{1.25(2.4)(2)}{2.1} = 2.8571$
$\underline{S_0 = 4.8 \text{ KPa}}$

Pt-XD
$C_w = 1.0$
$C_s = 1.0$
$C_a = 1.0$
$\underline{S_{XD} = 1.68 \text{ KPa}}$

Pt-10H $C_w = 0.75$
$C_s = 1.0$
$C_a = 1.0$ $S_{10H} = 1.26$ KPa

Separation $sep = 0$ $S_{SEP} = 4.8$ KPa

Lower edge $(sep + B1) > 10H$ $S_{EDGE} = 1.26$ KPa

TEST 23

Multi-level roof, upper roof = shed w/ high end near lower roof, $A1 = 20°$, $B1 = 25$ m, $H = 2$ m, separation = 0, lower roof not exposed, asphalt shingles on lower roof.

$S_0 = 2.1$ KPa
$C_B = 0.8$

Pt-0 $C_w = 1.0$
$C_s = 1.0$
$C_a = \frac{1.25(2.4)(2)}{2.1} = 2.8571$ $S_0 = 4.8$ KPa

Pt-XD $C_w = 1.0$
$C_a = 1.0$
$C_s = 1.0$ $S_{XD} = 1.68$ KPa

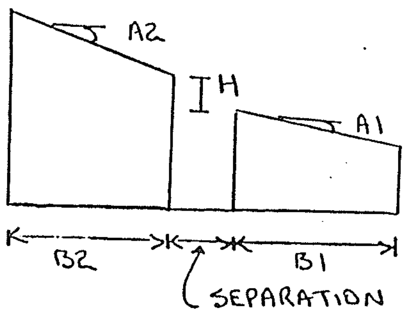
Pt-10H $C_w = 1.0$
$C_s = 1.0$
$C_a = 1.0$ $S_{10H} = 1.68$ KPa

Separation $sep = 0$ $S_{SEP} = 4.8$ KPa

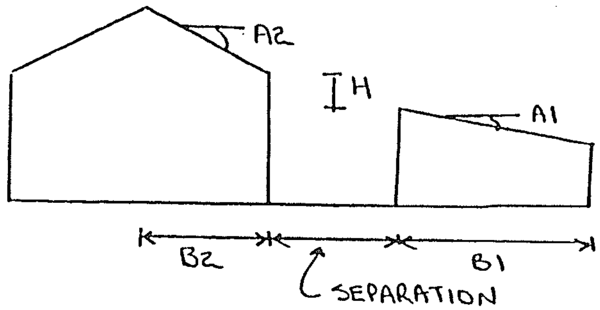
Lower Edge $(sep + B1) > 10H$ $S_{EDGE} = 1.68$ KPa

<u>MULTI-LEVEL ROOF TESTS</u> - LOWER ROOFS EXPERIENCE SLIDE LOAD
- ALL TESTS FOR WINNIPEG LOCATION
- ALL ROOFS HAVE ASPHALT SHINGLE COVERING, ARE NOT EXPOSED, HAVE NO PROJECTIONS

TEST	UPPER ROOF	A1 (°)	B1 (m)	A2 (°)	B2 (m)	H (m)	SEPARATION (m)
24	left shed	20	25	20	10	2	0
25	gable	20	25	20	10	2	0
26	gable	20	25	20	10	2	1
27	gable	20	25	20	10	2	6



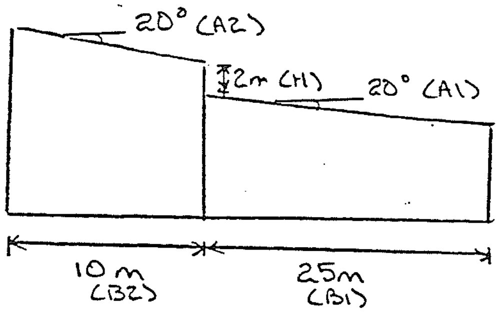
ex/ LEFT SHED UPPER ROOF IN MULTI-LEVEL ROOF



ex/ GABLE UPPER ROOF IN MULTI-LEVEL ROOF

TEST 24

Multi-level roof in Winnipeg, Upper roof is shed w/ low end next to lower roof. Neither roof exposed. Neither roof has projections. Both roofs have asphalt shingling.



Lower Roof without slide load = test 23.

$$S_0 = 2.1\,(0.8)(1.0)(1.0)(2.8571) = 4.8\text{ kPa}$$
$$S_{XD} = 2.1\,(0.8)(1.0)(1.0)(1.0) = 1.68\text{ kPa}$$
$$S_{10H} = 2.1\,(0.8)(1.0)(1.0)(1.0) = 1.68\text{ kPa}$$

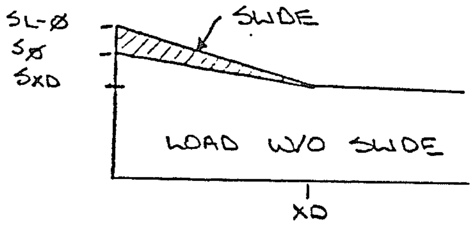
Slide load = $\frac{1}{2}$ (case 1 loading on upper roof)

- upper roof load is test 4

$$S_1 = (2.1)(0.8)(1.0)(1.0)(1.0) = 1.68\text{ kPa}$$

$$\text{Slide} = \tfrac{1}{2}(1.68)(10\text{m}) = 8.4\text{ KN/m}$$

Total load on lower roof:



$$S_{L-0} = \left[\frac{(S_0 - S_{XD})(XD) - 2\,SLIDE}{XD}\right] + S_{XD}$$

$$= \left[\frac{(4.8 - 1.68)(4) - 2(8.4)}{4}\right] + 1.68$$

$$\underline{S_{L-0} = 9\text{ kPa}}$$

$S_{L-SEP} = S_{L-0}$ $\underline{S_{L-SEP} = 9 \text{ KPa}}$

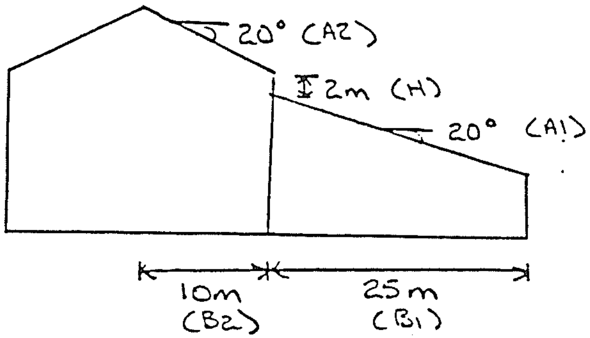
$S_{L-XD} = S_{XD}$ $\underline{S_{L-XD} = 1.68 \text{ KPa}}$

$S_{L-10H} = S_{10H}$ $\underline{S_{L-10H} = 1.68 \text{ KPa}}$

$S_{L-EDGE} = S_{10H}$ $\underline{S_{L-EDGE} = 1.68 \text{ KPa}}$

TEST 25

Multi-level roof in Winnipeg. Upper roof is gable. Neither roof is exposed. Neither roof has projections. Both roofs have asphalt shingling.



Lower roof without slide load = test 23

$S_0 = 4.8 \text{ KPa}$
$S_{XD} = 1.68 \text{ KPa}$
$S_{10H} = 1.68 \text{ KPa}$

slide load can be determined using test 13 results

$$\text{slide} = \tfrac{1}{2}(S_1)(B_2)$$
$$= \tfrac{1}{2}(1.68 \text{ KPa})(10\text{m})$$
$$= 8.4 \text{ KN/m}$$

Total load on lower roof = test 24

$$S_{L-0} = \left[\frac{(S_0 - S_{XD})(XD) - 2SLIDE}{XD}\right] + S_{XD}$$ $\underline{S_{L-0} = 9 \text{ KPa}}$

$S_{L-XD} = S_{XD}$ <u>$S_{L-XD} = 1.68$ KPa</u>

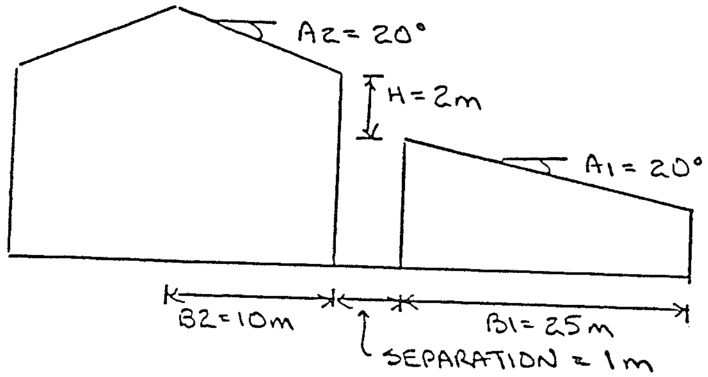
$S_{L-10H} = S_{10H}$ <u>$S_{L-10H} = 1.68$ KPa</u>

$S_{L-SEP} = S_{SEP}$ <u>$S_{L-SEP} = 9$ KPa</u>

$S_{L-EDGE} = S_{10H}$ <u>$S_{L-EDGE} = 1.68$ KPa</u>

TEST 26

Multi-level roof in Winnipeg. Upper roof is gable. Neither roof exposed. Both roofs have asphalt shingling



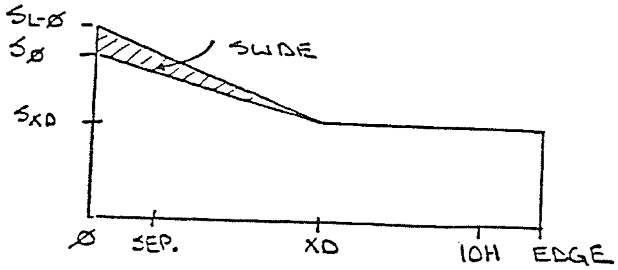
Lower roof without slide load = test 23

$S_0 = 4.8$ KPa
$S_{XD} = 1.68$ KPa
$S_{10H} = 1.68$ KPa

Slide load = $\frac{1}{2}$(case 1 snow load from test 13)(B2)

$$SLIDE = \frac{1}{2}(1.68)(10) = 8.4 \ \frac{KN}{m}$$

Total load on lower roof:



$$S_{L\text{-}0} = \left[\frac{(S_0 - S_{XD})(XD) - 2SLIDE}{XD}\right] + S_{XD}$$

$$= \left[\frac{(4.8 - 1.68)(4) - 2(8.4)}{4}\right] + 1.68$$

$S_{L\text{-}0} = 9$ KPa

$S_{L\text{-}XD} = S_{XD}$ $S_{L\text{-}XD} = 1.68$ KPa

$S_{L\text{-}10H} = S_{10H}$ $S_{L\text{-}10H} = 1.68$ KPa

$$S_{L\text{-}SEP} = \left[\frac{(S_{L\text{-}0} - S_{XD})(XD - SEPARATE)}{XD}\right] + S_{XD}$$

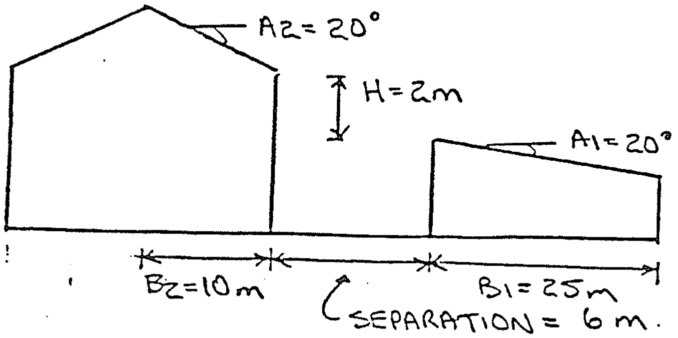
$$= \left[\frac{(9 - 1.68)(4 - 1)}{4}\right] + 1.68$$

$S_{L\text{-}SEP} = 7.17$ KPa

$S_{L\text{-}EDGE} = S_{10H}$ $S_{L\text{-}EDGE} = 1.68$ KPa

TEST 27

Multi-level roof in Winnipeg. Upper roof is gable. Neither roof is exposed. Both roofs have asphalt shingling.



Lower roof without slide load = test 13

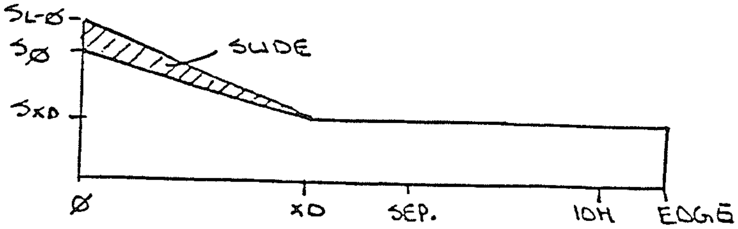
$S_0 = 4.8$ KPa
$S_{XD} = 1.68$ KPa
$S_{10H} = 1.68$ KPa

Slide load = $\frac{1}{2}$ (case 1 snow load from test 13)(B2)

$= \frac{1}{2}$ (1.68 KPa)(10 m)

$=$ 8.4 KN/m.

Total load on lower roof:



$S_{L-0} = \left[\frac{(S_0 - S_{XD})(XD) - 2SLIDE}{XD}\right] + S_{XD}$ $\underline{S_{L-0} = 9\ \text{KPa}}$

$S_{L-XD} = S_{XD}$ $\underline{S_{L-XD} = 1.68\ \text{KPa}}$

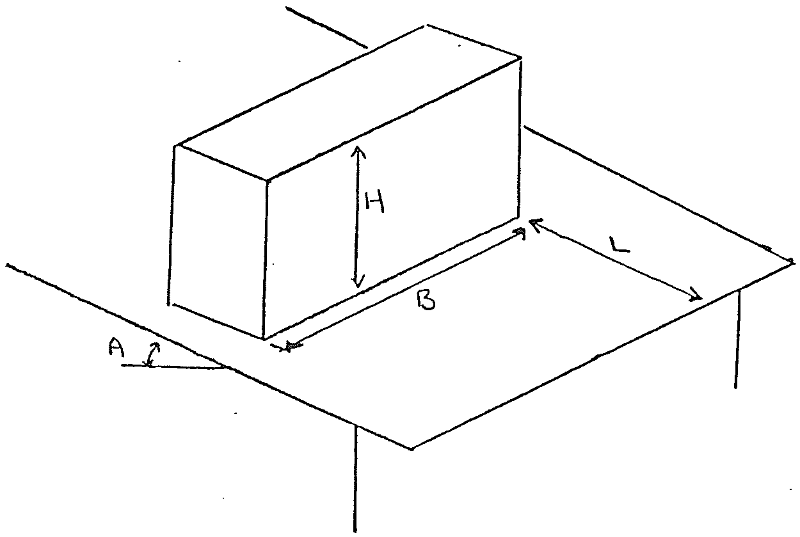
$S_{L-10H} = S_{10H}$ $\underline{S_{L-10H} = 1.68\ \text{KPa}}$

$S_{L-SEP} = S_{XD}$ $\underline{S_{L-SEP} = 1.68\ \text{KPa}}$

$S_{L-EDGE} = S_{10H}$ $\underline{S_{L-EDGE} = 1.68\ \text{KPa}}$

PROJECTION AREA ROOF TESTS - ALL TESTS FOR WINNIPEG LOCATION
- ALL ROOFS ARE EXPOSED AND HAVE ONLY ONE ROOF PROJECTION.

TEST	B (m)	H (m)	L (m)	A (°)	ROOFING
28	2	1	5	20	asphalt shingles
29	2.5	1	5	20	asphalt shingles
30	2.5	2	5	20	asphalt shingles
31	2.5	2	5	20	new metal.



TEST 28

Projection roof area. Building in Winnipeg. Proj. width = 2m, height = 1m, distance to roof edge = 5m, roof angle = 20° Exposed site, no other projections, asphalt shingling

$S_o = 2.1$ KPa
$C_B = 0.8$

|projection width| < |S_o| therefore projection does <u>not</u> cause drifting.

exposed site → $C_w = 0.75$
non-slippery, $a < 30°$ → $C_s = 1.0$
uniform snow load → $C_a = 1.0$

Pt-0 $S_0 = 2.1(0.8)(0.75)(1.0)(1.0)$ $S_0 = 1.26$ KPa
Pt-XD $S_{XD} = S_0$ $S_{XD} = 1.26$ KPa
Pt-10H $S_{10H} = S_0$ $S_{10H} = 1.26$ KPa
Edge $S_{EDGE} = S_0$ $S_{EDGE} = 1.26$ KPa

TEST 29

Projection roof area. Building in Winnipeg, projection width = 2.5m, height = 1m, distance to roof edge = 5m, roof angle = 20°, asphalt shingling.

$S_o = 2.1$ KPa
$C_B = 0.8$

|proj. width| > |S_o| ∴ have drift formation.

Pt-0
$C_w = 1.0$
$C_s = 1.0$
$C_a = \frac{0.8(2.4)(1)}{2.1} < 1 \Rightarrow C_a = 1.0$

$S_0 = 1.68$ KPa

Pt-XD
$C_w = 1.0$
$C_s = 1.0$
$C_a = 1.0$
$S_{XD} = 1.68$ KPa

Pt-10H
$C_w = 0.75$
$C_s = 1.0$
$C_a = 1.0$
$S_{10H} = 1.26$ KPa

EDGE - between XD and 10H
∴ $S_{EDGE} = S_{XD}$

$S_{XD} = 1.68$ KPa

TEST 30

Projection roof area. Building in Winnipeg, projection width = 2.5 m; height = 2m, distance to roof edge = 5m, roof angle = 20°, no other roof projections, asphalt shingling. Exposed site.

$S_o = 2.1$ KPa
$C_B = 0.8$

Pt-0
$C_W = 1.0$
$C_S = 1.0$
$C_a = \frac{0.8(2.4)(2)}{2.1} = 1.8286$

$S_0 = 3.07$ KPa

Pt-XD
$C_W = 1.0$
$C_S = 1.0$
$C_a = 1.0$

$S_{XD} = 1.68$ KP

Pt-10H
$C_W = 0.75$
$C_S = 1.0$
$C_a = 1.0$

$S_{10H} = 1.26$ KPa

EDGE $S_{EDGE} = S_{XD}$

$S_{EDGE} = 1.68$ KPa

TEST 31

Projection roof area. Building in Winnipeg. Proj. width = 2.5m, height = 2m, distance to roof edge = 5m, roof angle = 20°, Exposed site. No other roof projections. New metal roof

$S_o = 2.1$ KPa
$C_B = 0.8$

Pt-0
$C_W = 1.0$
$C_S = 1 - \left(\frac{20-15}{55}\right) = 0.9091$
$C_a = \frac{0.8(2.4)(2)}{2.1} = 1.8286$

$S_0 = 2.793$ KPa

Pt - XD

Cw = 1.0
Cs = 0.9091
Ca = 1.0

Sxd = 1.527 KPa

Pt - 10H

Cw = 0.75
Cs = 0.9091
Ca = 1.0

S10H = 1.145 KPa

EDGE

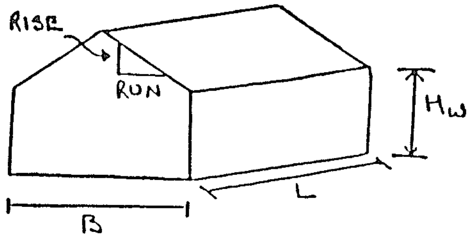
SEDGE = SXD

SEDGE = 1.527 KPa

WIND TESTS FOR WHOLE BUILDING AND PRIMARY MEMBERS

- LOCATION = WINNIPEG, MB , B=10m , L= 20m , Hw= 2.5m

TEST	Occupancy	Airtight	Rise	Run	Angle (°)	Design case	Openings
32	high	yes	0.0524	1	3	whole (1)	small, uniform
33	high	yes	0.3640	1	20	whole (1)	small, uniform
34	high	yes	0.5774	1	30	whole (1)	small, uniform
35	high	yes	0.3640	1	20	primary-side (2)	small, uniform
36	high	no	0.3640	1	20	primary-side (2)	small, uniform
37	low	no	0.3640	1	20	primary-side (2)	small, uniform
38	low	no	0.3640	1	20	primary-side (2)	large - wall 1
39	low	no	0.3640	1	20	primary-side (2)	large - wall 5
40	low	no	0.3640	1	20	primary-end (2)	small, uniform
41	low	no	0.3640	1	20	primary-end (3)	small, uniform
42	low	no	0.3640	1	20	primary-side (3)	small, uniform
43	low	no	0.3640	1	20	primary-roof (3)	small, uniform



TEST 32

Building in Winnipeg, MB. High human occupancy, airtight, roof angle = 3°, design whole building, small uniformly distributed openings

external : $P_e = qC_eC_gC_p$ internal : $P_i = qC_eC_{g_i}C_{p_i}$

$q = Q10 = 0.35$

reference ht = max {6m, mid-height of roof} = 6m

$C_e = \left(\frac{ref\ ht}{10}\right)^{0.2} = \left(\frac{6}{10}\right)^{0.2} = 0.9029$

$C_{g_i} = 1.0$; $C_{p_i} = -0.3$

Designing loading cases re. fig B-6. = A, A reversed, B_2, B_2 reversed.

A	Arev	CpCg	Pe	Pi	PT (KPa)
4	1	0.75	0.2370	-0.0948	0.3318
3	2	-1.3	-0.4108	"	-0.3160
2	3	-0.7	-0.2212	"	-0.1264
1	4	-0.55	-0.1738	"	-0.0790
6	5	-1.4	-0.4424	"	-0.3476
5	6	-1.4	-0.4424	"	-0.3476

B_1	Brev	CpCg	Pe	Pi	PT (kPa)
1	4	-1.4	-0.4424	-0.0948	-0.3476
2	3	-1.3	-0.4108	"	-0.3160
3	2	-0.7	-0.2212	"	-0.1264
4	1	-1.4	-0.4424	"	-0.3476
5	6	0.75	0.2370	"	0.3318
6	5	-0.55	-0.1738	"	-0.0790

TEST 33

Building in Winnipeg MB. High human occupancy, airtight. Roof angle = 20°, design whole building, small uniformly distributed openings

$q = Q10 = 0.35$

ref. ht = 6m → $Ce = 0.9029$

$Cg_i = 1.0$, $Cp_i = -0.3$

need to consider cases A, B_1, B_2 since angle ≥ 20° (both direction shown in Fig B-6 NBC + reversed)

A	Arev	CpCg	Pe	Pi	PT (KPa)
4	1	1.0	0.3160	-0.0948	0.4108
3	2	-1.3	-0.4108	"	-0.3160
2	3	-0.9	-0.2844	"	-0.1896
1	4	-0.8	-0.2528	"	-0.1580
6	5	-1.4	-0.4424	"	-0.3476
5	6	-1.4	-0.4424	"	-0.3476

B_1	B_1rev	CpCg	Pe	Pi	PT (KPa)
1	4	-1.4	-0.4424	-0.0948	-0.3476
2	3	-1.3	-0.4108	"	-0.3160
3	2	-0.7	-0.2212	"	-0.1264
4	1	-1.4	-0.4424	"	-0.3476
5	6	0.75	0.2370	"	0.3318
6	5	-0.55	-0.1738	"	-0.0790

B_2	B_2rev	CpCg	Pe	Pi	PT (KPa)
1	4	-0.85	-0.2686	-0.0948	-0.1738
2	3	-1.3	-0.4108	"	-0.3160
3	2	-0.7	-0.2212	"	-0.1264
4	1	-0.85	-0.2686	"	-0.1738
5	6	0	0	"	0.0948
6	5	0	0	"	0.0948

TEST 34

Building in Winnipeg. High human occupancy, airtight, roof angle = 30°, small uniformly spaced openings, design whole building

$q = Q10 = 0.35$
ref ht = 6m → $C_e = 0.9029$
$C_{gi} = 1.0$, $C_{pi} = -0.3$

angle ≥ 20° so consider all 3 design cases (A, B_1, B_2)

A	Arev	C_pC_g	P_e	P_i	P_T (kPa)
4	1	1.05	0.3318	-0.0948	0.4266
3	2	0.4	0.1264	″	0.2212
2	3	-0.8	-0.2528	″	-0.1580
1	4	-0.7	-0.2212	″	-0.1264
6	5	-1.4	-0.4424	″	-0.3476
5	6	-1.4	-0.4424	″	-0.3476

B_1	B_1rev	C_pC_g	P_e	P_i	P_T (kPa)
1	4	-1.4	-0.4424	-0.0948	-0.3476
2	3	-1.3	-0.4108	″	-0.3160
3	2	-0.7	-0.2212	″	-0.1260
4	1	-1.4	-0.4424	″	-0.3476
5	6	0.75	0.2370	″	0.3318
6	5	-0.55	-0.1738	″	-0.0790

B_2	B_2rev	C_pC_g	P_e	P_i	P_T (kPa)
1	4	-0.85	-0.2686	-0.0948	-0.1738
2	3	-1.3	-0.4108	″	-0.3160
3	2	-0.7	-0.2212	″	-0.1264
4	1	-0.85	-0.2686	″	-0.1738
5	6	0	0	″	0.0948
6	5	0	0	″	0.0948

TEST 35

Winnipeg, MB. High human occupancy, airtight, roof angle = 20°, small uniformly distributed openings. Design for primary members in side walls

$q = Q30 = 0.42$ $C_{gi} = 1.0$
$C_e = 0.9029$ $C_{pi} = -0.3$

Area	C_pC_g	P_e	P_i	P_T (KPa)
1	1.0	0.3792	-0.1138	0.4930
2	-1.3	-0.4930	"	-0.3792
3	-0.9	-0.3413	"	-0.2275
4	-0.8	-0.3034	"	-0.1896
5	-1.4	-0.5309	"	-0.4171
6	-1.4	-0.5309	"	-0.4171

B1	C_pC_g	P_e	P_i	P_T (KPa)
1	-1.4	-0.5309	-0.1138	-0.4171
2	-1.3	-0.4230	"	-0.3092
3	-0.7	-0.2655	"	-0.1517
4	-1.4	-0.5309	"	-0.4171
5	0.75	-0.2844	"	-0.3982
6	-0.55	-0.2086	"	-0.0948

B2	C_pC_g	P_e	P_i	P_T (KPa)
1	-0.85	-0.3223	-0.1138	-0.2085
2	-1.3	-0.4930	"	-0.3792
3	-0.7	-0.2655	"	-0.1517
4	-0.85	-0.3223	"	-0.2085
5	0	0	"	0.1138
6	0	0	"	0.1138

SIDE = wall 4 and wall 1.

max P_T = max of (0.4930, -0.1896, -0.4171, -0.2085)

max P_T = 0.493 KPa

min P_T = min of (0.4930, -0.1896, -0.4171, -0.2085)

min P_T = -0.4171 KPa

TEST 36

Winnipeg, high human occupancy, not airtight, small uniformly distributed openings, roof angle = 20°, Design for primary members in side walls.

$q = Q30 = 0.42$

$C_e = 0.9029$

$C_{g_i} = 2.0$

$C_{p_i} = -0.3$

Arev	C_pC_g	P_e	P_i	P_T (KPa)
1	1.0	0.3792	-0.2275	0.6067
2	-1.3	-0.4930	"	-0.2655
3	-0.9	-0.3413	"	-0.1138
4	-0.8	-0.3034	"	-0.0759
5	-1.4	-0.5309	"	-0.3034
6	-1.4	-0.5309	"	-0.3034

B1	C_pC_g	P_e	P_i	P_T (KPa)
1	-1.4	-0.5309	-0.2275	-0.3034
2	-1.3	-0.4230	"	-0.1955
3	-0.7	-0.2655	"	-0.0380
4	-1.4	-0.5309	"	-0.3034
5	0.75	0.2844	"	0.5119
6	-0.55	-0.2086	"	0.0189

B2	C_pC_g	P_e	P_i	P_T (KPa)
1	-0.85	-0.3223	-0.2275	-0.0948
2	-1.3	-0.4930	"	-0.2655
3	-0.7	-0.2655	"	-0.0390
4	-0.85	-0.3223	"	-0.0948
5	0	0	"	0.2275
6	0	0	"	0.2275

$\max P_T = \max \text{ of } \{0.6067, -0.0759, -0.3034, -0.0948\}$

(sidewall) $\underline{\max P_T = 0.6067 \text{ KPa}}$

$\min P_T = \min \text{ of } \{0.6067, -0.0759, -0.3034, -0.0948\}$

(sidewall) $\underline{\min P_T = -0.3034 \text{ KPa}}$

TEST 37

Winnipeg, low human occupancy, not airtight, small uniformly distributed openings, roof angle = 20°, design primary member on sidewall.

$q = Q10 = 0.35$ $\quad$ $C_{gi} = 2.0$

$C_e = 0.9029$ $\quad$ $C_{pi} = -0.3$

A	C_pC_g	P_e	P_i	P_T (kPa)
1	1.0	0.3160	-0.1896	0.5056
4	-0.8	-0.2528	-0.1896	-0.0632
B1				
1	-1.4	-0.4424	-0.1896	-0.2528
4	-1.4	-0.4424	-0.1896	-0.2528
B2				
1	-0.85	-0.2686	-0.1896	-0.0790
4	-0.85	-0.2686	-0.1896	-0.0790

max sidewall P_T = 0.5056 kPa

min sidewall P_T = -0.2528 kPa

TEST 38

Winnipeg, low human occupancy, not airtight, large opening in side wall 1, roof angle = 20°, design primary member in sidewalls

$q = Q10 = 0.35$

$C_e = 0.9029$

$C_{gi} = 2.0$

C_{pi} - north = -0.7

C_{pi} - south = -0.7

C_{pi} - east = -0.5

C_{pi} - west = 0.7

A	C_pC_g	P_e	P_i - west	P_i - east	P_T - west	P_T - east
1	1.0	0.3160	0.4424	-0.3160	-0.1264	0.6320
4	-0.8	-0.2528	0.4424	-0.3160	-0.6952	0.5688

B1	CpCg	Pe	Pi SOUTH/NORTH	PT SOUTH/NORTH
1	-1.4	-0.4424	-0.4424	0
4	-1.4	-0.4424	-0.4424	0

B2				
1	-0.85	-0.2686	-0.4424	0.1738
4	-0.85	-0.2686	-0.4424	0.1738

max sidewall P_T = 0.6320 KPa

min sidewall P_T = -0.6952 KPa

TEST 39

Winnipeg, low human occupancy, not airtight, large opening on wall 5, roof angle = 20°, design for primary member in sidewall

$q = Q10 = 0.35$
$C_e = 0.9029$
$C_{g_i} = 2.0$
C_{p_i} - north = -0.5
C_{p_i} - south = 0.7
C_{p_i} - east/west = -0.7

A	CpCg	Pe	Pi east/west	PT (KPa)
1	1.0	0.3160	-0.4424	0.7582
4	-0.8	-0.2528	-0.4424	0.1896

B1	CpCg	Pe	Pi-south	Pi-NORTH	PT-SOUTH	PT-NORTH
1	-1.4	-0.4424	0.4424	-0.3160	-0.8848	-0.1264
4	-1.4	-0.4424	0.4424	-0.3160	-0.8848	-0.1264

B2						
1	-0.85	-0.2686	0.4424	-0.3160	-0.7110	0.0474
4	-0.85	-0.2686	0.4424	-0.3160	-0.7110	0.0474

max sidewall P_T = 0.7584 KPa

min sidewall P_T = -0.8848 KPa

TEST 40

Winnipeg, low human occupancy, not airtight, small uniformly distributed openings, roof angle = 20°, design primary members in end wall

$q = Q10 = 0.35$ $\quad$ $C_{gi} = 2.0$
$C_e = 0.9029$ $\quad$ $C_{pi} = -0.3$

endwalls = 5 + 6

A	C_pC_g	P_e	P_i	P_T (kPa)
5	-1.4	-0.4424	-0.1896	-0.2528
6	-1.4	-0.4424	-0.1896	-0.2528
B1				
5	0.75	0.2370	-0.1896	0.4266
6	-0.55	-0.1738	-0.1896	0.0158
B2				
5	0	0	-0.1896	0.1896
6	0	0	-0.1896	0.1896

max endwall P_T = 0.4266 KPa

min endwall P_T = -0.2528 KPa

TEST 41

Winnipeg, low human occupancy, not airtight, roof angle = 20°, small uniformly distributed openings. Design primary members on end walls for vibration

$q = Q10 = 0.35$ $\quad$ $C_{gi} = 2.0$
$C_e = 0.9029$ $\quad$ $C_{pi} = -0.3$

- same C_pC_g, P_e, P_i, P_T as in test 40.

max endwall P_T = 0.4266 KPa

min endwall P_T = -0.2528 KPa

TEST 42

Winnipeg ; low human occupancy, not airtight , roof angle = 20°, small uniformly distributed openings. Design primary members in side walls for vibration

$q = Q10 = 0.35$ $C_{gi} = 2.0$
$C_e = 0.9029$ $C_{pi} = -0.3$

- same C_pC_g, P_e, P_i, P_T as in test 37.

max side wall P_T = 0.5056 KPa

min side wall P_T = -0.2528 KPa

TEST 43

Winnipeg, low human occupancy, not airtight, roof angle = 20°, small uniformly distributed openings, design primary members in roof for vibration.

$q = Q10 = 0.35$ $C_{gi} = 2.0$
$C_e = 0.9029$ $C_{pi} = -0.3$

roof surfaces = 2 + 3

A	C_pC_g	P_e	P_i	P_T (KPa)
2	-1.3	-0.4108	-0.1896	-0.2212
3	-0.9	-0.2844	-0.1896	-0.0948
B1				
2	-1.3	-0.4108	-0.1896	-0.2212
3	-0.7	-0.2212	-0.1896	-0.0316
B2				
2	-1.3	-0.4108	-0.1896	-0.2212
3	-0.7	-0.2212	-0.1896	-0.0316

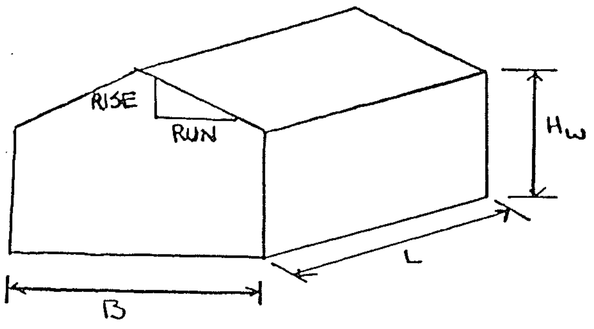
max roof P_T = -0.316 KPa

min roof P_T = -0.2212 KPa

WIND TESTS FOR SECONDARY MEMBERS:

- TEST FOR WINNIPEG, MB
- B = 10m, L = 20m, Hw = 2.5m

TEST	Occupancy	Airtight	Rise	Run	Angle	Openings
44	high	yes	0.364	1	20	small, uniformly distributed
45	high	no	0.364	1	20	small, uniformly distributed
46	low	no	0.364	1	20	small, uniformly distributed
47	low	no	0.0524	1	3	small, uniformly distributed
48	low	no	0.0524	1	3	small, walls 1 + 4
49	low	no	0.0524	1	3	small, walls 1+5+6



TEST 44

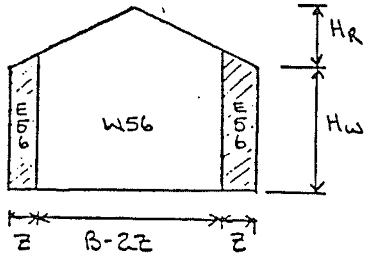
Winnipeg, high human occupancy, airtight, roof angle = 20°, small uniformly distributed openings, design of secondary members

$q = Q10 = 0.35$ $\quad C_{gi} = 1.0$

$C_e = 0.9029$ $\quad C_{pi} = -0.3 \rightarrow P_i = -0.0948$ kPa

$z = \min$ of $\{0.1B, 0.4H\}$ and $\geq 1m$ and $\geq 0.04B$

$\therefore z = 1m.$

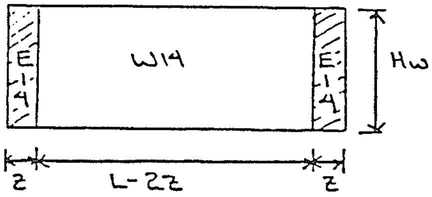


$H_R = 5\tan 20° = 1.8199m$

$H_w = 2.5m$

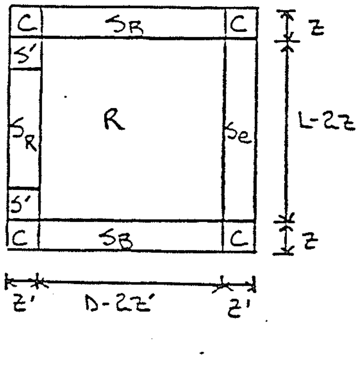
$E56 = zH_w + H_R \frac{z^2}{B} = 2.68m^2$

$W56 = H_R \frac{B}{2} + BH_w - 2E56 = 28.74m^2$



$E14 = zH_w = 2.5m^2$

$W14 = (L-2z)(H_w) = 45.0\ m^2$



$D = \frac{B}{2\cos A} = 5.321\ m$

$z' = \frac{z}{\cos A} = 1.064\ m$

$C = z'z = 1.064m^2$

$S' = z'z = 1.064\ m^2$

$S_e = (L-2z)(z') = 19.152m^2$

$S_B = (D-2z')(z) = 3.193\ m^2$

$S_R = (L-4z)(z') = 17.024\ m^2$

$R = (D-2z')(L-2z) = 57.474m^2$

REGION	AREA (m^2)	CpCa (max)	CpCa (min)
W14	45.0	1.352	-1.531
E14	2.5	1.795	-2.094
W56	28.74	1.521	-1.633
E56	2.68	1.793	-2.0915
C	1.064	0	-4.089
S′	1.064	0	-3.1
Se	19.152	0	-1.6
SB	3.193	0	-3.281
SR	17.024	0	-1.6
R	57.474	0	-1.5

REGION	PE (MAX)	PE (MIN)	Pi	PT (MAX)	PT (MIN)
W14	0.427	-0.484	-0.095	0.522	-0.389
E14	0.567	-0.662	"	0.662	-0.567
W56	0.481	-0.516	"	0.576	-0.421
E56	0.567	-0.661	"	0.662	-0.566
C	0	-1.292	"	0.095	-1.197
S′	0	-0.980	"	0.095	-0.885
Se	0	-0.506	"	0.095	-0.411
SB	0	-1.037	"	0.095	-0.942
SR	0	-0.506	"	0.095	-0.411
R	0	-0.474	"	0.095	-0.379

TEST 45

Winnipeg, high human occupancy, not airtight, roof angle = 20°, small uniformly distributed openings, design for secondary members.

$q = Q10 = 0.35$
$C_e = 0.9029$

$C_{gi} = 2.5$
$C_{pi} = -0.3 \rightarrow P_i = -0.237$ kPa

- areas same as in test 44, ∴ CpCg coefficients also same as in test 44.

$W14 = 45.0\ m^2$
$E14 = 2.5\ m^2$
$W56 = 28.74\ m^2$
$E56 = 2.68\ m^2$

$C = 1.064\ m^2$
$S' = 1.064\ m^2$

$Se = 19.152\ m^2$
$SB = 3.193\ m^2$
$SR = 17.024\ m^2$
$R = 57.474\ m^2$

REGION	PE(MAX)	PE(MIN)	Pi	PT(MAX)	PT(MIN)
W14	0.427	−0.484	−0.237	0.664	−0.247
E14	0.567	−0.662	"	0.804	−0.425
W56	0.481	−0.516	"	0.718	−0.279
E56	0.567	−0.661	"	0.804	−0.424
C	0	−1.292	"	0.237	−1.055
S′	0	−0.980	"	0.237	−0.743
Se	0	−0.506	"	0.237	−0.269
SB	0	−1.037	"	0.237	−0.800
SR	0	−0.506	"	0.237	−0.269
R	0	−0.474	"	0.237	−0.237

TEST 46

Winnipeg, low human occupancy, not airtight, roof angle = 20°, small uniformly distributed openings, design of secondary members.

$q = Q10 = 0.35$

$C_e = 0.9029$

$C_{gi} = 2.5$

$C_{pi} = -0.3 \rightarrow P_i = -0.237$ KPa

- change from high to low human occupancy does NOT affect design of secondary members

  ∴ results are identical to test 45.

TEST 47

Winnipeg, low human occupancy, not airtight, roof angle = 3°, small uniformly distributed openings, design for secondary members

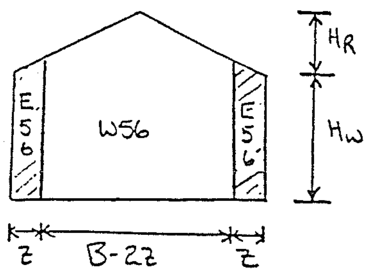
$q = Q10 = 0.35$

$C_e = 0.9029$

$C_{gi} = 2.5$

$C_{pi} = -0.3 \rightarrow P_i = -0.237$ KPa

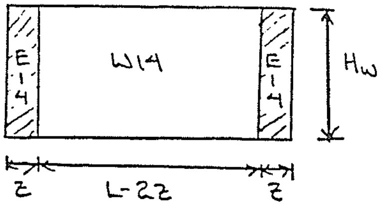
$z = 1\text{m}$



$H_R = 5 \tan 3° = 0.262\text{m}$

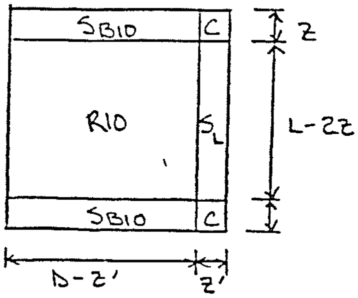
$E56 = zH_w + \frac{H_R z^2}{B} = 2.526\text{m}^2$

$W56 = \frac{H_R B}{2} + BH_w - 2E56 = 21.258\ \text{m}^2$



$E14 = zH_w = 2.5\ m^2$

$W14 = (L-2z)(H_w) = 45.0\ m^2$



$D = \dfrac{B}{2\cos A} = 5.007\ m$

$z' = \dfrac{z}{\cos A} = 1.001\ m.$

$C = z'z = 1.001\ m^2$

$S_L = (L-2z)(z') = 18.018\ m^2$

$SB10 = (D-z')(z) = 4.006\ m^2$

$R10 = (D-z')(L-2z) = 72.108\ m^2$

REGION	AREA (m^2)	CpCg (max)	CpCg (min)
W14	45.0	1.352	-1.531
E14	2.5	1.795	-2.094
W56	21.258	1.599	-1.680
E56	2.526	1.794	-2.093
C	1.001	0	-4.4
SL	18.018	0	-2.0
SB10	4.006	0	-2.5
R10	72.108	0	-1.5

REGION	PE(MAX)	PE(MIN)	Pi	PT(MAX)	PT(MIN)
W14	0.427	-0.488	-0.237	0.664	-0.251
E14	0.567	-0.662	"	0.804	-0.425
W56	0.505	-0.531	"	0.742	-0.294
E56	0.567	-0.661	"	0.804	-0.424
C	0	-1.390	"	0.237	-1.153
SL	0	-0.632	"	0.237	-0.395
SB10	0	-0.790	"	0.237	-0.553
R10	0	-0.474	"	0.237	-0.237

TEST 48

Winnipeg, low human occupancy, not airtight, roof angle = 3° small openings on walls 1 + 4, design for secondary members

$q = Q10 = 0.35$
$C_e = 0.9029$
$C_{g_i} = 2.5$

- external areas, C_pC_g same as in test 46

C_{p_i} - north = -0.7 → P_i - north = -0.553
C_{p_i} - south = -0.7 → P_i - south = -0.553
C_{p_i} - east = -0.3 → P_i - east = -0.237
C_{p_i} - west = -0.3 → P_i - west = -0.237

Max P_i = -0.237 KPa
Min P_i = -0.553 KPa

max $P_T = P_{E(MAX)} - P_{i(MIN)}$

min $P_T = P_{E(MIN)} - P_{i(MAX)}$

REGION	$P_{E(MAX)}$	$P_{E(MIN)}$	$P_{T(MAX)}$	$P_{T(MIN)}$
W14	0.427	-0.488	0.980	-0.251
E14	0.567	-0.662	1.120	-0.425
W56	0.505	-0.531	1.058	-0.294
E56	0.567	-0.661	1.120	-0.424
C	0	-1.390	0.553	-1.153
SL	0	-0.632	0.553	-0.395
SB10	0	-0.790	0.553	-0.553
R10	0	-0.470	0.553	-0.237

TEST 49

Winnipeg, low human occupancy, not airtight, roof angle = 3°, small openings on walls 1 + 5 + 6, design for secondary members

$q = Q10 = 0.35$
$C_e = 0.9029$
$C_{g_i} = 2.5$

- geometry + C_pC_g same as test 47

C_{p_i} - north / south = -0.7 → P_i - north/south = -0.237 KPa
C_{p_i} - east = -0.7 → P_i - east = -0.553 KPa
C_{p_i} - west = 0.7 → P_i - west = 0.553 KPa

Max P_i = 0.553 KPa
Min P_i = -0.553 KPa

max P_T = P_E (max) − P_i (MIN)
min P_T = P_E (MIN) − P_i (MAX)

REGION	PE(MAX)	PE(MIN)	PT(max)	PT(MIN)
W14	0.427	-0.488	0.980	-1.041
E14	0.567	-0.662	1.120	-1.215
W56	0.505	-0.531	1.058	-1.084
E56	0.567	-0.661	1.120	-1.214
C	0	-1.390	0.553	-1.943
SL	0	-0.632	0.553	-1.185
SB10	0	-0.790	0.553	-1.343
R10	0	-0.470	0.553	-1.023

Test 1

```
                          SNOW LOAD TUTORIAL
  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3        SUMMARY OF INPUTS
3
3        PROVINCE :        BC
3        LOCATION :        REVELSTOKE
3        ROOF TYPE :       shed
3        DIMENSIONS
3             slope of shed : 3/12
3
3        EXPOSED :          NO
3        OBSTRUCTION :      not required
3        OBSTR. HEIGHT :    not applicable
3
3
3        ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
                          SNOW LOAD TUTORIAL
 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3    CONSULTATION RESULTS
3
3    for roof shape = SHED
3
3                                          Snow load (kPa)
3
3    Case 1 - uniform load                    3.68
3    Case 2 - nonuniform load                 0
3
3       General Form :  S   =  So * Cb * Cw * Cs * Ca
3
3    case 1 :  3.68  =  4.6  *  0.8  *  1  *  1  *  1
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 2

```
                         SNOW LOAD TUTORIAL

Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3      SUMMARY OF INPUTS
3
3      PROVINCE :      MB
3      LOCATION :      WINNIPEG
3      ROOF TYPE :     shed
3      DIMENSIONS
3           slope of shed : 3/12
3
3      EXPOSED :        NO
3      OBSTRUCTION :    not required
3      OBSTR. HEIGHT :  not applicable
3
3      ROOF MATERIAL :  ASPHALT-SHINGLES
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                         SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3    CONSULTATION RESULTS
3
3    for roof shape = SHED
3
3                                                Snow load (kPa)
3
3    Case 1 - uniform load                          1.68
3    Case 2 - nonuniform load                       0
3
3       General Form :  S  =  So * Cb * Cw * Cs * Ca
3
3    case 1 :  1.68  =  2.1  *  0.8  *  1  *  1  *  1
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                         SNOW LOAD TUTORIAL
```

Test 3

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDI
3
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :      MB
3   LOCATION :      WINNIPEG
3   ROOF TYPE :     shed
3   DIMENSIONS
3        angle of shed : 14.04 degrees
3
3   EXPOSED :        NO
3   OBSTRUCTION :    not required
3   OBSTR. HEIGHT :  not applicable
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
                         SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
     CONSULTATION RESULTS
3
3    for roof shape = SHED
3
3                                          Snow load (kPa)
3
3    Case 1 - uniform load                   1.68
3    Case 2 - nonuniform load                0
3
3       General Form :  S  =  Sc * Cb * Cw * Cs * Ca
3
3    case 1 :  1.68  =  2.1  *  0.8  *  1  *  1  *  1
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 4

```
                              SNOW LOAD TUTORIAL
 Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

 3
 3
 3   SUMMARY OF INPUTS
 3
 3   PROVINCE :      MB
 3   LOCATION :      WINNIPEG
 3   ROOF TYPE :     shed
 3   DIMENSIONS
 3        angle of shed : 20 degrees
 3
 3   EXPOSED :        NO
 3   OBSTRUCTION :    not required
 3   OBSTR. HEIGHT : not applicable
 3
 3   ROOF MATERIAL : ASPHALT-SHINGLES
 3
 3
 3
 3** End - press ENTER to continue.
 @DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              SNOW LOAD TUTORIAL

 ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

 3     CONSULTATION RESULTS
 3
 3     for roof shape = SHED
 3
 3                                          Snow load (kPa)
 3
 3     Case 1 - uniform load                   1.68
 3     Case 2 - nonuniform load                0
 3
 3        General Form :  S  =  So * Cb * Cw * Cs * Ca
 3
 3     case 1 :  1.68  =  2.1  *  0.8  *  1  *  1  *  1
 3
 3
 3
 3
 3
 3
 3** End - press ENTER to continue.
 @DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 5

```
                          SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :       MB
3   LOCATION :       WINNIPEG
3   ROOF TYPE :      shed
3   DIMENSIONS
3        angle of shed : 20 degrees
3
3   EXPOSED :         YES
3   OBSTRUCTION :     NO
3   OBSTR. HEIGHT : not applicable
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                          SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3     CONSULTATION RESULTS
3
3     for roof shape = SHED
3
3                                             Snow load (kPa)
3
3     Case 1 - uniform load                      1.26
3     Case 2 - nonuniform load                   0
3
3        General Form :  S  =  So * Cb * Cw * Cs * Ca
3
3     case 1 :  1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 6

```
                                SNOW LOAD TUTORIAL
Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :       MB
3   LOCATION :       WINNIPEG
3   ROOF TYPE :      shed
3   DIMENSIONS
3         angle of shed : 20 degrees
3
3   EXPOSED :         YES
3   OBSTRUCTION :     YES
3   OBSTR. HEIGHT : 0.5 metres
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                                SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3     CONSULTATION RESULTS
3
3     for roof shape = SHED
3
3                                                 Snow load (kPa)
3
3     Case 1 - uniform load                          1.26
3     Case 2 - nonuniform load                       0
3
3        General Form :  S  =  So * Cb * Cw * Cs * Ca
3
3     case 1 :  1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                         SNOW LOAD TUTORIAL
```

Test 7

```
Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :      MB
3   LOCATION :      WINNIPEG
3   ROOF TYPE :     shed
3   DIMENSIONS
3        angle of shed : 20 degrees
3
3   EXPOSED :         YES
3   OBSTRUCTION :     YES
3   OBSTR. HEIGHT : 1 metres
3
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                         SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3     CONSULTATION RESULTS
3
3     for roof shape = SHED
3
3
3                                            Snow load (kPa)
3
3     Case 1 - uniform load                    1.68
3     Case 2 - nonuniform load                 0
3
3        General Form :  S  =  So * Cb * Cw * Cs * Ca
3
3     case 1 :  1.68  =  2.1  *  0.8  *  1  *  1  *  1
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 8

```
                      SNOW LOAD TUTORIAL

Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :      MB
3   LOCATION :      WINNIPEG
3   ROOF TYPE :     gable
3   DIMENSIONS
3        angle of gable : 14.04 degrees
3
3   EXPOSED :        YES
3   OBSTRUCTION :    NO
3   OBSTR. HEIGHT : not applicable
3
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                      SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3     CONSULTATION RESULTS
3
3     for roof shape = GABLE
3
3                                               Snow load (kPa)
3
3     Case 1 - uniform load                        1.68
3     Case 2 - nonuniform load                     0
3
3        General Form :  S   =  So * Cb * Cw * Cs * Ca
3
3     case 1 :  1.68  =  2.1  *  0.8  *  1  *  1  *  1
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 9

```
                                SNOW LOAD TUTORIAL
 (  Playback responses:   DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
 3
 3
 3   SUMMARY OF INPUTS
 3
 3   PROVINCE :        MB
 3   LOCATION :        WINNIPEG
 3   ROOF TYPE :       gable
 3   DIMENSIONS
 3        angle of gable : 20 degrees
 3
 3   EXPOSED :          YES
 3   OBSTRUCTION :      NO
 3   OBSTR. HEIGHT :  not applicable
 3
 3   ROOF MATERIAL : ASPHALT-SHINGLES
 3
 3
 3
 3
 3** End - press ENTER to continue.
 @DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD'
                               SNOW LOAD TUTORIAL
 (  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
 3
 3     CONSULTATION RESULTS                                                           3
 3                                                                                    3
 3     for roof shape = GABLE                                                         3
 3                                                                                    3
 3                                                                                    3
 3                                              Snow load (kPa)                       3
 3                                                                                    3
 3     Case 1 - uniform load                      1.68                                3
 3     Case 2 - nonuniform load                   2.1                                 3
 3                                                                                    3
 3        General Form :  S  =  So * Cb * Cw * Cs * Ca                                3
 3                                                                                    3
 3     case 1 :  1.68  =  2.1  *  0.8  *  1  *  1  *  1                               3
 3     case 2 :  2.1   =  2.1  *  0.8  *  1  *  1  *  1.25                            3
 3                                                                                    3
 3                                                                                    3
 3                                                                                    3
 3                                                                                    3
 3                                                                                    3
 3** End - press ENTER to continue.                                                   3
 @DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
 (
```

Test 10

```
                                   SNOW LOAD TUTORIAL
Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :       MB
3   LOCATION :       WINNIPEG
3   ROOF TYPE :      gable
3   DIMENSIONS
3         angle of gable : 45 degrees
3
3   EXPOSED :         YES
3   OBSTRUCTION :     NO
3   OBSTR. HEIGHT :  not applicable
3
3   ROOF MATERIAL :  ASPHALT-SHINGLES
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                                   SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD'

3      CONSULTATION RESULTS
3
3      for roof shape = GABLE
3
3                                                 Snow load (kPa)
3
3      Case 1 - uniform load                          1.05
3      Case 2 - nonuniform load                       1.31
3
3         General Form :  S   =   So * Cb * Cw * Cs * Ca
3
3      case 1 :  1.05   =   2.1   *   0.8   *   1   *   0.62   *   1
3      case 2 :  1.31   =   2.1   *   0.8   *   1   *   0.62   *   1.25
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 11

```
                              SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :       MB
3   LOCATION :       WINNIPEG
3   ROOF TYPE :      gable
3   DIMENSIONS
3        angle of gable : 20 degrees
3
3   EXPOSED :         YES
3   OBSTRUCTION :     YES
3   OBSTR. HEIGHT : 0.5 metres
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                              SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                             3
3     CONSULTATION RESULTS                                                    3
3                                                                             3
3     for roof shape = GABLE                                                  3
3                                                                             3
3                                              Snow load (kPa)                3
3                                                                             3
3     Case 1 - uniform load                        1.68                       3
3     Case 2 - nonuniform load                     2.1                        3
3                                                                             3
3        General Form :  S  =  So * Cb * Cw * Cs * Ca                         3
3                                                                             3
3     case 1 :  1.68  =  2.1  *  0.8  *  1  *  1  *  1                        3
3     case 2 :  2.1  =  2.1  *  0.8  *  1  *  1  *  1.25                      3
3                                                                             3
3                                                                             3
3                                                                             3
3                                                                             3
3                                                                             3
3** End - press ENTER to continue.                                            3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                              SNOW LOAD TUTORIAL
                                                                  Test 12
  Playback responses:   DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :      MB
3   LOCATION :      WINNIPEG
3   ROOF TYPE :     gable
3   DIMENSIONS
3        angle of gable : 20 degrees
3
3   EXPOSED :         YES
3   OBSTRUCTION :     YES
3   OBSTR. HEIGHT : 1 metres
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              SNOW LOAD TUTORIAL

 `DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     CONSULTATION RESULTS
3
3     for roof shape = GABLE
3
3                                            Snow load (kPa)
3
3     Case 1 - uniform load                     1.68
3     Case 2 - nonuniform load                  2.1
3
3        General Form :  S   =   So * Cb * Cw * Cs * Ca
3
3     case 1 :  1.68  =  2.1  *  0.8  *  1  *  1  *  1
3     case 2 :  2.1  =  2.1  *  0.8  *  1  *  1  *  1.25
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 13

```
                                SNOW LOAD TUTORIAL

  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :      MB
3   LOCATION :      WINNIPEG
3   ROOF TYPE :     gable
3   DIMENSIONS
3        angle of gable : 20 degrees
3
3   EXPOSED :        NO
3   OBSTRUCTION :    not required
3   OBSTR. HEIGHT : not applicable
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                                SNOW LOAD TUTORIAL

 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     CONSULTATION RESULTS
3
3     for roof shape = GABLE
3
3                                                Snow load (kPa)
3
3     Case 1 - uniform load                         1.68
3     Case 2 - nonuniform load                      2.1
3
3        General Form :   S   =   So * Cb * Cw * Cs * Ca
3
3     case 1 :   1.68   =   2.1  *  0.8  *  1  *  1  *  1
3     case 2 :   2.1   =   2.1  *  0.8  *  1  *  1  *  1.25
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 14

```
                         SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :       MB
3   LOCATION :       WINNIPEG
3   ROOF TYPE :      gable
3   DIMENSIONS
3        angle of gable : 20 degrees
3
3   EXPOSED :         NO
3   OBSTRUCTION :     not required
3   OBSTR. HEIGHT : not applicable
3
3   ROOF MATERIAL : GLASS
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
                         SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
                                                                                3
3     CONSULTATION RESULTS                                                      3
3                                                                               3
3     for roof shape = GABLE                                                    3
3                                                                               3
3                                            Snow load (kPa)                    3
3                                                                               3
3     Case 1 - uniform load                     1.52                            3
3     Case 2 - nonuniform load                  2.1                             3
3                                                                               3
3        General Form :  S  =  So * Cb * Cw * Cs * Ca                           3
3                                                                               3
3     case 1 :  1.52  =  2.1  *  0.8  *  1  *  0.9  *  1                        3
3     case 2 :  2.1  =  2.1  *  0.8  *  1  *  1  *  1.25                        3
3                                                                               3
3                                                                               3
3                                                                               3
3                                                                               3
3                                                                               3
3** End - press ENTER to continue.                                              3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 15

```
                          SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                             3
3   SUMMARY OF INPUTS                                                         3
3                                                                             3
3   PROVINCE :      MB                                                        3
3   LOCATION :      WINNIPEG                                                  3
3   ROOF TYPE :     valley                                                    3
3   DIMENSIONS                                                                3
3        angle of roof 1 :  8 degrees                                         3
3        angle of roof 2 :  5 degrees                                         3
3        length of roof 1 : 20                                                3
3        length of roof 2 : 30                                                3
3                                                                             3
3   EXPOSED :        YES                                                      3
3   OBSTRUCTION :    NO                                                       3
3   OBSTR. HEIGHT : not applicable                                            3
3                                                                             3
3   ROOF MATERIAL : ASPHALT-SHINGLES                                          3
3                                                                             3
3** End - press ENTER to continue.                                            3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                          SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                             3
3      CONSULTATION RESULTS                                                   3
3                                                                             3
3      for roof shape = VALLEY                                                3
3                                                                             3
3                                   snow load (kPA)     Region of Action (m)  3
3                                                                             3
3      CASE 1 - uniform load               1.26           - 20  -> 0          3
3                                          1.26              0 ->  30         3
3                                                                             3
3      CASE 2 and CASE 3 not applicable due to shallowness of roof slopes     3
3                                                                             3
3                                                                             3
3          GENERAL FORM : S = So * Cb * Cw * Cs * Ca                          3
3                                                                             3
3      case 1:  1.26   =  2.1  *  0.8  *  0.75  *  1  *  1                    3
3               1.26   =  2.1  *  0.8  *  0.75  *  1  *  1                    3
3                                                                             3
3                                                                             3
3** End - press ENTER to continue.                                            3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 16

```
                         SNOW LOAD TUTORIAL
( Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3   SUMMARY OF INPUTS
3
3   PROVINCE :      MB
3   LOCATION :      WINNIPEG
3   ROOF TYPE :     valley
3   DIMENSIONS
3        angle of roof 1 :  20 degrees
3        angle of roof 2 :  5 degrees
3        length of roof 1 : 20
3        length of roof 2 : 30
3
3
3   EXPOSED :        YES
3   OBSTRUCTION :    NO
3   OBSTR. HEIGHT : not applicable
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
                         SNOW LOAD TUTORIAL
(DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3     CONSULTATION RESULTS
3
3     for roof shape = VALLEY
3
3                               snow load (kPA)     Region of Action (m)
3
3     CASE 1 - uniform load         1.26             - 20  -> 0
3                                   1.26                0 ->  30
3
3     CASE 2 - nonuniform load      1.05               - 10  -> - 5
3                                   2.1              - 5  -> 0
3                                   2.1              0 ->  7.5
3                                   1.05              7.5  ->  15
3
3     CASE 3 - worst senario        1.05              - 10  -> - 2.5
3                                   3.15              - 2.5  -> 0
3                                   3.15              0 ->  3.75
3                                   1.05              3.75  ->  15
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD


(
```

```
                           SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3        GENERAL FORM : S = So * Cb * Cw * Cs * Ca
3
3      case 1:  1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3               1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3
3
3      case 2:  1.05  =  2.1  *  0.8  *  1  *  1  *  0.625
3               2.1  =  2.1  *  0.8  *  1  *  1  *  1.25
3               2.1  =  2.1  *  0.8  *  1  *  1  *  1.25
3               1.05  =  2.1  *  0.8  *  1  *  1  *  0.625
3
3
3      case 3:  1.05  =  2.1  *  0.8  *  1  *  1  *  0.625
3               3.15  =  2.1  *  0.8  *  1  *  1  *  1.875
3               3.15  =  2.1  *  0.8  *  1  *  1  *  1.875
3               1.05  =  2.1  *  0.8  *  1  *  1  *  0.625
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 17

```
                      SNOW LOAD TUTORIAL

Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3   SUMMARY OF INPUTS
3
3   PROVINCE :      MB
3   LOCATION :      WINNIPEG
3   ROOF TYPE :     valley
3   DIMENSIONS
3        angle of roof 1 :  20 degrees
3        angle of roof 2 :  40 degrees
3        length of roof 1 : 20
3        length of roof 2 : 30
3
3   EXPOSED :        YES
3
3   OBSTRUCTION :    NO
3   OBSTR. HEIGHT : not applicable
3
3   ROOF MATERIAL : ASPHALT-SHINGLES
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                      SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3      CONSULTATION RESULTS
3
3      for roof shape = VALLEY
3
3                                 snow load (kPA)    Region of Action (m)
3
3      CASE 1 - uniform load              1.26          - 20  -> 0
3                                         0.94             0 ->  30
3
3      CASE 2 - nonuniform load           1.05            - 10  -> - 5
3                                         2.1            - 5  -> 0
3                                         2.1            0 ->  7.5
3                                         1.05            7.5  ->  15
3
3      CASE 3 - worst senario             1.05            - 10  -> - 2.5
3                                         3.15            - 2.5  -> 0
3                                         3.15            0 ->  3.75
3                                         1.05            3.75  ->  15
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

SNOW LOAD TUTORIAL

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3       GENERAL FORM : S = So * Cb * Cw * Cs * Ca
3
3     case 1:  1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3              0.94  =  2.1  *  0.8  *  0.75  *  0.75  *  1
3
3
3     case 2:  1.05  =  2.1  *  0.8  *  1  *  1  *  0.625
3              2.1  =  2.1  *  0.8  *  1  *  1  *  1.25
3              2.1  =  2.1  *  0.8  *  1  *  1  *  1.25
3              1.05  =  2.1  *  0.8  *  1  *  1  *  0.625
3
3
3     case 3:  1.05  =  2.1  *  0.8  *  1  *  1  *  0.625
3              3.15  =  2.1  *  0.8  *  1  *  1  *  1.875
3              3.15  =  2.1  *  0.8  *  1  *  1  *  1.875
3              1.05  =  2.1  *  0.8  *  1  *  1  *  0.625
3                                                                                        3
3** End - press ENTER to continue.                                                       3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 18

```
                              SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3        SUMMARY OF INPUTS
3
3        PROVINCE :      MB
3        LOCATION :      WINNIPEG
3        ROOF TYPE :     lower roof
3        Upper roof :    flat
3
3        DIMENSIONS
3           lower roof
3                angle :  20 degrees
3                length : 25 metres
3
3           upper roof
3                angle :  0 degrees
3                length : not required
3
3           horizontal separation between roofs :  0 metres
3           vertical separation between roofs   :  2 metres
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
                              SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3
3        LOWER ROOF :-
3           EXPOSED :          YES
3           OBSTRUCTION :      NO
3           OBSTR. HEIGHT : not applicable
3           ROOF MATERIAL : ASPHALT-SHINGLES
3
3        UPPER ROOF :-
3           do not need to known details about upper roof since
3           NO SLIDING of snow from upper to lower roofs
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                         SNOW LOAD TUTORIAL

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3     CONSULTATION RESULTS
3
3     for : LOWER ROOF
3
3     Region of Action (m)      Snow load (kPA)
3
3     edge of upper roof             4.8
3     point XD                       1.68
3     point 10H                      1.26
3
3     separation point               4.8
3     edge of lower roof             1.26
3
3     General Form : S = So * Cb * Cw * Cs * Ca
3
3     upper roof edge      4.8  =  2.1  *  0.8  *  1.  *  1  *  2.85
3     point XD             1.68  =  2.1  *  0.8  *  1.  *  1  *  1
3     point 10H            1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                         SNOW LOAD TUTORIAL

 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      separation point     4.8  =  2.1  *  0.8  *  1.  *  1  *  2.85
3     lower roof edge      1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                         SNOW LOAD TUTORIAL
```

Test 19

```
 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3       SUMMARY OF INPUTS
3
3       PROVINCE :       MB
3       LOCATION :       WINNIPEG
3       ROOF TYPE :      lower roof
3       Upper roof :     flat
3
3       DIMENSIONS
3          lower roof
3               angle :  20 degrees
3               length : 25 metres
3
3          upper roof
3               angle :  0 degrees
3               length : not required
3
3          horizontal separation between roofs :  0 metres
3          vertical separation between roofs   :  2 metres
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
                         SNOW LOAD TUTORIAL

 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3       LOWER ROOF :-
3          EXPOSED :          YES
3          OBSTRUCTION :      NO
3          OBSTR. HEIGHT : not applicable
3          ROOF MATERIAL : GLASS
3
3       UPPER ROOF :-
3          do not need to known details about upper roof since
3          NO SLIDING of snow from upper to lower roofs
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                          SNOW LOAD TUTORIAL
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                         3
3    CONSULTATION RESULTS                                                 3
3                                                                         3
3    for : LOWER ROOF                                                     3
3                                                                         3
3    Region of Action (m)      Snow load (kPA)                            3
3                                                                         3
3    edge of upper roof            4.36                                   3
3    point XD                      1.52                                   3
3    point 10H                     1.14                                   3
3                                                                         3
3    separation point              4.36                                   3
3    edge of lower roof            1.14                                   3
3                                                                         3
3    General Form : S = Sc * Cb * Cw * Cs * Ca                            3
3                                                                         3
3    upper roof edge       4.36  =  2.1  *  0.8  *  1.   *  0.9  *  2.85  3
3    point XD              1.52  =  2.1  *  0.8  *  1.   *  0.9  *  1     3
3    point 10H             1.14  =  2.1  *  0.8  *  0.75  *  0.9  *  1    3
3                                                                         3
3** More - press ENTER to continue.                                       3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                          SNOW LOAD TUTORIAL
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3    separation point      4.36  =  2.1  *  0.8  *  1.   *  0.9  *  2.85  3
3    lower roof edge       1.14  =  2.1  *  0.8  *  0.75  *  0.9  *  1    3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3                                                                         3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 20

```
                              SNOW LOAD TUTORIAL

 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                              3
3        SUMMARY OF INPUTS                                                     3
3                                                                              3
3        PROVINCE :     MB                                                     3
3        LOCATION :     WINNIPEG                                               3
3        ROOF TYPE :    lower roof                                             3
3        Upper roof :   flat                                                   3
3                                                                              3
3        DIMENSIONS                                                            3
3           lower roof                                                         3
3                angle :  20 degrees                                           3
3                length : 24 metres                                            3
3                                                                              3
3           upper roof                                                         3
3                angle :  0 degrees                                            3
3                length : not required                                         3
3                                                                              3
3           horizontal separation between roofs :  1 metres                    3
3           vertical separation between roofs   :  2 metres                    3
3                                                                              3
3** More - press ENTER to continue.                                            3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
                              SNOW LOAD TUTORIAL

 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                              3
3        LOWER ROOF :-                                                         3
3           EXPOSED :        YES                                               3
3           OBSTRUCTION :    NO                                                3
3           OBSTR. HEIGHT : not applicable                                     3
3           ROOF MATERIAL : GLASS                                              3
3                                                                              3
3        UPPER ROOF :-                                                         3
3           do not need to known details about upper roof since                3
3           NO SLIDING of snow from upper to lower roofs                       3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3** End - press ENTER to continue.                                             3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                    SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
       CONSULTATION RESULTS
3
3      for : LOWER ROOF
3
3      Region of Action (m)      Snow load (kPA)
3
3      edge of upper roof             4.36
3      point XD                       1.52
3      point 10H                      1.14
3
3      separation point               3.65
3      edge of lower roof             1.14
3
3      General Form : S = So * Cb * Cw * Cs * Ca
3
3      upper roof edge     4.36  =  2.1  *  0.8  *  1.   *  0.9  *  2.85
3      point XD            1.52  =  2.1  *  0.8  *  1.   *  0.9  *  1
3      point 10H           1.14  =  2.1  *  0.8  *  0.75  *  0.9  *  1
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                    SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
       separation point    3.65  =  2.1  *  0.8  *  1.   *  0.9  *  2.39
       lower roof edge     1.14  =  2.1  *  0.8  *  0.75  *  0.9  *  1
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 21

```
                          SNOW LOAD TUTORIAL

 Z  Playback responses:   DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

 3
 3
 3        SUMMARY OF INPUTS
 3
 3        PROVINCE :       MB
 3        LOCATION :       WINNIPEG
 3        ROOF TYPE :      lower roof
 3        Upper roof :     flat
 3
 3        DIMENSIONS
 3           lower roof
 3                angle :  20 degrees
 3                length : 17 metres
 3
 3           upper roof
 3                angle :  0 degrees
 3                length : not required
 3
 3** More - press ENTER to continue.
 @DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                          SNOW LOAD TUTORIAL

 Z  Playback responses:   DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?

             horizontal separation between roofs :  8 metres                  3
 3           vertical separation between roofs   :  2 metres                  3
 3                                                                            3
 3        LOWER ROOF :-                                                       3
 3           EXPOSED :         YES                                            3
 3           OBSTRUCTION :     NO                                             3
 3           OBSTR. HEIGHT : not applicable                                   3
 3           ROOF MATERIAL : GLASS                                            3
 3                                                                            3
 3        UPPER ROOF :-                                                       3
 3           do not need to known details about upper roof since              3
 3           NO SLIDING of snow from upper to lower roofs                     3
 3                                                                            3
 3                                                                            3
 3                                                                            3
 3                                                                            3
 3                                                                            3
 3                                                                            3
 3                                                                            3
 3** More - press ENTER to continue.                                          3
 @DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 21...

```
                              SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3     CONSULTATION RESULTS
3
3     for : LOWER ROOF
3
3     Region of Action (m)      Snow load (kPA)
3
3     edge of upper roof              4.36
3     point XD                        1.52
3     point 10H                       1.14
3
3     separation point                1.52
3     edge of lower roof              1.14
3
3     General Form : S = So * Cb * Cw * Cs * Ca
3
3     upper roof edge      4.36  =  2.1  *  0.8  *  1.  *  0.9  *  2.85
3     point XD             1.52  =  2.1  *  0.8  *  1.  *  0.9  *  1
3     point 10H            1.14  =  2.1  *  0.8  *  0.75  *  0.9  *  1
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                              SNOW LOAD TUTORIAL

 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      separation point     1.52  =  2.1  *  0.8  *  1.  *  0.9  *  1
3     lower roof edge      1.14  =  2.1  *  0.8  *  0.75  *  0.9  *  1
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 22

```
                              SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3        SUMMARY OF INPUTS
3
3        PROVINCE :      MB
3        LOCATION :      WINNIPEG
3        ROOF TYPE :     lower roof
3        Upper roof :    shed, high end next to lower roof
3
3        DIMENSIONS
3           lower roof
3                angle :  20 degrees
3                length : 25 metres
3
3           upper roof
3                angle :  0 degrees
3                length : not required
3
3           horizontal separation between roofs :  0 metres
3           vertical separation between roofs   :  2 metres
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                              SNOW LOAD TUTORIAL

 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD'
3
3       LOWER ROOF :-
3          EXPOSED :        YES
3          OBSTRUCTION :    NO
3          OBSTR. HEIGHT : not applicable
3          ROOF MATERIAL : ASPHALT-SHINGLES
3
3       UPPER ROOF :-
3          do not need to known details about upper roof since
3          NO SLIDING of snow from upper to lower roofs
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD\
```

```
                             SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
(
      CONSULTATION RESULTS
3
3     for : LOWER ROOF
3
3     Region of Action (m)       Snow load (kPA)
3
3     edge of upper roof             4.8
3     point XD                       1.68
3     point 10H                      1.26
3
3     separation point               4.8
3     edge of lower roof             1.26
3
3     General Form : S = So * Cb * Cw * Cs * Ca
3
3     upper roof edge     4.8  =  2.1  *  0.8  *  1.  *  1  *  2.85
3     point XD            1.68  =  2.1  *  0.8  *  1.  *  1  *  1
3     point 10H           1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                             SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
(     separation point    4.8  =  2.1  *  0.8  *  1.  *  1  *  2.85
      lower roof edge     1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 23

```
                              SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3        SUMMARY OF INPUTS                                                     3
3                                                                              3
3        PROVINCE :      MB                                                    3
3        LOCATION :      WINNIPEG                                              3
3        ROOF TYPE :     lower roof                                            3
3        Upper roof :    shed, high end next to lower roof                     3
3                                                                              3
3        DIMENSIONS                                                            3
3           lower roof                                                         3
3                angle :  20 degrees                                           3
3                length : 25 metres                                            3
3                                                                              3
3           upper roof                                                         3
3                angle :  0 degrees                                            3
3                length : not required                                         3
3                                                                              3
3           horizontal separation between roofs :  0 metres                    3
3           vertical separation between roofs   :  2 metres                    3
3                                                                              3
3** More - press ENTER to continue.                                            3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
                              SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                              3
3        LOWER ROOF :-                                                         3
3           EXPOSED :          NO                                              3
3           OBSTRUCTION :      not applicable                                  3
3           OBSTR. HEIGHT :    not applicable                                  3
3           ROOF MATERIAL :    ASPHALT-SHINGLES                                3
3                                                                              3
3        UPPER ROOF :-                                                         3
3           do not need to known details about upper roof since                3
3           NO SLIDING of snow from upper to lower roofs                       3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3** End - press ENTER to continue.                                             3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                           SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      CONSULTATION RESULTS
3
3     for : LOWER ROOF
3
3     Region of Action (m)     Snow load (kPA)
3
3     edge of upper roof           4.8
3     point XD                     1.68
3     point 10H                    1.68
3
3     separation point             4.8
3     edge of lower roof           1.68
3
3     General Form : S = So * Cb * Cw * Cs * Ca
3
3     upper roof edge     4.8  =  2.1  *  0.8  *  1.  *  1  *  2.85
3     point XD            1.68  =  2.1  *  0.8  *  1.  *  1  *  1
3     point 10H           1.68  =  2.1  *  0.8  *  1.  *  1  *  1
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                           SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
      separation point    4.8  =  2.1  *  0.8  *  1.  *  1  *  2.85
      lower roof edge     1.68  =  2.1  *  0.8  *  1.  *  1  *  1
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 24

```
                                   SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3       SUMMARY OF INPUTS
3
3       PROVINCE :      MB
3       LOCATION :      WINNIPEG
3       ROOF TYPE :     lower roof
3       Upper roof :    shed, low end next to lower roof
3
3       LOWER ROOF DIMENSIONS
3       angle :                 20 degrees
3       length :                25 metres
3       separation distance : 0 metres
3
3       EXPOSED :         NO
3       OBSTRUCTION :     not required
3       OBSTR. HEIGHT : not applicable
3       ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
                                   SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3       SUMMARY OF INPUTS
3
3       PROVINCE :      MB
3       LOCATION :      WINNIPEG
3       ROOF TYPE :     lower roof
3       Upper roof :    shed, low end next to lower roof
3
3       UPPER ROOF DIMENSIONS
3            angle :                 20 degrees
3            length :                10 metres
3            height difference : 2
3
3       EXPOSED :         NO
3       OBSTRUCTION :     not required
3       OBSTR. HEIGHT : not applicable
3       ROOF MATERIAL : ASPHALT-SHINGLES
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                         SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3      CONSULTATION RESULTS
3
3      for : LOWER ROOF
3
3      Region of action (m)      Snow Load (kPa)
3
3      edge of upper roof             9
3      point XD                       1.68
3      point 10H                      1.68
3
3
3      separation point               9
3      edge of lower roof             1.68
3
3      GENERAL FORM : S = So * Cb * Cw * Cs * Ca
3                        + extra ld due to sliding (if applicable)
3
3      upper roof edge      9  = ( 2.1  *  0.8  *  1.  *  1  *  2.85 )
3                                    +  4.19
3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                         SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3      point XD              1.68  = ( 2.1  *  0.8  *  1.  *  1  *  1 )
3                                        +  0
3      point 10H             1.68  =  2.1  *  0.8  *  1.  *  1  *  1 )
3                                       +  0
3
3      load at separation point and at far edge of lower roof are determined
3      by extrapolation from above data and graph.
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              SNOW LOAD TUTORIAL
```

Test 25

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                             3
3                                                                             3
3       SUMMARY OF INPUTS                                                     3
3                                                                             3
3       PROVINCE :      MB                                                    3
3       LOCATION :      WINNIPEG                                              3
3       ROOF TYPE :     lower roof                                            3
3       Upper roof :    gable                                                 3
3                                                                             3
3       LOWER ROOF DIMENSIONS                                                 3
3       angle :                     20 degrees                                3
3       length :                    25 metres                                 3
3       separation distance : 0 metres                                        3
3                                                                             3
3       EXPOSED :        NO                                                   3
3       OBSTRUCTION :    not required                                         3
3       OBSTR. HEIGHT : not applicable                                        3
3       ROOF MATERIAL : ASPHALT-SHINGLES                                      3
3                                                                             3
3                                                                             3
3** More - press ENTER to continue.                                           3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                              SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                             3
3                                                                             3
3                                                                             3
3       SUMMARY OF INPUTS                                                     3
3                                                                             3
3       PROVINCE :      MB                                                    3
3       LOCATION :      WINNIPEG                                              3
3       ROOF TYPE :     lower roof                                            3
3       Upper roof :    gable                                                 3
3                                                                             3
3       UPPER ROOF DIMENSIONS                                                 3
3            angle :                20 degrees                                3
3            length :               10 metres                                 3
3            height difference : 2                                            3
3                                                                             3
3       EXPOSED :        NO                                                   3
3       OBSTRUCTION :    not required                                         3
3       OBSTR. HEIGHT : not applicable                                        3
3       ROOF MATERIAL : ASPHALT-SHINGLES                                      3
3                                                                             3
3                                                                             3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                              SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3     CONSULTATION RESULTS
3
3     for : LOWER ROOF
3
3     Region of action (m)       Snow Load (kPa)
3
3     edge of upper roof              9
3     point XD                        1.68
3     point 10H                       1.68
3
3     separation point                9
3     edge of lower roof              1.68
3
3     GENERAL FORM : S = So * Cb * Cw * Cs * Ca
3                        + extra ld due to sliding (if applicable)
3
3     upper roof edge      9  = ( 2.1  *  0.8  *  1.  *  1  *  2.85 )
3                                  +  4.19
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     point XD               1.68  = ( 2.1  *  0.8  *  1.  *  1  *  1 )
3                                         +  0
3     point 10H              1.68  =  2.1  *  0.8  *  1.  *  1  *  1 )
3                                         +  0
3
3     load at separation point and at far edge of lower roof are determined
3     by extrapolation from above data and graph.
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 26

```
                    SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3       SUMMARY OF INPUTS
3
3       PROVINCE :      MB
3       LOCATION :      WINNIPEG
3       ROOF TYPE :     lower roof
3       Upper roof :    gable
3
3       LOWER ROOF DIMENSIONS
3       angle :                 20 degrees
3       length :                25 metres
3       separation distance : 1 metres
3
3       EXPOSED :        NO
3       OBSTRUCTION :    not required
3       OBSTR. HEIGHT : not applicable
3       ROOF MATERIAL : ASPHALT-SHINGLES
3
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                    SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3       SUMMARY OF INPUTS
3
3       PROVINCE :      MB
3       LOCATION :      WINNIPEG
3       ROOF TYPE :     lower roof
3       Upper roof :    gable
3
3       UPPER ROOF DIMENSIONS
3            angle :                20 degrees
3            length :               10 metres
3            height difference : 2
3
3       EXPOSED :        NO
3       OBSTRUCTION :    not required
3       OBSTR. HEIGHT : not applicable
3       ROOF MATERIAL : ASPHALT-SHINGLES
3
3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                        SNOW LOAD TUTORIAL
 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3    CONSULTATION RESULTS
3
3    for : LOWER ROOF
3
3    Region of action (m)      Snow Load (kPa)
3
3    edge of upper roof              9
3    point XD                        1.68
3    point 10H                       1.68
3
3    separation point                7.17
3    edge of lower roof              1.68
3
3    GENERAL FORM : S = So * Cb * Cw * Cs * Ca
3                       + extra ld due to sliding (if applicable)
3
3    upper roof edge     9  = ( 2.1  *  0.8  *  1.  *  1  *  2.85 )
3                                  +  4.19
3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                        SNOW LOAD TUTORIAL
 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3    point XD             1.68  = ( 2.1  *  0.8  *  1.  *  1  *  1 )
3                                  +  0
3    point 10H            1.68  =  2.1  *  0.8  *  1.  *  1  *  1 )
3                                  +  0
3
3    load at separation point and at far edge of lower roof are determined
3    by extrapolation from above data and graph.
3
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              SNOW LOAD TUTORIAL
 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3       SUMMARY OF INPUTS
3
3       PROVINCE :      MB
3       LOCATION :      WINNIPEG
3       ROOF TYPE :     lower roof
3       Upper roof :    gable
3
3       LOWER ROOF DIMENSIONS
3       angle :                 20 degrees
3       length :                25 metres
3       separation distance : 6 metres
3
3       EXPOSED :        NO
3       OBSTRUCTION :    not required
3       OBSTR. HEIGHT :  not applicable
3       ROOF MATERIAL :  ASPHALT-SHINGLES
3
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 27

```
                              SNOW LOAD TUTORIAL
 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3       SUMMARY OF INPUTS
3
3       PROVINCE :      MB
3       LOCATION :      WINNIPEG
3       ROOF TYPE :     lower roof
3       Upper roof :    gable
3
3       UPPER ROOF DIMENSIONS
3            angle :                 20 degrees
3            length :                10 metres
3            height difference : 2
3
3       EXPOSED :        NO
3       OBSTRUCTION :    not required
3       OBSTR. HEIGHT :  not applicable
3       ROOF MATERIAL :  ASPHALT-SHINGLES
3
3
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                             SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3     CONSULTATION RESULTS
3
3     for : LOWER ROOF
3
3     Region of action (m)      Snow Load (kPa)
3
3     edge of upper roof            9
3     point XD                      1.68
3     point 10H                     1.68
3
3     separation point              1.68
3     edge of lower roof            1.68
3
3     GENERAL FORM : S = Sc * Cb * Cw * Cs * Ca
3                        + extra ld due to sliding (if applicable)
3
3     upper roof edge      9  = ( 2.1  *  0.8  *  1.  *  1  *  2.85 )
3                                  +  4.19
3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                             SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3     point XD              1.68  = ( 2.1  *  0.8  *  1.  *  1  *  1 )
3                                      +  0
3     point 10H             1.68  = ( 2.1  *  0.8  *  1.  *  1  *  1 )
3                                      +  0
3
3     load at separation point and at far edge of lower roof are determined
3     by extrapolation from above data and graph.
3
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 28

```
                         SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3        SUMMARY OF INPUTS
3
3        PROVINCE :      MB
3        LOCATION :      WINNIPEG
3        ROOF TYPE :     projection
3        DIMENSIONS
3             projection length :      2 metres
3             projection height :      1
3             distance to roof edge :  5
3             angle of roof :          20
3
3        EXPOSED :        YES
3        OBSTRUCTION :    NO
3        OBSTR. HEIGHT :  not applicable
3
3        ROOF MATERIAL :  ASPHALT-SHINGLES
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                         SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     CONSULTATION RESULTS
3
3     for roof shape = PROJECTION
3
3     Region of Action (m)      Snow load (kPA)
3
3     edge of projection           1.26
3     point XD                     1.26
3     point 10H                    1.26
3     edge of roof                 1.26
3
3     General Form : S = So * Cb * Cw * Cs * Ca
3
3     proj. edge 1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3     pt XD      1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3     pt 10H     1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3     roof edge  1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 29

```
                                 SNOW LOAD TUTORIAL

   Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
 3
 3        SUMMARY OF INPUTS
 3
 3        PROVINCE :       MB
 3        LOCATION :       WINNIPEG
 3        ROOF TYPE :      projection
 3        DIMENSIONS
 3            projection length :      2.5 metres
 3            projection height :      1
 3            distance to roof edge :  5
 3            angle of roof :          20
 3
 3
 3        EXPOSED :         YES
 3        OBSTRUCTION :     NO
 3        OBSTR. HEIGHT :  not applicable
 3
 3        ROOF MATERIAL :  ASPHALT-SHINGLES
 3
 3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                                 SNOW LOAD TUTORIAL

  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
 3
 3     CONSULTATION RESULTS
 3
 3     for roof shape = PROJECTION
 3
 3     Region of Action (m)      Snow load (kPA)
 3
 3     edge of projection           1.68
 3     point XD                     1.68
 3     point 10H                    1.26
 3     edge of roof                 1.68
 3
 3     General Form : S = So * Cb * Cw * Cs * Ca
 3
 3     proj. edge 1.68   =  2.1  *  0.8  *  1   *  1  *  1
 3     pt XD      1.68   =  2.1  *  0.8  *  1   *  1  *  1
 3     pt 10H     1.26   =  2.1  *  0.8  *  0.75  *  1  *  1
 3     roof edge  1.68   =  2.1  *  0.8  *  1   *  1  *  1
 3
 3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 30

```
                              SNOW LOAD TUTORIAL

Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3         SUMMARY OF INPUTS
3
3         PROVINCE :      MB
3         LOCATION :      WINNIPEG
3         ROOF TYPE :     projection
3         DIMENSIONS
3
3              projection length :      2.5 metres
3              projection height :      2
3              distance to roof edge : 5
3              angle of roof :          20
3
3         EXPOSED :         YES
3         OBSTRUCTION :     NO
3         OBSTR. HEIGHT : not applicable
3
3         ROOF MATERIAL : ASPHALT-SHINGLES
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                              SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3      CONSULTATION RESULTS
3
3      for roof shape = PROJECTION
3
3      Region of Action (m)      Snow load (kPA)
3
3      edge of projection          3.07
3      point XD                    1.68
3      point 10H                   1.26
3      edge of roof                1.68
3
3      General Form : S = So * Cb * Cw * Cs * Ca
3
3      proj. edge 3.07  =  2.1  *  0.8  *  1  *  1  *  1.82
3      pt XD      1.68  =  2.1  *  0.8  *  1  *  1  *  1
3      pt 10H     1.26  =  2.1  *  0.8  *  0.75  *  1  *  1
3      roof edge  1.68  =  2.1  *  0.8  *  1  *  1  *  1
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 31

```
                              SNOW LOAD TUTORIAL
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3         SUMMARY OF INPUTS
3
3         PROVINCE :       MB
3         LOCATION :       WINNIPEG
3         ROOF TYPE :      projection
3         DIMENSIONS
3              projection length :      2.5 metres
3              projection height :      2
3              distance to roof edge :  5
3              angle of roof :          20
3
3         EXPOSED :         YES
3         OBSTRUCTION :     NO
3         OBSTR. HEIGHT :  not applicable
3
3         ROOF MATERIAL :  METAL-NEW
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3     CONSULTATION RESULTS
3
3     for roof shape = PROJECTION
3
3     Region of Action (m)      Snow load (kPA)
3
3     edge of projection           2.79
3     point XD                     1.52
3     point 10H                    1.14
3     edge of roof                 1.52
3
3     General Form : S = So * Cb * Cw * Cs * Ca
3
3     proj. edge 2.79  =  2.1  *  0.8  *  1  *  0.9  *  1.82
3     pt XD      1.52  =  2.1  *  0.8  *  1  *  0.9  *  1
3     pt 10H     1.14  =  2.1  *  0.8  * 0.75  *  0.9  *  1
3     roof edge  1.52  =  2.1  *  0.8  *  1  *  0.9  *  1
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              SNOW LOAD TUTORIAL

Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3         SUMMARY OF INPUTS
3
3         PROVINCE :        MB
3         LOCATION :        WINNIPEG
3         ROOF TYPE :       projection
3         DIMENSIONS
3              projection length :      2.5 metres
3
3              projection height :      2 metres
3              distance to roof edge : 5
3              angle of roof :          20
3
3         EXPOSED :          NO
3         OBSTRUCTION :      not applicable
3         OBSTR. HEIGHT :    not applicable
3
3         ROOF MATERIAL : METAL-NEW
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
                              SNOW LOAD TUTORIAL

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3     CONSULTATION RESULTS
3
3     for roof shape = PROJECTION
3
3     Region of Action (m)       Snow load (kPA)
3
3     edge of projection           2.79
3     point XD                     1.52
3     point 10H                    1.52
3     edge of roof                 1.52
3
3     General Form : S = So * Cb * Cw * Cs * Ca
3
3     proj. edge 2.79  =  2.1  *  0.8  *  1  *  0.9  *  1.82
3     pt XD      1.52  =  2.1  *  0.8  *  1  *  0.9  *  1
3     pt 10H     1.52  =  2.1  *  0.8  *  1  *  0.9  *  1
3     roof edge  1.52  =  2.1  *  0.8  *  1  *  0.9  *  1
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 32

```
                              wind expert

(  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3     SIX DESIGN CRITERIA THAT THE BUILDING MUST MEET
3
3     ( Criteria with respect to wind pressure in kPa)
3
3
3
3     criteria 1 - case A, wind as shown, Fig. B-6
3          wall 1 =  -0.08
3          wall 2 =  -0.13
3          wall 3 =  -0.32
3          wall 4 =  0.33
3          wall 5 =  -0.35
3          wall 6 =  -0.35
3
3     criteria 2 - case A, wind reversed, Fig. B-6
3          wall 1 =  0.33
3          wall 2 =  -0.32
3          wall 3 =  -0.13
3          wall 4 =  -0.08
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              wind expert

(  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3          wall 5 =  -0.35
3          wall 6 =  -0.35
3
3     criteria 3 - case B1, wind as shown, Fig. B-6
3          wall 1 =  -0.35
3          wall 2 =  -0.32
3          wall 3 =  -0.13
3          wall 4 =  -0.35
3          wall 5 =  0.33
3          wall 6 =  -0.08
3
3     criteria 4 - case B1, wind reversed, Fig. B-6
3          wall 1 =  -0.35
3          wall 2 =  0.09
3          wall 3 =  -0.32
3          wall 4 =  -0.35
3          wall 5 =  -0.08
3          wall 6 =  0.33
3
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

(
```

Test 32...

```
Z Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3     criteria 5 - case B2, wind as shown, Fig. B-6                         :
3          Not applicable to structures with roof angles less than 20       :
3          degrees.                                                         :
3                                                                           :
3     criteria 6 - case B2, wind reversed, Fig. B-6                         :
3          Not applicable to structures with roof angles less than 20       :
3          degrees.                                                         :
3                                                                           :
3                                                                           :
3                                                                           :
3                                                                           :
3                                                                           :
3                                                                           :
3                                                                           :
3                                                                           :
3                                                                           :
3                                                                           :
3                                                                           :
3                                                                           :
3** End - press ENTER to continue.                                          :
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

wind expert

Test 33

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     SIX DESIGN CRITERIA THAT THE BUILDING MUST MEET
3
3     ( Criteria given with respect to wind pressure in kPa )
3
3
3
3     criteria 1 - case A, wind as shown, Fig. B-6
3          wall 1 =  -0.16
3          wall 2 =  -0.19
3          wall 3 =  -0.32
3          wall 4 =  0.41
3          wall 5 =  -0.35
3          wall 6 =  -0.35
3
3     criteria 2 - case A, wind reversed, Fig. B-6
3          wall 1 =  0.41
3          wall 2 =  -0.32
3          wall 3 =  -0.19
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

wind expert

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3          wall 4 =  -0.16
3          wall 5 =  -0.35
3          wall 6 =  -0.35
3
3     criteria 3 - case B1, wind as shown, Fig. B-6
3          wall 1 =  -0.35
3          wall 2 =  -0.32
3          wall 3 =  -0.13
3          wall 4 =  -0.35
3          wall 5 =  0.33
3          wall 6 =  -0.08
3
3     criteria 4 - case B1, wind reversed, Fig. B-6
3          wall 1 =  -0.35
3          wall 2 =  -0.13
3          wall 3 =  -0.32
3          wall 4 =  -0.35
3          wall 5 =  -0.08
3          wall 6 =  0.33
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 33

```
3DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     criteria 5 - case B2, wind as shown, Fig. B-6
3          wall 1 =  -0.18
3          wall 2 =  -0.32
3          wall 3 =  -0.13
3          wall 4 =  -0.18
3          wall 5 =  0.09
3          wall 6 =  0.09
3
3     criteria 6 - case B2, wind reversed, Fig. B-6
3          wall 1 =  -0.18
3          wall 2 =  -0.13
3          wall 3 =  -0.32
3          wall 4 =  -0.18
3          wall 5 =  0.09
3          wall 6 =  0.09
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 34

```
                                   wind expert

Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
      SIX DESIGN CRITERIA THAT THE BUILDING MUST MEET
3
3     ( Criteria given with respect to wind pressure in kPa )
3
3
3
3     criteria 1 - case A, wind as shown, Fig. B-6
3          wall 1 =  -0.13
3          wall 2 =  -0.16
3          wall 3 =  0.22
3          wall 4 =  0.42
3          wall 5 =  -0.35
3          wall 6 =  -0.35
3
3     criteria 2 - case A, wind reversed, Fig. B-6
3          wall 1 =  0.42
3          wall 2 =  0.22
3          wall 3 =  -0.16
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                                   wind expert

Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
           wall 4 =  -0.13
           wall 5 =  -0.35
3          wall 6 =  -0.35
3
3     criteria 3 - case B1, wind as shown, Fig. B-6
3          wall 1 =  -0.35
3          wall 2 =  -0.32
3          wall 3 =  -0.13
3          wall 4 =  -0.35
3          wall 5 =  0.33
3          wall 6 =  -0.08
3
3     criteria 4 - case B1, wind reversed, Fig. B-6
3          wall 1 =  -0.35
3          wall 2 =  -0.13
3          wall 3 =  -0.32
3          wall 4 =  -0.35
3          wall 5 =  -0.08
3          wall 6 =  0.33
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Task 34

```
Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3                                                                              3
3                                                                              3
3     criteria 5 - case B2, wind as shown, Fig. B-6                            3
3          wall 1 =  -0.18                                                     3
3          wall 2 =  -0.32                                                     3
3          wall 3 =  -0.13                                                     3
3          wall 4 =  -0.18                                                     3
3          wall 5 =  0.09                                                      3
3          wall 6 =  0.09                                                      3
3                                                                              3
3     criteria 6 - case B2, wind reversed, Fig. B-6                            3
3          wall 1 =  -0.18                                                     3
3          wall 2 =  -0.13                                                     3
3          wall 3 =  -0.32                                                     3
3          wall 4 =  -0.18                                                     3
3          wall 5 =  0.09                                                      3
3          wall 6 =  0.09                                                      3
3                                                                              3
3                                                                              3
3                                                                              3
3** End - press ENTER to continue.                                             3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

```
                              wind expert
```

Test 35

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3     RESULTS OF CONSULTATION
3
3     surface containing member       =   SIDE
3
3     maximum design pressure (kPa) =   0.49
3     minimum design pressure (kPa) =   -0.42
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              wind expert
```

Test 36

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3     RESULTS OF CONSULTATION
3
3     surface containing member       =   SIDE
3
3     maximum design pressure (kPa) =   0.6
3     minimum design pressure (kPa) =   -0.31
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              wind expert
```

Test 37.

```
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3    RESULTS OF CONSULTATION
3
3    surface containing member        =   SIDE
3
3    maximum design pressure (kPa) =   0.5
3    minimum design pressure (kPa) =   -0.26
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              wind expert
```

Test 38

```
Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3    RESULTS OF CONSULTATION
3
3    surface containing member        =   SIDE
3
3    maximum design pressure (kPa) =   0.63
3    minimum design pressure (kPa) =   -0.7
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 39

```
                                wind expert

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                              3
3                                                                              3
3                                                                              3
3     RESULTS OF CONSULTATION                                                  3
3                                                                              3
3     surface containing member        =   SIDE                                3
3                                                                              3
3     maximum design pressure (kPa) =   0.75                                   3
3     minimum design pressure (kPa) =  -0.89                                   3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3** End - press ENTER to continue.                                             3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 40

```
                                wind expert

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3                                                                              3
3                                                                              3
3                                                                              3
3     RESULTS OF CONSULTATION                                                  3
3                                                                              3
3     surface containing member        =   END                                 3
3                                                                              3
3     maximum design pressure (kPa) =   0.42                                   3
3     minimum design pressure (kPa) =  -0.26                                   3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3                                                                              3
3** End - press ENTER to continue.                                             3
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDY
```

Test 41

```
                              wind expert
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3     RESULTS OF CONSULTATION
3
3     surface containing member        =   END
3
3     maximum design pressure (kPa) =    0.42
3     minimum design pressure (kPa) =    -0.26
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 42

```
                              wind expert
Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3     RESULTS OF CONSULTATION
3
3     surface containing member        =   SIDE
3
3     maximum design pressure (kPa) =    0.5
3     minimum design pressure (kPa) =    -0.26
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

wind expert

Test 43

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD?
3
3
3
3     RESULTS OF CONSULTATION
3
3     surface containing member        =   ROOF
3
3     maximum design pressure (kPa) =   -0.04
3     minimum design pressure (kPa) =   -0.23
3
3
3
3
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

wind expert

Test 44

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3     DIMENSIONS
3
3     side wall main area, W   =  45. squ. m.
3     side wall edge area, E   =  2.5 squ. m.
3     end wall main area, W    =  28.74 squ. m.
3     end wall edge area, E    =  2.68 squ. m.
3
3     edge of gable, D         =  5.32 m.
3     distance Z               =  1 m.
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

wind expert

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                                wind expert
```

Test 44

```
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     RESULTS OF CONSULTATION
3
3     Pressures given in kPa :  maximum       minimum
3
3     side walls                 0.52          -0.39
3     side walls - edges         0.65          -0.57
3     end walls                  0.57          -0.42
3     end walls - edges          0.65          -0.57
3
3     roof                       0.09          -0.38
3     roof - corners             0.09          -1.2
3     roof - length edge         0.09          -0.41
3     roof - width edge          0.09          -0.94
3     roof - ridge square        0.09          -0.89
3     roof - ridge strip         0.09          -0.41
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                                wind expert
```

Test 45

```
DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3     DIMENSIONS
3
3     side wall main area, W  =  45. squ. m.
3     side wall edge area, E  =  2.5 squ. m.
3     end wall main area, W   =  28.74 squ. m.
3     end wall edge area, E   =  2.68 squ. m.
3
3     edge of gable, D        =  5.32 m.
3     distance Z              =  1 m.
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                                wind expert

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test45

```
 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3     RESULTS OF CONSULTATION
3
3     Pressures given in kPa :  maximum       minimum
3
3     side walls                 0.66          -0.25
3     side walls - edges         0.8          -0.43
3     end walls                  0.71          -0.28
3     end walls - edges          0.8          -0.43
3
3     roof                       0.23          -0.24
3     roof - corners             0.23          -1.06
3     roof - length edge         0.23          -0.27
3     roof - width edge          0.23          -0.8
3     roof - ridge square        0.23          -0.75
3     roof - ridge strip         0.23          -0.27
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 4b

```
                                            wind expert

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3     DIMENSIONS
3
3     side wall main area, W   =  45. squ. m.
3     side wall edge area, E   =  2.5 squ. m.
3     end wall main area, W    =  28.74 squ. m.
3     end wall edge area, E    =  2.68 squ. m.
3
3     edge of gable, D         =  5.32 m.
3     distance Z               =  1 m.
3
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                                            wind expert

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     DIMENSIONS
3
3     roof - central area, R =  57.44 squ. m.
3     roof - corners, C      =  1.06 squ. m.
3     roof - width edge, Sb  =  3.19 squ. m.
3     roof - length edge, Se =  19.15 squ. m.
3     roof - ridge strip, Sr =  17.02 squ. m.
3     roof - ridge square, S'=  1.06 squ. m.
3
3
3
3
3
3
3
3
3
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

wind expert

Test 46

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     RESULTS OF CONSULTATION
3
3     Pressures given in kPa :  maximum       minimum
3
3     side walls                 0.66          -0.25
3     side walls - edges         0.8          -0.43
3     end walls                  0.71          -0.28
3     end walls - edges          0.8          -0.43
3
3     roof                       0.23          -0.24
3     roof - corners             0.23          -1.06
3     roof - length edge         0.23          -0.27
3     roof - width edge          0.23          -0.8
3     roof - ridge square        0.23          -0.75
3     roof - ridge strip         0.23          -0.27
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 47

```
                              wind expert

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3     DIMENSIONS
3
3     side wall main area, W =  45. squ. m.
3     side wall edge area, E =  2.5 squ. m.
3     end wall main area, W  =  21.26 squ. m.
3     end wall edge area, E  =  2.52 squ. m.
3
3     edge of gable, D       =  5.01 squ. m.
3     distance Z             =  1 m.
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

                              wind expert

DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     DIMENSIONS
3
3     roof - central area, R =  72.15 squ. m.
3     roof - corner area, C  =  1 squ. m.
3     roof - length edge, Sl =  18.02 squ. m.
3     roof - width edge, Sb  =  4 squ. m.
3
3
3
3
3
3
3
3
3
3
3
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 47

```
 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3
3    RESULTS OF CONSULTATION
3
3    Pressures given in kPa :  maximum       minimum
3
3    side walls                 0.66          -0.25
3    side walls - edges         0.8          -0.43
3    end walls                  0.74          -0.3
3    end walls - edges          0.8          -0.43
3
3    roof                       0.23          -0.24
3    roof - corners             0.23          -1.15
3    roof - length edge         0.23          -0.4
3    roof - width edge          0.23          -0.56
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              wind expert
                                                                    Test 48
Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3    DIMENSIONS
3
3    side wall main area, W =  45. squ. m.
3    side wall edge area, E =  2.5 squ. m.
3    end wall main area, W  =  21.26 squ. m.
3    end wall edge area, E  =  2.52 squ. m.
3
3    edge of gable, D       =  5.01 squ. m.
3    distance Z             =  1 m.
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
                              wind expert

ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

3
3    DIMENSIONS
3
3    roof - central area, R =  72.15 squ. m.
3    roof - corner area, C  =  1 squ. m.
3    roof - length edge, Sl =  18.02 squ. m.
3    roof - width edge, Sb  =  4 squ. m.
3
3
3
3
3
3
3
3
3
3
3
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

wind expert

Test 48

```
 DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3
3    RESULTS OF CONSULTATION
3
3    Pressures given in kPa :  maximum       minimum
3
3    side walls                 0.97          -0.25
3    side walls - edges         1.11          -0.43
3    end walls                  1.05          -0.3
3    end walls - edges          1.11          -0.43
3
3    roof                       0.55          -0.24
3    roof - corners             0.55          -1.15
3    roof - length edge         0.55          -0.4
3    roof - width edge          0.55          -0.56
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Test 49

```
                              wind expert

Z  Playback responses:  DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3     DIMENSIONS
3
3     side wall main area, W =  45. squ. m.
3     side wall edge area, E =  2.5 squ. m.
3     end wall main area, W  =  21.26 squ. m.
3     end wall edge area, E  =  2.52 squ. m.
3
3     edge of gable, D       =  5.01 squ. m.
3     distance Z             =  1 m.
3
3
3
3
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

```
                              wind expert

 `DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3     DIMENSIONS
3
3     roof - central area, R =  72.15 squ. m.
3     roof - corner area, C  =  1 squ. m.
3     roof - length edge, Sl =  18.02 squ. m.
3     roof - width edge, Sb  =  4 squ. m.
3
3
3
3
3
3
3
3
3
3
3
3
3** More - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

wind expert

Test 49

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3
3
3
3
3     RESULTS OF CONSULTATION
3
3     Pressures given in kPa :  maximum       minimum
3
3     side walls                 0.97          -1.04
3     side walls - edges         1.11          -1.22
3     end walls                  1.05          -1.09
3     end walls - edges          1.11          -1.22
3
3     roof                       0.55          -1.03
3     roof - corners             0.55          -1.94
3     roof - length edge         0.55          -1.19
3     roof - width edge          0.55          -1.34
3
3
3
3** End - press ENTER to continue.
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```