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Determination of Loads Acting on Surfaces of Structural Steel Buildings in Canada

by

Jan Chmelicek

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of the requirements
for the degree of
Master of Engineering*

Department of Civil and Environmental Engineering
Carleton University
Ottawa, Canada

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* The Civil Engineering Program is a joint program with University of Ottawa,
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**"Determination of Loads Acting on Surfaces of
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Submitted by Jan Chmelicek

**in partial fulfilment of the requirements for the degree of
Master of Engineering**

A handwritten signature in black ink, appearing to read 'S.J. Kennedy', written over a horizontal line.

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**Associate Professor A.G. Razaqpur, Acting Chair
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**Carleton University
September 14, 1993**

Abstract

An interactive graphics based computer program has been developed to determine the dead loads and live loads due to use and occupancy, snow, and wind loads, acting on roof, wall and floor surfaces of steel buildings. The loads are computed in accordance with Part 4-Structural Design of the National Building Code of Canada 1990, NRC (1990). Interactive graphics, 3 dimensional display of structural systems, building geometry and load distributions, provide a simple, versatile program that emulates the design process, is simple to use (does not require a manual), instructive and informative (visual confirmation of geometry and loads). All the required data bases (climatic design data, dead tables, use and occupancy tables); library functions for snow and wind load calculations; modules for geometric modelling of surfaces; and subroutines for creating files that contain load information have been developed. This work is the first step of the module for determining loads and load combinations acting on the primary structural members of a steel building.

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List of Symbols

B	= Background turbulence factor
C	= Factor for computation of reference pressure, $C=0.00005$ if reference wind speed is in km/h
C_s	= Snow accumulation factor
C_{so}	= Coefficient of snow accumulation factor
C_b	= Basic roof snow load factor
C_e	= Exposure factor for wind load intensity
C_e^*	= Exposure factor for wind load intensity increased on the hill or escarpments
C_{eh}	= Exposure factor for wind load at the top of the building
C_g	= Gust effect factor
C_p	= External pressure coefficient
C_{pi}	= Internal pressure coefficient
C_s	= Roof slope factor
C_w	= Wind exposure factor for snow load accumulation
D	= Dead Loads, kN, kN/m, kNm, kJ per metre square
F	= Gust energy ratio
H	= Height of windward face of the building, in metres
K	= Factor related to the surface roughness coefficient of the terrain
L	= Live load due to use and occupancy, snow, ice, rain, kN, kN/m, kNm, kN per metre square

Q	= Live load due to wind and earthquake, kN, kN/m, kNm, kN per metre square
S	= Specified load due to snow, kN per metre square
S_r	= Rain load associated with snow load, kN per metre square
S_g	= Ground snow load, kN per metre square
T	= Load due to contraction or expansion, kN
V_H	= Mean wind speed at top of the structure, m/s
$\bar{V}$	= Reference wind speed, m/s, km/h
W	= Width of windward face of the building, m
W_p	= Maximum or peak loading effect of wind
Z	= Elevation above terrain, m
g_p	= statistical peak factor for the loading effect
h	= Height of the building for exposure factor by simple procedure or height of the adjacent wall above roof for snow accumulation, m
n_o	= natural frequency of vibration, Hz
p	= Specified external pressure, kN per metre square
q	= Reference velocity pressure, kN per metre square
p_i	= Specified internal pressure, kN per metre square
s	= Size reduction factor
x_d	= Length for drift accumulation of snow, m
$x_{sloping}$	= Length of snow accumulation from snow sliding from upper roof, m
α	= Load factors

β	= Critical damping ratio
γ	= Importance factor
μ	= mean loading effect
ν	= Average fluctuation rate
σ	= "root-mean-square" loading effect
ψ	= Load combination factor

Chapter 1

Introduction

1.1 Building Design Fabrication and Construction Process

Unlike many manufactured products, building structures tend to be unique. The analysis-design-fabrication-erection process for these structures exhibits great variability and has not been integrated to any significant extent. The process has tended to be sequential and segmented without adequate interaction between the architects, engineers and fabricators who are responsible for different parts of the process. The quality of design has also varied greatly.

The development of a system that integrates the process would lead to better and more cost effective structures. This would arise from ease of verification, opportunity for increased conceptual development, improved understanding of the loads acting on the structure and the behaviour under those loads, and the unimpeded flow of information throughout the entire process.

The essential steps for a complete integrated system for the layout, analysis, design, detailing, fabrication and erection of a steel building may be summarized as follows in Table 1.1.

Table 1.1 Design Fabrication and Construction Process

Step	Designation	Objectives
1	Preprocessing	Definition of structure and components, determination of loads, preliminary sizing of components
2	Structural analysis	Determination of displacements and internal forces, including second-order (non-linear) geometric effects
3	Component Design	Selection and verification of suitability of components
4	Reanalysis and redesign	Iteration of Steps 2 and 3 until all design requirements are satisfied in a consistent manner
5	Design of connections	Selection and verification of suitability of connections and joints
6	Erection considerations	Investigation of partial structures under construction loadings and bracing conditions
7	Description of structure	Preparation of drawings and specifications
8	Fabrication	Manufacture of all elements of the structure for field erection
9	Construction	Erection and completion of finished building

In North American practice there are generally a number of different organizations involved in this process. In a typical building project the architect may be responsible for portions of steps 1, 7 and 9; the consulting engineer responsible for a portion of 1, all of 2, 3 and 4 and portions of 5, 6, 7 and 9; steel fabricators responsible for portions of 5, 6, 7, all of 8 and portions of 9; and the general contractor responsible for portions of 6 and most of 9. Consequently, communication and coordination are crucial links and a high probability of litigation exists if problems arise.

A complete integrated system would provide a common database for, and the integration of, all the processes involved in all the above steps. Design data would be

shared by all the participants in the process.

A review of current building design-analysis programs on the market including; S-FRAME (Space Frame); SODA (Structural Optimization Design Analysis); M-STRUDL (Structural Design Language); DAST (Total Structural Analysis Design); STAAD III (Structural Analysis and Design); AMECO-17 (Automated Design in Metals and Concrete), GFD3, HESCO, SCADA/H, STEELCAD III, D.C.A., DESIGN DATA, DESCON, MICROCAD, STEELCON, CONXPRT and others, reveal that the structural engineer is responsible for determining loads; attributing loads to members; geometry and boundary conditions; preliminary sizing of members and for supplying additional information not calculated by but required by the program.

The development of a system for the determination of loads and load combinations acting on the structure is the first step in the overall design process and would fill one of the major gaps in existing software tools.

1.2 Required Attributes for Determining Loads

A system for determining loads should be designed to suit the process and must include the following attributes:

1. Common data bases, data base transfer mechanisms, and library functions. Certain databases such as climatic data, masses and weights, use and occupancy live load intensities will remain relatively fixed, while others with respect to geometry, layout, and loads acting on members will be project dependent.
2. Modular system which include the following modules (a) geometric modelling and

- surface definition, (b) determination of loads acting on surfaces, (c) determination of secondary structural systems, (d) definition of primary members, (e) determination of tributary areas, (f) determination of live load reduction factors, (g) attributing loads to members, (h) determination of load combinations.
3. Graphic interfaces for modelling this part of the design process.
 4. Comprehensive design notes, structural images, load and load combination summaries.
 5. Comprehensive help that should be self explanatory to a structural engineer or architect.
 6. Translation functions that generate geometric and load data input for existing structural analysis programs.

1.3 Components/Modules Description

1.3.1 Geometric Modelling and Surface Definition.

This module involves three distinct areas and the development of three corresponding sub-modules.

(a) Surface Definition

Surfaces define the form of the structure and may be classified as floor, wall or roof surfaces. Basic file structures have been created to describe the orientation, size, shape, location and type of surface. These surfaces may be generated from previously defined files or systematically through a series of library functions which identify nodes

and coordinates and draw the surfaces as they are created. Irregular shaped surfaces within a surface may have to be defined.

(b) Primary Member Definition

Primary members will have to be defined and a file structure created that will contain the following attributes: member type, orientation, location, shape designation, continuity and end conditions, identification and analysis codes. Features such as bay member generation and column stack drag (relocating column line or position) options should be included to facilitate the member generation process and modification process.

(c) Secondary Member Definition and Design

This will be invoked after the primary members have been defined and will automatically determine the optimum configuration given the primary member layout and the structural floor, wall, or roof system selected within the dead load determination phase. Extensive interaction with industry will be required to develop guidelines and codeable rules for determining these configurations given present construction techniques and costs. The design of these elements would occur at this stage as it does not require any further interaction with other parts of the system. Updated loads will be calculated and stored in the appropriate data base.

1.3.2 Determination of Loads Acting on Surfaces

This module embodies "Part 4 Structural Design" in the NBCC 1990, NRC (1990),

and the corresponding commentaries and climatic data within the supplement. Data bases, graphic interfaces and library functions which determine the loads described in Clause 4.1.5. Dead Loads, Clause 4.1.6 Live Loads Due to Use and Occupancy, Clause 4.1.7. Live Loads Due to Snow, Ice and Rain, Clause 4.1.8. Live Loads Due to Wind, Clause 4.1.9. Live Loads Due to Earthquakes and Clause 4.1.10. Other Effects must be developed. This module should be capable of importing wind tunnel and sand flume test data for unique load distributions on irregularly shaped structures.

1.3.3 Determination of Tributary Areas

Given the definition of both the primary and secondary members, the surfaces, and the types of structural systems, the determination of tributary areas will be essentially automatic. This will require extensive development of geometric algorithms to determine tributary areas of members arbitrarily oriented within a given surface. Library functions will be included to describe the tributary areas for primary and secondary members of well defined structures like those illustrated in commentary G of the NBCC supplement for (a) flat slabs without beams, (b) two way slabs with beams, (c) two way slabs with joists, beams and girders, (d) one way slabs with girders, (e) one way deck or slabs with joists, beams and girders, and (f) wall systems with girts and sag rods. The structural engineer will be given the option to view these areas graphically. The data should be retained as part of member definitions as it would be used subsequently for future load calculations.

1.3.4 Live Load Reduction Factors

Algorithms need to be developed to determine the appropriate live load reduction factors, to modify the live load due to use and occupancy, that reflect the probability of occurrence of a given intensity. These factors are a function of tributary area and the classification of use and occupancy and need to be calculated for each member independently, slabs or decks, joists, beams, girders, columns and column stacks. Values for the appropriate modification or adjustment of internal forces for any given member and analysis procedure (reflecting the live load reduction factors) should be calculated and stored in the data base for members.

1.3.5 Attributing Loads to Members

At this stage the program would automatically calculate the loads acting on the members. A database would be created to give a complete description of the loads (location, magnitude and direction) and the members on which they act. Loads should be displayed graphically on request for verification and the corresponding database should be printed.

File translator functions could be included so that the data may be reformatted into an acceptable format for any given structural analysis program. A special user interface would have to be developed to facilitate this operation.

1.3.6 Determination of Load Combinations

This module would automatically determine all the load cases that must be

considered in the design of the structure. Large and complex structures may have as many as 1000 load cases where medium and low rise structures may have as many as 30. Provision should be made for the structural engineer, erector or fabricator to introduce special load cases for structures under construction or where structural integrity is being investigated under accidental loads. For example, the Skydome was investigated for the potential of an airplane crash which could take out any portion of the roof 4.5 m in diameter. Between 200 and 300 load cases were considered for this condition alone, Allen (1988).

1.4 Objectives and Scope

The main objective of this work is to develop a computer system for determining loads acting on building surfaces. This includes:

1. the development of databases for climatic data, dead loads, live loads, snow loads, wind loads, and structural geometry, and
2. the development of a geometric modeller to define the surfaces (including subsurfaces) and shape of a structure, and
3. the development of algorithms to determine the corresponding snow and wind loads for the defined structure, and
4. the development of algorithms to attribute the load intensities to the appropriate areas, and
5. the development of user graphic interfaces that will;
(a) facilitate the generation of a geometric model, and

(b) models the design and load determination process, and

(c) that is easy to use and is self explanatory, making a users manual unnecessary.

Although, the scope of the work is limited to the determination of loads acting on surfaces, the file structure and architecture of the program have been designed to accommodate the remaining components of the complete load determination module as described in section 1.3. The determination of dead loads is tailored for steel construction.

1.5 Anticipated Technological and Socio-Economic Impact

The proposed system for determining loads and load combination acting on steel buildings should have a profound impact on the consulting engineering and fabricating community. It would allow for the systematic, simple and complete determination of loads acting on any building in Canada. The loads acting on a typical structure like salt and sand domes for Departments of Highways, for one part of the country could easily be redetermined by simply redefining its geographic location.

Updating the loads on a structure that result from modifications to the geometry could easily be accommodated. Errors such as the one described in the commissioners inquiry into the failure of the Station Square Development, pertaining to not reevaluated the dead loads as they were deemed to be insignificant when in fact, they contributed to the failure. Through interactive graphics, the loads will be displayed visually, making verification easier.

Code committee's could with little effort, investigate the influence of changes to the NBCC on the loads, hence the design of the structure and subsequently the cost, prior to introducing the changes in new releases. The impact across the country could be investigated on certain benchmark structures. Note, that recent changes in the 1990 NBCC, NRC (1990), have had a significant effect on building costs since its introduction; i.e. earthquake loads are now a more severe lateral loads than wind in most major centres in Canada with the exception of Saskatoon.

The development of this system will lead to advancements in computer representation of code, the development of user interfaces for structural engineering, and advances in database management and data base transfer mechanisms.

The load determination system in its completed form, with its enhanced graphics and visual displays will help architects, engineers, fabricators and students to visualize the structure and its components. The sophisticated interactive determination of loads acting on the structure will give designers an increased understanding of loads, shapes of structures and their impact on loads and how loads are carried by the structure. This knowledge will enable them to explore new framing systems and concepts. Removing the drudgery of mundane calculations from the process will generate enthusiasm amongst all users and will eliminate the corresponding errors.

Chapter 2

Determination of Load Intensities and Mesh Generation

2.1 Limit States Design

Limit states are those limiting states or conditions of a structure (serviceability and fatigue, ultimate) at which it ceases to fulfil its intended function. Limit States Design is that design philosophy in which the designer, recognizing the various limit states, proportions the structure such that these are not exceeded, and in general can be expressed as

$$\phi R \geq \alpha S \quad (2.1)$$

(factored resistance $\geq$ effect of the factored loads)

Where,

ϕ and α are resistance and load factors, respectively, and are based on statistical variations of the member resistance and load distributions

R is the member resistance

S is the effect of the loads

The effect of the factored loads is expressed in Part 4 of the National Building Code of

Canada 1990 (NBCC 1990), NRC (1990) in clause 4.1.4.2.(3) for ultimate limit states (strength and stability) as,

$$\alpha_D D + \gamma \psi [\alpha_L L + \alpha_Q Q + \alpha_T T] \quad (2.2)$$

and in clause 4.1.4.3.(2) for serviceability and fatigue limit states (deflection, vibration, fatigue cracking) as,

$$D + \psi [L + Q + T] \quad (2.3)$$

where,

D = dead loads

L = live loads due to intended use and occupancy, snow, ice and rain, earth and hydrostatic pressure, horizontal components of static or inertia forces

Q = live load due to wind or earthquake, whichever produces the more unfavourable effect

T = loads due to contraction or expansion, caused by temperature changes, shrinkage, moisture changes, creep in component materials, movement to differential settlement or combination thereof

$\alpha_D, \alpha_L, \alpha_Q, \alpha_T$ = are the corresponding load factors for each load type, refer to clause 4.1.4.2.(4)

ψ = load combination factor, refer to clause 4.1.4.2.(5) and (6)

γ = importance factor, refer to clause 4.1.4.2.(7)

Establishing the design loads acting on the structure, and hence its members, is essential to the design process and to the design of the building. The computation of the loads

described in Part 4 of the NBCC 1990, NRC (1990), and assessment of these loads to the appropriate surfaces of the building forms the basis of the program LDFSSBC, "Load Determination For Structural Steel Buildings in Canada", written for this thesis and is described in the following sections.

2.2 Dead Load

The specified dead load for a structural member that needs to be considered in design is defined in clause 4.1.5. of Part 4 of the NBCC 1990, NRC (1990) and consists of the self weight of the structural member, floors and floor finishes, ceilings, exterior walls, permanent partitions, electrical and mechanical equipment. Forces due to prestressing are not currently included in any load assessment. The composition of the structural sandwich systems for walls roofs and floors of the finished building are generally well defined, and the corresponding dead loads can be predicted with reasonable accuracy. Variations may occur due to construction practices (tolerances), substitutions or revisions of specified materials and/or construction errors. The loads for a given construction are determined per unit area and subsequently attributed to individual members according to their tributary area and framing scheme.

The program LDFSSBC provides the facility to interactively create and/or edit a list of load intensities (identified by name), from standard libraries of unit weights or standard dead load values, for any structural sandwich system and to attribute these to the appropriate surface or subsurface within the building.

2.3 Live Load Due to Use and Occupancy

The specified live load acting on floor and roof areas is a function of the intended use and occupancy and is defined in clause 4.1.6. of Part 4 of the NBCC 1990, NRC (1990). The minimum specified live load intensities are given in Tables 4.1.6.A. and 4.1.6.B. in Clause 4.1.6. for uniformly distributed and concentrated loads, respectively.

Live load reduction factors are applied to the specified live load intensity, according to the tributary area of the member and the classification of use and occupancy, to reflect the probability that the entire tributary area, may not be fully loaded simultaneously. Concentrated loads acting over a 750 mm x 750 mm square area, may be applied anywhere within the corresponding use and occupancy area to produce the worst load effect. Provisions have been made to incorporate these facets of live load determination in the program LDFSSBC.

Currently, the program provides the facility to interactively create and/or edit a list of loads (concentrated) and load intensities (uniformly distributed), identified by name, from reproduced versions of Table 4.1.6.A. and 4.1.6.B., and to attribute them to the appropriate surface or subsurface within the building.

2.4 Live Load Due to Snow, Ice and Rain

The specified live load due to snow, ice and rain, acting on roof area, is a function of the locale (climatic conditions snow fall, density), site conditions (exposure to wind) and the roof configuration. The load distributions are defined in Clause 4.1.7. of Part 4 of NBCC 1990, NRC (1990). The basic climatic data required for the determination of

snow load distributions, given in Chapter 1 "Climatic Information for Building Design in Canada" of the Supplement to the NBCC 1990, NRC (1990), is easily retrievable from a database created for the program LDFSSBC.

Currently, the program provides the facility to calculate and interactively display the snow load distributions for a building having any or all of the roof configurations (gable roof, shed roof, simple arch or curved roofs, valleys, lower level of adjacent roofs, lower roofs with sloping upper roofs and roof projections) given in Commentary H of the Supplement to the NBCC 1990, NRC (1990).

The specified loading, S (kPa), due to snow accumulation on a roof is given in Clause 4.1.7.1.(1) as

$$S = S_g (C_b C_w C_s C_a) + S_r \quad (2.4)$$

where,

S_g = is the ground snow load in kPa with 1-in-30 annual probability of exceedance. The value, S_g , given in the database for approximately 650 different locales across Canada, is based on measured depths and densities of snow. The unit weight of accumulated snow may vary from 1.0 to 4.5 kN per metre cubed depending upon the locale and time of year. The supplement recommends that a value of 3.0 kN per metre cubed be used for design in lieu of better local data.

S_r = the associated rain load in kPa (rain that fall into the snow cover). The rain load at any location on the roof must be less than the corresponding snow load

$$S_r \leq S_s (C_b C_w C_s C_a)$$

- C_b =** the basic roof snow load factor represents the fraction of the ground snow load which is expected to occur on the roof. Based on measurements from across Canada the value has been set to 0.80.
- C_w =** the wind exposure factor is defined in Clause 4.1.7.1.(2) and (3) as being 1.0, 0.75 or 0.5 depending on whether the site is considered exposed or exposed and north of the tree line. Values less than one indicate that the site is exposed to wind and a reduction in snow load intensity occurs from snow being blown off or by preventing accumulation use the guidelines given in Clause 4.1.7.1.(3) to determine whether or not the site is exposed.
- C_s =** the slope factor is defined in Clause 4.1.7.1.(4),(5) and (6) and reflects the reduction in accumulation of snow due to creep and sliding on a sloped roof. Roof surfaces are classified either as normal and have a slope factor that decreases linearly from 1.0 at a 30 degree slope to 0.0 at 70 degrees, or as unobstructed slipper (made of glass or metal) where the slope factor decreases linearly from 1.0 at 15 degrees to 0.0 at 60 degrees. Reductions in snow load intensity only apply to sloped roof surfaces where the snow can slide off.
- C_a =** accumulation factor is a function of the roof configuration and describes the snow load distribution of the roof surface for all probable load cases (uniformly distributed, drifts, unbalanced loads). The Supplement to the

NBCC 1990, NRC (1990), provides a series of snow load distributions (accumulation factors) for typical roof configurations that were derived from the results of model tests and measurements on existing structures. Figures H-1 to H-6 give the accumulation factor for gable, flat and shed roofs; simple arch or curved roofs; valleys; lower levels of adjacent roofs; lower roofs with sloping upper roofs; and roof projections, respectively. Wind tunnel or sand flume tests must be conducted to establish the snow load distributions for buildings that have roof configurations that cannot be adequately described by these figures. Note, the snow load distributions described by Fig H-6, triangular drift loads for roof areas adjacent to significant vertical obstructions, are calculated within the program using the functions for Fig H-4 with the width defined as the width of the obstruction.

Example calculations which illustrate the application of Clause 4.1.7 and Figures H-1, H-3, H-4 and H-5 for the low-rise building described in section 3.7 , located in Ottawa classified as not exposed, and with unobstructed slipper roofs are given below.

Design Data. Summary

Locale: Ottawa, Ontario

S_e : 2.2 kPa

S_r : 0.4 kPa

Site characteristics: classified as not exposed

Roof characteristics: unobstructed slippery

Application of Figure H-1:

Example solutions verified by LDFSSBC (figures on the left hand side) and the corresponding hand calculations for the design snow load cases for the gable roofs are given in Figure 2.1.

$$C_w = 1.0$$

$$C_s^L = \frac{60 - 23.6}{45} = 0.81$$

$$C_s^R = \frac{60 - 16.3}{45} = 0.97$$

LOAD CASE I :

$$C_a = 1.0$$

$$L: 2.2 \cdot (0.8 \cdot 1.0 \cdot 0.81 \cdot 1.0) = 1.43 > S_r$$

$$R: 2.2 \cdot (0.8 \cdot 1.0 \cdot 0.97 \cdot 1.0) = 1.71 > S_r$$

$$S^L = 1.43 + 0.4 = 1.83 \text{ kPa}$$

$$S^R = 1.71 + 0.4 = 2.11 \text{ kPa}$$

LOAD CASE IIa :

$$C_a^R = 1.25$$

$$R: 2.2 \cdot (0.8 \cdot 1.0 \cdot 0.97 \cdot 1.25) = 2.13 > S_r$$

$$S = 2.13 + 0.4 = 2.53 \text{ kPa}$$

LOAD CASE IIb :

$$C_s^L = 0.25 + \frac{\alpha}{20} = 0.25 + \frac{16.3}{20} = 1.065$$

$$L: 2.2 \cdot (0.8 \cdot 1.0 \cdot 0.81 \cdot 1.065) = 1.52 > S_r$$

$$S = 1.52 + 0.4 = 1.92 \text{ kPa}$$

where α = roof slope in degrees

Fig. 2.1 Example Calculations; Figure H-1.

Application of Figure H-3:

Example solutions verified by LDFSSBC (figures on the left hand side) and the corresponding hand calculations for the design snow load cases for the valley areas of roof are given in Figure 2.2.

Fig. 2.2 Example Calculations; Figure H-3.

Application of Figure H-4:

Example solutions verified by LDFSSBC (figures on the left hand side) and the corresponding hand calculations for the design snow load for lower levels of adjacent roofs are given in Fig. 2.3.

$$\text{slope} = 4.8^\circ \quad C_s = 1.0$$

$$C_w = 1.0$$

$$h = 2.4 \text{ m}$$

$$x_d = 2h = 4.8 \text{ m}$$

$$\text{but } 3\text{m} < x_d < 9\text{m} \quad \text{OK}$$

$$C_{ee} = \frac{\gamma h}{C_p S_s} = \frac{3.0 \cdot 2.4}{0.8 \cdot 2.2} = 4.1$$

$$\text{but if } C_{ee} > \frac{3}{C_b} \text{ use } \frac{3}{C_b} = 3.75$$

$$\text{at } x=0 :$$

$$S = 2.2 \cdot (0.8 \cdot 1.0 \cdot 1.0 \cdot 3.75) + 0.4 = 7.00 \text{ kPa}$$

$$\text{for } x \geq x_d \quad C_d = 1.0$$

$$S = 2.2 \cdot (0.8 \cdot 1.0 \cdot 1.0 \cdot 1.0) + 0.4 = 2.16 \text{ kPa}$$

Fig. 2.3 Example Calculations; Figure H-4.

Application of Figure H-5:

Example solutions verified by LDFSSBC (figures on the left hand side) and the corresponding hand calculations for the lower adjacent roof which is exposed to the possibility of the combination of snow drift accumulation and sliding snow from sloping upper roof are given in Fig. 2.4. Note, the snow load intensity of 6.71 kPa shown in Fig. 3.49. was computed as the average snow load intensity over a unit area defined by the mesh of points 1000 x 1000 mm (for this case this represents the load intensity 500 mm from the wall), not the snow load intensity at one point (at the foot of the wall).

*Snow load on upper roof was computed in Fig. 2.1 H-1 for right part as :
 $S = 2.11 \text{ kPa}$*

Snow drift on lower roof is shown in Fig. 2.3. H-4.

at $x = 0.0$: $S_{\max} = 7.00 \text{ kPa}$

at $x \geq x_d$: $S = 2.16 \text{ kPa}$

Volume of sliding snow from upper roof is 50 % of CASE I :

$$V = \frac{12.0 \cdot 2.11}{\gamma} \cdot 0.50 = \frac{12.66}{3.0} = 4.22 \text{ m}^3$$

$$x_{\text{sloping}} = \frac{2V}{h_s} = \frac{2 \cdot 4.22}{2.40} = 3.52 \text{ m}$$

$$L = x_d + x_{\text{sloping}} = 4.80 + 3.52 = 8.32 \text{ m}$$

Fig. 2.4 Example Calculations; Figure H-5.

2.5 Live Load Due to Wind

The specified live load due to wind acting on external surfaces of a building, is a function of the locale, site conditions and building geometry. The static design pressure distributions, defined in Clause 4.1.8. of Part 4 of the NBCC 1990, NRC (1990), are based on wind tunnel tests for structures classified as low-rise buildings (rectangular in plan, with or without a gable roof) that have widths greater than twice their heights and a reference height less than 10 m; and for medium to high-rise buildings (rectangular shaped, flat roofs) with height to width ratios greater than one and reference heights greater than 20 m. In absence of better data, the static design pressures for low-rise buildings may be used for buildings with geometry that places them between the two categories. Note, the static design pressures give the same maximum load effect as the dynamic resonant response to the actual turbulent wind. For all other structural shapes not described and for high-rise buildings where better estimates of design pressures for cladding is required or where the dynamic response is significant (lies outside the limits specified in Clause 4.1.8.2.) wind tunnel tests must be conducted to determine the design pressure.

Currently, the program LDFSSBC provides the facility to interactively determine the wind load intensities (static design pressures) acting on the exterior surfaces of buildings that meet the geometric constraints on the building form stipulated in the NBCC 1990, NRC (1990). The simple and detailed procedure for determining the exposure factor (including variation due to speed-up over hills and escarpments) and the gust factor have been incorporated. Unique building geometries and the corresponding wind tunnel

test data (describing the wind load distributions) can be imported. Details of wind load calculations are given in the following sections.

2.5.1 Definition of Static Design Pressures

The specified external pressure or suction due to wind on part or all of surface of a building, defined in Clause 4.1.8.1.(1), is calculated from Equation (2.5)

$$p = q \cdot C_e \cdot C_g \cdot C_p \quad (2.5)$$

and the specified internal pressure or suction due to wind, defined in Clause 4.1.8.1.(3), is calculated from Equation (2.6.)

$$p_i = q \cdot C_e \cdot C_g \cdot C_{pi} \quad (2.6.)$$

where,

- p = the specified external pressure acting statically and in a direction normal to the surface either as a pressure directed towards the surface or as a suction directed away from the surface
- q = the reference velocity pressure
- C_e = exposure factor evaluated at height of the element for external pressure and evaluated at the building mid height for internal pressure
- C_g = the gust effect factor
- C_p = the external pressure coefficient average over the area of the surface considered
- p_i = the specified internal pressure acting statically and in a direction normal to the surface either as pressure (directed outward) or as a suction (directed

inwards)

C_{pi} = the internal pressure coefficient

The net specified wind load for the building as a whole is computed as algebraic difference of wind pressure acting on the windward and suction acting on the leeward surfaces. The net specified wind load intensity on part or all surface of a building is computed as algebraic difference of the external pressure or suction and specified internal pressure or suction on the corresponding surface. Subroutines have been written to compute all possible wind load cases for individual external surfaces, only.

2.5.2 Reference Velocity Pressure

The reference velocity pressure is determined from reference wind speed by,

$$q = C \cdot \bar{V}^2 \quad (2.7)$$

where,

$\bar{V}$ = reference wind speed in km/h

C = an atmospheric condition factor that depends on the atmospheric pressure which is primarily a function of elevation above the sea and air temperature.

A nominal value of 0.00005 is used if $\bar{V}$ is given in km/h

The reference wind speed was determined by extreme value analysis of meteorological observations from 100 locations, during a period of 10 to 22 years. The annual maximum hourly wind speed was analyzed using Gumbel's extreme value method

to calculate the hourly wind speed with a return period of 10, 30 and 100 years. From this data the hourly wind speed for an additional 500 locations has been estimated and the corresponding reference velocity pressures computed. These are listed in the Table Design Data for Selected Locations in Canada in Chapter 4 of the Supplement to the NBCC 1990, NRC (1990).

Wind load intensities on surfaces for design of cladding and structural members for deflection and vibration are based on reference velocity pressures which have return period of 10 years and for the design of structural members for strength, 30 years, and for the design of structural members for strength for post-disaster buildings, 100 years.

2.5.3 Exposure Factor

The exposure factor reflects the changes in wind speed with respect to height (velocity profile) and is a function of the surrounding terrain and topography over which the wind crosses and the profile develops. Modifications to these profiles may be required to account for local speed increases (speed up) over hills and escarpments. Both the simplified and detailed procedure for calculating of exposure factor, as presented in the NBCC 1990, NRC (1990) have been incorporated into the program LDFSSBC.

a) Simple Procedure

The exposure factor (wind speed profile) simply expressed as a $1/5$ power of height, Equation 2.8 , is representative of the wind speed profile in open terrain, where, "h" is the height above ground in metres.

$$C_e = (h/10)^{1/5} \geq 0.9 \quad (2.8)$$

b) Detailed Procedure

The detailed procedure explicitly recognizes that the mean wind speed profile varies with the roughness of the terrain over which the wind has been blowing before it reaches the building and classifies the calculation for exposure factor into one of the following three categories.

Exposure A: is suitable for open or standard exposure of open level terrain with only scattered buildings, trees or other obstructions.

$$C_e = \left(\frac{Z}{10} \right)^{0.28} \geq 1.0 \quad (2.9)$$

where, Z = height above ground in metres

Exposure B: suburban and urban areas, wooded terrain or centres of large towns.

$$C_e = 0.5 \left(\frac{Z}{12.7} \right)^{0.50} \geq 0.5 \quad (2.10)$$

Exposure C: centres of large cities with heavy concentrations of tall buildings (at least 50 percent of the buildings should exceed 4 storeys)

$$C_e = 0.4 \left(\frac{Z}{30} \right)^{0.72} \geq 0.4 \quad (2.11)$$

c) Speed-Up over Hills and Escarpments

Wind speed can be significantly amplified near the ground if the building is situated on a hill or on escarpment and this is reflected by an increase in the exposure factor, given by Equation (2.12).

$$C_e^*(Z) = C_e(Z) \left(1 + \Delta S_{\max} \left(1 - \frac{|x|}{kL} \right) e^{\left(-\alpha \frac{z}{L} \right)^2} \right) \quad (2.12)$$

where,

$C_e(Z)$ = the exposure factor over flat terrain calculated from one of Equations (2.8), (2.9), (2.10), (2.11.)

$\Delta S_{\max}$ = relative speed-up factor expressed as a function of geometry of the hill, refer to Fig. 2.5

α = decay coefficient for the decrease in speed-up with height above ground

kL = distance from the crest of the hill to the building

L = length of the hill as shown in Fig. 2.5

2.5.4 Dynamic Response and Gust Effect Factor

The dynamic response and gust effect factor reflect the dynamic interaction of the wind and the structure (fluctuating forces induced by the motion of the structure through the wind; fluctuating forces induced by the wake of the structure) and increased forces due to random wind gusts acting for a short duration over all or part of the structure. Consequently, the factor is defined as the ratio of the maximum effect of the loading to the mean effect of the loading. Both the simplified and detailed procedure for calculating of gust effect factor, as presented in the NBCC (1990), have been incorporated into the program LDFSSBC.

a) Simple procedure

The majority of structures (low-rise) and components are relatively rigid and the gust effect factor can be calculated using the simplified procedure. For external pressures

Figure B-2 Definitions for wind speed-up over hills and escarpments

Table B-1
Parameters for Maximum Speed-Up Over Low Hills

Hill Shape	ΔS_{max}	α	k	
			$x < 0$	$x > 0$
2-dimensional ridges (or valleys with H negative)	$2.2 H/L$	3	1.5	1.5
2-dimensional escarpments	$1.3 H/L$	2.5	1.5	4
3-dimensional axisymmetrical hills	$1.6 H/L$	4	1.5	1.5
Column 1	2	3	4	5

Note to Table B-1:

For $H/L > 0.5$, assume in the formulae that $H/L = 0.5$ and substitute $2H$ for L in Equation (6)

Fig. 2.5 Speed-Up over Hills and Escarpments (reproduced from the Supplement to the NBCC 1990, NRC (1990))

calculated from Equation (2.5) the gust factor is 2.0 for the building as a whole and for the main structural members; and 2.5 for secondary members and cladding. For internal pressures, calculated from Equation (2.6.) the gust factor is 1.0 for building without large openings (Category 1 and 2), and 2.0 for buildings with large or significant openings (Category 3) or for post-disaster buildings.

b) Detailed Procedure

The detailed procedure explicitly recognizes the dynamic interaction between the wind and the building and applies to slender, relatively light weight, low frequency, lightly damped structures as specified in Clause 4.1.8.2. of the NBCC 1990, NRC (1990). The gust factor calculation as outlined in Commentary B of the supplement is as follows. The general expression for the maximum or peak loading effect is represented by

$$W_p = \mu + g_p \sigma \quad (2.13)$$

where,

μ = the mean loading effect

σ = the "root-mean-square" loading effect

g_p = a statistical peak factor for the loading effect

The dynamic response and gust factor is equal to the ratio of the peak loading to the mean loading and is expressed as

$$C_g = 1 + g_p \left(\frac{\sigma}{\mu} \right) \quad (2.14)$$

The value for (σ/μ) , given in Equation (2.15) is a function of the wind speed at the

top of the building, and the building geometry and dynamic characteristics

$$\frac{\sigma}{\mu} = \sqrt{\frac{K}{C_{eH}} \left(B + \frac{sF}{\beta} \right)} \quad (2.15)$$

where,

K = a factor related to the surface roughness coefficient of terrain, 0.08 for Exposure A, 0.10 for Exposure B, 0.14 for Exposure C.

C_{eH} = exposure factor at the top of the building and is calculated from the appropriate equations given in section 2.4.3

B = background turbulence factor given by Equation (2.16) and expressed as a function of W/H

$$B = \frac{4}{3} \int_0^{\frac{914}{H}} \left(\frac{1}{1 + \frac{xH}{457}} \right) \left(\frac{1}{1 + \frac{xW}{122}} \right) \left(\frac{x}{(1+x^2)^{4/3}} \right) dx \quad (2.16)$$

H = height of windward face of the building, for the program LDFSSBC this is taken as total height of the building

W = width of windward face of the building

s = size reduction factor, given by Equation (2.17) and expressed as a function of W/H and reduced frequency

$$s = \frac{\pi}{3} \left(\frac{1}{1 + \frac{8n_0H}{3V_H}} \right) \left(\frac{1}{1 + \frac{10n_{0w}}{V_H}} \right) \quad (2.17)$$

n₀ = natural frequency of vibration, Hz

V_H = mean wind speed (m/s) at the top of structure

F = gust energy ratio at the natural frequency of the structure, given by Equation

(2.18) and expressed as a function of wave number

$$F = \frac{x_0^2}{(1 + x_0^2)^{4/3}} \quad (2.18)$$

where,

$$x_0 = \left(1220 \frac{n_0}{V_H} \right) \quad (2.19)$$

β = critical damping ratio. Values of 0.01 and 0.02 are commonly used in the design of building with steel frames and concrete frames, respectively.

The peak factor for the loading effect, given by Equation (2.20) is a function of average fluctuation rate and is expressed as,

$$g_p = \sqrt{2 \log_e v T} + \frac{0.577}{\sqrt{2 \log_e v T}} \quad (2.20)$$

where, $T=3600$ s.

The average fluctuation rate is computed from,

$$v = n_0 \sqrt{\frac{sF}{sF + \beta B}} \quad (2.21)$$

The dynamic effects of vortex shedding, generally applicable for slender free standing cylindrical structures such as chimneys or observation towers and to some high-rise building, are not currently included in the program LDFSSBC.

2.5.5 External Pressure Coefficient

The external pressure coefficients are defined as non-dimensional ratios of wind-induced pressures on a building to the dynamic pressure of the wind speed at the reference height. Generally, these coefficients were determined from wind tunnel experiments on small-scale models. Some measurements on full-scale buildings have been incorporated directly. The coefficients are given in series of figures in Commentary B of the supplement for two categories of buildings, low-rise and high-rise.

Low-rise buildings are defined as buildings with widths greater than twice their heights that have a reference height less than 10 m. In the absence of more appropriate data these limits may be extended to buildings with $H/W < 1$ and a reference height less than 20 m. Buildings with geometry beyond these limits are classified as high-rise. The external pressure coefficients for low-rise buildings are given in the supplement as the product $C_p C_g$ for primary structural actions (Figure B-7) and for cladding and secondary members in Figures B-8, B-9 and B-10. Recognition of end zones and areas of local maxima on roofs and the determination of the corresponding $C_p C_g$ value have not yet been incorporated into the program. The external pressure coefficients for high-rise buildings are given directly (C_p) in the supplement for the structure in the direction of the wind in Figure B-11; and for end walls and local suction maxima on the roof in Figure B-12. The latter has not yet been incorporated into the program.

2.5.6 Internal Pressure Coefficient

The internal pressure coefficient represents the effect which is produced by wind

on air pressure inside the building. In some cases, the internal pressure contributes to the total pressure or suction on structural members or on cladding and is important for a proper estimate of the design load intensity acting on these members. Buildings are classified into one of three categories depending on the distribution and size of leakage paths and openings which vent the internal air space to the external wind. A guideline description for categorizing the building and the corresponding range of internal pressure coefficients and gust factors for each category follows.

Category 1 - Includes buildings without large or significant openings, but having small uniformly distributed openings. Most high-rise buildings that are nominally sealed and ventilated mechanically are included in this category. For these buildings, C_{pi} is taken as zero.

$$C_{pi} = 0.0 \text{ to } -0.3; C_g = 1.0$$

Category 2 - Most low-rise buildings fall into this category, provided, that all elements are designed to be fully wind resistant. This category includes buildings in which significant openings can be closed in storms and where the background leakage may not be uniformly distributed.

$$C_{pi} = 0.7 \text{ to } -0.7; C_g = 1.0$$

Category 3 - Includes post-disaster buildings and buildings with large or significant openings through which the gusts are transmitted to the interior.

$$C_{pi} = 0.7 \text{ to } -0.7; C_g = 2.0$$

If the classification of the building or the design value of an internal pressure coefficient

is unclear, the supplement suggests the use of the following values given in Fig. B-12.

$C_{pi} = +0.7$	if openings are mainly in windward wall
$C_{pi} = -0.5$	if openings are mainly in leeward wall
$C_{pi} = -0.7$	if openings are mainly in walls parallel to wind direction
$C_{pi} = -0.3$	if openings are uniformly distributed in all 4 walls

2.6 Attributing Loads and Mesh Generation Within any Given Surface

Loads that are attributed to surfaces of a building can be classified into two groups. The first group includes dead loads and live loads due to use and occupancy, where the load intensity is constant in magnitude and direction (gravity loads) over a defined area. Graphic display of these distributions has little value, hence, a mesh of points is not generated and the data is simply stored in the appropriate file containing only the load intensity and the node coordinates defining the area on which the load acts.

The second group includes snow loads and wind loads which have varying load distributions and are a function of climatic data and building geometry. For this group of loads a mesh of points is generated interactively along with the corresponding load intensities of each point to describe the distributions. These can be displayed graphically. The location of the points and the load intensities are stored separately. This eliminates the need to regenerate the mesh should the loads be re-evaluated for the same structure at another locale. The structure of the corresponding data files is described in detail in Appendix B - File Architecture.

2.6.1 Mesh Generation

Analytical geometry was used to create an array of mesh points within the surface or area. To simplify the solution, the surface was transformed from general 3 dimensional space to a two dimensional plane, the mesh of points generated and then transformed back to the original three dimensional space. The grid lines are located such that the direction of one set of grid lines is parallel to the maximum slope of the surface. Slope being defined as the dihedral angle between the surface and horizontal projection plane XZ. For surfaces with zero slope the grid lines are set parallel to axis x and z, for vertical walls the grid lines are set horizontally and vertically. The subroutine functions used to generate the mesh of points, part of the GEOMETRIC-MODELLER module, are described in order as follows.

create_data_nodes3D()

The array of 3D coordinates for all nodes of a given surface are retrieved from the corresponding surface data file.

compute_plane_EQ()

The HOOPS routine Compute_Polygon_Plane() is then executed to compute the equation of plane from array of node coordinates. A plane in three dimensional space is defined by three non-collinear points. A minimum of four points is necessary to determine all the coefficients for the equation describing that plane (the fourth point can be identical

with the first one).

compute_unit_vector()

The HOOPS routines **Compute_Polygon_Normal()** and **Compute_Normalized_Vector()** is then executed to determine the components of unit vector normal to the plane.

select_plane_for_transformation()

The 3D plane including all nodes is then transformed to one of the principal projection planes horizontal, profile or frontal according to the components of the normalized unit vector. The horizontal projection plane XZ was used for all slopes other than 90 degrees. For vertical surfaces, if the x component of unit vector was greater than z, then YX projection plane was used, otherwise the projection was made onto XY plane.

transform_nodes3D_to_nodes2D()

The coordinates of all nodes of the surface are then transformed by perpendicular projection to the selected principal projection plane. From this stage on, all computations are done with respect to the 2D plane.

compute_MAINLINE_EQ_parallel_to_one_axis()

MAINLINE is defined as the projection of a line, which is horizontal within original 3D plane (an array of points with constant y coordinates), to the selected projection plane. This routine is executed if the slope of the original plane is equal to 0.0 or 90.0 degrees

and the MAINLINE is selected as line parallel to axis x in case XZ and XY principal projection plane or parallel to axis z in case of ZY principal projection plane.

compute_MAINLINE_EQ_of_plane_at_point()

For case where the slope of plane is not equal zero, the equation of MAINLINE is computed for the first node of the plane.

line_parallel_through_point()

The equation of line m , parallel to MAINLINE at the reference point, is computed. The coordinates of the reference point R are selected such that the point lies in the quadrant defined by the planes unit vector components, and is far enough from the zero point to be not part of surface as illustrated in Figure 2.6.

find_point_with_minimum_distance_to_MAINLINE()

All nodes of the surface are check to determine the surface node closes to line m (minimum distance) and is designed as point P , as shown in Figure 2.6. Executing the function **line_parallel_through_point()** at point P gives the equation of the reference line marked r .

find_points_A_B()

By inspecting the coordinates of all nodes, the limit points A and B of mesh in one direction are determined. The value representing the range of mesh in the direction

marked **rangeXX** is given by the function **two_points_distance2D (A,B)**.

Fig. 2.6 Geometry for Mesh of Points

compute_range_ZZ()

The range in perpendicular direction, marked **rangeZZ**, is determined by finding the maximum distance of any node to the reference line **r**.

compute_steps_in_mesh()

The differential steps D_x , D_y , D_{yx} , D_{yz} in both directions of the mesh are computed from the slope of 3D plane, the selected projection plane, the normalized unit vector of the plane, the equation of plane and from the required mesh spacing.

create_XXX_array() and create_AZZ_array()

An array of coordinates for points along reference line r $AXX1... AXXn$, over the distance 'rangeXX', is created at a spacing determined by the differential steps D_y and D_x .

Along line a , perpendicular to reference line r and starting at point A , an array of points $AZZ1... AZZn$ over the distance 'rangeZZ', is created at spacing determined by the differential steps.

identify_nodes_ids_EE()

The surface nodes (defined by the intersection of two edges, EE points) are identified and coded by the column and row numbers of the generated mesh. For each node, a line d , perpendicular to line r , is created. Point N , shown in Figure 2.6., is the intersection of these two lines. The distance NA and from the node to line r are divided by the corresponding differential steps giving the points coded location on the mesh.

identify_XE_points()

Grid lines, ni , perpendicular to r are created through each point in the array $AXXi$. The

intersection of these lines with each edge of the surface gives a series of **XE** points that are identified and coded according to their location within the mesh.

identify_EZ_points()

The method to identify the points with an **EZ** code is the same as the described for **XE** points, except that the grid lines **pi** are parallel to line **r** and pass through the **AZZi** points.

identify_XZ_points ()

"XY" coded points all lie within the surface on the intersection of the **pi** and **ni** grid lines. To establish whether or not a point lies with the surface, the number of intersections of the **pi** line with surface edges for a given mesh point is determined. If the number of intersection is odd then the point lies within the surface, otherwise, it lies outside. Those that lie inside are identified and coded appropriately.

make_proper_order_of_2D_points()

Once all the points have been generated, they are ordered by this function starting from row 1, column 1 to the last column number, to the last row number.

transform_point2D_to_point_3D()

Using the equation of the original plane, the set of 2 dimensional mesh point coordinates are then transformed to the original 3-D plane. The identification code and three

coordinates of each point are then saved in a file as described in Appendix B - File Architecture.

2.6.2 Identification Code for Points defining the Mesh

The mesh of points for required surface is formed by intersection of two perpendicular grids in certain distance specified in file "mesh_spacing" or optionally by intersection of one mesh grid with the surface edge or nodes of the surface located between grid lines. An identification code for the mesh of points generated is required to define the relationship of neighbouring points (essential for 3D graphic display of load intensity polygons) and for subsequent work on attributing loads to structural members within a given surface.

An example mesh, points and the corresponding identification code is given in Figure 2.7.

The first four digits of the code represent column number of the mesh in one direction and the last four digits represent the row number, perpendicular to the previous direction. The same number is assigned to the point whether it is located exactly on the grid or it is located between this grid line and the next one. The fifth and sixth characters of the code are used to distinguish between these two cases.

The fifth character is either a "X" or a "E", where,

"X" indicates that the point is located on grid line n_i (with a constant x coordinate) but, only if this grid line is not coincident with an edge of a surface or area; and
"E" indicates that the point is either located at the intersection of two edges of

surfaces or areas, or the point is located on grid line n_i that is coincident with an edge.

The sixth character is either a "Z" or a "E", where,

"Z" indicates that the point is located on grid line p_i (with a constant z coordinate) but only, if this grid line is not coincident with an edge of a surface or area; and "E" indicates that the point is either located at the intersection of two edges of surfaces or areas, or the point is located on grid line p_i that is coincident with an edge.

Fig. 2.7 Identification Code for Points of Mesh

Point No.	ID Code	Point No.	ID Code	Point No.	ID Code
1 -	0001EE0001	13 -	0002EE0002	25 -	0002EE0003
2 -	0002XE0001	14 -	0003XE0002	26 -	0006XE0003
3 -	0003XE0001	15 -	0004XE0002	27 -	0004EZ0004
4 -	0004XE0001	16 -	0004EE0002	28 -	0005XZ0004
5 -	0004EE0001	17 -	0001EZ0003	29 -	0006XZ0004
6 -	0005XE0001	18 -	0002XZ0003	30 -	0006EZ0004
7 -	0001EZ0002	19 -	0002EZ0003	31 -	0004EE0004
8 -	0002XZ0002	20 -	0004EZ0003	32 -	0005XE0004
9 -	0003XZ0002	21 -	0005XZ0003	33 -	0006XE0004
10 -	0004XZ0002	22 -	0005EZ0003	34 -	0006EE0004
11 -	0005XZ0002	23 -	0001EE0003		
12 -	0005EZ0002	24 -	0002XE0003		

Chapter 3

Program Description

3.1 General Description of the Main Menu and Screen Configuration

The program LDFSSBC, "Load Determination For Structural Steel Buildings in Canada", has been designed to model the load determination phase of the design process. The program provides the capacity for the structural engineer to input the geographic location of the structure and the corresponding climatic data (including local characteristics that effect snow and winds loads); to define the surfaces (floors, walls and roofs) of a building; to define the composition of the surfaces for the purpose of estimating dead loads; to define the use and occupancy loads for any area; to determine the snow and wind loads acting on the structure according to the NBCC 1990, NRC (1990); and to attribute those loads to the appropriate surfaces. All relevant data files, library functions, geometric algorithms, user interface screens and graphic images have been developed. Structured data files containing the geographic location, climatic data and the corresponding load data are provided for further computations. Graphic representations of the structure and loads are easily obtained from postscript files created by the engineer using the program.

The program was written in "C" programming language in conjunction with Hoops graphic system to ensure flexibility and ease of portability to other environments. The

program has been developed on SPARC station running Sun OS 4.0.3.

Once all the requirements on the hardware, operating system and environmental variables, as described in Appendix A, are set up, then the program is ready to be used. To execute the program type LDFSSBC ("Load Determination For Structural Steel Buildings in Canada") on the keyboard, and enter RETURN. The first window with the title and main menu buttons will appear on the screen as shown in Fig. 3.1. The main menu buttons are continuously displayed on the screen during all operations of this program. All the buttons are selectable from the main frame window. On colour monitors

Fig. 3.1 Title Screen and Main Menu

these buttons have the light blue colour ("periwinkle") and are slightly shaded for black & white monitors. This colour or pattern of shading represents selectable buttons for all

windows, in the program -i.e. the appropriate action will be performed if the button is activated. For the purpose of this thesis, the shaded pattern of the buttons was removed to make the text on the hardcopies readable. A brief description of the function of each main menu button follows.

CLIMATIC DATA

The climatic data button is selected to define the geographic location of the building and the corresponding climatic data required for the determination of loads. Chapter 1 of the Supplement to the National Building Code of Canada 1990, NRC (1990) forms the data base.

DEAD LOAD

The dead load button is used to build structural sandwich systems for roofs, floors and walls, from libraries of masses and mass densities for different building materials for the purpose of determining the dead load of a building. A list of area names and load intensities can be created. Activating this button within the geometric modeller allows the engineer to attribute load intensities to specified areas.

LIVE LOAD USE & OCCUPANCY

The live load use and occupancy button is used to establish a list of area names and load intensities (both uniformly distributed and concentrated loads) for the use and occupancy of the structure under consideration. Tables 4.1.6.A and 4.1.6.B from the

NBCC 1990, NRC (1990) have been incorporated to form the basic live load use and occupancy load intensity data bases. Activating this button within the geometric modeller allows the engineer to attribute load intensities to specified areas.

SNOW, ICE & RAIN

The snow, ice and rain button is used to calculate snow loads acting on surfaces defined as roofs. It is activated within the geometric modeller to set up the geometry of the roof and surrounding surfaces which might influence the snow load intensities; to generate the mesh for each surface to attach snow load library functions for Figure H-1 to H-6 of the NBCC Supplement, NRC (1990) to the appropriate surfaces; and activated from the main window to compute and display the snow loads for each surface. Working menus and instructions with specialty subwindows guide the engineer through the process.

WIND LOAD

The wind load button is used to calculate wind loads acting on surfaces defined as roofs and walls. Required geometry definitions are made by activating this button within the geometric modeller window, while the load intensities are calculated and displayed by activating this button from within the main window.

EARTHQUAKE

Not currently active. Activation of the earthquake button will compute the base shear of the structure about each principle axis and will attribute the storey shears

appropriately. Overturning moments and centre of mass at each level will be calculated. Distribution of the shears to the lateral load resisting elements within each storey level and the calculation of the torsional moments is considered to be part of the analysis module.

GEOMETRIC MODELLER

The geometric modeller button is used to define the building surfaces and to attribute loads to them.

PRINT SCREEN

Print screen will provide the user with a hard copy of any portion of the screen display in the form of a postscript file.

QUIT PROGRAM

This button terminates the program session.

The screen is configured into 4 basic windows, as shown in Figure 3.2 , simplifying the appearance, making the program easier to learn and use. The largest window is generally reserved for a three dimensional graphic display of the structure or in the case of snow and wind loads for the load intensities acting on specified surfaces. The left window is used to display either three two dimensional views of the structure or load intensity graphs or additional data definitions required for determining loads or structural geometry data. The last window contains menu commands, status and other relevant

information that are specific to the main menu button selection.

Fig. 3.2 Screen Configuration

The following sections describe the process of creating or editing a geometric model of a structure and the determination of loads acting on the surfaces.

3.2 GEOMETRIC MODELLER - Display, Edit or Create Surfaces

The program is capable of simultaneous creating or editing as many projects as the capacity of the data storage device allows. Each project is stored in separate subdirectory and switching between project is handled within GEOMETRIC MODELLER. Each time the program is started, the last edited or created project becomes the current active project.

To display or edit the currently active project, or to create a new project select the **GEOMETRIC MODELLER** button. The corresponding window shown in Figure 3.3 will be displayed. The main command menu buttons of Geometric Modeller invoke following actions.

CLIMATIC DATA	LIVE LOAD USE & OCCUP.	WIND LOAD	Date: Jan 20 1988, 00:00:00	
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELER
<div>PLAN VIEW</div> <div>XY ELEVATION</div> <div>ZY ELEVATION</div>		<div>STRUCTURE DISPLAY</div> <div>LOADS TO SURFACES</div> <div>LIST EXISTING PROJECTS</div> <div>INFO ACTIVE PROJECT</div> <div>CREATE NEW PROJECT</div> <div>EDIT ACTIVE PROJECT</div>		
		<div>CURRENTLY ACTIVE PROJECT</div> <div>>> example_1 <<</div>		

Fig. 3.3 Geometric Modeller - Main Window

3.2.1 LIST EXISTING PROJECTS

The selection of this button activates a display of a list of existing projects in the right portion of the command menu window as shown in Fig. 3.4. Any project can be selected and made active by mouse selection. Scroll devices allow the engineer to browse through the list of existing projects.

CLIMATIC DATA	LIVE LOAD USE & OCCUP.	WIND LOAD	Date: Feb 11 1988, 13:45:57	
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELER

NOTE !

PROJECTS NAME WILL BE DELETED FROM LIST ONLY.
ALL PROJECTS FILES WILL REMAIN IN PROJECTS DIRECTORY

PLAN VIEW

XY ELEVATION

ZY ELEVATION

ARE YOU SURE YOU WANT
TO DELETE THIS PROJECT ???

RETURN

TO ACTIVATE OTHER PROJECT :
=>CLICK CURSOR ON IT<=<

TO DELETE PROJECT FROM LIST :
=>CLICK ON 'DELETE PROJECT' AND PROJECT<=<

LIST OF PROJECTS:

new_example	example_6
example_2	example_6
example_5	example_7
example_4	example_6
	example_6

Fig. 3.4 Geometric Modeller - Activate Existing or Delete Project

3.2.1.1 DELETE PROJECT

Deletion of any project name from list is possible by activating the button **DELETE PROJECT** and selecting the project to be deleted. As shown in Fig. 3.4 , a window asking for confirmation of the action is displayed, to avoid accidental deiction. As a precaution only the name is erased from the project list only. The files are retained in the projects subdirectory and can only be deleted by using the appropriate operation system commands. After deletion, the first project name from the list becomes the 'currently active project'.

3.2.1.2 RETURN

Selection of the return button returns the process one step back within the program.

3.2.2 INFO ACTIVE PROJECT

By selecting this button the name of the currently active project is displayed in the bottom command menu window as shown in Fig. 3.3.

CLIMATIC DATA	LIVE LOAD USE & OCCUP.	WIND LOAD	Date: Feb 10 1998, 16:59:54	
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELER
<div>PLAN VIEW</div> <div>XY ELEVATION</div> <div>ZY ELEVATION</div>		<div>NEW PROJECTS NAME ???</div> <div>new_example</div> <div><input type="button" value="OK"/> <input type="button" value="CANCEL"/></div>		
		<div>STRUCTURE DISPLAY</div>		
		<div>LIST EXISTING PROJECTS</div>		
		<div>INFO ACTIVE PROJECT</div>		
		<div>LOADS TO SURFACES</div>		
		<div>EDIT ACTIVE PROJECT</div>		
		<div>CURRENTLY ACTIVE PROJECT</div> <div>>> example_1 <<</div>		

Fig. 3.5 Create New Project

3.2.3 CREATE NEW PROJECT

Selection of this button, shown in Fig. 3.3 starts the process of creating a new project i.e. a geometric model of a building composed of a series of surfaces. First, the engineer inputs the name for the project as shown in Fig. 3.5. After confirmation that the

name selected is OK, the program checks if all characters of this name are permitted by system as a name for a subdirectory. All unacceptable characters are substituted by an underscore '_' character. The next window, shown in Fig. 3.6 , requires the engineer to

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD		Date Feb 16 1993 17:31:47
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G. MODELLER

PLAN VIEW

XY ELEVATION

ZY ELEVATION

DRAWING COORDINATES SET UP :

EXTENTS :

X :	-25000	TO	25000	mm
Y :	-5000	TO	95000	mm
Z :	-25000	TO	25000	mm

TO CHANGE VALUE CLICK ON IT !!!

STRUCTURE DISPLAY	LIST EXISTING PROJECTS
	INFO ACTIVE PROJECT
LOADS TO SURFACES	EDIT ACTIVE PROJECT

CURRENTLY ACTIVE PROJECT

>> new example <<

Fig. 3.6 Drawing Coordinate Set Up

confirm or to adjust the approximate range of coordinates that will be used to describe the structure. The values are adjusted by mouse selection and keyboard input. This provides the program with a definition of size so that the entire structure can be drawn within the 3D graphic display window during the first stage of the designing process (creation of new surfaces). Confirmation of the range of coordinates initiates the set up of a subdirectory for the project and all subsubdirectories for snow and wind loads required by system. Subsequently, the button menu for creating new surface will be displayed and is shown in Fig. 3.7.

If an existing structure is selected, made the currently active project, then the scale and the coordinates transformation are computed automatically.

CREATE FLOOR	SURFACE ID ON/OFF	CURRENTLY ACTIVE PROJECT >> new_example <<
CREATE ROOF	NODE ID ON/OFF	
CREATE WALL	EDIT NODE COORDINATES	
DELETE SURFACE ON/OFF	COORDINATES SETUP	
SAVE CHANGES	CANCEL-CREATE NEW	

Fig. 3.7 Create New Surface Button Menu

3.2.3.1 CREATE FLOOR

The creation of a new floor surface is started by the selection of this button. The three basic ways of creating a floor system, node number and coordinate definition, duplication of existing surfaces, or by drawing the surface directly on the screen with the

<div style="background-color: black; width: 100px; height: 20px; margin-bottom: 5px;"></div> DUPLICATE LAST FLOOR		NAME FOR NEW SURFACE <div style="border: 1px solid black; padding: 2px; display: inline-block;">floor_1</div> <div style="display: inline-block; width: 40px; height: 20px; background-color: black; margin-right: 10px;"></div> <div style="border: 1px solid black; padding: 2px; display: inline-block;">CANCEL</div>
	MODIFY VIEW	
	RETURN	

(a) Name Input

ES	NAME FOR NEW SURFACE
	<div style="border: 1px solid black; padding: 2px; display: inline-block;">wall_3</div>
	THIS NAME EXISTS - TRY AGAIN !

(b) Correction

Fig. 3.8 New Surface Definition

mouse make the system flexible and simple to use. Regardless of the method used, the

engineer is first prompted for a surface name. The program then checks for name duplication and if necessary will prompt for a new name. Refer to Fig. 3.8(a) and (b).

3.2.3.1.1 NEW SURFACE BY NODES

There are two ways of defining nodes as shown in Fig. 3.9. Either the value for each of three coordinates has to be inputted or an existing node ID is selected.

		CREATING NODES FOR : floor_1	
DUPLICATE LAST FLOOR		<input type="text"/>	
CREATE ON SCREEN	LIST NODES COORDINATES	<input type="button" value="BY NODE ID"/> <input type="button" value="CANCEL"/>	
	MODIFY VIEW		
	RETURN		

Fig. 3.9 Create New Surface By Nodes

3.2.3.1.1.1 BY COORDINATES

Keyboard input of x,y,z coordinates of node in millimetres is required and the node ID is automatically generated. Editing of any coordinate within the window is possible by mouse selection and input of new coordinate values as shown in Fig. 3.10(a). After the confirmation of coordinates for any given node, the application menu shown in Fig. 3.10(b) is displayed and the list of nodes ID belonging to the new surface are shown in the bottom portion of the window. To create another node within the surface, select the **NEXT NODE** button and the process will repeat itself, starting with the menu shown in Fig. 3.9. Selection of the **SURFACE FINISHED** button terminates the definition of surface, and the building (including the newly defined surface) is displayed in four typical views as shown in Fig. 3.11.

CREATING NODES FOR : floor_1																															
ES	X=	6000		mm																											
	Y=	0		mm	<input type="button" value="CANCEL"/>																										
	Z=	6000		mm																											
<table border="1"> <tr> <td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td> </tr> <tr> <td>11</td><td>12</td><td>1</td><td>13</td><td>14</td><td></td><td></td><td></td><td></td><td></td> </tr> </table>												1	2	3	4	5	6	7	8	9	10	11	12	1	13	14					
1	2	3	4	5	6	7	8	9	10																						
11	12	1	13	14																											

(a) X,Y,Z coordinates

CREATING NODES FOR : floor_1																															
ES																															
	<input type="button" value="NEXT NODE"/>					<input type="button" value="CANCEL"/>																									
<table border="1"> <tr> <td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td> </tr> <tr> <td>11</td><td>12</td><td>1</td><td>13</td><td>14</td><td>15</td><td>16</td><td>13</td><td></td><td></td> </tr> </table>												1	2	3	4	5	6	7	8	9	10	11	12	1	13	14	15	16	13		
1	2	3	4	5	6	7	8	9	10																						
11	12	1	13	14	15	16	13																								

(b) Application Menu

Fig. 3.10 Surface Definition By Coordinates

As shown by the active application menu in Fig. 3.11 , additional surface can be created (if required), or edited or saved if the definition of the structure is complete.

CLIMATIC DATA	WIND LOAD USE & OCCUP	WIND LOAD		Date Feb 14 1988, 16:50 10										
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELLE										
 <input type="button" value="PLAN VIEW"/>														
 <input type="button" value="XY ELEVATION"/>														
 <input type="button" value="ZY ELEVATION"/>														
<table border="1"> <tr> <td>CREATE FLOOR</td> <td>SURFACE ID ON/OFF</td> </tr> <tr> <td>CREATE ROOF</td> <td>NODE ID ON/OFF</td> </tr> <tr> <td>CREATE WALL</td> <td>EDIT NODE COORDINATES</td> </tr> <tr> <td>DELETE SURFACE ON/OFF</td> <td>COORDINATES SETUP</td> </tr> <tr> <td>SAVE CHANGES</td> <td>CANCEL-CREATE NEW</td> </tr> </table>		CREATE FLOOR	SURFACE ID ON/OFF	CREATE ROOF	NODE ID ON/OFF	CREATE WALL	EDIT NODE COORDINATES	DELETE SURFACE ON/OFF	COORDINATES SETUP	SAVE CHANGES	CANCEL-CREATE NEW			
CREATE FLOOR	SURFACE ID ON/OFF													
CREATE ROOF	NODE ID ON/OFF													
CREATE WALL	EDIT NODE COORDINATES													
DELETE SURFACE ON/OFF	COORDINATES SETUP													
SAVE CHANGES	CANCEL-CREATE NEW													

Fig. 3.11 Finished Surface Displayed

3.2.3.1.1.2 BY NODE ID

Selection of this button allows an engineer to add an existing node to a new surface

avoiding duplication of nodes. The corresponding application menu, shown in Fig. 3.12 , indicates that there are three ways of selecting existing nodes, by keyboard, from the screen or from a list of nodes.

1	2	3	4	5	6	7	8	9	10
11	12	1	13	14	15	16			

(a) By Keyboard Entry

1	2	3	4	5	6	7	8	9	10
11	12	1	13	14	15	16			

(b) Error Message

1	2	3	4	5	6	7	8	9	10
11	12	1	13	14	15	16			

(c) Verification

Fig. 3.12 Input Node ID

Keyboard input of existing node ID numbers can be made by activating the appropriate button shown in Fig. 3.12(a). The input values are compared with list of existing nodes and discrepancies are reported to the engineer within window as indicated by the error message shown in Fig. 3.12(b). Successful node ID number inputs are accepted and verification is called for, return to Fig. 3.12(c).

Selection of nodes from the screen is very fast and most useful for creating walls (generally walls are created after the floor and roof surfaces). The existing nodes are

represented in 3 dimensional display as small squares, as shown in Fig. 3.13 , and are selected with the mouse. The selected node ID number will appear in the lower right hand window. If a mistake has been made, simply delete the series of nodes that define the

Fig. 3.13 Select Node ID from Screen

surface back to the incorrect entry with the **DELETE LAST** button. To end the selection from the screen select **DONE** and menu will return to the application menu for surface definition shown in Fig. 3.10(b). At this point the surface definition may be complete and the process terminated by activating **SURFACE FINISHED** or additional nodes may be defined by activating **NEXT NODE**.

Creating a surface from a list of nodes function like the selection of nodes from the screen except, the nodes are selected from a list shown in the left hand window of

Fig. 3.14.

CLIMATIC DATA		LIVE LOAD USE & OCCUP		WIND LOAD		Date: Feb 10 1988 10:55:40	
DEAD LOAD		SNOW ICE & RAIN		EARTHQUAKE		PRINT SCREEN	
EXIT G. MODELLER							
LIST OF NODES :							
ID	x	y	z
300	0000	00000	0000				
301	0000	00000	0000				
302	0000	00000	0				
303	-01000	00000	-10000				
304	-01000	00000	-10000				
305	-10000	00000	-10000				
306	-10000	00000	-10000				
400	10000	00000	-10000				
401	10000	00000	-10000				
402	01000	00000	-10000				
403	01000	00000	10000				
404	10000	00000	10000				
405	10000	00000	10000				
406	-10000	00000	10000				
407	-10000	00000	10000				
408	-01000	00000	10000				
409	-01000	00000	0				
410	0000	01000	0				
411	0000	01000	0000				
412	-0000	01000	0000				
413	10000	00000	-10000				
414	-10000	00000	-10000				
415	10000	00000	10000				
416	01000	00000	-10000				
417	01000	00000	10000				
418	10000	00000	10000				
419	10000	00000	10000				
420	-10000	00000	10000				
421	-10000	00000	10000				
422	0000	00000	10000				
423	-10000	00000	10000				
424	-10000	00000	10000				
425	-01000	00000	10000				
426	-01000	00000	10000				
427	-01000	00000	10000				
428	-01000	00000	10000				
429	-10000	00000	-10000				
430	-01000	00000	-10000				
431	-10000	0	-10000				
432	-10000	00000	-10000				

LIST NODES COORDINATES
 MODIFY VIEW
 RETURN

CREATING NODES FOR: wall_15
 SELECT NODE FROM >>>LIST OF NODES<<<
 DONE DELETE LAST CANCEL
 CONTINUE SELECTION UNTIL >>>EXIT<<<
 302 303 411

Fig. 3.14 Select Node ID from List of Nodes

3.2.3.1.2 DUPLICATE LAST FLOOR

Activating this button gives the option to create floors or roofs by duplicating the shape of the last floor created. Simply input the new surface name as required, refer to Fig. 3.8 , and input the appropriate elevation of the new surface as shown in Fig. 3.15. Only horizontal surfaces can be created by activating button.

3.2.3.1.3 CREATE ON SCREEN

Horizontal surfaces can be created on the screen by mouse scrolling and button selection. Activating the **CREATE ON SCREEN** button will prompt the engineer to input

NEW SURFACE BY NODES		INPUT NEW ELEVATION	
CREATE ON SCREEN	LIST NODES COORDINATES	4200	mm
	MODIFY VIEW		
	RETURN		CANCEL

Fig. 3.15 Create Surface by Duplicating the Last Floor

the name of the new surface and the corresponding elevation as described previously, and subsequently, display the information and application buttons shown in the bottom right hand window shown in Fig. 3.16. Activating the left hand button of the mouse within the main window will give the 'x' and 'z' coordinates of the current cursor position. These

CLIMATIC DATA	LIVE LOAD USE & OCCUP.	WIND LOAD		Date Feb 10 1993, 16:20:42
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELER

PLAN VIEW

XY ELEVATION

ZY ELEVATION

NEW SURFACE BY NODES		COORDINATES x z	-21000	15000	mm
REPEAT LAST FLOOR		LEFT MOUSE BUTTON - SHOW COORDINATES			
	LIST NODES COORDINATES	<input type="button" value="DONE"/> <input type="button" value="DELETE LAST"/> <input type="button" value="CANCEL"/>			
	MODIFY VIEW	RIGHT MOUSE BUTTON - SELECT NODE			
	RETURN	307 308 309 400 401 402 403 404 405 406 407 408			

Fig. 3.16 Create Surface by Mouse Selection on Screen

will be constantly updated while scrolling the mouse if the button is held down. To select

any position as a node release the button and activate the right hand button. The selected coordinates are displayed in appropriate windows and the corresponding node ID is added in the bottom display. To edit use the **DELETE LAST** node option and recreate the remaining surface required. Because the sensitivity of physical motion of the mouse is limited, the coordinates displayed are rounded to the nearest 100 mm. Note, the sensitivity of the mouse increases as the range of coordinates (refer to section 3.2.3.9) or scale of the main window increases. To terminate creation of the surface select the **DONE** button and four views of the building, including the new surface, will be displayed.

3.2.3.2 CREATE ROOF

The process to create a new roof surface is similar to that for a new floor surface. The **CREATE ON SCREEN** option currently applicable to horizontal surfaces only, can be used for creating sloped roof surfaces by simply editing the 'y' coordinates of appropriate nodes as described in section 3.2.3.4 with the button **EDIT NODE COORDINATES**.

3.2.3.3 CREATE WALL

Again, the process to create a new wall surface is similar to that for new floor surfaces, except that the options **REPEAT LAST FLOOR** and **CREATE ON SCREEN** are not applicable. This is not seen as a shortcoming as floors and roofs are created before walls in the design process. Walls then can be created very quickly by the selection of existing nodes on the screen or from the list of nodes which are common with floors and

roofs.

3.2.3.4 Other Editing and Viewing Buttons.

DELETE SURFACE ON/OFF Selection of this button allows the deletion of any existing surface. Select the surface type (roofs, floors or walls) and the corresponding list of surfaces will be displayed in the lower right hand window as shown in Fig. 3.17. Locate and delete the required surface by mouse selection.

CREATE FLOOR	SURFACE ID ON/OFF	LIST OF SURFACES :		
CREATE ROOF	NODE ID ON/OFF	ROOFS	FLOORS	
CREATE WALL	EDIT NODE COORDINATES	wall_1	wall_6	wall_11
	COORDINATES SETUP	wall_2	wall_7	wall_12
			wall_8	wall_13
		wall_4	wall_9	wall_14
SAVE CHANGES	CANCEL-CREATE NEW	wall_5	wall_10	wall_15

Fig. 3.17 Delete Surface from List of Surfaces.

SAVE CHANGES Activating this button saves the data for created or edited surfaces and terminates the current creating or editing process session.

SURFACE ID ON/OFF Selection of the SURFACE ID ON/OFF button will activate or deactivate the surface identification routine. While activated, mouse selection of any surface within any of the four display windows will display the corresponding surface identification information in the bottom right window as shown in Fig. 3.18. The surface name and node numbers defining the surface are shown.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	Date Feb 11 1988 10:01 AM	
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELER

PLAN VIEW

XY ELEVATION

ZY ELEVATION

DISPLAY BUILDING		SURFACE ID INFORMATION :	
DISPLAY SURFACE ON/OFF	NODE ID ON/OFF	SURFACE NAME : floor 20	
ROOFS VISIBILITY ON/OFF	LIST NODES COORDINATES	CREATED BY NODES : 300 300 301 302 303 304 305 306 307 308 309 370 371 372 373 374 375 376 377	
FLOOR VISIBILITY ON/OFF	MODIFY VIEW		
WALLS VISIBILITY ON/OFF	RETURN		

Fig. 3.18 Surface ID Information.

NODE ID ON/OFF Selection of the NODE ID ON/OFF button will activate or deactivate the node identification routine. All nodes are displayed in 3D view as small squares. While activated, mouse selection of any node gives the node identification number and its coordinates in bottom right window as shown in Fig. 3.19.

EDIT NODE COORDINATES To correct errors in existing node data or to create sloped surfaces for roofs activate the EDIT NODE COORDINATES button. Select the appropriate node number from the list of nodes displayed in the left hand window shown in Fig. 3.20. The corresponding node number and coordinates will then be displayed in the lower right hand window. Select the coordinate to be edited and key in the new value. Confirm and save the changes. To determine the process select the

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	Date Feb 11 1999, 09:32:58	
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELER

LIST OF NODES :
ID	X	Y	Z	
1	01000	0	-10000	
2	10000	0	-10000	
3	10000	0	-10000	
4	10000	0	-10000	
5	10000	0	-10000	
6	01000	0	-10000	
7	01000	0	-10000	
8	10000	0	-10000	
9	10000	0	-10000	
10	10000	0	-10000	
11	10000	0	-10000	
12	01000	0	-10000	
13	0000	0	0	
14	0000	0	0	
15	0000	0	0000	
16	-0000	0	0000	
17	-01000	0000	-10000	
18	10000	0000	-10000	
19	10000	0000	-10000	
20	10000	0000	-10000	
21	10000	0000	-10000	
22	01000	0000	-10000	
23	01000	0000	-10000	
24	10000	0000	-10000	
25	10000	0000	-10000	
26	10000	0000	-10000	
27	-10000	0000	-10000	
28	-01000	0000	-10000	
29	01000	0000	-10000	
30	0000	0000	0	
31	0000	0000	0	
32	0000	0000	0000	
33	-0000	0000	0000	
34	-0000	0000	0	
35	-01000	0000	-10000	
36	01000	0000	-10000	
37	-10000	0000	-10000	
38	10000	0000	-10000	
39	10000	0000	-10000	
40	10000	0000	-10000	

DISPLAY BUILDING	SURFACE ID ON/OFF	NODES ID INFORMATION : NODE ID <input type="text" value="410"/> x = <input type="text" value="6000"/> mm y = <input type="text" value="81000"/> mm z = <input type="text" value="0"/> mm
DISPLAY SURFACE ON/OFF		
ROOFS VISIBILITY ON/OFF	LIST NODES COORDINATES	
FLOOR VISIBILITY ON/OFF	MODIFY VIEW	
WALLS VISIBILITY ON/OFF	RETURN	

Fig. 3.19 Nodes ID Information.

EDIT NODE COORDINATES button.

COORDINATES SETUP Activate this button if the initial coordinates setup (defines the scale within the windows) need to be changed. The function is similar to that described in selection 3.2.3 CREATE NEW PROJECT.

CANCEL CREATE NEW By activating this button, the changes made from the last saving of data (initiated by SAVE CHANGES) are deleted and the deleted data cannot be restored.

CLIMATIC DATA		LIVE LOAD USE & OCCUP		WIND LOAD		Date Feb 11 1988 09:30:10	
DEAD LOAD		SNOW ICE & RAIN		EARTHQUAKE		PRINT SCREEN	
LIST OF NODES :						EXIT G. MODELLER	
ID	x	y	z
300	0000	0000	0000				
301	0000	0000	0000				
302	0000	0000	0				
303	0000	0000	10000				
304	0000	0000	10000				
305	0000	0000	10000				
306	0000	0000	10000				
307	0000	0000	10000				
308	0000	0000	10000				
309	0000	0000	10000				
310	0000	0000	10000				
311	0000	0000	10000				
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313	0000	0000	10000				
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318	0000	0000	10000				
319	0000	0000	10000				
320	0000	0000	10000				
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322	0000	0000	10000				
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338	0000	0000	10000				
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342	0000	0000	10000				
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381	0000	0000	10000				
382	0000	0000	10000				
383	0000	0000	10000				
384	0000	0000	10000				
385	0000	0000	10000				
386	0000	0000	10000				
387	0000	0000	10000				
388	0000	0000	10000				
389	0000	0000	10000				
390	0000	0000	10000				
391	0000	0000	10000				
392	0000	0000	10000				
39							

Fig. 3.20 Edit Node Coordinates.

3.2.4 EDIT ACTIVE PROJECT

The process of editing the geometry of the surfaces of a building is similar to that described in section 3.2.3 CREATE NEW PROJECT, with the exception that the new name definition and coordinates setup steps are bypassed.

3.2.5 STRUCTURE DISPLAY

To view the structure or different parts of the structure (used to verify that the structural geometry form is correct) the engineer would activate the **STRUCTURE DISPLAY** button found in the geometric modeller main window shown in Fig. 3.3. The corresponding application menu is shown in Fig. 3.21. Functions that have been provided to facilitate the process include: display of one surface type or a given surface, surface and

node identification, and routines for modifying the view (scaling, panning and rotating). These are described below.

DISPLAY BUILDING	SURFACE ID ON/OFF	CURRENTLY ACTIVE PROJECT >> new_example <<
DISPLAY SURFACE ON/OFF	NODE ID ON/OFF	
ROOFS VISIBILITY ON/OFF	LIST NODES COORDINATES	
FLOOR VISIBILITY ON/OFF	MODIFY VIEW	
WALLS VISIBILITY ON/OFF	RETURN	

Fig. 3.21 Structure Display Application Menu.

DISPLAY BUILDING By activating this button, the image of the currently active project is displayed in plan, elevation (two views) and in the 3 dimensions, as shown in Fig. 3.22. The position and scale of the structure shown in each window on the screen (centred and within the window provided) has been computed from the nodal coordinate data.

DISPLAY SURFACE ON/OFF After the selection of this button, the engineer is asked to select the surface name to be displayed from the List of Surfaces in the bottom right hand window shown in Fig. 3.23. The corresponding plan view of the surface will be displayed in main window. Currently, only horizontal surfaces (floors and roofs) are displayed properly. Transformation or rotation of planes have not yet been implemented - i.e. vertical walls are displayed as a line. To obtain more information about displayed surface activate the SURFACE ID ON/OFF button.

Fig. 3.22 Display of Building.

ROOFS - FLOORS - WALLS VISIBILITY ON/OFF Identification and viewing of one surface type is possible by setting the visibility of the other surfaces to OFF. As illustrated in Fig. 3.18 , where only the roof and floor surfaces are shown (wall visibility is set to OFF) the display is consistent in all four windows.

LIST NODE COORDINATES A list of nodes and the corresponding coordinates will be displayed in the left hand window by selecting this button, refer to Fig. 3.19. Editing the coordinates for each node is only possible by activating EDIT NODE COORDINATES button.

Fig. 3.23 Display Selected Surface.

MODIFY VIEW To modify the 3 dimensional image of the building activate the **MODIFY VIEW** button. The corresponding application menu will be displayed in the bottom right hand window as shown in Fig. 3.22. Selection of the ON/OFF button (-i.e. 'ON' position) allows the values of displayed graphic attributes to be modified. Graphic attributes in Hoops are the details that determine how the picture is displayed rather than what the picture consists of. The buttons particular to this application menu are described below.

- ON/OFF** - Switches (toggles) the option to modify view ON and OFF.
- RESET** - The initial setting of the graphic attributes (default values) for the 3 dimensional image of the structure was selected to a view that clearly illustrates the structural form. The size of the scene, in terms of object space coordinates

around the 'target' shown in the relevant screen window, is dependent on what the virtual viewing device-like TV camera can see from a defined position (orbit). The initial default setting of the camera field and camera position, defined by Hoops (internally) are as follows:

- object space (camera field)

The coordinate system defined by Hoops graphics is shown in Fig. 3.24.

The object has been scaled to fit within the camera field defined by Hoops.

The limits along the x-axis and y-axis are set to vary from -1.0 to 1.0 in both directions.

- orbit of camera (camera position)

The initial viewing direction is along the z-axis. The default camera position is set counterclockwise in the x-z plane and rotated above that plane by 45 degrees and 30 degrees, respectively. The RESET button sets the graphic attributes to the default setting giving the original view.

- c) **SECTION** Sets the view to give an XY elevation of the structure.
- d) **NUMBERS 1-200** Numbers representing degrees of rotation or percent of magnification when modifying the view of the structure, while using the ORBIT CAM and ZOOM % button, respectively.
- e) **ZOOM %** Narrows or enlarges the viewing field of the camera. A value of 200 will zoom the picture in, until the viewing field is half as wide, while a value of 50 will zoom the picture out the same amount.
- f) **SOLID/TOGGLE** Visibility of the faces of surfaces in the 3 dimensional display

are toggle on and off by activating the SOLID/TOGGLE button. The corresponding image appears either as a solid or a wire framework showing the edges of the surfaces, as shown in Fig. 3.25.

Fig. 3.24 Object Space and Initial Camera Position.

- g) **DOLLY CAM** Dolly Camera moves the camera left and right, up and down (translates) along the target so that the field-of-view remains unchanged. The direction of movement is determined by selecting one of arrows with required

direction.

Fig. 3.25 Display Building - SECTION and SOLID/TOGGLE.

- h) **ORBIT CAM** Walks the point of view around the object being looked at. By selecting one of horizontal arrows the camera will "walk around" the target to the right or to the left. By selecting one of vertical arrows the camera will float up or down over the target.
- i) **PAN CAM** Sweeps the camera (pirots) across its current scene in the direction of selected arrow.

3.2.6 LOADS TO SURFACES

This button is located in the application menu for the geometric modeller - main

window shown in Fig. 3.3. Within the sequence of tasks for determining loads acting on building, attributing load intensities to surfaces follows the definition of dead and live loads (use and occupancy) and the specification of climatic data. The description of the functions performed by activating this button is given in the same sequence in section 3.6.

3.3 CLIMATIC DATA

The climatic information for building design in Canada given in the Supplement to the National Building Code of Canada 1990 and all subsequent revisions, NRC (1990), is accessible by activating the CLIMATIC DATA button in the main menu. To retrieve the data for snow, wind and earthquake load calculations;

- 1) Select the appropriate province or territory from the list in the left hand window (the province of British Columbia appears as the default) and the list of locations for that province or territory will be displayed in the middle window entitled "LOCATION" ("100 Mile House" appears as the default for British Columbia), refer to Fig. 3.26. The first 20 locations will be displayed.
- 2) Use the arrows in the top and bottom of the scroll bar meter to browse through the locations for that province or territory. The scroll bar meter indicates the current position within the list. Select the required location and the climatic data will be retrieved and displayed in the right hand window entitled, "CLIMATIC DATA".
- 3) These values can either be save to a text file, "location_climatic_data" located in the subdirectory for the currently active project, by activating the SAVE LOCATION button, or the values changed by mouse selection and keyboard entry,

DEAD LOAD	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date Feb 17 1998 16:45:00
SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT CLIMATIC DATA	

PROVINCE	LOCATION	CLIMATIC DATA
British Columbia	Michel	Design Temperature Jan. 2.5 % -26
Alberta	Mooseonee	Design Temperature Jan. 1 % -27
Saskatchewan	Morrisburg	Design Temp. July 2.5% Dry 30
Manitoba	Mount Forest	Design Temp. July 2.5% Wet 23
Ontario	Nelbna	Degree Days Below 18 C 4634
Quebec	Nanticoke (Jarvis)	15 Minutes Rain mm 23
New Brunswick	Nanticoke (Port Dover)	One Day Rain mm 83
Nova Scotia	Napanee	Annual Total Precipitation mm 848
Prince Edward Island	New Liskeard	Ground Snow Load Ss kPa 2.2
Newfoundland	Newcastle	Ground Snow Load Sr kPa 0.4
Yukon	Newcastle (Bowmanville)	Hourly Wind Pressure 1-10 kPa 0.30
Northwest Territories	Newmarket	Hourly Wind Pressure 1-30 kPa 0.37
	Niagara Falls	Hourly Wind Pressure 1-100 kPa 0.46
	North Bay	Seismic Data Za 4
	Norwood	Seismic Data Zv 2
	Oakville	Zonal Velocity Ratio v 0.10
	Orangeville	
	Orillia	
	Oshawa	
	Ottawa	

SAVE LOCATION

TO CHANGE ANY COEFFICIENT
CLICK THE MOUSE BUTTON ON IT

Fig. 3.26 Climatic Data.

and then saved. This feature is useful for building locations where the climatic data is different from that listed, -i.e. snow load values change radically from one valley to another in the mountains in British Columbia. Altered climatic data is particular to the project. The original library cannot be overwritten.

3.4 DEAD LOADS

The DEAD LOAD determination module is used to create list(s) of structural sandwich systems (identified by name) and the corresponding dead load intensities in kPa for floors, roofs and walls in the building being designed. These can be created and edited graphically from libraries of standard dead load intensities used in design for typical elements that make up these structural sandwich systems, such as, roofing materials,

insulation, vapour barriers, concrete slabs, steel deck, composite slabs, beams, OWSJ's, ceilings, floor finishes and other loads. As these building systems are created, the list of elements are compiled, the total dead load intensity is calculated and the corresponding system is illustrated (to scale - a representative 3m x 3m section) as shown in Fig. 3.27. Newly defined structural sandwich systems and the corresponding load intensities are added to the existing list stored in the appropriate files, "DL_roofs_defaults", "DL_floor_defaults", and "DL_walls_defaults". Subsequently, these loads will be attributed to specified surfaces selected in the geometric modeller.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date Feb 11 1988, 16:52:08																																					
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT DEAD LOAD																																					
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Fig. 3.27 Dead Load Structural Sandwich Systems.

Activating the DEAD LOAD button from the main menu generates the display given in Fig. 3.27. The buttons FLOOR, ROOF and WALL, shown in the application menu window, are selected in turn to create, edit or display the structural sandwich systems

required for the project. Specific button and the corresponding functions used in this module are described in detail below.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELER	Date Feb 11 1998 17:05:18
DEAD LOADS	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT DEAD LOAD

Wall.default_1		kPa
Brick veneer Brick 112 5h 100 mm		1.00
Air space		0.00
Polyethylene foils		0.02
Steel studs 152 mm @ 400 o.c.		0.06
Insulation Glass fibre rigid 150 mm		0.10
Vapour barrier		0.02
Gypsum wallboard 12 mm		0.13
TOTAL		2.20

EDIT

LIST OF STRUCTURAL SYSTEMS :		BRICK VENEER	ON / OFF	RESET	SECTION
Wall.default_1	2.20	CONCRETE BLOCK	1	5	20
Wall.default_2	0.20	PARTITIONS	50	80	105
prec_conc_glazing	2.50	CLADDING	120	180	200
metal_curtain_wall	1.20	INSULATION	ORBIT CAM		
DELETE STRUCT	MATERIAL INFO	CREATE NEW	PAN CAM		

WAPOUR BARR KNPBOARD RETURN

Fig. 3.28 Dead Load Structural Sandwich Systems for Walls.

ROOF, FLOOR, WALL To display the list of existing structural sandwich systems and to initiate the process for creating new systems or to edit existing systems for a given surface type, activate the appropriate button. An example for walls is illustrated in Fig. 3.28.

DELETE STRUCT. To delete a structural sandwich system from the list, select the DELETE STRUCT button and the system name. Confirmation is required.

MATERIAL INFO Select this button and the appropriate element type, -i.e. roofing, to review the library of materials and load intensities. An example for roofing materials is shown in Fig. 3.29.

CREATE NEW Activate this button to create a new structural sandwich system. First, enter the system identification name into the appropriate window and then use the editing buttons shown in the left hand window in Fig. 3.29, to build the structural sandwich system from the libraries provided.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date Feb 11 1988 16:29 15																																																
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Fig. 3.29 Create/Edit Dead Load Structural Sandwich Systems.

EDIT Activates the editing mode. Through the use of the editing buttons elements can be deleted, added or inserted from the list shown or the load intensities can be changed to

reflect better estimates.

a) ADD New elements can be added either by mouse selection from the screen libraries, as shown in Fig. 3.29, or by keyboard input as shown in Fig. 3.30.

INPUT ELEMENT BY KEYBOARD		
BRICK VENEER		DESCRIPTION OF ELEMENT <input type="text" value="precast concrete + glazing"/> Unit Weight in kPa : <input type="text" value="2.5"/> Thickness in mm : <input type="text" value="150.0"/> <input type="button" value="OK"/> <input type="button" value="CANCEL"/>
CONCRETE BLOCK		
PARTITIONS		
CLADDING		
INSULATION		
VAPOUR BARRIERS BOARD	RETURN	

Fig. 3.30 Input Element by Keyboard.

The libraries are organized in groups of the materials that are found in structural sandwich systems. The list of materials for any group is displayed by activating the corresponding button located in the lower right hand window. To add an element from library to the list for the system, select button ADD followed by required element. For elements with variable thickness (crushed stone ballast, insulation, concrete slab etc.) the engineer is required to input the thickness in mm. The load intensity in kPa is calculated and displayed. Note, the density may be redefined. The element is added to the end of the list once the data is confirmed. New elements, not existing in the current library listings, can be added through keyboard input. The corresponding window is shown in Fig. 3.30).

b) INSERT INSERT places an element between two existing elements within list.

Activate the INSERT button, select the element in the list just prior to the location where the element is to be inserted, and then select the element from the appropriate library list.

c) DELETE Activate the DELETE button and select the required elements to be deleted.

d) CHANGE VALUE The load intensity in kPa of any element in the list for the structural sandwich system, can be changed by activating the CHANGE VALUE button, selecting the required value to be changed and keyboard input of new value. The total load intensity of edited or newly created structural sandwich systems will be updated after each modification.

e) SAVE Activating the SAVE button will save edit or newly created structural sandwich systems in an output file, as described in Appendix B - File Architecture.

f) CANCEL All modifications are cancelled

3.5 LIVE LOADS DUE TO USE AND OCCUPANCY

The LIVE LOADS DUE TO USE AND OCCUPANCY module is used to create a list of areas (identified by a user specified name) and the corresponding uniformly distributed and concentrated loads due to the specified use and occupancy. Subsequently, these loads will be attributed to specified surfaces selected in the geometric modeller.

are used to browse through the pages. To view the related articles, select the appropriate button in the bottom left hand window.

CLIMATIC DATA		WIND LOAD	GEOMETRIC MODELLER	Date Feb 11 1998, 14:09:27
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT LIVE LOAD

CREATING : mechanical_room

SELECTED UDL: 3.60 kPa

kN

BY

KEYBOARD

CANCEL

Specified Concentrated Live Loads on an Area of Floor or Roof

Area of Floor or Roof	Minimum Specified Concentrated Load (kN)
Roof surfaces	1.5
Floors of classrooms	4.5
Floors of offices, manufacturing buildings, hospital wards & stages	11.0
Floors and areas used by passenger cars	18.0
Floors and areas used by vehicles not exceeding 3000 kg gross weight	36.0
Floors and areas used by vehicles exceeding 3000 kg but not exceeding 8000 kg gross weight	54.0
Floors and areas used by vehicles exceeding 8000 kg gross weight (See Appendix A.)	54.0
Driveways and sidewalks over arcades and basements (See Appendix A)	54.0

Fig. 3.32 Live Load Use and Occupancy - Select Concentrated Load.

INFO-CONCR.L. Selection of this button displays Table 4.1.6.B. Specified Concentrated Live Loads on an Area of Floor or Roof from NBCC 1990, NRC (1990), as shown in Fig. 3.32.

CREATE NEW To create a new listing, activate the CREATE NEW button, input of new area name and select the uniformly distributed load value from table (the selection must be confirmed) or input the value from the keyboard, as shown in Fig. 3.32. The same procedure is followed for the selection of the concentrated load value.

EDIT To edit a value from the list, activate the EDIT button, select the uniformly distributed load or concentrated load value from the list of defined areas to be changed and use the keyboard to input the new value.

DELETE To delete any defined are, select DELETE button, followed by the area to be deleted. Confirmation is not required.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD		Date Feb 11 1993 15 50 50
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G MODELLER
<div>PLAN VIEW</div>				
<div>XY ELEVATION</div>				
<div>ZY ELEVATION</div>				
		DEAD LOAD	SAVE - CREATED	
		LIVE LOAD		
		SNOW LOAD		
		WIND LOAD		
			CANCEL - CREATED	

Fig. 3.33 Attribute Loads to Surfaces.

3.6 Attributing Loads Within the Geometric Modeller

Once the structural geometry has been defined and the dead and live load intensities specified, then the process of attributing the loads to the appropriate surfaces can start by

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

STANDARD REFERENCE MATERIAL 1010a

(ANSI and ISO TEST CHART No. 2)

selecting the **LOAD TO SURFACES** button from the geometric modeller main window. To attribute any given load type (**DEAD**, **LIVE** (used and occupancy), **SNOW** and **WIND**) activate the corresponding button shown in the applications menu in Fig. 3.33.

3.6.1 DEAD LOAD

Selection of this button initiates the process for attributing dead loads to surfaces, utilizing specific menus as shown in Fig. 3.34 (a) (b) and functions similar to those for creating a new surface. The process follows the following steps.

STEP 1 Select the required surfaces from the **LIST OF SURFACES** shown in Fig. 3.34 (a), to which the load will be attributed. The list of existing surfaces for a given type is displayed when the corresponding surface type button, **ROOFS**, **FLOORS** or **WALLS** is activated.

STEP 2 Select the dead load intensity from the list shown in Fig. 3.34 (b) (a list of structural sandwich systems previously created) to be attributed; after which a plan view of the surfaces selected in STEP 1 will be displayed in the main window. Refer to Fig. 3.35. Areas in which dead loads have already been attributed are distinguished by dashed lines and a different shade pattern or colour for grey scale and colour monitors, respectively.

STEPS 3 Also shown in the application menu window in Fig.3.35 are buttons similar to those for creating a new surface. These are used to attribute the specified dead load intensity to any given area(s) shown by **LOAD AREA BY NODES** or

LOAD AREA ON SCREEN. The function of all button are described below

DEAD LOAD	RETURN	LIST OF SURFACES :		
		ROOFS	FLOORS	WALLS
		floor_1	floor_6	floor_11
		floor_2	floor_7	floor_12
		floor_3	floor_8	floor_13
		floor_4	floor_9	floor_14
		floor_5	floor_10	floor_15

(a) Select Surface

DEAD LOAD	RETURN	SELECT LOAD INTENSITY AREA	
		Floor.default_1	
		Floor.default_2	
		typ_floor_storage	
		typ_floor_corridor	

(b) Select Corresponding Structural Sandwich System

Fig. 3.34 DEAD LOAD - Surface and Load Intensity Identification

LOAD AREA BY NODES The load intensity is attached to an area by defining that area. The nodes defining the area are established by (a) keyboard input of three coordinates for each node (tedious) or (b) by selection of existing nodes from the list of nodes or (c) by keyboard input of node ID or (d) by node identification and selection on the screen.

LOAD AREA ON SCREEN The area is defined in the some manner as that where surfaces were created with the CREATE ON SCREEN option (described in section 3.2.3.1.3) by mouse scrolling and button selection. This option is extremely useful for defining subareas where nodes have not been previously defined.

Fig. 3.35 Select Surface with Attributed Dead Load Intensity.

AREA LOAD ID ON/OFF The selection of this button followed by the selection of any area identified on the screen will display the structural sandwich system name and the corresponding load intensity (kPa) in the lower right hand window as shown in Fig. 3.36.

LIST NODE COORDINATES Activating this button displays the list of all existing nodes and their coordinates in the left hand window as shown in Fig. 3.37.

NODE ID ON/OFF Selection of this button followed by the mouse selection of any node on the screen (identified by the square symbol) will display the node ID and the corresponding coordinates in the lower right hand window shown on Fig. 3.37.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	2D / 3D VIEW MODELLER	Date: Feb 12 1988 11:04:04
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELER

PLAN VIEW

XY ELEVATION

ZY ELEVATION

DEAD LOAD	APPROPRIATE ID CHOICE	LOAD AREA INFORMATION :
	NODE ID ON/OFF	DEAD LOAD
	LIST NODE COORDINATES	LOAD AREA NAME : typ_floor_office
	CONTINUE	UDL INTENSITY : 4.91 kPa
SAVE - CREATED	RETURN	

Fig. 3.36 Dead Load Intensity Area Information.

CONTINUE To attribute other load intensities, on the same surface, select the **CONTINUE** button and the appropriate dead load intensity from the list, shown in Fig. 3.34 (b). Attribute the load as per STEP 3.

SAVE-CREATED The **SAVE-CREATED** button saves the data, terminates the process for the specified surface and returns the program to the main menu, shown in Fig. 3.3.

RETURN **RETURN** button terminates the process for a given load type and returns the program to the load type selection menu, shown in Fig. 3.33.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date: Feb 12 1988 11:06:13
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G MODELLER

LIST OF NODES :

ID	X	Y	Z
405	-91000	84000	18000
406	-90000	91000	0
410	80000	91000	0
411	80000	91000	8000
412	-80000	91000	8000
413	150000	84000	-18000
414	150000	84000	-18000
415	150000	84000	-18000
416	210000	84000	18000
417	210000	84000	18000
418	150000	84000	18000
419	150000	84000	18000
420	150000	84000	18000
421	-150000	84000	18000
422	150000	84000	18000
423	-150000	84000	18000
424	-150000	84000	18000
425	-210000	84000	18000
426	150000	84000	18000
427	210000	84000	18000
428	210000	84000	18000
429	-150000	84000	-18000
430	210000	84000	-18000
431	150000	0	-18000
432	-150000	84000	-18000
433	120000	25000	8000
434	-120000	25000	8000
435	-80000	25000	8000
436	-80000	25000	-10000
437	-80000	25000	-10000
438	-80000	25000	-8000
439	80000	25000	-8000
440	80000	25000	-10000
441	80000	25000	-10000
442	80000	25000	8000
443	120000	25000	8000
444	120000	25000	8000
445	-150000	25000	-10000
446	-210000	25000	8000
447	80000	25000	-18000

DEAD LOAD
SAVE - CREATED

AREALOAD ID ON/OFF
LIST NODE COORDINATES
CONTINUE
RETURN

NODES ID INFORMATION :

NODE ID: 445

x = -150000 mm

y = 25200 mm

z = -10000 mm

Fig. 3.37 List of Nodes and Nodes ID Information.

3.6.2 LIVE LOAD

The procedure for attributing Live Load Use and Occupancy load intensities to surfaces is the same as that described for dead loads. The live load intensity name is selected from the corresponding list (compiled through the process described in section 3.5.), shown in the bottom right hand window in Fig. 3.38.

3.6.3 Snow Loads - Roof Geometry and Snow Load Distributions

The type of snow load distributions (function of the roof surface) and the geometry of each roof surface and the corresponding surrounding surfaces that influence snow load distributions and intensities are defined within the geometric modeller module by selecting

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD		Date: Feb 12 1990, 09:58:34												
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELER												
<div>PLAN VIEW</div>																
<div>XY ELEVATION</div>																
<div>ZY ELEVATION</div>																
		<div>LIVE LOAD</div>	<table border="1"> <tr> <th colspan="2">SELECT LOAD INTENSITY AREA</th> </tr> <tr> <td>roof</td> <td>library_stack_room</td> </tr> <tr> <td>typ_floor_storage</td> <td>library_reading_room</td> </tr> <tr> <td>typ_floor_corridors</td> <td>garage</td> </tr> <tr> <td>first_floor</td> <td>mechanical_room</td> </tr> <tr> <td>cafeteria</td> <td></td> </tr> </table>		SELECT LOAD INTENSITY AREA		roof	library_stack_room	typ_floor_storage	library_reading_room	typ_floor_corridors	garage	first_floor	mechanical_room	cafeteria	
SELECT LOAD INTENSITY AREA																
roof	library_stack_room															
typ_floor_storage	library_reading_room															
typ_floor_corridors	garage															
first_floor	mechanical_room															
cafeteria																
		RETURN														

Fig. 3.38 Live Load Use and Occupancy Load Intensity List.

the SNOW LOAD BUTTON. Note, the intensities for a given geographic location are calculated within the snow load module. After the SNOW LOAD button is activated within the geometric modeller menu, the process for each roof surface is as follows.

STEP 1. Select Roof Conditions

Select the appropriate roof surface condition regular or unobstructed slippery, from the lower right hand window shown in Fig. 3.39.

STEP 2. Select the Appropriate Snow Load Figure

Select the appropriate snow load distribution figure H-1 to H-6, as given in the Supplement to the National Building Code of Canada 1990, NRC 1990, to be applied to

		SELECT ROOF CONDITIONS	
SNOW LOAD	CHANGE MESH SPACING	REGULAR ROOF SURFACE	<input type="button" value="NO"/>
		UNOBSTRUCTED SLIPPERY ROOF	<input checked="" type="button" value="YES"/>
RETURN		<input checked="" type="button" value="OK"/>	<input type="button" value="CANCEL"/>

Fig. 3.39 Snow Load - Select Roof Conditions.

the specified roof surface. Refer to Fig. 3.40. These do not apply to special roof surfaces that have unique load distributions. Sand flume and wind tunnel tests that determined these distributions must be conducted. This data can be imported within the snow load module.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	SNOW LOAD	Date: 1 Feb 12 1993 12:06:30
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G. MODELLER

PLAN VIEW

XY ELEVATION

ZY ELEVATION

SELECT APPLICABLE SNOW LOAD FIGURE

FLAT OR SHED ROOF	<input checked="" type="button" value="H-1"/>
GABLE ROOF	<input checked="" type="button" value="H-3"/>
SIMPLE ARCH OR CURVED ROOF	<input type="button" value="H-2"/>
VALLEY AREAS OF ROOF	<input type="button" value="H-3"/>
LOWER LEVEL OF ADJACENT ROOF	<input type="button" value="H-4"/>
LOWER ROOF WITH SLOPPING UPPER RF	<input type="button" value="H-5"/>
AREA ADJACENT TO ROOF OBSTRUCTIONS	<input type="button" value="H-6"/>

SNOW LOAD

CHANGE MESH SPACING

RETURN

Fig. 3.40 Select Snow Load Figure from Table.

STEP 3. Select the Appropriate Mesh Spacing

The surface is discretized into a rectangular mesh and the load intensity will be

calculated at each point. The default mesh spacing is set at 1000 mm. The engineer can alter this spacing for each roof surface to give a more accurate representation of the surface. Refer to Fig. 3.41. For distributions with significant gradient changes, reduce the mesh spacing and for flat surfaces, increase the mesh spacing. Note, flat surfaces need only four points to describe the distribution accurately.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date Feb 12 1993 12:48:04
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G_MODELER

PLAN VIEW

XY ELEVATION

ZY ELEVATION

EDIT MESH SPACING :

1000 mm

CHANGE MESH SPACING

RETURN

LIST OF SURFACES :

<input type="button" value="SELECT"/>
roof_1
roof_2

Fig. 3.41 Mesh Spacing Definition and List of Surfaces.

STEP 4. Select a Roof Surface

Select the roof surface from the list of surfaces, shown in Fig. 3.41, to which the load distribution will be applied and the mesh created.

STEP 5. Identify Adjacent Roofs, Walls or Projections

The program will prompt the engineer to identify adjacent roofs, walls or

SELECT SECOND PART OF
GABLE ROOF
FROM LIST

(a) Gable Roofs - Figure H-1

SELECT SECOND PART OF
VALLEY ROOF AREA
FROM LIST

(b) Valleys - Figure H-3

SELECT ADJACENT WALL
FROM LIST

(c) Roofs with Obstructing Walls
- Figure H-4

SELECT SLOPING UPPER
ROOF
FROM LIST

(d) Roofs with Sliding Snow
Load - Figure H-5

SELECT OBSTRUCTION NAME
FROM LIST

(e) Roof Obstructions - Fig. H-6

		LIST OF SURFACES :		
		<input type="button" value="ROOFS"/> <input type="button" value="WALLS"/>		
<input type="button" value="SNOW LOAD"/>	<input type="button" value="CHANGE MESH SPACING"/>	wall_1	wall_6	wall_11
		wall_2	wall_7	wall_12
		wall_3	wall_8	wall_13
		wall_4	wall_9	<input type="button" value="wall_14"/>
	<input type="button" value="RETURN"/>	wall_5	wall_10	wall_15

(f) List of Adjacent Walls

Fig. 3.42 Select Adjacent Surfaces that Influence Snow Load Distributions and Intensities.

projections to the specified roof surface that will influence the snow load distribution. The prompt is automatic and is a function of the snow load figure selected in STEP 2. As shown in Fig. 3.42 (a), (b) and (d) for gable, valley and sloping roofs respectively, the engineer is prompted to select the adjacent roof from the list of roofs. A similar prompt is made for adjacent walls for lower roofs, Fig. 3.42 (d) and for roof obstructions, Fig. 3.42 (e). The corresponding list of walls for the building is shown in Fig. 3.42 (f). A file with the appropriate geometric data for the snow load calculations for this roof surface is generated at the end of this step.

STEP 6. Repeat STEPS 1 to 5 for each roof surface.

The RETURN button returns the program to the attribute loads to surfaces menu shown in Fig. 3.33.

3.6.4 WIND LOADS

The main functions of this part of the program are to attach building envelop characteristics to different surfaces subjected to wind pressure (the distribution of openings influence the internal pressure) and to define the appropriate size of mesh at which the load intensities will be calculated. The intensities for a given geographic location are calculated within the wind load module. After the WIND LOAD button is activated within the geometric modeller menu, the process for each exterior surface is as follows.

STEP 1. Select a Roof or Wall Surface

Select a roof or wall surface from the lists of surfaces shown in Fig. 3.43 for

which the distribution of openings in the walls and mesh size will be defined.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	STRUCTURE MODELLER		Date: 7-05-11 10:53 15-05-77
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G. MODELLER	

PLAN VIEW

XY ELEVATION

ZY ELEVATION

CHANGE MESH SPACING

RETURN

LIST OF SURFACES .

ROOFS		WALLS	
wall 1	wall 6	wall 11	
wall 2	wall 7	wall 12	
wall 3	wall 8	wall 13	
wall 4	wall 9	wall 14	
wall 5	wall 10	wall 15	

Fig. 3.43 Surface Selection for Attributing Wind Load

STEP 2. Define the Distribution of Openings in the Walls

Select the appropriate classification for the distribution of openings in the walls from the menus shown in Fig. 3.44 (a) and (b) for roof surfaces and walls, respectively. Note, the distribution of openings in exterior surfaces influences the internal pressures and hence the net specified pressure or suction on the surface. For example, the largest net specified pressure for a roof surface is generated when the openings are located in one wall and the wind direction is perpendicular to it. A file with the appropriate data is generated at the end of this step.

SELECT DISTRIBUTION OF OPENINGS :	
MAINLY IN ONE WALL	<input type="button" value="NO"/>
UNIFORMLY DISTRIB. IN ALL WALLS	<input checked="" type="button" value="YES"/>
<input checked="" type="button" value="OK"/> <input type="button" value="CANCEL"/>	

(a) Roof Surfaces

SELECT DISTRIBUTION OF OPENINGS :	
MAINLY IN THIS WALL	<input type="button" value="NO"/>
MAINLY IN OPPOSITE WALL	<input type="button" value="NO"/>
MAINLY IN THE PERPENDICULAR WALLS	<input type="button" value="NO"/>
UNIFORMLY DISTRIB. IN ALL WALLS	<input checked="" type="button" value="YES"/>
<input checked="" type="button" value="OK"/> <input type="button" value="CANCEL"/>	

(b) Walls

Fig. 3.44 Distribution of Openings for the Calculation of Wind Loads.

Step 3. Repeat STEPS 1 to 2 for each exterior surface

As with the snow load, the mesh spacing can be redefined using the **CHANGE MESH SPACING** button, otherwise the default value of 1000 mm will be used. Execute the **RETURN** button to exit this section of the program.

3.7 CALCULATION OF SNOW LOADS

The calculation of snow load intensities acting on roof surfaces of the structure is only possible once the climatic data and the geometry have been defined. The selection of the **SNOW LOAD** button from top main menu activates the screen display as shown in Fig. 3.45 with an applications menu containing the buttons **LIST ROOF AREAS**, **CLIMATIC DATA INFO**, **SAND FLUME DATA** and **WIND TUNNEL DATA**. The process for calculating snow loads is as follows:

STEP 1. Verify and Edit Climatic and Building Site Data

The climatic and building site data for the specified location must be verified before

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date: Feb 13 1992 14:07:10
DEAD LOAD	SNOW LOAD INFO	EARTHQUAKE	PRINT SCREEN	EXIT SNOW LOAD

SELECTED CLIMATIC DATA : PROVINCE: Ontario LOCATION: Ottawa GROUND SNOW LOAD S_g kPa <input type="text" value="2.2"/> ASSOCIATED RAIN LOAD S_r kPa <input type="text" value="0.4"/> BASIC ROOF SNOW LOAD FACTOR C_b <input type="text" value="0.8"/> UNIT WEIGHT OF SNOW kNm ³ gamma <input type="text" value="3.0"/> BUILDING IN EXPOSED LOCATION ?? <input type="text" value="YES"/> LOCATION NORTH OF THE TREE LINE: ??? <input type="text" value="NO"/> <input type="button" value="QUIT"/> <input type="button" value="UPDATE LOCATION"/> <input type="button" value="EDIT"/>				
--	--	--	--	--

	LIST ROOF AREAS	SNOW LOAD INFO
		SAND FLUME DATA
		WIND TUNNEL DATA

Fig. 3.45 Snow Load - Climatic Data Information.

the snow load intensity can be calculated. Selection of the CLIMATIC DATA INFO button gives the option of viewing and editing the climatic data shown in the left hand window in Fig. 3.45. Information about the building site, exposure and whether or not the location is north of the tree line must be verified to obtain the correct value for the wind exposure factor. To modify the data select the EDIT button and then the data value or building site information to be changed and enter the new value from the keyboard. YES NO values toggle when selected. This is particularly useful for mountainous areas where the ground snow load changes radically from one valley to the next or for the Maritime Provinces where the unit snow load may be greater than 3.0 kN per metre cubed. Select the UPDATE LOCATION button to save the revised climatic data for this project. To terminate the editing process select the QUIT button and the window displaying the

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date Feb 17 1995 09:31:42
DEAD LOAD		EARTHQUAKE	PRINT SCREEN	EXIT SNOW LOAD

FIGURE_H_1 kPa

SHAPE

CASE I

CASE II a

CASE II b

LIST OF ROOF AREAS:

roof_2
roof_4
roof_5

EXECUTE DELETE AREA

CLIMATIC DATA INFO	ON / OFF	RESET	SECTION
SAND PLUME DATA	1 5 20		ZOOM %
WIND TUNNEL DATA	80 90 105		SOLID / TOGGLE
	120 150 200		DOLLY CAM
	ORBIT CAM		
	PAN CAM		

Fig. 3.46 Snow Load Example for Gabled Roofs - Figure H-1.

climatic and building site data disappears.

STEP 2. Select Roof Area and Execute Calculation Procedure

Selection of the LIST ROOF AREAS button lists the roof surfaces defined by the process described in section 3.6.3. in the bottom left hand window in Fig. 3.46. Select the EXECUTE button and the surface to calculate the snow load intensity for all possible load cases at each point on the prescribed mesh. The data is stored in the appropriate output file described in Appendix B - File Architecture. Currently, the loads on each surface must be calculated individually. By selecting the DISPLAY LOADING button, followed immediately by surface name button, all the applicable snow load cases for the appropriate snow load figure, as applied to the specified roof, including a cross section of the roof, are

Fig. 3.47 Example Low-Rise Structure

displayed in the left hand window with the roof displayed in 3 dimensions in the main window as shown in Fig. 3.46. A 3 dimensional view of each snow load distribution is activated by the load case buttons, CASE I, CASE II (a) AND CASE II (b), shown in the main window. The depth of the displayed snow accumulation on the roof is based on average unit weight of snow of 3.0 kN per metre cubed as recommended in the NBCC 1990, NRC (1990). Figure 3.46 is an illustration of the snow load distributions for the gabled shape portions of the roof of the low rise industrial building shown in Fig. 3.47. Figure 3.48 and 3.49 illustrate the snow load distributions for the valley section and for the lower roof with the upper sloping roof respectively. The INFO ON/OFF button located in the header of the left hand window activates the option which will display the load intensity at any location on the snow load graphs or at any location within the 3

Fig. 3.48 Snow Load Example for Valleys - Figure H-3.

dimensional view by mouse selection at that location. The load intensity displayed is the average snow load intensity over area surrounded by neighbouring points of mesh. To modify the view of the 3 dimensional image activate the ON/OFF button in the lower right hand application window. All other buttons function as described in section 3.2.5.

Any surface can be deleted from the list of roof areas by selecting the DELETE AREA button and then the name of the surface from the list. Confirmation is required. The SAND FLUME DATA and WIND TUNNEL DATA buttons are reserved for future versions of the program where the snow load distributions for complex surfaces (cannot be determined from the standard library functions given in Fig. H-1 to H-6 of the NBCC Supplement, NRC 1990) obtained by model tests can be imported and displayed directly on the corresponding geometric model.

CLIMATIC DATA	LIVE LOAD USE & OCCUP.	WIND LOAD	GEOMETRIC MODELLER	Date Feb 17 1995, 09:54:00
DEAD LOAD		EARTHQUAKE	PRINT SCREEN	EXIT SNOW LOAD
FIGURE_H_5 <input type="text"/> 6.71 kPa
SHAPE				
CASE I				
LIST OF ROOF AREAS:				
☐ roof_1 ☐ roof_2 ☐ roof_4	<input type="button" value="EXECUTE"/> <input type="button" value="DELETE AREA"/>	<input type="button" value="CLIMATIC DATA INFO"/> <input type="button" value="BAND FLUME DATA"/> <input type="button" value="WIND TUNNEL DATA"/>	<input type="button" value="ON / OFF"/> <input type="button" value="ORBIT CAM"/> <input type="button" value="PAN CAM"/>	<input type="button" value="RESET"/> <input type="button" value="SECTION"/> <input type="button" value="ZOOM %"/> <input type="button" value="SOLID / WIREFRAME"/> <input type="button" value="DOLLY CAM"/>

Fig. 3.49 Snow Load Example for Lower Roof with Sliding Snow - Figure H-4 and H-5.

3.8 CALCULATION OF WIND LOADS

The calculation of wind load intensities acting on exterior surfaces of the structure is only possible once the climatic data and the geometry have been defined. The selection of the WIND LOAD button from top main menu activates the screen display as shown in Fig. 3.50 with an application menu containing the buttons LIST EXTERIOR SURFACES, LOCATION INFO, and STRUCTURE SET UP DATA. The process for calculating wind loads is as follows: The climatic and building site data for the specified location must be verified before the wind load intensity can be calculated.

STEP 1. Verify and Edit Climatic and Building Site Data

Selection of the LOCATION INFO button gives the option of viewing and editing

CLIMATIC DATA	LIVE LOAD USE & OCCUP		GEOMETRIC MODELLER	Date Feb 12 1993 13:03:34
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT WIND LOAD

SELECTED LOCATION DATA : PROVINCE ONTARIO LOCATION Oshawa HOURLY WIND PRESSURE 1/10 kPa 0.30 HOURLY WIND PRESSURE 1/20 kPa 0.37 HOURLY WIND PRESSURE 1/100 kPa 0.48 EXPOSURE OPEN OR STANDARD EXP A SPEED UP THE HILL & ESCARPMENTS YES HILL SHAPE 2-DIMENSIONAL RIDGES OR VALLEYS HILL HEIGHT M m 75.00 DISTANCE UPWIND OF THE CREST TO WHERE THE GROUND ELEVATION IS HALF THE HEIGHT OF THE HILL L m 225.00 DISTANCE OF BLD TO TOP OF THE HILL m -45.00 QUIT UPDATE LOCATION EDIT		
--	--	--

LIST EXTERIOR SURFACES	STRUCTURE SET UP DATA
	WIND TUNNEL DATA

Fig. 3.50 Wind Load - Climatic Data Information.

the climatic and building site data (exposure factor and parameters for speed up calculations), shown in the left hand window in Fig. 3.50. To modify the data select the EDIT button and then the data value or building site information to be changed and enter the new value from the keyboard. Non-numeric inputs either toggle or scroll through the available options when selected.

Select the UPDATE LOCATION button save the revised data for this project. To terminate the editing process select the QUIT button and the window displaying the climatic and building site data disappears.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	GEOMETRIC MODELLER		Date Feb 17 1993 13:05:07
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT WIND LOAD

STRUCTURE SET UP DATA :

POST DISASTER BUILDING ??? YES / NO NO

CRITICAL DAMPING RATIO 0.010

NATURAL FREQUENCY OF VIBRATION Hz 0.200

DETAILED / SIMPLE PROCEDURE FOR C_s D

DYNAMIC / SIMPLE PROCEDURE FOR C_g D

INTERNAL PRESSURE CATEGORY D

TOTAL HEIGHT OF BUILDING mm 8500

ZERO FLOOR ELEV ABOVE TERRAIN mm 0

TO CHANGE VALUE CLICK ON IT !!

CANCEL
SAVE CHANGES

LIST EXTERIOR SURFACES	<div style="border: 1px solid black; padding: 2px;">LOCATION INFO</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px;">WIND TUNNEL DATA</div>
------------------------	---

Fig. 3.51 Structural Characteristics.

STEP 2. Define Structural Characteristics and the Procedure for Calculating the Wind Loads

Selection of the **STRUCTURE SET UP DATA** button gives the option of defining dynamic properties of the building (critical damping ration, natural frequency of vibration) and the procedure for calculating the wind loads as shown in left hand window in Fig. 3.51. To modify the data select the **EDIT** button and then the data value or set up parameter to be changed and enter the new value from the keyboard. Non-numeric inputs either toggle or scroll through the available options when selected. Select the **SAVE CHANGES** to save the data for this project. To terminate the process select the **QUIT** button and the window displaying the structure set up data disappears. Note, if the height of the building is not specified, then it is set to the largest 'y' coordinate value.

Fig. 3.52 (a) Example Wind Load Distribution for a Wall of a High-Rise Building.

STEP 3. Select Exterior Surface and Execute Calculation Procedure

Selection of the LIST EXTERIOR SURFACES button lists the exterior surfaces of the building defined by the process described in section 3.6.4 in the bottom left hand window in Fig. 3.52 (a). Select the EXECUTE button and the surface to calculate the wind load intensities, for all possible load cases (refer to section 2.5), at each point on the prescribed mesh. The data is stored in the appropriate output file described Appendix B - File Architecture. Currently, the loads on each surface must be calculated individually.

By selecting the DISPLAY LOADING button, followed immediately by surface name button, all the applicable wind load cases for the specified surface are displayed in the left hand window with the surface displayed in 3 dimensions in the main window as

Fig. 3.52 (b) Example Wind Load Distribution for a Roof of a High-Rise Building.

shown in Fig. 3.52 (a). A 3 dimensional view of each wind load distribution is activated by selecting the corresponding button name, ie. WINDWARD, LEEWARD or END WALL. Figures 3.52 (a) and b) show the wind load distributions for the high-rise building example created in section 3.2. for a typical wall and roof, respectively. A typical low-rise building, shown in Fig. 3.53 (meets all the geometric requirements of a low-rise structure given in Chapter 4, Commentary B of the NBCC Supplement 1990, NRC (1990), was created to illustrate the application of Figures B-7 to B-10 of the commentary. Illustrated in Fig. 3.54 (a), (b) and (c) are wind load distributions for one roof surface, a wall parallel to the ridge and a wall perpendicular to the ridge, respectively.

Fig. 3.53 Example Low-Rise Building. Application of Figure B-7 to B-10.

As shown in the left hand window, the wind load distributions for structural members (Fig. B-7) and for secondary structural members and cladding (Fig. B-8, B-9 and B-10) are displayed independently by activating the corresponding button. The wind load profiles are shown for either the middle section or in the end zone depending upon which button is currently active. Note, for the high-rise example in Fig. 3.52 (a), additional button applicable to the type of building (CLADDING, LOCAL SUCTION, S.M.-SERVICEABILITY and NET LOAD ON BUILDING) serve similar functions. Although a limited number of load cases can be viewed at one time on the screen, all are calculated and stored in the appropriate output files.

Fig. 3.54 (a) Wind Load Distribution for a Roof of a Low-Rise Building.

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CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date Feb 13 1993, 14:20:31																		
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT WIND LOAD																		
AREA wall per 2 <input type="text"/> 0.74 kPa
0.0 m																						
0.0 m	LEEWARD				END WALL																	
SECONDARY STRUCTURAL MEMBERS AND CLADDING <input type="text"/> AT END ZONE																						
LIST OF EXTERIOR SURFACES:		LOCATION INFO STRUCTURE SET UP DATA WIND TUNNEL DATA																				
roof_1 roof_2 wall_perp_1 wall_perp_2	wall_per_1 wall_per_2	<table border="1"> <tr> <td>ON / OFF</td> <td>RESET</td> <td>SECTION</td> </tr> <tr> <td>1</td> <td>6</td> <td>20</td> </tr> <tr> <td>80</td> <td>90</td> <td>105</td> </tr> <tr> <td>120</td> <td>160</td> <td>200</td> </tr> <tr> <td colspan="3">ORBIT CAM</td> </tr> <tr> <td colspan="3">PAN CAM</td> </tr> </table>			ON / OFF	RESET	SECTION	1	6	20	80	90	105	120	160	200	ORBIT CAM			PAN CAM		
ON / OFF	RESET	SECTION																				
1	6	20																				
80	90	105																				
120	160	200																				
ORBIT CAM																						
PAN CAM																						
EXECUTE	DELETE AREA	<table border="1"> <tr> <td>ZOOM %</td> </tr> <tr> <td>SOLID / TOGGLE</td> </tr> <tr> <td>DOLLY CAM</td> </tr> <tr> <td> </td> </tr> </table>			ZOOM %	SOLID / TOGGLE	DOLLY CAM
ZOOM %																						
SOLID / TOGGLE																						
DOLLY CAM

Fig. 3.54 (b) Wind Load Distribution for a Wall Parallel to the Ridge of a Low-Rise Building.

CLIMATIC DATA		LIVE LOAD USE & OCCUP		GEOMETRIC MODELLER		Date Feb 13 1993 13:00:00																			
DEAD LOAD		SNOW ICE & RAIN		EARTHQUAKE		PRINT SCREEN																			
EXIT WIND LOAD																									
AREA : wall_perp_2		0.11 kPa
0.5 m																									
0.0 m																									
WINDWARD		LEEWARD																							
SECONDARY STRUCTURAL MEMBERS AND CLADDING		AT END ZONE																							
LIST OF EXTERIOR SURFACES:				LOCATION INFO																					
<table border="1"> <tr> <td>roof_1</td> <td>wall_perp_1</td> </tr> <tr> <td>roof_2</td> <td>wall_perp_2</td> </tr> <tr> <td>wall_perp_1</td> <td></td> </tr> </table>				roof_1	wall_perp_1	roof_2	wall_perp_2	wall_perp_1		<table border="1"> <tr> <td colspan="3">STRUCTURE SET UP DATA</td> </tr> <tr> <td colspan="3">WIND TUNNEL DATA</td> </tr> </table>				STRUCTURE SET UP DATA			WIND TUNNEL DATA								
roof_1	wall_perp_1																								
roof_2	wall_perp_2																								
wall_perp_1																									
STRUCTURE SET UP DATA																									
WIND TUNNEL DATA																									
EXECUTE				<table border="1"> <tr> <td>CIN / AMP</td> <td>REBET</td> <td>SECTION</td> </tr> <tr> <td>1 5 20</td> <td></td> <td>AXIS %</td> </tr> <tr> <td>50 90 105</td> <td></td> <td>SCALE / FORMS</td> </tr> <tr> <td>120 150 200</td> <td></td> <td>EXPLV CAM</td> </tr> <tr> <td>OPRT CAM</td> <td></td> <td></td> </tr> <tr> <td>PAN CAM</td> <td></td> <td></td> </tr> </table>				CIN / AMP	REBET	SECTION	1 5 20		AXIS %	50 90 105		SCALE / FORMS	120 150 200		EXPLV CAM	OPRT CAM			PAN CAM		
CIN / AMP	REBET	SECTION																							
1 5 20		AXIS %																							
50 90 105		SCALE / FORMS																							
120 150 200		EXPLV CAM																							
OPRT CAM																									
PAN CAM																									
DELETE AREA																									

Fig. 3.54 (c) Wind Load Distribution for a Wall Perpendicular to the Ridge of a Low-Rise Building.

Chapter 4

Examples

To demonstrate the capabilities of program LDFSSBC, the loads were determined and attributed to the surfaces of two buildings, a typical high-rise and low-rise building.

4.1 High-Rise Building

The building given in the Multi-Storey Steel Building Design Aid, Canadian Institute of Steel Construction (1987) was selected, as the high-rise building example. Detailed load calculations given in the design aid serve to verify those generated by LDFSSBC.

The structure is an office/retail building complex which includes a 20 storey office tower and two adjacent retail sections with 2 and 3 floors. South and east elevations of the building are shown in Figures 4.1. The lower 3 floors of 20 storey office tower are used as retail space. Mechanical equipment is housed in and on the penthouse. The structure is a steel framed building with composite floor systems. For this example, the building is located in North Vancouver, British Columbia, and is considered to be in an exposed location.

The isolated views of the floor, roof and wall surfaces of the building, to which

(a) South Elevation

(b) East Elevation

Fig. 4.1 High-rise Building Example

dead and live loads will be attributed are shown in Figures 4.2, 4.10 and 4.12, respectively. The floor plans for the retail space (floors 2 and 3), the office space (floors 4 to 19, inclusive) and the mechanical room on the 20th floor are shown in Figures 4.3, 4.4 and 4.5, respectively. The rectangular areas within the floor plan are elevator and mechanical shafts. The lines connecting these with the perimeter are part of the polygon used to draw the floor plan within HOOPS. These will be deleted from view in the next version of the program.

Fig. 4.2 Floor Surfaces - Dead Load and Live Load due to Use and Occupancy

Libraries of areas with the typical dead load and live load due to use and occupancy intensities were created for the building, as detailed in the design aid, and are listed in Figures 4.6 and 4.7, respectively. A typical sandwich system for a stub-girder system is shown in Figure 4.6 (a). Attributing dead load to floor, roof or wall surfaces is trivial

(a) 2nd Floor Plan

(b) 3rd Floor Plan

Fig. 4.3 Retail Space

(a) 4-12th Floor Plan

(b) 13-19th Floor Plan

Fig. 4.4 Office Space

Fig. 4.5 Mechanical Room - Floor Plan

since each surface consists of one structural system with constant dead load intensity. For example, a dead load intensity of 4.28 kPa has been attributed to the surface defined as "lowRoof_5", as shown in Figure 4.8.

Figure 4.9 shows the live loads due to use and occupancy distribution on 5th floor where two intensity types are imposed, core floor areas with a udl intensity of 4.8 kPa, and office areas with a udl of 2.4 kPa. Detailed architectural drawings were not available, therefore, the core floor area was taken to be the area within the dashed line. Both areas must also be designed for 9.0 kN of concentrated load, acting anywhere over a 750 mm x 750 mm area to produce the maximum load effects.

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date: Mar 20 1993 14:01:29
SNOW LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT DEAD LOAD

Typical_roof		kPa
Chopped stone butter th 25 mm		0.26
3-ply felt no gravel		0.15
Flashed curb 100 mm rigid th 100 mm		0.10
Vapour barrier		0.02
Waterproof T-BE/ dead + 60mm concrete th 100 mm		2.78
Sub grade exterior concrete		0.26
Fire proofing (concrete fire grade dead)		0.10
Mechanical services high ceiling		0.15
Electrical services		0.15
Ceiling supporting system (hangars the bars on)		0.10
Architectural ceiling fans		0.10
TOTAL		4.28

LIST OF STRUCTURAL SYSTEMS:

Typical_roof	4.28
Mechanical_room	1.94

100%

FLOOR

WALL

ON/OFF	RESET	SECTION
1 5 20		ZOOM %
50 90 105		SHUT/TORQUE
120 150 200		DOLLY CAM
ORBIT CAM		<input type="button" value="←"/> <input type="button" value="→"/> <input type="button" value="↶"/> <input type="button" value="↷"/>
PAN CAM		

(a) Roof Areas

LIST OF STRUCTURAL SYSTEMS :	
struc_area_no_1 4.91	struc_area_no_7 3.75
struc_area_no_4 4.75	struc_area_no_8 4.05
struc_area_no_5 5.45	
struc_area_no_6 4.55	

(b) Floor Areas

LIST OF STRUCTURAL SYSTEMS :	
Spandrel walls 1.00	Curb railing-atrium 1.60
Drywall_stairwell_e 0.70	
Other nter.perm.p 0.50	
Penthouse exterior 1.50	

(c) Wall Areas

LIST OF DEFINED AREAS		
AREA NAME:	UDL kPa	CONC.LD kN
Retail Office 2-3-4 FL.	4.80	9.00
Office 5-10 13-19 FL.	2.40	9.00
Special Office 11-12 FL.	3.6	9.0
Mechanical 20 FL.	7.2	9.0
Penthouse 21 FL.	4.8	9.0
Corridors all levels	4.8	9.0
Core Floors all levels	4.8	9.0
Roofs min.	2.0	1.3

Fig. 4.7 Live Load Use and Occupancy - Library of Areas

Fig. 4.6 Dead Load Libraries

CLIMATIC DATA	LIVE LOAD USE & OCCUP.	WIND LOAD	PRINT SCREEN	Date: Mar 20 1995 15:21:34
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G. MODELLER

PLAN VIEW

XY ELEVATION

ZY ELEVATION

	LOAD AREA INFORMATION DEAD LOAD LOAD AREA NAME: Typical roof UDL INTENSITY: 4.28 kPa	<table border="1"> <tr> <td>LOAD AREA BY: * INDEX</td> <td>LOAD AREA ON SCREEN</td> </tr> <tr> <td>LIST NODE COORDINATES</td> <td>CONTINUE</td> </tr> <tr> <td>SAVE CREATED</td> <td>RETURN</td> </tr> </table>	LOAD AREA BY: * INDEX	LOAD AREA ON SCREEN	LIST NODE COORDINATES	CONTINUE	SAVE CREATED	RETURN
LOAD AREA BY: * INDEX	LOAD AREA ON SCREEN							
LIST NODE COORDINATES	CONTINUE							
SAVE CREATED	RETURN							

Fig. 4.8 Dead Load Intensity for "LowRoof_5"

CLIMATIC DATA	LIVE LOAD USE & OCCUP.	WIND LOAD	PRINT SCREEN	Date: Mar 20 1995 16:20:07
DEAD LOAD	SNOW ICE & RAIN	EARTHQUAKE	PRINT SCREEN	EXIT G. MODELLER

PLAN VIEW

XY ELEVATION

ZY ELEVATION

	LOAD AREA INFORMATION LIVE LOAD USE AND OCCUPANCY LOAD AREA NAME: Core Floors all lev UDL INTENSITY: 4.80 kPa CONCENTRATED LOAD: 9.00 kN	<table border="1"> <tr> <td>LOAD AREA BY: * INDEX</td> <td>LOAD AREA ON SCREEN</td> </tr> <tr> <td>LIST NODE COORDINATES</td> <td>RETURN</td> </tr> </table>	LOAD AREA BY: * INDEX	LOAD AREA ON SCREEN	LIST NODE COORDINATES	RETURN
LOAD AREA BY: * INDEX	LOAD AREA ON SCREEN					
LIST NODE COORDINATES	RETURN					

Fig. 4.9 Live Load Intensity - Use and Occupancy, for "Floor_5"

Roof areas are subdivided into sections, interactively defined by the structural engineer, to give typical roof types that the snow load accumulation factor figures in commentary H of the supplement can be applied. Good engineering judgement is required. For this particular case the snow load accumulation factor for the majority of roof sections (the only exception is the penthouse, Figure H-1) are best described by Figure H-4 for lower levels of adjacent roofs. The roof sections illustrated in Figure 4.10. are defined by lines extending 45 degrees from the corners of the building with upper roof sections to the edge of the roof and further subdivided according to height differences of adjacent upper roof sections.

The upper roof of the office tower is simply divided into four equal parts (due to symmetry). The corresponding snow load distribution for each section is given in Figure 4.11(a). The roof area over the two storey retail space is subdivided into 3 sections with the accumulation factor, C_a , calculated using the height difference between the 3rd and 2nd floor for section 1; and the 20th and 2nd floor for sections 2 and 3. The line defining section 1 and 2 was extended at 30 degree from the corner indicating a slight dominance of the taller wall on the snow load distribution. The irregular shape of the wall for section 2 and 3 prevents a uniform definition of 'x', the distance from the wall to any given point on the roof perpendicular to the wall for that section. The controlling walls for section 2 and 3 are the bay window and the wall between bay windows, respectively. The corresponding snow load distributions are shown in Figure 4.11 (b), (c) and (d).

Both wall height differences and wall irregularities will lead to small discontinuities in snow load intensities along common boundaries. For example, the magnitudes as shown

in Figures 4.11 (c) and (d) at neighbouring points (highlighted on the figure) differ by a maximum of 11 percent. It should be noted that the distributions are approximations (snow load models) of the actual distributions and may contain discontinuities.

Fig. 4.10 Roof Surfaces - Live Load due to Snow and Wind

CLIMATIC DATA	LIVE LOAD USE & OCCUP.	WIND LOAD	GEOMETRIC MODELLER	Date: Mar 20 1999 14:49:29
DEAD LOAD		EARTHQUAKE	PRINT SCREEN	EXIT SNOW LOAD
FIGURE_H_4 <input type="text"/> 8.00 kPa
SHAPE				
CASE I				
LIST OF ROOF AREAS:				
lowRoof_1	lowRoof_5	highRoof_4	CLIMATIC DATA INFO	
lowRoof_2	highRoof_1	highRoof_mash	SAND PLUME DATA	
lowRoof_3		Entrance_R	WIND TUNNEL DATA	
lowRoof_4	highRoof_3		ON / OFF	
EXECUTE	DELETE AREA		1 5 20	
			80 90 100	
			120 180 200	
			ORBIT CAM	
			PAN CAM	
			ZOOM %	
			WIND / TUNNEL	
			DOLLY CAM	
			SECTION	

(a) Typical Upper Roof of Office Tower

CLIMATIC DATA	LIVE LOAD USE & OCCUP.	WIND LOAD	GEOMETRIC MODELLER	Date: Mar 20 1999 16:57:21
DEAD LOAD		EARTHQUAKE	PRINT SCREEN	EXIT SNOW LOAD
FIGURE_H_4 <input type="text"/> 8.00 kPa
SHAPE				
CASE I				
LIST OF ROOF AREAS:				
lowRoof_1	lowRoof_5	highRoof_4	LIST ROOF AREAS	
lowRoof_2	highRoof_1	highRoof_mash	CLIMATIC DATA INFO	
lowRoof_3	highRoof_2	Entrance_R	SAND PLUME DATA	
lowRoof_4	highRoof_3		WIND TUNNEL DATA	
EXECUTE	DELETE AREA		ON / OFF	
			1 5 20	
			80 90 100	
			120 180 200	
			ORBIT CAM	
			PAN CAM	
			ZOOM %	
			WIND / TUNNEL	
			DOLLY CAM	
			SECTION	

(b) Section 1 of the Lower Roof for the two storey retail space

(c) Section 2 of the Lower Roof for the two storey retail space

(d) Section 3 of the Lower Roof for the two storey retail space

Fig. 4.11 Snow Load Distributions on Selected Roof Surfaces

The exterior surfaces of the building used for the determination of wind loads are shown for roofs and walls in Figures 4.10 and 4.12, respectively. The wind loads acting on the office tower were calculated using the simplified procedure, Figure B-11 of Commentary B of the supplement, NRC (1990), and an internal pressure coefficient for a building with a uniform distribution of openings on all walls. Example wind load distributions for a typical roof and wall section are illustrated in Figures 4.13 (a) and (b), respectively. The load distributions determined by LDFSSBC compared directly with those calculated by CISC (1987).

Fig. 4.12 Wall Surfaces - Live Load due to Wind

(a) Typical Upper Roof of Office Tower

(b) Wall No. 10

Fig. 4.13 Wind Load Distributions for a High-rise

4.2 Low-Rise Building

A typical low-rise building constructed in Ottawa and designed by a local consulting engineering firm, Oliver, Mangione and McCalla (1992), was primarily used to illustrate the wind load calculations for low-rise buildings as prescribed in the NBCC 1990, NRC (1990), and to verify the loads generated by LDFSSBC.

The one storey building consists of two rectangular sections with the same ground floor elevation and 600 mm step in the roof. The exterior walls consist of reinforced load bearing hollow concrete blocks. Large door openings are situated along the south wall of the lower section and around on the south-east corner of higher section. The parapet above the doors is 1600 mm high and 300 mm high on the rest of the buildings perimeter. W-shape steel girders are seated on the perimeter walls and frame onto HSS columns inside the building. In turn these support a series of 600 mm deep open web steel joists. The roof is composed of a 38 mm deep steel deck, 150 mm of rigid insulation, 3-ply roofing felt and 40 mm of ballast. All the surfaces of the building were created according to dimensions given on the drawings and are shown in Figure 4.14.

The dead load values for the roof and walls for all the surfaces of the building are given in Figures 4.15 and 4.16.

The uniformly distributed and concentrated live loads due to use and occupancy for roof are 1.0 kPa and 1.3 kN, respectively. The corresponding library is shown in Figure 4.17.

Fig. 4.14 Low Rise Building Perspective

Fig. 4.15 Dead Load - Library of Wall Areas

Typical_roof	kPa
Crushed stone ballast th.40 mm	0.60
3-ply asphalt no gravel	0.18
Insulation : Glass fibre, rigid th.150.0 mm	0.10
Vapour barrier	0.03
Chipboard 12.7 mm	0.07
Roof deck, 381 mm x 0.76 mm	0.10
O.W.S.I; estimate for long spans	0.20
W-shape girders and beams, estimate	0.30
Mechanical services : low estimate	0.10
Electrical services	0.10
Fire proofing (sprayed bms,girders,deck)	0.07
Ceiling supporting system (hangers,tee bars etc.)	0.10
Acoustical ceiling tiles	0.10
TOTAL	2.05

Fig. 4.16 Dead Load - Structural Roof System

LIST OF DEFINED AREAS		
AREA NAME:	UDL kPa	CONC.LD kN
typical_roof	1.00	1.30

EDIT
CREATE NEW

DELETE
INFO-UDL
INFO-CONC.LD.

Fig. 4.17 Live Load Use and Occupancy - Library of Areas

CLIMATIC DATA	LIVE LOAD USE & OCCUP	WIND LOAD	GEOMETRIC MODELLER	Date: Mar 20 1993 16:20:15
DEAD LOAD	FIGURE M.4	EARTHQUAKE	PRINT SCREEN	EXIT SNOW LOAD
FIGURE M.4 5.20 tPa _____ SHAPE CASE I
LIST OF ROOF AREAS: <table border="1" style="width: 100%;"> <tr><td>roof_2</td></tr> <tr><td>roof_3</td></tr> <tr><td>roof_4</td></tr> </table> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> EXECUTE DELETE AREA </div>				
roof_2				
roof_3				
roof_4				
LIST ROOF AREAS <div style="border: 1px solid black; height: 100px; width: 100%;"></div>		CLIMATIC DATA INFO	ON / OFF	RESET
		SAND FLUME DATA	1 5 20	ZOOM %
		WIND TUNNEL DATA	50 80 105	HOLD / TOGGLE
			120 180 200	DOLLY CAM.
			ONSET CAM	
			PAN CAM	

Fig. 4.18 Snow Load Distribution on Lower Roof

The computation of snow load intensities are based on climatic coefficients for Ottawa and a wind exposure factor at location that is not exposed. The default value 1000 mm for the mesh spacing was used. The distribution of snow on lower roof due to the accumulation of snow along the 1600 mm high parapet is shown in Figure 4.18. The maximum value of 5.2 kPa occurs adjacent to the parapet. Similar snow load distributions occur on roof sections 3 and 4 of the upper roof as a result of the 1600 parapet on the south east corner. The 600 mm roof step and the 300 mm high parapet are insufficiently high to cause a drift to form.

Wind load intensity values were evaluated for exposure B terrain category (suburban and urban areas) and for Category 2 buildings for the internal pressure coefficient (buildings with significant openings - shipping doors). The simple procedure was used for computation of the exposure factor and the external peak pressure coefficients, $C_p C_g$, were determined appropriately from Figures B-7 to B-10 of the supplement. Typical wind load distributions on the lower roof are shown in Figure 4.19 (a). The roof is horizontal (zero slope). Four graphs marked WINDWARD, LEEWARD, PARALLEL c.1, PARALLEL c.2 indicate varying load intensity for the roof which is caused by a change in a internal pressure that accurse due to a change in wind direction. This variation must be considered when the openings are mainly in one wall. The wind directions are marked on Figure 4.19(a). The wind load intensities for any given point (highlighted) are shown in the upper left hand window of the figure. Figure 4.19(b) shows the wind load distributions on one typical external wall (west wall of the higher section). Note, the increase intensity within wall end zone areas.

(a) Lower Roof

(b) West Wall

Fig. 4.19 Wind Load Distributions

Chapter 5

Conclusions, Recommendations, and Future Work

5.1 Conclusions

Interactive graphics based computer software was developed for the geometric modelling of the surfaces of steel buildings and for the automatic determination of loads acting on those surfaces. The loads were determined in accordance with Part 4-Structural Design, from NBCC 1990, NRC (1990) and the corresponding commentaries in the Supplement. Currently the program is restricted to defining the building form, floors, roofs, and walls from flat surfaces (may be sloped) and generates files that contain surface geometry and the dead loads, live loads due to use and occupancy, snow, ice and rain and wind, acting on those surfaces. Live loads due to earthquake and loads from other effects are not included in this version. Snow load distributions are limited to those geometric configuration of the roof surfaces described in Figures H-1 through H-6 of the Supplement to NBCC 1990 Part 4, Commentary H, NRC (1990). A detailed description of the completed work is given below:

1. the development of a geometric modeller for the definition of building form and surface geometry including shape, orientation, location and type of surface (roof, wall, floor), and

2. the creation of a climatic design data database (reproduced from Chapter 1 of the Supplement) arranged according to province and location
3. the creation of the databases for masses, weights of typical construction materials and the development of 3-D graphical representations of structural sandwich systems for walls, roofs and floors
4. the development of a module that creates a database that specifies surfaces, surface areas and the corresponding dead load and live load (use and occupancy) intensities acting on those areas
5. the creation of a database for live load due to use and occupancy intensities (reproduced from Table 4.1.6.A and Table 4.1.6.B of Part 4 of the NBCC, NRC (1990))
6. a mesh generator for arbitrarily shaped polygons that calculates the coordinates of points on a flat surface arbitrarily located in space
7. the development of modules for the computation of snow and wind load intensities at each point on the mesh that takes into account the geometrical configuration of related surfaces and their effect on snow and wind load distributions. These modules also create database that contain all the relevant load determination information, the loads (may be more than one distribution for a given area) and the corresponding surface area geometry
8. The development of the interactive graphics design for the process of determining loads acting on buildings

The loads generated by the program LDFSSBC have been compared to many hand calculations and examples provided by others and are identical. All aspects and options have been thoroughly tested.

5.2 Recommendations and Future Work

The work completed in this thesis represents the first step for a fully interactive program for determining loads and load combinations acting on structural members. The remaining tasks that need to be completed are outlined in section 1.2. and 1.3. include:

1. inclusion of curved surfaces in geometric modeller
2. automatic self recognition of geometrical configuration of all surfaces bearing influence on selectability of applicable snow load figures on the roof or specific areas of the roof
3. development of earthquake load determination and other load effects module
4. development of algorithms for defining primary structural members including; member type , location, orientation, numbers representing structural analysis code, node and member numbering
5. development of algorithms for determining secondary member structural systems
6. development of algorithms for determining tributary areas for both secondary and primary structural members
7. development of algorithms for determining live load reduction factors
8. development of algorithms for determining load combinations and the

corresponding data bases with loads attributed to members

- 9. development of routine to accept unique data from wind tunnel tests for snow and wind load distributions**

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APPENDIX A

Programming Languages and Graphic Tools

A.1 Computer Programming Language Selection

Over the last couple of decades a number of programming languages have been developed by various computer companies, universities and private groups. Of these the most popular are Basic, Cobol, Algol, Pascal, Fortran and C. More recent, advanced and powerful languages like object oriented C++, Smalltalk, rules based systems Clips, are being used by thousand of research laboratories, corporations, systems development companies in government and private companies.

The selection of the most appropriate programming language for the purpose of this thesis was influenced by the previous decision to use HOOPS Graphic Systems for the interface of the Integrated Analysis, design and fabrication of steel buildings of which this thesis is one part. HOOPS Graphic System is supported by Fortran, C and C++. Although HOOPS is system dependant, versions exist for most platforms, making the interface code relatively portable.

A.1.1 Fortran Programming Language

Fortran was developed in 1957 and was the first high-level programming language.

It was originally used primarily for scientific computation but has evolved over the years into a general purpose programming language. Fortran is still the highly favoured language for numerical work among the scientists and engineers, and has the large library of available applications.

A.1.2 "C" Programming Language

During the last decade, C has become one of the most popular and important programming languages. C was created in 1972 in Bell Laboratories by Denise Ritchie and Ken Thompson as they worked on designing the Unix operation system, Waite, M., Prata, S. (1990).

The programming language C was selected for this thesis because of its attributes and potential, some of which are listed below:

1. Increase programming power, as C is designed to work with the hardware and gives access to manipulate individual bits in memory.
2. A program written in C can be broken down into short independent functions making it simpler for the programmer to document the program and easier for testing and debugging of each function.
3. Portability. Programs written on one system can be made to run on another system with little or no modification. Often, the changes can be made just in the header files.
4. C has a large library of useful functions that are generally available on most C implementations.

A.2 Hardware and Operating System Requirements

Program has been developed and tested on SUN SPARCstation 1 with a colour monitor and SUN SPARCstation 2 with a black and white monitor. Both workstations are running Sun OS 4.1.1. HOOPS will run on all Sun 4 (SPARC architecture) workstations running Sun 4.0.3 or higher.

A.3 Hoops Graphic Systems

Version 2.20 of Hoops Graphic Systems was used for the graphics interface. The Hoops Graphics System must be supported by GX Sun hardware graphics accelerator. The Hoops XGL, X11 and SunView Drivers all support this accelerator. The appropriate environment variables must be defined to successfully run the program.

A.3.1 Set Up of HOOPS Environment Variables

The environment variables were defined in terms of C shell "csh" and setting variables for Bourne shell were not tested. Run-time environment variables is an option that alters Hoops program execution. At start-up, the Hoops program reads the environment for variables beginning with "HOOPS_" and uses these to alter the default settings, given in the Hoops Manual, Ithaca Software (1991). The environment variables described in sections A.3.1.1, A.3.1.2 and A.3.2 were placed as the csh-style definition in ".cshrc" file following the command 'setenv'. The program runs under both Open Window version 2.0 and SunView for Unix OS.

A.3.1.1 Open Windows Driver

To run Hoops under Open Windows, the environment was set up, so that the X11 Driver was the default Hoops driver. The following line was inserted to .cshrc file:

```
setenv HOOPS_PICTURE "X11/unix:0.0"
```

A.3.1.2 SunView Driver

To run Hoops under SunView with the appropriate environment variables set up the following line was inserted to .cshrc file:

```
setenv HOOPS_PICTURE "sunview/wind0"
```

The program was run successfully under Open Window Driver on either the Black & White monitor or on the Colour monitor of the Sun SPARCstations when the environmental variables were set as described above. Note, under the SunView driver, the palette of colours were slightly modified on the Sun SPARCstation 1 with a colour monitor, and the black and white colours were reversed giving a black background with white lines and boxes (windows and buttons) on the Sun SPARCstation 2. The black background prevented the user from seeing highlighted buttons, hence the running of the program was a little confusing.

OpenWindow Driver handles the colours on the black and white monitor as different shaded patterns. The colours, are set up automatically at the beginning by the program, when it inspects whether the system is using a black & white or colour monitor. Different colours are set up for black & white monitor or colour monitor to make the text within black & white shaded areas more clearer.

For the hardcopies of the screen in this document all the colours except highlighted (selected) buttons were set to white, otherwise the picture when scaled down would make the text within shaded areas unreadable.

A.3.2 PostScript Driver

The PostScript Driver was used to obtain a hardcopy of the screen. To set the PostScript driver as the default Hoops driver, the environment variable was defined in .cshrc file by adding the following two lines:

```
setenv HOOPS_HARDCOPY "postscript/hoops.ps"
```

```
setenv HOOPS_HARDCOPY "force black-and-white"
```

Hardcopies of similar quality were made with the laser printers listed below:

1. QMS PS 810 with 2 MB RAM
2. Personal Apple LaserWriter NTR with 16 MHz CPU and 3 MB of RAM.

APPENDIX B

File Architecture

B.1 Source Code Files

Complete source code is formed by separate modules, each developed for the specific task, and are described in sections B.1.1 to B.1.7. Each module can be run independently with minor modifications.

B.1.1 File LDFSSBC.c

This module acts as a support frame which creates the first window image, shown in Figure 3.1 where the button in the menu shown along the top of the window represent all the other modules. This source code module contains following headers:

- ldfssbc.h** - the functions, that create segments and modify the geometric attributes in HOOPs, that are common for all source files, are defined within this header.
- c_hoops.h** - this header defines all 'C' and HOOPS library headers, functions defined as macros and short aliases for HOOPS subroutines utilized by LDFSSBC.
- c_hoops_var.h** - global variables for colour definition (initialized by inspecting the

type of running monitor device) and sizes of frequently used string variables are declared within this header.

The headers **c_hoops.h** and **c_hoop_var.h** are included in all source files.

B.1.2 File SELECT_LOCATION.c

This module retrieves the climatic data coefficients for a selected location in Canada from file "CLIMATIC_DATA_CND" and saves them in the file "location_clmtc_data" in the appropriate directory of the currently active project.

B.1.3 File DEAD_LOAD.c

This module is used to create typical structural sandwich systems, including the computation of the corresponding dead load intensities for a given project. This source code includes the following headers:

- dl_variables.h** - includes definition of colours for display of specific materials and default values for the camera position for 3D display.
- dl_materials.h** - is a library of typical building materials including their description, unit weight in kPa and thickness in mm (or density in kilonewtons per meter cubed if the unit weight is not specified).
- dl_graph_def.h** - defines the 3D graphic display of typical structural members, roof layers, floor and wall sandwiches.

B.1.4 File LL_USE_OCCUPANCY.c

Within this module, a list of selected areas is created for intended occupancy use according to Section 4.1.6 of the NBCC 1990, NRC (1990). Articles referred to in Table 4.1.6.A are reproduced and defined for display. The source code includes the following header:

ll_var.h - defines the description of areas for intended use and occupancy with the related load intensities per meter square and definition of required design concentrated load according Tables 4.1.6.A and 4.1.6.B, respectively.

B.1.5 File SNOW_LOAD.c

This module contains library functions which calculate snow load intensities at nodes of a mesh (defined in the GEOMETRIC_MODELLE module) according to the climatic data coefficients for the selected location, site condition, and the geometric configuration of the roof. The source code includes the following header:

snow_var.h - defines the structure data templates, macros for the length of character strings and default settings for the camera position for the 3D display.

B.1.6 File WIND_LOAD.c

This module contains library functions which calculate wind load intensities at nodes of a mesh (defined in the GEOMETRIC_MODELLE module) according to the climatic data coefficients for the selected location, site conditions, building characteristics and geometric configuration. The source code includes the following header:

wind_var.h - defines the structure data templates, macros for the length of character strings, and default setting for the camera position for the 3D display.

B.1.7 File GEOMETRIC_MODELLE.c

This module contains library functions to define surfaces of a building (roofs, floors and walls, -i.e. structural form), to determine the coordinates for a mesh of points on any specified surface and to retrieve information relating the geometry of adjacent surfaces. The source code includes the following header:

gm_var.h - defines the structure data templates, macros defining constants and default settings for the camera position for the 3D display.

B.2 The Executable File "LDFSSBC" and the Corresponding Defaults

The name of executable file is LDFSSBC and the following list of files must be present in the working directory for its proper execution:

CLIMATIC_DATA_CND -	table of design data (climatic data) for selected locations in Canada reproduced from Chapter 1 of the Supplement to the NBCC 1990, NRC (1990).
MESH_SPACING_default -	default spacing for grid lines that define the location of a mesh of points within a given surface.
DRAWING_SETUP_default -	default values specified at the start of a new project and is used to set-up coordinate ranges for the

computation of scale factors and coordinate transformation factors to maintain the display of the structure within the windows view.

DL_floor_defaults, DL_roof_default and DL_wall_defaults - default files, each with two typical structural sandwich systems including a description of the elements and their load intensity, and total dead load intensity.

SNOW_defaults - default values for the basic roof snow load factor, the unit weight of snow and those related to site conditions.

WIND_defaults - default values for building characteristics, site conditions and values for the exposure and gust effect factors that are specific to the procedure (simple or detailed) required to determine the wind loads.

B.3 Output Files

The working directory (containing the executable file LDFSSBC, common headers and default files) also houses a file "**jobs_list**" which contains a list of existing projects a simple text file containing one project name per line.

Output files created for each project are housed within a subdirectory of the same name as project. The data files related to the definition of structure geometry, climatic data for the selected location and data common for all types of load, are placed within the project subdirectory. Two additional sub-subdirectories **/snow** and **/wind** are created for the data files with snow and wind loads intensities.

The following data and output files within the project subdirectory are described in detail.

drawing_setup - stores the specific minimum and maximum values of x,y and z coordinates for the building space, as described in section 3.2.3
CREATE NEW PROJECT, and has the following file form:

```
-60000    25000
      0    90000
-50000    60000
```

location_clmtc_data - stores the selected location (province or territory, location) with the corresponding climatic data in the same sequence given in the Supplement as shown in following example:

```
BRITISH COLUMBIA
North Vancouver
-7.0 -9.0 26.0 19.0 2978.0 10.0 100.0 1889.0 2.7 0.3 0.44 0.55 0.68 4.0 4.0 0.20
```

nodes_list - identification number and x, y, and z coordinates for each node that defines a surface or area for the given building are stored in a text file as follows:

```
1      -6000      0      -27250
2      25500      0      -58854
.      .      .      .
.      .      .      .
1106   -8800      77200   -2000
1107   -6500      77200    2000
```

floors_dead_load - a series of structural sandwich systems specified for the floors of the given building and corresponding uniformly distributed dead load intensity are stored in this file as a C data structure block in binary form.

roofs_dead_load - as described above, but for roofs

walls_dead_load - as described above, but for walls

LL_areas_list - text file containing a list of names of live load use and occupancy areas for the given building and the corresponding values for their uniformly distributed and concentrated loads as shown:

```
Retail Office 2-3-4 FL.
4.80      9.00
Office 5-10-13-19 FL.
2.40      9.00
:
:
Roofs min.
2.0      1.3
```

floor_surfaces - a simple text file which lists floor by floor the surface name, the number of nodes and list of node IDs defining the surface. An example file is illustrated below. The format of this file makes it possible to combine it with files that define primary and secondary structures that lie within the surface.

```
floor 1
34
1 2 3 4 5 6 7 8 9 10 11 12 13 14 1 15 16 17
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
floor 20
49
974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992
993 994 995 996 997 998 999 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011
1012 1013 1014 1015 1016 1017 1018 1019 1020 1021 1022
```

This file is utilized by the program in this form until the loads are attributed to the appropriate surface. Subsequently the data is copied to a C data structure block and stored in binary form in a file called **floor_loads**

roof_surfaces - as described above, but for roofs

wall_surfaces - as described above, but for walls

floor_loads - contains data that defines the floor surfaces of the given building and the corresponding dead loads and live loads due to use and

occupancy

roof_loads - as described above, but for roofs

wall_loads - as described above, but for walls

The sub-subdirectory **/snow** houses the following files:

mesh_spacing - spacing in millimetres of the grid lines for the generated mesh of points are stored in this file

snow_areas_list - contains a list areas (surface names), one per line, for which the snow load intensity cases are calculated.

snow_load_defined - includes basic climatic data and site condition information that is utilized for the calculation of snow load on the building. An example file with explanation is illustrated below.

BRITISH COLUMBIA	- name of selected province or territory
North Vancouver	- name of selected location
2.70	- ground snow load in kPa
0.30	- associated rain load in kPa
0.8	- basic roof snow load factor
3.0	- average unit weight of snow
1	- building in exposed area ? 1 YES 0 NO
0	- building north of the tree line ? 1 YES 0 NO

Four files are created for each surface that the snow load distributions are calculated. The name of the files are created by joining the name of the surface with one of the following suffixes, **.nodes**, **.coord**, **.config** and **.mg**, to give for example **roof_2.nodes**.

.nodes - the number of nodes, node ID number and the x, y and z coordinates of all nodes defining the surface are listed as shown and are used by the graphics

portion of the program to play the surface shape in 3D in the main window.

```

4
1077      8800      80700      -6800
1078      8800      80700      -6800
1079      8800      80700      6800
1080     -8800      80700      6800

```

.coord - the identification code and x, y and z coordinates for each node (point) on the generated mesh for the surface are listed as shown

```

0001EE0001      8000      9500      0
0002XE0001      8000      9500     1000
.
.
.
0035XE0009     28000      9500     34000
0036EE0009     28000      9500     35000

```

.config - for geometric data required for the calculation of snow load intensity at each node, including data about adjacent roof surfaces that will influence the snow load distributions are stored in this file in the following form.

```

roof_2
FIGURE_H_3
1  0  0.0  0.0  0.0  0.0  12000.0  8000.0  163.7  23.6
866
0001EE0001     163.7353973      0.0      0.0      0.0      0.0      12000.0      0.0
0002XE0001     163.7353973      0.0      0.0      0.0      0.0      12000.0      0.0
.
.
.
0035XE0009     23.6353760      0.0      0.0      0.0      0.0      8000.0      0.0
0036EE0009     23.6353760      0.0      0.0      0.0      0.0      8000.0      0.0

```

Each data entry is defined below by line number, then by entry number, followed by a brief description. For example, 3.7 height of the external adjacent wall above the roof ("h" in Figure H-4), indicates line 3, entry 7 and the numerical value is 'h'.

ENTRY	DESCRIPTION
1.1	surface name
2.1	applicable snow load figure H-1 through H-6
3.1	type of the roof 0 - regular 1 - unobstructed slippery roof
3.2	information if the roof is circular 0 -NO 1 - YES
3.3	curved roof - distance from the top of roof to point where the slope is equal to 30 degrees
3.4	curved roof - total span ("b" in Figure H-2)
3.5	curved roof - total height of the curved portion of roof ("h" in Figure H-2)
3.6	distance from edge of roof to external adjacent wall ("a" in Figure H-4)
3.7	height of the external adjacent wall above the roof ("h" in Figure H-4)
3.8	total length of the first part of valley roof (left "b/2" in Figure H-3)
3.9	total length of the second part of valley roof (right "b/2" in Figure H-3)
3.10	roof slope of the first part of valley roof (alpha_1 in Figure H-3)
3.11	roof slope of the second part of valley roof (alpha_2 in Figure H-3)
4.1	number of points in file
5.1	point identification code
5.2	slope of roof at this point
5.3	distance of the point to the adjacent wall
5.4	height of the adjacent wall above the point elevation
5.5	curved roof - distance of the point to the top of roof ("x" in Figure H-2)
5.6	curved roof - difference of elevation of point and top of roof ("hx" in Figure H-2)
5.7	distance of the point to the bottom of valley roof for case of Figure H-3
5.8	width of the roof obstruction ("b" in Figure H-6)

.mg - lists the load intensity, for all possible snow load accumulation cases on the roof, for each node on the surface in the following form:

CASES OF SNOW LOAD INTENSITIES

highRoof_1

FIGURE_H 4

NODE	CASE_1	CASE_2	CASE_3	CASE_4	CASE_5
0001EE0001	1.87	0.00	0.00	0.00	0.00
0002XE0001	1.87	0.00	0.00	0.00	0.00
0036EZ0009	1.87	0.00	0.00	0.00	0.00

The sub-subdirectory **/wind** houses the following files:

mesh_spacing - spacing in millimetres of the grid lines for the generated mesh of points are stored in this file. This spacing may be different than that for snow load and should be selected to give an accurate representation of the load distribution. Distributions with varying gradients will require a smaller spacing.

wind_areas_list - contains a list of areas (surface names), one per line, for which the wind load intensity cases are calculated.

wind_load_defined - includes climatic data, building characteristics (dynamic properties simple building geometry, classification of openings) conditions and information on the surrounding terrain that is utilized for the calculation of wind load on the building. An example file with explanation is illustrated below:

BRITISH COLUMBIA	- name of selected province or territory
North Vancouver	- name of selected location
0.44	- hourly wind pressure 1/10 in kPa
0.55	- hourly wind pressure 1/30 in kPa
0.68	- hourly wind pressure 1/100 in kPa
0.010	- estimated critical damping of the structure
0.200	- estimated natural frequency of the structure in Hz
D	- exposure factor procedure D - detailed S - simple
D	- gust effect factor procedure D - dynamic S - simple
A	- exposure category influenced by terrain roughness A, B or C
2	- internal pressure category of building 1, 2 or 3

NO	- is building design for post-disaster purpose YES or NO
NO	- speed-up over hills and escarpments YES or NO
2DR	- hill shape 2DR - 2D ridges, 2DS - 2D escarpments, 3D - 3D axisymmetrical hills
0.00	- hill height in metres
0.00	- distance L upwind of the crest to where the ground elevation is half the height of the hill
0.00	- distance of the building to the crest of the hill
2.50	- gust effect factor for cladding by simple procedure
2.00	- gust effect factor for structural members by simple procedure
77200.00	- elevation of the roof of the building in millimetres
0.00	- height above the terrain of the building zero elevation

Three files are created for each surface that the wind load distributions are calculated. The file names and structure are similar to those for snow. The .config file is not applicable, therefore, not created.

.nodes - the file structure is identical to that described for the sub-subdirectory **/snow**.

.coord - additional data required for the calculation of wind load intensity on each surface and the identification code and x, y and z coordinates for each node on that surface are stored in this file in the following form.

```
highrise_wall_10
WALL HIGHRISE
1.0000000 0.0000000 0.0000000
4 77204 11500 90.0000000
0001EE0001 -18250 13500 -5750
0002XE0001 -18250 13500 -4750
0003XE0001 -18250 13500 -3750
0012XE0064 -18250 77204 5250
0012EE0064 -18250 77204 5750
```

Each data entry is defined below by line number, then by entry number, followed by a brief description.

ENTRY	DESCRIPTION
1.1	surface name
2.1	surface type designation WALL or ROOF
2.2	type of building HIGHRISE or LOWRISE
2.3	applicable for low rise buildings only and describes the wall position with respect to the ridge of the roof as being PARALLEL or PERPENDICULAR
3.1-3.3	components of unit vector normal to this surface
4.1	<p>defines the distribution of openings in the walls and is used for the computation of internal pressures. The symbols have following meaning:</p> <p>1 - openings mainly in this wall</p> <p>2 - openings mainly in opposite wall</p> <p>3 - openings mainly in perpendicular walls</p> <p>4 - openings uniformly distributed in all walls</p>
4.2-4.3	height and width of the surface. These values are utilized for low rise buildings only, to determine the end zone width.
4.4	slope of the surface in degrees

.mg - files with this suffix contain the calculated values of wind load intensities for each applicable loading case, a function of the type of surface and the surface orientation

to the wind, for each point of the mesh. The header of each file gives the explanation of the stored values.

Four possible cases, for walls and roofs, of a high-rise building and for walls and roofs of a low-rise building are shown in example files bellow.

```

CASES OF WIND LOAD MAGNITUDES
highrise_wall_10
NODE      STRUCTURAL MEMBERS:          CLADDING          STRUC N  SERVICEABILITY  LOCAL SUCTION  BLD G AS A WHOLE
          windward leeward end-wall  windward leeward end-wall  windward leeward end-wall  windward leeward end-wall  windward leeward
0001EE0001  1.933  -1.179  -2.172  1.475  -0.003  -1.635  1.546  -0.963  -1.730  1.950  2.410  1.692  1.619
0002XE0001  1.933  -1.179  -2.172  1.475  -0.003  -1.635  1.546  -0.963  -1.730  1.950  2.410  1.692  1.619
0012XE0064  2.998  -1.179  -2.172  2.282  -0.003  -1.635  2.399  -0.963  -1.730  1.950  2.410  2.757  1.619
0012XE0064  2.998  -1.179  -2.172  2.282  -0.003  -1.635  2.399  -0.963  -1.730  1.950  2.410  2.757  1.619

```

```

CASES OF WIND LOAD MAGNITUDES
highrise_roof_1
NODE      SUCTION
0002XE0001  -2.736
0002EE0001  -2.736
0025XE0013  -2.736
0025EE0013  -2.736

```

```

CASES OF WIND LOAD MAGNITUDES
lowrise_wall_9
NODE      PRIMARY STRUCTURAL ACTION  CLADDING & SEC. STRUC.MEMB.
          windward leeward  perpend  windward leeward
0001EE0001  0.666  -0.067  -0.366  0.650  -0.348
0002XE0001  0.666  -0.067  -0.366  0.650  -0.348
0051XE0005  0.666  -0.067  -0.366  0.650  -0.348
0051EE0005  0.666  -0.067  -0.366  0.650  -0.348

```

```

CASES OF WIND LOAD MAGNITUDES
lowrise_roof_1
NODE      PRIMARY STRUCTURAL ACTION  CLADDING & SEC. STRUC.MEMB.
          windward leeward  perp_1  perp_2  windward leeward
0001EE0001  -0.666  -0.067  -0.200  0.000  -0.108  0.270
0002XE0001  -0.666  -0.067  -0.200  0.000  -0.108  0.270
0034XE0023  -0.666  -0.067  -0.200  0.000  -0.108  0.270
0034EE0023  -0.666  -0.067  -0.200  0.000  -0.108  0.270

```


APPENDIX C

Program Installation and Maintenance

Source code files, connected libraries and headers are structured to allow easy and flexible updating, and modification of the program.

C.1 Installing the Software

The executable file, files with default settings and all files of source code, can be stored on one 3 1/2" high density floppy. Two tar files, **executable.tar.Z** and **source_code.tar.Z** are stored on the floppy in compressed version along with two installations files, **install_exe** and **install_source**. To install the executable file and files with default settings;

1. insert the floppy into the disk drive,
2. create a suitable new directory where the program is to be installed (cd new_directory)
3. execute the following command, **tar xf /dev/rfd0a install_exe** (assuming, for example, that the floppy disk drive is /dev/rfd0a)
4. type **install_exe**, and all files necessary for program running will be automatically installed. To retrieve the source code files follow the some procedure for

install_source instead of install_exe. Before running the program check to ensure that the proper libraries and environment variables for the Hoops Graphic System are set up.

C.2 Updating of Climatic Data Library

Design Data for selected location in Canada are stored in a text file "CLIMATIC_DATA_CND". This file is created in the same order as Table "Design Data for Selected Locations in Canada from Chapter 1 of the Supplement to the NBCC 1990, NRC (1990) (each one location with appropriate sixteen climatic coefficients per line). Updating of the Design Data for Selected Location in Canada is required each time revisions are made to this section and can be accomplished without recompiling, by editing the data file. Editing of existing coefficients in the file "CLIMATIC_DATA_CND" can be done with any text editor. To add or delete any location within any province or territory is also possible. To add a new location, insert the location name and all sixteen climatic data coefficients in the data file, at any position between the name of appropriate province or territory and the terminator 'END_OF_PROVINCE'. All of the sixteen coefficients have to be specified, if not with a value, then by '0.0'. There is no limitation for the maximum number of locations within any province. Data in the current file have been updated according to: Revision 1 January 1991, Revision 2 January 1992, Revision 3 January 1993.

C.3 Updating Dead Load Libraries and Tools

The library of typical building materials consists of material description, unit weight per meter square and thickness, or mass per meter cube, as applicable and is stored in header file "dl_materials.h" as a structure data form defined by the C language. The list of materials currently stored in this library were taken from the following references:

1. Handbook of Steel Construction, Fifth Edition 1991 section Mass and Forces for Materials.
2. Concrete Design Handbook, First Edition, Second Printing December 1989, Table 1.11. Dead Loads for Floors, Ceilings, Roofs and Walls and Table 1.12. Minimum Design Load, for Materials.

Space in data structure was left free, after each group of material, for adding new materials or updating existing materials. Editing of library can be done with any text editor. To add or delete any material the variables for example MINROOFING 0 and MAXROOFING 11 (specify the start and end of a list of materials) in a file "dl_variables.h" must be redefined accordingly. Only the owner of the source code can edit these files. The program must be compiled and linked after a change has been made. The data defining the three dimensional graphic display of created structural sandwich systems is given in a "dl_graph_def.h" file. Default member sizes include: W-shape girders, W410x67; W-shape beams, W310x60; C-shape beams, C250x37; angles, L200x200x13; height of OWSJ of 500 mm; top and bottom chord of OWSJ; two back to back angles L50x50x8; joist shoe height of 100 mm created by two back-to-back angles L75x75x10. To change these defaults, edit the function 'DL_display_picture_of_selected_structure()' in the source

code DEAD_LOAD.c, and then recompile and link the program.

C.4 Updating Live Loads Due to Use and Occupancy Libraries

The macros which define the text to be displayed in the tables or articles are found in the file "ll_var.h". Editing of the text can be done with any text editor. To change any load intensity value in the tables, edit the source code file "LIVE_LOAD.c" within functions 'LL_display_udl_table_page1()'...page2() e.t.c. Erasing or adding of any text or values requires new configuration of tables graphic image in the functions mentioned above. Recompile and link if modification are made to "LIVE_LOAD.c" and "LL.h".

C.5 Updating Live Loads Due to Snow, Ice and Rain Defaults

The default values as defined in the NBCC 1990, NRC (1990), for the basic roof snow load factor, $C_b = 0.8$, and average unit weight of snow on roofs, $\gamma = 3.0$ kN per metre cubed are stored in the file "SNOW_defaults". The default location is set to be not in an exposed area and not north of the tree line. Permanent changes in the default values can be done within the file "SNOW_defaults" by any text editor. The adjustment of default values for any particular job can be done during execution of the program within the screen window shown in Figure 3.45 by mouse selection and keyboard input.

C.6 Updating Live Loads Due to Wind Defaults

The default data utilized by the program are stored in the file "WIND_defaults" and are as follows:

- The building is not design for post disaster purpose.
- Gust effect factor, C_g , for the building as a whole and main structural members evaluated by simple procedure is 2.0.
- Gust effect factor, C_g , for the small elements including cladding evaluated by simple procedure is 2.5.
- Critical damping ratio, β , is 0.010.
- Natural frequency of vibration, n_ω is 0.200 Hz.
- Exposure factor is computed by the detailed procedure.
- Gust effect factor is computed by the detailed procedure (dynamic approach).
- Exposure of building according to surrounding terrain and topography: **Exposure A**
- Internal pressure category: **Category 2**
- No speed up over hills and escarpments.
- If speed up over hills and escarpments exist, the default for hill shape is **2 Dimensional Ridges**.

Permanent changes of default values can be done within file "WIND_defaults" by any text editor. The adjustment of default values for any particular job can be done during execution of the program within the screen windows, shown in Figures 3.50 and 3.51, by mouse selection and if applicable by keyboard input.

END

'20-07-94

FIN