Computer Program for the Analysis of Loads On Buildings

Using the ASCE 7-93 Standard

Minimum Design Loads for Buildings and Other Structures

by

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(ABSTRACT)

A computer program for the analysis of loads on buildings is developed. The program determines wind loads, earthquake loads, and snow loads according to the ASCE 7-93 Standard Minimum Design Loads for Buildings and Other Structures (ASCE 7-93). The program is developed using the object-oriented programming methodology and runs on the Microsoft Windows 95 graphical environment. It is a valuable and useful tool for determining loads on buildings.

Acknowledgment

I want to thank my advisor Dr. Kamal B. Rojiani for his patience during my struggle to complete this degree. Learning C and C++ proved to be a great challenge, but with perseverance and help from Dr. Rojiani, I succeeded.

Also, I want to thank the other members of my advisory committee, Dr. W. Samuel Easterling and Dr. Don A. Garst, for their continual patience and support.

Special thanks to my wife, mother, and four sisters for their continual encouragement. In memory of my father, Claude M. Browning, this degree is completed. He, along with my mother, worked diligently to provide their children with opportunities to learn and grow.

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CHAPTER ONE

INTRODUCTION

1.1 Determining Building Loads

Accurately designing a building for the loads sustained during its service life is not an exact science. During the design process, dead loads are typically approximated and then verified later, meaning that the dead loads are often unknown until the design is completed. Live loads are typically based upon accepted practice rather than calculated values, and they are often conservative (Salmon and Johnson, 5). This is due to the difficulty in accurately determining the magnitudes and positions of live loads.

Determining special design loads such as wind and earthquake loads is not a simple task either, and it often involves tedious calculations also. The development of building codes has aided in standardizing methods for calculating special design loads due to wind, earthquake and snow. Furthermore, the building codes have started to combine knowledge from research and practice to help with calculating all types of design loads. The calculations presented by the building codes are still complicated and tedious and engineers are subjected to time constraints. The constraints often limit their ability to fully learn and use the methods found in the building codes. Therefore, ways to simplify the complicated calculations are continually sought.

Computers are being used more and more to perform tedious calculations. Engineers are actively taking advantage of the speed and consistency provided by computers. Although computers have been used in structural engineering for quite some time now, there is still a great demand for reliable and accurate engineering analysis and design programs. Many of the structural engineering computer programs available today provide more design and analysis tools than what is needed, and they can also be a significant expense. Thus, there is a demand for more simple, lower cost computer programs to perform the day-to-day tedious calculations. An example of such a program is one which will compute special loads such as wind, earthquake and snow loads using a common building code.

1.2 Project Objective

The project objective was to develop a load analysis program for personal computers that computes design loads on buildings based on the ASCE Standard Minimum Design Loads for Buildings and Other Structures (ASCE 7-93). The Load Analysis Program determines wind loads, earthquake loads and snow loads on buildings according to the ASCE 7-93 Standard. The ASCE 7-93 Standard was chosen because it is nationally accepted and referred to by many regional building codes such as the Standard Building Code. The Load Analysis Program is intended to be used as a tool along with the ASCE 7-93 Standard. C++ was the chosen programming language because it is the most popular object-oriented programming language used to develop programs to run in the Windows 95 graphical environment. The Microsoft Windows 95 operating system is currently the most common operating system used on personal computers.

Since learning to calculate loads is a part of the Civil Engineering student's curriculum, it is hoped that this software can be used not only in a design office, but also in a classroom.

1.3 Report Objective

The objective of this report is not to replace, but to supplement the ASCE 7-93 Standard and describe the Load Analysis Program. The ASCE 7-93 Standard is the main source for load development methodology and a required item for the appropriate use of the Load Analysis Program. Therefore, this report will primarily focus upon subjects related to the Load Analysis Program and how it follows the ASCE 7-93 Standard. The following topics are discussed.

Chapter 2 discusses structural loads based upon the ASCE 7-93 Standard. Topics include how the ASCE 7-93 Standard defines gravity loads, wind loads, earthquake loads and snow loads. Chapter 3 describes the Load Analysis Program's features. Appendix A contains a users guide and two example problems and Appendix B contains output for the example problems and calculations performed for verification of the Load Analysis Program.

1.4 Load Analysis Program Features

The Load Analysis Program, as mentioned before, is a Windows 95 program. It has all of the functionality of a standard Windows 95 program, such as toolbars, dialog boxes, scrolling views and on-line help. The Load Analysis Program has the following features:

1. It runs under Microsoft Windows 95.

2. It utilizes the C++ programming language.

3. It is developed using the object-oriented programming approach.

4. It is a multiple document interface (MDI) program which allows for several projects to be open simultaneously.

5. It closely follows the ASCE 7-93 Standard in order to minimize error.

6. It calculates design wind loads as recommended by ASCE 7-93 by computing design pressures for component and cladding for multiple tributary areas and building locations.

7. It calculates earthquake loads for regular shaped buildings up to 240 feet high using the Equivalent Static Lateral Force Method.

8. It calculates regular and unbalanced roof snow loads.

9. It has clear and thorough output.

CHAPTER TWO

STRUCTURAL LOADS

This chapter presents a brief overview of the different types of structural loads which primarily apply to building analysis and design. The ASCE 7-93 Minimum Design Loads for Buildings and Other Structures (ASCE 7-93) will be used to for determining building design loads. Gravity loads, wind loads, earthquake loads and snow loads are discussed.

2.1 Types of Structural Loads

Structural loads are classified as either dead or live. Dead loads are gravity loads that remain constant in magnitude and location, such as walls, floors, roof members, plumbing, and miscellaneous fixtures. Live loads can vary in magnitude and location, and they are not always gravity loads. Examples of live loads are office furniture, construction loads, and occupancy floor loads. The life use of the building should be considered when determining loads for analysis and design.

The ASCE 7-93 Standard addresses each type of load. Furthermore, it separates wind loads, snow loads, and earthquake loads into individual categories and provides analytical procedures for determining magnitudes for each load. The Load Analysis Program, described in Chapter 3, is a tool for determining wind, earthquake and snow loads using the ASCE 7-93 Standard. It maintains the nomenclature of ASCE 7-93 and follows the procedures discussed in the subsequent sections.

2.2 Gravity Loads

Gravity loads are forces exerted by objects upon a building due to their weight, and weight is a function of gravity. The most obvious building gravity loads are dead loads such as a concrete floor, finished flooring materials, permanent partitions and the building's framework. Live loads, on the other hand, can be gravity loads. Building occupants, moveable partitions, furniture and construction loads are types of gravity live loads. Table 2, page 4 of ASCE 7-93 and Tables C1-C3, pages 94-96 of ASCE 7-93 provide data for determining both minimum live loads and material dead loads.

The ASCE 7-93 Standard also provides guidelines (Section 4.8, page 6) for reducing live loads in cases where the design live loads tend to be significantly large due to large influence areas. As an example, it is unlikely that a column's tributary areas will simultaneously sustain full design loads. Therefore, the design load on a column with a large influence area can be reduced according to the ASCE 7-93 Standard's guidelines.

2.3 Wind Loads

The ASCE 7-93 Standard provides analytical procedures for determining main wind-force resisting system wind loads and individual components and cladding wind loads for buildings and other structures. The main wind-force resisting system is described as major structural elements such as rigid and braced frames, roof and floor diaphragms and shear walls. Components and cladding are elements directly loaded by wind such as exterior windows, panels, studs, roof sheathing and roof trusses. As an alternative to the analytical procedure, a wind-tunnel procedure is acceptable but it is not specifically outlined within ASCE 7-93. A wind-tunnel procedure is recommended for buildings and structures having unusual geometry and response characteristics or site locations where channeling effects or buffeting in the wake of upwind obstructions may warrant special consideration.

The analytical procedure begins by choosing the appropriate equation from Table 4 of ASCE 7-93. Equations are presented for both the main wind-force resisting system and components and cladding for non-flexible buildings and other structures and flexible buildings and other structures. The Load Analysis Program determines loads for non-flexible buildings only. It does not determine loads for non-flexible structures other than buildings or flexible buildings and structures. The following equations are used and the external and internal pressures are algebraically combined to acquire the most critical load.

Main wind-force resisting system (All mean roof heights):

$$p = qG_hC_p - q_h(GC_{pi}) \qquad \text{(Eq. 2.1)}$$

where p is the design pressure, q is the velocity pressure, G_h is the gust response factor evaluated at mean roof height, C_p is the external pressure coefficient and GC_{pi} is the product of the internal pressure coefficient and the gust response factor. The velocity pressure, q, is evaluated at height z above the ground, and q_h is the velocity pressure evaluated at mean roof height. Equation 2.1 is used for all mean roof heights.

Components and cladding (buildings with a mean roof height less than 60 feet):

$$p = q_h\left[\left(GC_p\right) - \left(GC_{pi}\right)\right] \qquad \text{(Eq. 2.2)}$$

where p is the design pressure, GC_p is the product of the external pressure coefficient and the gust response factor, GC_{pi} is the product of the internal pressure coefficient and the gust response factor, and q_h is the velocity pressure evaluated at mean roof height. Since the velocity pressure , q, is only evaluated at mean roof height, the design pressure, p, will be uniform for both positive and negative values of GC_p. Equation 2.2 is to be used when the building's mean roof height is less than sixty feet.

Components and cladding (buildings with a mean roof height greater than 60 feet):

$$p = q\left[\left(GC_p\right) - \left(GC_{pi}\right)\right] \qquad \text{(Eq. 2.3)}$$

where p is the design pressure, GC_p is the product of the external pressure coefficient and the gust response factor, GC_{pi} is the product of the internal pressure coefficient and the gust response factor, and q is the velocity pressure. For positive values of GC_p, the velocity pressure, q, varies with respect to the height above the ground. Thus, the design pressure also varies with respect to the height above the ground. For negative values of GC_p, the design pressure is uniform since the velocity pressure, q, is referenced to the building's mean roof height. Equation 2.3 is to be used when the building's mean roof height is greater than 60 feet.

The gust response factor, G, accounts for additional loading due to turbulence but does not consider cross-wind deflection, vortex shedding or instability due to galloping or flutter. One value for G, which is evaluated at mean roof height, is used for the main wind-force resisting system. For components and cladding, the gust response factor, G, is combined with the external pressure coefficient, $C_{p,}$ to form the product GC_p. The ASCE 7-93 Standard requires that each component and cladding member be designed for the maximum positive and negative pressures. As a result, each component and cladding member's location and tributary area should be considered.

The external pressure coefficient, C_p, is used for determining main wind-force resisting system design pressures for walls and roofs. For windward walls, the pressure is positive and varies over the building's height due to the change in the velocity pressure over the height of the building. For side and leeward walls, the pressures are negative and uniform over the height of the building because the velocity pressure is calculated at the building's mean roof height.

The product of the gust response factor and the internal pressure coefficient, $GC_{pi,}$ accounts for the tendency of a building to become internally pressurized. The ASCE 7-93 Standard requires two conditions to be considered. Condition I is for buildings completely open or enclosed. Condition II is for partially open (or partially enclosed) buildings. Since ASCE 7-93 requires the algebraic combination of external and internal pressures, the value of GC_{pi} for Condition II will increase the design pressure for both the main wind-force resisting system and the components and cladding. Buildings with large windows susceptible to breakage from flying objects should be considered as partially open.

The velocity pressure, q, is determined from the following equation:

$$q_z = 0.00256 K_z (IV)^2 \qquad \text{(Eq. 2.4)}$$

where V is the basic wind speed, K_z is the velocity pressure exposure coefficient, I is the importance factor, and the constant 0.00256 is the air mass density for standard atmospheric pressure at sea level and a conversion to miles-per-hour.

Equation 2.4 is used to convert the basic wind speed, V, into a velocity-related pressure. The wind speeds shown in Figure 1 and Table 7 of ASCE 7-93 are based upon fastest-mile wind for smooth terrain (Exposure C) at a height of 33 feet above ground.

The velocity pressure exposure coefficient, K_z, accounts for the variation of wind speed with respect to height above ground and ground friction. The importance factor, I, adjusts the design wind speed based upon the type and importance of the structure. The design wind speeds given in Figure 1 and Table 7 of the ASCE 7-93 Standard are based on a probability of exceeding the design wind speeds once in 50 years. The importance factor allows one wind speed map to be used for average recurrence intervals of 25, 50 and 100 years. Design wind speeds are more likely to be exceeded at ocean lines, therefore the importance factors are higher in order to provide the same probabilities of exceeding the design wind speeds at ocean lines as for inland areas. The importance factors given in Table 5, page 11 of ASCE 7-93 depend upon the building occupancy classification category (described in Table 1 of ASCE 7-93).

The gust response factor calculations and the velocity pressure exposure coefficient calculations are a function of the exposure category constants given in Table C6 of ASCE 7-93. These constants vary depending upon the applicable exposure category. The building's exposure condition is to be matched to the suitable exposure category depending upon the ground surface characteristics of the building's site location. Exposure categories range from Exposure A to Exposure D and are discussed in Section 6.5.3 of ASCE 7-93. For the main wind-force resisting system, the exposure category constants affect only one value of G calculated at the building's mean roof height. For the building's components and cladding, the exposure category constants do not affect the value of the gust response factor. Both main wind-force resisting system pressures and component and cladding pressures are adjusted by the velocity pressure exposure coefficient K_z in the calculation of the velocity pressure.

2.4 Earthquake Loads

Earthquake loads are usually determined by approximating the horizontal component of the earthquake's acceleration and applying an equivalent, static lateral force to the base of the structure and distributing the force over the height of the structure. This approach is referred to as the Equivalent Seismic Lateral Force Procedure within the ASCE 7-93

Standard. One limitation is that the building is assumed to be fixed at the base. Other limitations are given in Section 9.3.5, page 49 of the ASCE 7-93 Standard.

A building's fundamental period, T, is first determined for each of the building's axes. The ASCE 7-93 Standard specifies using a "properly substantiated analysis" for determining the fundamental period. As an alternative, two empirical formulas are available for approximating the fundamental period. They are as follows:

$$T_a = C_t h_n^{3/4} \qquad \text{(Eq. 2.5)}$$

$$T_a = 0.1N \qquad \text{(Eq. 2.6)}$$

where T_a is the approximate fundamental period, C_T is the building period coefficient, h_n is the height above the base level to story number n, and N is the total number of stories. The building period coefficient, C_T, in Equation 2.5, varies depending upon the building's lateral-force resisting system (described on page 54 of ASCE 7-93). Equation 2.6 is an alternative to Equation 2.5 if the number of stories, N, does not exceed 12 and the lateral-force resisting system consists entirely of a concrete or steel moment resisting frame. The story height must also be at least 10 feet. Generally, fundamental periods determined by the approximate formulas are shorter than those calculated from a "properly substantiated analysis," therefore they increase the base shear.

The ASCE 7-93 Standard limits the calculated fundamental period by not allowing it to exceed the product of the approximate fundamental period, T_a, and the coefficient for upper limit on the calculated period, C_a. Values for C_a can be obtained from Table 9.4-1 of the ASCE 7-93 Standard. The coefficient for upper limit increases the approximate fundamental period and is dependent upon the peak velocity-related acceleration, A_v (determined from Figure 9-2 of the ASCE 7-93 Standard). Such an increase can ultimately decrease the base shear. Other practices commonly limit the base shear force to 80% of the value obtained using the empirical formulas (Paz, 1991).

The base shear, V, is determined by the following equation:

$$V = C_s W \tag{Eq. 2.7}$$

where W represents the total dead load and applicable portions of other loads (described in Section 9.4.2. of ASCE 7-93), and C_s is the seismic design coefficient. The seismic design coefficient is determined by the following equation:

$$C_s = \frac{1.2 A_v S}{R T^{2/3}} \tag{Eq. 2.8}$$

where A_v is the effective peak velocity-related acceleration, S is the site coefficient, R is the response modification factor and T is the building's fundamental period.

The seismic design coefficient, C_s, cannot be greater than the value obtained from following equation:

$$C_s(\text{max}) = \frac{2.5 A_a}{R} \tag{Eq. 2.9}$$

where A_a is the seismic coefficient representing the effective peak acceleration and R is the response modification factor.

The effective peak velocity-related acceleration, A_v, is determined from Figure 9-2 of the ASCE 7-93 Standard, and the effective peak acceleration, A_a, is determined from Figure 9-1 of the Standard. The site coefficient, S, accounts for the possibility of the building and site having close enough natural periods to encounter resonance. The site coefficient is obtained from Table 9.3-1 of ASCE 7-93. If a particular soil profile is not listed in the table, a value of 2.0 is to be used. Acceptable alternatives for determining soil-structure interaction are allowed. The response modification factor, R, varies depending upon the type of lateral resisting system and its ability to resist lateral forces. It is determined from Table 9.3-2 of ASCE 7-93.

The vertical distribution of the equivalent, lateral seismic force is accomplished by the following equations:

$$F_x = C_{vx} V \qquad \text{(Eq. 2.10)}$$

$$C_{vx} = \frac{w_x h_x^{\ k}}{\sum_{i=1}^{n} w_i h_i^{\ k}} \qquad \text{(Eq. 2.11)}$$

where F_x is the lateral seismic force at any level x, C_{vx} is the vertical distribution factor, V is the base shear, w_x and w_i are the gravity loads at story number x and i and h_x and h_i are the heights from the base level to story number x and i. The distribution exponent, k, is related to the building's fundamental period as follows:

$T \leq 0.5$ seconds $\quad k = 1$

$T \geq 2.5$ seconds $\quad k = 2$

For periods between 0.5 and 2.5 seconds, k can be taken as 2 or can be determined by linear interpolation between 1 and 2.

The seismic design story shear in any story is obtained by the next equation:

$$V_x = \sum_{i=x}^{n} F_i \qquad \text{(Eq. 2.12)}$$

where V_x is the story design shear and F_i is a portion of the seismic base shear imposed at level i.

The ASCE 7-93 Standard requires that the building be designed to resist overturning. The following equation determines overturning moments at any level within the structure.

$$M_x = t \sum_{i=x}^{n} F_i \, (h_i - h_x) \qquad \text{(Eq. 2.13)}$$

where M_x is the overturning moment at level x, F_i is the portion of the seismic base shear induced at level i, h_i and h_x are the height in feet from the base level to level i and x, and τ is the overturning moment reduction factor. The overturning moment reduction factor is determined as follows:

For top 10 stories	$\tau = 1.0$
For the 20th story from the top and below	$\tau = 0.8$

For stories between the 20th and 10th stories from the top	linear interpolation between 1.0 and 0.8

Building foundations are to be designed for overturning using the same equation but a value of 0.75 is to be used for the overturning moment reduction factor.

2.5 Snow Loads

Design snow loads are affected by geographic location, roof slope, roof surface texture, sheltering from adjacent objects and the potential for drift. The temperature of the space beneath the roof is also a consideration. The ASCE 7-93 Standard provides an analytical procedure for determining the flat roof snow load from a design ground snow load, and adjusting it for conditions such as roof slope and surface, wind effects and thermal effects. Unbalanced loading and snow drifts are also considerations.

The flat-roof snow load is determined by the following equation:

$$p_f = 0.7C_eC_tIp_g \qquad \text{(Eq. 2.14)}$$

For locations in Alaska, the equation changes to the following:

$$p_f = 0.6C_eC_tIp_g \qquad \text{(Eq. 2.15)}$$

where in both equations p_f is the design snow load, p_g is the ground snow load, C_e is the snow exposure factor, C_t is the thermal factor, and I is the importance factor. Within both equations, the exposure factor, C_e, adjusts the ground snow load due to wind effects and is found in Table 18 of the ASCE 7-93 Standard. The thermal factor, C_t, adjusts the ground snow load due to thermal effects and it is found in Table 19 of the ASCE 7-93

Standard. The importance factor, I, adjusts the design snow load for the probability of exceeding the snow loads recorded in Figures 5-7 of ASCE 7-93. The design snow load is increased for essential facilities due to a higher importance factor. Importance factors are found in Table 20 of the ASCE 7-93 Standard. Ground snow loads are found in Figures 5-7 of the Standard. Table 17 contains ground snow loads for locations in Alaska.

Sloped roof snow loads can be computed using the following equation:

$$p_s = C_s p_f \qquad \text{(Eq. 2.16)}$$

where p_s is the sloped roof design snow load, C_s is the roof slope factor, and p_f is the flat roof design snow load. The roof slope factor, C_s, adjusts the ground snow load due to a roof's tendency to shed snow. Roofs with higher slopes will have lower design snow loads. The roof slope factor is a function of the thermal factor, C_t and whether the roof has an "unobstructed slippery surface." Values for the roof slope factor are found in Figure 8 of ASCE 7-93.

For hip and gable roofs having a roof slope between 15 and 70 degrees, an unbalanced uniform snow load is considered on the lee side. The unbalanced load is determined using the following equation:

$$p_s(unbalanced) = \frac{1.5 p_s}{C_e} \qquad \text{(Eq. 2.17)}$$

where p_s(unbalanced) is the unbalanced design snow load, p_s is the sloped roof design snow load and C_e is the exposure factor.

2.6 Load Analysis Program Limitations

The Load Analysis Program determines wind, earthquake and snow loads for buildings according to the ASCE 7-93 Standard Minimum Design Loads for Buildings and Other Structures. It only determines wind loads for non-flexible buildings. The categories of non-flexible "other structures" and "flexible buildings and other structures" are not considered.

The Load Analysis Program only uses the Equivalent Lateral Force procedure for determining earthquake loads. Furthermore, it does not calculate the torsional moment, M_t, which involves type 1 torsional irregularities (See Table 9.3-3 of ASCE 7-93). Drift determination and P-Delta effects are not considered by the Load Analysis Program. To include these effects, it is necessary to use a matrix structural analysis program for determining internal member forces, drift conditions and second order effects once loads are determined using the Load Analysis Program.

CHAPTER THREE

LOAD ANALYSIS PROGRAM

3.1 Introduction

The purpose of this chapter is to provide an overview of the Load Analysis Program. The topics covered include input, processing and output, and related dialog boxes and views. A users' guide is presented in Appendix A.

The main window of the program is shown in Figure 3-1.

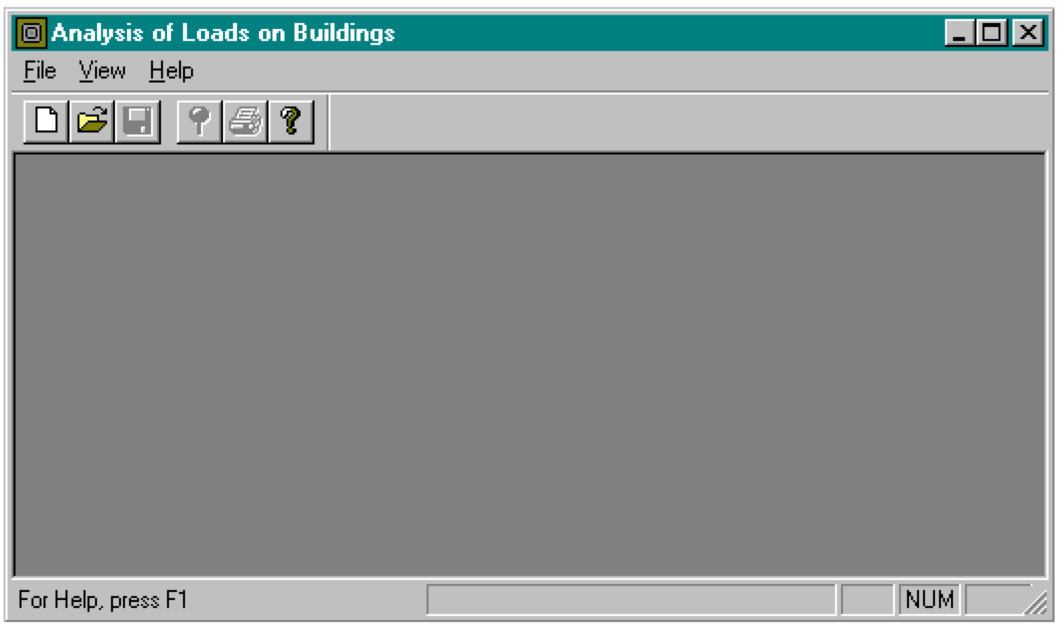


Figure 3-1: Main Window of the Load Analysis Program

When a new project is created, either by clicking on the first toolbar button from the left, or by choosing the File menu and selecting the New command, the main window shown in Figure 3-2 is displayed.

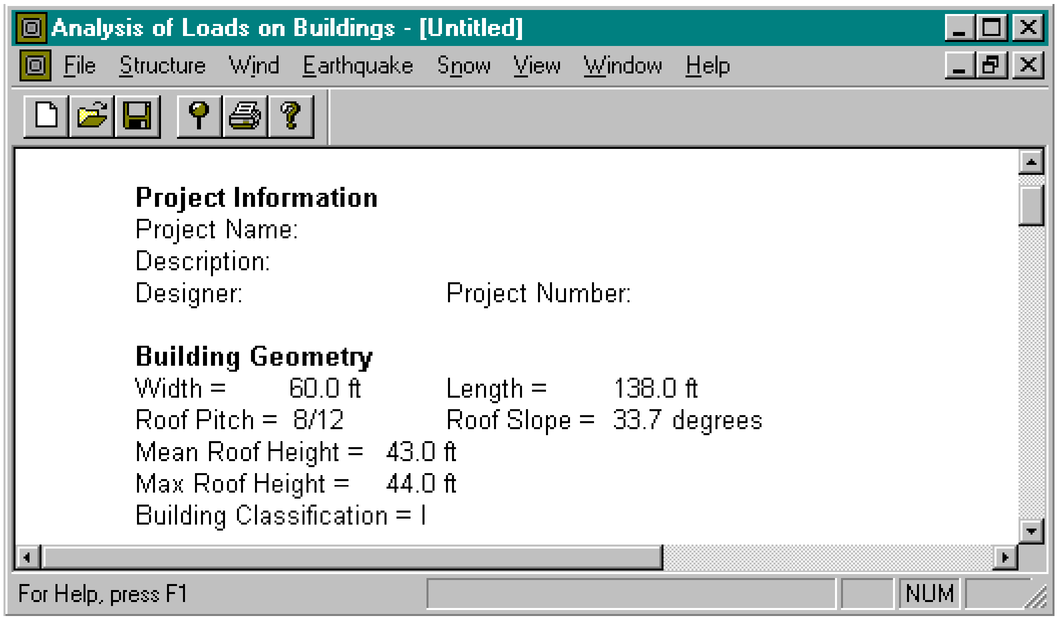


Figure 3-2: Main Window of the Load Analysis Program With an Untitled Project

Once a working project is created, several pull-down menus are displayed on the menu bar. Three of the menus represent the three load analysis modules incorporated within the program. As mentioned in Chapter 1, one of the features of this program is that it is a multiple document interface (MDI) application, which means it is possible to work on several projects simultaneously. Each project is represented by a separate window.

3.2 Building Properties and the Structure Menu

The Structure menu has three main commands: Project Information, Geometry and Classification. These commands are used for entering project information and structural data necessary for determining loads.

Project Information

The Project Information command displays the Project Information dialog box in Figure 3-3. Within this dialog box, a Project Name, Project Number, and Project Description can be entered. Any combination of letters or real numbers is acceptable. As is typical of most Windows applications, the OK button accepts the entered information and closes the dialog box, the Cancel button ignores the entered information and closes the dialog box, and the Help button executes a series of help screens which provide additional information regarding the input fields.

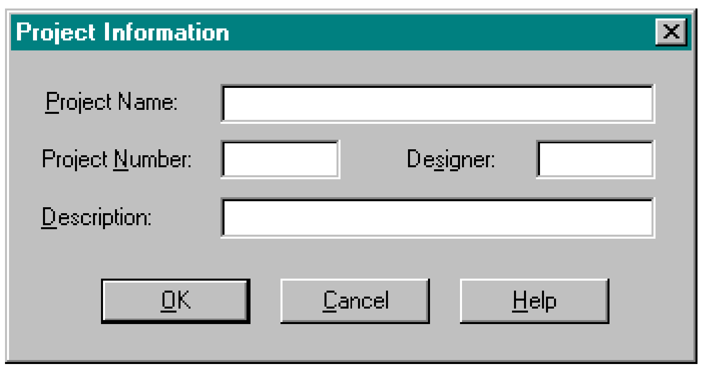


Figure 3-3: Project Information Dialog Box

Building Geometry

The second command on the Structure menu is the Geometry command. When selected, it displays the Building Geometry dialog box shown in Figure 3-4. The building geometry, such as building width, length, mean roof height, number of stories, and distance between floors, is entered in this dialog box. There is also a check box for forcing an exposure C condition on buildings with a mean roof height between 60 feet and 90 feet.

The check box labeled "Exposure C," when selected (checked), instructs the program to use the exposure C condition. Recall that in the ASCE 7-93 Standard, components and cladding for buildings up to 60 feet in mean height are required to be designed for exposure C. The Load Analysis Program will automatically apply this constraint to such buildings. For buildings between 60 feet and 90 feet, the designer has the option to determine components and cladding pressures using exposure C by selecting the check box. If the check box is not checked, the component and cladding design pressures for buildings between 60 feet and 90 feet will be determined using the exposure condition selected in the Building Exposure Category dialog box.

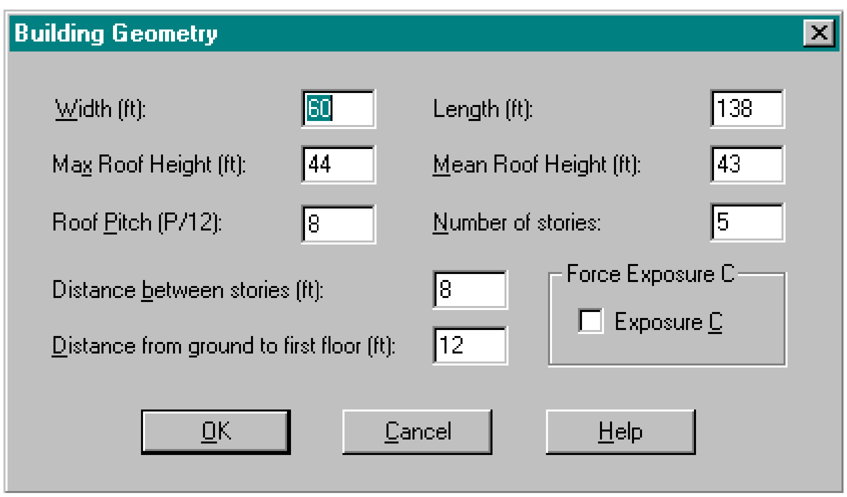


Figure 3-4: Building Geometry Dialog Box

Building Occupancy Classification Category

The Occupancy Classification Category dialog box (See Figure 3-5) is displayed when the Classification command is selected from the Structure menu. This dialog box is similar to

Table 1 of the ASCE 7-93 Standard. The appropriate occupancy classification category can be specified by selecting the corresponding radio button.

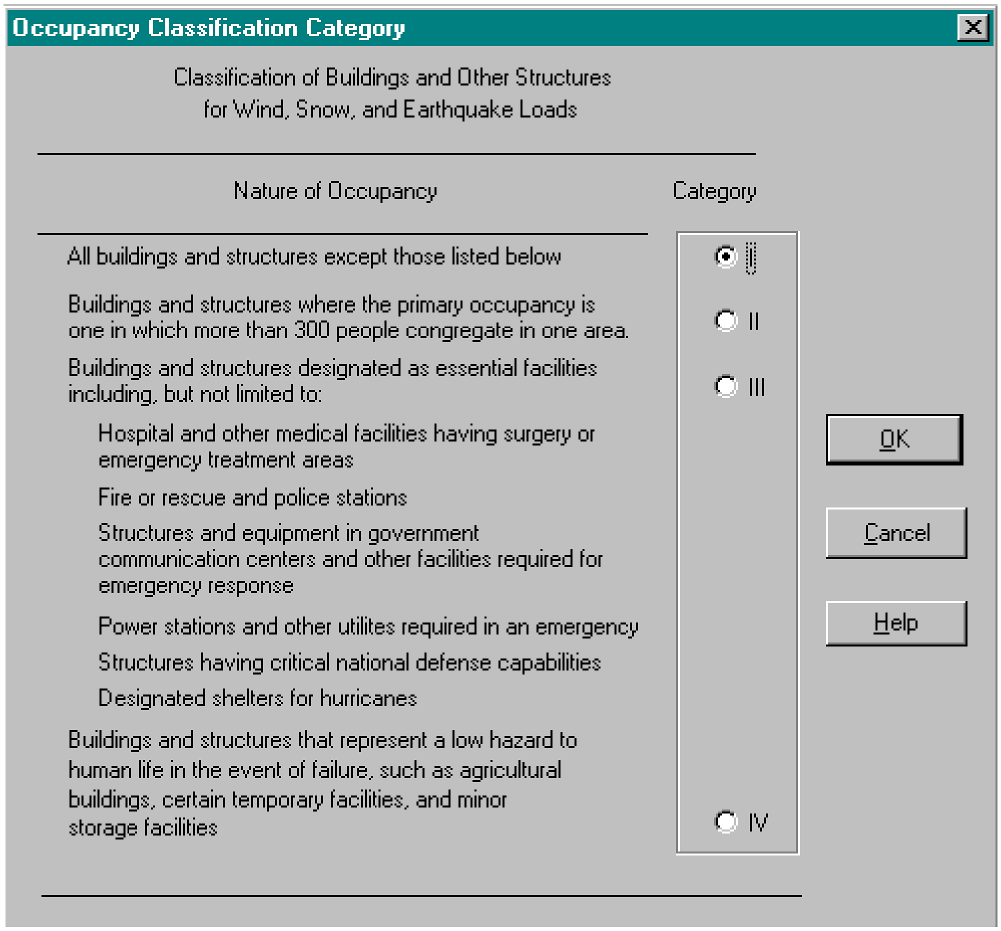


Figure 3-5: Occupancy Classification Category Dialog Box

3.3 Wind Loads and the Wind Menu

The Load Analysis Program determines wind loads, using the ASCE 7-93 Standard, for regular, non-flexible buildings, up to a mean roof height of 240 feet. Two parts to the wind load analysis exist. One part for the building main wind force resisting system and the other part for components and cladding design loads. Table 4 of ASCE 7-93 shows the applicable equations and variables for this two part wind load analysis. For components and cladding, design wind loads are categorized for specific locations on the building. For example, the wind load on an exterior corner panel is different (typically greater) than the wind load on an adjacent center panel, therefore different values are calculated. In its simplest form, the design wind load is the wind force, due to a particular wind speed, converted to a pressure. Once the wind pressure is determined, it is increased or decreased based upon the building's geometry, geographic location, location relative to it's surroundings, and importance.

The Wind Load menu deals with the wind load module of the Load Analysis Program. The Wind menu has four commands for using the wind load analysis module: Importance Factor, Wind Speed, Internal Pressure and Exposure.

Wind Importance Factor

The wind importance factor is selected in the Importance Factor dialog box shown in Figure 3-6. The dialog box displays a table of Building Classification Categories and the corresponding Importance Factor. Considering Figure 3-6, the "Category" column shows the building occupancy classification category that was previously selected in the Building Classification dialog box. If necessary, the building classification category can be changed here and the change will be reflected in the Building Classification dialog box. Once a category has been chosen, the appropriate importance factor is entered in the edit field.

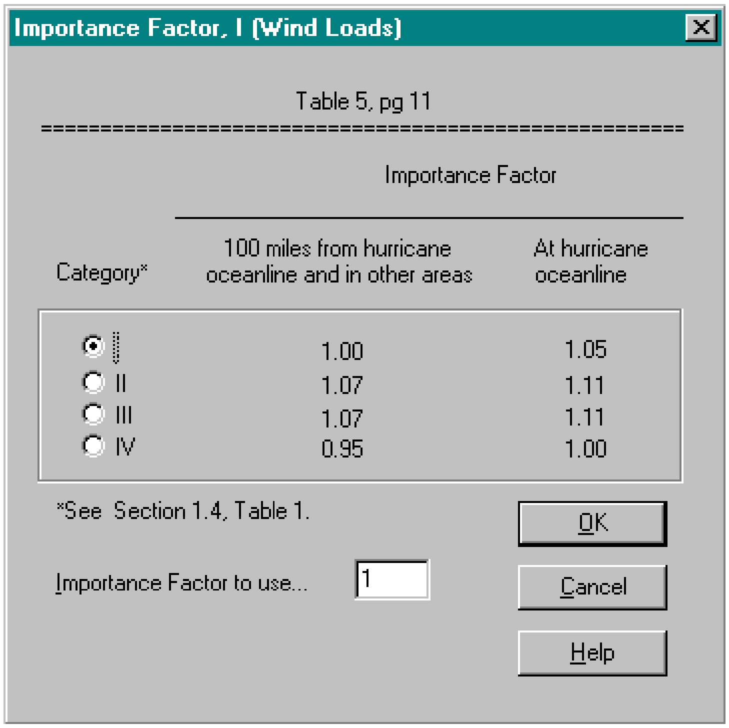


Figure 3-6: Wind Importance Factor Dialog Box

Wind Speed and Internal Pressure Coefficient

The Wind Speed dialog box simply allows the user to enter a basic wind speed from Figure 1 of ASCE 7-93.

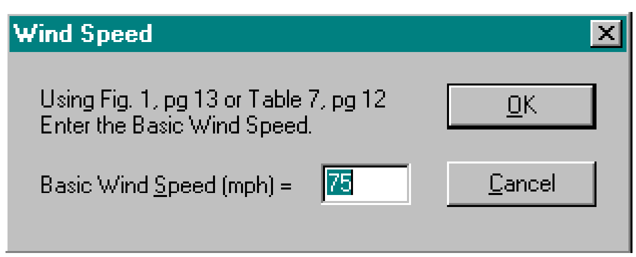


Figure 3-7: Wind Speed Dialog Box

The Internal Pressure Coefficients dialog box allows the user to select a value for the product of the internal pressure coefficient and the gust response factor. This product,

GC_{pi}, represents the tendency for a building to become internally pressurized. Two conditions are possible: condition I is for buildings which are open (or enclosed) and condition II is for partially open buildings. The dialog box is similar to Table 9 of ASCE 7-93.

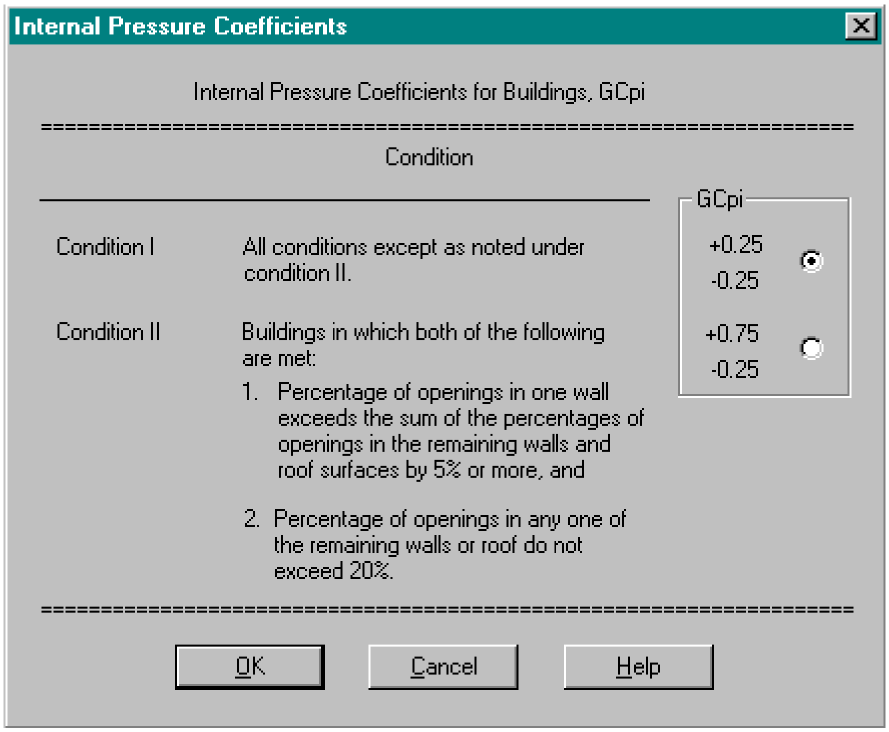


Figure 3-8: Internal Pressure Coefficients Dialog Box

Building Exposure

Figure 3-9 shows the Building Exposure Category dialog box, which is displayed when the Exposure command chosen. Once again, the dialog box matches the corresponding table within ASCE 7-93.

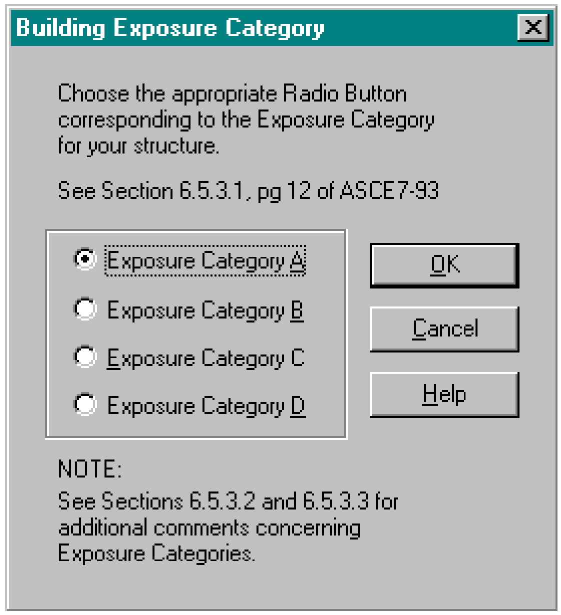


Figure 3-9: Building Exposure Dialog Box

The building exposure category represents a method for approximating boundary layer, surface roughness, and adjacent sheltering effects in the wind analysis. The building exposure category is selected by choosing the appropriate radio button on the Building Exposure dialog box (Figure 3-9). For a complete description of building exposure categories, see Section 6.5.3 of ASCE 7-93.

When determining components and cladding loads for buildings having a mean height less than 60 feet, ASCE 7-93 requires exposure category C to be used. The Load Analysis Program automatically takes this into account. For buildings having a mean height between 60 feet and 90 feet, ASCE 7-93 allows an exposure condition C to be used. The

Load Analysis Program implements this option by providing the “Exposure C” check box in the Building Geometry dialog box.

Wind Load Analysis and Output

After all building geometry and wind data has been entered, the program performs the wind load analysis and displays the results.

When computing wind loads for the main wind force resisting system and components and cladding, the program first calculates the pressure zone coefficient, a, and sets building geometry values such as width, height and roof pitch. Wind load information such as wind speed, V, and the product of the internal pressure coefficient and the gust response factor, GC_{pi}, are also established. Next, the exposure category constants, α, z_g and D_o (See Table C6 of ASCE 7-93) are established using the information obtained from the Building Exposure Category dialog box.

The product of the internal pressure coefficient and the gust response factor, GC_{pi}, is obtained from user input. The product of the external pressure coefficient and the gust response factor, GC_p, is determined using Figure 3 of ASCE 7-93. A logarithmic equation is fitted to each curve representing each component and cladding location of the building. The equation is arrived at by solving two simultaneous equations with the two known values of GC_p. For example, for roof components and cladding, GC_p is known for tributary areas of 10 and 100. Therefore, those values can be used in fitting the correct equation.

The values for the importance factor, I, and the wind speed, V, are acquired directly from user input. Since the velocity pressure exposure coefficient, K_z, varies with height, two values are calculated: K_h-calculated at mean roof height for buildings with a mean roof height less than 60 feet, and K_z-calculated at each story height for buildings with a mean height more than 60 feet. There is however one exception. If Exposure C is selected in the Building Geometry dialog box, loads on a building with mean height between 60 and 90 feet will be determined as for a building with mean height of 60 feet or less. The values of K_z and K_h are determined using Equation C3 in the ASCE 7-93 commentary.

The velocity pressure equation is the same for both the main wind force resisting system the components and cladding. On the other hand, the design wind pressure equation changes by separating the gust response factor and the external pressure coefficient into two separate variables.

The gust response factor, G_h, is determined by using the mean roof height value along with Equations C5 and C6 of the ASCE 7-93 commentary. Equations C5 and C6, similar to components and cladding, utilize the exposure category constants found in Table C6 of the ASCE 7-93 commentary. The external pressure coefficient, C_p, is separated into two tables within ASCE 7-93 Figure 2. The Load Analysis Program uses a series of conditional statements to determine the wall pressure coefficient, C_p. Based upon the roof pitch, mean height to length ratio and mean height to width ratio, the program selects an appropriate roof pressure coefficient, C_p.

The program displays the following results for the wind load analysis. First, the project information and building geometry parameters are displayed. This information is followed by input data which appears under the "Wind Loads" heading. Next, the program displays the roof and wall design values for components and cladding, and next displays the roof and wall design values for the main wind force resisting system. The output for components and cladding design values consists of two tables which show the tributary areas and the corresponding wind design pressures. A significant feature of the Load Analysis Program is that it provides components and cladding and main wind force resisting system design pressures, as a function of the tributary area, for the entire building. See Figure B-2 of Appendix B for example wind load analysis output.

3.4 Earthquake Loads and the Earthquake Menu

The Earthquake menu has three commands: Initial Data, Story Information and Performance Category. The Load Analysis Program uses the Equivalent Lateral Force Method for determining earthquake loads.

Initial Data

The Initial Data dialog box is shown in Figure 3-10. Using Figure 9-1 of ASCE 7-93, the effective peak acceleration, A_a, can be obtained. The effective peak velocity-related acceleration, A_v, can be obtained from Figure 9-2 of ASCE 7-93. Values for the site coefficient, S, can be obtained from Table 9.3-1 of ASCE 7-93. If a particular soil profile does not match one of the profiles given in Table 9.3-1, a value of 2.0 is to be used.

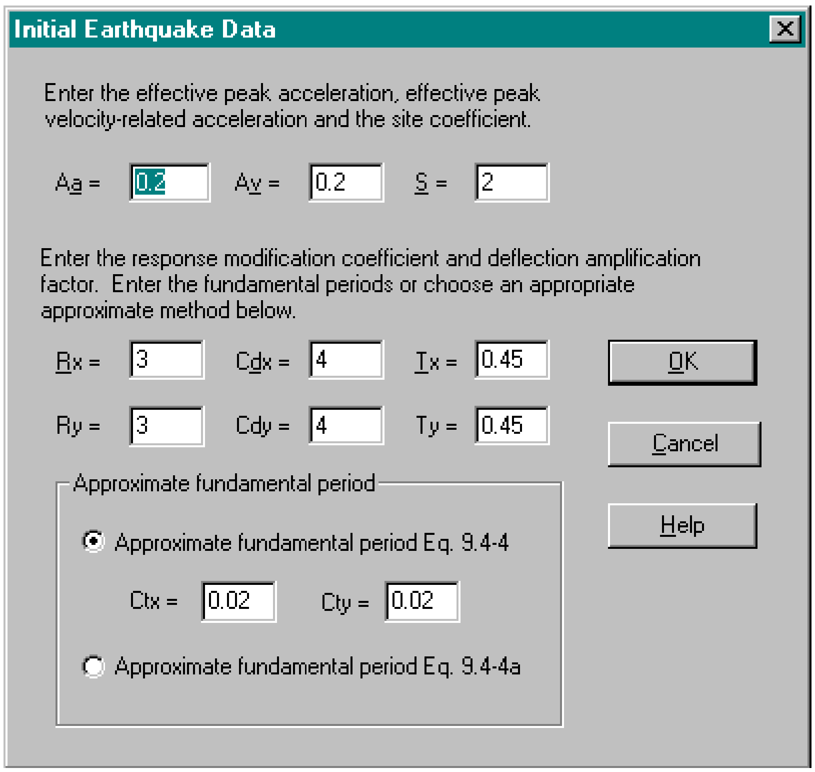


Figure 3-10: Initial Earthquake Data Dialog Box

The six remaining data items involve the two building axes, therefore there are two values for each item. The response modification factor, R, and the deflection amplification factor, C_d, are obtained from Table 9.3-2 of ASCE 7-93. The fundamental periods are determined by a structural analysis and are not to exceed the product of the coefficient for upper limit on calculated period, C_s, and the approximate fundamental period, T_a. Section 9.4.2.2 of ASCE 7-93 discusses the determination of the fundamental period and lists some approved approximate values. The Load Analysis Program allows both Equations 9.4-4 and 9.4-4a to be used for calculating the fundamental period. Whenever the entered fundamental period, T, exceeds the product of C_s and T_a, the calculations are based upon the approximate fundamental period and a note is printed on the calculations.. Also, if the approximate fundamental period is calculated using Equation 9.4-4, the building period coefficient, C_T has to be entered into the appropriate input field.

Story Information

The Story Information dialog box is executed when the Story Information command is selected. Building story heights relative to the ground, and the story dead loads and story live loads are entered in this dialog box (See Figure 3-11).

Performance Category

The Performance Category dialog box appears when this menu item is selected. Figure 3-12 shows the Performance Category dialog box.

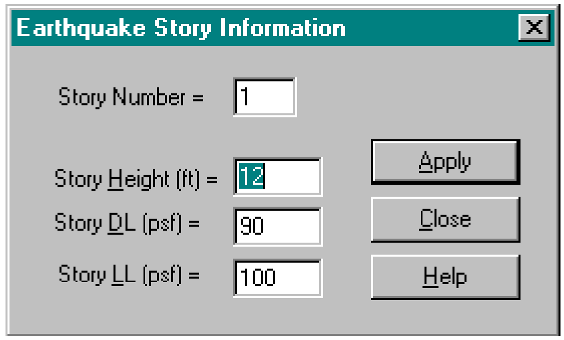


Figure 3-11: Story Information Dialog Box

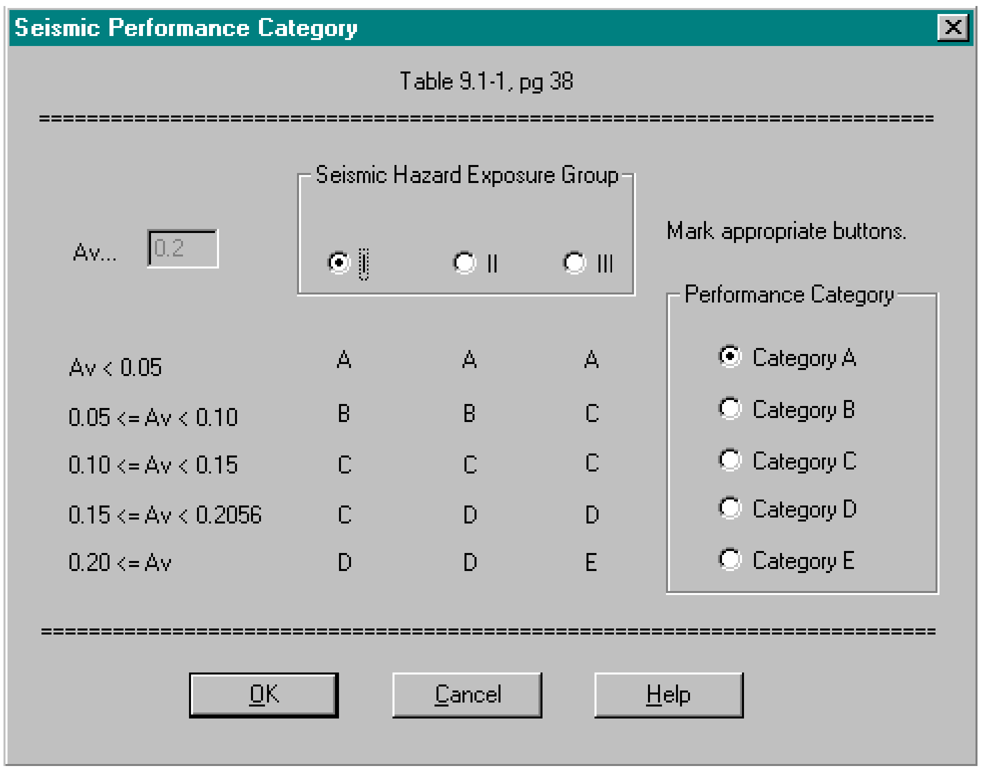


Figure 3-12: Performance Category Dialog Box

The appropriate performance category is chosen based upon the seismic hazard exposure group (Table 9.3.6 of ASCE 7-93) and the effective peak velocity-related acceleration, A_v. The effective peak velocity-related acceleration is shown in the upper left-hand corner of the Performance Category dialog box. The radio buttons for the seismic hazard exposure group are primarily an aid for choosing the correct performance category.

Earthquake Load Analysis and Output

As previously mentioned, the Load Analysis Program utilizes the Equivalent Lateral Force Procedure for determining earthquake loads on buildings. Once input is completed, the program calculates equivalent, static lateral forces for modeling seismic loads. The output of the calculations, which are shown in Figure B-9 of Appendix B, also includes the base shear and overturning moments. The information used for approximating the fundamental period is also printed. The output also indicates whether the maximum seismic design coefficient, C_s, is based upon ASCE 7-93 Equation 9.4-3.

3.5 Snow Loads and the Snow Menu

The Snow Menu provides access to the module for calculating snow loads. It has four commands: Importance Factor, Ground Snow Load, Thermal Factor and Exposure Factor.

Importance Factor

The snow importance factor adjusts the design snow load for the probability of exceeding the snow loads given in Figures 5-7 of ASCE 7-93. It also considers the risk of damaging essential facilities. A hospital, for example, has an importance factor of 1.2 versus 0.8 for a livestock barn. The importance factor can be selected using the appropriate radio button corresponding to the pre-chosen building classification category from Table 1 of ASCE 7-93.

Ground Snow Load

The Ground Snow Load command activates the Ground Snow Load dialog box (see Figure 3-13). This box contains three items to be entered. First, using Figures 5-7 of ASCE 7-93, the user can determine the ground snow load. If the building is located in Alaska, Table 17 should be used and the equation for calculating the design snow load changes. This is indicated by checking the box labeled "Alaska". If the building has a roof that can effectively shed snow, the ASCE 7-93 Standard allows a decrease in the design snow load. The program takes this into consideration if this option is checked in the corresponding check box.

Thermal Factor

The thermal factor, C_t, is a number representing the thermal condition of a building's roof. The warmer the roof, the more likely the snow is to melt and fall from the roof. The higher the thermal factor, the higher the design snow load. Figure 3-14 shows the Thermal Factor dialog box. The value of the factor is entered by selecting the appropriate radio button and the program adjusts the ground snow load according to the selection.

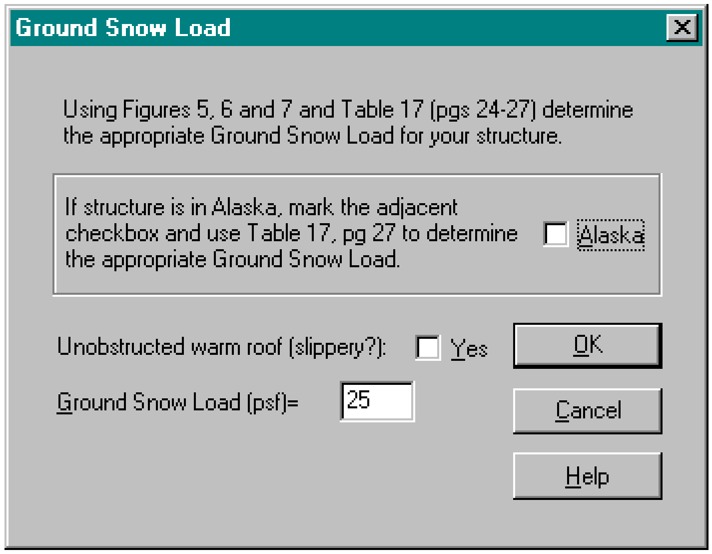


Figure 3-13: Ground Snow Load Dialog Box

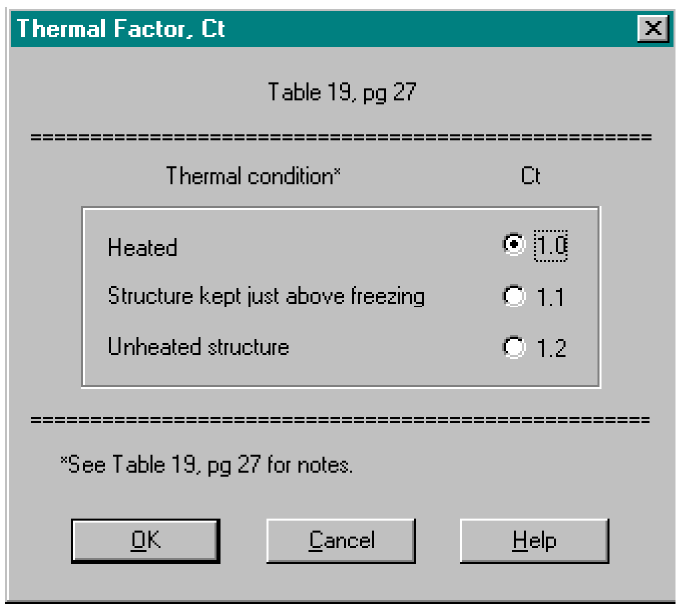


Figure 3-14: Thermal Factor Dialog Box

Exposure Factor

Figure 3-15 shows the Exposure Factor dialog box. The exposure factor, C_e, for snow load analysis, takes into account the possibility of wind blowing snow off of a building's roof but it does not consider the possibility of drift. The value is entered by selecting the appropriate radio button and the ground snow load is adjusted accordingly.

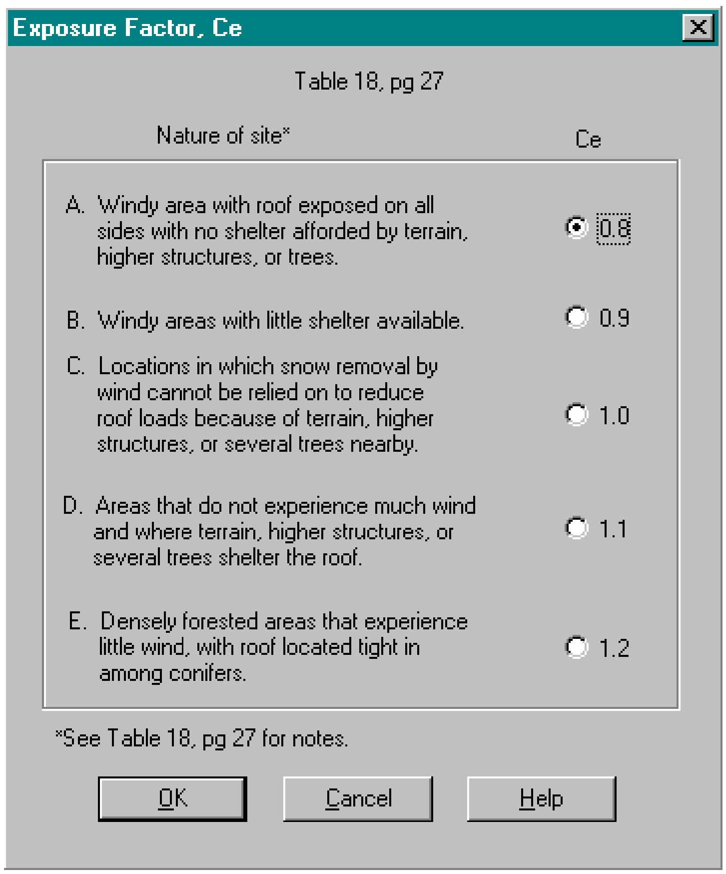


Figure 3-15: Exposure Factor Dialog Box

3.6 Object Oriented Programming

The Load Analysis Program, as mentioned before, was written in the C++ programming language. It uses class construction in an object oriented programming approach. Microsoft Visual C++ was the compiler.

Four classes were developed for the load analysis modules. Two were developed for the wind load module (one for components and cladding and another for the main wind force resisting system) and one for each of the remaining load modules. The Microsoft Foundation Class Library (MFC) was used to develop the graphical interface.

The recommended structure of most C++ programs, when using the MFC, is to utilize the document class for handling data and utilize the view class for handling graphical operations. The Load Analysis Program does such. All data is transferred from the view class to the load classes by the document class. The document class creates and deletes objects for each of the load classes. Furthermore, each of the objects contains all data and functions needed to perform their respective tasks. Regarding the views, the view class handles all viewing of input and output data. Code for viewing output was written at the end of each load analysis class in ShowData functions.

3.7 Verification

A Microsoft Excel spreadsheet was developed to calculate design wind loads for buildings with a mean roof height of 60 feet or less. Furthermore, the spreadsheet's results were verified by manual calculations produced by three individuals in an engineering office. Considering only buildings with a mean roof height less than 60 feet, the only difference between the spreadsheet and the Load Analysis program is that the spreadsheet calculates windward main wind-force resisting system design pressures uniformly over the height of the building. One design pressure is computed at the building's mean roof height, and another design pressure is computed 15 feet above the ground level. The Load Analysis Program, on the other hand, calculates the windward main wind-force resisting system design pressures as they vary along the building's height. This variation is from 15 feet to the mean roof height. The design pressures are not constant from 15 feet above ground to the mean roof height. The windward main wind-force resisting system design pressures, obtained from the spreadsheet (even though they are limited compared to the Load Analysis Program), and the windward main-wind force resisting system design pressures, obtained from the Load Analysis Program, were compared and found to not differ more than 3 percent. The calculated values for leeward and side main wind-force resisting system design pressures were found to not differ more than 3 percent as well.

Both the spreadsheet and the Load Analysis Program compute components and cladding design pressures (for buildings with a mean roof height less than 60 feet), and the roof main wind-force resisting system design pressures by the same method. The results of these calculations were also the same. Output from the Excel spreadsheet for Example 1 is in Appendix B.

With regard to earthquake loads, snow loads and wind loads on buildings with a mean roof height greater than 60 feet, verification of the Load Analysis Program's results were performed by manual calculations. Manual calculations of Example 1 and Example 2 are in Appendix B.

CHAPTER FOUR

SUMMARY AND CONCLUSIONS

4.1 Summary

A program for the analysis of loads on buildings was developed. The program is based on the ASCE 7-93 Minimum Design Loads for Buildings and Other Structures and was written in C++ using object-oriented programming methodology. The ASCE 7-93 Standard was chosen because it is nationally accepted and widely referenced by many local building codes.

The Load Analysis Program is a tool for determining wind loads, earthquake loads and snow loads, and it is to be used along with the ASCE 7-93 Standard. It is a Windows 95 application and has the functionality of Windows 95 programs. A series of dialog boxes can be accessed by selecting commands from the program's main menu. These dialog boxes allow the user to enter building data and load analysis data to be used to calculate loads. Input and output data can be printed or stored on standard computer storage media.

The Load Analysis Program is an object-oriented application written in the C++ programming language. It was developed using Microsoft Visual C++ and the Microsoft Foundation Class Library (MFC). Separate classes were created for each of the different load modules (one module for each load analysis type) and they can be used again in other C++ applications.

4.2 Conclusions

The Load Analysis Program provides accurate results for normal, non-flexible buildings up to 240 feet in mean height and less than 30 stories. It is an efficient tool for determining wind, earthquake and snow loads and it is also a useful tool for teaching students the fundamentals about calculating building loads. Although the program produced accurate results for the example problems given in Appendix A and Appendix B, it is recommended that the program be tested further before being used in the engineering workplace.

4.3 Future Improvements

Many possible future modifications can be made to the program. Suggestions for future modifications include the following:

- Update the load analysis classes to the latest ASCE 7 standard.
- Improve the output by using more graphics.
- Improve the earthquake load module to perform additional earthquake load analyses, such as the Modal Analysis Procedure.
- Improve the wind load module to perform load analysis on other structures than buildings alone.
- Improve the snow load module to include a more comprehensive unbalanced snow load analysis.

REFERENCES

ASCE Standard (1994), Minimum Design Loads for Buildings and Other Structures (ASCE 7-93 a revision of ANSI/ASCE 7-88), ASCE, New York, New York.

ASCE (1991), Guide To the Use of the Wind Load Provisions of ASCE 7-88 (formerly ANSI A58.1), first edition, ASCE, New York, New York.

Paz, Mario (1991), Structural Dynamics Theory and Computations, third edition, Van Nostrand Reinhold Publishing, New York, New York.

Salmon, Charles G., and John E. Johnson. (1990) Steel Structures Design and Behavior, third edition, Harper Collins Publishers, New York, New York.

APPENDIX A

USER’S GUIDE AND EXAMPLE PROBLEMS

This appendix provides information for installing and using the Load Analysis Program. Two examples are also provided to show the process of entering data for determining wind, earthquake, and snow loads. Printed output of Example 1 and Example 2 is in Appendix B.

A.1 Hardware and Software Requirements and Installation

Hardware and Software Requirements

The Load Analysis Program will run on an IBM compatible personal computer with an Intel 80486 or higher processor, a minimum of 8 MB of RAM and Microsoft Windows 95 or Windows NT.

Installation

To install the Load Analysis Program, follow these step-by-step instructions:

1. Create a subdirectory named ASCE on the computer hard drive.
2. Copy the executable file ASCE794.EXE and the help file ASCE794.HLP to the ASCE subdirectory.
3. Add the program to the Windows 95 Start Program Taskbar (See Figure A-1).
4. Execute the Load Analysis Program by choosing the program icon from the Taskbar.

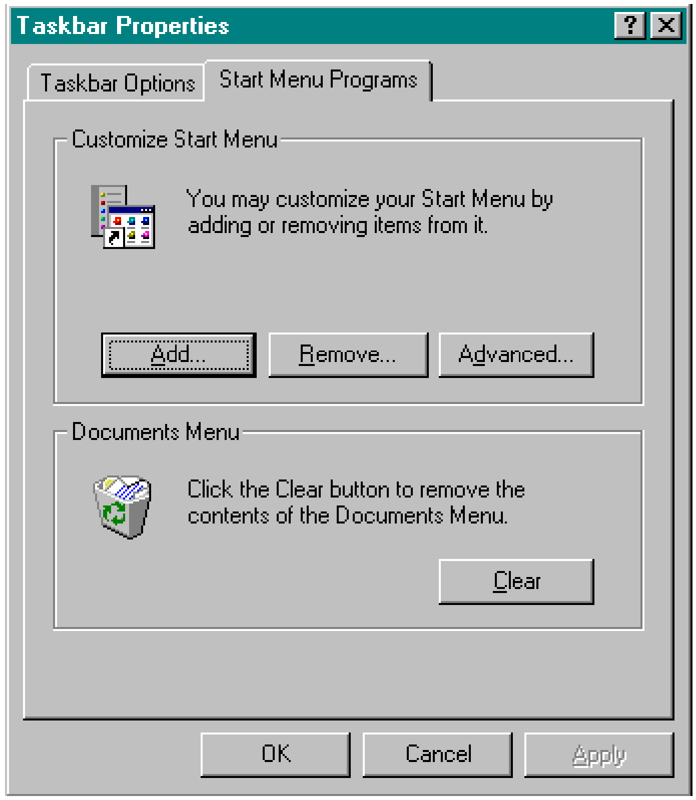


Figure A-1: Taskbar Properties-adding a program.

A.2 Using Standard Controls

A pull-down menu can be activated by selecting a command on the menu located at the top of the main program window (See Figure A-2). Tasks such as opening a file, saving a file, and entering building geometry can be accessed from the menu bar. See Figure A-2 for a view of the program menu bar and a pull-down menu with the Geometry command highlighted.

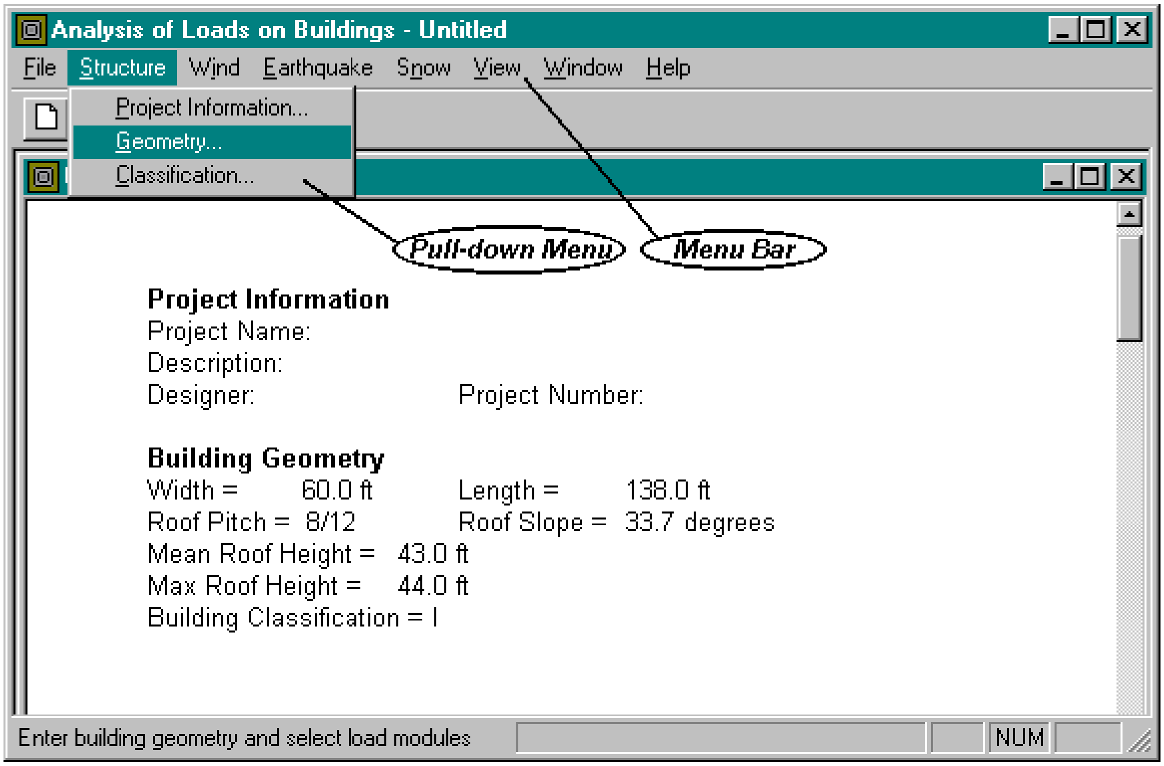


Figure A-2: Example Menu Bar and Pull-Down Menu

A *dialog box* is usually displayed when a command is selected. Within any dialog box, there are *edit boxes* for entering information, *check boxes* for turning an option on or off, *radio buttons* for selecting mutually independent choices and *command buttons* for executing specific tasks. The Building Geometry dialog box in Figure A-3 and the Building Exposure Category dialog box in Figure A-4 show examples of these standard controls.

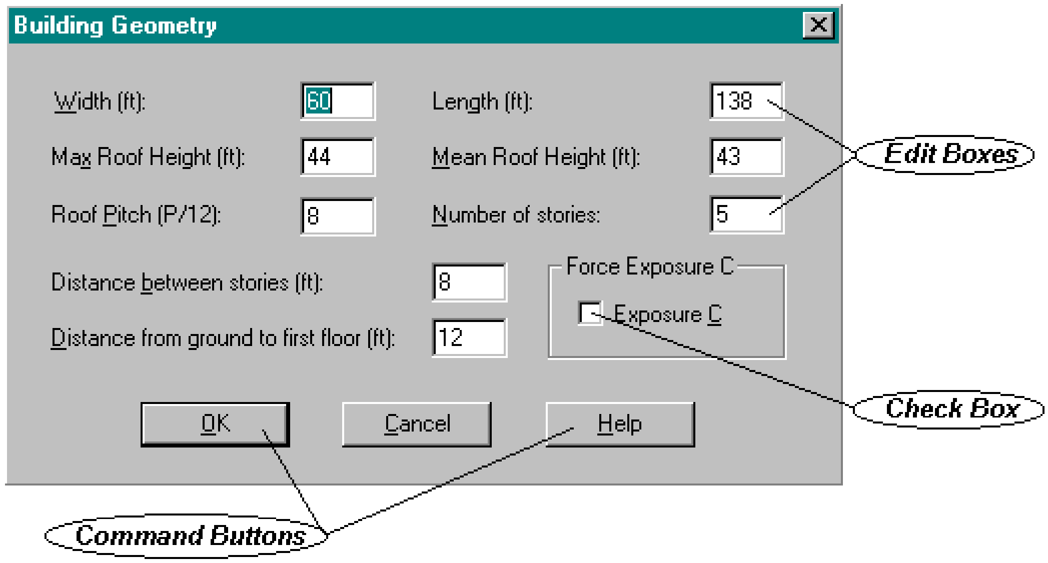


Figure A-3: Building Geometry Dialog Box

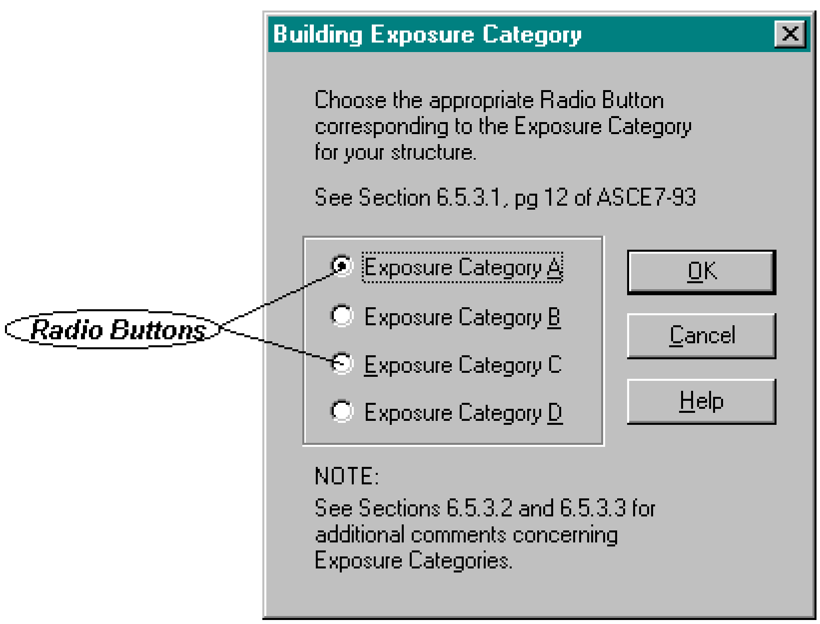


Figure A-4: Building Exposure Category Dialog Box

A.3 Online Help

Online help can be accessed from most dialog boxes by clicking the Help command button. When online help is accessed from a dialog box, the help subject displayed is the same as the dialog box from which online help was called. Online help can also be accessed by selecting the Index command from the Help pull-down menu. This command displays the Help Index for the Load Analysis Program (See Figure A-5). Users are encouraged to solicit help from the program's online help. A Getting Started topic, which is available for first time users, describes the basic steps involved in using the program.

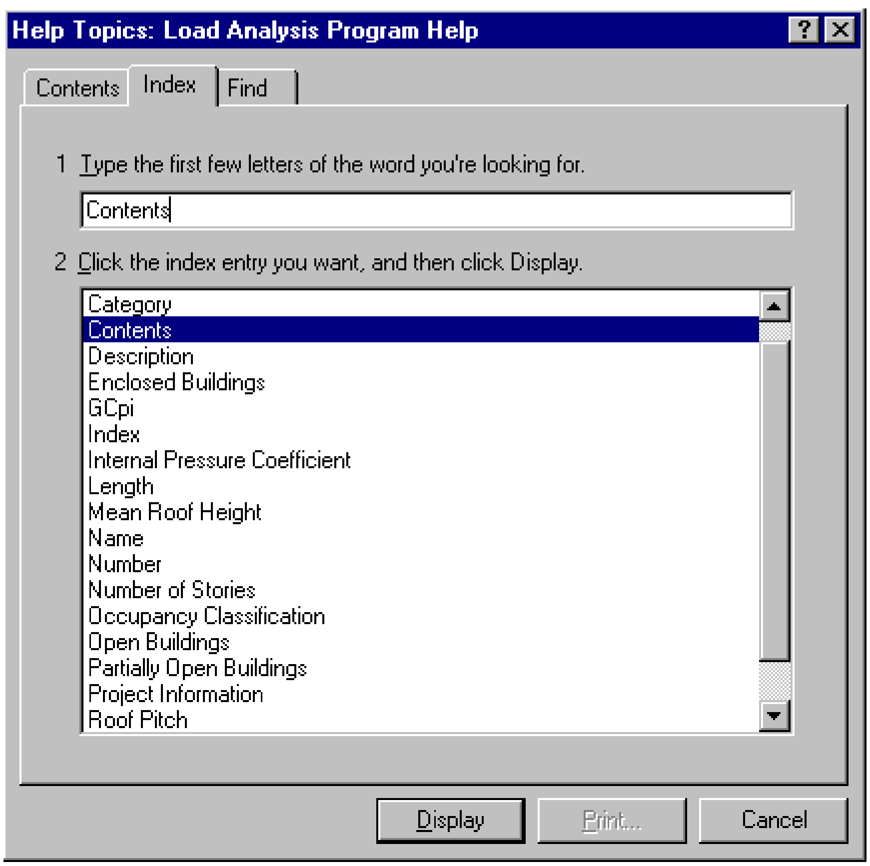


Figure A-5: Load Analysis Program Help Topics

A.4 Example 1-Two Story Residential Building

This step-by-step example is a rectangular, 2 story residential building (house) for which wind and snow loads will be determined. The building geometry is as follows.

Mean roof height: 21.0'
Length: 54.5'
Width: 31.0'
Roof pitch: 8/12
Location: Blacksburg, Virginia

The house is located in a residential subdivision with some shelter ing from trees, adjacent buildings or adjacent houses, therefore the wind will not be relied upon to remove any snow from the roof.

Structure data

The steps for entering the structure data are as follows.

1. Select the Project Information Command from the Structure pull-down menu (See Figure A-6). This command accesses the Project Information dialog box. Enter the project information, shown in Figure A-7, and click on the "OK" button.

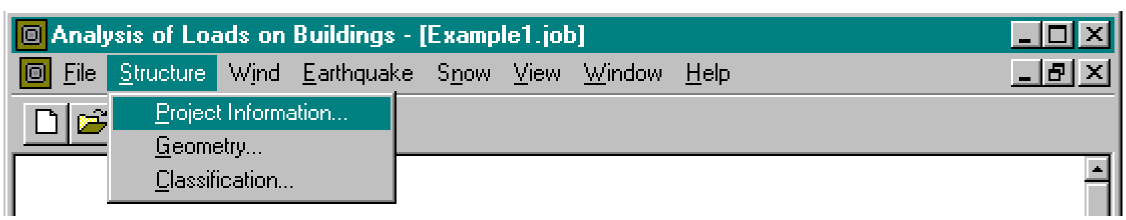


Figure A-6: Project Information Command

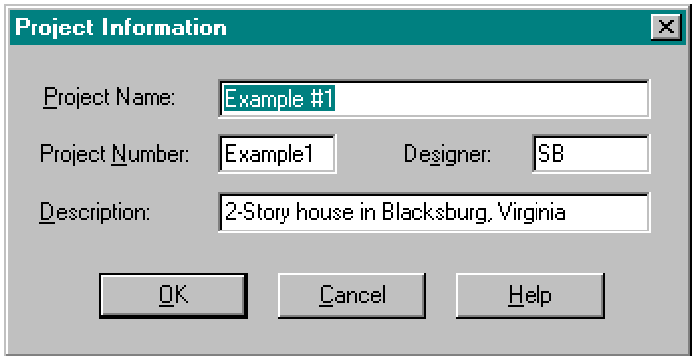


Figure A-7: Example 1 Project Information Data

2. Select the Geometry Command from the Structure pull-down menu (See Figure A-8). This command activates the Building Geometry dialog box. Enter the structural geometry shown in Figure A-9 and click on the "OK" button.

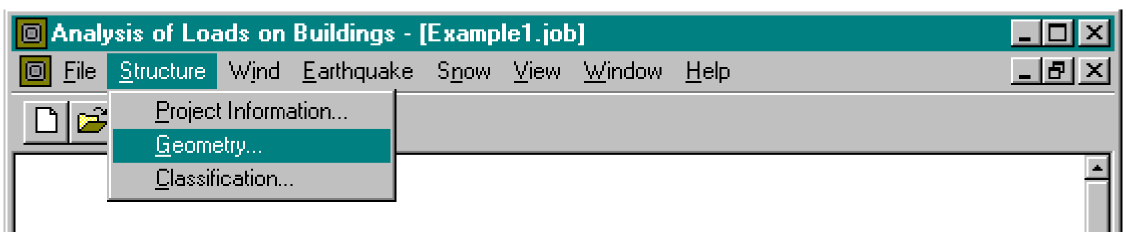


Figure A-8: Geometry Command

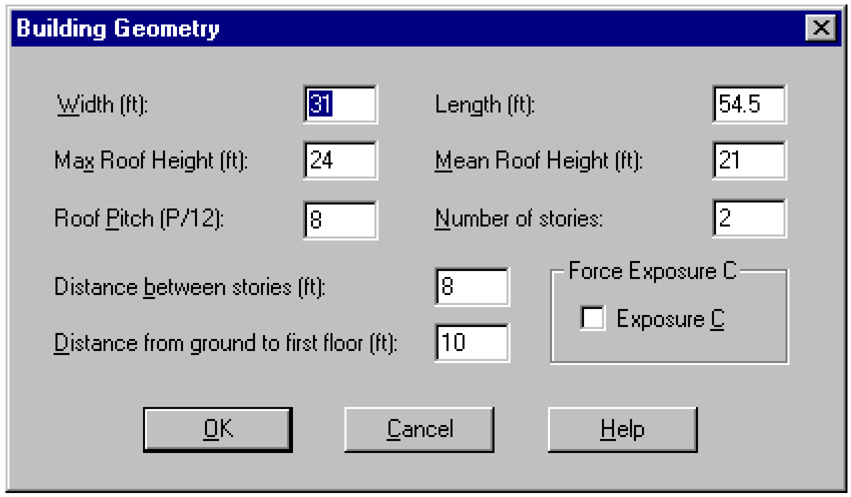


Figure A-9: Building Geometry Dialog Box

3. Select the Classification Command from the Structure pull-down menu (See Figure A-10). This command activates the Occupancy Classification Category dialog box seen in Figure A-11. Select the appropriate classification and click the "OK" button.

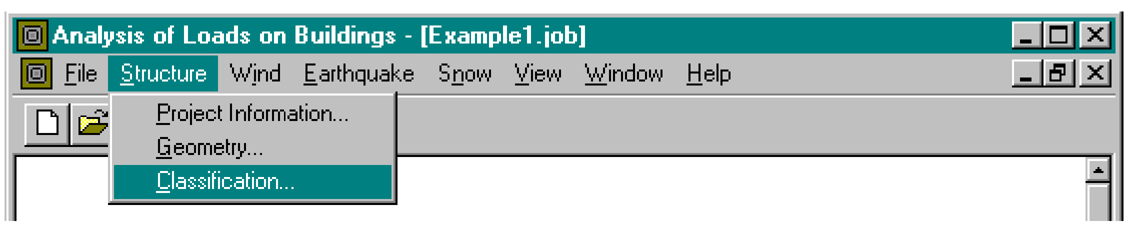


Figure A-10: Classification Command

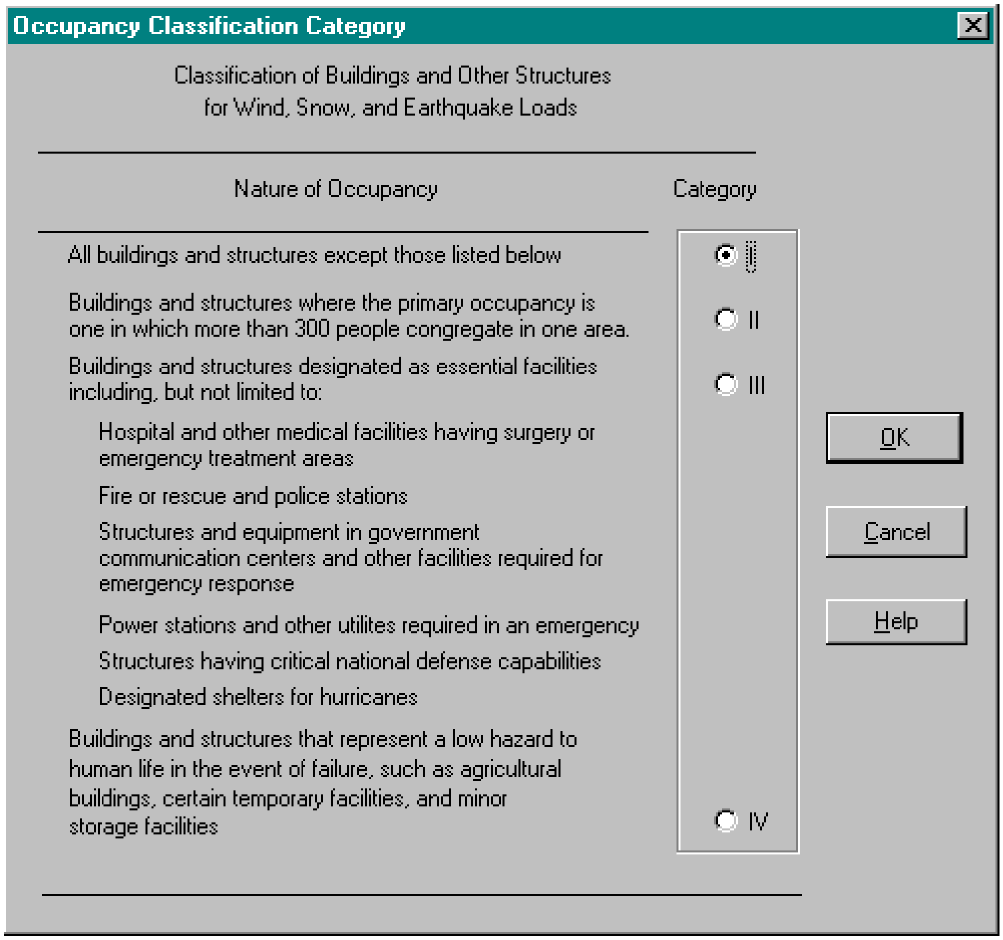


Figure A-11: Example 1 Occupancy Classification Category Selection

Wind Loads

The steps for entering wind load data and computing wind loads are as follows.

1. Select the Importance Factor Command from the Wind pull-down menu (See Figure A-12). This command activates the Wind Importance Factor dialog box. Enter the appropriate importance factor, shown in Figure A-13, and click on the "OK" button.

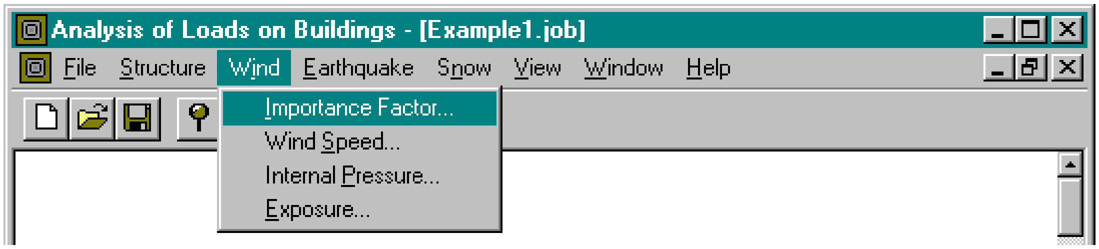


Figure A-12: Wind Importance Factor Command

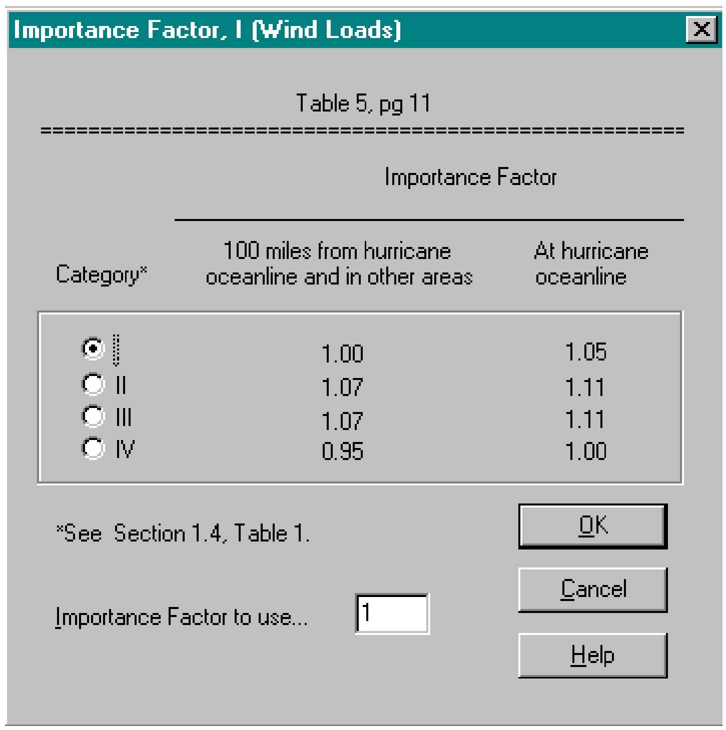


Figure A-13: Example 1 Wind Importance Factor Selection

2. Select the Wind Speed Command from the Wind pull-down menu (See Figure A-14). This command activates the Wind Speed dialog box shown in Figure A-15. Use Figure 1, page 13 of the ASCE 7-93 Standard and enter the wind speed. Next, Click on the “OK” button

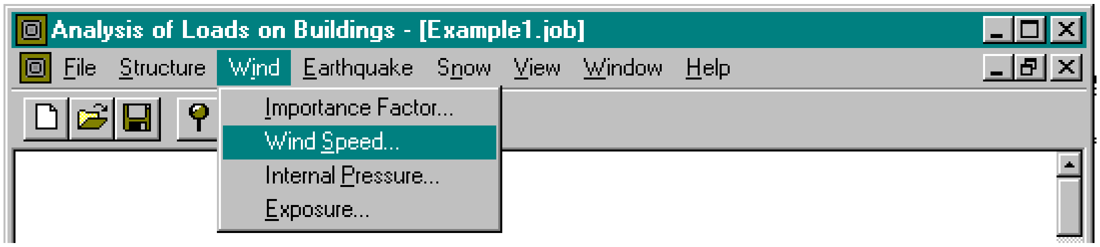


Figure A-14: Wind Speed Command

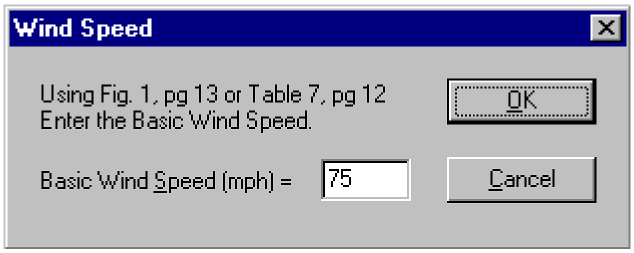


Figure A-15: Example 1 Wind Speed Input

3. Select the Internal Pressure Command from the Wind pull-down menu (See Figure A-16). This command activates the Internal Pressure Coefficient dialog box. Select the appropriate internal pressure coefficient seen in Figure A-17. Condition II indicates buildings which are likely to become internally pressurized while Condition I indicates the opposite. Next, click on the "OK" button.

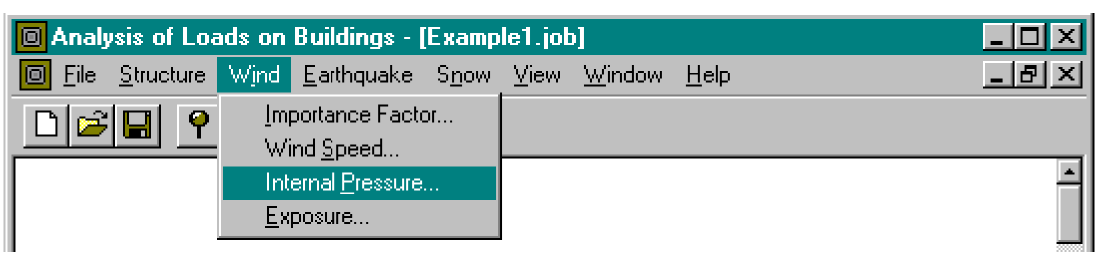


Figure A-16: Internal Pressure Command

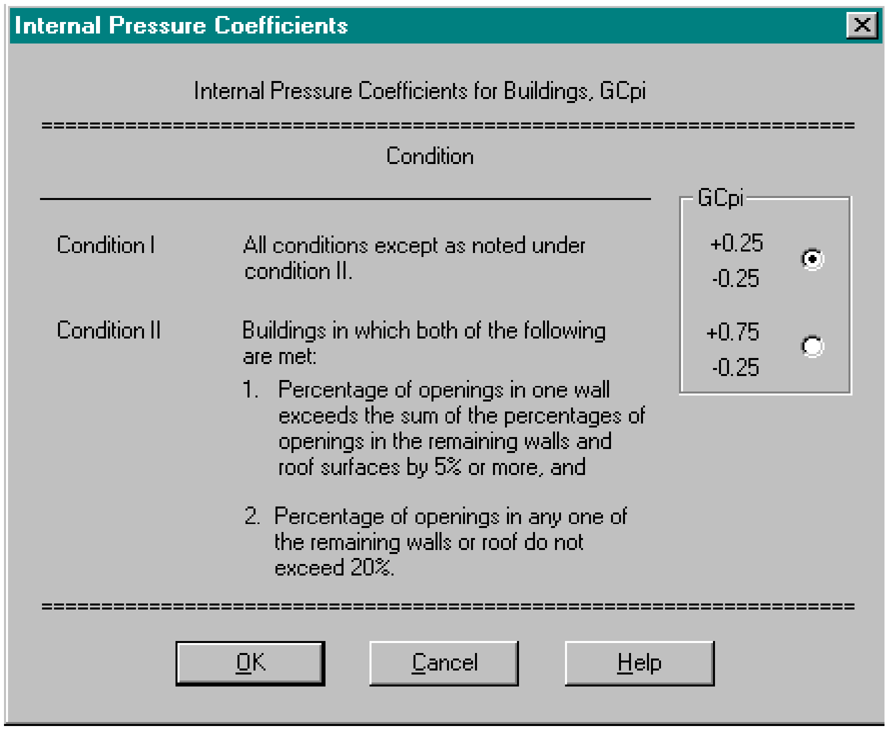


Figure A-17: Example 1 Internal Pressure Coefficient Selection

4. Select the Exposure Command from the Wind pull-down menu (See Figure A-18). This command activates the Building Exposure Category dialog box. Select the appropriate exposure category seen in Figure A-19. Section 6.5.3.1 of ASCE 7-93 contains descriptions of each category. Clicking on the “OK” button completes the data entry for determining wind loads.

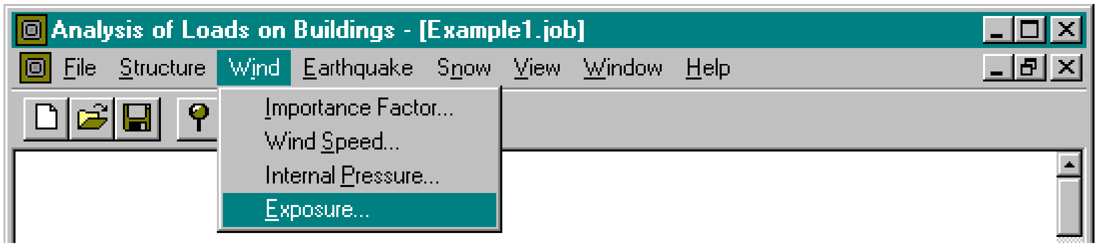


Figure A-18: Exposure Command

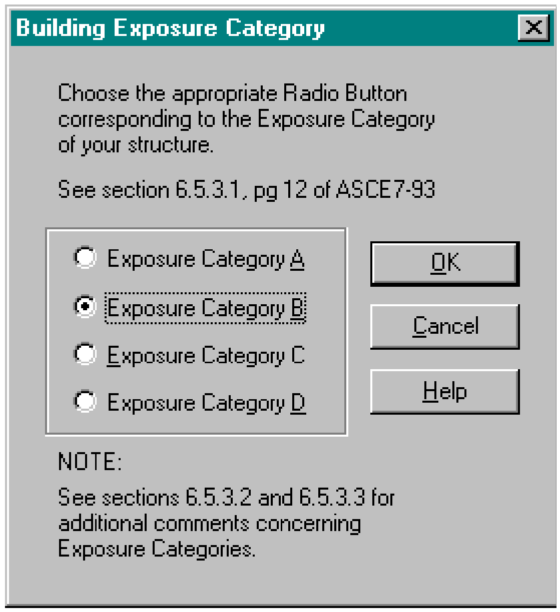
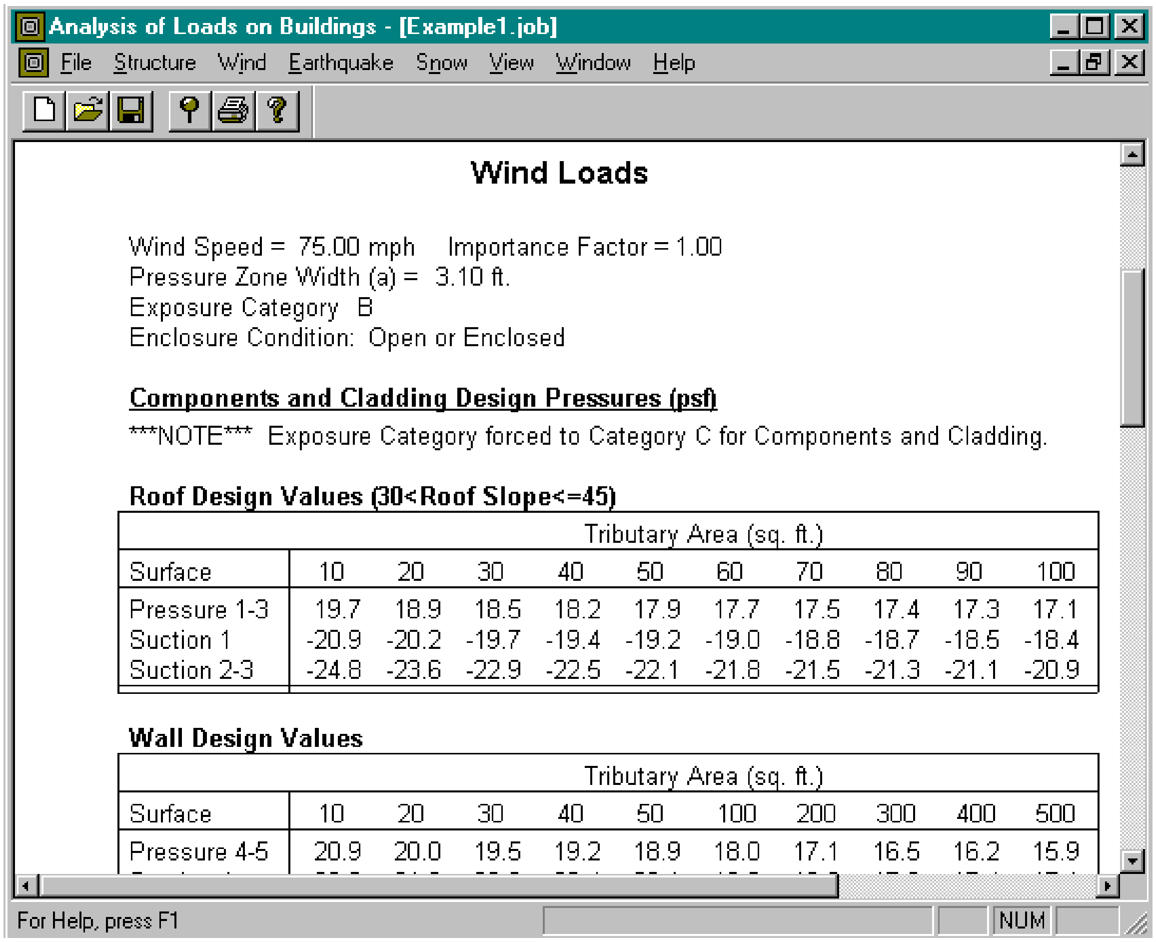


Figure A-19: Example 1 Building Exposure Category Selection

The program computes the wind loads and displays the results in the main window (See Figure A-20). The scroll bar at the right of the main window can be used to view the data not visible at the bottom of the screen. The results can be printed by selecting the Print Command from the File pull-down menu.



	Tributary Area (sq. ft.)									
Surface	10	20	30	40	50	60	70	80	90	100
Pressure 1-3	19.7	18.9	18.5	18.2	17.9	17.7	17.5	17.4	17.3	17.1
Suction 1	-20.9	-20.2	-19.7	-19.4	-19.2	-19.0	-18.8	-18.7	-18.5	-18.4
Suction 2-3	-24.8	-23.6	-22.9	-22.5	-22.1	-21.8	-21.5	-21.3	-21.1	-20.9

	Tributary Area (sq. ft.)									
Surface	10	20	30	40	50	100	200	300	400	500
Pressure 4-5	20.9	20.0	19.5	19.2	18.9	18.0	17.1	16.5	16.2	15.9

Figure A-20: Example 1 Final Wind Calculations

Snow Loads

The steps for entering snow load data and computing snow loads are as follows.

1. Select the Importance Factor Command from the Snow pull-down menu (See Figure A-21). This command activates the Snow Importance Factor dialog box. Select the appropriate importance factor seen in Figure A-22. The building classification category is provided since the importance factor is dependent upon the classification category.

Changing the classification category here will also change it at the Occupancy Classification Dialog Box (See Figure A-11). Next, click on the "OK" button.

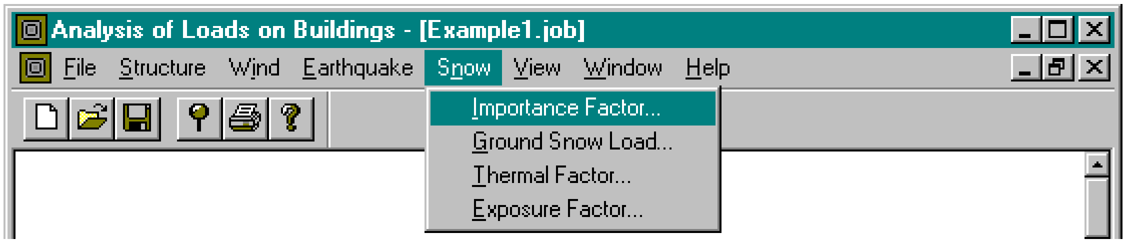


Figure A-21: Snow Importance Factor Command

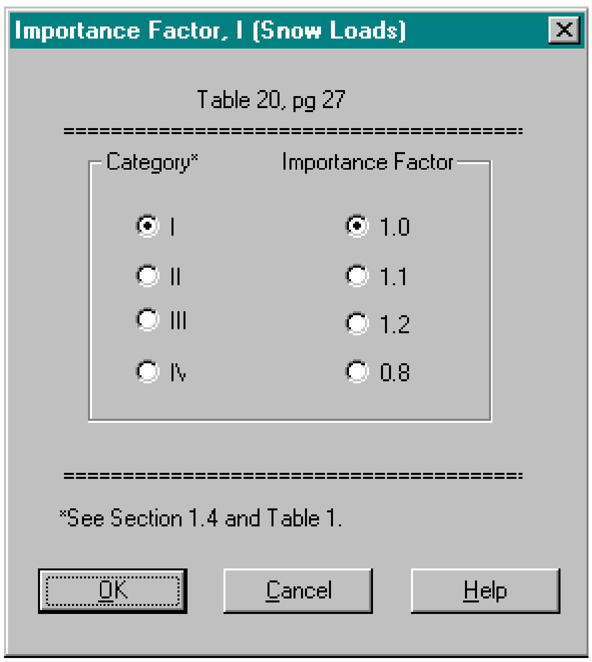


Figure A-22: Example 1 Snow Importance Factor Selection

2. Select the Ground Snow Load Command from the Snow pull-down menu (See Figure A-23). This command activates the Ground Snow Load dialog box. Use Figures 5, 6 an

7, pages 24-27 of ASCE 7-93 and enter the ground snow load seen in Figure A-24. Also, if the house has a warm unobstructed roof surface, the corresponding check box can be selected. The roof is not "slippery" in this example, therefore leave it unchecked. Next, click on the "OK" button.

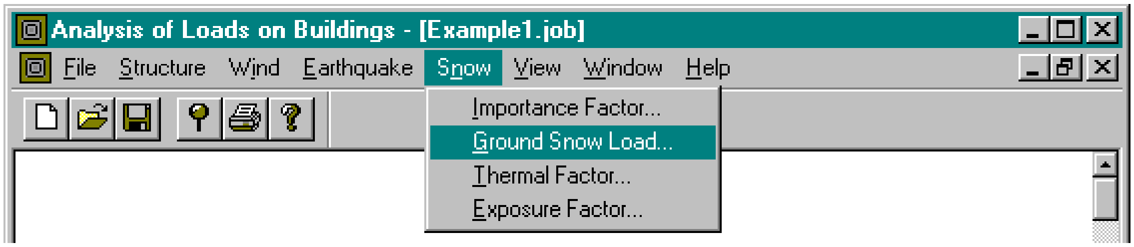


Figure A-23: Ground Snow Load Command

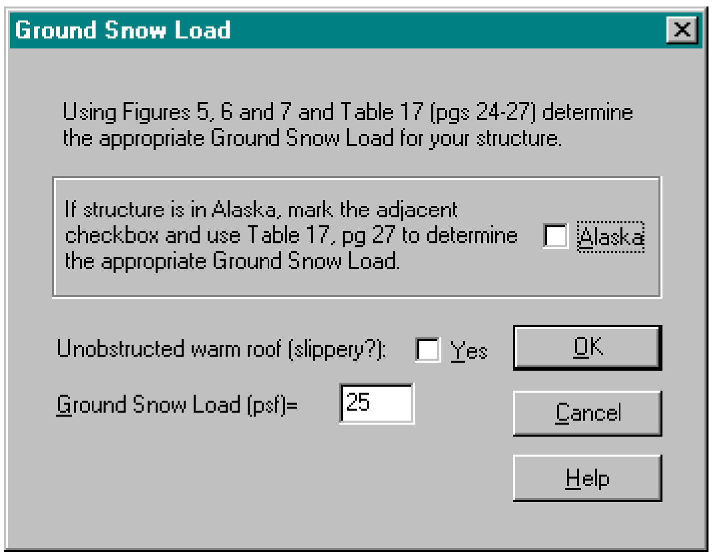


Figure A-24: Example 1 Ground Snow Load Input

3. Select the Thermal Factor Command from the Snow pull-down menu (See Figure A-25). This command activates the Thermal Factor dialog box. Select the thermal factor

corresponding to the appropriate thermal condition seen in Figure A-26. Next, click on the "OK" button.

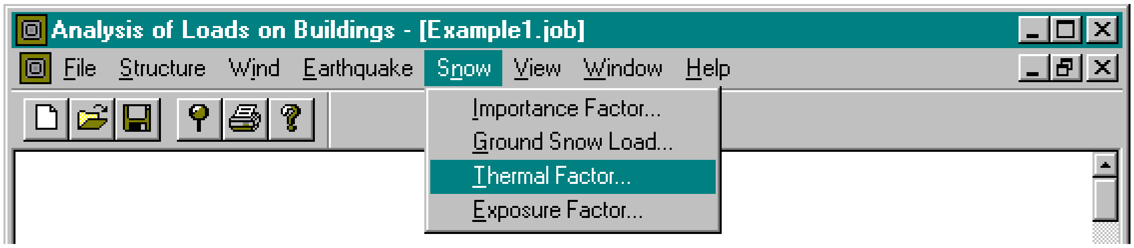


Figure A-25: Thermal Factor Command

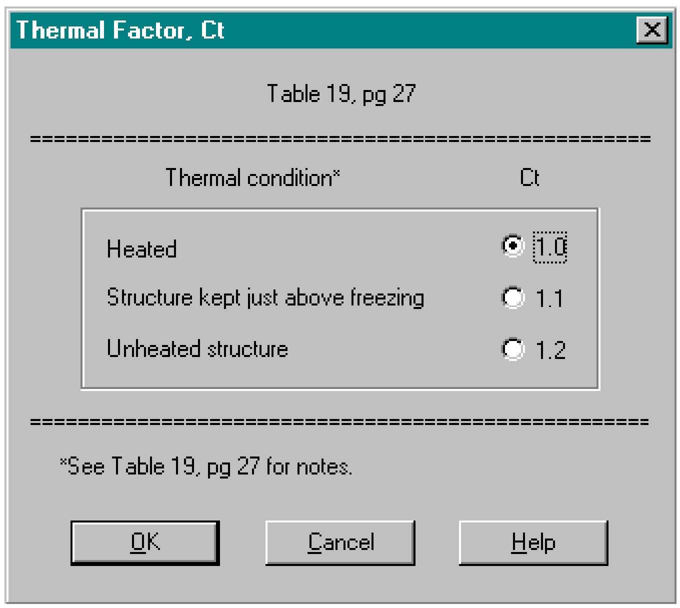


Figure A-26: Example 1 Thermal Factor Selection

4. Select the Exposure Factor Command from the Snow pull-down menu (See Figure A-27). This command activates the Exposure Factor dialog box. Select the exposure factor corresponding to the appropriate site condition seen in Figure A-28. Next, clicking on the "OK" button completes the data input for determining snow loads.

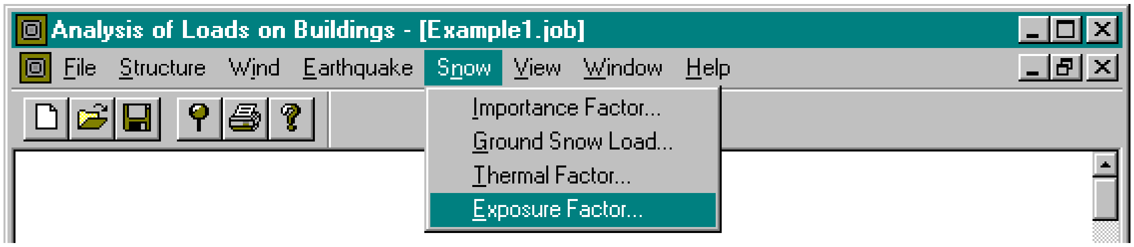


Figure A-27: Exposure Factor Command

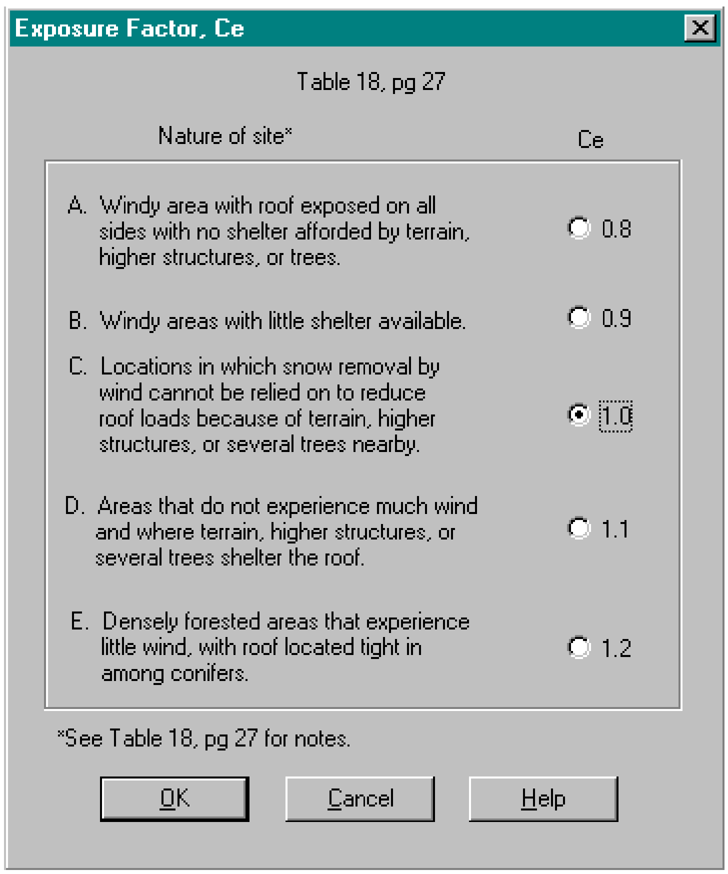


Figure A-28: Example 1 Exposure Factor Selection

The program computes the snow loads and displays the results in the main window (See Figure A-29). The scroll bar at the right of the main window can be used to view the data not visible at the bottom of the screen. The results can be printed by selecting the Print Command from the File pull-down menu.

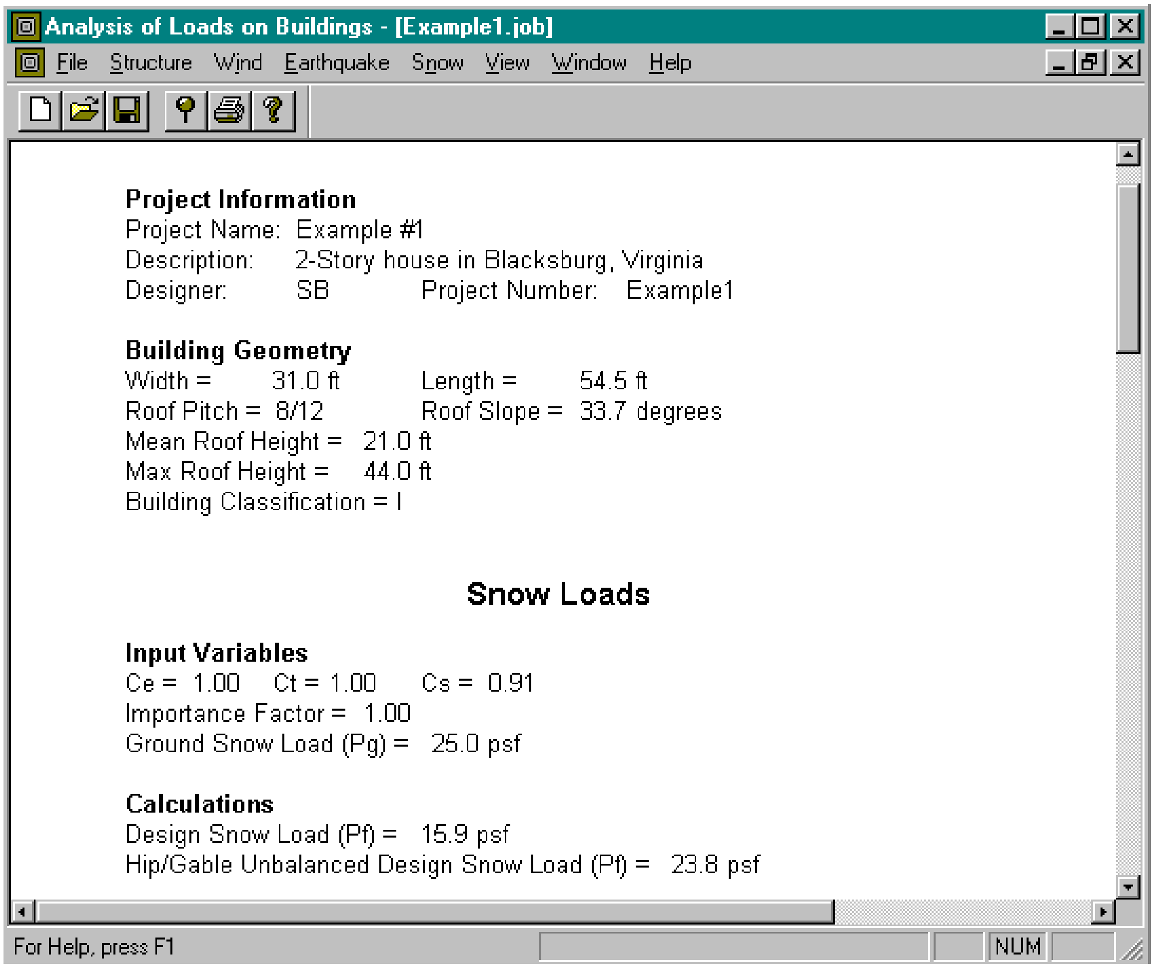


Figure A-29 : Example 1 Final Snow Calculations

A.5 Example 2-Eight Story Commercial Building

This step-by-step example is of an eight story (including the roof), reinforced concrete building for which wind and earthquake loads will be determined. The building contains reinforced concrete shear walls in both directions and is rectangular in both the plan and elevation. The building geometry is given below.

Mean roof height: 68.0’
Length: 110.0’
Width: 95.5’
Roof pitch: 1/12 (practically flat)
Location: Charleston, South Carolina

Story Live Load: 100.0 psf (including storage)
Story Dead Load: 90.0 psf (including partitions)
Fundamental Period from analysis: 0.56 (both axes)
Soil Profile Type: S1

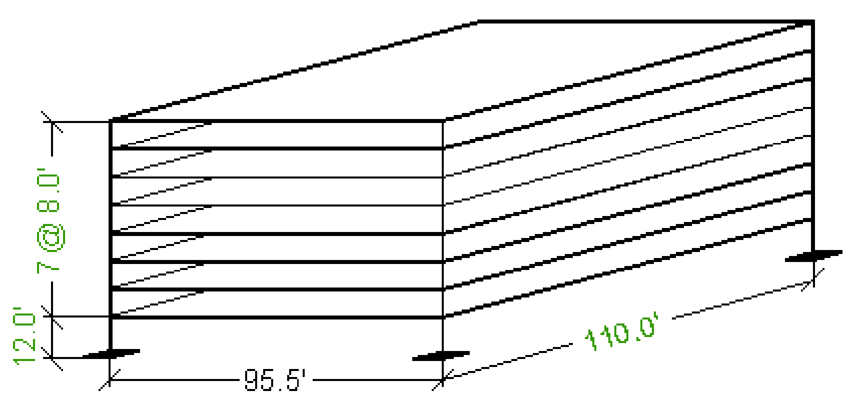


Figure A-30: Example 2 Building Dimensions

Wind Loads

1. Select the Geometry Command from the Structure pull-down menu (See Figure A-31) and enter the building geometry data seen in Figure A-32. Since the building's mean roof height is less than 90 feet, the "Exposure C" check box is selected to calculate components and cladding loads within the Exposure C constraints (See Table 4 footnotes, page 10 of ASCE 7-93). Next, click on the "OK" button. Enter the remaining data, such as Wind Importance Factor and Wind Speed as is shown in Example 1. The program performs calculations and displays the results in the main window. The calculations can be printed by selecting the Print Command from the File pull-down menu.

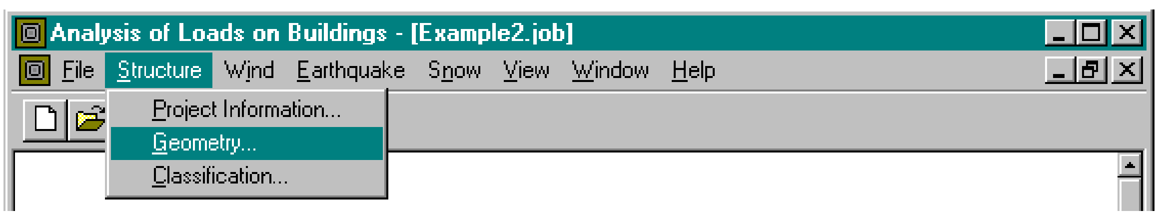


Figure A-31: Geometry Command

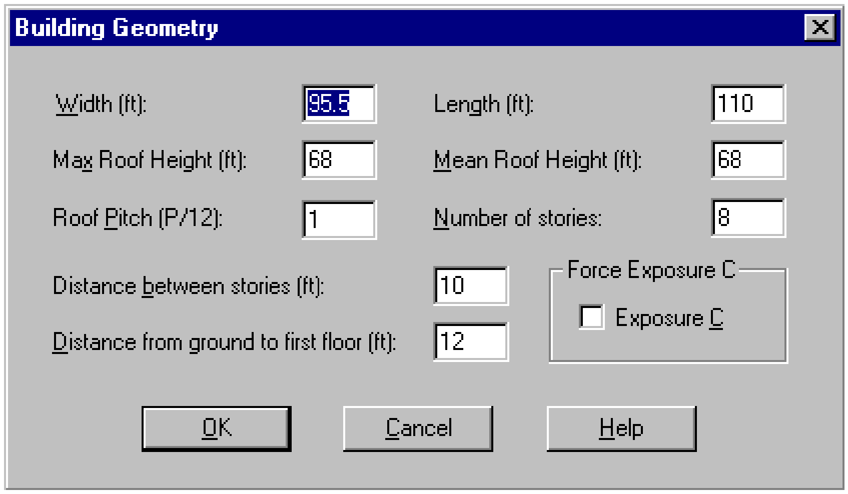


Figure A-32: Example 2 Building Geometry Data

Earthquake Loads

1. Select the Initial Data Command from the Earthquake pull-down menu (See Figure A-33). This command activates the Initial Earthquake Data dialog box. Enter the correct data and choose the approximate fundamental period equation to be used (See Figure A-34). Next, click on the "OK" button.

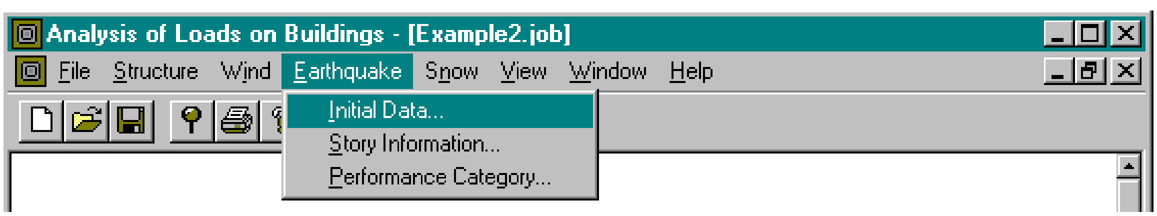


Figure A-33: Initial Data Command

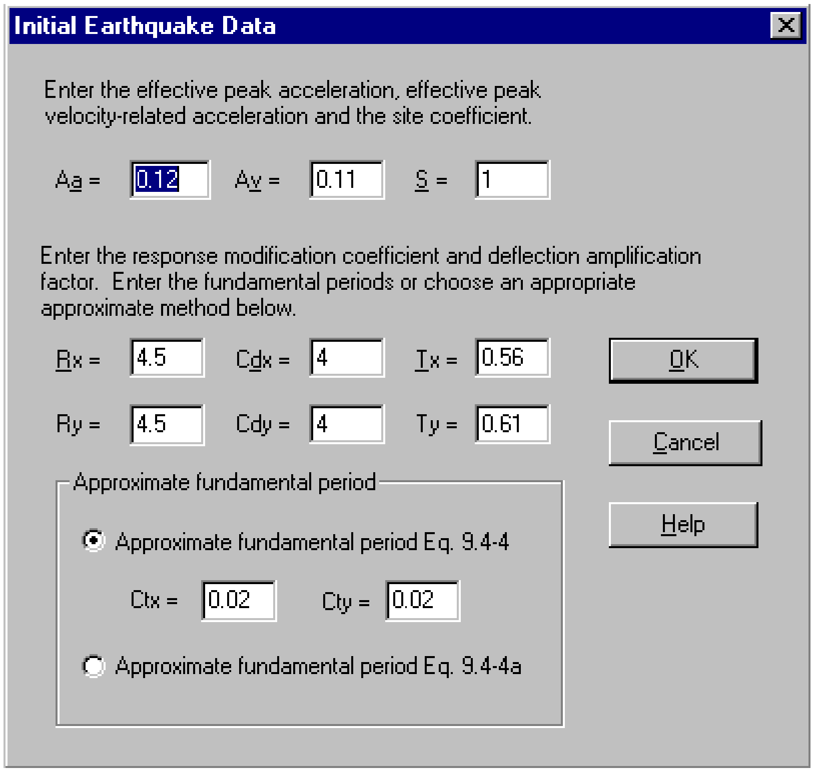


Figure A-34: Example 2 Initial Earthquake Data

2. Select the Story Information Command from the Earthquake pull-down menu (See Figure A-35). This command activates the Story Information dialog box. Enter the story height and gravity loads seen in Figure A-36 and click on the "Apply" button. There will be one dialog box for every story level.

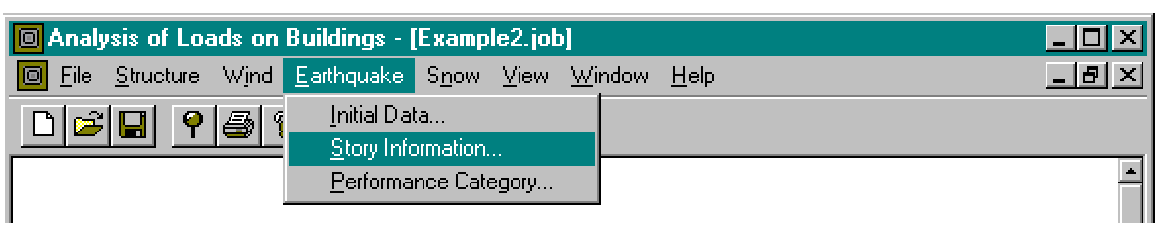


Figure A-35: Story Information Command

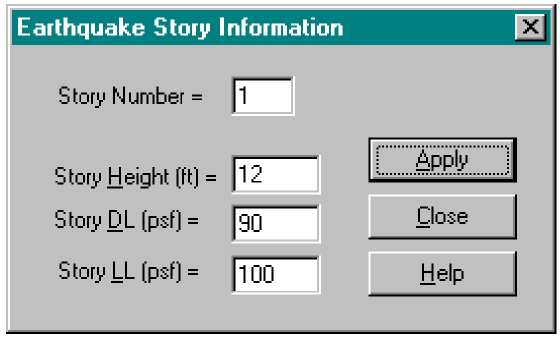


Figure A-36: Example 2 Story Information Data

3. Select the Performance Category Command from the Earthquake pull-down menu (See Figure A-37). This command activates the Seismic Performance Category dialog box. Select the appropriate seismic performance category (See Figure A-38). The seismic hazard exposure group is found in Section 9.1.4.2, page 33 of ASCE 7-93 and the effective peak velocity-related acceleration is shown in the dialog box.

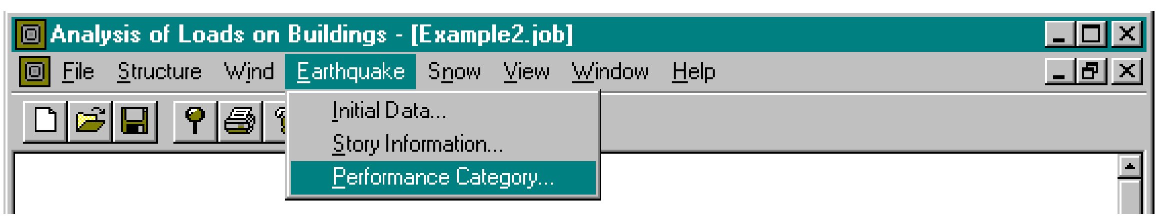


Figure A-37: Performance Category Command

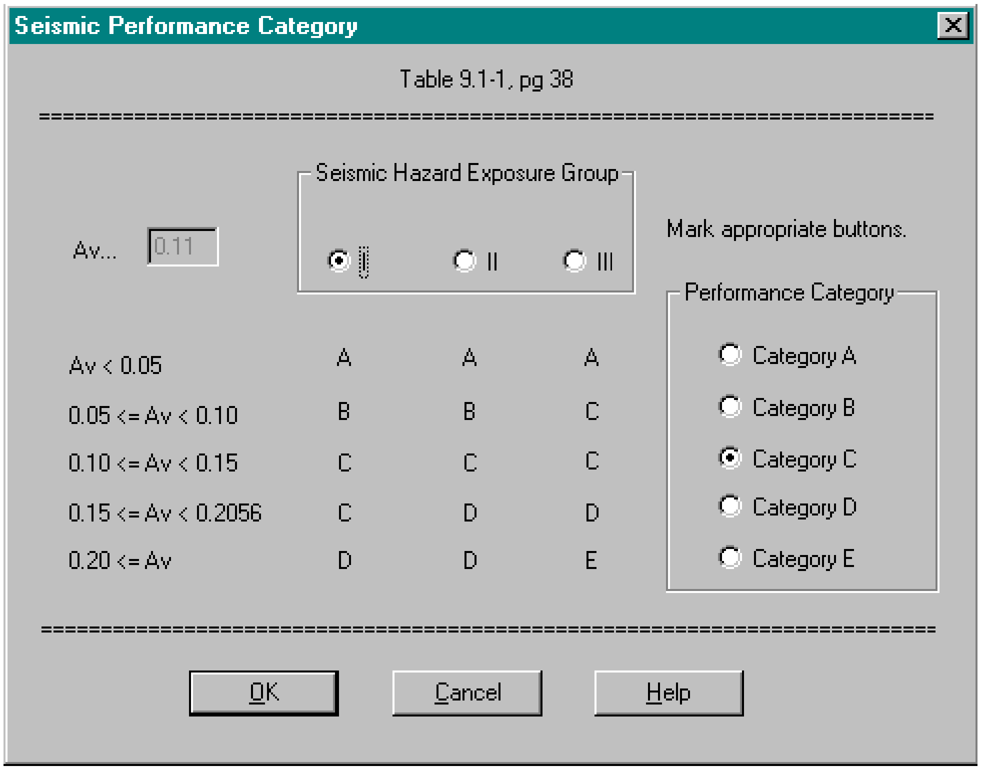


Figure A-38: Example 2 Seismic Performance Category Selection

The program computes the earthquake loads and displays the results in the main window (See Figure A-39). The scroll bars at the right and bottom of the main window can be used to view the data not visible at the bottom of the screen. The results can be printed by selecting the Print Command from the File pull-down menu..

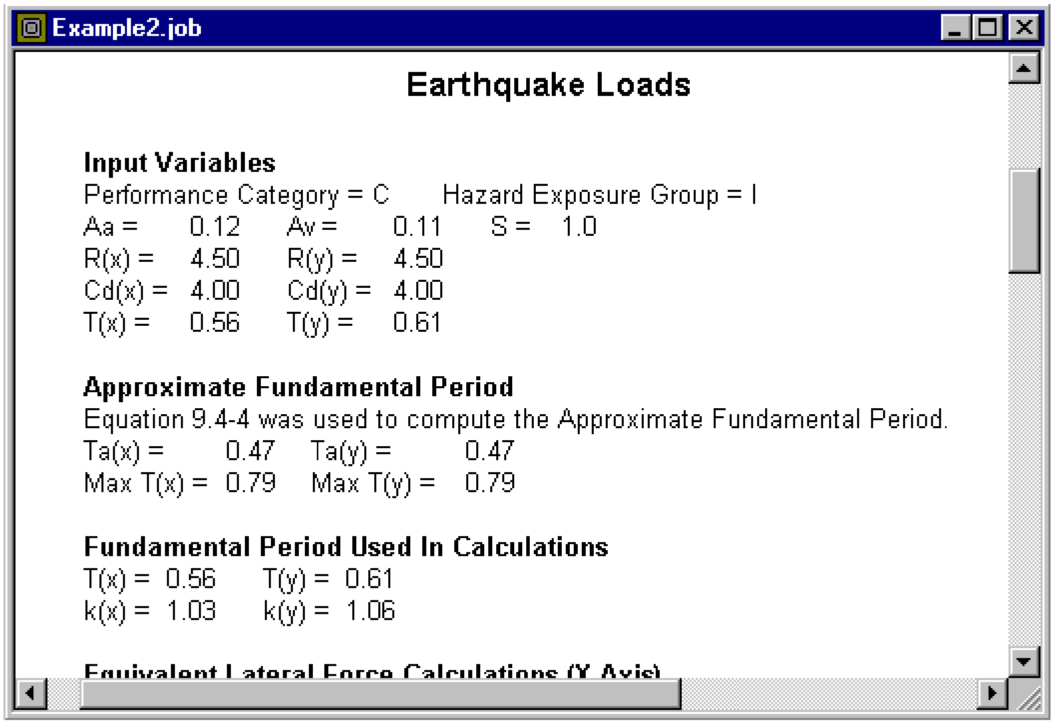


Figure A-39: Example 2 Final Earthquake Calculations

APPENDIX B

EXAMPLE OUTPUT AND VERIFICATION

The example problems given in Appendix A are used for verifying the Load Analysis Program. This appendix contains printed output of the example problems given in Appendix A, and calculations for verifying the Load Analysis Program. Output from the wind spreadsheet, which is discussed in Chapter 3, is compared to the wind output from the Load Analysis Program. Manual wind load calculations are provided for example 2 because of the spreadsheet's height limitation. Manual snow load and earthquake load calculations are provided for comparing the earthquake and snow load calculations produced by the Load Analysis Program.

B.1 Example 1 Load Analysis Program Output

This section contains output from the Load Analysis Program for Example 1 (See Figures B-1, B-2, and B-3). Data for verifying the output (wind spreadsheet results and manual snow load calculations) is shown in the following section.

Project Information
Project Name: Example #1
Description: 2-Story house in Blacksburg, Virginia
Designer: SB Project Number: Example1

Building Geometry
Width = 31.0 ft Length = 54.5 ft
Roof Pitch = 8/12 Roof Slope = 33.7 degrees
Mean Roof Height = 21.0 ft
Max Roof Height = 26.0 ft
Building Classification = I

Figure B-1: Example 1 Project Information and Building Geometry

Wind Loads

Wind Speed = 75.00 mph Importance Factor = 1.00
Pressure Zone Width (a) = 3.10 ft.
Exposure Category B
Enclosure Condition: Open or Enclosed

Components and Cladding Design Pressures (psf)

NOTE Exposure Category forced to Category C for Components and Cladding.

Roof Design Values (30<Roof Slope<=45)

	Tributary Area (sq. ft.)									
Surface	10	20	30	40	50	60	70	80	90	100
Pressure 1-3	19.7	18.9	18.5	18.2	17.9	17.7	17.5	17.4	17.3	17.1
Suction 1	-20.9	-20.2	-19.7	-19.4	-19.2	-19.0	-18.8	-18.7	-18.5	-18.4
Suction 2-3	-24.8	-23.6	-22.9	-22.5	-22.1	-21.8	-21.5	-21.3	-21.1	-20.9

Wall Design Values

	Tributary Area (sq. ft.)									
Surface	10	20	30	40	50	100	200	300	400	500
Pressure 4-5	20.9	20.0	19.5	19.2	18.9	18.0	17.1	16.5	16.2	15.9
Suction 4	-22.2	-21.3	-20.8	-20.4	-20.1	-19.2	-18.3	-17.8	-17.4	-17.1
Suction 5	-28.6	-26.5	-25.4	-24.5	-23.9	-21.8	-19.8	-18.6	-17.8	-17.1

Main Wind Force Resisting System Design Pressures

Roof Design Values (Parallel to Ridge)
Winward Roof(s) = -8.3 psf
Leeward Roof(s) = -8.3 psf

Roof Design Values (Normal to Ridge)
Winward Roof(s) = 3.4 psf
Leeward Roof(s) = -8.3 psf

Wall Design Values
Leeward Wall(s) = -4.9 psf
Side Wall(s) = -8.3 psf
Winward Wall(s)

Story	Elevation	Design Pressure
Roof	18.0 ft	8.8 psf
At 15'	15.0 ft.	8.2 psf

Figure B-2: Example 1 Wind Load Calculations from the Load Analysis Program

Snow Loads

Input Variables
Ce = 1.00 Ct = 1.00 Cs = 0.91
Importance Factor = 1.00
Ground Snow Load (Pg) = 25.0 psf

Calculations
Design Snow Load (Pf) = 15.9 psf
Hip/Gable Unbalanced Design Snow Load (Pf) = 23.8 psf

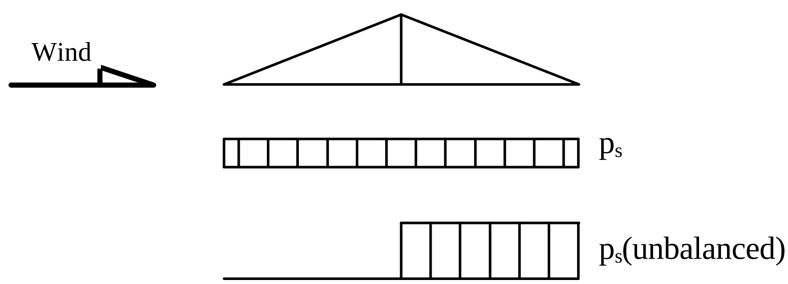


Figure B-3: Example 1 Snow Load Calculations from the Load Analysis Program

B.2 Example 1 Verification Calculations

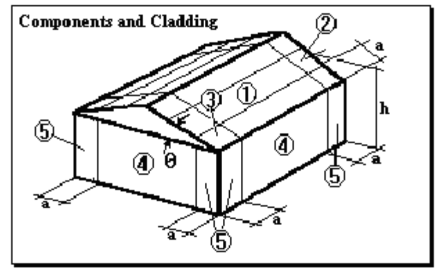
This section contains output from the wind spreadsheet (See Figure B-4) and manual snow load calculations (See Figure B-5) for verifying the Load Analysis Program.

Design Wind Pressures (ASCE 7-93) Verson 1.02; July 1996

Job Info... | Wind Info... | View | Print

JOB INFORMATION:

Job Name. . . . . Example 1 Verification of the Load Analysis Program
Job Number. . . Example1 Architect. . . . . N/A
Engineer. . . . . . . SB Contractor. . . . . N/A



INPUT DATA:

Width (W).	31.0 ft	Wind Speed.	75.0 mph
Length (L).	54.5 ft	Exposure Category. .	B
Roof Height (h).	21.0 ft	Enclosure Condition.	Open or Enclosed
Roof Pitch.	8 /12	Importance Factor. . .	1.00
Theta.	33.7 degrees	Pressure Zone (a). . .	3.10 ft

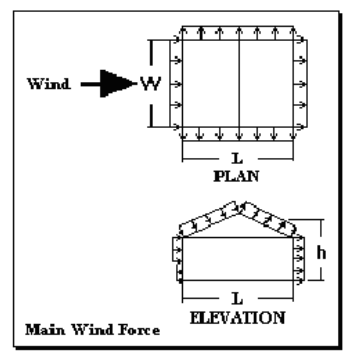
COMPONENTS AND CLADDING DESIGN PRESSURES (PSF)

Roof Design Pressures											Components and Cladding Tributary Area			
	Tributary Area													
Surface	10	20	30	40	50	60	70	80	90	100	Span (ft.)	Area (ft^2)	Span (ft.)	Area (ft^2)
Suction 1	-20.9	-20.2	-19.7	-19.4	-19.2	-19.0	-18.8	-18.7	-18.5	-18.4	8	21	14	65
2	-24.8	-23.6	-22.9	-22.5	-22.1	-21.8	-21.5	-21.3	-21.1	-20.9	10	33	16	85
3	-24.8	-23.6	-22.9	-22.5	-22.1	-21.8	-21.5	-21.3	-21.1	-20.9	12	48	>=18	108
Pressure 1,2&3	19.7	18.9	18.5	18.2	17.9	17.7	17.5	17.4	17.3	17.1	Area=1/3*Span^2			

Wall Design Pressures														
	Tributary Area													
Surface	10	20	30	40	50	60	70	80	90	100	200	300	400	500
Suction 4	-22.2	-21.3	-20.8	-20.5	-20.2	-19.9	-19.8	-19.6	-19.4	-19.3	-18.4	-17.9	-17.5	-17.1
5	-28.6	-26.5	-25.4	-24.5	-23.9	-23.3	-22.9	-22.5	-22.1	-21.8	-19.8	-18.6	-17.8	-17.1
Pressure 4&5	20.9	20.1	19.6	19.2	18.9	18.7	18.5	18.3	18.2	18.0	17.2	16.6	16.3	15.9

MAIN WIND FORCE RESISTING SYSTEM DESIGN PRESSURES

Walls			Roofs (Normal to Ridge)			Roofs (Parallel to Ridge)		
Windward >15'	9.3	psf	Windward	3.4	psf	Windward	-8.3	psf
Windward <=15'	8.3	psf	Leeward	-8.3	psf	Leeward	-8.3	psf
Leeward	-4.9	psf						
Side	-8.3	psf						



NOTES:

1. All notations, definitions and calculations based upon ASCE 7-93, "Minimum Design Loads for Buildings and other Structures".
2. Design wind pressures for tributary areas less than 10 sq. ft. or greater than 100 and 500 sq. ft. are equal to the design wind pressures for 10 sq. ft. and 100 and 500 sq. ft., respectively.
3. Positive (+) pressures act toward the surface.
   Negative (-) pressures act away from the surface.

Figure B-4: Example 1 Wind Load Calculations from the Spreadsheet

Building Geometry (Two Story House)

Width = 31.0 ft Length = 54.5 ft
Roof Pitch = 8/12 Roof Slope = 33.7 degrees
Mean Roof Height = 21.0 ft
Classification = I (From ASCE 7, Table 1)

Building site has minimum shelter from trees, adjacent buildings or adjacent houses. Since roof slope is 33.7 degrees, unbalanced loading must be considered.

Snow Input Data

Ground Snow Load, p_g = 25 psf (From ASCE 7, Figure 7)
Exposure Factor, Ce = 1.0 (From ASCE 7, Table 18)
Thermal Factor, C_t = 1.0 (From ASCE 7, Table 19)
Importance Factor, I = 1.0 (From ASCE 7, Table 20)
Slope Factor, C_s = 0.91 (From ASCE 7, Figure 8)

Snow Load Calculations

Flat roof snow load, $p_f = 0.7\times1.0\times1.0\times1.0\times25 =$ **17.5 psf** (by Eq. 2.14)

Sloped roof snow load, $p_s = 17.5\times0.91 =$ **15.9 psf** (by Eq. 2.16)

Unbalanced snow load, p_s(unbalanced) = $1.5\times15.9/1.0 =$ **23.9 psf** (by Eq. 2.17)

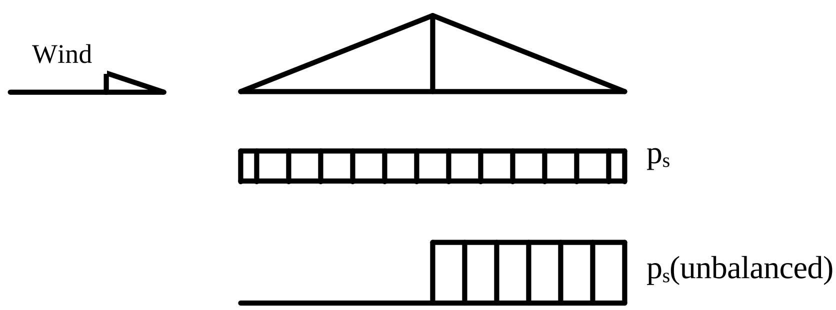


Figure B-5: Example 1 Manual Snow Load Calculations

B.3 Example 2 Load Analysis Program Output

This section contains output from the Load Analysis Program for Example 2 (See Figures B-6, B-7, B-8 and B-9). Data for verifying the output (manual wind load calculations and manual earthquake load calculations) is shown in the following section.

Project Information

Project Name: Example #2
Description: 8 Story Building in Charleston, SC
Designer: SB Project Number: Example2

Building Geometry

Width = 95.5 ft Length = 110.0 ft
Roof Pitch = 1/12 Roof Slope = 4.8 degrees
Mean Roof Height = 68.0 ft
Max Roof Height = 68.0 ft
Building Classification = I

Figure B-6: Example 2 Project Information and Building Geometry

Wind Loads

Wind Speed =95.00 mph Importance Factor =1.05
Pressure Zone Width (a) = 4.78 ft.
Exposure Category B Enclosure Condition: NOT Partially Enclosed

Components and Cladding Design Pressures (psf)

Roof Design Values (Roof Slope<=10)

	Tributary Area (sq. ft.)									
Surface	10	20	30	40	50	60	70	80	90	100
Suction 1	-41.3	-35.8	-32.5	-30.2	-28.5	-27.0	-25.8	-24.7	-23.8	-22.9
Suction 2	-50.5	-47.7	-46.1	-44.9	-44.0	-43.3	-42.7	-42.2	-41.7	-41.3
Suction 3	-78.0	-66.9	-60.5	-55.9	-52.3	-49.4	-47.0	-44.8	-43.0	-41.3
Suction 4	-96.3	-79.8	-70.1	-63.2	-57.9	-53.5	-49.8	-46.6	-43.8	-41.3

Wall Design Values

	Tributary Area (sq. ft.)								
Surface	100	150	200	250	300	350	400	450	500
Suction 5	-24.8	-23.4	-22.4	-21.6	-21.0	-20.5	-20.0	-19.6	-19.3
Suction 6	-37.6	-34.8	-32.9	-31.3	-30.1	-29.0	-28.1	-27.3	-26.6
Suction 7	-50.5	-45.8	-42.6	-40.0	-37.9	-36.2	-34.7	-33.3	-32.1

Story Level Pressures (Surfaces 5-7)

		Tributary Area (sq. ft.)									
Story	Elevation	10	20	30	40	50	100	200	300	400	500
Roof	82.0 ft	26.7	25.6	24.9	24.4	24.1	23.0	21.8	21.2	20.7	20.3
7	72.0 ft	25.2	24.1	23.5	23.1	22.7	21.7	20.6	20.0	19.5	19.2
6	62.0 ft	23.6	22.6	22.0	21.6	21.3	20.3	19.3	18.7	18.3	18.0
5	52.0 ft	21.8	20.9	20.3	20.0	19.7	18.8	17.8	17.3	16.9	16.6
4	42.0 ft	19.8	19.0	18.5	18.2	17.9	17.1	16.2	15.7	15.4	15.1
3	32.0 ft	17.6	16.8	16.4	16.1	15.9	15.1	14.4	13.9	13.6	13.4
2	22.0 ft	14.9	14.3	13.9	13.6	13.4	12.8	12.2	11.8	11.5	11.3
At 15'	15.0 ft	13.6	13.4	13.2	13.2	13.1	12.9	12.7	12.5	12.4	12.4

Figure B-7: Example 2 Wind Load Calculations from the Load Analysis Program

Main Wind Force Resisting System Design Pressures

Roof Design Values (Parallel to Ridge)
Winward Roof(s) = -22.1 psf
Leeward Roof(s) = -22.1 psf

Roof Design Values (Normal to Ridge)
Winward Roof(s) = -24.5 psf
Leeward Roof(s) = -22.1 psf

Wall Design Values
Leeward Wall(s) = -16.4 psf
Side Wall(s) = -22.1 psf
Winward Wall(s)

Story	Elevation	Design Pressure
Roof	82.0 ft	26.4 psf
7	72.0 ft.	25.1 psf
6	62.0 ft.	23.8 psf
5	52.0 ft.	22.4 psf
4	42.0 ft.	20.8 psf
3	32.0 ft.	18.9 psf
2	22.0 ft.	16.7 psf
At 15'	15.0 ft.	14.8 psf

Figure B-8: Example 2 Wind Load Calculations (Continued)

Earthquake Loads

Input Variables

Performance Category = C   Hazard Exposure Group = I

Aa = 0.12   Av = 0.11   S = 1.0

R(x) = 4.50   R(y) = 4.50

Cd(x) = 4.00   Cd(y) = 4.00

T(x) = 0.56   T(y) = 0.61

Approximate Fundamental Period

Equation 9.4-4 was used to compute the Approximate Fundamental Period.

Ta(x) = 0.47   Ta(y) = 0.47

Max T(x) = 0.79   Max T(y) = 0.79

Fundamental Period Used In Calculations

T(x) = 0.56   T(y) = 0.61

k(x) = 1.03   k(y) = 1.06

Equivalent Lateral Force Calculations (X-Axis)

Story	Elevation	Lateral Forces	Story Shears	Overturning	Story LL	Story DL
Roof	68.0 ft	89.8 kips	89.8 kips	0.0 kip-ft	100.0 psf	90.0 psf
7	60.0 ft	78.9 kips	168.7 kips	718.2 kip-ft	100.0 psf	90.0 psf
6	52.0 ft	68.1 kips	236.8 kips	2067.9 kip-ft	100.0 psf	90.0 psf
5	44.0 ft	57.3 kips	294.1 kips	3962.3 kip-ft	100.0 psf	90.0 psf
4	36.0 ft	46.6 kips	340.8 kips	6315.5 kip-ft	100.0 psf	90.0 psf
3	28.0 ft	36.0 kips	376.8 kips	9041.8 kip-ft	100.0 psf	90.0 psf
2	20.0 ft	25.5 kips	402.2 kips	12056.0 kip-ft	100.0 psf	90.0 psf
1	12.0 ft	15.0 kips	417.3 kips	15273.8 kip-ft	100.0 psf	90.0 psf

Equivalent Lateral Force Calculations (Y-Axis)

Story	Elevation	Lateral Forces	Story Shears	Overturning	Story LL	Story DL
Roof	68.0 ft	85.7 kips	85.7 kips	0.0 kip ft	100.0 psf	90.0 psf
7	60.0 ft	75.1 kips	160.8 kips	685.4 kip-ft	100.0 psf	90.0 psf
6	52.0 ft	64.6 kips	225.3 kips	1971.5 kip-ft	100.0 psf	90.0 psf
5	44.0 ft	54.1 kips	279.4 kips	3774.0 kip-ft	100.0 psf	90.0 psf
4	36.0 ft	43.8 kips	323.2 kips	6009.6 kip-ft	100.0 psf	90.0 psf
3	28.0 ft	33.6 kips	356.8 kips	8595.6 kip-ft	100.0 psf	90.0 psf
2	20.0 ft	23.6 kips	380.4 kips	11450.3 kip-ft	100.0 psf	90.0 psf
1	12.0 ft	13.7 kips	394.1 kips	14493.5 kip-ft	100.0 psf	90.0 psf

Base Shear

V(x) = 417.3 kips   V(y) = 394.1 kips

Figure B-9: Example 2 Earthquake Load Calculations from the Load Analysis Program

B.4 Example 2 Verification Calculations

Building Geometry (8 Story Building)

Width = 95.5 ft Length = 110.0 ft
Roof Pitch = 1/12 Roof Slope = 4.76 degrees
Mean Roof Height = 68.0 ft
Classification = I

Wind Input Data

Wind Speed = 95 mph
Importance Factor = 1.05
Exposure Category = B
Enclosure Condition = NOT Partially Enclosed

Pressure zone, a, is to be 5% of the minimum width or 0.5h, whichever is smaller.
a = 0.05(95.5) = **4.8 ft** (From ASCE 7, Figure 4)

Negative Wind Pressure Calculations (Components and Cladding)

Velocity pressure exposure coefficient, $K_z = K_h$ (evaluated at mean roof height)
K_h = **0.72** (From ASCE 7, Table 6)

Velocity pressure, $q = q_h$ (evaluated at mean roof height)
$q_h = 0.00256(0.72)[(1.05)(95)]^2$ = **18.3 psf** (by Eq. 2.4)

Internal pressure coefficient, GC_{pi} = **0.25** (From ASCE 7, Table 9)

Design pressure, $p = 18.3[(GC_p) - (0.25)]$ (by Eq. 2.3)
where GC_p varies with tributary area
(See Tables B-1 and B-2)

Table B-1: Components and Cladding Manual Roof Calculation Results

Roof Design Values

	Tributary Area									
Surface	10	20	30	40	50	60	70	80	90	100
Suction 1	-41.3	-35.8	-32.5	-30.2	-28.5	-27.0	-25.8	-24.7	-23.8	-22.9
Suction 2	-50.5	-47.7	-46.1	-44.9	-44.0	-43.3	-42.7	-42.2	-41.7	-41.2
Suction 3	-78.0	-66.9	-60.5	-55.9	-52.3	-49.4	-47.0	-44.8	-43.0	-41.2
Suction 4	-96.3	-79.8	-70.1	-62.8	-57.9	-53.5	-49.8	-46.6	-43.5	-41.2

Table B-2: Components and Cladding Manual Wall Calculation Results

Wall Design Values

	Tributary Area								
Surface	100	150	200	250	300	350	400	450	500
Suction 5	-24.8	-23.4	-22.4	-21.6	-21.0	-20.5	-20.0	-19.6	-19.3
Suction 6	-37.6	-34.8	-32.9	-31.3	-30.1	-29.0	-28.1	-27.3	-26.6
Suction 7	-50.5	-45.8	-42.6	-40.0	-37.9	-36.2	-34.7	-33.3	-32.1

Positive Wind Pressure Calculations (Components and Cladding)

Velocity pressure exposure coefficient, $K_{z,}$ varies with height. Values are obtained from ASCE 7, Table 6.

Velocity pressure, $q = q_z$ (evaluated at each story level z)

$q_z = 0.00256K_z[(1.05)(95)]^2$ (by Eq. 2.4)

Internal pressure coefficient, GC_{pi} = **-0.25** (From ASCE 7, Table 9)

Design pressure, $p = p_z$ (evaluated at each story level z)

$p_z = q_z[(GC_p) - (-0.25)]$ (by Eq. 2.3)

where GC_p varies with tributary area

(See Table B-3)

Table B-3: Component and Cladding Manual Wall Calculation Results

Story Level Pressures (Surfaces 5-7)

		Tributary Area									
Story	Elevation	10	20	30	40	50	100	200	300	400	500
Roof	82.0'	27.1	25.6	24.9	24.4	24.1	23.0	21.8	21.2	20.7	20.3
7	72.0'	25.4	24.1	23.5	23.0	22.7	21.6	20.5	19.9	19.7	19.8
6	62.0'	23.6	22.6	22.0	21.6	21.3	20.3	19.3	18.7	18.3	18.0
5	52.0'	21.8	20.9	21.0	20.0	19.7	18.8	17.8	17.3	16.9	16.6
4	42.0'	19.8	19.0	18.5	18.2	17.9	17.1	16.8	15.7	15.4	15.1
3	32.0'	17.6	16.8	16.4	16.1	15.9	15.1	14.4	13.9	13.6	13.4
2	22.0'	14.9	14.3	13.9	13.6	13.4	12.8	12.2	11.8	11.5	11.3
At 15'	15.0'	12.7	13.4	13.2	13.2	13.1	12.9	12.7	12.5	12.4	12.4

Wind Pressure Calculations (Main Wind Force Resisting System)

Velocity pressure exposure coefficient, $K_z = K_h$ (evaluated at mean roof height)

K_h = **0.72** (From ASCE 7, Table 6)

Velocity pressure, $q = q_h$ (evaluated at mean roof height)
$q_h = 0.00256(0.72)[(1.05)(95)]^2 =$ **18.3 psf** (by Eq. 2.4)

Internal pressure coefficient, $GC_{pi} =$ **0.25** (From ASCE 7, Table 9)

Gust response factor, G = Gh (evaluated at mean roof height)
Gh = **1.37** (From ASCE 7, Table 8)

Windward Roof Pressures (Parallel to Ridge)
Roof pressure coefficient, C_p, where h/L = 0.6
$C_p =$ **-0.7** (From ASCE 7, Figure 2)

Design pressure, p
$p = 18.3[(1.37)(-0.7) - (0.25)] =$ **-22.1 psf** (by Eq. 2.1)

Leeward Roof Pressures (Parallel to Ridge)
Roof pressure coefficient, $C_p =$ **-0.7** (From ASCE 7, Figure 2)

Design pressure, p
$p = 18.3[(1.37)(-0.7) - (0.25)] =$ **-22.1 psf** (by Eq. 2.1)

Windward Roof Pressures (Normal to Ridge)
Roof pressure coefficient, C_p, where θ=4.8 degrees and h/L = 0.6
$C_p =$ **-0.8** (From ASCE 7, Figure 2)

Design pressure, p
$p = 18.3[(1.37)(-0.8) - (0.25)] =$ **-24.6 psf** (by Eq. 2.1)

Leeward Roof Pressures (Normal to Ridge)
Roof pressure coefficient, $C_p =$ **-0.7** (From ASCE 7, Figure 2)

Design pressure, p
$p = 18.3[(1.37)(-0.7) - (0.25)] =$ **-22.1 psf** (by Eq. 2.1)

Leeward Wall Pressures
Roof pressure coefficient, C_p, where L/B = 1.2
$C_p =$ **-0.47** (From ASCE 7, Figure 2)

Design pressure, p
$p = 18.3[(1.37)(-0.47) - (0.25)] =$ **-16.3 psf** (by Eq. 2.1)

Side Wall Pressures

Roof pressure coefficient, C_p, where L/B = 1.2

C_p = **-0.7** (From ASCE 7, Figure 2)

Design pressure, p

p = 18.3[(1.37)(-0.7) - (0.25)] = **-22.1 psf** (by Eq. 2.1)

Windward Wall Pressures

Velocity pressure exposure coefficient, $K_{z,}$ is evaluated at the mean roof height and at each story level. Values for K_z are obtained from ASCE 7, Table 6.

K_h = **0.72** (From ASCE 7, Table 6)

Velocity pressure, q, is evaluated at the mean roof height and at each story level.

$q_h = 0.00256(0.72)[(1.05)(95)]^2$ = **18.3 psf** (by Eq. 2.4)

$q = q_z = 0.00256K_z[(1.05)(95)]^2$ (by Eq. 2.4)

Internal pressure coefficient, GC_{pi} = **-0.25** (From ASCE 7, Table 9)

Design pressure, p = p_z (at story level z)

$p = q_z(1.37)(0.8) - 18.3(-0.25)$ (by Eq. 2.1)

(See Table B-4)

Table B-4: Main Wind Force Resisting System Manual Wall Calculation Results

Windward Walls

Story	Elevation	Design Pressure
Roof	82.0'	26.3 psf
7	72.0'	25.1 psf
6	62.0'	24.0 psf
5	52.0'	22.3 psf
4	42.0'	20.8 psf
3	32.0'	18.9 psf
2	22.0'	16.6 psf
At 15'	15.0'	14.9 psf

Earthquake Input Data

Performance Category = C Hazard Exposure Group = I

A_a =	0.12	A_v =	0.11
R(x) =	4.50	R(y) =	4.50
Cd(x) =	4.00	Cd(y) =	4.00
T(x) =	0.56	T(y) =	0.61
S =	1.0		

Earthquake Period Calculations

Building period coefficient, C_T = **0.020** (ASCE 7, Section 9.4.4)

Coefficient for upper limit, Ca = **1.** (ASCE 7, Table 9.4-1)

Approximate fundamental period, T_a

$T_a = 0.020(68.0)^{3/4}$ = **0.47 seconds** (by Eq. 2.5)

The calculated fundamental period is limited by the product of the coefficient for upper limit, C_a and the approximate fundamental period, T_a. Therefore,

T(x) and T(y) < 1.66(0.47) = 0.79 **OK**

Use T(x) = **0.56 seconds**

Use T(y) = **0.61 seconds**

Earthquake Base Shear Calculations

Seismic coefficient, C_s

$$C_s(x) = \frac{1.2(0.11)(1.0)}{(4.5)(0.56)^{2/3}} = \mathbf{0.0432} \qquad \text{(by Eq. 2.8)}$$

$$C_s(y) = \frac{1.2(0.11)(1.0)}{(4.5)(0.61)^{2/3}} = \mathbf{0.0408} \qquad \text{(by Eq. 2.8)}$$

The seismic coefficient, C_s, need not be greater than the result of the following equation-arbitrarily called C_s(max):

$$C_s(\max) = \frac{2.5(0.12)}{4.5} = \mathbf{0.0667} \qquad \text{(by Eq. 2.9)}$$

Therefore, C_s(x) and C_s(y) < C_s(max) **OK**

Use C_s(x) = **0.0432**

Use C_s(y) = **0.0408**

Total load, W

W = [8(90) + 0.25(8)(100)] = **920 psf**

W = 920(95.5)(110) = **9,665 kips**

Base Shear, V

V(x) = 0.0432(9665) = **417.5 kips** (by Eq. 2.7)

V(y) = 0.0408(9665) = **394.3 kips** (by Eq. 2.7)

Once the base shear, V, is computed, Equations 2.10 - 2.13 are used to complete Table B-5. See Table B-5 for the final results of the manual earthquake calculations

Table B-5: Manual Earthquake Calculation Results

Story	Elev.(ft.)	W(kips)	Cv(x,y)	F(x)(kips)	V(x)(kips)	M(x)(kip-ft.)	F(y)(kips)	V(y)(kips)	M(y)(kip-ft.)
Roof	68.0	9665	0.213	88.7	88.7	0.0	83.8	83.8	0.0
7	60.0	9665	0.187	78.2	166.9	709.6	73.9	157.7	670.4
6	52.0	9665	0.162	67.8	234.7	2,044.8	64.1	221.8	1,932.0
5	44.0	9665	0.137	57.4	292.1	3,922.4	54.2	276.0	3,706.4
4	36.0	9665	0.112	46.9	339.0	6,259.2	44.3	320.3	5,914.4
3	28.0	9665	0.087	36.5	375.5	8,971.2	34.5	354.8	8,476.8
2	20.0	9665	0.062	26.1	401.6	11,975.2	24.6	379.4	11,315.2
1	12.0	9665	0.037	15.6	417.2	15,188.0	14.8	394.2	14,350.4

VITA

Stephen Edward Browning was born on January 17 of 1970 in Man, West Virginia. He attended Bluefield State College from September of 1988 to December of 1991 and received his Bachelor of Science degree in Civil Engineering Technology. After Bluefield State College, he attended West Virginia University for two semesters studying Civil Engineering preparing for graduate school. In September of 1993, he enrolled in the graduate program in the Department of Civil Engineering at Virginia Polytechnic Institute and State University where he earned his Master of Engineering degree.

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