ANALYSIS OF SNOW LOADS DUE TO DRIFTING ON MULTILEVEL ROOFS

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ABSTRACT

Drifted snow loads on multilevel flat roofed structures account for a large percentage of the building roof losses in the United States, yet little information has been available which quantitatively describes the factors which influences drift formation. A database of snowdrift case histories has been established, and its statistical analysis is summarized herein. The process of drift formation is discussed, and relationships between snowdrift characteristics and building geometry are obtained by utilizing linear regression techniques. It is shown that drift height is a function of roof lengths perpendicular to the change in roof elevation, roof elevation difference, and the ground snow load. Drift slope and snow density characteristics are also studied.

INTRODUCTION

Snow loads are an important consideration in the structural design of almost all building roof systems. Uniform snow loads are often the governing design load for roofs in many parts of the United States. When the geometry of a building is such that drift formation is possible, snow loads become even more critical. The importance of establishing appropriate design snow loads, especially in situations where drifting is possible, becomes evident when records of roof collapse are examined. O'Rouke et al. (1982) have reported that during the period 1974-78, snow loads accounted for approximately 55% of all roof losses, and of these snow related structural losses, approximately three-quarters were due to drifting at roof elevation changes.

It is common practice to superimpose unbalanced loads on top of uniform snow loads, wherever the potential exists for snow drifting. Although ground snow loads and uniform roof snow loads have been thoroughly examined, less information is available on the quantification of unbalanced snowdrift loads on roofs and their relationship with ground loads. Most building codes and standards use a building shape coefficient and the ground snow load to calculate the expected drift profile. When multiplied by an expected snow density, this drift profile is converted to a load distribution. Experience, engineering judgement, and work in related fields has formed the basis for these design methods.

The detailed natural processes and factors which contribute to the formation of drifts at roof elevation changes are complex and not easily generalilzed. Templin and Schriever (1982) have described the aerodynamics around buildings and have provided a basic explanation of the accumulation of snow on multilevel flat roofs. Actual drift configurations vary depending on the specific building geometry and the local storm conditions, but some common patterns can be explained by applying basic principles of fluid mechanics. A common example of drift formation is demonstrated on the right side of Figure 1. When wind blows from left to right, snow is scoured off the upper roof where wind speeds are high and deposited in the aerodymanic shade on the lower roof where wind speeds are lower. If a large amount of snow is available for drift formation, that is, if there is a large upper roof area and there is a large quantity of snow either falling or already on the roof, these drifts can become quite large and often extend to the upper roof.

Another example of drift formation is shown on the left side of Figure 1. In this case, snow from the lower roof elevation or possibly the ground is blown towards the change in roof elevation and deposited near the wall. A vortex usually forms near the upwind side of the elevation change that prevents the drift from extending all of the way to the upper roof.

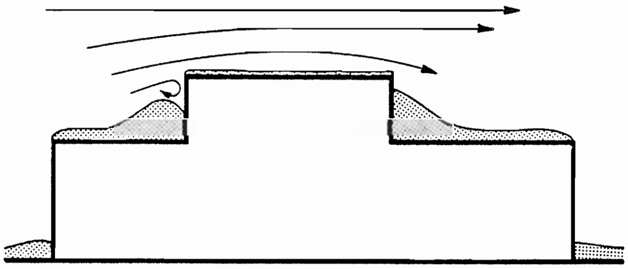

Figure 1. Process of Snowdrift Formation on Multilevel Flat Roofs

Presently, there are a number of procedures (ANSI (1982), ISO (1981), MBMA (1981), and NBCC (1970)) in use for predicting drift loads on multilevel roofs. However, no satisfactory method for accurately predicting drift profiles on multilevel roofs has become universally accepted. It is the purpose of this paper to examine a newly established large database of actual case histories of snowdrifting on multilevel roofs and to systematically determine which factors have the greatest effect on the formation of drifts on multilevel roofs. Statistical methods are used to analyze the database which includes actual drift configuration measurements, building geometry, and local climatological data. Relationships between parameters are examined and an empirical model for predicting drift load profiles is presented.

DATABASE

The snowdrift case histories were from a variety of sources. These sources include technical literature, failure reports prepared by practicing engineers, and failure investigations conducted by insurance companies and state agencies. Data from a total of nearly 350 sites located in the Northeast, Southeast, Midwest and Canada were included in the database. The dates of the measurements ranged back to 1959, though the majority of the cases were from the winters of 1977-78 and 1978-79. Forty-three percent of the cases involved structural failure, either full collapse, partial collapse, or excessive deflection. Seventy-five percent of the case histories involving structural failure occurred during the snowstorms of 1977-78 and 1978-79 in New England Coastal area and in the Illinois/Wisconsin area, respectively. The buildings were all of different sizes, shapes, and orientation, but only drifts on multilevel flat roofed buildings were included.

The database consisted of more than 30 different measurements for each case. Information on each building included the parameters of geographic longitude and latitude, building size, shape, orientation and exposure, and roof thermal properties. Snow and weather data included mean and fastest mile wind speed and direction for the period, ground snow depth and density, upper roof snow depth and density, and characteristic drift dimensions. The drifts were divided into two general shapes according to the previously discussed accumulation patterns; a trianglular shape in which the maximum snow depth was located at the roof elevation change (drift shape #1) and a quadralateral shape in which the maximum snow depth is located at some distance from the wall (drift shape #2). The drift geometry in most case histories was quantified only by the total length and height of the drift. Hence, further refinement of actual drift shape configurations into various non-linear profiles was not justified.

Because information was obtained from a variety of sources, not every case history had values for each parameter. In these situations, the case histories were supplemented with other available records. For example, if case histories lacked local wind conditions or actual ground snow loads, values from the nearest first-order weather station were used. These were stations that measured water-equivalent snow depth in addition to actual snow depth. In the database used for the analysis contained herein, wind data from the weather station was used exclusively to be consistent. For the few case histories which did contain actual wind information, it was not certain how and when the measurements were taken. For this reason, the wind information provided by the weather station for the monthly period containing the actual case history measurement was used in the database.

Another piece of data that was often not included is the original case histories was the lower roof uniform snow depth, H_b in Figure 2. For these cases, the relationship $H_b=0.048 \times P_g$ was used. This relation was obtained by correlating H_b with P_g for the 46 cases for which both pieces of information were available. Note that the equation corresponds closely to an assumed density of 12 pcf (193 Kg/m^3) and the ANSI (1982) conversion factor for normal exposed structures.

Figure 2 summarizes the important ground and roof load parameters in the database. Figure 2a defines the parameters for the case histories with drift shape #1, while Figure 2b applies to drift shape #2.

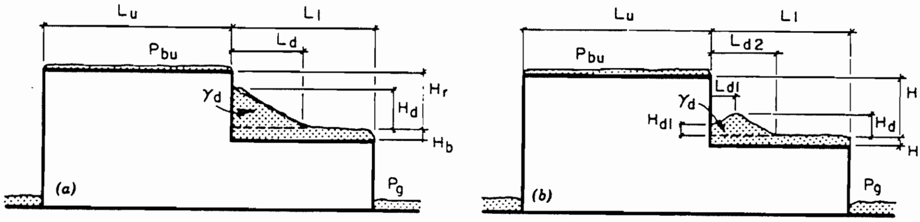

Figure 2. Ground and Roof Snow Load Characteristics and Geometry: (a) Drift Shape #1; (b) Drift Shape #2

DRIFT SHAPES

There are a number of factors that could influence which of the two general drift shapes forms. Wind direction, wind speed, snow moisture, thermal and geometric characteristics of the building, and the amount of snow available for drifting are possible factors. For example, a heated building tends to melt snow adjacent to its wall and over time, drift shape typical #2 might result. Also, as wind patterns change during a storm, or as snow is continually supplied to a drifting area, a drift that was previously shape #2 might "fill-in" and become drift #1.

An examination of the database showed that drift shape #1 was the more common drift configuration. Approximately 80% of the drifts corresponded to this profile. Correlation analysis between drift shape and various site parameters showed that as the upper roof length, average wind speed, ground snow load, or roof elevation difference increased, drift shape #1 was a little more likely to occur. Although the correlation coefficients were in most cases insignificant, further investigation supported most of the trends. For example, 75% of drift shape #1 occurred when the roof elevation difference was at least five feet. Also, if the upper roof length, L_u, and the ground snow depth, H_g, were combined to give a measure of available snow, it was shown that as this measure increased, drift shape #1 was more likely to occur.

Based on the previously discussed aerodynamics of drift formation, it would be expected that wind direction would be an important factor in determining the drift shape. Wind direction as measured in this study did not have a conclusive relationship with drift shape, but a number of trends were noted. Regardless of which shape was considered, drifting was more frequent for both wind measurements when the low roof was leeward of the upper roof, as opposed to being windward of the upper roof. Also, drift #1 was always the more common drift, though as expected from the aerodynmaic discussion, the percentage of cases that were drift shape #2 was greater when the low roof was on the windward side than when it was on the leeward side. Closer measurement of actual wind speed and direction during drift formation would be needed to substantiate these findings.

In addition to being the more common drift, drift shape #1 was also the more critical drift in terms of load magnitude. Figures 3a and 3b are historgams of the peak load intensity, P_d (H_d x γ_d) for drift shape #1 and drift shape #2, respectively. Note that drift loads for drift shape #1 are generally much higher than those for drift shape #2. Only 8% of drift shape #2 have peak loads greater than 20 psf (0.96KN/m^2), while 77% of drift shape #1 had peak loads greater than 20 psf.

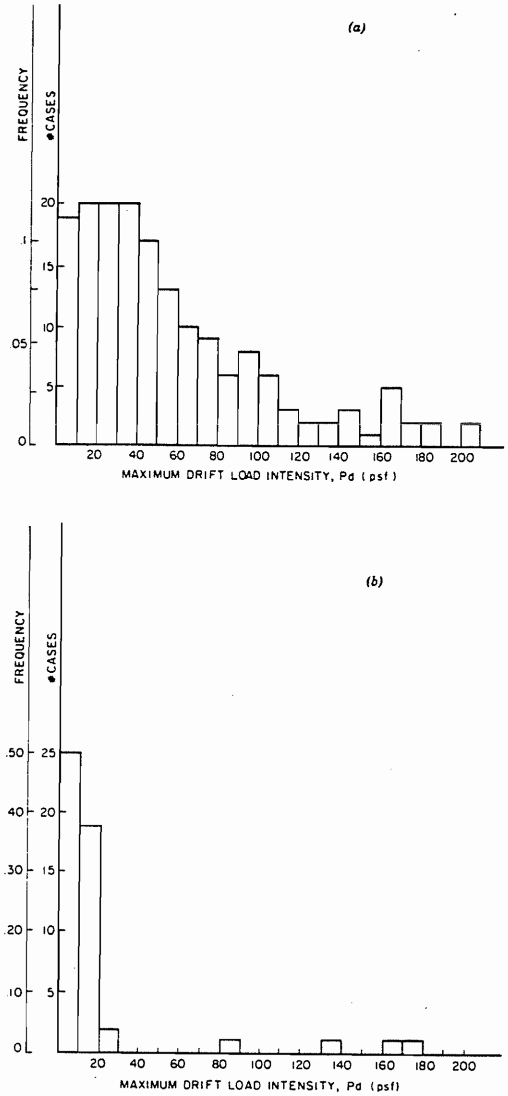

Figure 3. Histogram of Maximum Drift Load Intensity: (A) Drift Shape #2

Since drift shape #1 was both more common and more critical in terms of magnitude of load, this paper focuses on the characteristics of drift shape #1. These drifts are of more importance to design engineers. It is possible that drift shape #2 is simply an early form of drift shape #1, with drift shape #1 resulting as more snow accumulates. Whether this is in fact the case can only be answered by continuous monitoring of actual drifts during the accumulation process, which is beyond the scope of this present work.

EMPIRICAL RELATION FOR DRIFT LOADS

Drift Height

In order to design a structural system to resist drift loads, an engineer has to know both the magnitude and location of the loading profile. An empirical model must predict the drift height, length, and density of the snowdrift, and it must use as input parameters values which would be known to the engineer during design.

The process of determining an empirical relation began by performing simple correlation analyses between the long list of input parameters and characteristic drift load parameters. The charactistic drift load parameters were chosen to be the drift height, H_d, the cross-sectional area of the drift, $1/2\ H_dL_d$, and the peak drift load, $P_d(=H_d\gamma_d)$. Any one of these three parameters, when combined with a snow density and drift length/height relationship, would describe a snow loading profile.

The list of input parameters was shortened using two criteria. First of all, only those items which an engineer would likely know during design were considered further. Ground and upper roof snow depths and densities were thus eliminated. Secondly, input parameters which did not show significant correlation with the characteristic drift parmeters were eliminated.

One of the best simple correlation coefficients existed between the roof elevation difference and the drift height. These two variables are plotted in Figure 4. Note that the drift height rarely exceeds the upper roof elevation. For the few cases in which it did, depth of snow on the upper roof was not available from the case history information. Although it would be reasonable to assume the total drift height is equal to the total elevation difference plus the upper roof snow depth, these cases were omitted during the remaining analyses because of the lack of verifiable upper roof snow depth measurements. In most cases, the measured upper roof snow depth was negligible.

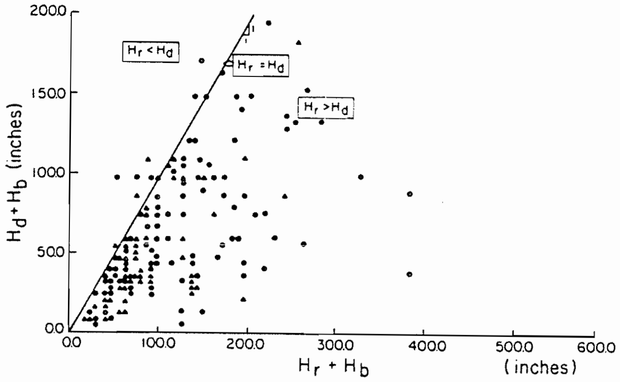

Figure 4. Scattergram of Total Drift Height versus Roof Elevation Difference

After using simple correlation analysis to narrow the list of potential input parameters, multiple linear regression was used to establish a precise relationship between them. The criteria used to establish the final set of input parameters was that a parameter would not enter the multiple linear regression equation unless the change in the coefficient of multiple determination was significant at the 90% level.

Empirical relationships were developed for each characteristic drift load parameter using three functional forms. The three functional forms, or variable transformations, considered were:

$$Y = A + BX1 + CX2 + DX3 + \ldots\ldots(\text{Linear-Linear}) \qquad (1)$$

$$Y = \ln A + B\ln X1 + C\ln X2 + D\ln X3 \ldots(\text{Linear-Ln}) \qquad (2)$$

$$\ln Y = \ln A + B\ln X1 + C\ln X2 + D\ln X3\ldots(\text{Ln-Ln}) \qquad (3)$$

where Y represents a characteristic drift load parameter such as the cross sectional area of the drift (1/2 H_dL_d), X1, X2, etc. represent input parameters such as the length of the upper roof (L_u), and A,B,C, etc. are constants or coefficients.

The resulting relationships were analyzed, and the associated multiple regression statistics were then compared. A few observations were made concerning the work that was involved in analyzing the relationships. First of all, although the upper roof elevation, the roof building width, ie. the dimension along the elevation change, and the lower roof elevation showed good simple correlation with the characteristic drift parameters, preliminary multiple regression analyses indicated that these parameters did not consistently enter the stepwise multiple regression procedure. That is, these parameters did not significantly improve the model for most cases using the entry requirements previously stated; they did not provide further explanation of the variance of the characteristic drift load parameters. The factors L_u, H_r, (P_g+10), and L_l consistently entered the regression procedure for all transformations.

A second point is that the parameter of (P_g+10) was used instead of P_g, the ground snow load, in the different multiple linear regression analyses. This is because the parameter (P_g+10) allowed the use of cases where the ground snow load was zero in all equations. Also, preliminary multiple regression analysis gave slightly better results when used with (Pg+10) instead of P_g, perhaps due to the above reasoning.

It was also observed that the upper roof length, L_u, the roof elevation difference, H_r, and the ground snow load were the three primary factors affecting drift height for almost all datasets analyzed. The lower roof length became more significant when only buildings with shorter lower roof lengths were considered. This implies that a "normal" drift is limited by the lower roof length if the lower roof length is short relative to the roof elevation difference.

Finally, it was observed that the linear-ln functional form gave good results for each characteristic drift load parameter. Correlation coefficients were relatively high, standard errors were low, and predicted results agreed with actual results when plotted against one another. Results were best when the drift height was used as the characteristic drift parameter. For this reason, the linear-ln equation (2) was selected for use and the drift height was chosen as the characteristic drift load parameter.

The selection of drift height, Hd, as the characteristic drift load parameter was based on two other considerations. First of all, the upper bound $H_d \leq H_r$ is easily taken into account when H_d is used, as opposed to, for example, the cross-sectional drift area 1/2 H_dL_d. Secondly, most empirical models in presently used codes and load standards use the drift height as the primary characteristic drift load parameter. The comparison of the empirical relation developed herein with codes and load standards would thus be facilitated.

In order to model drifted snow loads important to design, the selected multiple linear regression relationship for drift height given in equation (4), was based on case histories where peak drift load was greater than or equal to 30 psf (1.44 kN/m^2).

$$Hd=-9.275+1.216\ln(L_u)+1.514\ln(H_r)+1.209\ln(P_g+10)+0.362\ln(L_l) \quad (4)$$

In equation (4) the lengths (H_d, L_u, H_r, L_1) are in units of feet while the ground snow load P_g has units of psf.

The drift heights obtained from equation (4) were compared with actual values for <u>all</u> of the case histories and are plotted in Figure 5.

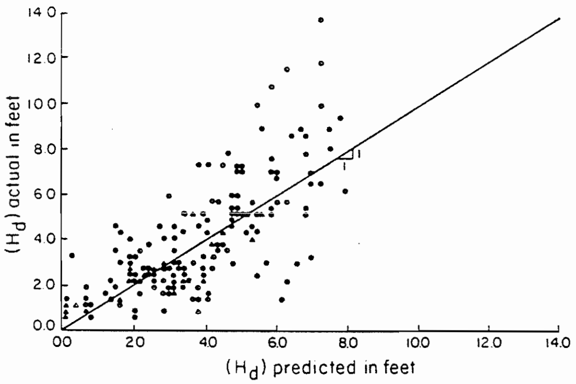

Figure 5. Scattergram of Actual Drift Height versus Predicted Drift Height

The slope of the least squares straight line through these points and the origin is 1.006, and the standard error of the drift height for this plot is 1.719 ft. Thus, equation (4), which was based on a datset containing drift loads greater than 30 psf (1.44kN/m2), is also sufficiently accurate for all load levels, including low loads.

<u>Drift Length</u>

Once the drift height is established, it is necessary to determine the drift length in order to fully describe the drift profile. Most building codes and load standards use a direct relationship between drift length and drift height. Analysis of the actual drift profiles in this study showed there was in fact a good relationship between the two parameters. Drift length is plotted versus drift height in Figure 6 for the 101 cases of drift shape #1 for which both measurements were available. The multiple correlation coefficient for this plot is 0.804 and the slope of the regression line is 0.228, or 1:4.4.

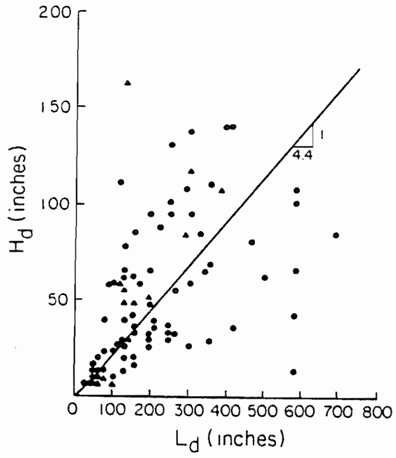

Figure 6. Scattergram of Drift Height versus Drift Length

Preliminary correlation analysis between the cross-sectional drift slope, H_d/L_d, and various site parameters, such as building and weather measurements, indicated that there were no significant or practical relationships. The best correlation coefficients were between drift slope and upper roof length, roof elevation difference, and upper roof snow measurements. The slope tended to be steeper for longer upper roof lengths and larger roof elevation differences, and flatter for higher values of upper roof snow depth, load, and percentage of coverage. These observations could be explained by intuition and physical reasoning, but statistical conclusions could not be made.

The relationship between drift height and drift length was also investigated by examining different subgroups of data to see if the drift slope, H_d/L_d changed under certain conditions. For the typical case where the lower roof was long enough so as not to influence the drift length ($L_1 \geq 5(H_r + H_b)$), and where the total drift height is less than the difference in roof elevation ($H_r - H_d < 6"$), drift slopes closely approximated 1:4. Drift slopes averaging about 1:5 or 1:6 were more common when the drift height was about equal to the roof elevation difference or the total peak load ($P_d + P_b$) was less than 30 psf. This corresponded to cases where the roof elevation difference was relatively low. It might thus be concluded that when there is continued snow available for drift accumulation and where the lower roof is long enough to accept additional blown snow, the "normal" 1:4 drift profile fills and additional snow ends up at the toe of the drift resulting in flatter slopes.

These findings are consistent with those of Finney (1939) and Tabler (1975), who have studied the process of drifting using wind tunnels and topographical catchments, respectively. Finney found that for vertical embankments with drifting to the top of the embankment, drift length was equal to 6.5 times the embankment height on downwind facing steps for heights between two and ten feet. Tabler found that drift length converged to a value close to 6.5 times the embankment height, but that flatter slopes were common for small embankment heights. In both studies, it was found that there was little accumulation on an embankment downslope of 1:6. It appears, therefore, that if a snowdrift fills an elevation difference with a slope of about 1:6, the profile is sufficiently streamlined so that additional drifting does not occur. For the common cases on multilevel roofs, though, where normal profiles are not full, where wind direction is random, and where total peak loads are important to design ($P_d + P_b \geq 30$ psf), the snow tends to accumulate at a 1:4 height to length ratio.

A histogram of the drift slopes, L_d/H_d, for the case histories in the database is given in Figure 7. Note that the substitution for H_b for cases missing H_b does not change the mean value of L_d/H_d significantly. The mean equals 4.96 in the figure for the datset using the substitution, it was 4.98 using the actual data only. Neglecting the upper regions of flat slopes, which were usually not associated with drift loads important to design in this database because they tended to be shallow, it can be seen that a 1:4 slope can be expected. Eighty percent of the L_d/H_d values for cases in the database fall between 1:1 and 1:6.

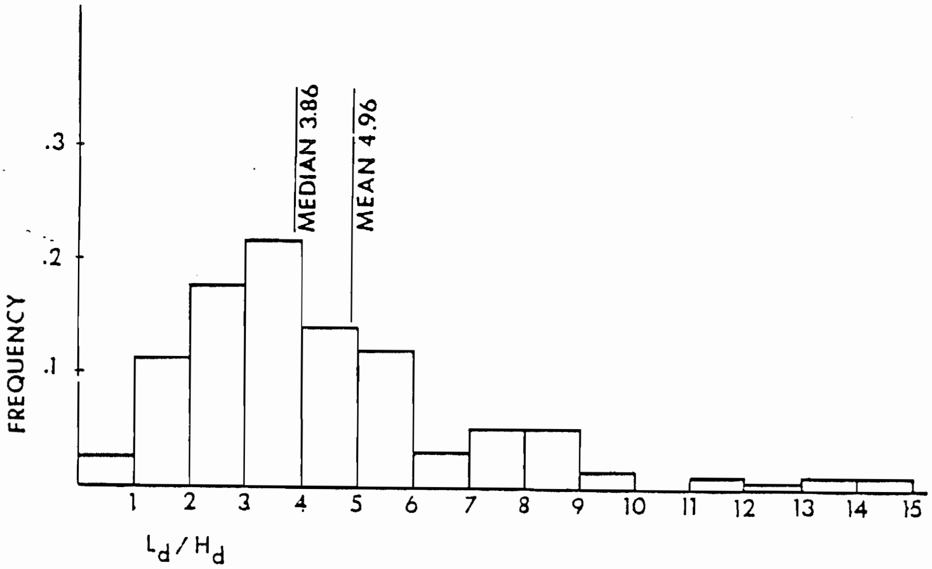

Figure 7. Histogram of Drift Slope, L_d/H_d

Drifted Snow Density

The density of drifted snow is needed in order to convert an expected drift shape profile into an expected drift load profile. For the 169 cases in the drift database for which drift density was available, the mean density was 15.6 pcf (215 kg/m3) with a standard deviation of 5.6 pcf (91 kg/m^3). A histogram of the data is shown in Figure 8. Some of the scatter in the data is naturally due to the fact that density measurements were made by a number of different individuals. Items such as sample location, time of sample measurement after initial deposition, and sampling technique could not be standardized because the case histories were obtained from a variety of sources. Note that Figure 8 suggests that the commonly used rules-of-thumb for density are unconservative for drifts. This observation is probably best explained by the fact that snow particles that form drifts have usually been dislodged and moved in a windy environment to where they are deposited. Particle sizes and air voids are thus likely to be smaller than they would be if the snow was deposited under calm weather conditions.

It would be useful to investigate the relationship between drifted snow density and various other parameters to see if there is another explanation for the variability in the snow density. It would be reasonable to assume that geographical location of site might be a factor affecting snow density as some locations might be characterized by different snow moisture contents. For the case histories in the database, there was no such relationship in evidence. For example, the average density for the eight failure cases in the Northeastern Coastal area for which snow densities were available was 17.2 pcf; it was 16.8 pcf for the 36 similar cases in the Midwest.

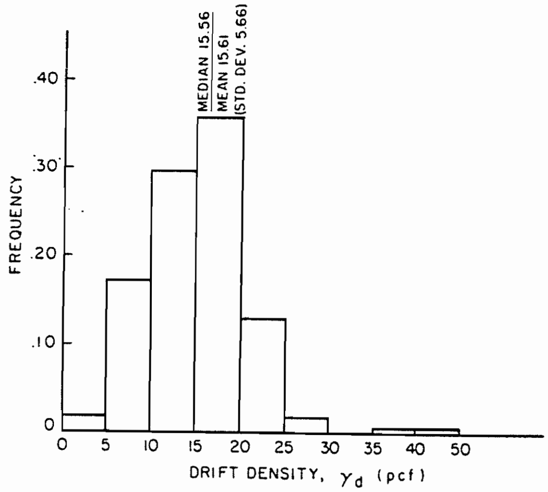

Figure 8. Historogram of Drifted Snow Density

One might expect drifted snow densities to increase with ground snow load or drift height. Although investigations have been performed by Tobiasson and Redfield (1973) relating ground snow load to a conversion drift density, a ratio between annual maxima of snow load and snow depth at a specific site, correlation coefficients between drift density and ground snow load as measured in this database were not conclusive, and standard errors of regression estimates were relatively high. The best relationship obtained is equation (5). The standard error of the estimate was 5.6 pcf.

$$\gamma_d = 13.8 + 0.13\ P_g \qquad (5)$$

There was one case history by Reidy (1978) in the database for which extensive measurements were made at various depths, and it was found that density of snow did increase with depth of drifted snow. It was also found that "older" drifts at lower depths had markedly higher snow densities. Data necessary to make generalizations was not available, as most case histories did not record the location or the time since deposition of the density measurement. It is felt that time since deposition is a major factor in determining drifted snow density; snow settles over time and under its own weight and, it can be expected that the density of the snow will increase the longer it sits and the higher it accumulates. However, controlled investigations are needed before conclusive statements can be made.

Since drift load, P_d, is the product of the drift height, H_d, and the drift density, γ_d, one expects a positive correlation between P_d, and γ_d.

This born out by the fact that for total drift loads greater than or equal to 30 psf (1.44 kN/m^2), the average density was 17.4 ± 4.9 pcf (280 ± 79 kgm^3), while for cases with total peak loads less than 30 psf, the average drift density was 10.4 ± 4.4 pcf (167 ± 71 kg/m^3). In order to model loads of importance to designers, a model drift density of 17.4 pcf (280 kg/m^3) is recommended.

ACCURACY OF EMPIRICAL RELATIONSHIP

As proposed herein, the predicted drift load is a function of the ground load, P_g, and the geometry of the multilevel building as characterized by the length of the upper roof, L_u, the length of the lower roof, L_l, and the roof elevation difference, H_r. The drift height, H_d, is given by equation (4) with an upper bound of H_r. The drift length, L_d, is taken as four times the drift height with an upper bound of L_l. Finally, the drift snow density is assumed to be 17.4 pcf (280 kgm^3). Figure 5 is a plot of the measured drift height, H_d, versus the corresponding value predicted by the empirical procedure. Figure 9 is a plot of the measured peak drift load, P_d ($=H_d \gamma_d$), versus the corresponding predicted value. The slope of the least squares regression line is 0.97 for Figure 9.

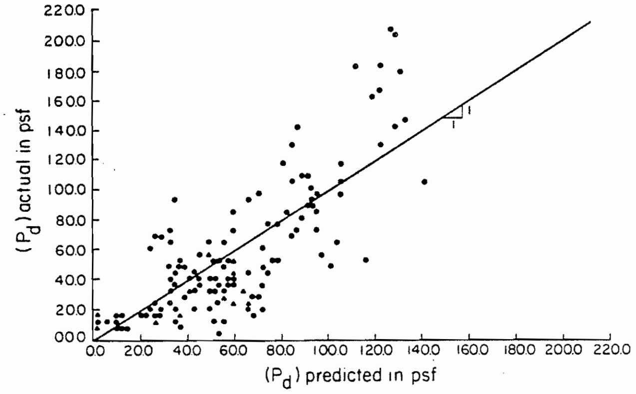

Figure 9. Scattergram of Actual versus Predicted Peak Drift Load

Although the empirical procedure overestimates drift loads for some cases and underestimates it for others, on average it provides fairly accurate estimates of the measured drift loads.

It is obvious that there are other factors influencing the formation of drifts on multilevel buildings. After all, the empirical procedure proposed herein which uses H_r, L_u, L_l, and H_r, as input parameters accounts for only about 50% of the total variation in the observed data. Although some of this scatter can be explained by the lack of controlled data gathering methods for a large part of the database, it is felt there are other factors which also contribute to the scatter of actual data points about the proposed empirical relation. One such factor is the specific wind condition at the time of drifting. It has been shown by Schmidt (1980) that the most important parameter to be considered when evaluating the horizontal transport of blown snow is the threshold wind speed, the wind speed at which a snow particle at rest begins motion. A function mainly of the cohesion of the snow surface, threshold wind speed governs how much snow will be blown at all wind speeds. Thus, careful measurement of the actual wind conditions at the time of drifting could explain much of the variability of the data about the proposed relationship.

The elevation of the roof above the ground showed relatively good correlation with the characteristic drift laod parameters. Although this measurement did not prove to be one of the most important factors as shown by the analysis summarized herein, the good correlation might indicate a tendency towards greater drifting with increased exposure and elevation. Wind speeds typically increase with elevation above the ground and building roofs that are high are typically less sheltered from wind. A more controlled investigation of the sites in the database would be required to provide validity to this observation, but the observation certainly agrees with the above reasoning concerning the importance of wind speed in determining drift loads.

Another factor closely related to wind which wasn't considered explicitly in the analysis because of its relative unavailability to design engineers, but which also may contribute to the scatter of data points about the empirical relationship, is the effect of blizzard conditions. Some of the drifts in the database were formed during blizzards, others were formed during more "normal" conditions. For "normal" conditions, the potential source for drifted snow is snow already present on the roofs. For blizzard conditons, an additional potential source is falling snow which is accompanied by high winds. It has been shown by Schmidt (1980) that the threshold wind speed decreases substantially if there is a source of snow particles, such as precipitating snow, that will help create initial snow transport. It is therefore reasonable to assume that the magnitudes of drifted snow accumulation are likely to be different under each weather condition.

Further analysis and research is required first to determine the critical combination of wind speed and amount of snow required to create drifting, and second, to determine a frequency of occurance of the critical conditions. That is, what magnitudes of wind speed result in critical snowdrifts under certain ground snow load conditons and how often do these occur together? In additon, wind direction and the time when the critical winds occur relative to the falling snow must be considered closely. It is felt by this author that most snowdrifting takes place when critical winds speeds occur during snowfall or immediately thereafter. A logical first step for this required research might thus be the specific investigation of blizzard conditions, since high winds and snowfall characterize such storms.

SUMMARY AND CONCLUSIONS

Information on snowdrifts from approximately 350 multilevel flat roofed structures gathered from a variety of sources has been analyzed. It was found that the right triangle drift configuration (drift shape #1) with the peak load intensity immediately adjacent to the roof elevation change is more common and also more critical in terms of load magnitude than the quadralateral drift shape (#2). The physical factors influencing drift configuration and loading profile for drift shape #1 were examined and an empirical relationship presented.

The purpose of this paper has been to provide an understanding of the primary physical factors that influenced the formation of a sample of actual snowdrifts on multilevel buildings, and the relative importance of these factors, so that an engineer can be more aware of the potential of drifted snow accumulation on similar shaped buildings. It was not the intent of this paper to provide a conclusive methodology that design engineers could use to design against a 50-year MRI snowdrift. More investigation is needed before it can be determined how the variable conditions of snow and wind relate specifically to the formation of critical snowdrifts.

Using probabilistic methods and statistical analysis, it has been demonstrated that the upper roof length, roof elevation difference, ground snow load, and lower roof length, repectively, are the most important factors that influence the formation and magnitude of snowdrifts on multilevel buildings. These factors not only best explain in astatistical sense the database of snowdrifts, they also provide physical and intuitive meaning to the process of drifting. The empirical relation presented herein utilizes these factors to predict drift height. For drifts of importance to structural design, the typical rise to run ratio was found to be about 1:4 and the average drift density about 17.4 pcf.

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