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THE EFFECTS OF BUILDING CONFIGURATION ON NATURAL VENTILATION COEFFICIENTS

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ABSTRACT:

Natural ventilation coefficient curves were generated using the NatVent 2.0 software, for naturally ventilated livestock building models with a total of 60 design variations including 5 building lengths, 2 sidewall opening heights, 3 ridge opening types, and the presence or absence of endwall openings. An average natural ventilation coefficient curve versus wind angle is also presented. As well, a general design natural ventilation coefficient has been developped and could be used without introducing major errors.

A new concept for a wind induced natural ventilation model is introduced in order to size adequately the necessary sidewall, roof and endwall openings with local weather data.

NOMENCLATURE

C_Q	=	natural ventilation coefficient for one wind angle for one building model.
C_{Q60}	=	average of the natural ventilation coefficients for 60 building models for a specific wind angle.
C_{Qave}	=	average natural ventilation coefficient over wind angles from 0° to 90° for a specific building model.
C_{QDE}	=	unique design natural ventilation coefficient for all wind angles and building models.

INTRODUCTION

Choinière (1991), Choinière et al (1992a) and Choinière et al (1992b) presented a methodology to predict wind-induced natural ventilation based on the pressure difference method. The basic pressure coefficient data were obtained from a study of scale models tested in a wind tunnel. However, presently a computer is needed to calculate the natural ventilation coefficients versus wind angle for each building having different sidewall, ridge or endwall openings.

The present research work considered the effects of building length, sidewall, ridge and endwall openings on the natural ventilation coefficients and attempted to develop a simplified and/or generalized equation for rapid, but reasonable, design of naturally ventilated buildings.

OBJECTIVES

A total of 60 models or variations of a naturally ventilated building were evaluated for wind angles from 0° to 90°, in 5° increments with the natural ventilation software, NatVent 2.0. (Choinière et al, 1992c). The model variations included five building lengths, two sidewall opening heights, three ridge openings and the presence or absence of endwall openings.

The objectives of this project were:

1 - to find the effects of building length, sidewall opening height, roof type and endwall openings on the natural ventilation rate coefficient, C_Q.
2 - to obtain a unique design natural ventilation coefficient, C_{QDE} , to be used in a simple design equation for wind-induced natural ventilation; and
3 - to propose a new wind induced natural ventilation model.

Effects of Sidewall Openings

The 1.07 m versus 0.76 m sidewall opening height represents a relative increase in the range of 28% to 38% of the total opening area, depending on the roof opening areas and the existence of endwall openings. Results presented in table 4 show some small effects of the sidewall opening heights. The effect of sidewall height was also small with the longer buildings, from 48.8 m to 73.2 m. However, with the 97.5 m and 121.9 m long buildings with chimneys, the C_Qs are lower with the 1.07 m sidewall height.

Effects of the addition of endwall openings

With endwall openings, the C_Q's with the 0.76 m sidewall opening height were generally greater then the C_{Q60}. For the 24.4 m long building, the endwall openings had a large effect on the natural ventilation coefficients.

In contrast, as shown in table 4 when the 1,07 m sidewall opening height was used, the relative importance of the endwall opening was reduced for all buildings lengths.

Effect of ridge opening

From the results of table 4, with the basic 24.4 m long model, the enlargement of the ridge opening area, from the use of chimneys to the 300 mm wide continuous ridge did not have a significant effect on the C_Q data. As discussed by Choinière et al. (1991), the relative pressure differences generated by the continuous ridge openings versus the sidewall or endwall opening are of similar order of magnitude. Consequently, the addition of 1 m^2 of opening at the ridge or on the sidewalls would increase natural ventilation airflows with roughly the same magnitude. Table 4 demonstrates the non-significant effect of the enlargement of the ridge opening area on the C_Q data for all building lengths with different sidewall heights and endwall openings.

Effects of building length with no endwall windows

The results from table 4 demonstrates the non significant effects of the building lengths on the C_Q data very little effect of anything except chimneys at 1.07 sidewall. The 24.4 m long building presented higher C_Q at 10 ° only as compare to all the other building lengths. With the 1.07 m sidewall heights and chimney configuration, the 97.5 m and 121.0 m long barn presented generally lowers C_Q data as compare to the other buildings.

Basically, the original wind tunnel test data from Choinière (1991) were obtained from a model proportionally scaled to simulate a 24.4 m long building. For longer buildings, the pressure coefficient data were redistributed along the building and extra pressure coefficients were generated according to the procedure explained by Suchorski-Tremblay et al. (1991). This methodology was developed based on the work of Akins (1976) who studied the effects of building lengths on pressure coefficients. His results showed that the pressure coefficients were largely modified near the end of the building (corner effect) but remained very constant otherwise. This would permit interpolation of coefficients from data obtained with a shorter building.

Where:

Q = wind induced natural ventilation
E_F = effectiveness factor,
0.2 to 0.3 for winds parallel to the building length
0.5 to 0.6 for winds perpendicular to the building length
V = wind speed, 50% of the average local wind speed
A_S = sidewall opening area; one side only

With this model, the effects of the ridge and endwall openings are not considered. As well, effectiveness coefficients ranging from 0.2 to 0.3 my lead to a 50% difference in the designed sidewall opening area. The use of 50% of the average local wind speed would appear to be a safety factor to accommodate for the general wind speed distribution curves. Also, this equation does not make reference to the type of animal to housed.

From the work of Choinière (1991), Zemanchik et al. (1991) and Choinière et al. (1992b), a more specific model could be used to predict wind-induced natural ventilation. For low-rise livestock buildings:

$$Q = C_Q V A_T \qquad (2)$$

Where:

C_Q = natural ventilation coefficient (function of wind angle: 0° to 360°)
V = wind speed
A_T = total opening area in sidewalls, roof and endwalls.

To use this equation to size the openings, the designer needs to have a complete set of wind speed and direction data. As well, a desired wind induced ventilation rate has to be selected by the designer to secure the success of natural ventilation.

Choinière et al. (1992d) presented the concept of the Level of Satisfaction for different animal species. Consequently, the NatVent 2.0 software was calibrated to use this model in order to suggest proper openings areas for different locations across Canada (Choinière et al. 1994a and Choinière et al., 1994b).

From this work a simple model is currently under investigation,

$$Q_S = C_L C_A C_{QDE} A_T \qquad (3)$$

SUMMARY AND CONCLUSION

Natural ventilation coefficient curves were generated using the natural ventilation software, NatVent 2.0, for a series of 60 naturally ventilated livestock building models. These models were modified with 5 building lengths, 2 sidewall opening heights, 3 ridge opening types and the presence or absence of endwall openings.

The results show that every building configuration produced a different curve of the natural ventilation coefficients versus the wind angles. The highest deviation from the average curve for all building configurations were observed for wind angles between 5° to 30° and 60° to 90°. As well, deviations tended to be greatest for the configuration of the shortest building, and presençe of endwall openings. Generally, all building lengths, sidewall and roof opening seem to have only a small effect on the generalised C_{Q60} curve.

Finally, a design natural ventilation coefficient of 0.1464 ± 0.0030 (1 STD) could be used in a proposed general design equation for sizing the openings in naturally ventilated buildings.

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Table 4. Comparison of C_Q and C_{Q60} for different building configurations and wind angles; situations where C_Q is outside range of C_{Q60} ± 2 Std. are noted.

Sidewall Opening Height (m) / Roof Type (mm)	0.76 Chimney	1.07 Chimney	0.76 150 Ridge	1.07 150 Ridge	0.76 300 Ridge	1.07 300 Ridge
Building Length (m)			Endwall windows open			
24.4	+: 15°, 20°, -: 60°, 65°, 70°, 75°	-: 55°	+:10°,15°, 20°,25°,30° ,35°,40°		+: 10°,15°, 20°, 25°, 30°, -: 70°, 75°, 80°, 85°, 90°	
48.8		-: 50°			-: 80°, 85°,90°	
73.2		-: 45°, 50°			-: 0°	
97.5		-: 45°, 50°			-: 0°	
121.9		-: 45°, 50°			-: 0°	-: 5°
Building Length (m)			No endwall windows			
24.4	+: 10°		+: 10°		+: 10°, 15°	
48.8						
73.2						
97.5	+: 0°	-: 25°, 30°,35°, 40°,45°				
121.9	+: 0°	-: 20°, 25°,30°, 35°, 40°, 45°				

Refer to Table 3 for the C_{Q60} values and standard deviations values.

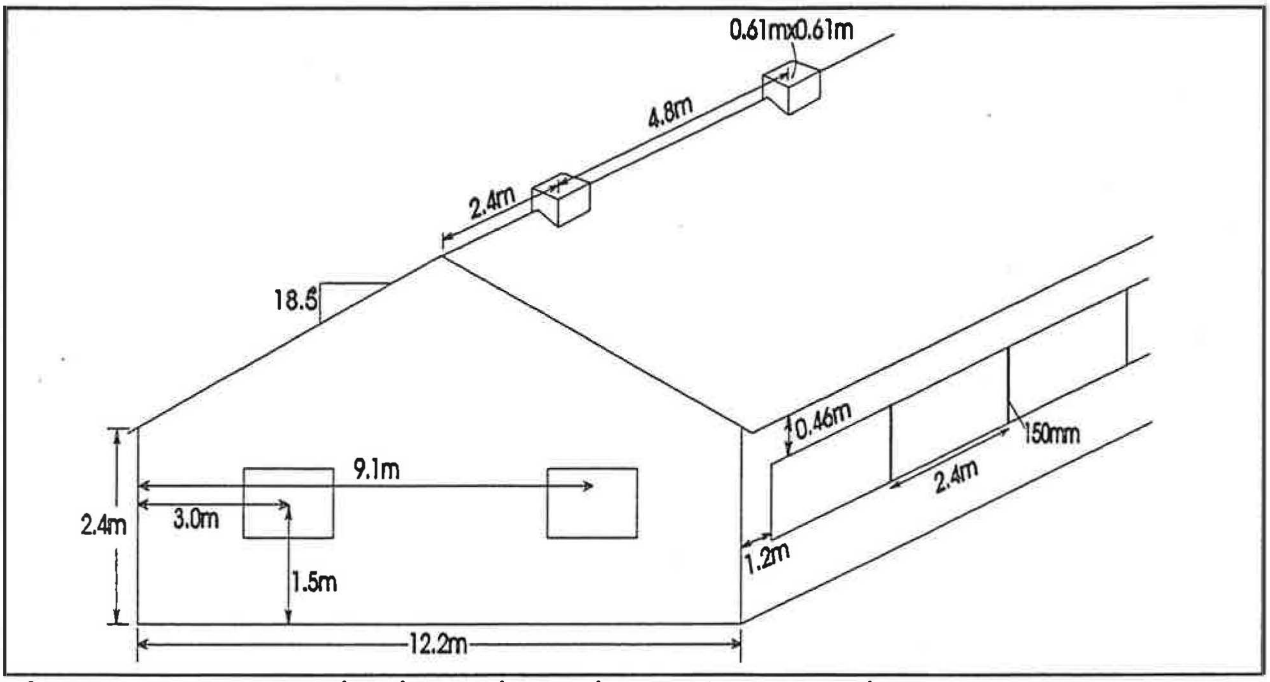

Figure 1 Building dimensions that remained constant for all models tested

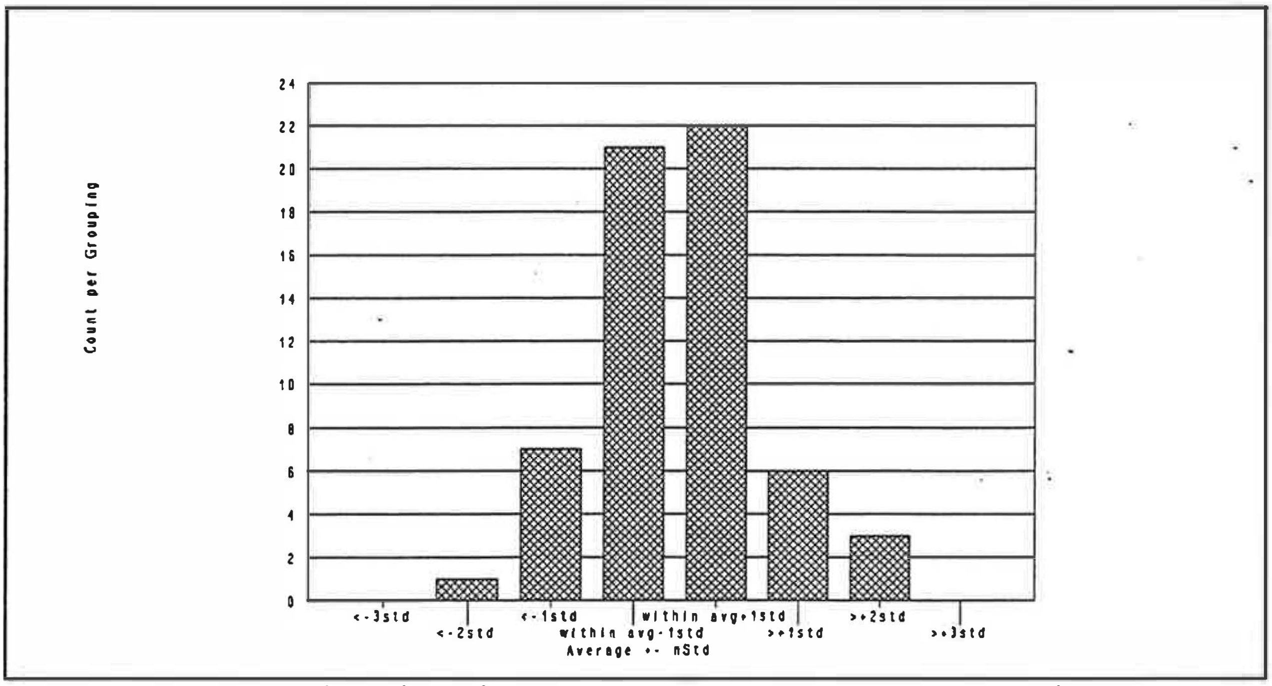

Figure 2 Distribution of the 60 C_Q for the 20° wind angle.