THUNDERSTORM DOWNDRAFTS FROM THE POINT OF VIEW OF BUILDING DESIGN

R.Panneer Selvam[1] and J.D.Holmes[2]

[1] University of Arkansas
[2] CSIRO, Division of Building, Construction and Engineering

INTRODUCTION

Maximum design winds recorded in many places in Australia and the U.S. are due to thunderstorm downdrafts. Oliver [1] reported that about 50% of maximum gusts in Sydney and Brisbane are due to thunderstorms, and Vickery [2] suggested that about 25% of annual gust maxima recorded at Observatory Hill in Sydney could be associated with thunderstorms. In the U.S., Thom [3] reported that about one third of extreme winds recorded in the U.S. were associated with thunderstorms.

An intense downdraft lasts from 2 to 30 minutes depending on the type, and can induce damaging winds as high as 75 m/s. A downdraft wind profile is different from a developed boundary layer (DBL) wind profile as observed in gales and tropical cyclones. Typical velocity profiles due to a thunderstorm downdraft and due to a DBL are compared in Figure 1. Profiles in downdrafts often display a maximum close to the ground, with lower velocities in the upper part of the outflowing layer of cold air. Fujita [4], using Doppler radar, found maxima at about 50 metres from the ground in Project NIMROD. Maxima at about 100 m from the ground were observed in the field for three thunderstorm gust fronts at Cape Kennedy, and three at Oklahoma City by Sinclair et al [5], and at Bald Hills near Brisbane by Sherman [6].

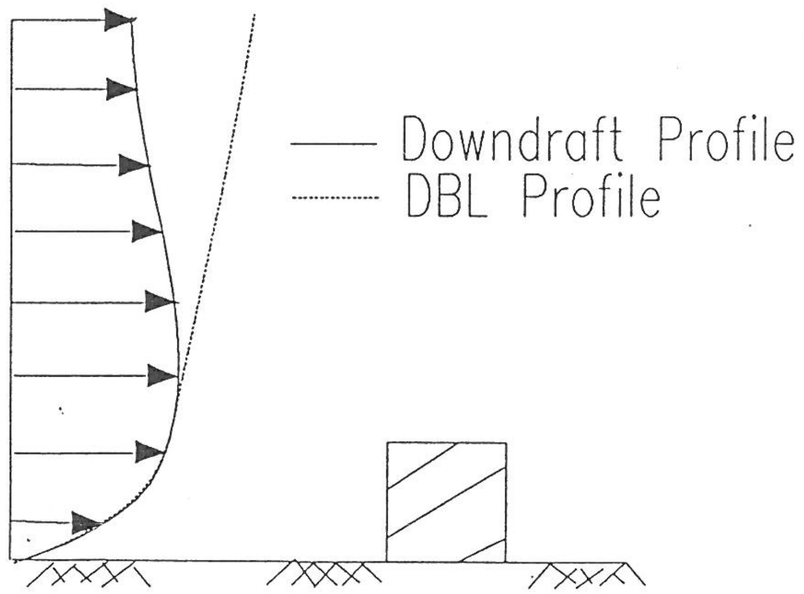

Figure 1. Velocity profiles due to thunderstorm downdrafts and developed boundary layers

Current building codes and standards for computing wind forces on structures, e.g.[7], have multipliers for height and terrain based on DBL profiles. The reference wind speed is usually that at 10 metres height above open country terrain. Even if the extreme wind are caused by thunderstorm downdrafts, a logarithmic or power law profile, monotonically increasing with height, is usually applied for design purposes. Thus at locations where the extreme winds are dominated by thunderstorms, current design procedures may be conservative for structures taller than about 50 metres.

When wind flows over hills, ridges and escarpments, the wind speed increases. Recent building codes and standards have included this effect through the use of "Topographic Multipliers", [7,8]. These Multipliers are normally based on DBL profiles in the approach flow. The aim of the work described in the present paper was to produce a simplified computer model of a thunderstorm downdraft, and to study the effect of topography on the downdraft wind profiles.

COMPUTER MODELLING

A thunderstorm downdraft was modelled as a two-dimensional, incompressible, steady, neutral jet impinging normally on a ground plane. Although the density differences and transient effects have been ignored in this simplified model, it is believed to be suffiently similar to a real thunderstorm wind for the present preliminary investigations for structural design purposes.

The equations of the flow were the Navier-Stokes equations with the turbulence represented by the k-e model, [9] The equations were solved numerically using finite volume approximations. A downdraft with a width of about 1 km at 2.7 km above the ground was considered.

RESULTS

The computed velocity profile above the flat level ground near the point was found to be very similar those measured in the field by Fujita [4], and computed by more sophisticated numerical models of downdrafts, with a maximum at about 50 metres above the surface.

A flat-topped ridge (embankment), as shown in Figure 2, was then incorporated in the model at the point of maximum velocity on the surface. The predicted velocity vectors are shown in Figure 3. The computed Topographic Multipliers at the upwind end of the crest of the ridge are compared with those computed for DBL flow, and specified in AS1170.2-1989 [7] in Table 1. Clearly, the computed values for the downdraft are much less than those expected in boundary-layer flows. Thus wind loads on structures in these situations may be overestimated by current procedures.

CONCLUSIONS

This study has indicated that, for locations where thunderstorm downdrafts are the dominant sources of extreme winds,

a) wind forces on structures taller than 50 metres on flat level ground may be overestimated using current design procedures, and

b) wind forces on topographic features (hills, ridges, escarpments) may also be overestimated, because the Topographic Multipliers are less for downdraft flow than for DBL flow.

Table 1. Comparison of Topographic Multipliers

Source	Topographic Multiplier at various heights			
	5m	15m	25m	35m
AS1170.2 (hill/ridge)	1.75	1.65	1.55	1.45
AS1170.2 (escarpment)	1.33	1.28	1.24	1.20
Computation (b.l. flow)	1.56	1.36	1.31	1.26
Computation (jet flow)	1.20	1.11	1.08	1.07

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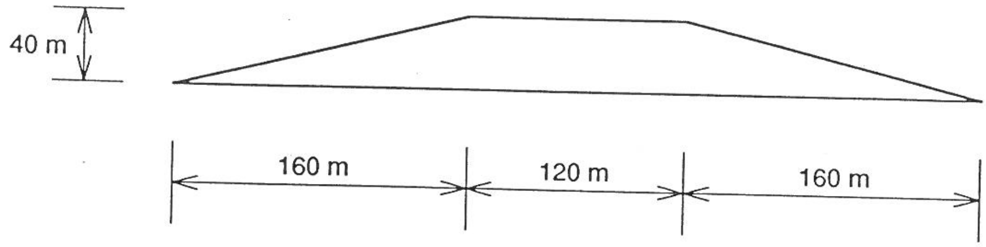

Figure 2. Flat-topped ridge used in the simulation

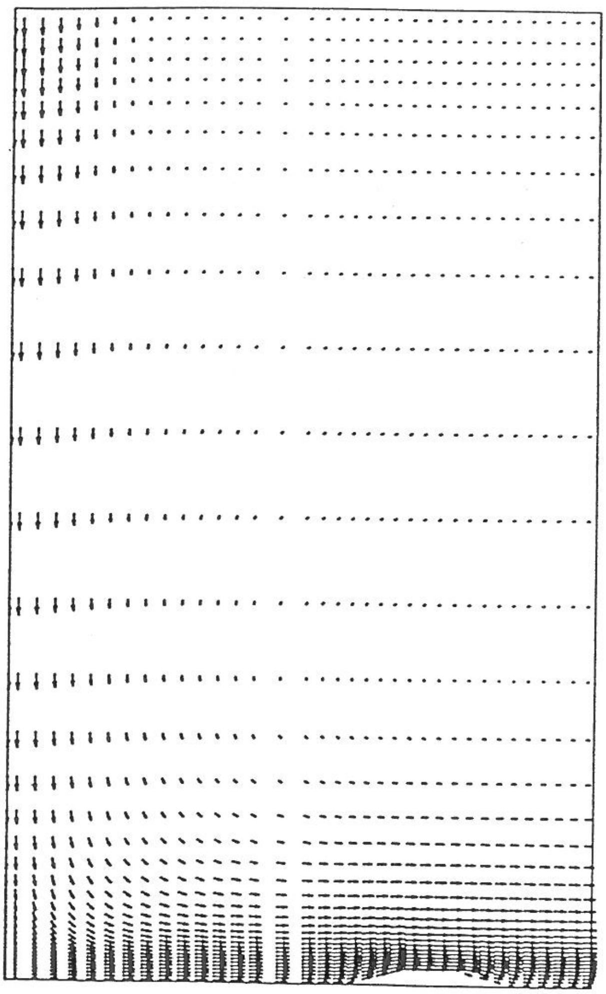

Figure 3. Velocity vectors for jet flow over a ridge