WIND LOADS ON HIP END ROOFS

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INTRODUCTION

Studies mainly carried out on buildings with flat roofs and gable-end roofs are the basis for data given in wind load standards such as AS 1170.2 (1989). Wind tunnel studies on hip-end roofs, since carried out by Meecham et al (1991), and Xu and Reardon (1998) have shown that local peak suction pressures are generally smaller than on a comparable gable-end roof. Post windstorm damage investigations also indicate lower levels of damage to hip-end roofs compared with gable-end roofs of similar construction, inferring smaller wind loads on hip-end roofs. In Australia house designs are generally subjected to "deemed to comply" provisions, with wind loading design based on data contained in AS 1170.2. The draft revision of AS/NZS1170.2 provides updated pressure coefficients for hip-end roofs of a range of roof pitches.

A gable-end roof consists of gable-end trusses at each end wall and regularly spaced "common" trusses in between. The structural system at a hip-end is more complex, with many interconnecting members. Creeper rafters are attached to the hip rafter and the jack rafters are supported by the girder truss which also supports the hip rafter. Roof wind loads are transmitted via hold-down connections on all four walls of the hip-end roof house, unlike the gable-end roof house where the gable-end walls are generally non-loadbearing.

Meecham et al (1991) studied the loads on 18.4° pitch gable-end and hip-end roofs, and showed that the overall roof uplift loads were similar on both types of roofs, but areas near the windward end on the gable-end roof were subjected to larger suction loads compared to hip-end roofs. Xu and Reardon (1998) found that the worst local peak suction pressures near the hips and ridges of hip-end roofs were smaller than those on the gable-end for roof pitches of 15° and 20°, but were of similar magnitude for a roof pitch of 30°.

This study is carried out to determine the wind pressure distribution on the hip-end of the roof of a typical house which is rectangular shaped in plan and has a roof pitch between 10° to 30°. The results of this study will provide more accurate design data and enable more efficient design of cladding and structural components on roofs (ie. battens, trusses) and may be used for reviewing data in the draft AS/NZS 1170.2

WIND TUNNEL TEST

The wind tunnel tests were carried out in the 2.0 m high × 2.5 m wide × 22 m long Boundary Layer Wind Tunnel at the School of Engineering at James Cook University. The approach wind flow was satisfactorily simulated at between terrain categories 2 and 3 (as per AS 1170.2) at a length scale of 1/50. This study was carried out on models at a length scale of 1/50 of rectangular plan 14m (b) × 7m (d) × 3m eaves height (h) hip-end roof houses with roof pitches (α) of 15°, 20° and 30° shown in Figure 1. The detailed study was carried out on the hip-end house with a 20° roof pitch which has eaves overhangs and verges of 0.6m. The cladding is attached to battens placed 900mm apart across rafters or trusses spaced at 900mm intervals. Pressure taps were located on the top surface of the roof and the underside of the eaves and verges, to measure the pressures acting on batten-rafter/truss connections. Pressure taps on the hip-end houses with 15° and 30° roof pitches were located on the same grid as that used by Xu and Reardon (1998).

External pressures were obtained on the roof for approach wind directions (θ) of 0° to 90° at intervals of 15°. The pressure signals were sampled at 500 Hz for 24 secs for a single run, and analysed to give mean, standard deviation, maximum and minimum pressure coefficients as;

$C_{\bar{p}} = \bar{p}/(\frac{1}{2}\rho\bar{U}_h^{\,2})$, $C_{\sigma_p} = \sigma_p/(\frac{1}{2}\rho\bar{U}_h^{\,2})$, $C_{\hat{p}} = \hat{p}/(\frac{1}{2}\rho\bar{U}_h^{\,2})$, $C_{\breve{p}} = \breve{p}/(\frac{1}{2}\rho\bar{U}_h^{\,2})$ where, $\frac{1}{2}\rho\bar{U}_h^{\,2}$ is the mean dynamic pressure at roof height (ie. ridge height for θ = 90° and eaves height for all other wind directions). The results were obtained from averaging the data from five separate runs.

PRESSURE DISTRIBUTIONS

The variation of mean, standard deviation, maximum and minimum pressure coefficients with wind direction θ, on the 15°, 20° and 30° pitch, hip-end roofs are given in Kane (1999). The mean pressure coefficients for θ = 0°, 45° and 90° on the 20° pitch, hip-end roof are given in Figures 2(a), (b) and (c) respectively. The largest peak pressure coefficients measured on the 15°, 20° and 30° pitch, hip-end roofs are given in Figures 3(a), (b) and (c). These values which are used for design of cladding and fixings may be compared with corresponding C_{peak} data derived from AS/NZS 1170.2 for θ = 0° and 90°, calculated by multiplying Cp with the local pressure factor K_l and the velocity gust factor $G_U^2 = (1.875)^2$. Figures 3(a), (b) and (c) show that flow separation near the eaves, ridge and hip lines generate large peak suction pressures ranging from –3.55 to -4.78 to –4.87. The equivalent C_{peak} derived from AS/NZS 1170.2 for these edges is –4.23, compared with a value of –6.34 obtained from using data in AS 1170.2 (1989).

CONCLUSIONS

A wind tunnel model study was carried out at a length scale of 1/50 to determine pressure distributions on the roofs of typical rectangular plan low-rise houses with 15°, 20° and 30° pitch hip-end roofs. These pressures compared with data derived from AS 1170.2 (1989). The following conclusions are reached, based on the wind tunnel study and data analysis;

- Regions near the eaves, ridge and hip lines on 15°, 20° and 30° pitch hip-end roofs are subjected to large suction pressures. The peak suction pressure coefficients at these locations are smaller in magnitude than the values prescribed in AS 1170.2 (1989), which are based on studies on gable-end roof houses.
- The Cps specified in the revised draft AS/NZS 1170.2 on upwind (U), downwind (D) and side slopes (R) of hip-end roofs for approach wind directions θ = 0° and 90° provide more satisfactory design pressures for cladding and fixings.

REFERENCES

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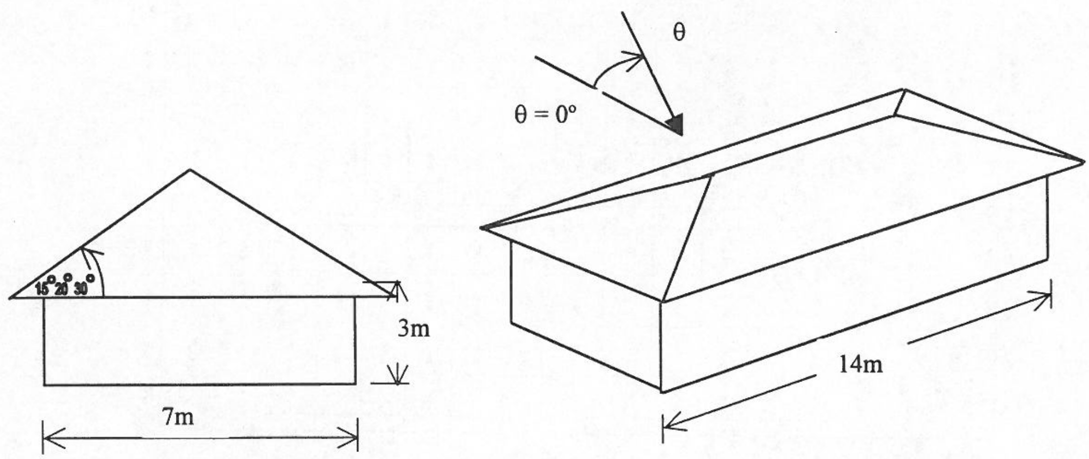
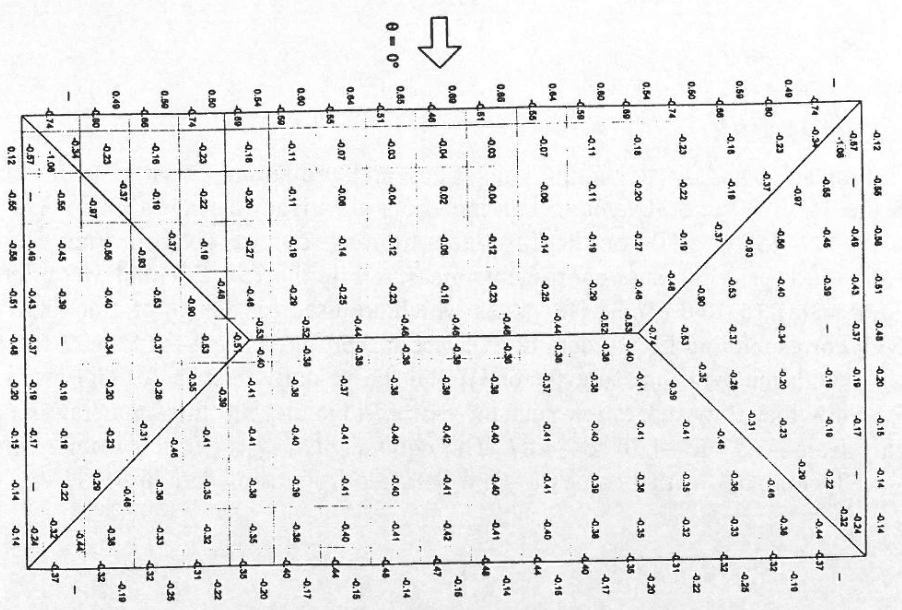


Figure1 14m (b) × 7m (d) × 3m (h) hip-end roof houses with roof pitches (α) of 15°, 20° and 30°

(a)



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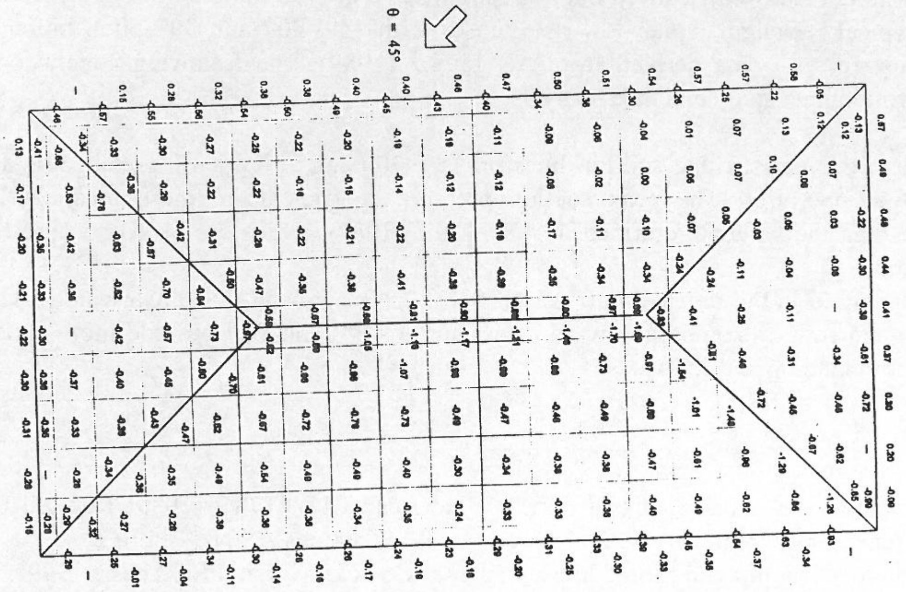

(c)

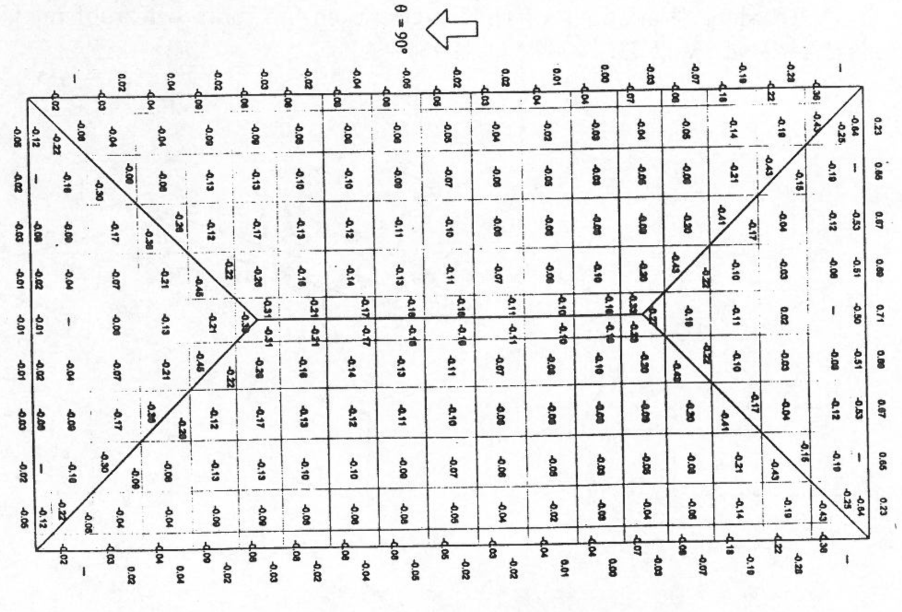

Figure 2 Mean pressure coefficients on 20° pitch hip-end roof, (a) θ = 0° (b) θ = 45° and (c) θ = 90°

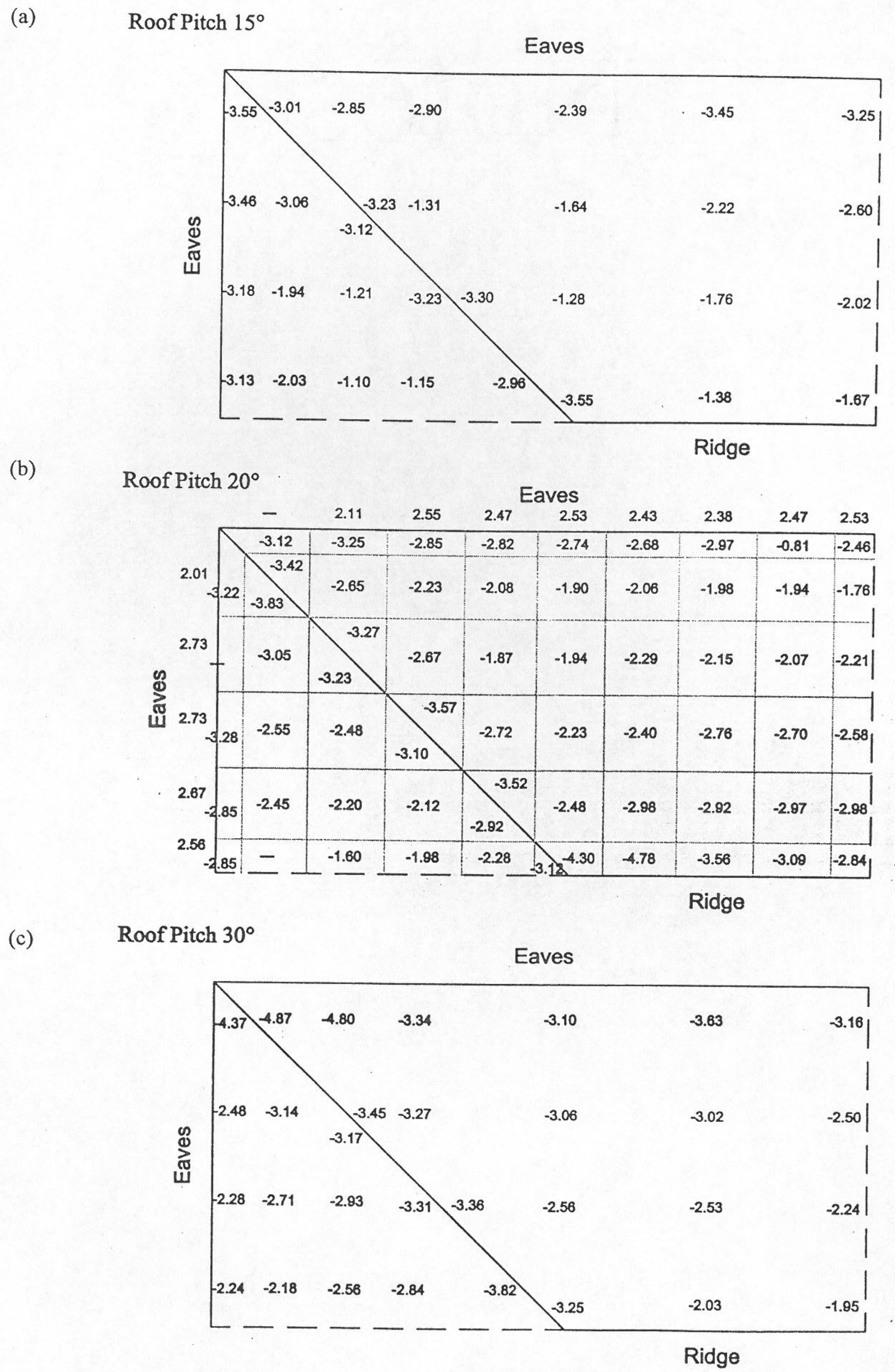

Figure 3 Largest peak pressure coefficients on hip-end roofs, (a) $\alpha = 15^o$ (b) $\alpha = 20^o$ and (c) $\alpha = 30^o$