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COMPREHENSIVE STUDY OF WIND-INDUCED TORSIONAL LOADS ON LOW- AND MEDIUM-RISE BUILDINGS

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1. INTRODUCTION

This paper summarizes the findings of extensive wind tunnel parametric investigations on wind-induced torsion acting on rectangular flat- and gable-roofed buildings. Experiments collected data for different configurations in terms of terrain exposure, wind direction and building height. In addition, wind load combinations (i.e. shear forces and torsion) in transverse and longitudinal building directions were examined. Comparisons with the results obtained from provisions specified in current design standards and codes of practice were also carried out. Three building models (scaled at 1:400) have the same horizontal dimensions (length = 61 m, width = 39 m) but with different gabled-roof angles (0º, 18.5º, and 45º). All building models were tested at different eave building heights (6, 12, 25, 30, 40, 50 and 60 m) in open and urban terrain exposures for different wind directions (every 15º). Figure 1 presents the three building models in addition to a schematic representative of external pressure distributions on building envelope at a certain instant, the exerted shear forces (F_X, F_Y) and torsional moment (M_T). The synchronized wind tunnel measurements are presented in terms of pressures, shear, and torsional coefficients.

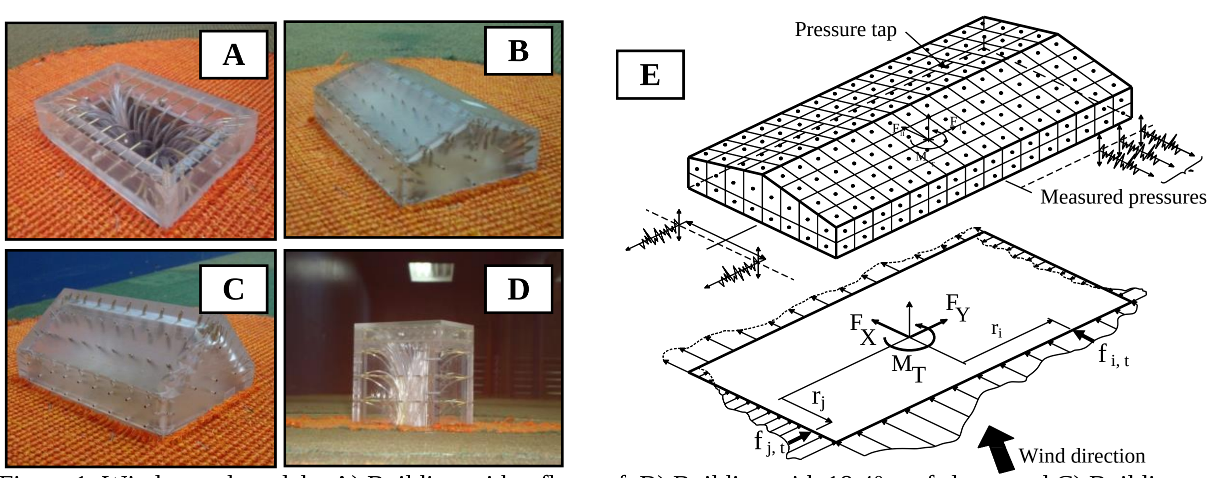


Figure 1: Wind tunnel models: A) Building with a flat roof, B) Building with 18.4º roof slope, and C) Building with 45º roof slope; D) Height extension part for all building models, E) Instantaneous wind pressure distributions, generated wind forces (F_X, F_Y) and torsional moment (M_T)

2. WIND TUNNEL MEASUREMENT RESULTS

Figure 2 presents the variation of the maximum torsion coefficient ($|C_T|_{Max} = M_{T\,max} / (0.5\rho V^2 B^2 L)$) with wind direction for the two buildings tested at different heights. As can be seen from the figure, $|C_T|_{Max}$ has increased significantly when the building height was increased from 6 to 60 m for both buildings with 0° and 45° roof angles. The lowest torsional coefficients are found for wind direction around 60° for all heights. The $|C_T|_{Max}$ occurs for wind directions ranging from 15° to 45° for the first three buildings (6, 12, 20 m) while for the other heights, another peak torsional coefficient zone has been recorded for wind directions between 75° and 90°. This may be attributed to different characteristics of wind flow interactions with buildings of heights lower than 20 m, particularly flow reattachment and 3-dimensionality compared to taller buildings.

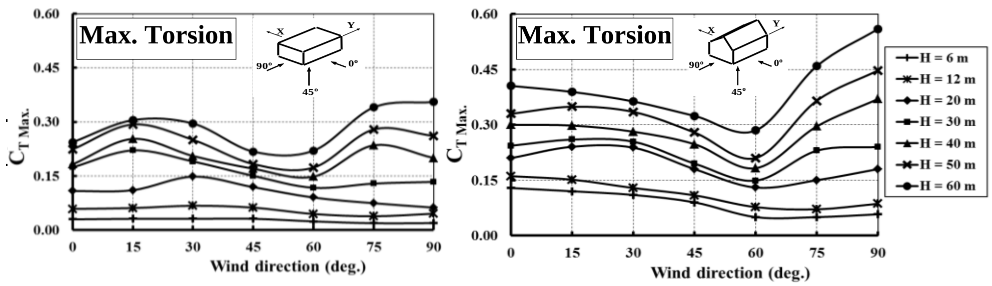
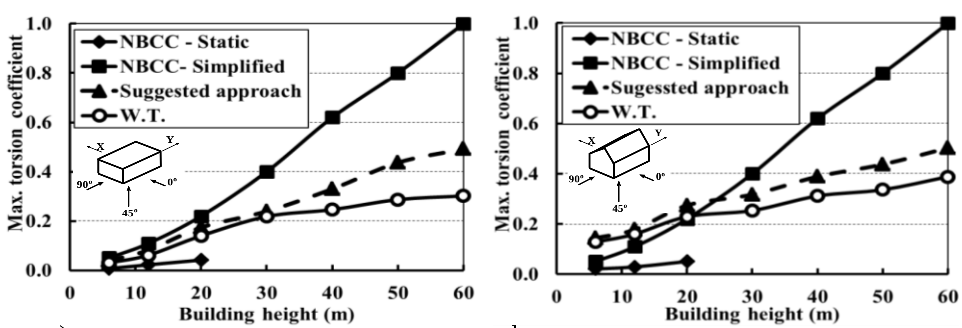


Figure 2: Variation of peak torsion coefficient ($|C_T|_{Max}$.) with wind direction for the tested buildings with flat and gabled roof

2.1 Comparisons with the current Canadian and American wind load provisions

The wind tunnel results have been compared with the Canadian and American provisions for all the buildings tested. Two main load cases (i.e. torsion load case: maximum torsion and corresponding shear, shear load case: maximum shear and the corresponding torsion) were examined. The results indicate that, while the American (ASCE7-10) provisions agree in most cases with the experimental data, the Canadian (NBCC 2010) code underestimate wind-induced torsional loads significantly on low rise-buildings. Significant discrepancies in both provisions found for medium-rise buildings. The current study introduced new design wind load cases that adequately include torsion in order to contribute to the enhancement of the current building codes and standards. The suggested approach introduces significantly lower torsion compared to the current provisions, as it can be seen in Figure 3.



a) b

Figure 3: Comparison of torsional load case evaluated using NBCC (2010) and wind tunnel measurements for buildings with 0° and 45° roof angles (Transverse direction)

3. CONCLUSIONS

Wind-induced torsional loads on low- and medium-rise buildings have been examined in the boundary layer wind tunnel. The experimental results show that wind-induced torsional moment is significantly affected by building geometries, wind directions and terrain exposures. Comparison of the wind tunnel results with current torsion provisions in the American wind standards and the Canadian wind codes demonstrate significant discrepancies. Suggested wind load cases were introduced aiming at an adequate evaluation of wind load effects on rectangular low- and medium-rise buildings. Significant differences were found between the suggested approach and current wind-induced loads provisions.

REFERENCES

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