Implication of Simplified Terrain Categories in the Singapore Annex to EuroCode 1

Thambirajah Balendra
Department of Civil Engineering
National University of Singapore
Singapore

1. Background

As reported in APEC2009 workshop (1), in order to adopt the Eurocode 1 for wind loads, Singapore National Annex to SS EN 1991-1-4:2009 has been prepared and now being published by SPRING Singapore (2). Simplifications are made to terrain categories, and the implication of this simplification is discussed in this article.

2. Terrain Categories and Basic Wind Speed

In the Singapore National Annex to Eurocode 1, the roughness categories has been simplified as given in Table 1. Thus all structures will be designed using a country terrain, except the low rise roof structures within 2 km from the sea which are designed using a sea terrain. The basic wind speed is specified as 20m/sec, which is 10 minutes mean wind in open/country terrain at 10m height for 50 year return period. This is an equivalent wind speed and not the actual wind speed recorded which is about 18.5 m/sec. The adjustment is made to account for the effects of higher wind speed in sea terrain. The equivalent wind speed also accounts partly for the gustiness caused by thunderstorm winds which are better represented by 3sec gust rather than 10minutes mean wind.

Table 1: Roughness parameters

Type of structures	Roughness Length (m)
1. Low rise roof structures up to 25m height within 2km from the sea	0.003
2. All structures except the ones under item 1	0.05

3. Implication of proposed terrain categories

The implication of the proposed terrain categories on low rise roof structures and high rise buildings are illustrated in Tables 2 and 3. Comparison is made with CP3 (3) using a basic wind speed of 33m/sec for 3 sec gust.

As seen from Table 2, for roof structures in sea terrain, using basic wind speed of 20m/sec instead of 18.5m/sec will overestimate the lift loads by 17%. However, if a basic wind speed of 18.5 m/sec is used then for the case of no opening the Singapore Annex will underestimate the loads by 10% compared to CP3 for Terrain 1. This justifies for a higher basic wind speed and with 20m/sec the load computed by Singapore Annex will be 5% higher. It is also evident from Table 3 that in order for the high rise buildings in sea terrain are not under- designed using a country terrain(Cat II instead of Cat 0), it is necessary to use a higher basic wind speed of 20m/sec instead of 18.5 m/sec. Furthermore, any overestimation of loads for buildings in a city terrain due to higher basic wind speed is not more than 40%.

Table 2: Uplift forces on low rise roof structures

Sea Terrain	21m tall roof structure	
	No opening	With opening
EN Cat 0 (20m/sec)/ EN Cat 0 (18.5m/sec)	1.17	1.17
EN Cat 0 (18.5m/sec)/ CP3 Terrain 1 (33m/sec)	0.90	1.3
EN Cat 0 (20m/sec)/ CP3 Terrain 1 (33m/sec)	1.05	1.5

Table 3: Base shear on high rise buildings

	16 Storey Building (48m)	25 Storey Building (80m)	40 Storey Building (135m)
EN Cat II (20m/sec)/ EN Cat 0 (18.5m/sec)	1.03	1.0	1.05
EN Cat II (20m/sec)/ CP3 Terrain 1(33m/sec)	1.25	1.2	1.2
EN Cat II (20m/sec)/ CP3 Terrain 3(33m/sec)	1.4	1.3	1.3

4. Conclusion

Through examples on low rise roof structures and high rise buildings, it is shown that when a basic wind speed of 20m/sec is used in the proposed simplified terrain categories of the Singapore Annex to Eurocode 1, the wind loads will be comparable to the loads that are being used when CP3 is used. Any overestimation will have small impact on the cost as the overall loads are still small due to low wind speeds in Singapore. In fact when these high rise buildings are founded on soft soil, the tremor loads may govern the design (4).

5. References

1. T. Balendra T and SC Tan, “Report on recent development on wind code in Singapore”, Proceedings of 5th Workshop on Regional Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies(APEC-WW2009), Tamkang University, Taiwan, 2009.
2. Singapore National Annex to Eurocode 1: Action on structures; Part 1-4 General actions-Wind actions, SPRING Singapore, 2009
3. CP3:Chapter V: Part 2: Wind Loads, Code of basic data for the design of buildings, British Standard Institution, 1972.
4. T Balendra and Z Li, “Seismic hazard of Singapore and Malaysia”, Special Issue on earthquake engineering in the low and moderate seismic regions of Southeast Asia and Australia, Electronic Journal of Structural Engineering, 2008, pp. 57-63.