Exascale Quantification of Uncertainties for Technology and Science Simulation

D7.1 - DELIVERY OF GEOMETRY AND COMPUTATIONAL MODEL

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Summary

This document describes the industrial application, on which the developments of the project are implemented, and the CFD set-up. The developments are implemented over six analysis cases with increasing complexity starting from a 2D geometry with mean wind inflow to a 3D geometry with turbulent inflow and real-time shape optimization. The application represents the CAARC tall building model, which has served as a benchmark model for many studies since the 1970's when it was first developed. Base moments (bending and torsional moments) of the building are extracted for validation by comparison of the results with the benchmark study.

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Nomenclature / Acronym list

Acronym	Meaning
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
v_{ref}	Reference wind speed
z_{ref}	Reference height
α	Power law exponent

1 Introduction

There is a great potential applying advanced computational wind engineering methods in the field of high-rise structures, as there is an increasing need worldwide to build more and slender, and hence wind prone, high-rise structures in densely urbanized parts of the world. A high-rise building is therefore chosen as the industrial application, on which the developments of the project are implemented.

1.1 Benchmark study

To be able to validate the wind forces on the structure, the numerically obtained results has to be compared with either wind tunnel tests or on-site measurements. In this study the comparative *International high-frequency base balance benchmark study* [3] will act in this purpose.

The initiative for the benchmark study was taken during a meeting held at the 12^{th} International Conference on Wind Engineering in July 2007 [3]. The study was conducted between the years 2007 and 2011 where eight international wind-tunnel laboratories carried out independent tests and subsequently presented their results for comparison [3].

The study was carried out on two prescribed tall building models.

- A "basic" building model intended to serve as a benchmark for newer test groups.
- An "advanced" building model intended to serve as a benchmark for more experienced test laboratories.

The former of the two is a metric version of the Commonwealth Advisory Aeronautical Council (CAARC) standard tall building model [4] which is hereinafter the model used in this study.

1.2 CAARC standard tall building

The CAARC standard tall building model was developed in 1970 [6] for analysis of wind loading on tall buildings. It has since then been one of the more popular high-rise building models for wind tunnel studies, as it originally was developed for, but has in recent times also been used extensively as application for numerical CFD analysis [1].

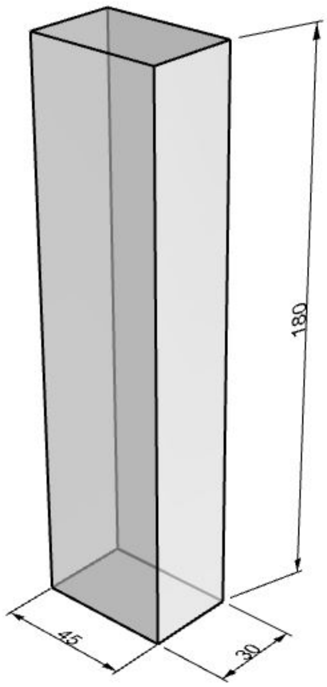

Figure 1: Dimensions of the CAARC standard tall building model [m].

1.3 Target values

It is known that only base moments are not sufficient for designing a structure. However, due to the complexity of the developments that are to be implemented the target values are chosen as simple as possible but at the same time sufficient enough to be able to validate the study.

The benchmark study presents resulting mean base moments (bending and torsional moments) of the building, shown in Appendix B. Mean base moments are thus used as target values also in this study.

2 CFD set-up

2.1 Turbulence modelling and inflow conditions

The Large-Eddy Simulation (LES) is used throughout the study to model the turbulence.

To model the natural wind conditions at the inlet the velocity boundary condition is separated into one mean wind part and one fluctuating part, described in the equation below.

$$v_i(z,t) = \bar{v}_i(z) + v_i'(z,t) \tag{1}$$

The mean wind part is generated using the power law (cf. chapter 2.2) and the fluctuating part is generated by an algorithm described by Jakob Mann [5].

2.2 Wind parameters

The mean wind profile is generally described by the power law.

$$\bar{v}(z) = v_{ref} \left(\frac{z}{z_{ref}} \right)^{\alpha} \tag{2}$$

The parameters that describes the wind profile depend on local design wind speeds and the terrain. The parameters to be used in this study are corresponding to the ones used in the benchmark study and are presented in the table below.

Table 1: Wind parameters to be used in the study.

Parameter	Value
v_{ref}	20 [m/s]
z_{ref}	10 [m]
α	0.25

2.3 Computational domain and orientation

It is recommended to place the inlet surface, the lateral surfaces and the top surface 5H away from the building and the outlet surface 15H away from the building (6H×10H×20H), where H is the total height of the building, according to the guidelines of CFD simulations in wind engineering [2].

These recommendations generates a quite big and expensive computational domain, the effects of a smaller computational domain was therefore investigated by Daniels et al. It is stated that the results obtained with a smaller domain (4H×8H×10H) were consistent with the results obtained with the bigger domain [1], the smaller domain was thus used throughout their study.

With the aim of doing the analysis more economic the size of the computational domain of the present study will follow those used by Daniels et al.

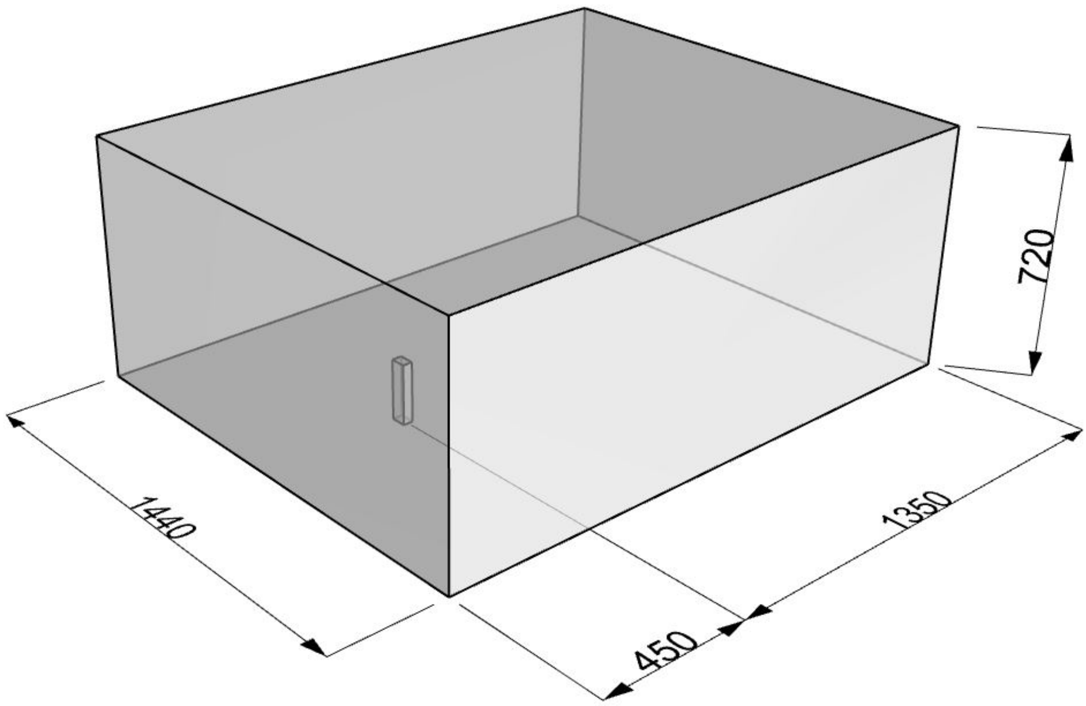

Figure 2: Dimensions of computational domain.

The orientation of the building is chosen to align with that from the benchmark study (cf. figure 3).

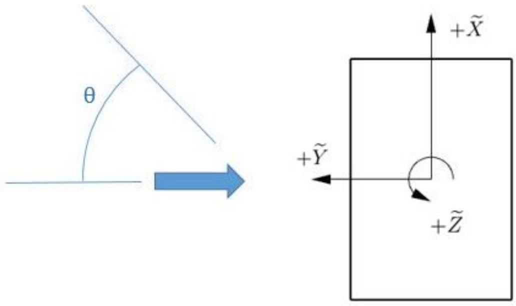

Figure 3: Local orientation of the building.

2.4 Boundary conditions

The boundary conditions are chosen in line with the benchmark study. The lateral surfaces and the top surface are set to symmetry-planes and a no-slip condition is assigned on the bottom of the domain and on the walls of the CAARC building [1, 3].

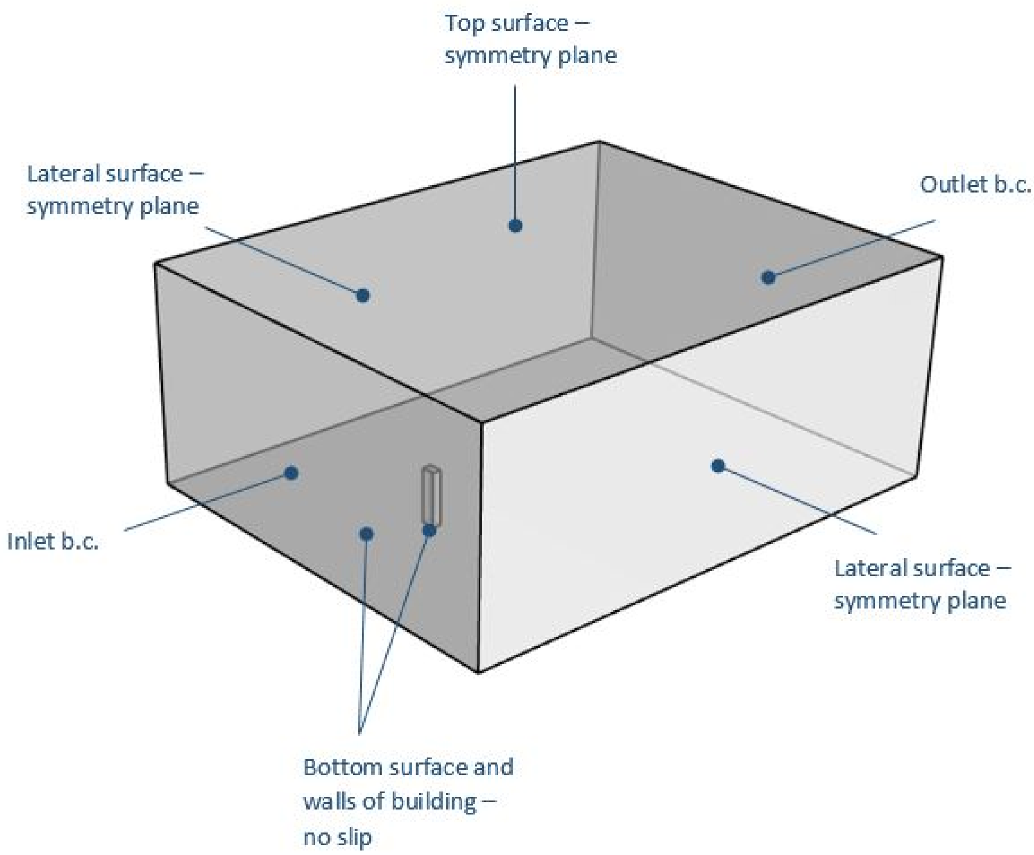

Figure 4: Boundary conditions.

3 Deliverable

A CAD model of the CAARC building can be delivered to the PO if required.

Appendix A Analysis cases

The complexity of the analysis is gradually increased over six analysis cases where the basic set-up for each individual case is presented below.

A.1 Case 1

Geometry:	2D 30x180 [m]
Computational domain:	1080x3600 [m]
Inflow conditions:	Mean wind profile
Morphing:	None
Target value(s):	Base moment $M_{\tilde{X}}$

A.2 Case 2

Geometry:	2D 30x180 [m]
Computational domain:	1080x3600 [m]
Inflow conditions:	Turbulent wind profile (Mann model)
Morphing:	None
Target value(s):	Base moment $M_{\tilde{X}}$

A.3 Case 3

Geometry:	3D 30x45x180 [m]
Computational domain:	1080x1800x3600 [m]
Inflow conditions:	Mean wind profile
Morphing:	None
Target value(s):	Base moments M_i $(i = \widetilde{X}, \widetilde{Y}, \widetilde{Z})$

A.4 Case 4

Geometry:	3D 30x45x180 [m]
Computational domain:	1080x1800x3600 [m]
Inflow conditions:	Mean wind profile
Morphing:	Real-time shape optimization
Target value(s):	Base moments M_i $(i = \widetilde{X}, \widetilde{Y}, \widetilde{Z})$

A.5 Case 5

Geometry:	3D 30x45x180 [m]
Computational domain:	1080x1800x3600 [m]
Inflow conditions:	Turbulent wind profile (Mann model)
Morphing:	None
Target value(s):	Base moments M_i $(i = \widetilde{X}, \widetilde{Y}, \widetilde{Z})$

A.6 Case 6

Geometry:	3D 30x45x180 [m]
Computational domain:	1080x1800x3600 [m]
Inflow conditions:	Turbulent wind profile (Mann model)
Morphing:	Real-time shape optimization
Target value(s):	Base moments M_i $(i = \widetilde{X}, \widetilde{Y}, \widetilde{Z})$

Appendix B Benchmark results

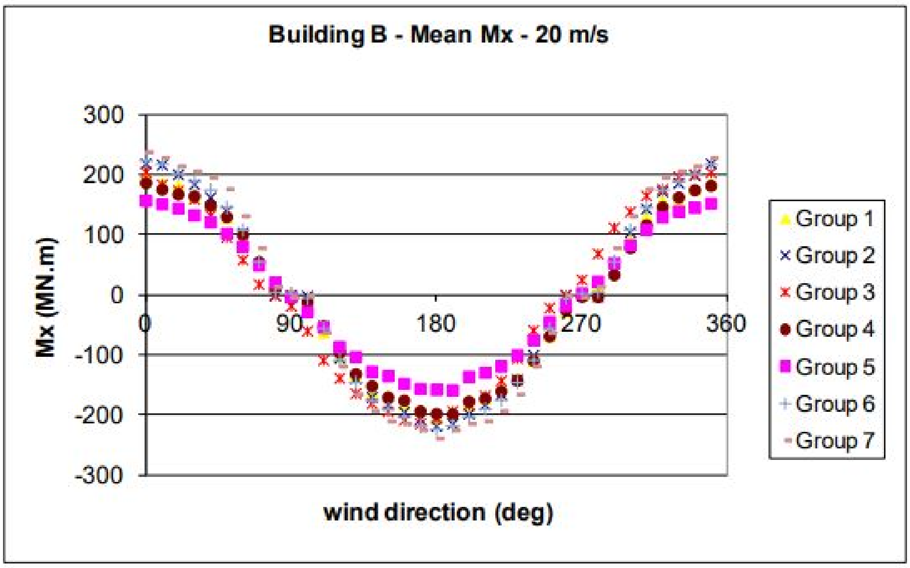

Figure 5: Mean base moments around local $\widetilde{X}$-axis for the seven test groups [3, 4].

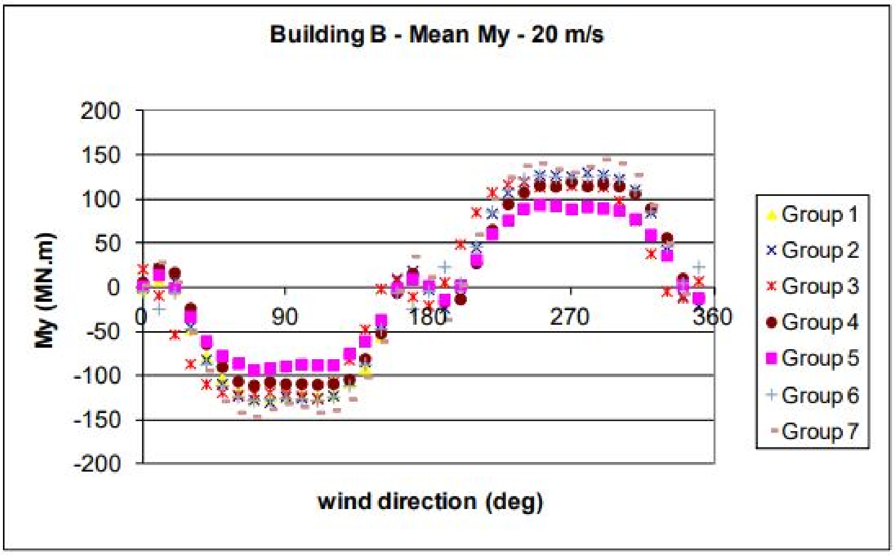

Figure 6: Mean base moments around local $\widetilde{Y}$-axis for the seven test groups [3, 4].

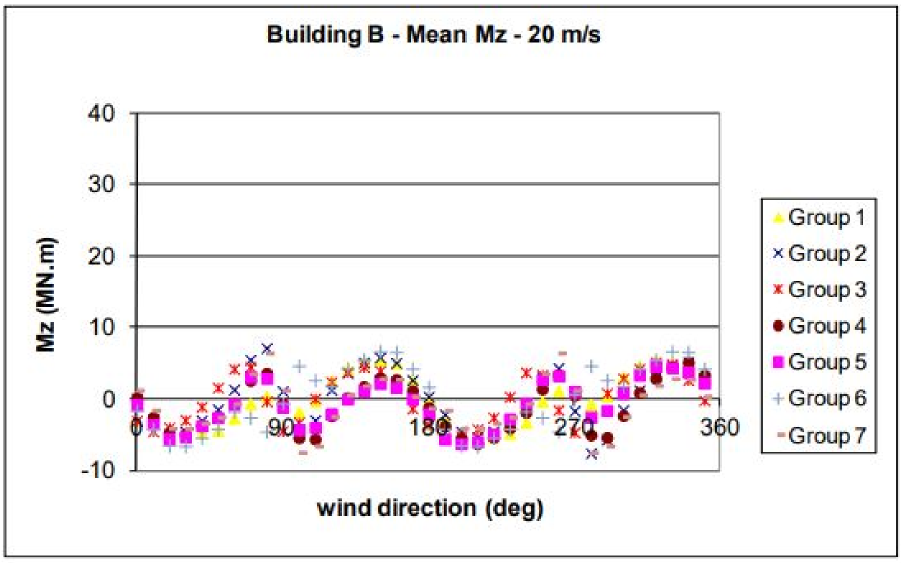

Figure 7: Mean base moments around local $\widetilde{Z}$-axis for the seven test groups [3, 4].

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