LOTUS Guidelines

CFD Simulation

Use Computational Fluid Dynamic (CFD) to calculate the weighted average air speed within a space

Content

1. General

1.1 Scope

These guidelines have to be followed when CFD is used for compliance with:

- Credit E-3 Natural Ventilation and Air-conditioning in LOTUS BIO V1
- Credit E-3 Natural Ventilation and Air-conditioning in LOTUS NR V2.0.
- Credit E-4 Building Cooling in LOTUS NC V3.

1.2 Background

In the credits and strategies on Natural Ventilation in the Energy category of LOTUS BIO V1, LOTUS NR V2.0 and LOTUS NC V3, spaces can be considered as naturally ventilated when it is justified by using CFD that the weighted average air speed within these spaces is satisfactory. This document is providing the methodology that projects should follow in order to perform a CFD analysis compliant with LOTUS requirements.

1.3 Computational Fluid Dynamics (CFD)

CFD is part of fluid mechanics which uses numerical data to solve problems related to fluid flows. It is a modelling technique that can provide data regarding airflow and temperature distribution throughout a building. CFD can be helpful for green design as it can be used to develop a natural ventilation system specific to each projects by optimising and modelling building-site plans and indoor layouts.

2. Modelling Requirements

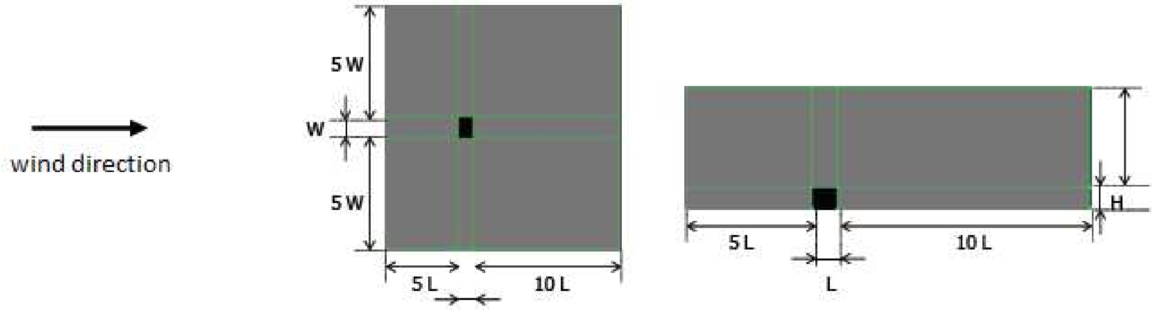
2.1 Software

The CFD software shall have the minimum capability of solving the Navier-Stokes fluid flow equations for a three-dimensional incompressible flow at steady state on a body conforming computational grid. Turbulence modelling shall also be included with the minimum requirement of using $k - \varepsilon$ turbulence model, coupled with standard wall function. The tool should also include calculations for buoyancy, turbulent convection, and the ability to do open boundary modelling.

2.2 Domain sizing

Building with height H_n may have a minimal influence if its distance from the region of interest is greater than 6-10H_n. Thus, as a minimum requirement a building of height H_n should be represented if its distance from the region of interest is less than 6H_n.

A domain size of 11W x 16L x 6H is recommended, in which W, L, and H are the dimensions of the building as shown below:



2.3 Meshing

In the area of interest, at least 10 cells per cube root of the building volume should be used and 10 cells per building separation to simulate flow fields. This must be understood as an initial minimum grid resolution.

With regard to the shape of the computational cells, hexahedra are preferable to tetrahedra. On walls the grid lines should be perpendicular to the wall.

2.4 Boundary conditions

Inflow boundary: At the inflow an equilibrium boundary layer is usually prescribed, at a distance of at least 5H_{max}. The mean velocity profile shall be obtained from a logarithmic profile with reference height at 10m. See Climate data section for determining the wind speed at the reference height.

For RANS simulations: Information about the turbulence quantities are required. A simple solution is to process a preliminary simulation in an empty domain, in which periodic conditions is set between the inflow and the outflow conditions: at each iteration i+1, inflow conditions are set as equal to the outflow conditions at the past iteration i.

For LES simulations: Time dependent boundary conditions are required. Artificial stochastic inflow data generation methods based on statistical description of turbulence or Synthetic Eddy Method (SEM) can be used.

Wall boundary: At solid walls the no-slip boundary condition is used for the velocities. For the shear stress at smooth and rough walls, two different approaches are available: the so called low-Reynolds number approach (smooth walls only) and the wall functions method (smooth and rough walls).

Top boundary: The prescription of a constant shear stress at the top, corresponding to the inflow profiles, is recommended.

Outflow boundary: Open boundary conditions are used. These are either outflow or constant static pressure boundary conditions. For LES, convective outflow boundary conditions should be used.

2.5 Climate data

The climatic **wind condition** used for the CFD simulations shall be based on the table 2.16 of QCVN 02:2009/BXD - Vietnam Building Code Natural Physical & Climatic Data for Construction or from meteorological data on the precise wind direction and velocity of the proposed site location.

Air temperature shall be determined using the monthly average maximum temperature values (*Nhiệt độ không khí cao nhất trung bình tháng và năm)* taken from the table 2.3 of QCVN 02:2009/BXD Vietnam Building Code Natural Physical & Climatic Data for Construction for the closest city to the project.

Table 1: Air temperature condition for CFD simulation

Maximum monthly average high temperature T (°C)	Air temperature condition for the simulation (°C)
N < T < N+1	N+2

2.6 Time step size

If the relevant frequency range can be estimated, then the time step should be adjusted to provide at least 10 - 20 steps for each period of the highest relevant frequency. Another method to estimate the time step in advection dominated problems is the relation:

$$\Delta t = CFL\frac{\Delta x_{min}}{U_{max}}$$

in which Δx_{min} is the minimum grid width, U_{max} is the maximum velocity and CFL is the Courant-Friedrichs-Lewy number.

3. Modelling Methodology

- All simulations should be realised following the Modelling Requirements (§2)

- 3 simulations to be realised for the 3 hottest months using the prevailing wind conditions. The prevailing wind is the wind that blows the most frequently. The direction and speed of the prevailing wind should be used for the simulations.

- Calculate the area weighted average air velocity inside each of the naturally ventilated spaces for the 3 simulations. The area-weighted average air velocities of these spaces are to be computed at horizontal plane 1.2m above the floor level.

- Calculate the average area-weighted average air velocity of the naturally ventilated spaces for the 3 hottest months as the average of the 3 simulations area-weighted average air velocities previously calculated.

- Will be considered as naturally ventilated under LOTUS requirements, any space that have an area-weighted average air velocity equal or higher than the values specified in the Table 2.

Table 2: Minimum area-weighted average air velocity requirements

Maximum monthly average high temperature °C	Average air velocity required (m/s)
30 < T°C < 31	0.2
31 < T°C < 32	0.5
32 < T°C <33	0.8
33 < T°C	1

4. Submission Requirements

A report on the CFD simulation shall be submitted and shall include:

- Methodology
    - Describe methodology used in the study
- Geometrical model
    - Isometric view of the development from various angles
    - Domain size used
    - Plan and 3D isometric model of spaces
- Simulation setting
    - Boundary conditions
    - CFD software/models used/numerical scheme
    - Mesh sizing used
    - Solution control-convergence criteria
- Results and discussions
    - Simulation results for all directions showing the main graphical plots of the plan pressure and velocity vector
    - List of spaces and the area-weighted average wind velocity where applicable
    - Calculation of percentage of spaces with effective natural ventilation, i.e. an area-weighted average air velocity meeting the requirements in Table 2.
- Conclusion

5. Example – Climate data for Hanoi

Air temperature values to use in the simulations:

Table 3: Extract of table 2.3 of the Vietnam Building Code Natural Physical & Climatic Data for Construction – monthly average maximum temperature values

Station	Month												Year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Hà Nội	19,7	20,1	22,9	27,2	31,4	32,9	33,1	32,3	31,2	28,8	25,3	22,0	27,2

As per Table 3, the 3 hottest months of the year in Hanoi are June, July and August and the maximum monthly average high temperature is in July with 33.1 °C. The simulation model shall then be carried out under isothermal condition of 35°C air temperature at steady state condition for the month of July and of 34°C for the months of June and August.

Wind conditions to use in the simulations:

Table 4: Extract of table 2.16 of the Vietnam Building Code Natural Physical & Climatic Data for Construction - frequency with no wind (PL %), frequency (P %) and wind velocity (V m/s).

Wind direction	Charac-teristic	Month											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
No wind	PL	20,0	15,7	15,0	13,1	11,8	17,1	18,0	22,1	23,9	22,1	25,9	25,6
N	P	11,6	9,1	5,2	3,9	4,7	4,4	4,0	6,4	11,4	16,3	15,7	12,4
	V	2,5	2,3	2,3	2,2	2,5	2,2	2,4	2,1	2,3	2,4	2,5	2,4
NE	P	27,4	27,8	19,1	10,7	9,1	7,8	6,6	8,6	11,9	16,3	20,9	22,4
	V	2,9	2,9	2,7	2,7	2,6	2,1	2,1	2,1	2,4	2,4	2,7	2,9
E	P	7,6	9,1	12,6	15,4	14,1	13,1	12,9	11,5	7,8	6,2	6,8	7,0
	V	2,1	2,1	2,1	2,3	2,3	2,0	2,2	2,1	2,1	2,0	1,9	2,0
SE	P	21,6	28,2	37,5	45,5	43,2	34,2	34,8	24,3	16,3	15,6	14,5	17,7
	V	2,7	2,7	2,7	2,8	2,8	2,5	2,5	2,2	2,0	2,2	2,3	2,4
S	P	3,3	4,3	5,8	6,8	7,5	9,4	9,8	6,5	4,9	4,0	2,9	3,4
	V	2,3	2,2	2,3	2,5	2,4	2,2	2,3	2,0	1,7	1,8	1,9	2,0
SW	P	1,1	0,9	1,0	1,4	2,7	4,4	4,3	3,6	2,6	1,5	1,4	1,1
	V	1,5	1,6	1,7	1,7	1,9	2,0	1,9	1,7	1,6	1,5	1,6	1,4
W	P	1,7	1,2	1,1	1,1	2,5	3,6	4,3	6,6	6,2	4,3	2,9	3,0
	V	1,3	1,5	1,4	1,6	1,7	1,9	2,2	2,0	2,0	1,7	1,6	1,6
NW	P	5,7	3,7	2,8	2,0	4,3	6,1	5,2	10,4	15,0	13,8	9,0	7,5
	V	1,8	1,7	1,6	1,8	2,3	2,6	2,4	2,3	2,3	2,2	1,9	1,8

Simulations should use the prevailing wind conditions during the 3 hottest months which, for Hanoi, are June, July and August. In this period, the prevailing wind direction is South-east.

Table 5: Summary of the climate data to use in the simulations for Hanoi.

Climate data to use in simulation	June	July	August
Air temperature	34°C	35°C	34°C
Prevailing wind direction	SE	SE	SE
Wind velocity	2.5 m/s	2.2 m/s	2.2 m/s