

Centre Scientifique et Technique du Bâtiment

SIMULATING CLIMATE IN WIND TUNNEL : WHY DO IT AT FULL SCALE ?

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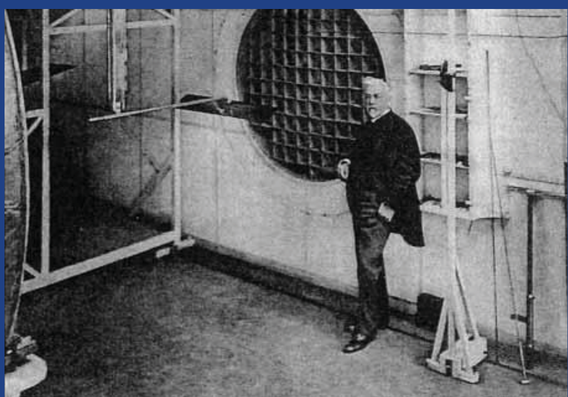
Downscaling in fluid mechanics

Since the first wind tunnels exist, downscaling has been an essential task in aerodynamics

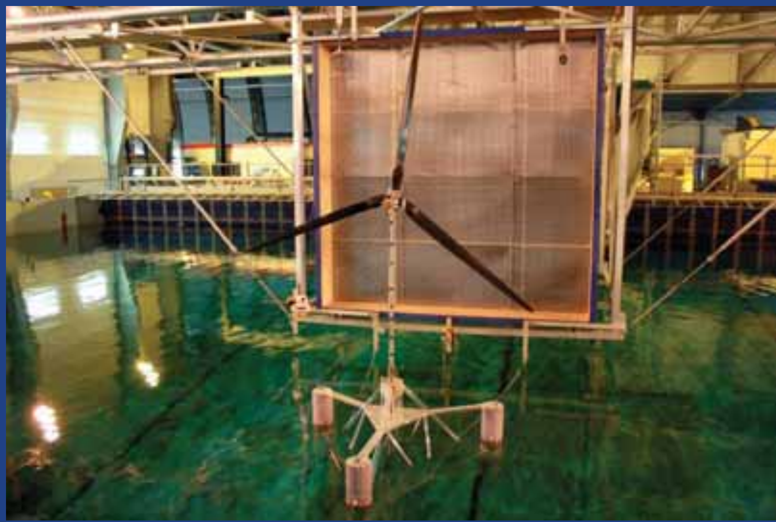



Gustave Eiffel's aerodynamic laboratory
this wind tunnel is still operating today

Downscaling in fluid mechanics

Not only wind tunnels, but other fluid simulators are used for reduced scale testing

At full scale : winfloat offshore turbine



Measurement in wave tank with blower

Scaling in fluid mechanics

The Vaschy-Buckingham theorem states that :

When a physical phenomenon is expressed by n physical variables which are using k independent physical units, this phenomenon is described by an equation involving a set of p = n – k dimensionless parameters (named Π_i)

$Re = \frac{\rho V D}{\mu}$ $Fr = \frac{V}{\sqrt{gD}}$ $Pr = \frac{\mu C_p}{\lambda}$ $S_c = \frac{m\zeta}{\rho D^2}$ $S = \frac{N_S D}{V}$ $\mathrm{Gr} = \frac{g\beta(T_s - T_o)L_c^3}{\nu^2}$ $Ma = \frac{V}{a}$

Reynolds, Froude, Prantl, Scruton, Strouhal, Grashof, Mach

Downscaling wind turbulence

The scale of the boundary layer gives the limits of the dimensional scaling

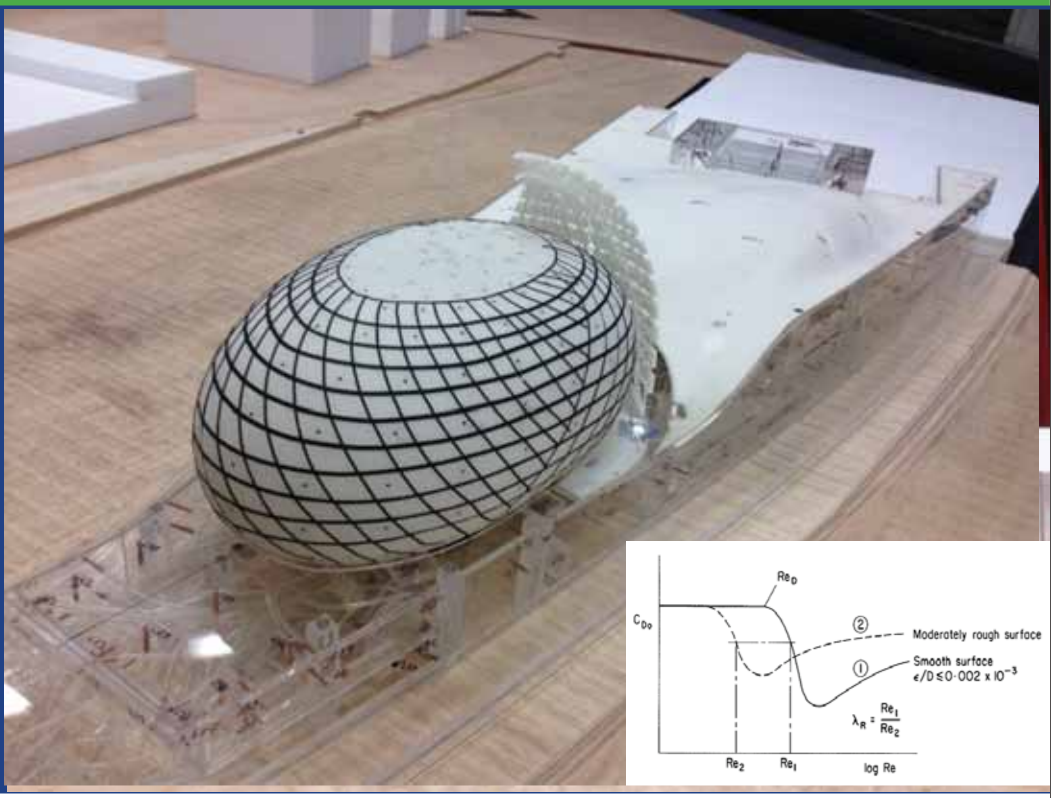
1/300 for buildings
1/3000 for mountains

Only when spatial correlation is of main importance

But Reynolds number is a problem

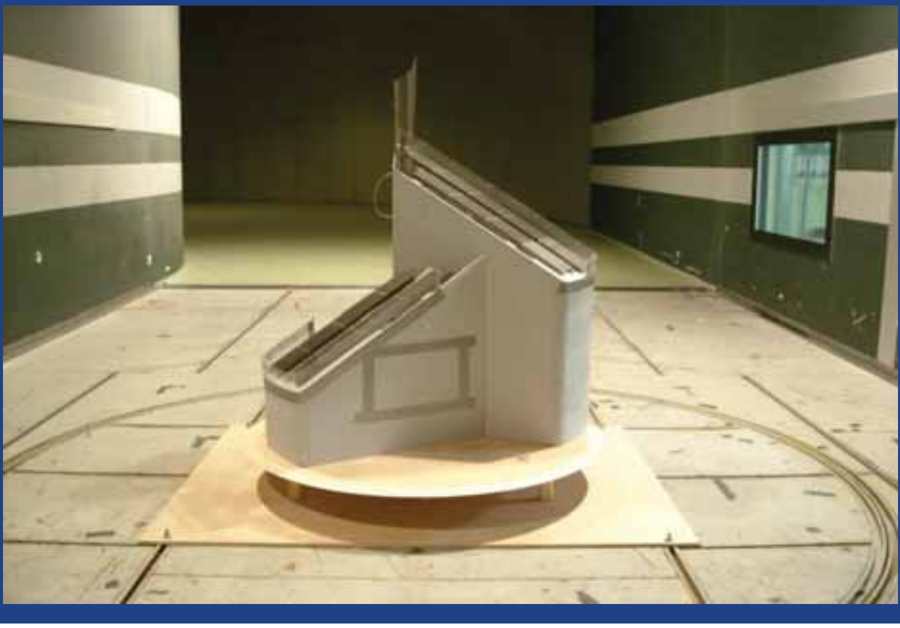
At reduced scale, trusses and round shapes, are in the subcritical regime

Some extra roughness elements must be added to the models



One solution : partial test at higher Re

For towers, it is usual to make a partial model of the summit only, in high speed WT

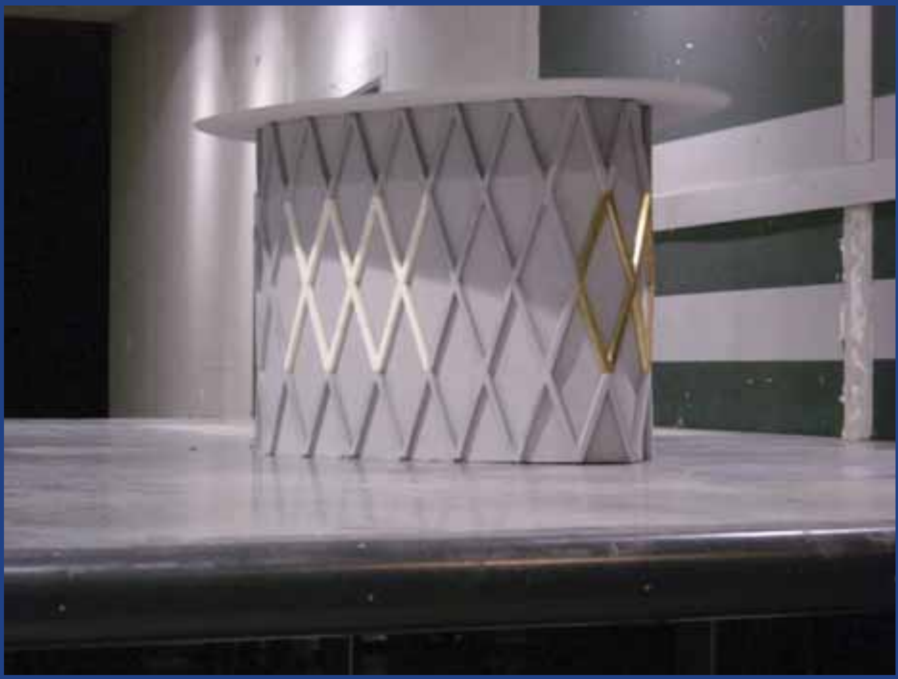


This method is specially used when the summit of the tower is composed of porous panels

No need for spatial correlation → no need for a BLWT

One solution : partial test at higher Re

Some typical cases



When there is no need for turbulence scale

the size of the model can be increased, up to full scale.

Downscaling wind LOADS is easy

It is convenient to operate 2 wind tunnels :

One for reproducing turbulence scale at low Reynolds number ➔ Loads on the structure

Another one for reproducing real loads, at real Reynolds number, on local elements ➔ Loads on elements

But in nature, there is more than WIND…

Rain + Wind

Snow + Wind

Flying Debris + Wind

Vegetation + Wind

Similarity laws do not allow downscaling when combining WIND + other parameters

How do you downscale…

A tent ?

drops ?

Frost ?

Trees ?

Many other phenomena are hard to scale

Aerodynamic water resistance (for instance roofs)
Snow accumulation, penetration, drift

Reproducing snow and ice in wind tunnel

What is the load due to snow accumulation ?

What is the risk snow will block windows, air ducts, … ?

What is the risk a big ice block can form and fall down in one piece?

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Attachment of small elements

Tiles, slates, antenna, gantry, many building components must be studied as full-scale prototypes subject to actual wind load

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Even small elements become dangerous

There are many items in the built environment that could turn into missiles when blown off by the wind. Make them "wind proof"

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The wind tunnel must be large enough

to install large elements of structures (large windows, PV panels, shadings, lights…) with less than 10% blockage

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The wind tunnel must be suited

to testing a whole solid house or a temporary home (like emergency tents) under rain and sun with extreme temperature

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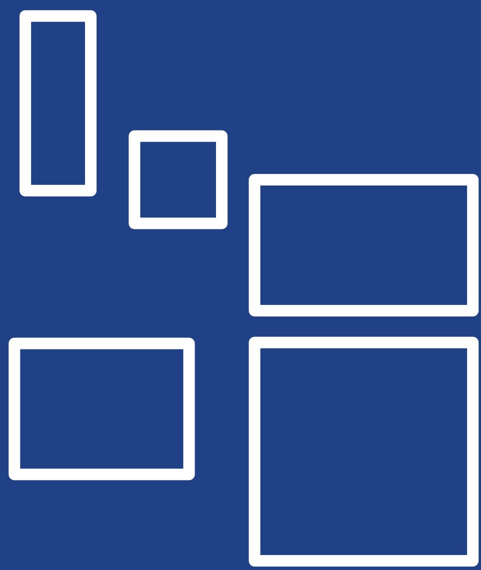
What could be the right size ?

For studying :

- Traffic lights : H 8m x W 3 m
- Roof elements : H 4m x W 4m
- Complete roof : H 6m x W 10m
- Large windows : H 6m x W 8m
- Small House : H 10m x W 10m



10mx10m seems the right dimension

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What could be the right combination ?

For studying :

- Typhoons : WIND (60m/s) + RAIN (100 mm/h)
- Sand Storms : WIND (20m/s) + SAND (1µm to 150µm)
- Snow Storms : WIND (30m/s) + SNOW (0 to 30% lwr) + Low Temperature (-3° C to -15° C) + HAIL (5mm to 35mm)
- Tornadoes : WIND (120m/s) + DEBRIS (1 to 100 g)
- Bush Fire : WIND (20m/s) + SPARKS (0.1mm to 10mm)

Required power increases with (wind speed)^3

Conclusions

Reducing hazard from wind and climate on buildings through tests in controlled conditions means :

- **Mixing WIND with RAIN + SUN + SAND + ….**
- **Operating at FULL-SCALE on genuine prototypes**
- **A large wind tunnel 10mx10m is convenient but…**

  … costly (60 M$) and energy hungry (25 MW)
- **One solution may be to build a large climatic wind tunnel with different testing sections of various size and speeds.**