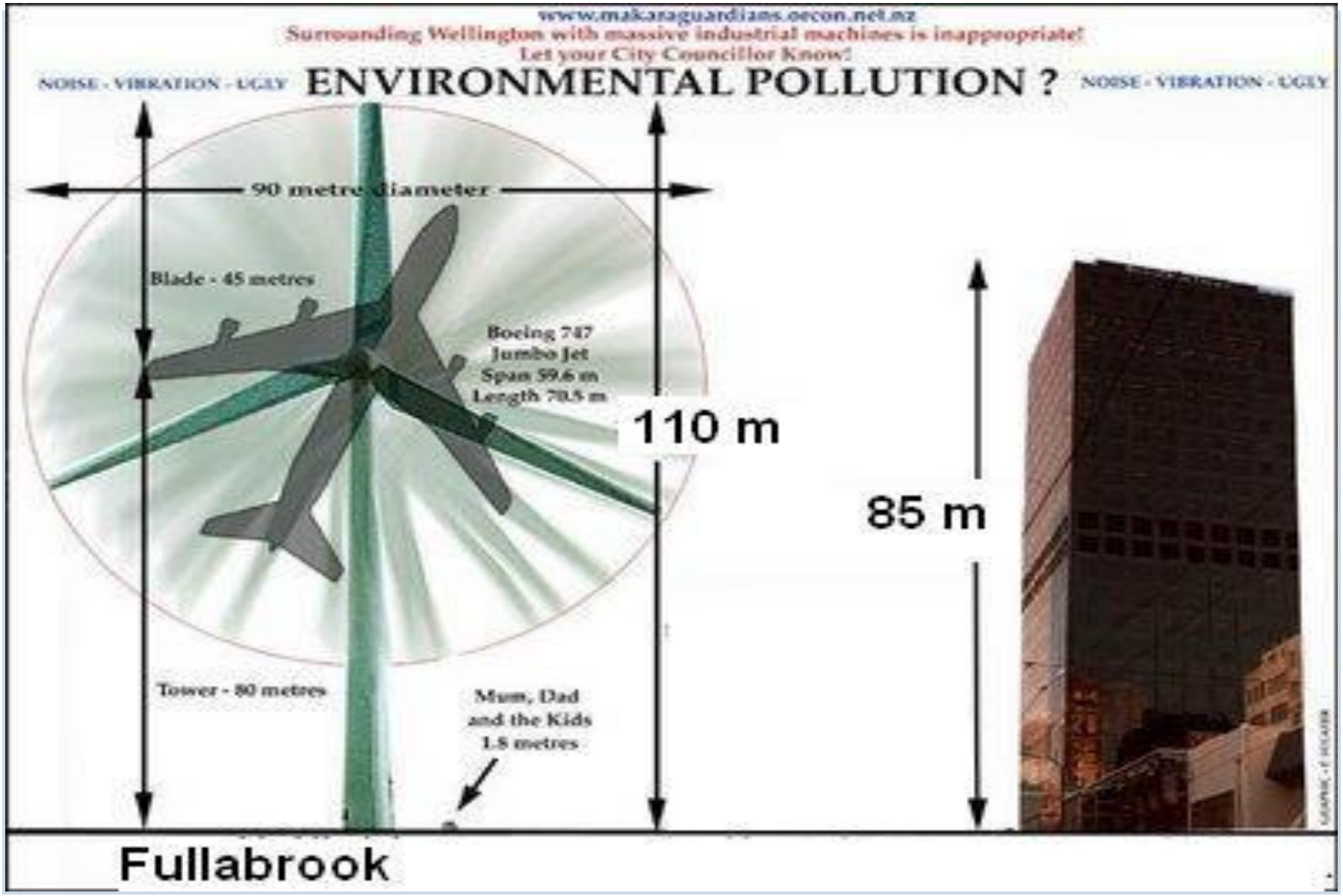
ESB International
ESBI Energy Innovation

Wind Turbine Foundations

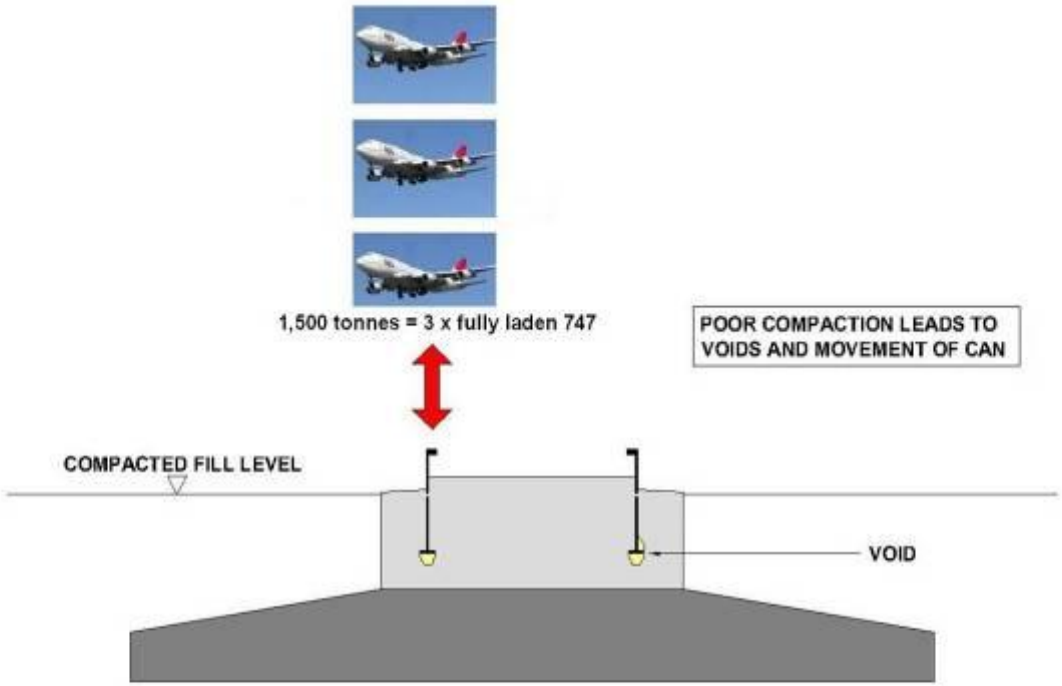
Risk Mitigation of Foundation Problems in the Industry

Content

- Background – WTG Foundations – Industry Problems
- Causes Identified and Solutions in Place
- Additional requirement for larger WTG

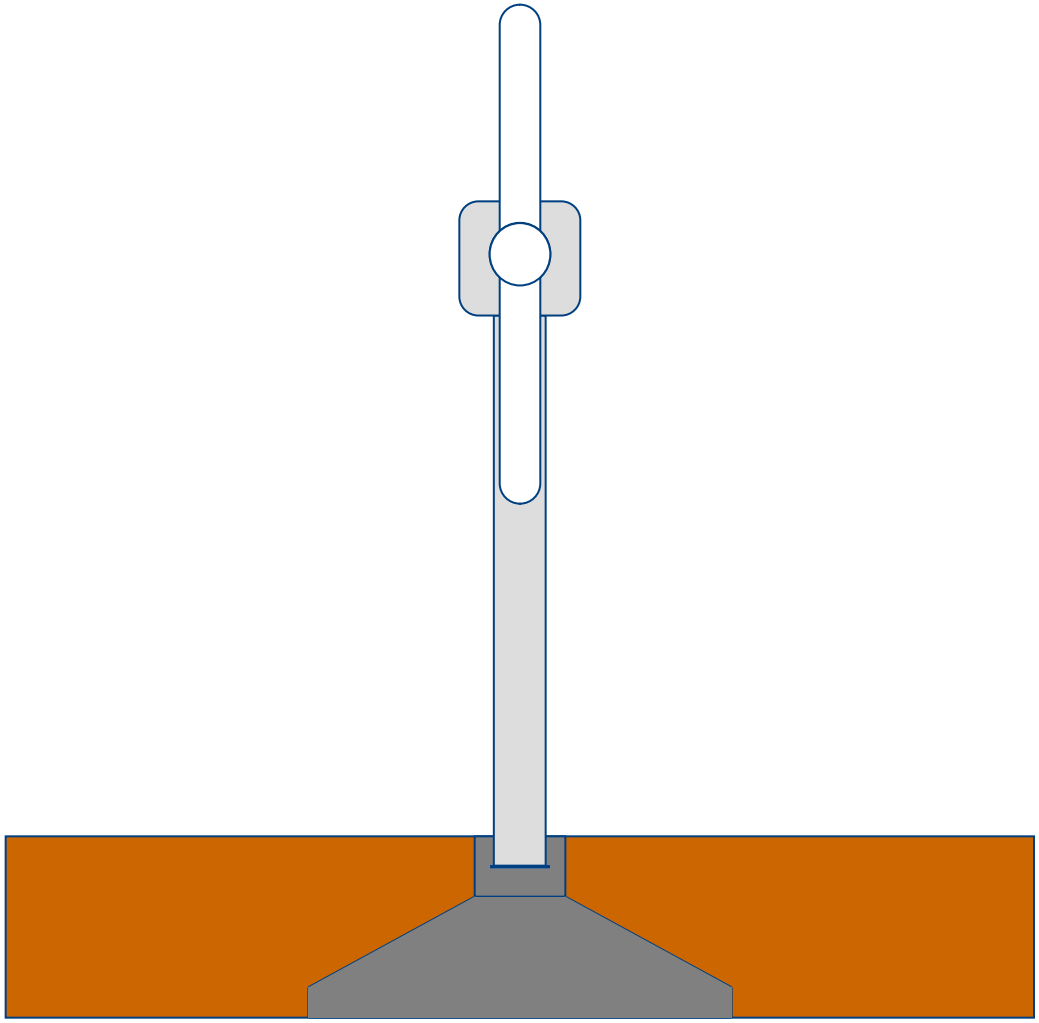

www.makaraguardians.oecon.net.nz
Surrounding Wellington with massive industrial machines is inappropriate!
Let your City Councillor Know!
NOISE - VIBRATION - UGLY
ENVIRONMENTAL POLLUTION ?
NOISE - VIBRATION - UGLY
90 metre diameter
Blade - 45 metres
Boeing 747
Jumbo Jet
Span 59.6 m
Length 70.5 m
110 m
85 m
Tower - 80 metres
Mum, Dad
and the Kids
1.8 metres
Fullabrook

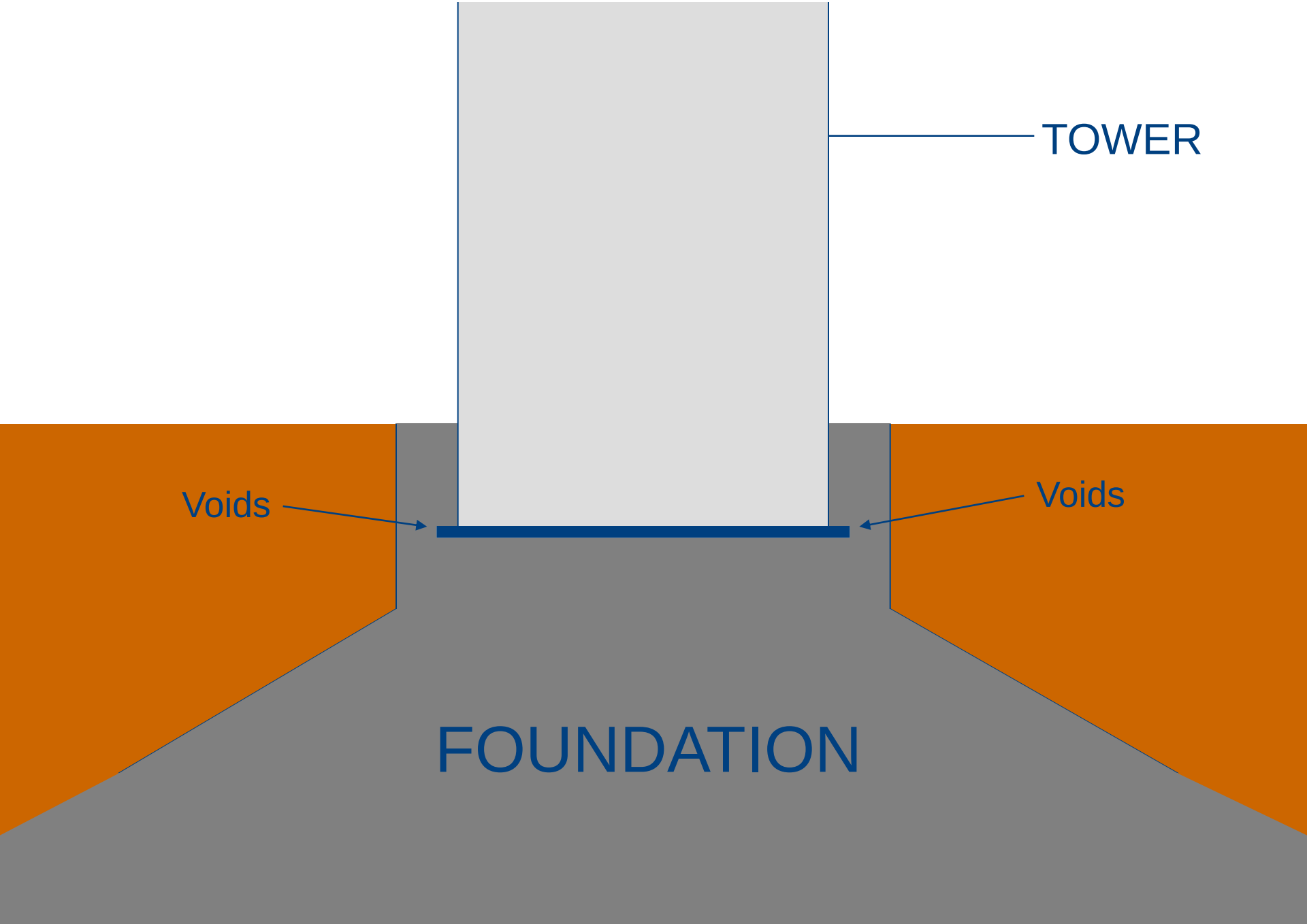
- ‘CAN’ Supplied by some WTG Manufacturers for installation in foundations by others
  - Interface issues



Steady Increase in size of machine over the last 8 Years:

- WTG Increase 850 kW to 3 MW
- Rotor Diameter 52 m to 90 m
- Hub Height 50 m to 90 m
- Loads Increase from 20,000 kNm to 90,000 kNm




TOWER
Voids
Voids
FOUNDATION

Foundation Problems the Causes

- Generally at the mechanical/civil interface i.e ‘CAN’

- Design
  - fatigue of concrete
  - **7**,000,000 cycles/Year;
  - Typical Bridge 500,000 cycles/Year
  - poor detailing – congested rebar – difficult to compact concrete

- Quality Control - Long pours c 500 m3 concrete over 9 hours often starting at 5 am

Foundation Problems and Solutions

- Poor Detailing/Quality Control
  - Design of two stage Concrete pour foundation
  - Reduced congestion of rebar
  - Reduced time for concrete pour around ‘CAN’ (9 hrs to 3 hrs)
- fatigue in concrete
  - Eurocode 2 Structural Design
- Quality Control - Training of onsite construction workforce

Design Standards/Documents

- **Guidelines for the Certification of Wind Turbines -** GL Renewables Certification Guidelines, 2003;
- **Wind Turbine Foundation Behaviour and Design Considerations -** Morgan, Ntambakwa, - Garrad Hassen, AWEA 2008;
- **Design of concrete structures** - BS EN 1992-1-1:2004 Eurocode 2:
- Wind Turbines – Part 1: Design Requirements - BS EN 61400-1:2005
- **Load/Technical Specification** – WTG Supplier

Design Information Loads

- Load factors vary from 0.9 (favourable) to 1.5 (unfavourable)

- Wind loads
  - Permanent loads
  - Extreme loads
  - Fatigue loads

- Foundation/Soil Interface
  - Rotational Stiffness – Rotating Spring rate
  - Bearing pressure

- Dynamic analysis - eigenfrequency

One Stage Pour -
‘Can’ Placed in Bottom Concrete
Workmanship and Detailing Problems
Very Congested Rebar
Quality control Difficult (9 hour pour)

One Stage Pour -
‘Can’ Placed in Pedestal Pour
Less congestion of Rebar
Better Quality Control (3 hour pour)


RGA
PLANT HIRE


07/10/2009 12:37

Solutions - Keeping up with new Developments

- Attendance at industry forums (European/UK/Ireland)
- Contact with other developers/designers/contractors
- Attendance at WTG Supplier information forums

New Problems

- 2.5MW+ WTG
  - Known foundation problems
    - Various site in Ireland/UK/Europe

- Design issues EC2
  - Fatigue design to EC2
  - Load transfer from ‘CAN’ to concrete

- Are there other problems in the industry we don’t know about?
  - ‘CAN’ or bolts – Which is better?

Going forward

- Properly designed and detailed HD bolts
- Finite Element Analysis And Design for fatigue
- Dynamic analysis of Ground, Foundation and Tower
- Details to reflect design assumptions
- Control of quality on site essential
- ‘User Friendly’ – Two Pours, Space for compaction