Design for TCs and EQs

Experience from Taiwan

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A simple design optimisation problem – or problem of enabling

Engineering models

Had loads and design tools

Cloud based

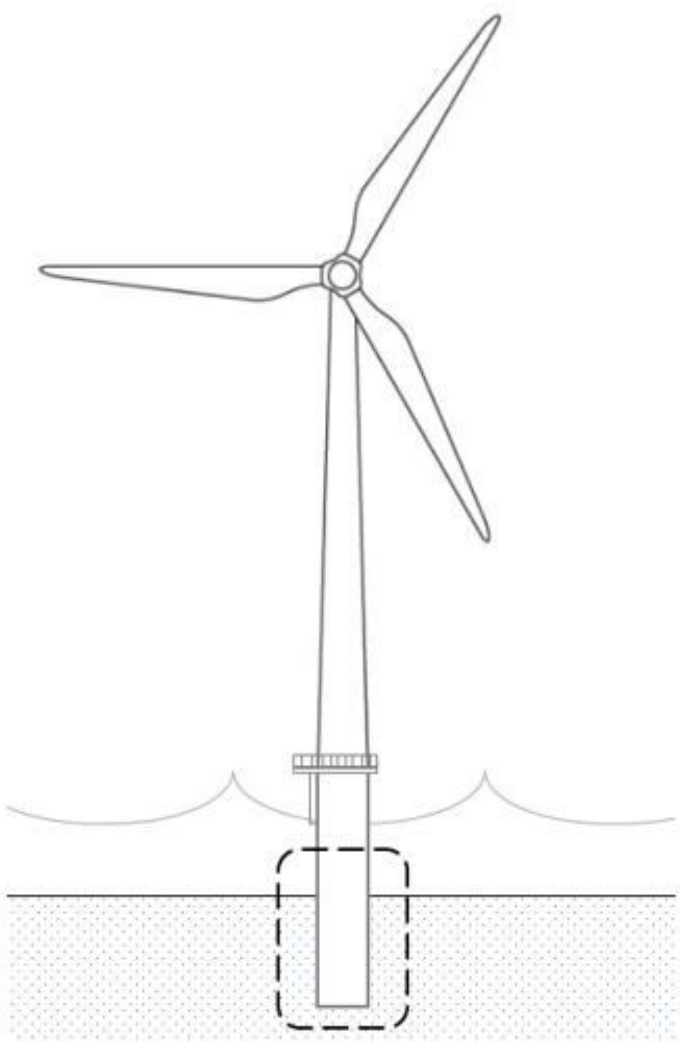
In 1 day:

1 design position

10.000 simulations

5 iteration steps

100 turbine positions



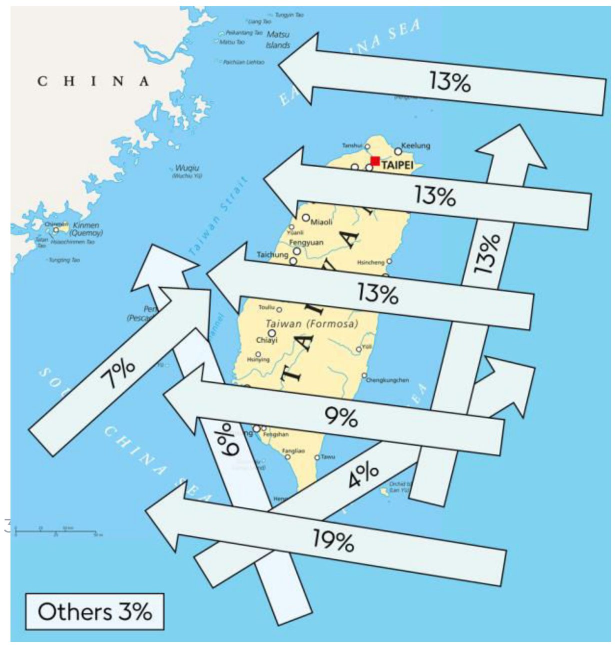
Spend time to understand design-driver development

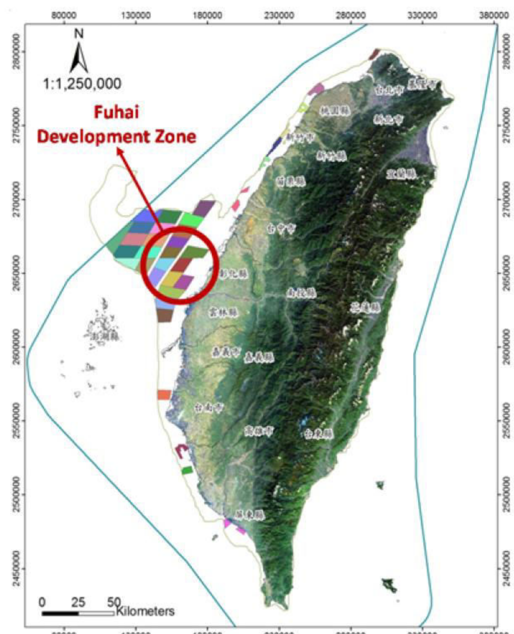
Manufacturing

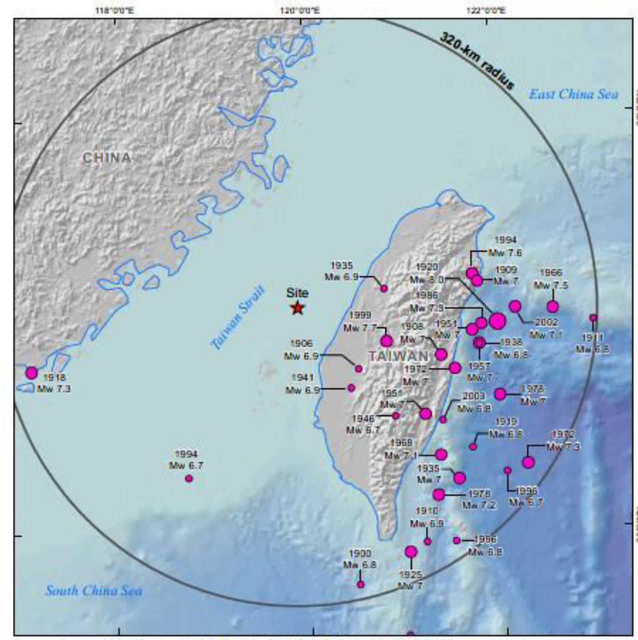
Handling

Installation

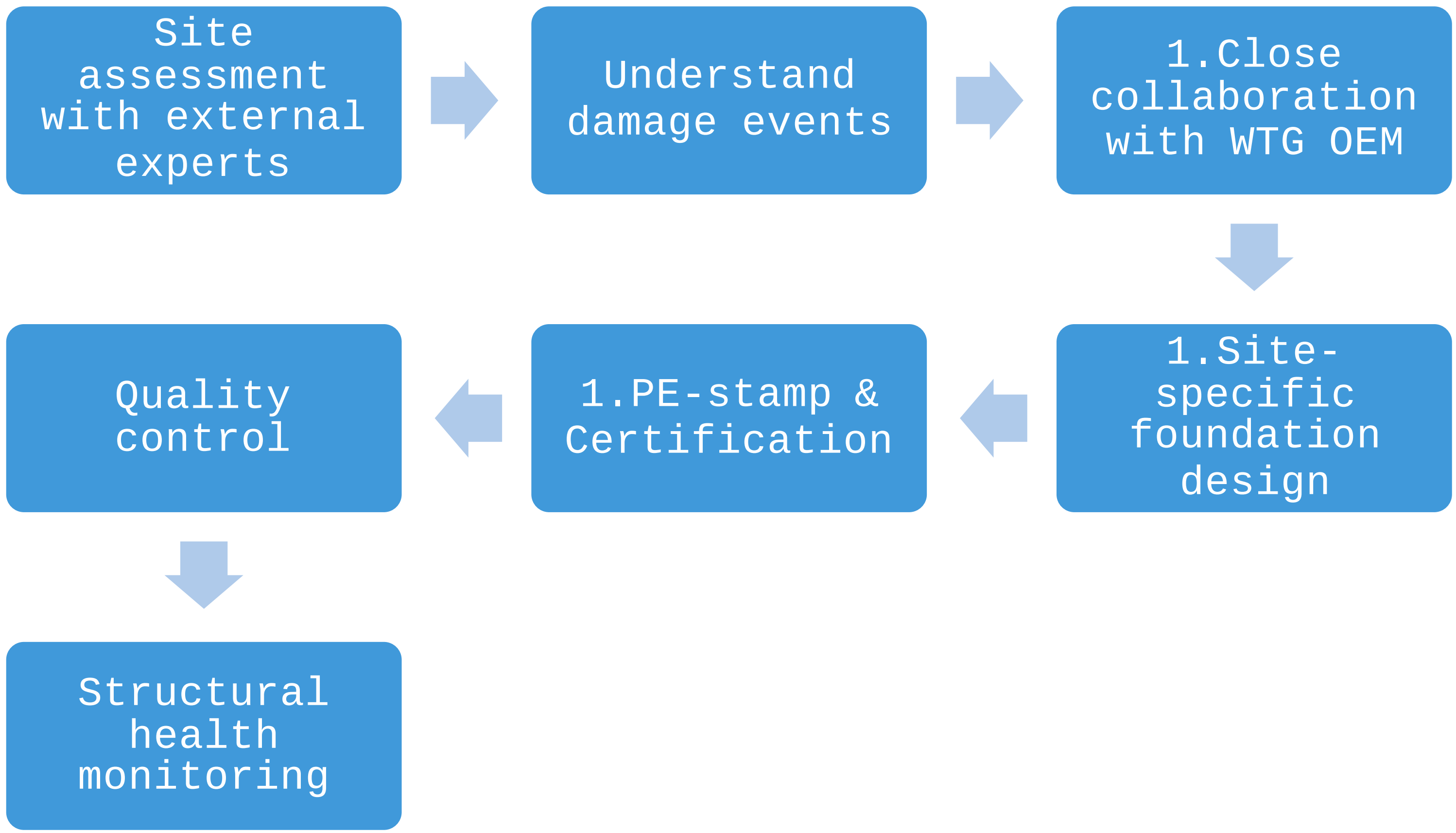
Natural Hazards Typhoons and Earthquake







Step-by-step Approach to Natural Hazards



TYPHOON FAILURE EVENTS

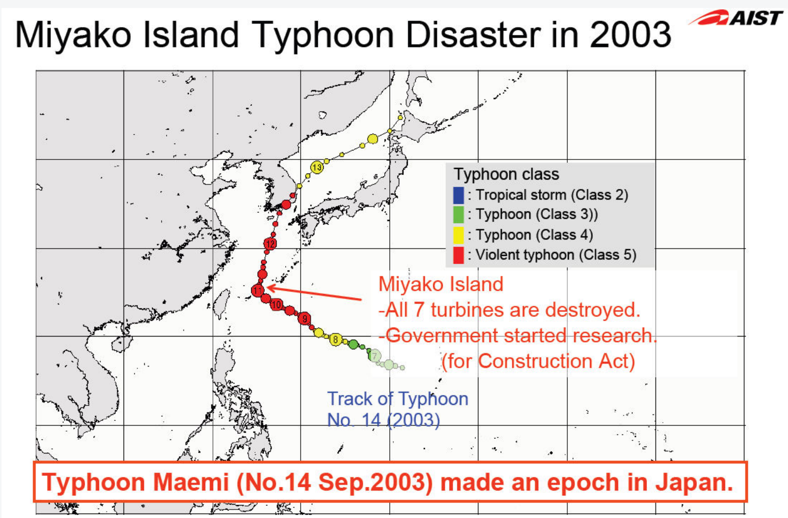
Event: Puerto Rico

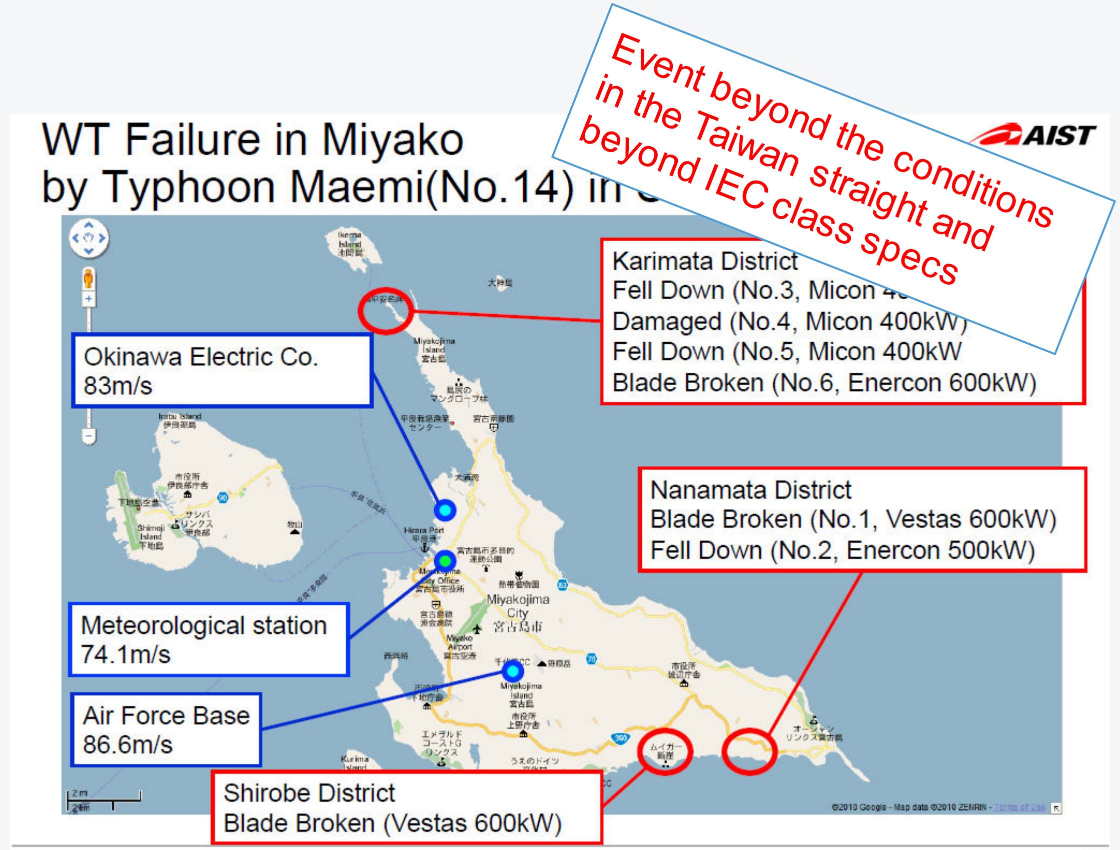
– Hurricane Maria, September 2017, Category 5

Event beyond the conditions in the Taiwan straight and beyond IEC class specs

Event: Miyako Island, Japan

- Typhoon Maemi September 2003
- Wind speeds: hub TBD
- Turbine loses and significant damages





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Event: Taichung harbour, Taiwan

- Jangmi (= Soudelor), Sep 28, 2015
- 3.62million households lost power
- Wind speed: hub anemometer, 3-sec, 54 m/s
- Too weak bolts
- Class IEC II turbine
- Over speed due to stall regulation and too weak a mechanical brake

Event within IEC I class conditions. Event tells about the importance of fabrication inspection and quality control

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Event: Shanwei city, China

- Super typhoon Dujan 2003
- Wind speeds: hub measured 3-sec, 57 m/s
- Blades secondary damages

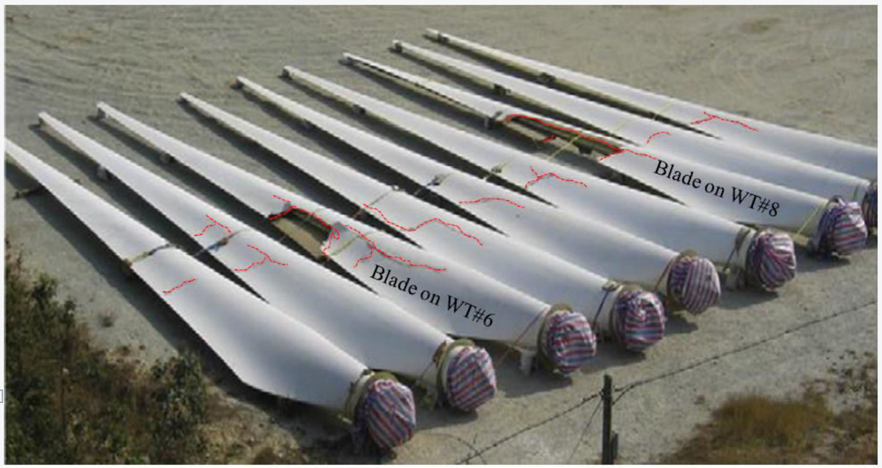


Fig. 8. Rotor blades damaged by super typhoon Dujuan in 2003.

- Super typhoon Usagi 201
- Wind speeds: hub estima 75.8 m/s
- Tower failure already c design and probably u

Event within IEC class conditions. Event tells about the importance of control strategy – e.g. yaw control

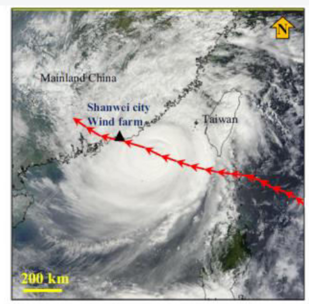


Fig. 1. Typhoon tracks and the wind farm location (satellite images from NASA (2015)). (a) Super typhoon Dujuan in 2003; (b) super typhoon Usagi in 2013.

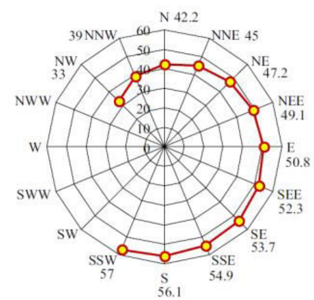


Fig. 7. Maximum wind speeds (3 s average) and wind directions recorded at 10 m elevation during Usagi.

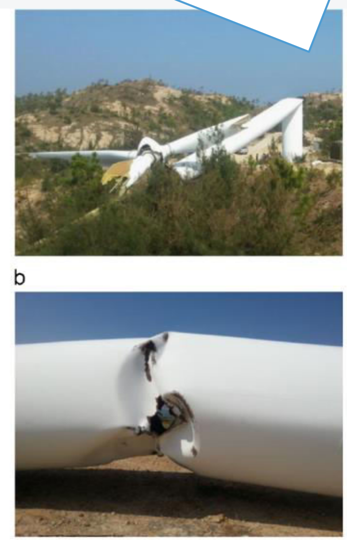


Fig. 10. Tower collapse due to super typhoon Usagi. (a) Tower collapsed towards SW; (b) buckling failure at a tower height of about 9 m.

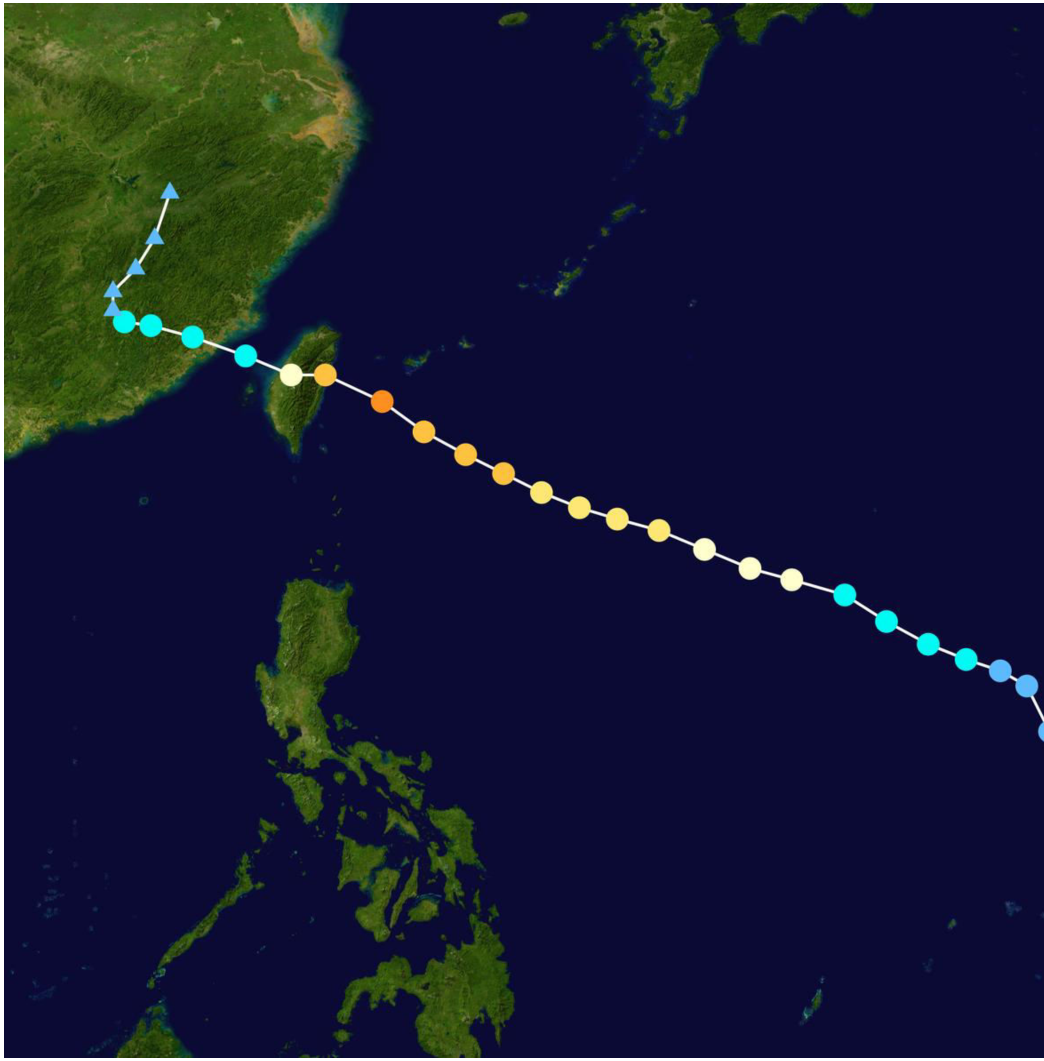
Public perception

Megi (2016)

Megi left 3.89 million households without power as it made landfall in Taiwan, the second worst blackout in history after Typhoon Soudelor's record-breaking 4.85 million households in August 2015.

At least four were killed across Taiwan, while more 625 others were injured, including 8 Japanese tourists whose bus overturned.

By October 1 the death toll in Taiwan had risen to 8 - five due to indirect causes, such as falls and traffic accidents, and three people who died when a landslide destroyed their house in southern Kaohsiung County.



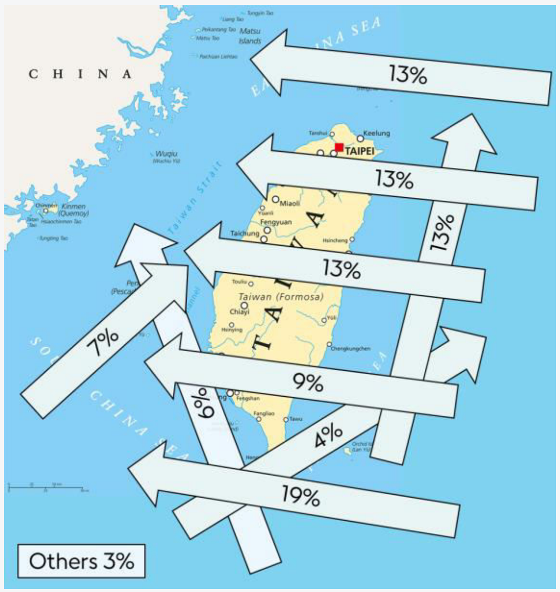
Morakot 2009

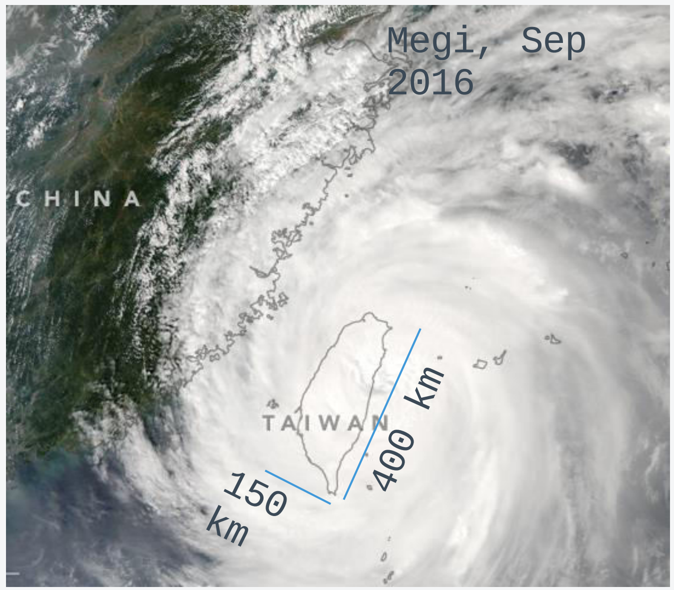
Typhoon Morakot was the deadliest typhoon to impact Taiwan in recorded history. .....

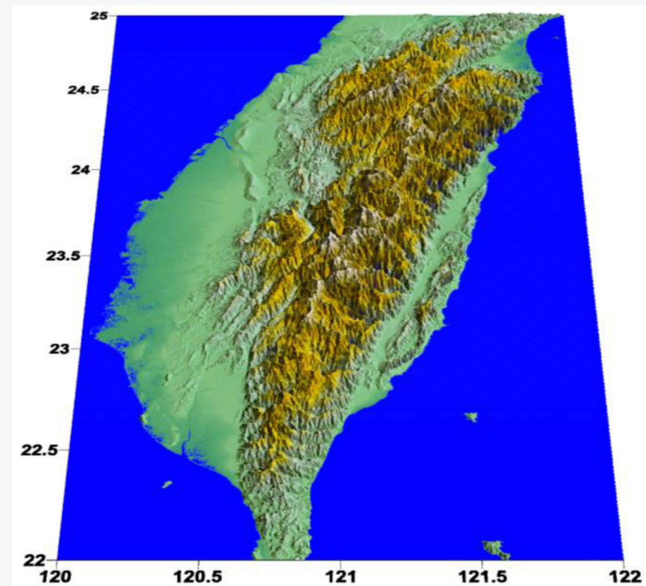
The extreme amount of rain triggered enormous mudflows and severe flooding throughout southern Taiwan. One landslide (and subsequent flood) destroyed the entire town of Xiaolin killing over 400 people.

Site assessment

The strait is on the lee site of Taiwan







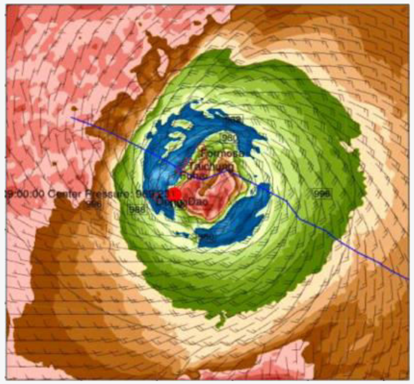
Offshore met mast gave significant events on record
State-of-the-art modelling

Formosa measurements

- Met-mast well-equipped - few years
- 3 significant events
- Turbulence, wind shear, gust factor, air-density
- Confirms World Meteorological Organization guidance

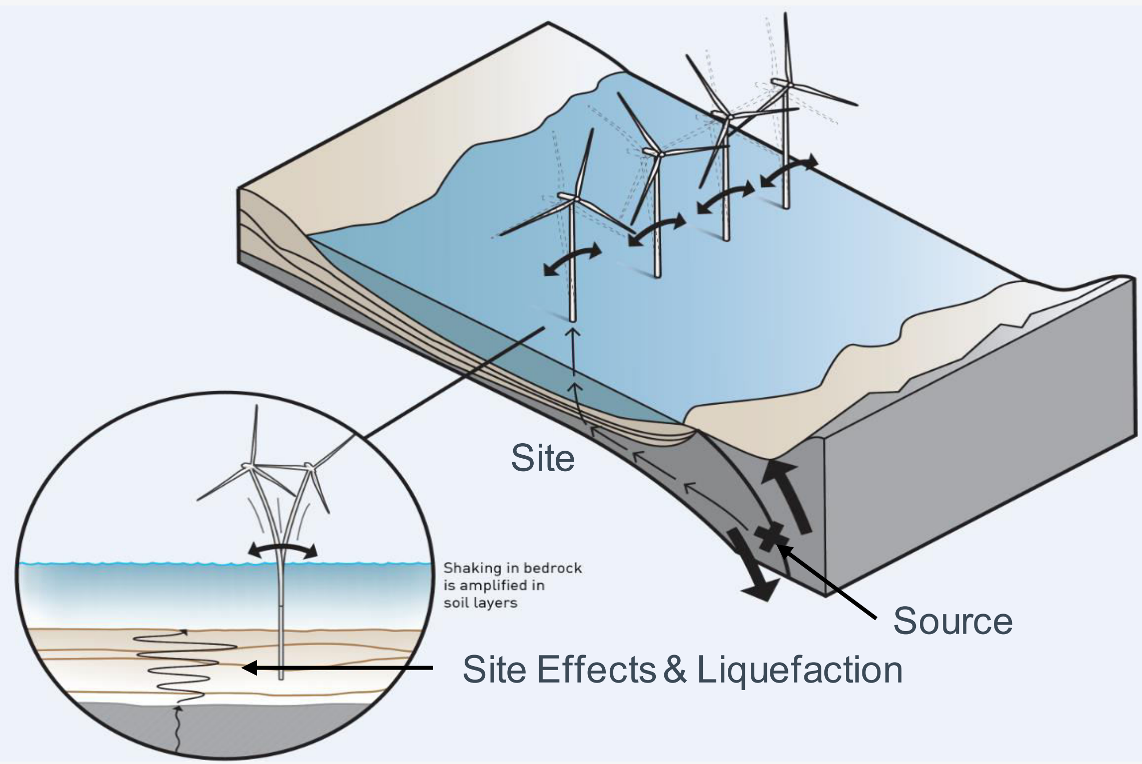
Sate-of-the-art modelling

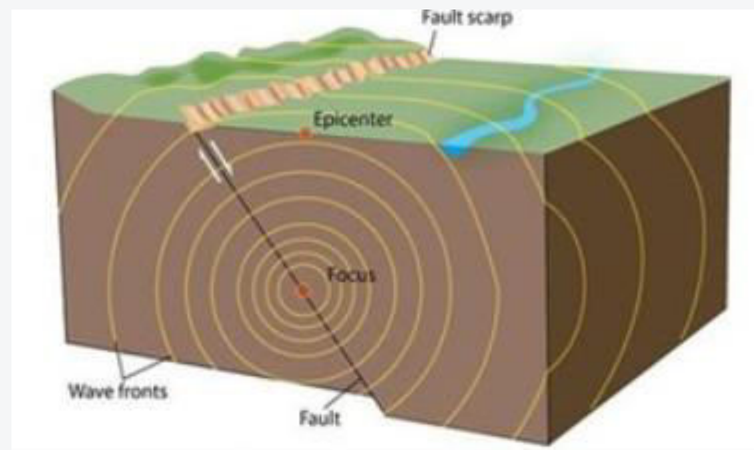
- Typhoon Monte Carlo simulation
- Meso scale modelling (WRF)
- Wave hindcast



Overview of Defining the Earthquake Hazard

Probabilistic Seismic Hazard Analysis → Site Response Analysis → Liquefaction Assessment → Input to Foundation Design



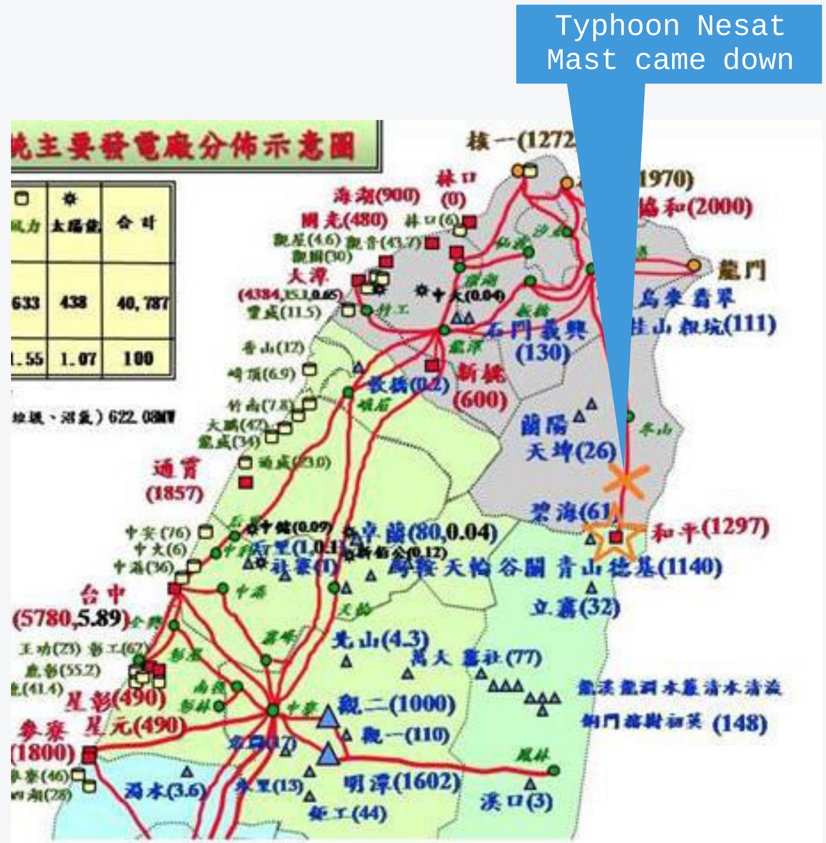


Grid loss

Typhoon grid loss risk is very low – similar to Europe

Grid loss risk on west coast is low and similar to Europe

- Strong inter-connected transmission grid due to high population
- Lower typhoon winds on the west coast
- No forced grid closure in a typhoon event
- Typhoon related events:
  - Overhead cable on the East coast
  - Land-slide in rural area - not back-bone



Design standards

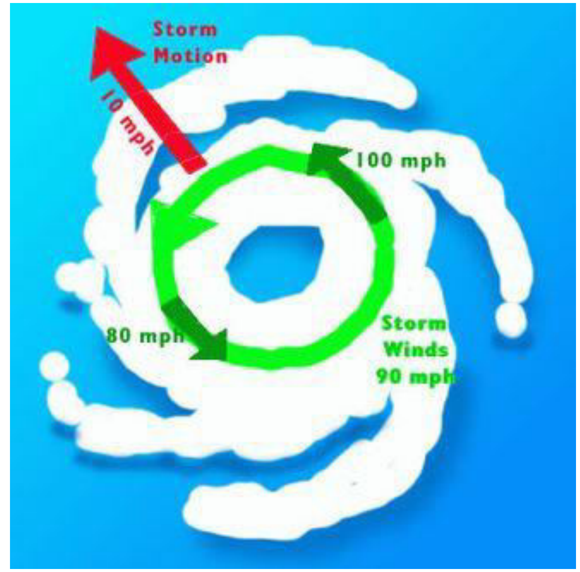
Do IEC 61400-1 and IEC 61400-3-1 support systems engineering ?

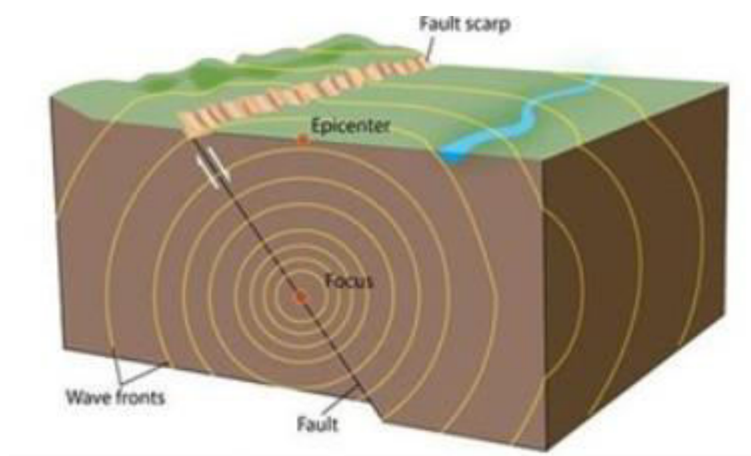
They do not prohibit it

- Single position logic
- 61400-1: Class type vs. site conditions
- 61400-1-3: Site-specific design support structure

When looking at natural hazards the engineer and society would consider

- Geographical spread over the site
- Geographical spread over sites





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