Brodagen 2009:

Stonecutters Bridge

WASHMS:

Wind and Structural Health Monitoring System,

2005-2008

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Stonecutters Bridge, Hong Kong S.A.R.
Tsing Ma Control Area

Kap Shui Mun Bridge

Tsing Ma Bridge

Ting Kau Bridge

Tsing Kwai Highway

North Lantau Highway

Lantau Toll Plaza

North West Tsing Yi Interchange

Cheung Tsing Tunnel

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Stonecutters Bridge - Location

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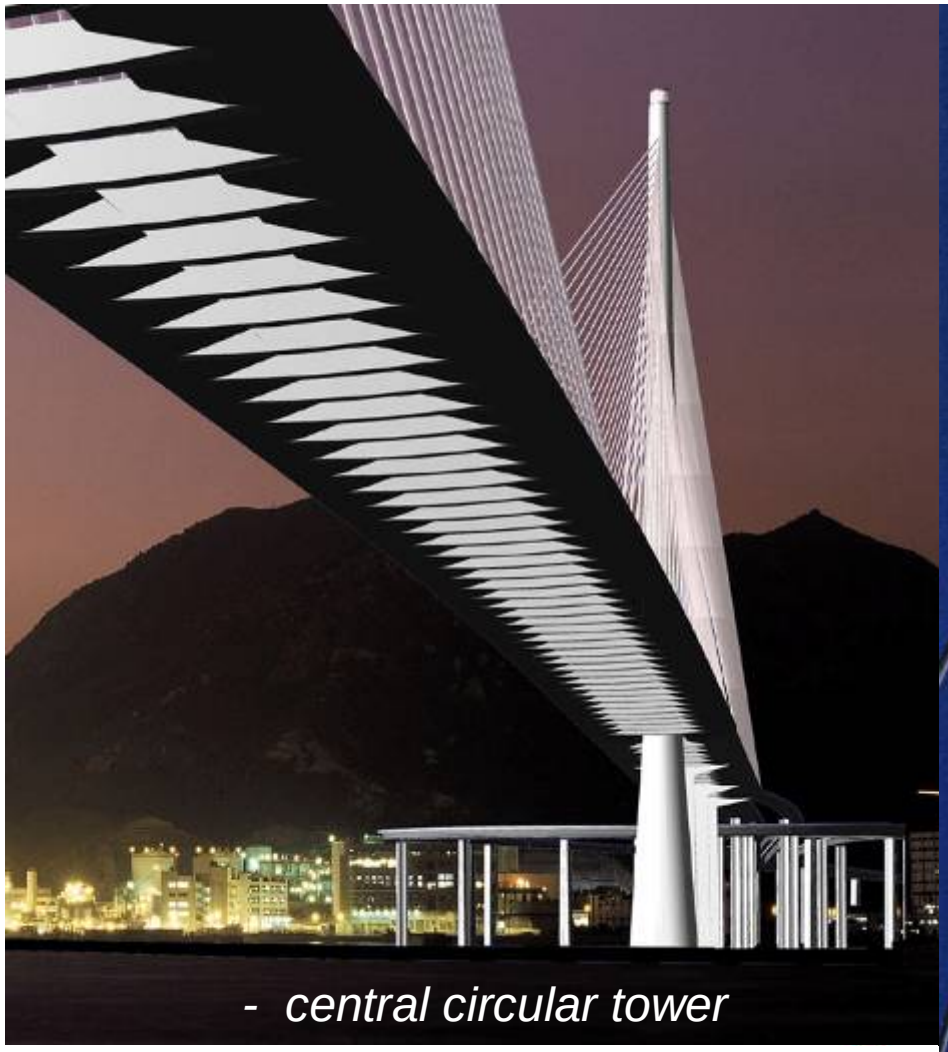
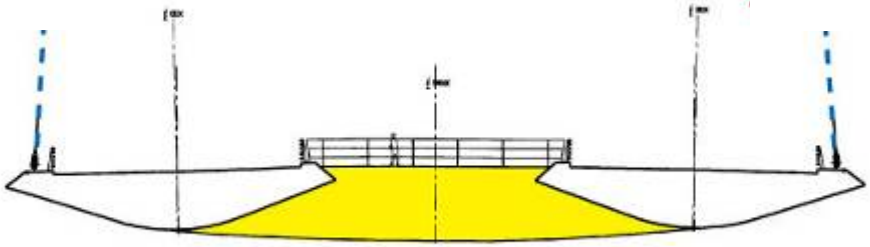
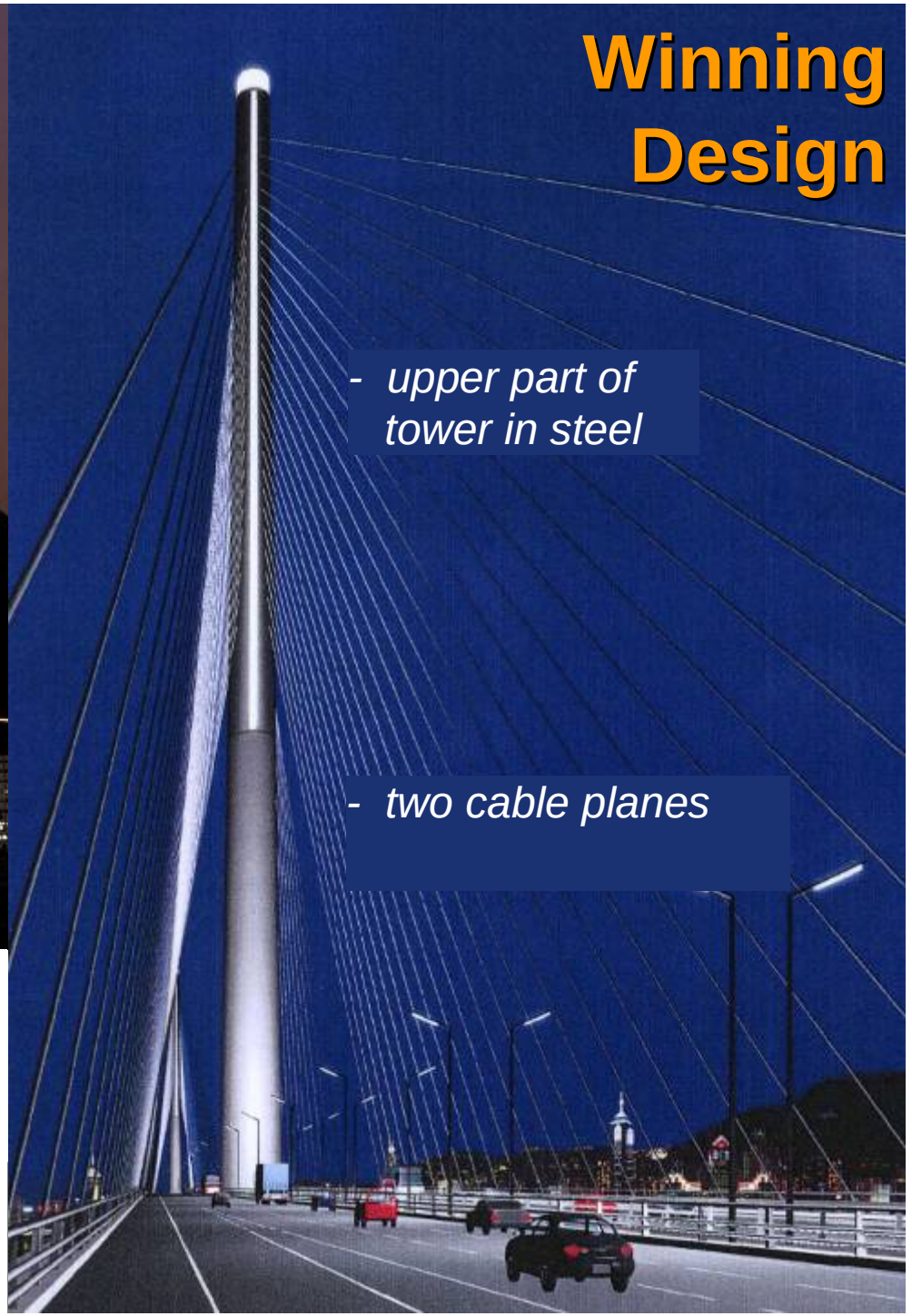
Winning Design



- central circular tower



- twin deck with curved soffit



- upper part of tower in steel

- two cable planes

Stonecutters Bridge - Involved Parties

Client:

- Highways Department, Hong Kong S.A.R.

Designer:

- Ove Arup & Partners, Ltd. Approach Bridges
- COWI A/S. Cable Stayed Bridge

Contractor:

- MHYH JV (Maeda - Hitachi - Yokogawa - Hsin Chong Joint Venture)

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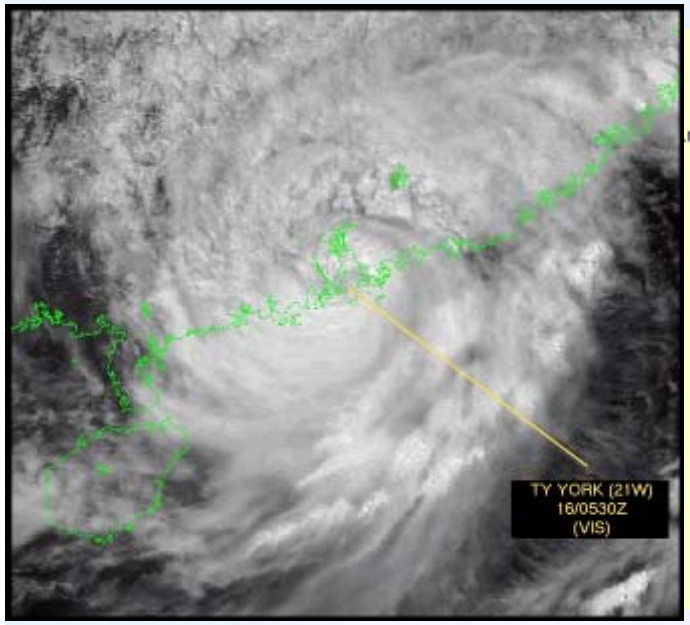
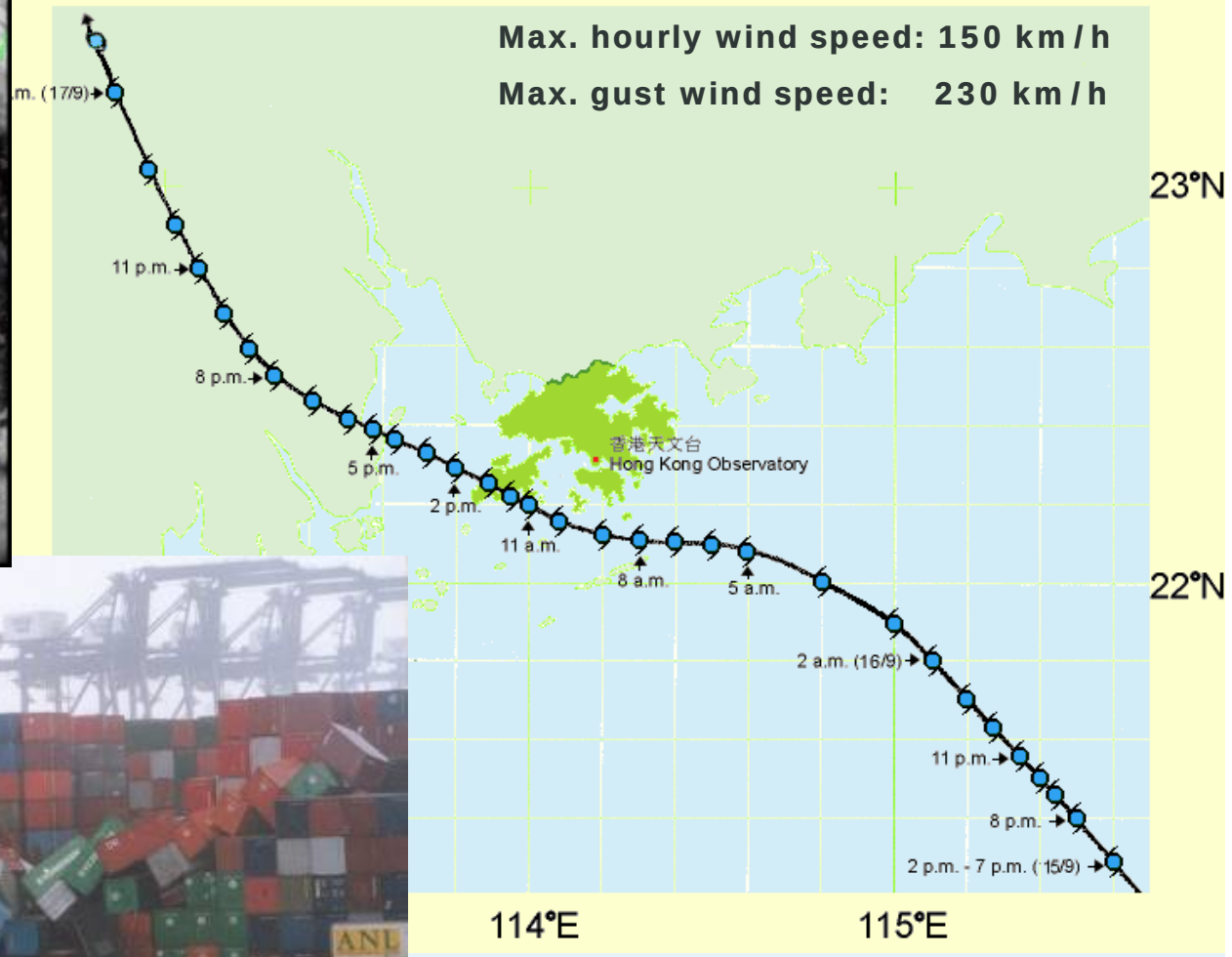
Stonecutters Bridge - Typhoons





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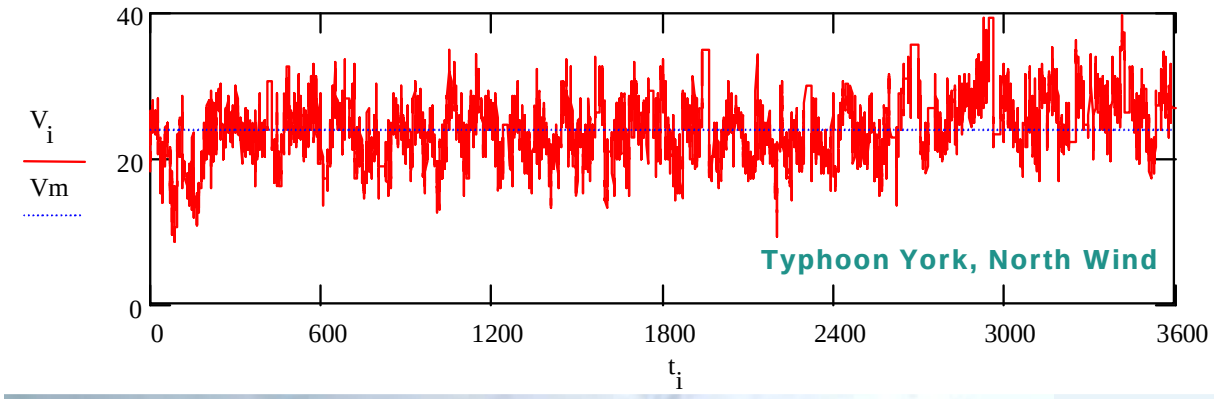
Stonecutters Bridge - Wind Studies



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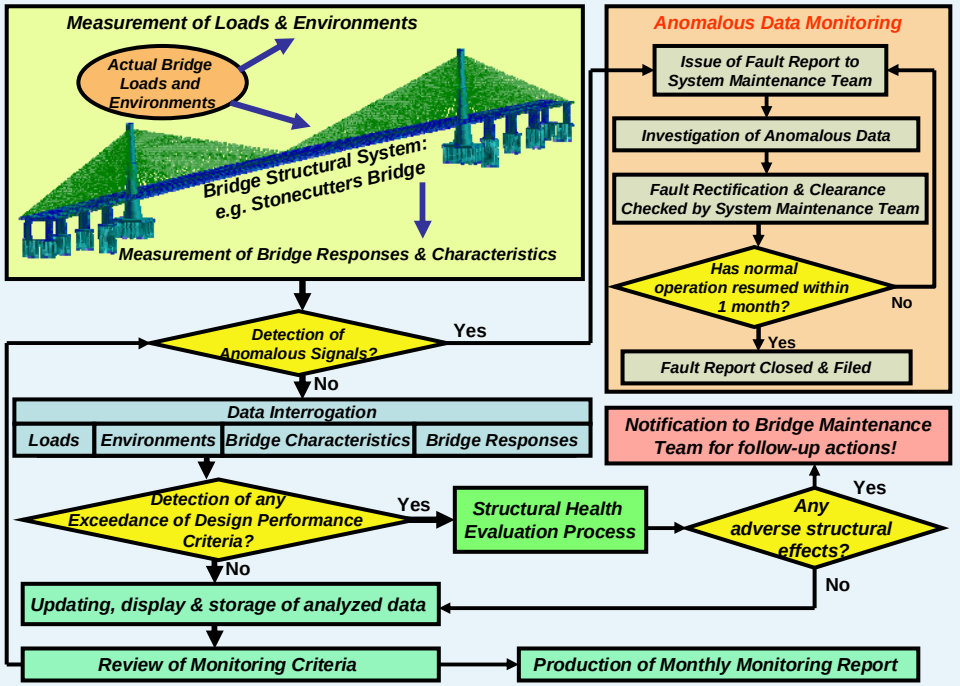
WASHMS - Wind and Structural Health Monitoring System

- Sensory System (SS)
- Data Acquisition and Transmission System (DATS)
- Portable Data Acquisition System (PDAS)
- Data Processing and Control System (DPCS)
- Structural Health Evaluation System (SHES)
- Portable Inspection and Maintenance System (PIMS)



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Loads & Responses

- Environments and status.
  - Wind monitoring.
  - Temperature monitoring.
  - Seismic monitoring.
  - Corrosion status monitoring.
- Traffic loads.
  - Highway traffic monitoring.
- Bridge characteristics.
  - Static influence coefficients monitoring.
  - Global dynamic characteristics monitoring.
- Bridge responses.
  - Cable forces monitoring.
  - Geometric configuration monitoring.
  - Strain/Stress distribution monitoring.
  - Fatigue stress monitoring.
  - Articulation monitoring.

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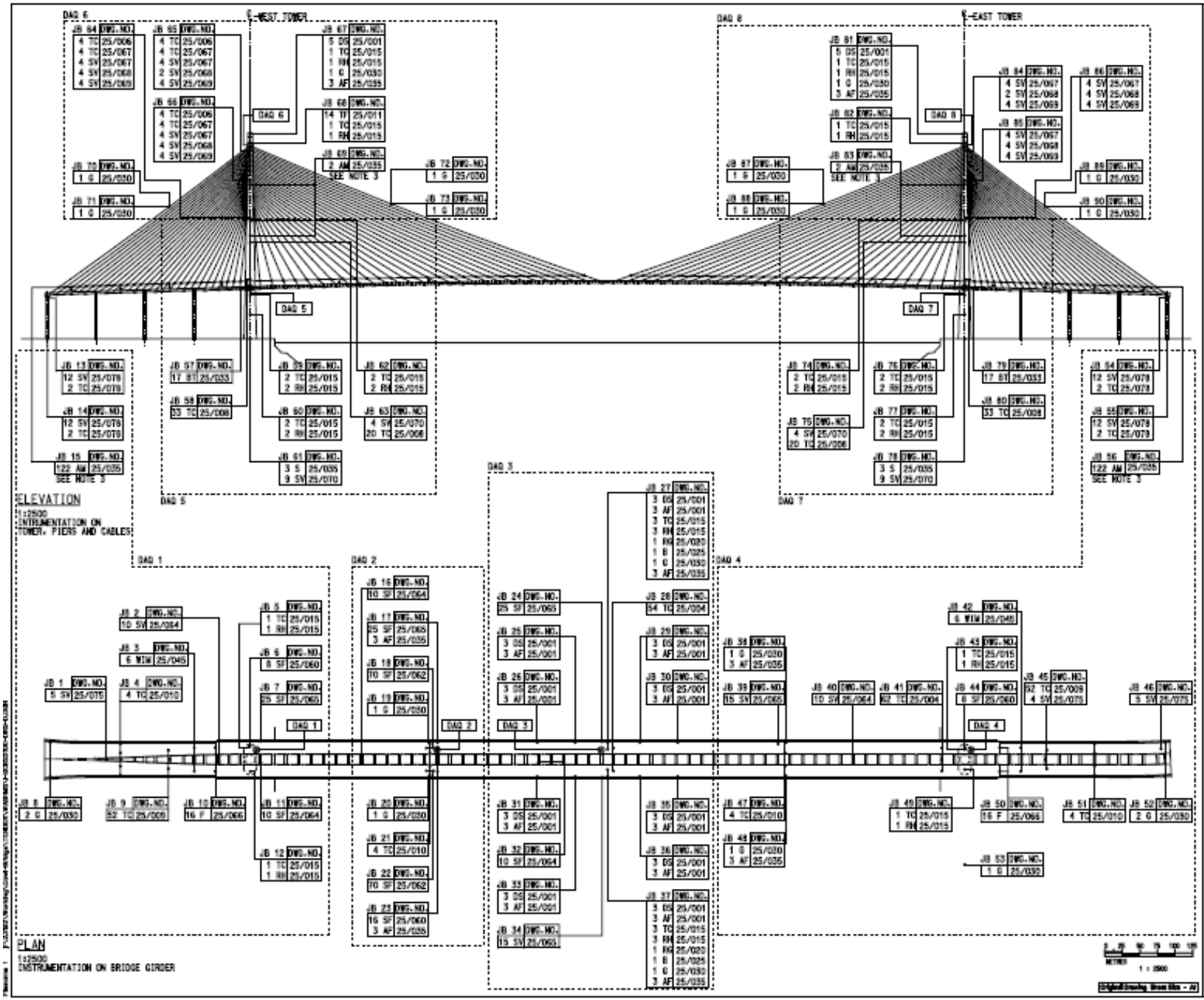


NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED.
2. FOR SENSOR LOCATIONS SEE DWG. NO. 25/001 - 25/099.
3. NUMBER OF SOCKETS AVAILABLE FOR THE 48 MOVABLE ACCELEROMETERS.
4. FOR CORROSION CELLS SEE DWG. NO. 23192/25/050 - 23192/25/059.
5. EXACT NUMBER OF DAU TO BE PROPOSED BY THE CONTRACTOR AND APPROVED BY THE ENGINEER.

LEGEND

⊛	DATA ACQUISITION UNIT
JB	JUNCTION BOX
# DS	NO. OF CHANNELS FOR SONIC AND PROPEL ANEMOMETERS
# TC	NO. OF CHANNELS FOR THERMO COUPLES
# RH	NO. OF CHANNELS FOR RELATIVE HUMIDITY
# RG	NO. OF CHANNELS FOR RAIN GAUGES
# B	NO. OF CHANNELS FOR BAROMETERS
# G	NO. OF DATA CHANNELS FOR GPS
# BT	NO. OF CHANNELS FOR BUFFER/BEARING TRANSDUCERS
# AF	NO. OF CHANNELS FOR ACCELEROMETERS, FIXED
# AM	NO. OF SOCKETS FOR ACCELEROMETERS, MOVABLE
# S	NO. OF CHANNELS FOR SEISMOMETERS
# WIM	NO. OF CHANNELS FOR WEIGH IN MOTION SENSORS
# SF	NO. OF CHANNELS FOR STRAIN GAUGES, WELDABLE FOILED
# SV	NO. OF CHANNELS FOR STRAIN GAUGES, VIBRATING WIRE
# F	NO. OF CHANNELS FOR TENDON FORCE
# TF	NO. OF CHANNELS FOR FIBRE OPTIC THERMO COUPLES

Rev	Description	By	Date
D	REVISED TENDER ISSUE	FSC	01/03
C	TENDER ISSUE	FSC	01/03
B	DRAFT TENDER ISSUE	JCA	3/00
A	REPORT ON BASING	JCA	11/00

Consultant
ARUP 奧雅納工程顧問 Ove Arup & Partners Hong Kong Limited

Supported By : COWI Consulting Engineers ⊛
BMT Asia Pacific Ltd. ○
Rauhi Hong Kong Ltd. ○

Project title
HY/2002/26
Stonecutters Bridge

Drawing title
MASHMS
DATA ACQUISITION NETWORK
DAQ LAYOUT

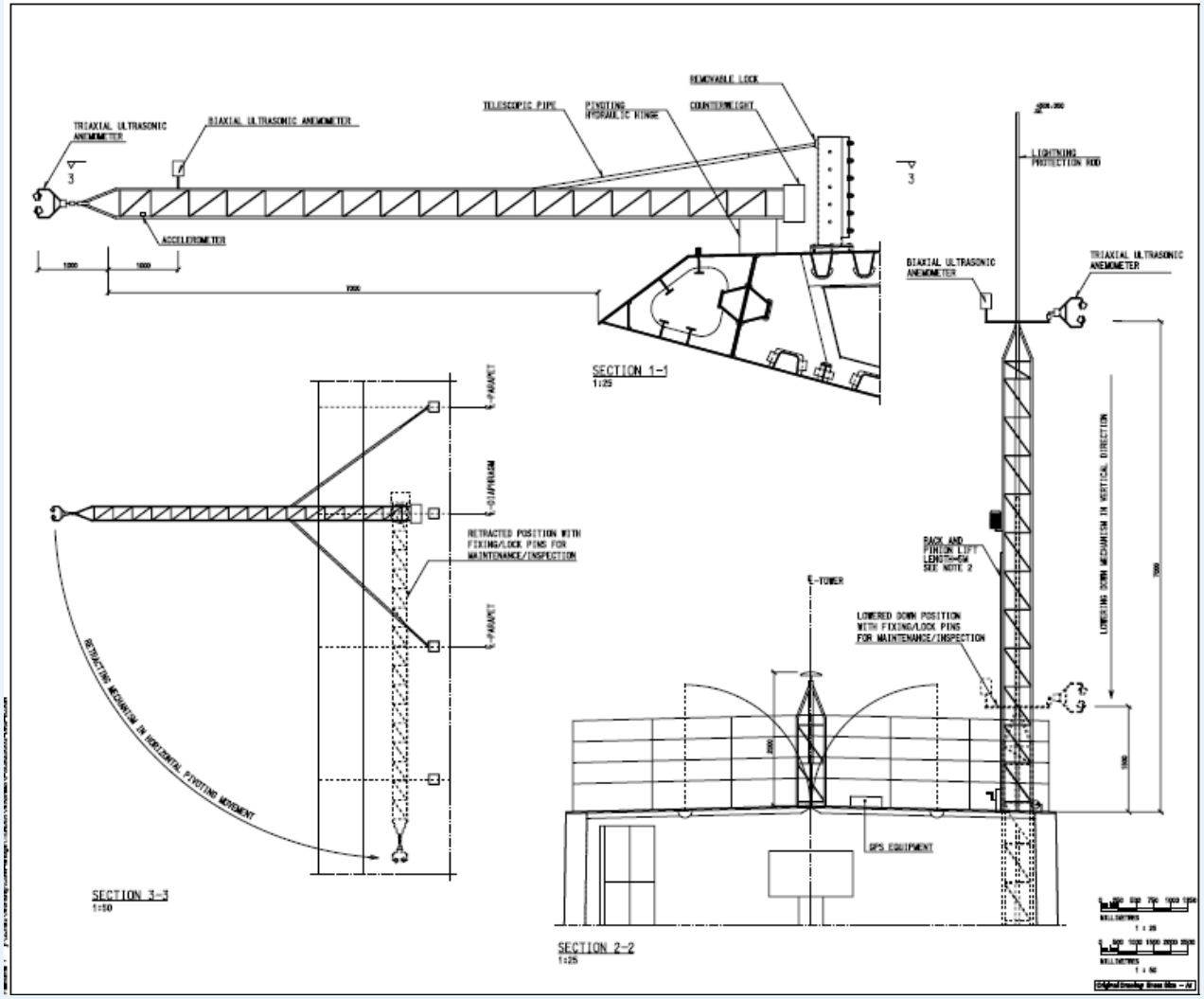
Drawing no. 23192/25/100 Rev. D

Drawn ABL/FSC | Date 01/03 | Checked JCA/JE | Approved RB

Scale 1:2500 | Status TENDER

HIGHWAYS DEPARTMENT 路政署 Major Works Project Management Office 主要工程管理處

Sonic anemometers



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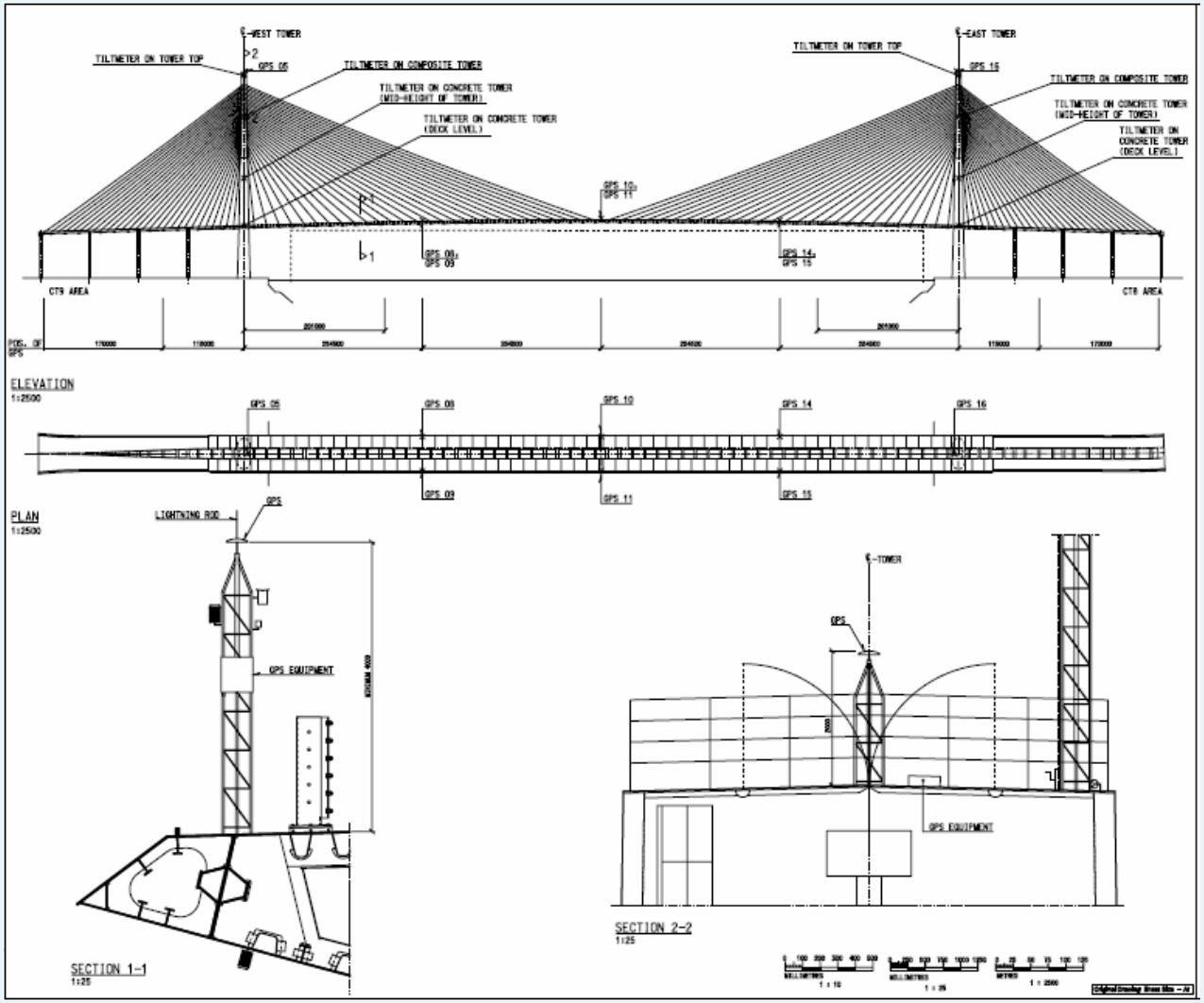
GPS



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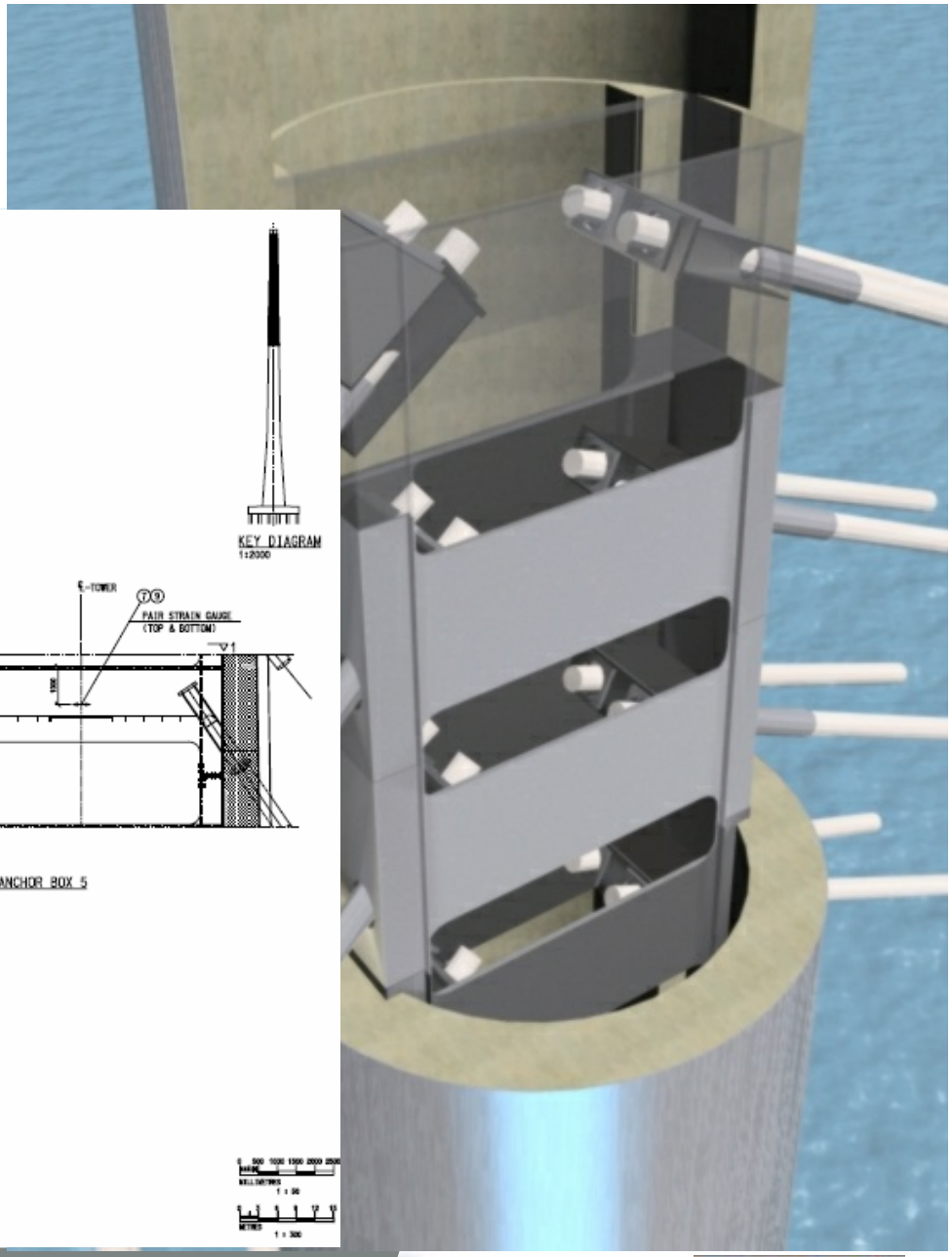
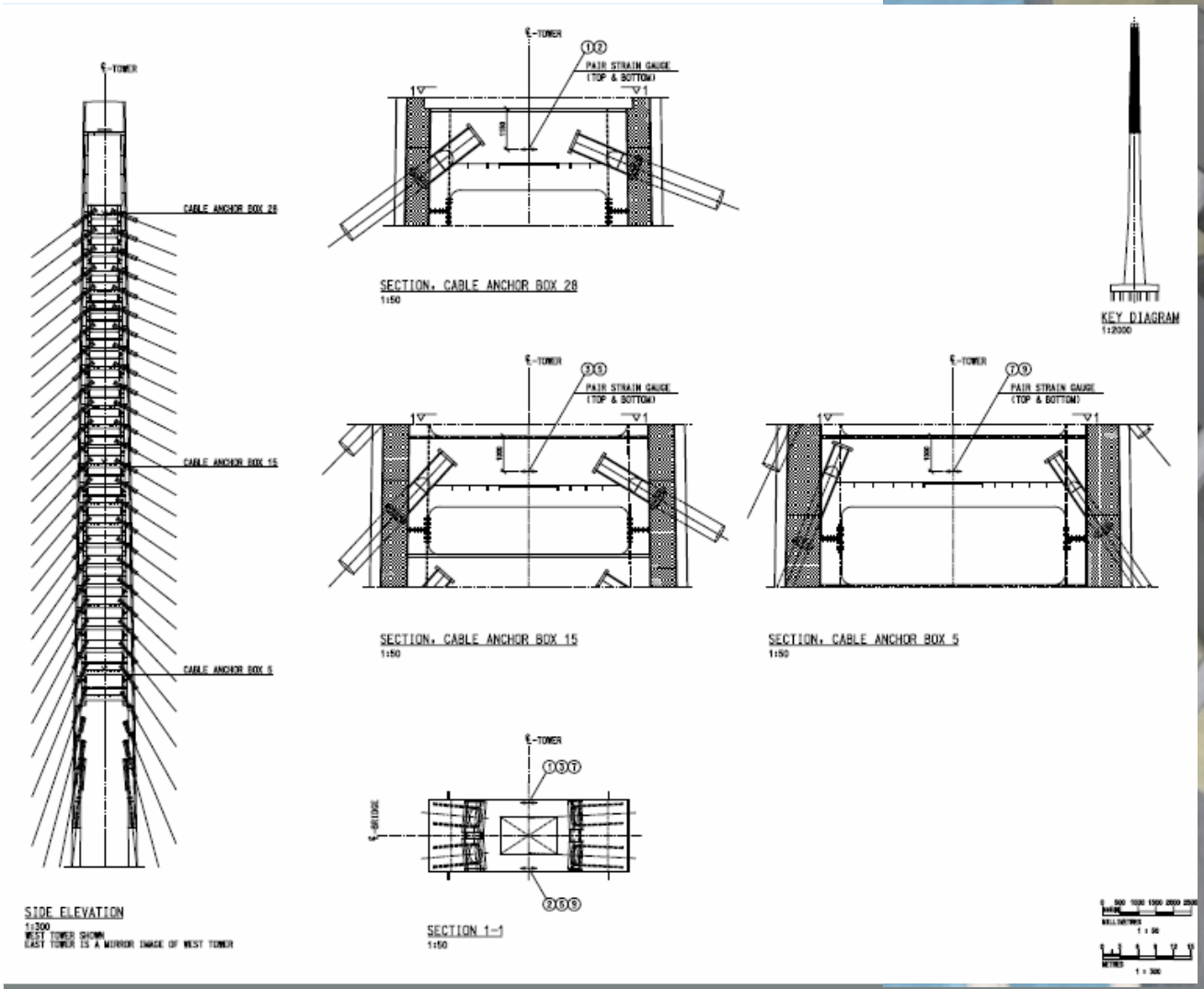
Stonecutters Bridge
Composite Upper Tower





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Corrosion monitoring

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Stonecutters Bridge
Fiber optic sensors

Stonecutters Bridge - Bearings & Dampers

Stonecutters Bridge
Feb. 2009

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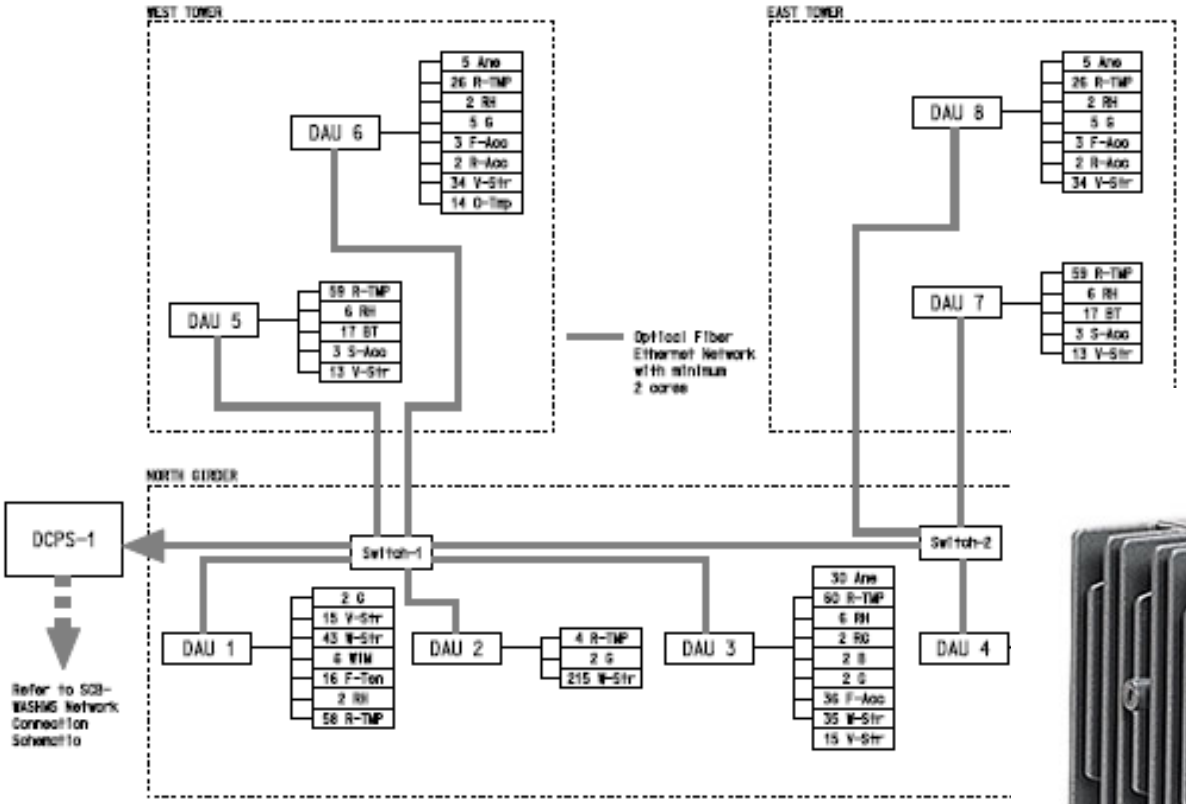
Data Acquisition and Transmission System (DATS)



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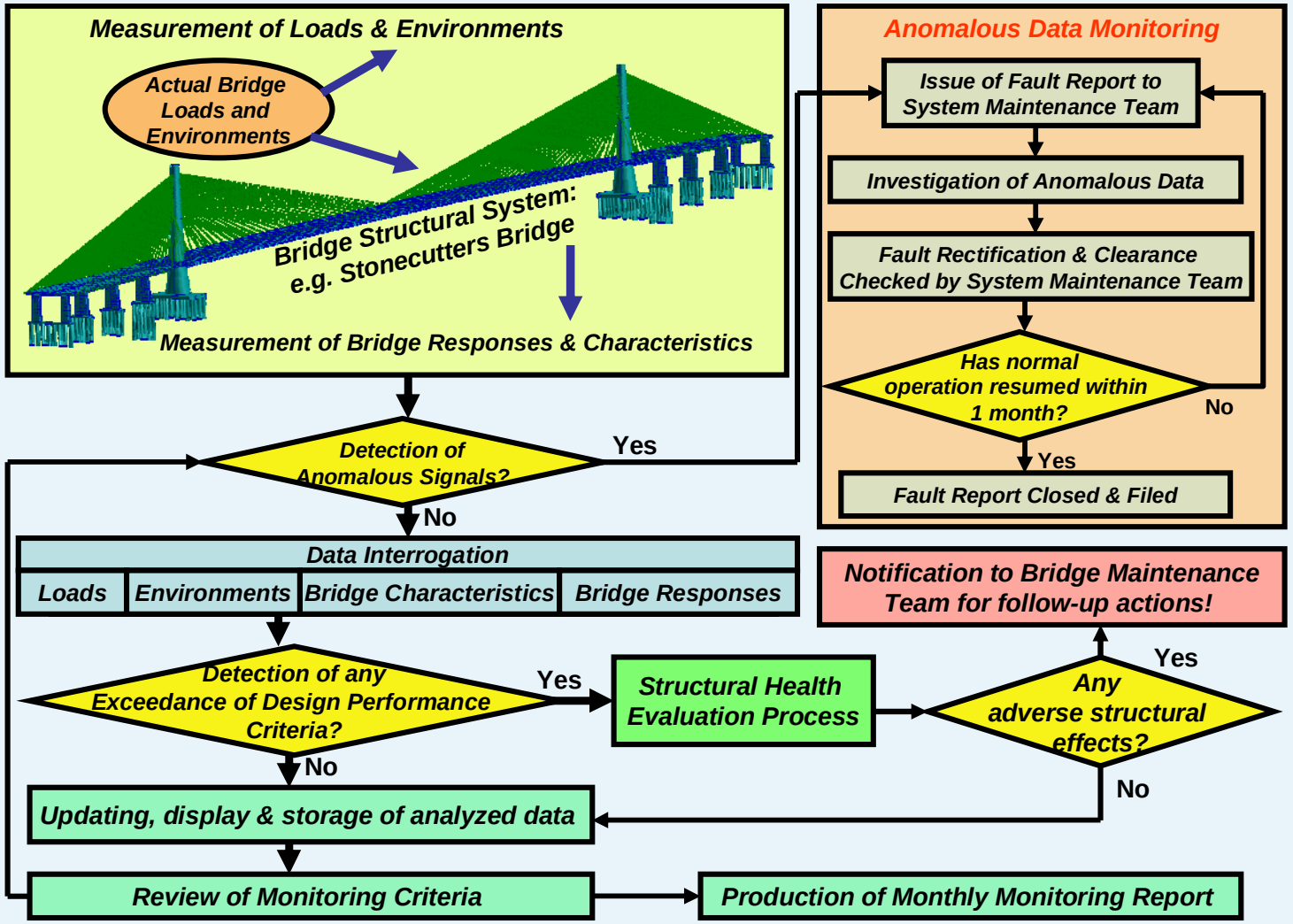
Data Processing and Control System (DPCS)



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Data Processing

Names and Requirements of Parameters or Plots for Monitoring	Duration	Presentation Formats			
		AD	TD	FD	FC
Global Dynamic Characteristics - Measurement and Tabulation of Modal Frequencies, Mode Shapes, Modal Damping Ratios and Modal Mas Participation Factors - Plots of Measured Mode Shapes for all Measured Modal Frequencies - Correlating the measured/extracted results to those Design/Theoretical Values - Calibration of Analytical Model for the bridge	For each frequency extraction, at least 8 hours of stationary and ergodic data are required. Only at manual trig	X		X	
Tensile Forces in Stay Cables - Measurement and Tabulation of Modal Frequencies, hence the Tensile Force in each Stay Cable - Plotting the measured frequency of stay cables along bridge-deck alignment and comparing with the first few lower frequencies (measured) of deck and tower for parametric effect validation - Comparing the measured/extracted force results with those Design Values at SLS & ULS - Assessing the vertical and horizontal forces induced in deck and towers as a result of cable vibration	Same as above.	X		X	
Spectra Plots - For extreme events such as heavy traffic flow, monsoons and typhoons, etc. - Acceleration, velocity and displacement spectra at bridge-deck - Acceleration, velocity and displacement spectra at tower-tops - Acceleration, velocity and displacement spectra at instrumented stay cables	Duration of the whole event	X		X	
Displacement Demand Ratio Plots - Plots of the ratio of the measured maximum displacement at instrumented location to the design values at SLS and ULS respectively - Correlating with corresponding requirements for inspection and maintenance	Monthly and Annually	X			

Notes:

1. AD = Amplitude Domain, TD = Time Domain, FD = Frequency Domain and FC = Frequency Count.
2. 'X' denotes format required.

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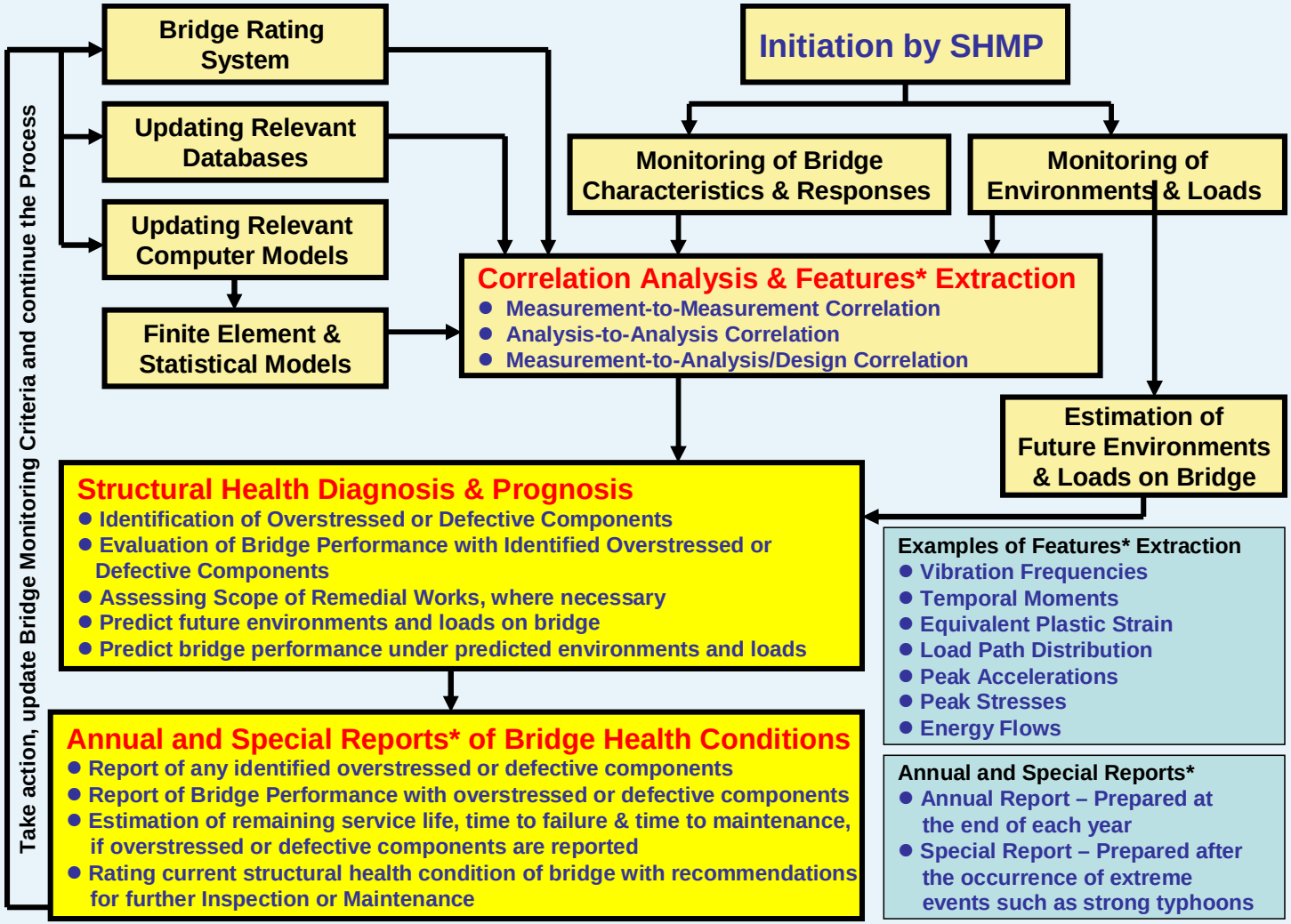
Structural Health Evaluation System (SHES)



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Software

- Software A – Customized LabVIEW or MATLAB Software for Data Acquisition and Processing or products having equivalent functions or performance
- Software B – Customized LabVIEW or MATLAB Software for Data Transmission and Filing Control or products having equivalent functions or performance
- Software C – Customized LabVIEW or MATLAB Software for Data Archiving and Backup or products having equivalent functions or performance
- Software D – Customized LabVIEW or MATLAB Software for Display, Operation and Control or products having equivalent functions or performance
- Software E – NI Developer Suite Professional Control Edition or products having equivalent functions or performance
- Software F – NI DIAdem Powerful Analysis and Report Generation Software or products having equivalent functions or performance
- Software G – MS Office Professional for 32-bit and 64-bit MS Windows or products having equivalent functions or performance
- Software H – Adobe Design Collection or products having equivalent functions or performance
- Software I – Adobe Digital Video Collection or products having equivalent functions or performance
- Software J – Adobe Publishing Collection or products having equivalent functions or performance
- Software K – NI VI Logger or products having equivalent functions or performance
- Software L – MATLAB “Data Analysis Suite” or products having equivalent functions or performance
- Software M – MSC.PATRAN or products having equivalent functions or performance
- Software N – MSC.Marc or products having equivalent functions or performance
- Software O – MSC.Fatigue or products having equivalent functions or performance
- Software P - ANSYS Physics Verticals Whole Package or products having equivalent functions or performance
- Software Q – GPS Monitoring Software
- Software R – CAD Software for viewing and editing of drawing files
- Software S – FEvis Finite Element Results Visualization Publisher for Windows with FEvis Viewer or products having equivalent functions or performance
- Software T – Customized Traffic Jam Recording Software

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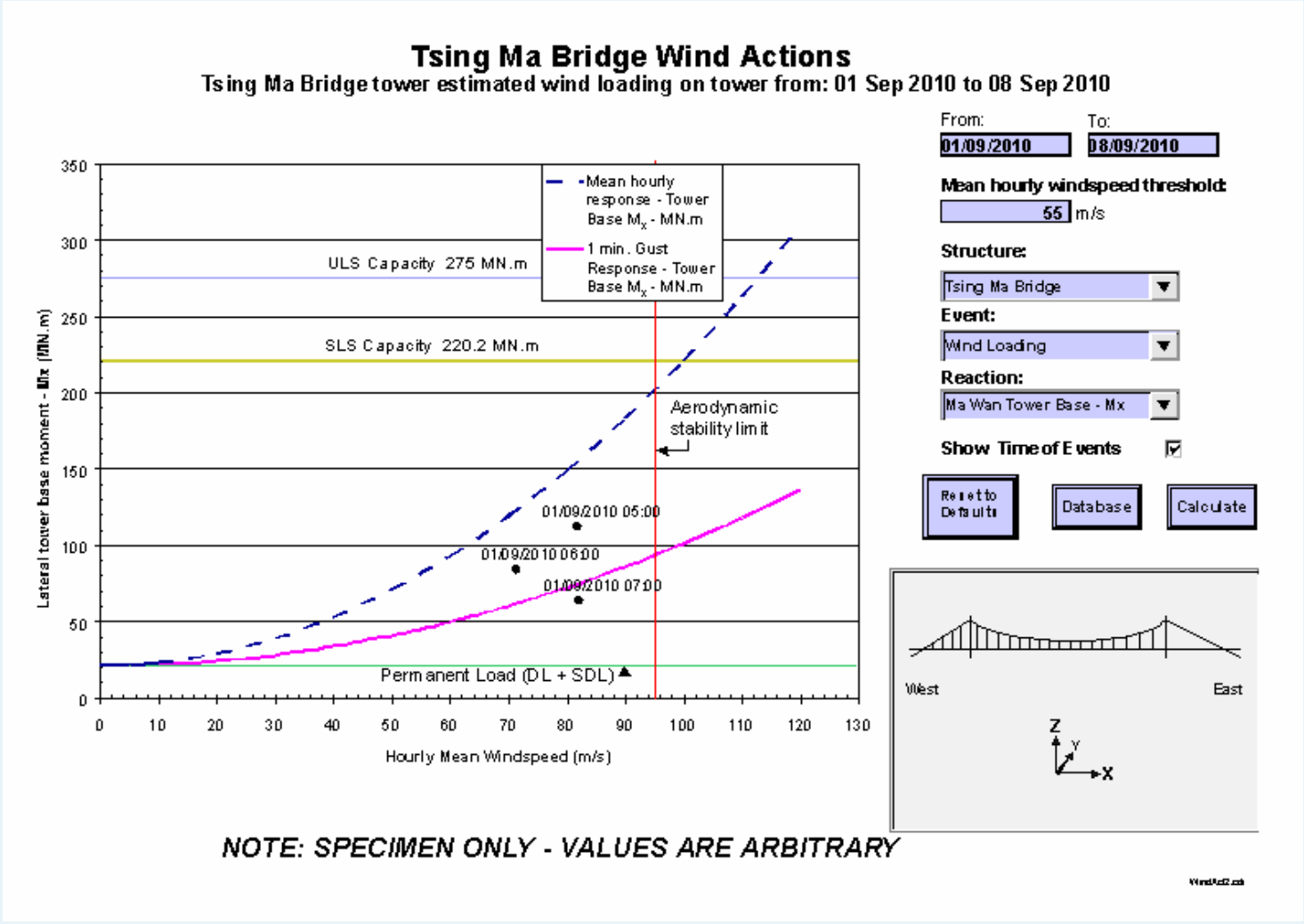
Wind Loading



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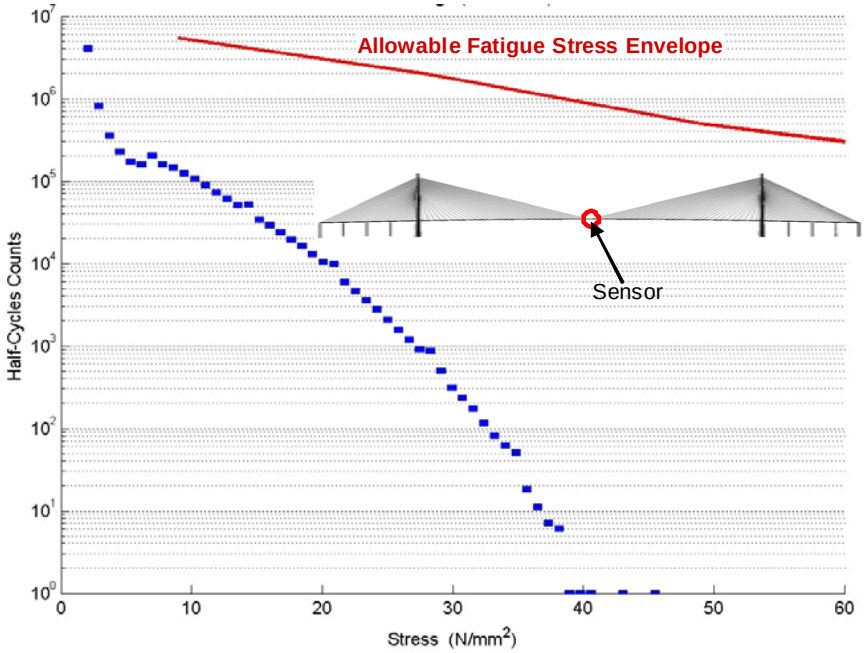
Fatigue

Histogram of Strain / Stress Half-Cycles for Fatigue Damage Assessment

Fatigue Damage deduced from Traffic Flow Conditions
– Fatigue Cycles from histogram data recorded at Longitudinal Girders of Stonecutters Bridge



Fatigue Cycle
Allowable Fatigue Stress

Fatigue Damage Statistics

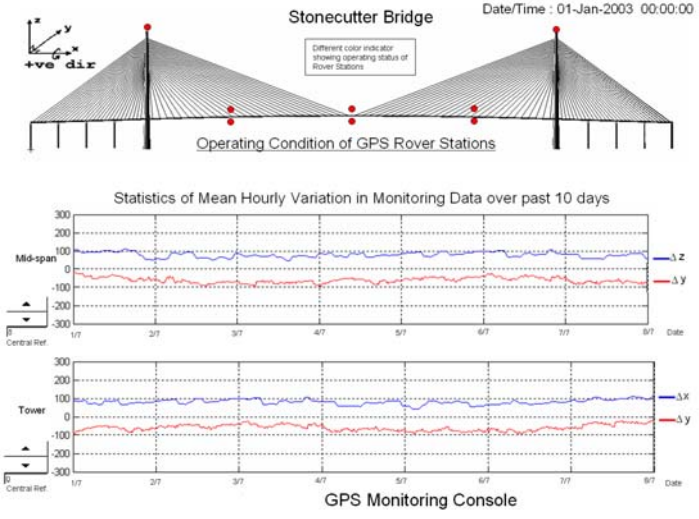
Fatigue Damage	365	micro-dar
Est Fatigue Life	1027	years
No. of Half-Cycles	8.97167e+006	
No. of Hours	3287	hours
Upper Valid Limit	1000	micro-stra
Lower Valid Limit	10	micro-stra
Fatigue Class	F	

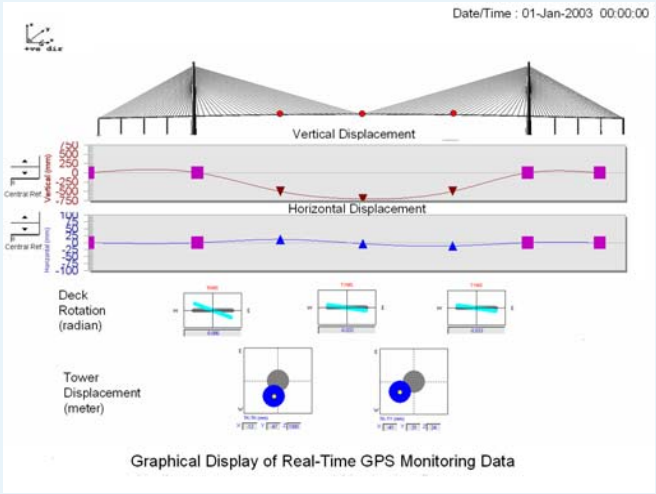
Stress Range Summary

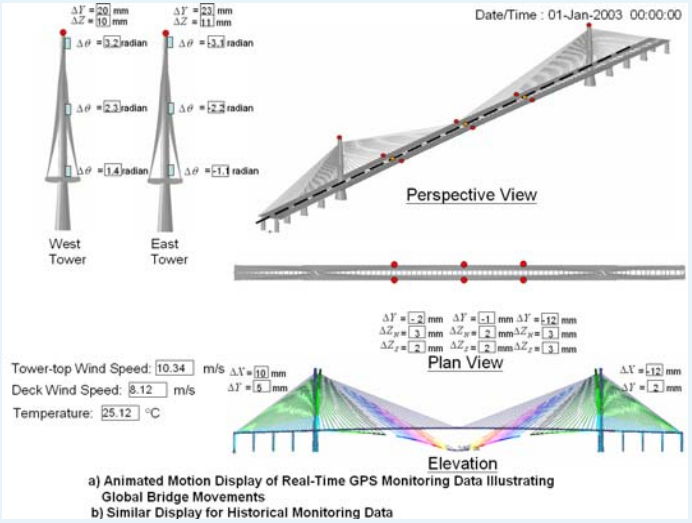
Stress Range (N/mm²)	No. of Half-Cycles
0 to 5	5.40746e+006
5 to 10	955498
10 to 15	429015
15 to 20	134583
20 to 25	36976
25 to 30	7374
30 to 35	709
35 to 40	44
40 to 45	2
45 to 50	1
50 to 55	0
55 to 60	0

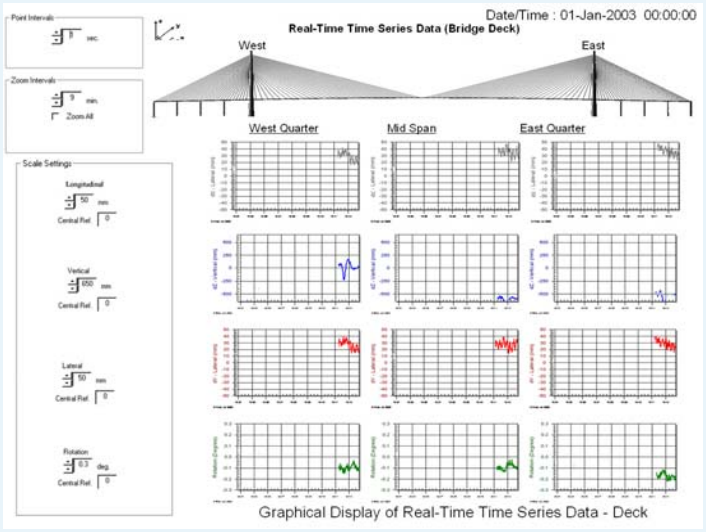
Figure 33-35 Example Plot of Fatigue Damage Assessment

GPS Monitoring Console – 4 in 1 Display of Selected Monitoring Regimes









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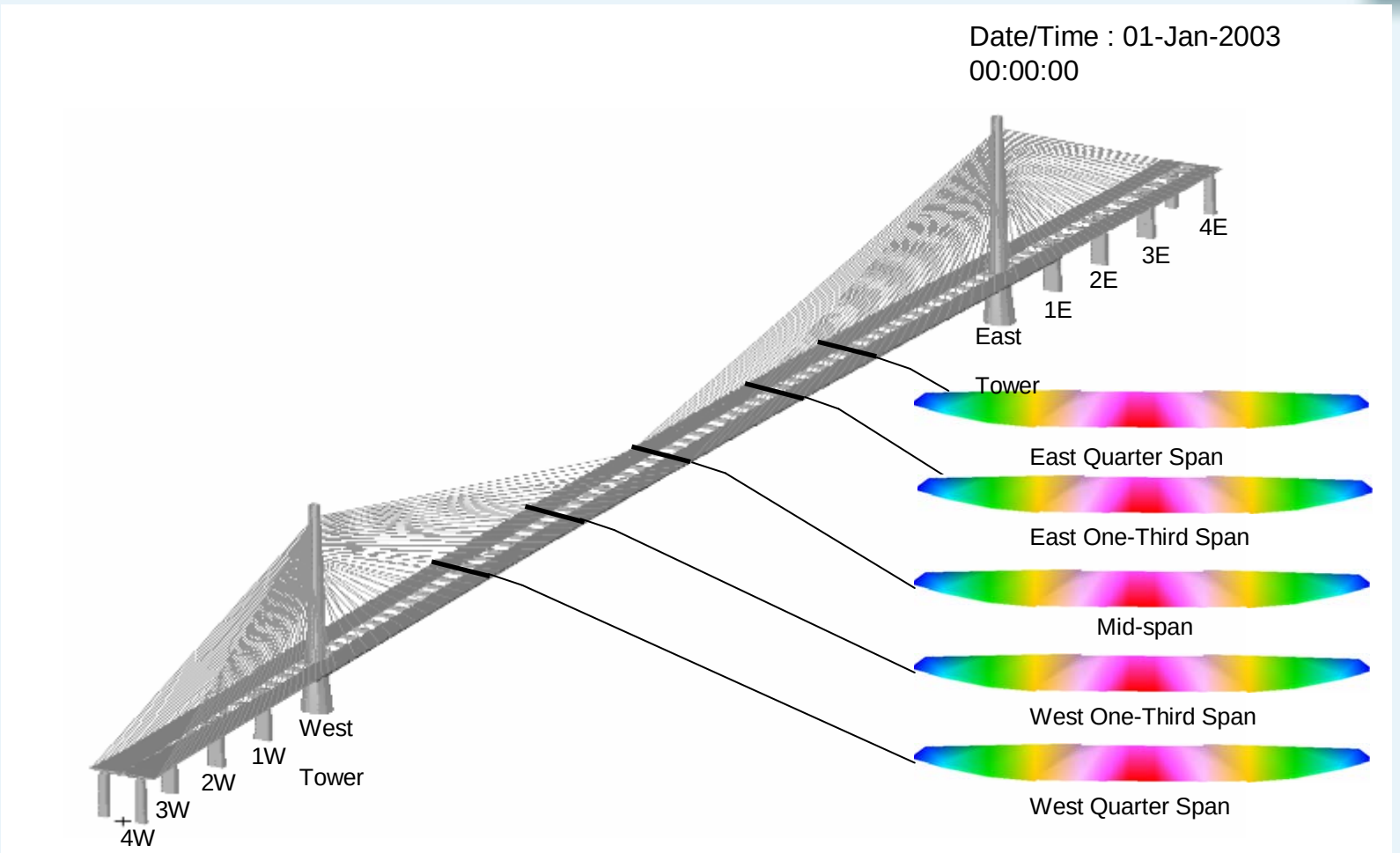
Damage Detection



Perspective View

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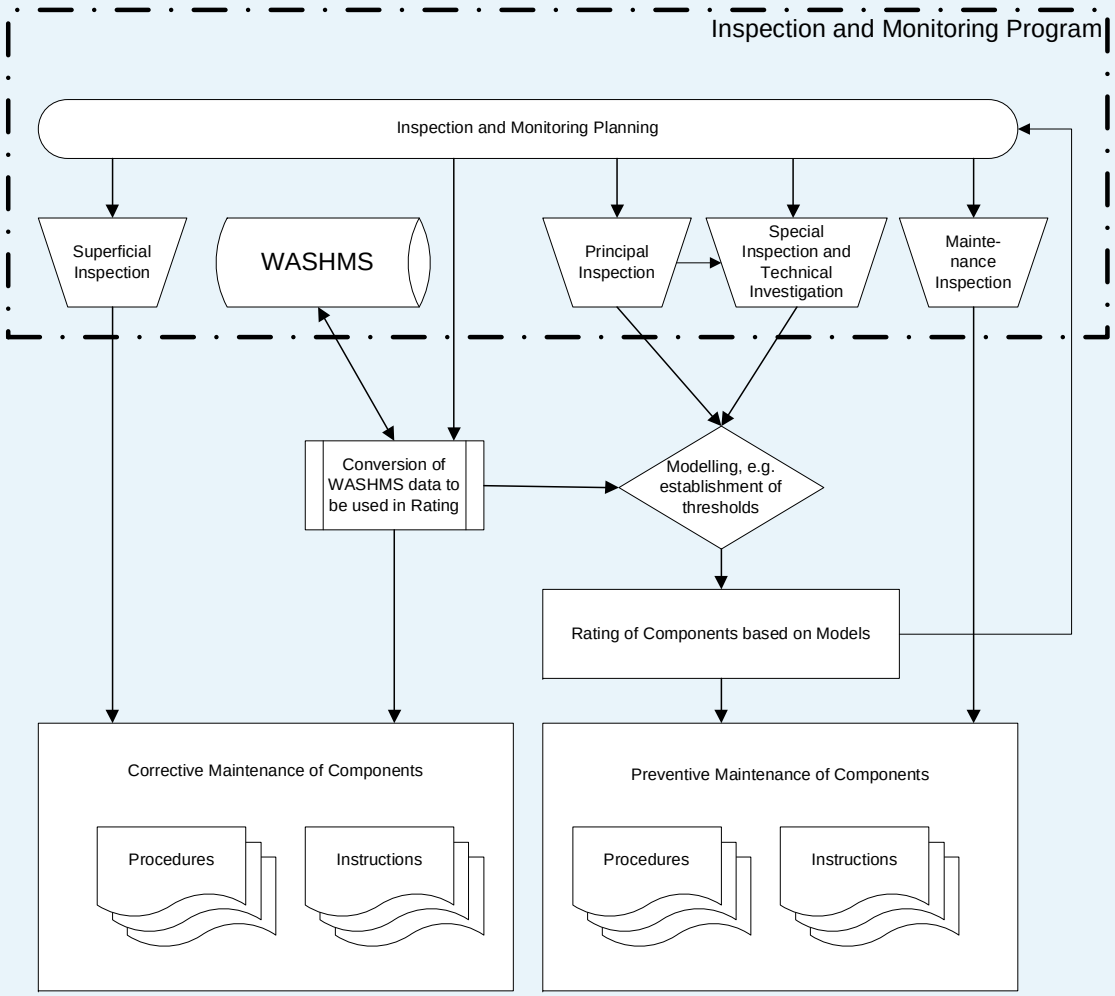
Inspection & Point Ranking



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WASHMS Status March 2009

- Sensory system: Basically, the installation for embedded sensory system is completed, but not for the associated cabling work. Installation for the other sensory systems are outstanding at the moment.
- The Global Cabling Network System is completed.
- Data Acquisition Units - The FAT for DAU 5 to 8 was conducted in mid February and the others (DAU 1 to 4) will be carried out around end of March 2009. The DAU 5 to 8 will be delivered to site in March and DAU 1 and 4 will be delivered to site in around April 2009.
- Computer servers - the hardware proposal are now under review and will be finalized in this month. Servers would be delivered to site around May 2009.
- Software development - Most of the development for customized software, such as Software A,B,C,D, Q, T, and the Historical Database is on-going. In term of percentage, it should be around 50-60% completed.

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Stonecutters SHMS compared to other major bridges

- **Stonecutters Bridge.**
  WASHMS, 80 mill DKK, **3,2%** of construction cost (2.500 mill DKK)
- **Sutong Bridge.**
  SHMS, 23 mill DKK, **0,5%** of construction cost (4.500 mill DKK)
- **Naini Bridge.**
  SHMS, 6 mill DKK, **1,2%** of construction cost (500 mill DKK)

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