Long Term Bridge Health Monitoring System in the Paira Bridge

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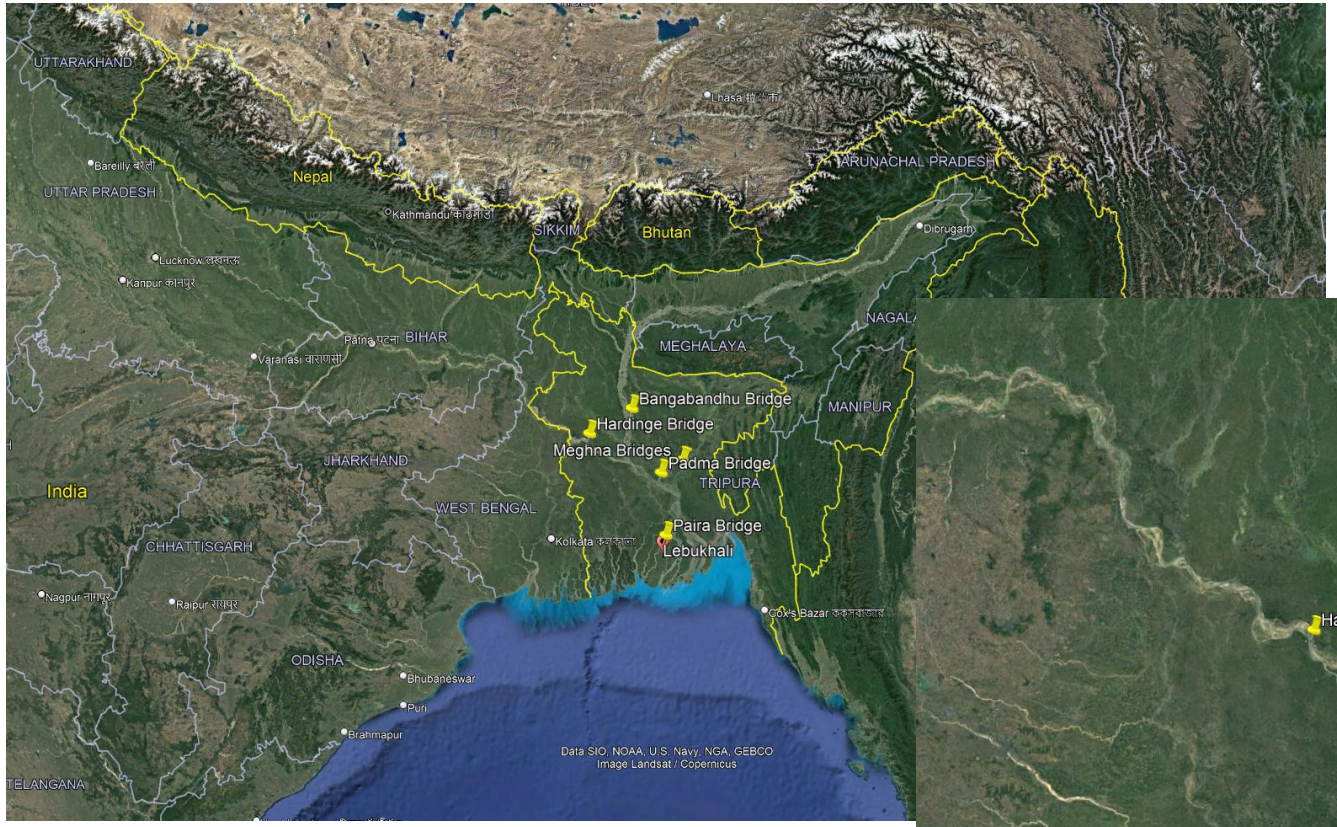
Objectives

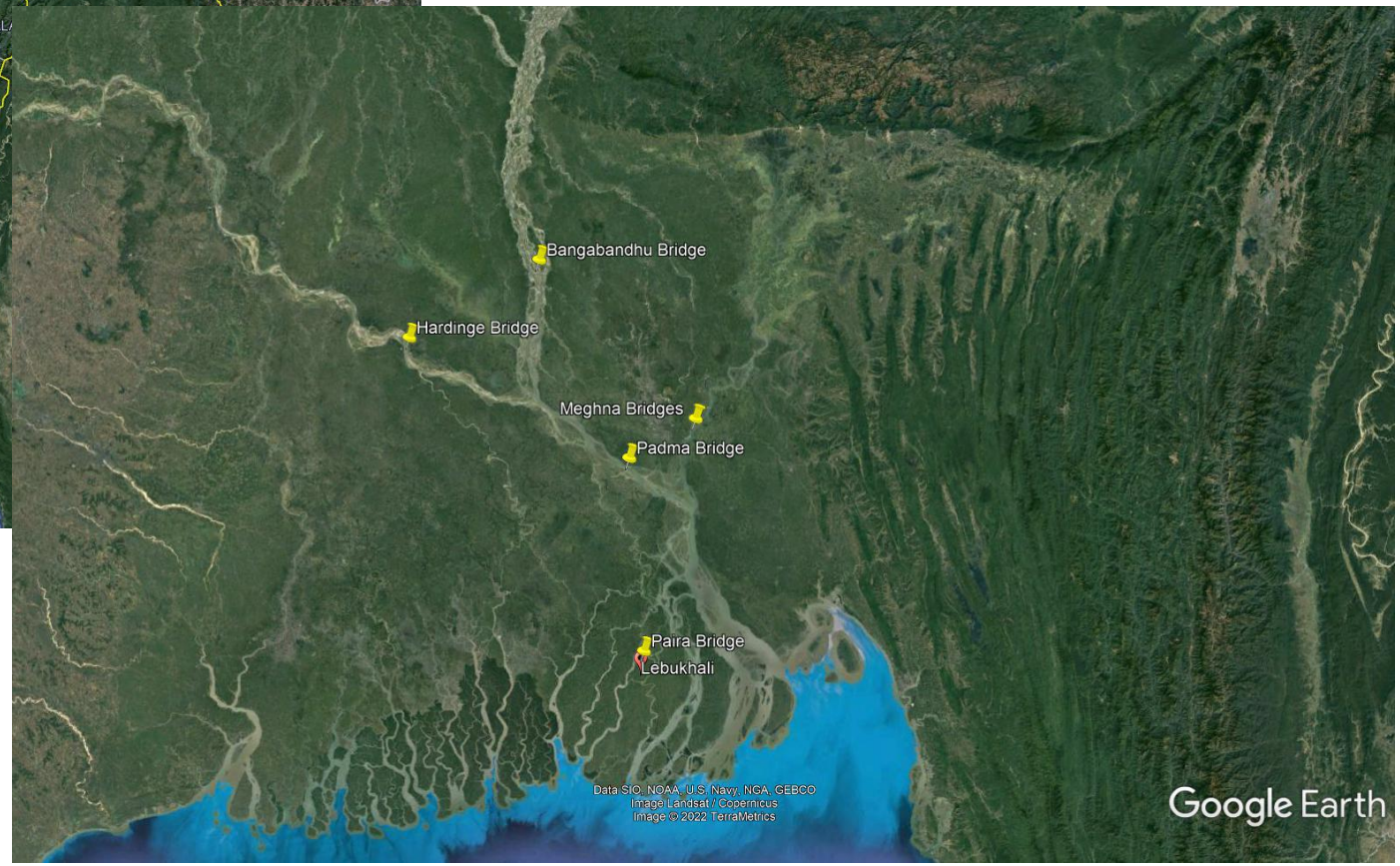
- Civil Infrastructures have been constructed across the Asian region; however, maintenance has already become a big issue
- Although a lot of monitoring technologies and products are developed, the administrators are struggling to choose technologies since the practical specifications are not standardized
- Given strict budget, appropriate technologies are needed.

TC-28 is to prepare the guidelines on the scheme for the maintenance of infrastructure; by making best use of monitoring technology, the maintenance work would be made logical, time sensitive and cost-efficient

Past difficulties



- Hardinge Bridge
- Meghna Bridges
- Bangabandhu Bridge
- Numerous small span bridges of RC, PC and steel

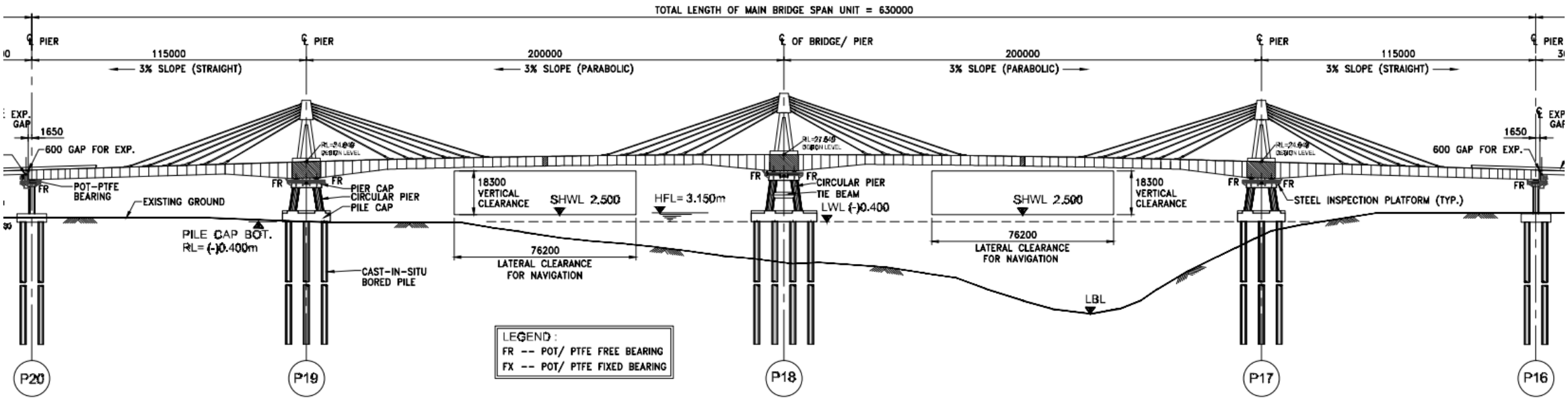


- Corrosion
- Overloading
- Scour
- Cracks in pre-stress concrete

Project Profile

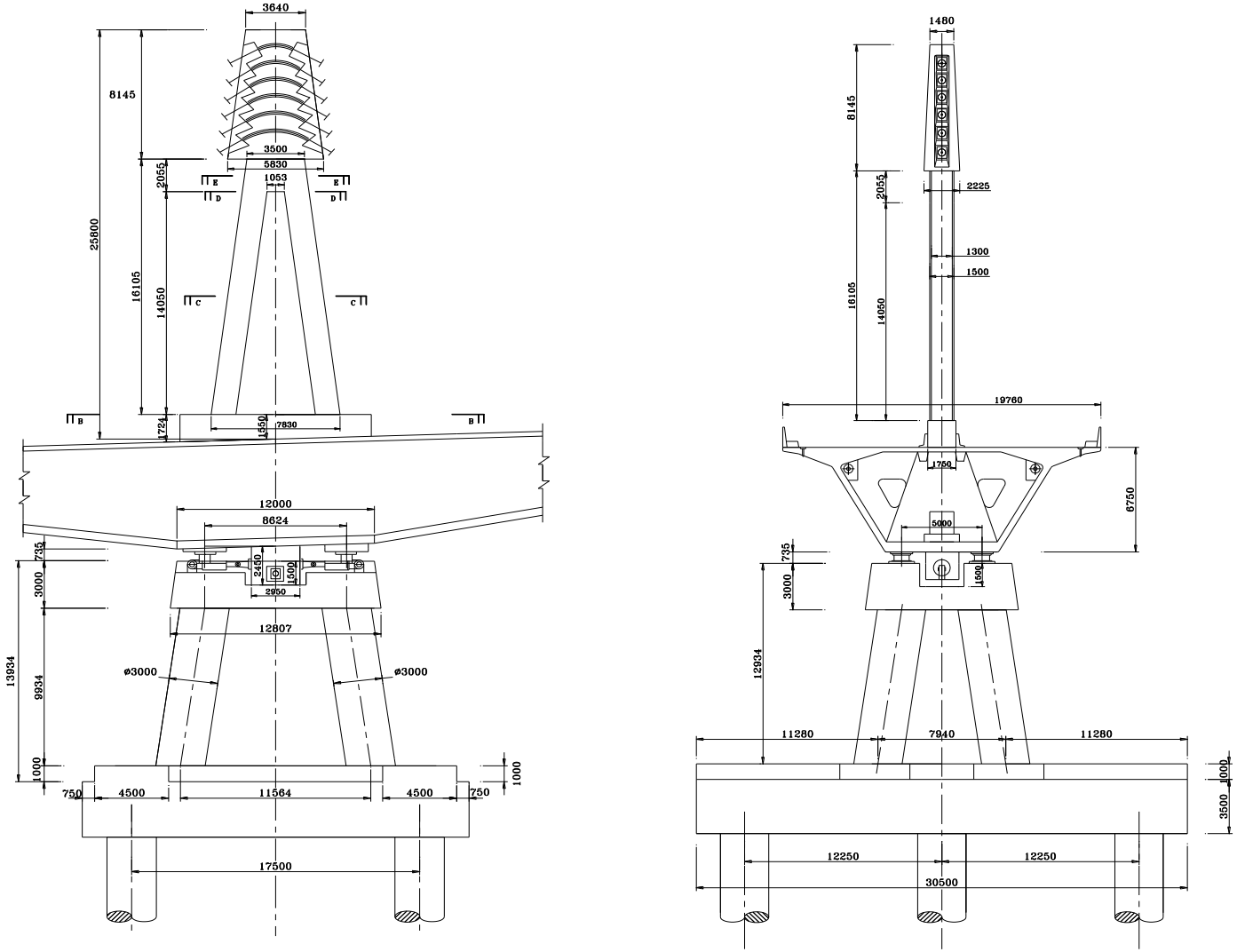
- Owner: Roads and Highways Department, Bangladesh
- General arrangement: 16@30m+（115+2@200+115）+12@30m.
- Total length: 1470m
- Total width: W=19.76m
- Foundation: CIP D2500 L=130m, 6pcs @P16, P20, 12pcs @P17, P19, 16 pcs @P18.
- Substructure: RC concrete D3000
- Superstructure: 200m span, single plane cable-supported bridge, 6 pairs per tower
- Construction stage: 2016~2021, to be completed in Jun 2021

Project Profile

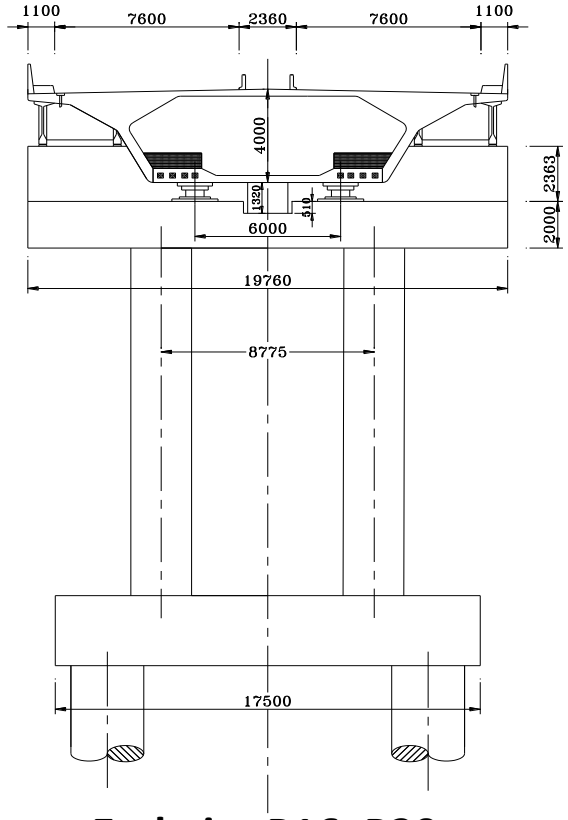


Main bridge configuration

Project Profile



Tower general view



End pier P16, P20

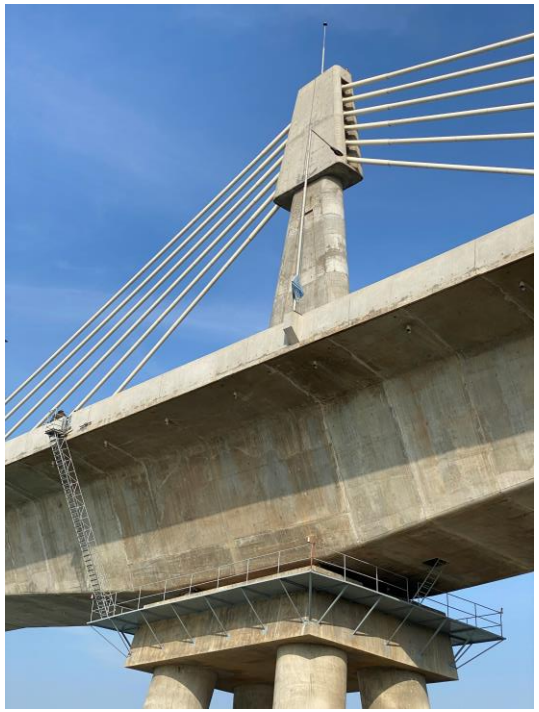
Project Profile

The bridge opened – October 2021

Project Profile

3D projected model of the bridge after completion

The Bridge



Inspiring Motivations

Key degradation factors considered

- Corrosive environment (temperature variation, humidity, salt, rain water…)
- Aging
- Long-term effects (creep, shrinkage, relaxation, fatigue …)
- Live load (repeatedly application, overload…)

Consequences

- Reduce driving safety
- Shorten bridge life span
- Cause accidents => costly recovery plan
- Negative impact to road traffic

Solutions:

- Bridge Health Monitoring System
- Real-time monitoring data
- Early warning possibility
- Take preventive actions => make sure the bridge in "*good health*" at all time

Concepts and Roles

Concepts

- ❑ Analyzing dynamic responses transferred by sensors
- ❑ Extract damage-prone characteristic values
- ❑ Evaluate safety levels

Roles

- ❑ Real-time monitoring, non-stop in project life
- ❑ Investigate "*bridge health*" by non-destructive method
- ❑ Detect damage areas accurately
- ❑ Provide authority with guidance for maintenance
- ❑ Maintain bridge life-span

Concepts and Roles

Principles of BHMS design

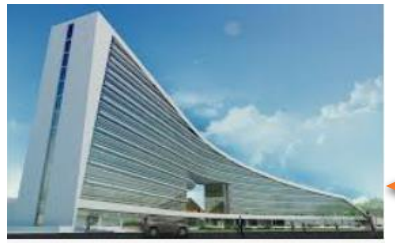
Fundamental requirements

- Suitable to bridge structures
- Practical, easy to use
- Economical, cost-effective
- Highly reliable
- Sufficient accuracy
- Durable

Where to place monitoring sensors?

- Stress: where maximum stress appears - @ mid-spans, piertable…
- Displacement: where maximum deformation is likely – @ mid-span, end girder, tower tops…
- Vibration: dependent on mode of vibration – @ mid-span, end-span, tower top…
- Cable force: most critical members - @ longest cables
- Weather station: tower tops
- Traffic surveillance camera: most convenient places – @ P18
- Lightning protection: tower top & inside girder

Long-term Bridge Health Monitoring Configuration



RHD HQ - Dhaka

System Configuration

Monitoring Center

Data processing server

Web server

Data collection server

Data collection equipment

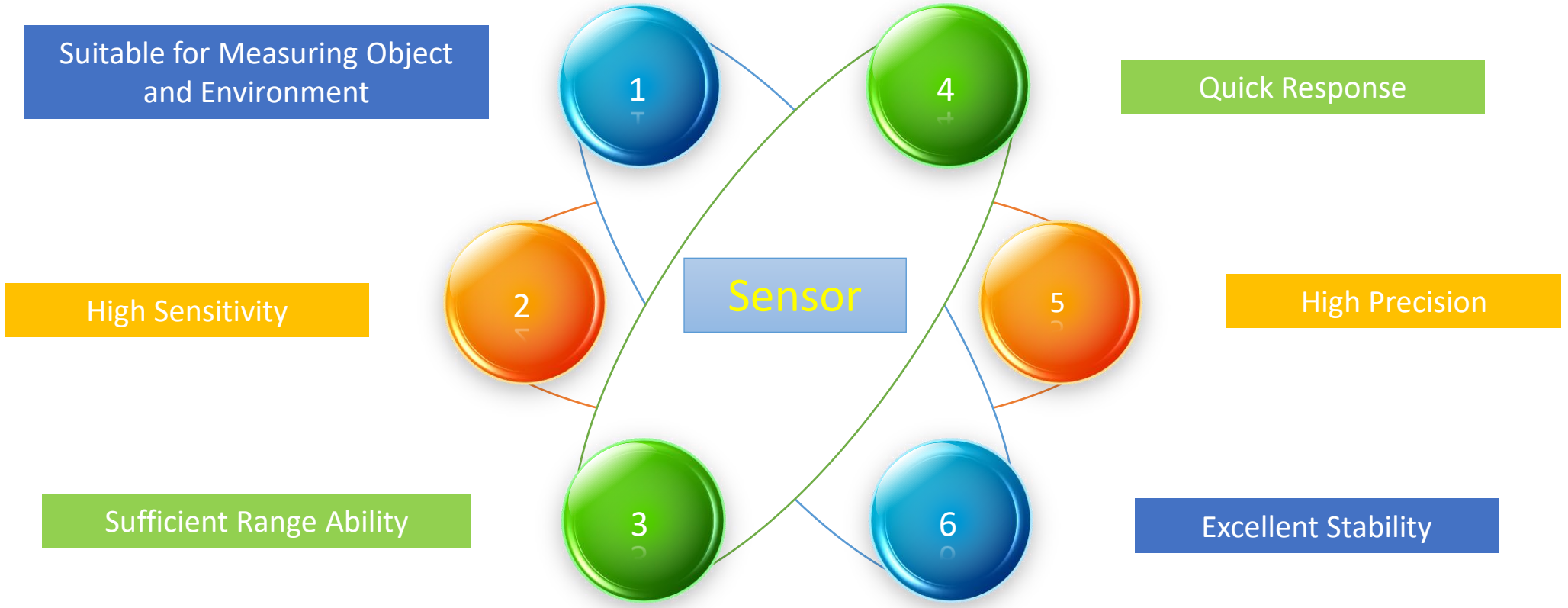
Remote users

Sensors

Paira Bridge Site

Long-term Bridge Health Monitoring Configuration

Principles of sensor selection



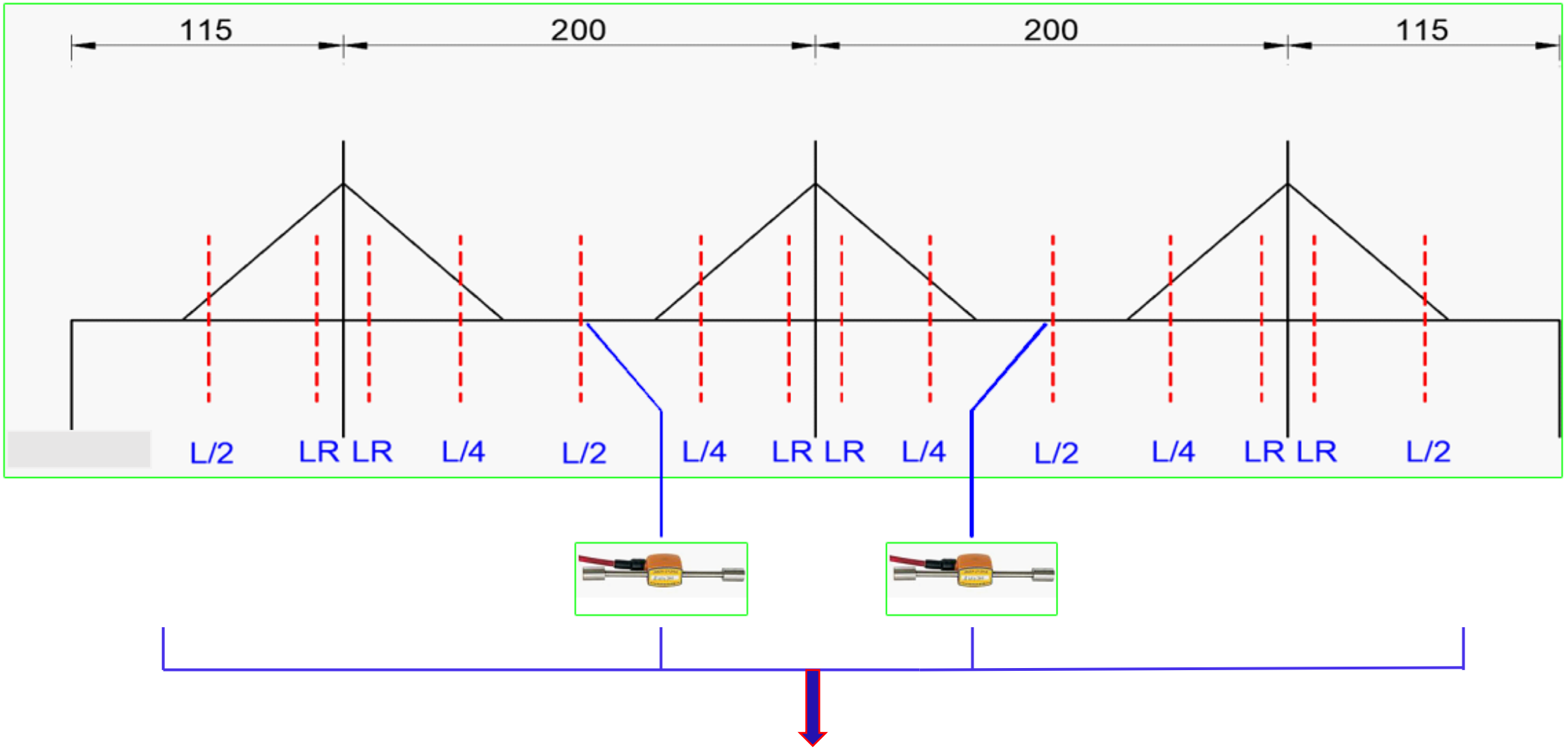
Monitoring Program

Paira Bridge (Lebukhali Bridge) is an Extradosed type Bridge. The super structure of Main bridge is composed of box girder and stay cable.

Regular health check up includes

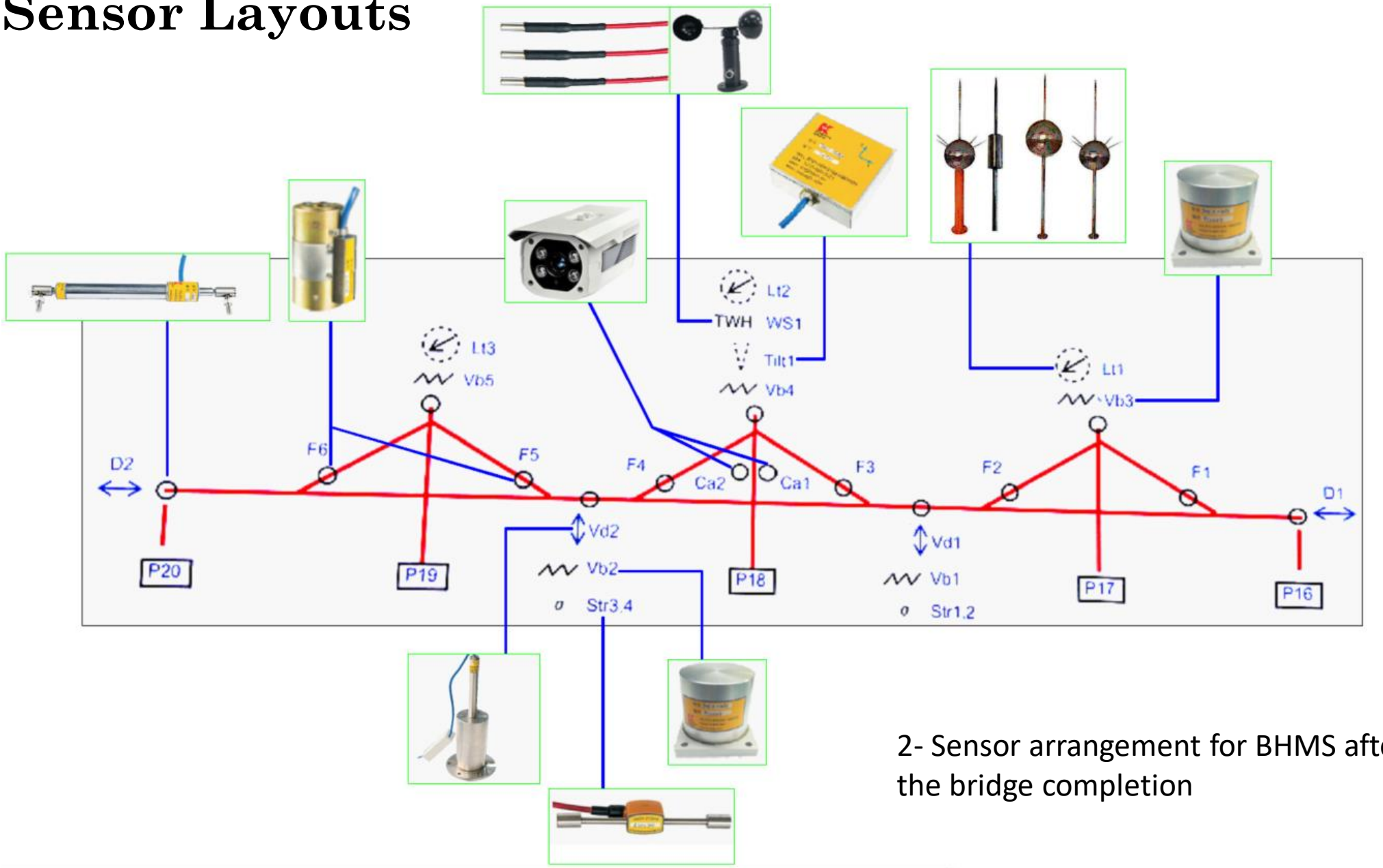
- Maintenance of pot bearing , Expansion joints
- Monitoring of wind speed with anemometer for stay cables' damping factor and vibration
- Settlement behind abutment
- Shrinkage cracking on box girder segment

Sensor Layouts



1- Sensors installed during construction stage can be integrated in BHMS

Sensor Layouts

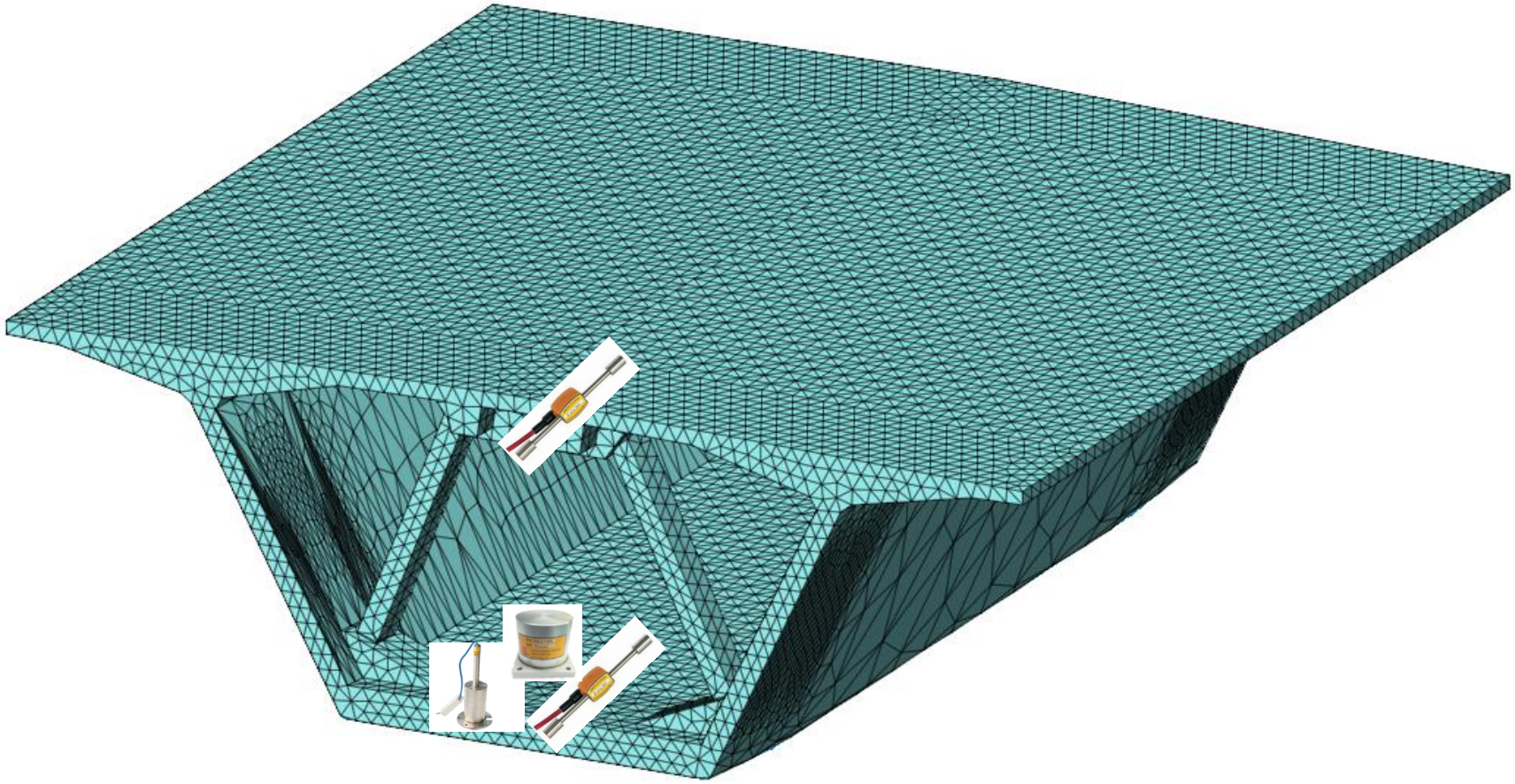


2- Sensor arrangement for BHMS after the bridge completion

Summary of sensors for Paira bridge

No	Sensor	Location	Function/Measurement	Quantity
1	Strain sensor (Str1~4)	Middle position of two mid span	Stress state of main girder	4
2	Displacement Sensor (Vd1~2)	Middle position of two mid span	Main girder displacement	2
3	Acceleration Sensor (Vb)	Mid span and top of tower	Vibration of girder and tower	5
4	Cable force sensor (F1~6)	At the six longest stay cable	Cable force	6
5	Wind Tester(WS1)	Top of the mid tower	Wind speed and direction	1
6	Temperature sensor (TWH)	Top of the mid tower	Ambient temperature, air humidity	1
7	End gap gauge(D1~2)	Expansion joint position	Deformation of expansion joints	2
8	Inclinometer Sensor (Tilt1)	Top of the middle tower	Tilt/Inclination of tower	1
9	Lightning protection (Lt1~3)	Top of each tower	Protect sensors from lightning	3
10	Camera(Ca1~2)	Both sides of the middle tower	Traffic flow monitoring	2

Feedback from FEM Model

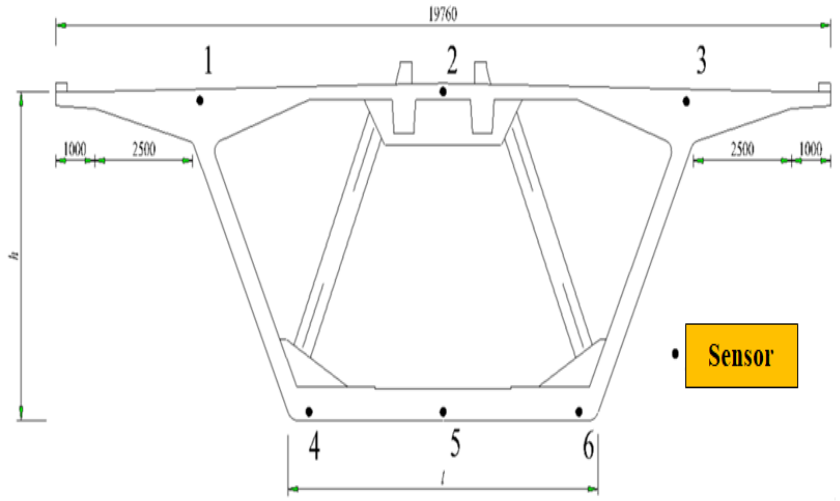


Example of sensor placement within the PC box girder

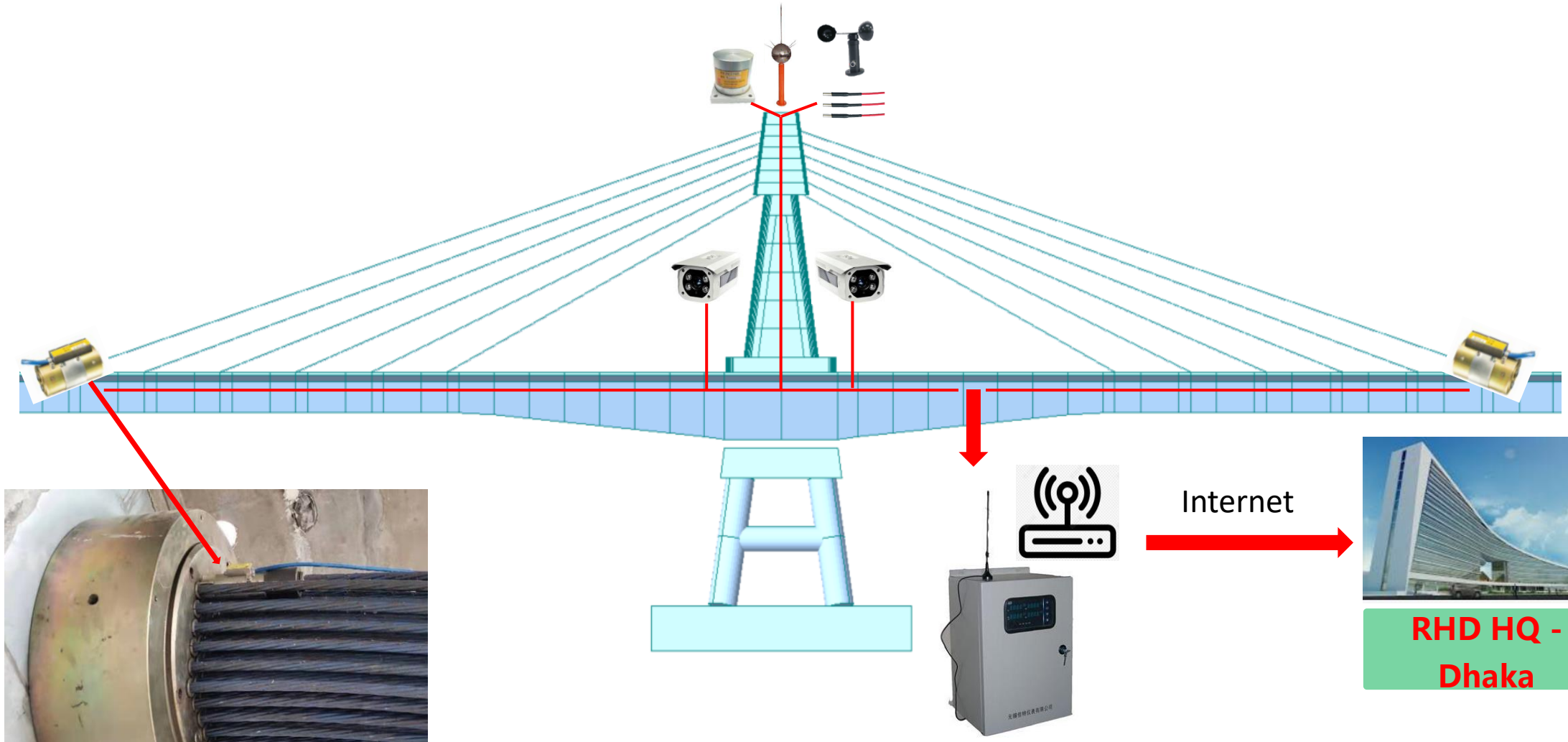
Monitoring the Pre-stress

Summary of construction stage sensors integrated to BHMS of Paira bridge

No	Sensor	Location	Function/Measurement	Quantity
1	Strain sensor	L/2, L/4, LR – L= span length	Stress state of main girder	84
2	Cable force sensor	Every stay cable	Tension force in single strand	36



Monitoring Program of Paira Bridge



Sensors arrangement at P18 tower

Deformation

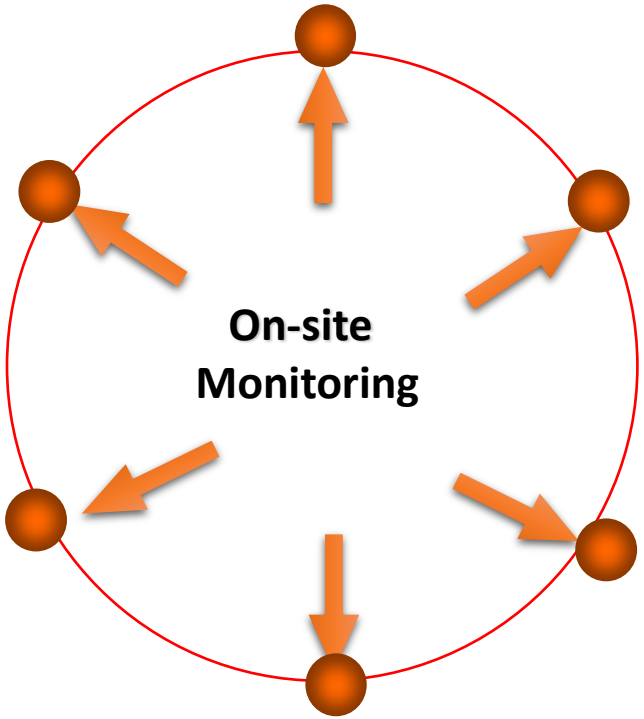
- Main girder
- Expansion joint

Stress

- Girder stress

Vibration

- Main girder
- Tower top



Permanent Pre-stress

- Cable force

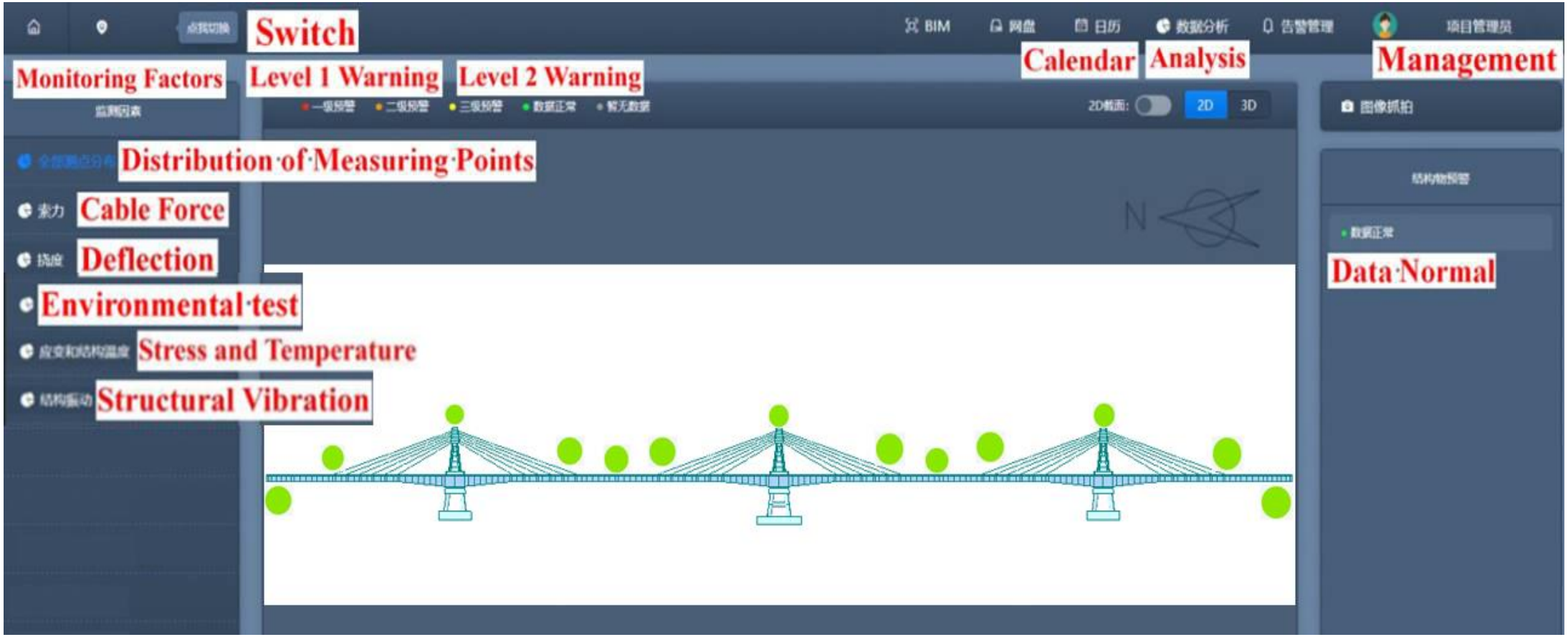
Environment

- Temperature
- Humidity

Wind

- Wind speed, directions

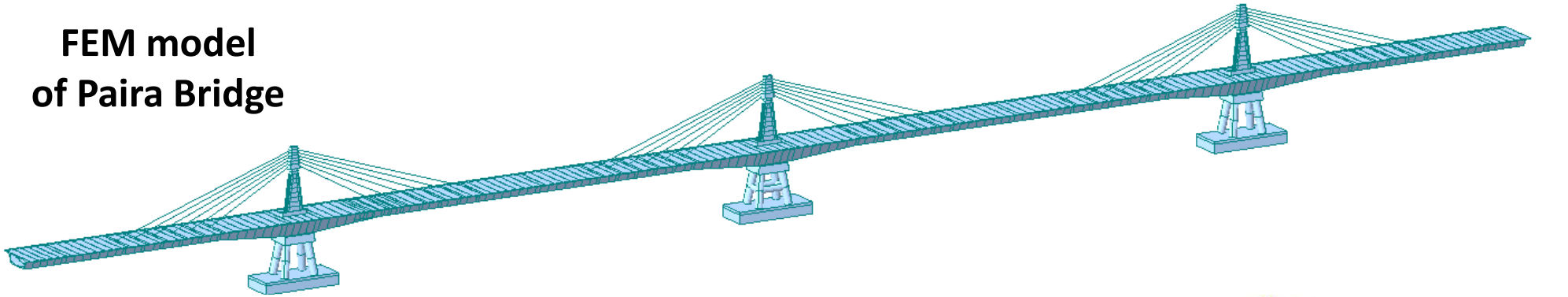
Monitoring Program of Paira Bridge

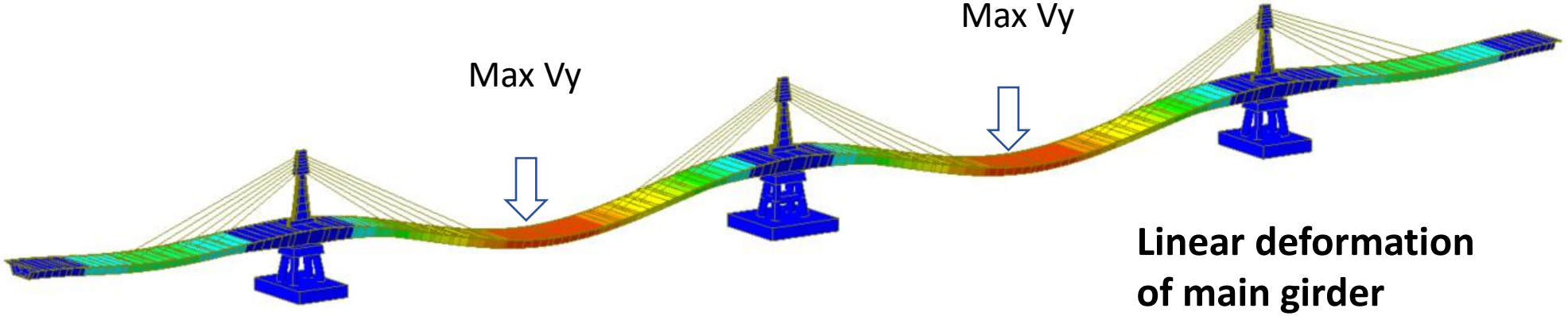


User Interface of BHMS

Data Analysis: Calculation Model

FEM model of Paira Bridge





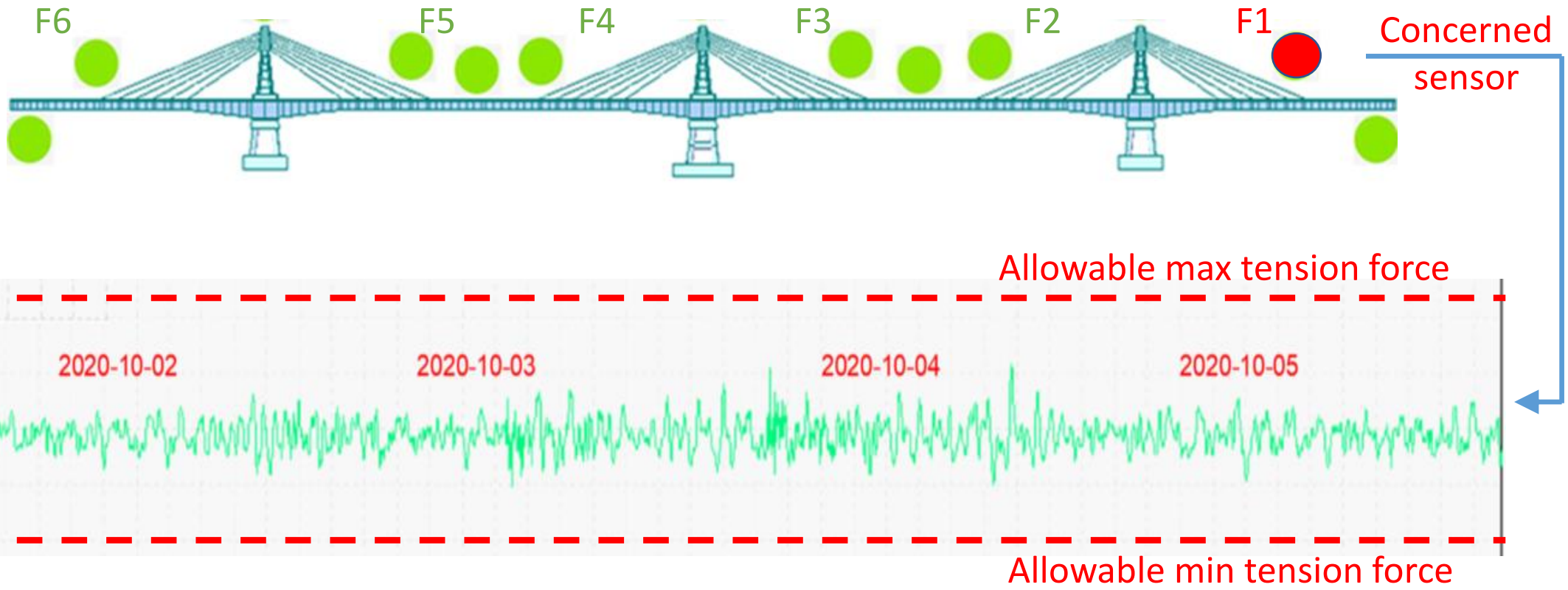
Linear deformation of main girder

- Early warning limits are provided by mean of finite element analysis.
- Compared with the measured data => enable authority to judge the safety levels

Data Analysis: Calculation Model

Example of monitored data – Expansion joint displacement vs time

Data Analysis: Calculation Model



Example of monitored data – Stay-cable force vs time

Maintenance and Upgrade

Regular inspections shall be conducted as guidelines below

(1) Weekly inspection (performed and reported by local engineers)

- Data: display functions
- Temperature/humidity: in the control room
- Power supply: voltage regulator

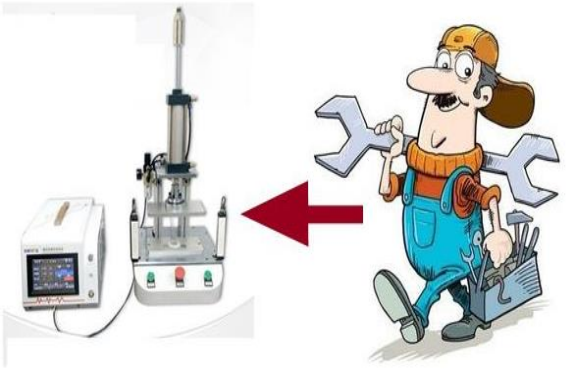
(2) Monthly inspection (by local engineers)

- Sensors: loosening, damage, aging, loss, rain water etc...
- Power supply: voltage regulator

Maintenance and Upgrade

(3) Annual inspection (by locals & expats)

- Data: display functions
- Sensors: loosening, damage, aging, loss, rain water...
- Temperature/ humidity: in control room.
- Power supply: voltage regulator, stable or interrupted...



(4) Maintenance after the warranty period (by expats)

- Maintenance service: comprehensive inspection of software/ hardware, prepare inspection results and relevant suggestions.
- BHMS functions normally: BHMS provider makes on-site maintenance annually
- If abnormal due to technical reasons: on-site maintenance shall be twice a year.

Maintenance and Upgrade

(5) Upgrade (by expats)

- Integrated system: Included construction sensors into BHMS
- Open system: more sensors can be added without changing the hardware
- Up-to-date technology: stay close contact with suppliers for better solutions

Key Takeaways

- First experience of Bangladesh to engage live data gathering and analysis system for bridge operation and health monitoring.
- Health monitoring system in installed based on systematic analysis of maintenance requirements for key structural elements for site conditions.
- Remote data gathering and real time interpretation of data is possible
- Extra redundancies for data in off line mode


THANK YOU