Performance Assessment of Damaged Suspension Bridge in Myanmar by Spatial Measurement and Structural Analysis

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SATREPS: JICA-JST Fund Research Project (FY2015-2019)

Development of a Comprehensive Disaster Resilience and Collaboration Platform in Myanmar



Principal institutions: University of Tokyo, JAPAN
Yangon Technological University, MYANMAR

ANZEN SATREPS : MYANMAR NIPPON ZERO-CASUALTY ENGINEERING NETWORK 2014-2020

Project Office at YTU

Research Centre for Urban Safety









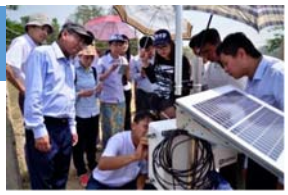
Meeting rooms



Equipment for measurement etc.

Myanmar's steady economic growth by safe cities formation

Hardware, Software, Human resources



Project Groups

1. **Water-related Disaster Group**
2. **Traffic / People mobility Group**
3. **Geo-spatial Technology Group**
3. **Earthquake-related Disaster Group**
4. **Infrastructure Management Group**
5. **Disaster Management Group**

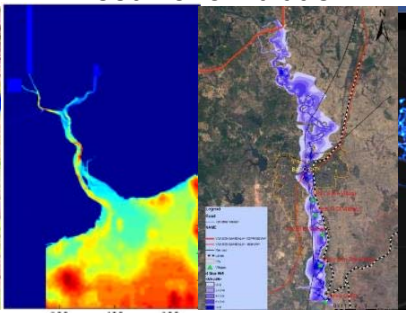




Land use



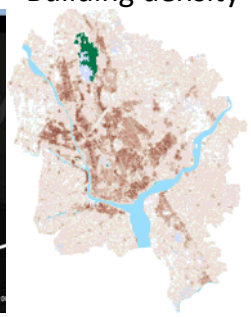
Flood risk simulation



People mobility



Building density



Infrastructure Management Group / Members

JAPAN

Univ. of Tokyo


Dr. Kohei Nagai


Prof. Reiko Kuwano


Dr. Koji Matsumoto


Dr. Tsukasa Mizutani


Dr. Hiroshi Dobashi (Metropolitan Expressway)

Hokkaido Univ.




Prof. Hiroshi Yokota Dr. Michael Henry

Nagaoka Univ. of Tech.




Prof Eiji Iwasaki, Dr. Takeshi Miyashita

4 students from Japanese universities

MYANMAR

Yangon Technological University (YTU)


Prof. Khin Than Yu, YTU
Civil Engineering

Ministry of Construction (MOC)

Daw Thein Nu, MOC
U Paing, MOC
U Tin Maung Htwe, MOC
U Myint Zaw, MOC
U Nyan Thar, YCDC

2 students from Myanmar universities

Activities of Infrastructure Group

Installation of simple monitoring system in damaged bridges analysis of the structural performance
(Short-term countermeasure)



Estimation of cause of early fracture of bolts in steel-truss bridge
(Long-term maintenance)



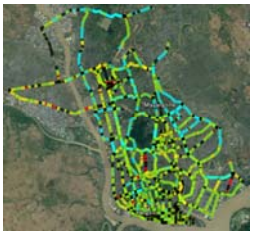


Establishment of bridge database system
(Strategic bridge management)





Measurement of road surface roughness
(Pavement management)



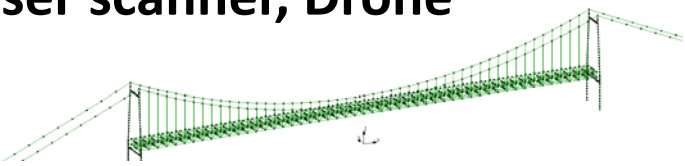
[Future plan] Construction quality control
Training for casting concrete (quality control)

Presentation Today

Assessment of
Damaged Suspension Bridge in Myanmar

1. **Twantay Bridge**
2. **Pathein Bridge (on-going)**

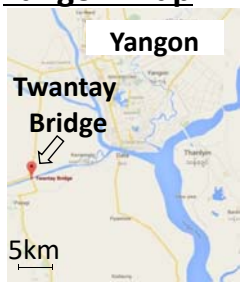
Key technologies: Simple monitoring
3D laser scanner, Drone
FEM

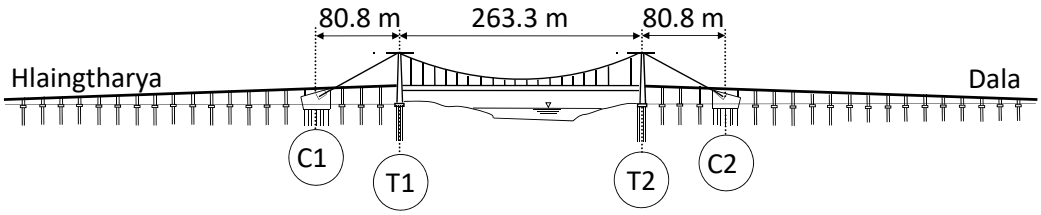



Twantay Bridge (constructed 2006)

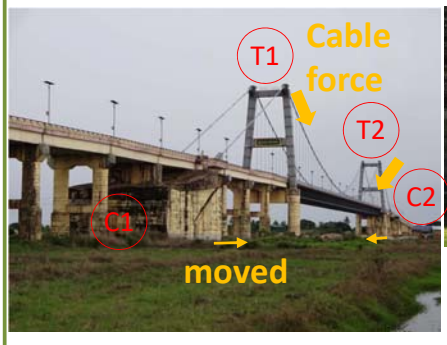
Yangon Map



General view:



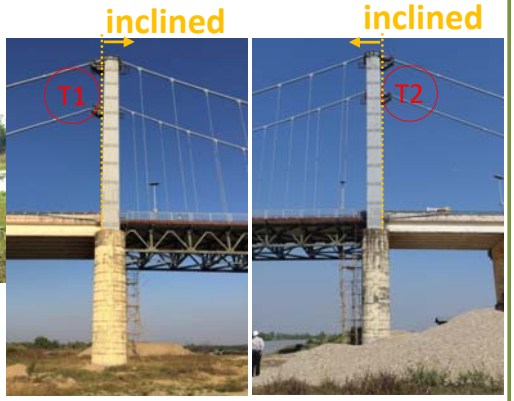
Suspension Bridge



Both anchorage blocks move



Soft soil condition



Both main towers are inclined

Main tower T2 is the target for the monitoring

Both main towers are inclined in bridge axis direction

Tower is inclined



Concrete Anchorage

Tower cable



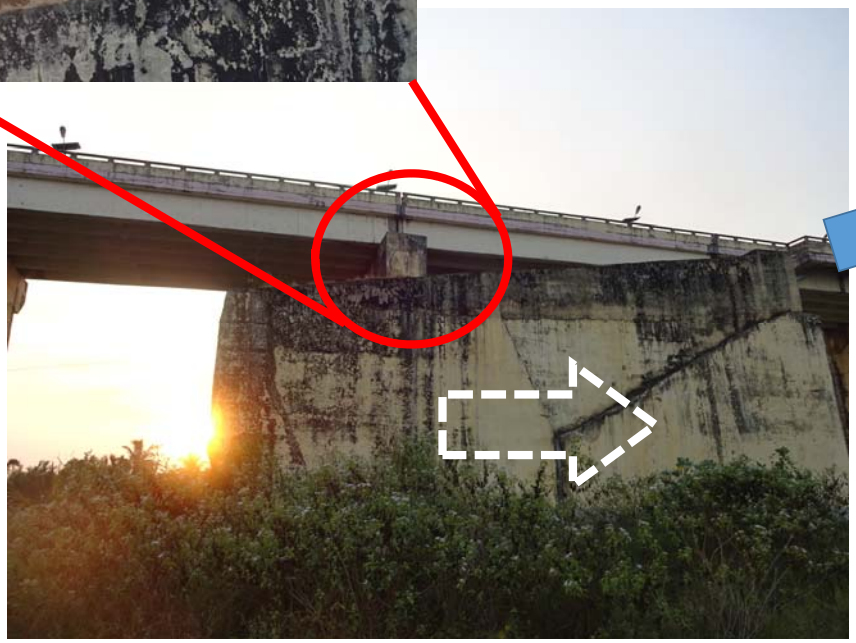
Moved ???



Simple soil test



Crack due to the movement of concrete anchorage



Tower cable

Recent cracked anchorage survey

South side anchorage



Crack under anchorage



Crack in neighboring pier

This cracks are supposed to be occurred due to movement of anchorage

North side anchorage



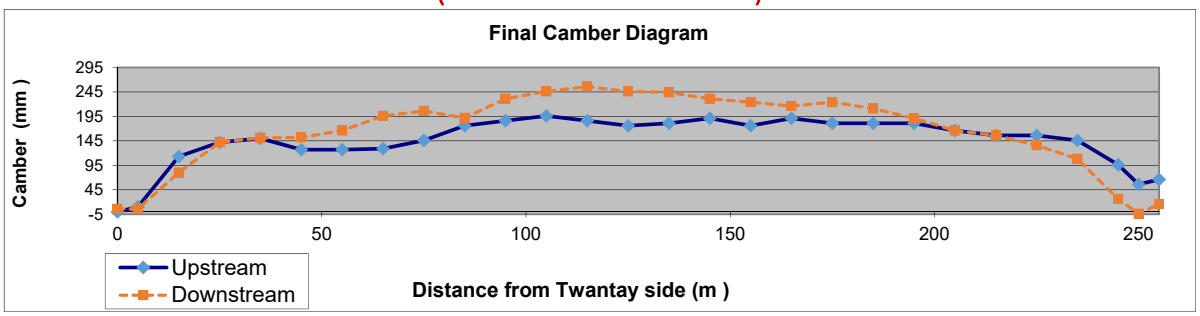


No crack in north side

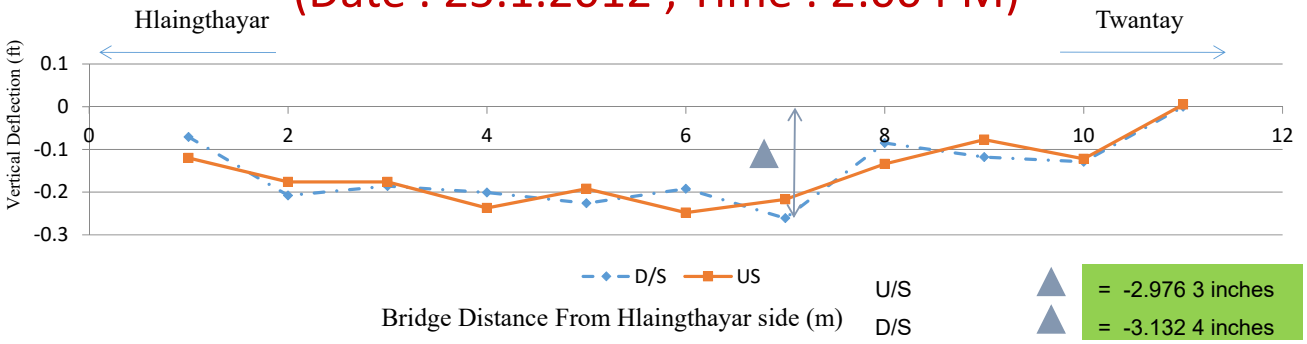
Measurement of road level by MOC

TWANTY BRIDGE MAIN BRIDGE STEEL TRUSS LEVEL CHECKING HLAINGTHAYAR TO DALA

(Date: 9.6.2006)



(Date . 25.1.2012 , Time : 2:00 PM)



Question

Is this bridge safe ?

Is it still moving??

Measure the tower inclination





Monitoring plan

Equipment: inclinometer and data logger

Measurement interval: 3 hours

Measurement term: 1 year (check every 3 months)

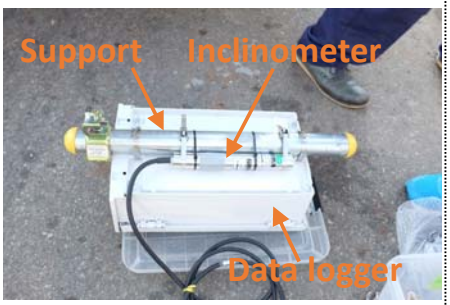
Monitor the inclination in bridge axis direction of the main tower

Twantay Bridge

1. Prepared support for Inclinometer & data logger



2. Set inclinometer and data logger at support



3. Connected inclinometer to data logger



4. Crane was used to reach the position



5. Mounted monitoring system at the main tower



6. Monitoring system was set at the main tower



Set an inclinometer and a data logger at the height of 10 m above read level

Twantay Bridge



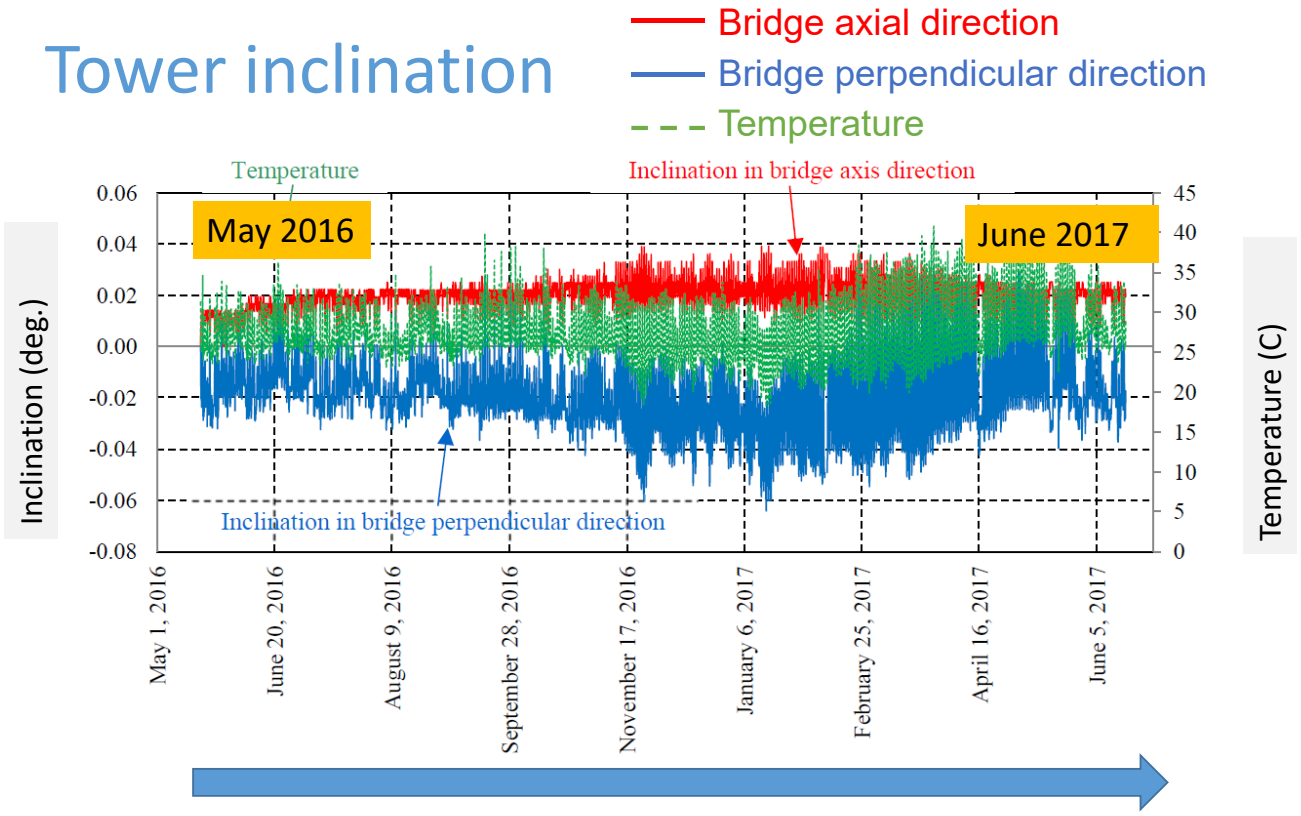
Monitoring system was set successfully at South Main Tower



Nagai

Correction of data

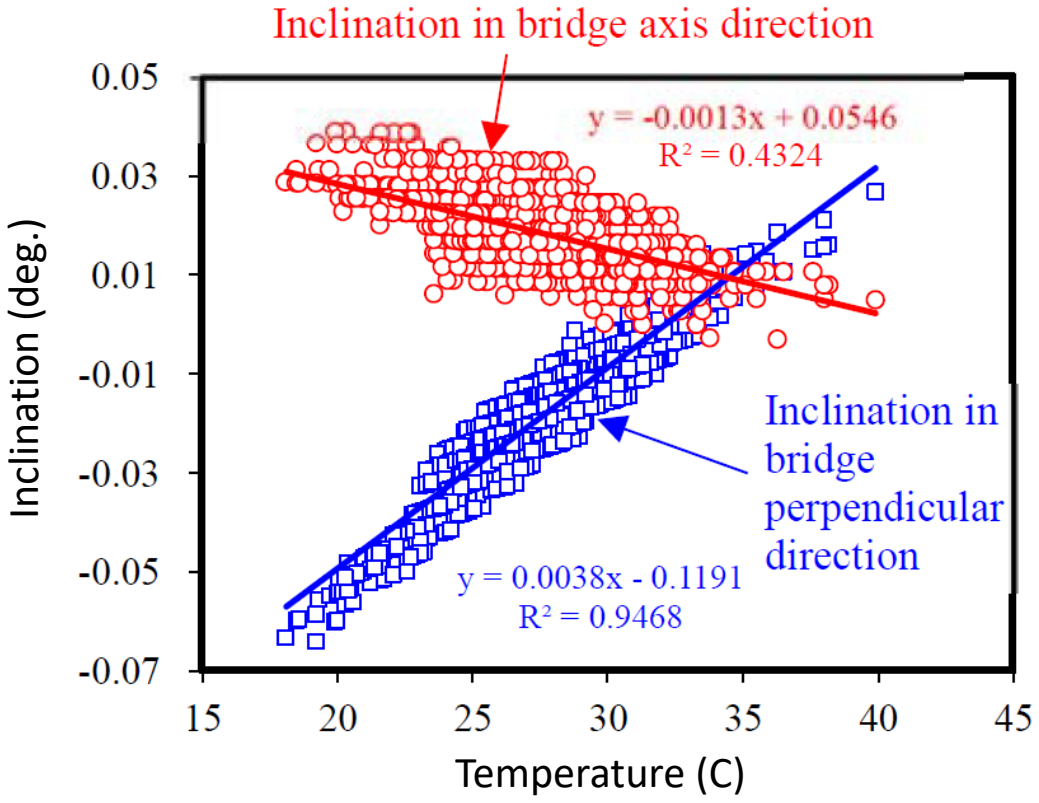
Tower inclination



12 months data: No significant change

Twantay bridge is now almost stable

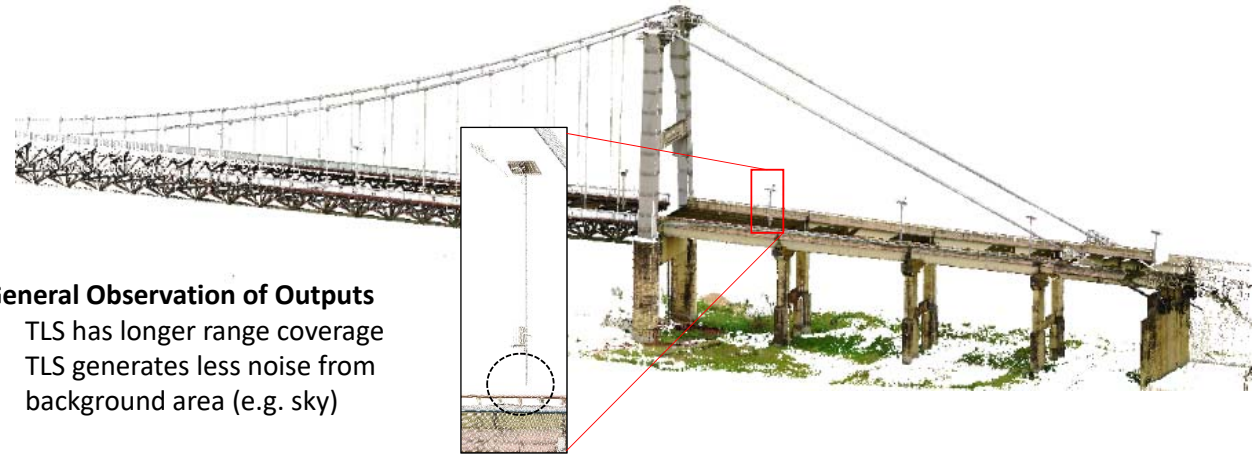
Data arranged by Dr. Miyashita



Tower inclination degree follows the temperature.

No damage is found from the data in 12 months.

3D Point Cloud from Terrestrial Laser Scanner



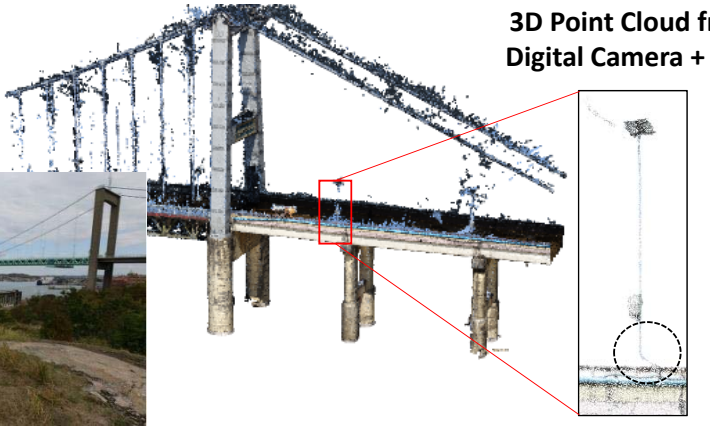
General Observation of Outputs

- TLS has longer range coverage
- TLS generates less noise from background area (e.g. sky)

- SfM uses images from various angle, capture details that miss by TLS
- SfM is generated in arbitrary unit and scaling of model is required







3D Point Cloud from Digital Camera + SfM

3D Point Cloud from Terrestrial Laser Scanner



Is this bridge still safe??

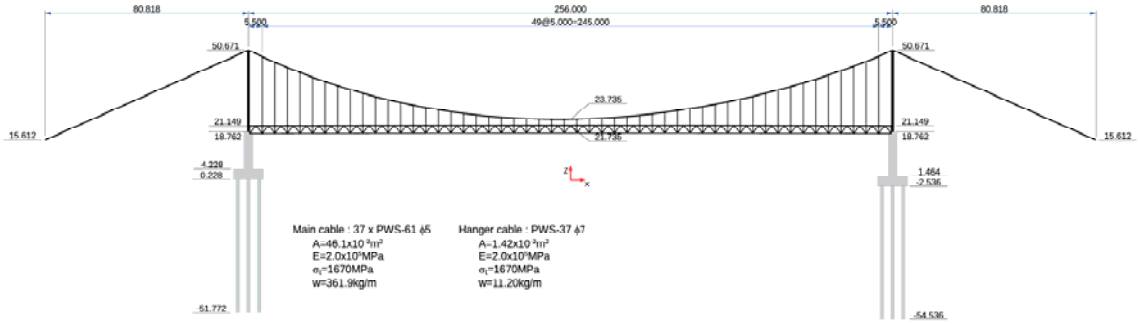
Analysis of Twantay Bridge

長岡技術科学大学
Nagaoka University of Technology
Prof. Eiji IWASAKI
Member of SATREPS Project
Nagaoka University of Technology

Simulation Procedure

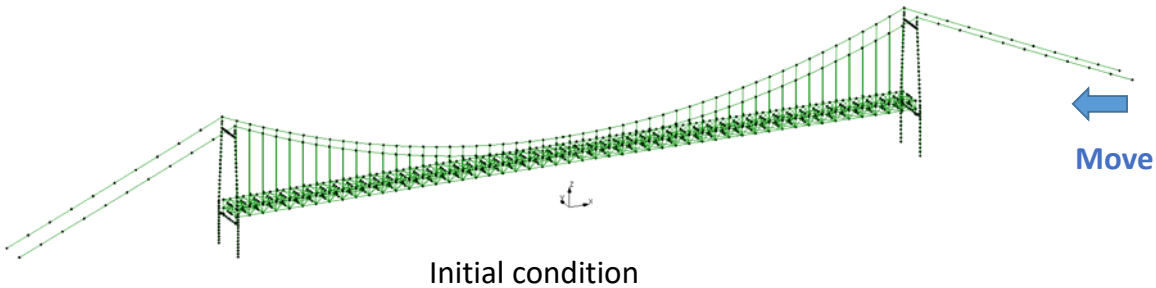
1.
Set the initial condition considering the tension force of cable and hangers.

2.
In the simulation, move the anchorage (right side only). In one step, 0.05m.
Then, check the deformation, plasticity damage, cable force etc.

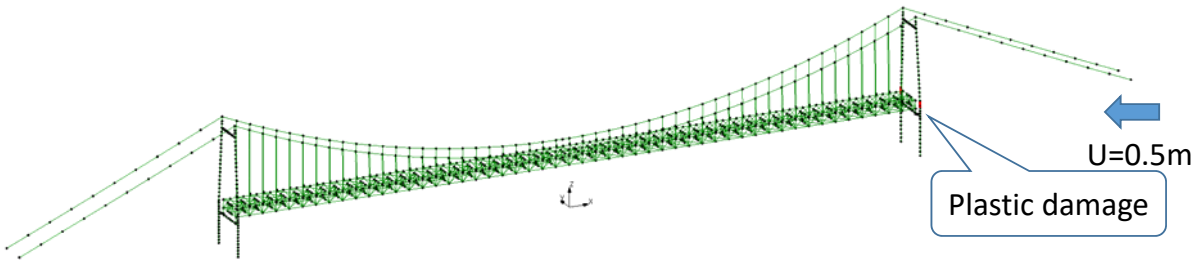


長岡技術科学大学
Nagaoka University of Technology

Overall deformation



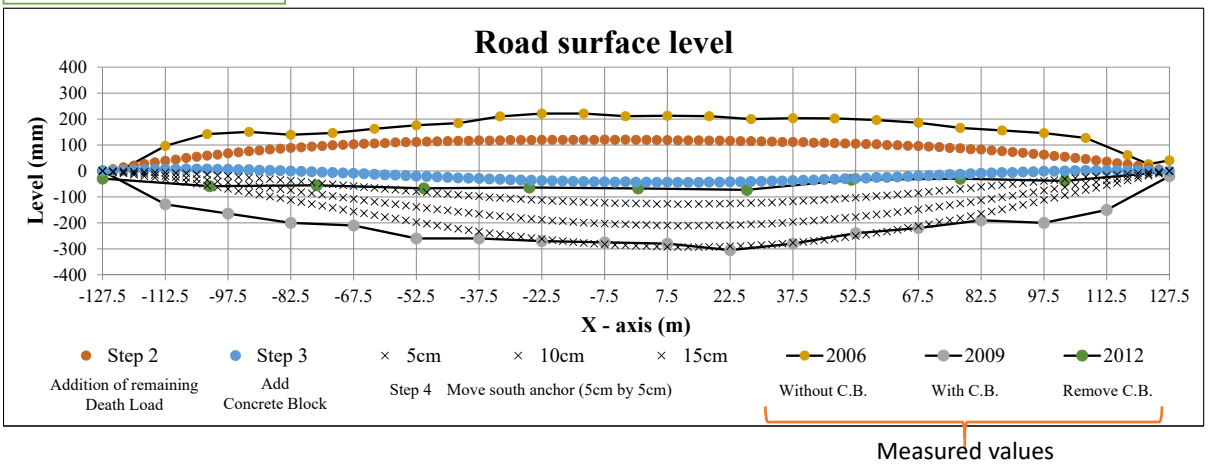
Initial condition



Plastic damage occurs at the base of tower at deformation of 0.5m

Road Surface Level

Step 3 & Step 4

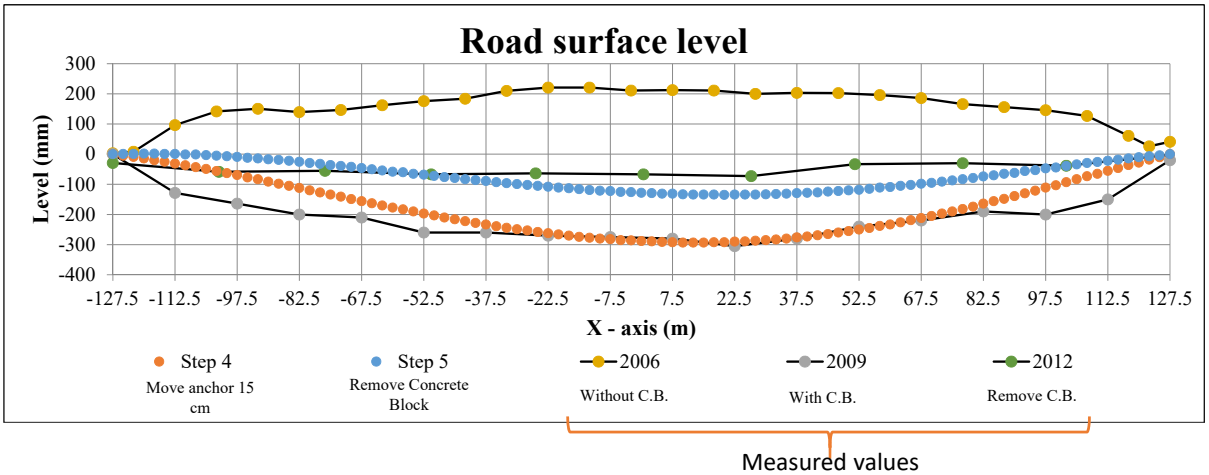


- Step 3 : Addition of 300ton Concrete block railing
- With only concrete block addition, could not be reproduced the 2009 data values
- Apply a 5cm by 5cm displacement in the South Anchor

With this there is a possibility that the concrete anchor may moved about 15cm in the course of 6years

Road Surface Level

Step 5



- Step 5 results of removing concrete block are close to 2012 data

After removing the bridge railing block, values well-matched and the current state of the bridge was reproduced

Tower Shape

Tower displacement results

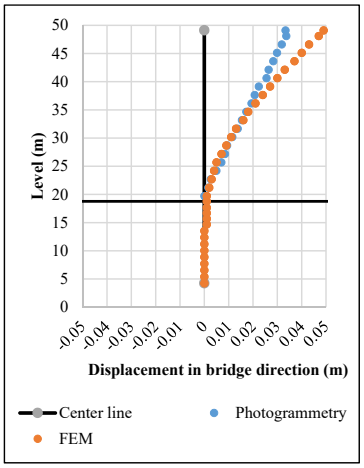
FEM results are from Step 5 (Twantay Bridge current state)

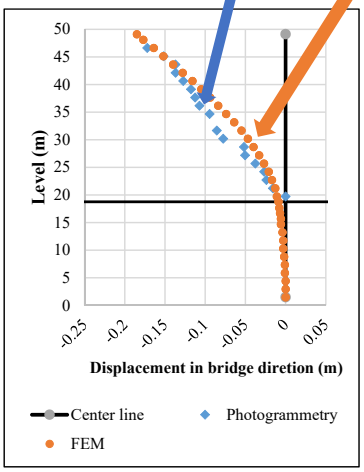
Photogrammetry results were obtained after FEM analysis

Measurement at site

FEM simulation

Tower North side





Tower South side

Error: 1.7cm

3D: top of tower disp = 3.3cm

FEM: top of tower disp = 5.0 cm

3D: top of tower disp = 17.2cm

FEM: top of tower disp = 18.5cm

Error: 1.3cm

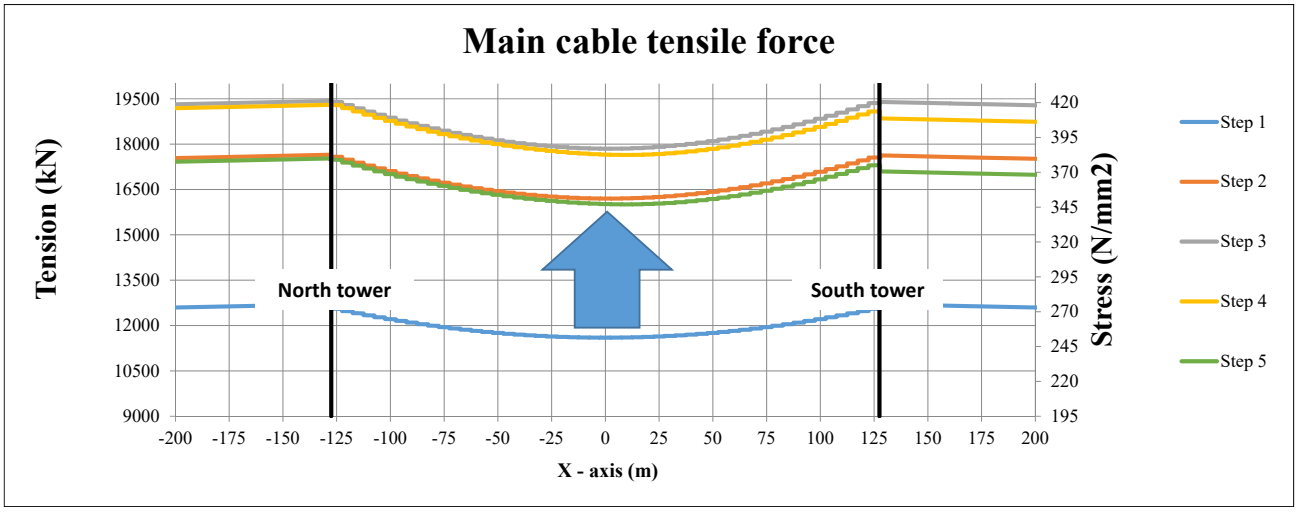
Results from photogrammetry well matched FEM analysis

Cable Stress Level

Main cable

Yield point σ_y = 1180 N/mm2

Tensile strength σ_t = 1570 N/mm2



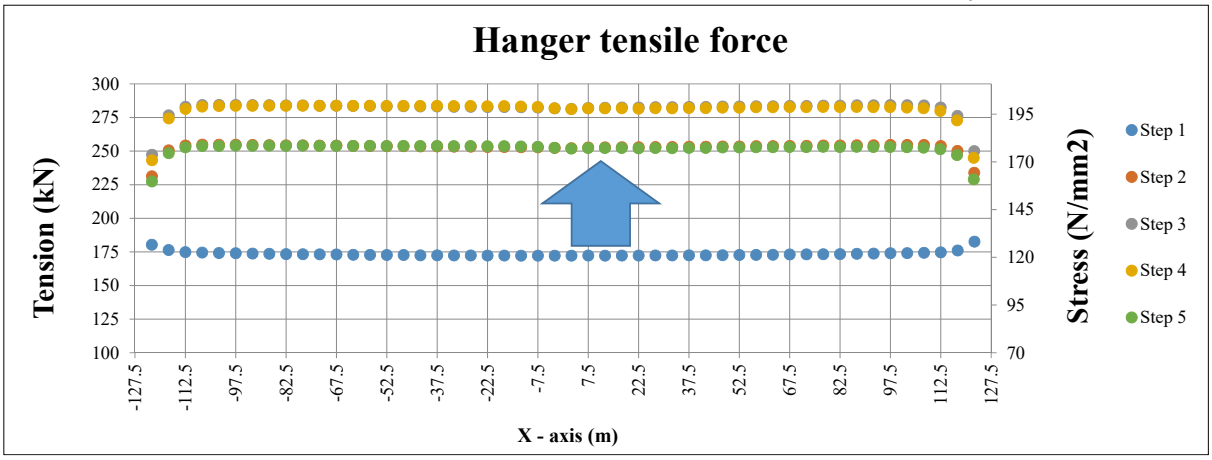
Stress level: 270 MPa -> 370 MPa (yielding stress: 1,180 MPa)

Cables are still in a safe level

Hanger Stress Level

Hanger cables

Yield point σ_y = 1180 N/mm2
Tensile strength σ_t = 1570 N/mm2



Stress level: 120 MPa -> 170 MPa (yielding stress: 1,180 MPa)

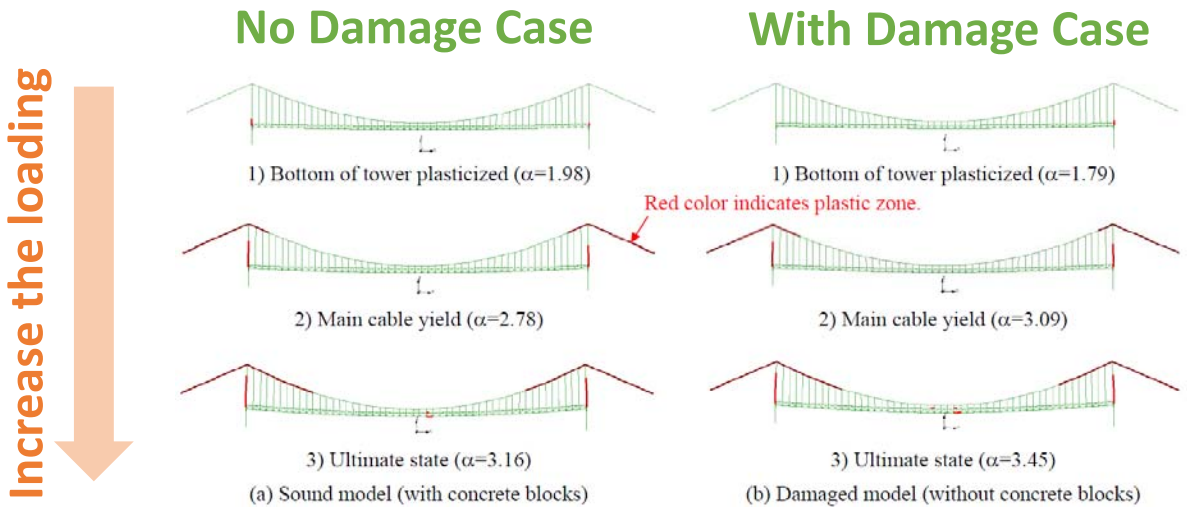
Hangers are still in a safe level

Countermeasure can be discussed based on monitoring and simulation

We propose just continue the monitoring

Safety at failure

Apply the load until the failure (yielding) of the truss system



Almost 6m deformation of road surface at the failure

Easy to detect the change before the failure

Countermeasure can be discussed based on monitoring and simulation

We propose just continue the monitoring

Recent suspension bridge failure in Indonesia

Kutai-Kartanegara Bridge in **Indonesia**

In November 26, 2011 Kutai-Kartanegara Bridge, the longest suspension bridge in Indonesia collapsed







In 2006, in order to an inspection by local government, the next damages was found:

- Anchorage block moved 13.5cm (from expansion device)
- Camber at center of main span was reduced by 55cm
- Towers inclined in bridge direction

Same problem as Twantay Bridge

Camber restoration work was done.
During this work, one clamp broke leading to the bridge collapse !

Based on our achievement

Simple monitoring for long-span bridges

New Bago River Bridge supported by JICA (planning)



Install similar monitoring system to new bridge in Yangon to check an early deflection of cable-stayed bridge.

Now in design process

Set inclinometer at the tower top.
Monitor several years.



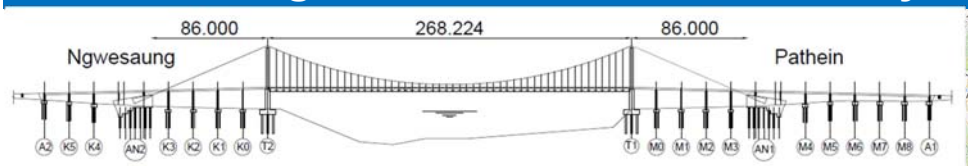


3D laser scan also is planned

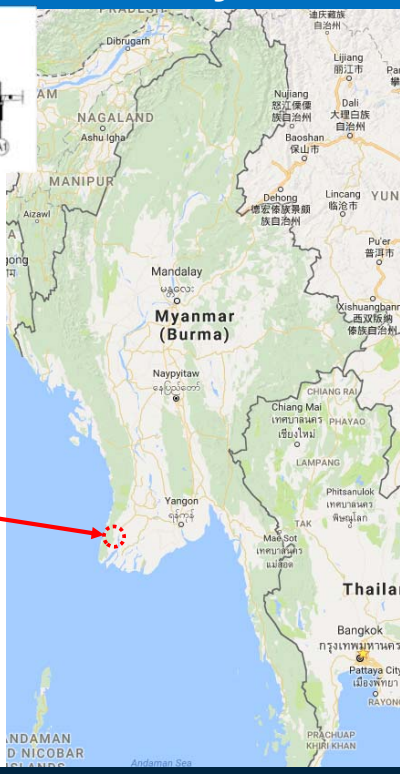
We wish this concept for new long-span bridge becomes standard

Pathein Bridge

Pathein bridge was constructed in 2004 by MOC of Myanmar

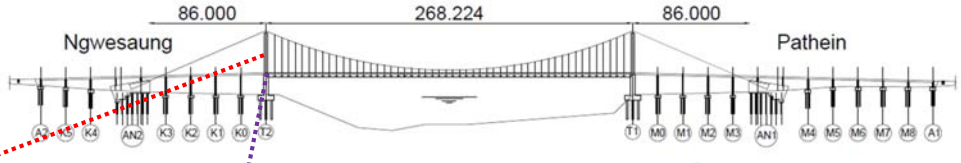






Pathein bridge is located in southern part of Myanmar

Problem Statement of Pathein Bridge





1.Towers are inclining



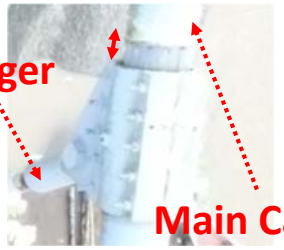
2.Road is sinking



3.Inclined hangers



4.Bearing Failure



5.Slippage of clamps



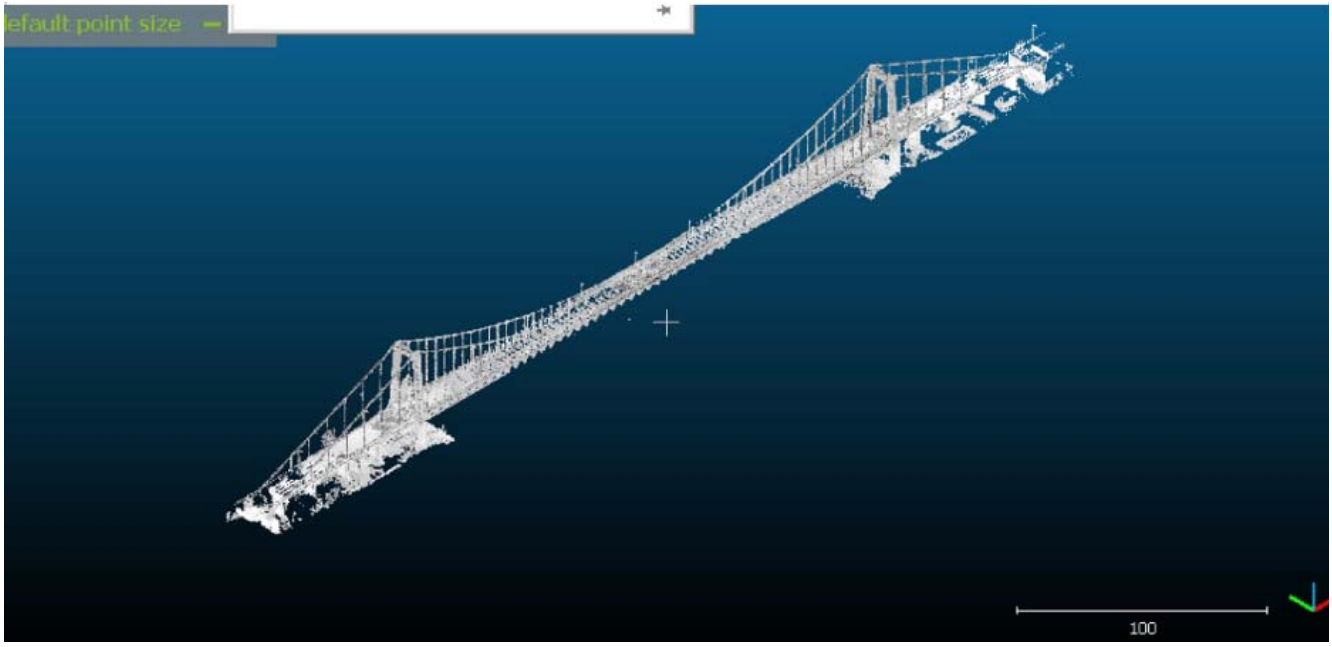
6.Corroded main cable

MOC detected damage, but, can't estimate cause or future condition

3D Laser Scanner

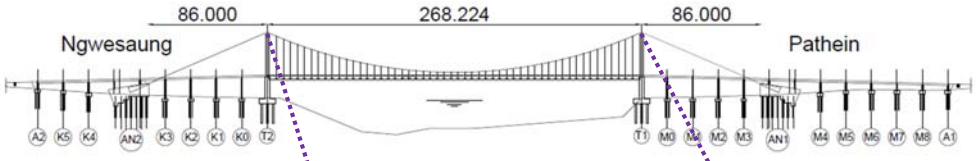
Model of Pathein bridge
in CloudCompare.





3D laser scanner

1-Estimate the cause (3D laser scanner)

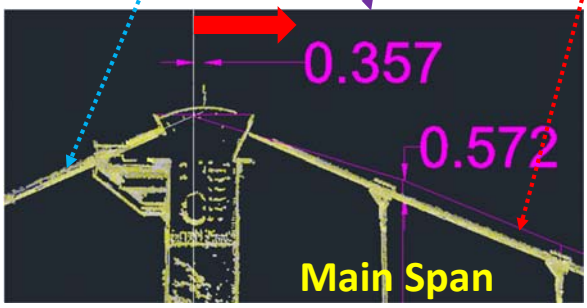


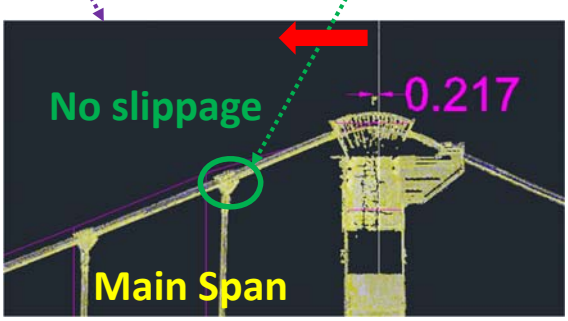


Both Towers are inclined

Current main cable

Design main cable

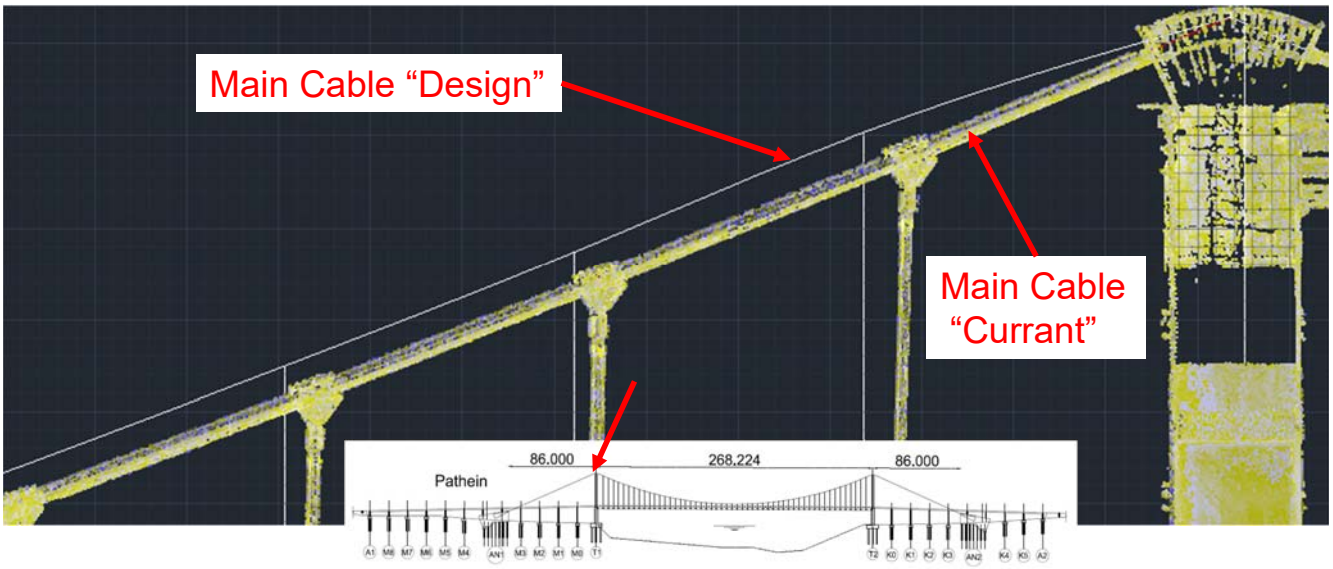




1. By 3D Laser Scanner, we could calculate both towers inclination.
2. 3D Laser Scanner couldn't detect slippage of clamps.

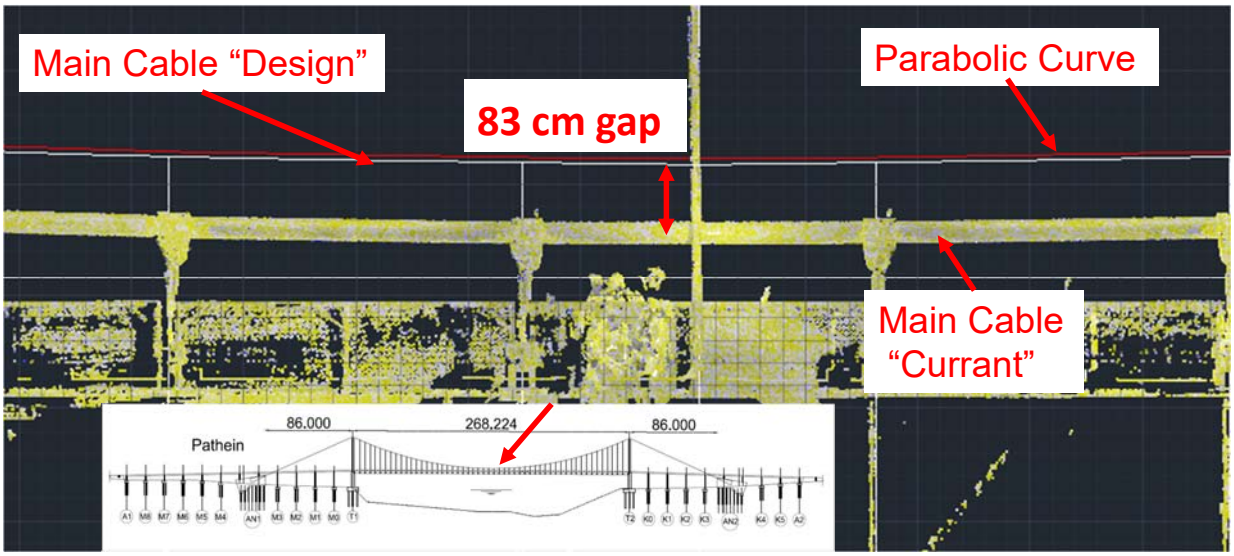
Tower and cable locations

At the beginning of the span (both sides), the cable by 3D Laser Scanner coincides with the Parabolic curve, while big difference with the design DWG.



Tower and cable locations

At the CL, the Parabolic curves almost coincides with the design cable, while big difference with the currant cable profile.



Slippage of Suspender Clamp near Towers about 4-7 Nos. each sides



Estimation of Slippage by Drone





Drone with 4K camera

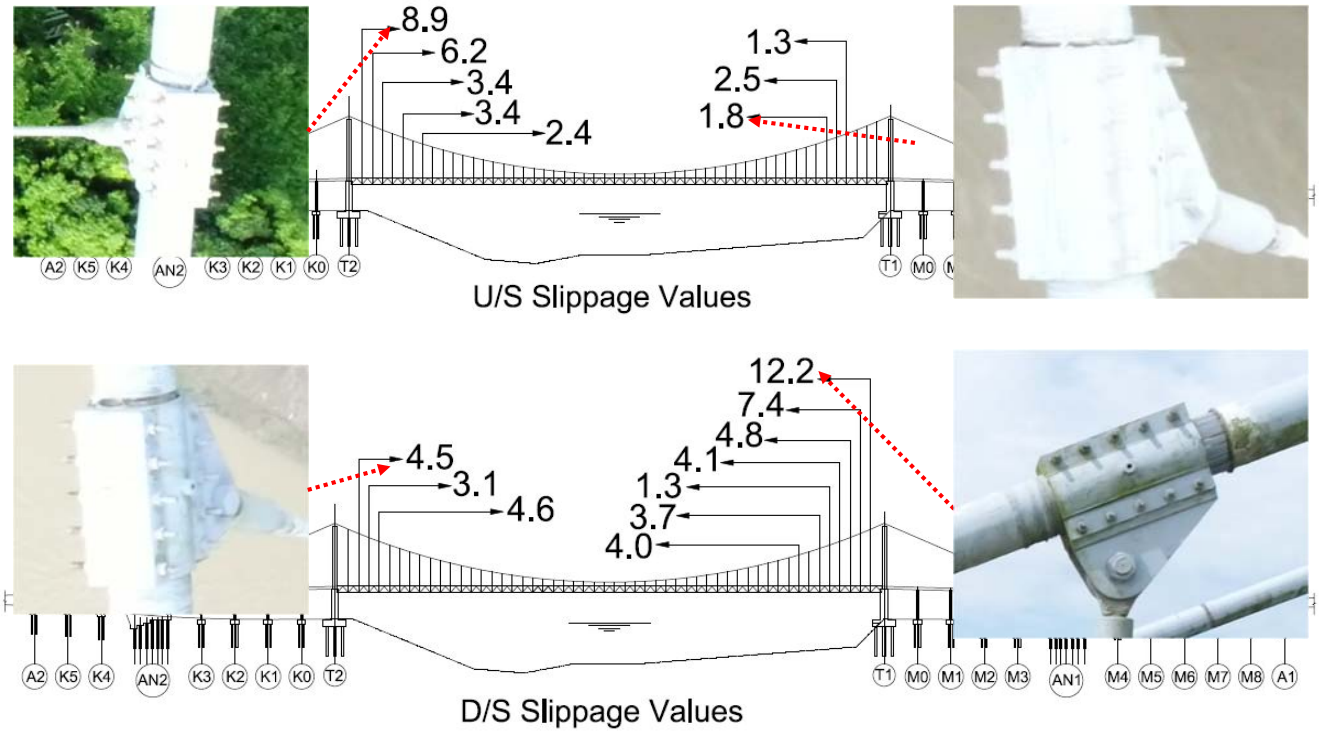
Capture HD pictures





Accuracy of measuring slippage is 1 mm

Estimation of Slippage by Drone



Dimensions are in cm

Drone could be used to measure slippage of all clamps

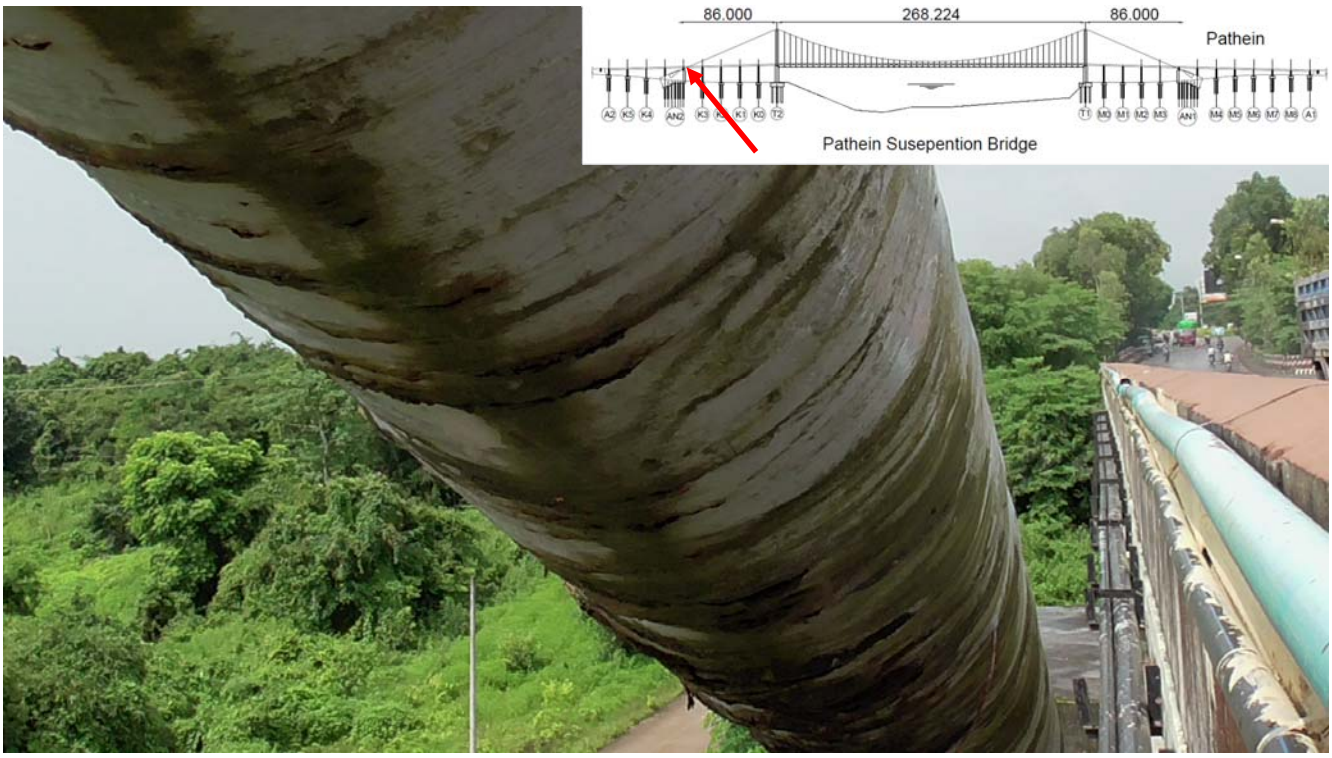
Corrosion Assessment by Drone



Drone could be used to detect corrosion of main cable

Field Observation (Visual)

Cover of main cable almost outclear.



Estimation of hanger forces

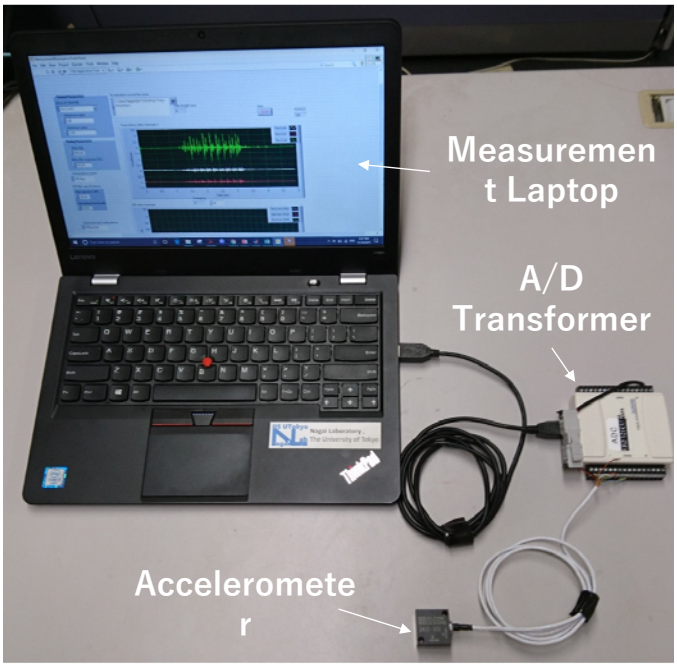
- Investigation was conducted from 6-9 November 2017.



3 Persons of The University of Tokyo led the task

Device Outline

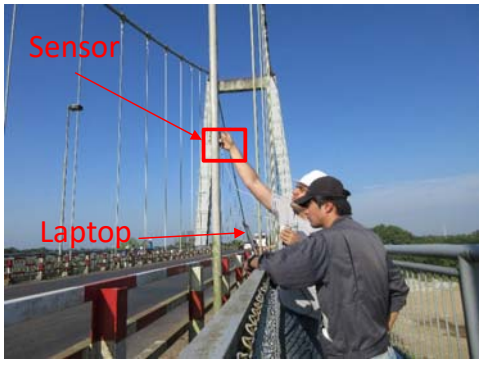
Measurement System





Three Axes Accelerometer

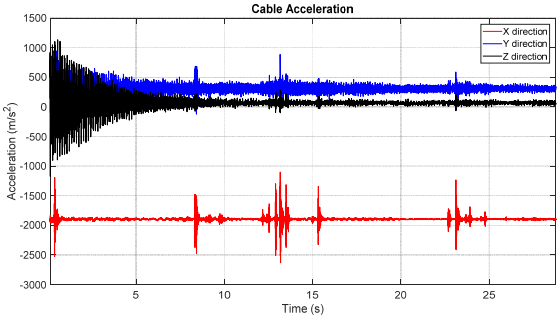
Methodology used



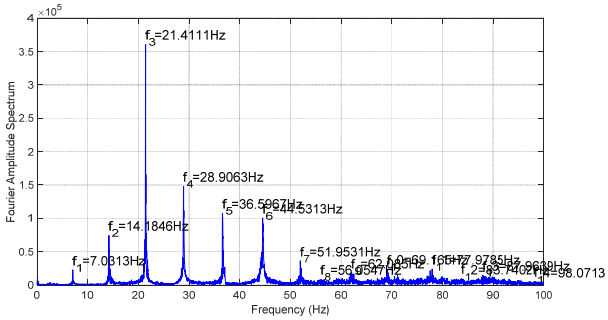
1-Attach the sensor to the object



2-Hit the object using hammer



3-Measure Time Domain Acceleration



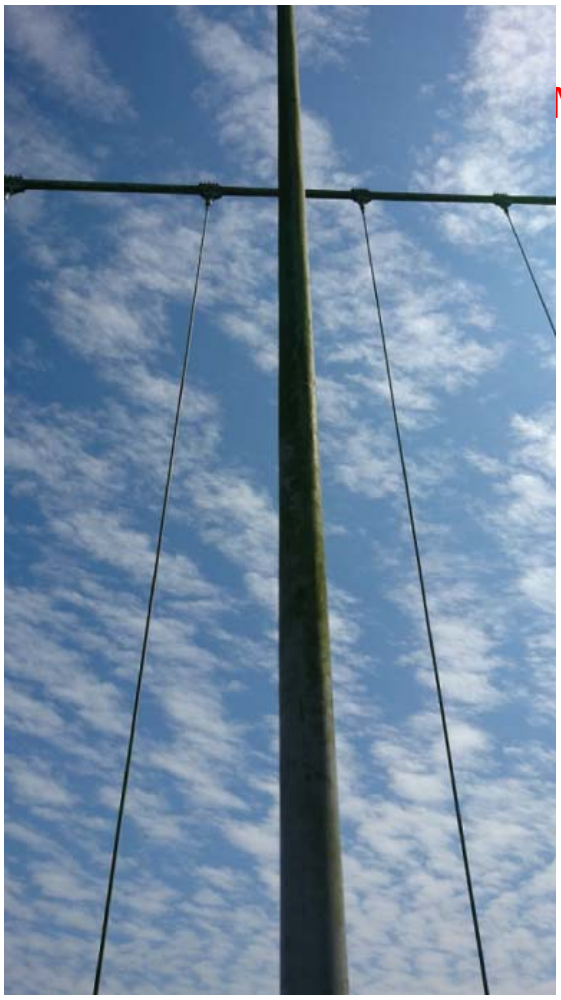
4-Using FFT, convert to Freq. Domain

Long hanger



Excitation : Almost-harmonic wave

Long hanger

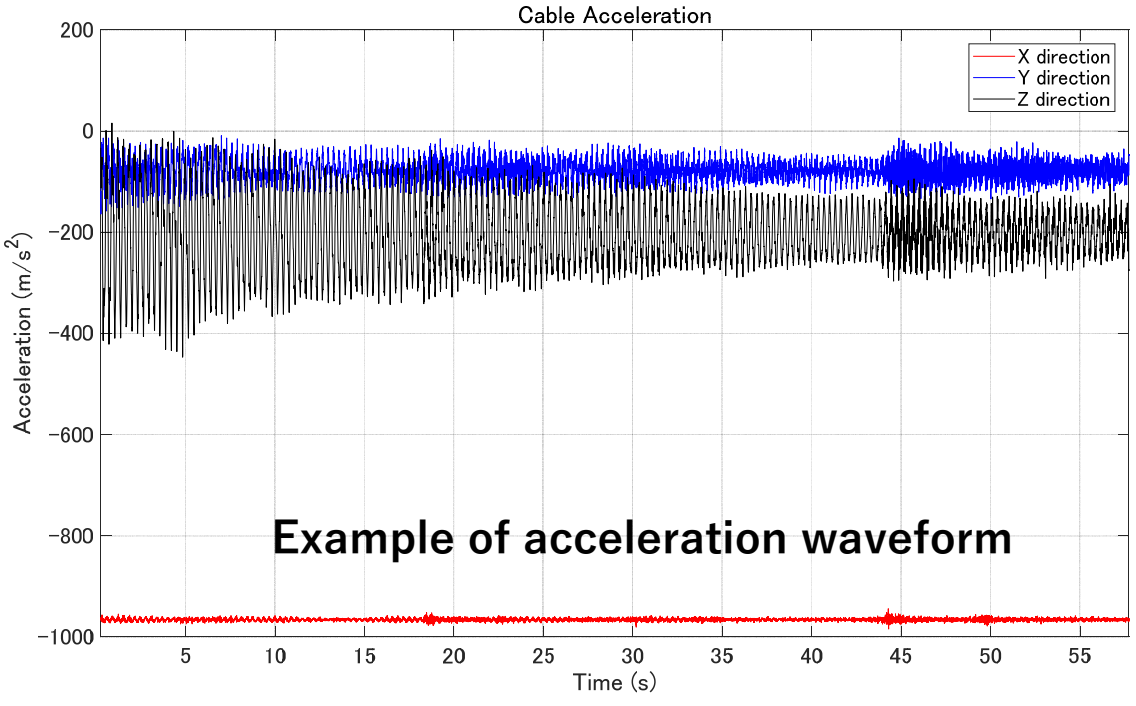


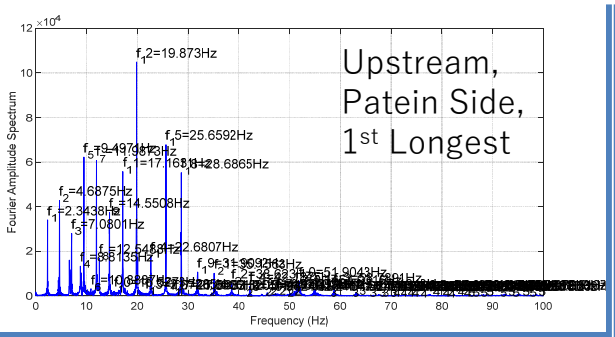
Movie

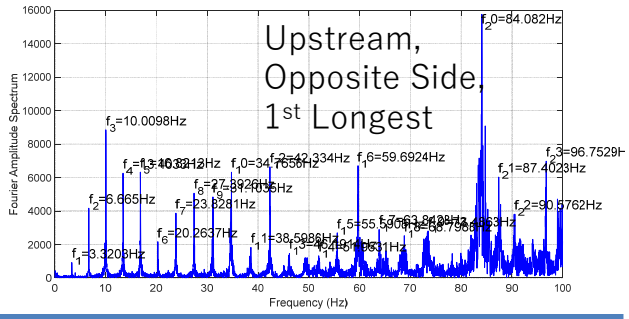
Excitation : Almost-harmonic wave

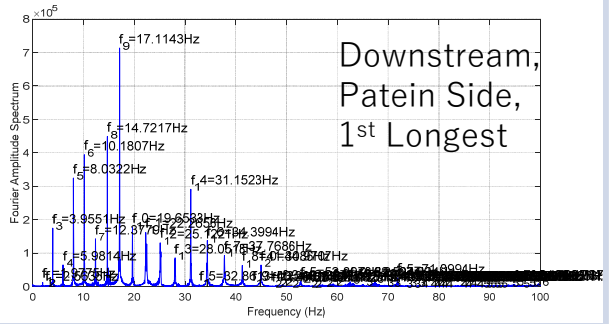
Short hanger

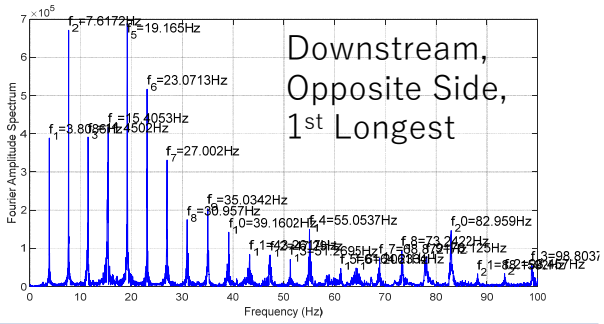






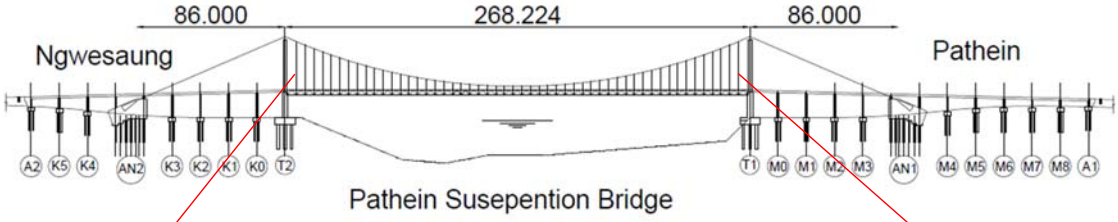


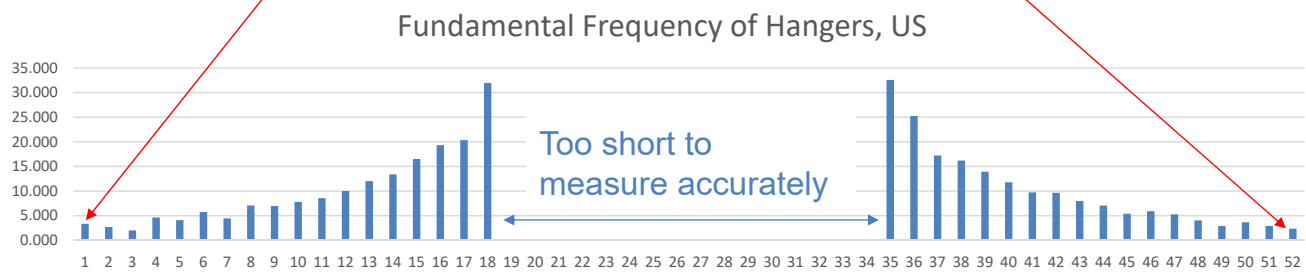


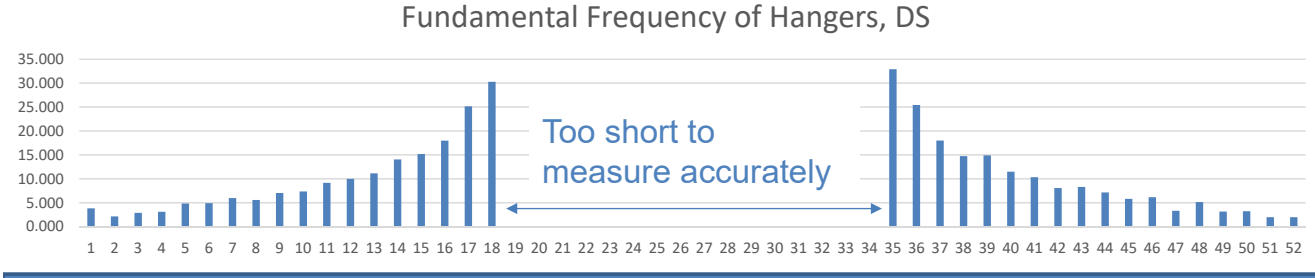


Frequency Property obtained by Discrete Fourier Transform

Frequency Distribution







Measuring the fundamental frequency of middle hangers is difficult

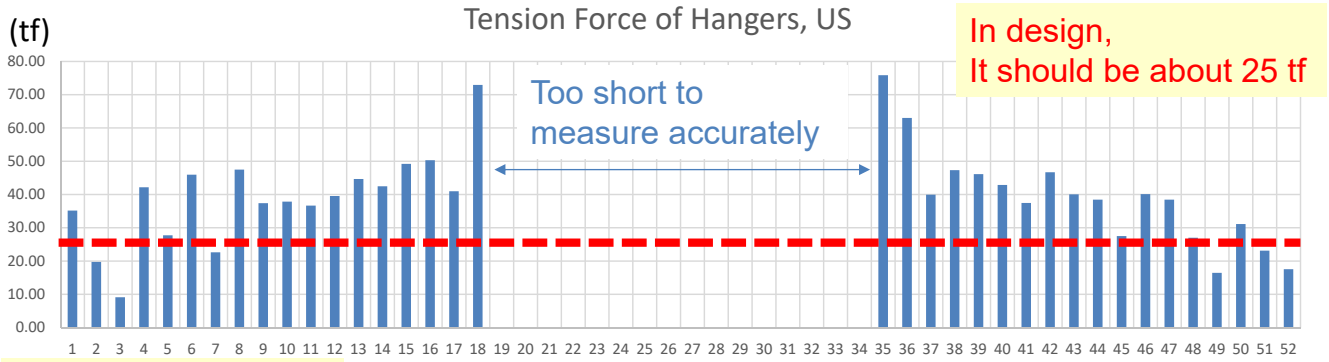
Tension Force Distribution

- The flat taut string theory is used to calculate the tension force knowing the frequency of the cable.

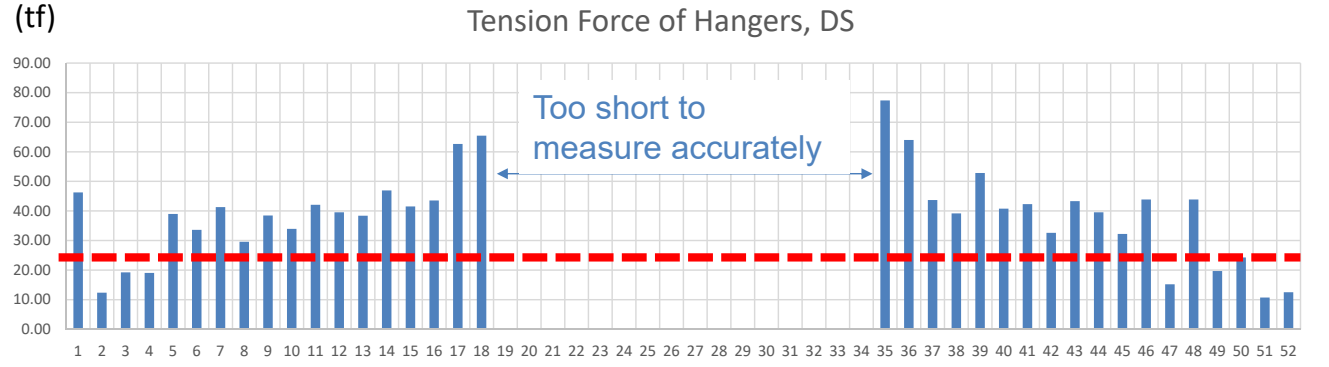
$$T = \frac{4ml^2 f_n^2}{n^2}$$

m: mass per unit length kg/m
fn: natural frequency HZ.
l: length of the cable m.
n: Mode number "1"
T: tension force in Newton

Tension Force Distribution



Bearing broke side

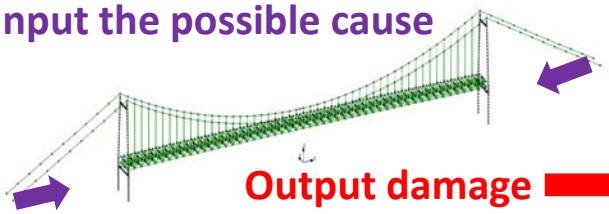


Different tensile forces are estimated in hangers

Future Works

1-FEM model will be developed to confirm the cause and evaluate current condition

Input the possible cause



Output damage → Compare with field measurements (RL, hanger force,…)

2- Collect data from the monitoring system.



Inclinometer to monitor towers inclination

Transducer to monitor girder movement



3- Assessment of the main cable (Cooperation with IHI)

SATREPS Project continues by 2020 !

Thank you for your kind attention

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