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ACECC TC 28 Seminar: Application of Monitoring Technology for Infrastructure Maintenance

Cable-stayed Bridge Tension Monitoring

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01 Essential Components of Cable-Stayed Bridges

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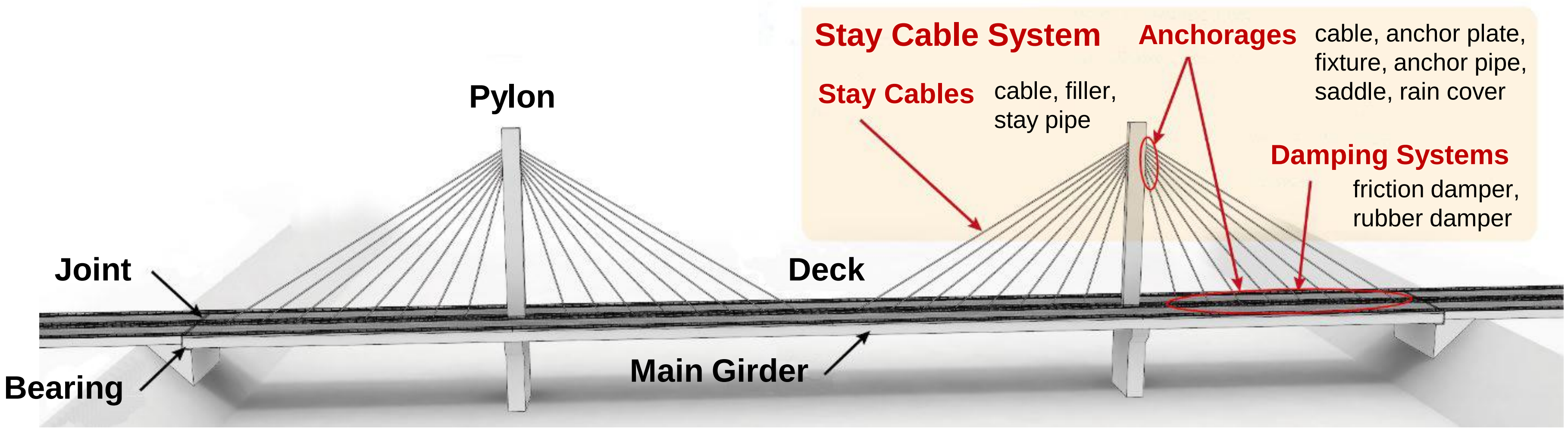
- The pylon and stay cable system are vital and fundamental components of cable-stayed bridges (including extradosed bridges).
- Our monitoring system focuses specifically on monitoring of the stay cable system.



"Guidelines for Utilization of Monitoring Systems for Civil Engineering Structures", Public Works Research Institute document #4408 (Translated)

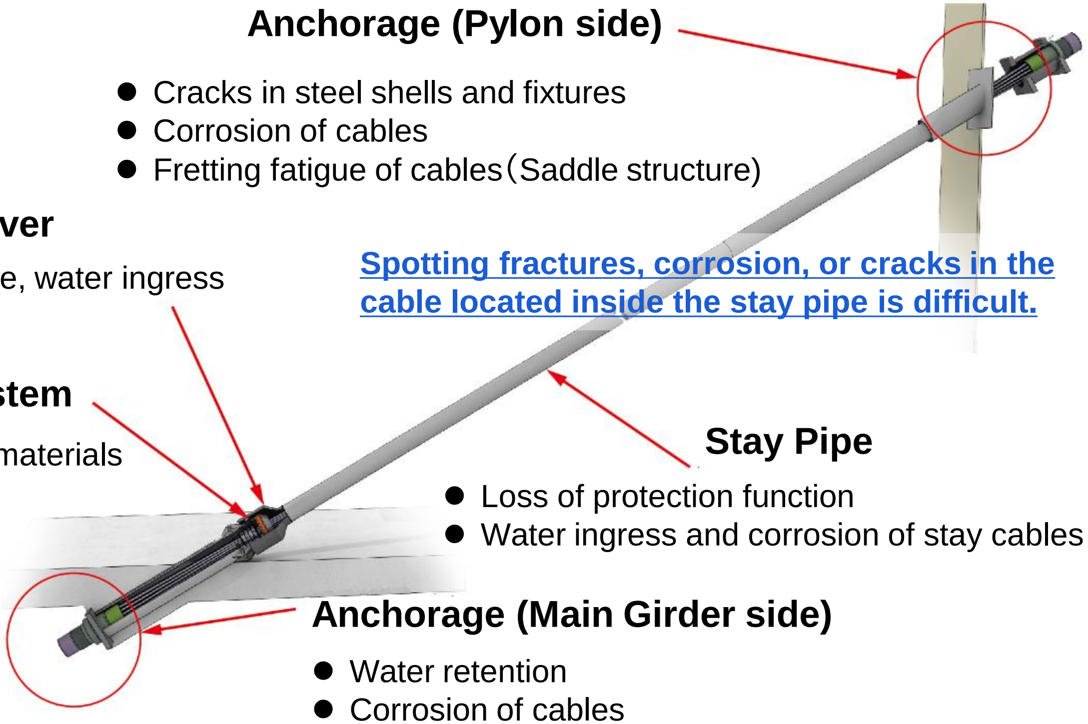
Components		Possible deformations
Stay Cable System	Stay Cable	Cable rupture, corrosion, fatigue crack, corrosion/crack of stay pipe, vibration
	Anchorages (Concrete)	Corrosion of fixture, cracks near fixture, delamination/exposed rebar, water leakage/efflorescence, floating
	Anchorages (Steel)	Corrosion of fixture, deformation/buckling near fixture, coating deterioration/corrosion, water leakage/water retention, fatigue crack
	Others	Deformation of damping systems, leakage of filler material

02 Importance of Stay Cable Monitoring

- Confirming the deformation of the cable encased the stay pipe through close visual inspection.is difficult.
- Utilizing ICT technology for stay cable monitoring comes highly recommended.

- The breakage of stay cables causes serious safety-related incidents. Thus, it is important to assure the integrity of the cables.
- Since the cable is inside the stay pipe, checking for cable deformations through close visual inspection is difficult.

Periodic or continuous monitoring of stay cable deformation is important.



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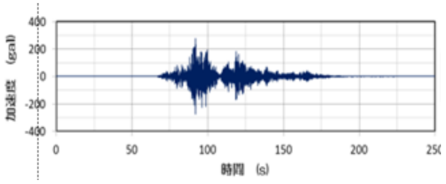
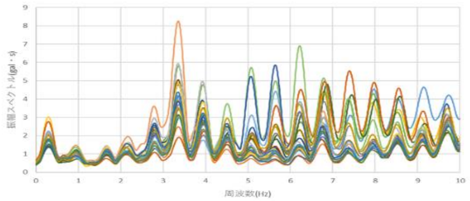
Tension Calculation Method

- Tension can be calculated using the measured low- and high-order natural frequencies of the stay cable.
- Forced vibration is NOT required and cable tensions can be monitored remotely and continuously.

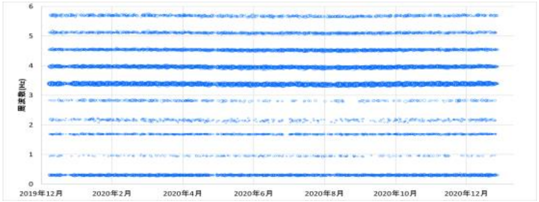
Acceleration Data



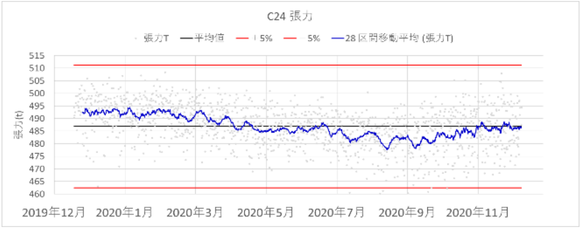
Frequency Spectrum



Natural Frequencies



Tension



Coef. A　　Coef. B

$$f_i^2 = \boxed{\frac{\pi^2 EI}{4\rho A L^4}} i^4 + \boxed{\frac{T}{4\rho A L^2}} i^2$$

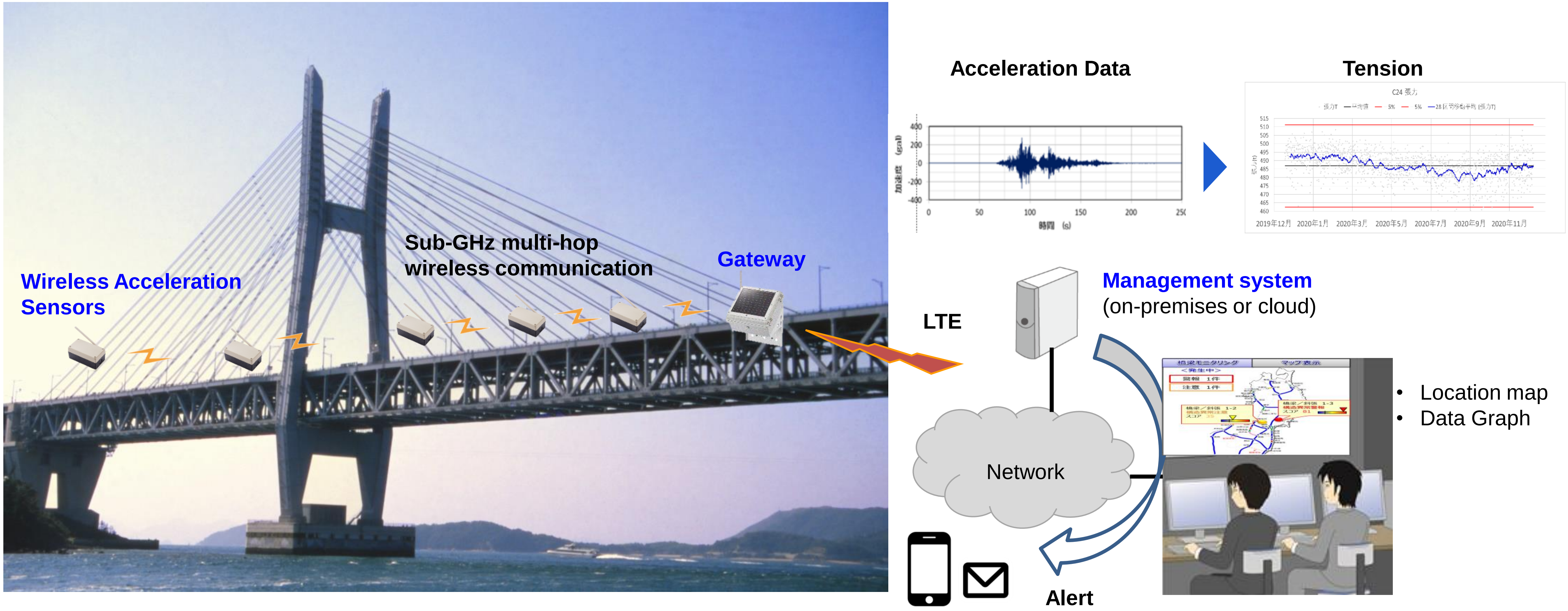
Two coefficients (A, B) can be identified using the least squares method.
The tension T can be calculated from coefficient B.

f_i :	Natural frequency (Hz)	i :	Order
T :	Tension (N)	EI :	Flexural rigidity (N・m^2)
L :	Cable length (m)	ρA :	Mass per unit length (kg/m)

Unlike conventional methods that require bridges to be closed to traffic and forced to vibrate, wireless acceleration sensors can calculate cable tensions from ambient vibrations, allowing for continuous monitoring without halting bridge operation.

04 Monitoring System Overview

- Acceleration sensors are installed on the stay cables, and the cable tension is calculated based on the measured acceleration data.
- The online system enables continuous and remote monitoring with maps and graphs.

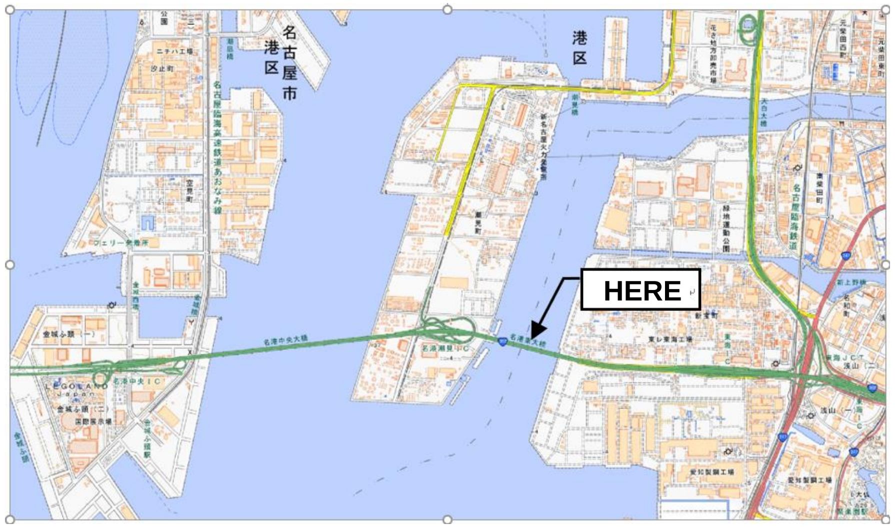


05 Field Examples

- Confirmed the feasibility of tension monitoring by conducting on-site measurements for more than 1 year at the Meiko Higashi Ohashi Bridge of NEXCO Central, Japan.

Bridge Overview

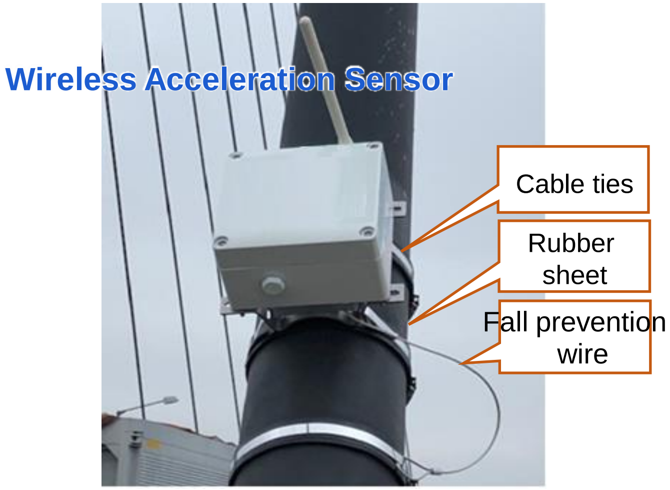
Name: Meiko Higashi Ohashi Bridge
Location: Between Tokai-city and Nagoya-city, Aichi
Type: 3-span continuous cable-stayed bridge
Length: 700m

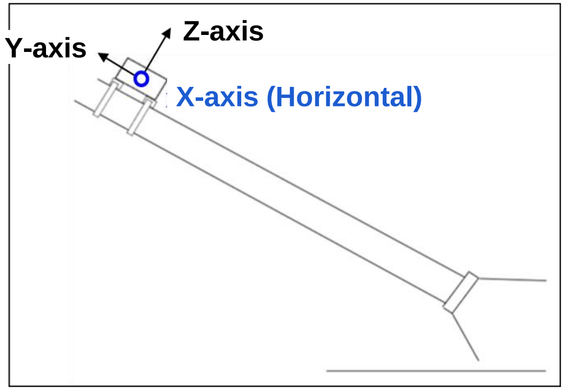


Published by Geospatial Information Authority of Japan

The most inner cable

The most outer cable



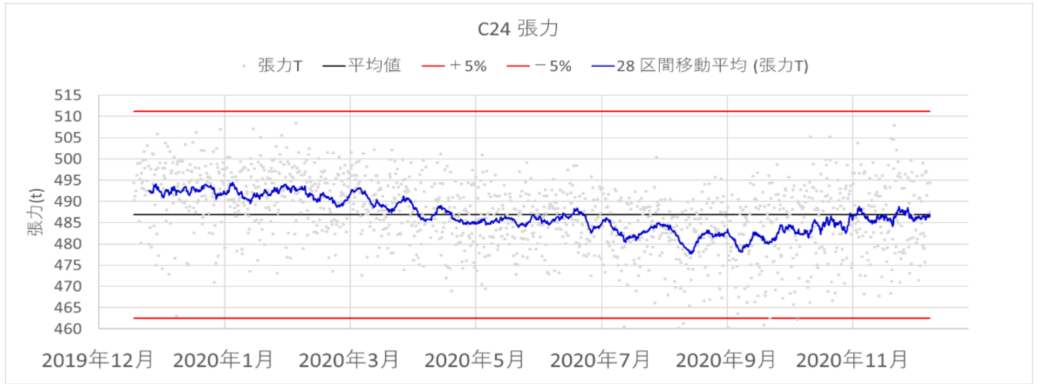


06 Threshold for Anomalies

- The threshold for judging anomalies in the tension of the stay cables is set at 5%, which is used as a maintenance standard.
- Permanently installed acceleration sensors can be used for monitoring with minimal annual variation error.

- Abnormal tension of a stay cable refers to a condition in which the tension becomes abnormal due to:
  - ✓ changes in the overall shape and load distribution,
  - ✓ time-related changes due to creep and drying shrinkage,
  - ✓ changes in stress due to cross sectional defects in the cable.

- The maintenance standard for judging tension anomalies is defined as a tension change of ±5% or more from the initial value measured by the higher-order vibration method.



- The annual variation in the on-site measurement ranges within ±2%, confirming the practicality of the system for detecting variations of 5%, which is the control standard.

- However, due to the large variation in one-shot measurements, averaging should be enabled by using a permanently installed acceleration sensor.

07 Conclusions

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- Intensive monitoring of the stay cable systems is critical to the structural integrity of cable-stayed bridges.
- Since it is difficult to detect critical deformations of the cables in the stay pipes by visual inspection, monitoring using ICT techniques is important.
- Calculating tension from natural frequencies using wireless accelerometers is an effective method for remote and continuous monitoring without the need for forced vibration.
- A tension change threshold of ±5% is recommended, providing a standard for detecting abnormal stay cable tension. Permanently installed acceleration sensors control the allowable range of variation and improve accuracy.

Zero Energy IoT Series

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- Easy installation: All devices are batteries or solar powered, NOT require external power supply.
- High accuracy sensing & High endurance reliability

Wireless sensing network & 4G public network

Battery & Solar power

Wireless Acceleration sensor
Keep working with battery for up to 5 years

Sensor & Camera with Gateway
Keep working with solar power panel even in non-sunshine weather for up to 9 days

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Thank you for listening!

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