ICRI
CONCRETE REPAIR
Restore | Repurpose | Renew

2024 SPRING CONVENTION

APRIL 21-24, 2024
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VIBRATION ANALYSIS AND MONITORING OF BRIDGES

APRIL 21-24, 2024

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PRESENTATION GOALS

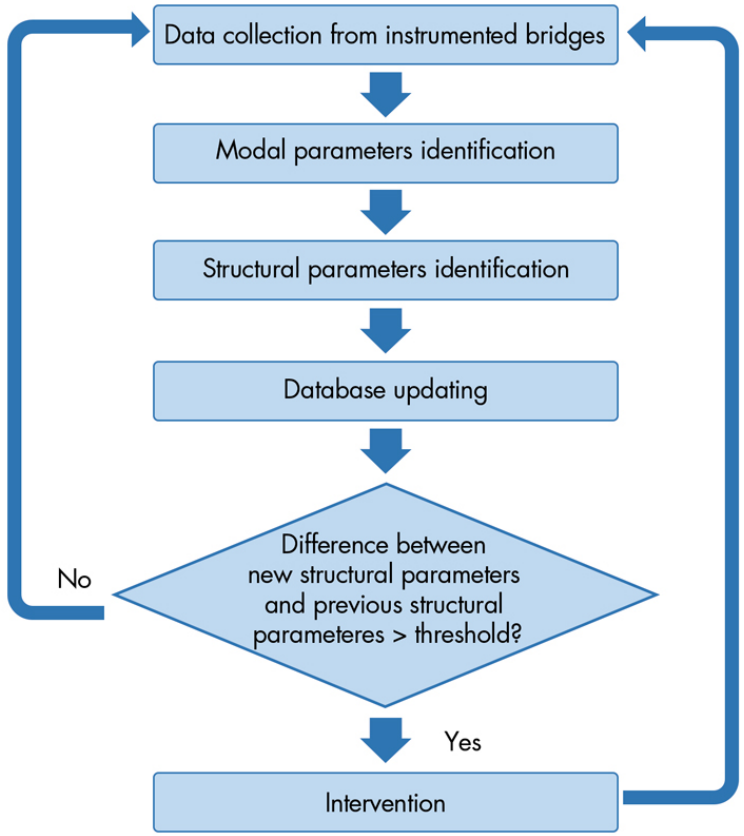
Gain a basic understanding of vibration analysis

Understand the typical results from a vibration analysis

Be able to distinguish the benefits of vibration analysis over other inspections

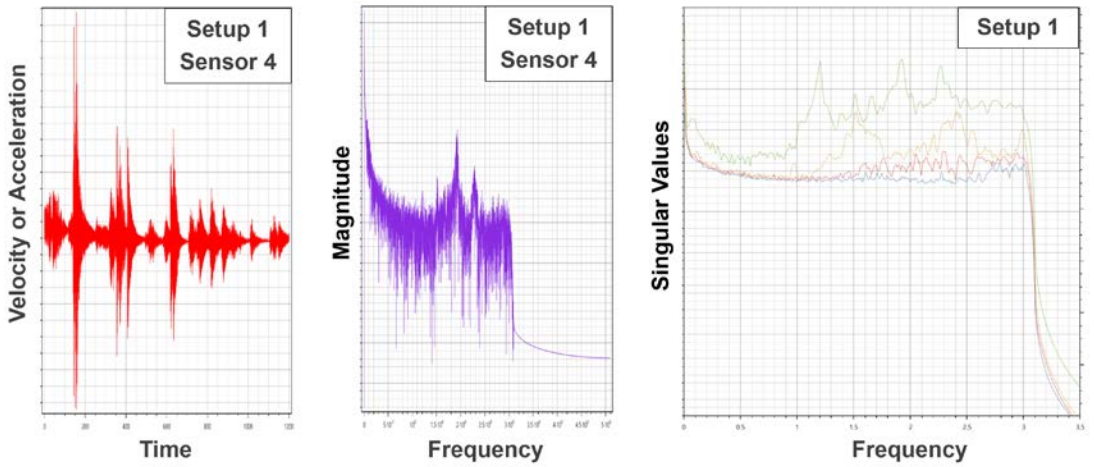
Understand how owners and engineers can use a vibration analysis to assist in design or repair or improvement

TECHNICAL METHODOLOGY



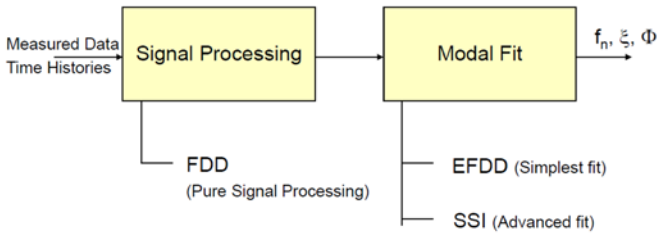
Structure Magazine (https://www.structuremag.org/?p=18776)

TECHNICAL
DATA COLLECTION

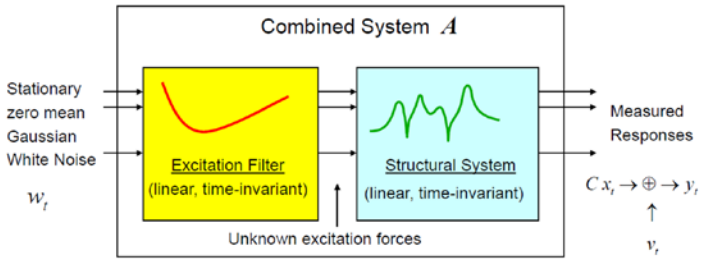


Sensequake

TECHNICAL
MATHEMATICAL MODELS
CONTROL THEORY



- Non-parametric method:
  - Frequency Domain Decomposition, FDD
- Parametric methods:
  - Enhanced Frequency Domain Decomposition, EFDD
  - Stochastic Subspace Identification, SSI



Discrete-time Stochastic State Space Model

State Equation $x_{t+1} = Ax_t + w_t$ Model of the dynamics of the system

Observation (Output) equation $y_t = Cx_t + v_t$ Model of the output of the system

w_t: Process noise - v_t: Measurement noise - Model order: Dimension of A

Singular Value Decomposition of Hermitian matrices

$$[A] = [V]\,[S]\,[V]^H = s_1\, v_1\, v_1^H + s_2\, v_2\, v_2^H + ..$$

The Singular Value Decomposition of the response matrices is performed for each frequency

Singular values

$$[S] = \begin{bmatrix} s_1 & 0 & 0 & 0 & \cdots & 0 \\ 0 & s_2 & 0 & \cdots & & \\ 0 & 0 & \ddots & & & \\ 0 & \cdots & & s_r & & \\ \vdots & & & & 0 & \\ & & & & & 0 \\ 0 & & & & & 0 \end{bmatrix}$$

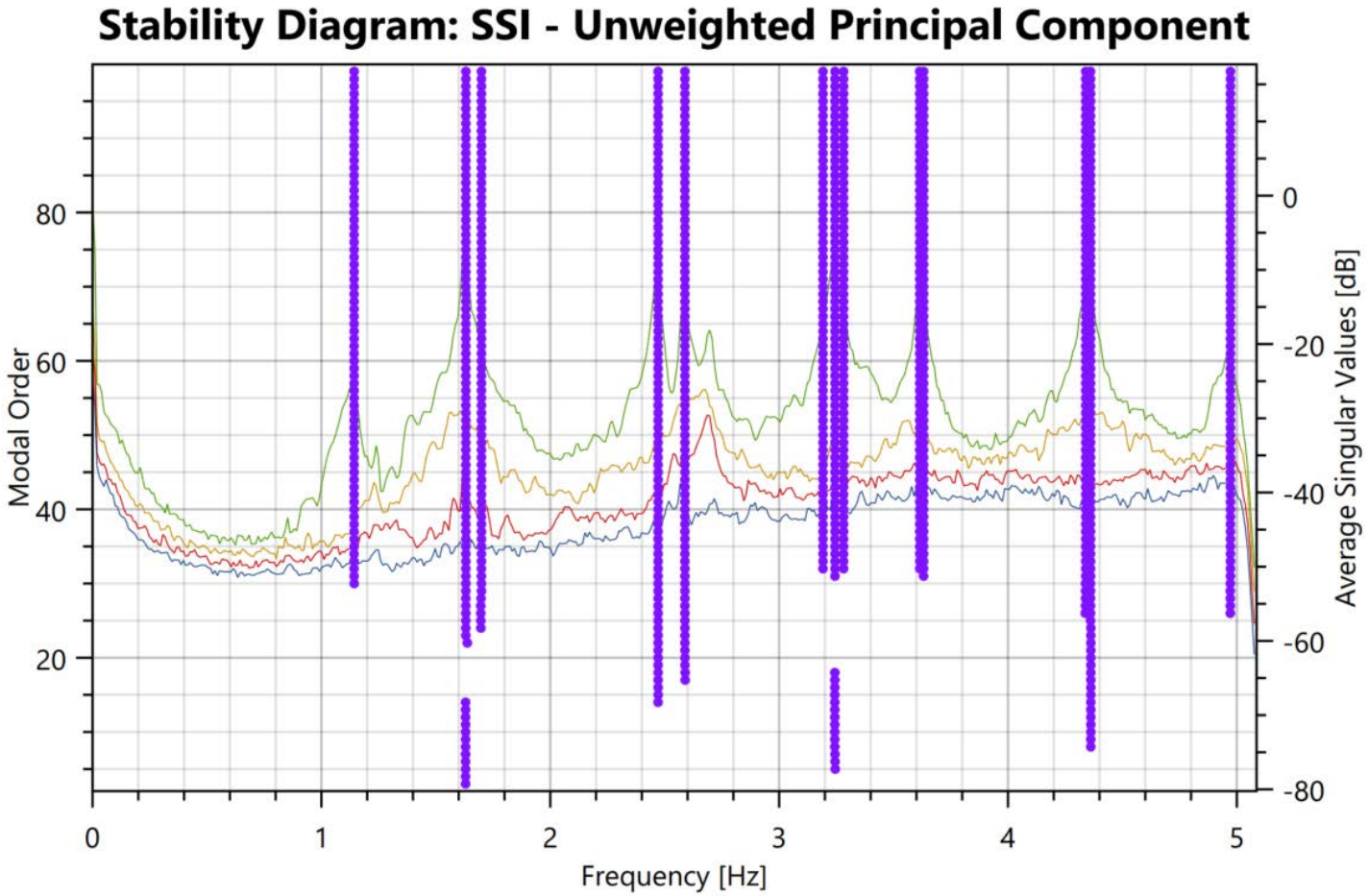
- A real diagonal matrix
- Identify Natural frequencies from Singular Value spectra

Singular vectors

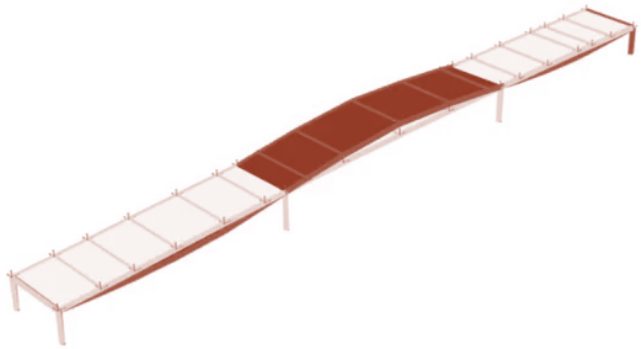
$$[V] = [\{v_1\}\ \{v_2\}\ \{v_3\}\ \ldots\ \{v_n\}]$$

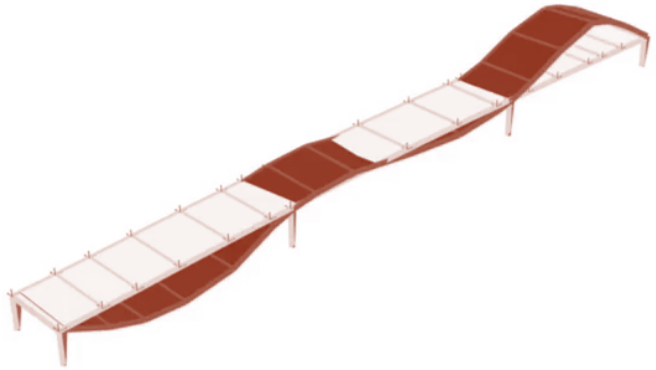
- Orthogonal columns
- Unity length columns
- Approximates the Mode shapes

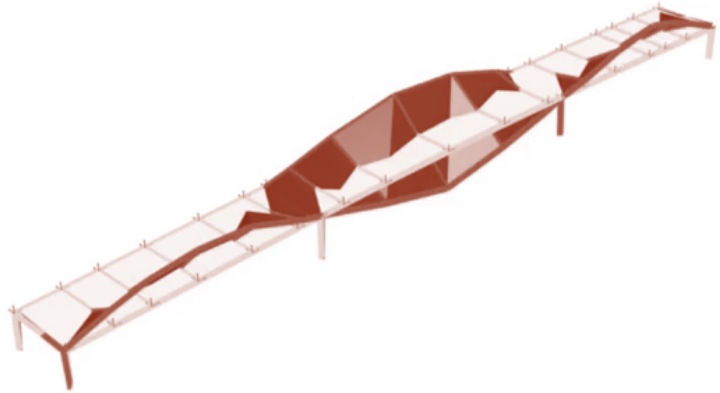
TECHNICAL
MODAL IDENTIFICATION



TECHNICAL
MODAL SHAPES





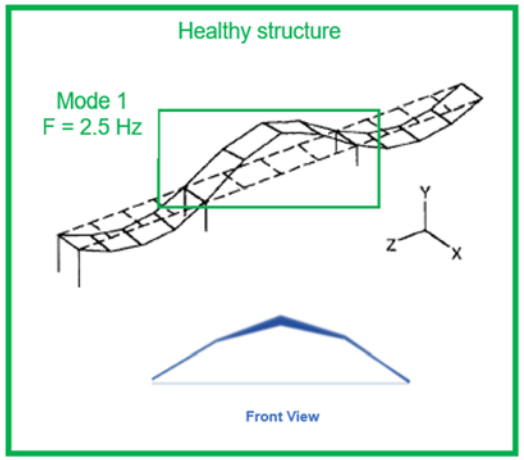


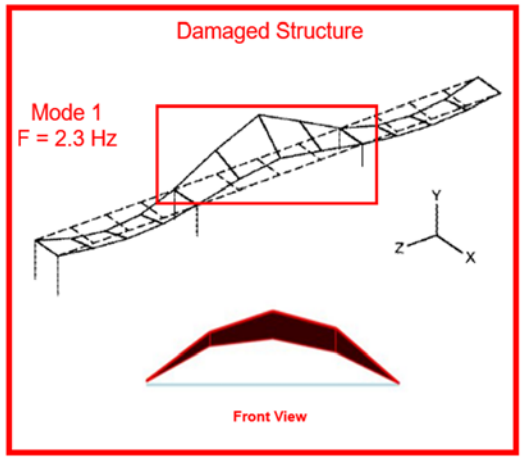
RESULTS
ANALYSIS

Checking for local deficiency due to lack of stiffness or material loss

Checking for deficiency in support conditions

Checking for global deficiency due to gradual loss of stiffness



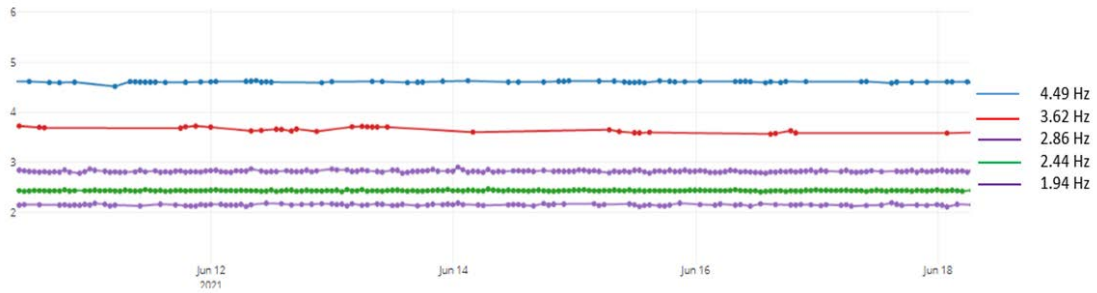


RESULTS
LONG TERM

Use the previous results as a new baseline for future analysis

Provide realtime monitoring of worsening conditions

Provide realtime monitoring detecting an event causing immediate decrease in stiffness



RESULTS ENGINEERS

In-situ natural frequencies, opposed to using assumptions based on ideal construction

Accurate determination of where the deficiency is, whether that deficiency is visible or not

Long term monitoring with an appropriate interval between analysis enables engineers to react faster ahead of visible deficiencies

CASE STUDY

Frijolillo Bridge
Tuxpan, Mexico

APRIL 21-24, 2024

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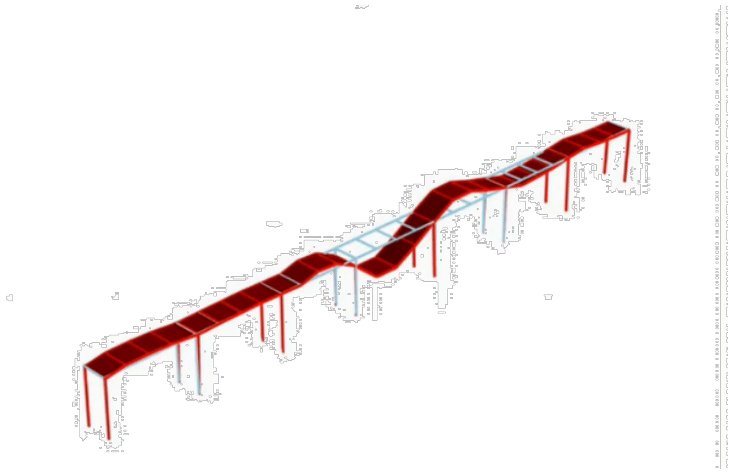
CASE STUDY
Frijolillo Bridge
Tuxpan, Mexico



CASE STUDY
Whitewater Cutoff Bridge California, USA

APRIL 21-24, 2024

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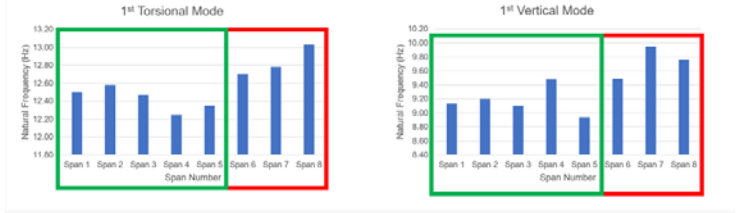
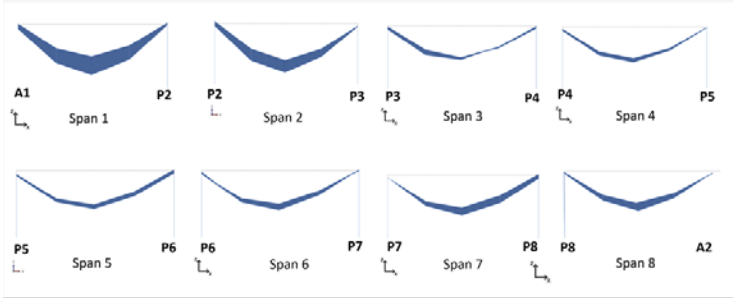
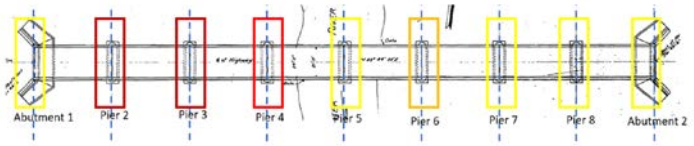
CASE STUDY
Whitewater Cutoff Bridge
California, USA

Mode number	Mode name	Natural Frequency (Hz)							
		Span 1	Span 2	Span 3	Span 4	Span 5	Span 6	Span 7	Span 8
1	1st Vertical Mode	9.13	9.20	9.10	9.48	8.94	9.49	9.95	9.76
2	1st Torsional Mode	12.50	12.58	12.47	12.25	12.35	12.70	12.78	13.03







CASE STUDY

Whitewater Cutoff Bridge California, USA

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CASE STUDY

Highway Bridge
Toronto, Canada

APRIL 21-24, 2024

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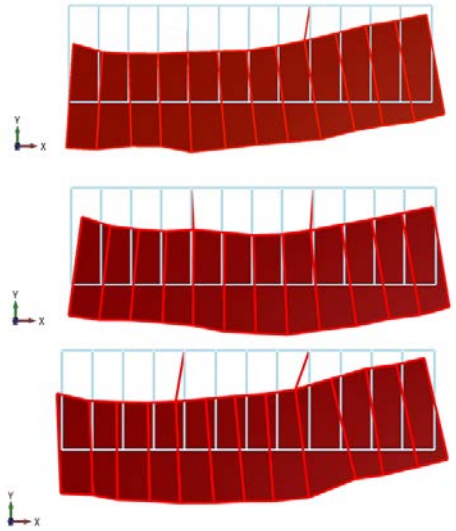
CASE STUDY

Highway Bridge
Toronto, Canada

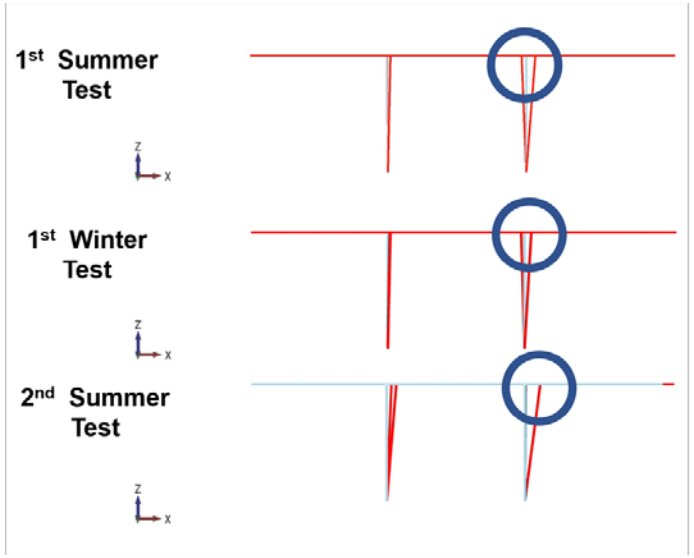
CASE STUDY
Highway Bridge
Toronto, Canada



1st Summer Test

1st Winter Test

2nd Summer Test



WHY VIBRATION ANALYSIS

Time
Setup

Cost
Labor, Equipment

Engineering
Locate specific areas of concern
Provide in-situ properties for repair

VISUAL

Equipment for access

Significant technician experience

Visible deficiencies

DRONE

Significant amount of data

Visible deficiencies

THERMAL

Different use-case

WHY VIBRATION ANALYSIS

Quick data collection, with a majority of analysis completed off-site

Access to the top-side of structure is sufficient

Small team of one to two people

Clear identification of deficiencies

In-situ natural frequencies for use in a more precise engineering of repairs, without idealized assumptions

THANK YOU

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