CSHM2 Workshop

WIM (Weigh In Motion), LOAD CAPACITY, AND BRIDGE PERFORMANCE
In the Context of Risk Assessment, Maintenance and Life Cost Based Design

Taormina 2008

Bridge-WIM systems

Evaluation of dynamic effects and load position

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POLITECNICO DI TORINO UIC

1 The B-WIM (Bridge Weigh in Motion) concept

= Evaluation of the weight of vehicles through the response of the structure with the least numbers of Sensors (3)

⇕

To instrument members of the structure, which is used like a natural scale.

- The total stress detected by the sensors placed on the bridge would in turn have a direct relationship to the load and consequently to the weight of the vehicle causing the stress.
- B-WIM may provide information not only about traffic data, but also about the actual service state of the bridge.

⟹ **A tool to combine Structural Health Monitoring and Weigh in Motion purposes**

2 B-WIM: General aspects

a) INFLUENCE OF THE TRAFFIC DENSITY :

= Difficulty in detecting the single component of the load applied

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The bridge returns the total response of the loads applied

The higher number of vehicles on the bridges, the more difficult is to detect the weight of a single vehicle.

2 B-WIM: General aspects

b) DYNAMIC INFLUENCE:

- **Bridge characteristics:**
  1. Dynamic characteristics of the bridge
  2. Damping characteristics of the bridge elements

- **Vehicles characteristics:**
  1. **Suspension characteristics**
  2. **Type of wheels**
  3. **Pressure of wheels.**

- **Roughness of the surface**

2 B-WIM: General aspects

The effect of dynamics results generally less for B-WIM

than

for pavement WIM systems which are more sensitive to dynamic influence, since they can record just a small part of the dynamic oscillation

In addition if the truck mass is negligible compared to the bridge mass, dynamic effects are naturally reduced by the bridge inertia.

2 B-WIM: General aspects

c) EFFECTS OF BRACKING

d) TYRE PRESSURE Change in the shape of load printfoot

e) SPEED OF VEHICLES

Possibility to install axle and speed detectors at the beginning of the bridge

However

It seems more convenient to study an integrated system for the detection of speed and axle detection to be installed on the structure

3 Fiber Optic Sensor (FOS) technology

Use the capacity of the optical fiber to register changes in:

intensity, wavelength and phase

for the detection of:

strain, acceleration, elongation, change of temperature…

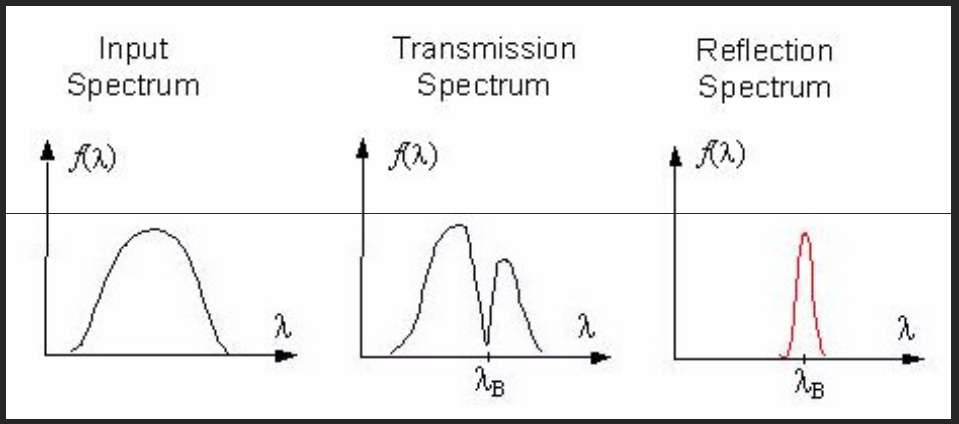
ADVANTAGES:

- High resolution, dynamic and accuracy
- Immunity from electro-magnetic noise
- Stability in time
- Installation at big distances
- Low intrusivity
- Multiplexing.

3 Fiber Optic Sensor (FOS) technology

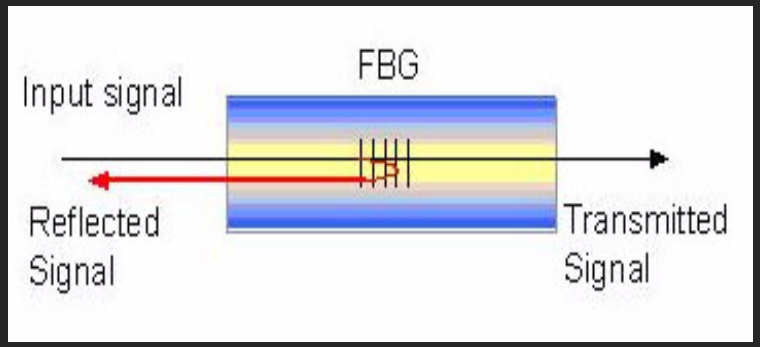
FIBER BRAGG GRATINGS (FBG)

⇨ **Change of the characteristics of the optical fiber:**



Thanks to the periodic modulation of the grating (semi-reflector)

Period of the grating depending on the elongation and on the temperature of the fiber



4 To develop a FOS sensor

ISSUES TO BE CONSIDERED IN DEVELOPING A FIBER OPTIC SENSOR (FOS)

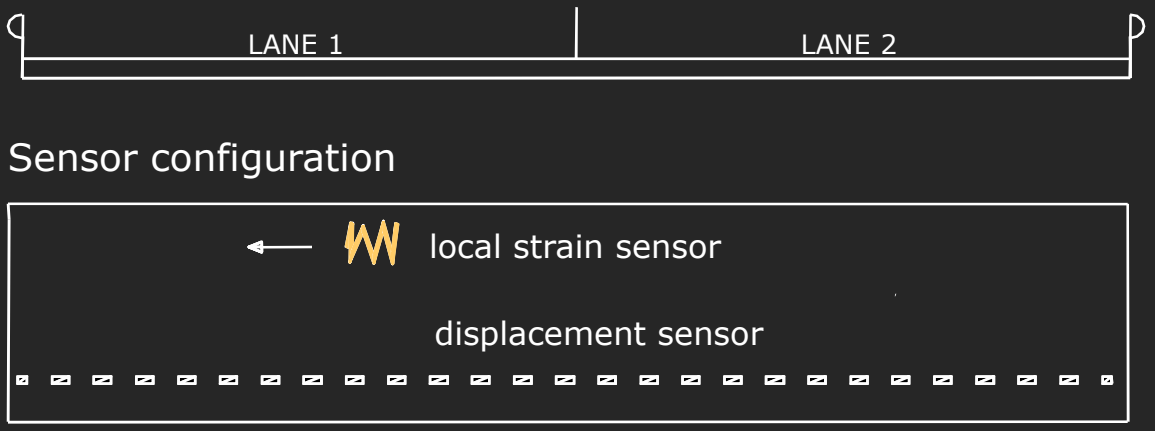
- **Configuration of the system;**
- **Protection packaging;**
- **Calibration and referencing;**
- **Dynamic range, resolution, and sensitivity;**
- **Data acquisition, analysis, and management.**

4 System configuration: theoretical approach

APPLICATION OF THE INFLUENCE LINE PRINCIPLE

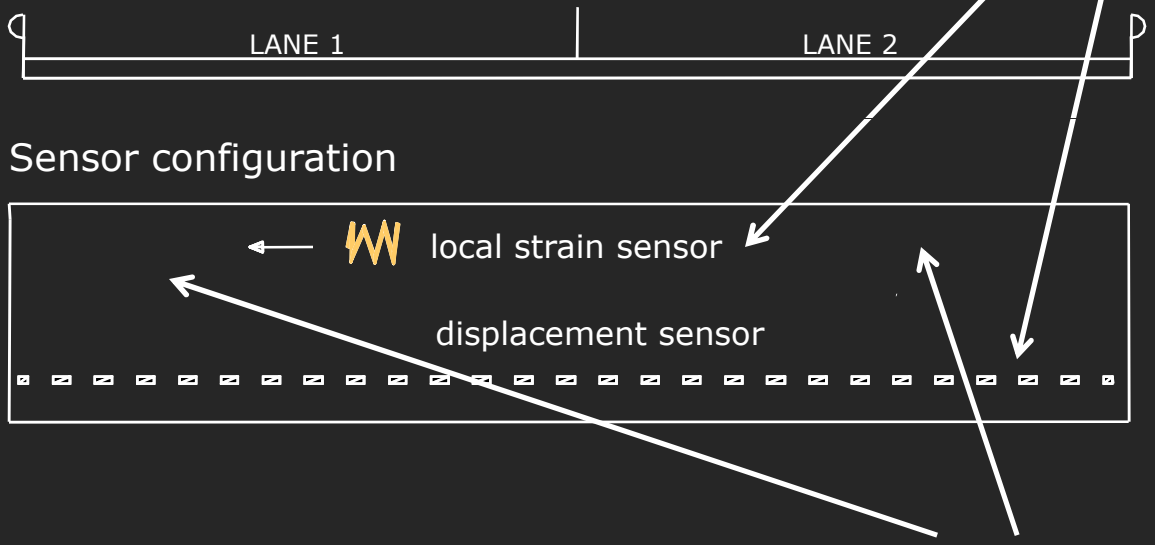
AS INVERSE PROBLEM: FROM reaction & load position → TO load value

Applied in direction orthogonal to the traffic flow



4 System configuration: theoretical approach

- **Vehicles' speed estimation and axle distance detection →** **by using two parallel sensors**



- **Load position detection →** **by comparing the results of sensors placed in different positions.**

5 Packaging: strain and displacement sensors

FBGs are sandwiched between two thin sheets of POLYIMIDE and glued together:

•High resistance of polymide ⟹ Robustness

•Thickness around few microns and high resistant glue

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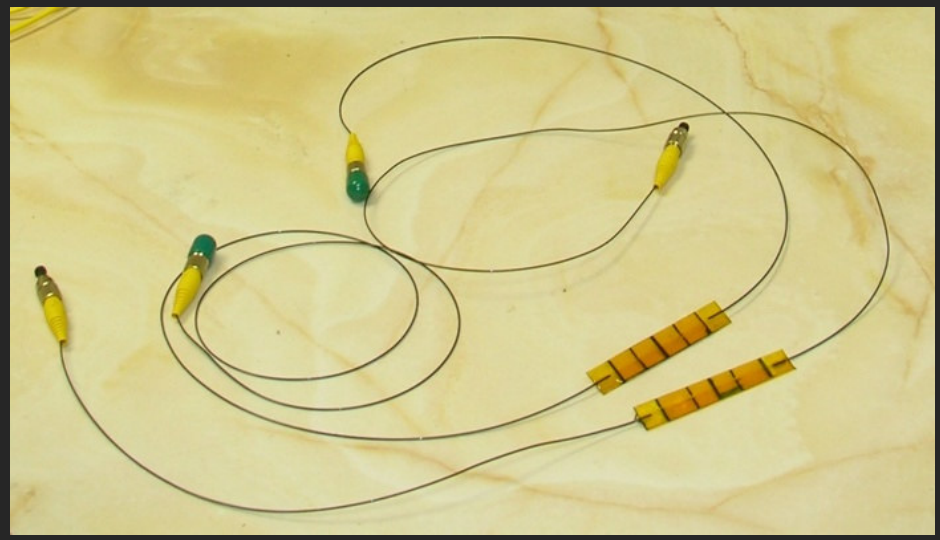
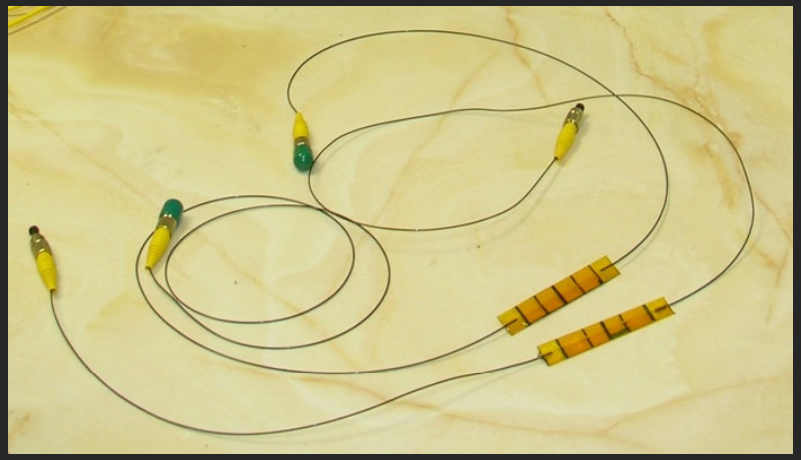
sensibility of the FBGs
and
strain transmission



5 Packaging: strain and displacement sensors

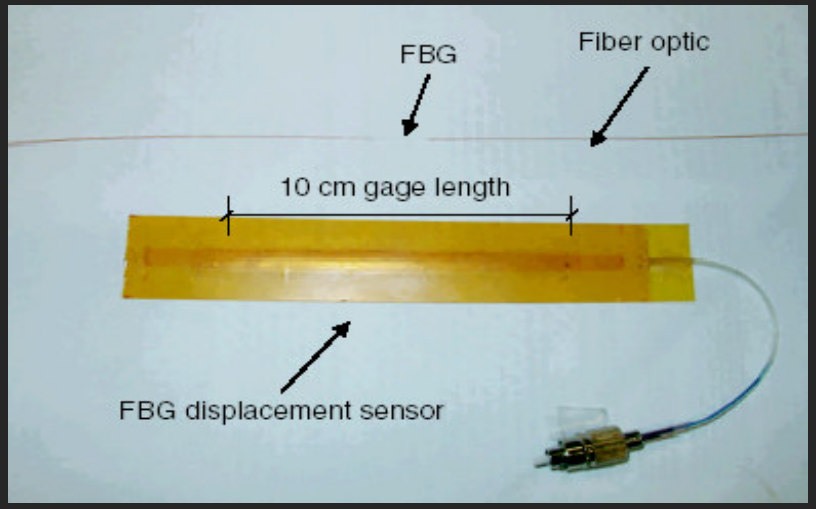


STRAIN SENSOR:

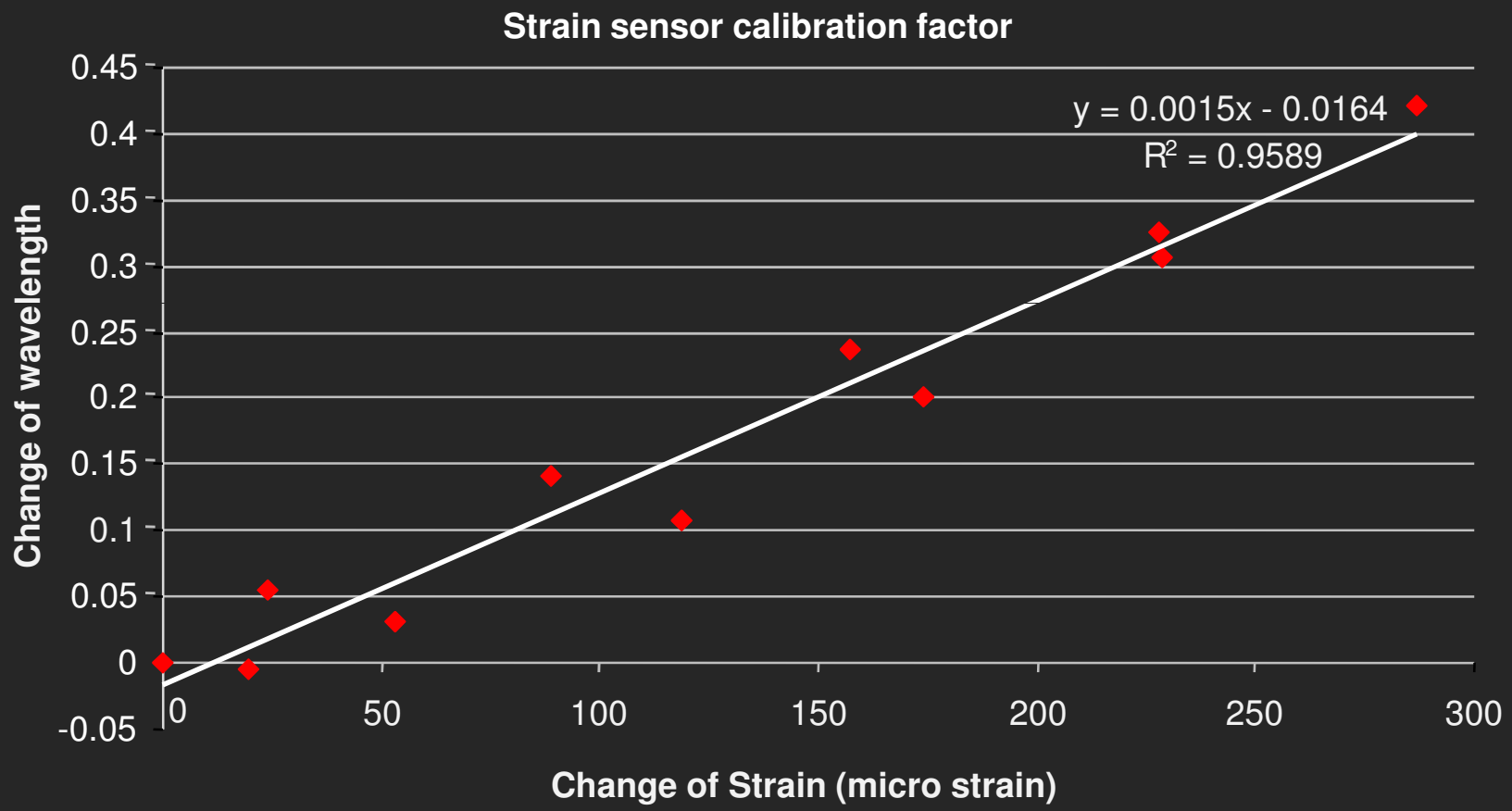
the optical fiber is fixed for the whole length

DISPLACEMENT SENSOR:

the optical fiber is only fixed at the ends



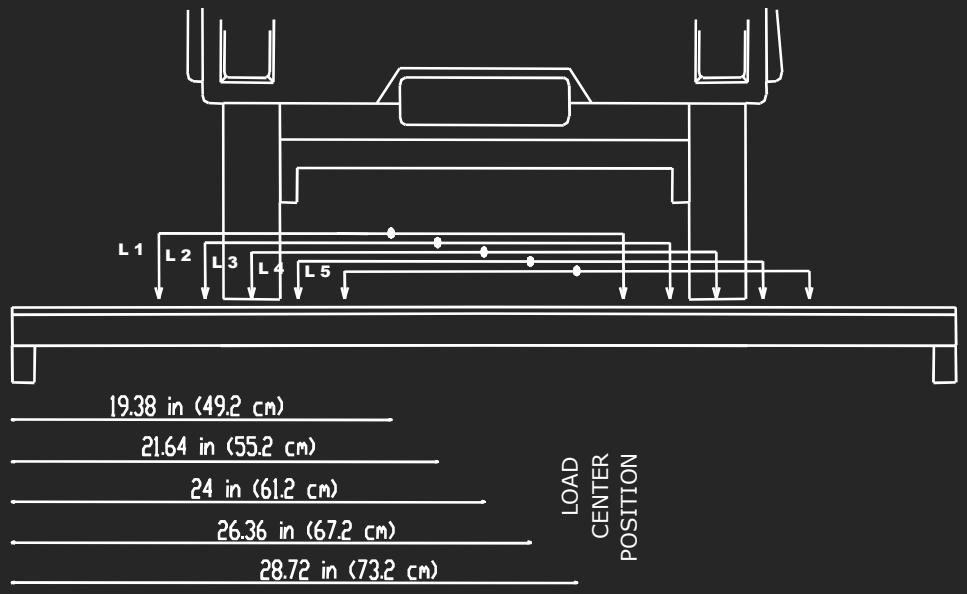
6 Sensor calibration



7 Tests setup

- **Application load trhough little wheels with MTS machine**

Moving loads from left to right ends (middle application points: 20.64 and 25.36 in)



→ **STATIC LOAD SIMULATION:**

Slow loading ramp until a maximum of 7.11 kN

Load steps of 0.44 kN

7 Tests setup

→ **DYNAMIC LOADING SIMULATION:**

Different speeds are obtained by applying loading ramps in different time intervals.

Loading = 4.45 e 6.67 kN,

Frequencies = 0.01 to 1.5 Hz

T [s]	F [Hz]
100	0.01
30	0.03
10	0.10
5	0.20
2	0.50
0.67	1.50

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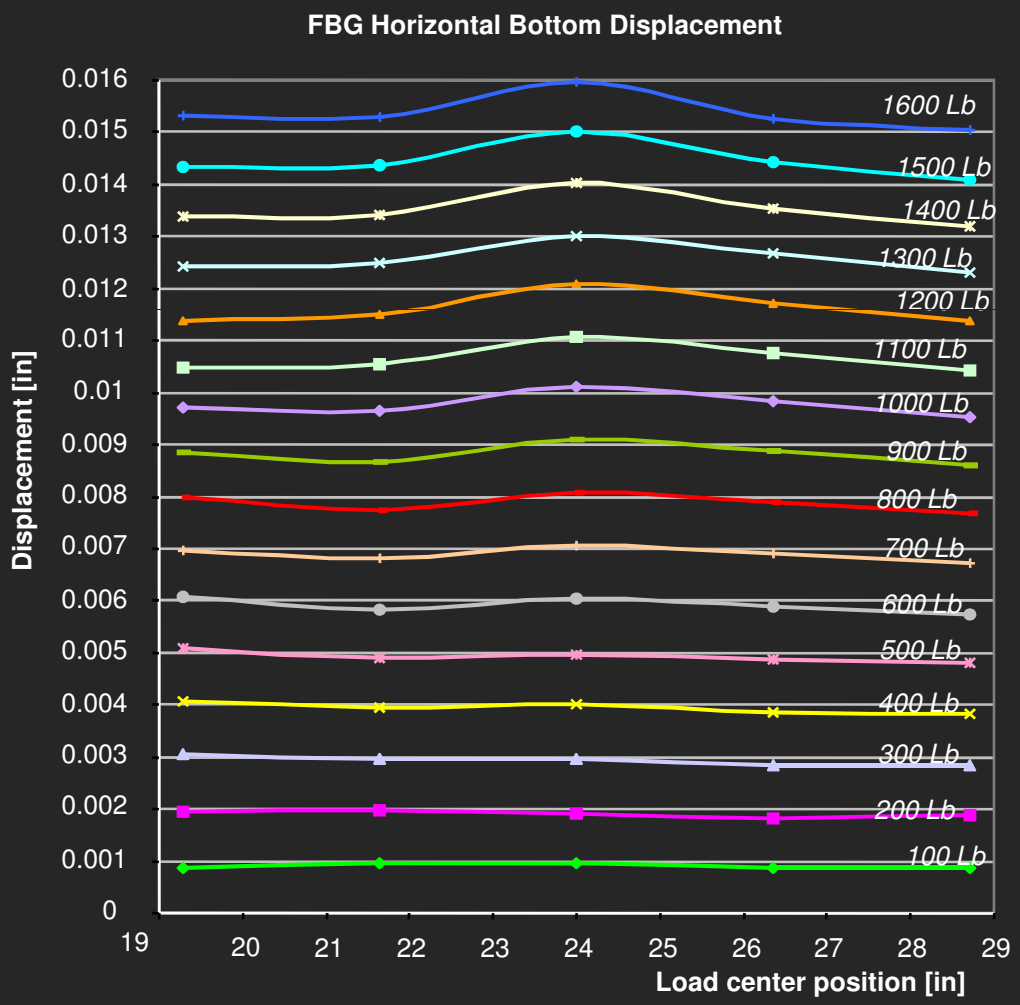
7 Tests setup

8 Static loading results

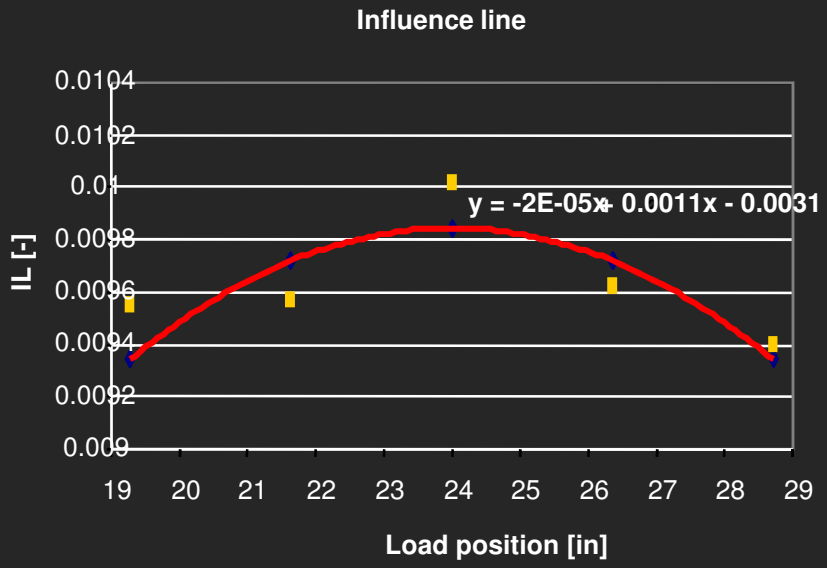
- Plot of displacement sensor values

INFLUENCE LINES



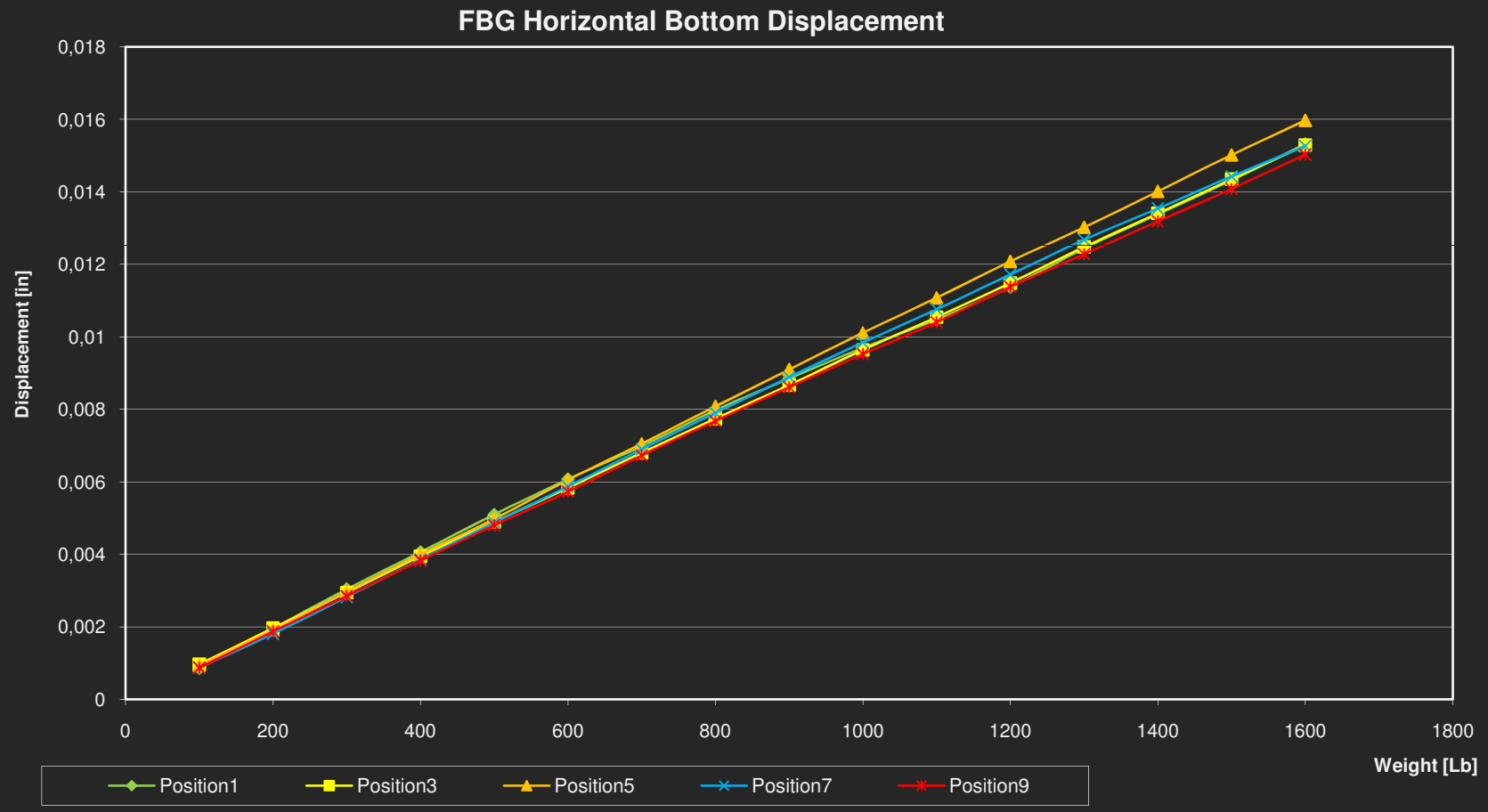
Theoretical influence lines

$$d = \int_L \varepsilon \cdot dl$$



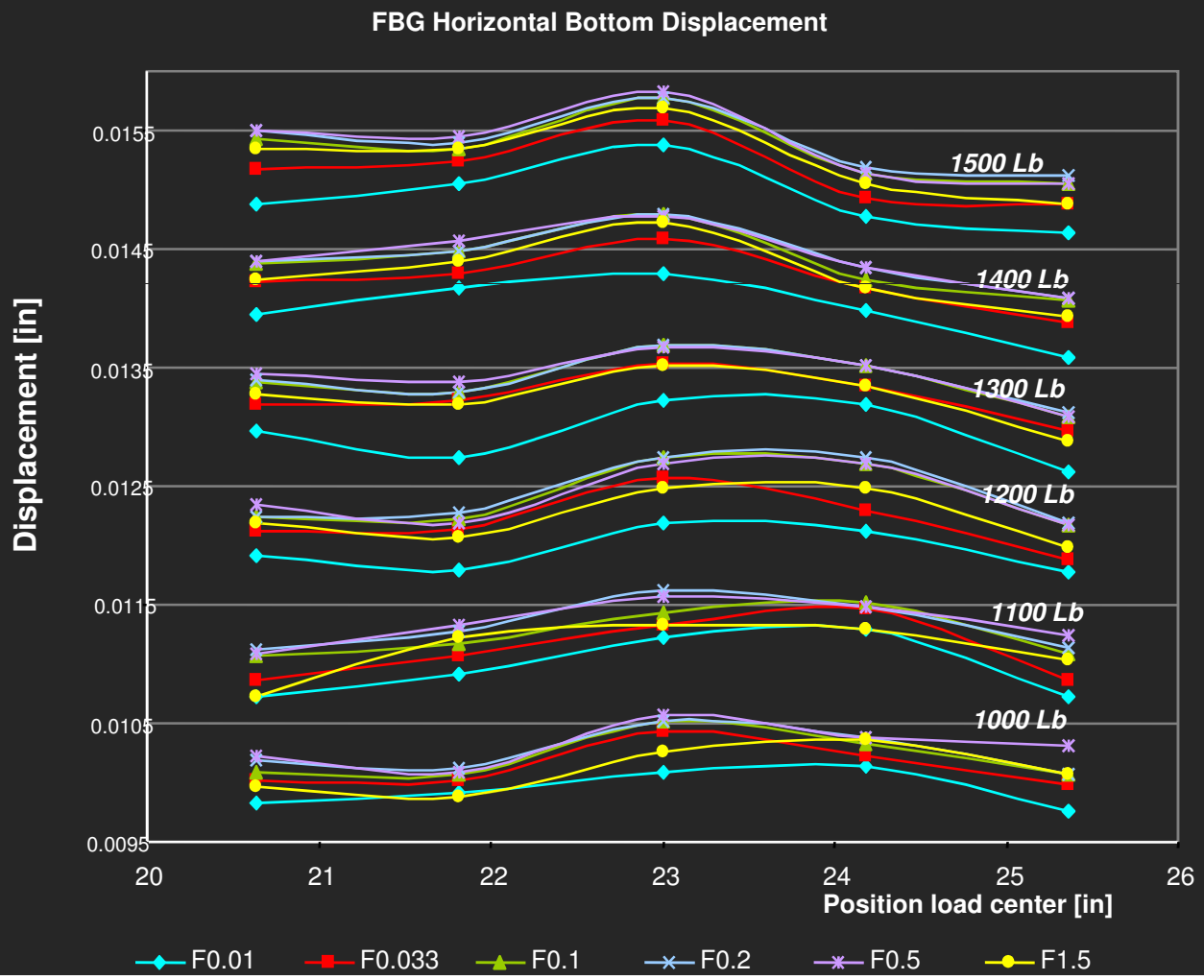
8 Static loading results

- **Plot of displacement sensor values: Displacement – Load applied (for different load positions)**



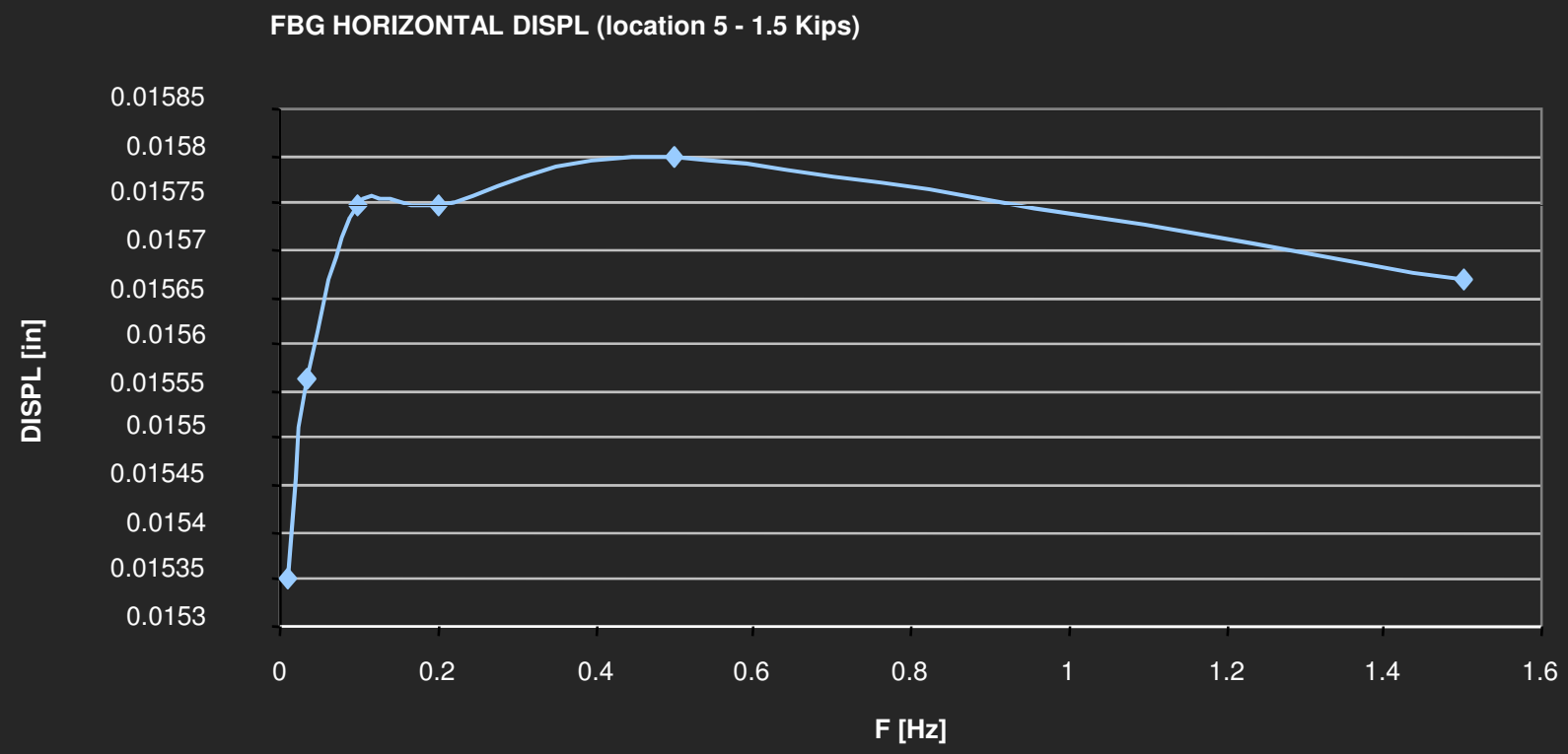
8 Dynamic loading results

- Plot of displacement sensor values INFLUENCE LINES



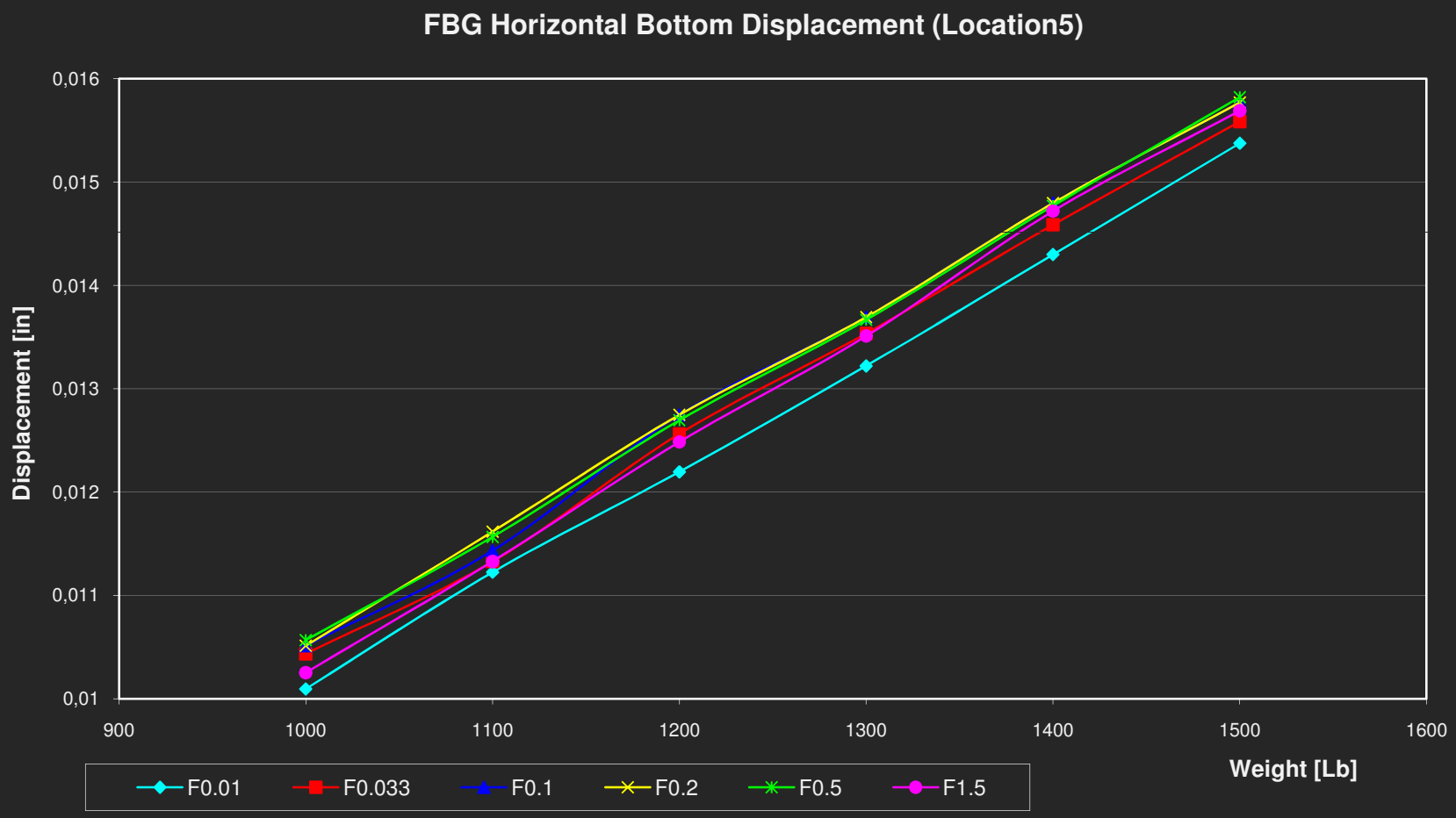
8 Dynamic loading results

- **Plot of displacement sensor values: Displacement – Frequency (for middle load position and load = 1.5 kips)**



8 Dynamic loading results

- **Plot of displacement sensor values: Displacement – Load applied (for different frequencies)**



Health monitoring of the Patroon Bridge

- Weight in Motion system
- Dynamic analysis
- Fatigue Analysis

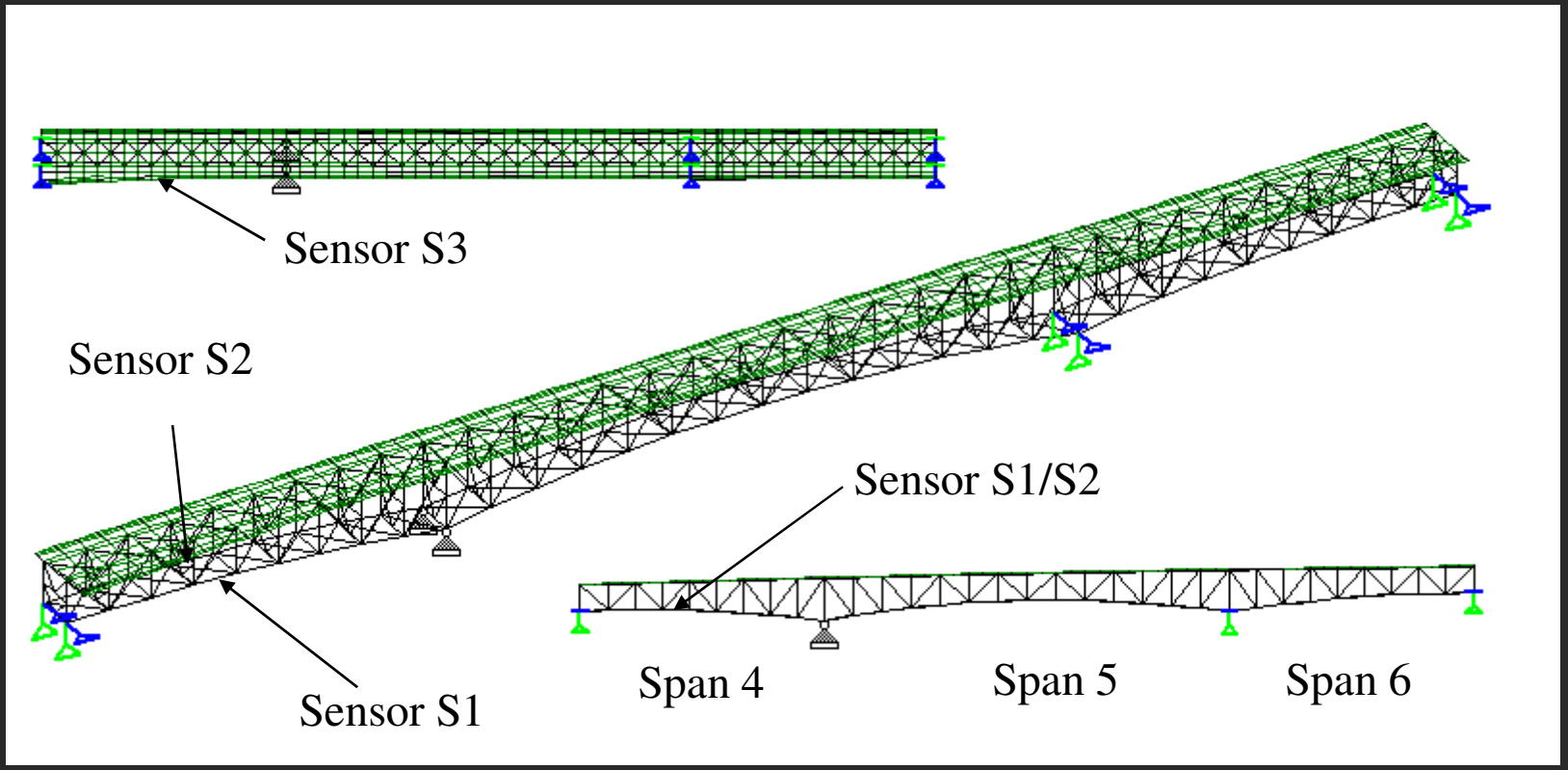
Health monitoring of the Patroon Bridge

WEIGHT IN MOTION SYSTEM

- •FBG strain Sensor and Data acquisition system
- •Sensor Plan
- •Test Plan
- •Data Analysis
  - Location of the Truck
  - Weight of the Truck
  - Speed of the Truck

Health monitoring of the Patroon Bridge

SENSOR PLAN



Health monitoring of the Patroon Bridge

- **TEST PLAN**

  - Three different truck load
  - Three different Location (three lanes)
  - Total number of tests: 9

  - Load – strain Curve for each lane
  - Strain ratio for each lane

Health monitoring of the Patroon Bridge

- Data Analysis
  - Location of the Truck
    - Strain ratio is constant for any unknown truck loading moving over the specific lane

$$\frac{\varepsilon_1}{\varepsilon_2} = C1 \ \ (for \ \ lane \ \ 1)$$

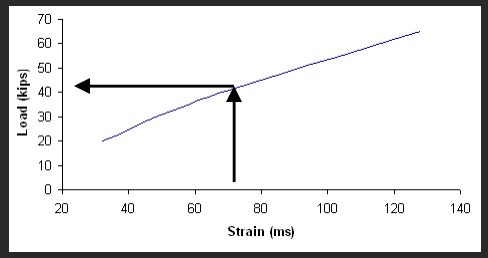
$$\frac{\varepsilon_1}{\varepsilon_2} = C2 \ \ (for \ \ lane \ \ 2)$$

$$\frac{\varepsilon_1}{\varepsilon_2} = C3 \ \ (for \ \ lane \ \ 3)$$

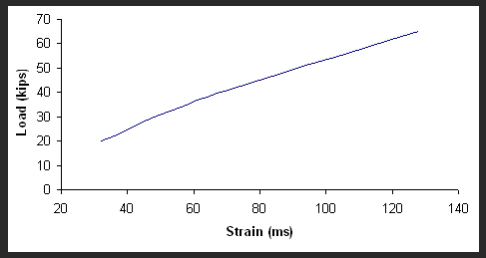
Location of the Truck

Health monitoring of the Patroon Bridge

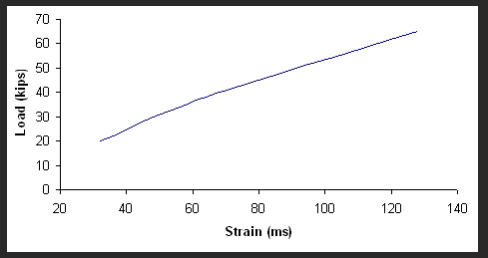
- Data Analysis
  - Weight of the Truck
    - After finding the location of the truck, Load-strain curve is used to calculate the truck weight



Lane 1



Lane 2



Lane 3