Monitoring Bridge Performance Under Vehicle Loading with Dynamic Fiber Optic Strain Sensing

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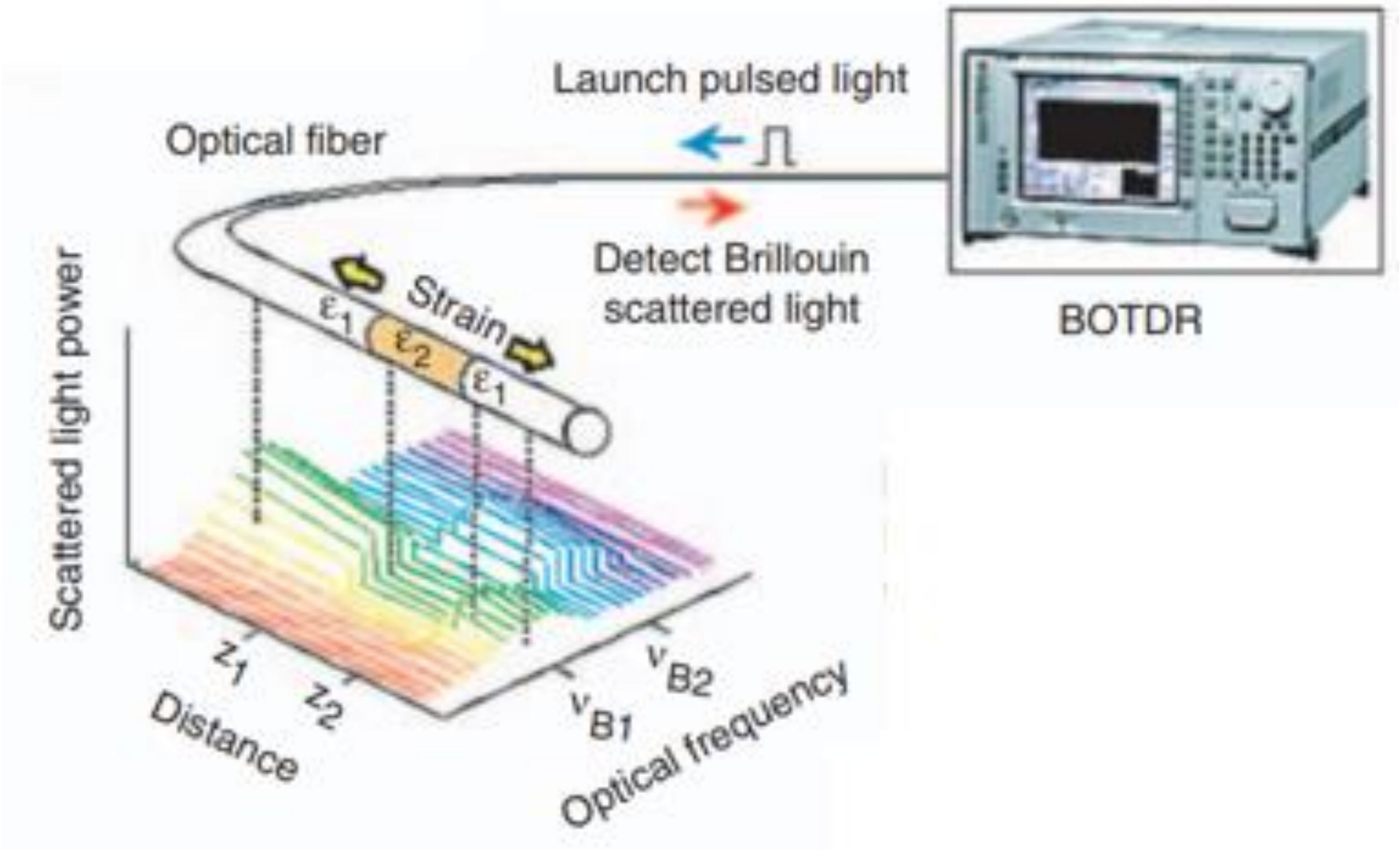
Objectives

Service load performance assessment of an RC bridge

- Collect and analyze strain data efficiently
- Characterize load distribution across the bridge structure
- Develop and validate computational models for performance analysis
- Evaluate long-term bridge monitoring using dynamic fiber optic strain sensing
- Post-earthquake damage evaluation

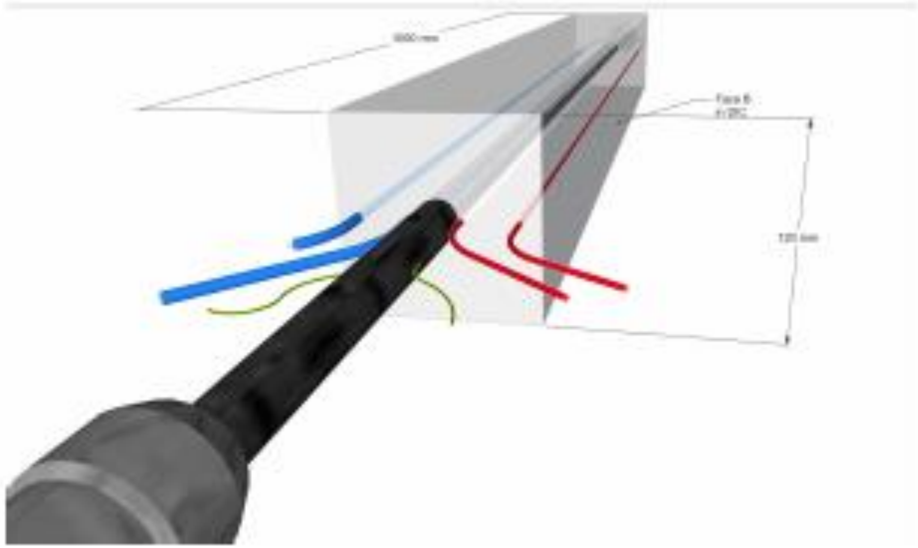
Background

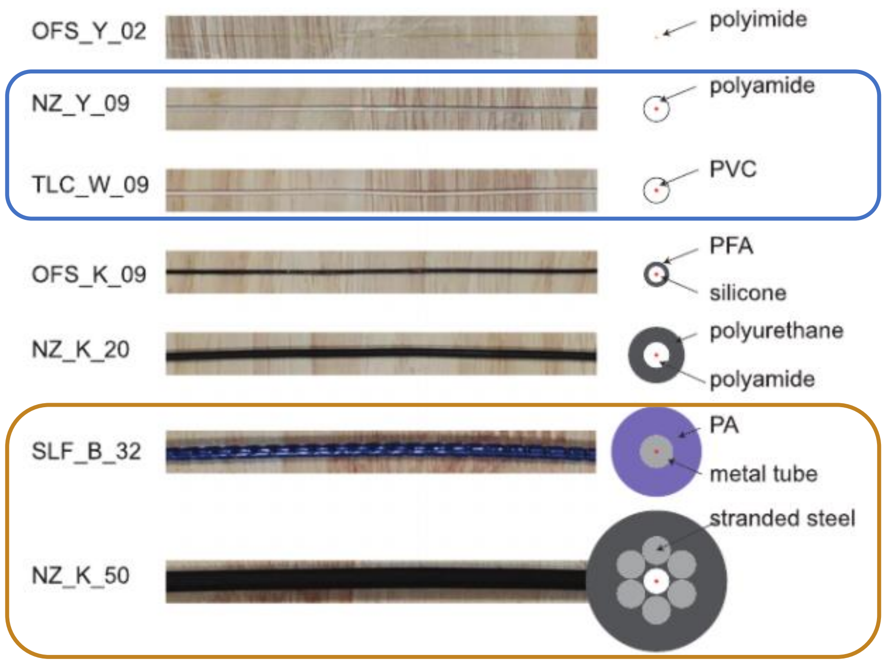
Fiber optic strain sensing



(reference: Nicky De Battista
https://www.repository.cam.ac.uk/handle/1810/255405)

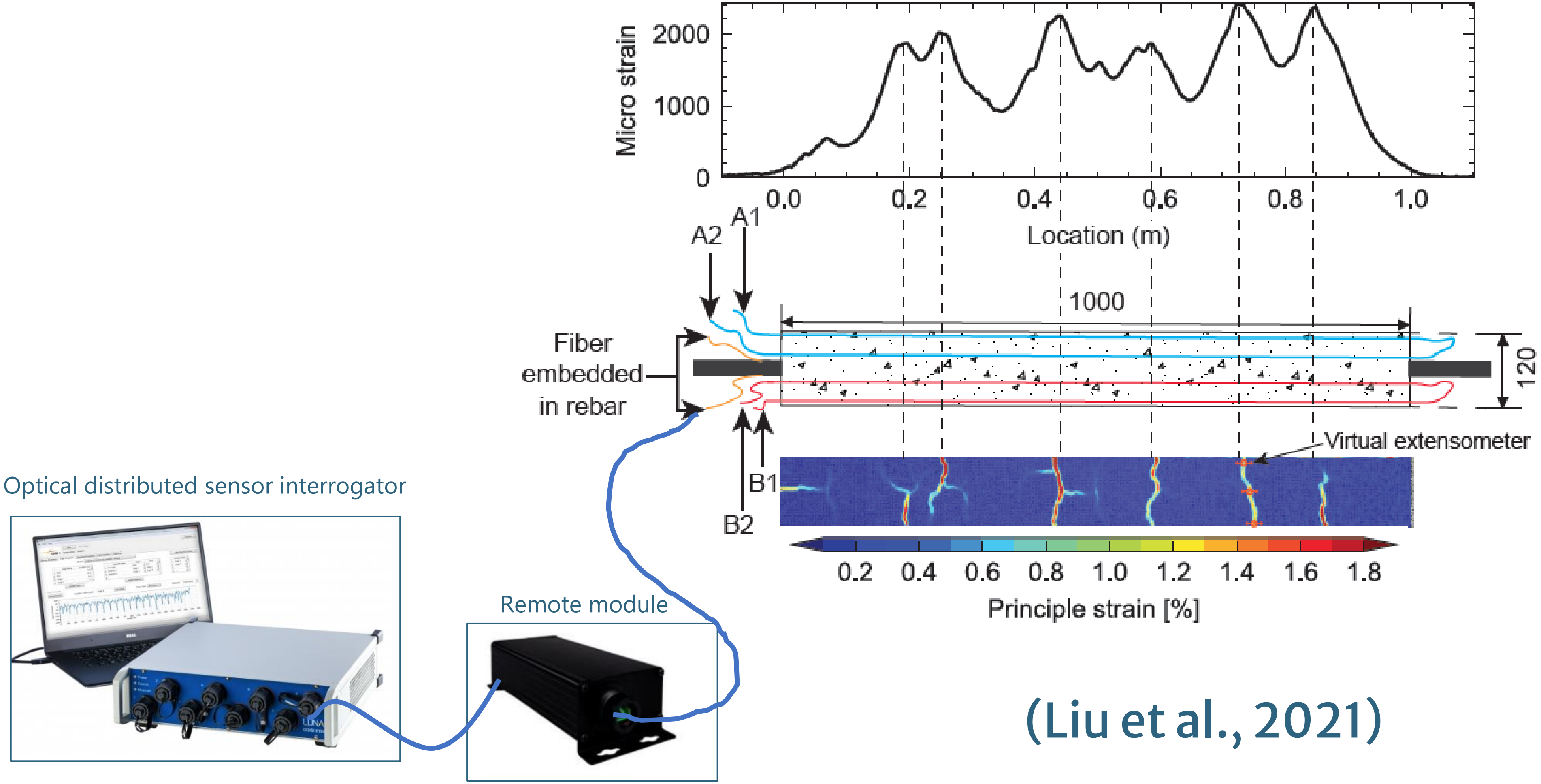
Crack measurement using fiber optic sensing





(Zhang et al., 2020)

Crack measurement using fiber optic sensing

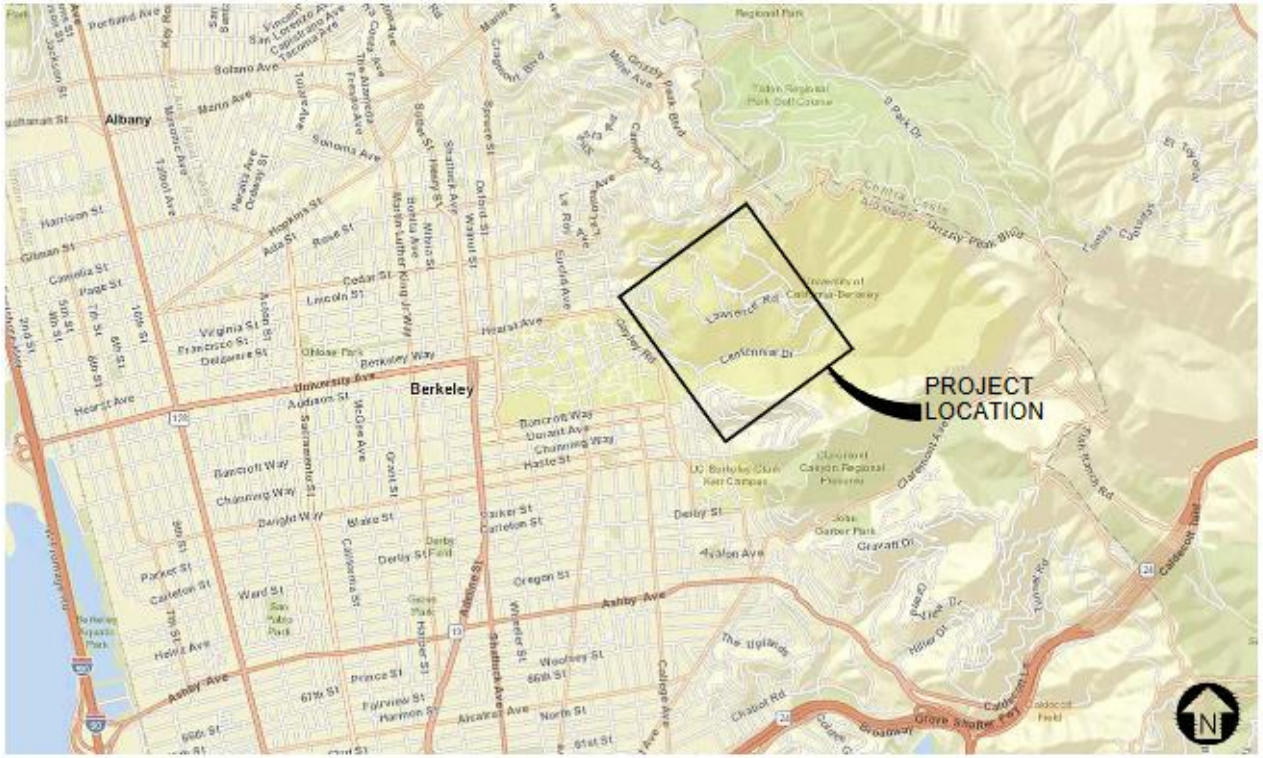


(Liu et al., 2021)

Motivation

Evaluate use of fiber optics for quantifying real service loads and structural performance

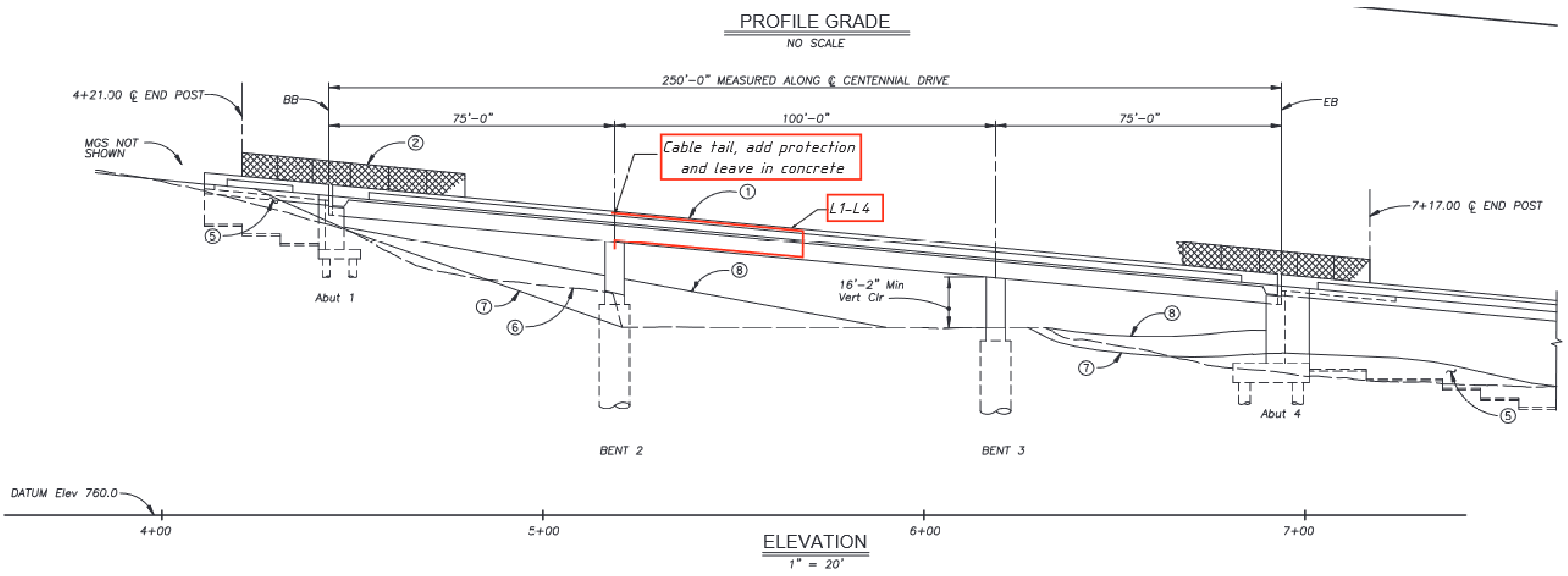
Centennial Viaduct



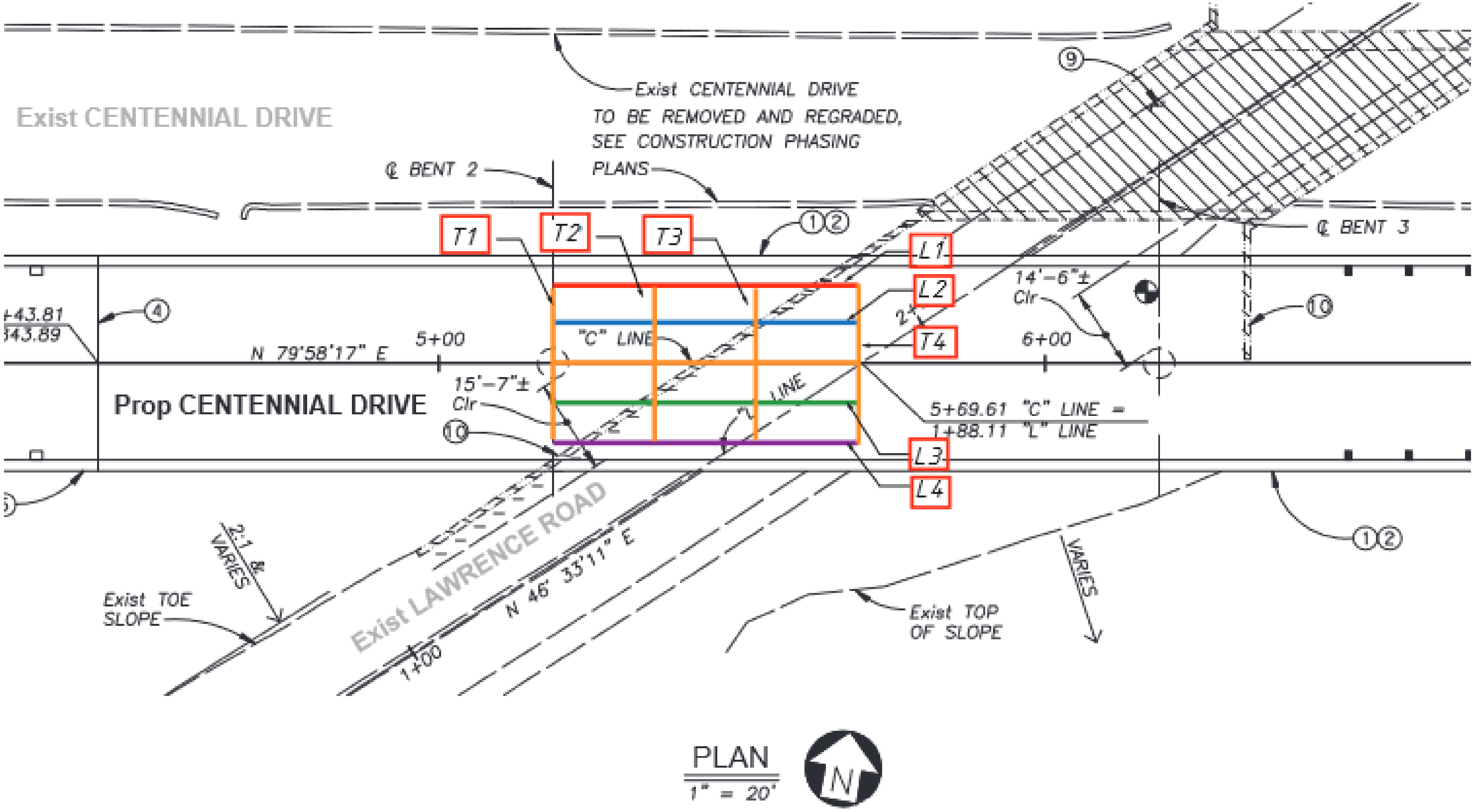
VICINITY MAP
SCALE: N.T.S.

LOCATION MAP
SCALE: N.T.S.

FO sensing plan - deck



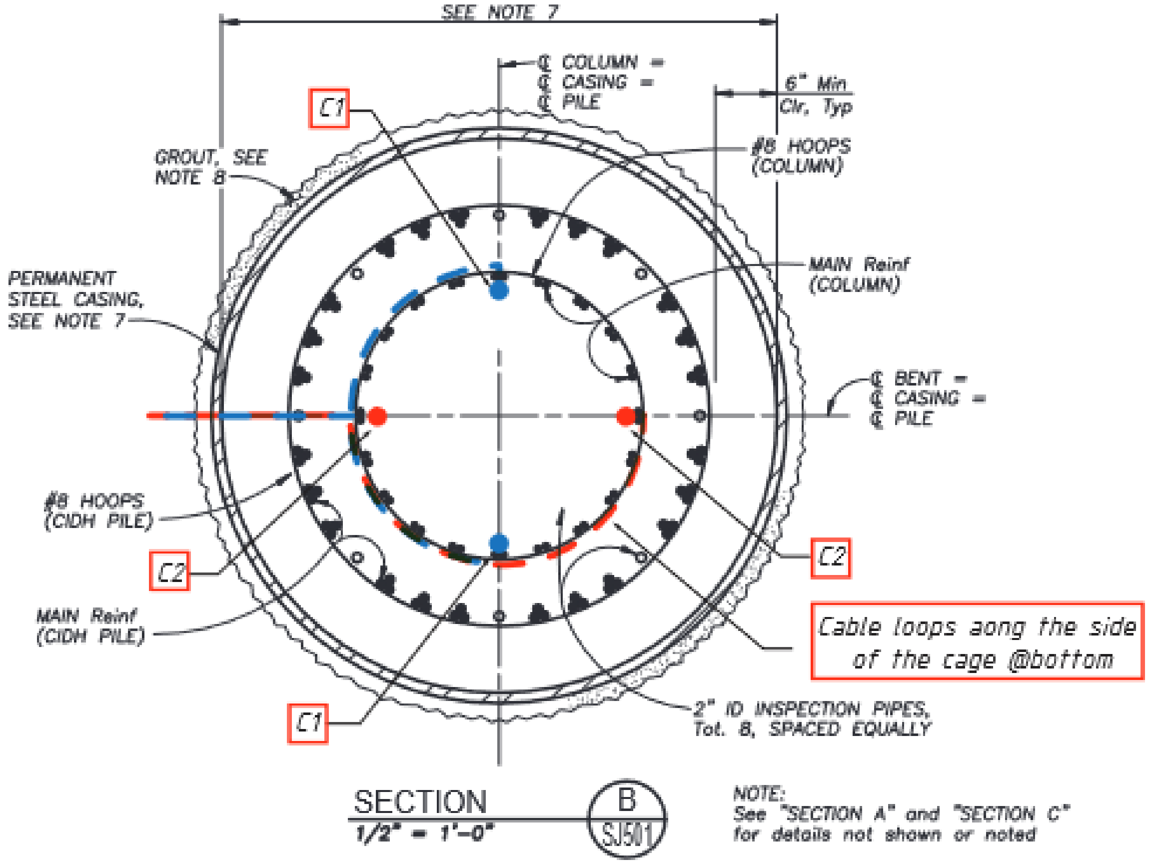
FO sensing plan - deck

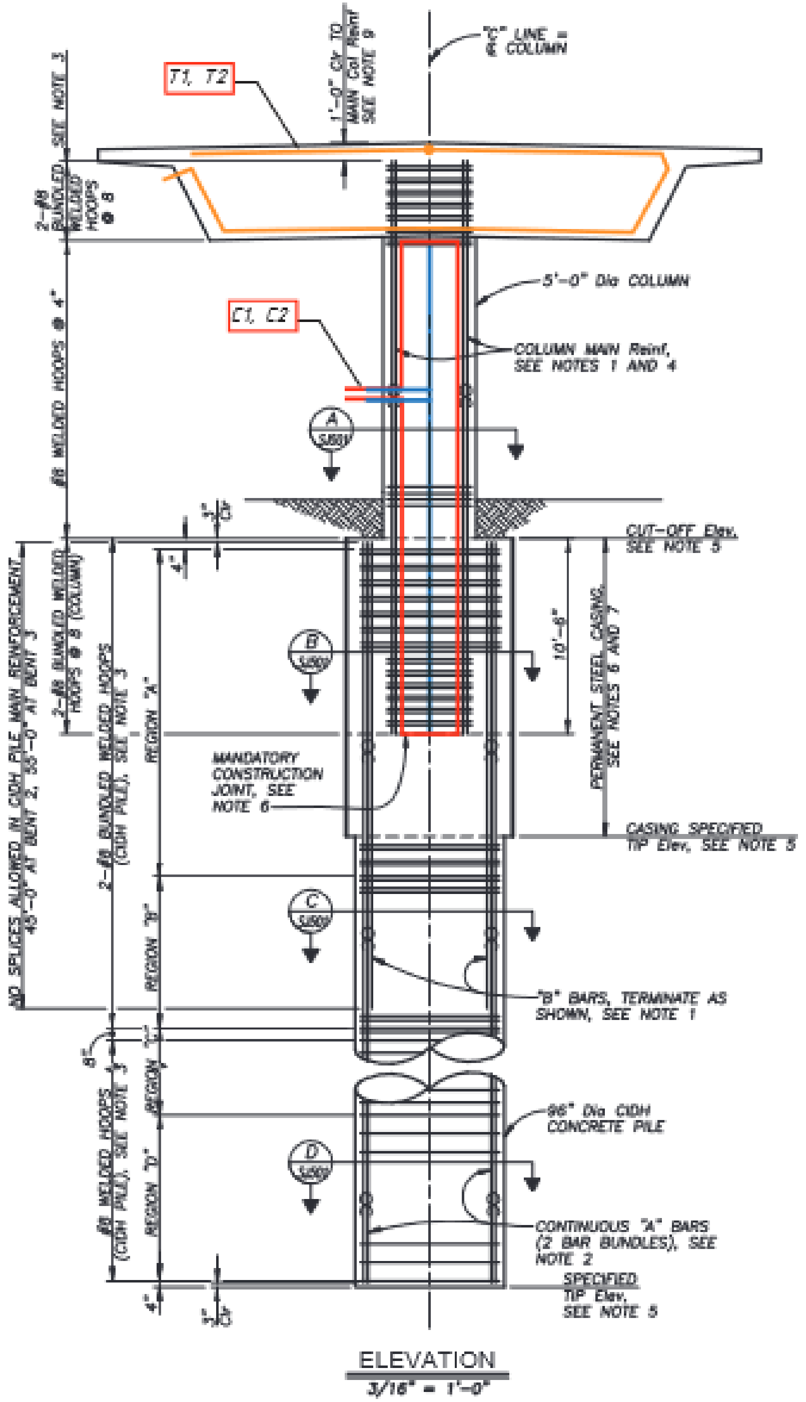


PLAN
1" = 20'

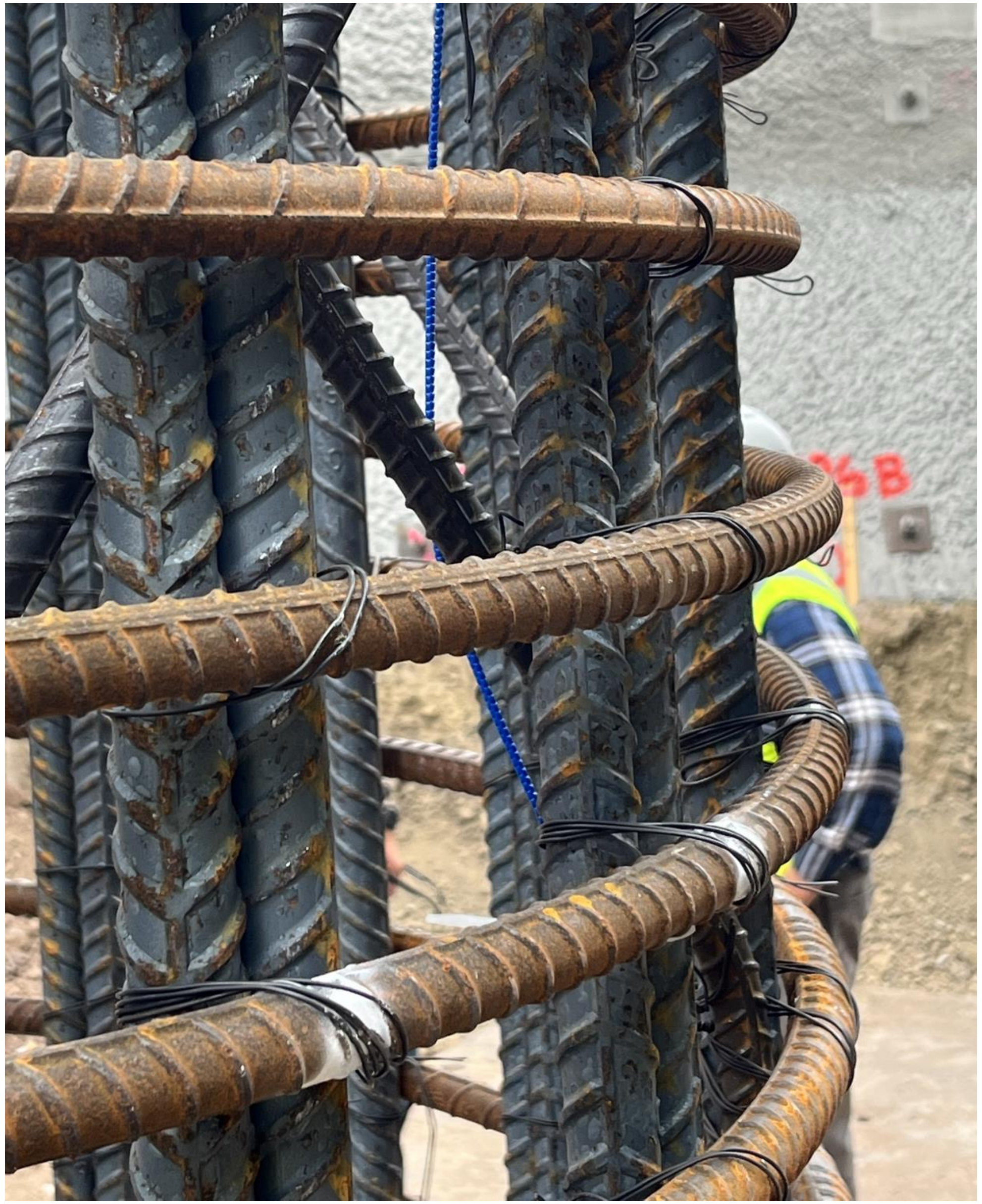
FO cables embedded in deck

FO sensing plan - columns



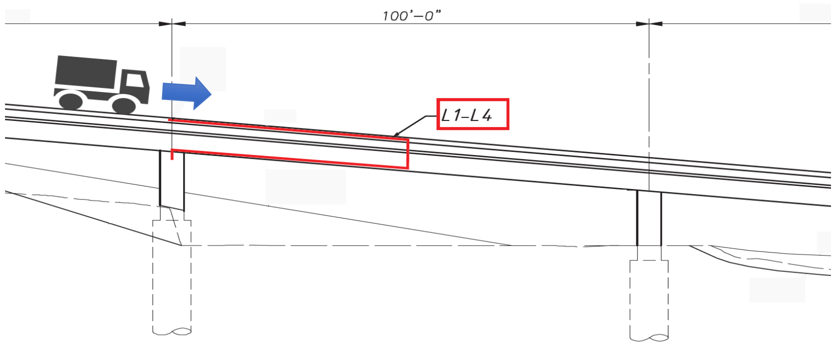


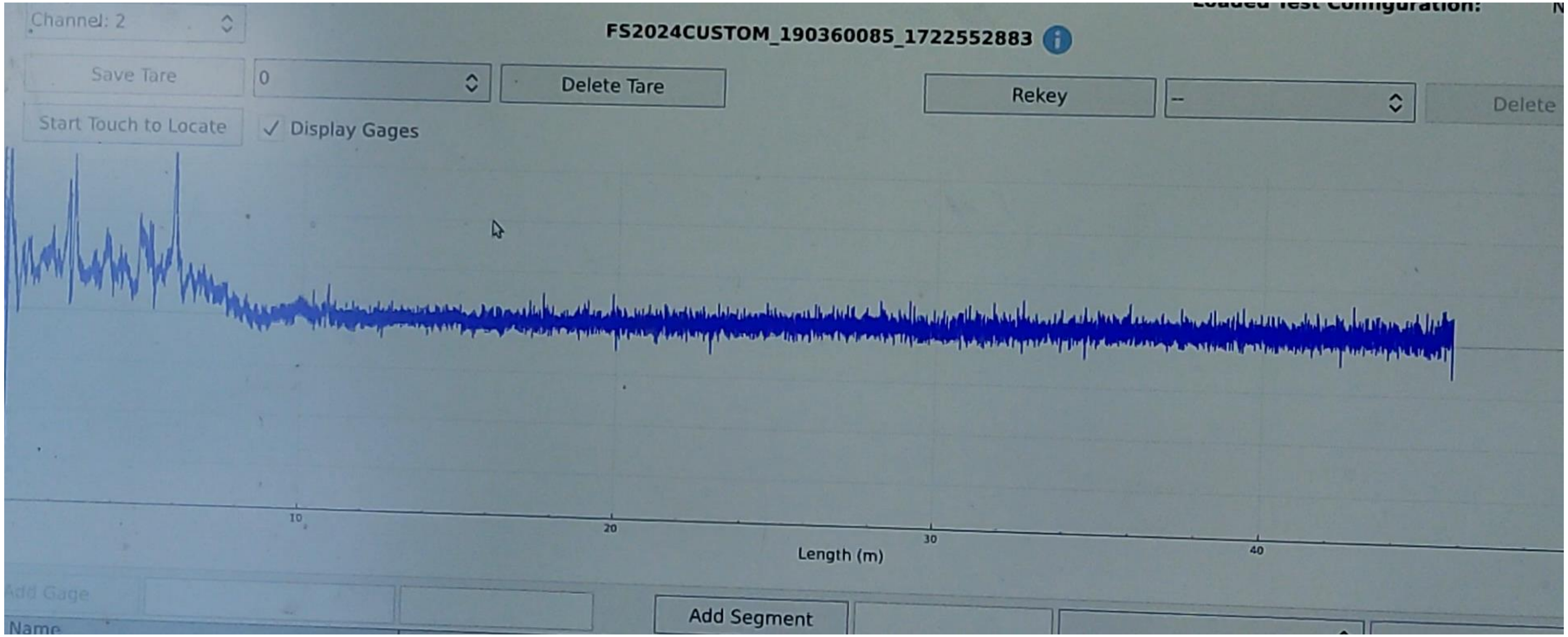
FO cables embedded in columns



Data collection

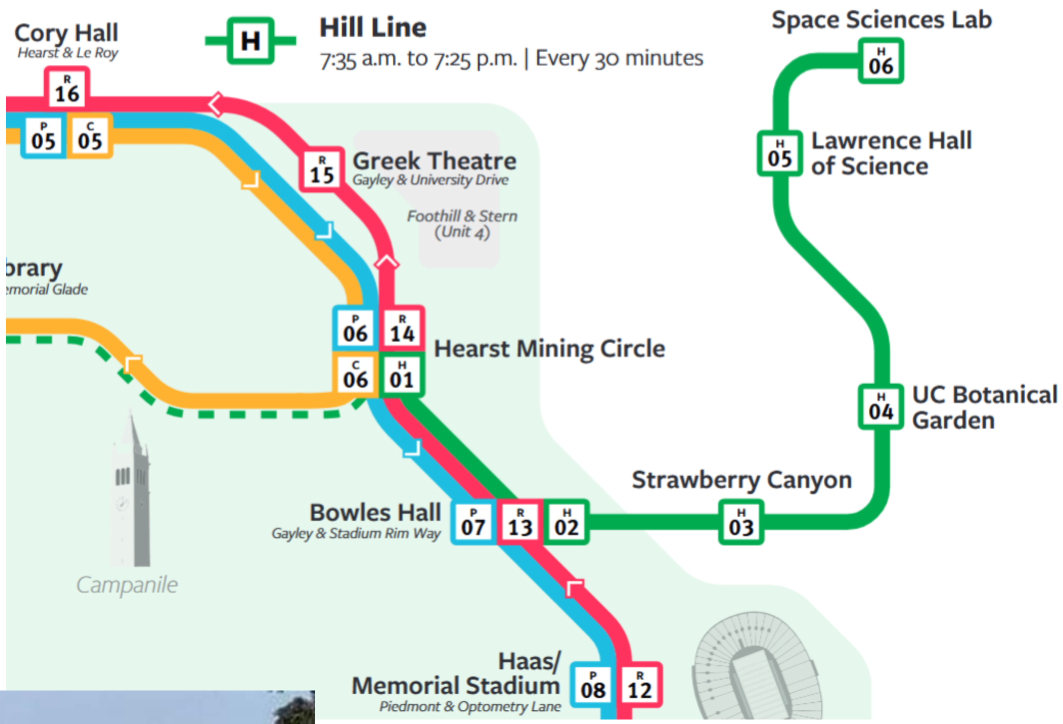
Example measurement





Model consideration

- Shuttle Load:
  - Total weight ≈ 5.9 tons
  - Load per wheel
    - (in 2D, two wheels) ≈ 2,950 kg per wheel
  - Wheelbase ≈ 4.7 m
  - Track Width ≈ 2.2 m

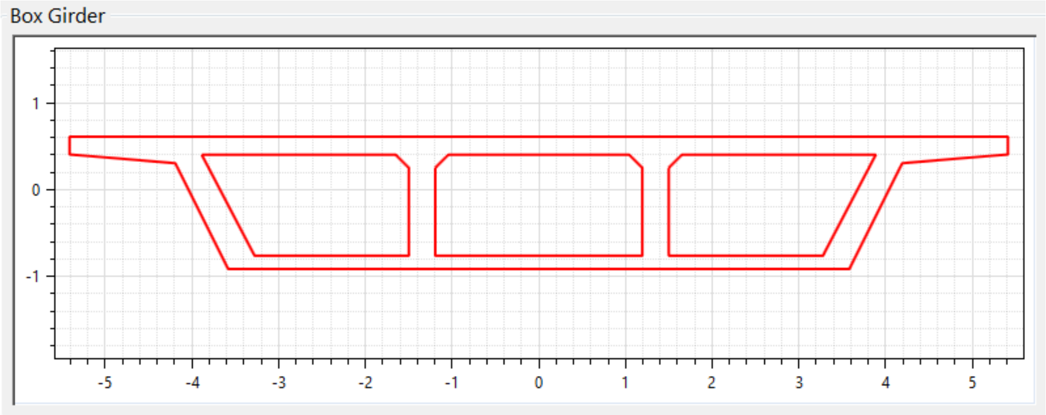


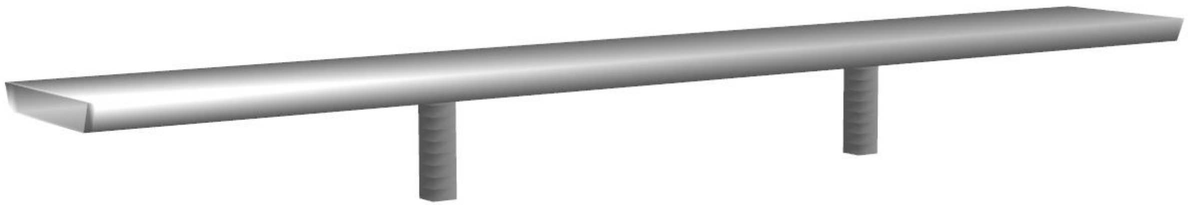
(reference: UC Berkeley Bear Transit https://pt.berkeley.edu/transportation-mobility/bear-transit)

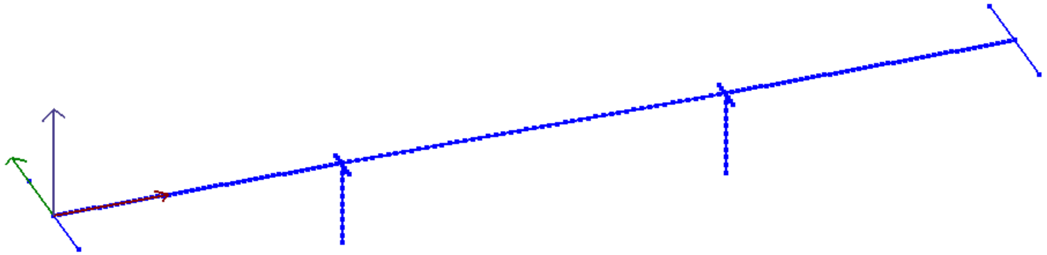
(reference: UC Berkeley Bear Transit https://www.visitberkeley.com/directory/uc-berkeley-bear-transit/)

Model consideration

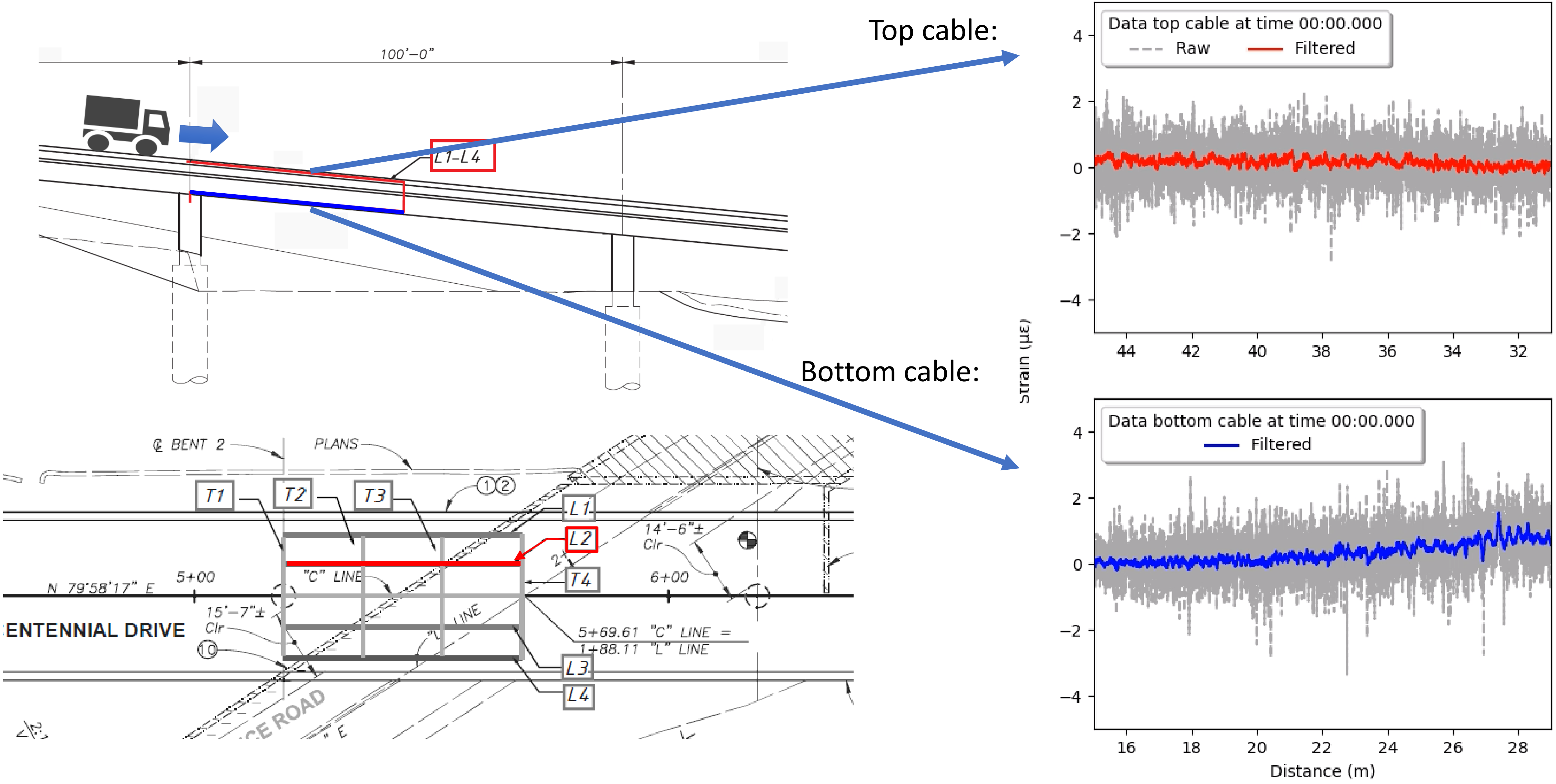
- Simple Linear Elastic Model for Initial Validation
  - Cross-sectional Area: ≈ 53.22 ft^2 ≈ 4.94 m^2
  - Reinforced Concrete Properties:
    - Yield Strength (fy) = 60 ksi
    - Compressive Strength (fc') = 3.6 ksi
    - Modulus of Elasticity (E) ≈ 23,520 MPa

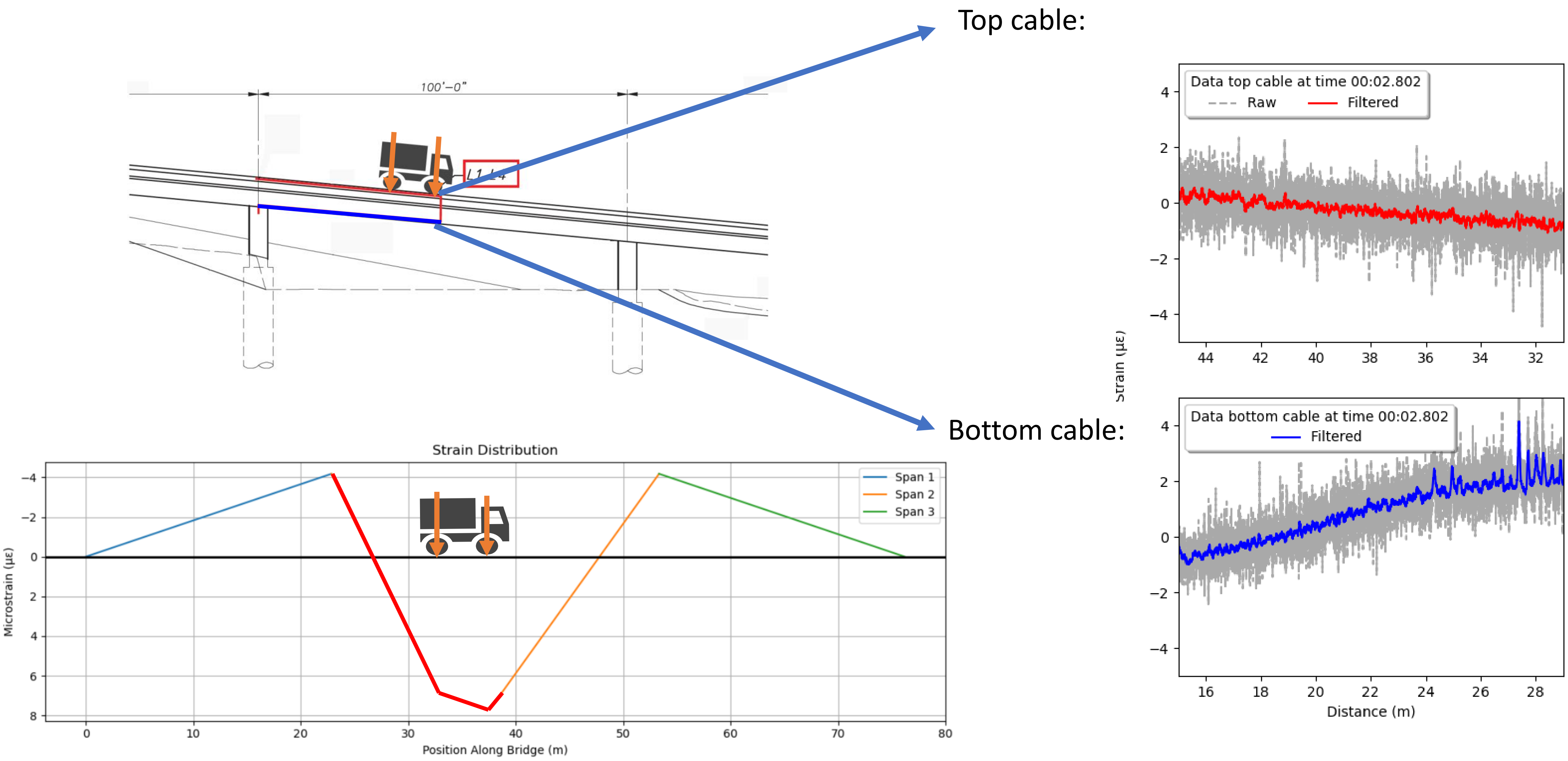


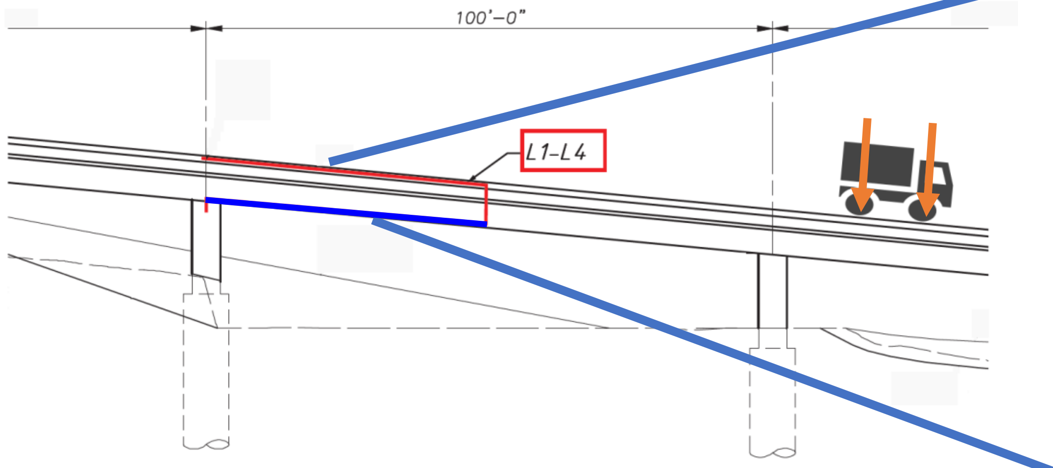




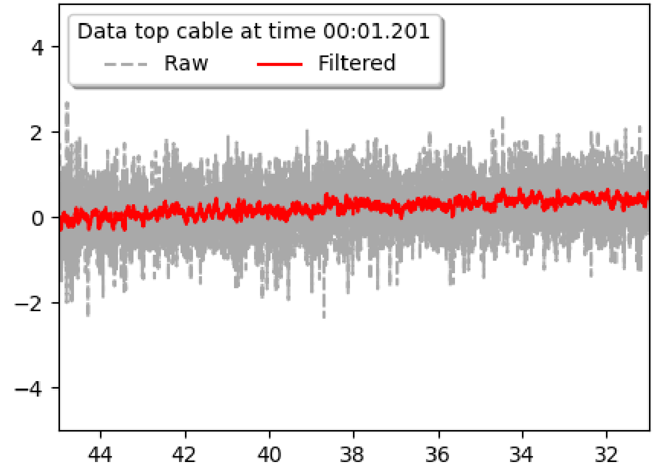
Measurement: Longitudinal



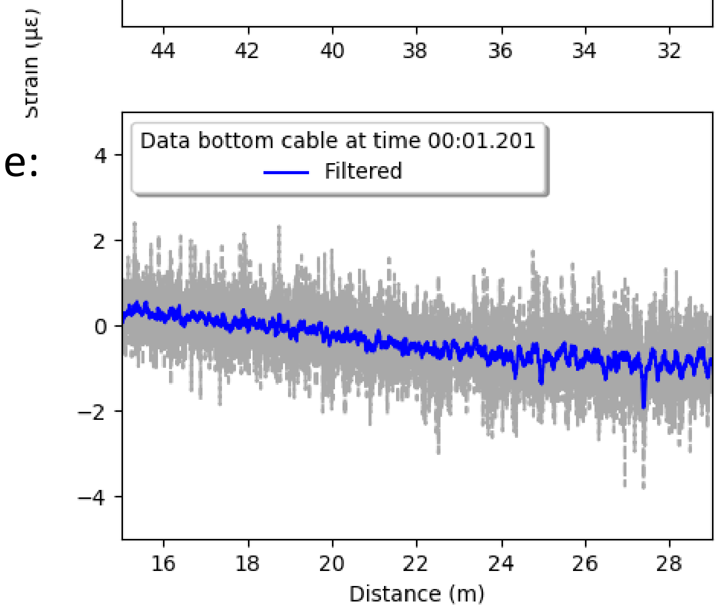

100'–0"
L1 L4
Top cable:
Bottom cable:
Data top cable at time 00:02.802
Raw
Filtered
Data bottom cable at time 00:02.802
Filtered
Strain (με)
Distance (m)
Strain Distribution
Span 1
Span 2
Span 3
Microstrain (με)
Position Along Bridge (m)

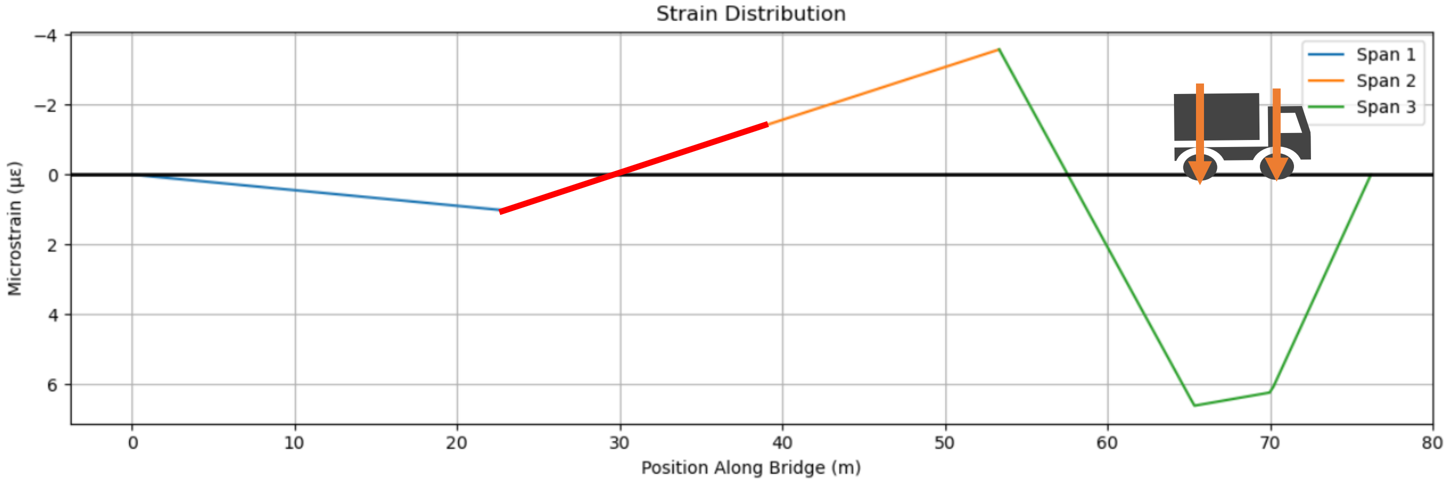


Top cable:

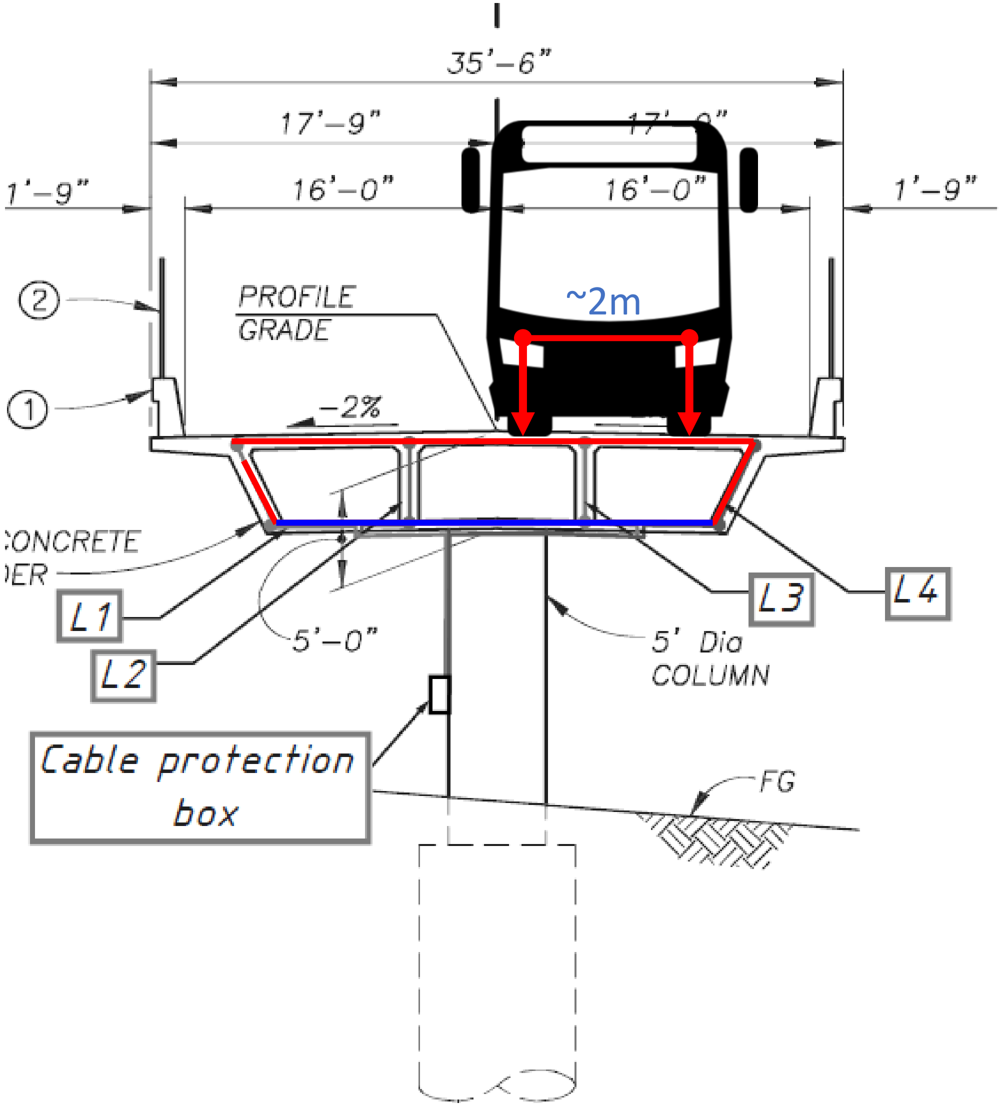


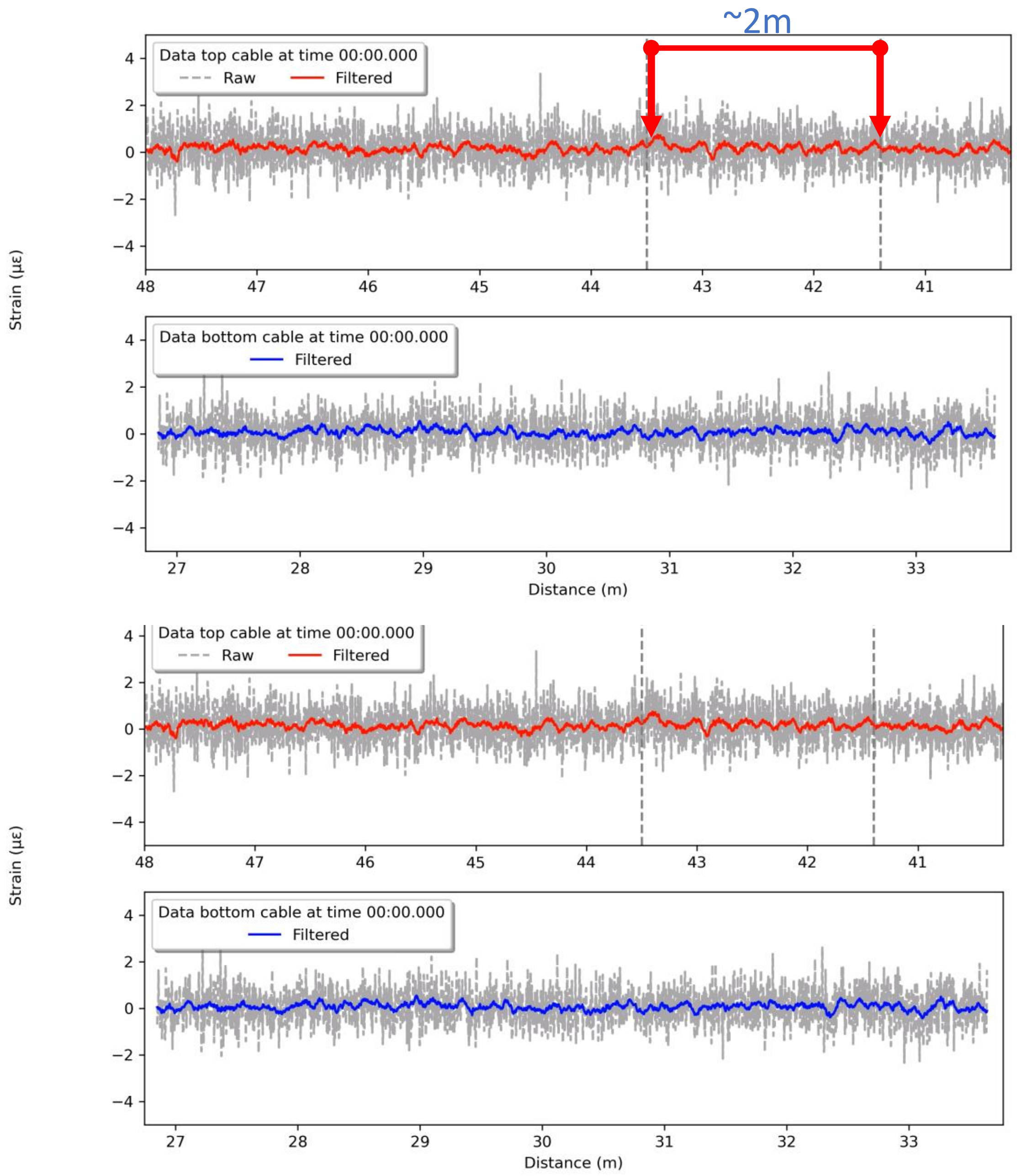
Bottom cable:

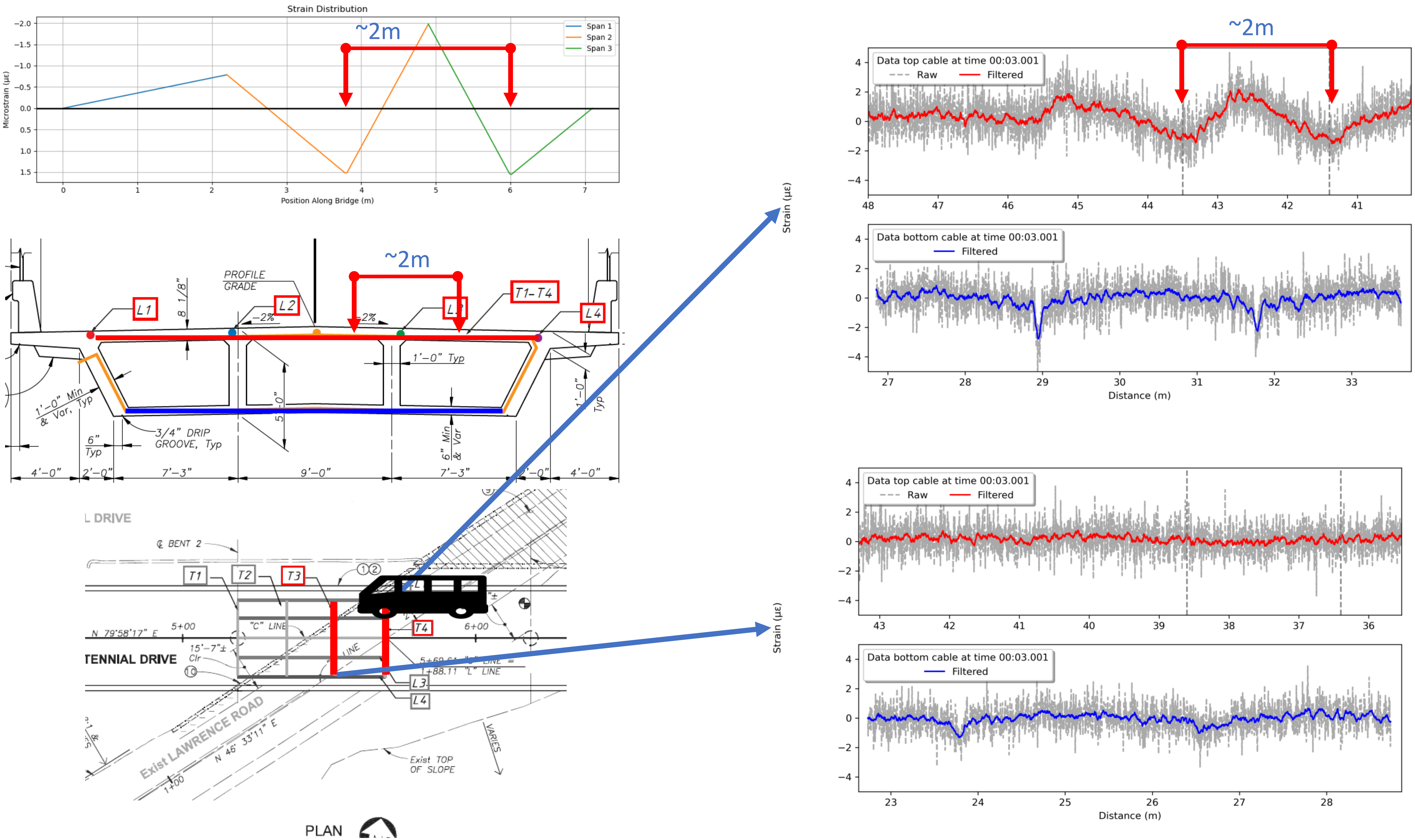


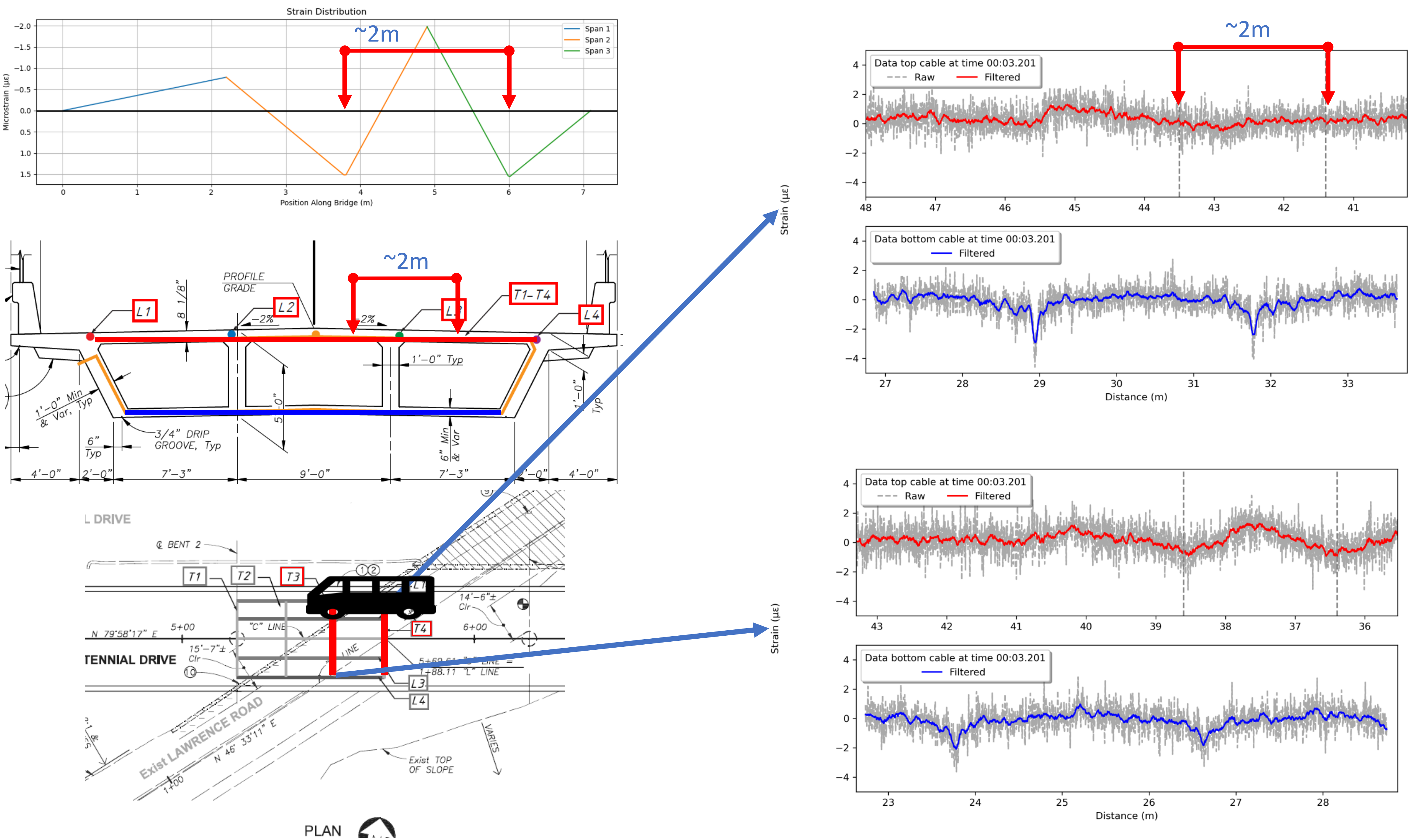


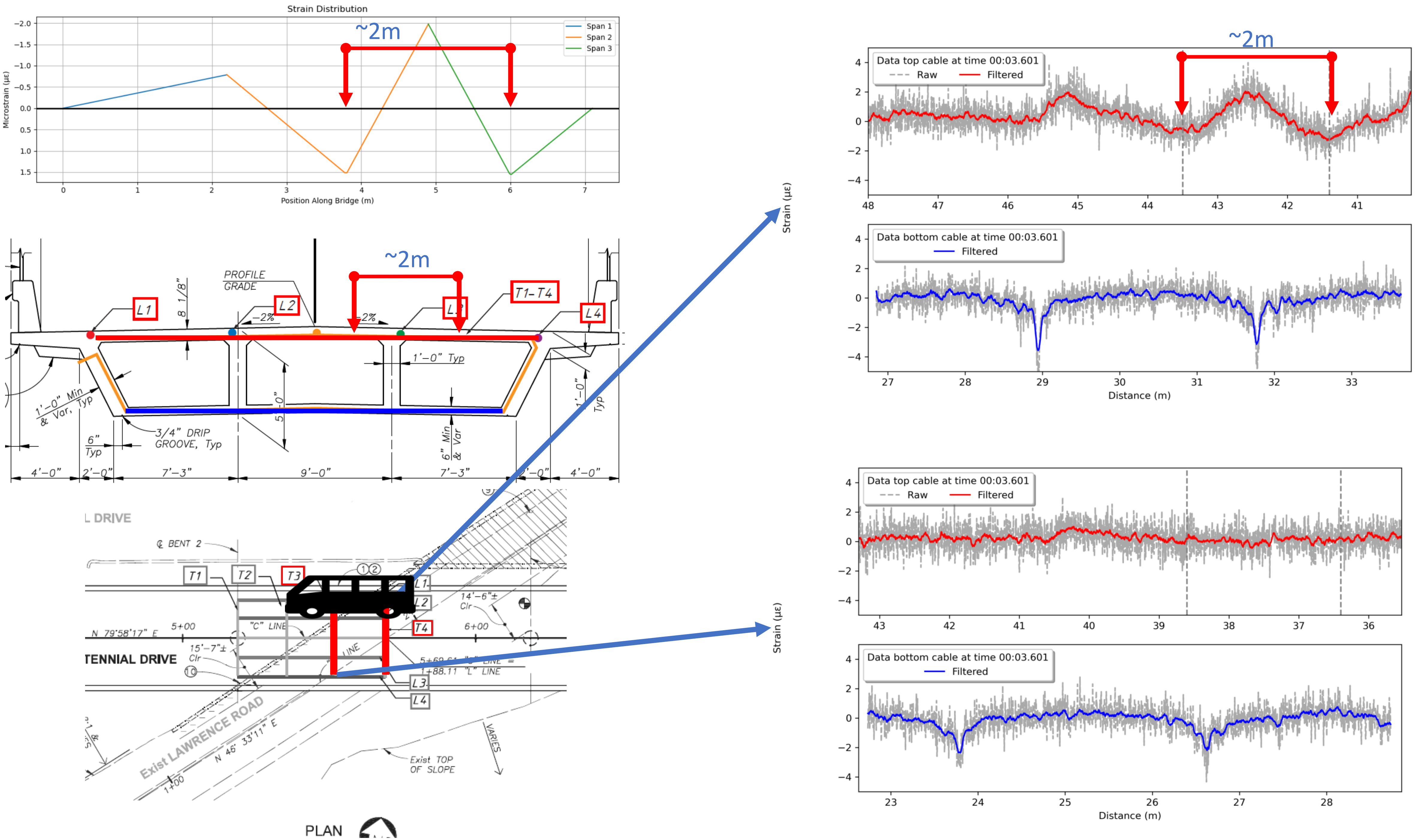
Measurement: Transversal






Strain Distribution
~2m
Span 1
Span 2
Span 3
Microstrain (με)
Position Along Bridge (m)
PROFILE GRADE
L1
L2
L3
L4
T1–T4
–2%
1'–0" Typ
1'–0" Min & Var, Typ
3/4" DRIP GROOVE, Typ
6" Typ
6" Min & Var
4'–0"
2'–0"
7'–3"
9'–0"
L DRIVE
℄ BENT 2
T1
T2
T3
T4
5+00
6+00
N 79°58'17" E
TENNIAL DRIVE
"C" LINE
15'–7"± Clr
1+88.11 "L" LINE
Exist LAWRENCE ROAD
N 46° 33'11" E
Exist TOP OF SLOPE
VARIES
PLAN
Strain (με)
Data top cable at time 00:03.001
Raw
Filtered
Data bottom cable at time 00:03.001
Distance (m)

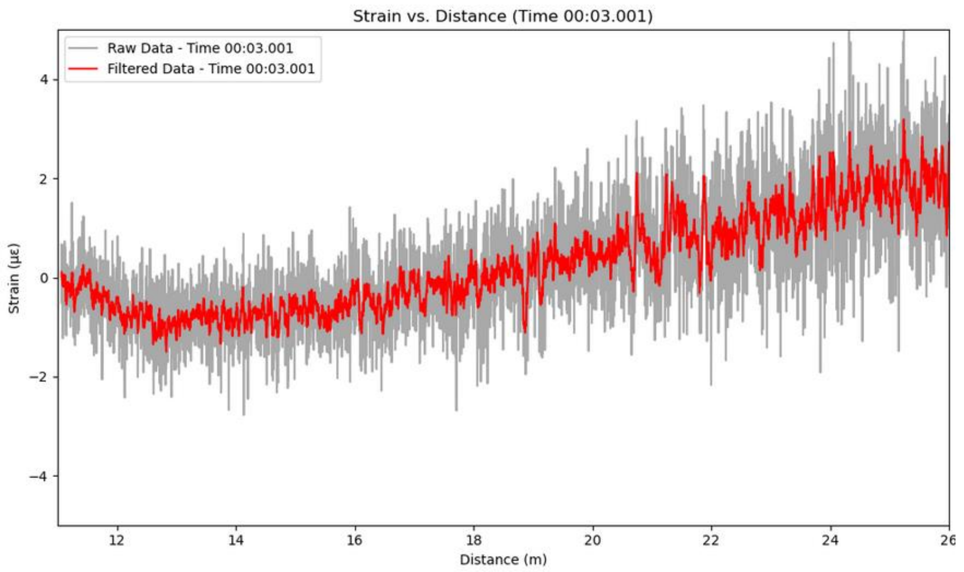

Strain Distribution
Span 1
Span 2
Span 3
~2m
Microstrain (με)
Position Along Bridge (m)
PROFILE GRADE
L1
L2
L3
L4
T1–T4
−2%
1'–0" Typ
1'–0" Min & Var, Typ
3/4" DRIP GROOVE, Typ
6" Typ
4'–0"
2'–0"
7'–3"
9'–0"
L DRIVE
℄ BENT 2
T1
T2
T3
T4
14'–6"± Clr
5+00
6+00
"C" LINE
N 79°58'17" E
15'–7"± Clr
TENNIAL DRIVE
Exist LAWRENCE ROAD
N 46° 33'11" E
1+88.11 "L" LINE
Exist TOP OF SLOPE
VARIES
PLAN
Strain (με)
Data top cable at time 00:03.201
Raw
Filtered
Data bottom cable at time 00:03.201
Distance (m)

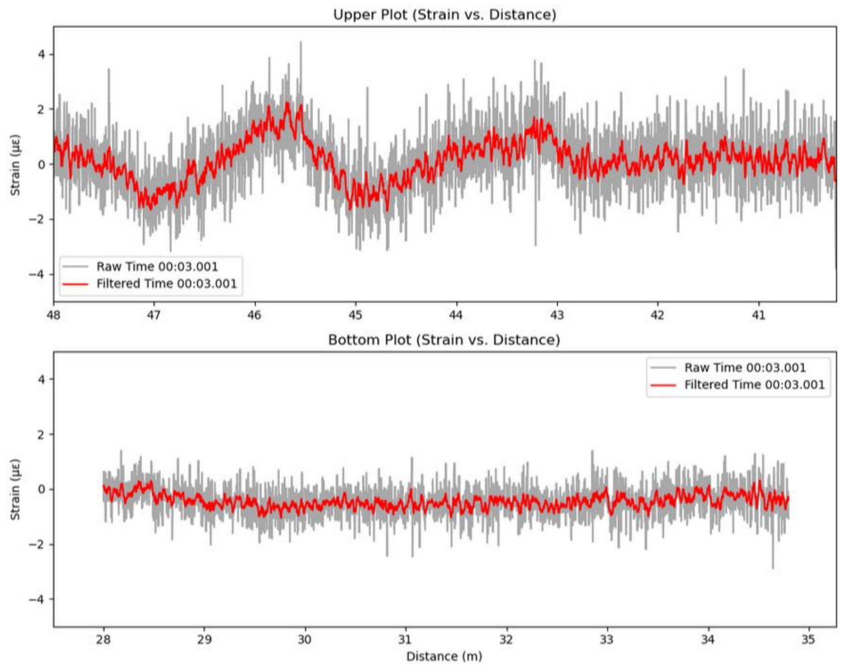


Strain Distribution
~2m
Span 1
Span 2
Span 3
Microstrain (με)
Position Along Bridge (m)
PROFILE GRADE
L1
L2
L3
L4
T1–T4
−2%
8 1/8"
1'–0" Typ
1'–0" Min & Var, Typ
3/4" DRIP GROOVE, Typ
6" Typ
5'–0"
6" Min & Var
1'–0" Typ
4'–0"
2'–0"
7'–3"
9'–0"
L DRIVE
℄ BENT 2
T1
T2
T3
T4
N 79°58'17" E
5+00
6+00
"C" LINE
14'–6"± Clr
15'–7"± Clr
TENNIAL DRIVE
Exist LAWRENCE ROAD
N 46° 33'11" E
1+00
Exist TOP OF SLOPE
VARIES
PLAN
Strain (με)
Data top cable at time 00:03.601
Raw
Filtered
Data bottom cable at time 00:03.601
Distance (m)

Summary

- Collected and analyzed strain data efficiently
- Characterized load distribution across the bridge structure
- Developed an initial validation model for the strain data





Future work

- Enhance computational modeling for improved accuracy
- Implement weight-in-motion (WIM) analysis
- Conduct long-term bridge performance monitoring
- Perform post-earthquake structural assessment