



Novel Self-sensing concrete sensor (SSCS) for SHM of Bridges; A numerical and experimental study

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Section 1

Introduction and Background

Available Sensors Introduction

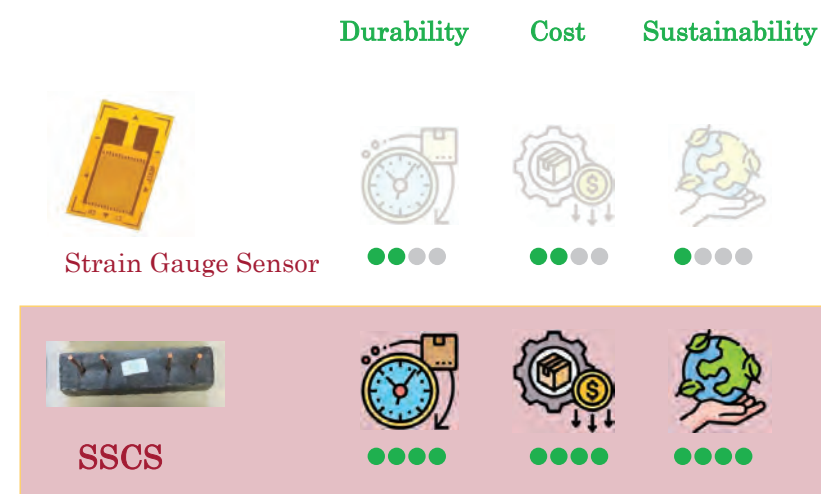
No.	Sensor name	Measuring data	Price (\$)	Ref.
1	Anemometers	wind speeds and directions	290-450	[7]
2	Temperature sensors	Temperature, thermal Expansion and Contraction	5-10	[8]
3	Strain gauges	The strain or deformation	5-20	[5]
4	Accelerometers	Acceleration, dynamic response, and vibrations	50-1000	[9]
5	Displacement transducer	The movement and displacement	175-300	[10]
6	Global positioning system	Bridge Settlement and Subsidence, Geodetic Control and Reference Frames	30-100	[11]
7	Weigh-in-motion systems	the dynamic loads	3000-5000	[12]
8	Corrosion sensors	The corrosion of steel elements	50-200	[13]
9	Elasto-magnetic sensors	The deformations and stresses	-	[14]
10	Optic fiber sensors	Strain and Displacement, and temperature	60-100	[15]
11	Tiltmeters	Angular displacements and rotations	70-150	[16]
12	Total stations	Deformation, and settlement,	1000-2000	[17]
13	Seismometer	Seismic measurement, dynamic behavior	1000-2000	[18]
14	Barometers	Atmospheric pressure	60-100	[19]
15	Hygrometers	Humidity levels	5-15	[20]
16	Pluviometers	Rainfall	150-200	[21]
17	Digital image correlation	Displacement, and Crack strains	500-700	[22]
18	Light Detection and Ranging (LiDAR)	3D Modeling and Documentation, deformation	1500-2000	[23]

No.	Structure type	Number of sensors	No. of strain gauge	No. of accelerometers	Ref.
1	533-m long cable stayed bridge	144	28	44	[29]
2	Tsing Ma suspension bridge	282	110	19	[30]
	Kap Shui Mun cable-stayed bridge	272	30	3	
	Ting Kau cable-stayed bridge	238	88	45	
	5.5 km long western corridor bridge	425	212	44	
	Stonecutters cable-stayed bridge	1505	836	58	
3	Saint Anthony Falls Bridge	62	24	26	[31]
4	Sutong cable-stayed bridge	430	211	-	[3]
5	Four span box girder bridge	102	28	28	[32]

Comparison Introduction

Smart Self-sensing Concrete Sensors (SSCS) are at the forefront of **resilient infrastructures** and **manufacturing innovation**, offering **sustainable monitoring solutions** for structural health monitoring (SHM).

Compared to traditional strain gauges and accelerometers, SSCS provides **higher durability**, **lower cost**, and **a sustainable monitoring system**. This sustainable manufacturing approach enhances accuracy, durability, and cost-effectiveness, driving advancements in the field of SHM and contributing to sustainable transportation practices.

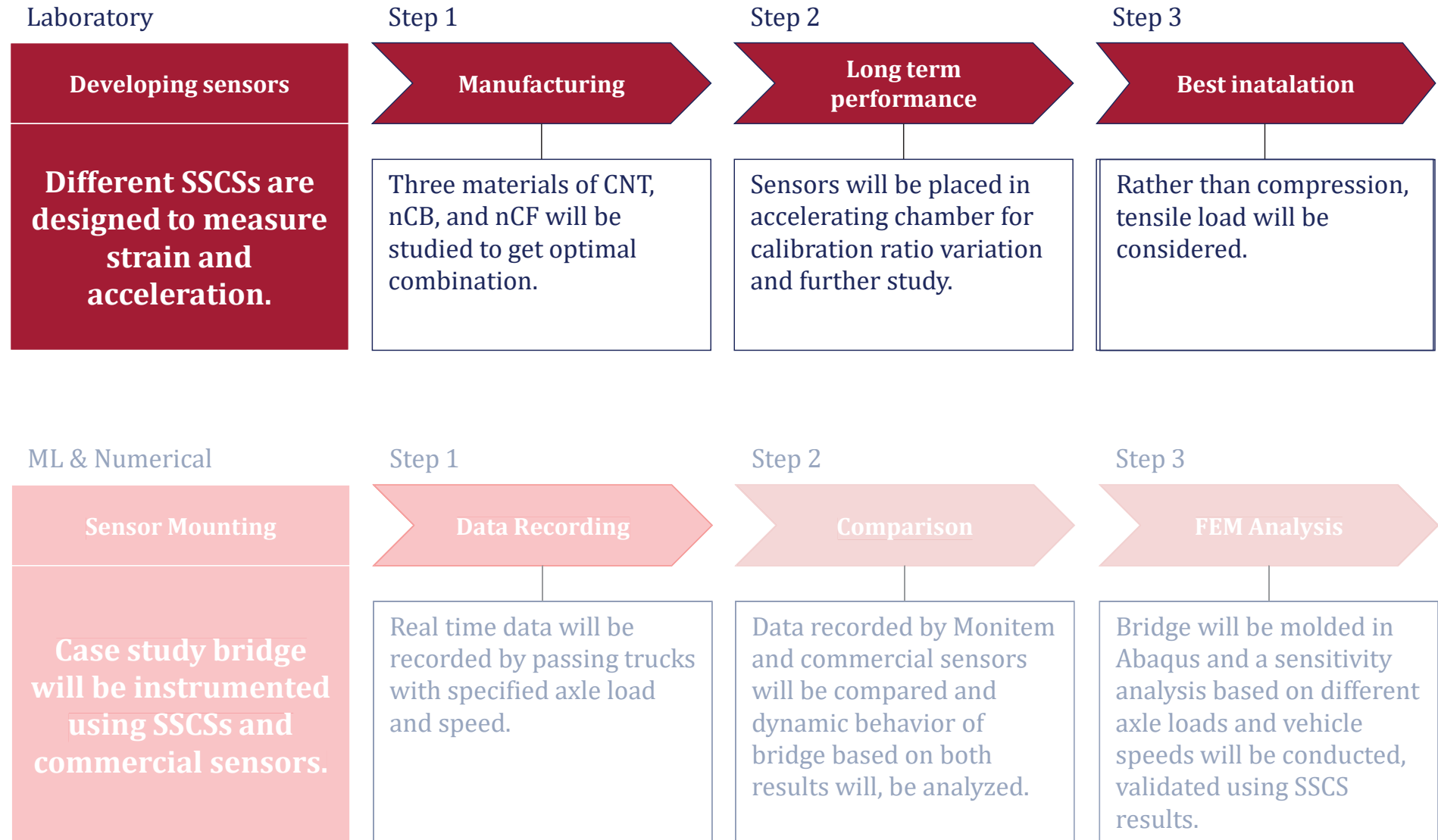


Goal 9 seeks to build resilient infrastructure, promote sustainable industrialization and foster innovation. Economic growth, social development and climate action are heavily dependent on investments in infrastructure, sustainable industrial development and technological progress.

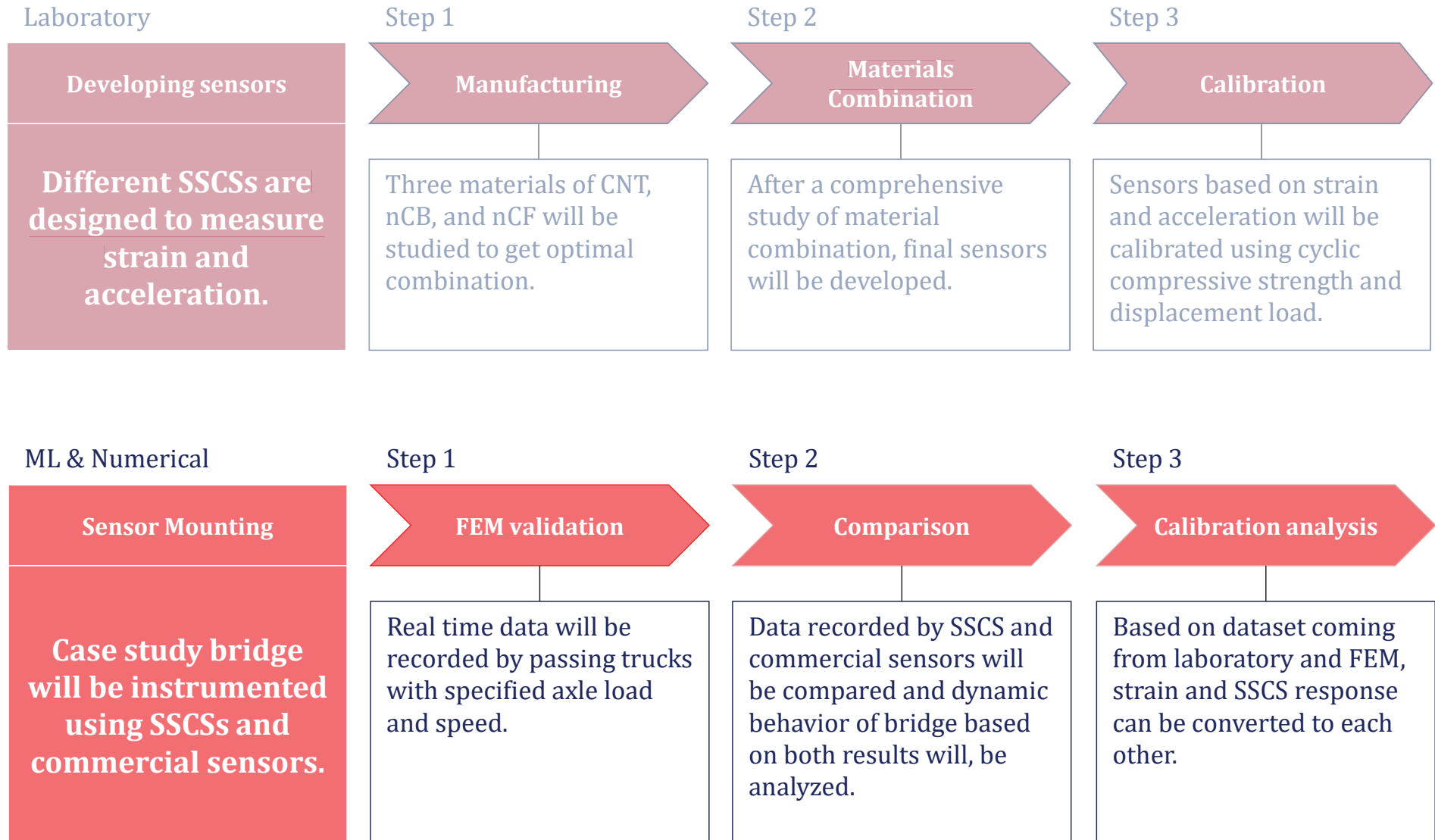


Goal 11 is about making cities and human settlements inclusive, safe, resilient and sustainable. Cities represent the future of global living. The world's population reached 8 billion on 2022 over half living in urban areas.

Intelligent Monitoring System Using Monitem-Steps



Intelligent Monitoring System Using Monitem-Steps



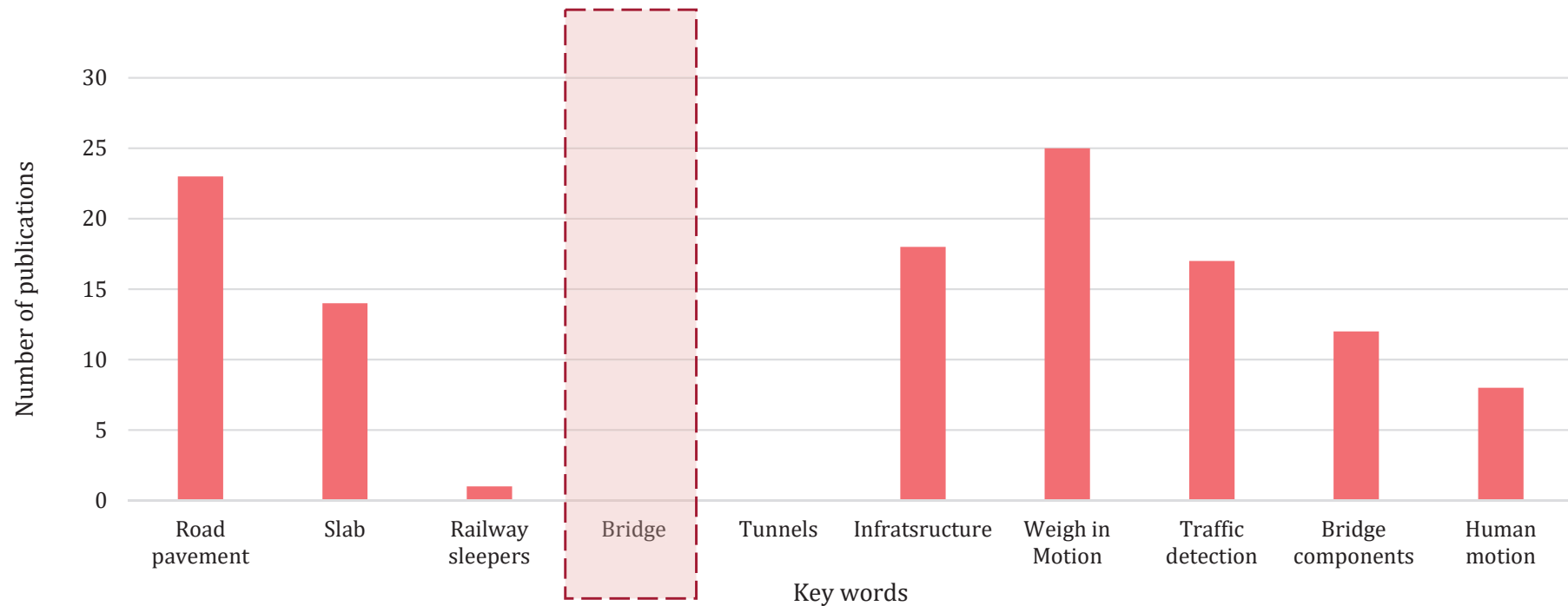


Section 2

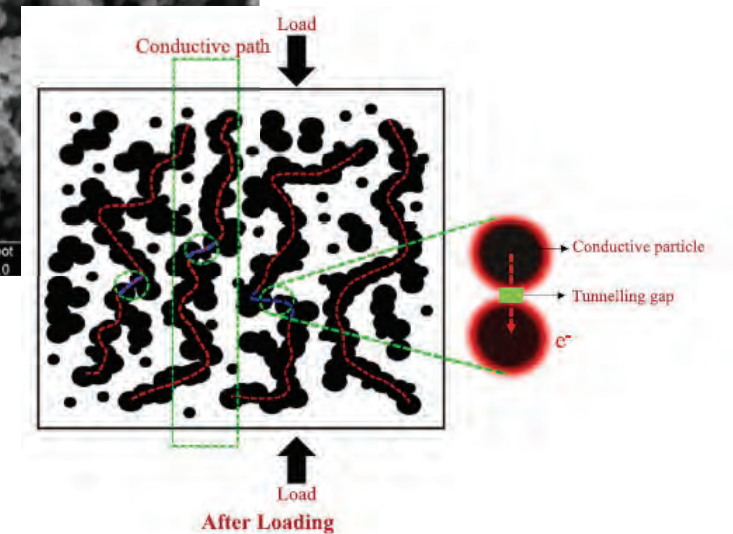
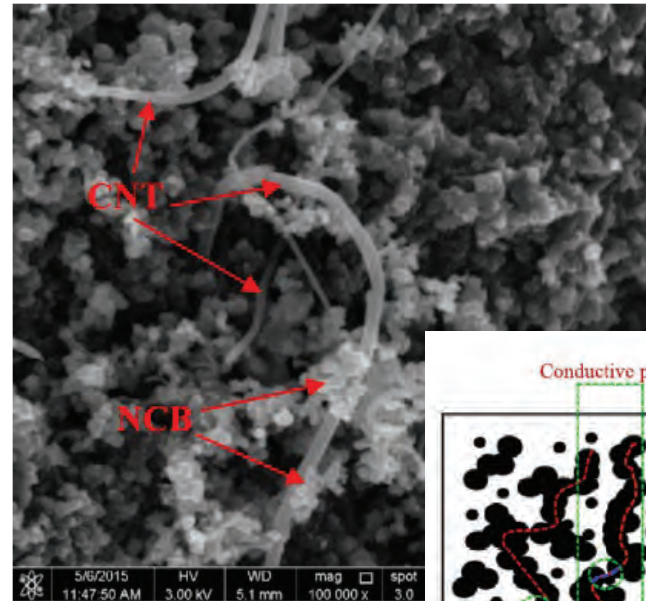
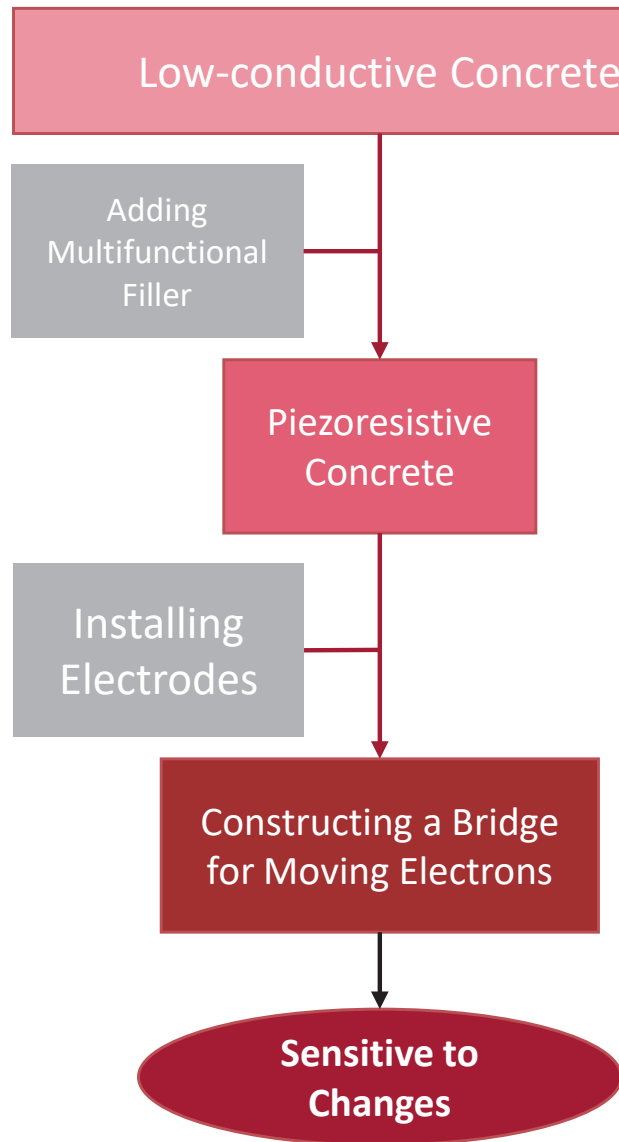
Research Motivation

Application of SSCS in Infrastructures

No one has studied application of SSCS in a real bridge monitoring .



Self-sensing Concrete Sensors (SSCS)



Advantages

Why smart self-sensing cement composite concrete ?

- Higher durability than normal sensors as long as normal concrete;
- High flexibility in construction;
- Higher gauge factor and sensitivity.

Disadvantages

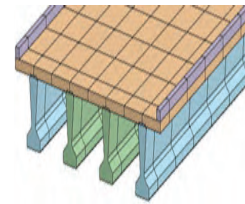
- Changing calibration over the time.
- Difficult to embed in structures;
- Difficulty in manufacturing

Knowledge Gap

Having a predictive maintenance based on a SHM system increase bridge service life and safety.
This SHM system can detect bridge defects in the early stages which results in **lower maintenance cost and higher effectiveness in defects maintenance actions:**



For the first time application of a **sustainable health monitoring system based on SSCs.**



A **numerical FEM analysis** will be performed on dynamic behaviour of bridge based on data coming from SSCs.



A **new shape** and layout of self-sensing concrete sensor **is designed** to record bridge displacement using a **pull-out load.**



In the laboratory the **recyclable** feature of sensors will be studied and after **how many years** they need to be **calibrated.**

Field Study- Sensor Placement idea

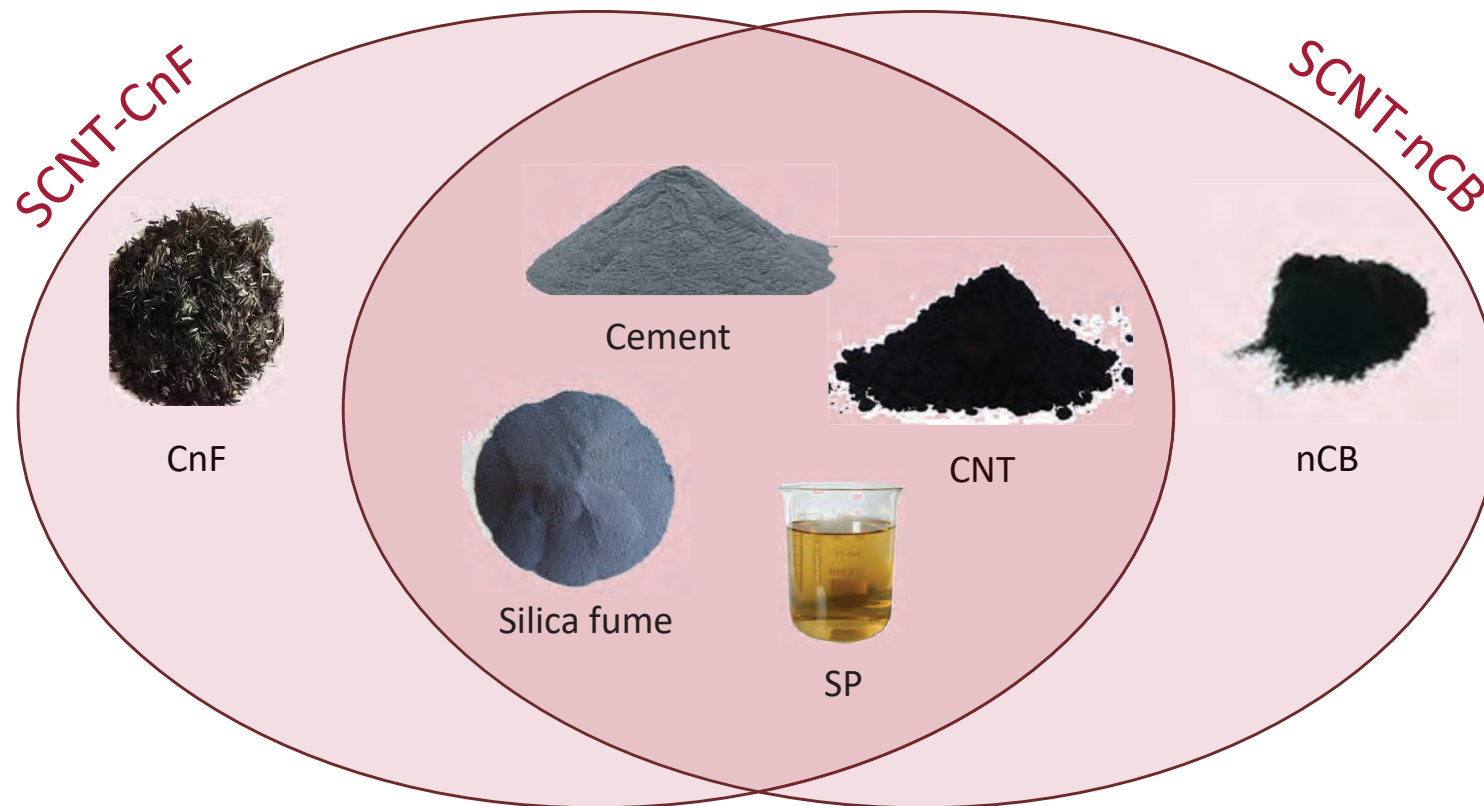


Section 3

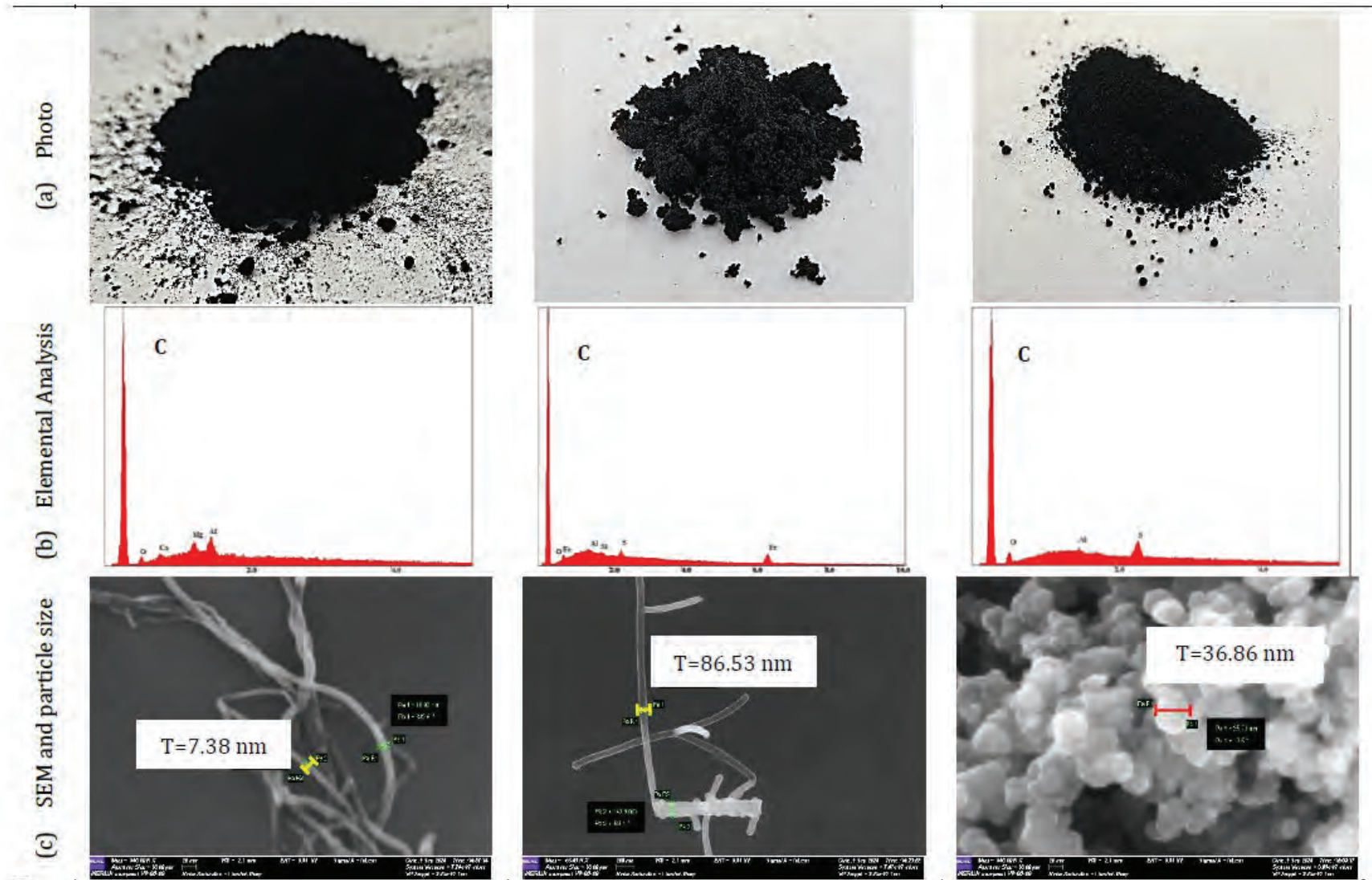
SSCS Manufacturing

Laboratory Study- Material

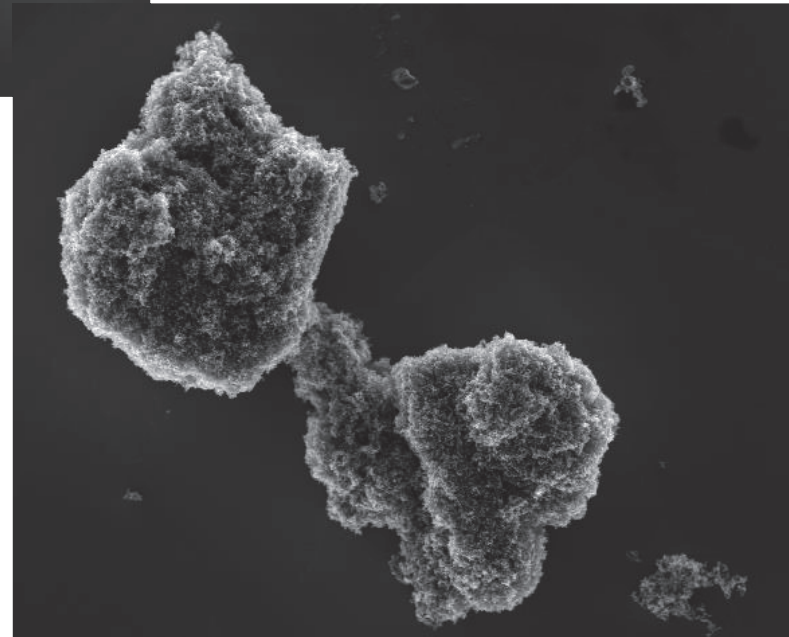
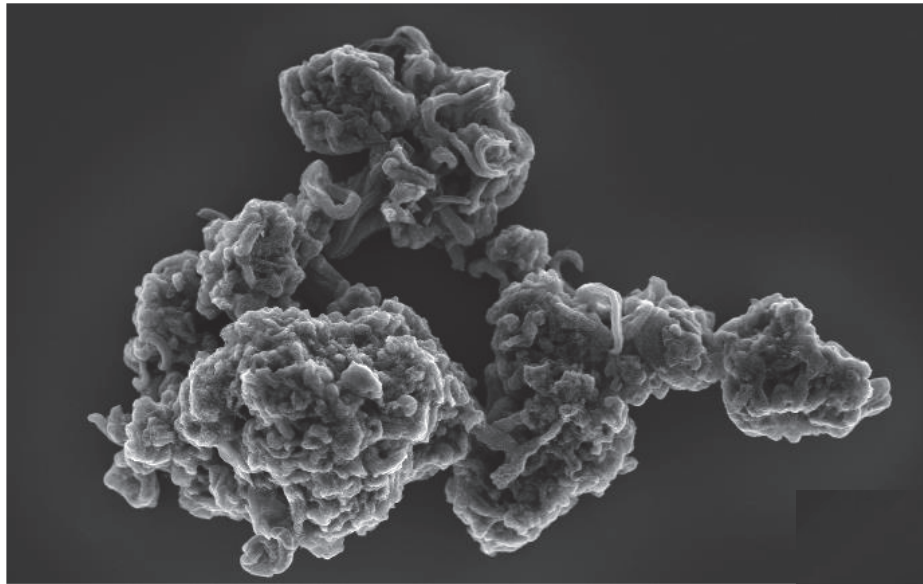
Three materials in **nano scale** would be mixed and tested by following ratio to get the optimal combination:



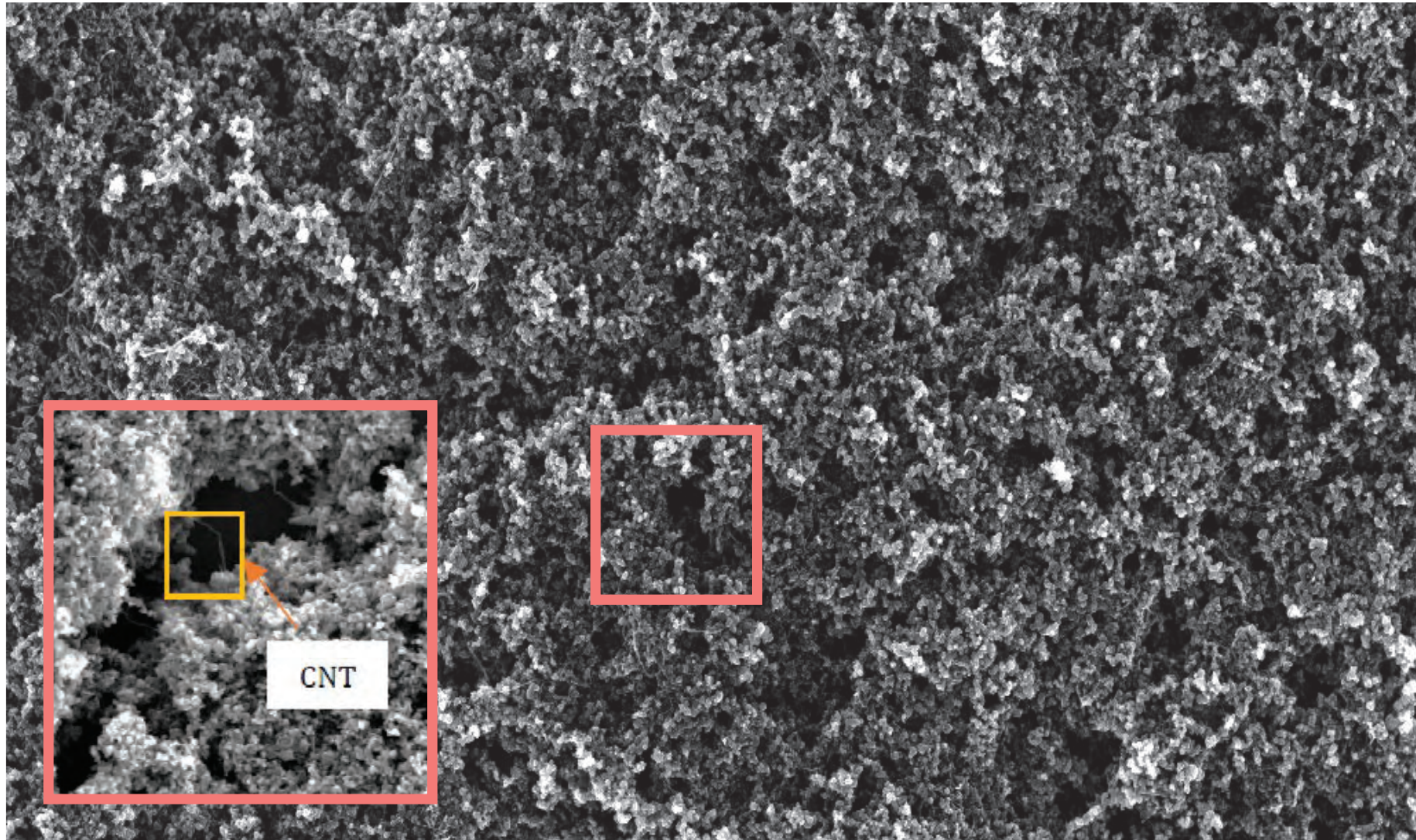
Laboratory Study- Material-SEM



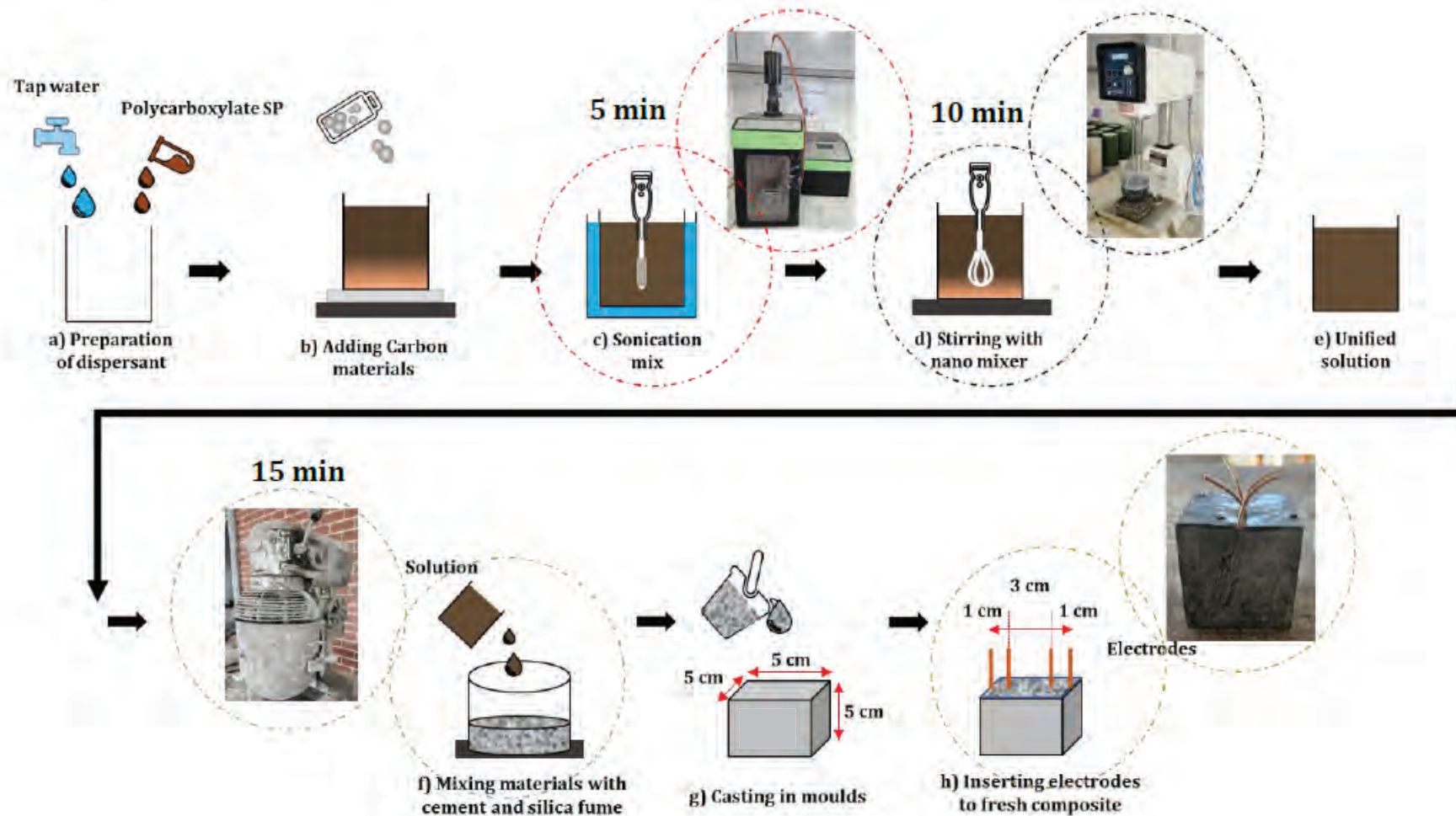
Laboratory Study- SEM



Laboratory Study- SEM



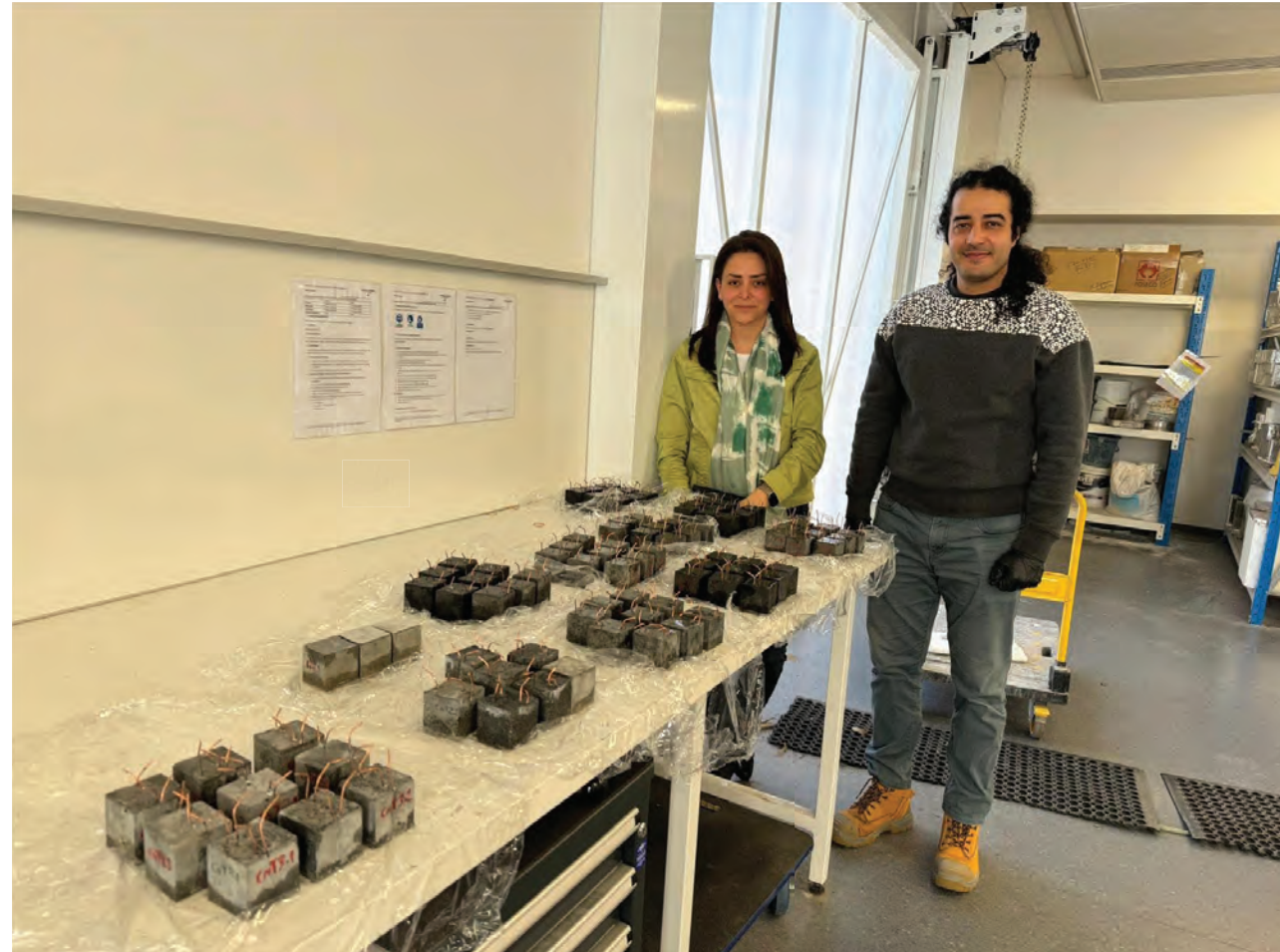
Laboratory Study- Manufacturing

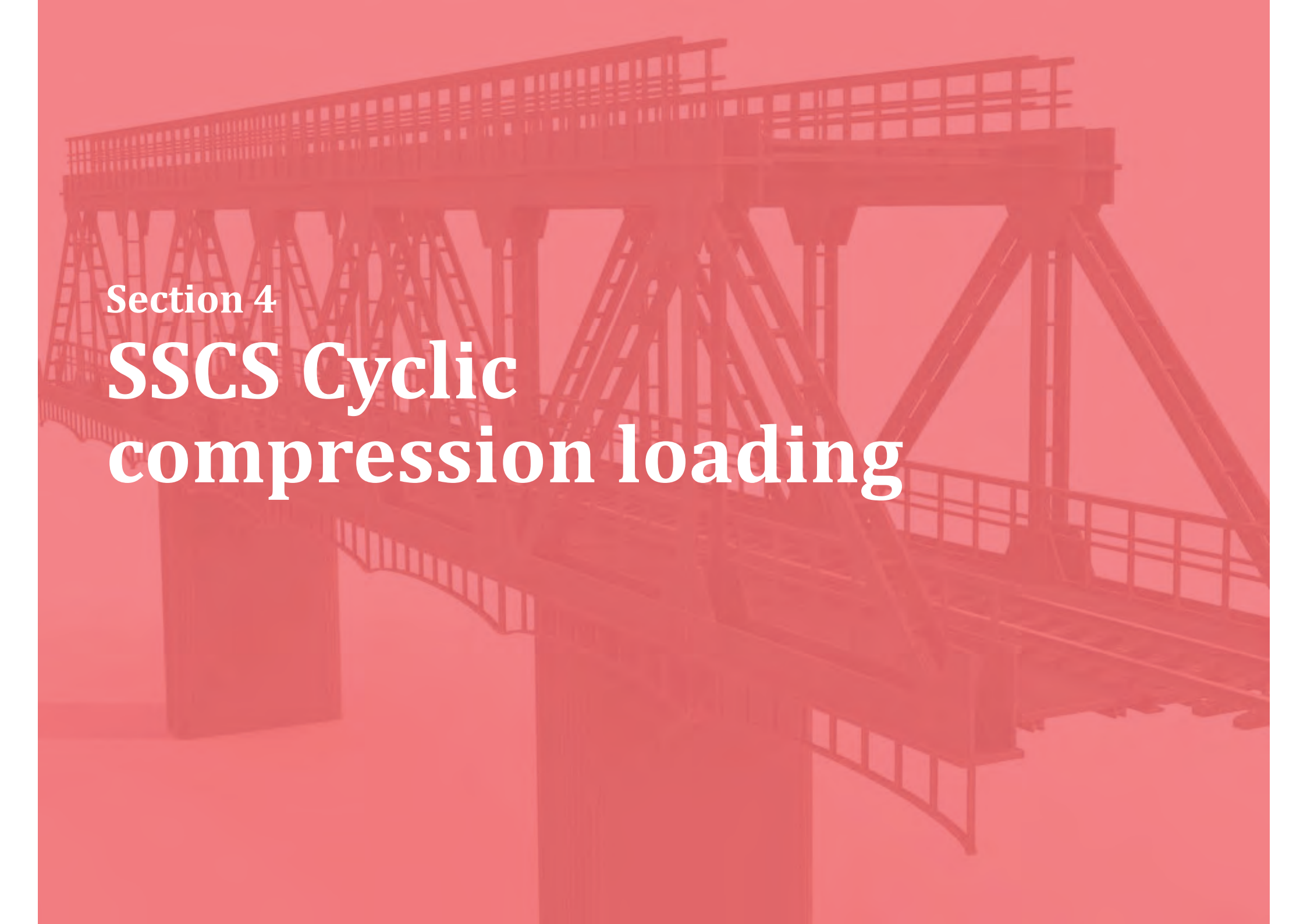


Laboratory Study- Manufacturing

Laboratory Study- Manufacturing

Three materials in nano scale would be mixed and tested by different ratios to get the optimal combination:





Section 4

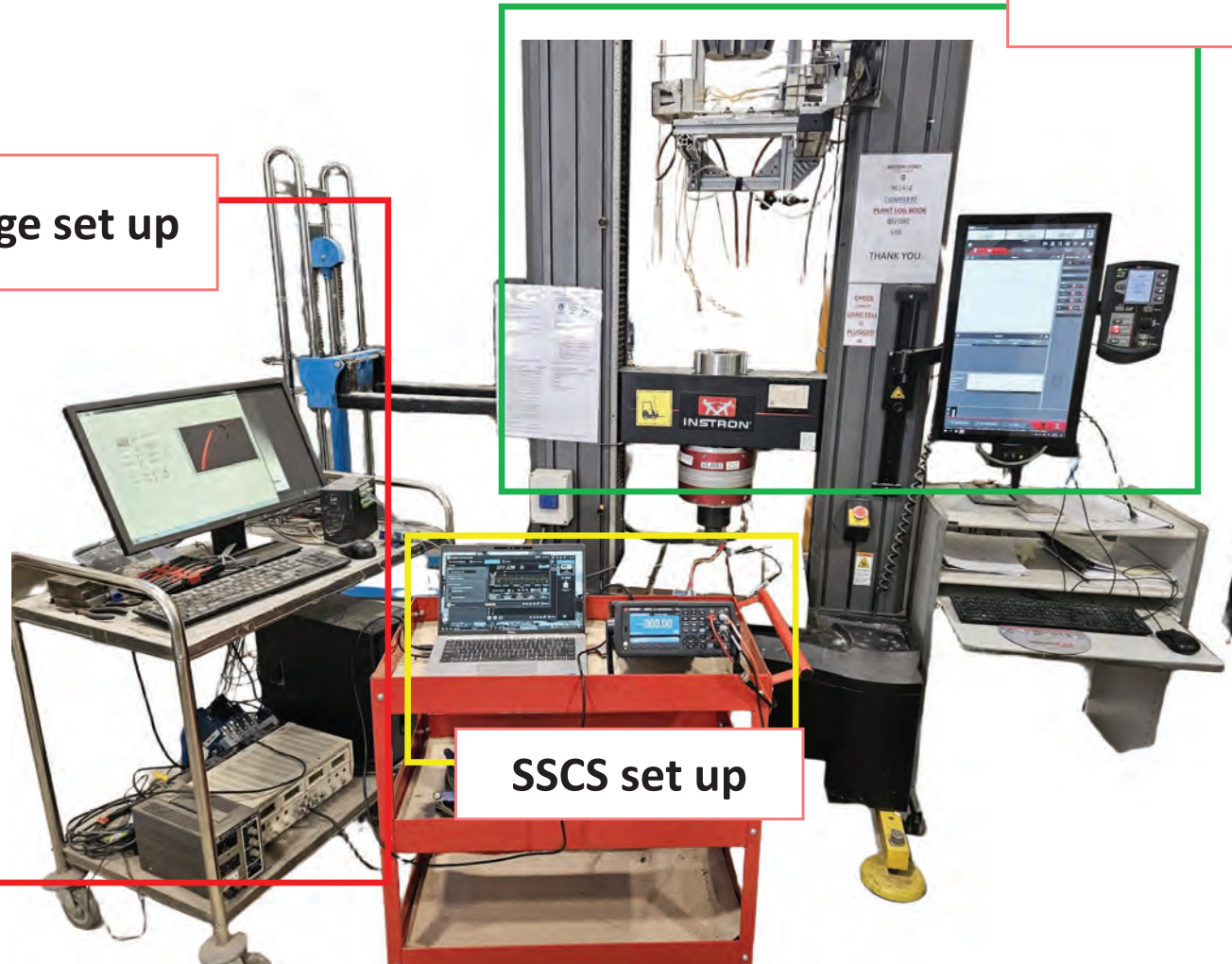
SSCS Cyclic compression loading

Data Collection

Load cell set up

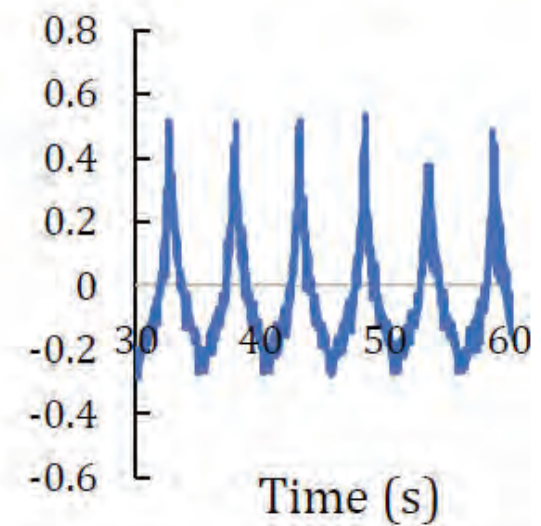
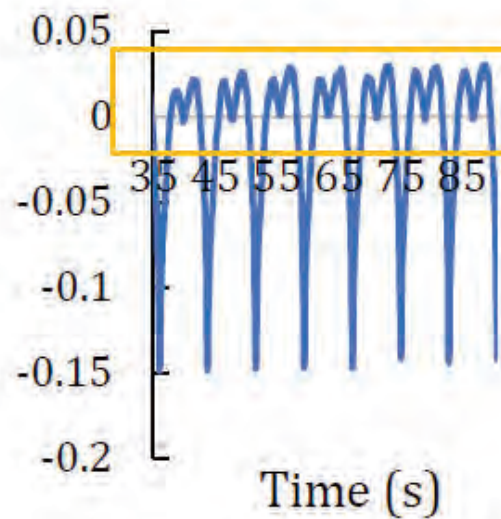
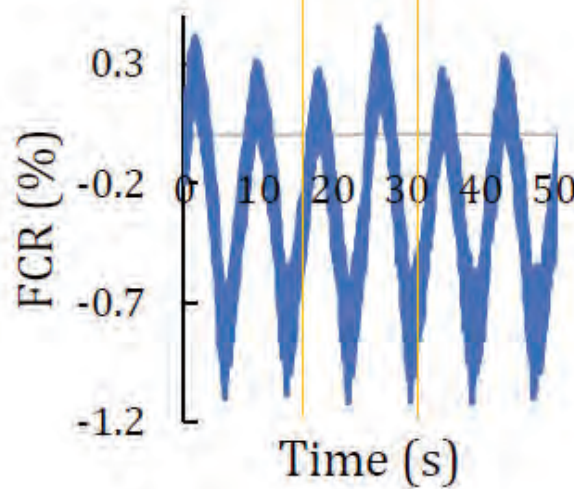
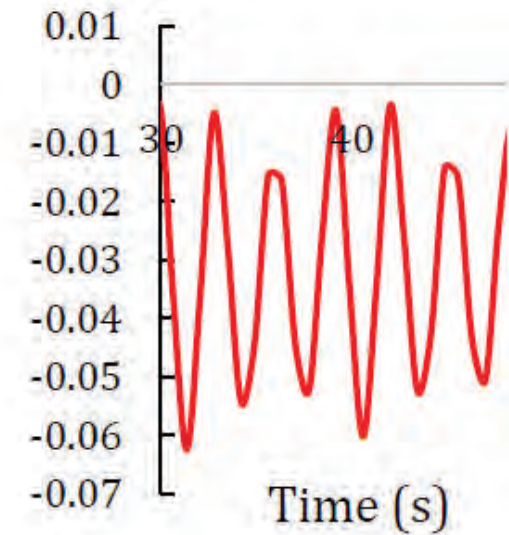
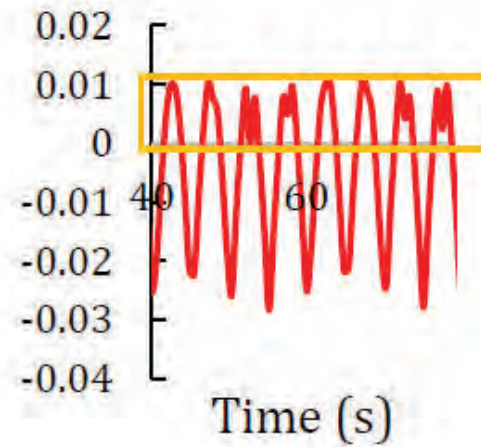
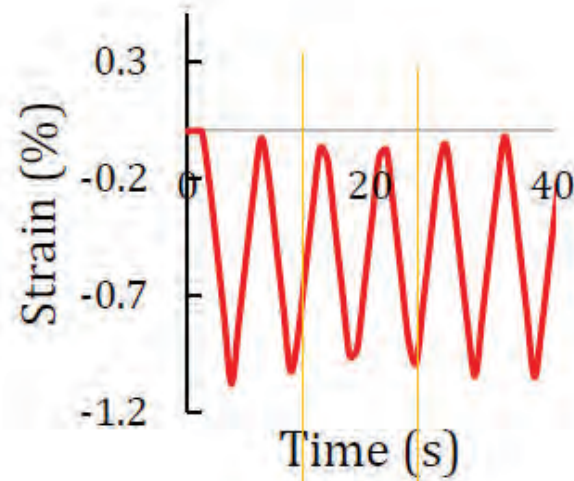
Strain Gauge set up

SSCS set up

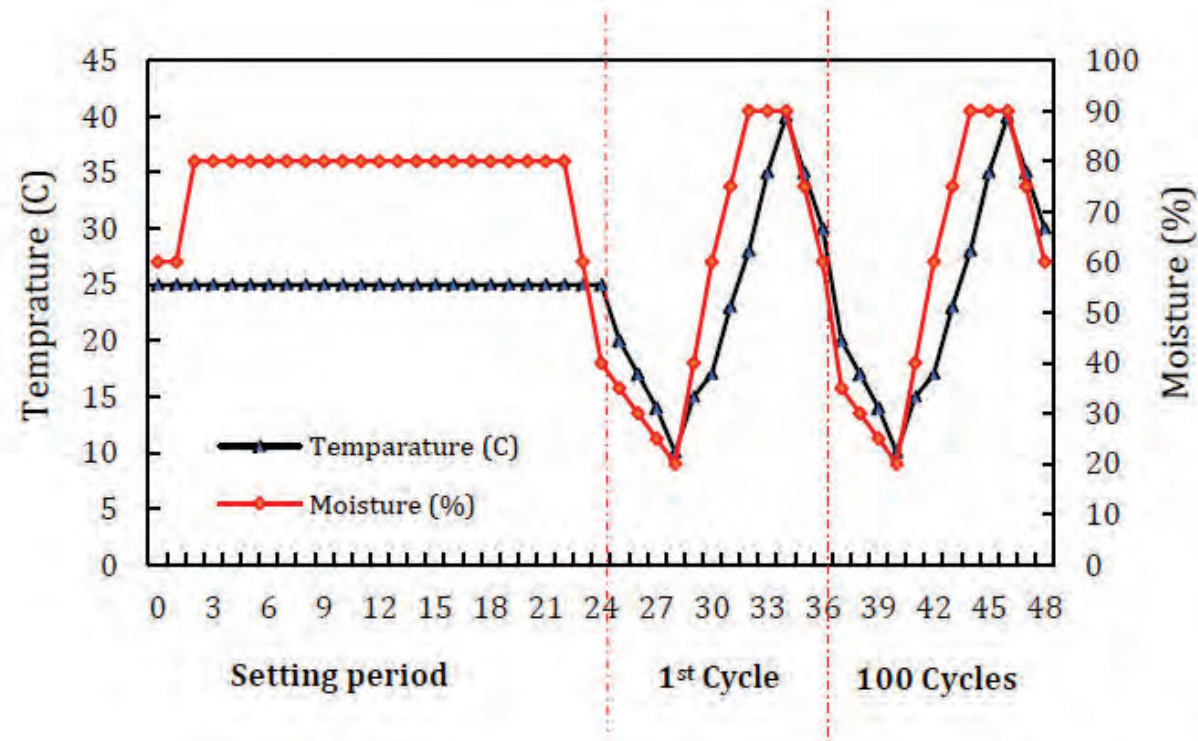


Data Collection

Data Collection

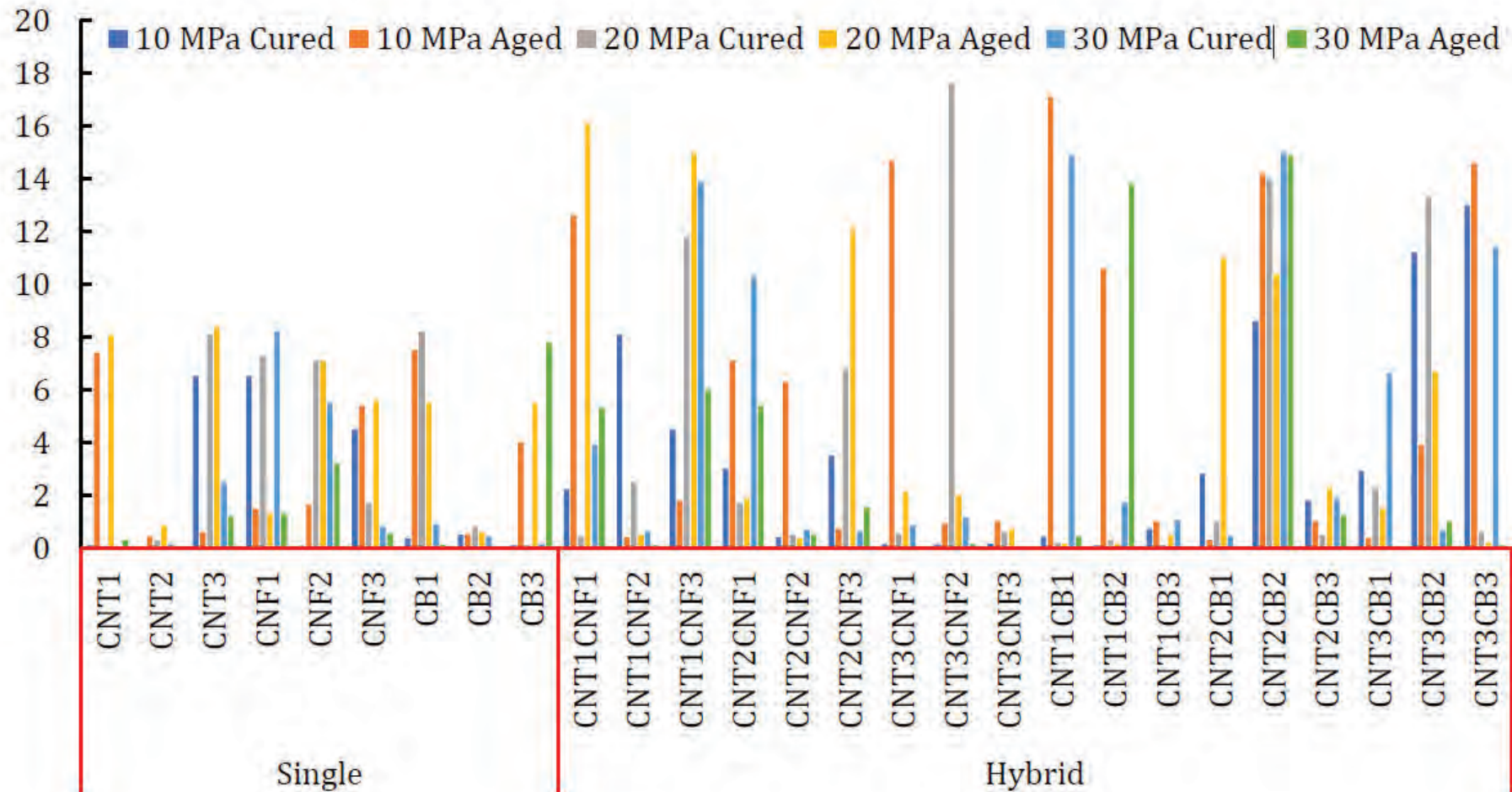


Data Collection- Environmental Chamber



Data Collection- Aged SSCS

Data Collection- Gauge Factor

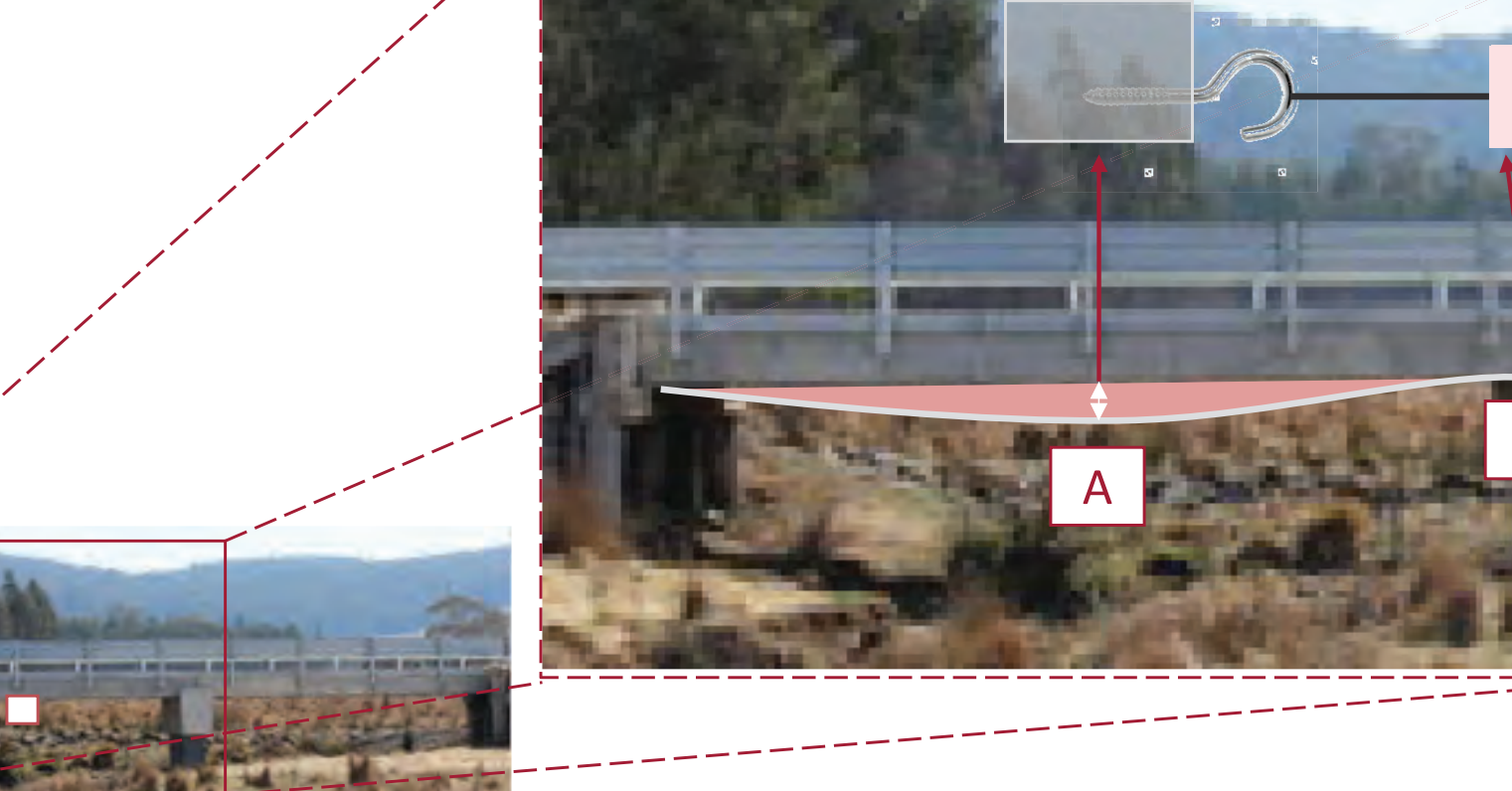




Section 5

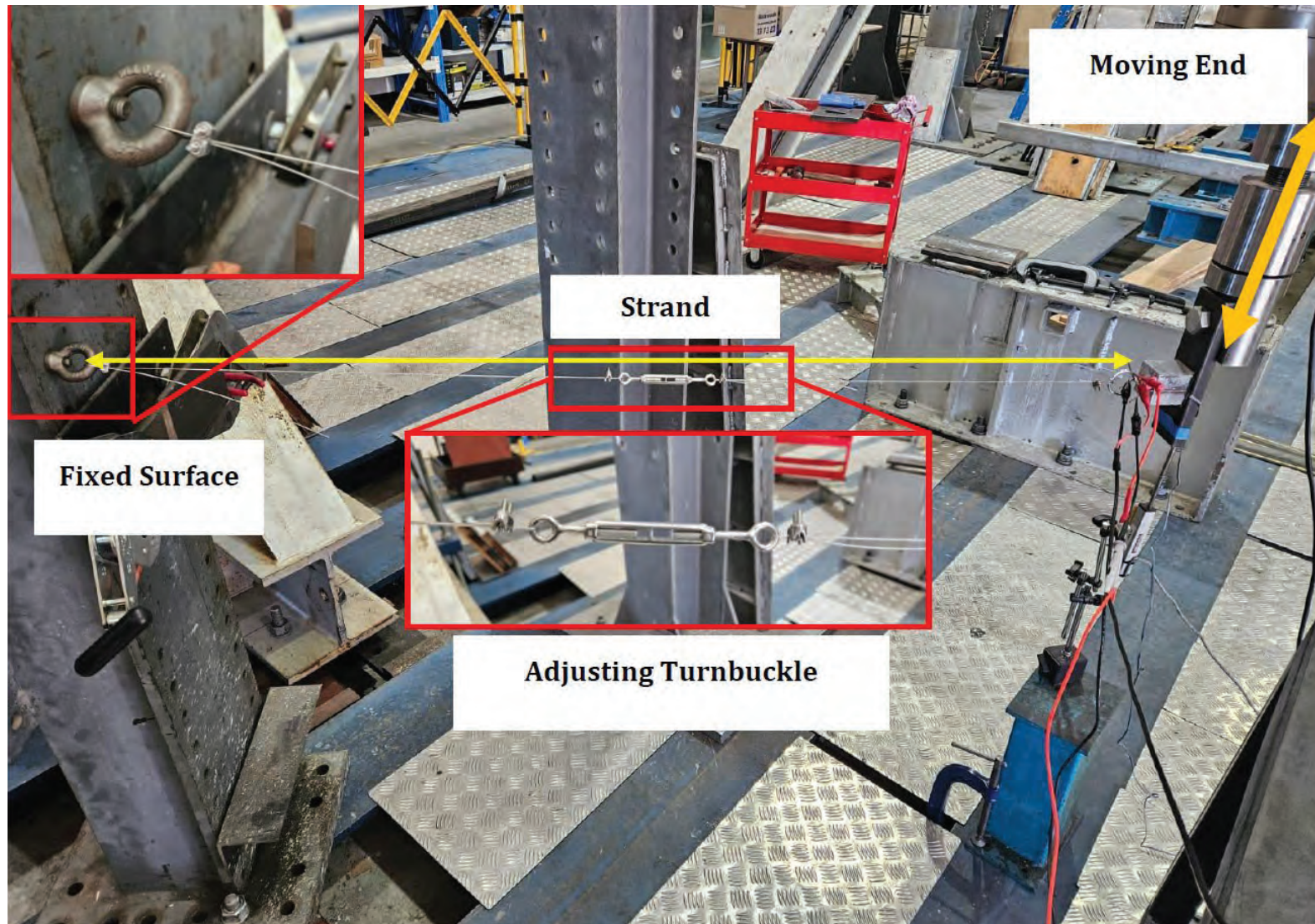
SSCS bridge assessment

Bridge innovative installation method:



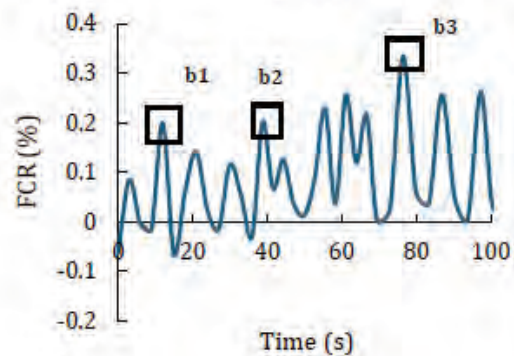
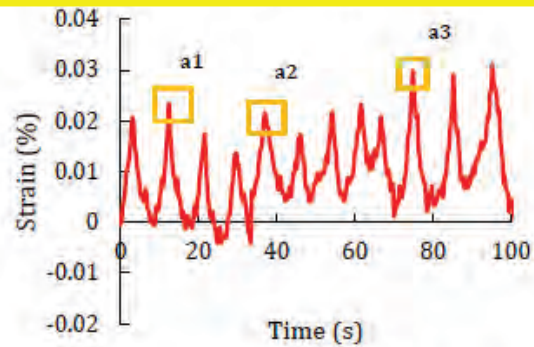
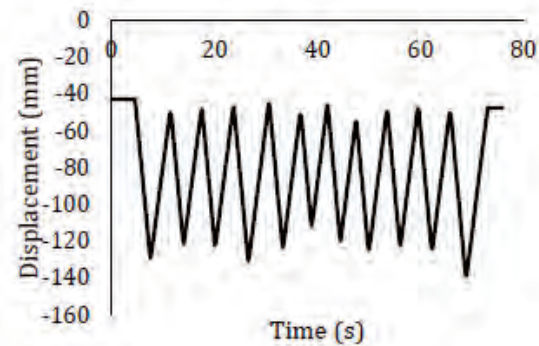
The diagram illustrates a bridge innovative installation method. It shows a bridge deck with a red curved area labeled A and a red L-shaped area labeled B. A red dashed line connects the text 'Bridge innovative installation method:' to the diagram. A red dashed line also connects the text 'Bridge innovative installation method:' to a small inset image showing a bridge deck with a red curved area labeled A and a red L-shaped area labeled B.

Numerical Study- Sensor Placement

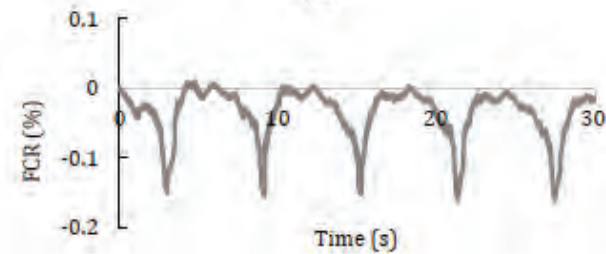
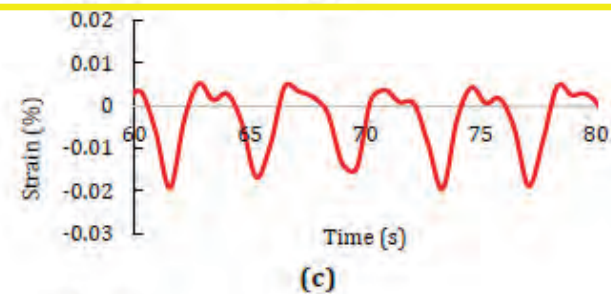
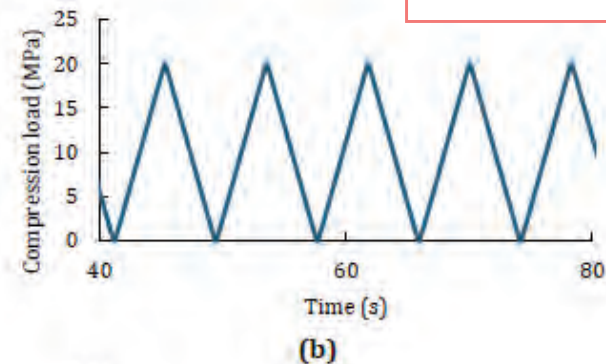


Numerical Study- Sensor Placement

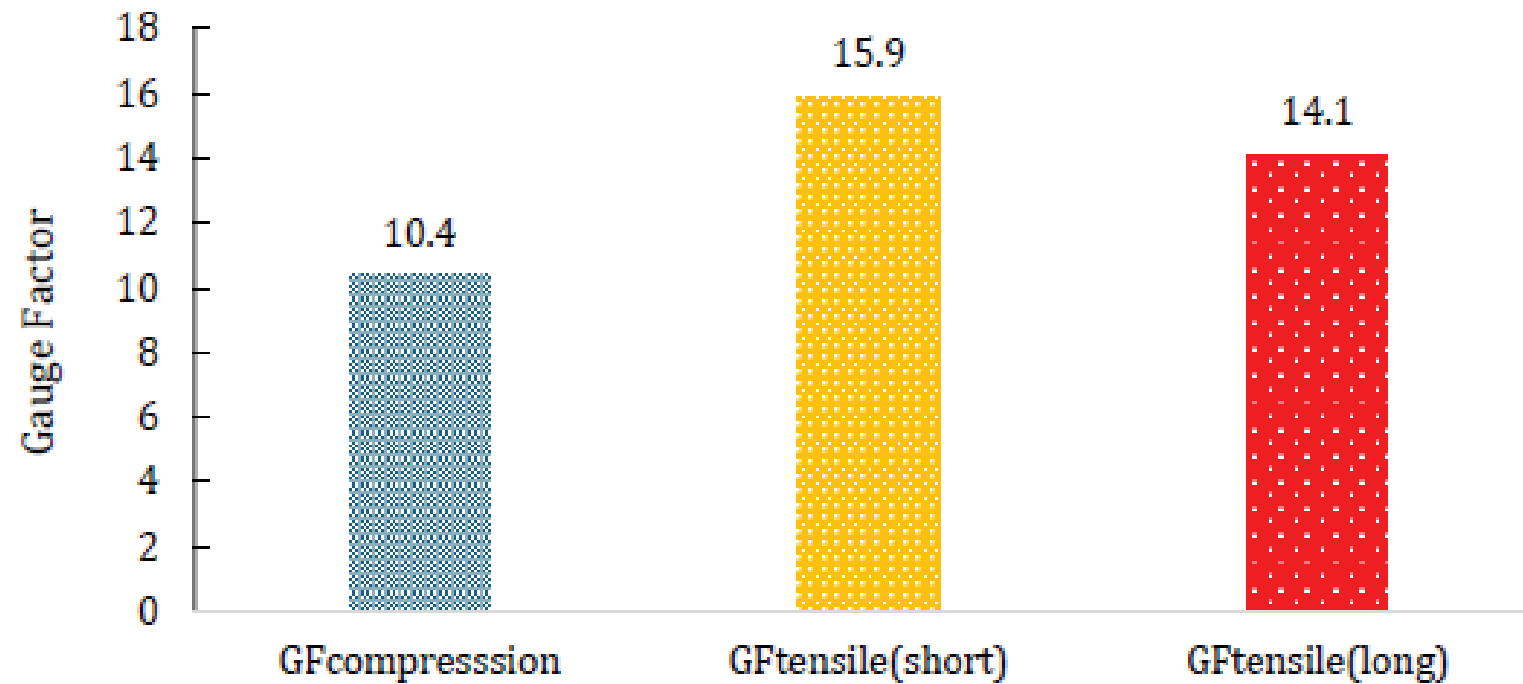
Displacement



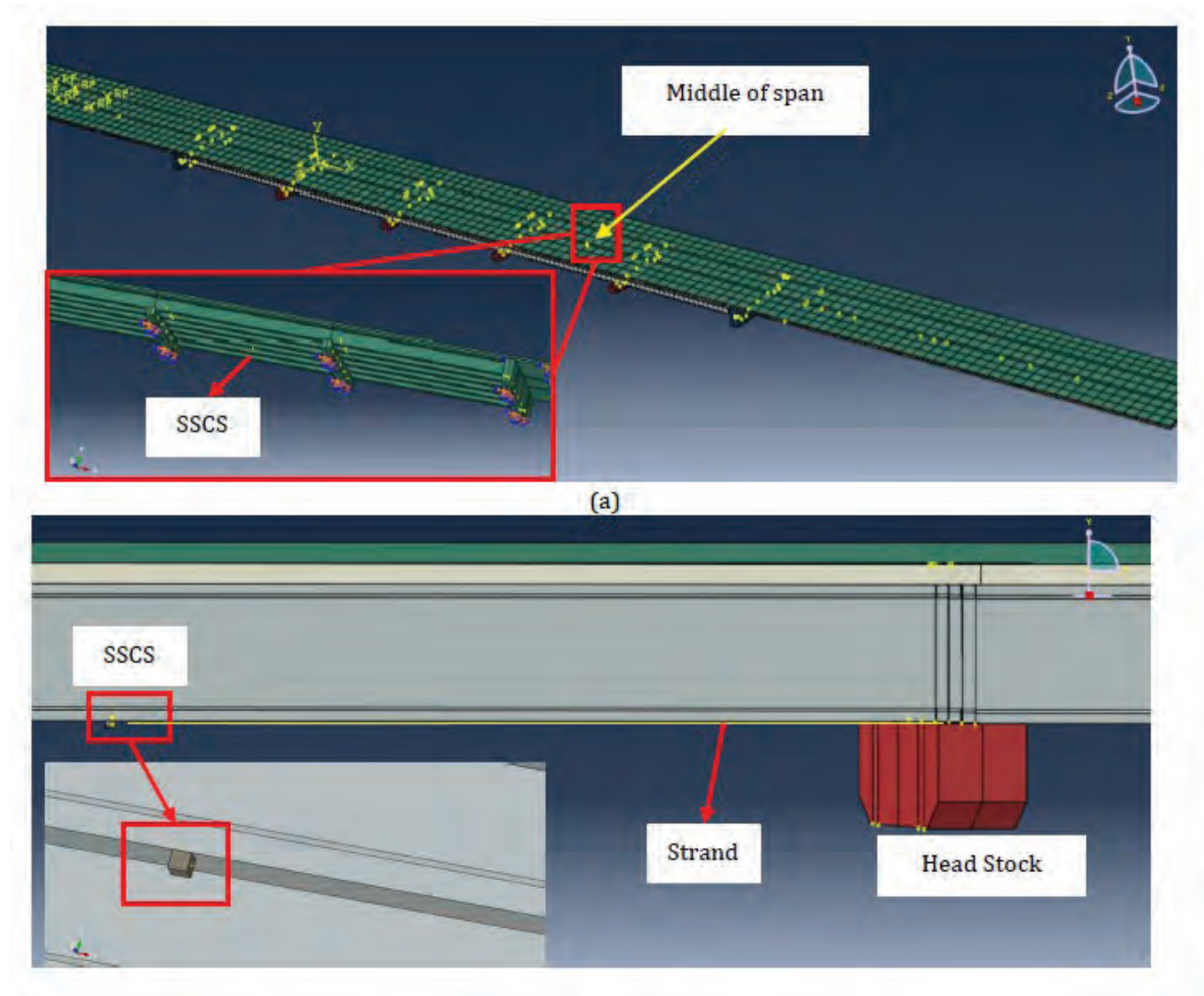
Compression Load



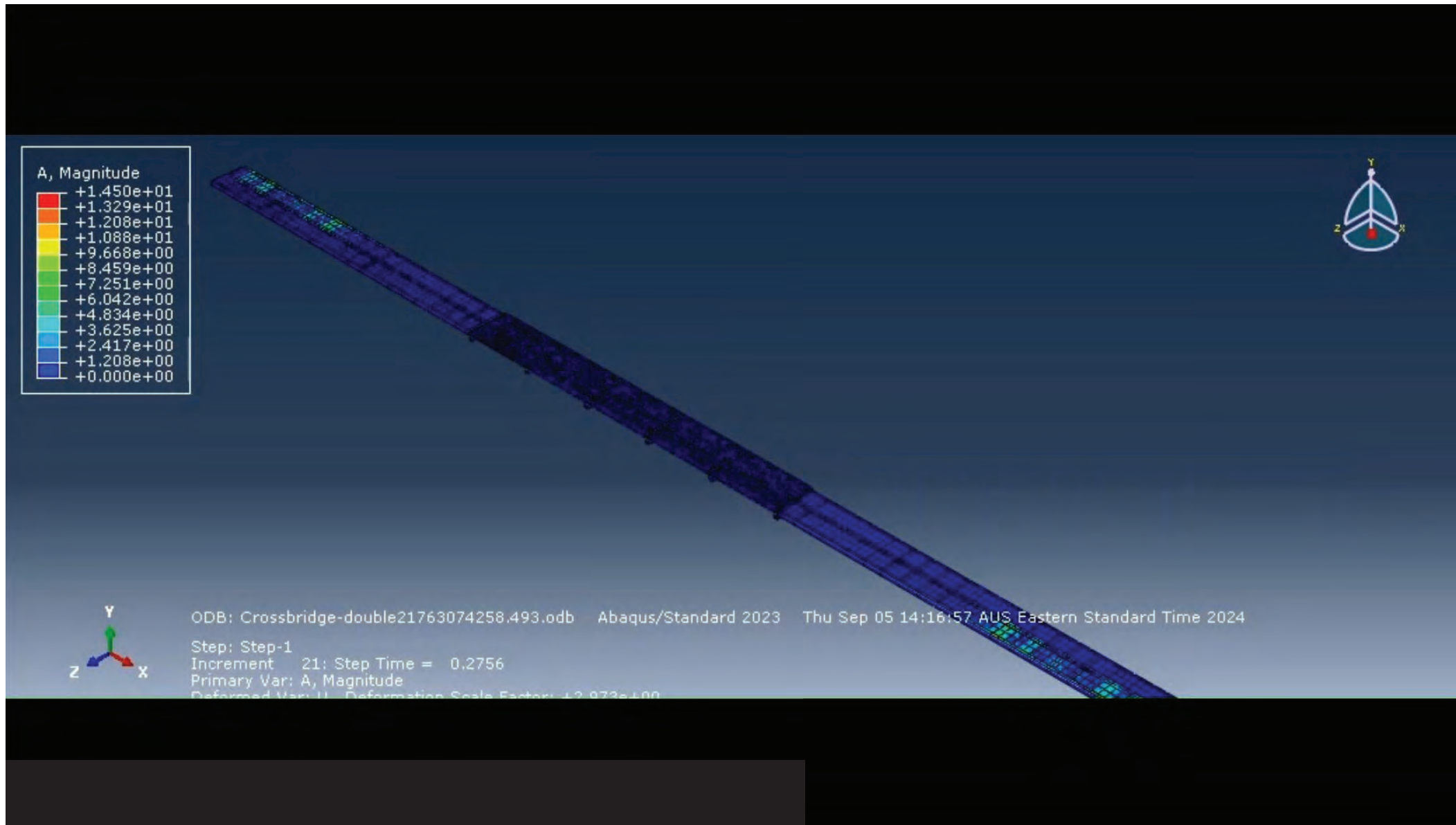
Numerical Study- Sensor Placement



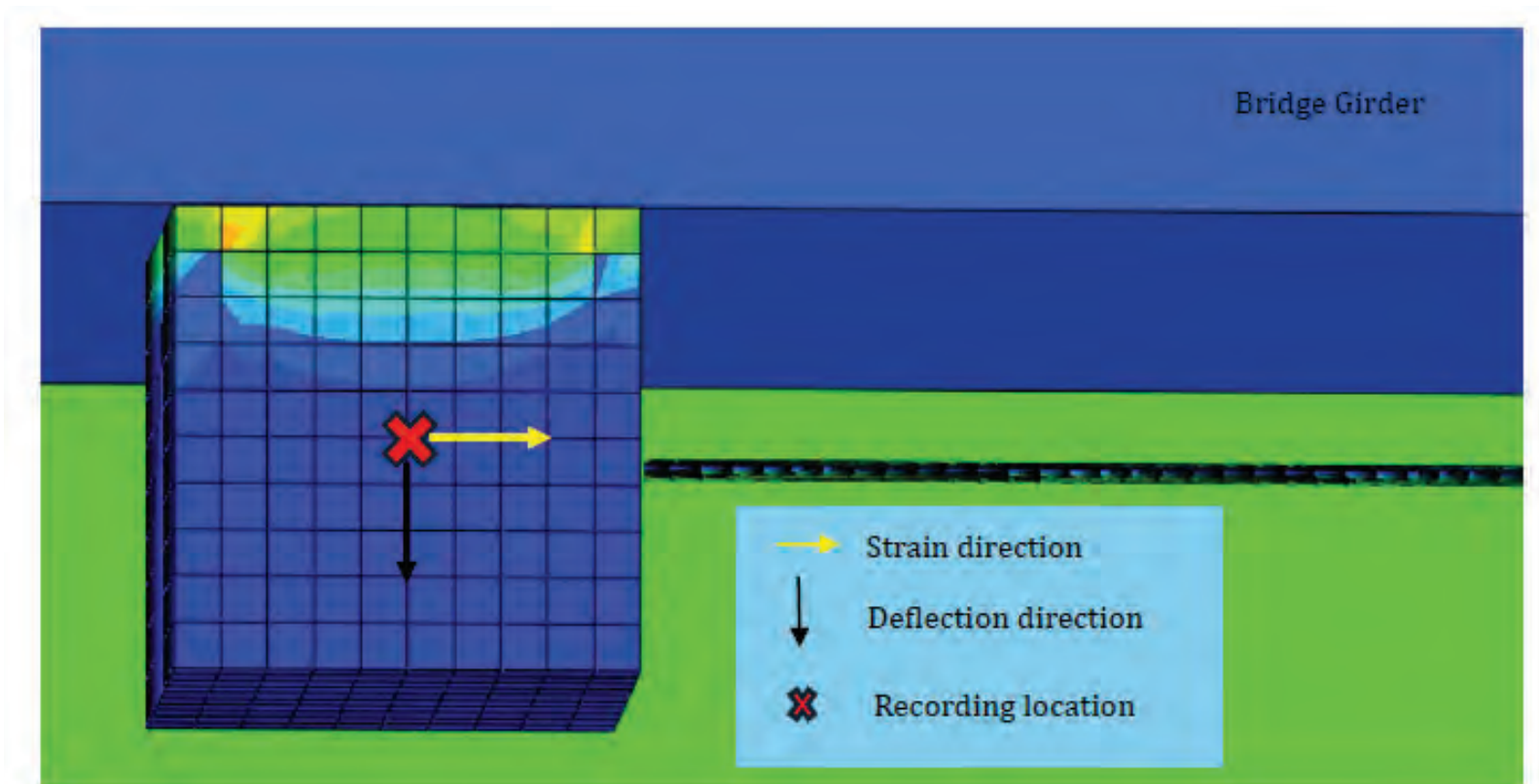
Numerical Study- Sensor Placement



Numerical Study- Sensor Placement

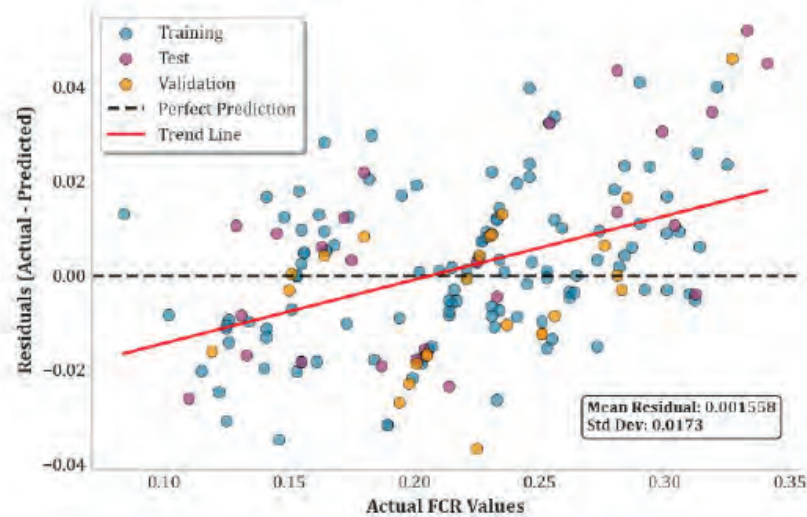


Numerical Study- Sensor Placement

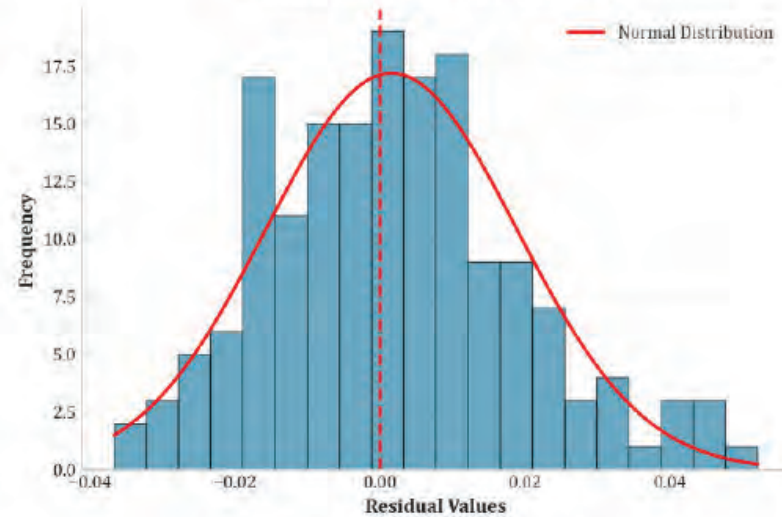


Numerical Study- Sensor Placement

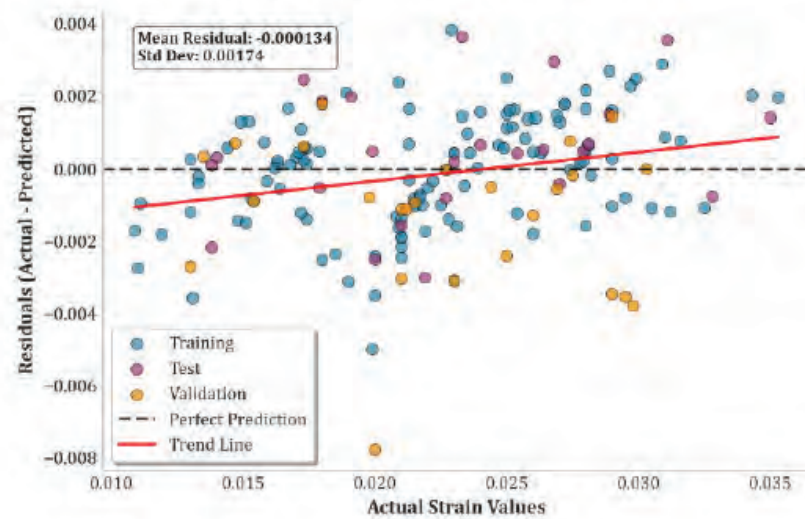
(a) FCR Model Residual Distribution



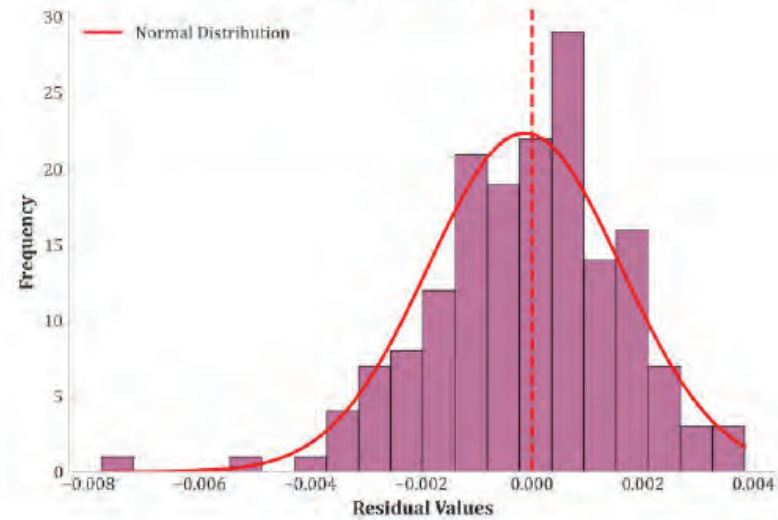
FCR Model Residual Distribution



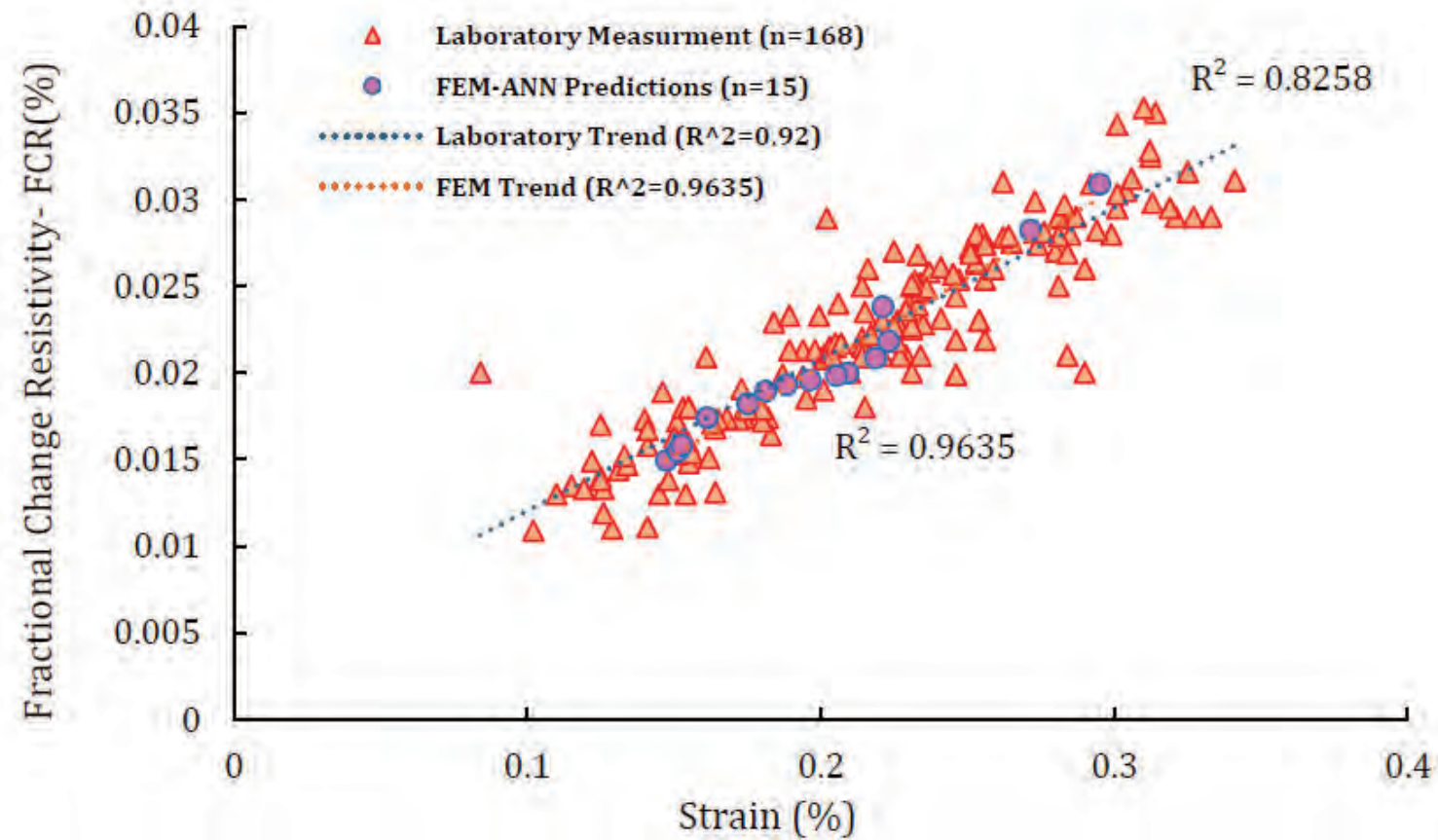
(b) Strain Model Residual Distribution



Strain Model Residual Distribution



Numerical Study- Sensor Placement





**Thank you
for your attention.**

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November 2025

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