Artificial Intelligence (AI) Applications for Design and Inspection of Bridges

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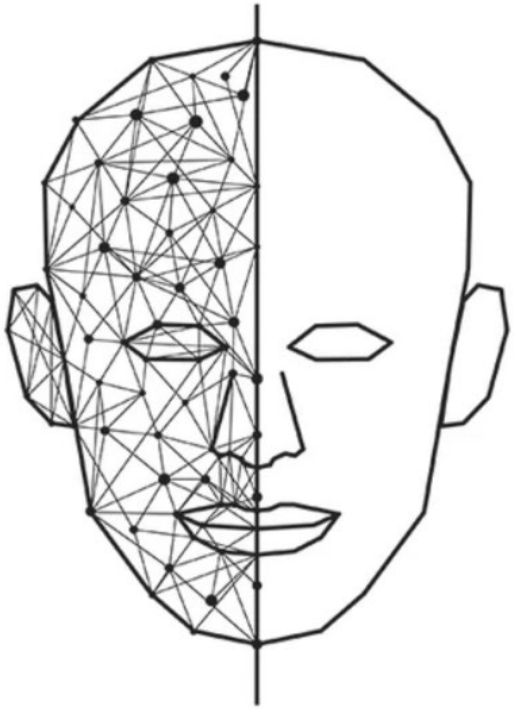
Contents

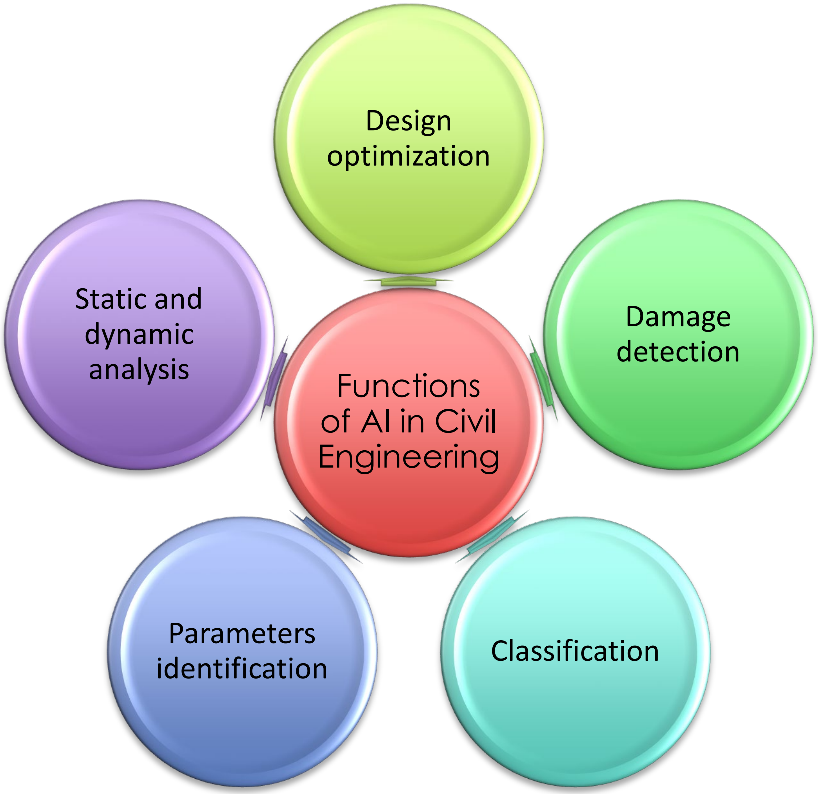
Introduction

- Artificial Intelligence
- Optimization
- Machine Learning

Artificial intelligence

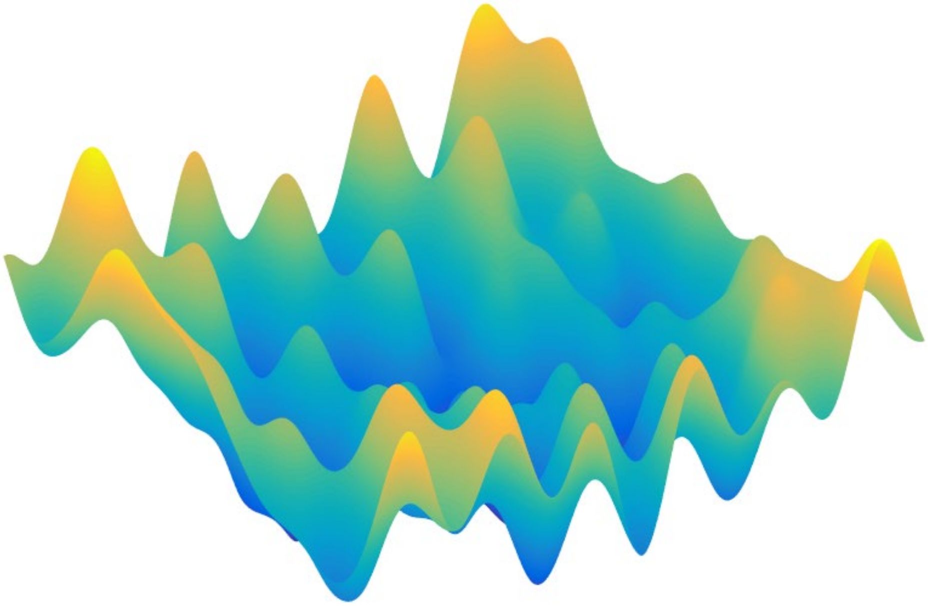
- Using computers to solve problems that require "intelligence"
- Replicate or simulate human intelligence in machines

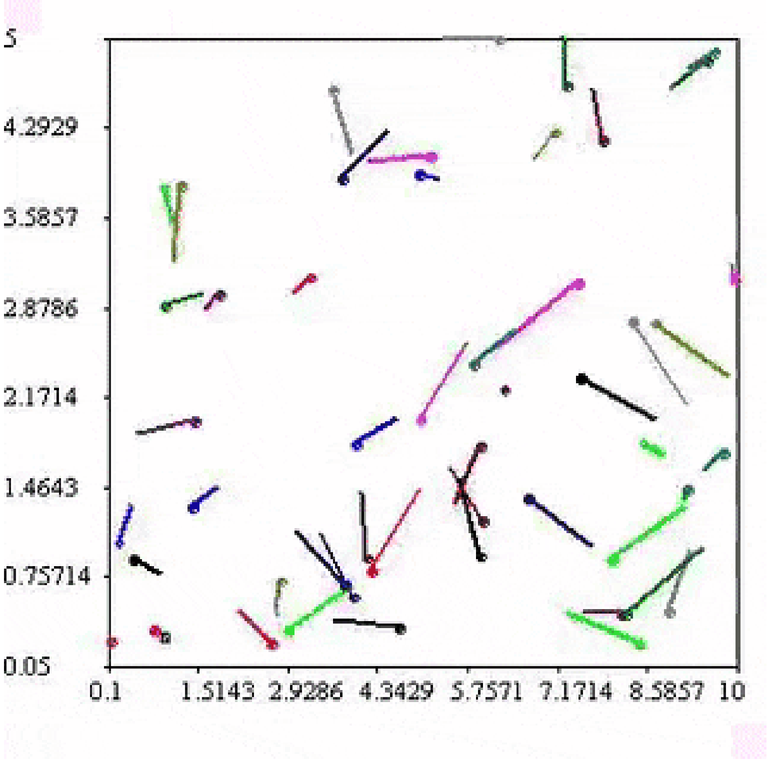




Optimization

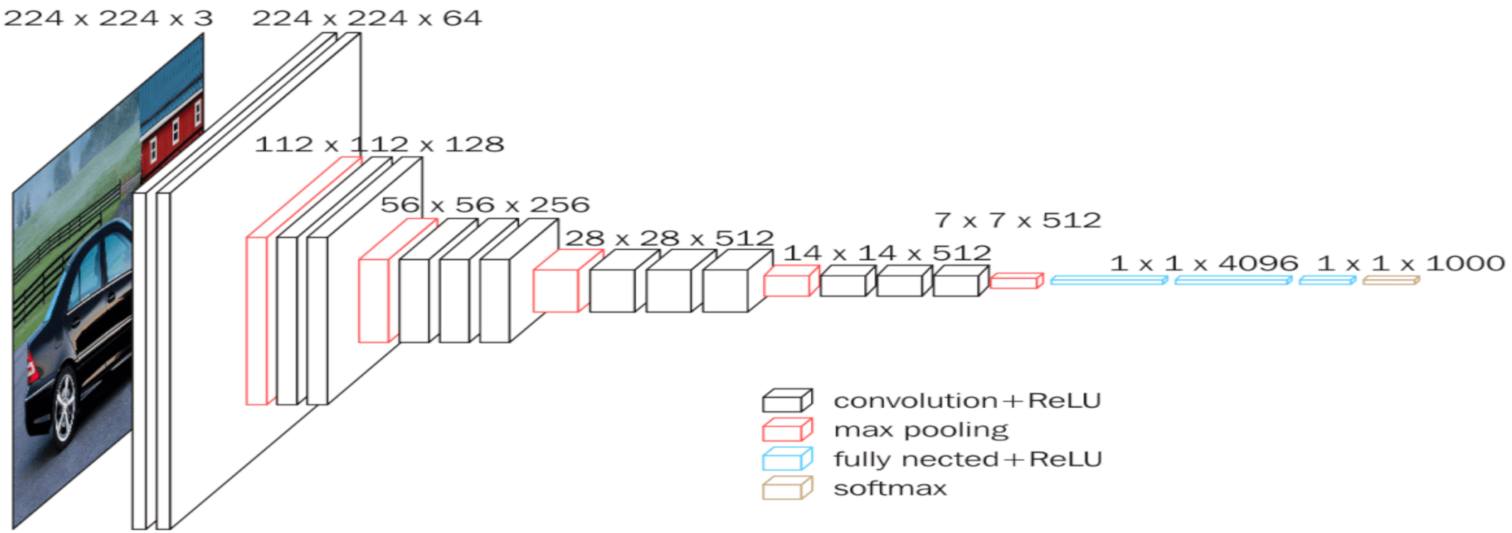
- Finding optimal solution of a problem through an iterative process





Machine learning

- Modify itself when exposed to new data



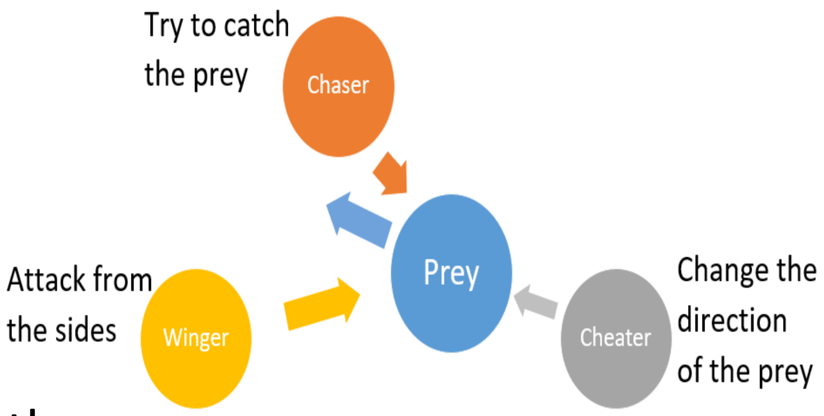
Research topics

- Design optimization of multi-span steel box girder bridge
- Damage classification for concrete bridge decks using images
- Prediction of bond strength of steel bars embedded in UHPC

Developing a new optimization algorithm

Lion pride optimization algorithm

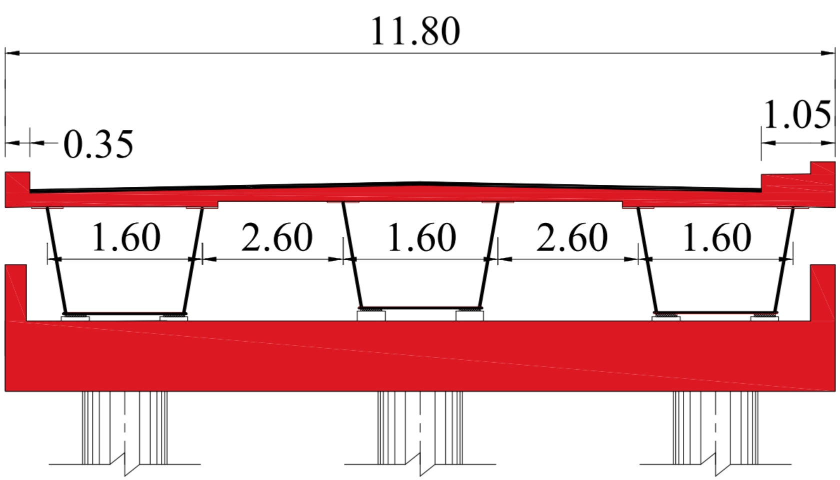
- Cooperative hunting of lionesses
- Excursion of the male lions
- Mating behavior
- Intragroup interactions between different pride groups
- Migration of lionesses from their birth pride group to another one

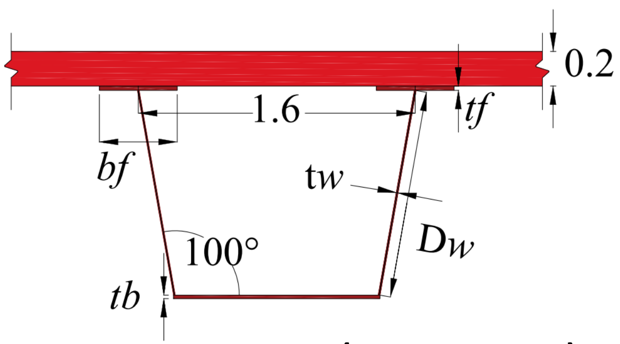


Apply algorithm to bridge design optimization

The bridge:

- 3 continuous spans: 15 m + 34 m + 21 m
- Composite section with 3 girders
- 8 pre-built segments
- Code: AASHTO HS standard moving loads



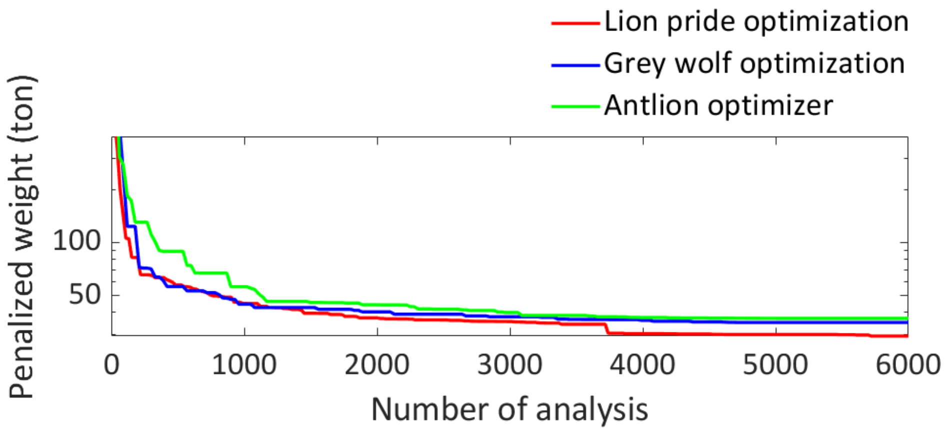


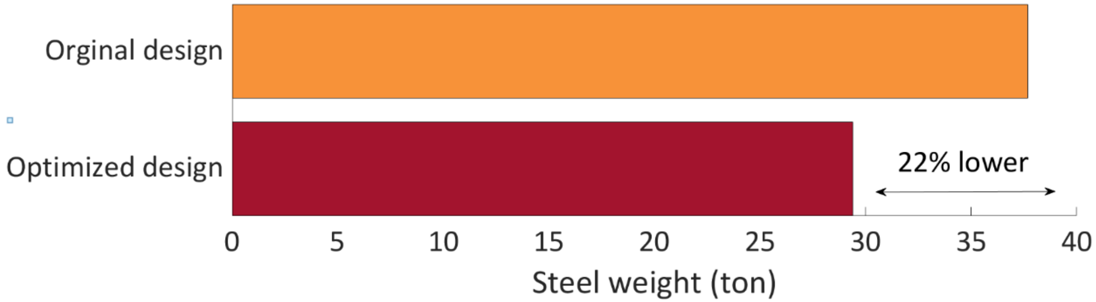
Dimensions (unit in m)

(1m = 3.28 ft)

The results

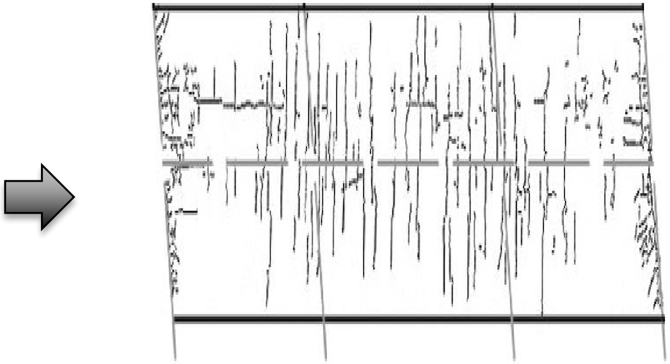
The optimization algorithm helps save 22% material cost of the bridge while retaining the performance of the bridge.





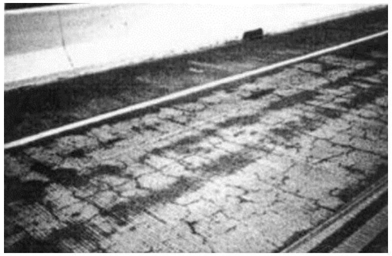
Damage classification for concrete bridge decks using images

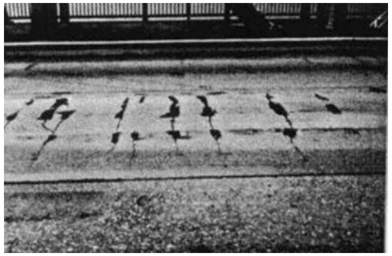
- Gather crack data using crack survey and getting images



Crack map

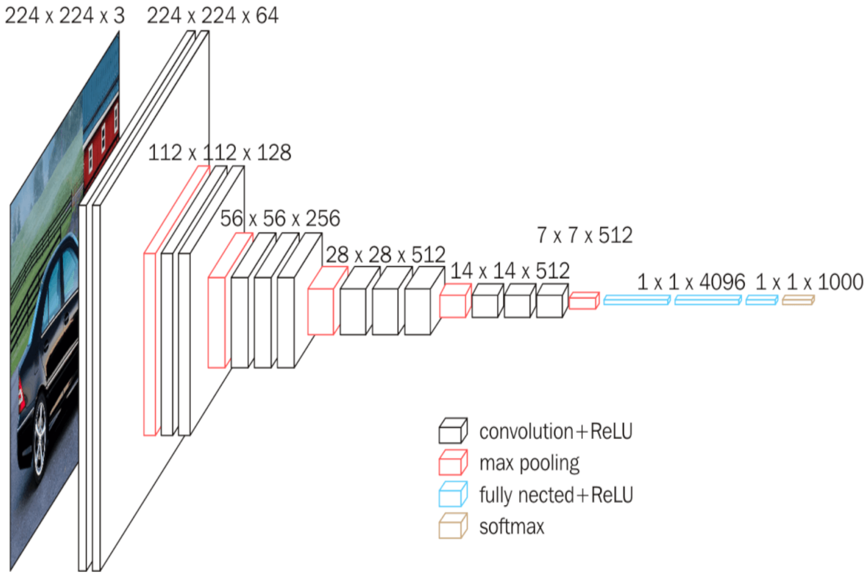
- Classification of cracks

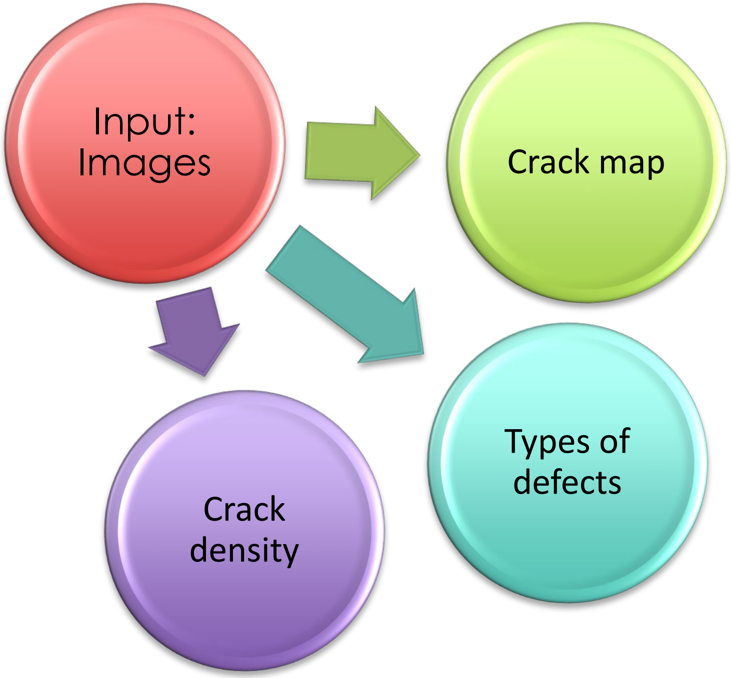




The Input and outputs

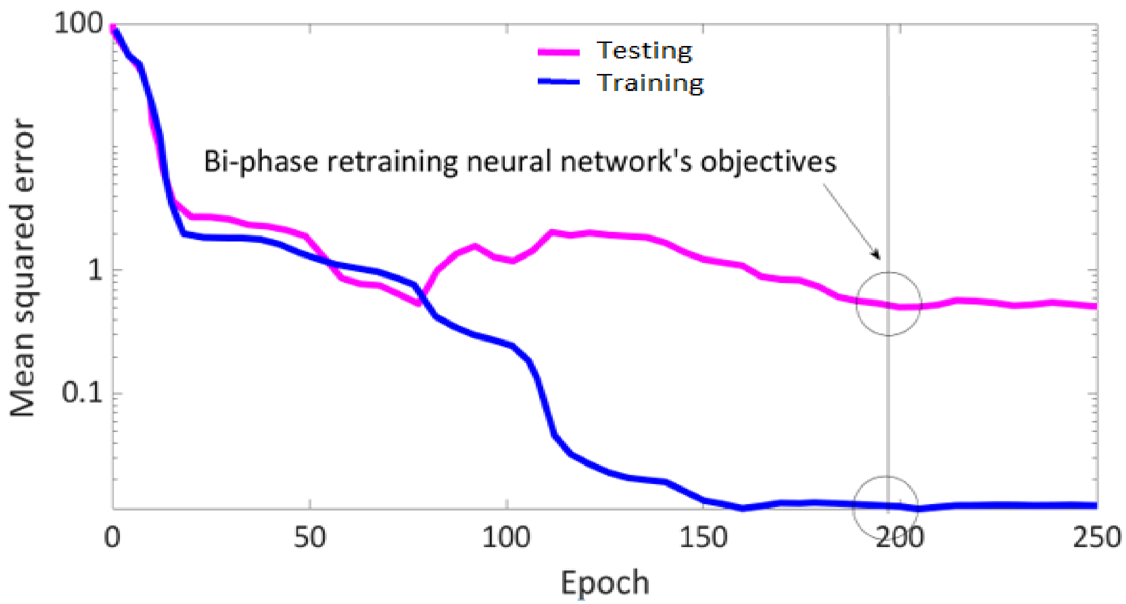
- Method: VGG16 (Oxfordnet)
- Different concrete deck bridges





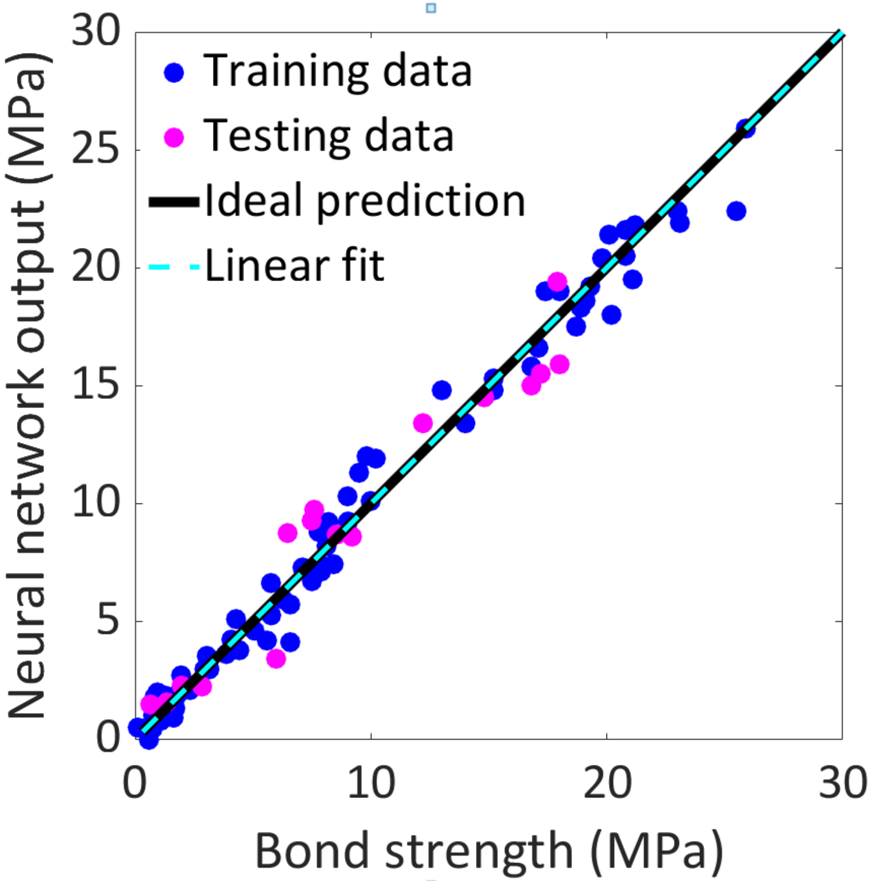
Prediction of bond strength of steel bars embedded in UHPC

- A posteriori Pareto-front selection method: decrease total and empirical error at the same time
- Other neural networks: conventional neural network, and retraining neural network



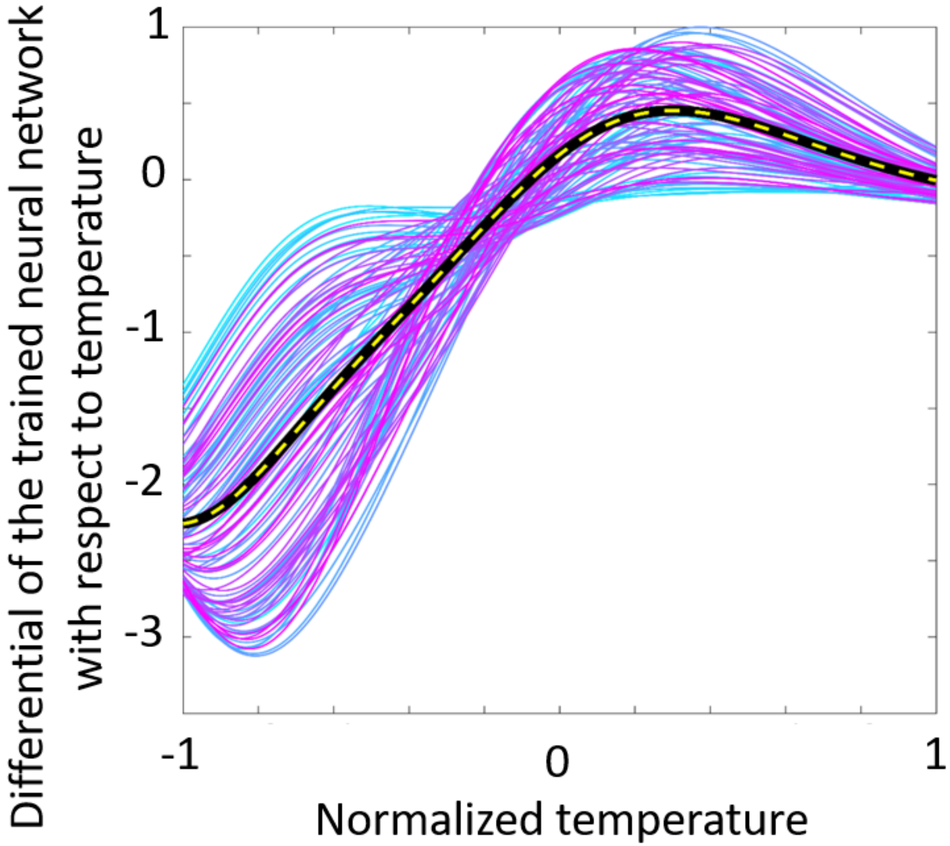
The results

- Demonstrate desired prediction accuracy (error < 5%)



Relationship between variables and bond strength

- Reveal complicated relationship between temperature and bond strength



Ongoing Research

- Design of joints of prefabricated bridge components for accelerated bridge construction
- Predict the properties of high-performance fiber-reinforced cementitious composites (HPFRCC) using artificial neural networks
- Identification and classification of multiple types of defects using novel convolutional neural networks

Conclusions

- The lion pride optimization algorithm helps save 22% material cost of the bridge while retaining the performance of the bridge.
- The VGG16 (OxfordNet) can be trained using online available images and applied to identify cracks in concrete bridge decks.
- The bi-phase retaining neural network can be trained and applied to predict the bond strength of steel bars embedded in HPFRCC. The analysis results from the neural network help reveal the underlying effects of the heating temperature.

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Thank you for your attention

Improving Bridge Performance Using Fiber Reinforced Polymer (FRP), Shape Memory Alloy (SMA), and Engineered Cementitious Composites (ECC)

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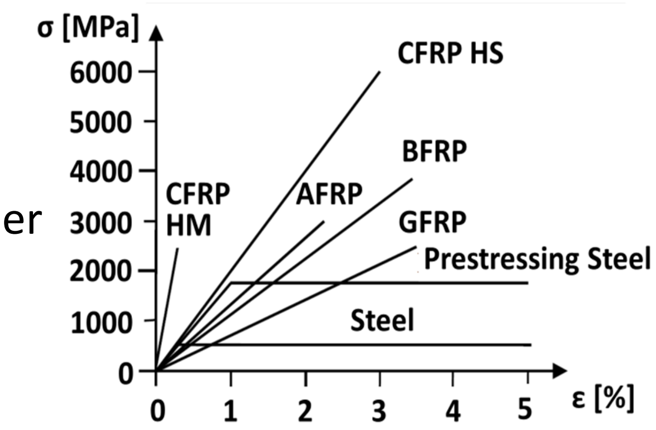
Outline

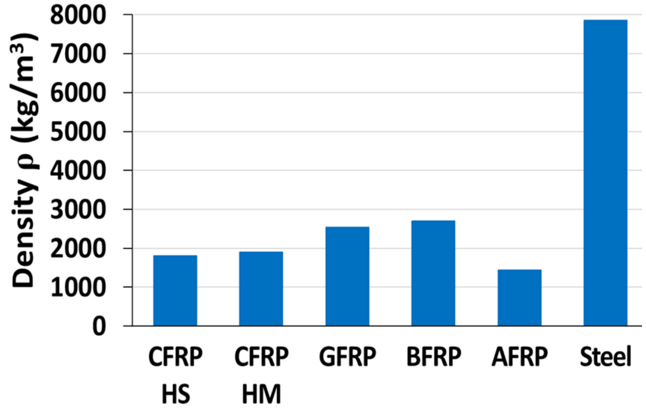
- My research aims to improve bridge performance through using innovative materials.
- This research addresses the following contents:
  - Advantages of FRP, SMA and ECC;
  - Applications in highway bridges;
  - On-going research;
  - Conclusions.

Fiber reinforced polymers

- Combination of fibers in polymer matrix:
  - ➢ Most loading is carried by the fibers
  - ➢ Matrix provides support and keeps the fibers together
  - ➢ Different types of fibers are used
    - ✓ *Glass, Carbon, Kevlar49, Boron, Silicon Carbide, etc.*

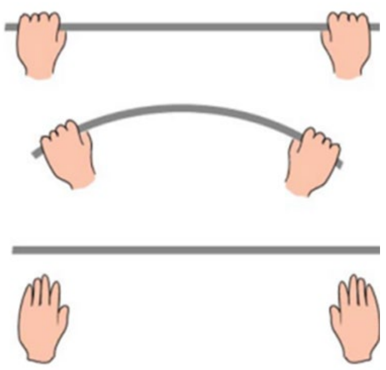


- Has many advantages
  - ➢ **High strength**
  - ➢ **Lightweight**
  - ➢ Fatigue & corrosion resistance
  - ➢ Low thermal conductivity & life-cycle cost

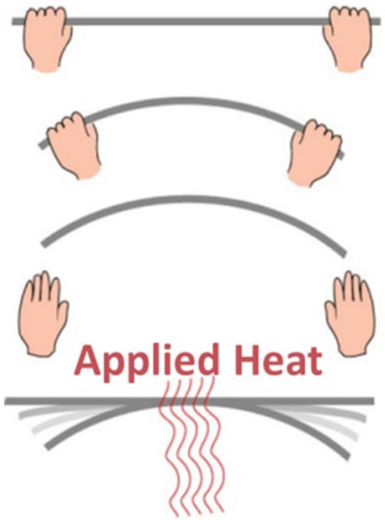


Shape memory alloys are smart materials

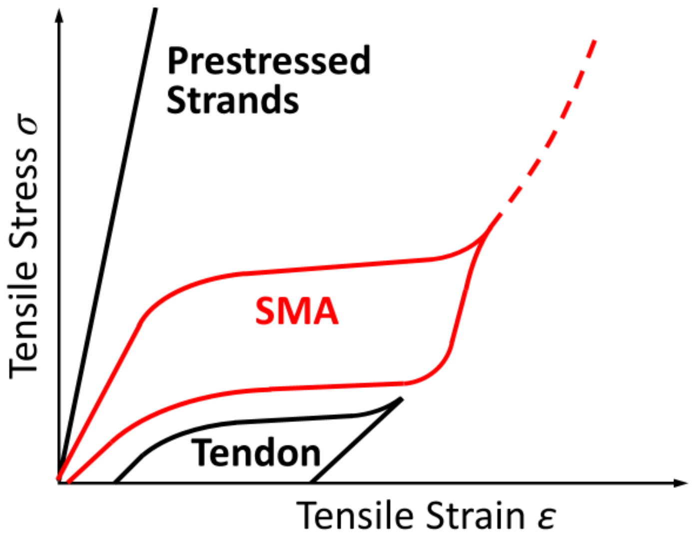
- With unique capability to "remember" the original shape:
  - **Super-elasticity**: Return to the original shape (6%~8% strain)
  - **Shape memory effect**: Recover from large deformations after heating



Super-elasticity



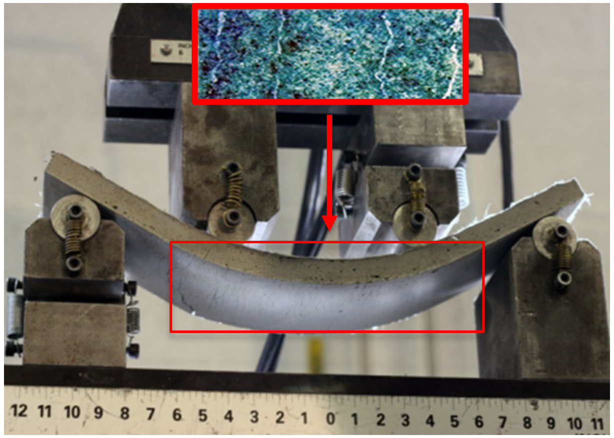
Shape memory effect



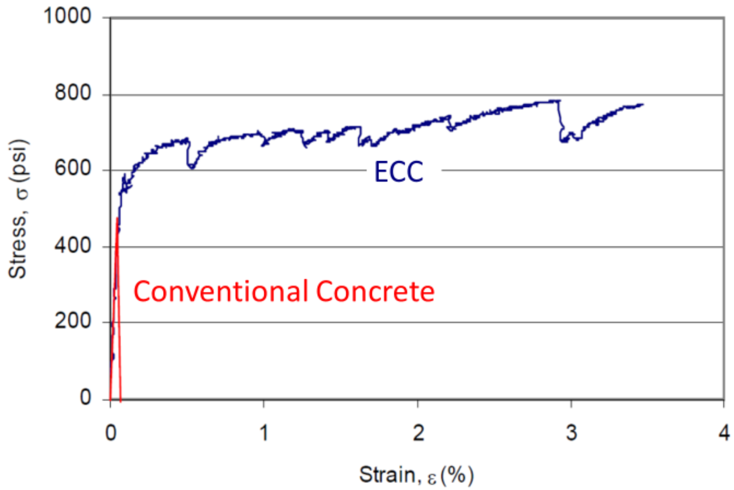
Tensile behavior of steels and SMA

Engineered cementitious composites (ECC)

- ECC is a smart material with multiple unique properties and functions:
  - ➢ Unique mechanical properties
    - ✓ **Tensile strain-hardening**, high tensile ductility (4% strain)
  - ➢ Excellent **durability**
    - ✓ Controlled crack width, self-healing of cracks
  - ➢ Superior temperature resistance
    - ✓ High-temperature, low-temperature
  - ➢ Multi-functionality (smart functions)
    - ✓ Self-sensing, self-cleaning, air-purifying, etc.



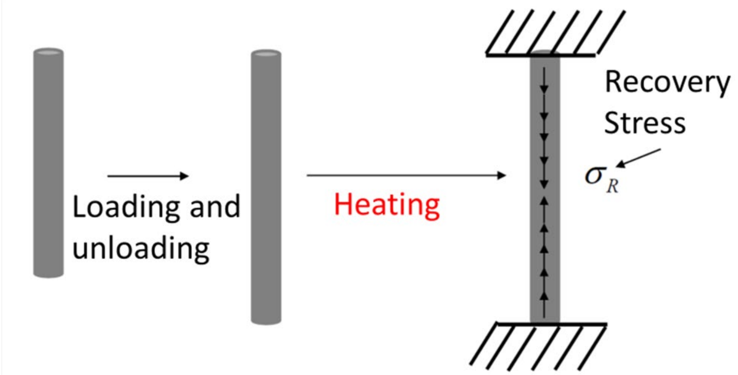
Flexural test of ECC



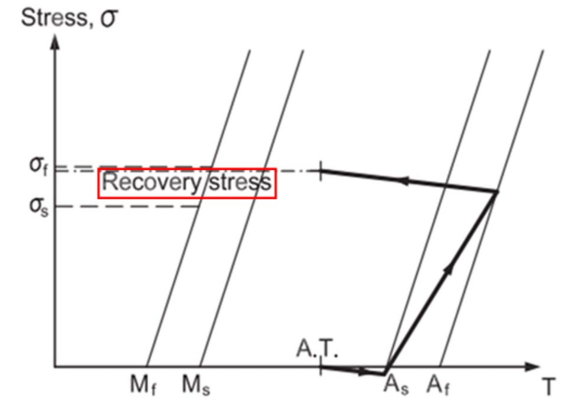
Applications in Highway Bridges

- **Lateral confinement of bridge piers**
  - Active confinement of concrete bridge piers with NiTiNb SMA spirals and FRPs
- **Innovative connection**
  - Column-footing connections in seismic zones with SMA bars and ECC
- **Bridge vibration control**
  - SMA devices for vibration isolation
  - Cable damping devices

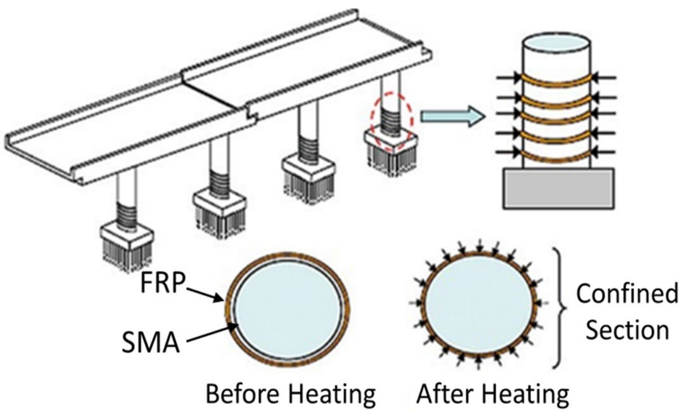
Lateral confinement of bridge piers



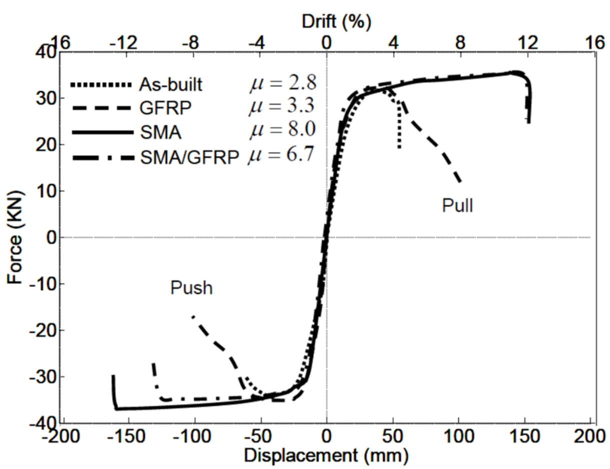
SEM in constrained recovery



Permanent prestressing after heating

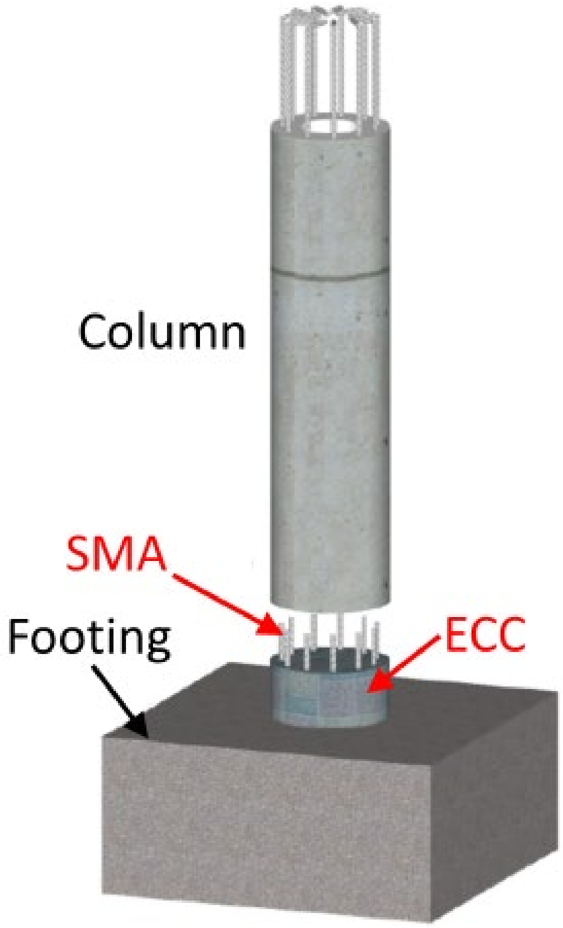


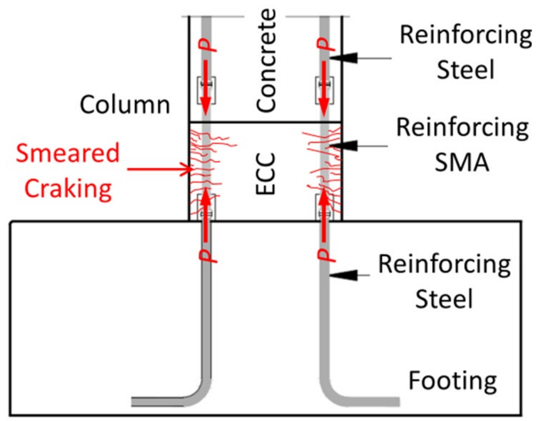
Lateral **active** confinement of bridge piers



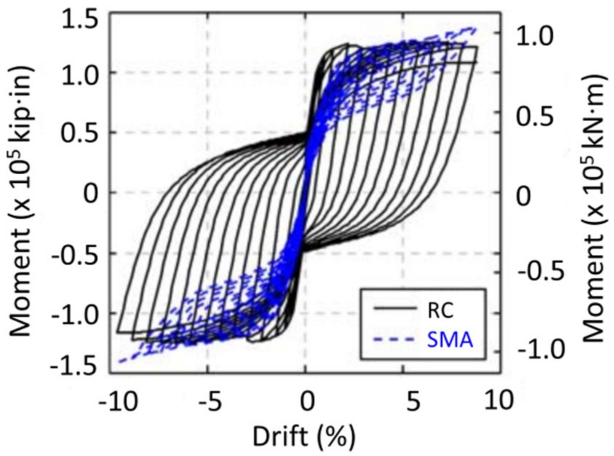
Comparison of force-displacement backbone curves of the four columns

Innovative connection



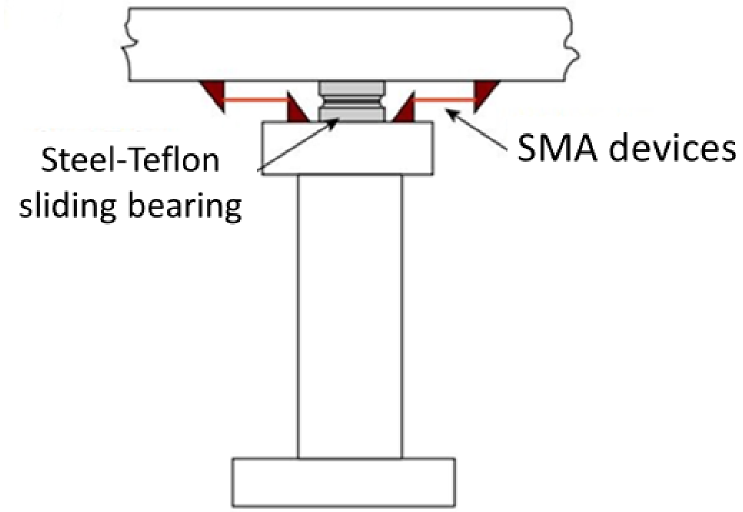


Self-centering & self-healing of cracks



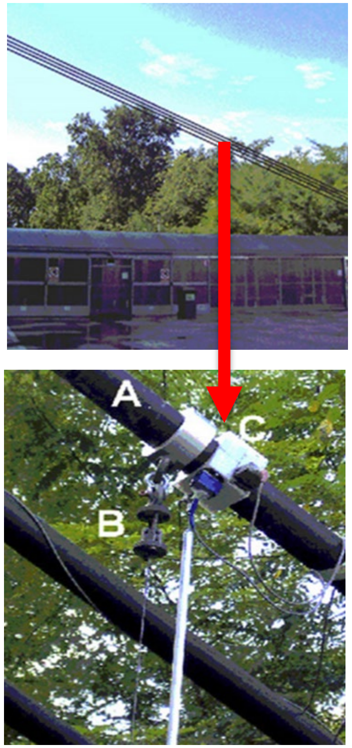
Isolate vibration with SMA devices

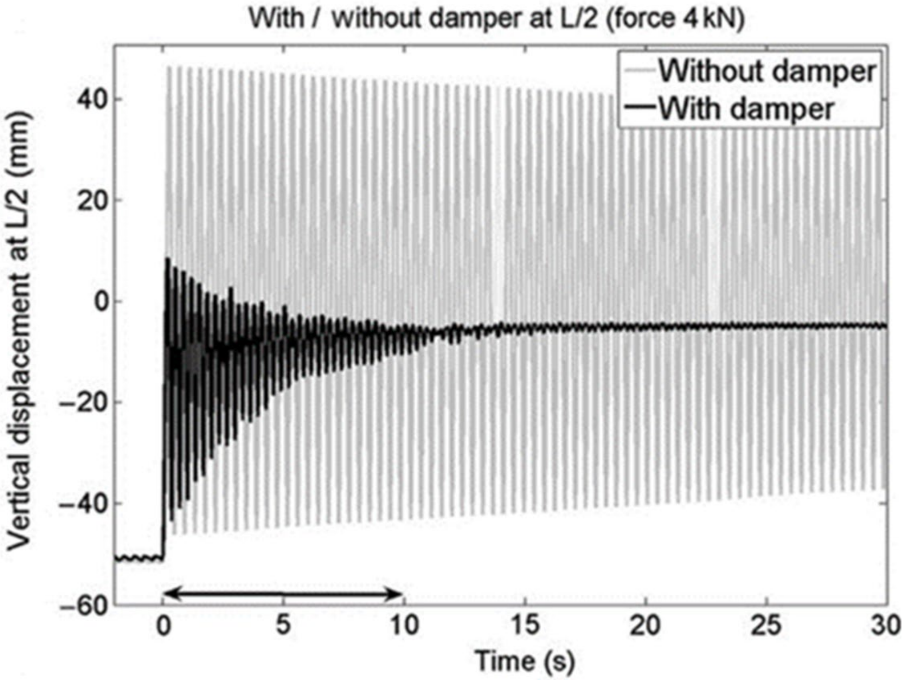
- Improving the **position stability** of bridges
- Benefits
  - Improving safety and resilience under dynamic loadings
  - Convenient installation and replacement



Cable vibration control with damping devices

- The **vibration amplitude** of cables and hangers are **reduced** by 50% using SMA dampers, increasing the service life of the cables/hangers.



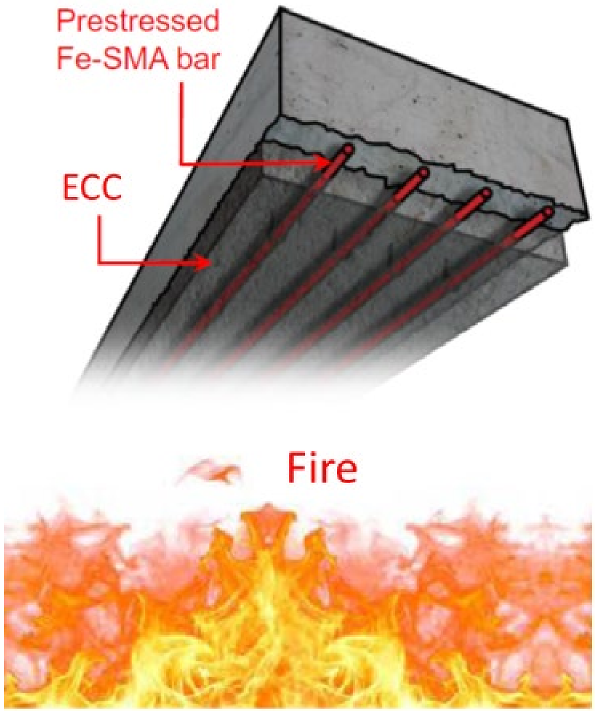


A = structural cable, B = SMA damper, and C = accelerometer

On-going research 1:

Improve fire resistance of highway bridges

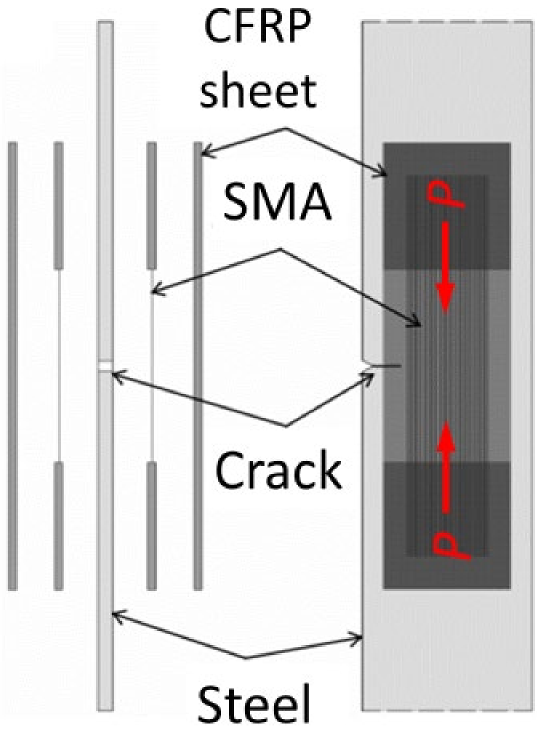
- Fire may result in permanent damage or even collapse of the bridge
- We improve the **fire resistance** using prestressed Fe-SMAs and fire-resistive ECC



On-going research 2:

Improve fatigue life of bridges Using SMAs and CFRP

- An **active retrofitting** technique using SMA/CFRP composite
- Crack-closing capability of SMA and fatigue resistance of FRP



Conclusions

- The combination of FRPs, SMAs, and ECC demonstrated advantages in bridge engineering, especially in earthquake resistsance design.
- **Active confinement** delivered better performance of the bridge piers compared with the passive confinement strategy.
- The piers with SMA/ECC connection recovered the position and demonstrated the minimal permanent drifts.
- The SMAs are promising to **control structural vibration**, **improve fire resistance**, and **enhance the fatigue resistance** of bridges.