

Emerging Technologies for Climate Resilience: Nature Inspired AI Algorithms for Building Design & Monitoring

“Human ingenuity may make various inventions... but it will never devise any inventions more beautiful, nor more simple, nor more to the purpose than Nature does...”

-Leonardo da Vinci



Courtesy: Internet



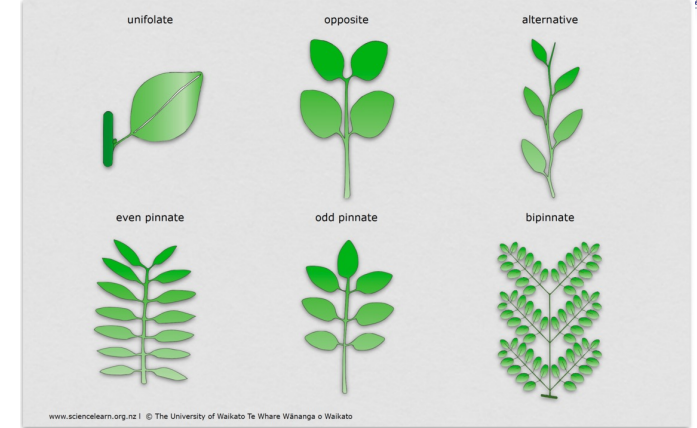
Dr. (Ms.) N. Anandavalli

Cyclone-resistant shelter

Director, CSIR-Structural Engineering Research Centre, Chennai

Why Nature based solutions?

- ❖ Evolution of complexity in nature – distinctive order
- ❖ Information processing in nature – distributed, self-organised, optimal manner
- ❖ Activities change due to changed circumstances
- ❖ Other than humans, other things adapt to nature and its changes
- ❖ One common aspect – nature maintains its equilibrium by any means
- ❖ Idea of optimum seeking – best solution – there is a goal to be achieved – with constraints to be satisfied

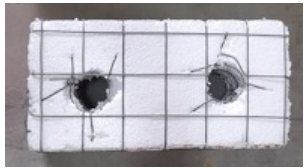


Courtesy: Internet

பகுத்துண்டு பல்லுயிர் ஒம்புதல் நூலோர்
தொகுத்தவற்றுள் எல்லாந் தலை.

The chief of all (the virtues) is the partaking of food that has been shared with others, and the preservation of the manifold life of other creatures.

SECROBUILT TECHNOLOGY FOR HOUSING



Lightweight Block



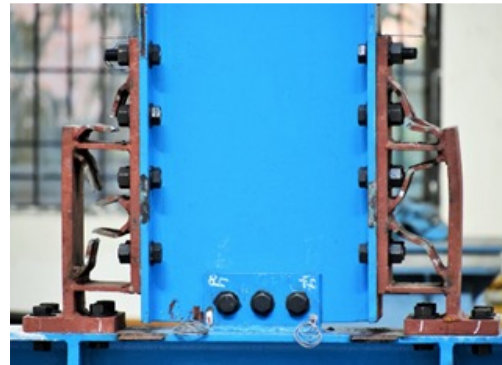
Rapid Assembly (1 storey per day)

View of Climate Resilient DEMO Building



Jut cavity bricks for enhanced seismic resilience

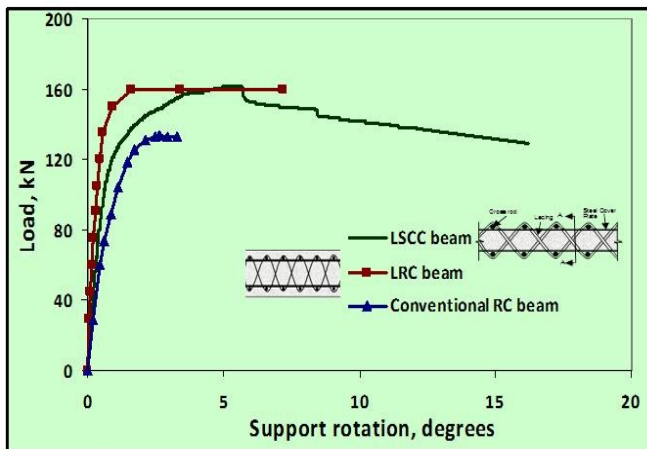
- Sintered blocks
- Stabilised blocks using industrial wastes



Dissipative fuse link

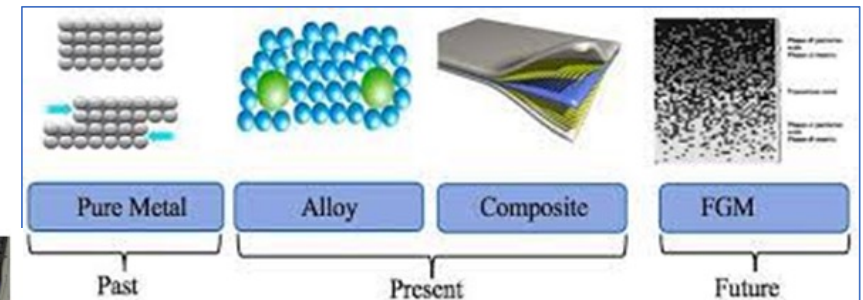
Laced Steel-Concrete Composite System

modular construction system with enhanced blast resistance



Bio-Inspired Functionally Graded Cementitious panels for Impact Resistance

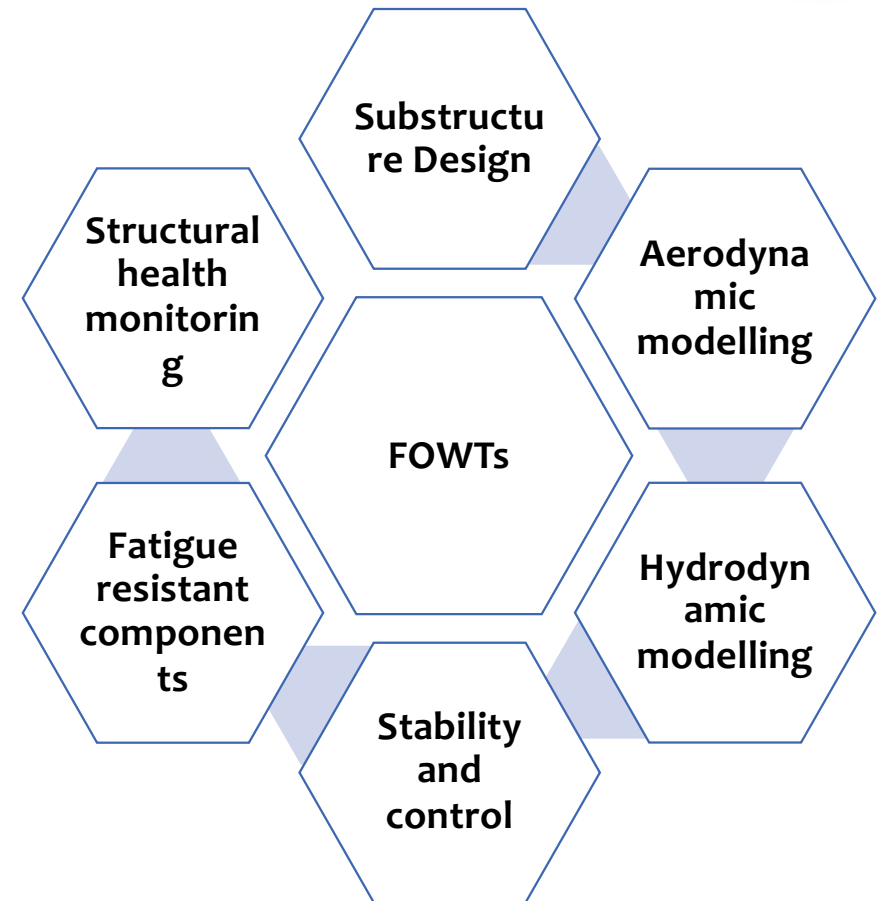
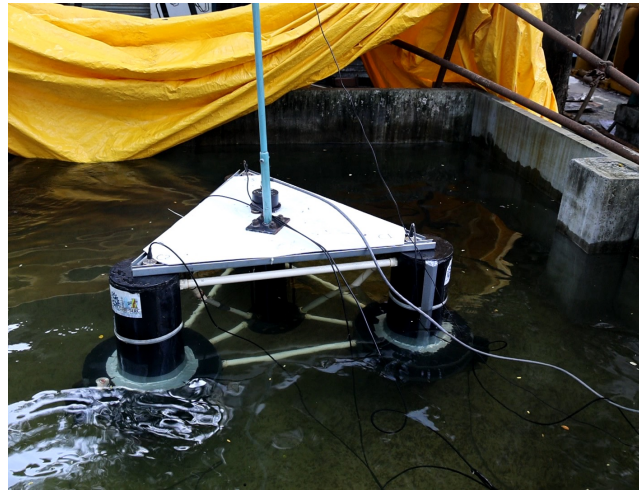
Fruit Peels/Nut Shells:
Survive fall from a height of 10-50 m

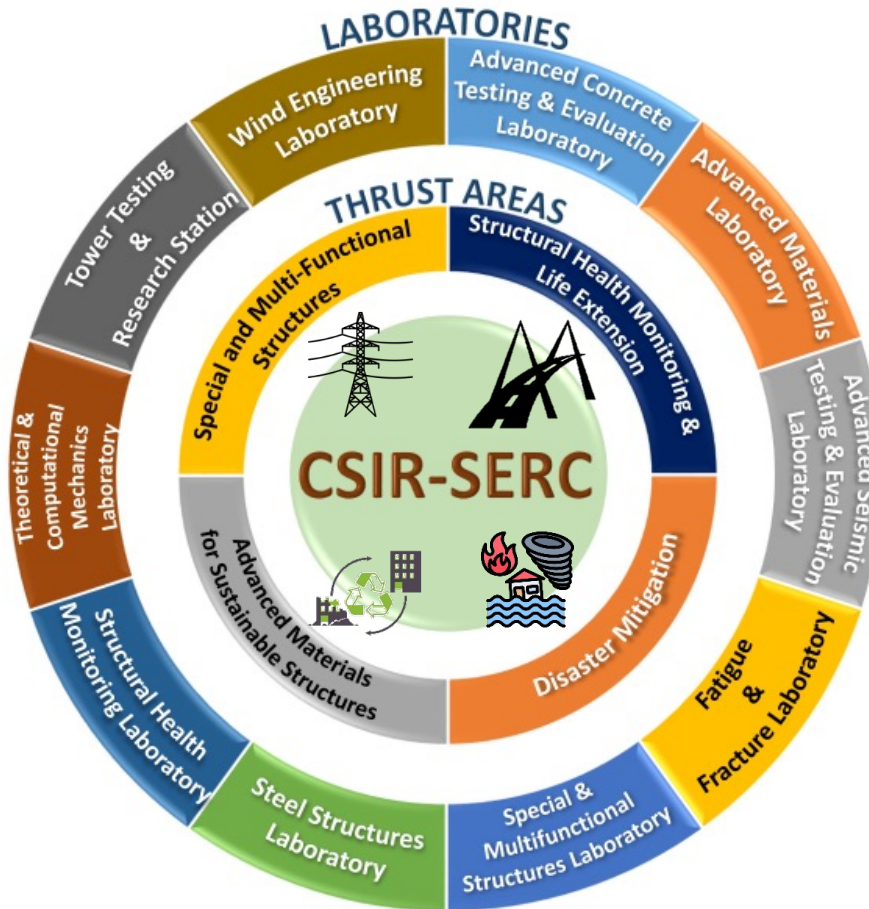


Floating offshore supporting structure for wind turbine



Floatability and free decay test in water tank





Uncertainties

- ❖ an unavoidable part of structural engineering problems.
- ❖ In seismic design - earthquake demands are not known with precision
- ❖ In structural health monitoring - uncertainties in the amplitude of the input excitation, measurement noise, and spatial density of measurements.
- ❖ Uncertainties – in models to predict structural response, and constitutive behaviour.
- ❖ Geotechnical information for foundation design - limited information and/or based on laboratory tests with high levels of uncertainty.

AI - to deal with such uncertainty problems

AI for Design of unit supporting structure

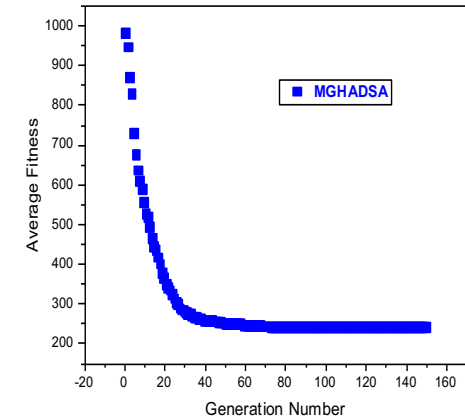
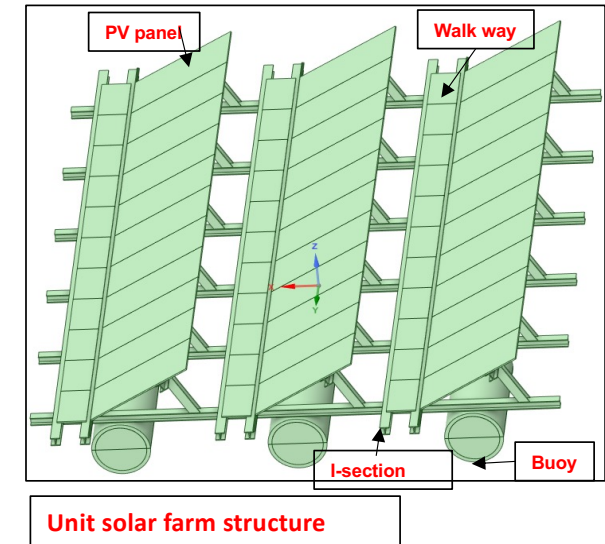
Objective function - minimisation of weight of the unit structure of floating offshore solar farms

Constraints - criteria for strength & buckling.

Few successful AI algorithms for design:

1. Variational Autoencoder (VAE) models - Mirra and Pugnale (2021)
2. Unsupervised machine learning models (Convolutional Autoencoders, CAE)- Maqdah et al. (2021), Palmeri et al 2021
3. Genetic Algorithms
4. Neural Networks
5. Metaheuristic optimisation

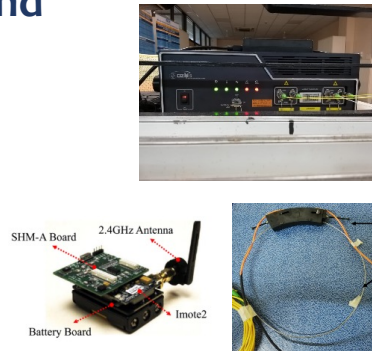
- Optimal sections arrived : [1 1 1 1 1 1 3]
- 1 denotes section 63x63x3.5 and 3 denotes section 52X102X6.4
- Optimal Weight of the unit structure : 238.456 Kg



Structural Health Monitoring

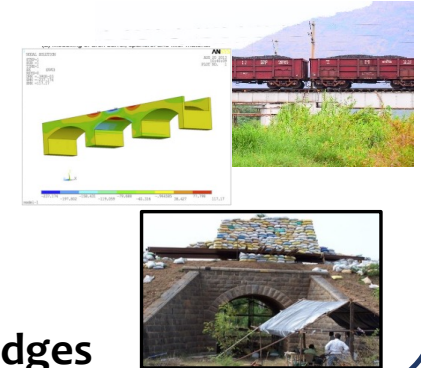
Instrumentation Techniques and Sensor Development

- ❖ Distributed Fiber sensing
- ❖ Indigenous Packaged FBG sensors for pipelines
- ❖ Smart wireless sensing



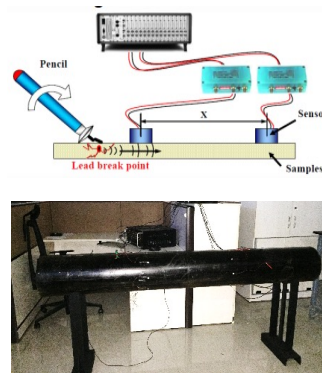
Bridges and Infrastructures

- ❖ Capacity enhancement of existing Bridges
- ❖ Innovative technique for evaluation & mitigation of longitudinal force on bridges
- ❖ Safety assessment of old bridges



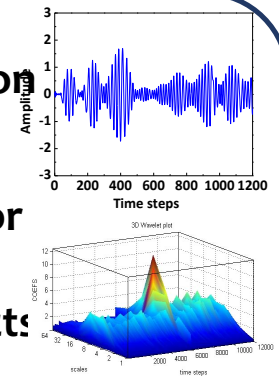
Pipeline structures

- ❖ Leakage detection using vibration, acoustic and guided wave propagation techniques
- ❖ Development of a baseline-free for localization of the defect/damage

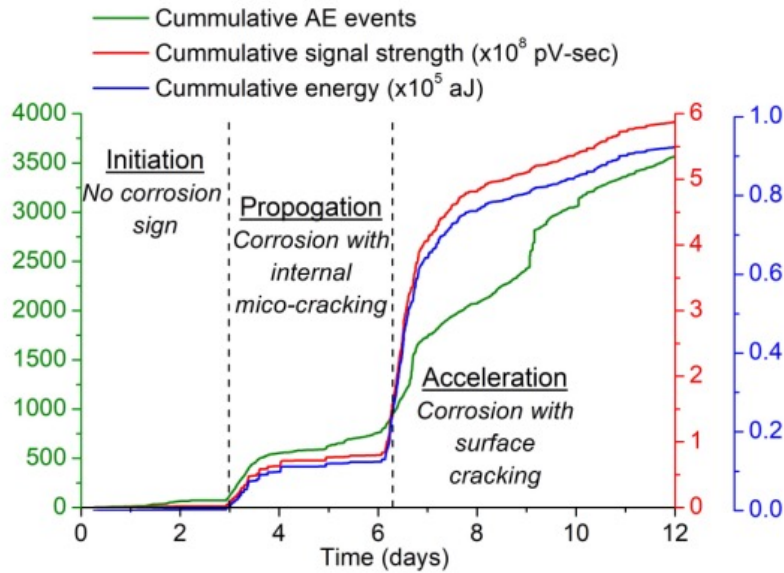


Damage Detection and Localization

- ❖ Subdomain based damage detection strategies
- ❖ Multivariate analysis techniques for damage detection considering environmental & operational effects
- ❖ Signal Decomposition & Reconstruction



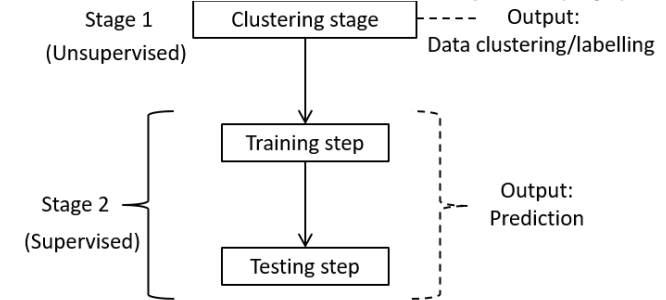
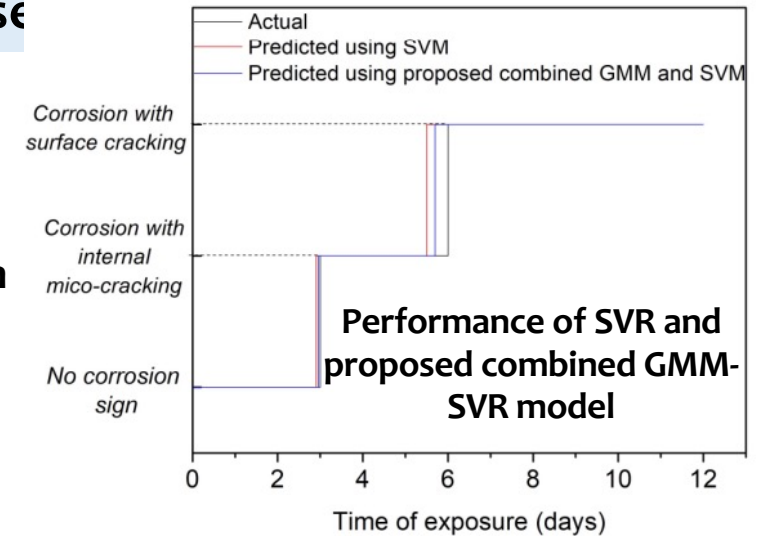
Multi-layer method combining unsupervised and supervised



An automated corrosion monitoring diagnostic system – extremely important

Cumulative Acoustic emission activity recorded

The developed AI model is found to be efficient in detecting the initiation of corrosion damage



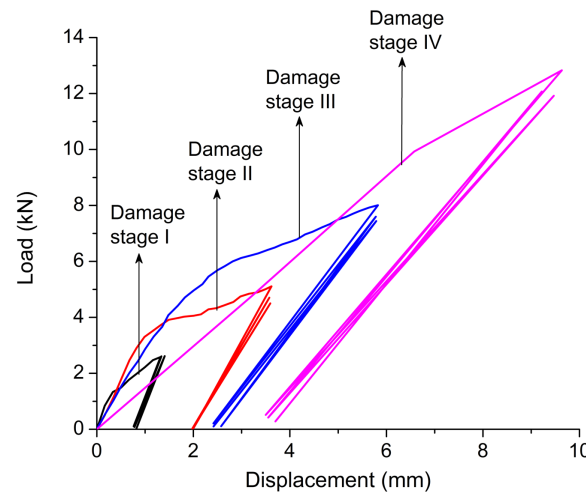
Proposed multi-layer method

AI-augmented pattern recognition for SHM of structures – Early warning system

SHM of concrete bridge model through AI-augmented Acoustic Emission (AE) technique

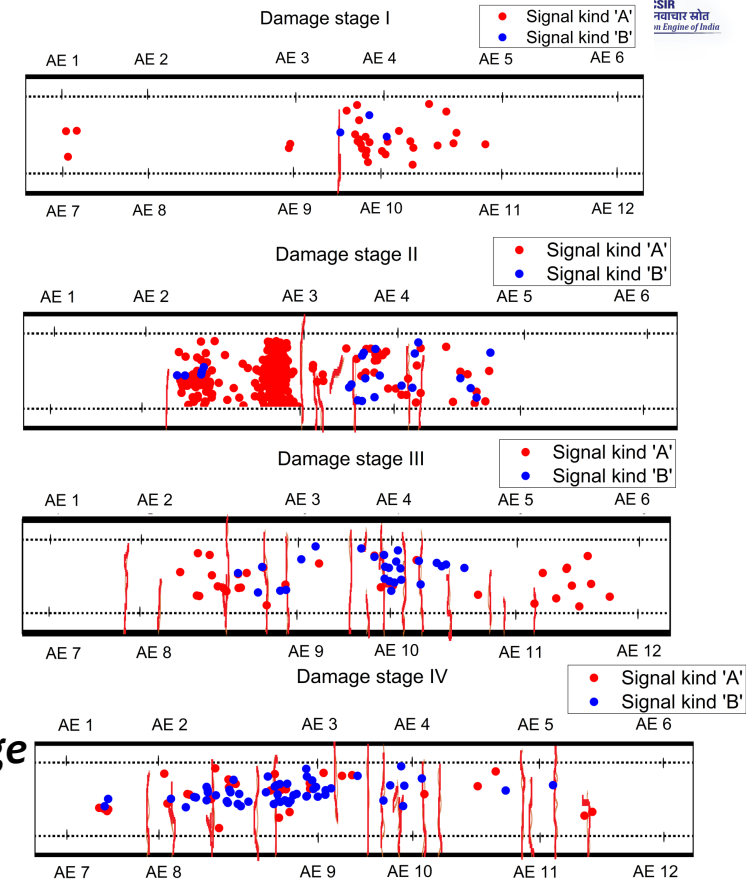


Instrumentation of Acoustic emission (AE) measurement



Progression of mechanical damage

The developed pattern recognition supported AE-based methodology will be very effective in condition monitoring of in-service structures



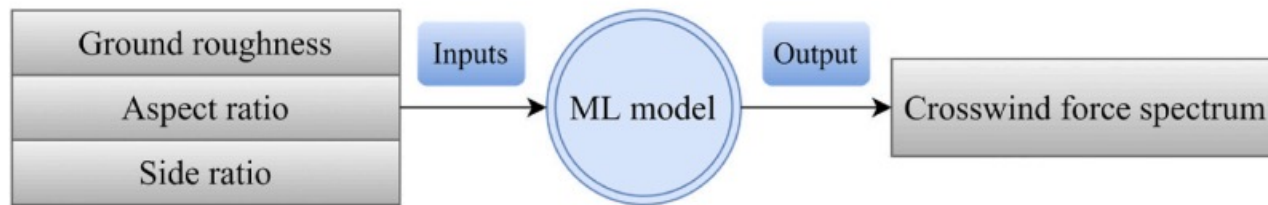
Classified cracking at different damage stages

AI for wind load assessment on structures

Gap/need :

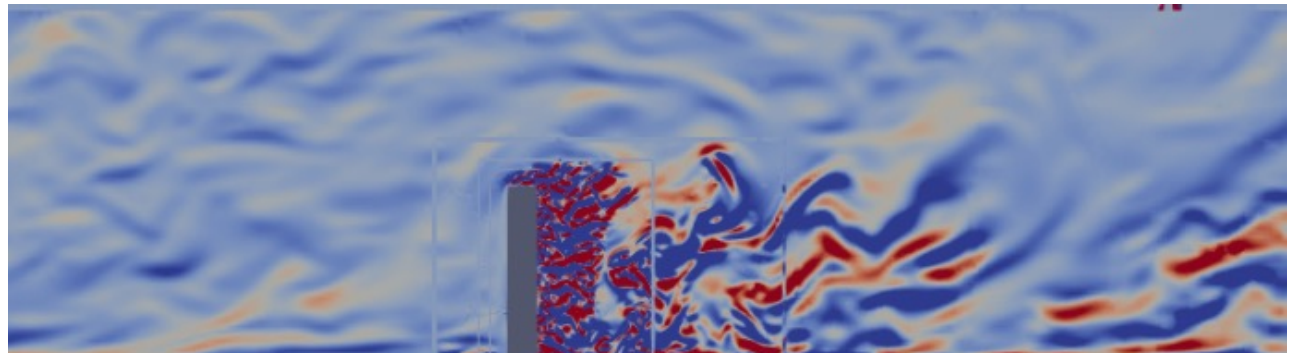
- Existing Database Assisted Design accepts discrete and limited inputs for evaluation of **crosswind and torsional loads** on buildings
- Specific to aspect ratio, side ratio and terrain category

AI driven Solution: Data driven ML based design



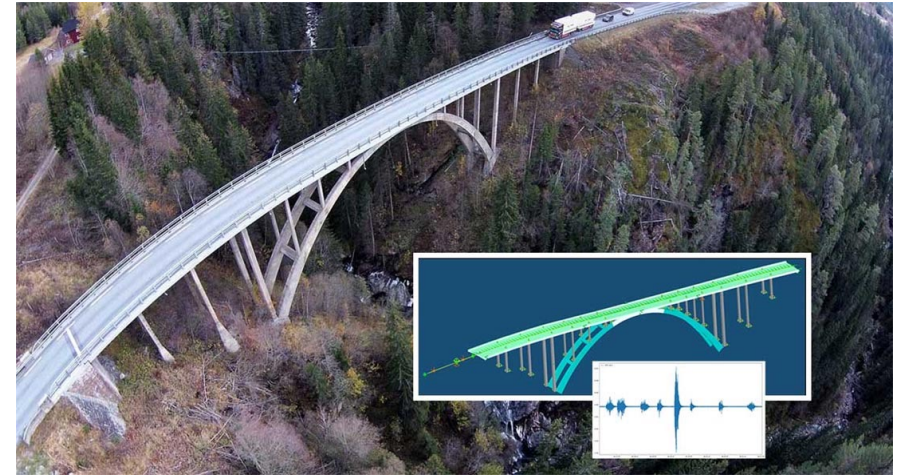
OUTCOME

Framework for assessment of wind induced cross-wind and torsional effects



Tomorrow's SHM- Digital Twin for predictive assessment

- *Validate system model with real-world data*
- *Provide decision support and alerts to users*
- *Predict changes in physical system over time*
- *Discover new application opportunities for critical infrastructure*



Digital Twin of a long-span bridge – Continuous interaction and updation of physical & simulated structure.
 Courtesy: Internet

Poised to be the game-changer technology for Monitoring, Assessment, Life Extension and Predictive performance of critical structures



Acknowledgement



Dr. Mohit Verma, Dr. –Ing. Saptarishi Sasmal, Dr. Lakshmikandan, Dr. S R Balasubramanian, Dr. Amar Prakash, Dr. Arun Sundaram, Dr. (Ms.) Keerthana, Scientists of CSIR-SERC

APCTT of UNESCAP

அருமை உடைத்தென்று அசாவாமை வேண்டும்
பெருமை முயற்சி தரும்.

Which means

Perseverance is needed even when excellence is achieved;
greatness is attained through effort.

Thank You