Technology and Innovation Conclave 2.0

AI for climate action and resilience: CSIR-SERC's Role

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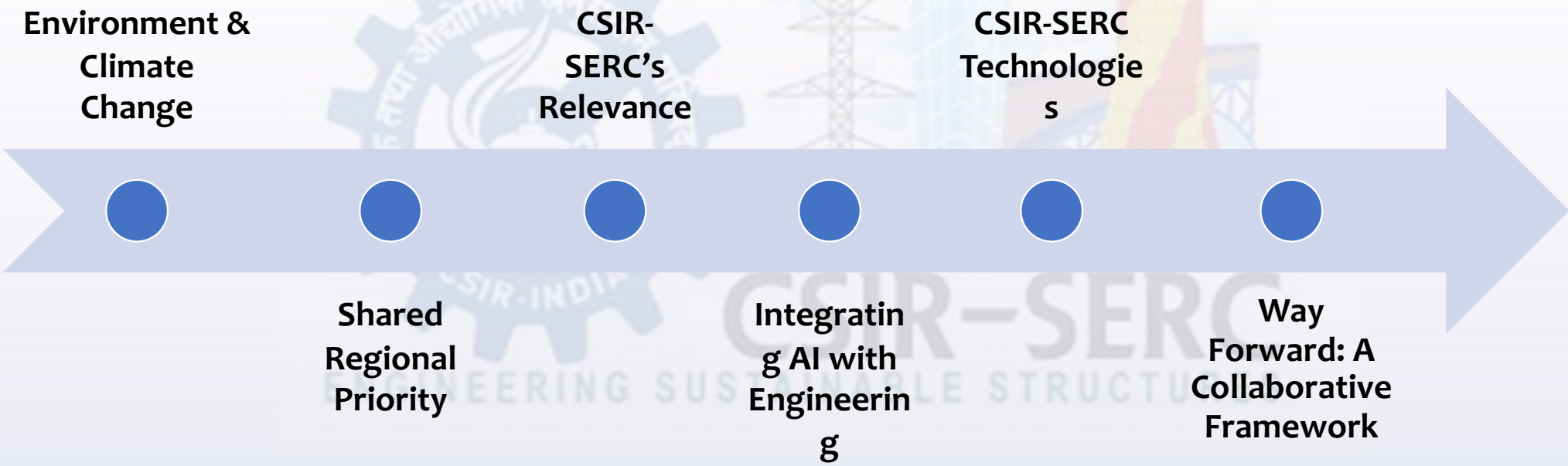
Outline


Environment & Climate Change
CSIR-SERC's Relevance
CSIR-SERC Technologies
Shared Regional Priority
Integrating AI with Engineering
Way Forward: A Collaborative Framework

Environment and Climate Change – a perspective

நிலம் தீ நீர் வளி விசும்போடு ஐந்தும் கலந்த மயக்கம் உலகம்
(Tholkappiyam, the oldest extant work of Tamil literature and the earliest Tamil grammar text)

The world is nothing but a delicate balance of the five elements

Earth, Fire, Water, Air and Sky (Space)

This balance has sustained life for millennia

Under increasing strain today and hence this message is more relevant today than ever before.

Environment and perception of life - inseparable

Earth:

- Our soils and land resources under pressure from urbanisation, mining, and deforestation
- Shrinking fertile lands
- Waste occupies more space than ever

Water:

Both extremes—no water and devastating floods.

வான்நின்று உலகம் வழங்கி வருதலால்
தான்அமிழ்தம் என்றுணரற் பாற்று

Rain is not just water but a life-sustaining nectar that allows for all forms of existence and sustenance

Fire: Fossil fuels – dependence to be reduced
Renewable energy - challenges of storage, recycling & sustainable adoption
True wisdom is foresight—protecting in advance, not repairing in ruin

Air: helps to sustain life on earth
declining air quality

Space: connects all others
In today's context - reminds us of the global atmosphere
the climate system that regulates our monsoon, rainfall, and temperature
Climate change has disrupted this equilibrium -cyclones, sea-level rise, heatwaves

environmental problems – interconnected
A disturbance in one element cascades into others.

Climate Resilience: Shared Regional Priority

Cyclones & Floods
Heat & Cold waves
Sea-level rise
Infrastructure degradation

Risks – transboundary

Solution- Regional cooperation
Data driven decision making
Rapid technology transfers

Basic necessities of humans

Food, Clothing & Shelter

INFRASTRUCTURE

Energy to Environment
Materials to Infrastructure
Sensors to Robotics

Civil, Infrastructure and Engineering for

Connect with mobility infrastructure

Collaborate for automation, monitoring & mitigation

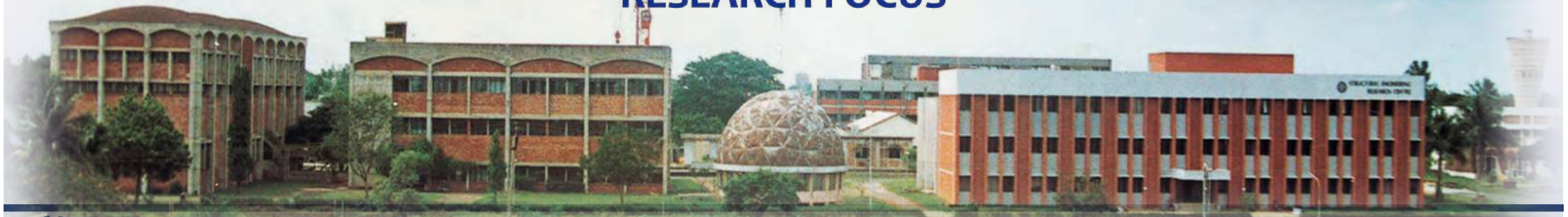
Converge to implementable technology

Convert Waste to Wealth

Shelter – Safe, Sustainable and Environmental friendly
Mobility – Planned and Durable – multi modal
Monitor – Prevention of any unwanted events
Mitigate – Natural and Man-made disaster
Automate – for quick implementation
Address – waste generation towards sustainability

Building Physics & Materials	Rural Infrastructure	Mobility Infrastructure & Planning	Automation & Robotics	Waste to Wealth	Structural Health Monitoring & Life Extension	Disaster Mitigation for Infrastructure
						

CSIR-Structural Engineering Research Centre



OUR LEGACY

1965-1984: ADVANCED MATERIALS AND INNOVATIONS IN STRUCTURAL DESIGNS

India's First Fly-Ash Building

Prefabricated housing complex

Catenary Shell Roofs

Beacon Tower

Prestressed Concrete Sleepers

Analysis of Matri Mandir

Preservation of Stone Heritage

OUR LEGACY

1985-2004: NATIONAL CAPACITY BUILDING AND SOCIETAL DEVELOPMENT

Lowering of HBJ Pipeline

Bubble Dome Unit

Tower Testing Research Station

Space Grid Roof Structures

Vigyan Auditorium

OUR LEGACY

2004-2015: INTERDISCIPLINARY RESEARCH AND DEVELOPMENT

Seismic testing G+7 scaled building model

Spent-fuel Tank

Remote Structural Health Monitoring

Slurry Infiltrated Fibrous Concrete hardened Shelter

Butt Weld Rail Joints

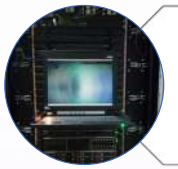
Control and Safety Rod Drive Mechanism

OUR THRUST AREAS AND LABORATORIES

- Structural Health Monitoring and Life Extension
- Offshore Structures
- Disaster Mitigation
- Energy Infrastructure
- Advanced Materials for Sustainable Structures
- Special and Multi-functional Structures

CSIR–SERC
ENGINEERING SUSTAINABLE STRUCTURES


Advanced Seismic Testing & Research Laboratory


Advanced Protective Structures & Mechanics Laboratory


Advanced Concrete Testing & Evaluation Laboratory


Wind Engineering Laboratory


Steel Structures Laboratory


Tower Testing & Research Station


Advanced Materials Laboratory


Special & Multi-functional Structures Laboratory


Fatigue & Fracture Laboratory


Structural Health Monitoring Laboratory

RECENT SCIENTIFIC CONTRIBUTIONS

3D Printed Building

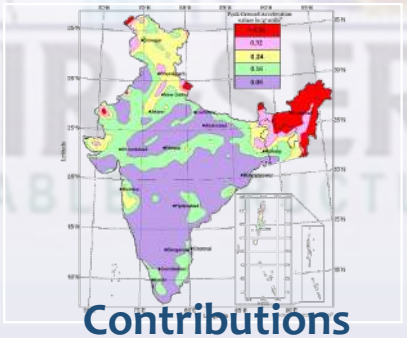
SHM of Dams

Emergency Retrieval System for Power Restoration

Floating Offshore Renewable Energy Structure

Multi-hit Security Booth

SHM of Railway Bridges

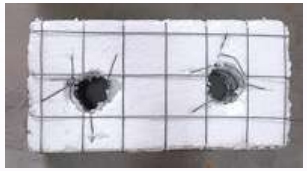


Contributions towards BIS

Condition Assessment of RCC Structures

Technologies for Climate resilience

SECROBUILT TECHNOLOGY FOR HOUSING



Lightweight Block

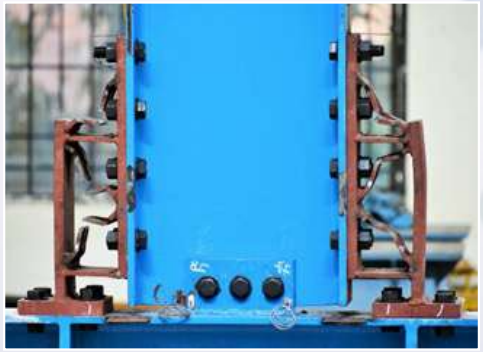
Rapid Assembly (1 storey per day)

Prefabricated Building Systems using EPS Panels

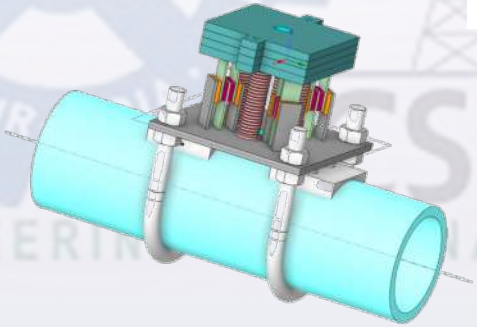
Technologies for Disaster resilience

Jut cavity bricks for enhanced seismic resilience

A cyclone-resistant shelter



Dissipative fuse link

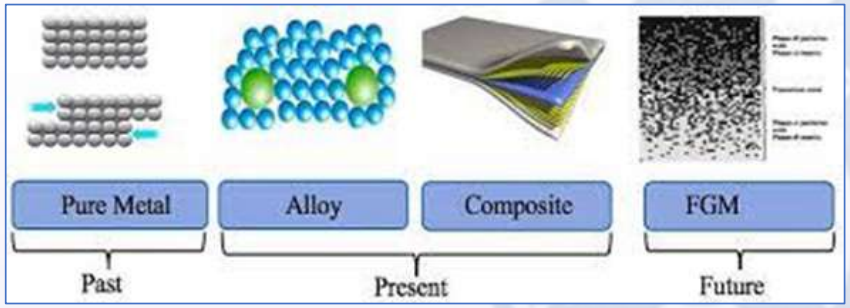


Adaptive dampers

Emerging Technologies

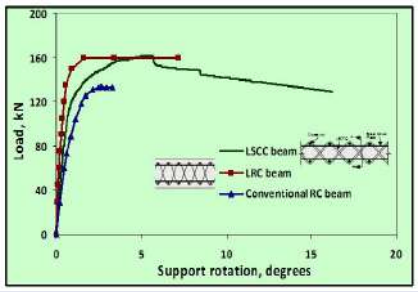
Bio-Inspired Functionally Graded Cementitious panels for Impact Resistance

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

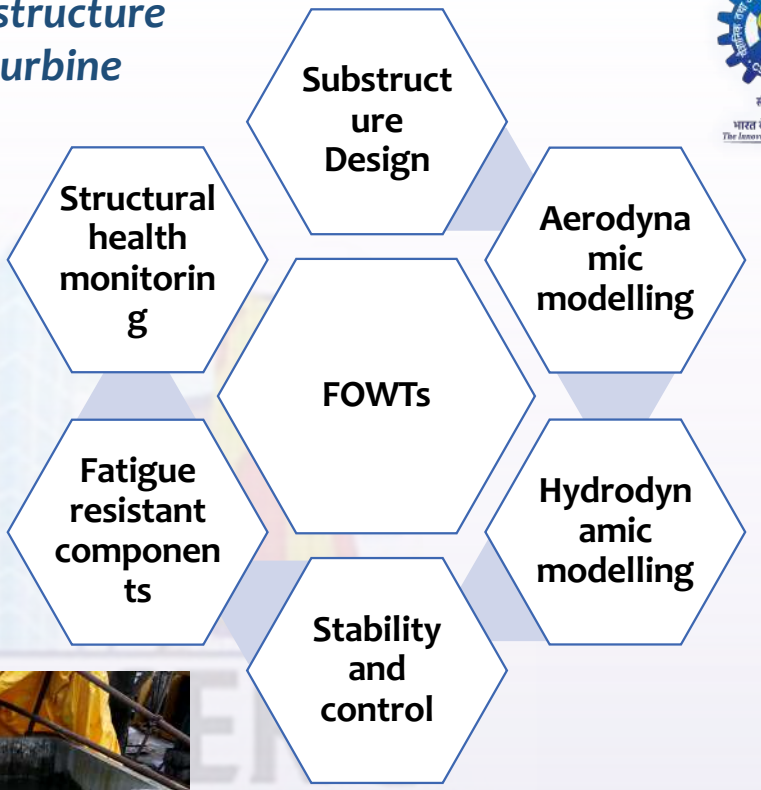


Laced Steel-Concrete Composite System

modular construction system with enhanced blast resistance



Supporting structure for wind turbine



Floatability and free decay test in water tank

Role & Relevance of CSIR-SERC

- *Climate resilient infrastructure*
- *Disaster Risk Reduction*
- *Sustainable and low carbon construction materials*
- *Translation of research into deployable technologies*

Science
Engineering
Policy

Engineering design inspired by nature

"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

- **Nature itself is an engineer; Nature has extensive talents**
- **Inquisitive to know how nature works; How this could be used to solve problems**
- **Bio-inspired engineering – biomimicry – biomimetics – abstraction of good design from the natural world to inspire engineering solutions**

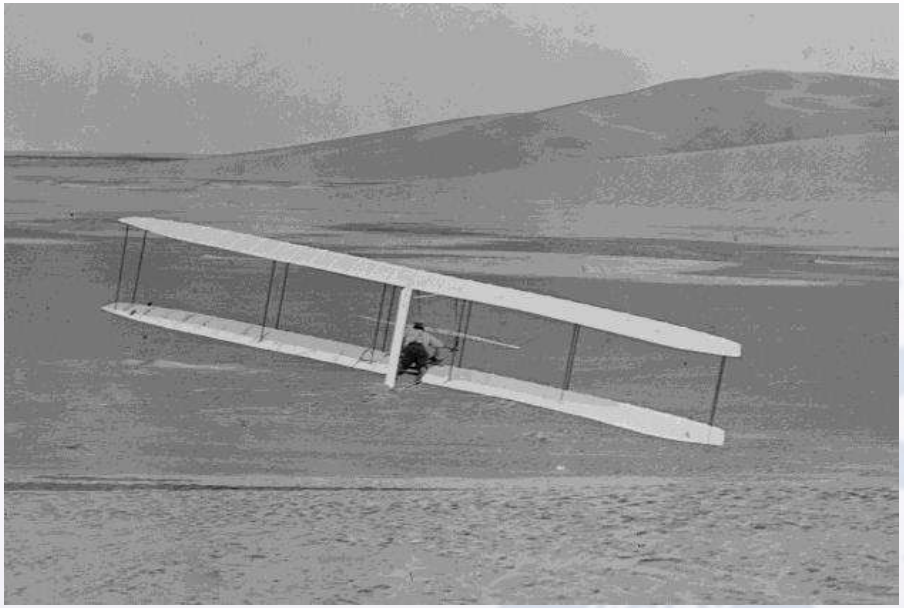
பறவையை கண்டான்
விமானம் படைத்தான்

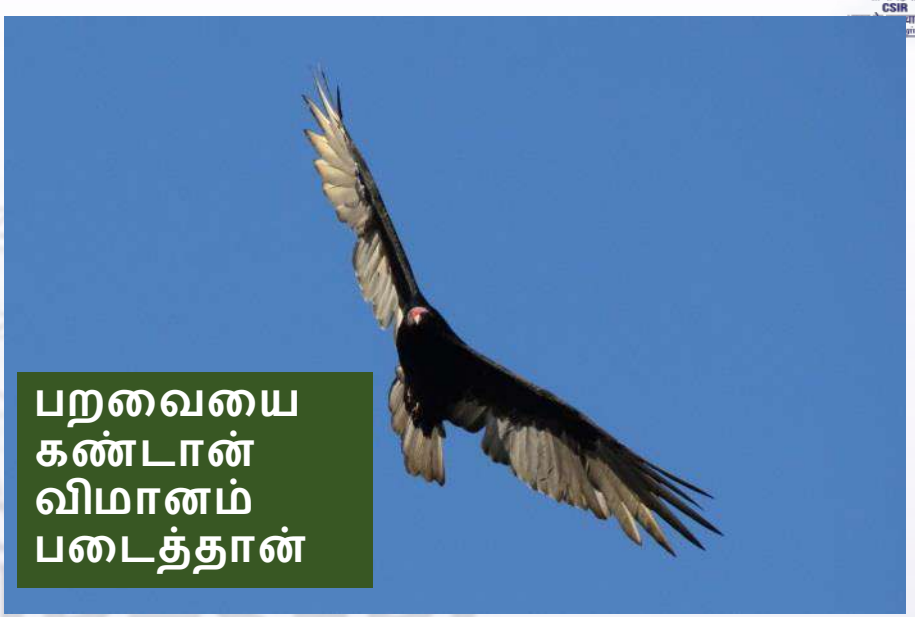
பாயும் மீன்களில்
படகினை கண்டான்

எதிரொலி கேட்டான்
வானொலி படைத்தான்

Air craft

Best example – inspiration from birds - action

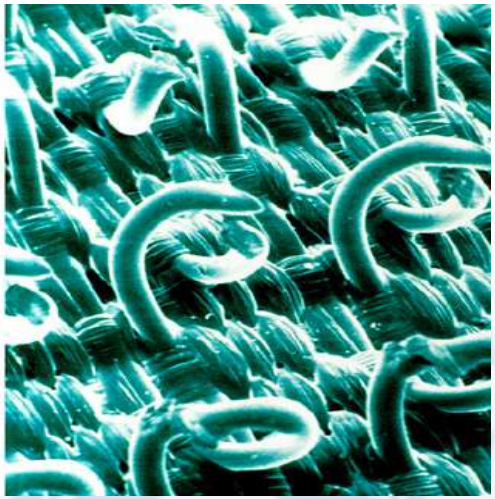


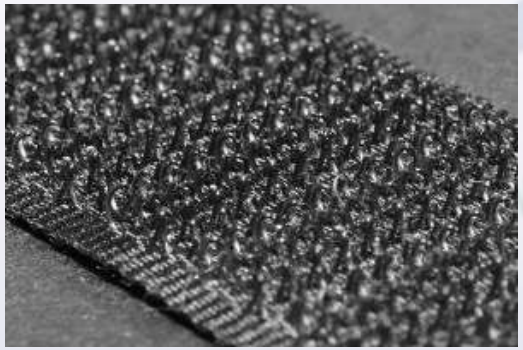


- around 1799, an Englishman named George Cayley began to document his observations of bird flight
- to develop a theoretical framework of flight that underlies modern human aviation today

Wilbur Wright flying in a glider he and his brother Orville designed, October 24, 1902.
Breakthrough - wing warping concept - Wright brothers success - the behavior in turkey vultures

Velcro inspiration from plants





Velcro Hooks. *Velcro Loops.*

- 1941 – George de Mestral – Swiss Engineer
- After a nature hike, noticed he and his dog covered with burrs – plant seed-sacs clung to surface
- Curious and analysed to find small hooks were found clinging to the surface
- He designed Velcro – two sided fastener – one side with stiff hooks and other side with soft loops - hook-and-loop principle
- Velcro - Velour + Crochet

Photographs by Scott Camazine; Custom Medical Stock Photo
http://www.bloomberg.com/slideshow/2013-08-18/14-smart-inventions-inspired-by-nature-biomimicry.html#slide2
https://sites.psu.edu/eseminar/2014/03/09/inspiration-of-velcro-from-nature/

Bullet Train inspiration from birds - shape

- Bullet Train - the fastest train in the world
- air pressure changes when the trains emerged from tunnels produced loud noise
- Designers needed to meet noise reduction standards for environmental and human experience considerations

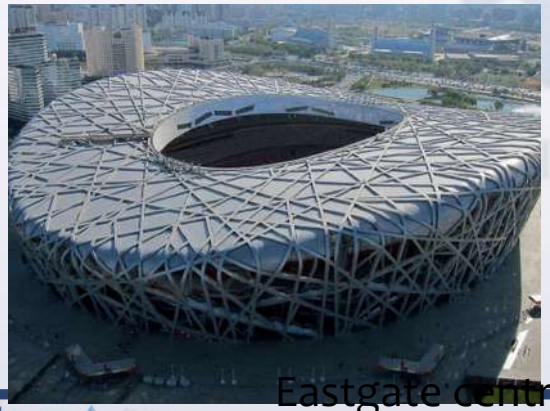
- Inspiration from the beaks of Kingfisher birds to model the noses of the trains
- Beaks of these birds gradually increase in diameter from tip to head allowing them to dive at high speeds into water with hardly any Splash
- By modeling the beak geometry on the bullet train noses, the West Japan Railway Company was able to produce the *500 Series trains with overwhelming functional* benefits.
- The new trains were quieter, ten percent faster, and used 15 percent less electricity than previous models (Venton, 2011).

Photographs by Hiromi Okano/Corbis; West Japan Railway Co. via Bloomberg http://www.bloomberg.com/slidesho
nature-biomimicry.html#slide4

Canopy structure inspiration from plants - shape

- use of fractal geometry - efficient shapes often seen in nature
- fractal geometry mixes art with mathematics to demonstrate that equations are more than just a collection of numbers
- best existing mathematical descriptions of many natural forms, such as coastlines, mountains or living organisms
- stand-alone structures obtain structural stability and strength from their shapes
- canopy structure of Terminal 3 at Germany's Stuttgart Airport

Organism level



Behaviour level

Eastgate centre, Zimbabwe

Ecosystem level

What is special about Nature

- 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

> - *computing that study problem solving techniques inspired by nature*
> - *attempts to understand the underlying principles and mechanisms of natural, physical, chemical and biological organisms that perform complex tasks in a befitting manner with limited resources and capability*

- 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

Nature inspired algorithm

In general, natural computing approaches should be considered when:

- **The problem is complex and nonlinear and involves a large number of variables or potential solutions or has multiple objectives.**
- **The problem to be solved cannot be suitably modelled using conventional approaches such as complex pattern recognition and classification tasks.**
- **Finding an optimal solution using traditional approaches is not possible, difficult to obtain or cannot be guaranteed, but a quality measure exists that allows comparison of various solutions.**
- **The problem lends itself to a diversity of solutions or a diversity of solutions is desirable.**

Types of Nature inspired algorithms

Evolutionary Algorithm (EA)

(based on Darwin's theory of evolution)

- Evolutionary Programming (EP)
- Evolution Strategies (ES)
- Genetic Algorithms (Ga)
- Genetic programming
- Differential Evolution
- Cultural Algorithm

Bio-inspired Algorithms (BIA)

(based on commonly observed phenomenon in animals)

- Particle Swarm Optimisation (PSO)
- Bird Flocking (BF)
- Fish School (FS)
- Artificial Immune Systems
- Lindermayer system
- Flower Polination

Swarm Intelligencebased Algorithms (SIA)

(based on collective behaviour of insects living in colonies)

- Ant colony optimization
- Bee Algorithm
- Bat algorithm
- Firefly algorithm

Applications of Artificial Intelligence in Structural Engineering

- Estimation of Effects of Natural Hazards
- Monitoring & Life Extension of Structures
- Design Optimisation
- Image processing for generation of numerical models

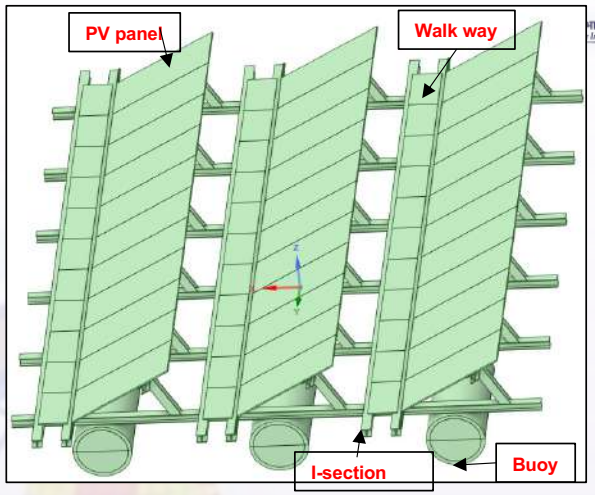
AI for Design of unit supporting structure

Objective function - minimisation of weight of the unit structure.

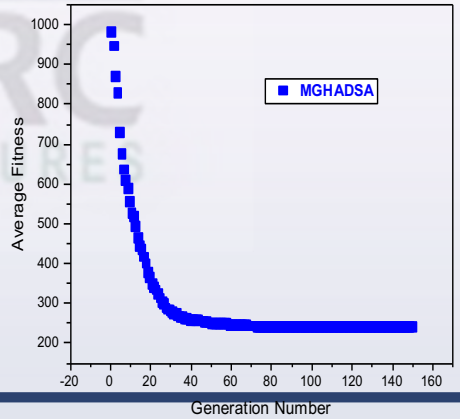
Constraints - criteria for strength & buckling.

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



Unit solar farm structure

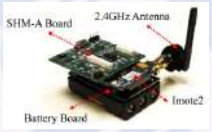


- **Optimal sections arrived : [1 1 1 1 1 1 3]**
- **1 denotes section 63x63x3.5 and 3 denotes section 52X102X6.4**
- **Optimal Weight of the unit structure : 238.456 Kg**

Structural Health Monitoring

Instrumentation Techniques and Sensor Development

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

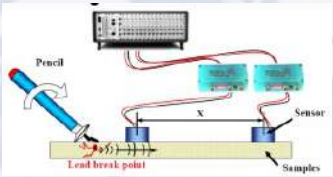


Bridges and Infrastructures

- Capacity enhancement of existing Bridges Innovative technique for evaluating / mitigation of longitudinal force on bridges
- Safety assessment of old bridges

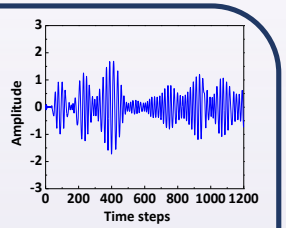
Pipeline structures

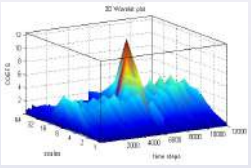
- Leakage detection using vibration, acoustic and guided wave propagation techniques
- Development of a baseline-free for localization of the defect/damage



Damage Detection and Localization

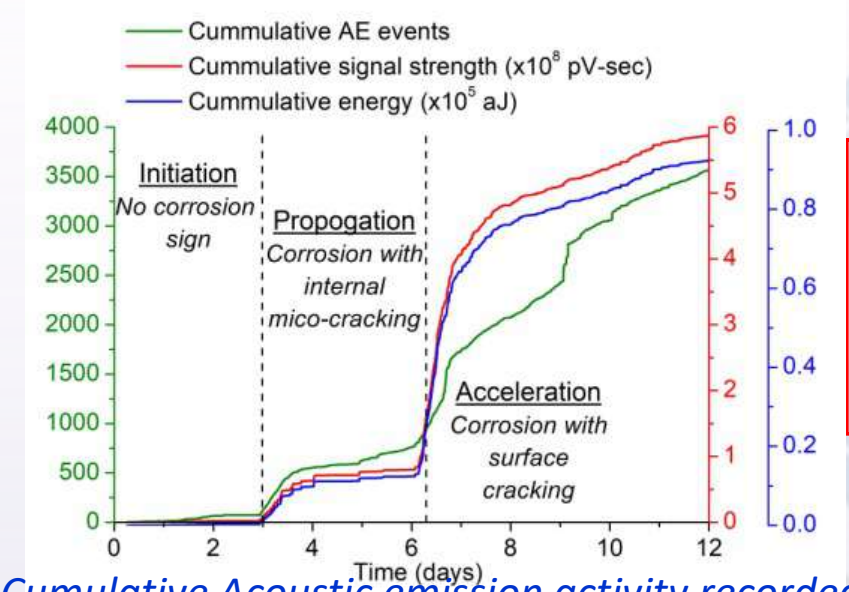
- Subdomain based damage detection strategies
- Multivariate analysis techniques for damage detection considering environmental and operational effects
- Signal Decomposition & Reconstruction





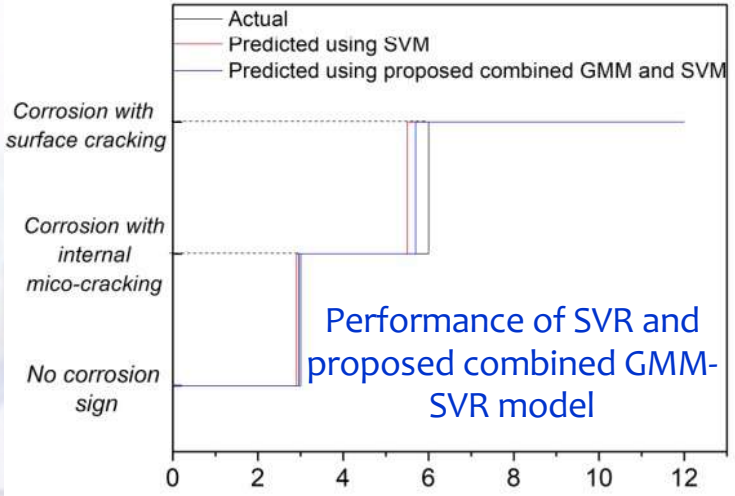
AI technique for corrosion-induced damage prognosis

Multi-layer method combining unsupervised and supervised



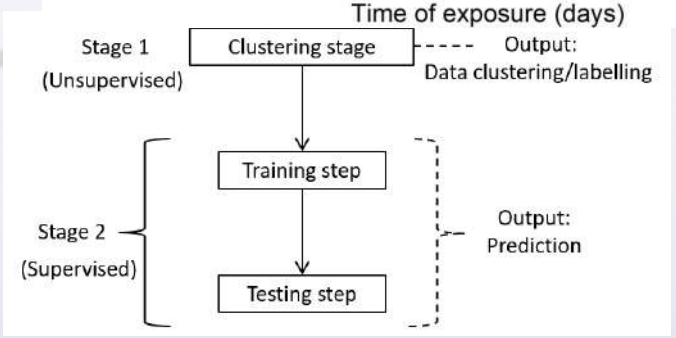
Cumulative Acoustic emission activity recorded

An automated corrosion monitoring diagnostic system – extremely important



Performance of SVR and proposed combined GMM-SVR model

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

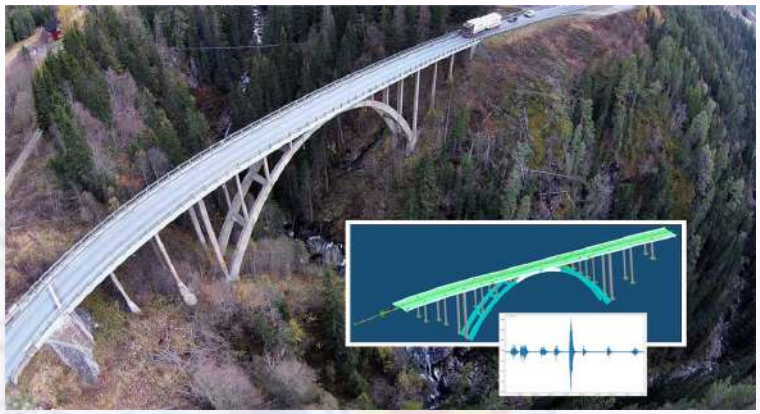


Proposed multi-layer method

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 infrasctuture*

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



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

அருமை உடைத்தென்று அசாவாமை வேண்டும்
பெருமை முயற்சி தரும்.

Which means

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

Thank You