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ENGINEERING SUSTAINABLE STRUCTURES

APCTT
Asian and Pacific Centre
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Technology and Innovation Conclave 2.0
Artificial Intelligence (AI) for Climate Action and Resilience

CSIR
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The Innovation Engine of India

AI-DRIVEN ENGINEERING FOR CLIMATE-RESILIENT INFRASTRUCTURE

Dr. Mohit Verma, Principal Scientist, ASTaR Laboratory
CSIR-Structural Engineering Research Center

OUTLINE

01 CLIMATE CHANGE

02 RENEWABLE ENERGY INFRASTRUCTURE

03 DISASTER RESILIENT ENGINEERING

04 CONCLUDING REMARKS

THE TWO-FRONT WAR ON CLIMATE CHANGE

Climate Change

Strategy A: Treating the Cause	Strategy B: Managing the Effect
Decarbonizing using Renewable Energy Infrastructure	Survival through Disaster-Resilient Engineering

The Accelerator: Artificial Intelligence

To effectively combat climate change; we cannot choose between prevention and protection.

WE MUST DO BOTH SIMULTANEOUSLY!

Strategy A: Treating the Cause

Renewable Energy Infrastructure

OFFSHORE WIND POTENTIAL ZONES

India has huge potential to generate the offshore renewable energy

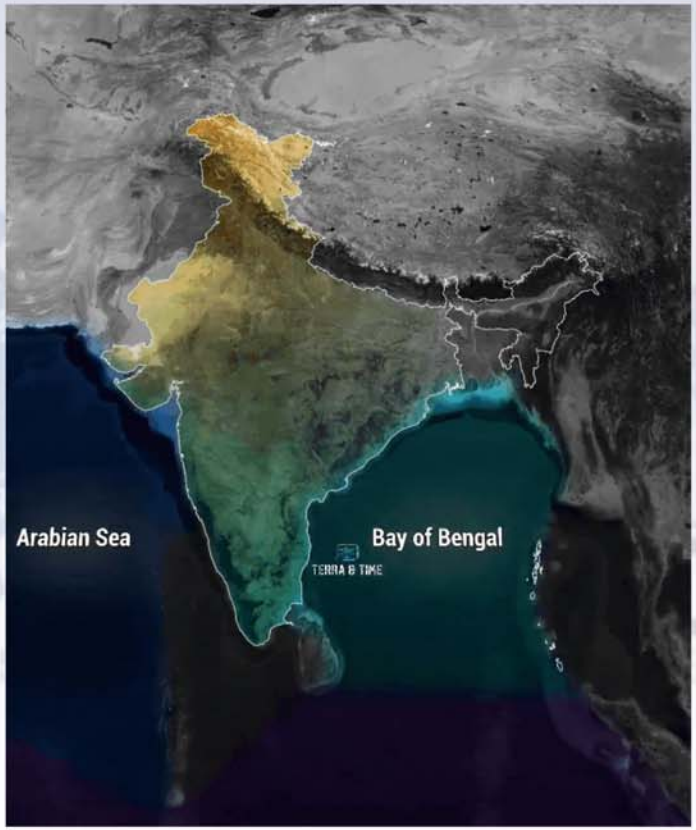
- Considering the vast coastal length (~11000 Km)
- Exclusive Economic Zone of up to 370 km extending to the sea

Ministry of New and Renewable Energy (MNRE), GoI

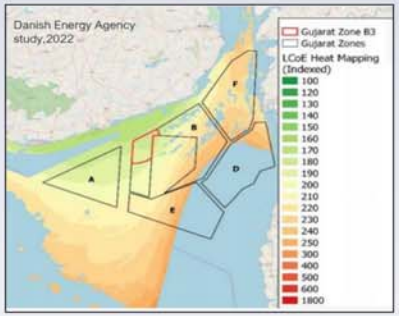
- FOWIND in 2013; National Offshore Wind Energy Policy in 2015; FOWPI in 2017
- First offshore wind project of 1 GW power near the Gulf of Khambat (2019) - 34 companies provided EOI

Ministry of Earth Sciences (MoES), GoI

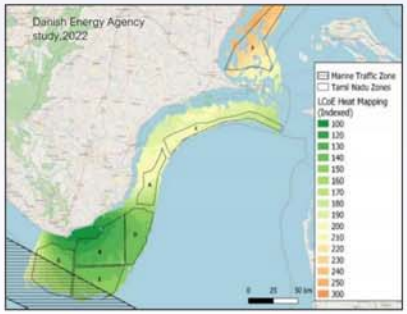
- Deep Ocean Mission



Gujarat



Tamil Nadu



Offshore Wind Potential Zones from 2022 studies by CoE for Offshore Wind & Renewable Energy

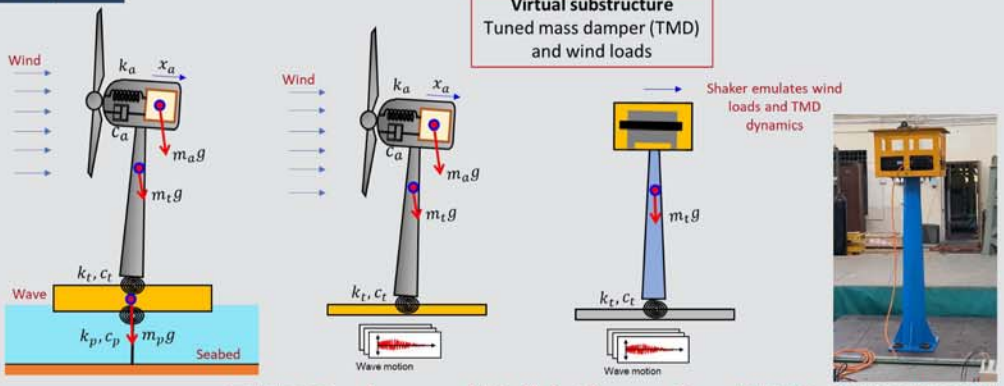
FLOATING OFFSHORE WIND TURBINES

Uncoupled

Free-Decay of the Floating Platform

Wind Loads on Turbine

Coupled

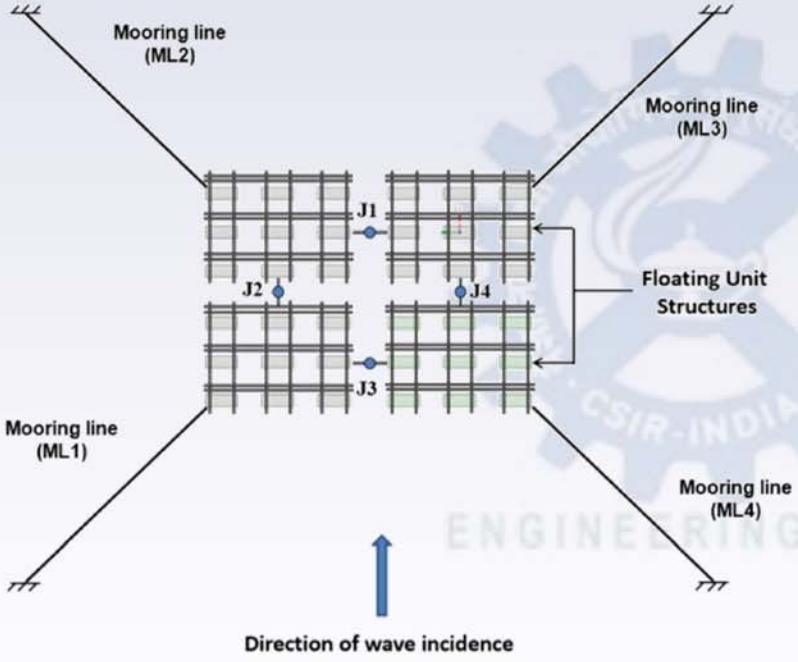


TMD Design and Validation using RTHS

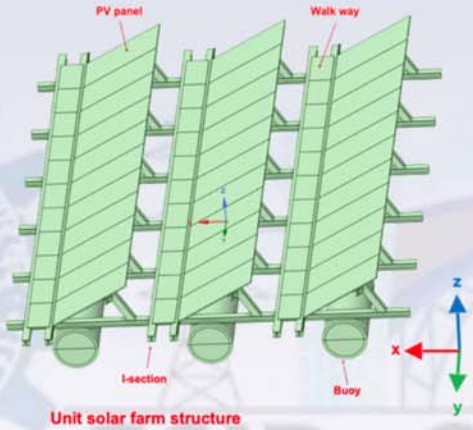
Tower-nacelle assembly

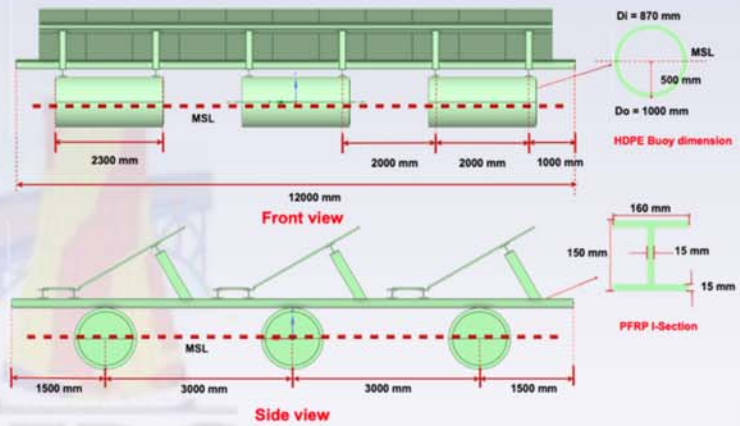
- Fully-coupled analysis
- Digital twin for monitoring and predictive maintenance
- Mooring failure analysis
- Fatigue crack growth studies
- High-capacity wind turbines
- Hybrid mooring system

FLOATING OFFSHORE SOLAR FARM



Design of Unit Floating Solar Farm Structure (10 kW unit structure)





- Hydrostatic and hydrodynamic analyses on a pontoon-type FOSF unit
- Wave-structure interaction simulations
- Analysis for regular and irregular wave conditions
- Performance with catenary mooring system

FLOATING OFFSHORE HYBRID ENERGY PLATFORM

Non-complaint configurations:

Withstand external forces without significant movement

- **Challenges of transportation**
- **Complex assembly**
- **Higher structural stresses**

Compliant configurations:

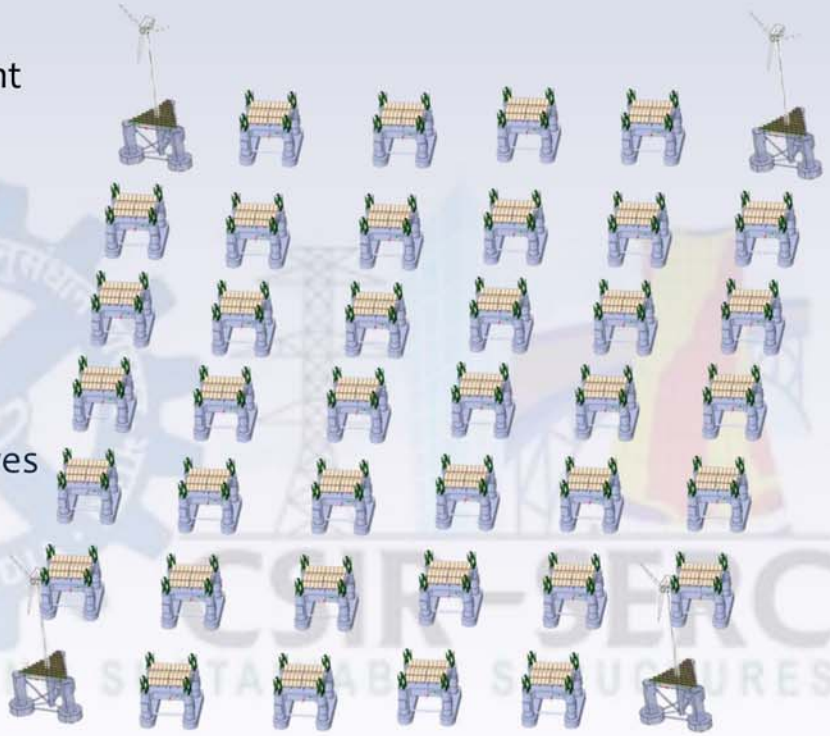
Flexible and designed to move with the waves and wind

- **Durability concerns**

Partially-complaint configurations:

Balance compliance and rigidity

- **Resilience to Extreme Conditions**
- **Reduced Stresses**
- **Versatility and Scalability**



Floating Offshore Hybrid Wind and Solar Farm

4-Column Configuration

3-Column Configuration

AATMA-NIRBHAR BHARAT

GOVERNMENT OF INDIA

MINISTRY OF NEW AND RENEWABLE ENERGY

7 AFFORDABLE AND CLEAN ENERGY

FLOATING OFFSHORE HYBRID ENERGY PLATFORM

Wind tunnel testing:
Scaled model of 5MW wind turbine with geometric scale ratio of 1:200 (Reynold's scaling)

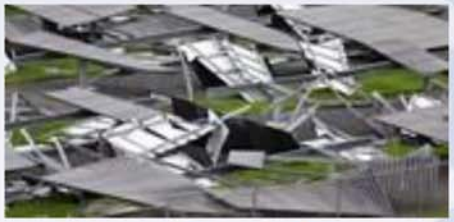
- Rotor Response for various Wind Speeds

Wave flume testing:
Scaled model of 5MW wind turbine with geometric scale ratio of 1:67 (Froude's scaling)

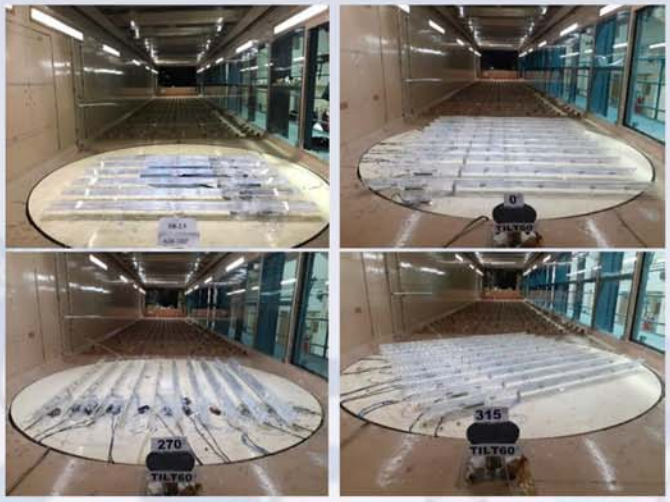
- Platform response for different wave conditions
- Simulated for 150m water depth

ONSHORE GROUND MOUNTED SOLAR

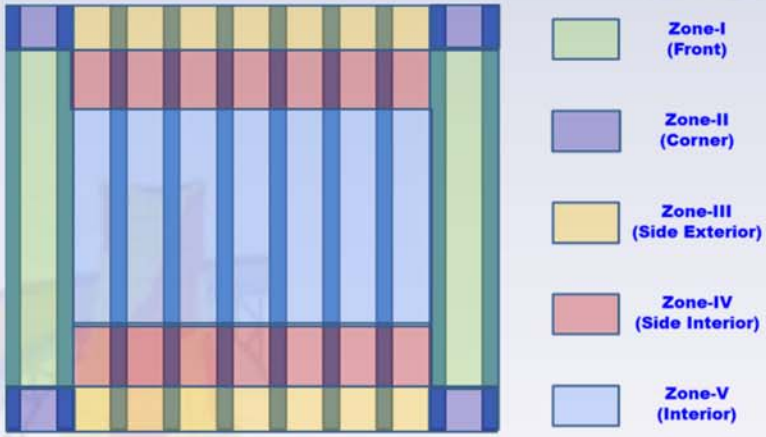
Solar Farm



Vulnerability to Wind Induced Damage



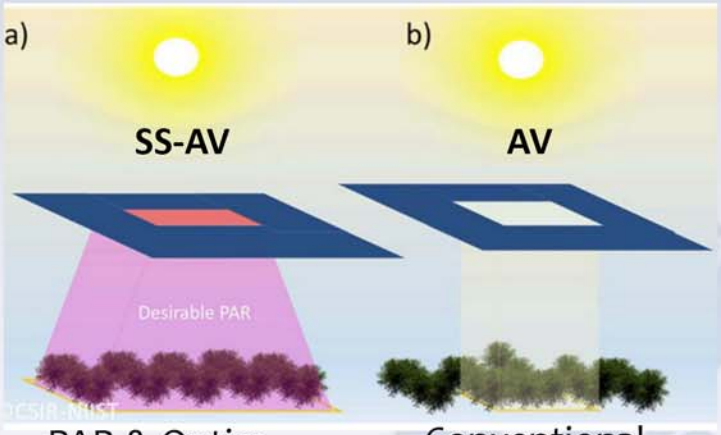
Models of Solar Arrays in Wind Tunnel



Design Guidelines

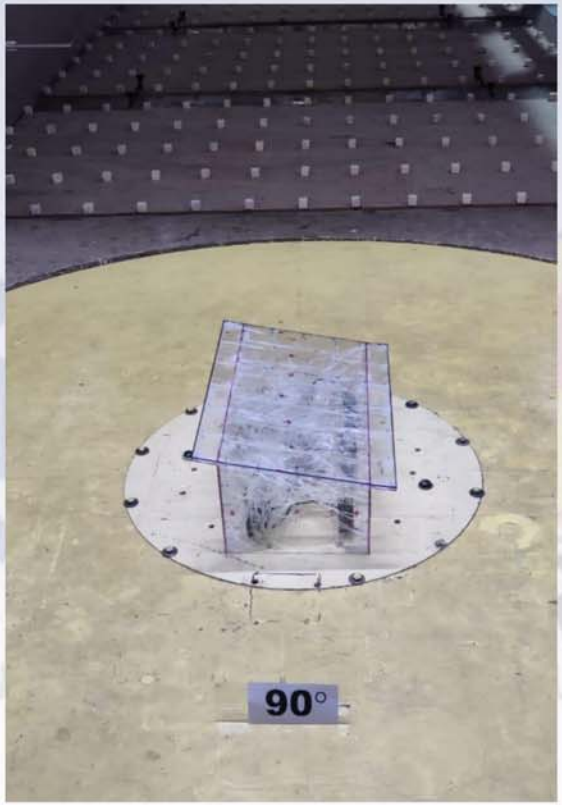
- Wind tunnel investigations on models of ground mounted solar PV arrays to evaluate wind force coefficients
- CFD simulations with the wind tunnel investigation
- Design guidelines for wind loads on ground mounted solar PV arrays
- Optimum design of support systems for selected solar PV array configurations

AGRIVOLTAICS: ONSHORE SOLAR GREEN HOUSE

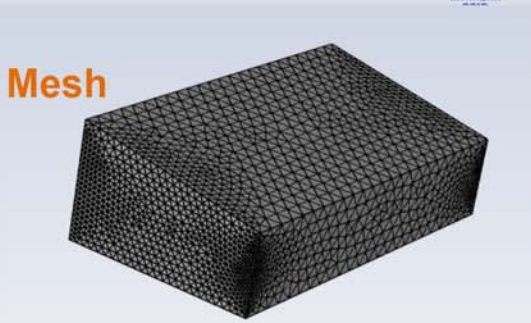


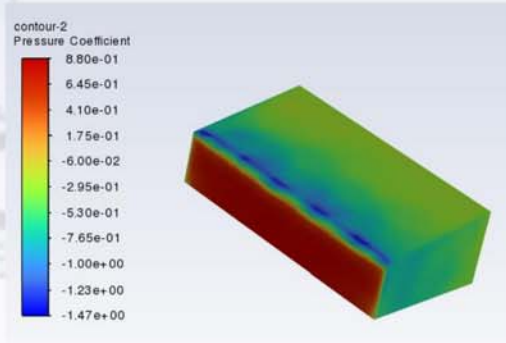
Spectral Converting Diverging Optics Integrated Solar Sharing Agrivoltaics Technology

- Wind tunnel and CFD investigations on Agrivoltaics
- Analysis and design of the 3-D frame work including members, joints and foundations of the structural system



Wind Tunnel Investigations





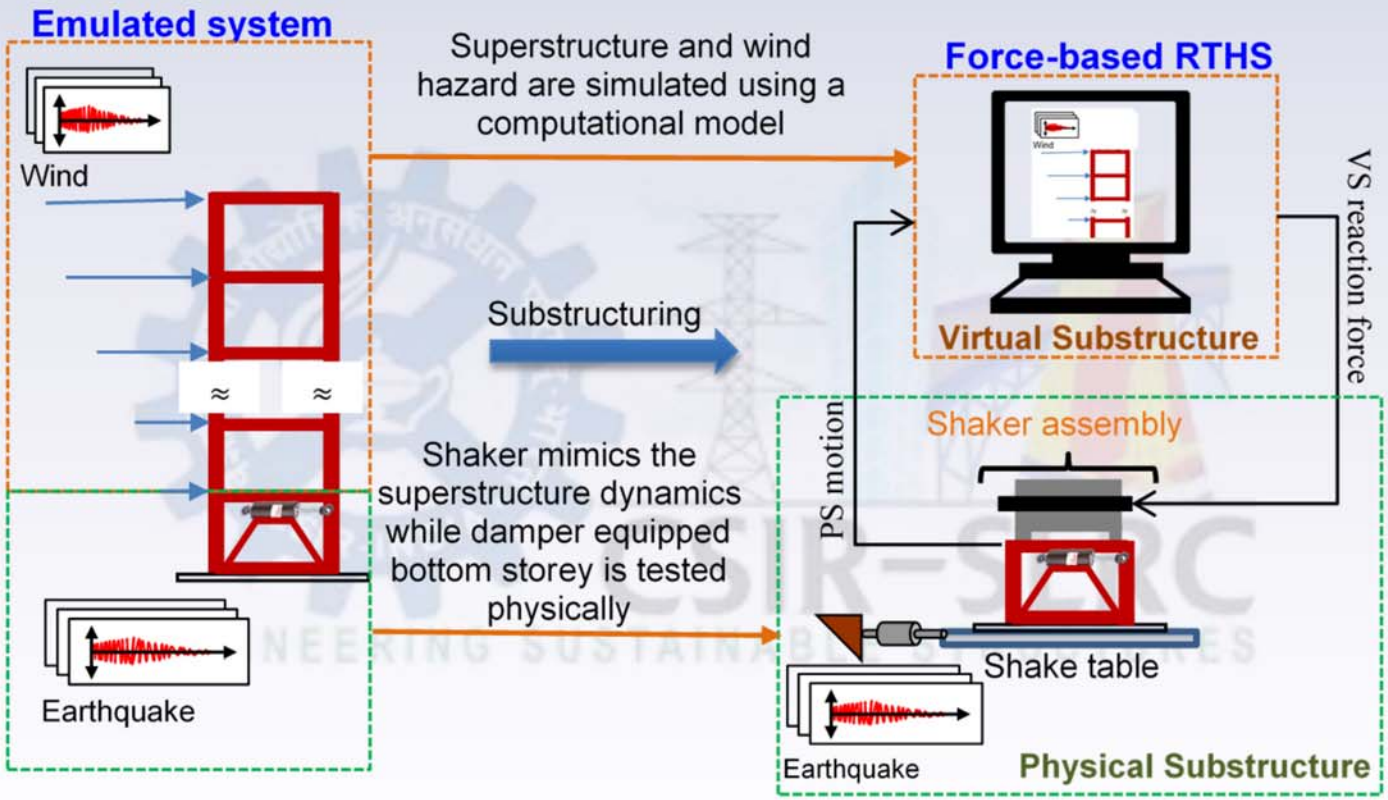
CFD Simulations on Low-rise Unit with Mono-Slope Roof

EXPERIMENTAL TESTING METHODS

Shake table for simulating earthquake hazard

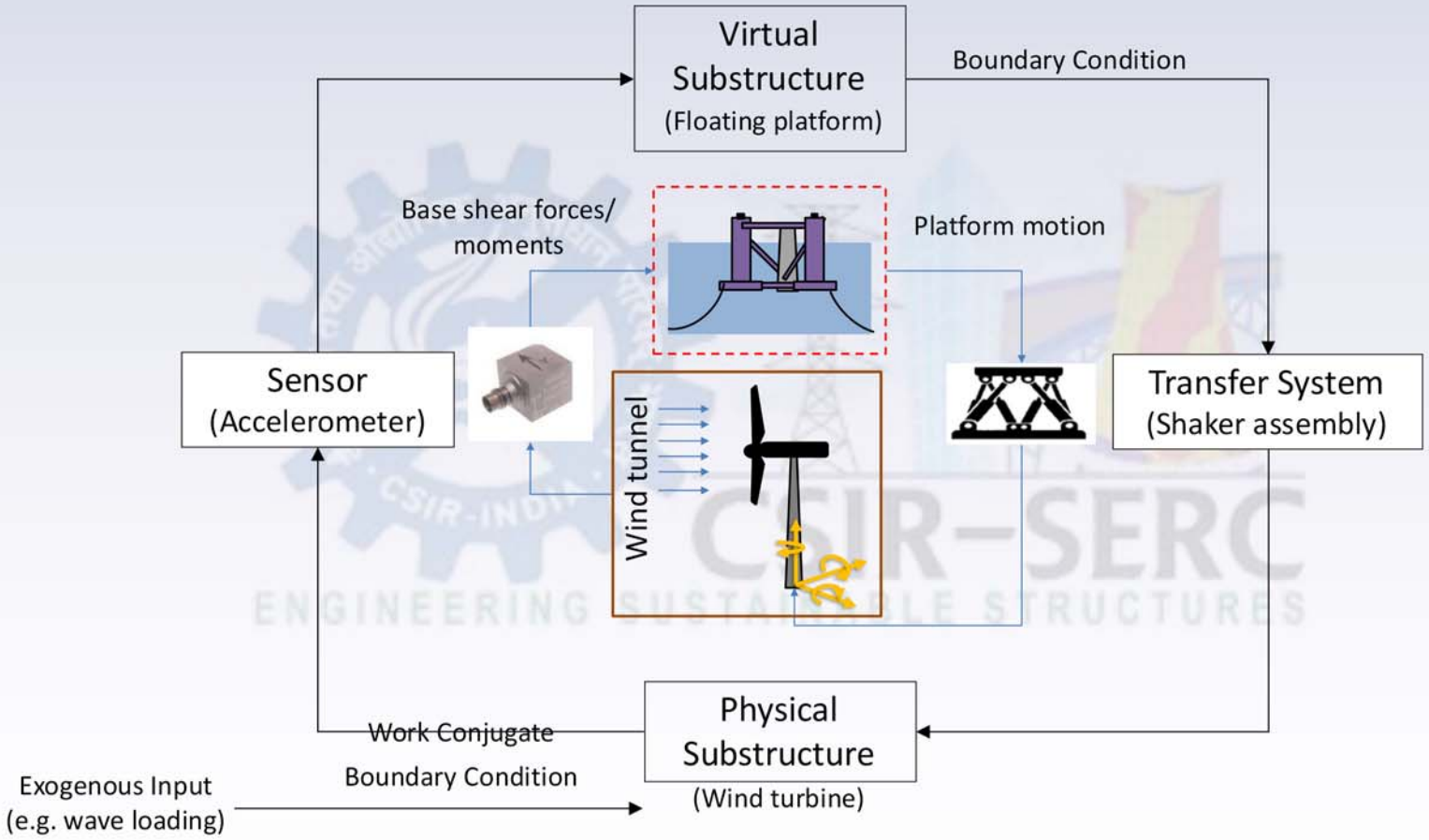
Wind tunnel for simulating wind hazard

MULTI-HAZARD REAL-TIME HYBRID TESTING

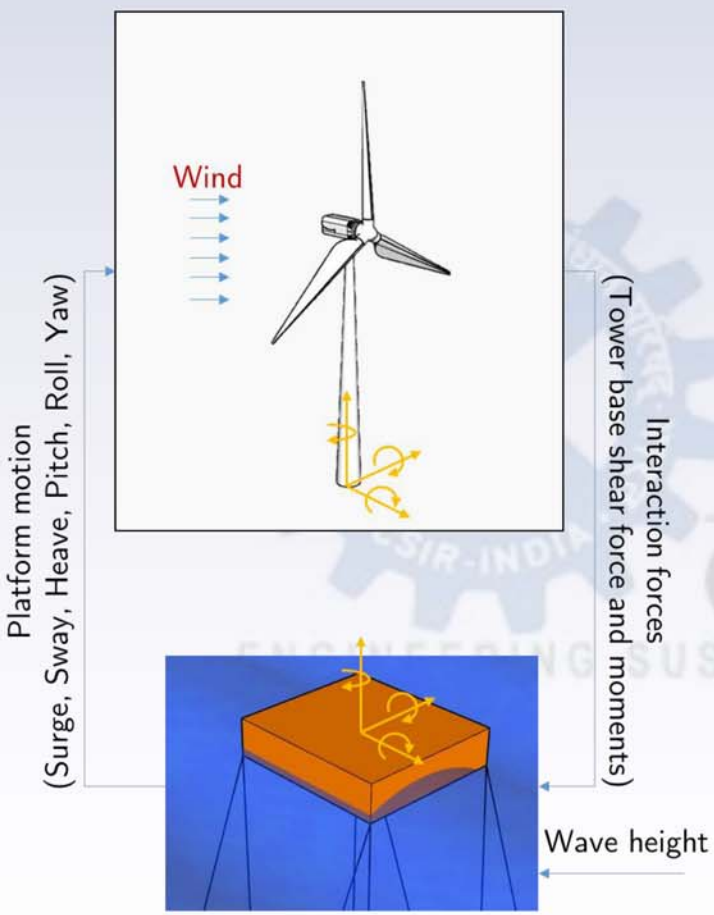


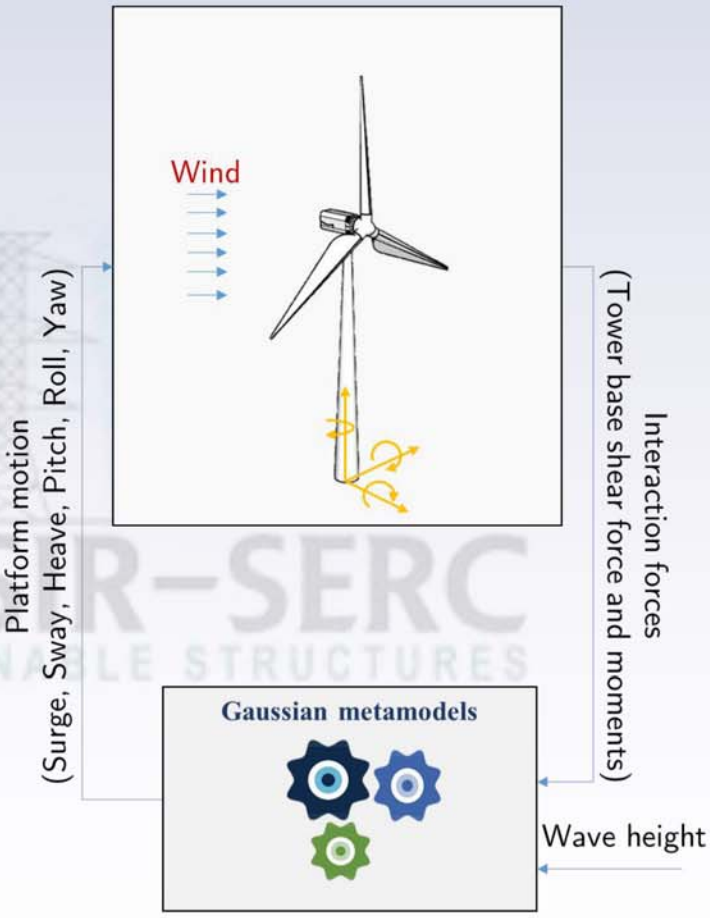
Multi-hazard RTHS

RTHS FOR FLOATING OFFSHORE WIND TURBINES



AI-IN-THE-LOOP

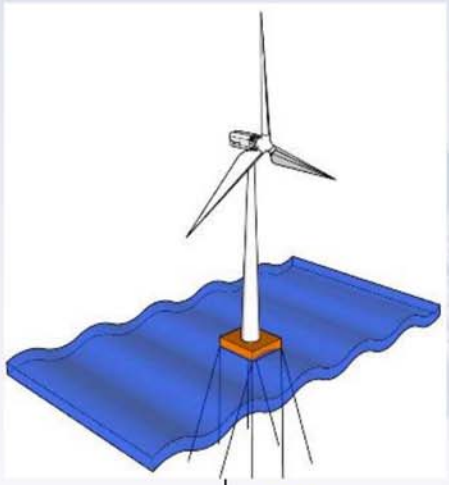




AI-BASED METAMODEL FOR FLOATING PLATFORM

Dataset generation	Metamodel development	Performance assessment

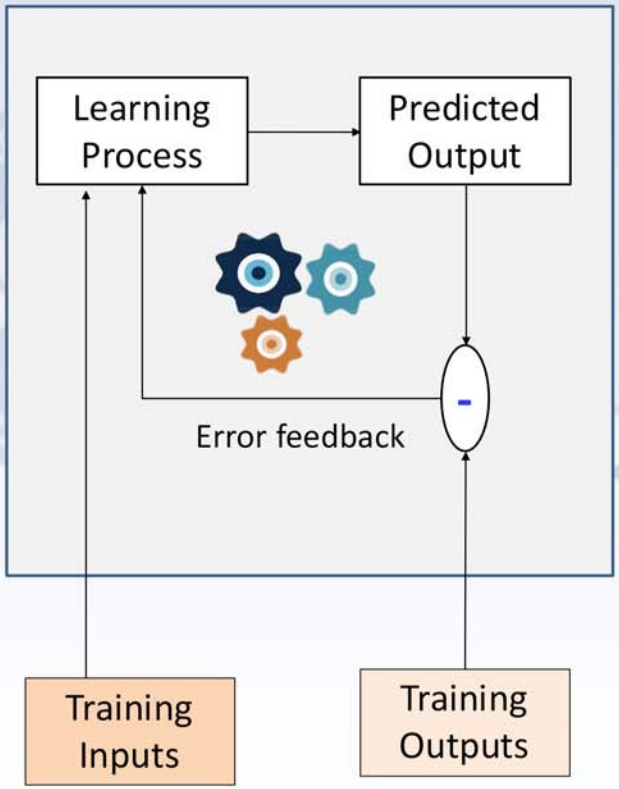
Aero-hydro-servo-elastic analysis



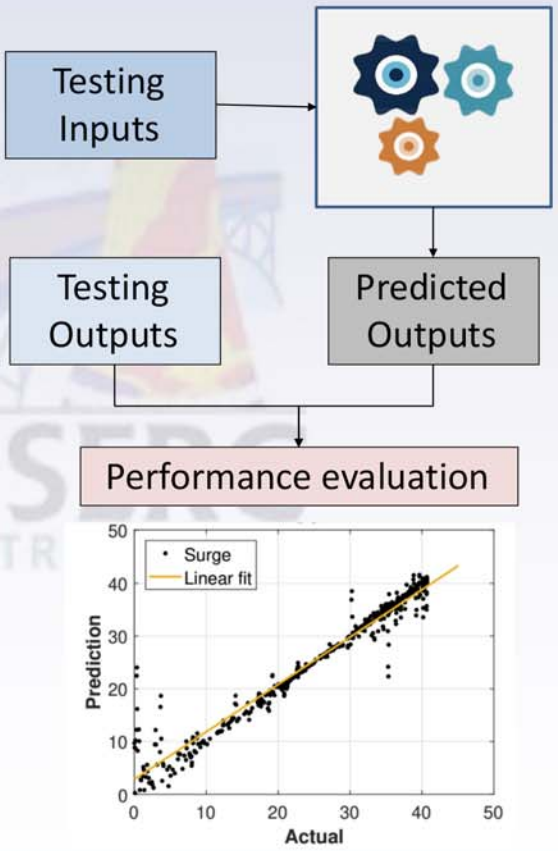
70% 30%

Training dataset	Testing dataset
Inputs	Inputs
Outputs	Outputs

Gaussian process metamodelling



Trained metamodel



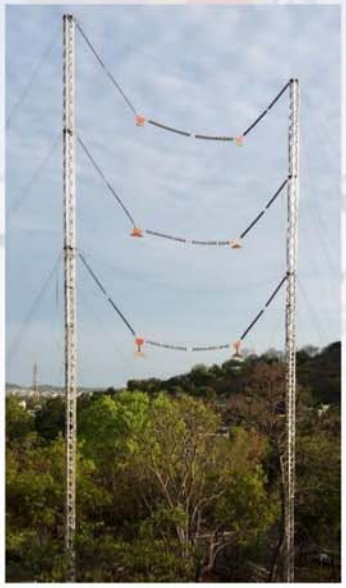
Strategy B: Managing the Effect

Disaster-Resilient Engineering

EMERGENCY RETRIEVAL SYSTEM

How the solution will facilitate in achieving the objectives

- Use of ERS will enhance performance of power distribution and supply by minimizing the power transmission interruption duration.
- ERS technologies available across the globe are very expensive.
- CSIR-SERC has developed an indigenous technology to produce cost-effective ERS is suitable for 33 to 800 kV transmission lines.
- The cost of indigenous ERS is about 40% compared to the imported ERS system.



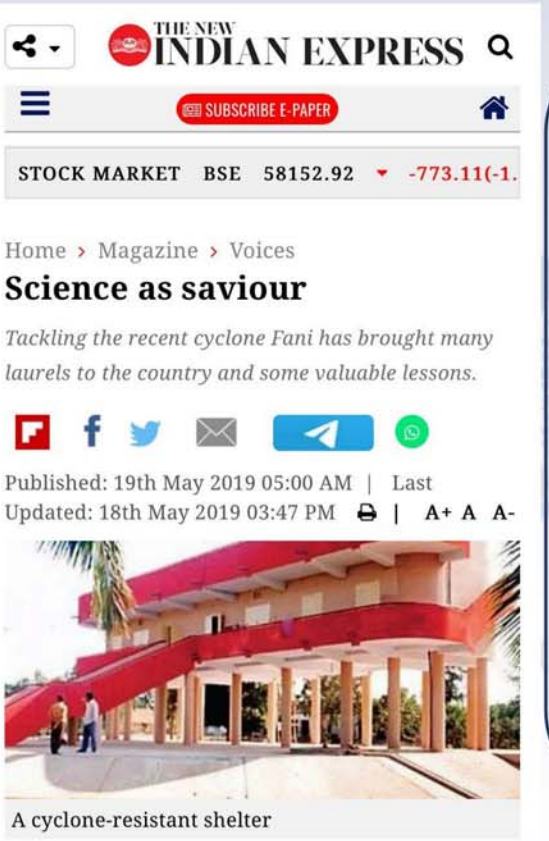
Technology Readiness level/transfer status :

TRL 8, Patents filled – 4 Nos. in India, USA and Canada

Tech. transferred on non-exclusive basis to –

- **M/s Advait Infratech Ltd., Ahmedabad**
- **M/s Hi-Tech Systems & Services Ltd., Kolkata &**
- **M/s IAC Electricals Pvt. Ltd., Kolkata**

ENGINEERING RESILIENCE AGAINST CYCLONES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Science as saviour

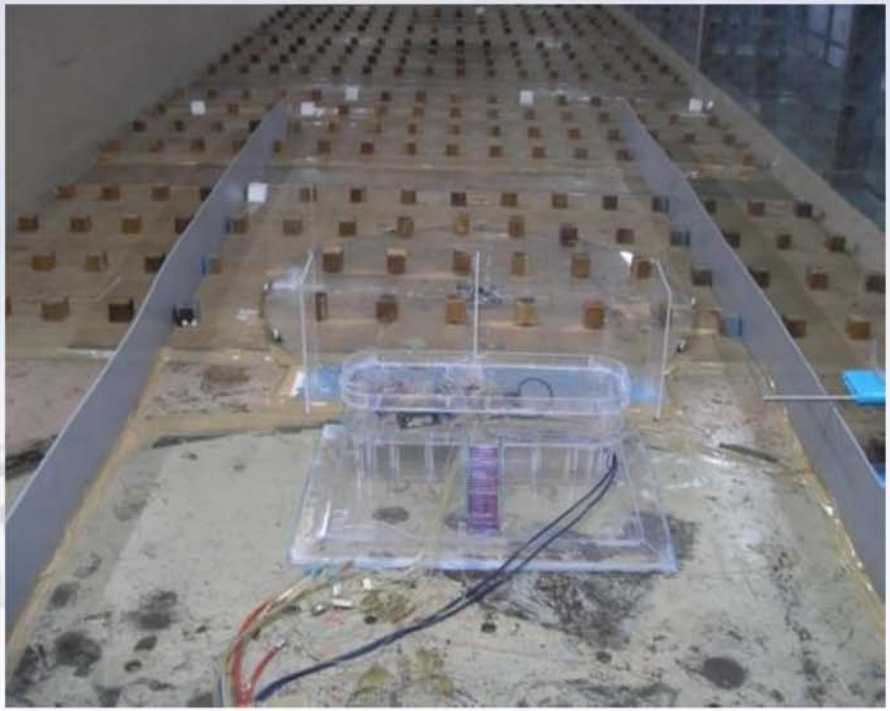
Tackling the recent cyclone Fani has brought many laurels to the country and some valuable lessons.

Published: 19th May 2019 05:00 AM | Last Updated: 18th May 2019 03:47 PM | A+ A A-

A cyclone-resistant shelter

Cyclone Shelters

- Shelter to more than 2 lakh people in 75 cyclone shelters (http://www.indianredcross.org/press-rel12-nov2013-2.htm)
- Withstood cyclones Phailin (2013), Hudhud (2014), Fani (2019), …



Wind tunnel investigations on cyclone shelter

EFFECT OF WIND ON TALL BUILDINGS

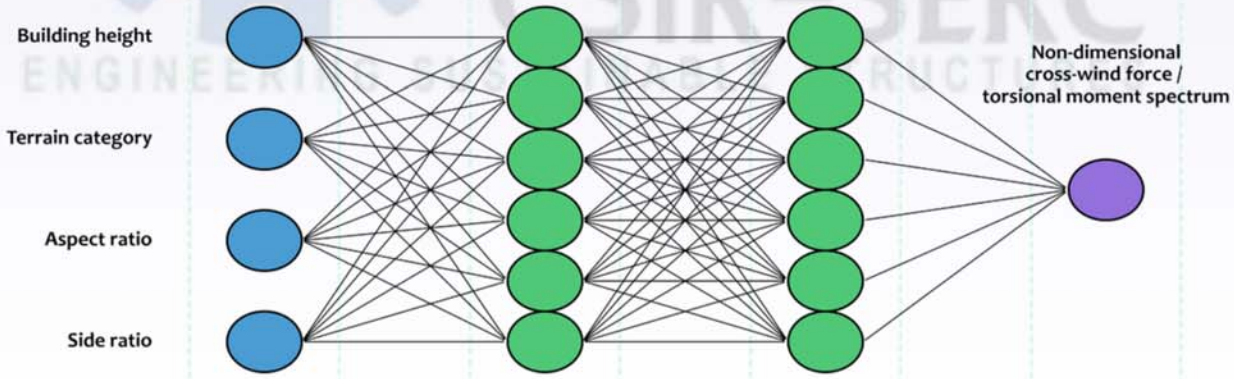
Wind hazard

National/international status : Empirical expressions for cross wind and torsional spectra applicable certain range / values of aspect ratio

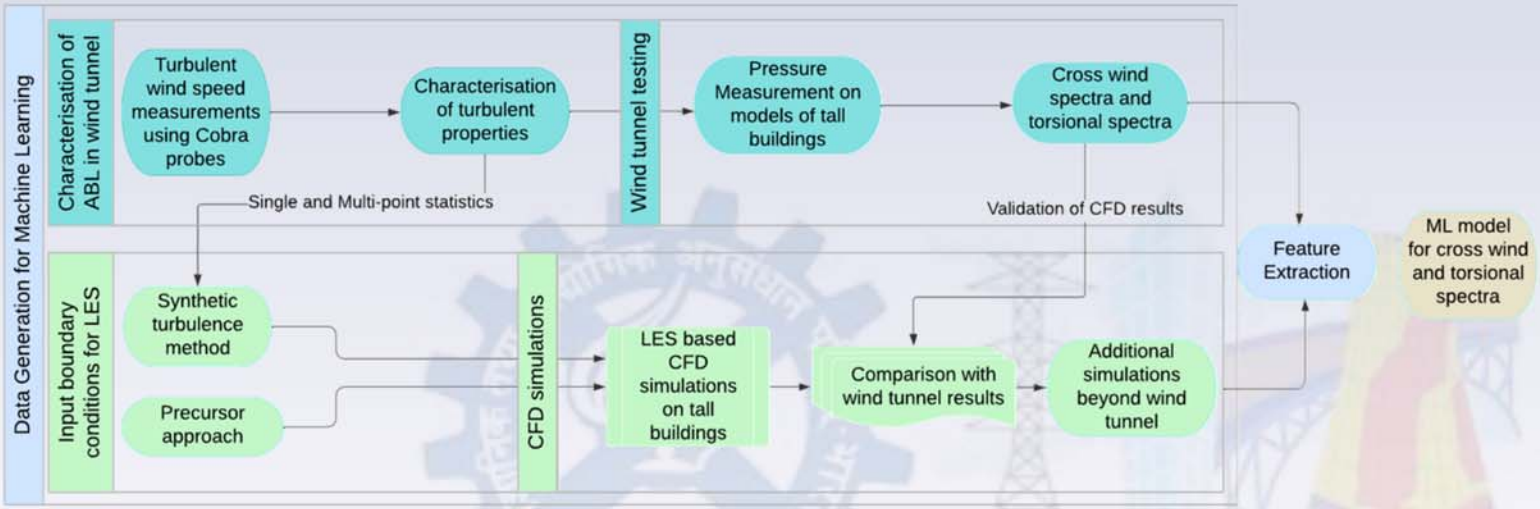
Gap/need :

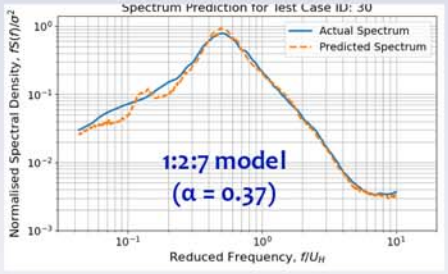
- Existing DAD accepts discrete and limited inputs - aspect ratio, side ratio and terrain category
- **Solution: Data driven ML based design**

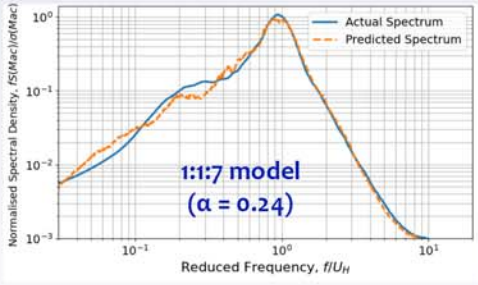
Impact after successful completion - Ensure safety of tall buildings against wind hazards

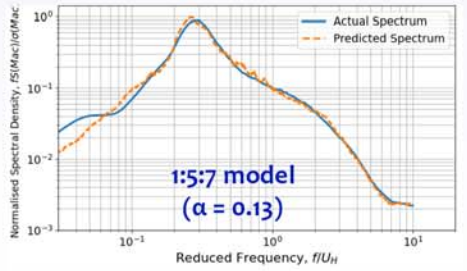


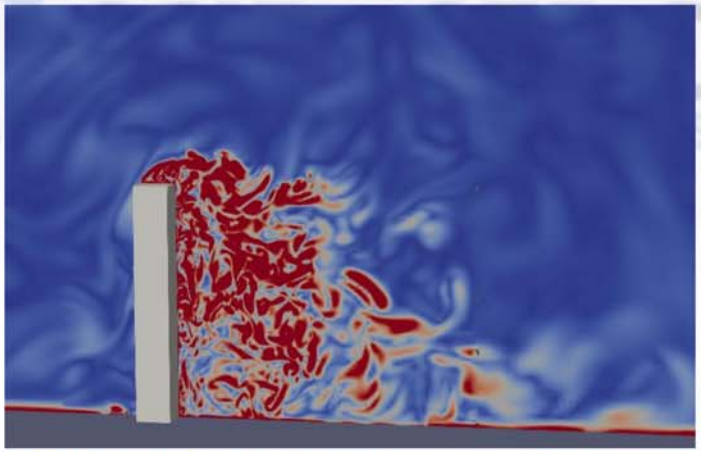
AI-DRIVEN MODEL FOR CROSSWIND AND TORSIONAL SPECTRA





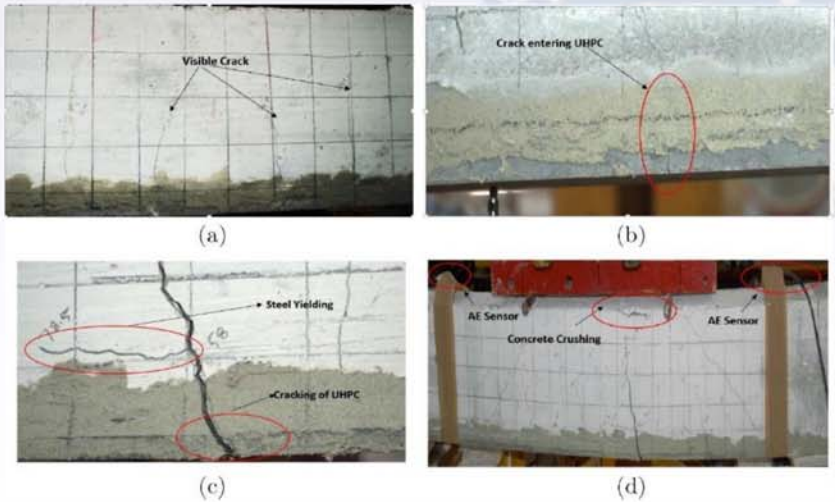




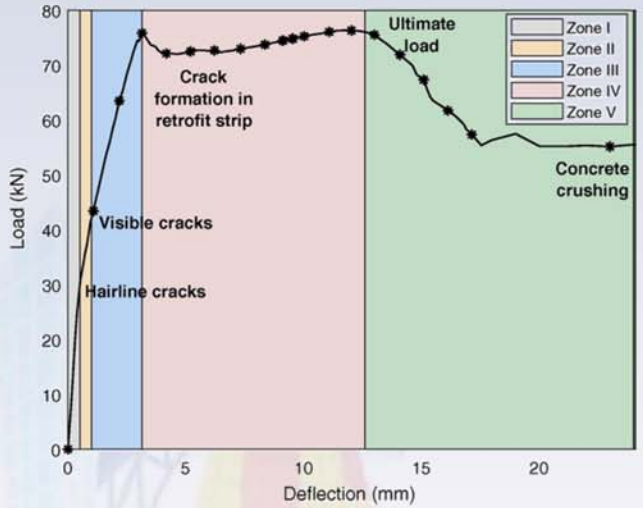


AI-BASED SHM OF RCC STRUCTURES

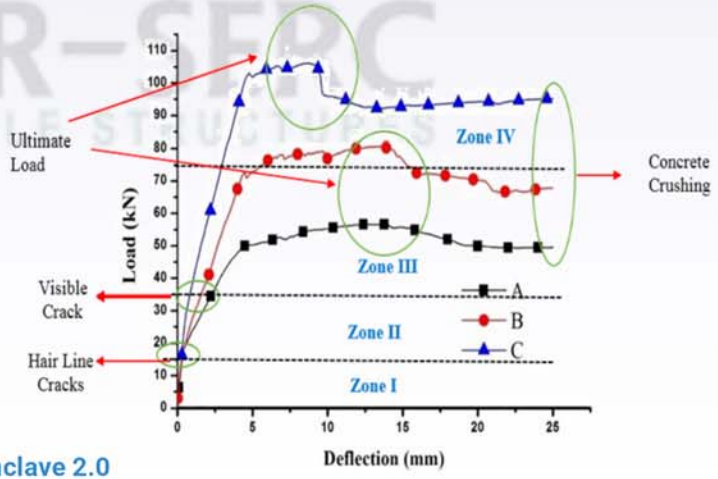
Test setup



Sequence of crack growth

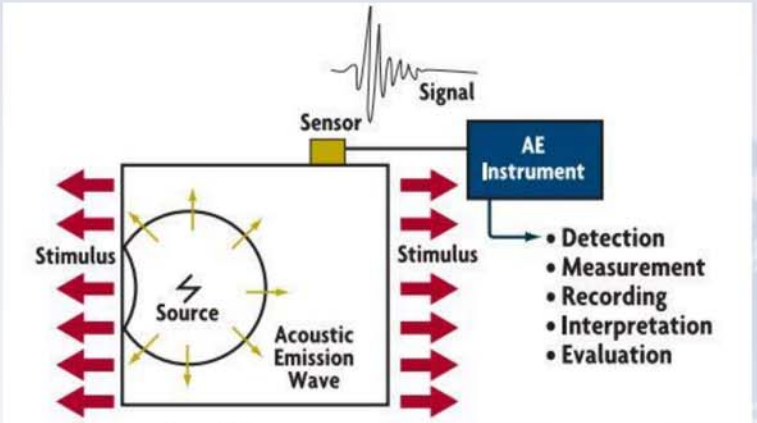


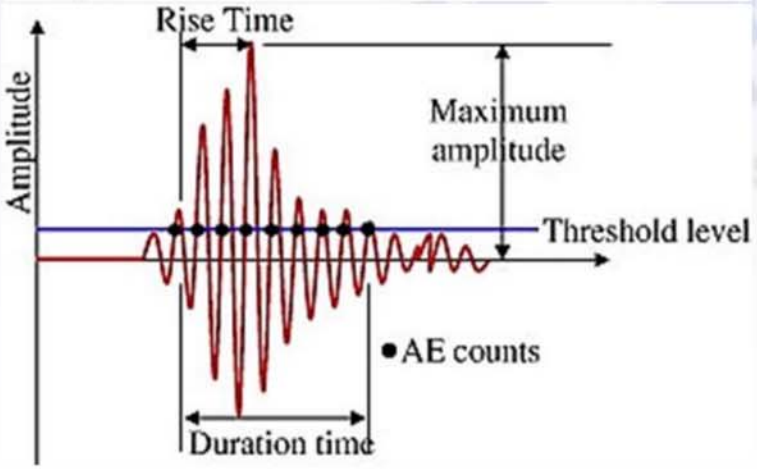
Damage zone classification



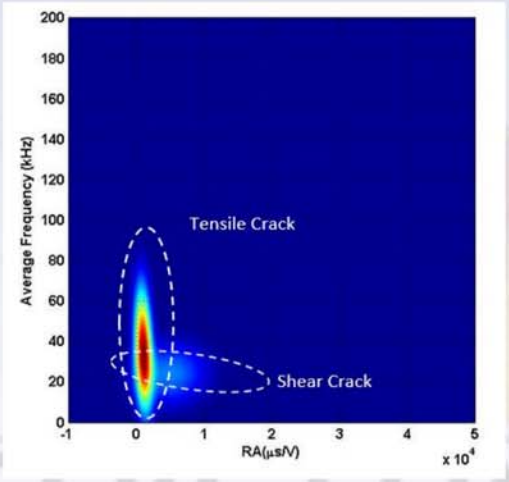
AI-ENABLED CRACK MONITORING

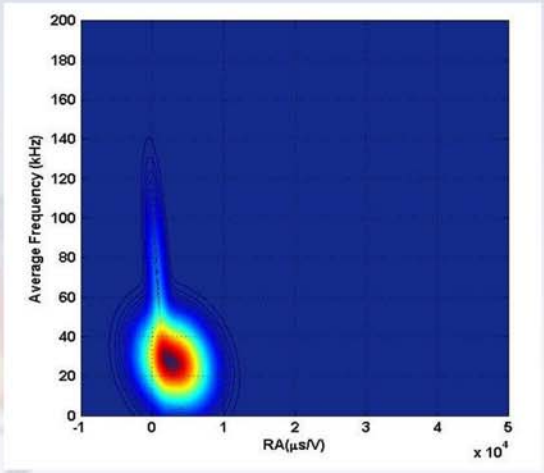
ACOUSTIC EMISSION MONITORING

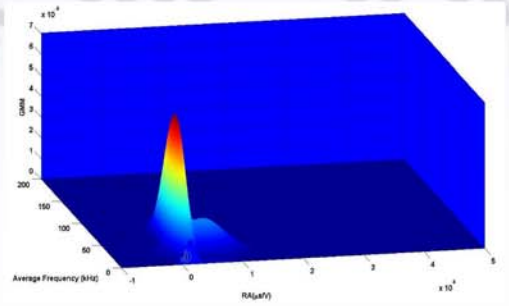


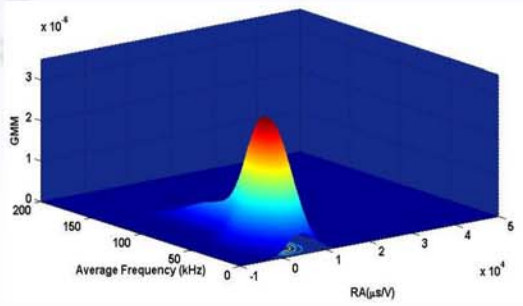


GMM Classification









AE results

THE CSIR-SERC COMMITMENT

- **The Challenge:** Climate change requires a "Dual Strategy"—Mitigating the cause (Renewable Energy) and hardening against the effect (Disaster Resilience).

- **The Solution:** CSIR-SERC combines Advanced Experimental Verification (RTHS) with AI-Driven Analytics to deliver this infrastructure faster and safer.

- **The Offer:** We are ready to collaborate on technology transfer, capacity building and policy formulation to scale these solutions across the Asia-Pacific region.

CSIR-SERC is prepared to partner with the nations represented here to deploy these tools, ensuring that our infrastructure is not a victim of climate change, but our first line of defense against it.

Thank you