OMAINTEC CONFERENCE EXHIBITION 2024

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ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING: THE FUTURE OF CONCRETE TECHNOLOGY AND MAINTENANCE

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Background on Concrete

- Concrete is the most widely used human-made material, second only to water in consumption.
- It is Essential for modern infrastructure due to its strength, affordability, moldability, and durability.

8% of global GDP

7% of global CO_2 emissions.

8 billion tons of natural aggregates and 2 billion tons of Portland cement globally.

$700 billion market value

Challenges in Modern Concrete Design

- Designing concrete with specific properties is increasingly complex due to the diverse components in the system.

Raw Materials:
Cement
Water
Aggregate
Admixtures

+

Processing:
Mixing
Transportation
Placing
Curing
Finishing

INPUTS

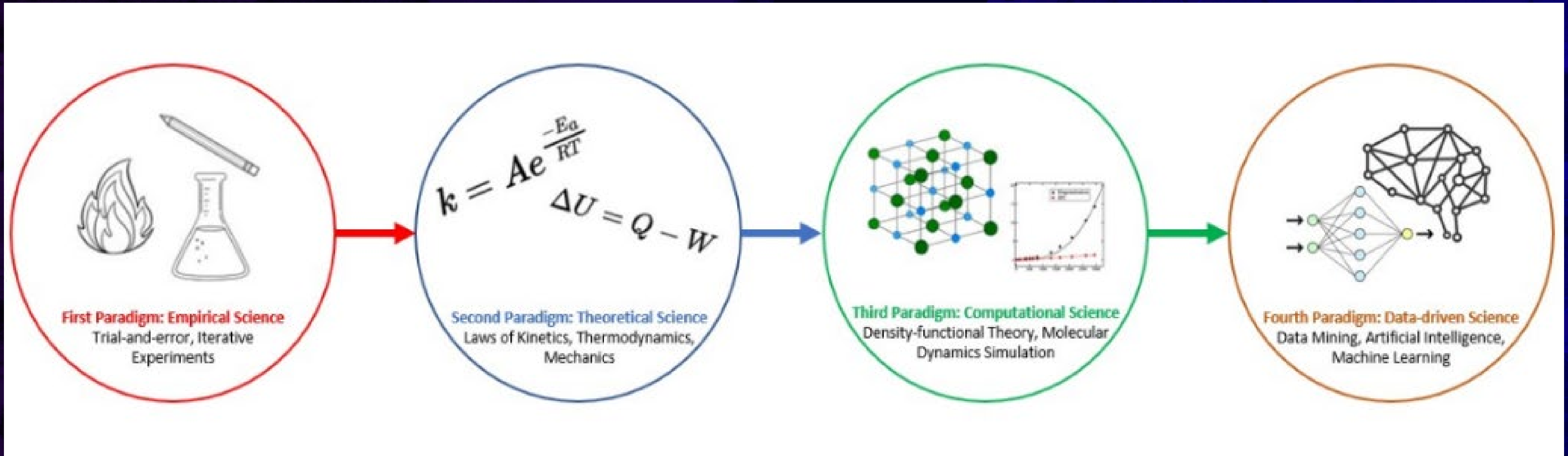
=

Product:
Strength
Durability
Permeability
Aesthetics
Insulation
Fire Resistance
Chemical Attack Resistance

OUTPUTS

Evolution of Concrete Science

- Concrete mix design and manufacturing have evolved significantly from 1900s to the current age
- Concrete went through 4 major paradigms



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AI and ML Applications in Concrete Technology

- AI optimizes and predicts concrete mix design for strength, durability, and sustainability by:
  - Prediction of concrete properties like compressive and tensile strength.
  - Creating low-carbon concrete mixes by reducing cement usage.
  - Analyzing hydration and shrinkage for better material performance.
  - Ensuring real-time quality control during concrete production.
  - Developing Digital twins to simulate and optimize concrete manufacturing processes.
  - Predict maintenance and structural health needs using real-time sensor data.
  - Detect and monitor cracks through visual inspections.

Casestudy 1: Optimizing Mix Design with Additives

- An expirmental study conducted in collaboration with the Arab Center for Engineering Studies (ACES) and the University of Sharjah.

- **Unconfined Compressive Strength** (MPa)
- **GGBS Content** (%)
- **Microsilica Content** (kg/m³)

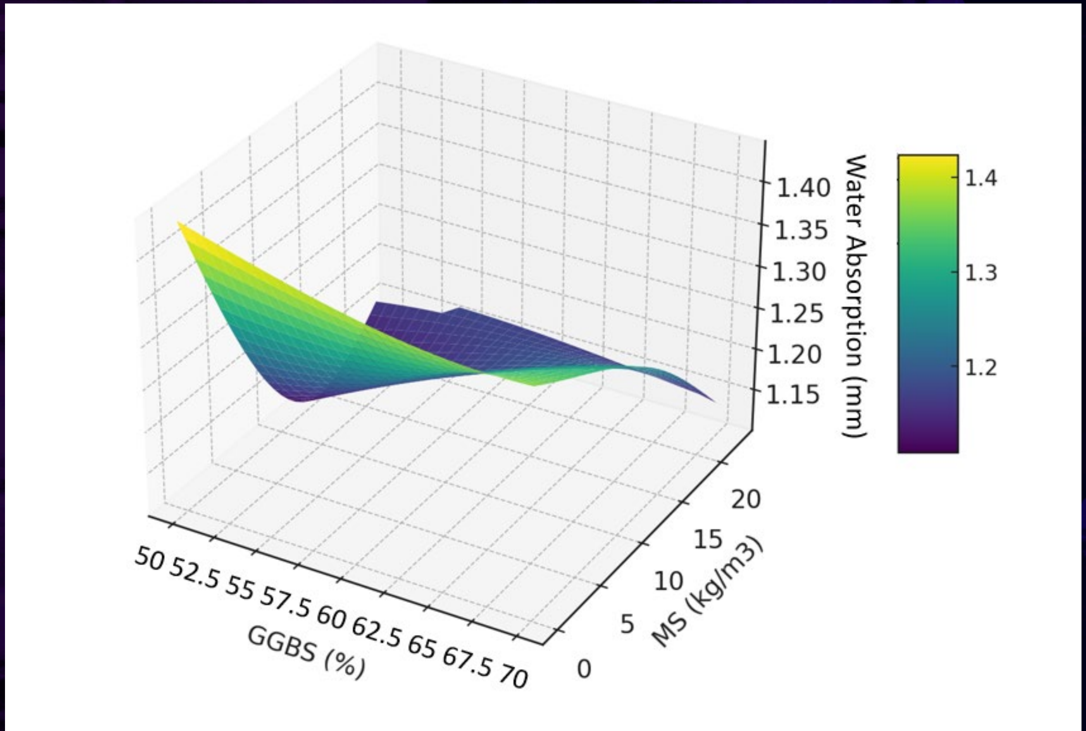
- **Water Absorption** (mm)

Minimize Water Absorption

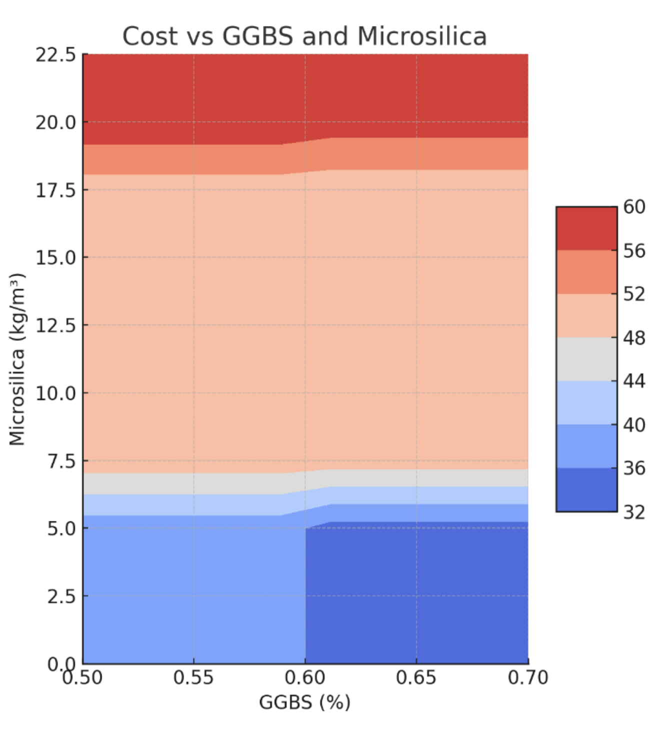
> 50 USD per m³

The identified optimal mix—61.1% GGBS and 14 kg/m³ Microsilica—achieved:
Water permeability: 1.37 mm.
Cost: 49.5 USD/m³.

Casestudy 1: Optimizing Mix Design with Additives



3D Surface-Plot between MS, GGBS and Water Absorption



Contour plot illustrating the relationship between GGBS percentage, Micro silica content, and concrete mix costs

Casestudy 2: Concrete.ai

concrete.ai

- The model was trained using historical data from concrete producers, including material properties, supply chain information, and past mix performance.

- Material properties and availability (e.g., cement type, aggregate quality)
- Desired performance objectives (e.g., target compressive strength, durability).
- Sustainability goals (e.g., carbon footprint reduction).
- Cost constraints.
- External factors like regional regulations or environmental conditions.

INPUTS

=

- Optimized concrete mix designs that meet the specified performance, cost, and sustainability requirements.
- Predicted properties of the proposed mix, such as compressive strength, setting time, and carbon footprint.
- Cost analysis and carbon footprint reduction metrics for each design.
- Recommendations for implementing the mix design in production.

OUTPUTS

Casestudy 2: Concrete.ai

- Field testing showed average material savings of $6.59 per cubic meter.
- Achieves an average carbon footprint reduction of 30% within one month of deployment.

Predicted properties

Property	Target	Reference	Optimized	
1d strength		1929 ± 284 psi	1091 ± 229 psi	↓838
3d strength		2367 ± 285 psi	2488 ± 270 psi	↑121
7d strength		3280 ± 229 psi	3596 ± 398 psi	↑316
14d strength		4283 ± 262 psi	4569 ± 384 psi	↑286
28d strength	≥ 5200 psi	5354 ± 450 psi	5604 ± 363 psi	↑250
56d strength		6310 ± 668 psi	6456 ± 563 psi	↑146

Casestudy 3: China Hebei Bridges

- A case study in Hebei Province in China analysed data from 2000 regional highway bridges.
- Data sources include manual inspections, remote sensing technologies (e.g., UAVs, thermal imaging, radar scanning), and integrated datasets from ground-penetrating radar (GPR) and satellite imaging.
- Structural conditions are rated on a scale of 1 (best) to 5 (worst) based on the Chinese Highway Bridge Structural Condition Evaluation Standard.

Casestudy 3: China Hebei Bridges

- **Current Condition Rating** (1-5 Scale)
- **Traffic load (ADT, ADTT).**
- **Environmental conditions (temperature, rainfall, etc.).**
- **Structural features (bridge length, age, type, etc.).**
- **Maintenance history (actions taken and their timing).**

INPUTS

=

- **Predicted Bridge Condition Ratings** (1-5 Scale)
- **Optimal Maintenance Schedules**
- **Estimated Repair Cost**
- **Maintenance Priority**

OUTPUTS

Casestudy 3: China Hebei Bridges

- **Generate Maintenance Schedule: The optimal solution (x_opt) specifies which components of which bridges require maintenance.**

Bridge ID	Current Condition	Predicted Condition (Next Year)	Maintenance Priority	Scheduled Time	Estimated Cost (USD)
B001	4 (Poor)	5 (Critical)	High	Q1 (Jan–Mar)	50,000
B002	3 (Fair)	4 (Poor)	Medium	Q2 (Apr–Jun)	20,000
B003	2 (Good)	3 (Fair)	Low	Q3 (Jul–Sep)	5,000
B004	5 (Critical)	5 (Critical)	Very High	Q1 (Jan–Mar)	100,000
B005	1 (Excellent)	2 (Good)	Low	Q4 (Oct–Dec)	2,000

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