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Vidya Academy of Science and Technology, Thrissur

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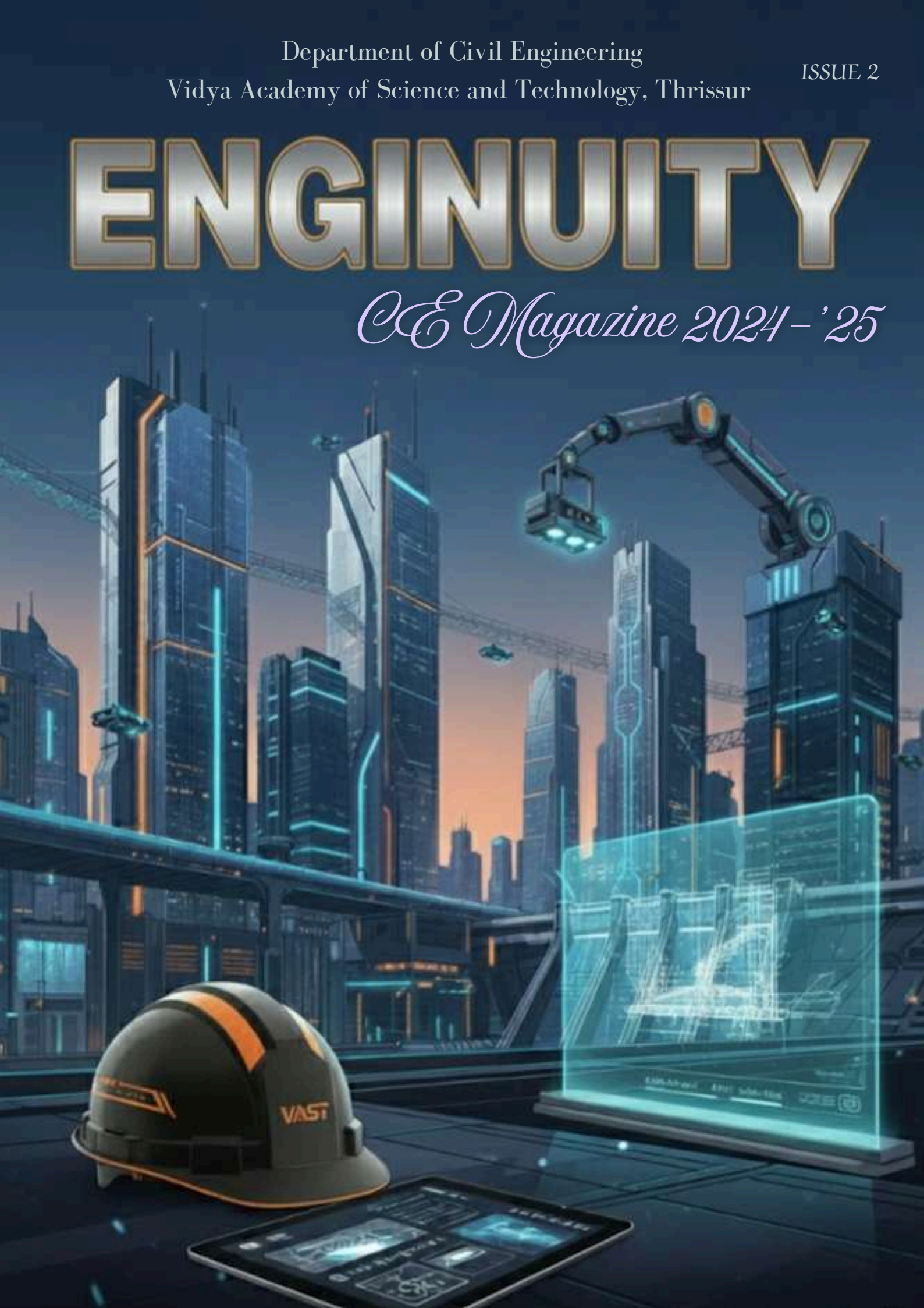

"WORK PERFORMED WITH HIGHER KNOWLEDGE OR SKILL, CAPACITY OR AMBITION, USUALLY BRINGS A CORRESPONDINGLY HIGHER REWARD."

~SIR MOKSHAGUNDAM VISVESVARAYA

Department of Civil Engineering
Vidya Academy of Science and Technology

Thalakottukara P.O., Thrissur - 680501

VISION

"Progress through quality education by keeping pace with new challenges in the field of Civil Engineering".

MISSION

M1: To provide an academic environment for the students for developing as capable professionals by empowering them with knowledge, skills, moral values and confidence.

M2: To prepare the students to become global leaders of tomorrow by promoting team work practices and inculcating communication and managerial skills.

M3: To equip the students to accept new challenges by ensuring effective teaching and learning processes; involving them in research, consultancy and development activities; and providing them with exposure to the state of the art infrastructure.

Dr SUNITHA C.
PRINCIPAL

PRINCIPAL'S MESSAGE

It gives me immense pleasure to present the 2024–2025 edition of "ENGINUITY", the annual technical magazine of our Civil Engineering Department. This publication continues to be a symbol of the passion, innovation, and academic rigour that our department consistently upholds.

Civil Engineering remains one of the most impactful disciplines, laying the groundwork—both literally and figuratively—for the development of modern society. From sustainable urban planning to resilient infrastructure design, the field continues to evolve, driven by the ideas and efforts of visionary minds. This edition of ENGINUITY captures that spirit of progress, featuring a diverse array of scholarly articles, technical explorations, and creative insights contributed by our talented students and esteemed faculty members.

The pages of this magazine reflect more than technical knowledge—they represent collaboration, curiosity, and a shared commitment to excellence. Each article is a testament to the intellectual enthusiasm within our department and the drive to address real-world challenges through engineering ingenuity.

I extend my sincere appreciation to the editorial board for their dedication and precision in curating this publication, to the contributors for enriching it with their valuable perspectives, and to all those who supported this endeavor behind the scenes. Your collective efforts have made this magazine not only a platform for knowledge-sharing but also a source of inspiration for all readers.

As you delve into this edition, I encourage you to engage with the ideas presented, reflect on the evolving role of civil engineering in building a better world, and take pride in being part of a community that is shaping the future with resilience, sustainability, and innovation at its core.

Warm regards,
Dr Sunitha C.
Principal

Dr ABHILASHA P. S.
PROFESSOR & HOD, CED

HOD'S MESSAGE

As we step into the academic year 2025–2026, I am delighted to greet all readers of the Civil Engineering Department Technical Magazine. This annual publication has evolved into a platform that captures the creativity, technical competence, and research spirit of our students and faculty, while reflecting our vision to contribute to the ever-expanding horizons of civil engineering.

The discipline is rapidly transforming under global challenges such as climate resilience, urban sustainability, and digital innovation. Our department is committed to preparing engineers who can address these issues with skill, foresight, and responsibility. Through rigorous academics, industry collaboration, and emerging technologies—including Artificial Intelligence in civil engineering—we aim to equip students with the expertise to design smarter systems and promote sustainable development.

Our faculty and students are engaged in impactful work ranging from smart construction materials and innovative structural solutions to environmentally conscious designs. Alongside, seminars, technical festivals, industrial visits, consultancy works and interdisciplinary collaborations continue to enrich learning and broaden perspectives.

This edition of the magazine stands as a testimony to our department's dynamic spirit. I sincerely appreciate the efforts of the editorial team, faculty advisors, and student contributors in bringing it to life. Together, let us uphold excellence, integrity, and innovation as we build a future where civil engineering remains a cornerstone of progress and societal well-being.

Wishing you an insightful and inspiring reading experience.

"Civil Engineering is not just about building structures, but about building a sustainable future for generations to come."

Warm regards
Dr Abhilasha P. S.
Professor & Head of the Department
Department of Civil Engineering

MS RANJITHA K. S.
TECHNICAL STAFF, CE

&

MS NIRMALA KRISHNAN
ASST. PROFESSOR, CE

STAFF EDITOR'S MESSAGE

We are pleased to present the 2024–2025 edition of ENGINUITY, the annual technical magazine of the Department of Civil Engineering. This issue continues our tradition of celebrating knowledge, innovation, and the spirit of inquiry that defines our academic community.

The magazine provides a platform for students and faculty to share ideas, highlight emerging trends, and address the evolving challenges in civil engineering. This edition focuses on climate-resilient infrastructure, sustainable construction technologies, and digital transformation—key areas shaping the future of our profession.

We acknowledge with pride the contributions of our students and faculty, whose articles, case studies, and project features combine academic depth with practical relevance. As civil engineers, our role extends beyond technical problem-solving to promoting sustainable development for society and the environment.

We thank the editorial team, contributors, and readers for their support in making ENGINUITY a reflection of our department's vision and values. We invite you to engage with this issue and draw inspiration as we collectively work toward a more sustainable and innovative future.

Warm regards,

Ms Ranjitha K. S.
TECHNICAL STAFF, CE
Staff Editor

Ms Nirmala Krishnan
ASSISTANT PROFESSOR, CE
Staff Editor

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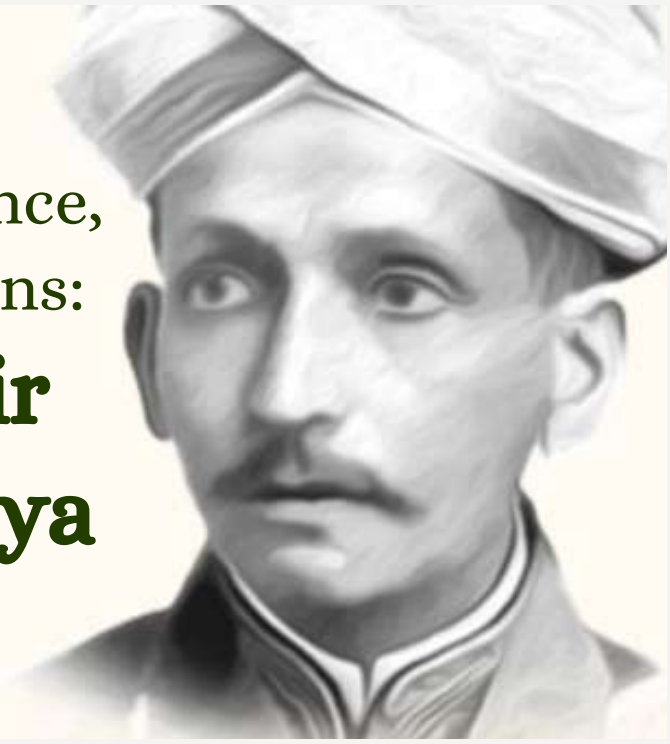
Engineering Excellence, Inspiring Generations:

The Life of Sir M. Visvesvaraya



Compiled by: Ms Seetha Pisharikkel
Assistant Professor

SIR M. VISVESVARAYA

The Father of Indian Civil Engineering Sir M. Visvesvaraya is celebrated as the Father of Indian Civil Engineering. His Innovation Visionary Thinking, discipline, Commitment, dedication, Ethics and Professional Integrity and innovative spirit set a benchmark for engineers. Today's students and young professionals need such role models to understand how technical expertise, combined with integrity, can transform society. He at his various capacities as an Engineer, Statesman, and Nation-builder, transformed dreams into structures and struggles into success. His life is a beacon of inspiration for generations.

EARLY LIFE: RISING FROM HUMBLE BEGINNINGS

Sir M. Visvesvaraya was born on 15th September 1861, in Muddenahalli, a small village in Karnataka. His early life was marked by hardship—he lost his father at a young age, and the family lived in modest conditions. Yet, adversity never dampened his spirit. He walked miles to attend school, studied under street lamps when resources were scarce, and nurtured an unshakable determination to learn.

After completing his initial education in Bangalore, he joined the College of Engineering, Pune, and graduated in Civil Engineering in 1883. This marked the beginning of a journey that would one day change the face of Indian infrastructure.

Sir M. Visvesvaraya receving Bharat Ratna from President Dr Rajendra Prasad

Prime Minister Nehru with administrator-statesman M. Visvesvaraya at Bangalore in 1959

ENGINEERING EXCELLENCE AND ACHIEVEMENTS

Visvesvaraya began his career with the Bombay Public Works Department, where his brilliance soon became evident. His design of automatic sluice gates at the Khadakwasla reservoir near Pune became a pioneering solution for irrigation and water supply. This invention was later adopted in many dams across India.

His most celebrated engineering feat was the construction of the Krishna Raja Sagar (KRS) Dam across the Cauvery River in Mysore. At the time, it was one of the largest reservoirs in Asia, turning vast barren lands into fertile fields and uplifting thousands of lives.

In 1908, when Hyderabad was devastated by the Musi River floods, Visvesvaraya was called upon to design flood protection measures. His visionary plans not only safeguarded the city but also laid the foundation for modern urban planning in Hyderabad.

Krishna Raja Sagara (KRS) Dam

LITERARY & ECONOMIC CONTRIBUTIONS

- **Planned Economy for India**

Sir M. Visvesvaraya advocated for planned economic development in India, notably through his book "Planned Economy for India" (1934), which proposed a decade-long vision for national industrialization and infrastructure development, establishing the groundwork for India's future economic planning. He is widely considered the "Father of Indian Economic Planning" for his pioneering work in systematically proposing and implementing economic strategies to foster growth and self-reliance.

- **Reconstructing India**

Reconstructing India is a book written in 1920 by Sir M. Visvesvaraya, an Indian engineer and statesman, focusing on the need for systematic economic planning to develop India's infrastructure, industries, and agriculture. The book reflects his vision for improving the nation's economy through planned development, a concept he advocated for throughout his illustrious career.

- **Memoirs of My Working Life**

Memoirs of My Working Life is an autobiography by the renowned Indian engineer, statesman, and scholar Sir M. Visvesvaraya. The book details his long and impactful career, focusing on his contributions to engineering and public service in India, his role as the Dewan of Mysore, and his observations on India's journey toward independence and nation-building.

THE MOTIVATIONAL LEGACY

What makes Visvesvaraya's life truly inspirational is not just his achievements, but the values that shaped them:

- Discipline: He was known for his punctuality and work ethic.
- Simplicity: Despite his stature, he lived a simple life, rooted in humility.
- Dedication to Nation: His decisions were always guided by the principle of national interest above personal gain.
- Belief in Education: He emphasized technical knowledge as the key to India's self-reliance.

Sir M. Visvesvaraya's journey from a small village boy to the Father of Indian Civil Engineering is a powerful story of determination, discipline, and devotion to the nation. He proved that with vision and perseverance, one can rise above all odds and create lasting impact.

As India continues to grow, his legacy reminds us that true progress lies in combining knowledge with service, and engineering with humanity.

DEWAN OF MYSORE: THE NATION-BUILDER

In 1912, Visvesvaraya was appointed the Dewan of Mysore (Prime Minister of the state). Under his leadership, Mysore became a model of progress and development.

He established:

- The University of Mysore (1916)
- State Bank of Mysore
- Mysore Iron and Steel Works
- Mysore Soap Factory
- Hydroelectric power plants, which brought electricity to the state

He believed industrialization and education were the twin engines of progress. His reforms modernized Mysore and earned him the title "Maker of Modern Mysore."
Recognition and Honors

For his unparalleled contributions, Visvesvaraya received several honors:

- Knighted as "Sir" by the British Government in 1915
- Awarded Bharat Ratna in 1955, India's highest civilian award
- Honored worldwide for his engineering brilliance and visionary leadership

His birthday, 15th September, is celebrated as Engineer's Day in India, to pay tribute to his legacy and inspire future generations of engineers.

" REMEMBER, A NATION'S STRENGTH LIES NOT IN ITS RICHES, BUT IN THE CHARACTER AND CONTRIBUTION OF ITS PEOPLE."
SIR M. VISVESVARAYA

WOOD FIBRE FILLED STEEL TUBULAR SYSTEM

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ABSTRACT

Hybrid-timber construction has gained growing interest for its environmental benefits and structural efficiency. By combining timber, steel, and concrete, lighter and more resilient buildings with reduced carbon footprints can be achieved. This study developed small-scale fibre-filled steel tubular (FFST) modules by inserting dried wood fibres into cold-formed steel sections without adhesives. Experimental results showed that FFST columns had 44% higher axial stiffness and 55% higher strength than steel-only columns, while FFST beams achieved 8.5% and 28% improvements in flexural stiffness and strength, respectively. With significantly better weight-to-performance ratios and ductile beam-to-column connections, FFST frames show strong potential for low-rise residential applications.

1. INTRODUCTION

Timber is a widely used building material due to its high strength-to-weight ratio, especially when loaded parallel to the grain. Although timber has weaknesses in shear and lateral tension, it can be effectively combined with materials like concrete, FRP, and steel to form strong, cost-effective composite systems. Cold-formed steel (CFS), in particular, has gained attention in modular and low-to-mid-rise construction for its high strength-to-weight ratio, cross-sectional flexibility, construction efficiency, and transportation convenience.

This study explores the structural behavior of Timber-Filled Steel Tubular (TFST) columns, which achieve effective composite action without adhesives or mechanical anchors. Building on this, the research extends the concept to Fibre-Filled Steel Tubular (FFST) elements by evaluating different fibre infills and testing methods to determine optimal materials. Short column tests, bending tests, and frame testing were conducted to compare the performance of FFST elements to pure steel. The results confirm improved structural performance, promoting FFST as a viable, sustainable solution for modular construction.

2. BENEFITS

Structural and mechanical benefits

- Enhanced strength

The synergy between steel's high tensile strength and the stiffness provided by wood fibers results in a composite material with excellent mechanical properties. This combination allows the material to withstand significant loads, making it suitable for structural applications where both compression and tension forces are prevalent, such as beams, columns, and bridges.

- Lightweight

The introduction of wood fibers into steel tubes reduces the overall density of the material. This lighter weight simplifies the logistics of transportation and installation, lowering costs and reducing the need for heavy lifting equipment. Additionally, lighter materials can reduce the load on foundations and support structures, leading to overall cost savings in construction.

- Flexibility and toughness

Wood fibers add ductility to the steel, improving its ability to absorb energy and deform under stress without breaking. This flexibility enhances the material's toughness, making it more resistant to impacts, vibrations, and dynamic loads, which are common in applications like bridges and high-rise buildings.

Thermal and acoustic benefits

- Thermal insulation

Wood fibers have inherent thermal insulating properties due to their cellular structure, which traps air and reduces heat transfer. Incorporating these fibers into steel tubes helps in creating a composite material that reduces thermal bridging, leading to better thermal performance of the structure. This can significantly lower energy consumption for heating and cooling, contributing to improved energy efficiency in buildings.

- Sound absorption

The porous nature of wood fibers helps absorb sound waves, reducing noise transmission through the material. This property is particularly beneficial in urban environments and multi-story buildings, where reducing noise pollution is essential for creating comfortable living and working spaces.

3. LIMITATIONS

Moisture Sensitivity

- Absorption and Swelling

Wood fibers can absorb water, leading to swelling and potential degradation. This can cause changes in dimensions and loss of structural integrity. Over time, repeated cycles of wetting and drying can weaken the fibers and the bond between the fibers and the steel.

- Protection Requirements

To mitigate moisture issues, protective coatings or treatments are often necessary, which can add to the cost and complexity of the system.

Durability Concerns

- Biological Degradation

Wood fibers are susceptible to attack by fungi, mold, and insects, especially in humid or wet environments. This biological degradation can compromise the structural integrity over time.

- Maintenance and Treatments

Regular maintenance and the use of preservatives or treatments can mitigate these issues, but again, this increases costs and complexity.

Thermal Expansion

- Differential Expansion

Steel and wood fibers expand and contract at different rates when exposed to temperature changes. This can create internal stresses at the interface between the materials, potentially leading to delamination, cracking, or other forms of structural failure.

- Design Considerations

Addressing this issue requires careful design to accommodate differential expansion, such as the inclusion of flexible joints or the use of materials with matched thermal properties.

Complex Manufacturing

- Specialized Processes

The manufacturing process for combining wood fibers with steel involves ensuring proper bonding and uniform distribution of the fibers. This often requires specialized equipment and precise control over processing conditions.

4. CASE STUDY

Wood fiber-filled steel tubular systems represent a significant step forward in sustainable engineering, as demonstrated by a pedestrian bridge constructed in Portland, Oregon. Designed to meet the demand for eco-friendly building materials, the project combined the structural strength of steel with the lightweight, renewable qualities of treated wood fibers. Using an advanced extrusion process, wood fibers were uniformly distributed within steel tubes, forming a strong, cohesive composite with enhanced tensile and compressive strength, as well as improved thermal and acoustic insulation. During construction, challenges such as maintaining the bond between materials and managing transport and assembly were successfully overcome. Post-construction evaluations confirmed the bridge's durability under expected loads and environmental conditions, with minimal maintenance. The composite material significantly reduced both structural weight and environmental impact compared to traditional materials like concrete and steel. Additionally, the bridge offered aesthetic appeal and greater comfort through reduced thermal conductivity and noise. The project not only highlighted the technical and environmental advantages of this hybrid system but also demonstrated its potential for broader applications in transportation and infrastructure.

Figure 1: Pedestrian bridge in Portland, Oregon

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INTELLIGENT TRANSPORTATION SYSTEM

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ABSTRACT

Intelligent Transportation Systems (ITS) rely on information and control technologies to perform their functions. While familiar tools like loop detectors are widely used, many lesser-known devices are also essential. At the core of ITS are information systems, but human factors remain complex and important. ITS integrates data from networks, vehicles, and passengers to enhance efficiency and safety. These systems improve traffic management, reduce congestion, emissions, and travel time. For users, ITS offers easier ticketing, real-time updates, and accurate travel information. ITS can be mode-specific or multi-modal, involving vehicles, infrastructure, drivers, and travelers. Key goals include improving traffic flow, comfort, and commuter safety. Features like live traffic info, route tracking, and flight updates support informed travel. This paper explores ITS technologies and factors critical to infrastructure design.

1. INTRODUCTION

In today's era of rapid urbanization and growing population density, traditional transportation systems are under increasing pressure. Intelligent Transportation Systems (ITS) offer a transformative solution by integrating information and communication technologies with transportation infrastructure. These systems use electronics, computers, advanced sensors, and real-time data to enhance traffic efficiency, safety, and sustainability. ITS enables smarter traffic management, improved accessibility, and better-informed travelers, representing a significant shift in how people and goods are moved.
However, in the context of India, several challenges hinder the widespread adoption of ITS. Issues such as inadequate infrastructure, poor air quality, and limited implementation of intelligent systems continue to pose obstacles. The slow pace of development further risks India falling behind in global technological advancements. Nevertheless, initiatives like "Make in India" are paving the way by encouraging local manufacturing and innovation, potentially strengthening the foundation for future smart transportation systems.

2. NEED FOR INTELLIGENT TRANSPORTATION SYSTEM

ITS is gaining traction in India's transportation system, but there remains significant room for improvement. A systematic approach is needed to enhance ITS integration across all road types. Current applications are underutilized, requiring greater focus on diverse services and technologies. More projects are essential to address the rising number of vehicles and evolving transport needs.

- Road accidents

Road accidents in developing countries represent a significant and complex challenge, posing threats to public safety, economic development, and public health. Several factors contribute to the high incidence of road accidents in these regions, often creating a challenging environment for road safety measures.

- Infrastructure Challenges

Many developing countries face limitations in the quality and design of road infrastructure. Poorly maintained roads, lack of proper signage, inadequate lighting, and insufficient road markings contribute to hazardous conditions that increase the risk of accidents.

- Traffic Congestion

Rapid urbanization in developing countries often leads to increased traffic congestion. Overloaded road networks, combined with a lack of efficient public transportation, can result in chaotic traffic conditions, increasing the likelihood of accidents

- Vehicle Conditions

Developing countries frequently have a mix of old and poorly maintained vehicles on the roads. Inadequate vehicle maintenance, lack of regular inspections, and the prevalence of outdated vehicles contribute to a higher risk of mechanical failures and accidents.

- Pedestrian Safety

Pedestrian safety is often a concern in developing countries due to a lack of proper infrastructure such as sidewalks and pedestrian crossings. Additionally, a combination of factors like informal settlements and a high reliance on walking for transportation can make pedestrians vulnerable to accidents.

In developing countries, road traffic accidents lead to economic losses of up to 2% to 3% of their national income due to injuries, physical damage, disability, trauma, and loss of schooling. Each, year, around 1.3 million people lose their lives due to road traffic accidents, as per UN statistics. Additionally, between 20 and 50 million more people suffer nonfatal injuries, with many experiencing disabilities as a result.

3. INTELLIGENT TRANSPORTATION TECHNOLOGIES

Wireless Communication

- Dedicated short range communication(DSRC)

DSRC is a wireless communication technology that enables vehicles to communicate with each other and other road users directly, without involving cellular or other infrastructure. It offers communication between the vehicles and the road side in specific locations (toll plazas) applications such as Electronic toll fee collection (EFC) will operate over DSRC. It is a subset of RFID Technology (Radio Frequency Identification).

- Continuous air interference long and medium range (CALM)

Continuous air interference long and medium range provides continuous communication between a vehicle and road side using a variety of communication media, including cellular and infra-red links. CALM will produce a range of applications, including vehicle safety and information, as well as entertainment for passengers and drivers.

Computational technologies

The CTS (Computational Transportation Science) fellows will develop technologies in which sensors, travellers computers, in-vehicle computers, and computers in the static infrastructure. The processors on transportation vehicles have also allowed software applications and artificial intelligence systems to be installed. These systems include internal control of model based processors, ubiquitous computing and other programs designed to be integrated into a greater transportation system.

Video vehicle detection (VVD)

Video vehicle detection is an advanced method used in transportation systems to detect and monitor vehicles using camera-based technology. This approach leverages image processing and computer vision techniques to analyze video footage in real-time.

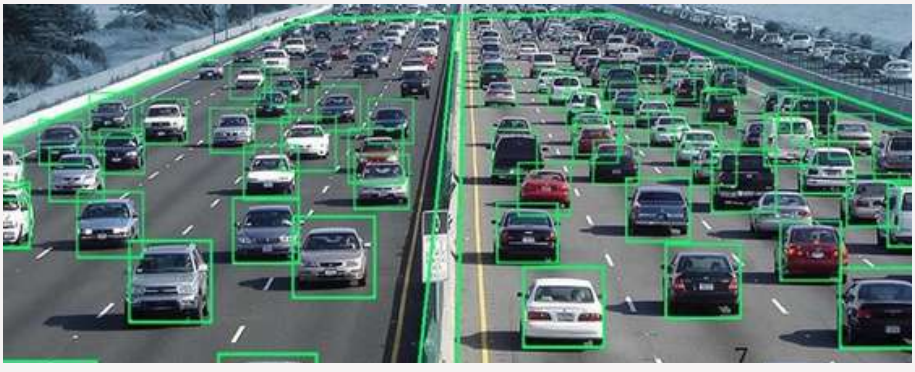

Figure 1: Video vehicle detection

4. TYPES OF ITS AND SPECIFIC APPLICATION

Sl. No.	ITS Category	Specific ITS Applications
1	Advanced traveler information (ATIS)	Information on traffic in Real-time route navigation and guidance systems. Google Maps ,Transit Apps Variable Message Signs (VMS)
2	Advanced Transportation management system (ATMS)	Traffic management centers, dynamic signal for traffic. SMART Traffic Signal Systems Integrated Corridor Management (ICM)
3	ITS Enabled Transportation pricing system (ITSETPS)	Electronic toll collection, dynamic parking fee, Parking Management Systems
4	Advanced public transportation system (APTS)	Real-time status information for public transit systems, Automatic vehicle location
5	Fully integrated intelligent transportation (FIIT)	Collision avoidance, intelligent speed adaptation
6	Advanced traffic management system (ATMS)	Real time traffic status, Dynamic traffic control incident response, SMART Traffic Signal Systems
7	Commercial vehicle operation (CVO)	Tracebility and safety of commercial vehicles such as trucks, vans and taxis
8	Advanced vehicle control system (AVCS)	Collision warning of the vehicles
9	Advanced rural transportation system (ARTS)	Provide information about remote roads via radio

5. BENEFITS OF ITS

- Systematically employs advanced technologies in the field of transportation to enhance benefits for road users.
- Improves the existing transportation services through interconnected embedded technologies.
- The mean speed can be increased by efficiently monitoring the vehicle speeds
- Provides system to avoid collision, accidents, and improves night vision and road alertness
- Enables the rapid arrival of emergency vehicles during accidents to transfer the victims to trauma care centers within the golden hour through incident management systems.
- Provides novel applications by smart technology
- Offers a range of convenient and affordable transport options making best use of infrastructure
- Improved Road Safety: Reduces the incidence of traffic violations and accidents by deterring risky driving behaviors.
- Efficient Law Enforcement : Frees up law enforcement personnel to focus on more critical tasks by automating routine traffic enforcement.
- Consistent and Impartial Enforcement : Ensures traffic laws are enforced consistently without human error or bias.
- Data Collection and Analysis : Provides valuable data on traffic patterns and violations, helping in urban planning and traffic management.

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USE OF SEWAGE SLUDGE ASH AS BRICK MATERIAL

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ABSTRACT

The rapid growth of urban populations generates large amounts of sewage sludge, posing disposal and environmental challenges. Incineration of this sludge produces Sewage Sludge Ash (SSA), which can be reused in construction. This seminar focuses on using SSA as a partial replacement for clay in brick manufacturing. The study examines the physical, chemical, and mechanical properties of SSA-based bricks, assessing strength, water absorption, durability, and environmental impact. Results show that SSA bricks are eco-friendly, cost-effective, and sustainable, making them a promising alternative in the construction industry.

1. INTRODUCTION

The rapid growth of urbanization has led to increased wastewater generation and, consequently, large volumes of sewage sludge, creating major disposal and pollution challenges. Incineration of this sludge produces Sewage Sludge Ash (SSA), which is rich in silica and alumina, making it suitable as a partial replacement for clay in brick manufacturing. Utilizing SSA not only provides an eco-friendly solution for sludge management but also conserves natural resources, reduces landfill usage, and minimizes the risks of heavy metal leaching. Moreover, this approach lowers greenhouse gas emissions from clay mining and firing, supports circular economy practices, and aligns with sustainable development goals. SSA bricks have shown promising performance in terms of strength, durability, and cost-effectiveness, making them a sustainable and practical alternative to conventional construction materials.

2. BENEFITS

- Waste Utilization; SSA provides an effective way to manage sewage sludge by converting it into a useful construction material instead of dumping it in landfills.
- Resource Conservation; It reduces the dependence on natural resources like clay, sand, and cement by serving as a partial replacement material.

- Eco-Friendly Construction; The use of SSA minimizes environmental pollution, lowers carbon emissions, and supports circular economy practices.
- Cost-Effectiveness; Since SSA is obtained from waste, it helps reduce the cost of raw materials in construction projects.
- Energy Efficiency; The properties of SSA can lower the energy required in processes such as brick firing, making construction more energy-efficient.
- Adequate Strength and Durability; When used in suitable proportions, SSA enhances or maintains the mechanical properties of construction materials like bricks, mortar, and concrete.
- Support for Sustainability; Incorporating SSA in construction aligns with sustainable development goals by promoting green building practices and responsible waste management.

3. APPLICATION

Sewage Sludge Ash (SSA) is increasingly recognized as a sustainable substitute for natural clay in brick manufacturing, typically used at replacement levels of 10–30%. Its high silica and alumina content ensure strong chemical compatibility with clay, allowing effective bonding during the firing process. SSA bricks, especially at 10–20% incorporation, consistently meet or exceed construction-grade compressive strength standards. Their porous structure leads to reduced density, resulting in lighter bricks that are easier to handle and offer improved thermal insulation. From an environmental perspective, SSA use reduces the need for clay mining and topsoil depletion, diverts sewage sludge from landfills, and lowers greenhouse gas emissions associated with traditional brick production. It also supports circular economy principles by transforming waste into a valuable construction material. Overall, SSA-based bricks are technically feasible, economically viable, and environmentally beneficial—making them a promising solution for sustainable building practices. SSA can safely replace clay, producing eco-friendly, cost-effective bricks that meet IS 1077 standards.

Figure 1: Manufacturing of SSA bricks

5. CHALLENGES

The use of Sewage Sludge Ash (SSA) in brick manufacturing faces several challenges. The composition of SSA varies with its source and treatment process, leading to inconsistent brick quality. At higher replacement levels, SSA can reduce the compressive strength of bricks and increase water absorption due to its porous nature. There is also a risk of heavy metal leaching, which raises environmental and health concerns. In addition, handling and processing SSA is difficult because of its fine powdery form, and the lack of industry standards and awareness limits its large-scale adoption. Finally, the need for additional treatment and testing increases production costs, creating economic barriers.

6. CONCLUSION

The incorporation of sewage sludge ash (SSA) in brick production provides a sustainable solution for waste management and reduces the use of natural clay. SSA bricks, with proper treatment and optimized mix design, show adequate strength for non-load-bearing and eco friendly structures. Lower firing temperatures offer energy savings, supporting green construction and circular economy practices. Continued research, standardization, and public awareness are essential for the widespread adoption of SSA bricks in the construction industry.

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ADSORPTION-BASED ATMOSPHERIC WATER HARVESTING: A SUSTAINABLE PATH FOR ARID REGIONS

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ABSTRACT

Water scarcity is one of the most urgent global challenges, especially in arid and semi-arid regions where freshwater availability is extremely limited. Conventional solutions such as groundwater extraction, desalination, and wastewater treatment often prove expensive, energy-intensive, or unsustainable in the long term. Atmospheric Water Harvesting (AWH) has therefore emerged as an innovative approach to address the crisis. Among the various AWH methods, adsorption-based systems are particularly promising because they can function even in low-humidity environments typical of deserts. This article explores the principles, materials, and applications of adsorption-based AWH, highlighting the role of advanced sorbents such as metal-organic frameworks (MOFs). A case study conducted in Arizona using MOF-801 demonstrates the feasibility of harvesting potable water from dry desert air with only solar energy. While high material costs and scalability remain challenges, adsorption based AWH represents a sustainable and decentralized solution that can transform future water security

1. INTRODUCTION: THE WATER CRISIS OF THE 21ST CENTURY

The demand for freshwater has been growing rapidly due to climate change, urbanization, and population expansion, placing unprecedented stress on already scarce resources. In arid and semi-arid regions, the problem is even more severe, as natural water reserves are either depleted or too limited to meet the needs of people, agriculture, and industry. Traditional solutions such as groundwater pumping and desalination provide temporary relief but often create new challenges such as aquifer depletion, ecosystem imbalance, and excessive energy consumption. This calls for alternative, more sustainable methods of securing freshwater.

One such approach is Atmospheric Water Harvesting (AWH). The atmosphere contains an enormous and untapped reservoir of water vapor—far exceeding the quantity of freshwater found in rivers and lakes combined. Unlike rainfall-dependent systems, AWH technologies can operate year-round by drawing moisture directly from the air, making them an attractive option for regions with chronic water stress.

2. ADSORPTION-BASED AWH: PRINCIPLES AND OPERATION

AWH technologies are generally categorized into condensation-based and sorption-based systems. Condensation methods rely on cooling air below the dew point, either passively through fog or dew harvesting or actively using refrigeration. These methods are effective in humid regions but consume large amounts of energy or depend on specific climatic conditions. Sorption-based systems, on the other hand, use materials that can capture water vapor directly from the air, making them especially effective in arid climates.

Adsorption-based AWH relies on porous, hygroscopic materials that attract water molecules to their surfaces during the cooler, more humid night hours. When exposed to solar energy during the day, these materials release the stored water vapor, which then condenses into liquid form. This process, known as adsorption-desorption cycling, requires no electricity and makes use of freely available solar heat. Its ability to function in environments with relative humidity as low as 10–20 percent gives it a unique edge over other water-harvesting technologies.

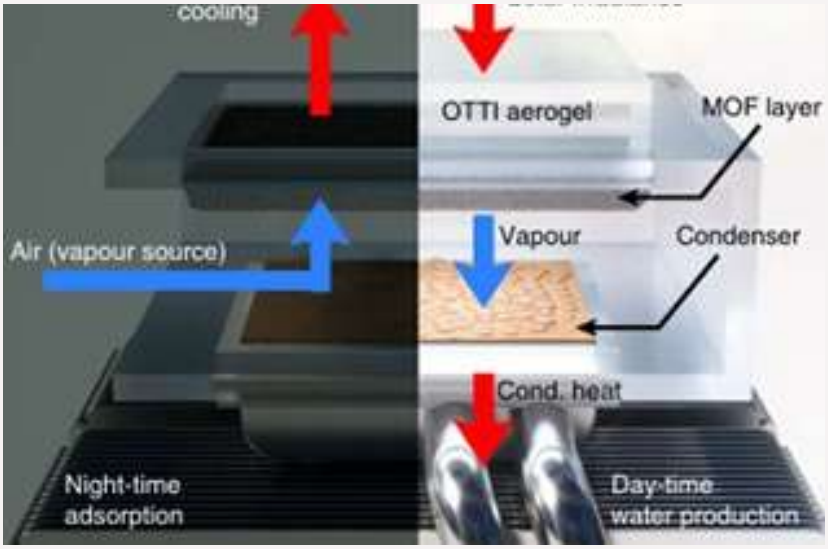

Figure 1: Working principle of the MOF-801-based water harvesting device

3. MATERIALS FOR ADSORPTION-BASED AWH

The performance of adsorption-based systems depends heavily on the properties of the adsorbent material. Silica gels are inexpensive and widely available, though they perform best under moderate humidity and require high regeneration temperatures. Zeolites offer excellent thermal stability but face similar regeneration challenges. Hygroscopic salts such as calcium chloride and lithium chloride have high water absorption capacity but present issues of corrosion and leakage. Hydrogels are cost-effective and eco-friendly, yet their stability under repeated cycles is limited.

The most promising materials to date are Metal-Organic Frameworks (MOFs). These crystalline compounds consist of metal ions connected by organic linkers, creating highly porous structures with enormous surface areas. MOFs such as MOF-801 can adsorb significant amounts of water even at very low humidity levels and can be regenerated using only sunlight. Although they are still relatively expensive to synthesize, their potential efficiency makes them ideal candidates for future water-harvesting devices.

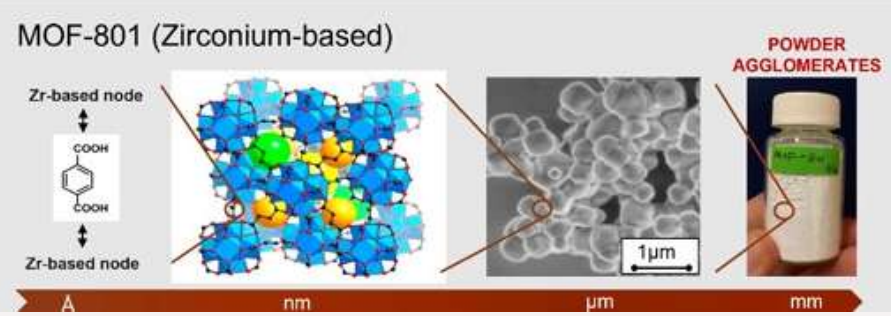

Figure 2: MOF 801

4. CASE STUDY: MOF-801 IN DESERT CONDITIONS

A striking demonstration of adsorption-based AWH was carried out in Tempe, Arizona, where the relative humidity often falls below 15 percent. Researchers developed a prototype device filled with MOF-801, a zirconium-based material known for its strong affinity for water. During night hours, the MOF adsorbed water vapor from the dry desert air. In the daytime, solar heating caused the water to desorb and condense, producing measurable quantities of liquid water without the need for electricity.

The device was able to yield between 0.12 and 0.28 liters of water per kilogram of MOF per day. Importantly, chemical analysis confirmed that the harvested water was free of contaminants and safe for drinking. This case study illustrates the remarkable potential of adsorption-based AWH to provide clean water in some of the most challenging environments on Earth.

5. BENEFITS

Adsorption-based atmospheric water harvesting systems provide several benefits that make them especially suitable for arid and semi-arid regions. One of the most important advantages is their ability to function effectively even under very low humidity conditions, where other methods fail. These systems are also highly energy-efficient, since they rely primarily on solar heat for regeneration rather than electricity. Their decentralized nature means that they can be installed in remote or off-grid locations without the need for extensive infrastructure, making them ideal for rural households, small communities, or disaster-hit areas. Another strength is their scalability; adsorption systems can be designed as compact household units or expanded to serve larger groups. With fewer moving parts and passive opera on, they also require minimal maintenance and have low long-term running costs, contributing to their overall sustainability.

6. CHALLENGES

Despite their promise, adsorption-based systems are still in the early stages of widespread adoption and face certain limitations. A major barrier is the high cost of advanced adsorbent materials, particularly metal-organic frameworks, which require complex and expensive synthesis processes. While short-term experiments have shown excellent results, there is limited data on the long-term durability and stability of these materials under continuous opera on. Another challenge is the dependence on solar irradiation for the desorption phase; cloudy or shaded conditions may reduce efficiency and water yield. Compared to mechanical condensation systems in humid climates, adsorption-based methods may still deliver lower overall water output. Furthermore, large-scale demonstrations are relatively few, and further research is needed to optimize device design and reduce costs. Overcoming these challenges will be essential for making adsorption-based AWH more practical and economically competitive.

7. FUTURE PROSPECTS

With continued advancements in material science and engineering, adsorption-based water harvesting has the potential to play a transformative role in addressing global water scarcity. Economic analyses suggest that optimized systems could eventually deliver water at costs comparable to or lower than conventional methods in remote or arid areas. Potential applications range from household-level drinking water solutions to agricultural irrigation and emergency relief in drought or disaster-hit regions.

As climate change increases the frequency of droughts and further stresses freshwater supplies, adsorption-based AWH could emerge as a vital tool for ensuring sustainable and equitable access to clean water worldwide.

8. CONCLUSION

Adsorption-based atmospheric water harvesting represents an exciting leap forward in sustainable water resource management. By capturing and condensing moisture from the air using advanced materials and solar energy, this technology provides a clean, renewable, and decentralized solution to one of humanity's greatest challenges. While challenges of cost and scalability remain, the rapid pace of innovation suggests that adsorption-based AWH will soon move from experimental prototypes to real-world applications, offering hope for millions living under water stress.

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BIO-BASED REJUVENATORS IN ASPHALT PAVEMENTS: A SUSTAINABLE INNOVATION FOR ROAD INFRASTRUCTURE

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ABSTRACT

The deterioration of asphalt pavements due to oxidative aging presents a significant challenge to infrastructure longevity and maintenance costs. Conventional rejuvenators, typically derived from petroleum, have been effective in restoring aged binders but raise environmental concerns. In response, bio-based rejuvenators formulated from renewable resources such as vegetable oils, biomass waste, and animal by-products have emerged as sustainable alternatives. This article explores the multifaceted benefits of bio-based rejuvenators, their mechanisms of action, practical applications in asphalt mixtures, real-world success stories, and the challenges that must be addressed for broader adoption. The discussion is grounded in recent analytical studies and performance evaluations, offering a roadmap for integrating green technologies into pavement engineering.

1. INTRODUCTION

Asphalt pavements are subjected to continuous environmental and mechanical stresses that lead to aging and degradation over time. The primary mechanisms of aging include thermo-oxidative reactions, UV exposure, and volatilization of lighter binder components. These processes result in increased stiffness, reduced ductility, and a higher propensity for cracking and fatigue failure. Traditionally, rejuvenators have been used to restore the functional properties of aged asphalt by replenishing lost maltenes and improving binder flexibility. However, petroleum-based rejuvenators contribute to greenhouse gas emissions and pose ecological risks. Bio-based rejuvenators, derived from natural and waste materials, offer a sustainable alternative that aligns with global efforts to reduce carbon footprints and promote circular economy practices. Their integration into pavement systems not only enhances performance but also supports environmental stewardship.

2. BENEFITS OF BIO-BASED REJUVENATORS

- Renewable sourcing: Derived from plant oils (e.g., soybean, castor), waste cooking oils, lignin, and animal waste, reducing dependency on fossil fuels.
- Biodegradability: Naturally decomposes without leaving harmful residues, minimizing long-term environmental impact.
- Improved binder rheology: Restores the viscoelastic balance of aged binders, reducing stiffness and enhancing flexibility.
- Enhanced mechanical performance: Increases resistance to cracking, fatigue, and rutting, thereby extending pavement service life.
- Lower carbon footprint: Reduces greenhouse gas emissions during production and application, contributing to climate goals.
- Supports circular economy: Utilizes industrial and agricultural waste, promoting resource efficiency and waste valorization.
- Chemical rejuvenation: Replenishes light fractions and reduces oxidative indices (carbonyl, sulfoxide), improving binder chemistry.
- Compatibility with RAP: Facilitates high-percentage reclaimed asphalt pavement usage, reducing virgin material demand.

3. APPLICATION IN ASPHALT PAVEMENTS

Bio-based rejuvenators are applied either by direct blending with aged asphalt binders or through surface treatments in reclaimed asphalt pavement (RAP) mixtures. Their integration can be tailored based on binder grade, climate conditions, and traffic loads. Feedstocks vary widely from vegetable oils and lignin to animal waste derivative search offering unique chemical profiles and performance characteristics. Analytical techniques such as Fourier Transform Infrared Spectroscopy (FTIR), Dynamic Shear Rheometer (DSR), and Bending Beam Rheometer (BBR) are employed to evaluate the rejuvenator's impact on binder properties. These tests confirm reductions in stiffness, improvements in strain tolerance, and restoration of viscoelastic behavior. Field trials have demonstrated that bio-based rejuvenators can reduce mixing and compaction temperatures, enhance workability, and improve long-term durability under diverse environmental conditions.

4. SUCCESS STORY

A compelling example of bio-based rejuvenator application involves the use of swine manure-derived additives in RAP mixtures. Research conducted by Oldham et al. (2018) and Kowalski et al. (2017) revealed that this rejuvenator significantly improved binder performance. The treated mixtures exhibited a 30% reduction in complex modulus, indicating enhanced flexibility. Additionally, fatigue life under cyclic loading conditions

was markedly improved, and fracture temperatures were lowered, reducing the risk of low-temperature cracking. These results underscore the potential of waste-derived rejuvenators to not only restore aged binders but also contribute to sustainable waste management. The success of this case highlights the feasibility of integrating bio-waste into high-performance pavement systems, offering both environmental and economic advantages.

5. CHALLENGES

Despite their promising attributes, bio-based rejuvenators face several challenges that must be addressed to ensure widespread adoption. Chemical compatibility with aged binders can vary, leading to phase separation or inconsistent performance. Dosage optimization is critical excessive amounts may result in over-softening and reduced structural integrity, while insufficient quantities fail to achieve desired rejuvenation. Long-term durability under UV exposure, moisture ingress, and temperature fluctuations remains a concern, particularly in regions with extreme climates. Economic feasibility is another barrier; while bio-based materials offer environmental benefits, their production and processing costs can be higher than conventional alternatives. Moreover, the lack of standardized testing protocols and performance benchmarks hinders regulatory approval and industry confidence. Addressing these challenges requires interdisciplinary collaboration, robust field validation, and the development of climate-specific formulations.

6. CONCLUSION

Bio-based rejuvenators represent a pivotal advancement in the pursuit of sustainable and resilient road infrastructure. By leveraging renewable resources and waste-derived materials, these additives offer a dual benefit: restoring the functional properties of aged asphalt binders and significantly reducing the environmental footprint of pavement rehabilitation. Their proven ability to enhance rheological and mechanical performance combined with compatibility in high-RAP mixtures positions them as viable alternatives to petroleum-based rejuvenators. However, their widespread adoption hinges on overcoming key challenges such as chemical compatibility, dosage optimization, long-term durability, and economic feasibility. Continued research, field validation, and the development of standardized performance protocols are essential to unlock their full potential. As the infrastructure sector moves toward climate-conscious engineering, bio-based rejuvenators stand out as a promising solution that aligns technical performance with ecological responsibility.

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ARTIFICIAL INTELLIGENCE IN TRAFFIC SYSTEMS

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ABSTRACT

The rapid growth of urban populations has intensified traffic congestion, road accidents, and environmental challenges, highlighting the need for smarter transportation solutions. Artificial Intelligence (AI) offers transformative opportunities for optimizing traffic systems through real-time data processing, predictive modeling, and adaptive control mechanisms. By leveraging technologies such as machine learning, computer vision, and intelligent sensor networks, AI can enable dynamic traffic signal control, improve traffic flow prediction, enhance road safety, and support autonomous vehicle navigation. Furthermore, AI-driven traffic management contributes to reduced fuel consumption and emissions, fostering sustainable urban mobility. This paper explores the role of AI in modern traffic systems, emphasizing its potential to improve efficiency, safety, and environmental sustainability while addressing challenges related to data privacy, scalability, and system integration.

1. INTRODUCTION

Artificial intelligence (AI) is the development of computer systems capable of performing tasks that typically require human intelligence, such as learning, reasoning, problem-solving, perception, and language understanding. AI in traffic management refers to the application and strategic deployment of AI and associated technologies to adjust , augment and enrich the flow, safety, economy, efficiency, and ecological sustainability of traffic and to automate transportation systems. AI algorithms are built to analyze and process huge quantities of data that is obtained from a large variety of sources, including sensors, cameras, and historical traffic patterns, to make intelligent decisions and automate traffic management tasks.

2. FUNDAMENTALS OF TRAFFIC SYSTEMS

- Traffic Flow Theory

Traffic flow theories are mathematical models that seek to explain how vehicles, drivers, and infrastructure interact with each other's presence on the road. They are used by transportation engineers to stimulate (model), understand and analyze traffic flow. They help in finding ways to introduce and redesign infrastructure elements like signage, traffic lights, traffic cameras and markings.

- Traffic Management Strategies

Traffic management strategies are approaches and techniques used to coordinate vehicular flow, minimize collisions and the likelihood of roads shutting down and cause furtherance in the safety of motorway networks. This falls under traffic engineering, transportation engineering or highway engineering.

- Traffic Signal Control

Signal control is a fundamental strategy in traffic management. It uses traffic lights and signaling devices to regulate vehicle flow at intersections. It plays a key role in urban transportation by activating a better traffic flow, lowering the probability of traffic jams, and stirring road safety levels. The primary objectives of signal control include maximizing traffic throughput, minimizing delays, boosting safety, and mitigating road closures.

3. AI TECHNOLOGIES AND THEIR APPLICATIONS IN TRAFFIC MANAGEMENT

AI technologies which involve statistical analysis, machine learning, deep learning, reinforcement learning, unsupervised learning, semi-supervised learning and so on, are gradually becoming the new normal in traffic management. With accumulating human population and an escalation in traffic pressure on urban areas, AI-powered technologies are providing the necessary innovation to cohere traffic flow in a way that suits the demands of metropolitan zones. These innovative technologies upgrade transportation supportability, value, and resilience for road users.

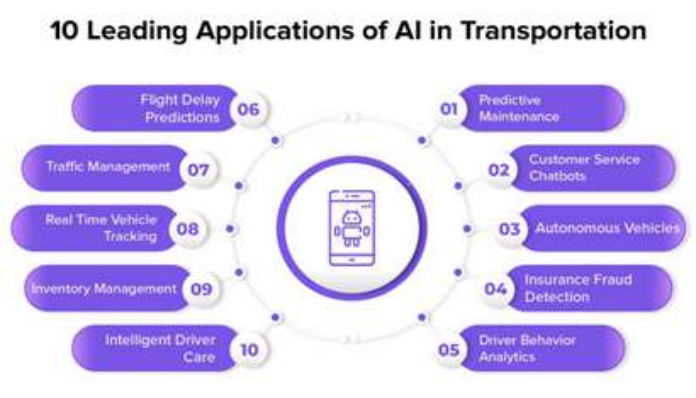

Figure 1: Applications of AI

4. FUTURE DIRECTIONS IN AI FOR TRAFFIC MANAGEMENT SYSTEMS

The future of AI in traffic systems is set to be transformative. Its future is primed to be helmed by advancements in sensor fusion, mechatronics, communication technologies, multimodal transportation integration, and ethical AI development. A key area of growth is the integration of AI with 4G and 5G networks and the IoT . The more developed communication capabilities will be, the lower the latency and the higher the data transfer rates will be. Such potential is exhibited by the proliferation of 5G. Autonomous traffic control centers represent another promising direction in the evolution of AI for traffic systems. It will also handle emergencies and streamline the movement of emergency vehicles.

Research and innovation in AI traffic systems are advancing rapidly. Numerous ongoing initiatives explore new technologies and methodologies. Areas such as deep learning, reinforcement learning, Bayesian networks, logistic regression, semi-supervised and unsupervised learning, evolutionary computing, and quantum computing are being researched for their potential to modernize traffic predictions, to restructure routing, and to augment the success of traffic management systems.

5. CONCLUSION

The integration of AI in traffic management shows credible promise to revolutionize transportation management. With the incorporation of AI, urban transportation is becoming more responsive to the needs of their citizens. AI technologies are briskly advancing and converging with emerging trends, inter alia, self-driving vehicles, and autonomous systems. This makes the possibility for innovation in traffic management vast and optimistic. The capability of AI-powered systems to analyze vast amounts of real-time data to make valid predictions about traffic patterns, which improves traffic movement and enables traffic administration to augment its measures to reduce on-road overcrowding, to improve air quality, and to enhance the experience for all the stakeholders.

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GEOSYNTHETICS IN DAM ENGINEERING: COST-EFFECTIVE, SUSTAINABLE, AND RESILIENT SOLUTIONS

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1.INTRODUCTION

Embankment dams are among the most widely constructed hydraulic structures across the world, particularly in regions like Kerala where abundant rainfall and complex river systems demand effective water resource management. Traditionally, such dams were built using natural materials like clay, sand, and gravel to provide filtration, reinforcement, and drainage. However, with advancements in materials science, geosynthetics have emerged as superior alternatives, offering enhanced performance, cost-effectiveness, and long-term durability. Their multifunctional applications—spanning filtration, separation, reinforcement, drainage, and seepage control—not only improve structural safety and efficiency but also align with sustainable engineering practices. By reducing dependence on natural aggregates and simplifying construction in challenging terrains, geosynthetics have become an indispensable component of modern dam engineering and rehabilitation.

2. FUNCTIONS OF GEOSYNTHETICS IN EMBANKMENT DAMS

- Filtration

Geotextiles are widely used as filter layers in embankment dams. Placed between soil and drainage materials, they allow water to pass while retaining soil particles, thereby preventing internal erosion and piping. Unlike conventional graded filters, geotextiles are easier to install, require less space, and provide consistent performance.

- Reinforcement

Geogrids and high-strength woven geotextiles are employed to reinforce embankments, especially in soft foundation conditions. They enhance the shear strength of the soil, improve slope stability, and reduce settlement. Reinforcement with geosynthetics allows the construction of steeper embankment slopes, thereby reducing the footprint of the dam and minimizing land acquisition.

- Separation

Geosynthetics act as separators by preventing intermixing of dissimilar soil layers. For example, in the foundation of a dam, geotextiles can be placed between soft subsoil and granular fill to ensure long-term stability and prevent contamination of drainage layers. This function is crucial in Kerala's lateritic and clay-rich soil profiles. This separation function also helps maintain the designed permeability and load- bearing capacity of each layer, ensuring the overall structural integrity of the embankment over time.

- Drainage

Geonets and geo composites serve as efficient drainage paths within the dam body and foundation. By rapidly conveying seepage water to designated drainage zones, they reduce pore water pressure and enhance stability. Compared to traditional sand or gravel drains, geosynthetics offer faster installation and reduced material requirements.

- Leakage Prevention (Seepage Control)

Geomembranes and geosynthetics clay liners (GCLs) are used as impermeable barriers to control seepage through embankment dams. These liners have low hydraulic conductivity and can replace thick clay cores, making them suitable for sites with limited clay availability. In rehabilitation of aging dams, geomembrane systems provide a practical solution for leakage control without large-scale reconstruction.

3. ADVANTAGES OF GEOSYNTHETICS IN DAM ENGINEERING

One of the most compelling advantages of geosynthetics in embankment dam engineering is their cost-effectiveness. By incorporating geotextiles, geomembranes, and geogrids, engineers can significantly reduce the use of traditional construction materials such as sand, gravel, or clay. This reduction not only lowers material costs but also minimizes excavation and transportation expenses. Additionally, the lighter weight of geosynthetics compared to conventional materials can reduce the overall construction time and associated labor costs, making large-scale projects more economically feasible.

Geosynthetics are also space-efficient, allowing thin layers to replace thick zones of traditional filter, drainage, or structural layers. This property optimizes the cross-sectional profile of the dam, reducing the footprint of the structure and minimizing and acquisition requirements. Space efficiency is particularly advantageous in constrained or environmentally sensitive sites where land availability is limited. Moreover, the ability to precisely engineer the thickness and strength of geosynthetic layers enables better control over the hydraulic and structural performance of the dam.

From a sustainability perspective, geosynthetics help reduce dependence on natural aggregates and other raw materials. By minimizing the extraction of sand, gravel, and clay, they contribute to the conservation of natural resources and the protection of ecosystems. Furthermore, their lightweight and efficient design contribute to reduced carbon emissions during transportation and installation. These eco-friendly characteristics align with modern green engineering principles and sustainable infrastructure development.

Ease of installation is another practical benefit of geosynthetics. Their lightweight and flexible nature allows for rapid deployment, even in remote or geologically challenging terrains. Installation can often be completed with minimal heavy machinery, reducing both lab or intensity and construction risks. The modularity and adaptability of geosynthetics also allow engineers to tailor the materials to specific project needs, such as steep slopes, soft foundations, or irregular topographies.

Beyond these practical advantages, geosynthetics provide hydraulic efficiency by maintaining consistent permeability in filtration and drainage applications. This helps control seepage, prevent piping, and manage pore-water pressures within the dam structure. Their mechanical versatility further enables engineers to improve stability, reduce settlement, and enhance the seismic resilience of embankment dams. By combining filtration, reinforcement, separation, and waterproofing functions in a single material, geosynthetics simplify design and improve overall dam performance.

Collectively, the cost-effectiveness, space efficiency, durability, sustainability, ease of installation, hydraulic efficiency, and mechanical versatility of geosynthetics make them a technically and economically superior solution for modern embankment dam engineering. Their integration into dam design not only ensures long-term structural reliability but also supports environmentally responsible and resource-efficient construction practices.

4. APPLICATIONS OF GEOSYNTHETICS IN AN EMBANKMENT DAM

A schematic cross-section of an embankment dam as shown in Figure 1, highlights the integrated applications of geosynthetics in modern dam engineering. Geotextiles are employed for filtration and separation, geogrids provide reinforcement, geonets facilitate internal drainage, and geomembranes or GCLs ensure effective seepage control. Together, these applications enhance the safety, efficiency, and sustainability of embankment dams. Their use also minimizes dependence on scarce natural resources like clay and aggregates, aligning with sustainable construction practices. In addition, geosynthetics simplify construction in challenging terrains, enable faster installation, and ensure long-term durability, making them indispensable in both new construction and rehabilitation projects.

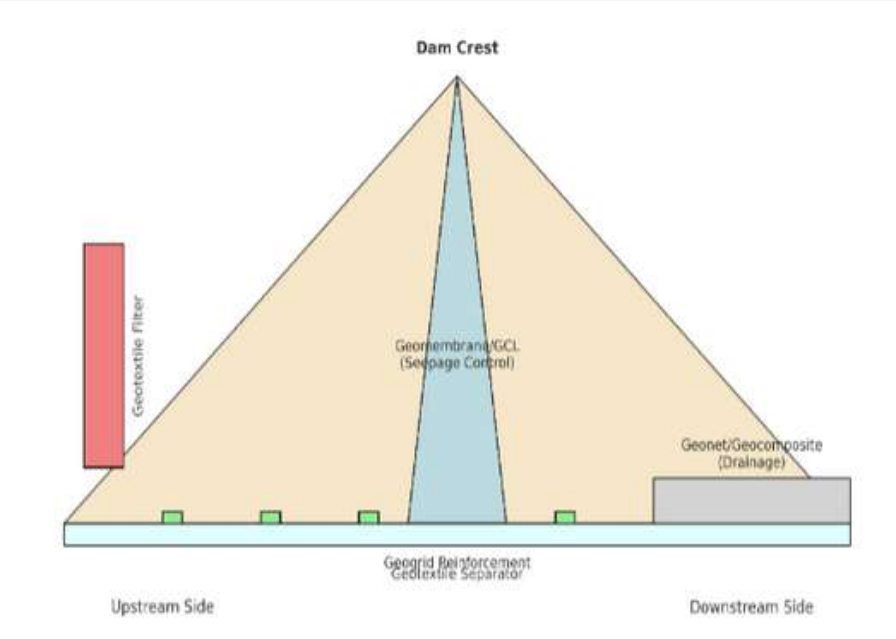

Figure 1: A schematic cross-section showing multiple geosynthetics applications within an embankment dam

Use of geosynthetics to stabilize embankments over peat and swamp soils, minimizing settlement and enhancing overall stability. This application demonstrates the effectiveness of geogrid and geotextile reinforcement in challenging foundation conditions. Use of geosynthetics to stabilize embankments over peat/swamp soils, mitigating settlement and improving stability is shown in Figure 2.

The incorporation of geosynthetics also improves load distribution and reduces differential settlement, ensuring uniform structural performance across weak soil zones. Additionally, these materials facilitate faster construction and lower maintenance requirements, making them a practical solution for both new embankments and rehabilitation projects.

Figure 2: Use of geosynthetics to stabilize embankments over peat/swamp soils, mitigating settlement and improving stability

5. APPLICATIONS IN INDIA AND KERALA

In India, geosynthetics have become a transformative solution in embankment dam engineering, enhancing structural stability, hydraulic efficiency, and long-term durability. In Kerala, where lateritic soils dominate and rainfall intensity is high, these materials help strengthen embankments against seepage, internal erosion, and slope failures. Their role is particularly vital in dam rehabilitation projects, where aging structures demand cost-efficient and technically advanced interventions.

Several successful projects across India demonstrate the multifunctional capabilities of geosynthetics. At the Kadamparai Dam, Tamil Nadu, a flexible geomembrane waterproofing system installed in 2005 provided effective seepage control and enhanced the masonry dam's long-term performance (Source: CBIP, 2020).

In Karnataka's Upper Bhadra Project, geosynthetics were employed for filtration, separation, and slope reinforcement, stabilizing embankments and preventing erosion while supporting irrigation over extensive agricultural land (Source: Geoquest Group, India).

Similarly, at the Joda East Iron Ore Mines, Odisha, geosynthetics reinforced tailings pond embankments, offering structural support, slope stability, and seepage mitigation, thereby ensuring the safety of surrounding areas (Source: Geoquest Group, India).

These examples highlight that geosynthetics offer not only technical advantages but also economic and environmental benefits. Their adoption reduces reliance on natural aggregates, accelerates construction, and supports sustainable water infrastructure development. By integrating multifunctional geosynthetic systems, engineers can achieve resilient, long-lasting dams capable of withstanding complex geotechnical and climatic challenges, thereby safeguarding water security and infrastructure sustainability across India.

6. CONCLUSION

The use of geosynthetics in embankment dams represents a major advancement in modern civil engineering. By integrating functions such as filtration, separation, reinforcement, drainage, and seepage control within a single material system, geosynthetics significantly enhance dam stability, mitigate risks of internal erosion, and ensure durable long-term performance. In Kerala's lateritic soils and high-rainfall regions, as well as throughout India, these materials offer a cost-effective, resource-efficient, and environmentally responsible solution for both new constructions and the rehabilitation of aging dams. Their adoption not only strengthens water infrastructure but also promotes sustainable engineering practices, accelerates construction, and delivers resilient performance under diverse climatic and geological conditions. By reducing reliance on natural aggregates and minimizing environmental disturbance, geosynthetics contribute directly to the sustainability of water resource management. This ensures safer and more reliable water resources for generations to come.

SMART RESIN TECHNOLOGY: ADVANCING WASTEWATER TREATMENT TOWARD RESOURCE RECOVERY

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1. INTRODUCTION

Water is among the most stressed natural resources in the world in the 21st century and increasing urbanization, population, and industrialization have correspondingly resulted in a steep upwards generation of wastewater. Most conventional wastewater treatment plants are primarily designed to deal with and treat wastewater. However, most of these plants, and wastewater treatment in general, fail to utilize the valuable materials often contained in water.

Recently, the field of environmental engineering has developed engineered porous resin beads designed to function simultaneously as filters and exchangers. These resins can seize and retain certain wastewater nutrients such as NH_4^+ and PO_4^{3-}. After being captured, the nutrients can be used in the production of fertilizers, thus repurposing wastewater treatment facilities as resource recovery sites.

Figure 1 demonstrates the adsorption–regeneration cycle wherein the beads trap the nutrients and after a certain period of time, the beads release the nutrients during regeneration and hence can be used again.

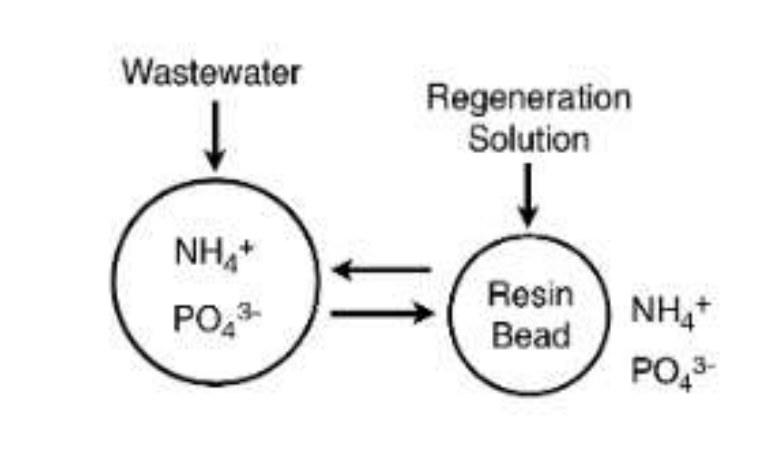

Figure 1: Resin Bead Adsorption–Regeneration Cycle

2. TECHNOLOGY OVERVIEW

The resin beads are made from polymeric materials with a highly porous internal network. Their surfaces are functionalized with ionic groups that selectively attract dissolved nutrients.

When wastewater flows through a resin column:

- Selective Binding: Ammonia and phosphate ions are captured by the resin.
- Clean Water Output: The effluent leaving the column has reduced nutrient content.
- Regeneration Step: Once the resin is saturated, mild chemical treatment is applied to release the bound nutrients.
- Reuse Cycle: The same resin beads can be regenerated and reused multiple times.

This adsorption–desorption cycle provides a cost-effective and sustainable method of nutrient recovery.

3. ADVANTAGES OVER CONVENTIONAL METHODS

Feature	Smart Resin Technology	Conventional Biological/Membrane Methods
Nutrient Removal	Highly selective (NH_4^+, PO_4^{3-})	General removal with varying efficiency
Reusability	Resin regenerates for multiple cycles	Limited
Energy Demand	Low	High in aeration/membrane systems
Resource Recovery	Nutrients collected as fertilizer	Often wasted as sludge
Scalability	Modular, easy to integrate	Requires large infrastructure

4. APPLICATIONS

- Municipal Wastewater Plants – For nutrient capture from sewage.
- Industrial Effluents – Agro-processing, fertilizer, and food industry wastewater.
- Decentralized Systems – Village-scale treatment with direct reuse of recovered fertilizer.
- Emergency/Remote Units – Portable treatment modules for disaster relief or arid regions.

As illustrated in Figure 10, the flow of wastewater through resin technology allows simultaneous purification and nutrient recovery.

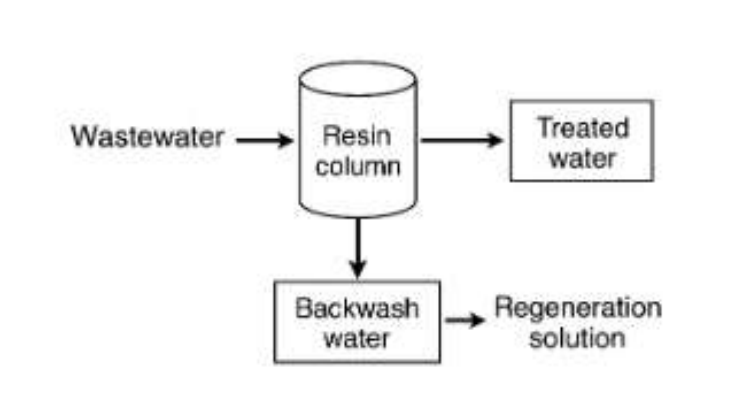

Figure 2: Flow Diagram of Resin-Based Wastewater Treatment

5. MATERIAL CHARACTERISTICS

The resin beads are made from polymeric materials with a highly porous internal network. Their surfaces are functionalized with ionic groups that selectively attract dissolved nutrients. The physical properties, such as pore size distribution, surface charge density, and hydrophilicity, strongly influence nutrient adsorption efficiency.

Typical physical features include:

- Pore size: 10–100 nm range
- Surface area: 200–500 m^2/g
- Functional groups: sulfonic acid, quaternary ammonium
- Mechanical stability: withstands multiple regeneration cycles

These engineered features help achieve both selectivity and reusability.

6. TECHNICAL CHALLENGES

Despite its advantages, resin technology faces several engineering challenges:

- Influent Variability: Wastewater composition changes daily, affecting adsorption efficiency.
- Regeneration Chemicals: The choice and cost of regenerating agents must be optimized.
- Scaling Up: Pilot-scale studies have shown success, but integration into large-scale municipal systems requires further trials.
- Regulatory Approval: Standards for safe reuse of recovered nutrients are still under development.

Coupling with renewable energy systems to make regeneration more eco-friendly.

7. FUTURE OUTLOOK

Resin-based technologies represent a shift from waste treatment to resource recovery. In the near future, wastewater plants may not only produce clean water but also generate valuable fertilizer streams, contributing to circular economy goals.

8. CONCLUSION

Smart resin technology offers an innovative pathway to enhance wastewater treatment beyond simple contaminant removal. By selectively capturing and recovering nutrientslike ammonia and phosphate, the process turns wastewater plants into centers for circular resource management. Although challenges remain in terms of regeneration chemistry, scaling, and standardization, continuous research and pilot applications show strong promise. With further development, this approach can deliver both cleaner water and valuable by-products, making it an essential tool for future environmental engineering solutions.

NEXT GENERATION HYDROPOWER: BALANCING DEVELOPMENT AND THE ENVIRONMENT

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1. INTRODUCTION

A new era of dam and hydropower engineering is emerging, defined by a paradigm shift that integrates technological innovation, enhanced environmental practices, an integrated water management to prioritize sustainability. Modern projects move beyond simply generating power, leveraging advancements like AI and IoT sensors to create “smart grids” that optimize real-time operation, enabling hydropower to act as a crucial, flexible energy storage solution for a grid increasingly dominated by intermittent sources like solar and wind. From an engineering standpoint, this includes the development of fish-friendly turbines and run-of-river designs that minimize ecological impact, along with the strategic use of environmental flow (E-flow) management and sediment bypass systems to restore river health and support aquatic ecosystems. Furthermore, the modern approach recognizes the vital importance of social responsibility, guided by principles of Integrated Water Resource Management (IWRM) and comprehensive Social Impact Assessments (SIA) to ensure that local communities are engaged, fairly compensated, and have their livelihoods protected.
This holistic philosophy is demonstrated by landmark projects like the Elwha River Dam removal in the United States, which demonstrated the transformative power of river restoration, and is supported by recent research in journals like the Journal of Sustainability Science and Management and Frontiers in Ecology and Evolution, which analyses the long-term benefits of these sustainable practices.

2. REDEFINING THE ENGINEERING APPROACH

Modern sustainable hydropower moves beyond a singular focus on energy generation to embrace a holistic, multidisciplinary approach. This involves integrating ecological and social considerations from the very first stages of a project.

- Integrated Water Resource Management (IWRM)

Integrated Water Resource Management (IWRM) is a crucial framework for dam and hydropower projects, evolving from a simple concept into a guiding practice that holistically manages entire river basins. It breaks down the traditional, fragmented approach to water

management by recognizing that water, land, and related resources are deeply interconnected. This approach considers the competing demands on a water body—from the needs of hydropower generation and agricultural irrigation to the requirements of municipal water supply, environmental flows for ecosystems, and flood control for communities and aims to balance them for overall economic efficiency, social equity, and environmental sustainability. For a dam project, IWRM ensures decisions are not made in isolation but are part of a larger plan involving all stakeholders, from local farmers to government agencies. This collaborative process relies on a robust institutional framework, clear policies and legislation, and a suite of management instruments (like water pricing and real-time monitoring) to achieve its goals. By adopting IWRM, dam projects can be designed and operated to serve multiple purposes, such as simultaneously providing flood protection, a reliable water source for downstream communities, and a habitat for aquatic life, thereby reducing negative impacts and maximizing benefits across the entire watershed.

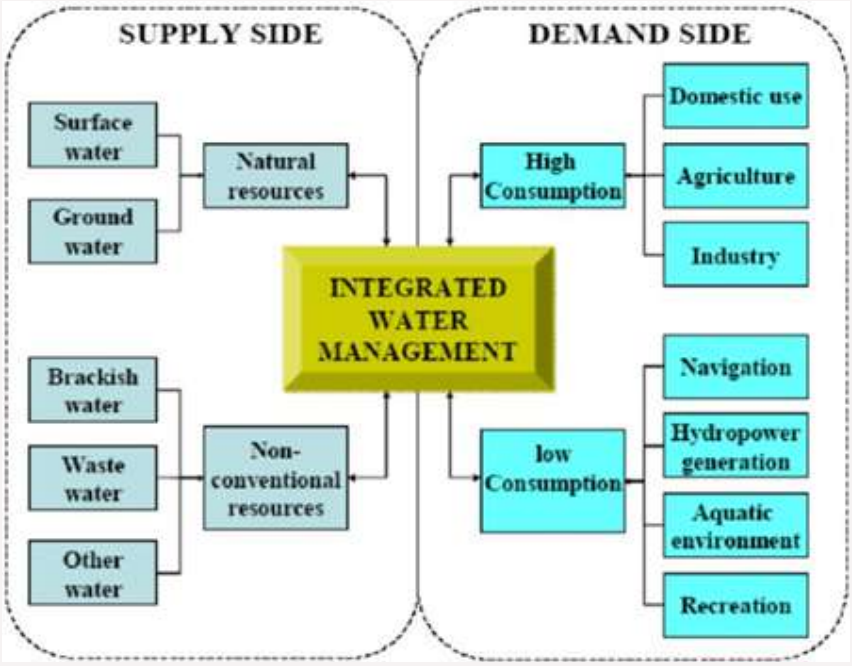

Figure 1: schematic representation of integrated water management

- Environmental Flow (E-Flow) Management

Releasing water in a way that mimics natural river flow patterns, a practice known as environmental flows (E-Flows), is a crucial shift in sustainable hydropower. Rather than maintaining a static, minimum release, E-Flows ensure that dams provide a dynamic flow regime that mirrors the natural river's frequency, magnitude, duration, timing, and rate of

change. This holistic approach is vital for the health of downstream ecosystems. For example, specific flow pulses can trigger spawning cues for fish, while seasonal low flows are essential for the lifecycles of certain aquatic insects and for maintaining stable riparian vegetation. The transport of essential sediments, which is often completely blocked by dams, is also a key function of E-Flows. By allowing controlled high-flow events, dams can flush fine sediment from spawning beds and nourish downstream floodplains, which are critical for both agriculture and ecosystem services. The latest research, including a 2024 study on the Middle Yangtze River, shows that even with increased water discharge from a dam, riverbed erosion can lower water stages and negatively impact riparian habitats, underscoring the need for a more comprehensive E-Flow strategy that considers both water and sediment dynamics. Overall, by implementing E-Flows, hydropower projects can balance energy production with the preservation of riverine ecosystems, ensuring the long-term sustainability of the entire river basin.

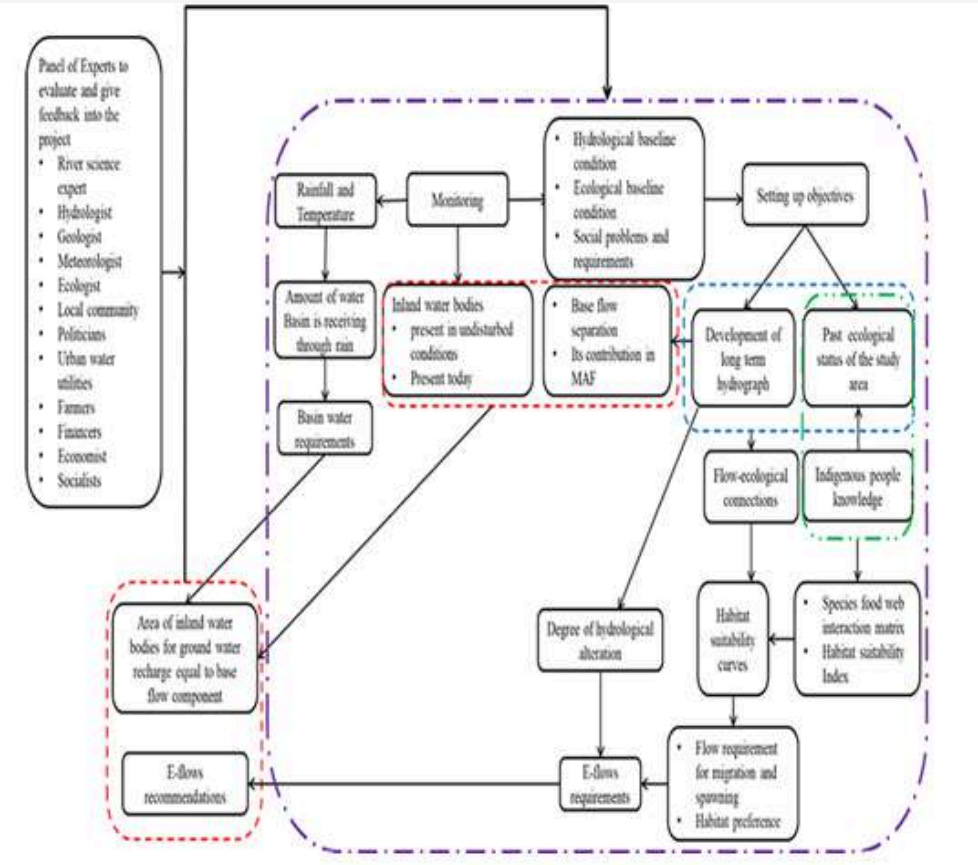

Figure 2: Framework for determining environmental flows requirements for data deficient Indian rivers

- Dam Decommissioning

Dam removal has emerged as a recognized and effective strategy for river restoration, particularly when structures are obsolete, unsafe, or causing irreparable ecological harm.

This process is a targeted intervention to reverse the long-term negative impacts of dams, such as habitat fragmentation, altered water flow, and blocked sediment transport. The removal of a dam allows a river to return to its natural, free-flowing state, which restores vital ecological processes. The most immediate and celebrated benefit is the re-establishment of fish passage, allowing migratory fishlike salmon and sturgeon to access historical spawning grounds that were blocked for decades or even centuries. This reconnection revitalizes entire ecosystems and supports a wider range of biodiversity. Furthermore, dam removal helps to restore the natural sediment transport regime, which nourishes downstream floodplains, rebuilds coastal deltas, and improves habitat quality. While the initial release of accumulated sediment can cause temporary downstream turbidity, studies have consistently shown that river systems are remarkably resilient and can recover naturally within weeks to years. Landmark projects, such as the removal of the Elwha River dams in Washington, have demonstrated the successful return of native fish populations and the restoration of natural geomorphic processes, proving that dam decommissioning is not just an endpoint for an old structure, but a powerful beginning for a revived river.

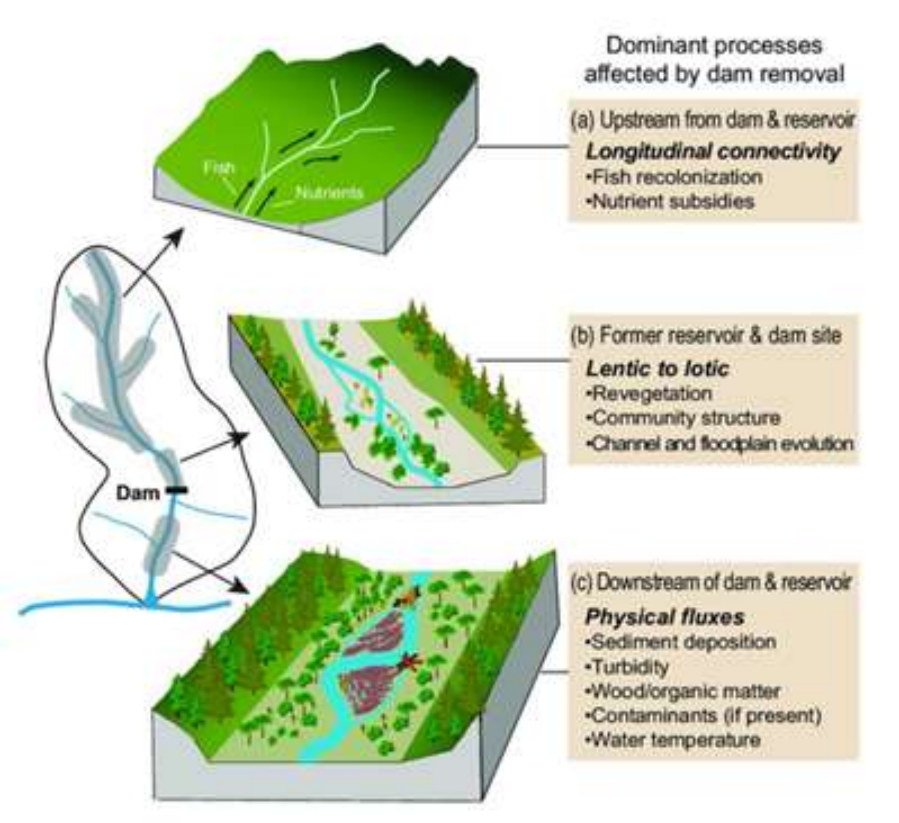

Figure 3: Spatial domains influenced by dam removal

3. EMERGING TECHNOLOGIES AND INNOVATIONS

Cutting-edg4e technologies are at the forefront of sustainable dam design, improving both efficiency and environmental performance.

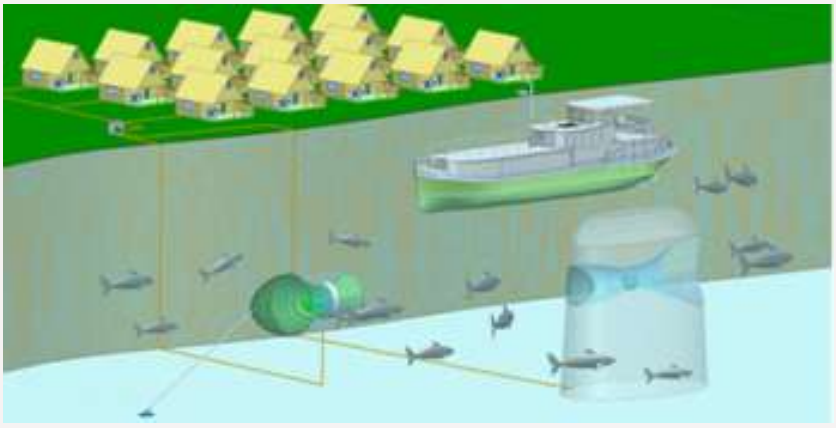

Figure 4: Fish friendly turbine

- Pumped-Storage Hydropower (PSH)

As the grid becomes more reliant on intermittent renewables like solar and wind, PSH is gaining traction as a massive, on-demand battery. Recent research from the Stanford Woods Institute highlights how closed-loop PSH systems, which do not require a connection to a natural waterway, are emerging as a low-impact solution for grid stability and energy storage.

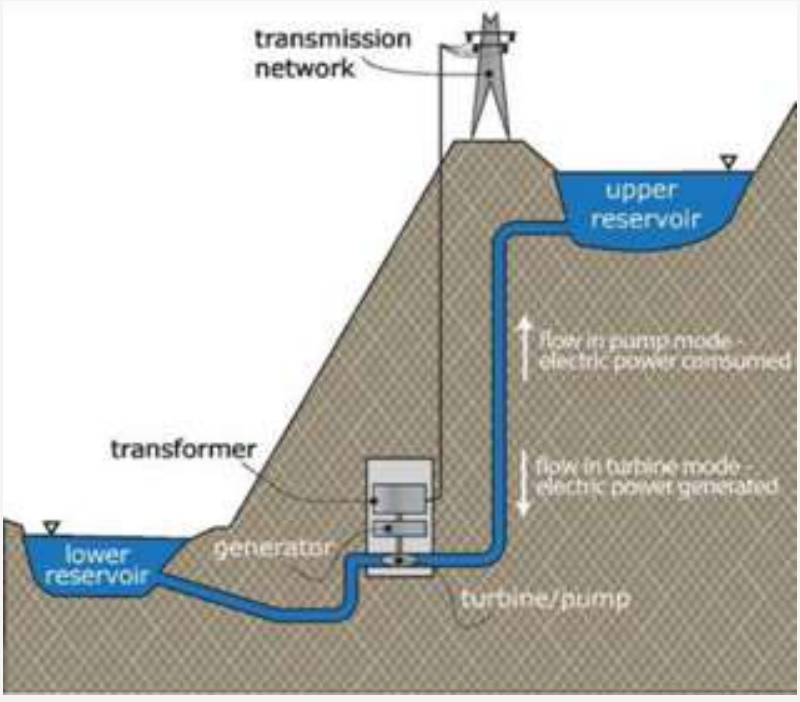

Figure 5: Pumped storage plant

- Digitalization and AI

The use of IoT sensors, digital twins, and AI is transforming dam operations. Smart dam technology, as highlighted in a 2024 review in Civil Engineering Journals, is revolutionizing dam management by leveraging real-time data and predictive analytics. Instead of relying on manual inspections and reactive repairs, dams are being equipped with a network of IoT sensors that continuously monitor key metrics like structural stress, water pressure, and equipment vibration. This constant stream of data is fed into sophisticated AI-powered platforms that can identify subtle changes and predict potential failures long before they occur, allowing for proactive and preventative maintenance. This not only increases the dam's operational efficiency and safety but also significantly reduces unplanned downtime and costly repairs.

Furthermore, this data-driven approach extends beyond structural management to the dam's primary function. AI algorithms can analyse real-time data on water levels, downstream demand, and weather forecasts to optimize power generation. They can also execute more precise water releases to meet specific environmental flow (E-Flow) requirements. For instance, the system can autonomously release a controlled pulse of water to mimic a natural flood event, supporting fish spawning or sediment transport, a level of precision that was previously difficult to achieve. This integration of technology transforms dams from static, manually-operated structures into dynamic, intelligent systems that balance energy production with ecological sustainability.

4. SOCIO-ECONOMIC CONSIDERATIONS AND POLICY

The social dimension of hydropower is now a central part of any sustainable project.

- Social Impact Assessments (SIA)

Social Impact Assessments (SIAs) are a vital part of modern dam projects, moving beyond just economic metrics to ensure social responsibility. Guided by reports like the World Commission on Dams (WCD), SIAs are now mandatory to evaluate a project's full impact on a community's livelihoods, culture, and social structures. Their goal is to proactively identify and mitigate negative effects, ensuring any necessary resettlement is handled with transparent, fair compensation and a clear plan to help people rebuild their lives. This confirms that for a project to be truly sustainable, it must protect the rights and well-being of the people it affects.

- Stakeholder Engagement

Collaborative stakeholder engagement is now a cornerstone of sustainable hydropower development, moving beyond a simple consultation to an integrated, participatory process. By involving local communities, Indigenous groups, and other stakeholders in planning and decision-making from the earliest stages, projects can incorporate valuable local knowledge and address concerns proactively. This shared responsibility not only builds crucial trust but

also ensures that the final design of the project aligns with the specific needs and cultural values of those most directly affected, leading to outcomes that are both more equitable and more resilient. Ultimately, this approach transforms a project from a purely engineering feat into a community-supported initiative that delivers long-term benefits to all parties.

5. CONCLUSION

By integrating collaborative stakeholder engagement from the earliest stages, sustainable hydropower projects move beyond simple consultation to a truly participatory process. Involving local communities and Indigenous groups ensures that projects can incorporate valuable local knowledge and address concerns proactively, which is essential for identifying potential social and environmental risks that a technical assessment might miss. This shared approach builds crucial trust and ensures the final design aligns with the specific needs and cultural values of those most directly affected, transforming a project from a purely engineering feat into a community-supported initiative that delivers long-term benefits. Furthermore, this active collaboration often leads to more innovative and resilient project designs that are better suited to the local context and are more likely to be accepted by the community. This shift not only fulfils an ethical obligation but also strengthens the long-term viability and success of the project by fostering a sense of shared ownership and responsibility among all parties.

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ARTIFICIAL INTELLIGENCE IN CIVIL ENGINEERING

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1.INTRODUCTION

Artificial Intelligence (AI) is a specialized field focused on creating systems that mimic human-like intelligent behaviour, making tasks faster and more efficient. Built on multiple disciplines such as computer science, neurophysiology, and psychology, AI enables machines to carry out tasks traditionally requiring human decision-making. In civil engineering, AI is being used to improve construction management, design optimization, material handling, hydraulic systems, transportation, and automation, among other areas.

2. AI IN CIVIL ENGINEERING

AI plays a crucial role in improving productivity, reducing costs, and ensuring safety in civil engineering. It is particularly beneficial in design, construction, and decision-making processes, enabling engineers to handle data collection, analysis, and optimization. Its applications range from optimizing materials to enhancing safety measures on construction sites.

Figure 1: Applications of AI in Civil Engineering

3. APPLICATIONS OF AI

AI is transforming various aspects of civil engineering, including:

- Construction Management – AI tools help optimize scheduling, resource allocation, and risk management, leading to better project outcomes.
- Material Management – AI can predict the optimal usage and delivery of construction materials, reducing waste and improving efficiency.
- Infrastructure Design – AI is used in designing more efficient buildings, bridges, and roads, improving both safety and sustainability.

4. AI TECHNIQUES IN CIVIL ENGINEERING

Some common AI techniques include:

- Quality Management: AI helps maintain high standards throughout construction projects.
- Design Optimization: AI algorithms can suggest more efficient and cost-effective designs.
- Risk Management: AI identifies potential risks in both design and construction, helping prevent accidents.
- Maintenance: AI aids in predictive maintenance, ensuring infrastructure lasts longer with fewer repairs.

5. ADVANTAGES OF AI

- Cost Reduction: AI minimizes the risk of budget overruns by streamlining processes.
- Safety Improvements: AI systems reduce accidents by continuously monitoring construction site activities.
- Efficient Project Planning: AI tools allow for more precise project schedules and resource management.
- Increased Productivity: AI boosts worker efficiency, enhancing output and reducing delays

6. CASE STUDIES AND SUCCESS STORIES

Incorporating case studies and success stories into discussions about the integration of artificial intelligence (AI) into civil engineering practice provides concrete examples of how these technologies are being applied in real-world scenarios.

Here are some detailed case studies and success stories showcasing the use of AI in civil engineering:

Predictive Maintenance for Infrastructure Assets

- Case Study

A civil engineering firm implemented an AI-driven predictive maintenance system for monitoring the structural health of bridges. The system integrated sensor data from bridge sensors, such as strain gauges and accelerometers, with AI algorithms to detect signs of deterioration and predict maintenance needs. By analysing historical data and identifying patterns indicative of potential failure, engineers were able to prioritize maintenance activities, extend asset lifespan, and reduce maintenance costs.

- Success Story

The predictive maintenance system enabled the civil engineering firm to proactively identify structural issues before they escalated into costly failures or safety hazards. By implementing targeted maintenance interventions based on AI-driven insights, the firm achieved significant cost savings and improved the overall safety and reliability of the bridges under its management.

Generative Design for Optimized Infrastructure Designs

- Case Study

An architectural and engineering firm utilized AI-driven generative design tools to optimize the design of a new pedestrian bridge. The firm inputted design parameters such as span length, load requirements, and material constraints into the generative design software, which automatically generated and evaluated thousands of design alternatives. By analyzing the performance metrics of each design iteration, engineers identified a design that minimized material usage while meeting structural integrity and aesthetic requirements.

- Success Story

The use of generative design enabled the firm to explore a wide range of design possibilities and identify an optimal solution that achieved significant material savings without compromising structural performance or design aesthetics. The resulting pedestrian bridge not only met the project requirements but also garnered recognition for its innovative design approach.

Construction Project Management and Risk Mitigation

- Case Study

A construction company implemented an AI-powered project management system to optimize construction workflows and mitigate project risks. The system analysed historical project data, including schedules, budgets, and performance metrics, to identify potential bottlenecks,

delays, and cost overruns. By leveraging AI-driven insights, project managers were able to allocate resources more effectively, anticipate project risks, and implement mitigation strategies to ensure timely and cost-effective project delivery.

- Success Story

The AI-powered project management system enabled the construction company to improve project outcomes and mitigate risks by providing real-time visibility into project performance and facilitating proactive decision-making. As a result, the company achieved higher project success rates, reduced project delays and cost overruns, and enhanced client satisfaction.

7. FUTURE AI APPLICATIONS IN CIVIL ENGINEERING (2025)

- Digital Twin Modeling: AI-powered digital twins create real-time virtual models of infrastructure, helping track performance and predict failures, which can reduce maintenance costs by up to 30%.
- Autonomous Robotics & Equipment Control: AI-driven robots and self-operating machines enhance construction efficiency, reduce fuel consumption, and improve safety.
- Traffic Flow Optimization: AI enhances traffic management by analysing real-time data to adjust traffic signals and reduce congestion.
- Energy Management: AI optimizes HVAC systems in buildings, reducing energy consumption and operational costs.
- Flood Prediction: AI-powered models predict flooding events, improving disaster preparedness and mitigation strategies.
- Concrete Mix Design: AI optimizes concrete compositions, reducing carbon footprints while ensuring structural strength.
- Drone-Based Surveying: AI-integrated drones improve land surveying efficiency, capturing vast areas and producing high-precision maps.
- Climate-Resilient Infrastructure: AI is used to design infrastructure that can withstand extreme weather events and adapt to climate change.
- Underground Construction Automation: AI-driven tunnel boring machines optimize construction processes, saving both time and money.
- Construction Waste Management: AI sorting technologies increase recycling rates and reduce waste in construction projects.
- Structural Health Monitoring: AI identifies early signs of wear and tear in buildings and bridges, ensuring timely maintenance and safety.
- Project Management: AI helps predict potential delays and optimize scheduling, reducing costs and project durations.
- Geotechnical Engineering: AI models enhance soil behaviour predictions, aiding in the design of stable foundations.

- Automated Design Systems: AI tools generate multiple design options, speeding up the design process and optimizing resources.
- Water Resource Management: AI assists in efficient water distribution and leak detection, ensuring sustainability.
- Pavement Maintenance: AI helps assess road conditions, enabling proactive repairs and extending the lifespan of road networks.
- Earthquake Risk Assessment: AI enhances the prediction of seismic events and helps design structures that can withstand earthquakes.
- Site Safety Monitoring: AI systems track safety violations on construction sites, improving worker safety and preventing accidents.
- Environmental Impact Analysis: AI models predict the environmental impact of projects, enabling more sustainable construction practices.
- Noise and Vibration Control: AI helps monitor and mitigate noise and vibration levels around construction sites, enhancing community relations.

8. CONCLUSION

AI is significantly simplifying tasks in civil engineering by enhancing design, construction, and management practices. Its ability to predict and optimize various processes is not only saving time and costs but also improving the safety and sustainability of infrastructure. As AI continues to evolve, it will play an even larger role in shaping the future of civil engineering, helping engineers tackle complex challenges more efficiently.

RING-SHAPED TUNED LIQUID DAMPERS: A MODERN SOLUTION FOR BRIDGE VIBRATION CONTROL

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1.INTRODUCTION

Suspension bridges are among the greatest achievements of modern civil engineering, connecting distant landscapes and serving as symbols of progress. However, these structures also face significant technical challenges. One of the most critical issues is the vibration of suspender cables. These slender elements are highly susceptible to oscillations caused by wind, rain, vortex shedding, and even vehicular movement. If left uncontrolled, these vibrations can gradually cause fatigue damage, anchor zone deterioration, excessive noise, and in extreme cases, structural failure.

Traditional vibration control methods, particularly Tuned Mass Dampers (TMDs), have been widely used for decades. While effective to a certain degree, they bring disadvantages such as large self-weight, higher costs, and the need for frequent maintenance. In recent years, an innovative solution has gained attention: the Ring-Shaped Tuned Liquid Damper (RSTLD). This system harnesses the principles of fluid dynamics to suppress vibrations efficiently, offering a lightweight, adaptable, and practical approach for both new and existing bridges.

2. WORKING PRINCIPLE OF RSTLDS

The RSTLD operates on a simple yet highly effective principle. It consists of a circular liquid- filled container that is attached around the midpoint of a suspender cable. This location is not random the midpoint corresponds to the position of maximum displacement in the fundamental vibration mode of the cable. When the cable begins to oscillate under dynamic loads, the liquid inside the ring is set into sloshing motion. The movement of this liquid produces hydrodynamic forces that oppose the motion of the cable, thereby dissipating energy and reducing vibration amplitude.

The energy transfer process is cyclical. The vibrating cable imparts energy to the liquid, which begins to oscillate. The oscillation of the liquid then generates restoring forces that act out of phase with the vibration of the cable. In effect, the damper absorbs part of the energy and releases it in a controlled manner, reducing the net amplitude of the cable's

vibration. This mechanism allows the RSTLD to provide continuous damping without the need for heavy mechanical components or complicated control systems.

3. DESIGN AND COMPONENTS

A typical RSTLD is made up of several simple yet functional components. The core element is the liquid container, a ring-shaped chamber designed to hold the damping medium. Transparent containers are often preferred, as they allow engineers to monitor liquid levels easily through marked graduations. A top cap protects the chamber, preventing evaporation of the liquid and protecting it from external contaminants such as rainwater and dust.

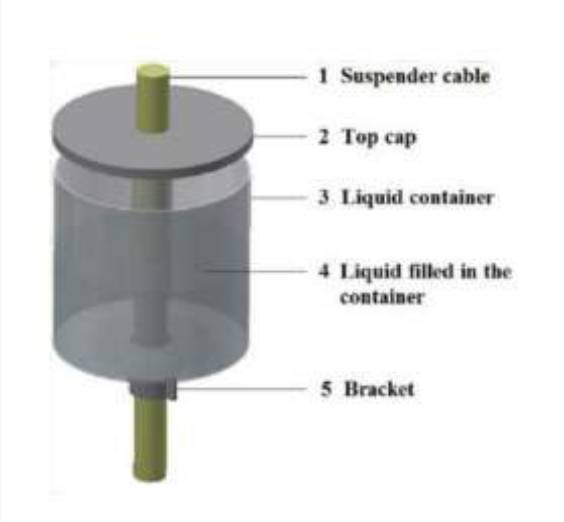

Figure 1: Proposed Ring Shaped Tuned Liquid Damper (RSTLD) for suspender cables

The damping liquid itself may vary depending on the environment and required performance. Ordinary water is commonly used, but in regions with high evaporation rates or extreme climates, more stable liquids such as methyl silicone oil are preferred, as they provide enhanced damping with minimal evaporation. A supporting bracket connects the damper securely to the suspender cable and may also house small sensors such as accelerometers, which help in monitoring cable behavior and the performance of the damper.

For new bridge projects, the RSTLD can be integrated directly into the design of the cables. In retrofit situations, the device can be fabricated in modular, semicircular sections that are bolted together around the cable and sealed to ensure water resistance. This makes it practical to install on existing bridges without major structural modifications.

4. ADVANTAGES OF RSTLDS

The greatest advantage of RSTLDs lies in their lightweight design. Unlike conventional TMDs, which require large masses and heavy assemblies, liquid dampers rely on the inertia of fluid motion, significantly reducing the added dead load on the structure. They are also highly adaptable; by adjusting the depth or viscosity of the liquid, engineers can fine-tune the device to match specific vibration characteristics of different cables.

Inspection and maintenance are made simpler by the use of transparent containers, which allow quick visual checks of fluid levels even from a distance. Installation is also straightforward due to their modular design, enabling engineers to retrofit existing bridges with minimal disruption. Durability is another notable benefit, as high-viscosity liquids resist both evaporation and temperature variations, ensuring consistent performance over long periods. When compared with TMDs, RSTLDs are also more cost-effective, both in terms of fabrication and maintenance, while offering greater flexibility in field applications.

5. APPLICATIONS IN STRUCTURAL ENGINEERING

While the primary application of RSTLDs is in suspension bridges, their potential extends much further. In bridge engineering, they can be used not only for suspender cables but also for main cables and stay cables in cable-stayed bridges. Beyond bridges, liquid dampers have already proven their worth in high-rise buildings across Japan and Korea, where tuned liquid column dampers have been successfully employed to reduce sway during typhoons and earthquakes. These successes in buildings provide strong evidence that liquid damping technology is effective and reliable across a range of structures.

Towers, chimneys, metro rail viaducts, and offshore platforms also stand to benefit from this technology. In each case, structures exposed to dynamic wind or wave loading can experience significant oscillations, and RSTLDs provide a practical solution to suppress them. Their versatility strengthens the argument for wider adoption in the field of civil engineering.

6. RESEARCH IMPORTANCE

Research into RSTLDs has considerable significance, both academically and practically. On the theoretical side, studying the fluid-structure interaction between cables and liquid sloshing deepens our understanding of dynamic systems. Laboratory models and numerical simulations provide valuable insights into how parameters such as liquid viscosity, container shape, and installation location influence damping efficiency. On the practical side, field experiments have consistently validated these theoretical models

Large-scale studies in China demonstrated that RSTLDs could suppress cable vibrations by more than 40 percent under rain–wind excitation. Comparative studies, such as those published in Lecture Notes in Civil Engineering by Springer, confirm that while TMDs offer steady performance, RSTLDs provide superior adaptability, easier retrofitting, and lower costs. Research in India, particularly at IIT Kanpur and engineering colleges in Kerala and Tamil Nadu, has already explored liquid damper systems in high-rise buildings, paving the way for their application in bridges.

7. ELIMINATING VIBRATIONS IN BRIDGES

The process of eliminating vibrations with RSTLDs follows a clear sequence. Engineers first identify the most critical vibration mode of the cable, which is usually the first mode, where maximum displacement occurs at the midpoint. The damper is then installed precisely at this location to maximize efficiency. Once operational, the vibrating cable transfers energy to the liquid inside the damper. This liquid, in turn, moves in the opposite direction, producing hydrodynamic forces that counteract the cable's motion.

Over repeated cycles, this process reduces the overall amplitude of vibration. Studies have shown that amplitudes can be reduced by up to half in some cases, significantly decreasing the fatigue stresses acting on the cable. In the long term, this not only improves structural safety but also extends the service life of bridges by reducing the risk of cable failure.

8. INDIAN CONTEXT AND FUTURE PROSPECTS

At present, there are no reported applications of RSTLDs in Indian suspension bridges. However, the increasing number of long-span bridge projects across the country, such as the Chenab Bridge, Bogibeel Bridge, and upcoming sea bridges, presents a strong opportunity. With India's diverse climate, there are challenges to consider, such as higher evaporation rates during summers, which can be addressed through the use of silicone-based liquids. Another challenge lies in the need for new inspection protocols and training, as engineers are generally more familiar with TMDs.

Looking forward, the adoption of RSTLDs in India could bring substantial benefits. By collaborating with academic institutions like IITs and NITs and with government agencies such as NHAI, DMRC, and BRO, pilot projects can be launched to test the efficiency of these devices in Indian conditions. With successful trials, RSTLDs could gradually become a standard feature in bridge design and maintenance.

9. CONCLUSION

Ring-Shaped Tuned Liquid Dampers combine simplicity with innovation to address one of the most persistent problems in suspension bridges. By absorbing and dissipating oscillatory energy through controlled fluid motion, they provide a lightweight, adaptable, and durable solution. International studies and applications already confirm their effectiveness, and India now stands at the threshold of adopting this promising technology.

As engineers, our role extends beyond construction to ensuring the long-term resilience and safety of the structures we create. Embracing technologies such as RSTLDs is a step toward this responsibility. By introducing them into Indian bridge engineering, we can move closer to building structures that are not only visually impressive but also technically enduring.

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CONSULTANCY WORKS FROM GOVERNMENT DEPARTMENTS AND PRIVATE FIRMS

The faculty members in the department are actively involved in the consultancy works from both government departments and private firms. Important Civil engineering fields in which consultancy works are being done include:

Nature of consultancy work	Associated Government department/Private firm
Concrete cube compression tests over various periods	Private firms and government departments
Soil strength, bearing capacity, CBR tests, foundation recommendations	Government departments
Concrete mix design (M25, etc.)	Private firms and government departments
Mild steel reinforcement testing	Private firms and government departments
Soil Stability Analysis	Private firms

Students are also given opportunity to participate in the consultancy works, so that, they can associate with real time projects. Some additional facilities/equipments were added to the laboratories to carry out consultancy works and funded projects.








RESEARCH CONTRIBUTIONS 2024-2025

PAPER PUBLICATIONS

SL. No.	Authors	Title of the paper	Publication Details
1.	Ardra K. Manoj Ameena Inas Gaurav Krishna Ms Kalyani Vijayakumar	Correlation between Soil Shear Strength and Water Content Ratio as substitute for Liquidity Index	National Conference on Innovations in Civil Engineering 2025 (NCICE 2025)
2.	Aneena Johnson Dhana Mohammed M. Asif A. Z. Kelvin Jaiso Ms Gloria Anto	Strengthening of Reinforced Concrete Beam using bolted steel plate and carbon fiber reinforced polymer	National Conference on Innovations in Civil Engineering 2025 (NCICE 2025)
3.	Ajith C. B. Mr Kiran Babu A. R.	Flexural Behavior of One-Way Slabs Reinforced with BFRP and Steel Bars : An Experimental and Numerical Investigation	National Conference on Innovations in Civil Engineering
4.	P. H. Sai Krishna Ms Ardra P. Nair	Study on Strengthening of concrete filled double-skin tubular columns with intermittent weld reinforcing	National Conference on Innovations in Civil Engineering 2025 (NCICE 2025)
5.	Anandsagar P. S. Fathimath Sahla K. A. Athul Krishna V. M. Apsara P. S. Ms Chithra M.	Sustainable Removal of Chloride from Water Using Agricultural Byproducts	National Conference on Innovations in Civil Engineering 2025 (NCICE 2025).

RESEARCH CONTRIBUTIONS 2024-2025

PAPER PUBLICATIONS

SL. No.	Authors	Title of the paper	Publication Details
6.	Nishana K. S. Lakshmipriya K. V. Indeevara P. S. A. S. Poojalakshmi Ms Ardra P. Nair	Strengthening of Concrete Beam Using Rice Husk Ash and Glass Powder	National Conference on Innovations in Civil Engineering 2025 (NCICE 2025)
7.	Vignesh V. Suranjan A. Sneha T. N. Renjima Jojo Ms Nirmala Krishnan	Sugarcrete blocks : A sustainable building material	National Conference on Innovations in Civil Engineering 2025 (NCICE 2025)
8	Sarath M. B. Mr Kiran Babu A. R.	Investigation on Structural Behaviour of Metallic Foam Sandwich Panel as Steel Plate Shear Wall	National Conference on Innovations in Civil Engineering
9.	Meenakshi C. V. Nandana K. Sajeev Nandhana M. M. Sourav M. S. Mr Kiran Babu A. R.	Axial Compressive Behaviour of Predamaged RC Columns Retrofitted with Precast Steel Reinforced Grout Jacket	National Conference on Innovations in Civil Engineering 2025 (NCICE 2025)
10.	Mr Kiran Babu A. R.	Study on Moment Carrying Capacity of Eaves Connection in Cold Formed Steel Sections in Portal Frames	International Conference on Structural Engineering and Construction Management (SECON'25)

RESEARCH CONTRIBUTIONS 2024-2025

PAPER PUBLICATIONS

SL. NO.	Authors	Title of the paper	Publication Details
11.	Alfin Kunjuvareed Dr Abhilasha P. S.	Compressive Behavior of Concrete Columns Confined with Aramid Fiber Reinforced Polymer Twinning Tubes	International Conference on Structural Engineering and Construction Management
12.	Adarsh K. P. Dr Abhilasha P. S.	Investigation And Enhancement of Seismic Resilience in Structural Columns Using Dual Pipe, U & Slit Dampers	REACT 2025
13.	Alfin Kunjuvareed Dr Abhilasha P. S.	Compressive Behavior of Concrete Columns Confined with Bamboo Sheet Twinning Tubes	REACT 2025
14.	Dr Anjali P. Sasidharan	Eco-Friendly Utilization of Mango Leaves As Biosorbent To Eliminate Iron Content From Water	International Journal of Creative Research Thoughts
15.	Athul Krishna V. R. Athulya Premlal Lakshmi K. S. Arjun C. Ms Nirmala Krishnan	Replacement And Optimization of Biochar Brick & Plastering, For Carbon Sequestration	REACT 2025

PAPER PUBLICATIONS

SL. NO.	Authors	Title of the paper	Publication Details
16.	Ms Nisha Varghese	Structural Performance and Development of a Hybrid Coupling beam	International Journal of Scientific Research in Engineering & Technology(REACT 2025)
17.	Ms Nisha Varghese	Structural Performance of Partially Encased Orthogonal Composite Columns with Bond Strength Strategies	International Journal of Scientific Research in Engineering & Technology(REACT 2025)
18.	Divya Prabha T. R. Arunima C. Anaina E. S. Arundhadhi A. P. Ms Seetha Pisharikkel	Effect of Contamination on Geotechnical Properties of Clay Soil	International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)
19.	Mr Kiran Babu A. R.	Sustainable Practices on Metallic Foam Sandwich Panels in Steel Plate Shear Walls as a Part of Green Building	International Conference on Structural Engineering and Construction Management(REACT 2025)
20.	Mr Kiran Babu A. R.	Sustainable Retrofitting of Pre-damaged RC Columns Using Precast Steel-Reinforced Grout Jackets	International Conference on Structural Engineering and Construction Management

RESEARCH CONTRIBUTIONS 2024-2025

PAPER PUBLICATIONS

SL. NO.	Authors	Title of the paper	Publication Details
21.	Mr Kiran Babu A. R.	Sustainable Practices on Metallic Foam Sandwich Panels in Steel Plate Shear Walls as a Part of Green Building	National Conference on Innovations in Civil Engineering 2025
22.	Mr Kiran Babu A. R.	Retrofitting of Pre-damaged RC Columns Using Precast Steel-Reinforced Grout Jackets	National Conference on Innovations in Civil Engineering 2025
23.	Ms Anu Maria Antony	Rainfall induced landslide analysis	REACT 2025
24.	Shine Jose K. Rishi Govind V. S. Nandana M. M. Dr Anjali P. Sasidharan	Phosphate Removal From Waste Water using Zinc Oxide	International Journal of Creative Research Thoughts (IJCRT)
25.	Mr Kiran Babu A. R.	Numerical investigation of Slabs	International Journal of Scientific Research in Engineering & Technology, REACT 2025

RESEARCH CONTRIBUTIONS 2024-2025

PAPER PUBLICATIONS

SL. NO.	Authors	Title of the paper	Publication Details
26.	Mr Renjith R.	Utilization of Plastic Waste for Soil Stabilization: An Experimental Investigation on Clayey and Granular Soils	REACT 2025
27.	Mr Renjith R.	Road Safety Audit of Paliyekkara-Nenmanikkara Road	REACT 2025
28.	Mr Renjith R.	Macro seismic intensity attenuation of the Peninsular Craton	Journal of Emerging Technology and Innovative Research (JETIR)
29.	Ms Ponsy Paul	Recent rainfall patterns & their Consequences in Kerala : A comprehensive review	REACT 2025
30.	Nandakishore K. A. Neeraja K. R. Vino C. M. Vishnu C. K. Dr Abhilasha P. S.	Integrating Geocomposite with Retaining Walls for Improved Slope Stability in Wadakkanchery	International Conference on Structural Engineering and Construction Management

FUNDED PROJECT 2024-2025

The proposal titled as 'Replacement and Optimization of Biochar Brick and Plastering, for Carbon Sequestration' for student projects has been approved for a financial assistance of Rs 37,500/- under Centre for Engineering Research and Development (CERD) of APJ Abdul Kalam Technological University. The team includes

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Nisha Varghese	Assistant Prof.	Co investigator
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Athulya Premlal	Student S8 CE	student member
Lakshmi K. S.	student S8 CE	student member
Arjun C.	student S8 CE	student member

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"The Future depends on what we do in the present"
- mahatma gandhi

VIDYA ACADEMY OF SCIENCE AND TECHNOLOGY
THALAKKOTTUKARA

DEPARTMENT OF CIVIL ENGINEERING
IN ASSOCIATION WITH VYVIDH '24 PRESENTS

VASTATVA 2024

VASTATVA ‘24

INTRODUCTION

The Civil Engineering Department of Vidya Academy of Science and Technology conducted a two-day tech fest named **"Vastatva" on October 4th and 5th, 2024**. The event aimed to provide a platform for engineering students from various institutions to showcase their technical skills and knowledge.

EVENTS AND PAVILIONS

The Department of Civil Engineering hosted tech fest Vastatva ’24-25 on October 4th and 5th, 2024. The main expo, Aakriti, was centered on sustainable, disaster-resilient infrastructure, and innovative technologies. Focus areas included eco-friendly materials, resilient urban planning, and advanced disaster response mechanisms. This event showcased cutting-edge initiatives in civil engineering, emphasizing sustainability and the interconnectedness of elemental forces (earth, water, fire, wind, and space) for a harmonious habitat.

Aakriti at Vastatva’24-25 was a significant platform promoting sustainable and resilient civil engineering solutions. The highlight of Aakriti was a 2V Geodesic Dome. It is small scale dome structure composed of 12-20 triangular facets. It is the lowest frequency geodesic dome, offering a compromise between structural strength and simplicity. The construction prioritized cost-effectiveness without compromising structural integrity. The exhibition also showcased diverse architecture models, providing a comprehensive display of various design approaches within the field. Notably, virtual reality (VR) was employed to demonstrate building designs, and a dedicated pavilion honored the placements and memories of senior students who had graduated and contributed significantly to past projects.

Zora, The Junior Expo was a showcase of creative solutions developed by young minds in response to challenges faced by communities after the Wayanad landslide. One of the key themes of the expo was to showcase the area affected by the landslide and post-landslide management. The event aimed to educate and empower students to think critically about infrastructure design, disaster recovery, and sustainability. The event also facilitated networking opportunities with professionals and peers, acting as a catalyst for knowledge exchange and career development in civil engineering. In today's era of environmental challenges and increased disasters, civil engineering is crucial for mitigating risks and promoting sustainable living. The Expo facilitates knowledge exchange, fostering collaboration among professionals and academia. This contributes to the evolution of civil engineering practices, prioritizing sustainability, resilience, and community well-being for a harmonious and secure future.

Apart from the expo, the tech fest featured several technical games, such as Design wizard, Girder King, Workshop, Seminar, and Concrete crush. These games provided a platform for students to showcase their technical skills and knowledge. The games were challenging and allowed students to demonstrate their creativity and problem-solving abilities.

Design wizard

A CAD drawing is provided for the participants and the one who completed the replica of the given drawing first, meeting all the provided conditions, won the game. The event was conducted on the first day at 10.30 am.

Girder King

Girder models are made with given ice-cream sticks and glue. The maximum load bearing girder wins the game. The event was conducted on the second day at 10.30 am.

Concrete Crush

The participant casted concrete cube with given materials and after 7 days, the cube with the most strength wins the game. The event was conducted on the second day at 2.00 pm. Winner will be announced after 7 days of casting.

Workshop on Structural Analysis and Designing

A free workshop on Structural Analysis and Designing by Mr. Sarath was conducted with full attendance. The event was conducted on the first day at 2.30 pm.

Seminar on Building Beyond Space

The session was handled by Mr. Renjith R. He is an assistant professor of CE at VAST. He discussed the topic 'Building Beyond Space. The event was conducted on second day at 10.30 am.

NON TECHNICAL EVENTS

In addition to technical events, non-technical events were also conducted to engage students from different backgrounds. These events included Neon Football, Face Painting, Fear Chamber, Casino Royale, and Mini Militia. These events were aimed at providing a fun-filled experience to the participants and helped them to showcase their creative abilities.

Neon Football

This is a 3s football game set within a dark room with neon lightings. The event was conducted on the first day.

Casino Royale

A bunch of small games ensured maximum participation with minimal entry fee. The event was conducted on both days.

Mini Militia
Participants actively involved in the 2D multiplayer action game. The event was conducted on the first day.

Face Painting
Visitors can do a painting on their body with any design of their choice. The event was conducted on both days.

Nashville
A room setup which was created to experience the horror in real life for the visitors. The event was conducted on both days.

CONCLUSION

In conclusion, the Vastatva tech fest conducted by the Civil Engineering Department of Vidya Academy of Science and Technology was a remarkable event. It brought together engineering students from various institutions to showcase their technical skills and knowledge. The tech fest was a great success and a fantastic opportunity for students to network with peers and experts in the field under the common name of Vyvidh. Overall, the event was a testimony to the efforts of the organizers, students, and faculty members who worked tirelessly to make the event a grand success. The students' hard work and dedication were clearly reflected in this fest. It was a wonderful opportunity for the participants to showcase their talents.


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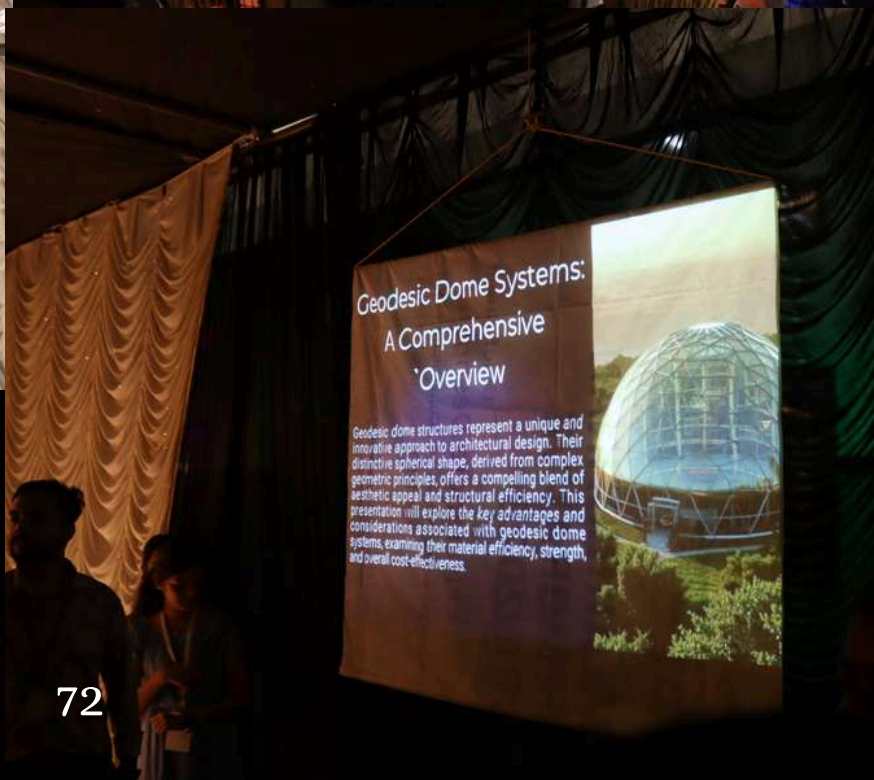
PLACEMENTS


RESILIENCE


WAYANAD

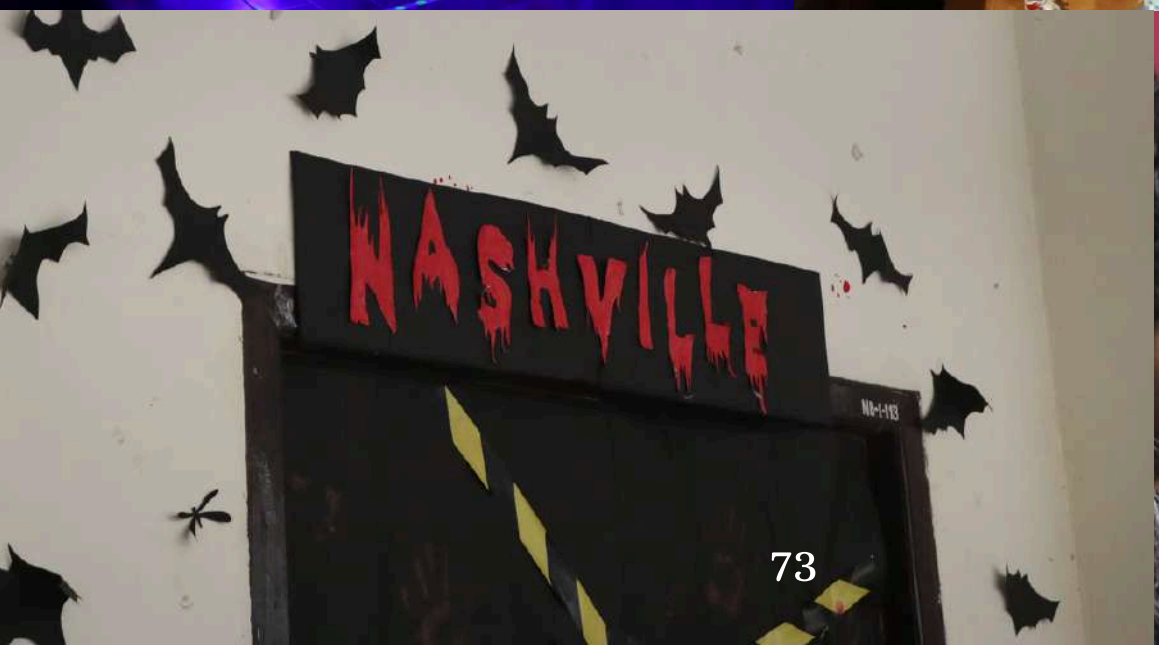

Geodesic Dome Systems:
A Comprehensive
`Overview
Geodesic dome structures represent a unique and innovative approach to architectural design. Their distinctive spherical shape, derived from complex geometric principles, offers a compelling blend of aesthetic appeal and structural efficiency. This presentation will explore the key advantages and considerations associated with geodesic dome systems, examining their material efficiency, strength, and overall cost-effectiveness.


BASE DIA 4.2 M


GAME ON


CASINO
ROYALE


RONALDO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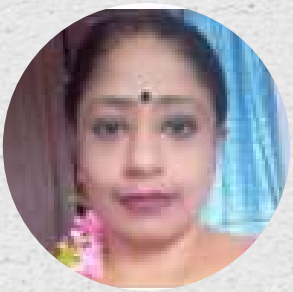

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