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INTEGRATED STRATEGIES FOR WATER-EFFICIENT CONSTRUCTION: A MULTI-THEMATIC ANALYSIS USING RII

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Abstract: *The construction industry, as a major consumer of freshwater, significantly contributes to global water stress, especially in rapidly urbanizing regions. This mini project investigates a wide array of strategies aimed at enhancing water efficiency across the construction lifecycle—spanning planning, execution, and post-construction phases. It evaluates traditional water-intensive practices against innovative, sustainable alternatives including low-water curing methods, modular construction, smart metering, rainwater harvesting, greywater recycling, and site-specific water management systems.*

The study integrates findings from literature, policy frameworks, and real-world case studies in India and Singapore to illustrate the practical implementation of these strategies. Standards such as IGBC, LEED, and the National Building Code of India are analysed for their role in shaping regulatory and incentive-based adoption. Through detailed cost-benefit analyses and flow diagrams, the report demonstrates that water-efficient practices not only yield environmental benefits but also offer long-term economic savings and compliance advantages.

Ultimately, the project presents a strategic roadmap for engineers, developers, and policymakers to transition toward water-resilient construction practices that align with Sustainable Development Goal 6 (Clean Water and Sanitation). This work contributes to a growing body of knowledge that supports the integration of circular water management within the construction industry.

Key Words: *Water-efficient construction, sustainable building practices, rainwater harvesting, greywater reuse, recycled wastewater, water auditing, leak detection, green construction technologies, low-flow plumbing fixtures.*

1. INTRODUCTION:

Water plays an indispensable role in construction, one of the most water-intensive sectors globally. Activities such as concrete mixing, curing, equipment cleaning, and dust suppression rely heavily on freshwater, further stressing already limited resources—especially in rapidly urbanizing nations like India. The construction sector alone accounts for around 12% of global water withdrawals (UNEP), a figure with significant implications for water sustainability. India, in particular, faces a critical water crisis, with over 600 million people under severe stress (NITI Aayog).

The construction industry exacerbates this crisis through reliance on groundwater, tanker water, and municipal supply. Traditional methods such as pond curing, inefficient site practices, and unregulated water use lead to excessive consumption and environmental degradation. Adoption of water-efficient construction is thus an urgent necessity, aligning with green building standards like IGBC, GRIHA, and LEED, and contributing directly to Sustainable Development Goal 6 (Clean Water and Sanitation).

This study aims to evaluate practical strategies to reduce water usage during the construction phase without compromising on quality or safety. Focusing primarily on the Indian context while drawing on international examples, the project examines technological, material, and policy innovations that enable water savings. By identifying the barriers and drivers influencing water-efficient practices, the study offers actionable insights for developers, policymakers, and engineers.

2. LITERATURE REVIEW:

Research has increasingly addressed water-saving interventions in construction, ranging from technology to stakeholder behaviour. Bhagat & Khan (2021) emphasized integrating rainwater harvesting and greywater reuse with monitoring systems, while Thomas & George (2023) highlighted the impact of IoT-based smart metering on reducing consumption. Green certification frameworks like LEED and IGBC have institutionalized efficiency benchmarks ([3]), encouraging broader adoption.

Materials and construction methods also play a pivotal role. Studies by Mistry & Shah (2022) and Nagaraja & Shankar (2021) demonstrate that Ready-Mix Concrete and treated wastewater use can significantly cut water usage. Prefabricated systems ([4]) and AAC blocks ([7]) offer further savings. Patil & Raut (2023) and Kulkarni & Joshi (2023) reinforced the importance of water audits, site monitoring, and retrofitting labour accommodations with efficient fixtures ([11]).

Other researchers, including Ramesh & Kuldeep (2020), proposed decentralized recycling systems, while Tripathi & Singh (2022) promoted vacuum-flush toilets in labour camps to achieve up to 70% water reduction. Policy frameworks ([18]; [19]) advocate for rainwater harvesting and offer local governance models that reinforce sustainability. Collectively, these studies underscore the need for a holistic approach that integrates design, technology, behaviour, and regulation to improve water efficiency.

3. OBJECTIVES:

To fulfil the study's purpose and within its defined scope, the following specific objectives are established:

1. To analyse current water usage patterns in the construction industry.
2. To compare traditional construction practices with water-efficient methods.
3. To identify innovative materials, technologies, and methods for water conservation.
4. To develop actionable recommendations for improving water efficiency in future projects.

   By pursuing these objectives, this project aims to contribute to the body of knowledge on sustainable construction and provide a strategic guide for implementing water-saving practices in diverse construction environments.

4. RESEARCH METHODOLOGY:

This study adopts a quantitative, questionnaire-based approach to assess the awareness and implementation of water-efficient construction practices. The research design is both descriptive and exploratory, targeting six core themes: awareness, planning strategies, technology, on-site practices, stakeholder roles, and barriers. A total of 30 Likert-scale statements were developed and validated through a pilot test with construction professionals.

A purposive sampling method was used to survey 40 respondents—including engineers, contractors, and project managers—from both public and private sectors. The questionnaire was administered via Google Forms, ensuring accessibility and consistency. The collected data was processed in Microsoft Excel and analyzed using the Relative Importance Index (RII), calculated as:

- $RII = \Sigma W / (A \times N)$
- Where:
  W = weight assigned to each statement (1 to 5)
  A = highest possible weight (5)
  N = total number of respondents
  This method enabled the prioritization of factors based on stakeholder perception, offering a structured basis for identifying key areas of focus and challenge in implementing water-efficient practices.

5. DATA COLLECTION & ANALYSIS:

To understand stakeholder perceptions of water-efficient practices in construction, a structured questionnaire-based survey was administered using Google Forms. The survey remained active for two weeks and gathered 40 valid responses from professionals in the construction sector, including civil engineers, project managers, site supervisors, consultants, and government officials. The digital format enabled efficient data capture and ensured consistency in response structure. Participant backgrounds were documented under two categories:

- Educational qualification: 50% held bachelor's degrees in civil engineering, 25% had a master's degree, while others included diploma holders and specialists in architecture or environmental engineering.
- Professional role: 30% were site engineers, followed by project managers (22.5%), consultants (17.5%), and contractors (15%).

The questionnaire comprised 30 Likert-scale statements grouped under six key themes. The collected responses were graphically analysed using Excel charts. The Relative Importance Index (RII) was applied to rank all statements. Top-ranked items included:

1.BIM optimizes water use (RII = 0.912)
2. Mandating rainwater harvesting (RII = 0.901)
3. RMC improves water management (RII = 0.889)

These results indicate strong professional support for digital tools, green policies, and prefabricated technologies. Barriers such as high cost and lack of benchmarks were noted but received relatively lower RII scores.

Table 5.1: RII Scores and Ranking of Survey Statements

S. No.	Question No.	RII Value	Rank
1	Q21	0.850	1
2	Q16	0.845	2
3	Q3	0.840	3
4	Q23	0.835	4
5	Q17	0.830	5
6	Q27	0.830	5
7	Q10	0.825	7
8	Q18	0.825	7
9	Q4	0.820	9
10	Q29	0.820	9
11	Q11	0.820	9
12	Q14	0.815	12
13	Q30	0.815	12
14	Q5	0.815	12
15	Q12	0.810	15
16	Q25	0.810	15
17	Q20	0.810	15
18	Q22	0.805	18
19	Q28	0.805	18
20	Q13	0.805	18
21	Q15	0.800	21
22	Q6	0.800	21
23	Q7	0.795	23
24	Q2	0.795	23
25	Q8	0.790	25
26	Q24	0.790	25
27	Q26	0.790	25
28	Q19	0.775	28
29	Q1	0.775	28
30	Q9	0.770	30

Table 5.2: Top-Ranked Water Efficiency Strategies

S. No	Question No.	Factor Statement	RII Value	Rank
1	Q13	Digital design tools (e.g., BIM) can optimize water usage	0.912	1
2	Q7	Rainwater harvesting should be mandated in new construction	0.901	2
3	Q15	Use of RMC leads to better water management	0.889	3
4	Q1	I am well-informed about water-efficient strategies	0.872	4
5	Q9	Digital tools help simulate efficient design	0.870	5
6	Q4	Water-efficient practices contribute to green certification	0.864	6
7	Q2	Water conservation is a critical sustainability parameter	0.851	7
8	Q11	RMC is more water-efficient than site mix	0.845	8
9	Q8	Greywater systems are technically feasible	0.838	9
10	Q5	Stakeholders understand long-term benefits	0.835	10

6. RESULTS AND DISCUSSIONS :

The RII analysis revealed strong consensus on the importance of smart design tools (BIM), rainwater harvesting mandates, and RMC usage. These were perceived as the most effective water-saving strategies, along with treated water reuse and contractor motivation.

Design-stage integration and stakeholder-driven policy were highly prioritized. In contrast, implementation barriers such as cost, complexity, and lack of enforcement received lower scores but remain limiting factors. Notably, experienced professionals emphasized regulatory strategies, while early-career respondents focused more on technologies and materials—highlighting a perception gap that can be addressed through targeted education and training. Overall, stakeholders demonstrated high readiness to adopt water-efficient practices, though practical implementation continues to face systemic, financial, and cultural hurdles.

Table 6.1: Top Statements and Insights by Sections

Section	Theme	Top-Ranked Statement (RII)	Observation
A	Awareness & Perception	Q3 – Water efficiency less prioritized	General awareness is high but actual priority is low
B	Planning & Design	Q13 – BIM supports water optimization	Strong support for digital design tools
C	Technology & Materials	Q16 – Smart meters improve monitoring	Technology adoption is favoured
D	On-Site Practices	Q21 – Treated water is safe	High practicality but needs stricter implementation

E	Policy & Stakeholders	Q23 – Contractors are motivated	Stakeholder roles are increasingly proactive
F	Barriers to Implementation	Q30 – Traditional methods are a challenge	Resistance to change is still strong

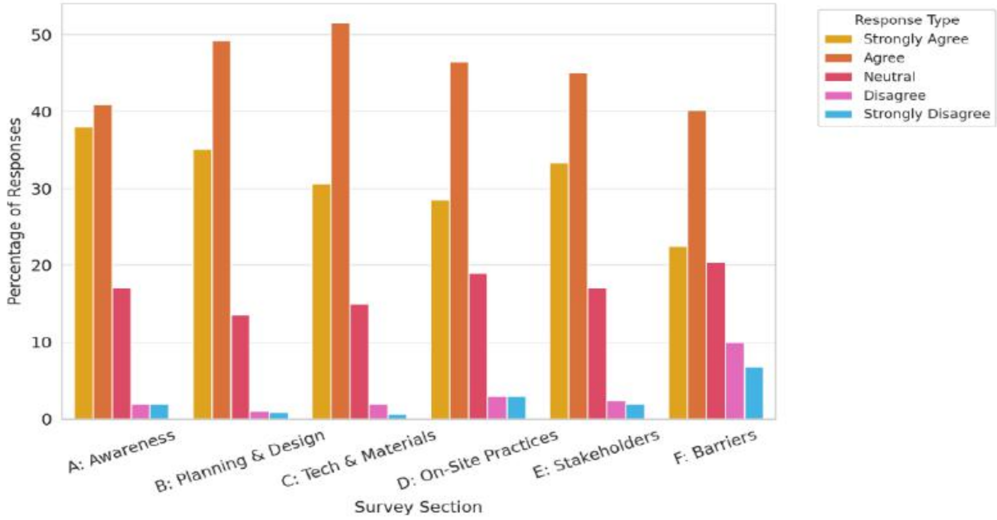

Figure 6.2: Overall Stakeholder Response

8. CONCLUSION:

This study confirms that water efficiency in construction is widely recognized but inconsistently implemented. High-ranking strategies—such as BIM, rainwater harvesting, and RMC—point to a growing industry shift toward design-centric and technology-driven sustainability.

While awareness is strong, actual prioritization is hindered by cost, lack of enforcement, and limited technical benchmarks. Bridging these gaps requires policy support, stakeholder training, and cross-disciplinary collaboration. Findings also show that professional experience shapes perception, underlining the need for knowledge-sharing across levels. With the right tools and governance, water-efficient construction can become mainstream and contribute meaningfully to Sustainable Development Goal 6.

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