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Groundwater Dependency And Depletion In Indian Construction: A Literature-Based Review Of Management Practices And Sustainable Strategies

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Abstract: The construction sector in India is rapidly expanding, contributing significantly to urban development—but also emerging as a major consumer of groundwater, a resource already under severe stress. This literature-based review explores the complex relationship between construction activities and groundwater depletion across India. While agriculture has long been considered the primary driver of groundwater extraction, recent studies indicate that construction practices—such as concrete curing, material mixing, and site preparation—consume substantial amounts of water, often sourced directly from local aquifers through unregulated borewells. Evidence from national standards (IS: 456-2000) and empirical studies suggests that water demand during construction can reach up to 27 kiloliters per square meter of built-up area. Urbanization and land use changes have further exacerbated recharge loss, with impervious surfaces reducing infiltration by nearly 30%. This review consolidates findings from government reports, journal articles, and policy analyses to underscore the urgent need for water-efficient construction technologies, regulatory frameworks, and sustainable site management. Recommendations include rainwater harvesting, groundwater impact assessments, water audits, and integration of green building norms. The study concludes that recognizing and addressing the construction sector's groundwater footprint is essential for ensuring long-term water security and sustainable urban development in India

Index Terms - Construction Management, Groundwater, etc.

I. INTRODUCTION

India is undergoing rapid urban transformation, characterized by large-scale construction of residential, commercial, and infrastructural projects. This unprecedented growth has intensified the demand for natural resources, especially water. Among all water sources, groundwater has become the primary and most accessible resource for construction activities. Whether for concrete mixing, site cleaning, or curing, groundwater is extensively used due to its availability and the lack of reliable municipal supply, especially in peri-urban and developing areas. However, this unregulated and intensive extraction has contributed significantly to the ongoing groundwater crisis in India.

According to reports from the Central Ground Water Board (CGWB) and various satellite studies (e.g., NASA GRACE), several regions in India are experiencing alarming rates of groundwater depletion. This depletion is not only linked to agriculture and domestic use but increasingly to the construction sector, which remains largely unregulated in its water usage. The irony is stark: while construction projects depend heavily on groundwater, they also contribute to its degradation by reducing recharge areas through surface sealing, altering drainage paths, and neglecting conservation practices.

This dual role of the construction industry—as both a consumer and contributor to groundwater stress—highlights the urgent need to integrate water management principles into construction planning and management. Yet, conventional construction management frameworks in India often overlook groundwater considerations, treating water as an infinite and low-cost resource. There is a critical gap between construction project planning and sustainable water resource management.

This paper aims to explore this intersection through a review of existing literature, focusing on how construction activities impact groundwater levels in India, the extent of groundwater dependency in construction, and how construction management practices can evolve to support sustainable water use. Special emphasis is placed on identifying management-level interventions, regulatory gaps, and sustainable alternatives that can reduce the construction sector's water footprint.

By connecting these themes, the study seeks to provide a comprehensive perspective that not only acknowledges the role of construction in groundwater stress but also charts a pathway toward more responsible, water-sensitive construction management in India.

1.1 Description

This study reviews the growing dependency of India's construction sector on groundwater and its contribution to nationwide water depletion. Through analysis of existing literature, the paper highlights how construction practices such as concrete curing, site preparation, and material usage demand high volumes of water—often extracted unsustainably through private borewells. It also examines the impact of urbanization and impervious land use on natural groundwater recharge. The review identifies key gaps in current construction management and proposes sustainable strategies such as rainwater harvesting, water-efficient technologies, and regulatory reforms to reduce the sector's water footprint.

II. LITERATURE

2.1 Central Ground Water Board (2020). has studies in their reprt "Ground Water Year Book India" Groundwater is the backbone of India's water security, accounting for nearly 60% of irrigation and 85% of domestic water needs (CGWB, 2020). However, over-extraction and inadequate recharge mechanisms have led to severe depletion in many parts of the country. India is the world's largest extractor of groundwater, and large regions in North India have become critical zones of water stress. The GRACE satellite mission confirms that aquifers in northern plains, western Maharashtra, and coastal regions like Goa are depleting at unsustainable rates.

Although agriculture has traditionally been viewed as the dominant cause of depletion, recent studies indicate that urbanization and construction activities are emerging as significant contributors. The construction sector's role in groundwater stress has been under-researched, but growing evidence suggests it is a non-negligible factor, particularly in rapidly developing urban and peri-urban areas.

2.2 The Bureau of Indian Standards (IS: 456-2000) note that about 30–35 litres of water are consumed per square meter of built-up area during the construction of reinforced concrete structures. This includes water used for concrete mixing, curing, and other site operations such as dust suppression and equipment cleaning. For larger projects, this water demand scales up rapidly, often exceeding thousands of litres per day. In the absence of a dedicated municipal water connection, most construction sites rely on private borewells or tanker supplies, drawing heavily from local groundwater reserves. This widespread reliance contributes significantly to aquifer stress, particularly in regions where recharge rates are already low due to urban sealing and poor stormwater infiltration.

2.3 Rajeev Garg (2023) had Studies in their paper "Determining Water Footprint of Buildings During Construction Phase: An Activity-based Approach" highlight that construction activities consume substantial amounts of water for various on-site operations, including material preparation, application, and curing. Their research focuses on estimating water consumption during the construction phase of conventional RCC and load-bearing buildings in the Indian context. The study provides theoretical benchmarks for water use in building materials and methods, emphasizing the urgent need for water-efficient construction strategies. As urbanization accelerates, especially in developing countries like India, improving water efficiency in construction is essential for sustainable development.

2.4 Kumar and Singh (2020), in their paper "Impact of land use changes and management practices on groundwater recharge in India" investigate the significant influence of land use changes on groundwater recharge patterns across India, particularly focusing on the transition from traditional agriculture to urban

development. Their study reveals that the expansion of impervious surfaces such as roads, buildings, and paved areas has drastically reduced natural infiltration, leading to a 30% decline in groundwater recharge in affected regions. This reduction has been linked to falling water tables and the drying up of shallow wells, especially in peri-urban and rapidly developing zones.

The authors emphasize the critical need for integrated land and water management practices to counteract these effects. Strategies such as rainwater harvesting, preservation of open green spaces, afforestation, and sustainable site planning are suggested as effective tools for enhancing recharge rates. They also highlight the importance of incorporating groundwater impact assessments in urban planning and development policies. The study concludes that without proactive measures, continued urban expansion could severely compromise India's water security. Overall, this research contributes to a broader understanding of how land management choices directly affect hydrological sustainability and supports the call for more responsible urbanization practices

2.5 Rahman et al. (2022), studies in their paper "The impact of land use and land cover change on groundwater recharge in northwestern Bangladesh" Rahman et al. (2022) conducted a comprehensive study to assess the impact of land use and land cover (LULC) changes on groundwater recharge in northwestern Bangladesh. Utilizing a semi-physically based water balance model, the research analyzed spatially distributed monthly groundwater recharge over a decade, from 2006 to 2016. The findings revealed a significant increase of 80.3% in impervious built-up areas and a 16.4% decrease in vegetated land cover during this period. These LULC changes led to a reduction in groundwater recharge, with a minimal decrease at the basin scale (2.6 mm/year) but a more pronounced decline at the regional level (17.1 mm/year), particularly in urbanized zones. Additionally, seasonal variations in LULC were found to affect recharge rates, with a substantial difference of 20.6 mm/year between dry and wet seasons. The study underscores the critical need for sustainable land management practices to mitigate the adverse effects of urbanization on groundwater resources. By highlighting the spatial and temporal dynamics of LULC impacts, this research provides valuable insights for policymakers and urban planners aiming to ensure groundwater sustainability in the face of rapid land use changes.

2.6 The Harvard Kennedy School (2024), he has studied in his article named as "Mitigation of Groundwater Depletion in India" policy paper presents a comprehensive analysis of groundwater depletion in India, identifying multiple contributing sectors, including agriculture, industry, and notably, the construction sector. The report emphasizes that while agriculture remains the dominant consumer of groundwater, the unregulated use of borewells in construction activities has emerged as a growing concern, especially in urbanizing regions.

The paper critically examines the lack of coordination between water resource management authorities and urban planning bodies, resulting in unchecked groundwater extraction. It argues that current policies do not adequately address the sector-specific demands of construction projects, which often operate outside formal municipal water supply systems. The report recommends a robust regulatory framework that includes mandatory groundwater impact assessments for construction approvals and the integration of community-based water monitoring systems. Furthermore, it highlights the need for local-level recharge initiatives, such as rainwater harvesting and treated greywater reuse, to offset depletion. By linking institutional reform, technology adoption, and community participation, the paper provides a blueprint for sustainable groundwater management that construction stakeholders must urgently adopt.

2.7 Bothra (2024), he studied in their article "World Water Day: Alternate ways to conserve water for the construction sector" sheds light on the alarming water consumption patterns within India's construction sector, emphasizing its growing reliance on groundwater. The article reports that constructing just one square meter of wall can require approximately 350 liters of water, underscoring the sector's substantial demand. With increasing urbanization and infrastructure development, this demand is expected to rise significantly, posing serious risks to already depleting aquifers. Bothra emphasizes that the sector lacks sufficient regulation on water use, particularly during site-level operations such as curing, mixing, and cleaning.

The article advocates for alternative water conservation strategies, including the use of curing compounds, recycled greywater, rainwater harvesting systems, and modular construction techniques to reduce dependency on fresh water. The importance of planning water budgets in construction project management is highlighted as a necessary shift toward sustainable practices. Bothra's insights reinforce the urgent need to adopt eco-efficient technologies and green building norms to conserve groundwater in India's rapidly growing construction industry.

2.8 The study published in *Science Advances* (2020), "Groundwater depletion will reduce cropping intensity in India" primarily addresses the severe implications of groundwater depletion on India's agricultural productivity, particularly the decline in cropping intensity. However, it also indirectly emphasizes that the construction sector is not immune to the broader impacts of groundwater scarcity. As groundwater tables fall, competition for water between agriculture, domestic, and construction needs intensifies. The study warns that if depletion continues at the current rate, non-agricultural sectors such as construction may face restrictions or operational challenges due to limited water availability.

The findings highlight the interconnectedness of water resource pressures across economic sectors. While not the central focus, the paper reinforces the argument that groundwater depletion is a cross-sectoral threat and that industries like construction must proactively adopt sustainable water use practices. The article contributes to a broader understanding of groundwater as a shared and finite resource, urging policy reforms and sector-specific interventions to prevent long-term ecological and economic disruptions.

2.9 The United Indian (2024), " Groundwater Depletion in India: Urgent Concerns & Solutions" presents a detailed overview of India's escalating groundwater crisis, highlighting the significant role played by the construction sector in accelerating depletion. The article emphasizes that rapid urban expansion and infrastructure development have led to unchecked groundwater extraction, particularly through unregulated borewells on construction sites. It draws attention to the lack of sector-specific policies to monitor and control water use in construction, unlike agriculture, which is more closely governed.

The piece advocates for the implementation of strict regulatory frameworks, such as groundwater extraction permits and project-based water audits. It also recommends the adoption of water-efficient construction technologies, including curing alternatives, rainwater harvesting systems, and on-site greywater recycling. The article calls for mandatory integration of water sustainability measures into building codes and green certification systems (e.g., IGBC, GRIHA). By framing groundwater as a shared national resource, the article stresses the importance of cross-sectoral accountability and urgent action to promote resilient and water-sensitive construction practices.

2.10 Bardhan (2011), "Assessment of Water Resource Consumption in Building Construction in India" presents a comprehensive study on the water footprint of India's building construction sector, emphasizing the significant volume of water consumed directly on-site and indirectly through material production. The study introduces the concept of "embodied water", which includes the water used in manufacturing building materials such as cement, steel, and bricks—highlighting that the total water consumption per square meter of built-up area can reach up to 27 kiloliters in typical urban projects. This figure reveals the substantial environmental burden posed by conventional construction practices. Bardhan also details how activities such as concrete curing, cleaning, and earthwork require continuous water supply, often sourced from local groundwater through private borewells.

The study draws attention to the absence of water budgeting in construction planning and the lack of regulatory mechanisms to monitor water use. It recommends the adoption of water-efficient technologies, rainwater harvesting, and the use of recycled materials to reduce the sector's water footprint. Overall, the research underscores the urgent need for a systematic approach to water management in the construction industry, particularly in water-stressed regions of India.

III. LITERATURE SUMMARY

Groundwater is a critical resource in India, fulfilling around 85% of domestic and 60% of agricultural water needs (CGWB, 2020). However, recent studies highlight that, beyond agriculture, the construction sector is increasingly contributing to groundwater depletion, especially in urban and peri-urban regions. According to IS:456-2000, construction of RCC structures requires 30–35 litres of water per square meter, and this scales to thousands of litres daily for large projects, often sourced from private borewells. Bardhan (2011) and Garg (2023) demonstrate that building construction has a high water footprint—both directly on-site and through the embodied water in materials like cement and steel. Bardhan notes up to 27 kiloliters of water use per square meter in urban projects. Kumar and Singh (2020) report that impervious land use due to urbanization has reduced recharge rates by 30%, while Rahman et al. (2022) observe similar declines in Bangladesh due to land cover changes. The Harvard Kennedy School (2024) identifies construction as an unregulated water consumer and recommends groundwater impact assessments and decentralized monitoring. Bothra (2024) stresses the sector's unsustainable practices and suggests adopting rainwater harvesting, curing alternatives, and water budgeting. Science Advances (2020) links groundwater depletion to broader cross-sectoral risks, warning of

future water access conflicts. The United Indian (2024) calls for regulation of borewell usage, water audits, and green building norms. Collectively, these studies emphasize the urgent need to recognize and regulate the construction sector's groundwater footprint through policy reform, sustainable practices, and integrated water planning.

IV. Conclusion

The literature survey clearly demonstrates that the Indian construction sector plays an increasingly significant role in groundwater depletion due to high water consumption during activities such as curing, mixing, and cleaning. Studies reveal that water use can reach up to 27 kiloliters per square meter, often sourced from unregulated borewells, placing severe stress on aquifers. Rapid urbanization and the spread of impervious surfaces further reduce natural groundwater recharge. Despite these challenges, the sector remains largely under-regulated in terms of water use. Sustainable alternatives—such as rainwater harvesting, greywater recycling, and curing alternatives—are available but underutilized. Integrating groundwater impact assessments and water audits into project planning is essential. Regulatory frameworks need strengthening to control extraction and promote conservation practices. A shift towards water-efficient construction management is critical for long-term sustainability. Recognizing and managing the sector's water footprint is key to protecting India's groundwater resources.

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