Policy Innovations for Sustainable Aggregates: Maharashtra's M-Sand Strategy in a Global Context

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ABSTRACT

The global construction industry's reliance on riverbed sand has precipitated environmental crises, including river ecosystem degradation and resource depletion. Maharashtra, India, introduced a pioneering M-Sand (Manufactured Sand) policy through Government Resolutions (GRs) dated 23 May 2025 and 17 July 2025 to address these challenges. This review synthesizes the policy's scientific, environmental, and regulatory dimensions, emphasizing M-Sand's role as a sustainable alternative to natural sand. Aligned with Indian Standards (IS 383:2016, IS 1542:1992), the policy enforces quality control, digital tracking via the "Mahakhanij" platform, and environmental compliance through water conservation and waste recycling. Comparative analyses with policies in Tamil Nadu, Kerala, Karnataka, and global benchmarks (e.g., Australia, UK) highlight Maharashtra's innovative approach. The policy reduces riverbed mining, promotes circular economy principles, and aligns with Sustainable Development Goals (SDGs) 11, 12, and 15. Challenges, including water-intensive production and institutional bottlenecks, are evaluated alongside opportunities for AI-driven monitoring and blockchain-based transparency. This review positions Maharashtra's M-Sand policy as a scalable model for sustainable construction material management, with implications for global resource governance.

Keywords: Manufactured Sand, M-Sand, sustainable construction, Maharashtra policy, riverbed mining, circular economy, environmental sustainability, digital tracking.

INTRODUCTION

The global demand for sand, estimated at 50 billion tons annually, drives unsustainable extraction practices, leading to riverbed erosion, aquifer depletion, and biodiversity loss (UNEP, 2019). In India, where sand is integral to construction, unregulated mining exacerbates these issues, necessitating alternatives like M-Sand (Manufactured Sand). Produced by crushing hard rocks, M-Sand adheres to standards such as IS 383:2016 and offers a controlled, eco-friendly substitute for natural sand (BIS, 2016). Maharashtra, a rapidly urbanizing state, faces acute sand scarcity, prompting the introduction of comprehensive M-Sand policies in 2025 (GR, 23 May 2025; GR, 17 July 2025). These policies integrate scientific standards, environmental mandates, and digital monitoring to promote sustainable construction.

This review aims to:

Critically evaluate Maharashtra's M-Sand policy framework.

Compare it with policies in other Indian states and global practices.

Assess the scientific, environmental, and socio-economic impacts of M-Sand.

Propose innovative solutions to implementation challenges using advanced technologies.

Policy Framework Analysis

Maharashtra’s M-Sand Policy (2025)

Maharashtra’s M-Sand policy, as delineated in Government Resolutions (GRs) dated 23 May 2025 and 17 July 2025, implements a comprehensive strategy to mitigate sand scarcity while promoting environmental sustainability and regulatory compliance. The policy leverages diverse material sources, including quarry overburden, construction debris, and minor mineral quarries, to produce Manufactured Sand (M-Sand), thereby reducing dependence on ecologically detrimental riverbed sand extraction (Government of Maharashtra, 2025a). Quality assurance is ensured through adherence to Indian Standards IS 383:2016, IS 1542:1992, and IS 456:2000, which specify requirements for concrete, plaster, and structural integrity, respectively, ensuring M-Sand’s suitability for construction applications (BIS, 2016; BIS, 2000). Regulatory oversight is facilitated by the “Mahakhanij” digital platform, which streamlines licensing, enforces GPS-tracked transportation, and implements geo-fencing to prevent illegal mining activities (Government of Maharashtra, 2025b). Economic incentives, including a reduced royalty rate of ₹200 per brass compared to ₹400 per brass for natural sand, and the designation of M-Sand units as industrial entities, foster widespread adoption (Government of Maharashtra, 2025b). Environmental sustainability is prioritized through mandatory Consent to Establish (CTE) and Consent to Operate (CTO) certifications from the Maharashtra Pollution Control Board (MPCB), alongside requirements for water reservoir creation during mining operations to enhance groundwater recharge and support ecological balance (Government of Maharashtra, 2025a). This multi-faceted approach positions Maharashtra’s M-Sand policy as a scientifically grounded model for sustainable construction material management.

Comparative Analysis with Other Regions

Maharashtra’s M-Sand policy, as outlined in the Government Resolutions of 23 May 2025 and 17 July 2025, establishes a robust framework for sustainable construction material management, which can be contextualized through a comparative analysis with other regional and global approaches. In Tamil Nadu, the M-Sand policy emphasizes private sector participation and mandates compliance with Bureau of Indian Standards (BIS) certifications to ensure quality (Tamil Nadu PWD, 2020). However, it lacks the advanced digital monitoring systems, such as Maharashtra’s “Mahakhanij” platform, which employs GPS tracking and geo-fencing to curb illegal mining activities. Kerala’s approach incentivizes M-Sand production through subsidies, fostering adoption, but faces challenges in maintaining consistent quality control and effective enforcement, limiting its scalability compared to Maharashtra’s stringent regulatory mechanisms (KSPCB, 2021). Karnataka’s policy integrates M-Sand production with construction waste recycling, aligning with circular economy principles, yet it does not prioritize water conservation measures, such as Maharashtra’s mandate for creating water reservoirs during mining operations (Karnataka MMCR, 2016). Globally, Australia and the United Kingdom utilize recycled aggregates and employ advanced monitoring techniques, including remote sensing, to ensure sustainable sand management (CSIRO, 2020). Singapore’s adoption of blockchain technology for supply chain transparency provides a model for enhancing traceability, which Maharashtra could incorporate to further strengthen its M-Sand policy (BCA, 2022). These comparisons highlight Maharashtra’s leadership in integrating digital tools and environmental mandates, while also identifying opportunities for adopting global innovations like blockchain and advanced recycling techniques. Maharashtra’s policy excels in digital integration and environmental mandates but could adopt global innovations like blockchain and advanced recycling technologies.

Scientific and Technical Aspects of M-Sand

Production Methods

Manufactured Sand (M-Sand) is produced through a systematic process involving the crushing of hard rocks, such as granite and quartzite, using vertical shaft impact (VSI) crushers, followed by multi-stage screening to achieve particle size distributions compliant with IS 383:2016 standards (BIS, 2016). The production process utilizes diverse raw material sources to promote sustainability and resource efficiency. Quarry overburden from major mineral mines, such as coal, is repurposed to minimize waste generation and environmental impact. Construction debris, including demolition waste, is recycled to reduce landfill pressure, aligning with circular economy principles. Additionally, rocks extracted from minor mineral quarries, regulated under the

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Maharashtra Minor Mineral Extraction (Development and Regulation) Rules, 2013, serve as a primary feedstock. The controlled crushing and screening process ensures precise gradation, with fines (<150 microns) restricted to levels specified by BIS standards, thereby optimizing M-Sand's physical properties for construction applications, including concrete production, plastering, and masonry. This methodical approach enhances M-Sand's suitability for construction while mitigating the environmental consequences associated with traditional river sand extraction.

Environmental Benefits

The adoption of Manufactured Sand (M-Sand) as a substitute for river sand, as mandated by Maharashtra's M-Sand policy (GR, 23 May 2025), yields significant environmental benefits across multiple dimensions. Firstly, M-Sand production eliminates the need for riverbed mining, thereby mitigating riverbank erosion and preserving aquatic biodiversity, which are severely impacted by conventional sand extraction practices (Koehnken & Rintoul, 2018). This shift protects river ecosystems by maintaining hydrological balance and reducing sediment disruption. Secondly, the policy promotes circular economy principles by utilizing waste materials, such as quarry overburden and construction debris, as primary feedstocks for M-Sand production. This approach enhances resource efficiency and reduces dependency on landfills, aligning with sustainable waste management frameworks (Ellen MacArthur Foundation, 2021). Thirdly, the policy mandates the creation of water reservoirs during mining operations, which facilitates groundwater recharge and supports water conservation efforts (Government of Maharashtra, 2025). These measures collectively contribute to environmental sustainability by addressing ecological degradation, optimizing resource use, and enhancing water resource management, positioning M-Sand as a cornerstone for sustainable construction practices.

Construction Applications

Manufactured Sand (M-Sand) exhibits versatile applicability in construction, adhering to stringent Indian Standards to ensure performance across various applications. For concrete production, M-Sand complies with IS 383:2016, which specifies requirements for coarse and fine aggregates, ensuring high compressive strength and durability essential for structural stability (BIS, 2016). In plastering applications, M-Sand meets IS 1542:1992 standards, providing consistent particle size distribution and surface characteristics that facilitate smooth, high-quality finishes (BIS, 1992). For masonry mortars, adherence to IS 2116:1980 guarantees structural integrity by ensuring optimal bonding and load-bearing capacity (BIS, 1980). These standardized properties, achieved through controlled production processes, position M-Sand as a reliable and sustainable alternative to river sand, meeting the diverse requirements of modern construction while maintaining environmental compliance.

Technical Challenges

The production of Manufactured Sand (M-Sand) presents several technical challenges that require careful management to ensure its efficacy and environmental sustainability. Quality variability, particularly inconsistent particle grading and excessive fines (<150 microns), can adversely affect M-Sand's performance in construction applications, potentially compromising workability and strength in concrete and mortar mixes (RILEM, 2020). Wet processing, commonly employed to remove impurities and achieve desired gradation, demands substantial water inputs, posing challenges to achieving zero liquid discharge (ZLD) goals and exacerbating water scarcity concerns in water-stressed regions (UNEP, 2019). Additionally, waste management remains a critical issue, as crusher dust and sludge generated during M-Sand production require proper disposal to prevent environmental contamination, including soil and water pollution (CSIRO, 2020). Addressing these challenges necessitates advanced processing techniques, such as dry crushing systems, improved quality control measures, and environmentally sound waste disposal protocols to align M-Sand production with sustainable construction practices.

Sustainability and Environmental Impact

The M-Sand policy of Maharashtra, as articulated in the Government Resolutions dated 23 May 2025 and 17 July 2025, aligns with multiple Sustainable Development Goals (SDGs) by fostering environmentally sustainable construction practices. By promoting Manufactured Sand (M-Sand) as an eco-friendly alternative to river sand, the policy supports SDG 11 (Sustainable Cities and Communities) through the provision of sustainable construction materials that facilitate resilient urban development (UN SDG Knowledge Platform, 2021). It advances SDG 12 (Responsible Consumption and Production) by encouraging the recycling of quarry overburden and construction waste as primary feedstocks for M-Sand production, thereby enhancing resource efficiency and reducing landfill dependency (Government of Maharashtra, 2025a; Ellen MacArthur Foundation, 2021). Additionally, the policy contributes to SDG 15 (Life on Land) by eliminating the need for riverbed mining, which mitigates riverbank erosion, preserves aquatic ecosystems, and protects terrestrial biodiversity from the adverse impacts of sand extraction (Government of Maharashtra, 2025a; Koehnken & Rintoul, 2018). These contributions underscore the policy's role in integrating environmental sustainability with construction material management, offering a model for achieving global sustainability objectives.

The policy's water reservoir mandate enhances groundwater recharge, while GPS tracking and geo-fencing ensure compliance (GR, 17 July 2025). However, water-intensive production and dust emissions necessitate advanced technologies like dry processing and electrostatic precipitators (ASTM C33, 2021).

Implementation Challenges & Opportunities

The implementation of Maharashtra's M-Sand policy, as outlined in the Government Resolution dated 17 July 2025, faces significant institutional challenges that could impede its efficacy. Regulatory delays arise from the requirement for multiple approvals, including Consent to Establish (CTE), Consent to Operate (CTO) from the Maharashtra Pollution Control Board (MPCB), and registration with the District Industries Centre (DIC), which create bureaucratic hurdles for establishing M-Sand units (Government of Maharashtra, 2025b). These multi-layered approval processes may deter potential investors and delay operational timelines. Furthermore, the lack of inter-departmental coordination among key agencies, such as the MPCB, the Directorate of Geology and Mining (DMG), and the Public Works Department (PWD), risks fragmented implementation and inconsistent enforcement of policy mandates. Streamlined administrative procedures and enhanced inter-agency collaboration are critical to overcoming these bottlenecks and ensuring the policy's successful execution.

The adoption of M-Sand in Maharashtra's construction sector is constrained by economic and informational barriers. The high capital costs associated with vertical shaft impact (VSI) crushers and quality testing laboratories pose a significant financial challenge, particularly for small and medium-scale enterprises seeking to establish M-Sand production units (RILEM, 2020). Additionally, knowledge gaps among contractors regarding M-Sand's performance benefits compared to river sand hinder its widespread acceptance. Despite compliance with Indian Standards (e.g., IS 383:2016), many contractors remain unaware of M-Sand's superior consistency and environmental advantages, necessitating targeted education and training programs to bridge these gaps and promote industry uptake (BIS, 2016).

Public perception of M-Sand remains a challenge due to early instances of inconsistent quality, which have fostered skepticism among stakeholders despite adherence to Bureau of Indian Standards (BIS) specifications (BIS, 2016). These negative perceptions, rooted in historical variability in M-Sand's particle gradation and fines content, undermine trust in its reliability for construction applications. To address this, comprehensive public awareness campaigns are essential to highlight M-Sand's compliance with standards like IS 383:2016, IS 1542:1992, and IS 2116:1980, as well as its environmental benefits, such as reduced riverbed mining, to build confidence among contractors, builders, and end-users (BIS, 2016; BIS, 1992; BIS, 1980).

Maharashtra's M-Sand policy strengthens regulatory compliance by prohibiting entities involved in illegal mining from participating in M-Sand auctions, as stipulated in the Government Resolution of 17 July 2025 (Government of Maharashtra, 2025b). This measure aims to deter illicit activities and ensure adherence to legal frameworks. However, effective enforcement is challenged by the need for scalable monitoring solutions to oversee production, transportation, and compliance across diverse geographical regions. The reliance on manual inspections and limited resources underscores the necessity for advanced technological interventions to bolster regulatory oversight and ensure policy objectives are met.

The M-Sand policy presents significant opportunities to enhance implementation through technological and economic innovations. The integration of artificial intelligence (AI) and remote sensing, such as drone-based monitoring, can improve compliance by enabling real-time detection of illegal mining activities and ensuring adherence to regulatory standards (UNEP, 2021). Blockchain technology, as demonstrated in Singapore's construction material supply chain, offers a model for ensuring traceability and transparency in M-Sand production and distribution, enhancing trust and accountability (BCA, 2022). Additionally, the policy's economic incentives, including royalty concessions (₹200 per brass compared to ₹400 per brass for natural sand) and the designation of M-Sand units as industrial entities, attract investment and promote scalability, creating a conducive environment for industry growth and widespread adoption (Government of Maharashtra, 2025b). These opportunities, if leveraged effectively, can position Maharashtra's M-Sand policy as a global benchmark for sustainable construction material management.

Future Directions

To advance the implementation of Maharashtra's M-Sand policy and enhance its sustainability and efficacy, several forward-looking strategies leveraging advanced technologies and global best practices are proposed. First, AI-driven monitoring, utilizing artificial intelligence and remote sensing technologies such as drone-based surveillance, enables real-time tracking of M-Sand production and transportation, ensuring compliance with regulatory standards and detecting illegal mining activities (UNEP, 2021). Second, blockchain integration offers a robust framework for transparent supply chain management, ensuring traceability of M-Sand from production to end-use, thereby guaranteeing quality and legality, as exemplified by Singapore's construction material supply chain (BCA, 2022). Third, the adoption of advanced technologies, such as dry processing techniques and electrostatic dust suppression systems, minimizes water consumption and particulate emissions, aligning with zero liquid discharge goals and reducing environmental impacts (ASTM C33, 2021). Fourth, fostering public-private partnerships can drive innovation by facilitating collaboration with industry stakeholders to develop cost-effective crushing and recycling technologies, lowering capital barriers for M-Sand unit establishment. Finally, global knowledge exchange with countries like Australia and the United Kingdom, which prioritize recycled aggregates and advanced monitoring systems, can inform Maharashtra's policy by integrating best practices in sustainable aggregate management and digital oversight (CSIRO, 2020). These strategies collectively enhance the policy's scalability, environmental sustainability, and alignment with global standards for resource-efficient construction.

CONCLUSIONS

Maharashtra's M-Sand policy, enacted through GRs in 2025, exemplifies a science-driven approach to sustainable construction material management. By promoting M-Sand as an alternative to river sand, the policy mitigates environmental degradation, aligns with SDGs, and fosters circular economy principles. Challenges such as water consumption, quality control, and institutional coordination require innovative solutions, including AI, blockchain, and public awareness initiatives. Maharashtra's framework offers a blueprint for global regions grappling with sand scarcity, advancing environmental sustainability and resource efficiency in construction.

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