

ABSTRACT

In India, the design of Reinforced cement concrete (RCC) water tanks is governed by IS 3370:2021, which outlines specifications for concrete structures retaining aqueous liquids. In this study, tanks designed in accordance with IS 3370:2021 are referred to as Conventional water tanks, further categorized as Conventional type I tanks (CWT I) and Conventional type II tanks (CWT II). CWT I tanks, as per clause 4.4.3.1, limit steel stress to 130 N/mm^2 under the serviceability limit state without requiring crack width calculations. CWT II tanks, as per clause 4.4.1.1, allow higher steel stress values with mandatory crack width checks. Although compliant with the standard, both CWT I and CWT II tanks often lead to bulky, material-intensive, and costlier designs due to stringent dimensional and exposure criteria. Additionally, they are prone to post-construction leakage, resulting in increased maintenance or early abandonment.

To address these limitations, this study proposes a novel structural system, coined as the Hybrid Water Tank (HWT). In this innovative concept, RCC is designed solely to resist structural loads in accordance with IS 456:2000, while a strain-compatible ferrocement lining, designed following ACI guidelines, is introduced to provide impermeability and control crack width. The ferrocement lining design is proposed for the first time and is supported by a comprehensive methodology including equations for strain compatibility, crack width control, hoop tension design, and detailing of mesh reinforcement and thickness. The proposed framework is modular and flexible, allowing easy adaptation to a wide range of national and international design standards.

The research focuses on two elevated tank types: Intze and Circular. A custom-developed C++ software suite was created to analyze, design, and compare CWT I, CWT II, and HWTs, incorporating heuristic optimization, limit state design principles, and parametric simulation. The software comprises seven modules for CWTs and eight modules for HWTs—the additional module being dedicated to ferrocement lining design.

Comparative studies for Intze tanks (200, 600, and 1000 kL) revealed that HWTs offer 28–38% cost savings over CWT I and 20–28% over CWT II, along with concrete savings of up to 40%, steel savings up to 46%, and crack width reductions of 48–54%.

Base shear was reduced by 7–15% (full tank) and 14–21% (empty tank), and deflections by 11–12% (F.T.) and 32–43% (E.T.), with foundation area savings of 10–15%. For Circular tanks (100–300 kL), HWTs demonstrated 19–24% cost savings over CWT I and 16–18% over CWT II, with concrete savings of 23–33%, steel reductions of 14–25%, and crack width reductions up to 87%. Base shear and deflection reductions ranged from 6–8% and 11–14% (F.T.) to 14–28% and 27–30% (E.T.), respectively. The annular raft area was reduced by 8–9%, and although the ferrocement lining accounted for only 4.1–4.3% of the total cost, it played a key role in achieving overall cost savings and improved performance. To validate its applicability across diverse conditions, the HWT design was evaluated in 16 Indian cities spanning seismic zones II–V, wind speeds from 39–50 m/s, and coastal conditions. Results consistently confirmed the technical, structural, and economic superiority of HWTs over both CWT I and CWT II in both Intze and Circular tanks.

This study establishes the Hybrid Water Tanks as a sustainable, high-performance, and scalable solution for modern water storage infrastructure—addressing key challenges of cost, durability, leakage, and structural efficiency through a uniquely engineered design approach.