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Generalized steps of RCC Design of Chlorination Tank in Sewage Treatment Plant

Manesh N. Sawane*, Dr. L. S. Mahajan**
*(M.Tech Student, Department of Civil Engineering, Shreeyash College of Engineering & Technology, Ch. Sambhajinagar
Email: sawanemanesh@gmail.com)
** (Head, Department of Civil Engineering, Shreeyash College of Engineering & Technology, Ch. Sambhajinagar
Email : loms786@gmail.com)

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Abstract:

The design and construction of chlorination tanks in Sewage Treatment Plants (STPs) represent a critical stage in wastewater management. These tanks serve as the final disinfection unit, where treated wastewater is exposed to chlorine or other disinfecting agents to eliminate pathogenic microorganisms. Reinforced Cement Concrete (RCC) is the most widely adopted structural material for such tanks due to its strength, durability, and water-retaining capacity. However, the RCC design of chlorination tanks requires a systematic methodology, guided by codal provisions, to ensure serviceability, safety, and long-term performance.

This review article presents a detailed account of the step-by-step design methodology for RCC chlorination tanks. The discussion begins with functional requirements and hydraulic considerations, followed by load calculations, structural analysis, and RCC design of individual components such as the base slab, walls, and cover slab. The role of crack control, durability provisions, reinforcement detailing, and water-tightness measures are highlighted in accordance with Indian Standards (IS 456:2000, IS 3370:2009) and international codes such as ACI 350. In addition, recent advances including finite element modeling, the use of supplementary cementitious materials, and sustainability considerations are reviewed.

Keywords — **RCC Design, Chlorination Tank, STP, Water-Retaining Structures, Disinfection.**

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I. INTRODUCTION

With rapid urbanization and industrialization, the need for effective sewage treatment has become paramount. Untreated sewage not only depletes water quality but also poses severe risks to human health and aquatic ecosystems. To address this, Sewage Treatment Plants (STPs) are constructed to treat municipal and industrial wastewater, rendering it safe for disposal or reuse [1].

Among the various units of STPs, the chlorination tank serves as the last line of defense. After the removal of suspended solids, organic matter, and nutrients in preliminary, primary, and secondary treatment stages, the effluent still contains pathogens such as bacteria, viruses, and protozoa. Chlorination is one of the most economical and widely used disinfection methods, where chlorine or its compounds are mixed with treated water in a contact tank for a stipulated time to achieve microbial inactivation.

II. IMPORTANCE OF RCC DESIGN IN CHLORINATION TANKS

Chlorination tanks are generally constructed using RCC because of its structural integrity, load-bearing capacity, and water-retaining ability. However, unlike ordinary building structures, the design of water-retaining structures involves stricter serviceability requirements[2]. These include:

Water-tightness: Leakage from tanks is unacceptable as it leads to environmental pollution and reduced efficiency.

Durability: Chlorinated water is chemically aggressive and can deteriorate concrete if not properly designed.

Crack control: Limiting crack width is crucial, as cracks provide pathways for leakage and corrosion of reinforcement.

Structural stability: Tanks must resist hydrostatic pressure, earth pressure, and uplift forces.

Therefore, a systematic RCC design procedure, compliant with codal provisions, is necessary to ensure the safety and longevity of the structure.

III. ROLE OF CODAL PROVISIONS

The design of chlorination tanks in India is primarily guided by:

IS 456:2000 – Plain and reinforced concrete code.

IS 3370 (Parts 1–4):2009 – Concrete structures for storage of liquids.

IS 1893:2016 – Criteria for earthquake-resistant design of structures.

IS 875 (Parts 1–5) – Loading codes for dead, live, wind, and other loads.

Globally, the ACI 350 (Code Requirements for Environmental Engineering Concrete Structures) and Eurocode EN 1992-3 also provide guidelines, particularly emphasizing durability and crack control. A comparative understanding of these codes helps in adopting best practices[3].

A. Challenges in RCC Design of Chlorination Tanks

The Designers face several challenges while working on RCC chlorination tanks, including:

Aggressive Environment – Chlorinated water accelerates steel corrosion and concrete degradation.

Uplift Pressure – High groundwater tables can create buoyancy forces, risking flotation.

Serviceability – Crack width and deflection control are more stringent than in conventional structures.

Construction Joints – Improper joint detailing often results in leakage.

Sustainability Concerns – With the need for eco-friendly construction, integrating SCMs like fly ash or GGBS is becoming essential.

B. Scope of Work

This review article aims to consolidate knowledge on the RCC design of chlorination tanks in STPs. Specifically, it:

Outlines the step-by-step RCC design methodology (data collection, hydraulic design, load calculation, analysis, design, detailing).

Provides flowcharts and diagrams for better understanding.

Highlights codal provisions and practical considerations.

Discusses modern challenges and advancements in design and materials.

Reviews case studies and field experiences to identify best practices.

By covering methodological, codal, and practical aspects, the article serves as a reference for postgraduate students, research scholars, design engineers, and practitioners engaged in environmental infrastructure development.

IV. FUNCTIONAL AND DESIGN REQUIREMENTS OF CHLORINATION TANK

The chlorination tank is essentially a contact chamber where treated wastewater is held for sufficient time to allow chlorine (or equivalent disinfectant) to inactivate pathogenic organisms [4]. For this reason, the design must ensure:

1. **Adequate retention time** (30–60 minutes depending on flow and chlorine demand).
2. **Uniform mixing** of chlorine throughout the effluent.
3. **No dead zones** or short-circuiting in the flow pattern.
4. **Ease of cleaning and maintenance** (drainage and sludge removal).
5. **Hydraulic efficiency** through suitable tank geometry (rectangular with baffles or circular with central feed).

A. *Hydraulic Design Parameters*

The first step before RCC design is hydraulic design:

Design flow (Q): Peak hourly flow of treated sewage (m^3/hr).

Retention time (t): As per CPHEEO Manual, usually 30–60 minutes.

Tank capacity (V): $V = Q \times t$

Depth of water: 2.5–4.0 m (economical for RCC).

Length to breadth ratio: typically 3:1 for rectangular tanks.

Freeboard: 0.3–0.5 m above water level.

B. *Design Considerations for RCC Chlorination Tanks*

Water-tightness: No leakage is allowed (per IS 3370, permissible crack width = 0.2 mm).

Durability: M30 or higher grade concrete with low permeability.

Chemical resistance: Protective coatings or admixtures are recommended against chlorinated water.

Stability: Must resist uplift (buoyancy) due to groundwater.

Accessibility: Walkways, stairs, and handrails for operators

V. RCC DESIGN METHODOLOGY

Step 1: Data Collection

- Average and peak sewage flow.
- Site conditions: soil bearing capacity, depth of groundwater table.
- Seismic zone and wind data (for above-ground tanks).
- Functional requirements: baffling, drain arrangements, freeboard.

Step 2: Hydraulic Design

- Compute volume from flow and retention time.
- Fix preliminary dimensions (length, breadth/diameter, depth).
- Provide baffles for effective mixing.
- Check for self-cleansing velocities at inlets/outlets.

Step 3: Load Considerations [5-7]

- Dead Load – Self-weight of tank walls, base, and cover slab.
- Live Load – 1.5–2 kN/m^2 for walkways and maintenance platforms.
- Hydrostatic Pressure – $p = \gamma \times h$

where
γ = unit weight of water,
h = depth.

- Earth Pressure (for underground tanks): Active earth pressure on external walls.

- Uplift Pressure – Buoyancy force = displaced volume × γ of water table.
- Seismic Loads – As per IS 1893.
- Wind Loads – As per IS 875 (Part 3).

Step 4: Structural Analysis

- **Base Slab:** Designed as a slab on soil/raft subjected to water pressure (upward) and tank load (downward).
- **Walls:** Designed as vertical cantilevers fixed at base and supported at top (if covered).
- **Cover Slab (if provided):** One-way or two-way slab subjected to live load.
- **Baffle Walls:** Designed as thin RCC partitions with minimum reinforcement.

[1] Step 5: RCC Design of Components

(a) Base Slab

- Thickness governed by uplift and bending.
- Keyed edges may be provided to resist sliding.
- Reinforcement: bottom steel to resist uplift.

(b) Tank Walls

- Pressure distribution triangular with depth.
- Thickness chosen based on crack control (usually 200–400 mm).
- Reinforcement provided on **both faces** (due to reversal of stresses).

(c) Cover Slab (optional)

- Designed as RCC slab with load = self-weight + 1.5 kN/m² live load.
- Waterproofing treatment may be applied.

(d) Joints

- **Construction Joints:** Staggered, with water bars.
- **Expansion Joints:** Needed if tank is very large.

[2] Step 6: Crack Control and Serviceability

- IS 3370 limits **crack width = 0.2 mm**.
- Minimum reinforcement = 0.3–0.35% of gross cross-sectional area.
- Proper spacing of bars (≤ 300 mm).

[3] Step 7: Detailing of Reinforcement

- Clear cover: 25 mm (internal face) & 40 mm (external face in contact with soil).
- Double-layer reinforcement in walls for durability.
- Lap length as per IS 456 (usually 40–50 × bar diameter).

[4] Step 8: Durability and Water-Tightness

- Concrete grade: M30 or above, water-cement ratio ≤ 0.45.
- Admixtures: plasticizers, waterproofing agents.
- Curing: at least 14 days (preferably 21 days).
- Protective coatings: epoxy or polyurethane for added resistance.

VI. CONCLUSION

The RCC design of chlorination tanks in sewage treatment plants is a multidisciplinary process that integrates hydraulic design principles, structural engineering concepts, and codal provisions to ensure safety, serviceability, and long-term durability. Unlike conventional RCC structures, water-retaining structures such as chlorination tanks require stringent crack control, water-tightness, and chemical resistance against aggressive chlorinated effluent.

This review article highlighted a step-by-step methodology for the design process: beginning with data collection and hydraulic calculations, moving through load assessment and structural analysis, and culminating in the RCC design of base slab, walls, and cover slab. Emphasis was placed on crack control (0.2 mm limit), durability provisions (M30 or higher grade concrete, low water–cement ratio, coatings, and admixtures), and reinforcement detailing in accordance with IS 3370:2009 and IS 456:2000. The inclusion of flowcharts and schematic diagrams illustrates how systematic planning can simplify and standardize the design process.

Despite the availability of codal guidelines, challenges remain—particularly in addressing uplift pressures in high groundwater conditions, ensuring construction quality at joints, and mitigating long-term deterioration due to chlorinated water. Emerging approaches such as finite element modeling, the use of supplementary cementitious materials (fly ash, GGBS), and protective surface treatments provide innovative solutions to improve sustainability and resilience.

In summary, the safe and effective design of RCC chlorination tanks ensures not only the structural performance of the tank itself but also the public health function of the entire sewage treatment plant. By following codal provisions, adopting best practices, and incorporating sustainable materials, engineers can deliver chlorination tanks that are structurally sound, durable, water-tight, and environmentally sustainable.

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