Final Year Internship

Bachelor of Technology in Civil Engineering VIT, Vellore

Internship Report

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I would like to express our sincere gratitude to Dr. Porchelvan P, our project supervisor at the School of Civil Engineering, VIT Vellore, for his invaluable guidance, encouragement, and support throughout this project.

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Executive Summary

This report presents two critical infrastructure initiatives designed to enhance resilience and functionality in major public projects. The first focuses on the implementation of stormwater control gates at Bhogapuram International Airport, Andhra Pradesh. Given the susceptibility of the region to heavy monsoonal rains, the project involves the design, fabrication, and installation of three manually operated gates—one weir-type tilting gate and two vertical lifting gates—to manage stormwater flow and prevent flooding. These gates have been engineered for structural robustness, ease of maintenance, and compliance with relevant Indian Standards, contributing to the airport's long-term sustainability and operational reliability.

The second project addresses the redesign of the sump pit for the Toilet Block at Kapodra Station under the Surat Metro UG P1 contract. In response to operational feedback and site constraints, the sump pit was re-engineered with a deeper profile and a precast, replaceable top slab. This enhances hydraulic capacity, structural resilience against uplift and seismic forces, and provides easier access for maintenance. Detailed structural analysis and design revisions ensure compliance with GMRC's updated Operation Design Standards and applicable codes.

Together, these projects reflect a proactive approach to infrastructure planning that prioritizes resilience, sustainability, and long-term serviceability in the face of evolving climatic and operational challenges.

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List of Abbreviations

Abbreviation	Full Form
GMRC	Gujarat Metro Rail Corporation
ODS	Operation Design Standards
RCC	Reinforced Cement Concrete
IS	Indian Standard (Bureau of Indian Standards)
STAAD Pro	Structural Analysis and Design Program (Bentley Systems)
IIT	Indian Institute of Technology
NIT	National Institute of Technology
FEA	Finite Element Analysis
GAD	General Arrangement Drawing
HSFG	High Strength Friction Grip (bolts)
MS	Mild Steel
EPDM	Ethylene Propylene Diene Monomer (rubber)
NDT	Non-Destructive Testing
MCE	Maximum Considered Earthquake
ODE	Operating Design Earthquake
SLS	Serviceability Limit State
ULS	Ultimate Limit State
GIR	Geotechnical Investigation Report
fy	Yield Strength
fck	Characteristic Compressive Strength of Concrete
Es	Modulus of Elasticity of Steel
ISMB	Indian Standard Medium Beam
ISMC	Indian Standard Medium Channel

List of Symbols and Notations

Symbol / Notation	Description	Unit
fy	Yield strength of steel	MPa
fck	Characteristic compressive strength of concrete	MPa
Es	Modulus of elasticity of steel	N/mm^2
E	Modulus of elasticity	N/mm^2
τ	Shear stress	N/mm^2
M	Bending moment	kNm or kNm/m
V	Shear force	kN or kN/m
P	Axial load	kN
Z	Section modulus	mm^3
I	Moment of inertia	mm^4
L	Span or length of beam/member	mm or m
d	Effective depth of section	mm
acr	Distance from tension face to point considered for crack width	mm
Wcr	Crack width	mm
γ	Unit weight (of material/soil)	kN/m^3
H	Height (of gate or wall)	m or mm
ρ	Density (e.g., soil, water)	kg/m^3 or kN/m^3
θ	Angle (e.g., of tilt)	Degrees (°)
μ	Coefficient of friction	-
α	Seismic coefficient	- (g)
Sf	Factor of safety	-
p	Pressure	kN/m^2
D	Total depth of section	mm
ϕ	Diameter of reinforcement bar	mm
Ast	Area of tensile reinforcement	mm^2
Asc	Area of compression reinforcement	mm^2
δ	Deflection	mm

1. INTRODUCTION

Project 1: Stormwater Gate Design at Bhogapuram Airport

Stormwater management is a vital component in the planning and execution of any major infrastructure project, particularly airports, where large impervious areas can contribute to significant surface runoff. Bhogapuram International Airport, being developed in the Vizianagaram district of Andhra Pradesh, is a landmark project designed to cater to increasing air traffic demands in the region. Given the scale and importance of this development, ensuring effective and reliable drainage systems is essential to safeguard infrastructure, ensure operational continuity, and comply with environmental standards. This report outlines the implementation of stormwater control gates across three critical points in the airport premises, focusing on their design, fabrication, and installation to mitigate flood-related risks.

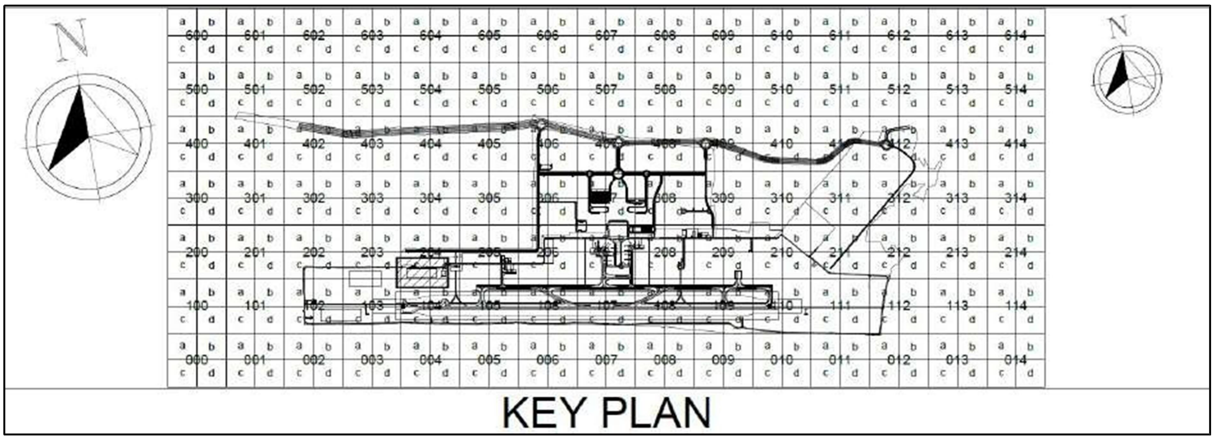


Fig. 1. Key Plan of the Bhogapuram Airport.

1.1 Objective

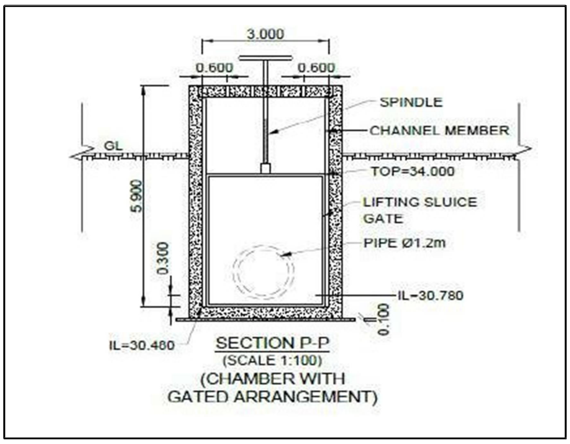
The primary objective of this project is to develop and deploy stormwater control gates at designated high-risk zones within the Bhogapuram International Airport site. These gates are intended to regulate the flow of stormwater runoff, especially during periods of heavy rainfall, in order to prevent water accumulation, backflow, and potential flooding. By introducing a combination of weir-type tilting and vertical lifting gates, the airport's drainage system becomes capable of actively managing water levels and flow velocities in various structural and topographical conditions. The gates will be designed for manual operation, ensuring functionality even in the event of power outages, thereby enhancing the system's resilience and reliability. This strategic integration of active water control components into the airport's infrastructure will ultimately support the safe, efficient, and uninterrupted functioning of airport operations.

1.2 Motivation

The motivation behind this project lies in the need for long-term sustainability, safety, and operational reliability at Bhogapuram International Airport. Given the region's susceptibility to seasonal monsoon rains and extreme weather events, such as cyclones and cloudbursts, unregulated stormwater poses a considerable threat to infrastructure and services. Flooding within the airport premises could lead to runway closures, damage to civil structures, erosion of foundations, and safety hazards for both personnel and passengers. In addition, climate change has resulted in increased variability and intensity of rainfall, placing further stress on conventional drainage systems. To address these risks proactively, the implementation of mechanical stormwater gates provides a flexible and robust solution. The use of manually operated gates also ensures minimal dependence on external energy sources, enabling control even under emergency conditions. Furthermore, this approach aligns with the broader goals of environmental responsibility and sustainable design, as it supports controlled discharge into surrounding ecosystems while minimizing ecological disruption.

1.3 Background

Extensive hydrological studies and site evaluations were conducted during the airport's design phase to identify critical flood-prone zones. Based on this analysis, three key locations—designated as Sections U-U, P-P, and R-R in the approved project drawings—were selected for the installation of stormwater gates (Shown in figure 2 and 3). Each of these sections presents unique challenges related to water flow dynamics, structural layout, and spatial limitations. Section U-U will feature a weir-type tilting gate, suitable for regulating surface water in open channels through a hinged mechanism that allows the gate to tilt and control overflow. Meanwhile, Sections P-P and R-R will be equipped with vertical lifting gates, which operate within enclosed chambers or culverts and provide vertical control of flow. These gates are particularly effective in constrained environments where horizontal movement is impractical.



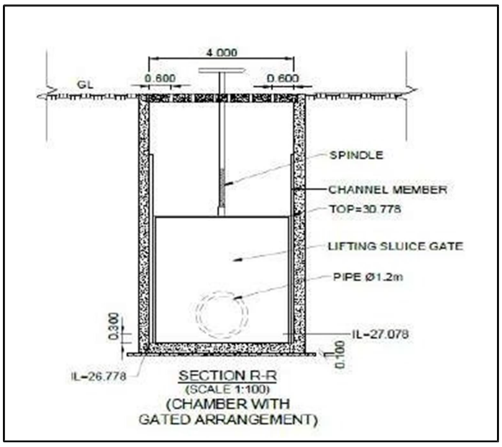


Fig. 2. Section Plan of Lifting Gate

The structural and functional design of these gates has been carried out in accordance with relevant Indian Standards, including IS 456 for concrete design, IS 800 for structural steel, and IS 9349 and IS 4622 for hydraulic gate systems. Materials such as high-grade steel, water seals, and protective coatings have been specified to ensure durability, corrosion resistance, and ease of maintenance. Additional features, including provisions for fish passages and algae-cleaning mechanisms, have been considered to enhance environmental compatibility. All designs undergo third-party validation and proof-checking by accredited institutions such as IITs or NITs, ensuring safety, performance, and compliance with best engineering practices. These gates are a key component of the airport's overall stormwater management strategy, contributing significantly to the resilience and sustainability of the airport infrastructure.

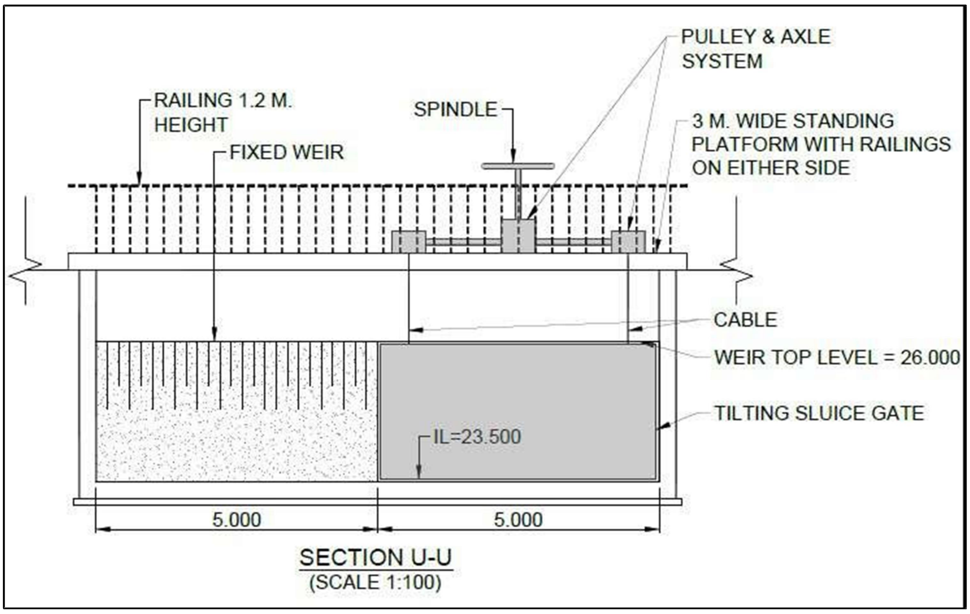


Fig. 3. Section Plan of Tilting Gate

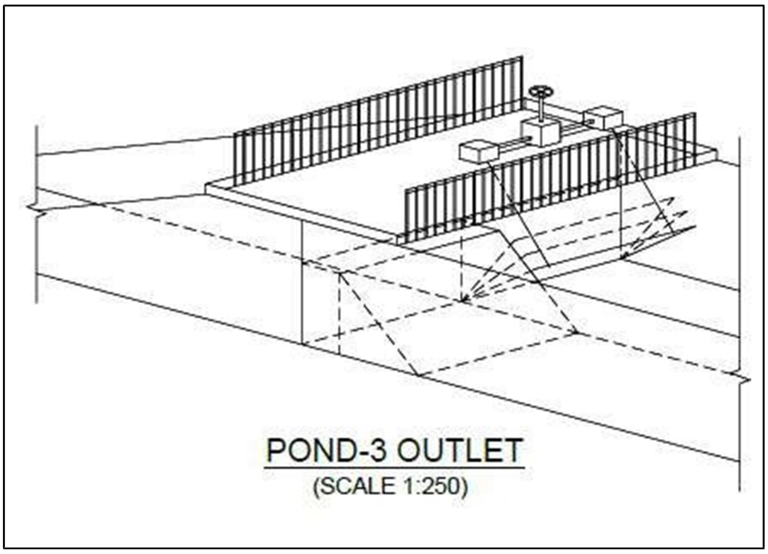


Fig. 4. Tilting Gate

Project 2: Redesign of the Sump Pit of the Toilet Block at Kapodra Station of Surat Metro

The Gujarat Metro Rail Corporation (GMRC) Limited has undertaken the implementation of the Surat Metro Rail Project – Phase I, which includes the construction of underground stations and tunnels from Kapodra Ramp to Surat Railway Station under Contract UG P1. The underground works comprise twin bored tunnels, cut-and-cover sections, and three underground stations—Kapodra, Labheshwar Chowk, and Central Warehouse. As part of these developments, several ancillary structures are being constructed, including a dedicated Toilet Block and Firemen Staircase at Kapodra Station. These structures are constructed using the cut-and-cover method and are essential for station operation and emergency response infrastructure.

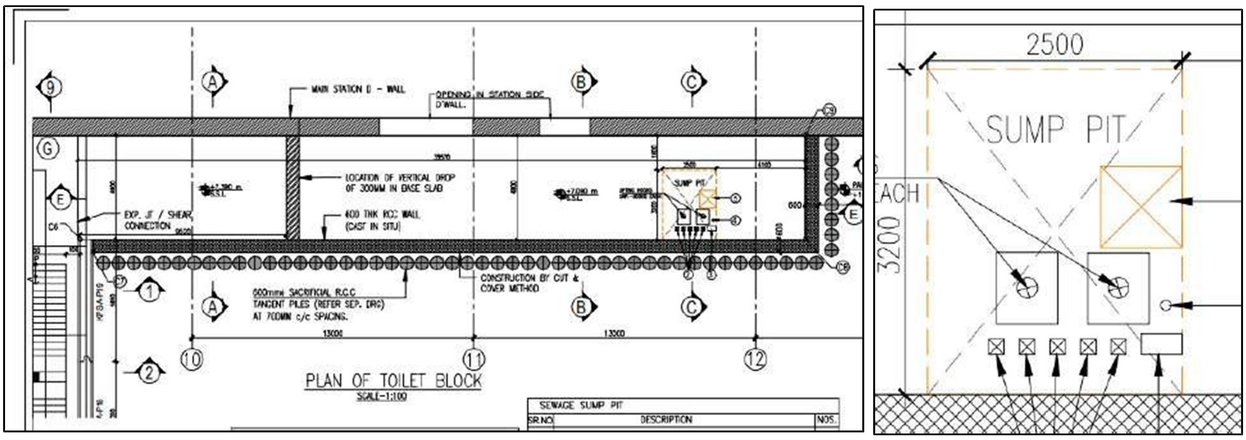


Fig. 5. Toilet Block and Sump Pit of Kapodrea Station of Surat Metro

One of the critical components of the Toilet Block is the sump pit, which serves as a stormwater and wastewater collection point. The sump structure is essential for the functioning of the dewatering system and helps ensure the serviceability of the facility during rainfall and flood events. During the review and execution phase, the need for modification in the original sump design was identified. This necessity arose from site-specific constraints, operational requirements, and client feedback. Consequently, the design team proposed a change in the sump configuration, which was formally incorporated in Revision R1 of the design report, submitted on 18.02.2025.

This introduction outlines the background and scope of the revised sump design. The design revision specifically replaced the previously planned cast-in-situ top slab with a precast, replaceable cover slab, thereby enhancing access for maintenance and inspection. Additionally, the changes improved structural performance under hydrostatic uplift and seismic conditions. The revised sump design was developed in compliance with GMRC's Operation Design Standards (ODS) and the applicable Indian and international codes. The present report captures the engineering rationale, design methodology, analysis results, construction approach, and performance expectations of the revised sump pit within the overall framework of the Kapodra Station development.

1.1 Objective

The objective of this report is to comprehensively detail the revised design of the sump pit structure associated with the Kapodra Station's Toilet Block. The sump is an integral component for stormwater and wastewater management and is critical for ensuring that ancillary structures like the toilet block remain dry and functional during both normal and extreme service conditions. The revision has been undertaken to improve performance, ease of access, and compliance with updated site requirements and operational directives from GMRC and the Operation Design Standards (ODS). The revised design eliminates earlier limitations, particularly around the top slab detailing, and introduces a more maintainable and service-friendly configuration.

1.2 Motivation

The motivation for revising the sump design stems from several interrelated factors. Firstly, the original cast-in-situ top slab configuration limited access to internal components such as sump pumps and check valves, which are vital for maintenance. Secondly, there were constructability challenges at the site due to coordination with other underground utilities and the need for efficient water-tight sealing at slab joints. Thirdly, GMRC's updated ODS recommended a design that could better handle long-term operation, especially in a high groundwater table environment. These changes led to the design team opting for a precast, replaceable cover slab and improvements in structural reinforcement details to accommodate uplift and seismic forces more efficiently.

1.3 Background

Kapodra Station is a part of the Surat Metro Rail Project, Phase-I, within the Underground Package UG P1. The sump structure is located within the footprint of the Toilet Block, which itself is a buried, two-level service structure constructed by the cut and cover method. The revised sump design takes into account not just the hydraulic requirements but also considers structural safety, flotation control, and earthquake resilience.

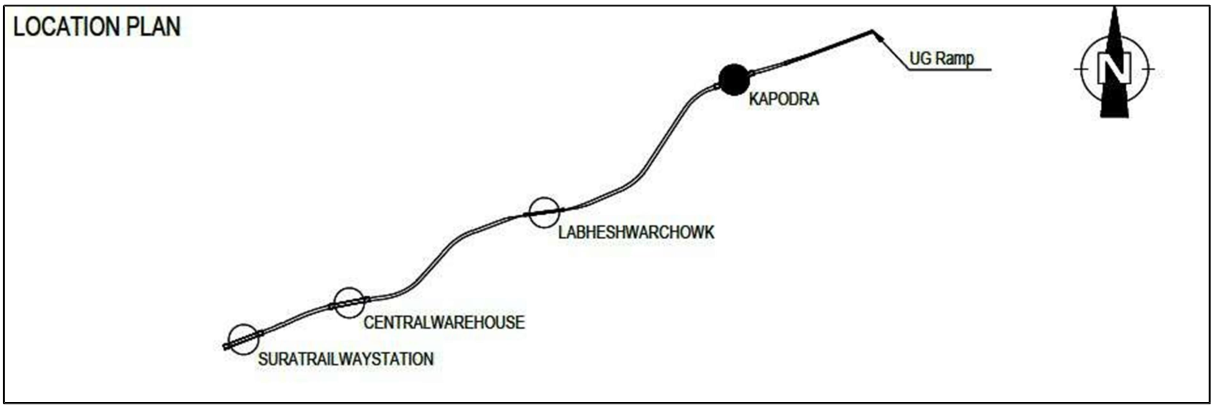


Fig. 6. Key Plan of Surat Metro

2. PROJECT DESCRIPTION AND GOALS

Project 1: Stormwater Gate Design at Bhogapuram Airport

The stormwater gate installation project at Bhogapuram International Airport is a focused civil infrastructure initiative aimed at enhancing flood control and water regulation capabilities within the airport's premises. This project is a part of the larger stormwater drainage system designed to handle intense monsoonal rains and potential flash flooding scenarios common in coastal Andhra Pradesh. The scope of the project includes the engineering design, structural detailing, fabrication, and on-site installation of stormwater control gates at three hydraulically sensitive locations identified during site investigations and hydrological modeling. These include two vertical lifting gates and one tilting weir gate, each tailored to site-specific requirements to manage varying flow conditions and structural constraints.

The stormwater gates will serve a dual purpose: first, to control the direction and volume of water flow across the airport's drainage channels, and second, to prevent flooding in operational zones such as runways, taxiways, and terminal access roads. The project responds to the challenges posed by rapid surface runoff over large paved areas, which if left uncontrolled, could lead to localized waterlogging, structural deterioration, and operational delays. The gates are therefore strategically positioned at the outfall or junction points of primary stormwater drains to regulate both inflow and outflow, acting as passive barriers during peak flow conditions and controlled outlets during low to medium flow situations.

Each of the gate types selected plays a critical role in this context. The tilting gate, proposed for Section U-U, is ideal for regulating overflow across a weir structure. It functions by rotating around a hinge fixed at its base, allowing for gradual modulation of flow and height control during excess water levels. This gate is particularly effective in open channel applications, where space allows for rotational movement and where visual inspection and manual access are feasible. On the other hand, the vertical lifting gates at Sections P-P and R-R are designed to be operated within confined structures, such as box culverts or stormwater collection chambers. These gates are manually lifted via a screw or pulley mechanism, permitting controlled vertical displacement to adjust discharge based on upstream conditions.

The broader goals of the project align with the airport's mission to establish resilient and sustainable infrastructure. One of the primary goals is to reduce the risk of flood-related disruptions and enhance safety for passengers, personnel, and aircraft. The project also aims to extend the life cycle of civil structures by preventing water stagnation and soil erosion around key facilities. Another important objective is to comply with regional environmental and hydrological regulations by ensuring that discharged stormwater is managed in a manner that minimizes ecological disruption to nearby water bodies and settlements.

In addition to flood control, the system is designed with long-term maintainability and operational simplicity in mind. By incorporating manually operated mechanisms, the system avoids dependency on electrical or automated controls, making it reliable even during power failures or emergency scenarios. The gates are constructed using corrosion-resistant steel with protective coatings to withstand exposure to water, debris, and atmospheric elements over extended periods. Furthermore, provisions are included for future upgrades, such as motorized actuators or remote monitoring systems, should operational needs evolve with the airport's growth.

In summary, the stormwater gate project at Bhogapuram International Airport is a strategic infrastructure enhancement that supports both current and future drainage needs. It reflects a proactive approach to climate resilience, safety, and engineering innovation, and is expected to play a crucial role in ensuring the airport remains functional and secure during adverse weather events.

Project 2: Redesign of the Sump Pit of the Toilet Block at Kapodra Station of Surat Metro

The sump pit at Kapodra Station, forming part of the ancillary Toilet Block structure, plays a crucial role in managing stormwater and wastewater within the station premises. Initially, the sump was designed as a cast-in-situ RCC structure integrated within the base slab, covered with a monolithic slab. However, during the course of design coordination and subsequent review of site conditions and operational requirements, a revised configuration was proposed and finalized under Revision R1. This change aimed to address multiple issues observed in the original layout, including limited access for maintenance, inadequate depth for flood conditions, and construction constraints associated with cast-in-place components.

One of the key revisions involved increasing the depth of the sump to elevation 4.69 meters, which significantly enhanced its storage capacity and ensured better hydraulic performance under high rainfall or emergency conditions. The increased depth now provides sufficient submergence for the submersible pumps, allowing more efficient operation and improved protection against pump cavitation or dry running. Additionally, this deeper configuration helps prevent backflow and provides a safer margin against overflow during peak inflow scenarios.

Another major improvement was the redesign of the top covering slab. The monolithic cast-in-situ slab from the original design was replaced with a 300 mm thick precast RCC slab. This precast cover rests on a ledge formed on the inner wall of the sump and is designed to be removable, facilitating direct access for inspection, cleaning, or pump replacement—tasks that were previously cumbersome and invasive. This modular approach also allows for future upgrades of mechanical components without requiring demolition, significantly reducing long-term maintenance costs and disruptions.

Structurally, the base and side walls of the sump were retained at 600 mm thickness, but reinforcement detailing was revised to withstand increased hydrostatic pressures resulting from the greater depth. The revised sump design was analyzed using a 3D finite element model in STAAD Pro, considering a wide range of loading scenarios including uplift pressures (up to 111.5 kN/m^2), lateral soil pressures (~59.6 kN/m^2), seismic raking forces up to 0.28g, and extreme flood conditions. The design complies with GMRC's updated Operation Design Standards (ODS) and applicable Indian codes such as IS 3370 and IS 1893, ensuring structural stability, serviceability, and durability.

The changes were driven by the need for improved functionality, maintainability, and structural resilience. The revised sump now supports long-term operational goals, providing a robust and accessible solution to stormwater management within the Kapodra Station infrastructure. This update reflects a proactive response to real-time construction feedback and highlights the collaborative approach between the contractor, design consultant, and GMRC to deliver an optimized and future-ready facility.

3. TECHNICAL SPECIFICATION

Project 1: Stormwater Gate Design at Bhogapuram Airport

The stormwater gates to be installed at Bhogapuram International Airport have been designed in accordance with relevant IS codes and engineering standards to ensure structural strength, hydraulic performance, and long-term durability. The technical specifications for the three gates—one tilting-type and two vertical lifting-type—are as follows:

A. General Specifications

- **Total Number of Gates**: 3
  - 1 Tilting Gate (Section U–U)
  - 2 Vertical Lifting Gates (Sections P–P and R–R)
- **Purpose**:
  The gates are designed to regulate stormwater flow, prevent backflow and flooding, and ensure controlled discharge into the drainage network.
- **Operation Type**:
  Manual operation using a screw mechanism or lifting handle. This ensures operability even during power outages or emergency scenarios.
- **Design Life**:
  Minimum of 25 years, provided with regular inspection and maintenance.
- **Proof Checking**:
  All structural and mechanical designs shall be reviewed and certified by reputed technical institutions such as IITs or NITs.

B. Gate-Specific Specifications

1. Tilting Gate (Section U–U)

- **Type**: Weir-type tilting gate
- **Dimensions**: Custom-fabricated based on site drawings and hydraulic design
- **Mounting**: Hinged at the base with a tilting arm and counterweight assembly
- **Control**: Operated manually via lever or winch
- **Application**: Effective for open channel flow regulation and overflow control

Accessories:

- Bottom rubber sealing edge
- Optional algae scraper
- Mechanical locking for fixed open/closed states

2. Vertical Lifting Gates (Sections P–P and R–R)

- **Type**: Vertical rising sluice gate
- **Dimensions**: As per culvert or chamber specifications
- **Mounting**: Installed with stainless steel roller supports inside side guide channels
- **Control**: Hand-operated screw lifting system mounted on the top frame
- **Application**: Suitable for confined spaces such as culverts and drainage ducts

Accessories:

- Rubber seals on sides and bottom edges
- Locking mechanism for height retention
- Anti-rust protective coatings for guide rails and screw mechanisms

C. Civil Interface Requirements

- **Foundation/Embedment**:
  RCC foundation as per **IS 456:2000**, designed to handle structural and hydraulic loads.
- **Fixing Method**:
  Gate frames to be either grouted into cast-in-situ grooves or anchored using expansion bolts.
- **Alignment**:
  Installation to be precisely aligned using total station and spirit level to ensure vertical and horizontal tolerances.

D. Design Data

- **Tilting Gate Size**: 5.0 m (W) × 2.5 m (H)
- **Lifting Gate 1 Size**: 3.0 m (W) × 3.22 m (H)
- **Lifting Gate 2 Size**: 4.0 m (W) × 3.702 m (H)

- **Design Water Density**: 1 kg/m^3

D. Material Specifications of Components

Table 1. Material Specification

Component	Specification
Structural Steel Skin Plates	fy = 250 MPa
Hot Rolled Steel Sections / Rails	fy = 250 MPa
Pins / Bolts	HSFG, Grade 8.8
Mechanical Steel Components	fy = 250 MPa
Wire Ropes	12 mm diameter, Fiber core, 1570 grade
Welds	3 mm / 6 mm continuous fillet welds (as required)

H. Permissible Loads and Stresses

- **Modulus of Elasticity (E)**: 2×10^5 N/mm^2

Allowable Stress Limits:

Type of Stress	Allowable Limit
Flexural Tension (ft)	0.66 × fy
Flexural Compression (ft)	0.60 × fy
Direct Tension (ft)	0.60 × fy
Direct Compression (ft)	0.60 × fy
Shear Stress (τ)	0.40 × fy

- **Allowable Deflection**: L / 350
- **Wire Rope Breaking Load**: 75 kN

Project 2: Redesign of the Sump Pit of the Toilet Block at Kapodra Station of Surat Metro

☐ **Location**: Integrated within the Toilet Block structure at Kapodra Station, below the base slab.

☐ **Purpose**: Collection and discharge of stormwater and wastewater during regular and flood conditions.

☐ **Base Level of Sump**: El. 4.69 meters.

☐ **Structural Dimensions**:

- **Dimension:** 2500mm x 3200mm x 2800mm
- **Base Slab Thickness**: 600 mm (monolithically cast with walls).
- **Wall Thickness**: 600 mm.
- **Top Cover Slab**: Fabricated Plate (replaceable/removable type).

☐ **Material Specifications**:

- **Concrete Grade**: M45 for all structural elements (walls, base slab, cover).
- **Concrete Density**: 25 kN/m^3.
- **Reinforcement**: Corrosion-resistant steel bars with crack control detailing.

☐ **Design Loads**:

- **Uplift Pressure**: 111.5 kN/m^2 (under full groundwater condition).
- **Active Lateral Earth Pressure**: ~59.6 kN/m^2.
- **Vehicular Surcharge Load**: 24 kN/m^2 (on adjacent roof area).
- **Live Load on Base Slab**: 10 kN/m^2.
- **Flood Load (extreme condition)**: up to 113.2 kN/m^2 lateral pressure considered.

☐ **Seismic Design**:

- **ODE Acceleration**: 0.14g.
- **MCE Acceleration**: 0.28g.
- **Seismic Loads**: Applied in both X and Z directions, including point and distributed raking forces.

☐ **Accessibility Features**:

- **Precast RCC cover** enables direct access for:
  - Pump inspection and replacement.
  - Cleaning and maintenance.
  - Structural inspection of internal walls and base.

☐ **Waterproofing & Durability**:

- Use of hydrophilic waterstops at joints (cover slab interface).
- Crack width control:
  - **≤ 0.2 mm** for soil-exposed sides.
  - **≤ 0.25 mm** for internal faces.
- Designed as a **watertight buried structure**.

- **Soil Parameters (from GIR)**:
  - **Saturated Soil Density**: 20 kN/m^3.
  - **Submerged Soil Density**: 10 kN/m^3.
  - **Dry Soil Density**: 15.3 kN/m^3.
- **Software Used for Design**: STAAD Pro (3D Finite Element Model).
- **Safety Considerations**:
  - Factor of safety against flotation ensured > 1.1.
  - Reinforcement detailing verified for all load combinations (SLS & ULS).

4. DESIGN APPROACH AND DETAILS

Project 1: Stormwater Gate Design at Bhogapuram Airport

The design of stormwater control gates at Bhogapuram International Airport has been carried out with a comprehensive understanding of the site's topography, hydrology, and infrastructure layout. The focus was on developing a system that is not only structurally sound and hydraulically efficient but also simple to operate, maintain, and integrate with the existing civil structures. The following subsections provide a detailed breakdown of the adopted design methodology, codes and standards followed, and the engineering decisions made after evaluating various practical constraints and alternatives.

4.1 Design Approach / Materials & Methods

The design and implementation of the stormwater control gates at Bhogapuram International Airport were carried out through a meticulously planned and technically rigorous workflow. The methodology integrated field assessment, engineering design, structural analysis, component sizing, and fabrication to ensure a system that meets functional, structural, and environmental requirements. Each stage was approached systematically to ensure precision and adherence to best practices in hydraulic and structural engineering.

Once the site data was consolidated, the engineering team proceeded with the preparation of General Arrangement Drawings (GADs). These drawings illustrated the positioning, dimensions, and orientation of the proposed gates—one tilting gate at Section U-U and two vertical lifting gates at Sections P-P and R-R. The GADs also included the integration of gates into the civil works, such as concrete channels or culverts, indicating anchoring arrangements and space requirements for operating mechanisms. The GADs formed the foundation of structural modeling and component detailing.

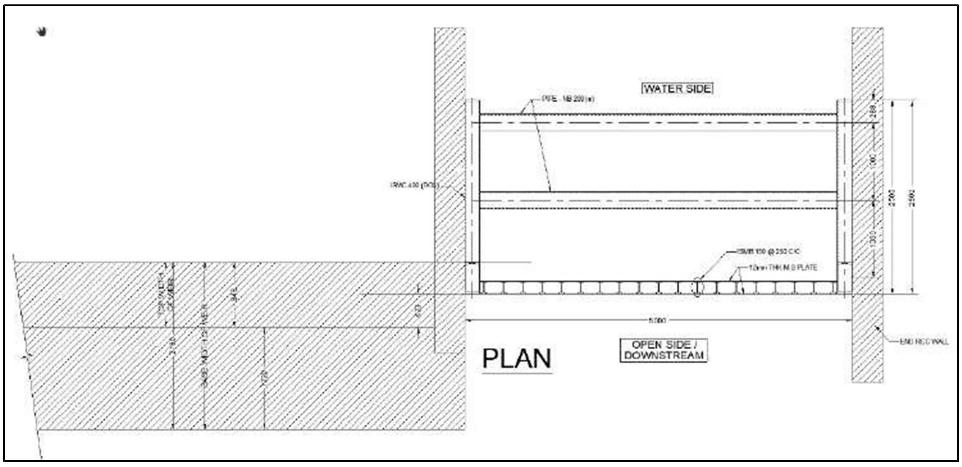


Fig. 7. Plan of Tilting gate

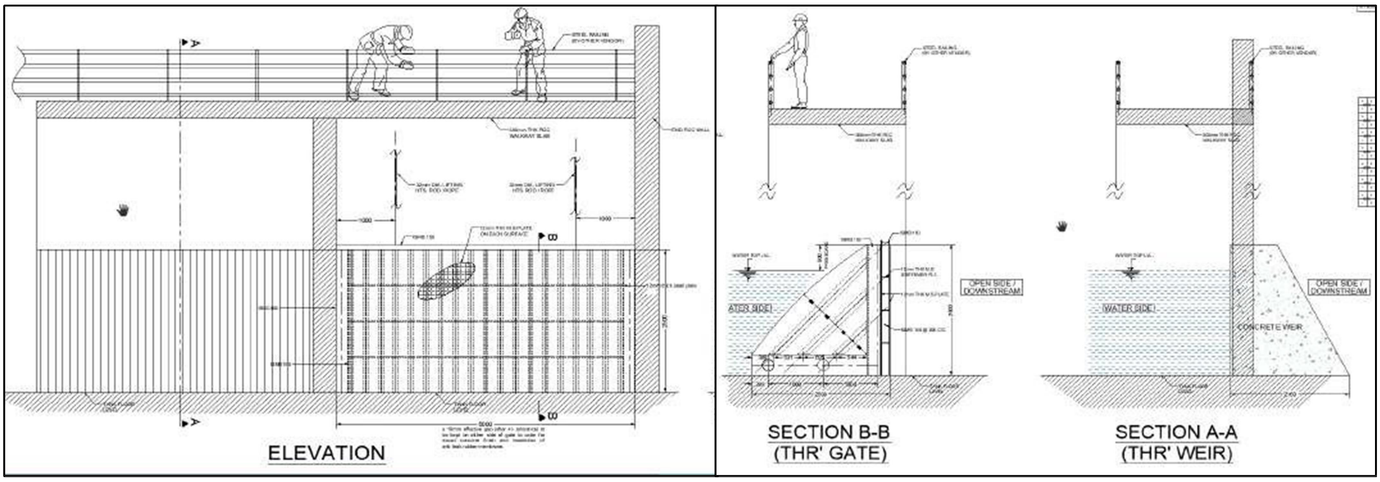


Fig. 8. Elevation and Section of Tilting Gate

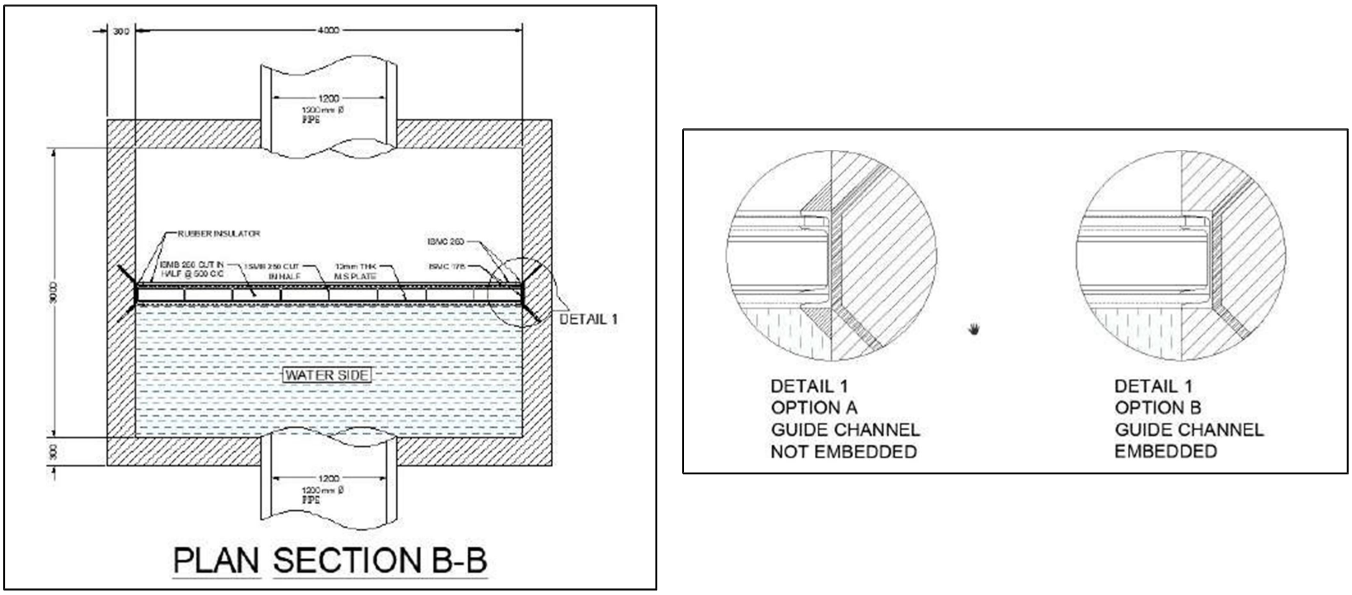


Fig. 9. Plan of Lifting Gate

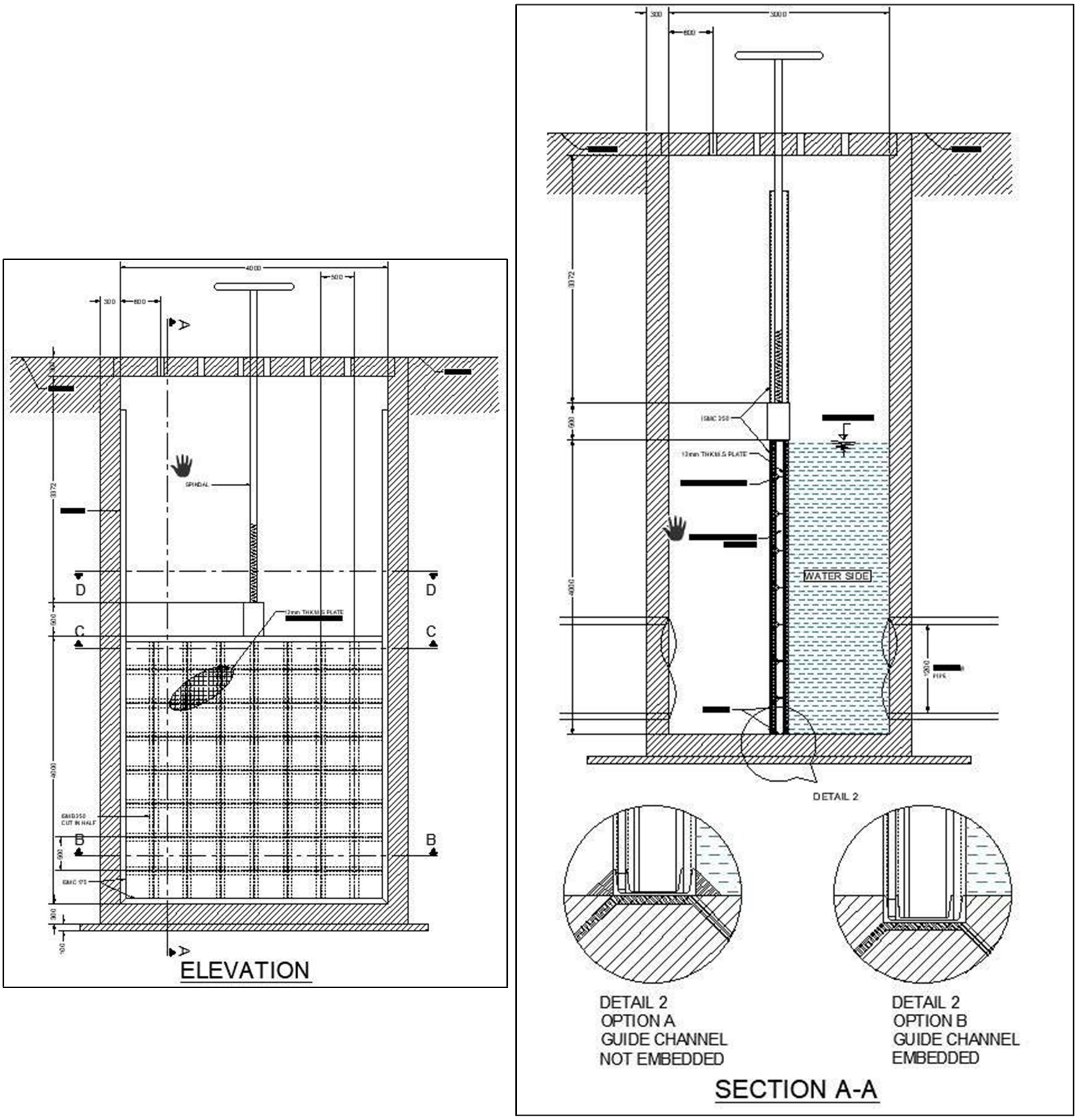


Fig 10. Elevation and Section of Lifting Gate

Following the completion of GADs, 3D modeling and structural analysis were performed using STAAD.Pro, a widely adopted finite element analysis (FEA) software. The gates were modeled to simulate real-world load conditions, including hydrostatic pressure from stormwater, self-weight of the gate components, and the mechanical loads resulting from manual operation (screw lifting or tilting forces). The analysis considered boundary conditions such as fixed supports at hinge or rail connections, and load cases were developed for fully open, partially open, and fully closed gate positions. From the analysis, outputs such as bending moments, shear forces, deflection values, and stress contours were extracted for each component, including gate leaves, supporting frames, and roller or hinge assemblies.

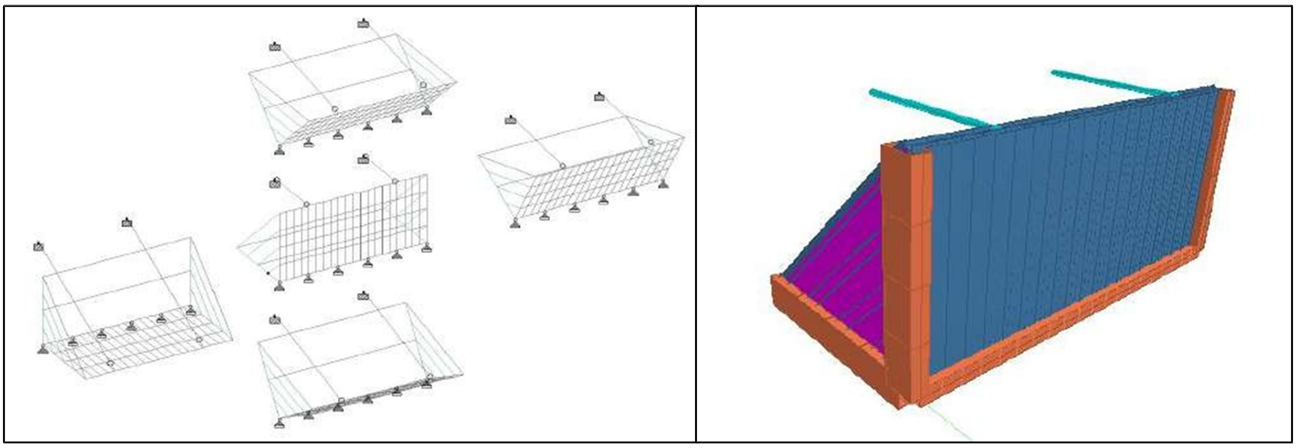


Fig 11. Staad Model of Tilting type gate at various angle of tilting and rendered modal

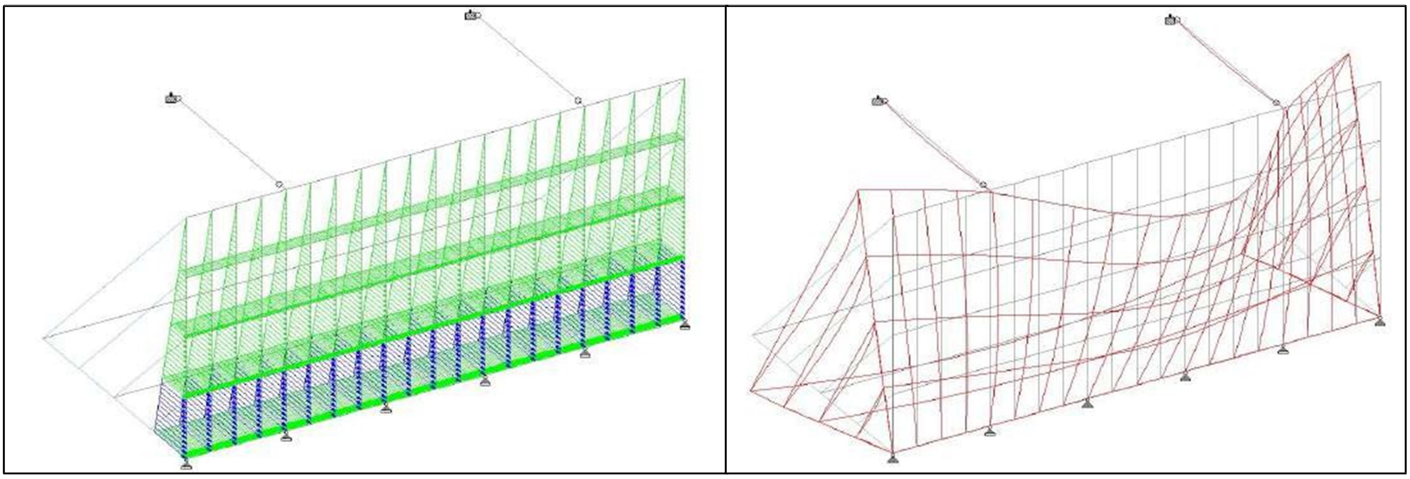


Fig 12. Hydrostatic Load Applied and Deflected Shape of Tilting Gate

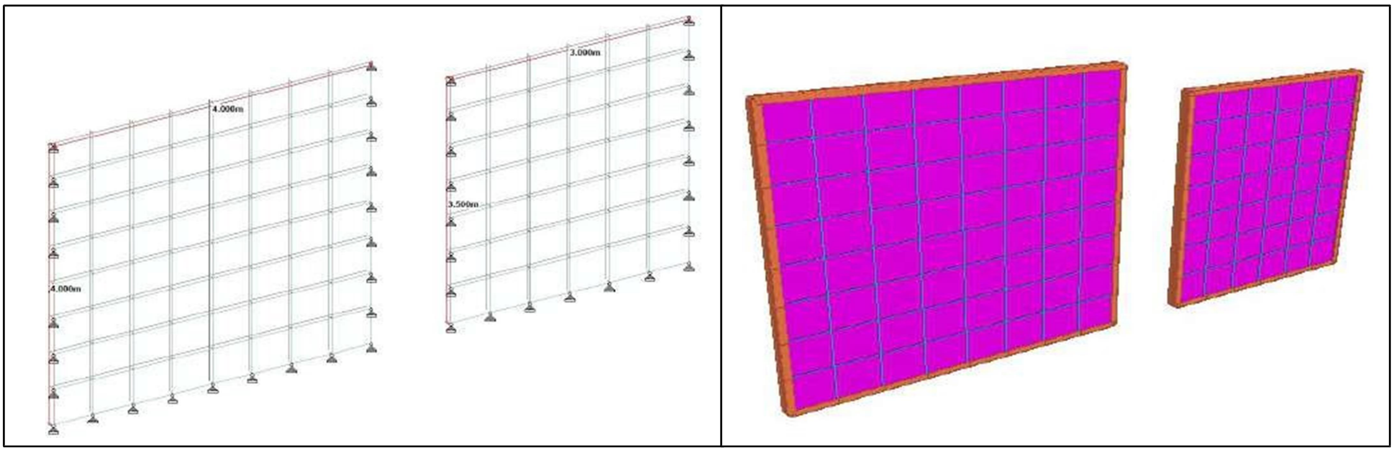


Fig 13. Staad Model of both Lifting type gate and rendered modal

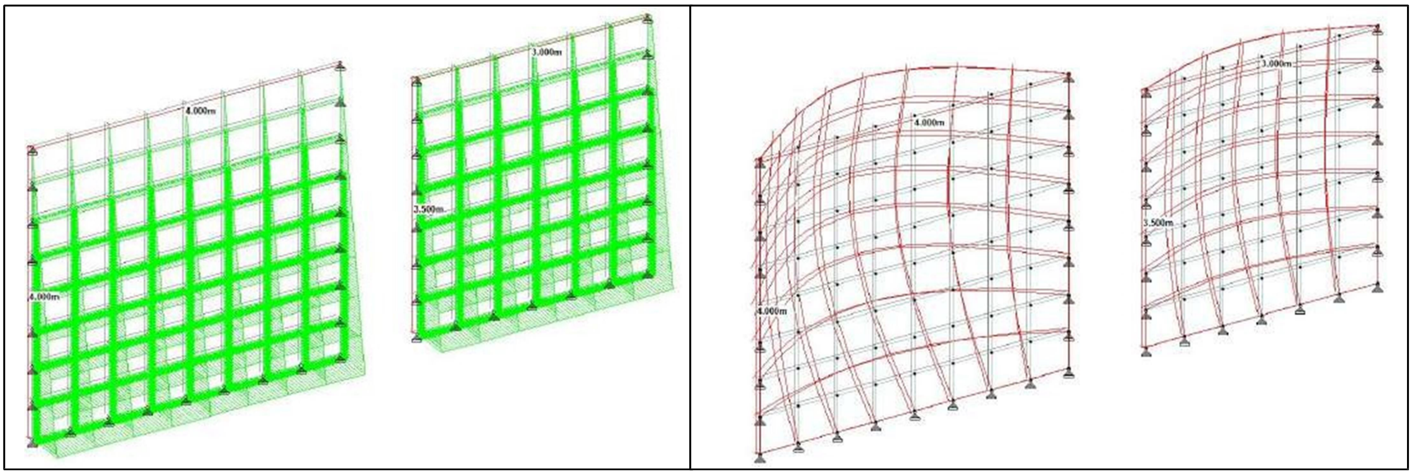


Fig 14. Hydrostatic Load Applied and Deflected Shape of Lifting Gate

These STAAD analysis results were then exported and used for detailed manual design calculations in Microsoft Excel, following IS code provisions. Each component was evaluated based on allowable stresses and deflection criteria, with reference to IS 800 (structural steel), IS 456 (reinforced concrete), and IS 11228 (mechanical hoists). The design calculations included:

- Section modulus and moment of resistance for gate panels.
- Axial and shear strength checks for support members and fasteners.
- Deflection limits based on span/350 criteria.

Additionally, Excel tools were used to cross-check weld sizes, bolt configurations (especially HSFG bolts, Grade 8.8), and bearing stresses at anchorage points. For wire ropes and screw mechanisms, the design adhered to IS 2266 and IS 11228, with factors of safety applied as per lifting and hoisting equipment standards.

Once the design and sizing were finalized, the fabrication phase was initiated. All structural materials, including high-strength mild steel plates (E250 grade), hot-rolled sections, and stainless steel bolts (SS304/316), were procured from approved vendors. The fabrication involved precision cutting, drilling, welding, and surface treatment. Weld joints were executed using continuous fillet welds of 3 mm or 6 mm thickness, with visual and NDT (Non-Destructive Testing) inspection as applicable. Anti-corrosive coatings such as epoxy primers and polyurethane topcoats were applied, and for components exposed to high moisture, hot-dip galvanization was used as per IS 2629. Rubber seals made of neoprene or EPDM were installed to the gate perimeters to ensure water-tight operation.

Simultaneously, civil interface works were executed on-site. RCC foundations and culvert modifications were constructed based on IS 456:2000 guidelines, with preformed grooves or embedded anchor plates for gate installation. Once site preparation was complete, the gates were transported to the site and installed using lifting mechanisms such as cranes or chain pulleys. Alignment checks were performed using precision instruments like total stations and spirit levels to ensure gates were plumb and level, critical for smooth operation.

The final stage involved dry and wet testing (project demonstration). Dry tests were first carried out to verify the mechanical operation—checking smoothness, synchronization, and alignment of the gates. Once these passed, wet tests were conducted by channeling controlled water flow through the gate systems to observe sealing performance, gate responsiveness, and flow regulation. Any minor issues were addressed on-site, and final adjustments made. A commissioning report was prepared, including design validation, material test certificates, as-built drawings, and operation and maintenance (O&M) manuals. The airport maintenance personnel were trained for gate operation, lubrication schedules, and inspection routines.

This structured methodology ensured the delivery of a reliable, robust, and maintainable stormwater gate system that meets both operational and environmental requirements of a modern international airport.

4.2 Codes and Standards

The design and construction of the gates strictly adhere to Indian Standards to ensure structural stability, safety, and performance. The key codes and guidelines referenced include:

- **IS 800:2007 – General steel construction practices**
- **IS 808:2021 – Hot rolled steel section dimensions**
- **IS 456:2000 – Reinforced concrete design**
- **IS 816:1969 – Mild steel arc welding**
- **IS 4000:1992 – HSFG bolt usage guidelines**
- **IS 2266:2002 – Steel wire rope specifications**
- **IS 4622:2003 – Fixed-wheel gate design**
- **IS 5620:1985 – Low head slide gate design criteria**
- **IS 13349:1992 – Sluice gate specifications (thimble mounted)**
- **IS 3042 – Single faced sluice gate specifications**

- **IS 11228 – Screw hoist design for hydraulic gates**

In addition to IS codes, design validation and proof-checking have been undertaken through certified third-party agencies or premier institutions such as IITs or NITs to ensure conformity with national and international engineering practices.

4.3 Constraints, Alternatives and Tradeoffs

Several constraints were encountered during the planning and design phases of the project. Space limitation was a major consideration, especially for Sections P-P and R-R, where the installation had to be accommodated within narrow culverts. This ruled out the use of radial or flap gates, making vertical lifting gates the most viable option. Similarly, for Section U-U, while a sluice gate could have been used, the open nature of the channel and the need for overflow regulation made the weir-type tilting gate a more appropriate and cost-effective choice.

Manual operation was chosen over automated systems due to the limited need for frequent operation and the desire to minimize dependency on electrical systems, especially during emergency conditions like power failures. This decision offers significant advantages in terms of simplicity, cost savings, and reliability but comes with a tradeoff in terms of slower operation and manual labor involvement. Additionally, while stainless steel gates offer superior corrosion resistance, their cost was significantly higher than that of epoxy-coated mild steel. After careful cost-benefit analysis, epoxy-coated mild steel was selected as the base material, with enhanced surface treatment to mitigate corrosion risks.

In terms of tradeoffs, the design balances long-term durability with economic feasibility. Advanced materials and automation could enhance performance but were considered excessive for the specific hydraulic demands and frequency of operation expected at these sites. The final design represents a practical compromise that meets functional, structural, and economic criteria, ensuring a robust and maintainable system that aligns with the broader goals of infrastructure sustainability and operational resilience at Bhogapuram International Airport.

Project 2: Redesign of the Sump Pit of the Toilet Block at Kapodra Station of Surat Metro

4.1 Design Approach / Materials & Methods

The design of the revised sump pit at Kapodra Station follows a performance-based engineering approach, focused on structural stability, watertightness, serviceability, and operational access. A full 3D finite element model was developed in STAAD Pro to simulate the structural response of the sump under all relevant loading conditions, including hydrostatic uplift, earth pressure, seismic raking, and service loads. The model considered the interaction between the base slab, walls, and surrounding soil using plate elements with varied elevations and boundary conditions. Loads applied included self-weight, lateral soil pressure, water pressure, surcharge loads, and seismic forces based on ODE and MCE scenarios.

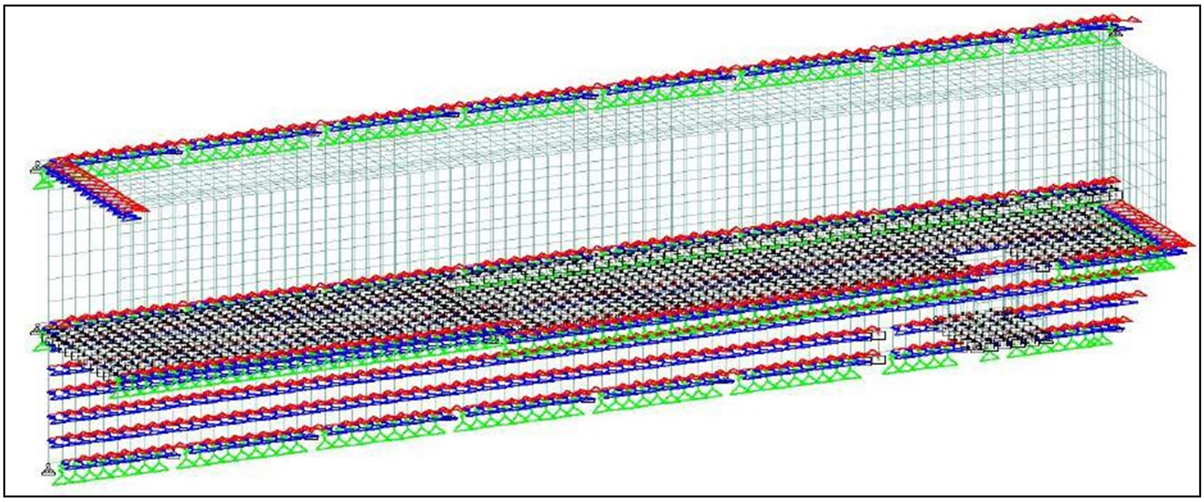


Fig 15. Staad Modal of Toilet Block

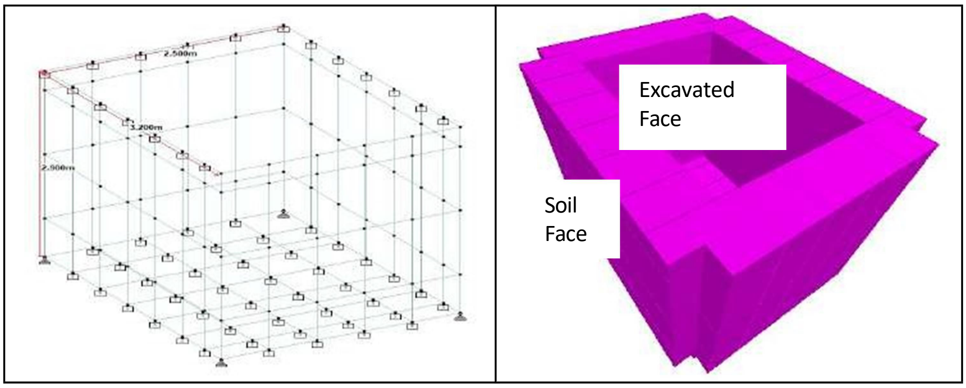


Fig 16. Staad Modal and Rendered of Sump Pit

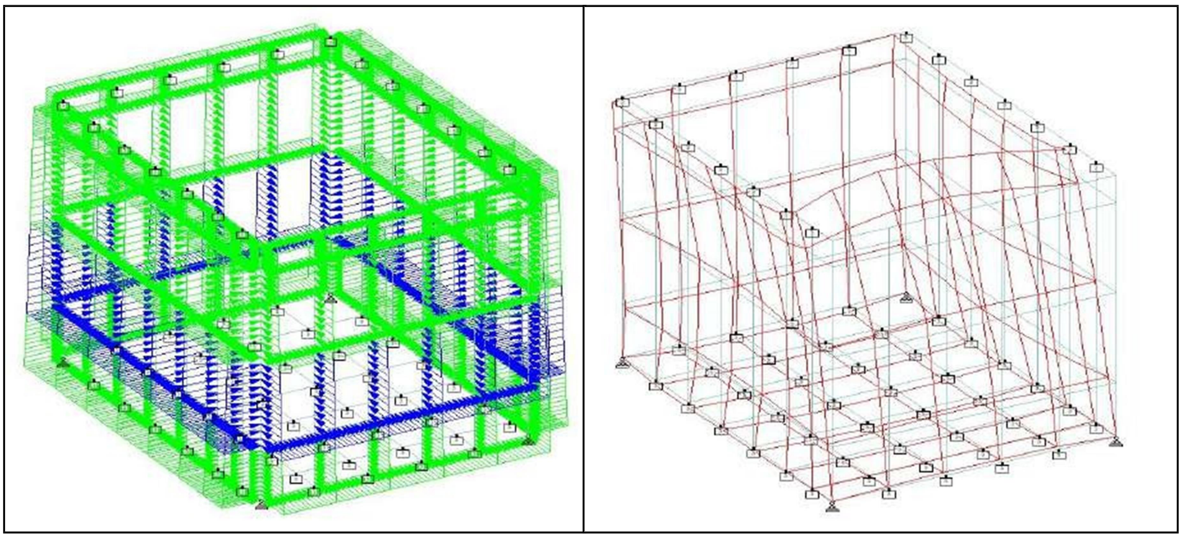


Fig 17. Staad Modal and Rendered of Sump Pit

The sump walls and base slab were designed to act monolithically to resist the combined effects of vertical and horizontal pressures. Special attention was given to uplift pressure, which is particularly critical in this underground buried structure due to the high groundwater table. To mitigate uplift, the structure relies on self-weight and passive resistance from surrounding soil, ensuring that the factor of safety against flotation exceeds the minimum threshold.

The removeable top slab was introduced to replace the earlier cast-in-situ slab for reasons related to operational convenience. All structural elements use M45 grade concrete with reinforcement detailed to ensure durability, control of crack widths, and structural ductility. Reinforcement calculations were performed based on ultimate limit state (ULS) and serviceability limit state (SLS) results extracted from STAAD, with manual verification of crack width, deflection, and shear strength using design spreadsheets.

4.2 Codes and Standards

The design and detailing of the sump pit were carried out in accordance with a combination of Indian and international standards, along with specific project requirements defined by GMRC and the ODS. The following standards were used:

- **IS 456:2000** – Code of Practice for Plain and Reinforced Concrete.
- **IS 3370 (Part 1 to 4)** – Design of Concrete Structures for Storage of Liquids (for watertightness and pressure resistance).

- **IS 1893 (Part 1): 2016 –** Criteria for Earthquake Resistant Design of Structures.
- **IS 1786:2008** – High Strength Deformed Steel Bars for Reinforcement.
- **EN 1992-1-1 (Eurocode 2) –** Design of Concrete Structures (referenced for crack width and stress checks where required).
- **ODS Part 1 and 2** – GMRC's Operation Design Standards, which outline specific design loads, seismic zoning, flood levels, and access requirements for underground metro facilities.
- **Design Basis Report** (Document No. R-EUGP1-TPT-F-000-GEN-REP-001-R00) – Provided the governing parameters, load combinations, material properties, and methodology guidelines.
- **Foundation Analysis and Design by J.E. Bowles** – Used as a reference for soil-structure interaction, uplift pressure calculation, and bearing checks.

4.3 Constraints, Alternatives and Tradeoffs

The original sump design posed several practical and functional constraints. A major limitation was the fixed, cast-in-situ top slab, which hindered maintenance and inspection. Access to the sump for tasks like pump replacement or debris removal would have required partial demolition of the slab—a costly and operationally disruptive process. In addition, the original depth of the sump was insufficient to accommodate expected stormwater volume, especially during high rainfall or potential flood events, as defined by updated hydraulic studies and GMRC's ODS guidelines.

Another constraint involved structural behavior under uplift conditions. The original configuration had limited vertical resistance against hydrostatic pressure due to its shallow depth and thinner slab profile. This necessitated a deeper sump with a heavier structural mass to resist flotation, while still ensuring constructability within the limited working space of the cut-and-cover section.

To address these issues, an alternative design was proposed: a deeper sump pit with a removable precast top slab. The precast solution eliminated the need for demolition during future maintenance, making the system more user-friendly and operationally robust. However, this approach introduced tradeoffs, including additional detailing at the slab-seat interface, installation planning for the precast component, and higher initial costs due to factory casting and handling logistics.

Despite these tradeoffs, the revised design offered long-term benefits such as ease of access, faster installation, and reduced lifecycle maintenance costs. The change was deemed a technically superior solution after evaluating multiple options through stakeholder discussions and design optimization studies. It successfully balances structural integrity, operational flexibility, and construction feasibility, making it a forward-looking upgrade aligned with best practices for metro utility infrastructure.

5. SCHEDULE, TASKS AND MILESTONES

Project 1: Stormwater Gate Design at Bhogapuram Airport

The design phase forms the foundation of the stormwater gate project, setting the direction for all subsequent fabrication, civil integration, and installation activities. This phase is scheduled over a period of 5 weeks and involves both conceptual and detailed engineering work, supported by technical validation through certified proof-checking agencies. The tasks and milestones for the design stage are outlined below:

Table 2. Schedule

Phase	Task Description	Duration	Milestone / Deliverable
1. Planning & Site Review	Obtain architectural and civil layout plans	Week 1	Site and layout data obtained
	Conduct site survey, drainage mapping, and topographic analysis	Week 1	Site assessment report prepared
	Identify gate locations and flow paths	Week 1–2	Gate positions finalized
2. Design & Engineering	Prepare General Arrangement Drawings (GADs)	Week 2–3	GAD drawings submitted for review
	Perform STAAD modeling and structural analysis	Week 3–4	Structural analysis completed
	Carry out Excel-based component sizing and IS code checks	Week 4–5	Detailed design calculations finalized
	Submit design for proof-checking (IIT/NIT/Third-party agency)	Week 5–6	Design validation and approval received

Project 2: Redesign of the Sump Pit of the Toilet Block at Kapodra Station of Surat Metro

Table 3. Schedule

Phase	Task Description	Duration	Milestone / Deliverable
Conceptualization	Identification of limitations in the original sump design	3 days	Design issue formally recorded for redesign
Preliminary Design	Development of revised design concept and STAAD Pro 3D model setup	4 days	New sump configuration integrated into structural model
Data Integration	Review of GIR data, ODS parameters, and hydraulic inputs	5 days	Verified design criteria and depth requirements
Option Evaluation	Evaluation of alternatives and selection of precast cover system	5 days	Finalized decision for removable precast slab
Structural Design	Final design of sump geometry, load analysis, and reinforcement	5 days	Structural detailing completed and validated
Internal Review	Cross-checking of calculations, crack width, uplift checks	5 days	Design verified internally by structural team
Documentation	Preparation of drawings, design sheets, and revision report	3 days	Submission package (Rev. R1) compiled
Final Submission & Approval	Client review, clarification, and formal approval of revised design	23 days	Revised Design Report (Rev. R1) approved by GMRC

6. PROJECT DEMONSTRATION

Project 1: Stormwater Gate Design at Bhogapuram Airport

The demonstration of the project's technical soundness was carried out primarily through a combination of structural analysis using STAAD.Pro and detailed manual design verification through Excel-based design sheets. This phase was essential in confirming that the gate structures, including the weir-type tilting gate and the two vertical lifting gates, would perform safely under design loading conditions and comply with relevant Indian Standards.

The process began with the development of a detailed structural model in STAAD.Pro, where each gate was modeled with accurate geometry, boundary conditions, and material properties. Loadings applied to the models included hydrostatic pressure due to water retained on the upstream side and self-weight of the structural components acting through the screw mechanism or hinge assemblies. The boundary conditions reflected the physical constraints of each gate: the tilting gate was modeled with rotational support at its base to simulate the hinge mechanism, while the vertical lifting gates were modeled with lateral guides and bottom supports to represent fixed and guided boundary conditions. The loading combinations were developed in line with the provisions of IS 800:2007 and IS 456:2000, considering critical service and ultimate load conditions.

Upon analysis, STAAD.Pro generated detailed output for bending moments, shear forces, axial forces, and support reactions at various key points along the gate structures. The highest bending moments were typically observed near the mid-span of the gate leaf and at the base connections of the supporting frames, especially in the vertical lifting gates where the full hydrostatic head acts on the gate face. Shear forces were critical near the hinges and guide channel interfaces, while axial loads were present in upright support members. Support reactions derived from the analysis were especially important for designing anchor bolts and base plate connections to the RCC structures.

Table 4. Flextural Member of Structure

Flextural Member										
Gate Type	Elements of	Beam	L/C	Node	Axial Force	Shear -Y	Shear -Z	Torsion	Moment-Y	Moment-Z

	structure		kN	kN	kN	kNm	kNm	kNm
Lifting type gate 4m x 4m	Horizontal Stiffners	Max	189.742	16.629	6.241	0.04	1.622	7.492
		Min	-189.742	-16.629	-6.106	-0.04	-1.622	-7.492
	Verticle Stiffners	Max	137.54	18.525	6.829	0.041	1.783	5.484
		Min	-137.674	-18.525	-6.829	-0.041	-1.783	-3.726
	End Beam Results	Max	0	1.107	1.308	0.028	0.253	0.324
		Min	0	1.107	1.308	0.028	0.253	0.324
Lifting type gate 3m x 3.52 m	Horizontal Stiffners	Max	101.318	11.498	3.535	0.02	0.882	3.212
		Min	-101.318	-11.498	-3.4	-0.02	-0.677	-3.22
	Verticle Stiffners	Max	101.318	11.498	3.535	0.02	0.882	3.212
		Min	-101.318	-11.498	-3.4	-0.02	-0.677	-3.22
	End Beam Results	Max	1.427	0.896	4.122	0.023	0.953	0.261
		Min	-1.427	-0.896	-4.122	-0.023	-1.046	-0.247
5m x 2.5m Tilting type Gate	Horizontal Stiffners	Max	1.745	1.171	1.66	0.066	1.037	9.297
		Min	-2.315	-5.753	-1.66	-0.066	-1.037	-7.228
	Verticle Stiffners	Max	2.376	8.514	3.066	0.062	2.82	7.228
		Min	-2.945	-14.929	-3.066	-0.062	-2.82	-0.166
	Frame Beam Results	Max	19.315	1.934	0.187	0.008	0.023	0.987
		Min	-19.315	-3.144	-0.187	-0.008	-0.023	-0.987
	Top Beam	Max	16.152	32.263	2.684	0.012	0.336	12.781
		Min	-16.152	-32.263	-2.684	-0.012	-0.336	-12.781
	Bottom Shaft	Max	4.496	38.588	14.395	0.136	4.242	36.302
		Min	-4.496	-38.588	-14.395	-0.136	-4.242	-36.302

Table 5. Plate Member of Structure

Plate Member										
Gate Type	Plate	L/C	SQX N/mm2	SQY N/mm2	MX kNm/m	MY kNm/m	MXY kNm/m	SX N/mm2	SY N/mm2	SXY N/mm2
Lifting type gate 4m x 4m	Max		0.127	0.113	0.114	0.127	0.081	5.242	16.752	8.505
	Min		-0.045	-0.113	0	0	-0.081	-17.814	-12.216	-8.505
Lifting type gate 3m x 3.52m	Max		0.079	0.077	0.059	0.067	0.039	2.093	6.012	4.372
	Min		-0.029	-0.077	0	0	-0.04	-8.453	-6.391	-4.337
5m x 2.5m Tilting type Gate	Max		0.048	0.063	0.045	0.036	0.015	0.546	0.367	0.214
	Min		-0.048	-0.063	-0.045	-0.036	-0.015	-0.238	-1.507	-0.069

These structural results were then used to perform detailed design checks using Excel-based spreadsheets, custom-developed for the project. The STAAD results for maximum bending moments and shear forces were input into these sheets to determine whether the selected sections met safety and performance criteria. Section modulus calculations were used to ensure that the bending stress did not exceed 0.66 × fy, and shear checks confirmed compliance with the allowable stress limit of 0.40 × fy. Additionally, deflection under service loads was calculated and verified to remain within L/350, as prescribed by IS codes.

Table 6. Tilting Type Gate Load Calculation and Front Leaf Beam Design

1) Load Calculation			
height of gate	=	**2.5**	m
g	=	**10**	m/s^2
pressure at bottom of gate	=	25	KN/m^2
width of plate	=	**0.25**	m
total pressure	=	6.25	KN/m

Total Shear force due to water		=	7.8125	KN	
C.G. of triangle		=	**0.833**	m	
Total Moment on section		=	**6.510**	KN m	

2.1) Forces Summary on the Front Leaf Beams — As per staad Pro results

	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
Max	**19.315**	**11.7**	**3.07**	**0.07**	**2.82**	**9.30**
Min	**-19.32**	**-14.9**	**-3.07**	**-0.07**	**-2.82**	**-7.69**

2.2) Front Leaf Beam Design

Length of the beam	=	**2500**	mm	
Moment of Inertia - Ixx	=	**7180000**	mm^4	
Modulous of Elasticity - E	=	**2E+05**	N/sqmm	
Moment on the section	=	9.30	KN m	
Shear force on the section	=	15.00	KN	
Section modulus Z req	=	56345.455	mm^3	
Section modulus Z provided	=	**95700**	mm^3	**Hence OK**

Section provided ISMB 150 at 250mm c/c

Area of the section	=	**1910**	mm^2	
Allowable Flexural Tensile stress = 0.66xFy	=	**165**	Mpa	
Allowable avg. shear stress - 0.4 x Fy	=	**100**	Mpa	
Allowable Deflection - L/350	=	7.14	mm	
Actual Flexural Stress =	=	97.1	Mpa	**Hence OK**
Actula shear stress =	=	7.85	Mpa	**Hence OK**
Actual Deflection =	=	3.3	mm	**Henc**

									e OK

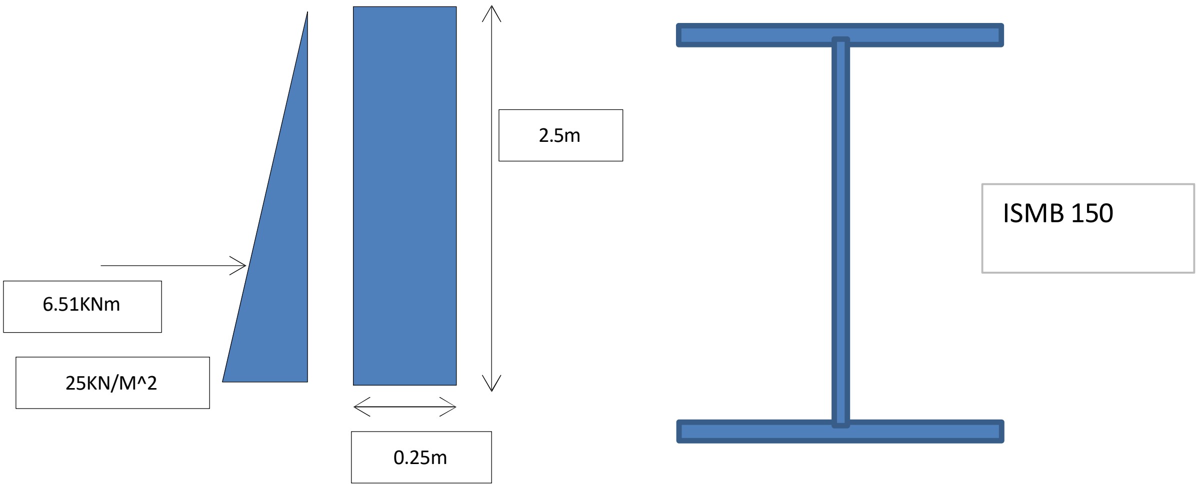


Fig 18. Load Diagram and Front Leaf Member of Tilting Gate

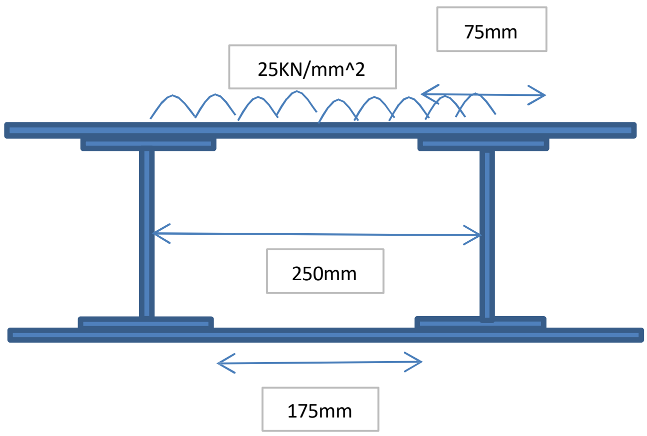


Fig 19. Built-up Section of Gate Tilting Gate

Table 7. Tilting Type Gate Plate Design

2.3) Front Leaf Plate Design						
		Max spacing of the stiffners	=	250	mm	
		Width of the stiffners	=	75	mm	
		Depth of the stiffners	=	150	mm	
		Distance between plates	=	175	mm	
		Moment of Inertia - Ixx	=	144000	mm^4/m	
		Modulous of	=	200000	N/sqmm	

Elasticity - E			
Bending moment	=	0.0765625	KNm/m	
Section modulus Z req	=	464.01515	mm^3	
Section modulus Z provided	=	24000	mm^3	**Hence OK**
Breadth of plate	=	**1000**	mm	
Thickness of plate required	=	1.6685595	mm	
12mm thick plate is provided both top and bottom of ISMB 150				
Thickness of the plate provided	=	**12**	mm	
Allowable Flexural Tensile stress = 0.66xFy	=	**165**	Mpa	
Allowable Deflection - L/350	=	0.7	mm	
Actual Flexural Stress	=	3.2	Mpa	**Hence OK**
Actual Deflection	=	0.00003	mm	**Hence OK**

Table 8. Lifting type Gate Load Calculation and Front Beam Design

1) Load Calculation			
height of gate	=	**4**	m
g	=	**10**	m/s^2
pressure at bottom of gate	=	40	KN/m^2
width of plate	=	**0.5**	m
total pressure	=	20	KN/m
Total Shear force due to water	=	40	KN
C.G. of triangle	=	**1.333**	m
Total Moment on section	=	**53.333**	KN m
2.1) Forces Summary on the Front Leaf Beams	As per staad Pro results		

	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
Max	**189.74**	**16.6**	**6.24**	**0.04**	**1.622**	**7.49**
Min	**-189.7**	**-16.6**	**-6.11**	**-0.04**	**-1.622**	**-7.49**

2.2) Front Leaf Horizontal and Verticle Beam Design

Length of the beam	=	**4000**	mm	
Moment of Inertia - Ixx	=	**3590000**	mm^4	
Modulous of Elasticity - E	=	**2E+05**	N/sqmm	
Moment on the section	=	7.49	KN m	
Shear force on the section	=	17.00	KN	
Section modulus Z req	=	45406.061	mm^3	
Section modulus Z provided	=	**47850**	mm^3	**Hence OK**

Section provided ISMB 150 at 250mm c/c

Area of the section	=	**955**	mm^2	
Allowable Flexural Tensile stress = 0.66xFy	=	**165**	Mpa	
Allowable avg. shear stress - 0.4 x Fy	=	**100**	Mpa	
Allowable Deflection - L/350	=	11.43	mm	
Actual Flexural Stress =	=	156.6	Mpa	**Hence OK**
Actula shear stress =	=	17.80	Mpa	**Hence OK**
Actual Deflection =	=	10.5	mm	**Hence OK**

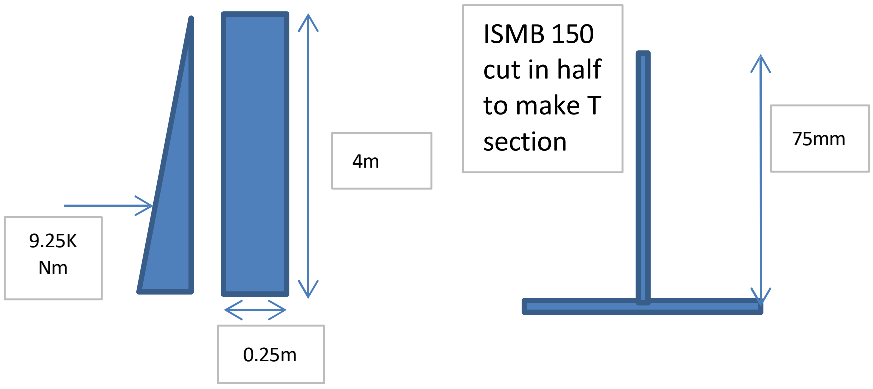


Fig 20. Load Diagram and Front Leaf Member of Lifting Gate

Table 9. Lifting Type Gate Plate Design

2.3) Front Leaf Plate Design						
		Max spacing of the stiffners	=	**500**	mm	
		Width of the stiffners	=	**75**	mm	
		Depth of the stiffners	=	**150**	mm	
		Moment of Inertia - Ixx	=	144000	mm^4/m	
		Modulous of Elasticity - E	=	200000	N/sqmm	
		Bending moment	=	1	KNm/m	
		Section modulus Z req	=	6060.6061	mm^3	
		Section modulus Z provided	=	24000	mm^3	**Hence OK**
		Breadth of plate	=	**1000**	mm	
		Thickness of plate required	=	6.0302269	mm	
		12mm thick plate is provided on top of Half cut ISMB 150				
		Thickness of the plate provided	=	**12**	mm	
		Allowable Flexural Tensile stress = 0.66xFy	=	**165**	Mpa	

		Allowable Deflection - L/350				=	1.4	mm	
		Actual Flexural Stress				=	41.7	Mpa	**Hence OK**
		Actual Deflection				=	0.02826	mm	**Hence OK**

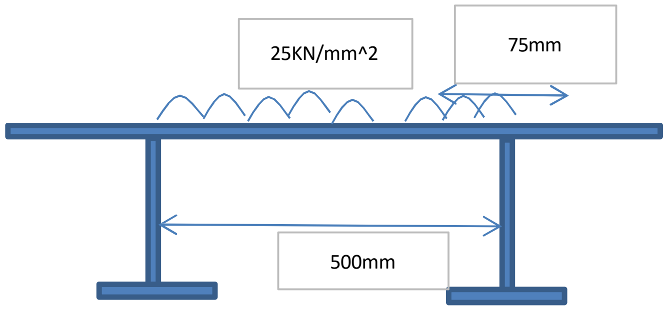


Fig 21. Built-up Section of Gate

The Excel sheets also included all the members of the gates such as the frame structure, Top beam, bottom beam and tilting gate shaft design. The anchor bolts and base plates were also designed using support reactions obtained from STAAD to verify that the foundation embedment and bearing pressures remained within safe limits.

This combined analytical and manual design verification approach provided a robust demonstration that the stormwater gates are structurally adequate, code-compliant, and engineered for long-term durability. The outputs from both STAAD and Excel tools were included in the project's design dossier, forming the technical foundatixon for fabrication, installation, and certification processes.

Project 2: Redesign of the Sump Pit of the Toilet Block at Kapodra Station of Surat Metro

The design revision and finalization of the sump pit at Kapodra Station were based on rigorous structural analysis using a 3D finite element model developed in STAAD Pro. This model simulated the behavior of the sump structure as part of the overall Toilet Block under a range of service and ultimate load conditions. The STAAD model incorporated all relevant loads, including self-weight, soil pressure, hydrostatic uplift, vehicular surcharge, live load, seismic forces, and extreme flood conditions. Based on the results obtained—particularly the stress contours, support reactions, and moment distributions—a redesign of the sump was undertaken to optimize its structural performance and improve its functional accessibility.

The outputs from the STAAD analysis were used to extract the most critical values of bending moments, shear forces, and axial loads in the base slab and wall elements of the sump. These design forces were then exported to Excel-based structural design spreadsheets, where detailed section-wise calculations were performed. The spreadsheets were used to compute the required reinforcement, verify flexural and shear capacities, and ensure compliance with applicable codes for crack control and durability.

Table 10. Results obtained from Staad Ananlysis

			Toilet block			
sections	**Span**	**Tension on**	**ULS**		**SLS**	
			Moments	**Shear**	**Axial**	**Moments**
			BM	**SF**	**Pu**	**BM**
			kN-m/m	**kN/m**	**kN/m**	**kN-m/m**
Wall 600mm Thk		Excavation face	269.19	329.4	191.4	218.1
		Soil Face	-85.44			-67.6
Base slab 600mm Thk		Excavation face	7.46	76.2	151.8	24.1
		Soil Face	-37.78			-28.0

Additionally, the sump redesign included several critical performance checks to ensure long-term serviceability. A short-term deflection check was conducted under serviceability limit state combinations to ensure that vertical displacements remained within permissible limits. Further, a creep deflection check was performed to account for the time-dependent deformation of concrete under sustained loads. This was particularly important for buried structures like the sump, which are continuously subjected to hydrostatic pressure and earth loads. The design also accounted for long-term deflection, considering both immediate elastic deformation and time-dependent effects due to creep and shrinkage. The calculated deflections were well within the serviceability criteria, ensuring that the structure remains stable, durable, and watertight throughout its design life.

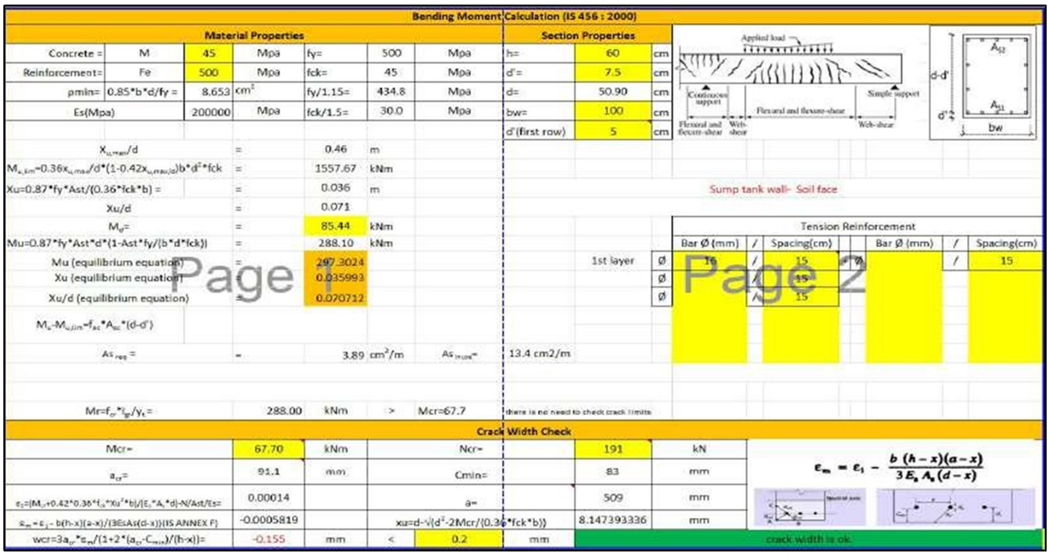
Table 11. Crackwidth Calculation for Toilet block Base slab -Support Soil face

Crackwidth Calculation for Toilet block Base slab -Support Soil face		
	-	
Cases for Reinforcement Combinations	*Unit*	*1*
		Soil face
Slab Depth	*mm*	600
Tension Reinforcement provided (1st layer)	*mm*	Y25.0
	mm	@150c/c
		+
Tension Reinforcement provided (2nd layer)	*mm*	Y0
	mm	@150c/c
		+
Tension Reinforcement provided (3rd layer)	*mm*	Y0
	mm	@250c/c
-		
a) Max. B.M. Capacity (ULS)	*kN-m*	262.6
B.M. Capacity (SLS)	*kN-m*	188
Axial Compression (P)	*kN*	25
Design B.M. in ULS (M_{ULS})	*kN-m*	263
Design Parameters		
Actual Clear Cover (c)	*mm*	75
Nominal cover (C_{nom}) (For Calculating Crack Width)	*mm*	50
Width of Section (b)	*mm*	1000
Concrete Grade (f_{ck})	*N/mm²*	45
Main R/f Steel Grade (f_y)	*N/mm²*	500
Stirrup Steel Grade (f_{ys})	*N/mm²*	415
Dia of each leg of stirrup provided	*mm*	10
Percentager of distribution reinforcement	*%*	0.125
Diameter of distribution reinforcement alternatively placed	*mm*	0
	mm	0
Required spacing	*mm*	0.00
Provided spacing	*mm*	150.0015
Modulus of Elasticity of Steel (E_s)	*N/mm²*	2E+05
$X_{u(max)}$ / d		0.456
Total Depth of Section (D)	*mm*	600
Distance of compression face to point of crack (a)	*mm*	575
Dia.of 1st layer of tension R/f Provided (Φ_{1t})	*mm*	25.0000
Spacing of 1st Layer tension of Reinforcement (s_{1t})	*mm*	150.0015
Spacer Bar Between Layer 1 and Layer 2	*mm*	25

Area of 1st Layer of Reinforcement $(Ast)_{FIRST\ LAYER}$	mm^2	3272.46
Vertical Distance of Bar center line from Bottom bar center line	mm	0
Distance of CG of 1st layer from Bottom $(h_1)_{BOTTOM}$	mm	88
$(Ast)_{FIRST\ LAYER}*(h_1)_{BOTTOM}$	mm^3	286340
Dia.of 2nd layer of tension R/f Provided (Φ_{2t})	mm	0
Spacing of 2nd Layer of tension Reinforcement (s_{2t})	mm	150.0015
Dia.of 3rd layer of tension R/f Provided (Φ_{3t})	mm	0
Spacing of 3rd layer of tension Reinforcement (s_{3t})	mm	250
Area of 3rd Layer of Reinforcement $(Ast)_{THIRD\ LAYER}$	mm^2	0
Vertical Distance of Bar center line from Bottom bar center line	mm	0
Distance of CG of 3rd layer from Bottom $(h_3)_{BOTTOM}$	mm	0
$(Ast)_{THIRD\ LAYER}*(h_3)_{BOTTOM}$	mm^3	0
$A_{st\ (Provided)}$	mm^2	3272
Σ (Ast) * ht	mm^3	286340
CG. Of Steel from Bottom = Effective Cover $(h)_{BOTTOM}$	mm	88
Effective Depth of Section from Bottom $(d_{eff})_{BOTTOM}$	mm	512.50
Dia.of 1st layer of compression R/f Provided (Φ_{1C})	mm	Y32.0
Spacing of 1st Layer of compression Reinforcement (s_{1c})	mm	150
Dia.of 2nd layer of compression R/f Provided (Φ_{2c})	mm	Y0.0
Spacing of 2nd Layer of compression Reinforcement (s_{2c})	mm	333
Dia.of 3rd layer of compression R/f Provided (Φ_{3c})	mm	0
Spacing of 3rd layer of compression Reinforcement (s_{3c})	mm	250
CG. Of Steel from Top = Effective Cover $(h)_{TOP}$	mm	88
Effective Depth of Section from Top $(d_{eff})_{TOP}$	mm	513
Factored Moment on Section = M_u	kN-m	262.60
Limiting Moment of Resistance = $M_{u(lim)}$	kN-m	1569
Type of Section		SinglyR/f
a		4.89
b		-222938
c		262600000
For Singly R/f Section$A_{st} = A_{st,\ required}$	mm^2	1210
For Doubly R/f Section $(P_{t,lim})$		0.00%
For Doubly R/f Section $(A_{st,lim}) = P_{t,lim} * b*d$	mm^2	0
For Doubly R/f Section $(\Delta A_{st})_{reqd}$	mm^2	0
For Doubly R/f Section $A_{st,reqd} = A_{st,lim} + (\Delta A_{st})_{reqd}$	mm^2	0

$A_{st,required}$	*mm^2*	1210
$A_{st,provided}$	*mm^2*	3272
		-2062
Strain at compression Steel Level (e_{sc}) =0.0035*(1-$(d_{eff})_{TOP}$/$X_{u,max}$)		0
Compression Steel Stresses (f_{sc})=MIN (0.87*fy, e_{sc}*E_s)	*t/m^2*	0
$A_{sc, required}$ = 0.87*f_y*(Δ A_{sc})$_{reqd}$ / (f_{sc} - 0.46*f_{ck})	*mm^2*	0
$A_{sc, provided}$	*mm^2*	0
<u>Max. B.M. Capacity in SLS for Crack Width of 0.25mm</u>		
<u>Cases for Reinforcement Combinations</u>	Unit	1
Allowable Crack Width	*mm*	**0.2**
Dia.of 1st layer of tension R/f Provided (Φ_{1t})	*mm*	25
Spacing of 1st Layer tension of Reinforcement (s_{1t})	*mm*	150.0015
Spacer Bar Between Layer 1 and Layer 2	*mm*	0
Area of 1st Layer of Reinforcement $(Ast)_{FIRST\ LAYER}$	*mm^2*	3272.46
Vertical Distance of Bar center line from Bottom bar center line	*mm*	0
Distance of CG of 1st layer from Bottom $(h_1)_{BOTTOM}$	*mm*	88
$(Ast)_{FIRST\ LAYER}$*$(h_1)_{BOTTOM}$	*mm^3*	286340
Dia.of 2nd layer of tension R/f Provided (Φ_{2t})	*mm*	0
Spacing of 2nd Layer of tension Reinforcement (s_{2t})	*mm*	150.0015
Dia.of 3rd layer of tension R/f Provided (Φ_{3t})	*mm*	0
Spacing of 3rd layer of tension Reinforcement (s_{3t})	*mm*	250
Area of 3rd Layer of Reinforcement $(Ast)_{THIRD\ LAYER}$	*mm^2*	0
Vertical Distance of Bar center line from Bottom bar center line	*mm*	0
Distance of CG of 3rd layer from Bottom $(h_3)_{BOTTOM}$	*mm*	0
$(Ast)_{THIRD\ LAYER}$*$(h_3)_{BOTTOM}$	*mm^3*	0
$A_{st\ (Provided)}$	*mm^2*	3272
Σ (Ast) * ht	*mm^3*	286340
CG. Of Steel from Bottom = Effective Cover $(h)_{BOTTOM}$	*mm*	88
Effective Depth of Section from Bottom $(d_{eff})_{BOTTOM}$	*mm*	512.50
Dia.of 1st layer of compression R/f Provided (Φ_{1C})	*mm*	32
Spacing of 1st Layer of compression Reinforcement (s_{1c})	*mm*	150.0015

Dia.of 2nd layer of compression R/f Provided (Φ_{2c})	*mm*	0
Spacing of 2nd Layer of compression Reinforcement (s_{2c})	*mm*	333.3333333
Dia.of 3rd layer of compression R/f Provided (Φ_{3c})	*mm*	0
Spacing of 3rd layer of compression Reinforcement (s_{3c})	*mm*	250
CG. Of Steel from Top = Effective Cover $(h)_{TOP}$	*mm*	88
Effective Depth of Section from Top $(d_{eff})_{TOP}$	*mm*	513
$A_{st,provided}$	*mm²*	3272
<u>Servicibility Checks</u>		
Modular Ratio (m) = 280 / f_{ck}		6.22
Percent Reinforcement prov.(p) = $(A_{st})_{provided}$ / (b*d)		0.64%
Calculating neutral Axis Depth by WSM (n*d)	*mm*	178.63
<u>Crack Width Check</u>		
Moment (SLS Normal Case)	*kN-m*	188
a_{cr} = $((C_{nom}+ \Phi /2)^2 + (S/2)^2))^{0.5} - \Phi / 2$	*mm*	85
Stresses in Concrete (f_c)	*kN/m²*	6062
Stresses in concrete at compressive steel level ($f$csc) = $(f_c)*(1-(d_{eff})_{TOP} / (n*d))$	*kN/m²*	3093
In Compression Steel (f_{sc})	*kN/m²*	28865
Stress at centroid of Tension Steel (f_{st})	*kN/m²*	115128
Stress in 1st layer of Tension Steel (f_{st})	*kN/m²*	115128
Stress in 2st layer of Tension Steel (f_{st})	*kN/m²*	0
Stress in 3st layer of Tension Steel (f_{st})	*kN/m²*	0
Tensile stress at the level of crack	*kN/m²*	133769
Strain at the centroid of tension steel (e)=f_{st} / E_s =		5.8E-04
Strain at the Tension Face (e_1) =		6.7E-04
<u>Crack Width As Per IS-456 / BS-8110</u>		
Reduction in strain due to tension stiffning (e_2) =		2.5E-04
b*(D-x)*(a-x)		
(3* Es*Ast*(d-x))		
Avg. steel strain at level considered (e_m) = e_1-e_2 =		4E-04
Crack Width (W_{cr}) =	*mm*	0.0906
3*a_{cr}*e_m		
(1+2*(acr-Cnom)/(D-x))		



Bending Moment Calculation (IS 456 : 2000)

Material Properties							Section Properties		
Concrete =	M	45	Mpa	fy=	500	Mpa	h=	60	cm
Reinforcement=	Fe	500	Mpa	fck=	45	Mpa	d'=	7.5	cm
pmin=	0.85*b*d/fy =	8.653	cm²	fy/1.15=	434.8	Mpa	d=	50.90	cm
Es(Mpa)		200000	Mpa	fck/1.5=	30.0	Mpa	bw=	100	cm
							d'(first row)	5	cm

$X_{u,max}/d$	=	0.46	m
$M_{u,lim}$=0.36$x_{u,max}$/d*(1-0.42$x_{u,max/d}$)b*d²*fck	=	1557.67	kNm
Xu=0.87*fy*Ast/(0.36*fck*b) =	=	0.036	m
Xu/d	=	0.071	
M_d=	=	85.44	kNm
Mu=0.87*fy*Ast*d*(1-Ast*fy/(b*d*fck))	=	288.10	kNm
Mu (equilibrium equation)	=	297.3024	
Xu (equilibrium equation)	=	0.035993	
Xu/d (equilibrium equation)	=	0.070712	
M_u-$M_{u,lim}$=f_{sc}*A_{sc}*(d-d')			
As_{req} =	=	3.89	cm²/m
As_{incl}=	13.4 cm2/m		
Mr=f_{cr}*I_{gr}/y_t=	288.00	kNm	> Mcr=67.7

there is no need to check crack limits

Sump tank wall- Soil face

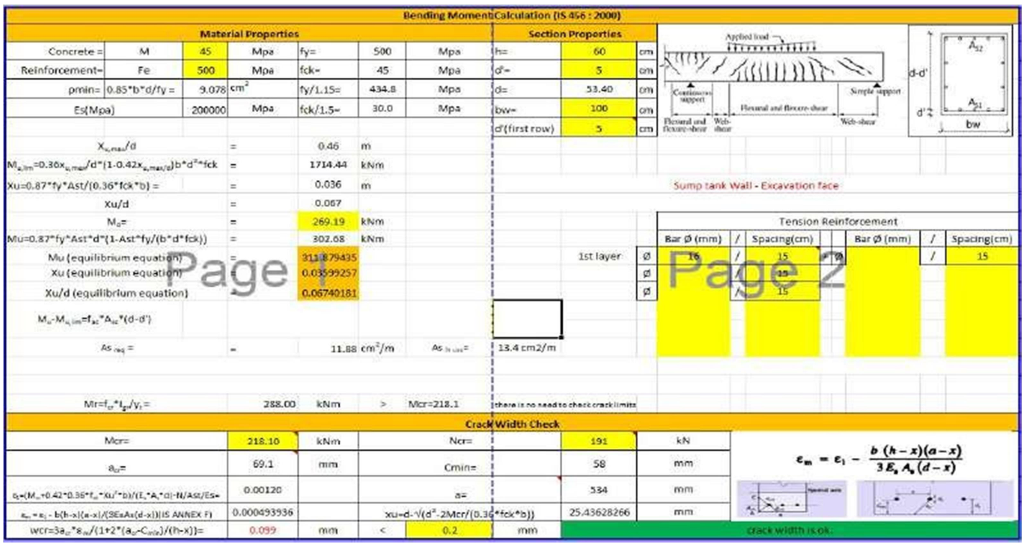
Tension Reinforcement	Bar Ø (mm)	/	Spacing(cm)	Bar Ø (mm)	/	Spacing(cm)
1st layer Ø	16	/	15	Ø	/	15
Ø		/	15			
Ø		/	15			

Crack Width Check

Mcr=	67.70	kNm	Ncr=	191	kN
a_{cr}=	91.1	mm	Cmin=	83	mm
ε_1=(M_s+0.42*0.36*f_{ck}*Xu²*b)/(E_s*A_s*d)-N/Ast/Es=	0.00014		a=	509	mm
ε_m=ε_1- b(h-x)(a-x)/(3EsAs(d-x))(IS ANNEX F)	-0.0005819		xu=d-√(d²-2Mcr/(0.36*fck*b))	8.147393336	mm
wcr=3a_{cr}*ε_m/(1+2*(a_{cr}-C_{min})/(h-x))=	-0.155	mm	< 0.2	mm	crack width is ok.

$$\varepsilon_m = \varepsilon_1 - \frac{b\,(h-x)(a-x)}{3E_s A_s (d-x)}$$

Fig 22. Bending Moment Calculation and Crack width Check of Soil Face wall



Bending Moment Calculation (IS 456 : 2000)

Material Properties							Section Properties		
Concrete =	M	45	Mpa	fy=	500	Mpa	h=	60	cm
Reinforcement=	Fe	500	Mpa	fck=	45	Mpa	d'=	5	cm
pmin=	0.85*b*d/fy =	9.078	cm²	fy/1.15=	434.8	Mpa	d=	53.40	cm
Es(Mpa)		200000	Mpa	fck/1.5=	30.0	Mpa	bw=	100	cm
							d'(first row)	5	cm

$X_{u,max}/d$	=	0.46	m
$M_{u,lim}$=0.36$x_{u,max}$/d*(1-0.42$x_{u,max/d}$)b*d²*fck	=	1714.44	kNm
Xu=0.87*fy*Ast/(0.36*fck*b) =	=	0.036	m
Xu/d	=	0.067	
M_d=	=	269.19	kNm
Mu=0.87*fy*Ast*d*(1-Ast*fy/(b*d*fck))	=	302.68	kNm
Mu (equilibrium equation)	=	311.879435	
Xu (equilibrium equation)	=	0.03599257	
Xu/d (equilibrium equation)	=	0.06740181	
M_u-$M_{u,lim}$=f_{sc}*A_{sc}*(d-d')			
As_{req} =	=	11.88	cm²/m
As_{incl}=	13.4 cm2/m		
Mr=f_{cr}*I_{gr}/y_t=	288.00	kNm	> Mcr=218.1

there is no need to check crack limits

Sump tank Wall - Excavation face

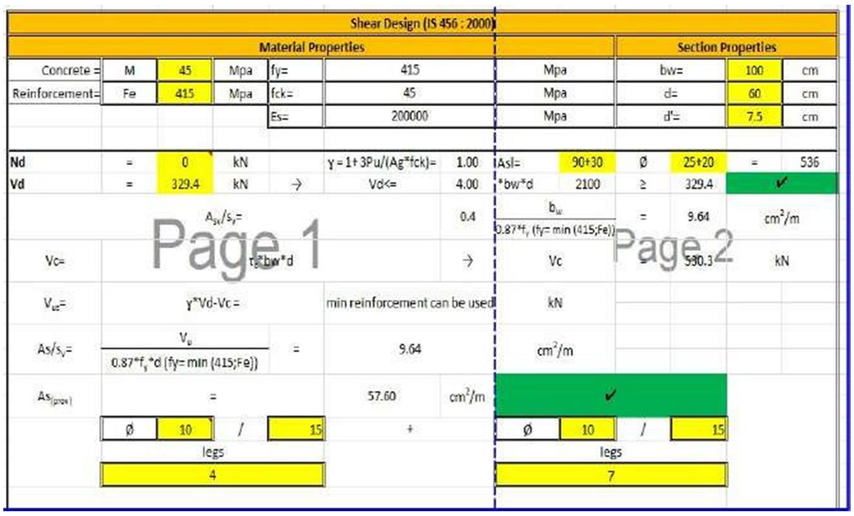
Tension Reinforcement	Bar Ø (mm)	/	Spacing(cm)	Bar Ø (mm)	/	Spacing(cm)
1st layer Ø	16	/	15	Ø	/	15
Ø		/	15			
Ø		/	15			

Crack Width Check

Mcr=	218.10	kNm	Ncr=	191	kN
a_{cr}=	69.1	mm	Cmin=	58	mm
ε_1=(M_s+0.42*0.36*f_{ck}*Xu²*b)/(E_s*A_s*d)-N/Ast/Es=	0.00120		a=	534	mm
ε_m=ε_1- b(h-x)(a-x)/(3EsAs(d-x))(IS ANNEX F)	0.000493936		xu=d-√(d²-2Mcr/(0.36*fck*b))	25.43628266	mm
wcr=3a_{cr}*ε_m/(1+2*(a_{cr}-C_{min})/(h-x))=	0.099	mm	< 0.2	mm	crack width is ok.

$$\varepsilon_m = \varepsilon_1 - \frac{b\,(h-x)(a-x)}{3E_s A_s (d-x)}$$

Fig 23. Bending Moment Calculation and Crack width Check of Excavated Face wall



Shear Design (IS 456 : 2000)

Material Properties							Section Properties		
Concrete =	M	45	Mpa	fy=	415	Mpa	bw=	100	cm
Reinforcement=	Fe	415	Mpa	fck=	45	Mpa	d=	60	cm
				Es=	200000	Mpa	d'=	7.5	cm

Nd	=	0	kN	γ = 1+ 3Pu/(Ag*fck)=	1.00	Asl=	90+30	Ø	25+20	= 536
Vd	=	329.4	kN	→ Vd<=	4.00	*bw*d	2100	≥	329.4	✔
A_{sv}/s_v=					0.4	b_w / 0.87*f_y (fy= min (415;Fe))	=	9.64	cm²/m	
Vc=		τ_c*bw*d			→	Vc	=	530.3	kN	
V_{us}=		γ*Vd-Vc =		min reinforcement can be used		kN				
As/s_v=		V_u / 0.87*f_y*d (fy= min (415;Fe))	=	9.64		cm²/m				
$As_{(prov)}$		=		57.60	cm²/m	✔				
	Ø 10	/	15	+		Ø 10	/	15		
	legs					legs				
	4					7				

Fig 24. Shear Design wall

Short-Term Deflection Check (IS 456 : 2000)			
Material Properties			
Concrete -	M	45	Mpa
Reinforcement-	Fe	500	Mpa
fy=		500	Mpa
fck=		45	Mpa
fcr=		4.80	Mpa
Es=		200000	Mpa
Ec=		33541.02	Mpa
Sectin Properties			
h(D)=		60	cm
d'=		5	cm
d=		55	cm
b_w=		100	cm
l=		605	cm
Deflection limit (span/)		350	
Reinforcement			
spacing		15	cm
ø=		16	mm
As=		13.40	cm^2
Deflection Calculation			
Xu=0.87*fy*Ast/(0.36*fck*b) =		3.60	cm
z=d-0.42Xu		53.49	cm
n=Es/Ec		5.96	
$I_r=b_w*x^3/3+n*As*(d-x)^2$		212666.33	cm^4
$Igr=bh^3/12$		1800000	cm^4
$Mr=f_{cr}*I_{gr}/y_t$ =		288.00	kNm
M=		67.70	kNm
I_{eff}=		Ieff<Ir	cm^4
I_{gr}/I_{eff} =		1	
δi =		0.1	cm
δt = δi * Igr/Ieff =		0.1	cm
Deflection Check (δt) l/350			
0.1000		<	1.73
✔			

C-2 SHORT-TERM DEFLECTION

C-2.1 The short-term deflection may be calculated by the usual methods for elastic deflections using the short-term modulus of elasticity of concrete, E_c and an effective moment of inertia I_{eff} given by the following equation:

$$I_{eff} = \frac{I_r}{1.2 - \frac{M_r}{M}\frac{z}{d}\left(1-\frac{x}{d}\right)\frac{b_w}{b}}; \text{but}$$

$$I_r \le I_{eff} \le I_{gr}$$

where

I_r = moment of inertia of the cracked section,

M_r = cracking moment, equal to $\frac{f_{cr} I_{gr}}{y_t}$ where f_{cr} is the modulus of rupture of concrete, I_{gr} is the moment of inertia of the gross section about the centroidal axis, neglecting the reinforcement, and y_t is the distance from centroidal axis of gross section, neglecting the reinforcement, to extreme fibre in tension,

M = maximum moment under service loads,

z = lever arm,

x = depth of neutral axis,

d = effective depth,

b_w = breadth of web, and

b = breadth of compression face.

Fig 25. Short Term Deflection Check

Creep Deflection Check (IS 456 : 2000)			
Material Properties			
Concrete =	M	45	Mpa
Reinforcement=	Fe	500	Mpa
fy=		500	Mpa
fck=		45	Mpa
fcr=		4.80	Mpa
Es=		200000	Mpa
Ec=		33541.02	Mpa
Sectin Properties			
Age at Loading		7 days	
θ (the creep coefficient)		2.2	
$E_{ce}= E_c / (1+θ)$ =		10481.569	Mpa
E_{ce}/E_c=		0.3125	
δi =		0.1	
$a_{i,acc(perm)}$= δt = δi / E_{ce}/E_c =		0.32	cm
$a_{i(perm)}$=		0.1	cm
$a_{cc(perm)} = a_{i,cc(perm)} - a_{i(perm)}$ =		0.22	cm
l=		605	cm
Deflection limit (span/)		350	
Deflection Check (acc(perm) + ai(perm)) l/350			
0.32		<	1.72857
✔			

IS 456 : 2000

where $P_t = \frac{100 A_{st}}{bd}$ and $P_c = \frac{100 A_{sc}}{bd}$

and D is the total depth of the section, and l is the length of span.

C-4 DEFLECTION DUE TO CREEP

C-4.1 The creep deflection due to permanent loads $a_{cc(perm)}$ may be obtained from the following equation:

$$a_{cc(perm)} = a_{i,cc(perm)} - a_{i(perm)}$$

where

$a_{i,cc(perm)}$ = initial plus creep deflection due to permanent loads obtained using an elastic analysis with an effective modulus of elasticity,

$E_{ce} = \frac{E_c}{1+θ}$; θ being the creep coefficient, and

$a_{i(perm)}$ = short-term deflection due to permanent load using E_c.

Age at Loading	*Creep Coefficient*
7 days	2.2
28 days	1.6
1 year	1.1

NOTE—The ultimate creep strain, estimated as described above does not include the elastic strain.

Fig 26. Creep Deflection Check

Through this detailed modeling and iterative design process, the sump pit was successfully reconfigured with increased structural capacity, improved access for maintenance, and full compliance with GMRC's design requirements. The project demonstrates a practical application of structural modeling tools integrated with manual calculations to achieve a technically sound and field-applicable design solution.

7. COST ANALYSIS / RESULT & DISCUSSION

Project 1: Stormwater Gate Design at Bhogapuram Airport

The Bill of Qunatities for the proposed stormwater gates at Bhogapuram International Airport includes all structural components

Table 12. 3m x 3.52 Lifting Type Gate Bill of Quantities

Item	Sub-Item	Description	Unit	c/c	Nos.	L	B	H/thk	Wt.	Qty	Total Qty
				mm		m	m	mm	kg/sqm		Qty
Vertical Wall	Skin plate	10 mm Thk Plate	kg		**1**	**3.1**	**3.52**	**10**	78.6	857.7	**1942**
	Verticals Stiffeners	Prismatic Tee	kg	**500**	5	3.52			**18.65**	341.4	
	Horiz. Stiffeners	Prismatic Tee	kg	**500**	7	3.1			**18.65**	407.0	
	Corner column	ISMC-150	kg		**2**	3.52			**17.1**	120.4	
	Top Horiz	ISMC-150	kg		**2**	3.1			**17.1**	106.0	
Lifting setup	Lifting eyes	250 x 500 x 50Thk	kg		**2**	**0.5**	**0.25**	**50**	393	98.3	
						dia	area				
	deduction for holes	60dia	kg		2	**0.06**	0.003	-50	-393	-2.2	
	Doubler plate	200dia	kg		2	**0.20**	0.031	32	252	15.8	
	deduction for holes	60dia	kg		2	0.06	0.003	-50	-393	-2.2	
Wall Section	Guide Channel embedded in wall	ISMC-200	kg		**2**	3.52			**24.3**	171.1	**200.7**
						dia	area				
	Anchor Lugs	12mm dia	kg	**200**	19	**0.012**	0.0001	**0.45**	3.537	29.6	
Total											**2143**
Total : Considering additional 10% (miscillenous)											**2357**

Table 13. 4m x 4 Lifting Type Gate Bill of Quantities

Item	Sub-Item	Description	Unit	c/c	Nos.	L	B	H/thk	Wt.	Qty	Total
				mm		m	m	mm	kg/sqm		Qty
Vertical Wall	Skin plate	10 mm Thk Plate	kg		1	4.1	4	10	78.6	1289.0	2825
	Verticals Stiffeners	Prismatic Tee	kg	500	7	4			18.65	537.1	
	Horiz. Stiffeners	Prismatic Tee	kg	500	8	4.1			18.65	611.7	
	Corner column	ISMC-150	kg		2	4			17.1	136.8	
	Top Horiz	ISMC-150	kg		2	4.1			17.1	140.2	
Lifting setup	Lifting eyes	250 x 500 x 50Thk	kg		2	0.5	0.25	50	393	98.3	
						dia	area				
	deduction for holes	60dia	kg		2	0.06	0.003	-50	-393	-2.2	
	Doubler plate	200dia	kg		2	0.20	0.031	32	252	15.8	
	deduction for holes	60dia	kg		2	0.06	0.003	-50	-393	-2.2	
Wall Section	Guide Channel embedded in wall	ISMC-200	kg		2	4			24.3	194.4	227.8
						dia	area				
	Anchor Lugs	12mm dia	kg	200	21	0.012	0.0001	0.45	3.537	33.4	
Total											3052
Total : Considering additional 10% (miscillenous)											3358

Table 14. 5m x 2.5 Tilting Type Gate Bill of Quantities

Item	Sub-Item	Description	Unit	c/c	Nos.	L	B	H/thk	Wt.	Qty	Total
				mm		m	m	mm	kg/sqm		Qty

Vertical Wall	Skin plate	12mm Thk Plate	kg		**2**	**5**	**2.5**	**12**	94.32	2358.0	**4469**
	Verticals	ISMB-150 @ 250mm c/c	kg	**250**	19	2.5			**15**	712.5	
	Corner column	ISMC-400 Box	kg		**2**	2.5			**100.2**	501.0	
	Horiz. Stiffeners	150 x 12thk M.S. Flat	kg		**3**	5	**0.15**	**12**	94.32	212.2	
	Top Horiz	ISMB-150	kg		**1**	5			**15**	75.0	
	Bottom Shaft	ISMC-400 Box	kg		**1**	5			**100.2**	501.0	
	Lifting eyes	250 x 500 x 50Thk	kg		**2**	**0.5**	**0.25**	**50**	393	98.3	
						dia	area				
	deduction for holes	60dia	kg		2	**0.06**	0.002827433	-50	-393	-2.2	
	Doubler plate	200dia	kg		2	**0.20**	0.031415927	32	252	15.8	
	deduction for holes	60dia	kg		2	0.06	0.002827433	-50	-393	-2.2	
Side Verticle Wall (both walls included)	Skin plate	12mm Thk Plate	kg		**2**	**2.5**	**2.5**	**12**	94.32	589.5	**1357**
	Slant Members	ISMB-150	kg		**2**	**3.54**			**15**	106.2	
	Slant Members	ISMB-150	kg		**2**	**2.65**			**15**	79.5	
	Slant Members	ISMB-150	kg		**2**	**1.79**			**15**	53.7	
	Slant Members	ISMB-150	kg		**2**	**0.89**			**15**	26.7	
	Corner column	ISMC-400 Box	kg		**2**	**2.5**			**100.2**	501.0	
Horizontal Open Section	Horizontal pipe	ISNB-200(M)	kg		**2**		**5**		**29.5**	295	**295**
Total											**6121**
Total : Considering additional 10% (miscillenous)											**6733**

Project 2: Redesign of the Sump Pit of the Toilet Block at Kapodra Station of Surat Metro

The Bill of Qunatities of Reinforcement detail is proposed.

Table 15. 5m x 2.5 Tilting Type Gate Bill of Quantities

	BAR MKD.	DIA	LAYER	SPACING	LENGTH	ZONE	NOS	WT(kg).	REMARK
SUMP REBAR	201	16	1st	150	4250	3200	22	148	
	202	16	1st	150	4950	2500	17	133	
	203	16	1st	150	7450	2500	17	200	
	204	16	1st	150	9050	3200	22	315	
	111	16	1st	150	4250	600	8	54	
	112	16	1st	150	3550	600	8	45	
SUMP WALL REBAR	**BAR MKD.**	**DIA**	**LAYER**	**SPACING**	**LENGTH**	**ZONE**	**NOS**	**WT(kg).**	**REMARK**
	301	16	1st	150	6220	1800	24	236	
	302	16	1st	150	4065	8900	60	385	
	303	16	1st	150	7620	3600	24	289	
	304	16	1st	150	2280	11400	76	274	HAUNCH BAR PERIPHERAL LENGTH
	305	12	1st	150	3050	424	6	16	HAUNCH BAR Distr.
	306	12	1st	150	2350	424	6	13	HAUNCH BAR Distr.
SHEAR LINKS	**LOCATION**	**DIA**	**LAYER**	**SPACING**	**LENGTH**	**ZONE**	**NOS**	**WT(kg).**	**REMARK**
	RCC WALLS	10	1st	150	780	-	9624	4634	
	END WALL	10	1st	150	780	-	1376	663	
	BASE & ROOF	10	1st	150	780	-	14324	6897	
	SUMP WALL	10	1st	150	780	-	912	439	
	SUMP BASE	10	1st	150	780	600	724	349	

8. SUMMARY

Project 1: Stormwater Gate Design at Bhogapuram Airport

The stormwater gate infrastructure proposed for Bhogapuram International Airport is a critical component of its broader flood management and drainage system. Designed for long-term durability and ease of operation, the project includes one weir-type tilting gate and two vertical lifting gates, each customized for its specific location based on hydraulic profiles and structural constraints. The gates are fabricated using high-grade E-410A structural steel conforming to IS 2062, with corrosion-resistant features such as aluminum cladding on the water-facing sides and epoxy or zinc coating on all exposed surfaces. Sealing integrity is ensured using high-performance rubber or elastomeric seals.

All gates are designed to operate manually using spindle systems, pulleys, and worm gears, eliminating the need for electrical or hydraulic power and simplifying maintenance. The gate movement mechanisms are carefully synchronized to prevent asymmetric loads or jamming, and all moving parts are designed for easy lubrication and service access. Safety and ecological considerations are also embedded into the design, with the inclusion of fish passage openings, algae cleaning mechanisms, and steel grated access platforms with handrails.

Backed by a five-year functional warranty and bi-annual servicing commitments, the system ensures reliability and service continuity. The design has been vetted against relevant IS codes and will be proof-checked by reputed institutions such as IITs or NITs before fabrication. In essence, the stormwater gates represent a well-engineered, resilient, and sustainable solution that supports the operational integrity and environmental goals of Bhogapuram International Airport.

Project 2: Redesign of the Sump Pit of the Toilet Block at Kapodra Station of Surat Metro

The revised design of the sump pit at Kapodra Station represents a significant improvement in both structural performance and long-term operational efficiency. The original configuration, which included a cast-in-situ top slab and limited depth, was found to be sub-optimal due to its constrained access for maintenance and insufficient resistance to uplift and hydrostatic pressure. In response, a redesign was undertaken as part of Revision R1, focusing on increasing the sump depth and replacing the fixed slab with a 300 mm thick precast removable cover. This approach provided enhanced accessibility for maintenance and ensured greater adaptability to operational needs without compromising structural safety.

The design was supported by a detailed 3D finite element model developed in STAAD Pro, which accurately simulated the behavior of the sump under all critical loading conditions, including seismic, surcharge, and flood loads. Design forces obtained from the model were further processed in Excel-based design sheets for the calculation of reinforcement, shear and bending checks, and compliance with serviceability and ultimate limit state criteria. Deflection, creep, and long-term deformation checks confirmed that the structure would perform satisfactorily throughout its lifecycle, without exceeding acceptable limits.

9. References

1. **IS 456:2000 –** *Plain and Reinforced Concrete – Code of Practice*, Bureau of Indian Standards, New Delhi.
2. **IS 800:2007 –** *General Construction in Steel – Code of Practice*, Bureau of Indian Standards, New Delhi.
3. **IS 3370 (Part 1 to 4) –** *Concrete Structures for the Storage of Liquids*, Bureau of Indian Standards.
4. **IS 1893 (Part 1):2016 –** *Criteria for Earthquake Resistant Design of Structures*, Bureau of Indian Standards.
5. **IS 2266:2002 –** *Steel Wire Ropes for General Engineering Purposes*, Bureau of Indian Standards.
6. **IS 4622:2003 –** *Recommendations for the Design of Fixed Wheel Gates*, Bureau of Indian Standards.
7. **IS 11228 –** *Design of Hoists for Hydraulic Gates*, Bureau of Indian Standards.
8. **IS 808:2021 –** *Dimensions for Hot Rolled Steel Beam, Column, Channel and Angle Sections*, Bureau of Indian Standards.
9. **IS 816:1969 –** *Code of Practice for Use of Metal Arc Welding for General Construction in Mild Steel*, Bureau of Indian Standards.
10. **IS 4000:1992 –** *Code of Practice for High Strength Bolts in Steel Structures*, Bureau of Indian Standards.
11. **EN 1992-1-1 (Eurocode 2) –** *Design of Concrete Structures – General Rules and Rules for Buildings*, European Committee for Standardization.
12. **STAAD.Pro –** *Structural Analysis and Design Software*, Bentley Systems Inc.
13. **GMRC Operation Design Standards (ODS) –** *Design Guidelines and Load Parameters for Underground Metro Infrastructure*, Gujarat Metro Rail Corporation Ltd.
14. **Design Basis Report –** *Document No. R-EUGP1-TPT-F-000-GEN-REP-001-R00*, Surat Metro Rail Project UG P1.
15. **Foundation Analysis and Design –** J.E. Bowles, McGraw-Hill Education, Reference for soil-structure interaction and uplift analysis.

10. Internship Day to Day Activities

Date	Day	Activity
2025-01-13	Mon	Orientation, Introduction to Firm's Projects, Review of IRC 5 & 6 Codes
2025-01-14	Tue	Reading IRC 5 and IRC 6
2025-01-15	Wed	Kolkata Metro Project: Study of Launching Girder Mechanism
2025-01-16	Thurs	Studing the bridge design and Introduction to launching girder
2025-01-17	Fri	Studing the project drawings for Girder movement
2025-01-20	Mon	Studing the project drawings for Girder movement
2025-01-21	Tue	Calculation of Forces & Moments on 50m Bridge Span Due to Girder Movement
2025-01-22	Wed	Inalizing Drawings, Cross-Checking Calculations with Mentor
2025-01-23	Thurs	Kolkata Metro: Girder movement drawing (AutoCAD)
2025-01-24	Fri	Kolkata Metro: Girder movement drawing (AutoCAD)
2025-01-27	Mon	Bhogapuram Airport: Introduction to Storm Water Gates Proposal
2025-01-28	Tue	Initial BOQ prepartion for 5 x 2.5 m Tilting Gate
2025-01-29	Wed	Initial BOQ prepartion for 4 x 4 m Lifting Gate
2025-01-30	Thurs	Initial BOQ prepartion for 3 x 3.52 m Lifting Gate
2025-01-31	Fri	Initial modeling for Gates in Staad and autocad
2025-02-03	Mon	Initial modeling for Gates in Staad and autocad
2025-02-04	Tue	Factory Proposal: Layout, BOQ & Drawing
2025-02-05	Wed	Factory Proposal: Layout, BOQ & Drawing
2025-02-06	Thurs	Learning Tunnel Engineering (NATM Methodology)
2025-02-07	Fri	Learning Tunnel Engineering (NATM Methodology)
2025-02-10	Mon	Attended ISSE Seminar
2025-02-11	Tue	Surat Metro Changes according to the Compliance report
2025-02-12	Wed	Surat Metro Changes according to the Compliance report
2025-02-13	Thurs	NATM Gantries and Design Principles-Case Study
2025-02-14	Fri	NATM Gantries and Design Principles-Case Study
2025-02-17	Mon	Study of Surat Metro-Kapodra Statiob-Toilet Block Structure
2025-02-18	Tue	Study of Surat Metro-Kapodra Statiob-Toilet Block Structure
2025-02-19	Wed	Surat Metro Kapodra Sump Pit: Remodelling, Design, Checks

2025-02-20	Thurs	Surat Metro Kapodra Sump Pit: Remodelling, Design, Checks
2025-02-21	Fri	Surat Metro Kapodra Sump Pit: Remodelling, Design, Checks
2025-02-24	Mon	Surat Metro Kapodra Sump Pit: Remodelling, Design, Checks
2025-02-25	Tue	Surat Metro Kapodra Sump Pit: Remodelling, Design, Checks
2025-02-26	Wed	Surat Metro Kapodra Sump Pit: Remodelling, Design, Checks
2025-02-27	Thurs	Temporary Structures: Struts & Walers Design
2025-02-28	Fri	Temporary Structures: Struts & Walers Design
2025-03-03	Mon	Learning Raking Analysis (M.A. Hashash Paper)
2025-03-04	Tue	Learning Raking Analysis (M.A. Hashash Paper)
2025-03-05	Wed	Project Documentation: DD, CRD, GFC, As-built Drawings
2025-03-06	Thurs	Project Documentation: DD, CRD, GFC, As-built Drawings
2025-03-07	Fri	Project Documentation: DD, CRD, GFC, As-built Drawings
2025-03-10	Mon	Storm water gate design (5x2.5m): Staad + Excel
2025-03-11	Tue	Storm water gate design (5x2.5m): Staad + Excel
2025-03-12	Wed	Storm water gate design (5x2.5m): Staad + Excel
2025-03-13	Thurs	Storm water gate design (5x2.5m): Staad + Excel
2025-03-14	Fri	Storm water gate design (5x2.5m): Staad + Excel
2025-03-17	Mon	Storm water gate design (5x2.5m): Staad + Excel
2025-03-18	Tue	Storm water gate design (4x4m): Staad + Excel
2025-03-19	Wed	Storm water gate design (4x4m): Staad + Excel
2025-03-20	Thurs	Storm water gate design (4x4m): Staad + Excel
2025-03-21	Fri	Storm water gate design (3x3.5m): Staad + Excel
2025-03-24	Mon	Storm water gate design (3x3.5m): Staad + Excel
2025-03-25	Tue	Storm water gate design (3x3.5m): Staad + Excel
2025-03-26	Wed	Storm water gates: GAD Drawing (AutoCAD)
2025-03-27	Thurs	Storm water gates: GAD Drawing (AutoCAD)
2025-03-28	Fri	Prepartion of Design Sheet of Beams slab in Excel
2025-03-31	Mon	Prepartion of Design Sheet of Beams slab in Excel
2025-04-01	Tue	Prepartion of Design Sheet of Beams slab in Excel
2025-04-02	Wed	Prepartion of Design Sheet of Beams slab in Excel
2025-04-03	Thurs	Study of Temporary Bridge Design for Jetty
2025-04-04	Fri	Study of Temporary Bridge Design for Jetty

2025-04-07	Mon	Surat Metro: Ancillary Bldg. Reinf. Changes & Drawing Updates
2025-04-08	Tue	Surat Metro: Ancillary Bldg. Reinf. Changes & Drawing Updates
2025-04-09	Wed	Designing Elevated Slab for Heavy Equipment (Surat Metro)
2025-04-10	Thurs	Designing Elevated Slab for Heavy Equipment (Surat Metro)
2025-04-11	Fri	Designing Elevated Slab for Heavy Equipment (Surat Metro)