DESIGN OF A CONSTRUCTED WETLAND FOR A DORMITORY

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DAFFODIL INTERNATIONAL UNIVERSITY

DESIGN OF A CONSTRUCTED WETLAND FOR A DORMITORY

Submitted by

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A Project submitted to the Department of Civil Engineering, Daffodil International University in Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science in Civil Engineering

Department of Civil Engineering
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APPROVAL

I'm confirming that the student mentioned below has finished his project on "Design of a constructed wetland for a dormitory" under my guidance. The project was carried out in the Department of Civil Engineering, Faculty of Engineering, Daffodil International University, as part of their B.Sc. degree in Civil Engineering.

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Signature of the Supervisor

13/05/2025

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This report titled "Design of a constructed wetland for a dormitory" is submitted by Atiqur Rahman Biswas (Student ID: 201-47-299) Session, Spring 2020 and Spring 2024 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Civil Engineering 2nd July 2025.

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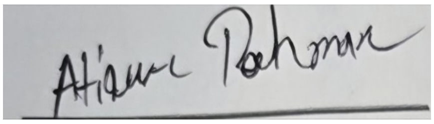
I now declare that this project has been carried out under Dr. Miah M. Hussainuzzaman Associate Dean & Associate Professor, Department of Civil Engineering, Daffodil International University.

Signature of the candidates



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DEDICATION

Dedicated

To

Our Families

ABSTRACT

This thesis presents the implementation of a constructed wetland system for a student hostel of 2250 students (Younus Khan Scholar's Garden-2), located in Ashulia, within Daffodil Smart City. The main aim of this project is to create an environmentally sustainable approach to wastewater treatment, in accordance with the principles of ecological integrity and resource conservation. The system is specifically designed for purifying the waste water discharged from the hostel to tackle the local water pollution challenges by employing natural mechanisms for water filtration and purification. The thesis explores the theoretical framework of wetland design, presents comprehensive calculations and schematics, and assesses the anticipated environmental and socio-economic advantages. Furthermore, the research investigates the feasibility of integrating the constructed wetland into the surrounding landscape, thereby enhancing both the aesthetic and ecological significance of Younus Scholar's Garden-2. Approximately 1275 m^2 area is needed for constructing the wetland.By utilizing native plant species and locally available materials, the project seeks to minimize operational expenses while fostering local biodiversity. The results of this study indicate that constructed wetlands can serve as a cost-effective and sustainable method for wastewater treatment, thereby improving water quality and advancing the objectives of environmental stewardship in urban environments.

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Chapter 1:
Introduction

1.1 Overview

Constructed wetlands are nature based solutions for wastewater treatment. This process enhances the natural process of remediation to reduce biological loads from the flowing wastewater. Being a natural system this method is safe, cost effective but requires some extra land space.

1.2 Background

The university authority is looking for a suitable system to treat the wastewater discharged from the residential dormitories before releasing them to a natural canal. Therefore, the total inhabitants from the dormitory cluster consisting of two multi-storied building is considered to determine the expected or design flow rate for the treatment facility.

1.3 Objectives

The objectives of this report are:

- To outline the design considerations for the constructed wetland.
- To provide detailed design calculations.
- To develop comprehensive CAD drawings for the design.

1.4 Summary

This report serves as a detailed guide on the design and implementation of constructed wetlands for wastewater treatment in Bangladesh. It explores horizontal flow (HF) and vertical flow (VF) wetlands, covering their functions, design principles, construction methods, ecological benefits, and operational strategies. Key specifications include an HF wetland area of 1274.72 m^2 with a 50 cm depth and a VF wetland area of 638.55 m^2 with a 70 cm depth, tailored to the local environment. The report emphasizes the sustainability and efficiency of wetlands in treating wastewater, offering practical insights for integration into urban and rural ecosystems.

Chapter 2:
Configuration and Functions of Constructed Wetlands

2.1 Overview of Constructed Wetlands

Constructed Wetlands (CWs) are engineered systems designed to mimic the processes of natural wetlands for treating wastewater. They provide a cost-effective, sustainable, and environmentally friendly solution for managing wastewater, treating stormwater runoff, and improving water quality. CWs utilize substrate materials, microorganisms, and vegetation to filter, absorb, and break down contaminants.

2.2 Project Location

The project is situated at Daffodil Smart City (DSC), Birulia, Savar, Dhaka-1216. Coordinates: 23.877404691309632, 90.3201727969049.

2.3 Types of Constructed Wetlands

Constructed wetlands are classified into two primary types based on water flow patterns:

2.3.1 Surface Flow (SF) Wetlands

Water Flow: Water travels across the surface of a substrate, typically composed of soil or gravel.

Vegetation: Emergent plants, such as reeds and cattails, are rooted in the substrate.

Common Uses: These wetlands are employed for treating stormwater, managing agricultural runoff, and providing secondary wastewater treatment.

Benefits: Simple to build and relatively inexpensive.

Drawbacks: Require a larger land area and may encourage mosquito breeding.

2.3.2 Subsurface Flow (SSF) Wetlands

Water Flow: Water moves beneath the surface through a medium like gravel or sand, avoiding direct exposure to air.

Subtypes:

Horizontal Subsurface Flow (HSSF): Water flows horizontally through the medium, where treatment occurs as it interacts with the biofilm on the substrate surface.

Vertical Subsurface Flow (VSSF): Water is applied from the top and filters downward through the medium, improving oxygen availability and boosting microbial degradation.

Vegetation: Uses emergent macrophytes, similar to SF wetlands

Benefits: Requires less land, produces minimal odor, and reduces mosquito issues.

Drawbacks: More intricate design and maintenance requirements.

2.4 Key Components

The components and processes for a constructed wetland is described in the previous thesis report (Rahman, S. M. R., 2024). The volume requirements for that demand is determined in that report. Hence in this report, the structural design component of the design is discussed in detail.

2.5 Benefits

- **A sustainable future**: Low-cost, natural processes with minimal mechanical intervention.
- **Pollution Reduction**: The efficient removal of nutrients, heavy metals, and pathogens.
- **Ecological diversity:** Provides habitats for species, which benefits local ecosystems.

2.6 Mechanisms of Constructed Wetlands

Constructed wetlands purify water through a combination of physical, chemical, and biological processes:

2.6.1 Physical Processes

Sedimentation: As water flow slows, suspended particles settle out, particularly in surface flow wetlands.

Filtration: The substrate (e.g., gravel) acts as a barrier, trapping solids, organic matter, and other particulates.

2.6.2 Chemical Processes

Adsorption: Pollutants like heavy metals and phosphorus adhere to the surfaces of soil or gravel particles.

Precipitation: Chemical reactions convert dissolved contaminants into insoluble forms, which then settle out of the water.

2.6.3 Biological Processes

Plant Uptake: Wetland plants absorb nutrients such as nitrogen and phosphorus, lowering their concentrations in the water and preventing eutrophication.

Microbial Activity: Microorganisms in the rhizosphere (root zone) degrade organic pollutants and nutrients. Aerobic bacteria break down organic matter in oxygen-rich zones, while anaerobic bacteria support processes like denitrification in low-oxygen areas.

Denitrification: In anoxic environments, microbes transform nitrate (NO_3^-) into nitrogen gas (N_2), reducing nitrogen levels in the water.

2.7 Uses of Constructed Wetlands

Municipal Wastewater Treatment: CWs treat domestic sewage by removing nutrients, pathogens, and organic matter.

Storm-water Management: They reduce pollutant loads in natural water bodies by treating urban runoff.

Agricultural Runoff: CWs mitigate nutrient loads from farms, preventing eutrophication in downstream water bodies.

Industrial Effluent Treatment: They are used to treat wastewater from industries such as food processing, mining, and textiles.

Chapter 3:
Design of Constructed Wetland

3.1 General Information

This project proposes an eco-friendly, sustainable technology with low operational, maintenance, and energy costs. As constructed wetlands are a simple wastewater treatment system, this approach is cost-effective and environmentally friendly. The management of this system is straightforward, avoiding complex technical processes and minimizing energy use. The treated water will be reusable and discharged into the lake at Daffodil International University. To design the constructed wetland, the first step is to assess the occupancy and wastewater discharge.

3.2 Total Occupants for the project

In Younus Khan scholar's garden-2 there are 2 buildings one is Block-A and another is Block-B.

3.2.1 Block-A

Block-A is a 9 storey building with 1 basement.

29 rooms each floor and 4 students can stay in each room.

9 rooms are reserved for foreign students and 2 students stay on a single room.

Up to 4th floor 1 room at each floor is occupied as office rooms.

Total capacity of this building for students and officials is 1050 people.

3.2.2 Block-B

11 storey building with 2 basements.

26 rooms at ground floor 4 students can stay.

27 rooms from ground to top each floor.

Stuff room at basement of 5 people

Total capacity of this buildings for students and officials is 1200 people.

So the number of occupants for this project is 2250.

3.3 Occupancy and discharge

Total occupancy	2250 person
Total discharge	157.5m^3/day

3.4 Septic tank

	Depth (m)	Volume (m^3)
Scum zone	0.01	0.72
Sediment zone	0.45	31.5
Digestion zone	0.68	47.58
Sludge zone	1.28	90
Total	2.42	2.45

3.5 Dimension of tank

	Septic tank (m)	Anaerobic baffle reactor (m)
Length	14.6	31.15
Width	4.86	4.45
height	2.75	2.75

Note: This chapter contains only the data from the mother report.

Chapter 4:
Septic Tank Design

4.1 Tank Geometry and Assumptions

Dimensions:

Length: 49'5" = 49.4167 ft.

Left chamber: 30'7" = 30.5833 ft.

Right chamber: 17'1" = 17.0833 ft.

Depth: 9 ft.

Width: 12 ft (assumed, as calculated previously).

Sloped Base: The base slopes to collect sludge, with an assumed maximum sludge depth of 1.5 ft at the center of the left section.

Materials:

Concrete: $f'_c = 4000\,\text{psi}$.

Steel: $f_y = 60{,}000\,\text{psi}$.

Concrete density: 150 lb/ft^3.

Loads:

Water: 62.4 lb/ft^3, depth ≈ 7.5 ft (9 ft minus 1.5 ft sludge).

Sludge: 75 lb/ft^3, average depth 1.5 ft.

Soil bearing capacity: 2000 psf (assumed).

Walls: RCC walls are on all four sides, extending 9 ft high, and are likely cast monolithically with the base slab, acting as cantilevers fixed at the base.

4.2 Base Slab Design (Two-Way Slab)

Since the slab is supported by walls on all four sides, it behaves as a two-way slab. The partition wall (dividing the tank into two sections) will also provide some support, but for simplicity, The slab will be designed for the larger section (30'7" × 12') and ensure it works for the smaller section.

4.2.1 Slab Thickness

For two-way slabs in water-retaining structures, ACI 350 suggests a minimum thickness of span$/$36 for edge-supported slabs.

Short span = 12 ft = 144 in.

Minimum thickness = $144/36=4$ in, but this is too thin for a tank base with water contacts, loads and durability requirements.

Use a thickness of 15 inches to handle shear and durability:

Self-weight: 150 × 1.25 = 187.5 psf.

4.2.2 Loads on Base Slab

Water: 62.4 × 7.5 = 468 psf.

Sludge: 75 × 1.5 = 112.5 psf.

Total (excluding slab): 468 + 112.5 = 580.5 psf.

Total (including slab): 580.5 + 187.5 = 768 psf.

4.2.3 Two-Way Slab Analysis (ACI 318-19)

Using the Direct Design Method for two-way slabs:

Spans: 30.5833 ft (long direction), 12 ft (short direction).

Load: 768 psf.

Moments:

Total static moment $M_0=\frac{w L_s^2 L_n}{8}$, where $L_s=12\,\text{ft}$ (short span), $L_n=30.5833-1=29.5833\,\text{ft}$ (clear span in long direction, assuming 1 ft wall thickness).

$$M_0=\frac{768\times(12)^2\times29.5833}{8}=768\times144\times\frac{29.5833}{8}=408{,}672\,\text{lb-ft}.$$

Moment distribution (for a flat plate with walls, approximate coefficients):

Short direction (12 ft span):

Negative moment at wall: 0.65 × $M_0/12=0.65\times408{,}672/12=22{,}137\,\text{lb-ft/ft}$.

Positive moment at midspan: 0.35 × $M_0/12=0.35\times408{,}672/12=11{,}906\,\text{lb-ft/ft}$.

Long direction (30.5833 ft span):

Negative moment: 0.65 × $M_0/30.5833=0.65\times408{,}672/30.5833=8{,}681\,\text{lb-ft/ft}$.

Positive moment: 0.35 × $M_0/30.5833=4{,}674\,\text{lb-ft/ft}$.

4.2.4 Reinforcement for Base Slab

Effective depth: 15 - 2 - (0.75/2) = 12.625 in (using #6 bars, 2-inch cover).

Short direction (12 ft span):

Negative moment: 22,137 lb-ft/ft = 265,644 lb-in/ft.

$$R=\frac{M_u}{\phi b d^2}=\frac{265,644}{0.9\times 12\times (12.625)^2}=154.2\,\text{psi}.$$

$\rho=0.0026,\ A_s=0.0026\times 12\times 12.625=0.394\,\text{in}^2/\text{ft}.$

Minimum (ACI 350): $0.003\times 12\times 15=0.54\,\text{in}^2/\text{ft}.$

Provide #5 bars at 6-inch spacing (0.62 in^2/ft).

Positive moment: 11,906 lb-ft/ft requires less, so use the same reinforcement.

Long direction:

Negative moment: 8,681 lb-ft/ft = 104,172 lb-in/ft.

$A_s\approx 0.15\,\text{in}^2/\text{ft}$, but use minimum 0.54 in^2/ft.

Provide #5 bars at 6-inch spacing.

Slope adjustment: In the sloped region, increase reinforcement by 10%: #5 bars at 5.5-inch spacing (0.676 in^2/ft).

4.2.5 Shear Check

At the wall (critical section at d from the face): $V_u=w\times(\text{distance to } d)$.

Shear is low due to two-way action and wall support, and the 15-inch thickness is sufficient.

4.3 Wall Design (Cantilever Walls)

The walls are 9 ft high, fixed at the base, and resist lateral pressure from water and sludge. Assume a wall thickness of 12 inches (typical for such heights and loads).

4.3.1 Loads on Walls

Water pressure: Triangular distribution, maximum at the bottom: 62.4 × 7.5 = 468 psf.

Sludge pressure: 75 × 1.5 = 112.5 psf (rectangular).

Total pressure at base: 468 + 112.5 = 580.5 psf.

Pressure distribution:

Water: 0 at the top, 468 psf at 7.5 ft depth.

Sludge: 112.5 psf from 7.5 ft to 9 ft.

4.3.2 Moment and Shear (Long Wall, 49'5")

Pressure diagram:

Water: Triangular, resultant = $\frac{1}{2} \times 468 \times 7.5 = 1755\,\text{lb/ft}$, acting at $7.5/3 = 2.5\,\text{ft}$ from the bottom.

Sludge: Rectangular, resultant = 112.5 × 1.5 = 168.75 lb/ft, acting at $(7.5+9)/2 = 8.25\,\text{ft}$.

Total lateral force: 1755 + 168.75 = 1923.75 lb/ft.

Moment at base:

Water: 1755 × 2.5 = 4387.5 lb-ft/ft.

Sludge: 168.75 × 8.25 = 1392.2 lb-ft/ft.

Total: 4387.5 + 1392.2 = 5779.7 lb-ft/ft = 69,356 lb-in/ft.

Shear at base: 1923.75 lb/ft.

4.3.3 Wall Reinforcement

Thickness: 12 in, effective depth: 12 - 2 - (0.75/2) = 9.625 in.

Flexure:

$$R = \frac{69,356}{0.9 \times 12 \times (9.625)^2} = 69.3\,\text{psi}.$$

$\rho = 0.0012$, $A_s = 0.0012 \times 12 \times 9.625 = 0.139\,\text{in}^2/\text{ft}$.

Minimum (ACI 350): 0.003 × 12 × 12 = 0.432 in^2/ft.

Provide #5 bars at 8-inch spacing (0.465 in^2/ft) on the inner face (tension side).

Horizontal reinforcement: #4 bars at 12-inch spacing (0.2 in^2/ft).

Shear: Concrete capacity exceeds 1923.75 lb/ft, so no shear reinforcement is needed.

4.3.4 Short Wall (12 ft)

Same pressure, same design as the long wall due to cantilever action per unit width.

4.4 Final Design Summary

4.4.1 Sedimentation Tank Design

4.4.1.1 Base Slab (Two-Way Slab)

Thickness: 15 inches.

Reinforcement:

Short direction (12 ft span): #5 bars at 6-inch spacing (0.62 in^2/ft), both top and bottom.

Long direction (30'7" span): #5 bars at 6-inch spacing (0.62 in^2/ft), both top and bottom.

Sloped region: #5 bars at 5.5-inch spacing (0.676 in^2/ft).

4.4.2 Walls (All Four Sides)

Thickness: 12 inches.

Vertical reinforcement (inner face, tension side): #5 bars at 8-inch spacing (0.465 in^2/ft).

Horizontal reinforcement: #4 bars at 12-inch spacing (0.2 in^2/ft).

Chapter 5:
Anaerobic Baffle Reactor

5.1 Slab Design (Base Slab)

5.1.1 Structure and Dimensions

Overall dimensions: The structure is 102' long, 6'-2" wide, and 9' deep.

Partition walls: There are 10 partition walls, each spaced 10' apart (since 102' divided by 11 segments gives approximately 10' per segment, with 10' between walls).

Wall thickness: Not explicitly given, but let's assume a typical thickness of 8" (0.67') for partition walls in such structures.

Slab thickness: Not given, but a two-way slab for such a span (10' x 6'-2") typically requires a thickness of around 6" (0.5') based on span-to-depth ratios for two-way slabs (e.g., ACI 318 recommends a minimum thickness of span/36 for two-way slabs with edge support, so 10'/36 ≈ 0.28', but 6" is a practical minimum for water tanks).

Water depth: The water level is not specified, but the diagram shows a depth of 9', so let's assume the water fills the tank to a depth of 8' (leaving 1' freeboard, which is common for design).

5.1.2 Assumptions

Material properties:

Concrete compressive strength ($f_c^{'}$) = 4000 psi (typical for water-retaining structures).

Steel yield strength (f_y) = 60,000 psi (Grade 60 rebar).

Loads:

Water pressure: Water has a unit weight of 62.4 lb/ft³. At a depth of 8', the pressure at the base is $62.4 \times 8 = 499.2\,psf$.

Self-weight of concrete: 150 lb/ft³.

No additional live loads are assumed (since this appears to be a water tank).

Design code: Using ACI 318 for reinforced concrete design.

Cover: Assume 1.5" clear cover for concrete exposed to water (to protect rebar from corrosion).

5.1.3 Analyze the Two-Way Slab

The bottom slab is a two-way slab because it spans in both directions (10' along the length between partitions and 6'-2" along the width). Two-way slabs are typically designed using the direct design method or equivalent frame method, but for simplicity, we'll use approximate coefficients for moments (as per ACI 318).

5.1.3.1 Slab Loading

Self-weight of slab: For a 6" (0.5') thick slab, self-weight = $150 \times 0.5 = 75\,\text{psf}$.

Water load: Pressure at the base = 499.2 psf (from 8' of water).

Total uniform load (w): $75 + 499.2 = 574.2\,\text{psf}$.

5.1.3.2 Slab Moments

For a two-way slab, we calculate moments in both directions. The shorter span is 6'-2" (6.167'), and the longer span is 10'. The aspect ratio is $10/6.167 = 1.62$, which is less than 2, confirming two-way action.

Using ACI moment coefficients for a two-way slab with all edges fixed (since the slab is supported by partition walls and perimeter walls):

Short direction (6'-2"):

Positive moment (midspan): $M = C \times w \times L_n^2$, where $C \approx 0.036$ for fixed edges, $w = 574.2\,\text{psf}$, and $L_n = 6.167 - 0.67 = 5.5'$ (clear span, assuming 8" walls).

$M_{\text{pos, short}} = 0.036 \times 574.2 \times (5.5)^2 = 625.4\,\text{ft-lb/ft}$.

Negative moment (at supports): $M_{\text{neg, short}} \approx 0.048 \times 574.2 \times (5.5)^2 = 833.9\,\text{ft-lb/ft}$.

Long direction (10'):

Clear span $L_n = 10 - 0.67 = 9.33'$.

Positive moment: $M_{\text{pos, long}} \approx 0.021 \times 574.2 \times (9.33)^2 = 1049.5\,\text{ft-lb/ft}$.

Negative moment: $M_{\text{neg, long}} \approx 0.028 \times 574.2 \times (9.33)^2 = 1399.3\,\text{ft-lb/ft}$.

5.1.4 Slab Reinforcement

Effective depth (d): For a 6" slab with 1.5" cover and #4 bars (0.5" diameter), $d = 6 - 1.5 - 0.25 = 4.25'' = 0.354'$.

Short direction:

Positive moment: $M_u = 1.6 \times 625.4 = 1000.6\,\text{ft-lb/ft}$ (using load factor for water load, assuming it's a fluid load).

Required area of steel (A_s): $M_u = \phi A_s f_y (d - a/2)$, where $\phi = 0.9$, $f_y = 60,000\,\text{psi}$. Assume $a \approx 0.5''$ (to be verified), so $M_u = 0.9 \times A_s \times 60,000 \times (4.25 - 0.25)/12$.

$1000.6 \times 12 = 0.9 \times A_s \times 60,000 \times 4/12$.

$A_s = 0.067\,\text{in}^2/\text{ft}$.

Negative moment: $M_u = 1.6 \times 833.9 = 1334.2\,\text{ft-lb/ft}$.

$A_s = 0.089\,\text{in}^2/\text{ft}$.

Long direction:

Positive moment: $M_u = 1.6 \times 1049.5 = 1679.2\,\text{ft-lb/ft}$.

$A_s = 0.112\,\text{in}^2/\text{ft}$.

Negative moment: $M_u = 1.6 \times 1399.3 = 2238.9\,\text{ft-lb/ft}$.

$A_s = 0.149\,\text{in}^2/\text{ft}$.

5.1.4.1 Minimum Reinforcement (ACI 318)

For slabs, minimum $A_s = 0.0018 \times b \times h = 0.0018 \times 12 \times 6 = 0.1296\,\text{in}^2/\text{ft}$.

Use the larger of calculated and minimum. So, use #4 bars at 12" spacing ($A_s = 0.2\,\text{in}^2/\text{ft}$) in both directions, both top and bottom, to satisfy minimum reinforcement and calculated requirements.

5.2 Slab Design (Top)

5.2.1 Problem and Geometry

Dimensions:

Panel size: 10 ft (longer span) x 6 ft 2 in (6.167 ft, shorter span).

Aspect ratio: $\frac{10}{6.167} = 1.62 < 2$, confirming two-way action.

Supported by walls on all four sides (10 ft x 6.167 ft grid).

Assumptions:

Concrete: $f'_c = 4,000\,\text{psi}$.

Steel: $f_y = 60,000\,\text{psi}$ (Grade 60 rebar).

No upward water pressure, so loads are downward only.

Loads:

Dead Load (DL): Self-weight of the slab.

Live Load (LL): 100 psf (assumed for accessible roof slabs; typical per ASCE 7).

5.2.2 Determine Slab Thickness

For a two-way slab supported on all sides (flat plate), ACI 318-19 Table 8.3.1 gives minimum thickness for deflection control:

For an exterior panel without edge beams: $h_{\min} = \frac{l_n}{30}$.

Clear span $l_n = 10\,\text{ft} - \text{wall thickness}$. Assume wall thickness = 12 in (typical), so $l_n = 10 - 1 = 9\,\text{ft} = 108\,\text{in}$.

$h_{\min} = \frac{108}{30} = 3.6\,\text{in}$.

However, for a water-retaining structure, we need to ensure durability and crack control. Let's try:

$h = 8\,\text{in}$ (same as previous for consistency, and to handle potential environmental exposure).

Self-weight:

Concrete density = 150 pcf.

$150 \times \frac{8}{12} = 100\,\text{psf}$.

5.2.3 Calculate Loads

Dead Load (DL): 100 psf (self-weight).

Live Load (LL): 100 psf.

Total Service Load: $100 + 100 = 200\,\text{psf}$.

Factored Load (ACI 318-19, Section 5.3):

$U = 1.2\,D + 1.6\,L$.

$w_u = 1.2 \times 100 + 1.6 \times 100 = 120 + 160 = 280\,\text{psf}$.

5.2.4 Analyze the Two-Way Slab

Use the **Direct Design Method** (ACI 318-19, Section 8.10) for a slab supported on all sides.

Total Static Moment (M_o):

$$M_o = \frac{w_u l_2 (l_1)^2}{8}.$$

$l_1 = 10\,\text{ft}$, $l_2 = 6.167\,\text{ft}$, $w_u = 280\,\text{psf}$.

$$M_o = \frac{280 \times 6.167 \times (10)^2}{8} = \frac{280 \times 6.167 \times 100}{8} = 21,584\,\text{lb-ft}.$$

Moment Distribution:

Longer Span (10 ft):

Negative moment at exterior support: 0.65 M_o.

$M_{\text{neg, long}} = 0.65 \times 21,584 = 14,030\,\text{lb-ft}$.

Positive moment: 0.35 M_o.

$M_{\text{pos, long}} = 0.35 \times 21,584 = 7,554\,\text{lb-ft}$.

Shorter Span (6.167 ft):

$\frac{l_2}{l_1} = 0.6167$.

For $\frac{l_2}{l_1} = 0.6$, negative = 0.70 M_o, positive = 0.30 M_o.

$M_{\text{neg, short}} = 0.70 \times 21,584 = 15,109\,\text{lb-ft}$.

$M_{\text{pos, short}} = 0.30 \times 21,584 = 6,475\,\text{lb-ft}$.

Distribute to Column and Middle Strips:

Column strip width = $l_1/4 = 10/4 = 2.5\,\text{ft}$.

Middle strip = $6.167 - 2 \times 2.5 = 1.167\,\text{ft}$.

Column strip takes 75% of moments (per ACI 318-19 Table 8.10.5.1).

Longer Span (column strip, per ft width):

Negative: $\frac{0.75 \times 14,030}{2.5} = 4,209\,\text{lb-ft/ft} = 50,508\,\text{lb-in/ft}$.

Positive: $\frac{0.75 \times 7,554}{2.5} = 2,266\,\text{lb-ft/ft} = 27,192\,\text{lb-in/ft}$.

Shorter Span (column strip, per ft width):

Negative: $\frac{0.75 \times 15,109}{2.5} = 4,533\,\text{lb-ft/ft} = 54,396\,\text{lb-in/ft}$.

Positive: $\frac{0.75 \times 6,475}{2.5} = 1,943\,\text{lb-ft/ft} = 23,316\,\text{lb-in/ft}$.

5.2.5 Check Shear (Punching Shear at Walls)

Critical perimeter at $d/2$ from wall face, $d_{\text{avg}} = \frac{6.3125 + 6.9375}{2} = 6.625\,\text{in}$.

$b_o = 2 \times (12 + 6.625) + 2 \times (12 + 6.625) = 74.5\,\text{in}$.

$V_u = 280 \times (9 \times 5.167) = 280 \times 46.5 = 13{,}020\,\text{lb}$.

$\phi V_c = 0.75 \times 4 \times \sqrt{4{,}000} \times 74.5 \times 6.625 = 93{,}600\,\text{lb} > 13{,}020$, OK.

5.2.6 Design for Flexure

Effective Depth:

#5 bars (0.625 in diameter), 3/4 in cover, two layers:

$d_{\text{long}} = 8 - 0.75 - 0.625 - \frac{0.625}{2} = 6.3125\,\text{in}$ (long direction on bottom for downward load).

$d_{\text{short}} = 8 - 0.75 - \frac{0.625}{2} = 6.9375\,\text{in}$.

Longer Span (Column Strip, Negative Moment):

$M_u = 50{,}508\,\text{lb-in/ft}$, $\phi = 0.9$.

$M_n = \frac{50{,}508}{0.9} = 56{,}120\,\text{lb-in/ft}$.

$A_s \approx \frac{56{,}120}{60{,}000 \times 6.3125} = 0.148\,\text{in}^2/\text{ft}$.

Use #5 at 24 in ($A_s = \frac{0.31}{2} = 0.155\,\text{in}^2/\text{ft}$), but check max spacing.

Shorter Span (Column Strip, Negative Moment):

$M_u = 54{,}396\,\text{lb-in/ft}$.

$M_n = \frac{54{,}396}{0.9} = 60{,}440\,\text{lb-in/ft}$.

$A_s \approx \frac{60{,}440}{60{,}000 \times 6.9375} = 0.145\,\text{in}^2/\text{ft}$.

Use #5 at 24 in ($A_s = 0.155\,\text{in}^2/\text{ft}$).

Middle Strip:

Use minimum reinforcement: $A_s = 0.0018 \times 12 \times 8 = 0.1728\,\text{in}^2/\text{ft}$.

Use #4 at 12 in ($A_s = 0.2\,\text{in}^2/\text{ft}$) in both directions.

5.2.7 Crack Control for Water-Retaining Structures

ACI 318-19 Section 24.4:

Max spacing $s \le \frac{\phi f_y}{4\beta f_s}$, $\beta = 1.2$, $f_s = 36{,}000\,\text{psi}$.

$s \le \frac{0.9 \times 60{,}000}{4 \times 1.2 \times 36{,}000} = 3.75\,\text{in}$.

Adjust column strip: Use #5 at 3.5 in in both directions.

5.2.8 Final Design:

Slab Thickness: 8 inches.

Column Strip (2.5 ft wide):

Longer span: #5 at 3.5 in (bottom layer).

Shorter span: #5 at 3.5 in (top layer).

Middle Strip (1.167 ft wide):

Both directions: #4 at 12 in.

Concrete Cover: 3/4 inch.

Note: For cost cutting and inaccessible place, we are not including the top slab to the main design. As after some days there will be a foam coat on the water to make in anaerobic. At rainy season we can use plastic cover on top of it.

5.3 Analyze the Partition Walls

Each partition wall is 6'-2" wide, 9' tall, and 8" thick, acting as a vertical cantilever fixed at the base (since it’s embedded in the slab). The walls resist hydrostatic pressure from the water.

5.3.1 Wall Loading

Hydrostatic pressure: Varies linearly from 0 at the top to $62.4 \times 8 = 499.2\,\text{psf}$ at the base (assuming 8' water depth).

Resultant force per unit width: $F = \frac{1}{2} \times 499.2 \times 8 = 1996.8\,\text{lb/ft}$, acting at $8/3 = 2.67'$ from the base.

Moment at base: $M = 1996.8 \times 2.67 = 5331.5\,\text{ft-lb/ft}$.

5.3.2 Wall Reinforcement

Effective depth (d): For an 8" wall with 1.5" cover and #4 bars, $d = 8 - 1.5 - 0.25 = 6.25'' = 0.52'$.

Moment: $M_u = 1.6 \times 5331.5 = 8530.4\,\text{ft-lb/ft}$.

$A_s = \frac{M_u}{\phi f_y (d - a/2)}$, assume $a \approx 0.5''$, so $A_s = \frac{8530.4 \times 12}{0.9 \times 60{,}000 \times (6.25 - 0.25)/12} = 0.379\,\text{in}^2/\text{ft}$.

Use #5 bars at 10" spacing ($A_s = 0.31/10 \times 12 = 0.372\,\text{in}^2/\text{ft}$, close enough).

5.3.3 Vertical and Horizontal Reinforcement

Vertical reinforcement: #5 at 10" spacing on the tension face (water side).

Horizontal reinforcement (shrinkage and temperature): Use minimum $A_s = 0.0018 \times 12 \times 8 = 0.173\,\text{in}^2/\text{ft}$. Use #4 at 12" spacing ($A_s = 0.2\,\text{in}^2/\text{ft}$).

5.4 Final Reinforcement Summary

Two-way slab:

Short direction (6'-2"): #4 at 12" spacing, top and bottom.

Long direction (10'): #4 at 12" spacing, top and bottom.

Partition walls:

Vertical reinforcement: #5 at 10" spacing on the water side.

Horizontal reinforcement: #4 at 12" spacing on both faces.

Chapter 6:
Construction of Constructed Wetland

6.1 Overview

Constructing a wetland involves planning, site preparation, and construction phases. Key activities include earthworks (excavation, leveling, compaction), building berms or walls, lining the basin, adding substrates, installing inlet/outlet structures, and planting vegetation. This section outlines the unique aspects of constructing horizontal flow (HF) and vertical flow (VF) wetlands.

6.2 Site Selection and Planning

6.2.1 Hydrology

Verify the site has suitable hydrological features, such as sufficient water supply and effective drainage.

6.2.2 Soil Conditions

Evaluate soil permeability; clay or loam soils are ideal to prevent leakage.

6.2.3 Space Requirements

Allocate space as follows:

- HF wetland: 1274.72 m^2
- VF wetland: 638.55 m^2

6.2.4 Permits and Approvals

Obtain necessary permits from local environmental and construction authorities in Bangladesh.

6.3 Design Finalization

6.3.1 Depths

Set depths at 50 cm for HF wetlands and 70 cm for VF wetlands, considered optimal. Before adding substrates, designate inlet and outlet zones, ensuring proper outlet placement during filling. Sieve and wash substrates to remove debris, and categorize them by size for inlet, outlet, and treatment zones. For VF wetlands, mark substrate layers clearly, install the basal collection network per design, and wash substrates to eliminate unwanted particles.

Sand Suitability Test: Use a 300 mm long, 110 mm diameter PVC pipe on pea gravel, filled with 200 mm of moist sand. Place a pan scourer on the sand to reduce disturbance. Pour 500 ml of tap water quickly, record drainage time, and repeat until times stabilize. Plot results. Test sand properties (grain size, hydraulic conductivity) in an accredited lab.

6.3.2 Sand Suitability Test

Position a 300 mm long, 110 mm diameter PVC pipe on pea gravel, fill with 200 mm of moist sand, and cover with a pan scourer. Pour 500 ml of tap water, time the drainage, and repeat until consistent. Sand draining 500 ml in 50–150 seconds (when saturated) is suitable

6.3.3 Flow Control

Design inlet and outlet structures to manage water levels and ensure even distribution.

6.3.4 Substrate Selection

Choose appropriate materials like gravel and sand, with gravel depth matching water depth. After lining the basin, fill with washed substrates to avoid clogging, using rounded river substrates for better packing.

6.3.5 Plant Selection

Select native species like Kolaboti and Typha, suited to Bangladesh's climate and capable of handling nutrient loads.

6.4 Site Preparation

6.4.1 Excavation

Excavate to:

- 50 cm for HF wetlands
- 70 cm for VF wetlands

6.4.2 Liner Installation

Install a synthetic liner or compact soil to prevent seepage.

6.4.3 Water Distribution Systems

Place inlet and outlet pipes to optimize water flow. For HF wetlands, align pipes perpendicular to flow. For VF wetlands, position distribution holes for uniform wastewater spread and design outlet networks to avoid short-circuiting.

6.5 Substrate Installation

6.5.1 Horizontal Flow Wetland

Fill the base with 50 cm of coarse gravel.

6.5.2 Vertical Flow Wetland

Layer coarse gravel at the base, topped with finer gravel or sand for filtration, to a total depth of 70 cm.

6.6 Planting

Transplant native wetland plants into the substrate, spacing them to allow growth. Water immediately post-planting to support root establishment.

6.7 Water Level Management for Vegetation Growth

Let plants establish before introducing wastewater to reduce stress. Gradually increase wastewater concentration and maintain low initial water levels to encourage deep root growth.

6.8 Flow Regulation and Testing

Set up flow controls to maintain proper water levels. Conduct a pre-wastewater water test to check for leaks, confirm flow, and evaluate plant establishment.

6.9 Water Flow Adjustment

Monitor and adjust water flow during the first few weeks as needed.

Chapter 7:
Conclusion And Recommendations

7.1 General

Constructed wetlands offer a sustainable and effective method for wastewater treatment and water resource management by mimicking natural wetland processes. They remove contaminants through plant uptake, microbial activity, and soil filtration, improving water quality while providing benefits like habitat creation, biodiversity enhancement, and carbon storage.

Their versatility, demonstrated in applications from municipal wastewater to storm-water management, highlights their cost-effectiveness and adaptability. With low energy demands and minimal operational costs, they are well-suited for both developed and developing regions, especially where infrastructure is limited.

This project underscores how constructed wetlands advance sustainable water management, supporting environmental conservation and promoting long-term ecological resilience.

7.2 Conclusion

This report delves into the complexities of horizontal and vertical flow constructed wetland systems, highlighting critical site-specific factors such as climate, hydrology, and community requirements. It outlines key design considerations, provides detailed design calculations, and includes comprehensive CAD drawings for the wetland system. Serving as a valuable resource for engineers, the report integrates natural filtration processes with contemporary engineering to deliver an eco-friendly solution to water management challenges.

7.3 Recommendations

We strongly endorse this book on Constructed Wetlands for environmental engineers, urban planners, and those passionate about sustainable wastewater management. This thoroughly researched guide provides practical and detailed insights into the design and operation of horizontal and vertical flow wetland systems. Here is some recommendation for future:

- Should be built in an isolated place as no roof slab provided
- The cost should be estimated properly as the mother report of this project provides a lump-sum estimation of 53,415,266 BDT.
- Must be monitored properly so no sludge can interrupt with water flow.
- Plants must be handled with sensitivity.

As for now we provided what we able to research in our short time. It must need more research to be construct in several places in our country.

Chapter 8:
Detailing

8.1 Septic Tank

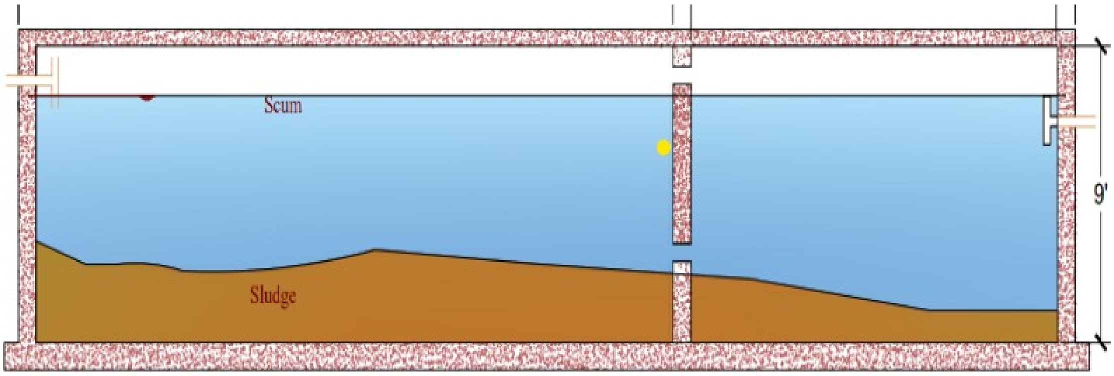

Figure 1: Septic Tank

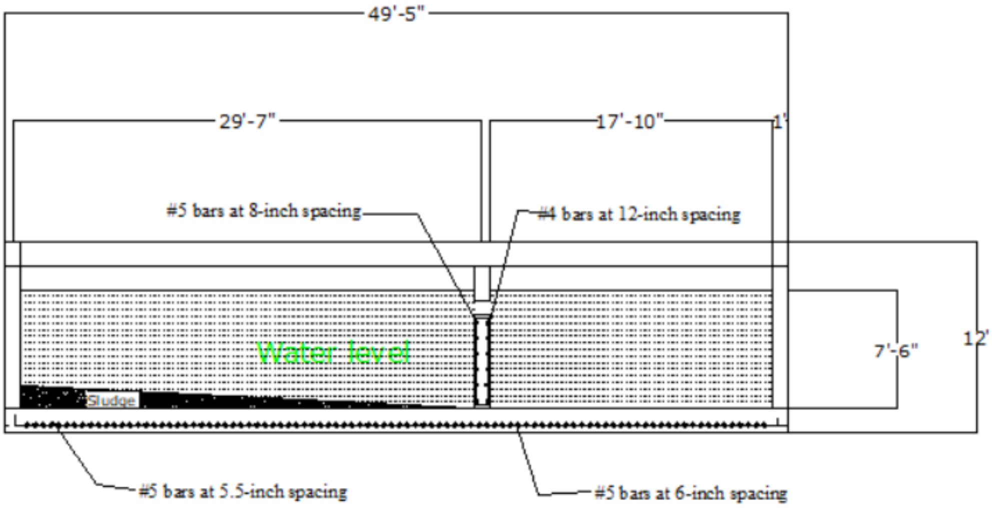

Figure 2: Reinforcement Detailing of Septic Tank

8.2 Anaerobic Baffle Reactor

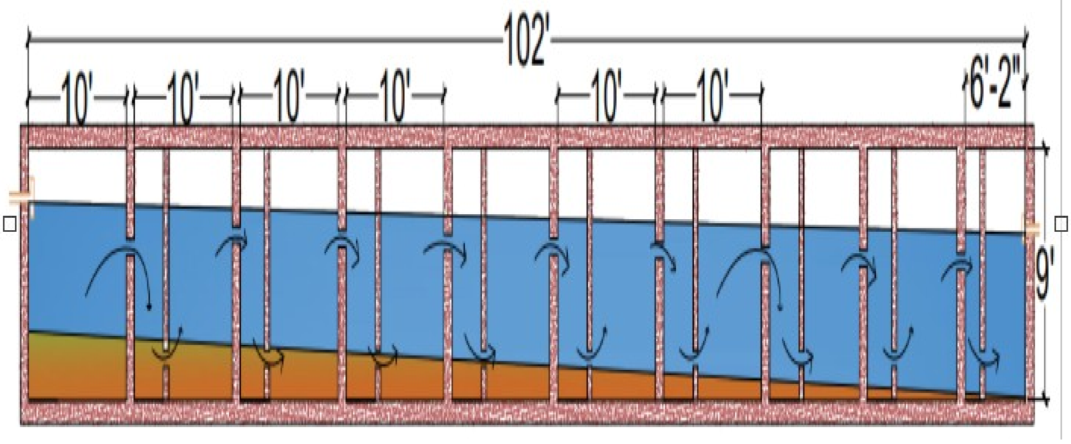

Figure 3: Anaerobic Baffle Reactor

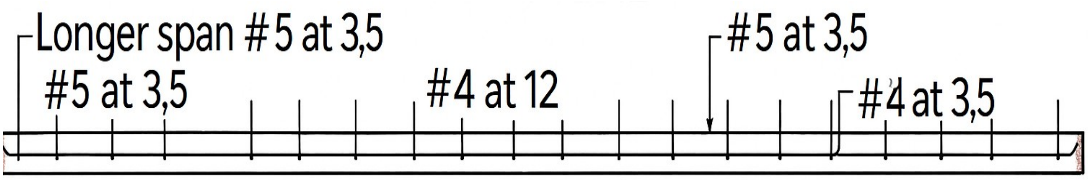

Figure 4: Base Slab Reinforcement

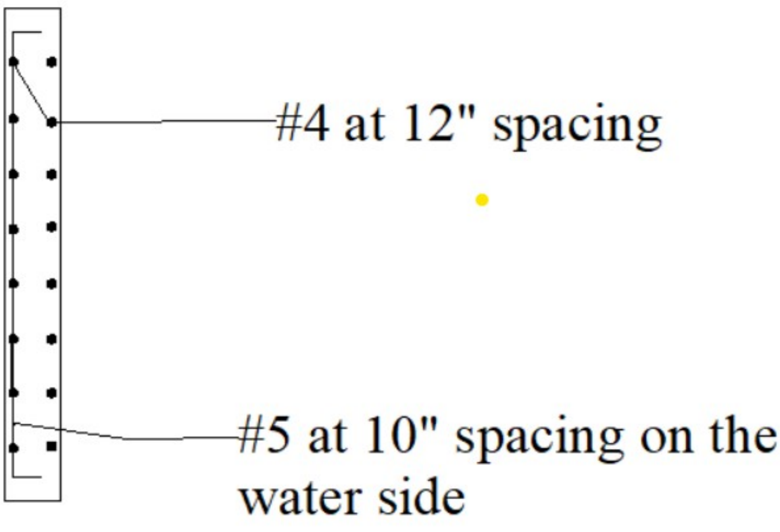

Figure 5: Wall Reinforcement

Chapter 9:
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