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Design of a Suspended Septic Tank As An Alternative To Open Defecation Over River Bodies In Rural Riverine Communities (Otuan Community In Bayelsa State As A Case Study)

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ABSTRACT

Open defecation particularly in river bodies especially in the rural riverine communities within the Niger Delta Region has greatly affected the environment and the health of the residents in those areas. This project addresses the urgent need for a sustainable sanitation solution by designing a suspended septic tank system as an alternative to inadequate toilet facilities commonly used in these areas. The objective of this project is to estimate the population that can utilize a unit of this system and to design a durable septic tank that minimizes the effects of open defecation. The arithmetic method of population estimation was used to estimate the average number of users per unit; the design capacity derived was for 20 persons. Manual analysis was conducted to determine the best septic tank dimension as follows: Length = 3300mm Breadth = 1100mm Depth = 2000mm. Structural loading analysis was also undertaken to determine the structural performance of the system at various operational conditions using civil engineering application software, ProtaStructure and AutoCAD. The analysis confirmed the suitability of the design, with the septic tank supported by columns measuring 200mm x 200mm and footings of 1000mm x 1000mm, functioning effectively as a pad-type foundation. The design of the suspended septic tank provides a long-term economic solution that not only curbs open defecation but also minimizes pollution of the ground and river bodies. Through the provision of proper sanitation systems in these areas, this project fosters the accomplishment of improved health, environment, and general well standard of the people in the Niger Delta Region.

KEYWORDS: Septic tank, open defecation, suspended system, inhabitants of riverine, Niger Delta, fecal pollution, sanitation facilities, environmental conservation.

I. INTRODUCTION

1.1 Motivation and Incitement

Niger Delta, especially the rural riverine areas of the Ijaw people, has for several decades suffered from various problems associated with waterborne diseases and pollution. The riverine Ijaw populations' rural areas are contaminated and lack access to good drinking water [7]. Most of these are associated with dirty habits and poor sanitation, where open defecation is reported to be among the major causes. As such, diseases such as cholera which periodically affect the nation, and other emerging waterborne diseases demonstrate the need to enhance sanitation. Even with continued aid from organizations from other countries and collaboration with other agencies at the rural level like the Rural Water Supply and Sanitation Agencies (RUWASSA), access to good and safe drinking water is still

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restricted, and the physical surrounding is not spared either. The practice of open defecation, especially over the river bodies, intensifies these difficulties as it pollutes water sources, thus, encouraging more diseases and contamination of the environment. Figure 1 and 2 shows a typical example of a hanging pit latrine used for defecation in the Niger Delta regions.

Figure 1: Exterior of hanging pit latrine

Figure 2: Interior view of hanging pit latrine

1.2 Literature Overview and Contribution

It is seen that water has long been understood to be essential to all life forms by humans. Unquestionably, the availability of pure water determined whether ancient civilizations survived or perished. Because most residents of developed nations have relatively easy access to affordable potable water, people in these nations now view water as an infinite resource. Even though water covers more than two-thirds of the Earth, there is a shortage of potable water. The term "fecal pollution of water" refers to the contamination of water with disease-causing organisms (pathogens) that may live in mammals' gastrointestinal tracts, with a focus on human feces as the most significant source of illnesses in humans worldwide. In addition to stating that poor sanitation is a known primary contributor to water-borne illnesses like cholera, typhoid, diarrhea, and ringworm, UNICEF defined sanitation as the provision of facilities and services for the safe disposal of human wastes and urine. The act of humans defecating outside (or "in the open") as opposed to into a toilet is known as "open defecation." Defecation can take place in fields, woods, forests, ditches, streets, canals, or other public areas. It has been noted that open defecation contributes to the cycle of poverty and disease and is widely viewed as a violation of one's dignity. The highest rates of under-five mortality, high rates of undernutrition, high rates of poverty, and significant gaps between the rich and the poor are seen in the nations where open defecation is most prevalent. The transmission of diseases like cholera, dysentery, and typhoid can occur as a result of open defecation [9]. Moreover, it harms the ecosystem and may contaminate groundwater, increasing the risk to one's health [8]. It may also contribute to environmental deterioration [3]. There are many causes of open defecation. A choice may be made voluntarily, partially voluntarily, or involuntarily. The main cause is frequently a lack of access to a bathroom. However, there are some localities where even those with indoor toilets prefer to urinate outside. Following this discovery, UNICEF launched a program in Bayelsa State in collaboration with the EU and RUWASSA to discourage unclean behavior and promote the adoption of Ecological Sanitation (ECOSAN), which is known as an improved technique in Nigeria for sanitation. However, these initiatives often fail to fully address the unique challenges faced by riverine communities in the Niger Delta**.** The River Niger splits into multiple tributaries in the southern region of Nigeria, creating the Niger Delta. It crosses nine states and is made up of a river, creeks, and estuaries. Riverine communities are the numerous towns and villages found in this area near the Atlantic Ocean. [6]. The Niger Delta region of Nigeria has become increasingly affected by inadequate sanitation, leading to several health and environmental issues [5]. As a result, many people in the Niger Delta have limited access to safe drinking water and are exposed to waterborne and vector-borne diseases [4]. The Niger Delta states of Nigeria are shown in figure 3.

Figure 3: Map of the Niger Delta region

The main contribution of this paper lies in the design and proposal of a suspended septic tank system specifically tailored to the needs of riverine communities in the Niger Delta. This approach aims to provide a sustainable and practical solution to the problem of open defecation in these areas. Unlike previous interventions, which often overlook the unique geographical and environmental challenges of riverine communities, the suspended septic tank system is designed to reduce the contamination of

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water bodies, thereby addressing both the health and environmental issues associated with open defecation. By focusing on the structural and functional aspects of the septic tank design, this paper offers a solution that is both feasible and adaptable to the specific conditions of the Niger Delta. The proposed system not only aims to improve sanitation and reduce the incidence of waterborne diseases but also contributes to the broader goal of enhancing the quality of life in these vulnerable communities.

1.3 Paper Organization

The remainder of this paper is organized as follows: Section 2 of the study is a literature review regarding sanitation practices and their relation to riverine societies. Section 3 outlines the methodology used in the design and analysis of the suspended septic tank, including population estimation and structural considerations. Section 4 gives the design outcomes such as dimensions, loading analysis, and structural integrity assessments and discussions on them. Lastly, the conclusion section 5 presents the implications and recommendations for future research and the implementation of the study.

II. MATERIALS AND METHODS

This section points out the materials and methods used for this research work.

Materials:

The materials used were:

Population census data, AutoCAD, Protastructure, and BS8110

Methods:

Ascertaining the Population Coverage for the Design of the Suspended Septic Tank

The most recent population census figure (1991-1996 projected) for the Otuan community states that it has a male and female population of 6,093 and 2,361 respectively. It was assumed this septic tank unit would serve ten persons in the current year as the initial population. The arithmetic method of population forecast was used to estimate the future population. Equation 1 gives the arithmetic population forecast relation.

$P_f = P_i + K_a (t_f - t_i)$ Eqn. 1

Where P_f = Future population

P_i = initial population

K_a = constant for arithmetic progression

t_f = final time

t_i = initial time

Designing of a Functional Suspended Septic Tank as an Alternative to Open Defecation

Septic tanks are wastewater treatment systems that are typically used in rural and suburban areas where access to centralized sewage systems is not available [2].

First, the volume and septic tank dimensions were attained using Equation 2. The slabs were then calculated using load and equations 3 to 18. This was followed by the calculation for the block work for the septic tank walls. After which the column parameters were then calculated using equations 19 to 22. The reinforcement bars were also attained using the bar bending schedule seen in equations 23 to 29.

Volume Calculation:

Volume = Population x Waste flow (liters) x Factor Eqn. 2

The population as computed by the arithmetic method is given as 20 persons.

We assume a factor of 3 and waste flow as 120 liters per capita daily.

Equations used in Top and Bottom Slab Calculation:

i. Slab dimension:

$d_{min} = \frac{\text{Effective span}}{\text{modification factor x Basic l/d}}$ Eqn. 3

$H_{min} = d_{min} + \text{cover} + \Phi/2$ Eqn.3b

ii. Loading:

$N = 1.4gk + 1.6qk$ Eqn.4

$gk = A\gamma_c$, where A=BH; B = 1m (for slabs)

iii. Analysis:

Maximum bending moment for UDL = $\frac{nL^2}{8}$ Eqn.5

Shear Stress, V = $\frac{nL^2}{2}$ Eqn.6

Ultimate moment capacity $M_{uc} = 0.156f_{cu} \times bd^2$ Eqn.7

iv. Design proper:

K factor = $\frac{M}{f_{cu}\, bd^2}$ Eqn.8

Lever arm, $z = (0.5 \pm \sqrt{0.25 - \frac{k}{0.9}})\, d$ Eqn.9

Neutral axis, $x = \frac{d-z}{0.45}$

Eqn.10

v. Area of reinforcement:

A_s required $= \frac{M}{0.95fyz}$

Eqn..11

A_s min $= \frac{100A_s}{A_c}$

Eqn.12

Area of reinforcement $= \frac{\pi d^2}{4}$

Eqn.13

Number of main bars $= \frac{Ly}{Spacing} + 1$

Eqn..13b

vi. Check for deflection:

Allowable length = modification factor x Basic l/d x d Eqn..14

If allowable length > actual length, then deflection is okay

Modification factor $= 0.55 + \frac{477-fs}{120(0.9+\frac{m}{bd^2})}$

Eqn..15

vii. Check for shear:

Allowable shear stress = $0.8\sqrt{f_{cu}}$ or $5N/mm^2$

Eqn..17

Shear force $= \frac{V}{bd}$

Eqn..18

$$V = \frac{0.79\,(\frac{100A_s}{bd})^{\frac{1}{3}}x(\frac{400}{d})^{\frac{1}{4}}}{1.2}$$

Eqn..18b

Equations used in Column Calculation:

i. Area of footing, $A = \frac{10\%\ of\ P+P}{S.B.C}$

Eqn..19

Where, P = Applied load

S.B.C = Soil Bearing Capacity

ii. Soil Reaction, $q_u = \frac{P_u}{A}$

Eqn..20

Where P_u = Factor load of column = 1.5P

iii. Factor Moment, $M_u = P \times B \times \left(\frac{L-D}{2}\right)^2 \times 0.5$

Eqn..21

Where P = Applied load; B = Breadth of footing; L = Length of footing; D = Breadth of column

iv. Required depth:

$$d = \sqrt{\frac{M_u}{0.138 \times f_{cu} \times b}}$$

Eqn.22

Where f_{cu} = compressive strength

Requirement: The height of the columns will depend on the depth of the water table and the elevation of the disposal field. The columns should be tall enough to allow for proper drainage and treatment of wastewater.

Bar Bending Schedule:

The bar bending schedule for each column of isolated footing will require calculations of the number of main reinforcement bars (X-bars), number of distribution reinforcement bars (Y-bars), cutting length of main reinforcement bars (Cm), cutting length of distribution reinforcement bars (Cd) and steel quantity required which are calculated as follows.

i. Main reinforcement bars (X-bars)

$$N_m = \frac{Y}{Spacing\ of\ Main\ Reinforcement} + 1$$

Eqn..23

Where Y = breadth of footing

ii. Distribution reinforcement bars (Y-bars)

$$N_d = \frac{X}{Spacing\ of\ Distribution\ Reinforcement} + 1$$

Eqn..24

Where X = length of footing

iii. Cutting length of main reinforcement (X-bars)

C_{m1} = [length of footing – 2 (cover)] + 2[thickness of footing - 2 (cover)] - 2[bend]

= [x-2c] + 2[h-2c] – 2[$2d_m$]

Eqn..25

Total cutting length main reinforcement = Number of main reinforcement x cutting length of single main bar

= N_m x C_{m1}

= N_m x [x-2c] + 2[h-2c] – 2[$2d_m$]

Eqn.26

Where, h = height of footing (thickness); d_m = main reinforcement bar diameter; c = cover

iv. Cutting length of distribution reinforcement (Y-Bars)

C_{d1} = [Breadth of footing – 2 (cover)] + 2[Thickness of footing – 2(cover)]- 2 bend

= [Y-2c] +2[h-2c]-2[$2d_m$]

Eqn.27

Total cutting length of main reinforcement, C_d = Number of main reinforcement x cutting length of single main bar

= N_d x C_{d1}

C_d = Nd x [Y-2c] +2[h-2c]-2[$2d_m$]

Eqn.28

v. The estimation of steel quantity is determined by the formula

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$W = \frac{D^2L}{162}$
Eqn..29

It is also to be noted that weight of steel (W) = Volume of the material (V) x Density of material Where, V= Area of steel x length of steel; Density of steel = 7850 kg/m^2

III. RESULTS AND DISCUSSIONS

The outcome of this research paper is presented here and discussed as needed.

Results:

The dimensions of the hydraulic parameters obtained for the suspended septic tank are summarized in Table 1.

Table 1: Tank Hydraulic Parameters

S/N	Septic Tank Hydraulic Parameters	Value	Units
1.	Population	20	Persons
2.	Waste flow per capita daily	120	l/pcd
3.	The effective volume of the tank	7200	Liters
4.	Depth of the septic tank	2000	Mm
5.	Length of septic tank	3300	Mm
6.	Width of septic tank	1100	Mm
7.	Freeboard	0.15	Mm
8.	Discharge (Q)	68290	L/s
9.	Detention time	24	Hrs
10.	Velocity	10.16	m/s

The dimensions of the key structural parameters obtained for the suspended septic tank are summarized in Table 2.

Table 2: Suspended Septic Tank Structural Parameters

Suspended Septic Tank Key Structural Parameters				
Parameter	**Top Slab**	**Bottom Slab**	**Column**	**Column Footing**
Concrete grade	C35	C40	C25	-
Exposure condition	Moderate	Moderate	Mild	-
Cover	35mm	40mm		-
Fire Resistance	1.5 hours	!.5 hours	1 hour	-
Modification Factor	1.35	1.4	-	-
Basic l/d	20	-	-	-
Aspect Ratio	3 > 2 (one way)	-	-	-
Compressive strength of steel	460N/mm	460N/mm	-	-
Reinforcement Diameter	12mm	12mm	16mm	-
Effective Span	1050mm	1020mm	1350mm	
Dimensions	3300mm x 1100mm x 125mm	3300mm x 1100mm x 200mm	200mm x 200mm	1000mm x 1000mm
Total load	5.8kN/m	169kN/m	26.2kN	-

A preliminary sketch of the area is outlined in Figure 4. The sectional plan of the septic tank is highlighted in Figure 5 while the three-dimensional model is presented in Figure 6.

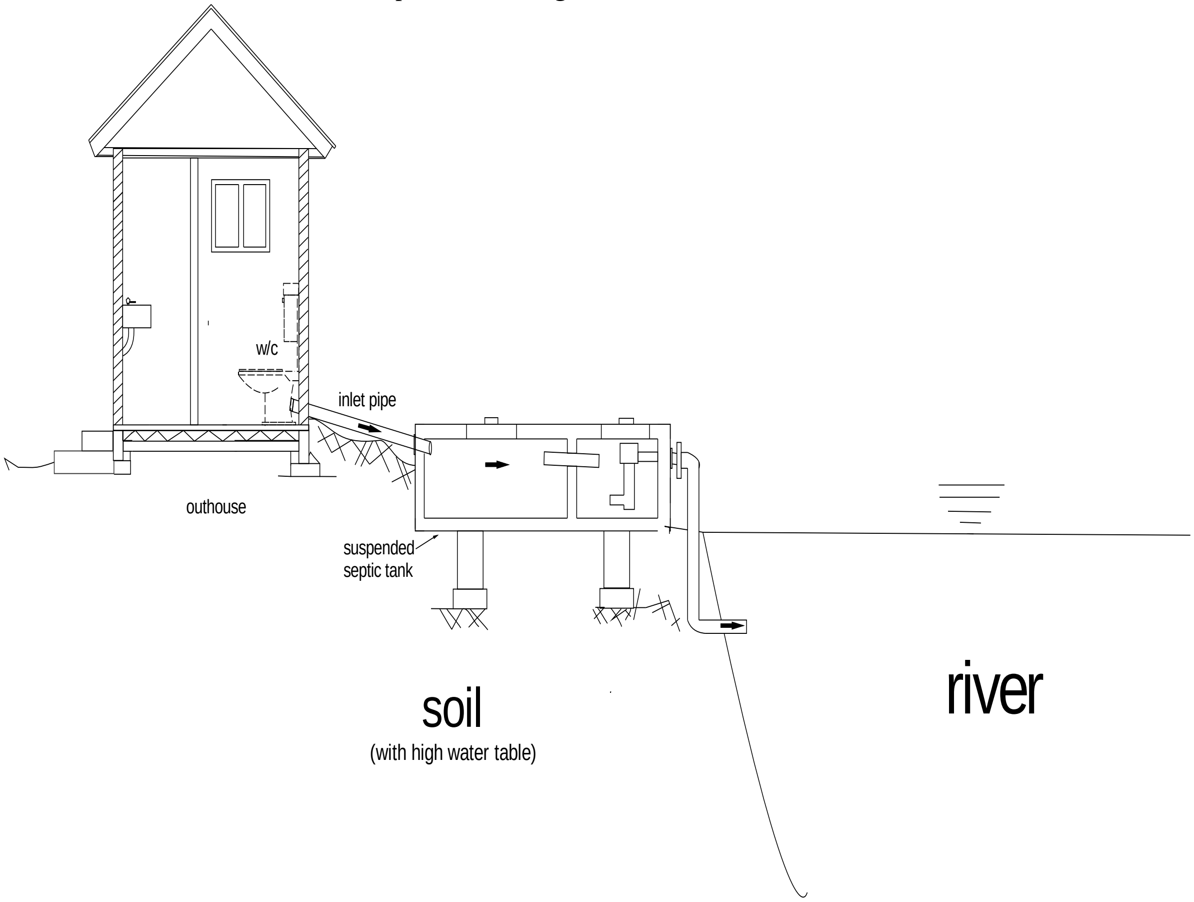

Figure 4. Schematic Diagram of Suspended Septic Tank

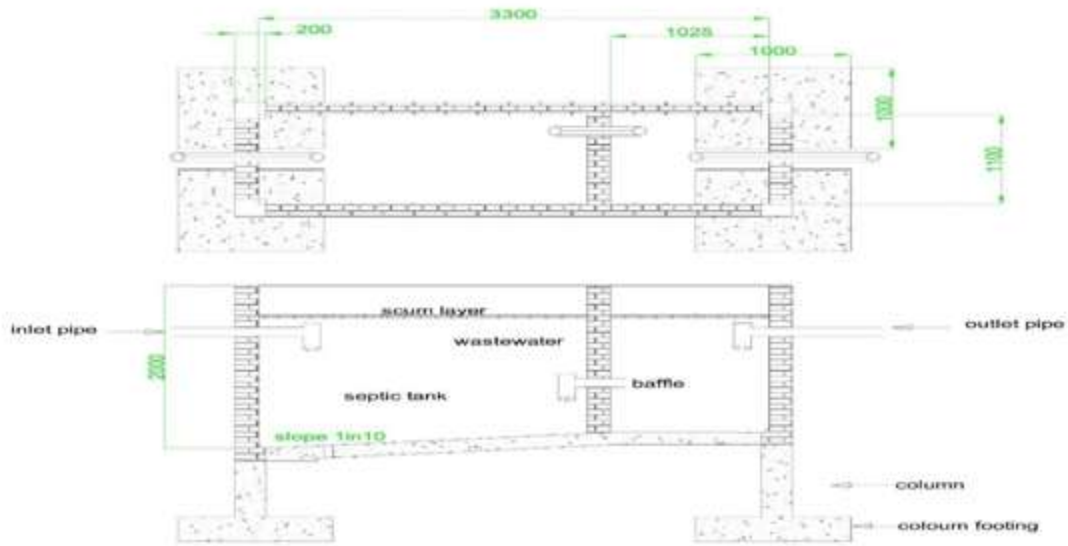

Figure 5: Sectional Plan of Suspended Septic Tank

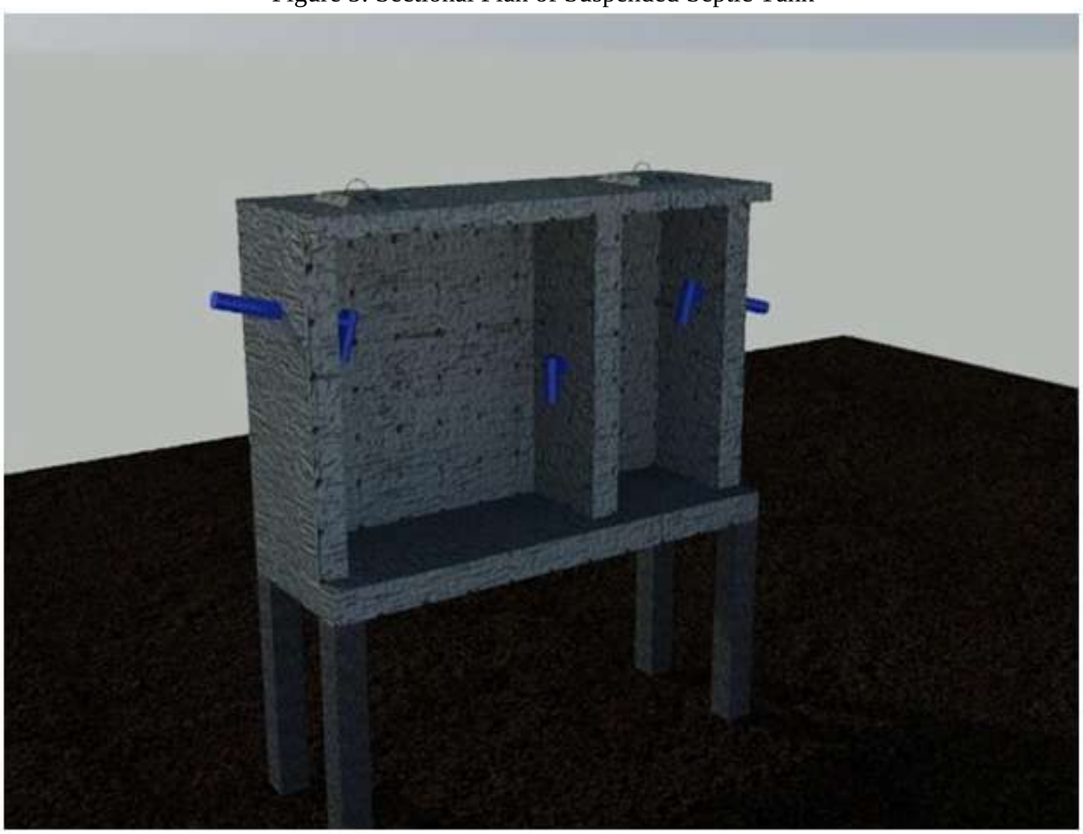

Figure 6: 3D Elevation of Suspended Septic Tank

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Discussion

The whole system leading from the outhouse to the septic tank and disposal site which includes the river will be seen to reduce the concentration of the effluents. After the dimensions needed for the proper drafting of the suspended septic tank were calculated, using relevant standards, ProtaStructure 2018 and AutoCAD were both used to render and model the two- and three-dimensional engineering drawings of the suspended septic tank.

The beam bar schedule, beam reinforcement, column reinforcement, and pad footing details obtained from the software are presented in Figures 7, 8, 9, and 10.

Codes		
BS8110-1997,BS6399,BS 5950		
Soil Parameters		
Soil Bearing Capacity (kN/m2)		200.00
Subgrade Reaction (kN/m3)		50000.000
Material Properties (Default)		
	Material	Rebar Grade
Columns	C20/25	Grade 460 (Type 2)
Walls	C20/25	Grade 410 (Type 2)
	Long. Web Rebar	Grade 410 (Type 2)
	Lat. Web Rebar	Grade 410 (Type 2)
Beams	C20/25	Grade 460 (Type 2)
Slabs	C35/45	Grade 460 (A-Fabric)
Ribs	C20/25	Grade 410 (Type 2)
Footings	C20/25	Grade 410 (Type 2)
Links	-	Grade 250 (Plain)

BEAM ELEVATIONS QUANTITY TAKE OFF -					
SIZE	UNIT WEIGHT (Kg/m)			Length (m)	T. WEIGHT (kg)
R8	0.395			83.3	32.9
T16	1.580			115.3	182.1
T. WEIGHT (kg)					215.0
BM	SIZE	QTY	Length (mm)	TOTAL	FORM
1	16	11	4150	45.65	32 180 30 180 270 270
2	16	10	3550	35.50	31 180 70 180
3	8	98	850	83.30	15 0 90 200 200

					15 0
4	16	8	1950	15.60	10 30 180 270 180 270
5	16	8	1350	10.80	180 97 180 0
6	16	2	2100	4.20	14 30 180 180 170 170
7	16	2	1750	3.50	13 180 70 180

Concrete Beam Rebar Schedule:[0] [1] [2]															
Beam					Top Reinforcements			Bottom Reinforcements			Links			Side Bars	Remarks
Mark	Width (mm)	Depth (mm)	Span (mm)	Type	Left	Center	Right	Left	Center	Right	Left	Center	Right		Similar
1B 1	200	250	3300	SS		4T16			3T16		T8-150	T8-150	T8-150		
1B 2	200	250	3300	SS		3T16			3T16		T8-175	T8-175	T8-175		
1B 3	200	250	1100	SS		2T16			2T16		T8-175	T8-175	T8-175		
1B 4	200	250	1100	SS		2T16			2T16		T8-175	T8-175	T8-175		
1B 5	200	250	1110	SS		2T16			2T16		T8-175	T8-175	T8-175		
2B 1	200	250	3300	SS		2T16			2T16		T8-175	T8-175	T8-175		
2B 2	200	250	3300	SS		2T16			2T16		T8-175	T8-175	T8-175		
2B 3	200	250	1100	SS		2T16			2T16		T8-175	T8-175	T8-175		

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2B 4	200	250	110 0	SS		2T16			2T16		T8-175	T8-175	T8-175		

Figure A 1 Beam Bar Schedule

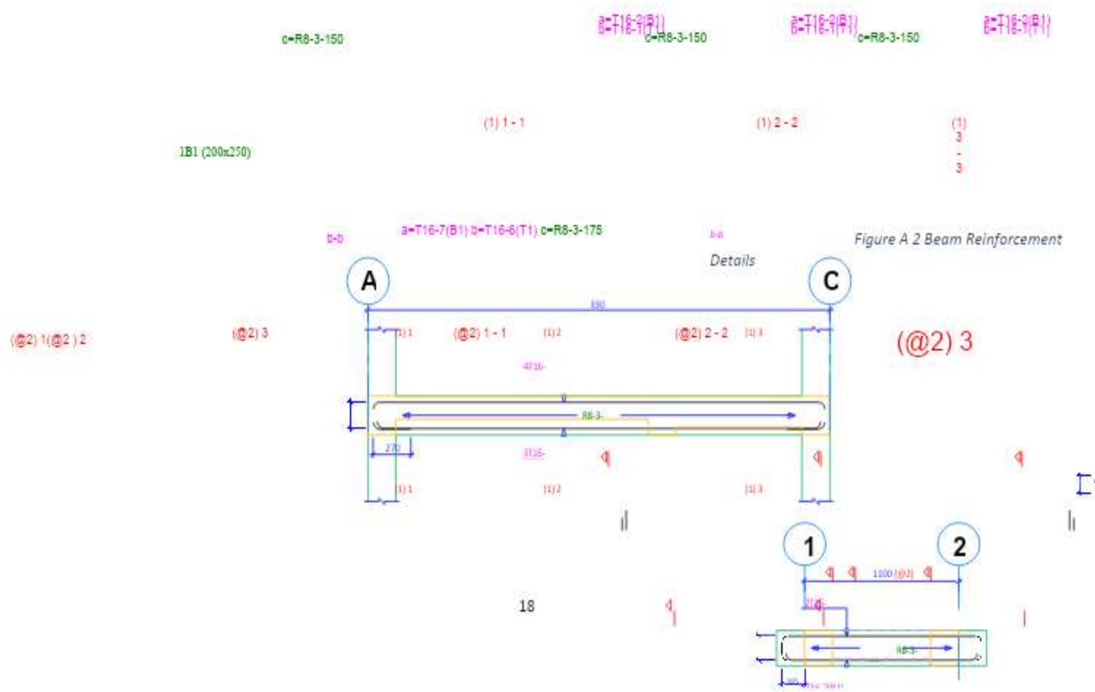

Figure A 2 Beam Reinforcement Details

PAD FOOTINGS QUANTITY TAKE OFF					
SIZE	UNIT WEIGHT (Kg/m)			Length (m)	T. WEIGHT (kg)
Y13	1.043			45.6	47.6
T. WEIGHT (kg)					47.6
BM	SIZE	QTY	Length (mm)	TOTAL	FORM
1	13	48	950	45.60	220 220 920

Codes	
BS8110-1997,BS6399,BS 5950	
Soil Parameters	
Soil Bearing Capacity (kN/m2)	200.00
Subgrade Reaction (kN/m3)	50000.000

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Ribs	C20/25	Grade 410 (Type 2)
Footings	C20/25	Grade 410 (Type 2)
Links	-	Grade 250 (Plain)

F4 1000 / 1000 (d = 300)

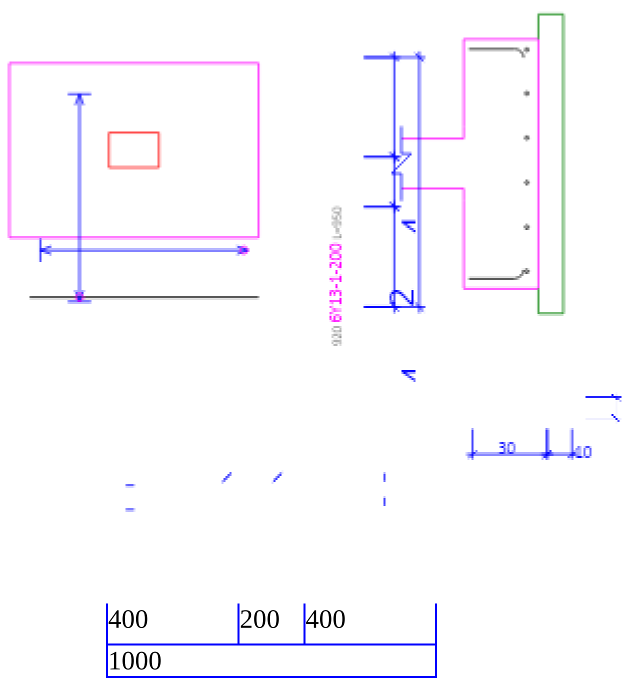
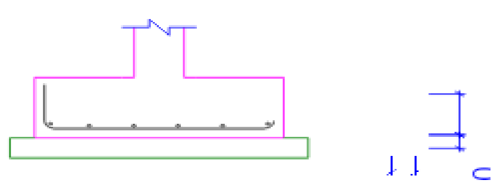


Figure A 3 Pad Footing Details



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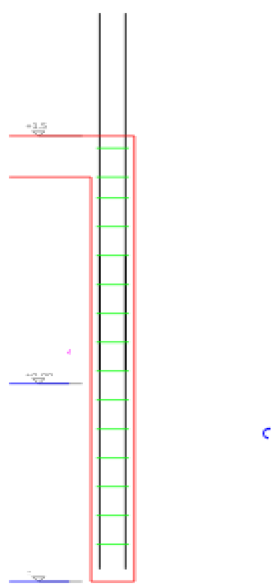
COLUMN ELEVATIONS QUANTITY TAKE-OFF - (ALL STOREYS)			
SIZE	UNIT WEIGHT (Kg/m)	Length (m)	T. WEIGHT (kg)
T0	0.000	0.0	0.0
T8	0.395	74.4	29.4
T12	0.889	15.6	13.9
T16	1.580	85.2	134.6
T. WEIGHT (kg)			177.9

BM	SIZE	QTY	Length (mm)	TOTAL	FORM
1	12	4	2000	8.00	2000
2	12	4	1900	7.60	150 1740
3	0	0	700	0.00	150 11550050 150
4	16	12	2200	26.40	2170
5	16	28	2100	58.80	200 1910
6	8	93	800	74.40	150 115501000150

+3.50



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Slabs	C35/45	Grade 460 (A-Fabric)
Ribs	C20/25	Grade 410 (Type 2)
Footings	C20/25	Grade 410 (Type 2)
Links	-	Grade 250 (Plain)

4T16
+1.50
1

C

Figure A 4 Column Reinforcement Details

IV. CONCLUSION AND RECOMMENDATION

Conclusion

The project entailed developing and putting into use a suspended septic tank system to improve wastewater treatment effectiveness and lessen its negative effects in riverine areas. The septic tank schematically designed in this work is a rectangular-shaped tank that receives wastewater from the outhouse to enhance anaerobic digestion and solids settling processes through the use of suspended tank architecture, making sewage treatment methods in areas with high water table more efficient and long-lasting. The key findings in this paper are described below;

Environmental Impact Reduction: The suspension of the septic tank reduces the extent of the harm done on the environment in areas that involve discharge of wastewater in rivers. In this way, the system is protecting direct contamination of water bodies thus protecting aquatic life and decreasing the cases of waterborne disease.

Design Efficiency: The suspended septic tank is small in size and unique in its construction which helps it overcome problems that are associated with high water table and therefore more effective than the conventional septic system. The use of this design in riverine areas has shown promise in improving the overall efficiency of wastewater treatment processes.

Practicality and Sustainability: The project underscores the practicality of implementing suspended septic tanks in riverine communities, offering a sustainable and long-lasting solution to contemporary sanitation challenges. The system's ability to function effectively in areas where regular septic tanks fail highlights its potential for widespread adoption.

Maintenance and Longevity: Maintenance procedures were also underlined by design and research in relation to the life cycle and overall efficiency of the suspended septic tank system. Proper maintenance will not only extend the system's lifespan but also enhance its environmental benefits.

These findings provide great insights into design, construction, operation, and maintenance of suspended septic tanks and give avenues for further studies and applications in such environments.

Recommendation

The following recommendations are made;

i. Eco-friendly materials and flood-resilient design should be prioritized to ensure the durability and functionality of the suspended septic tank in riverine areas prone to flooding.

ii. Comprehensive community awareness and maintenance programs should be established to promote proper usage and upkeep of the suspended septic tank, minimizing pollution, and safeguarding water quality.

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