Design and Structural Analysis of Elevated Gasoline Storage Tank for Flood-Prone Areas in Barangay San Gabriel, Macabebe, Pampanga

Albert O. Bautista[1], Jeffrey D. Sinica[1], John Carlo C. Aquino[1], Merwin Jay C. Santos[1], Joshua Andrei D. Timbang[1], Mark Edrian L. Yabut[1], Mike Diether B. Galvez[2], Ariel G. Pabalate[2]

[1]Student, College of Engineering and Architecture – Civil Engineering Department, Don Honorio Ventura State University, Cabambangan, Bacolor, Pampanga, Philippines

[2]Professor, College of Engineering and Architecture – Civil Engineering Department, Don Honorio Ventura State University, Cabambangan, Bacolor, Pampanga, Philippines

Corresponding Author: albertbautista553@gmail.com

Abstract— **This study examines the design and structural analysis of elevated gasoline storage tanks for flood-prone areas in Barangay San Gabriel, Macabebe, Pampanga, Philippines. Due to the country's susceptibility to natural disasters such as typhoons and floods, Macabebe frequently experiences severe flooding, raising concerns about the contamination of gasoline storage tanks by floodwaters and other pollutants. To address these concerns, an elevated gasoline storage tank was designed and tested to prevent contamination and reduce hazards such as corrosion, leakage, and vehicle damage. The structural design process utilized STAAD Pro software for analysis, including foundation analysis and anchor bolt design, in accordance with the 2015 National Structural Building Code of the Philippines. Flood data from the Municipality of Macabebe, Pampanga, along with key material properties and design parameters, were used to ensure the design's effectiveness and reliability. This study aims to propose a practical and safe alternative for gasoline storage in flood-prone areas, thereby enhancing safety and operations.**

Index Terms—**Flood, Storage Tank, Design and Analysis, STAAD Pro Software.**

1. Introduction

The Philippines is one of the most affected countries by disasters, with an estimated 60% of its geographical area and 74% of its population being vulnerable to various types of natural disasters. Since 1990, the country has experienced 565 disasters, causing $23 billion in damages and 70,000 fatalities. Climate change is expected to worsen these natural hazards, except for earthquakes and volcanic eruptions.

Manuscript revised June 17, 2024; accepted June 18, 2024. Date of publication June 21, 2024.
This paper available online at www.ijprse.com
ISSN (Online): 2582-7898; SJIF: 5.59

Floods are a type of natural disaster caused by tropical cyclone storm surges, tsunamis, and severe rainfall, causing widespread health effects, property and infrastructure destruction, damage to businesses, and even loss of lives. In 2019, about 0.05 million individuals in the Philippines were affected by floods, with the highest number affected in 2012 at 4.61 million.

Flood-prone areas are found in low-lying locations, close to significant river flows, on floodplains and alluvial plains, and typically in areas with a lot of habitation and agriculture. Large amounts of water can be distributed by floods, resulting in harm to infrastructure and property, and adversely affecting individual standards of living.

The University of the Assumption School of Business and Public Administration (SPA) found that the Province of Pampanga is a low-lying province with a lower elevation, making it more susceptible to flooding. The province's coastal municipalities, such as Masantol, Lubao, Sasmuan, and Macabebe, are located in the red zone, which is highly susceptible to flooding that could last or more than three days and reach a height of one to two meters.

Flooding can cause significant damage to infrastructure, including electricity, fuel, water supply, and transport. Hazardous chemicals, such as gasoline and diesel, can spill out of vehicles, industrial facilities, and fuel supplies, posing a risk to people. Storage tanks, which can be located above or below ground, are essential for holding liquids or gases. Approximately 95% of underground storage tanks (USTs) store petroleum products like oil or gasoline, with most found in gas stations. However, tanks during floods are exposed to additional risks, such as valves allowing floodwaters to enter the tank, rapid erosion, debris strikes, and oxidation of metallic tank components.

The Provincial Disaster Risk Reduction and Management Office in Pampanga reports that 34 barangays in the coastal towns of Masantol and Macabebe are currently flooded, with eight from Macabebe. Despite being a low-pressure area (LPA), some areas in Pampanga are already experiencing floods. Flooding is expected to rise in some areas as monsoon rains continue due to the LPA still prevailing in most of Luzon. San Gabriel Macabebe, a city with no drainage system, experienced a 3-foot-tall flood on July 29, 2022, submerging the entire barangay for about two weeks.

Elevated gasoline storage tanks are an alternative to underground tanks, designed to prevent fuel leaks into floods and contamination of water. These tanks are safer and recommended globally due to their lower hazards compared to underground storage tanks (UST). Above-ground fuel tanks (AST) are the safest option for fuel storage needs, and are recommended globally due to their lower risk.

Due to buoyant forces, submerged tanks may also be lifted out of the ground by floodwaters. An above-ground tank may be displaced if the flood forces are greater than the weight of the tank and the fuel within. Elevating gasoline storage tanks above the Design Flood Elevation (DFE) is the most efficient way to prevent flooding. The DFE, which is often based on the 100-year flood, is the elevation of the highest flood that a protective measure is intended to endure. The tanks themselves need to be supported and anchored in order to withstand wind loads and, in seismic regions, earthquake loads, even though they are elevated and unlikely to be subjected to flood forces during a design flood.

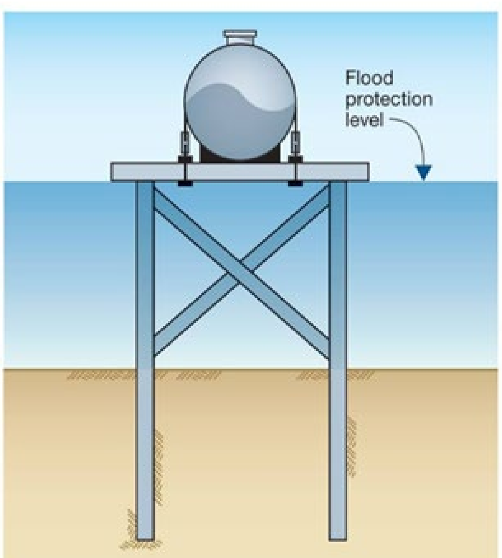


Fig.1. Elevated Storage Tank Anchored

Aboveground storage tanks (ASTs) are designed with seismic concerns in mind to ensure their structural integrity and functionality. These tanks can handle various liquids like chemicals, liquefied natural gas, petroleum, and water, making them applicable to various industries. The study emphasizes the importance of seismic response and soil-structure interaction (SSI) in developing ASTs. Unplanned tanks during seismic events can be vulnerable, highlighting the need for strong seismic design principles. Improving the design methodology requires considering historical lumped mass models for tectonic analysis. The adaptability of ASTs, which can handle various liquids, highlights their wide application in various industries. The main component of an AST's operation is its physical design, which includes large-capacity cylindrical tanks.

The study serves as a solution to prevent hazardous events in gasoline storage tanks caused by flooding. The researchers are proposing a solution to solve the problem by designing and analyzing the structural design of an elevated gasoline tank for flood-prone in Barangay San Gabriel, Macabebe, Pampanga. In order to prevent flood contamination, it is also necessary to ascertain the location to avoid things like corrosion, leakage, and vehicle damage caused by flooding. The researchers make sure the tanks comply with safety standards and regulations.

In order to prevent floodwater from overflowing the tank, the research will specifically objective to: (1) determine the top elevation of the tank; (2) provide the structural design and analysis of the structure that will support the elevated gasoline tank; (3) create a 3D model of the tank with its designed supporting structure; and (4) estimate the cost of the materials needed to design the elevated gasoline storage tanks.

2. Methodology

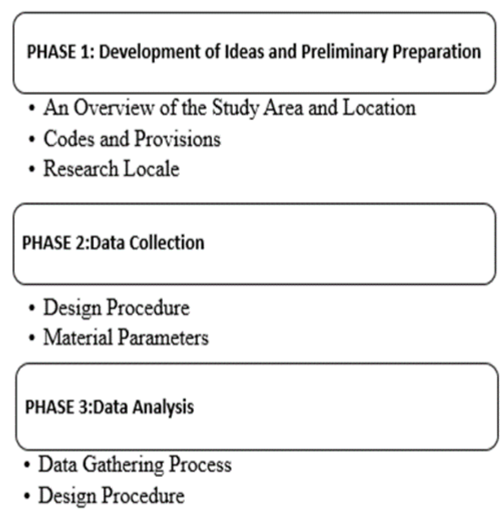


Fig.2. Methodological Framework

A. Phase 1: Development of Ideas and Preliminary Preparation

1) An Overview of the Study Area and Location

The researchers analyzed the Gasoline Station in Barangay San Gabriel, Macabebe, Pampanga using Google Maps and Topographical Maps to provide an overview of the study's profile region.

Fig.3. Satellite View of Gas Station

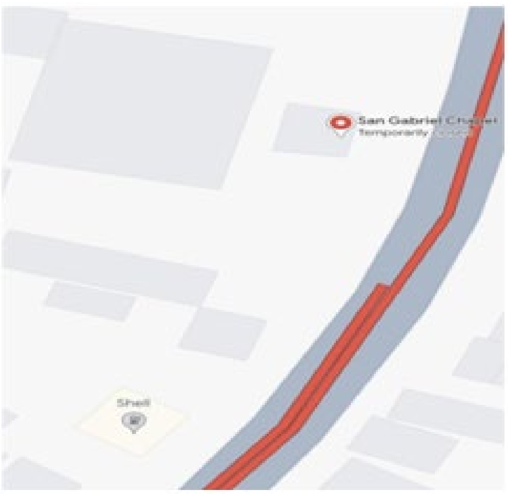


Fig. 4. Digital View of Gasoline

2) Codes and Provisions

The Elevated Gasoline Storage Tank was designed and analyzed using a quantitative method, adhering to the National Structural Code of the Philippines (NSCP 2015) and the American Concrete Institute standards.

3) Research Locale

The study will be conducted in Barangay San Gabriel, Macabebe, Pampanga, focusing on information from the Municipal Engineer. The location is chosen due to high tide experiences and calamities in Central Luzon, making San Gabriel the most flooded area.

B. Phase 2: Data Collection

The researchers gathered the data from the office of the Municipal Engineer to assess the maximum flood level as the elevation for the design phase of a proposed elevated storage tank. After obtaining the necessary data, the researchers will study and analyze the collected data to determine the suitable elevation of the elevated gasoline storage tank.

The researchers use STAAD Pro and formulas from the NSCP 2015 as a manual. This data will be used to analyze the elevation of the tank.

1) Design Procedure

The researchers demand customization, and information gathered from market websites is taken into account when determining the tank dimension. The researchers perform a comprehensive analysis involving the computation of loads from standard and seismic forces. The calculation of the anchor bolts necessary to withstand earthquake loads is conducted. The application of STAAD Pro and Design Analysis based on the National Structural Code of the Philippines 2015 (NSCP 2015) is employed to adhere to design specifications. The researchers utilize the specialized software application Enscape for 3D modeling and concrete proportion for the cost of the material used in the elevated gasoline storage tank.

2) Material Parameters

The NSCP's code and standards will be applied to the materials' parameters. The National Structural Code of the Philippines 2015 will serve as the basis and guide for the application and design of the elevated gasoline tank, considering the strength of the design and material properties.

- According to NSCP 2015 Section 419.2.1.3, concrete material must have a minimum compressive strength of 21 MPa at 28 days.
- Reinforcing steel must use G60 steel bars with a 25 mm diameter or adhere to NSCP 2015 section 420.2.2.5 requirements if it is not otherwise specified.

C. Phase 3: Data Analysis

The researchers in Barangay San Gabriel, Macabebe, Pampanga, collected and analyzed data from Municipal Engineer officials. The study used design and analysis to understand issues, their causes, and effects on the community, environment, and riders/drivers. The researchers identified potential issues and proposed improvements and significant projects to help gather data and support the study's objectives.

D. Data Gathering Process

1) Data for the Tank

Table.1. Detailed Parameters of Gasoline Tank by Customers' Requirements

Double walled diesel fuel tanks with Australia standard					
No	Capacity	Size(mm)	Thickness of cylinder	Thickness of dish end	Compartments
1	10	D1800*L4500	6	8	two chambers
2	20	D2200*L5500	6	8	two or three
3	30	D2200*8300	6	8	two or three
4	40	D2500*8600	8	10	two or three

2) *Seismic Consideration*

Section 208.4.1 of NSCP 2015 mandates that structures' design procedures and limitations are based on seismic zoning, site characteristics, occupancy, configuration, structural system, and height. These structures must be designed with sufficient strength to withstand lateral displacements, considering the structure's inelastic response and the inherent redundancy, over-strength, and ductility of the lateral force-resisting system.

Table.2.
NSCP Table 208-1 -Seismic Importance Factors

Occupancy Category [1]	Seismic Importance Factor, I	Seismic Importance [2] Factor, I_p
I. Essential Facilities [3]	1.50	1.50
II. Hazardous Facilities	1.25	1.50
III. Special Occupancy Structures	1.00	1.00
IV. Standard Occupancy Structures	1.00	1.00
V. Miscellaneous structures	1.00	1.00

Table.3.
NSCP Table 208-2 – Soil Profile Types

Table 208-2 - Soil Profile Types

Soil Profile Type	Soil Profile Name / Generic Description	Average Soil Properties for Top 30 m of Soil Profile		
		Shear Wave Velocity, V_S (m/s)	SPT, N (blows/ 300 mm)	Undrained Shear Strength, S_U (kPa)
S_A	Hard Rock	> 1500		
S_B	Rock	760 to 1500		
S_C	Very Dense Soil and Soft Rock	360 to 760	> 50	> 100
S_D	Stiff Soil Profile	180 to 360	15 to 50	50 to 100
S_E[1]	Soft Soil Profile	< 180	< 15	< 50
S_F	Soil Requiring Site-specific Evaluation. See Section 208.4.3.1			

Table.4.
NSCP 2015 Table 208-3 - Seismic Zone Factor Z

Table 208-3 Seismic Zone Factor Z

ZONE	2	4
Z	0.20	0.40

Table.5.
NSCP Table 208-24– Seismic Source Types

Table 208-4 - Seismic Source Types [1]

Seismic Source Type	Seismic Source Description	Seismic Source Definition
		Maximum Moment Magnitude, M
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity.	$7.0 \leq M \leq 8.4$
B	All faults other than Types A and C.	$6.5 \leq M < 7.0$
C	Faults that are not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity.	$M < 6.5$

[1]*Subduction sources shall be evaluated on a site-specific basis.*

Table.6.
NSCP 2015 Table 208-5 and 208-6 – Near-Source Factor, Na, Nv

Table 208-5 Near-Source Factor N_a [1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]		
	≤ 2 km	≤ 5 km	≥ 10 km
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

Table 208-6 Near-Source Factor, N_v [1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]			
	≤ 2 km	5 km	10 km	≥ 15 km
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

Table.7.
NSCP 2015 Table 208-7 and 208-8 –Seismic Response Coefficients, Ca, Cv

Table 208-7 Seismic Coefficient, C_a

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_a$
S_B	0.20	$0.40N_a$
S_C	0.24	$0.40N_a$
S_D	0.28	$0.44N_a$
S_E	0.34	$0.44N_a$
S_F	*See Footnote 1 of Table 208-8*	

Table 208-8 Seismic Coefficient, C_v

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_v$
S_B	0.20	$0.40N_v$
S_C	0.32	$0.56N_v$
S_D	0.40	$0.64N_v$
S_E	0.64	$0.96N_v$
S_F	*See Footnote 1 of Table 208-8*	

Table 8.
NSCP 2015 Table 208-12 – R and Ωo Factors for Non-Building Structures

Table 208-12 R and Ω_o Factors for Non-building Structures

STRUCTURE TYPE	R	Ω_o
1. Vessels, including tanks and pressurized spheres, on braced or unbraced legs.	2.2	2.0
2. Cast-in-place concrete silos and chimneys having walls continuous to the foundations	3.6	2.0
3. Distributed mass cantilever structures such as stacks, chimneys, silos and skirt-supported vertical vessels.	2.9	2.0
4. Trussed towers (freestanding or guyed), guyed stacks and chimneys.	2.9	2.0
5. Cantilevered column-type structures.	2.2	2.0
6. Cooling towers.	3.6	2.0
7. Bins and hoppers on braced or unbraced legs.	2.9	2.0
8. Storage racks.	3.6	2.0
9. Signs and billboards.	3.6	2.0
10. Amusement structures and monuments.	2.2	2.0
11. All other self-supporting structures not otherwise covered.	2.9	2.0

E. Footing Design

According to NSCP 2015 Section 302.2 Soil Classification, for the design of the elevated gasoline storage tank the soil materials should be classified and designed in accordance to Table 304-1 and ASTM D-2487.

Table.9.
NSCP 2015 Table 304-1 – Allowable Foundation and Lateral Pressure

Table 304-1 Allowable Foundation and Lateral Pressure

Class of Materials[1]	Allowable Foundation Pressure[2] (kPa)	Lateral Bearing Below Natural Grade[3] (kPa/m of depth)	Lateral Sliding[4]	
			Coefficient[5]	Resistance[6] (kPa)
1. "Intact" Tuffaceous Sandstone [a]	1,000	300	-	-
2. "Lightly Weathered" Tuffaceous Sandstone [b]	500	150	-	-
3. Sandy Gravel and /or Gravel(GW & GP)	100	30	0.35	-
4. Well-graded Sand, Poorly-graded Sand, Silty Sand, Clayey Sand, Silty Gravel and Clayey Gravel (SW, SP, SM, SC, GM and GC)	75	25	0.25	-
5. Clay, Sandy Clay, Silty Clay and Clayey Silt (CL, ML, MH, and CH)	50 [c]	15	-	7

[1] *A geotechnical site investigation is recommended for soil classification (Refer to Section 303).*

[2] *All values of allowable foundation pressure are for footings having a minimum width of 300mm and a minimum depth of 300mm into the natural grade. Except as noted in Footnote 'a', an increase of 20% is allowed for each additional 300mm of width and/or depth to a maximum value of three times the designated value. An increase of one-third is permitted when using the alternate load combinations in Section 203.4 that include wind or earthquake loads.*

F. Cost Estimating Design

Table.10.
Classification of Concrete

Table 4: Classification of Concrete

Class of Concrete	Cement: Sand: Gravel	Probable Strength after 28 days
Class AA	1: 1 ½ : 3	4, 000 – 3, 500 psi
Class A	1: 2: 4	3, 000 – 2, 500 psi
Class B	1: 2 ½: 5	2, 000 – 1, 500 psi
Class C	1: 3: 6	1, 000 – 500 psi
Class D	1: 3 ½: 7	Less than 500 psi

Table.11.
Concrete Proportion

Table 5: Concrete Proportion

Class	Mixture Cement: Sand: Gravel	Cement		Sand m³	Gravel m³
		40 kg	50 kg		
AA	1: 1 ½ : 3	12.0	9.5	0.50	1.0
A	1: 2 : 4	9.0	7.0	0.50	1.0
B	1: 2 ½: 5	7.5	6.0	0.50	1.0
C	1: 3: 6	6	5.0	0.50	1.0

Design Procedure

Tank Parameters

- Length of the Tank, L
- Diameter of Tank, d
- Density of Diesel, pd
- Pressure of the Tank with Diesel,
- Selfweight, W,
- Pressure of the Empty Tank
- Unit weight of tank
- Volume of the Tank, V
- Total Pressure, P_T, $P_T = P_d + P_e$

Data Parameters in STAAD Pro

- *Seismic Parameters*
  - Occupancy Category, I
  - Soil Profile Type,
  - Seismic Source Type,
  - Seismic Zone Factor, Z
  - Near-Source Factor, Na, Nv
  - Seismic Response Coefficients, Ca, Cv
  - Factors for Non-Building Structures, R, Ω_o

- *Concrete Parameters*
  - Compressive Strength of Concrete, f'c
  - Tensile Strength of Steel, fy
  - Tensile Strength of Steel, fyt
  - Maximum Diameter Bars
  - Minimum Diameter Bars
  - Minimum Temperature Diameter Bars

- *Slab Parameter*
  - Thickness

- *Beam Parameters*
  - Beam Dimension
  - Length of Beam
  - Longitudinal Direction
  - Transverse Direction

- *Column Parameter*
  - Column Dimension

Footing Parameters

- Compressive Strength of Concrete, f'c
- Tensile Strength of Steel, fy
- Allowable Bearing Capacity of Soil, qa
- Diameter Bars for Footing
- Diameter Bars for Column

Check the Foundation Thickness for Shear

For the foundation thickness to be safe for shear, the allowable shear φV_C, should be greater than the ultimate shear, V_u.

For one-way shear:

$$V_u \leq \varphi V_c$$

$\varphi V_C = \varphi 0.17\sqrt{f_C} b_w d$ (NSCP 2015 Section 422.2.5.1)

Where $\varphi = 0.75$ (NSCP 2015 Table 421.2.1)

For Punching Shear:

$$V_u \leq \varphi V_c$$

$\varphi V_C = \varphi 0.33\sqrt{f_C} b_o d$ (NSCP 2015 Section 422.6.5.2)

Where $\varphi = 0.75$ (NSCP 2015 Table 421.2.1)

Design the Foundation for flexure:

$$M_u = \o M_n$$

Where: $\o = 0.90$

$$M_n = \o R_n b d^2$$

To get the value of ρ,

Use:

$$\rho = \frac{0.85\,f'_c}{f_y}(1 - \sqrt{1 - \frac{2R_n}{0.85(f'_c)}})$$

Note on ρmin using NSCP 2015:

$$\rho min = \frac{1.4}{f_y} \le \frac{\sqrt{f'_c}}{4f_y}$$

For $f'c \le 31.36Mpa, \rho min = \frac{1.4}{f_y}$

For $f'c \ge 31.36Mpa, \rho min = \frac{\sqrt{f'_c}}{4f_y}$

**Note use the highest value of* ρ

For area of reinforcement:

$$\boldsymbol{A_s = \rho b_W d}$$

Number of bars:

$$\boldsymbol{N = \frac{A_s}{A_b}}$$

For spacing:

$$\boldsymbol{S = \frac{1000(A_b)}{A_s}}$$

Development Length:

(NSCP 2015 Table 425.4.2.2)

$$\boldsymbol{L_d = \frac{f_y \psi_t \psi_e}{1.7\lambda\sqrt{f'_c}} x d_b}$$

(NSCP 2015 Section 425.4.3.1)

$$\boldsymbol{ld = 8d_b}$$

$$\boldsymbol{ld = 150mm}$$

Dowels:

- Factored bearing force, P_u
- Permissible Bearing Stress:

$$\phi 0.85 f'_c A_1$$

But this may multiplied by $\sqrt{\frac{A_2}{A_1}} \le 2$

Permissible Bearing Stress > Factored Bearing Force, (no need)

Anchor Bolts Parameters

- Base Shear, V
- Axial Force, P
- Using High Strength A325

Capacity of Bolts:

For 20mm diameter $ft = 120kN$

For 25 mm diameter $ft = 230kN$

Number of Anchor Bolts:

$$N = \frac{\text{Tension induce by the structure}}{\text{Capacity of Bolts}}$$

Embedment Length:

Development Length:

$$\boldsymbol{ld = \left\{\left(\frac{1}{1.1}\right)\left(\frac{ft}{\sqrt{f_c}}\right)\left(\frac{1}{2.5}\right)\right\} x bolt\varphi}$$

Recommended Hook:

Table.12. Recommended Hook

φ	**Hook**
12	50°
16	65°
20	75°
22<above	90°

Check for Shear Resistance (Vr):

$$\boldsymbol{V_r = 0.42 \emptyset A_b F_u}$$

$$\emptyset = \boldsymbol{0.65}$$

Total $V_{r=} V_r(Number\ of\ Bolts)$

where: $Total\ V_r > Base\ shear$

3. Results And Discussion

Floods brought on by tropical cyclones and heavy rainfall can have detrimental effects, such as destroying infrastructure and causing property damage, as well as contaminating gasoline storage tanks. This is the problem that the researchers aim to prevent the contamination of the gasoline storage tank from the flood by proposing the design of an elevated gasoline storage tank in Barangay San Gabriel, Macabebe, Pampanga.

A. An Overview of the Gasoline Station

Fig.5. Profile of the Gasoline Station

This profile of the gasoline station provided by the illustration served as the foundation of the data that will be used to interpret the structural analysis of the elevated gasoline storage tank. This profile serves as a reference for the structural design calculation process, outlining important aspects to take into account during the design process.

B. Elevation of the Tank

The gathered data of the flood was determined according to the records and recent measurements conducted by the Municipal Engineer of Macabebe. With the details to be considered, the experienced maximum flood level in the San Gabriel Road on Macabebe is approximately 0.2 meters.

The highest elevation of the concrete pad from the natural grade level is 500mm. Barangay San Gabriel in Macabebe, Pampanga, has a maximum flood level of approximately 200 mm. As a result, the elevation of the elevated gasoline storage tank has a clearance of 300 mm from the maximum flood level, providing for potential future floods.

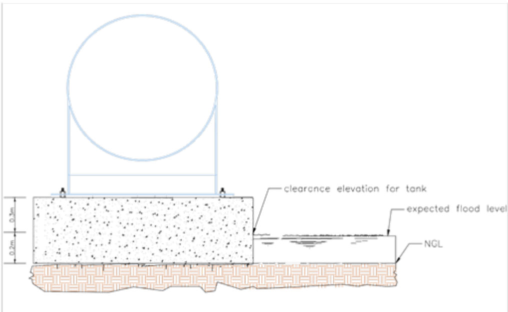


Fig.6. Elevation of the Gasoline Storage Tank

C. Design of the Concrete Pad

The following design was computed by the researchers using the STAAD Pro and in accordance with the National Structural Code of the Philippines 2015. For the design of the concrete pad and the gathered results of the calculation from, its value is the following:

- Fy = Grade 60 (420 Mpa)
- Unit Weight of the Concrete = 23.5 kN/m^3
- Fc (Compressive Strength of Concrete) = 21 Mpa

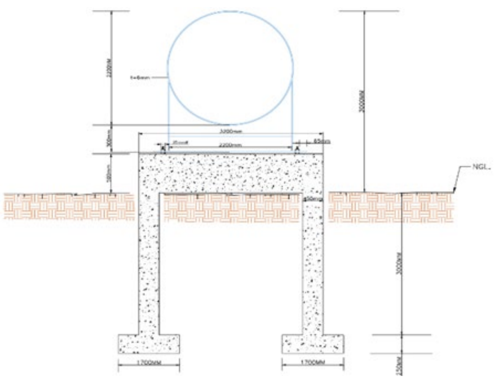


Fig.7. Designed of Elevated Gasoline Storage Tank

D. Tank Details

The researchers customized the tank used in the elevated gasoline storage tank design. To guarantee the correct design of the concrete pad, researchers intend to seek customization in the "Made-in-China" online market.

Fig.8. Above Ground Carbon Steel Diesel Fuel Storage Tank

Table.13. Detailed Parameters of Diesel Fuel Skid Tank

Capacity:	20000L
Shape:	Cylinder
Mounting Type:	Horizontal
Position:	On the Ground
Material:	Metal
Medium:	Diesel, Gasoline, Crude Oil
Length:	5500mm
Diameter:	2212mm
Weight of the Tank	4.93tons

E. Slab Details

The researchers opted for a two-way slab design for the elevated gasoline storage tank pad to support the weight of the tank and any additional loads it may encounter.

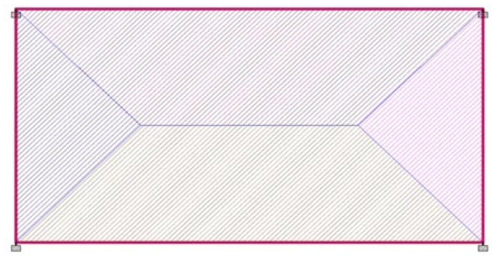


Fig.9. Two-way Slab Design

7– 12mm Diameter RSB Spaced @ 140mm both traverse and longitudinal direction.

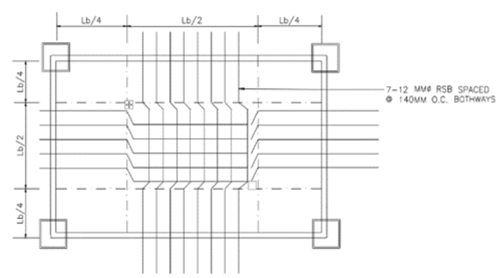


Fig.10. Detailed Slab Design

F. Beam Details

ACI 318-11 Beam Design Result Longitudinal Direction

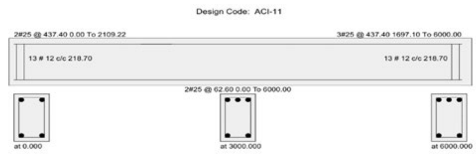
```
LEN -  6000. MM  FY -  420.  FC -  21.  MPA, SIZE -  300. X  500. MMS

LEVEL    HEIGHT     BAR INFO        FROM         TO          ANCHOR
          (MM)                      (MM)        (MM)         STA  END
--------------------------------------------------------------------

  1        63.     2 - 25MM          0.       6000.         YES  YES
  2       437.     2 - 25MM          0.       2109.         YES  NO
  3       437.     3 - 25MM       1697.       6000.         NO   YES


AT START SUPPORT - Vu=  124.59 KNS  Vc=  104.66 KNS  Vs=   61.46 KNS
Tu=    0.00 KN-MET  Tc=    4.2 KN-MET  Ts=    0.0 KN-MET  LOAD     5
NO STIRRUPS ARE REQUIRED FOR TORSION.
REINFORCEMENT IS REQUIRED FOR SHEAR.
PROVIDE 12 MM 2-LEGGED STIRRUPS AT 219. MM  C/C FOR 2562. MM

AT END   SUPPORT - Vu=  130.68 KNS  Vc=  101.39 KNS  Vs=   72.84 KNS
Tu=    1.62 KN-MET  Tc=    4.1 KN-MET  Ts=    0.0 KN-MET  LOAD     9
NO STIRRUPS ARE REQUIRED FOR TORSION.
REINFORCEMENT IS REQUIRED FOR SHEAR.
PROVIDE 12 MM 2-LEGGED STIRRUPS AT 219. MM  C/C FOR 2562. MM
```



Design Load

Mz(Kn Met)	Dist.et	Load
108.099998	0.000000	5
-125.580002	0.000000	5
-166.270004	0.000000	9

Design Parameter

Fy(Mpa)	420.000000
Fc(Mpa)	21.000000
Depth(m)	0.500000
Width(m)	0.300000
Length(m)	6.000000

Fig.11. Detailed Beam Design Longitudinal

ACI 318-11 Beam Design Result Transverse Direction

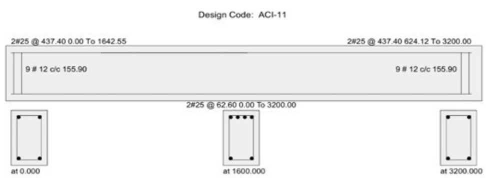
```
LEN -  3200. MM  FY -  420.  FC -  21.  MPA, SIZE -  300. X  500. MMS

LEVEL    HEIGHT     BAR INFO        FROM        TO          ANCHOR
          (MM)                      (MM)       (MM)        STA   END
-----------------------------------------------------------------------

  1        63.     2 - 25MM          0.       3200.        YES   YES
  2       437.     2 - 25MM          0.       1643.        YES   NO
  3       437.     2 - 25MM        624.       3200.        NO    YES


AT START SUPPORT - Vu=   47.29 KNS  Vc=   97.97 KNS  Vs=    0.00 KNS
Tu=    5.83 KN-MET  Tc=    4.0 KN-MET  Ts=    7.8 KN-MET  LOAD     2
STIRRUPS ARE REQUIRED FOR TORSION.
REINFORCEMENT FOR SHEAR IS PER CL.11.5.5.1.
PROVIDE 12 MM 2-LEGGED STIRRUPS AT 156. MM  C/C FOR 1162. MM
ADDITIONAL LONGITUDINAL STEEL REQD. FOR TORSIONAL RESISTANCE =   1.56 SQ.CM.

AT END   SUPPORT - Vu=   86.60 KNS  Vc=   97.69 KNS  Vs=   17.78 KNS
Tu=    5.83 KN-MET  Tc=    3.9 KN-MET  Ts=    7.8 KN-MET  LOAD    10
STIRRUPS ARE REQUIRED FOR SHEAR AND TORSION.
PROVIDE 12 MM 2-LEGGED STIRRUPS AT 156. MM  C/C FOR 1162. MM
ADDITIONAL LONGITUDINAL STEEL REQD. FOR TORSIONAL RESISTANCE =   1.56 SQ.CM.
```



Design Load

Mz(Kn Met)	Dist.et	Load
75.669998	0.000000	2
-26.190001	0.000000	5
-99.449997	0.000000	10

Design Parameter

Fy(Mpa)	420.000000
Fc(Mpa)	21.000000
Depth(m)	0.500000
Width(m)	0.300000
Length(m)	3.200000

Fig.12. Detailed Beam Design Transverse

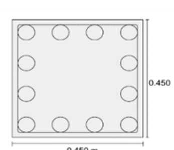
G. *Column Design Details*

ACI 318-11 Column Design Results

```
FY - 420.0  FC -  21.0 MPA,  SQRE SIZE - 450.0 X 450.0 MMS, TIED
        AREA OF STEEL REQUIRED =  4576.5  SQ. MM

BAR CONFIGURATION       REINF PCT.   LOAD   LOCATION   PHI
-----------------------------------------------------------

 12 - 25 MM               2.909        9      END     0.650
(PROVIDE EQUAL NUMBER OF BARS ON EACH FACE)
TIE BAR NUMBER   12 SPACING 400.00 MM
```



Design Load

Load	9
Location	END
Pu(Kns)	241.830002
Mz(Kns-Mt)	226.960007
My(Kns-Mt)	31.299999

Design Results

Fy(Mpa)	420
Fc(Mpa)	21
As Reqd(mm²)	4576.000000
As (%)	2.909000
Bar Size	25
Bar No	12

Fig.13. Detailed Column Design

- Foundation Details

1700mmx1700mmx250mm

3-20mm Diameter RSB @ 550 Spacing o.c. Both ways

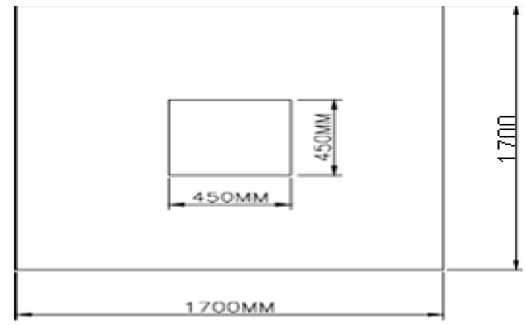


Fig.14. Dimension of the Footing

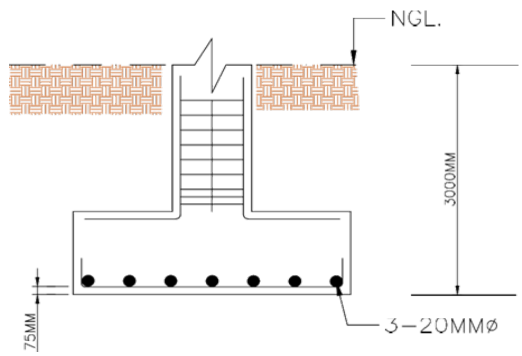


Fig.15. Detailed Footing Design

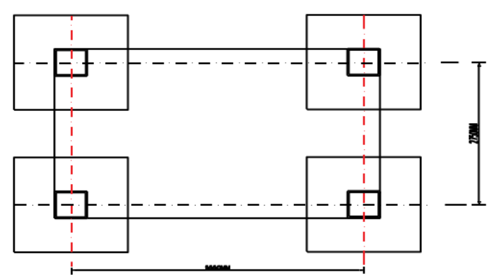


Fig.16. Foundation Plan of the Concrete Pad

H. *Anchor Bolts Details*

25mm Diameter A325 Anchor Bolt, 450mmx90° c/w Standard nut and Washer

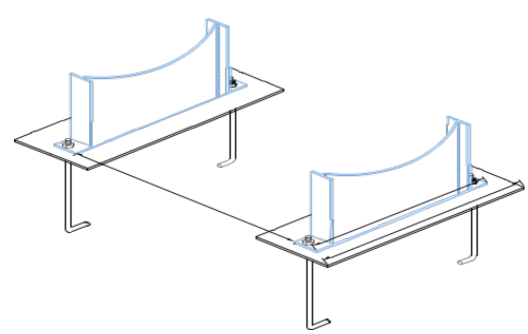


Fig.17. Design of Anchor Bolts

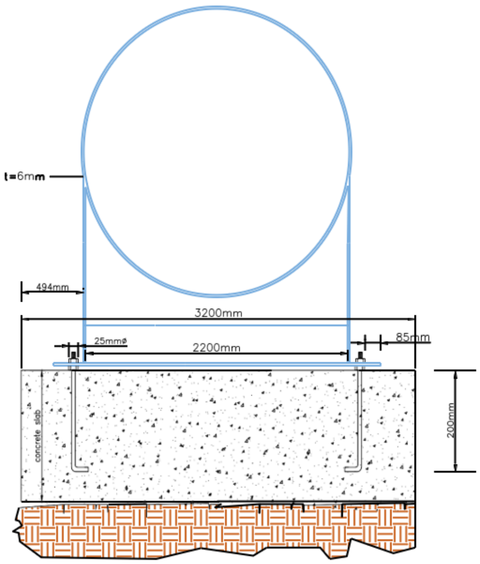


Fig.18. Detailed Anchor Bolts Design

3D Model of the Elevated Gasoline Storage Tank

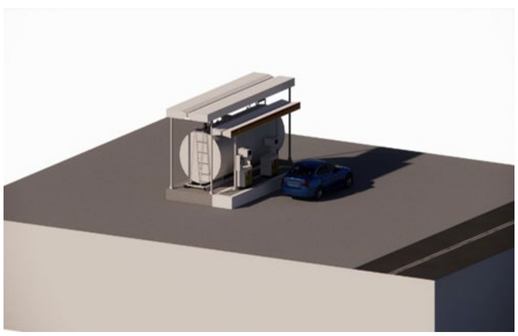


Fig.19. 3D Model Isometric View

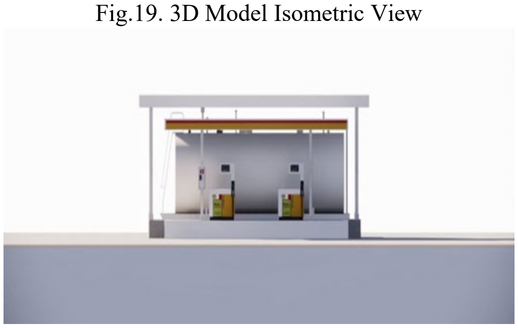


Fig.20. 3D Model Front View

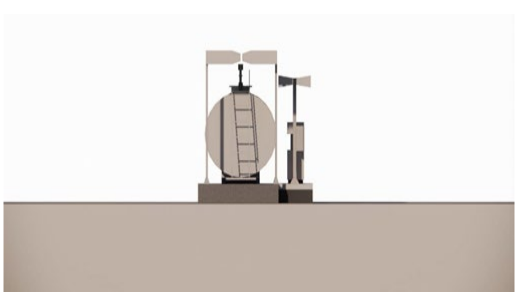


Fig.21. 3D Model Side View

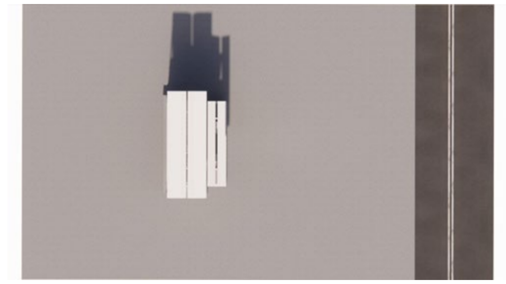


Fig.22. 3D Model Aerial View

I. Bill of Materials

The researchers estimated the cost of materials needed to construct the elevated gasoline storage tank in Barangay San Gabriel in Macabebe, Pampanga.

Table.14. Bill of Materials

Items of Work	Quantity	Unit	Unit Cost	Cost
I. Tank				
a. Storage Tank	1	pcs	\$2000-\$3000	₱174,346.00
b. Shipping			\$350-\$500	₱29,057.00
II. Concrete				
a. Slab				
40kg Cement	32	Bags	₱200.00	₱6,400.00
Sand	1.755	cu.m	₱1,600.00	₱2,808.00
Gravel	3.51	cu.m	₱2,000.00	₱7,020.00
b. Beam				
40kg Cement	24	Bags	₱200.00	₱4,800.00
Sand	1.29	cu.m	₱1,600.00	₱2,064.00
Gravel	2.58	cu.m	₱2,000.00	₱5,160.00
c. Column				
40kg Cement	21	Bags	₱200.00	₱4,200.00
Sand	1.114	cu.m	₱1,600.00	₱1,782.40
Gravel	2.23	cu.m	₱2,000.00	₱4,460.00
d. Footing				
40kg Cement	27	Bags	₱200.00	₱5,400.00
Sand	1.15	cu.m	₱1,600.00	₱1,840.00
Gravel	2.89	cu.m	₱2,000.00	₱5,780.00
III. Reinforcement				
6m, ϕ12mm	30	pcs.	₱215.00	₱6,450.00

RSB				
6m, ϕ20mm RSB	24	pcs.	₱590.00	₱14,160.00
6m, ϕ25mm RSB	70	pcs.	₱920.00	₱64,400.00
25mm ϕA325	4	pcs.	₱400.00	₱1,600.00
Total Cost Estimated				₱341,727.40

4. Conclusion

The specific objectives of this research are:
Determine the top elevation of the tank to prevent overtopping of flood water (2) To provide the structural design and analysis of the structure that will support the elevated gasoline tank (3) To create a 3D model of the tank with its designed supporting structure (4) Determine the estimated cost of the materials required to design the elevated gasoline storage tanks. According to the gathered data and findings, the researchers conclude that:

- In consideration of a maximum flood level of approximately 200 mm, a concrete pad thickness of 500mm. If future floods are severe, there is a 300- mm clearance above the projected maximum flood level for the flood.
- The software application STAAD Pro was utilized in the structural design process of the elevated gasoline storage tank, ensuring conformity with the stipulations outlined in the National Structural Code of the Philippines. Additionally, based on the loading calculations from the software, the calculations of specifications needed for the design were performed with regards to the concrete pad, foundation, and anchor bolts.
- The software Enscape was utilized to create a three-dimensional model of the elevated gasoline storage tank.
- The construction materials for the elevated gasoline storage tank are projected to cost ₱341,727.40.

References

[1]. Countries - Flood Resilience Portal," Flood Resilience Portal, Mar. 12, 2024.
[2]. "World Bank Climate Change Knowledge Portal."
[3]. "Number of people affected by flood Philippines 2010-2019," Statista, May 16, 2024.
[4]. S. Maryati, "Identification of Flood Prone Areas for Natural Disaster Mitigation using Geospatial Approach (A Case Study in Bone Bolango Regency, Gorontalo Province)," IOP Conference Series. Earth and Environmental Science, vol. 145, p. 012080, Apr. 2018.
[5]. "Geo-hazard Mapping of the Province of Pampanga: A Reference for Disaster Preparedness Panorama," Issuu.
[6]. "Chemical Hazards in Floods and Disasters."
[7]. "About Storage Tanks," Storage Tanks, May 28, 2022.
[8]. "Fuel Tanks Anchored for Disaster Resistance | Building America Solution Center," Apr. 01, 2012.
[9]. "What are the advantages of an above ground fuel storage tank?," EnivrosafeTM, Jul. 20, 2020.
[10]. "More barangays flooded in Masantol, Macabebe," SunStar Publishing Inc., Aug. 09, 2022.
[11]. A. V. Kumar, S. A. Basha, S. A. Tej, and C. M. Babu, "Seismic behaviour of elevated liquid storage tanks by considering the different soil types using MATLAB software," Materials Today: Proceedings, Mar. 2023.