DESIGN OF A WATER STORAGE AND TRANSMISSION SYSTEM FOR WASTEWATER REUSE IN COVENANT UNIVERSITY

BY

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CERTIFICATION

I, **Adeyinka Michael Oluwadare**, of Civil Engineering Department of Matric no. **15PCI01016**. Certify that this project was carried out by me.

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DEDICATION

This work is dedicated to my uncle Pastor. Ibukunoluwa. Adeyinka. Who was murdered by hired assassin, at his duty post as a servant of Christ on 30th day of May 2017, in our hearts your memory lingers. You are a faithful servant of Christ to the core, accountable in your duty, and hardworking man of God. Sleep on sir, till we meet to part no more.

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Abbreviations and Symbols

1 GPS - Global Positioning System

2 PRV-Pressure Reducing Valves

3 P-5 - pipe labelled

4 T-1 - Tank

5 H-2 - Hydrant

6 PMP - Pump

7 J-16 - junction labelled

8 γ_s – Unit weight of soil

9 γ_w - Unit weight of water

10 L/min – litre per minute

11 BEP - best efficiency point

12 KN/m² - Kilo newton per meter square

13 UC – Universal column

14 UB – Universal beam

15 UA- Universal angle

16 m/sec – meter per seconds

17 Kg/m² - Kilo gram per meter square

18 m - meter

19 BS - British Standard

20 STAAD.Pro. V8i Structural analysis and design program

21 p/γ – Pressure head

22 z – Elevation head

23 P.E – Potential Energy

24 Kpa – Kilopascal

25 SQX, SQY - Shear stresses (Force/ unit length/ thickness) in different direction.

26 SX, SY - Membrane stresses (Force/unit length/ thickness)

27 SXY - Inplane Shear Stress (Force/unit length/ thickness)

28 MX, MY, MXY - Moments per unit width (Force x Length/length) For Mx, the unit width is a unit distance parallel to the local Y axis. For My, the unit width is a unit distance parallel to the local X axis. Mx and My cause bending, while Mxy causes the element to twist out-of-plane.)

29 SMAX, SMIN - Principal stresses in the plane of the element (Force/unit area). The 3rd principal stress is 0.0

30 TMAX - Maximum 2D shear stress in the plane of the element (Force/unit area)

31 VONT, VONB - 3D Von Mises stress at the top and bottom surfaces, where: VM = 0.707[(SMAX - SMIN)2 + SMAX2 + SMIN2]1/2

32 TRESCAT, TRESCAB - Tresca stress, where TRESCA = MAX[|(Smax-Smin)|, |(Smax)| , |(Smin)|]

33 FX, MY, and MZ provide the axial force, moment in local y-axis and moment in local z-axis respectively. Although STAAD does consider all the member forces and moments to perform design, only FX MY and MZ are printed since they are the ones which are of interest, in most cases.

ABSTRACT

This research is focused at designing of water storage facilities of size 875,000 litres (750,000 litres for underground water storage, and 125,000 Litres for elevated steel tank) of treated wastewater and its transmission system for the storage and re-use of treated wastewater. The project is aimed to structurally design water storage facilities and its transmission system from the reservoir to the overhead tank for the re-use of treated wastewater in Covenant University. The design works was divided into two major parts namely: Transmission system design, and water storage facility Design. Transmission design was divided into two, which are the field activities, and the software activities. Magellan eXplorist 350H North America GPS (Global Positioning System) was used for the field activities, it was used to determine coordinates (Longitudinal and Latitudinal) of various location of points in the university campus, its key usage was to determine the lowest and the highest elevation points on campus, the highest elevated coordinate point was located in between the male postgraduate hall of residence and the postgraduate cafeteria, and the lowest elevated point was at the existing wetland which is directly opposite Daniel's hall in the campus. The software used for transmission system is WaterCAD, which was used to design the flow path network from the lowest elevation to the highest elevation point. The water storage facility design software used are Staad pro., Orion, and AutoCAD. Staad pro. Was used to analyse and design for the underground water tank, and the elevated steel water tank, while Orion software was used for concrete design and it was used to detail the underground water tank. The result gotten from all the design software were imported to AutoCAD software for editing, scaling, and proper output result.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Hydraulic structure such as underground reservoirs and overhead tanks are used to store liquid products such as water and wastewater. The force analyses (such as internal pressure) of the underground reservoirs or overhead tanks are about the same irrespective of the chemical structure (steel or concrete) of the storage unit. Wastewater reuse has been in existence for a very long time more precisely is an ancient practice, which has been taken into consideration since the beginning of human history, and being practiced in virtually all part of the world, of which suffer from drought conditions (Burgess, Meeker, Minton, O'Donohue, Devine, Cook, & Weinstein, 2015). Reuse of untreated city or town wastewater has been practiced in many countries with the aim of diverting of human waste outside of urban settlements. In a similar way, land application of domestic wastewater is an ancient and universal practice, which has gone through various stages of development. This has led to better understanding of process involve in treatment technology and the eventual development of water quality standards (Paranychianakis, Salgot, Snyder, & Angelakis, 2015).

Wastewater reuse of which is also known as water reclamation and wastewater recycling can be defined as used water that contains waste substances from homes, factories and farms and can also be defined as the use of reclaimed water for beneficial purposes, such as agricultural, landscape and field irrigation, industrial processes, toilet flushing, fire protection, and replenishing of surface water and groundwater recharge. Wastewater reuse is integral to workable water management due to the fact that it enables water to remain in the environment and be reserved for future consumption while meeting water prerequisite of the water.

US EPA, states that water is a limiting resource of which the force or pressure applied to groundwater resources should be minimized or at best maintained, instead of increased, as the number human increased and industrial development increase. Wastewater reuse and water recycling is thus an increasing importance, of which is not often use in arid regions only but also in municipal and contaminated environments, Groundwater aquifers used by over 50% of the world population are being over-drafted, as the matter of fact, it is not encouraged to use water once and dispose of it; it is important to ascertain ways to reuse water. Reuse will continue to escalate as the population of the world becomes increasingly urbanized and more condensed. Abundant quantities of freshwater can be saved by wastewater reuse and recycling, lowering costs, reducing environmental pollution and enhancing carbon footprint; thereby knowing reuse is a sustained and cost-efficient option for water supply (Burgess, et al., 2015).

Wastewater reuse can reduce water use in both rural and urban households. Most likely most home at presently, use portable drinkable water for virtually everything in the house i.e. we are literally flushing our drinking water down the toilet. Vividly domestic wastewater can be divided into two parts, which is Grey water and Black water. Grey water is wastewater of which is from non-toilet plumbing such as basins, taps, and showers. Black water is wastewater that has various wastes from the toilet. Because of the prospective contamination by grease and organism that cause diseases (pathogen).

Covenant University, Ota has the population of eight thousand, one hundred and eleven (8,111) people living on campus. About one million, ninety-two thousand, five hundred and fifty-two litres

(1,092,552) of water is pumped out every day to serve the university. Eight hundred and seventy-four thousand, eighty-one (874,081) litres of wastewater is generated per day (Emenike, Tenebe, Omole, Ndambuki, Ogbiye, & Sojobi, 2015).

Winners Chapel generate eight hundred thousand litres of wastewater daily (800,000 Litres), and the university generate over seven hundred and twelve thousand litres of wastewater daily (712,000 Litres), which sum up to one million, five hundred and twelve thousand Litres of wastewater daily (1,512,000 Litres), the wastewater generated are captured at point within the university campus where the wastewater undergoes treatment before discharging them to the river. Wastewater reuse reduces the cost of fuelling to bear minimal, the cost of pumping drastically reduced if wastewater is effectively reused.

1.2 Statement of the Problem

The research is focused at designing of water storage facility, and its transmission system for the storage and re-use of treated wastewater.

Conventionally, water is returned to the water bodies (e.g. rivers, lagoon) after use in form of wastewater. This wastewater reduces the quality of water present in the water body, thereby creating the need for further treatment when considered for domestic use. There is the need to use water sustainably because of the problem of scarcity, pollution of water bodies, high treatment cost and high cost of transport.

The design of large water storage facilities is employed as a repository for treated wastewater through the use of Civil Engineering aided design software.

1.3 Aim of Study

The aim of this project is to structurally design water storage facility (concrete reservoir and overhead steel tank) and the transmission system from the reservoir to the overhead tank for the re-use of treated wastewater.

1.4 Objectives of Study

The Objectives of this project are:

- To design underground storage facility for capturing of treated wastewater.
- To design elevated steel water tank for capturing treated wastewater.
- To design transmission system from underground concrete water tank to elevated steel water tank.

1.5 Justification for the Research

Due to the ever-growing population of human, water consumption will continually increase and the end use is wastewater. Water is a limitless resource but freshwater is not limited, which is man's main source of consumption. There is the need to sustainably use water as a limited resource. Due to large volume of water and wastewater been used and generated respectively, it is necessary to have a water storage which can accommodate the volumes of wastewater after treatment process.

1.6 Scope of Study

The scope of study is to design Underground storage water tank that can capture Seven hundred and fifty thousand (750,000) litres of treated wastewater, and one hundred and twenty-five thousand (125,000) litres of elevated tank, and the pipe network system of the underground tank to the overhead tank in Covenant University, Ota. Structural engineering design software will be used to carry out the water storage design, while WaterCAD will be used to carry out transmission system.

1.7 Limitation of the Study

- The design of the hydraulic structure was limited to the soil test data given, therefore no soil test was carried out.
- The designed hydraulic underground structure cannot capture the total volume of treated wastewater due to many factors, therefore an overhead tank of capacity 125,000 litres.
- The hydraulic structure design is limited to software modelling without any prototype to simulate the model.
- The underground water tank cannot capture the whole treated wastewater generated at once due to its capacity. The capacity of the reservoir is 750,000 Litres of wastewater.

CHAPTER TWO

LITERATURE REVIEW

2.1 Wastewater

Water has several utilization in many sectors including the industrial, agricultural and domestic activities. These activities generate contaminated wastewater with chemical and biological residue. Decreasing per-capita water availability and increasing pollution of freshwater resource are huge challenges as the population continues to grow (Bastiaan & Rochi, 2016). There is a significant high pressure due to the high-water demand pattern in urban environment. The condition is worsening with rising demand due to increasing urbanization. Almost Eighty percent of water supply to municipalities flow back into the ecosystem as untreated wastewater, which is a critical and environmental health hazard.

Wastewater consumption contribution is not only to proffer solution to storages of water problems but also belittle the menace of health and environment. Consequently, the use of wastewater must fulfil the following elementary requirements.

I. The wastewater collection technique must be comprehensive.
II. Wastewater treatment flairs must be well operated.

Wastewater utilisation flairs are three main types of which it enables it to make use of the best relevance of wastewater reuse and in addition to having impact or effect on increasing the accessibility and availability of the total amount of water. They are

I. Treatment systems for collection,
II. Wastewater treatment and
III. Wastewater reuse.

The pointers which are used to enumerate the accomplishment of wastewater reuse are:

I. The percentage of the total wastewater produced in municipal.
II. The percentage of the supplied total tap water.
III. The flow rate.
IV. Percentage of treated wastewater.
V. Percentage of water supplied for urban.
VI. Percentage of total area to be irrigated,
VII. Percentage of water supply for agriculture.

Wastewater consumption includes the generation, the collection, the treatment and the reuse of wastewaters (Abu-Madi & Al-Sa ’ed, 2004).

2.2 Water Reticulation System

This part illustrates water reticulation system schemes and their potential benefits and limitations to the affected regions. Red Sea-Dead Sea pipeline (Jordan, Israel, Syria) reticulation system delivers water from the Red Sea so as to enable it to raise the level of the Dead Sea (Gavrieli, Bein, & Oren, 2005) moreover, supply desalinated drinking water to the societies (Beyth & Shorr, 2002) located in one of the most water-limited regions of the world (Harding, McCullum, & Canadian Wildlife Service., 1994).

2.3 Socio-Economic Studies on Reticulation System

Water management has become a significant issue in recent years, and a multicultural methodology which enables equitable distribution, water conservation, environmental flows, and economic and social development is paramount (Gunningham & Sinclair, 2002). Water shortages are leading many countries to explore a dual reticulation model for water supplies where households receive recycled water, derived from sewage, for toilet flushing and outdoor use and conventional potable-quality water for other uses (Sinclair, O'Toole, Forbes, Carr, & Leder, 2010).

Internationally, different categories of dual water reticulation systems with diverse design specifications, conveying diverse non-potable water qualities for different water requirements, have been implemented. Many of these systems can be found in the United Kingdom, United States of America, Singapore and Australia (Dimitriadis, 2005; Po, Kaercher, & Nancarrow, 2003; Po, Nancarrow, Leviston, Porter, Syme, & Kaercher, 2005).

In South Africa, the use of dual systems was investigated by Botha & Pretorius, (1998). The report concluded that dual systems offer new possibilities for maintaining adequate water supply and appropriate use of the available water resources in South Africa. Dual systems were reported to be especially beneficial in the following areas:

- Where sea or brackish water (with high total dissolved solids (TDS) concentrations) is the closest available water source;
- Where intensive indirect reuse of water may cause high Total Dissolved Solids concentrations in the source waters (as with the Vaal River barrage).
- Where the incremental cost of developing, new freshwater sources may be high and therefore less attractive in comparison to recycling sewage effluent. The mass balances and cost comparisons conducted in Botha & Pretorius, (1998) study indicated that using dual systems would result in smaller desalination streams, less salts to be removed from sewage, better water utilisation indices and probably, better economics than the reclamation of treated effluent for direct potable reuse.

2.4 Synopsis of Related Elevated Water Tanks

The water is source of every conception. In day to day life, one cannot live without water. The overhead liquid storing tank is the most effectual storing competence used for domestic or even industrial rationale. Depending upon the location of the water tank, the tanks can be name as overhead, on ground and underground water tank. The tanks can be made in different shapes like rectangular and circular types. The tanks can be made of reinforced concrete or even of Structural steel. Steel tanks are widely used in railway yards as Overhead tanks and storage (Thakkkar & Rethaliya, 2015). Numerous researches have been done on various viewpoints of seismic behaviour and design of elevated water tanks. A comprehensive study also primarily suggested improved recommendation for seismic design of water tanks. A report of the literature reviewed to examine the dynamic behaviour of the elevated water tank, and liquid structure interaction is briefly discussed by (Shajee & Nandagopan, 2017). Elevated water tanks are one of the most important lifeline structures in earthquake prone regions. In the main cities and also in rural areas elevated water tanks forms an integral part of water supply scheme. These constructions have large mass concentrated at the top of slender supporting structure hence these structures are especially exposed to horizontal forces due to an earthquake. Elevated water tanks that are inadequately analysed and designed have experienced extensive destruction during past earthquakes. The elevated water tanks must remain operative despite after the earthquakes as water tanks are required to supply water for drinking and firefighting purpose (Hirde, Asmita Bajare, & Hedaoo, 2011).

Water supply is a lifeline facility that must remain functional. Most municipalities have water supply system which depends on elevated tanks for storage. An elevated water tank is a large water storage constructed for the purpose of holding a water supply at a height sufficient to pressurise a water distribution system. In the main cities, the primary supply scheme is grown by private supply systems of institutions and estates for which elevated tanks are an essential part. These structures have a configuration that is especially vulnerable to horizontal forces like earthquake due to the large total mass concentrated at the top of slender supporting structure. So, it is important to check the severity of these forces for a particular region (Hirde *et al.*, 2011). Past experiences revealed that elevated water tanks were heavily damaged or collapsed during earthquakes and this might be due to the lack of knowledge about the proper behaviour of supporting system of the tank against dynamic effect and also due to improper geometrical selection of staging patterns. Further, there have been a few instances of failure of tanks and reservoirs occurred not because of shortcomings of specifications but due to other reasons that surfaced from the failures of water tanks. Krisha, Rathish, & Divya Dhatri. K, (2005) stated that, failure of tanks during Chilean earthquake of 1960 and Alaska earthquake of 1964 gave way for investigations on seismic analysis of liquid storage tanks and brought two aspects such as,

I. due consideration to sloshing effects of liquid and flexibility of container wall in evaluating seismic forces on tanks and

II. Less ductility and low energy absorbing capacity and redundancy of water tanks in comparison to conventional building systems.

CHAPTER THREE

MATERIAL AND METHODOLOGY

3.1 Materials

The design works is divided into two major parts namely:

1. **Transmission System**

Tools used for transmission system are:

Field Activities

Magellan eXplorist 350H North America GPS (Global Positioning System)

Software

Google Earth.

WaterCAD

2. **Water storage Design**

Tools used for hydraulic design are:

Software tools

- StaadPro.V8i
- Orion 18
- AutoCAD 2013

3.2 Method

3.2.1 Transmission System

3.2.1.1 Magellan eXplorist 350H North America GPS (Global Positioning System)

Magellan eXplorist 350H North America GPS (Global Positioning System) is a space-based radio navigation system It is a global navigation satellite system that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The GPS system operates independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the GPS positioning information. The GPS system provides critical positioning capabilities.

Magellan eXplorist 350H North America GPS (Global Positioning System) was used to determine coordinates (Longitudinal and Latitudinal) of various locations of points in the university campus, its key usage was to determine the lowest and the highest elevation points on campus, at which the proposed underground water tank and elevated tank will be installed. More than ten coordinates points where taken. The lowest point was taken using the GPS at the downstream of the existing groundwater wastewater tank directly opposite Daniel’s hall which was the first coordinate point, the second coordinate point was taken at 83m away from the first coordinate point, the third coordinate point was taken 57m away from the second coordinate point, the forth coordinate point was also taken 243m away from the previous coordinate point, the fifth coordinate point was taken 4m away from the previous coordinate point, the sixth coordinate point was taken 60m away from the fifth coordinate point, the seventh point was taken 133m away from the sixth coordinate point, the eighth coordinate point was taken 201m away from the previous coordinate point, the highest elevated coordinate point was taken 319m away from the eighth coordinate point, which was located in between the male postgraduate hall of residence and the postgraduate cafeteria, subsequently the last coordinate point of which was 106m away from the highest elevated coordinate point. All the distances taken were taken according to the direction of route to the highest elevation coordinate point. All coordinates gotten were transferred to Google earth to perform adequate distance measurement, to determine the elevation and to draw the elevation profile. .

3.2.1.2 Google Earth

Google Earth is a virtual globe, map and geographical information program that was originally called Earth Viewer 3D, It maps the Earth by the superimposition of images obtained from satellite imagery, aerial photography and geographic information system (GIS) onto a 3D globe. Google Earth is computer based map software which was used to determine the location of the coordinates, distances, elevations, and profiles.

The coordinate points gotten from the GPS were inputted on the add path tool of the Google earth, each of the coordinate points gotten were added respectively to the add path of the Google earth, of which it automatically rotate the earth to where the coordinates points were located on real sense of the earth surface, immediately after coordinates were added to the add path, the distance were measured from one coordinate point to another respectively, therefore the connectivity of path, from the first coordinate point to the last coordinate point enables the drawing of the elevation profile (i.e. levelling profile).

3.2.1.3 WaterCAD

WaterCAD is a complete geographic information management system that enables engineers and decision makers to analyse and manage distribution networks. It provides a modelling environment for building the pipe network from scratch or using existing data sources.

WaterCAD software was used to draw the flow path networks of pipes from the downstream to the elevated tank. The elevation and distance of each point that were gotten from the Google earth were inserted in the information table of the WaterCAD modelling.

The modelling of the WaterCAD which comprises similitude of the Google earth distance path measured, gotten from the GPS result, the similitude was imported to AutoCAD, for editing before being imported to WaterCAD software for proper transmission system analysis.

The following tools were used in WaterCAD software: Reservoir, Pump, Junction, Hydrant, Pressure Reducing Valves (PRV), Tank, and Pipes.

Reservoir tools was placed at the downstream of an elevation of 34m gotten from GPS (which happen to be the least elevation), of which pipe labelled (P-5) was connected to the reservoir of pipe length 29m away from the reservoir, the pump was placed at an elevation of 31m. Then connected by pipe labelled (P-6) to a junction labelled (J-16), where we have the first corner, the length of pipe labelled (P-6) that connects the pump with the junction is 54m away from the pump at the elevation of 41m, after which another pipe labelled (P-2) was connected to hydrant at 57m away from the first junction labelled (J-16) at elevation of 43m, another pipe labelled (P-3) was also connected to another junction labelled (J-1) at the elevation 48m of length of 294m, away from the hydrant, subsequently another pipe labelled (P-4) was connected to another junction labelled (J-2) at elevation of 48m, at length of 4m away from the previous junction labelled (J-2), afterward another pipe labelled (P-5), was connected to junction labelled (J-3) it was connected at 60m away from junction labelled (J-2) at elevation of 49m, Junction labelled (J-4) was connected by pipe labelled (P-6) at elevation of 50m, at length 133m away from junction labelled (J-3), Junction labelled (J-5) was connected to junction labelled (J-4) by pipe labelled (P-7), at elevation 50m, length 35m away from labelled (J-5), Junction labelled (J-6) was connected to junction labelled (J-5) by pipe labelled (P-8) at elevation of 51m, length of 166m away from labelled (J-5), junction labelled (J-6) was connected to pressure reducing valves labelled (PRV) via pipe labelled (P-9) at elevation of 49m, length of 80m away from junction labelled (J-6), PRV was connected to junction labelled (J-7) via pipe labelled (P-10) at elevation of 51m, length 51m away from labelled (PRV). Junction labelled (J-7) was connected to the Tank Via pipe labelled (P-11) at elevation 54m, length of 159m away from joint labelled (J-7). Junction labelled (J-8) was connected to the tank trough pipe labelled (P-12) at length 106m, elevation 52m.

The diameter of pipes used is: 1. Pipes used from the reservoir to the pump, and from pump to junction labelled (J-16) is concrete pipe, and ductile iron, of 300mm diameter, where the Hazen Williams C used is 110 for the concrete pipe and 130 for ductile iron. While every other pipe from junction labelled (J-16) to the last junction labelled (J-8) is 100mm diameter, material type ductile iron, Hazen-Williams C is 130. The demand of water at every junction were assumed (fact of assumption was based on population around the junctions).

The pump definition type used is standard (3 point), of which its

1. **Shutoff:** 0 (flow L/min), 30m (Head).
2. **Design:** 3800 (flow L/min), 27.4m (Head),
3. **Maximum operating**: 7500 (flow L/min), 24.80m (Head). Pump efficiency type used is best efficiency point (BEP), BEP flow is 0 (L/min), BEP efficiency is 100%, motor efficiency is 100%.

After the result has been computed the analysis was run to see if there is any possible error. If there is any error the software will alert, and it will indicate where the error occurred, of which there will be room for adjustment.

3.3 Water Storage Design

3.3.1 STAAD.Pro V8i (SELECT series 4)

STAAD.Pro V8i (SELECT series 4) is the most popular structural engineering software product for 3D model generation, analysis and multi-material design. It has an intuitive, user-friendly GUI, visualization tools, powerful analysis and design facilities and seamless integration to several other modelling and design software products. For static or dynamic analysis of bridges, containment structures, embedded structures (tunnels and culverts), pipe racks, steel, concrete, aluminium or timber buildings, transmission towers, stadiums or any other simple or complex structure, STAAD.Pro has been the choice of design professionals around the world for their specific analysis needs.

STAAD.Pro V8i (SELECT series 4) was used to generate the structural modelling, structural analysis, and structural design of the concrete underground water tank, and also was used in steel elevated water tank design. The volume of water that the concrete underground water tank can capture is 750000liters, therefore the total size of underground concrete water tank that was designed for, was derived from total litters of water divided by 1000 i.e. $\frac{Total\ liters}{1000} = \frac{750000}{1000} = 750m^3$. Therefore, the size of concrete designed for was 15m x 10m x 5.001m.

The modelling was drawn using the add beam and node tool on the software. Subsequently the properties to be used were assigned to the modelling. (I.e. the property that was selected is concrete) using 300mm thickness for wall and base slab, and 200mm thickness was selected for the upper slab), subsequently the loading was assigned. The loading which were assigned are:

1. The self-weight load: The self-weight load factor of $1.5kN/m^2$ was used for the whole concrete structure.

2. Dead load: The dead load of $90KN/m^2$ was selected (i.e. Unit weight of soil multiply by the height of wall (γ_s x H) = 18.5 x 5=$90KN/m^2$). Therefore, as pressure increases in depth the value of hydrostatic pressure decreases at the apex point of the reservoir, which is zero (0), while the hydrostatic pressure at the base of the reservoir is $90KN/m^2$. This principle was used for the pressure of soil acting externally to the wall,

3. Live load: The live load which are active and passive pressure of soil acting externally to the wall, and hydraulic pressure acting internally to the wall.

while the live load was calculated using (Unit weight of water multiply by the height of wall (γ_s x H) = $9.81KN/m^2 \sim 10KN/m^2$ x 5 = $50KN/m^2$), therefore as pressure increases in depth so the value of hydrostatic pressure at the apex point of the reservoir will decrease to zero (0), meanwhile the hydrostatic pressure at the base of the reservoir is $50KN/m^2$, these value was used for pressure of water acting internally to the wall.

Subsequently analysis was done and thereafter the design was done using BS 8110.

Elevated Steel Tank the volume of litres of water that the elevated steel tank can capture is 125,000 litres, of which is estimated as $\frac{Total\ liters}{1000} = \frac{125000}{1000}$ = $125m^3$. Elevated steel tank constructed is $125m^3$

of size 5m X 5m X 5m, of stanchion height of 17.5m. The modelling was done using add beam and node tool, subsequently the properties were selected of which are:

- UC 203 X 203 X 46kg/ m^2, for stanchion, the horizontal beams and braced used are
- UA 90X 90 X 10kg/ m^2, Sit of the reservoir beam used was
- 254 X 146 X 43kg/ m^2,
- Thickness of the plate used for the reservoir is 15mm,

Subsequently the loading were assigned to the properties of the material selected, the loading that were taken into consideration are:

- Dead Load which was the Self-weight, the load factor of 1.5kN/m^2 was used for the whole steel structure.
- Live load which are:
- Hydrostatic pressure which are acting internally in the reservoir wall (Unit weight of water multiply by the height of reservoir (γ_w x H) = 9.81KN/m^2 ~ 10KN/m^2 x 5 = 50KN/m^2) therefore as pressure increases in depth, the value of hydrostatic pressure at the apex point of the reservoir reduces to zero (0), meanwhile the hydrostatic pressure at the base of the reservoir is 50KN/m^2, then the
- Live load acting on the stanchion is 0.6KN/m^2.
- Wind load was also considered at the four directions of the reservoir, considering the wind speed of 55m/sec. from the base of the tank to the top of the reservoir of which act horizontally to the steel member.

After the modelling, next was the assigning of properties (section of steel), next was assigning of loading, subsequently analysis is done, finally design was done using BS 5950 2000. Note before the selected sections were picked series of section were tried using trial by error method, but they failed in design, until a section which passed design was selected. Before they are recommended to be used for design.

3.3.2 Orion 18

Orion 18 is a dedicated analysis, design and drafting solution for reinforced concrete building structures. Detailed calculations, material quantities, structural layout plans, beam and slab elevations and column schedules are all produced automatically from one central model.

Orion 18 was used purposely for detailing of the concrete structure (Underground water tank), after the analysis was done using STAAD.Pro. V8i Software. The modelling was replicated on Orion 18, as it was done on STAAD.Pro. V8i, then the material was assigned using column size of 150mm x 150mm, the purpose of the column was to support the upper floor slab, because of the span the slab, also to withstand the load that will be imposed on the slab. hidden beam were also considered at the upper floor and the base floor(slab) respectively, which sit directly on the column, the size of the beams designed for were 200mm x 200mm, and the top slab 200mm thickness was considered, shear wall (cantilever type of was used with the heel of 1000mm length and 300mm thickness) was used, base slab of 300mm was used, of which it accommodate hidden beam as well of size 300mm X 300mm, in other to stabile the imposed loading acting on the base of the slab, The load which were taking into consideration are load acting on the wall, after which the Finite Element method analysis were taking into consideration, subsequently the design was performed using BS code 8110, which automatically detail and export the detailing drawing to AutoCAD.

3.3.3 AutoCAD 2013

AutoCAD 2013 is a commercial computer aided design (CAD) and drafting software application, is used across a wide range of industries, by architects, project managers, engineers, graphics designers and many other building professionals.

AutoCAD 2013 was majorly used for editing of design done, scaling of drawing export from all the software used for these project, more so it was used for proper output of the design work done. Most of the design software used for design are very bad in output; it is required and recommended to export those drawing from design software to AutoCAD for accurate output, which can be understandable by everyone who lays their hand on the drawing.

4 CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Preamble

The results of this project are divided into two categories of which they are:

- Reticulation System and
- Hydraulic Structural design

4.2 Reticulation System

4.2.1 Field Activities

Table 1 below shows the result from field activities using the Magellan eXplorist 350H North America GPS (Global Positioning System). The GPS was majorly employed to determine the coordinate points, and elevation of various positions.

Table 4.1: GPS result from field activities, it indicate the coordinates, elevations, and distances of various point in the university.

S/N	POINT	COORDINATE	DISTANCE (m)	ELEVATION (m)
1.	**Downstream**	**6º 40’ 23.40″ N 3º 09’10.40″ E**	**0**	**34**
2.	**B**	**6º 40’21.30″ N 3º 9’ 8.70″ E**	**83**	**41**
3.	**C**	**6º 40’ 20.30″ N 3º 09’ 10.30″ E**	**57**	**43**
4.	**D**	**6º 40’ 14.50″ N 3º 9’ 17.90″ E**	**294**	**48**
5.	**E**	**6º 40’ 12.83″ N 3º 09’ 16.91″ E**	**4**	**48**
6.	**D″**	**6º 40’ 6.30″ N 3º 9’ 22.40″ E**	**60**	**49**
7.	**D″2**	**6º 40’ 6.21″ N 3º 09’ 22.70″ E**	**133**	**50**
8.	**G**	**6º 40’ 06.00″ N 3º 9’ 22.70″ E**	**201**	**51**
9.	**ELEVATED TANK**	**6º 39’ 55.30″ N 3º 09’ 27.83″ E**	**319**	**54**
10.	**I**	**6º 39’ 57.30″ N 3º 09’ 24.00″ E**	**106**	**52**
			TOTAL=1,257m	

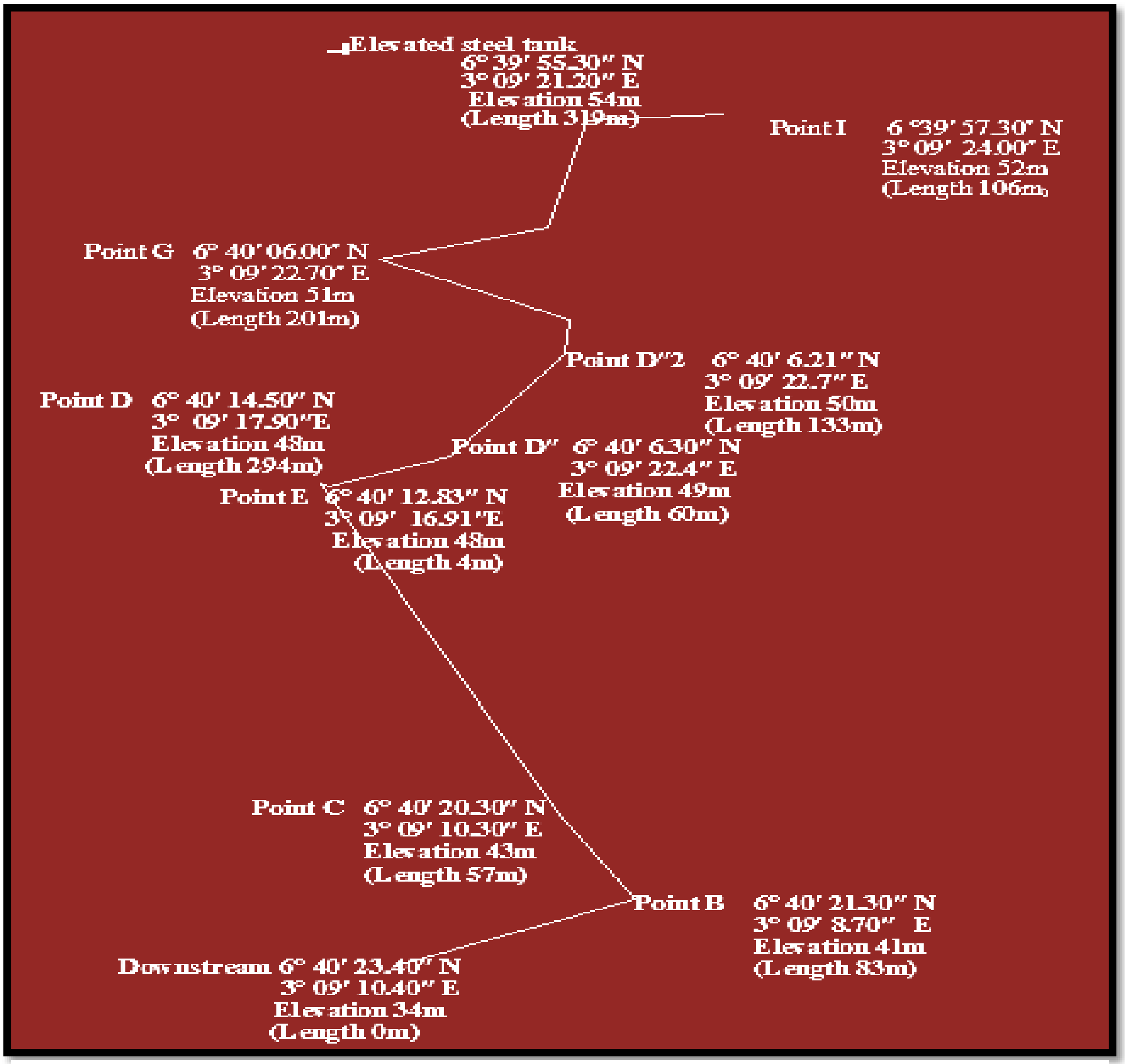


Plate 1: lines joining different coordinate points, forming flow path from downstream to the highest elevated point along the proposed route of transmission pipeline

4.2.2 Software

4.2.2.1 **Google Earth**

Plate 2 shows the representation of coordinate points on Google earth software, and it also indicate aerial view of some part of the university, and elevation profile in Covenant University, Ota.

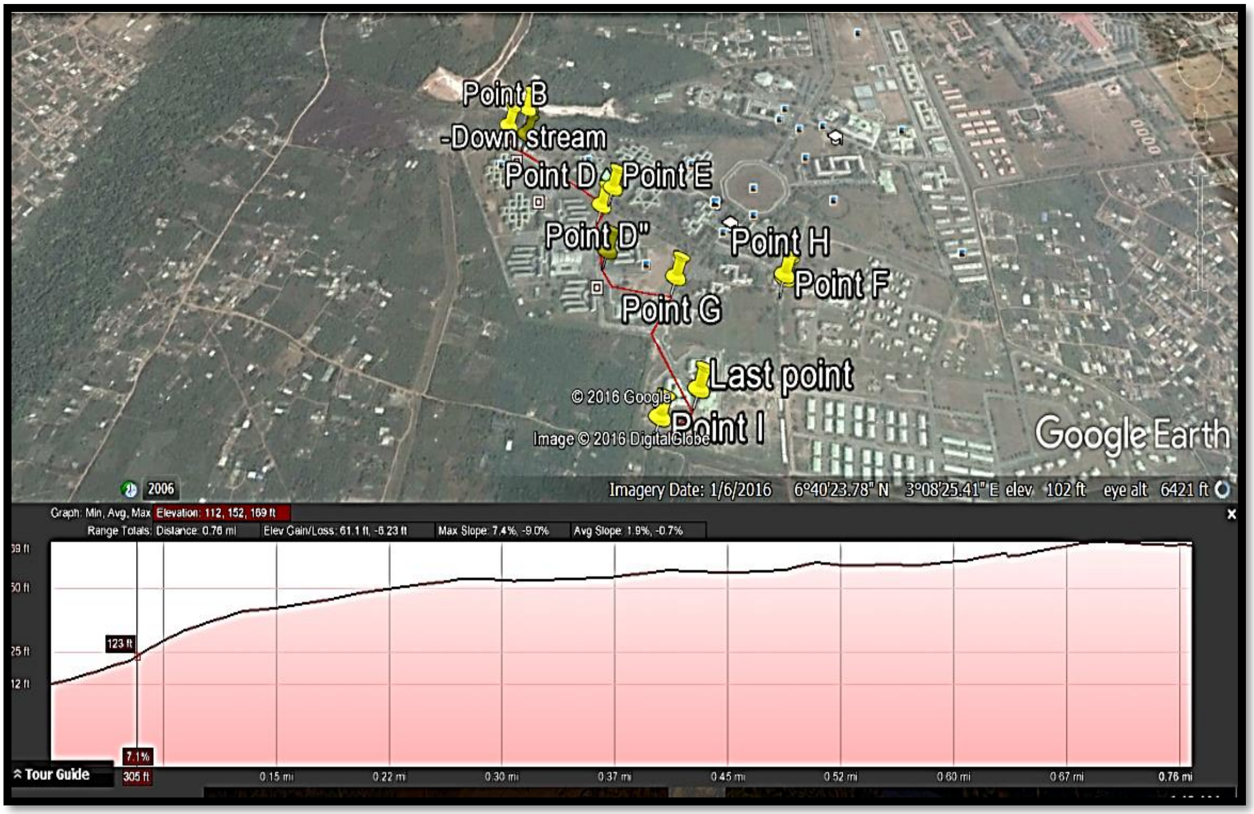


Plate 3: aerial view, coordinate points, and elevation profile of transmission route in Covenant University. Ota.

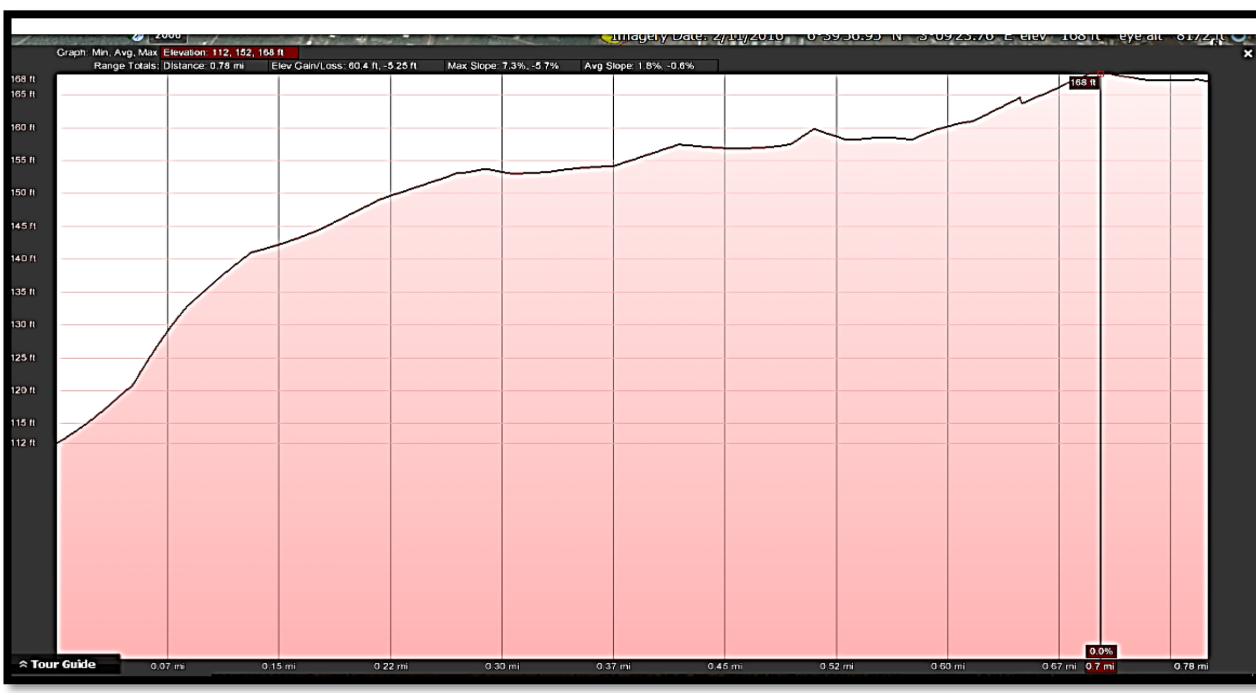


Plate 2: elevation profile from the lowest elevation point to highest elevation point along the transmission route

4.2.2.2 WaterCAD:

The table below shows the result from the software as a result of the input of data inserted on the software, these also shows the summary of materials that best complement the flow path, after the analysis.

Table 4.2: Flow parameters and materials for flow for transmission pipeline

Node Label	Start Node	Stop Node	Diameter (mm)	Material	Hazen Williams C (L/min)	Flow (m/s)	Velocity Gradient (m/s)	Headloss Gradient (m/m)	Length (m)
P-4	J-1	J-2	300.0	Ductile Iron	130.0	184	0.39	0.002	4
P-7	J-4	J-5	300.0	Ductile Iron	130.0	81	0.17	0.000	35
P-5	J-2	J-3	300.0	Ductile Iron	130.0	153	0.32	0.002	60
P-12	T-1	J-8	300.0	Ductile Iron	130.0	0	0.00	0.000	106
P-2	J-16	H-2	300.0	Ductile Iron	130.0	222	0.47	0.003	57
P-11	J-7	T-1	300.0	Ductile Iron	130.0	0	0.00	0.000	159
P-6	J-3	J-4	300.0	Ductile Iron	130.0	119	0.25	0.001	133
P-8	J-5	J-6	300.0	Ductile Iron	130.0	81	0.17	0.000	166
P-3	H-2	J-1	300.0	Ductile Iron	130.0	222	0.47	0.003	294
P-9	J-6	PRV-1	300.0	Ductile Iron	130.0	41	0.09	0.000	80
P-10	PRV-1	J-7	300.0	Ductile Iron	130.0	41	0.09	0.000	80
P-5	R-1	PMP-2	300.0	Concrete	130.0	222	0.02	0.000	29
P-6	PMP-2	J-16	300.0	Ductile Iron	130.0	222	0.02	0.000	54

From the flow information table above, the table give the mode of operation of each segment at which they all have their start and stop node, diameter (mm) of pipe, velocity (m/s), and flow (m/s) respectively in order to enhance their mode of operation effectively.

Plate 4: shows the path of flow, from the lowest elevated point to the highest elevated point, it also indicates details of various key representation on the flow path. Source of flow path was from Google earth, out of the outcome of coordinate’s point gotten from GPS

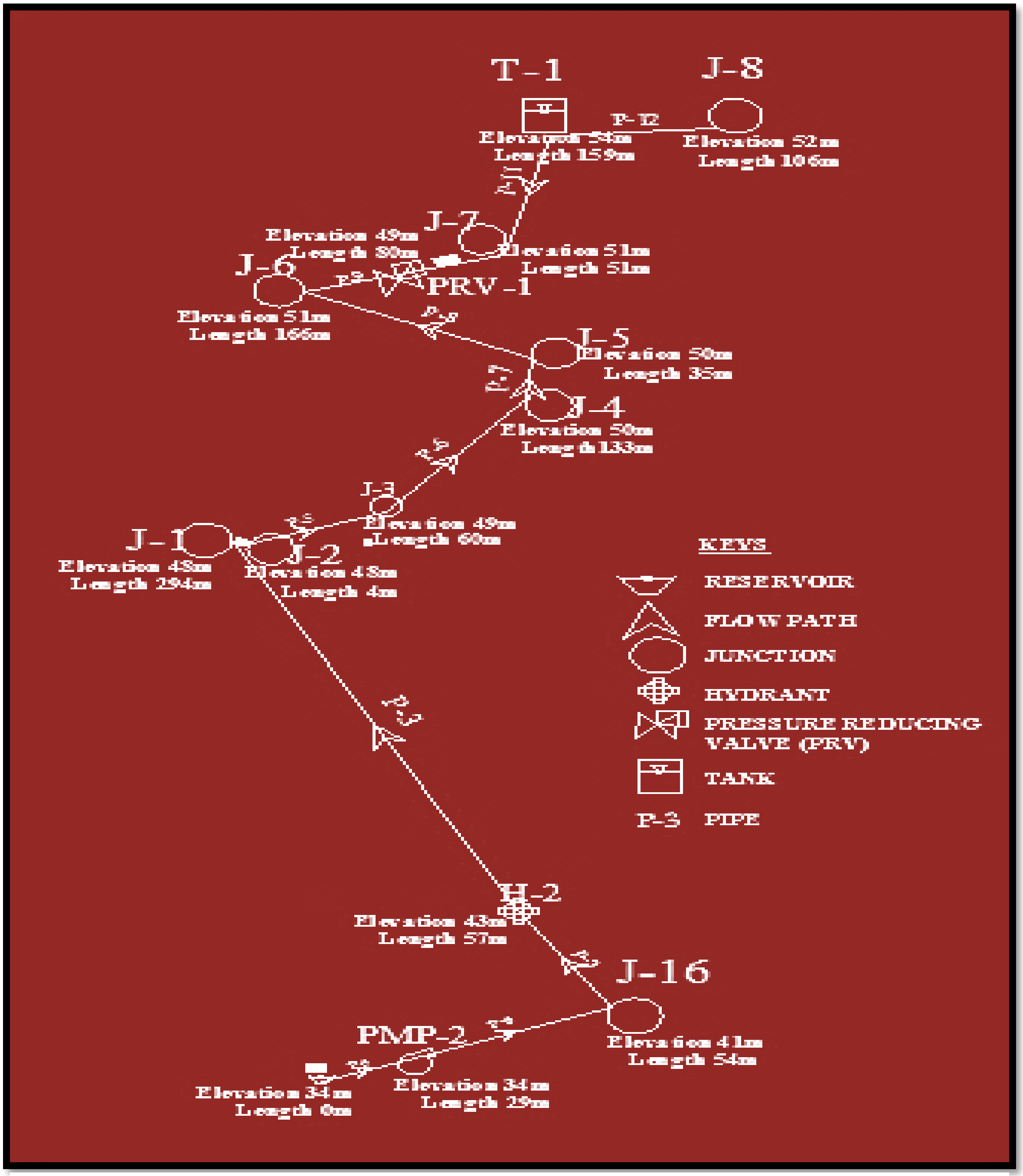


Plate 4: Detail of flow path and key representation on WaterCAD software.

From figure 1, the first graph in blue colour shows the base-hydraulic grade graph, base simply mean all working data, i.e. default data inputted on software, while Hydraulic grade is the sum of the pressure head (p/γ) and elevation head (z). From the graph, the efficiency of pump provides appreciable potential energy (P.E), which enables the flow path of water to rise or move orderly in accordance to the topography of the existing earth surface. I.e. flow path from the intake to the point of reserved. The second graph in yellow color indicate the Base(m) – Elevation (m) graph, which simply shows the various elevation, distance, and their point of location inputted in the software, and these also show the elevation profile.

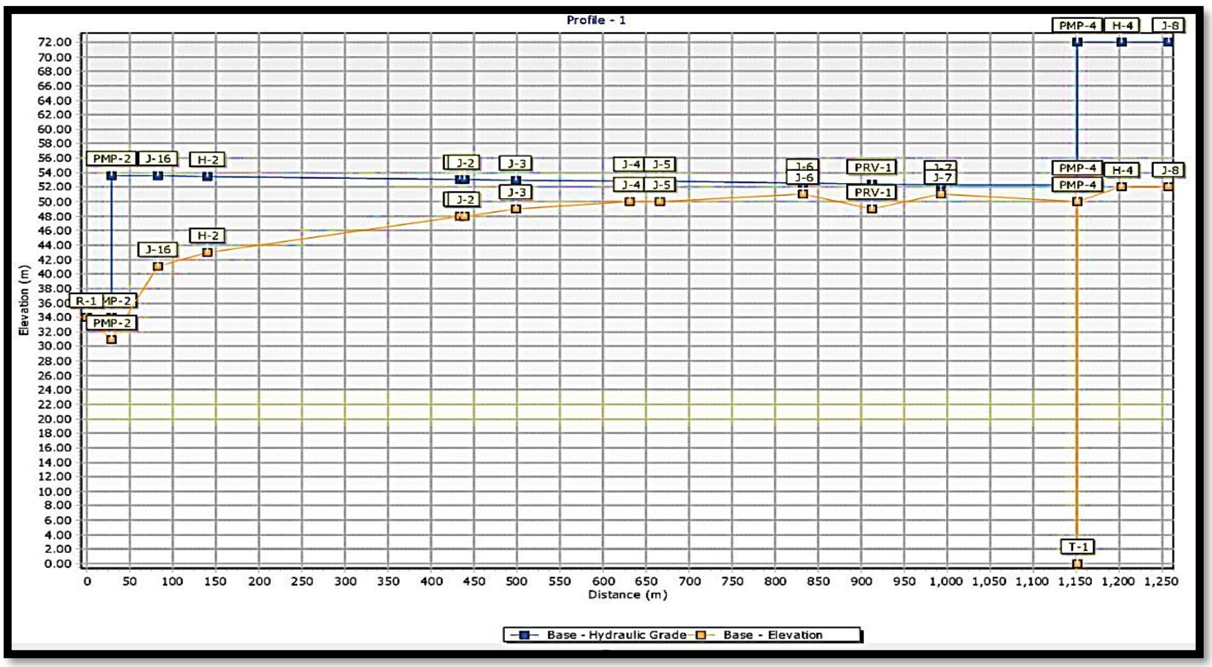


Figure 4.1: Base-Hydraulic grade graph, and Base-Elevation graphs

Figure 2 indicate two graphs which are 1. Base (m) – pressure (Kpa) graph, and 2. base-pressure head, the first graph in purple color shows the implication of pressure from the pump to the flow path, at every location of pump the force in the flow path increase drastically, which further decreases as a matter of distance away from the pump, and it was also observed that the pressure of pump does not have the capability to raise the flow of water to the elevated steel tank, due to the fact that in these case of consideration, pressure flow with distance, but not in height. In that case a new surface pump is required to raise the water to the elevated height of the reservoir.

The second graph in pink color indicate the base (m)-pressure head (m), this shows how pressure head rise and fall of pressure head i.e. immediately after pump location, the pressure head start falling with distance.

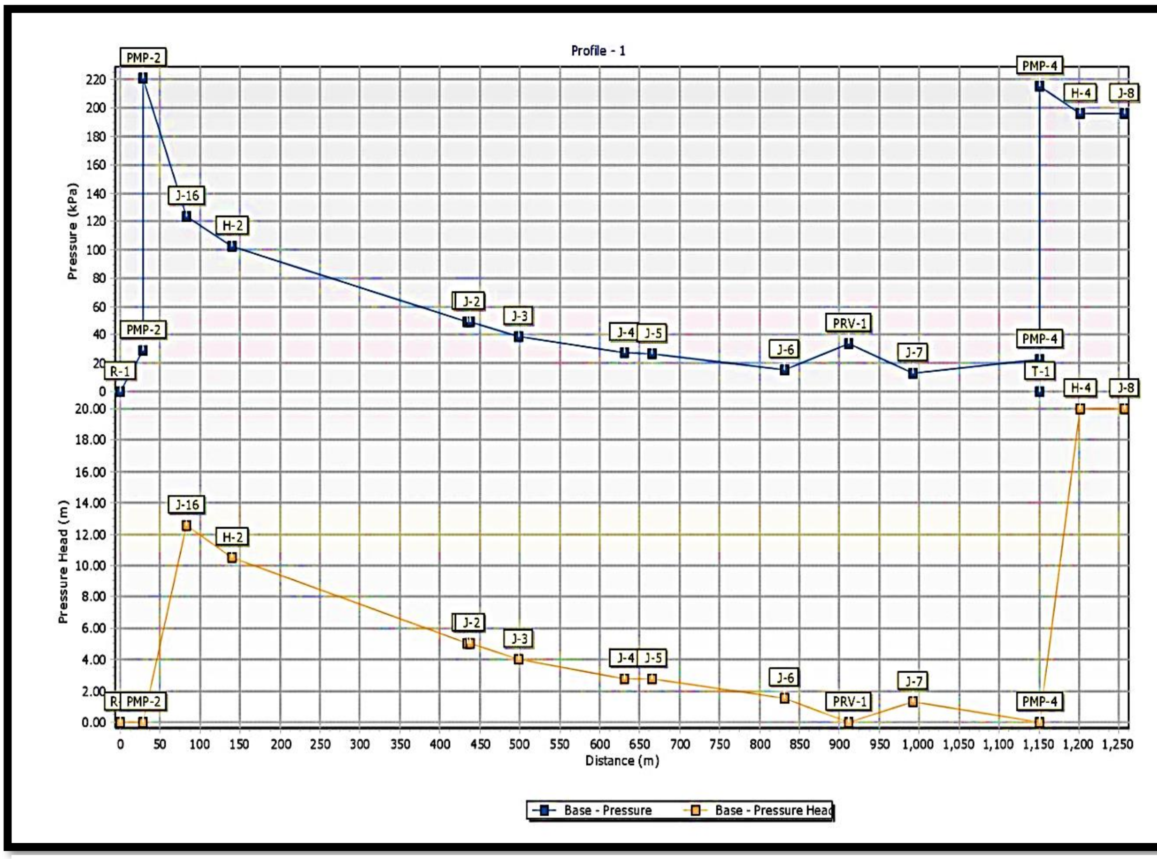


Figure 4.2: Base (m)- pressure (kpa), and Base (m) – pressure head (m) graph

Figure 3, and figure 4 shows the pump curves of the two pump used. In figure 3, the pump definition type was standard of (3 point), it shut off at 0 flow (L/min), the head is 21.00m, while the design at flow of 4,000 (L/min), the head is 19.00m, and the maximum operating flow is 8,500 (L/min), and the Head is 17.00m, and its efficiency is 100%. In figure 4, the pump definition type has the same similarities with the pump in figure 3. Their best efficiency point (BEP) is 51,590 L/min, there coefficient a=21.00m, b=9.743e-004m/(L/min)ˆc, c=0.920.

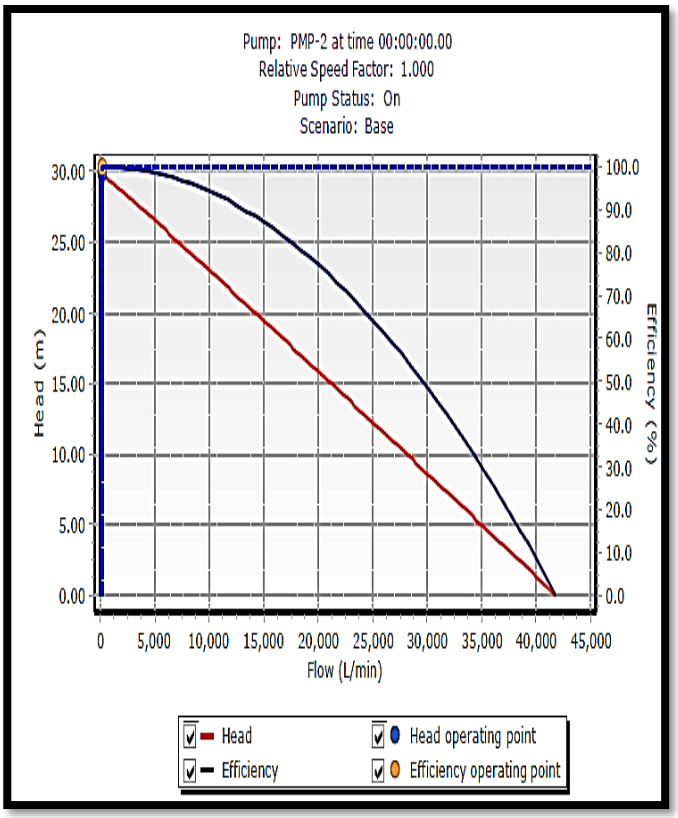


Figure 4.3: Pump curve of the second pump located Very close to the Tank

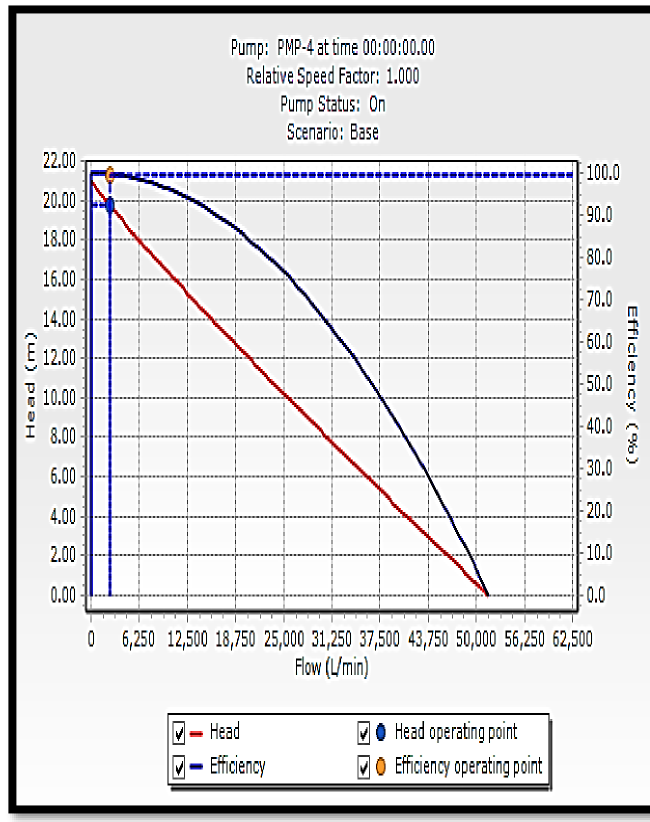


Figure 4.4: Pump curve of the first pump located immediately after the reservoir

4.3 HYDRAULIC STRUCTURE

4.3.1 Software

4.3.1.1 STAAD.Pro V8i (SELECT series 4) and Orion 18 (UNDERGROUND WATER TANK)

From the table 3, it indicates the summary of maximum and minimum shear force, membrane, and bending moment value, gotten after analysis has been performed using the method of finite element method (FEM), which result subsequently used for design, the result were realized as a matter of loads imposed on plate. I.e. load combination such as Dead, load Live load, self-weight of plate, hydrostatic pressure, and both active and passive pressure acting directly on the plate, in 3 dimensions (3D) I.e. X,Y,Z direction

Table 4.3: Summary of maximum, and minimum shear force, membrane, and bending moment on plate element

			Shear force		Membrane			Bending Moment		
	Plate	**L/C**	**SQX (local) N/mm2**	**SQY (local) N/mm2**	**SX (local) N/mm2**	**SY (local) N/mm2**	**SXY (local) N/mm2**	**Mx kNm/m**	**My kNm/m**	**Mxy kNm/m**
Max Qx	**652**	**3 GENERATED BRITISH BS 5950 1**	**4.231**	**9.012**	**-3.311**	**-5.751**	**-0.984**	**1015.573**	**1365.051**	**1160.553**
Min Qx	**643**	**3 GENERATED BRITISH BS 5950 1**	**-4.614**	**8.491**	**-3.72**	**-5.463**	**1.074**	**1117.754**	**1321.65**	**-1138.024**
Max Qy	**652**	**3 GENERATED BRITISH BS 5950 1**	**4.231**	**9.012**	**-3.311**	**-5.751**	**-0.984**	**1015.573**	**1365.051**	**1160.553**
Min Qy	**562**	**3 GENERATED BRITISH BS 5950 1**	**4.219**	**-9.024**	**-3.287**	**-5.764**	**1.021**	**1010.37**	**1368.467**	**-1166.484**
Max Sx	**535**	**3 GENERATED BRITISH BS 5950 1**	**3.434**	**-7.649**	**6.139**	**5.174**	**-1.371**	**-225.583**	**-917.76**	**306.565**
Min Sx	**65**	**3 GENERATED BRITISH BS 5950 1**	**1.353**	**-0.606**	**-17.305**	**4.076**	**4.049**	**318.822**	**65.39**	**-119.383**
Max Sy	**552**	**3 GENERATED BRITISH BS 5950 1**	**-3.623**	**-8.282**	**5.99**	**7.528**	**1.678**	**-246.303**	**-981.361**	**-323.515**
Min Sy	**562**	**3 GENERATED BRITISH BS 5950 1**	**4.219**	**-9.024**	**-3.287**	**-5.764**	**1.021**	**1010.37**	**1368.467**	**-1166.484**
Max Sxy	**75**	**3 GENERATED BRITISH BS 5950 1**	**0.035**	**-0.28**	**0.12**	**-0.925**	**4.126**	**-27.54**	**-5.333**	**-96.426**
Min Sxy	**159**	**3 GENERATED BRITISH BS 5950 1**	**-0.032**	**0.294**	**0.133**	**-0.845**	**-4.193**	**-52.716**	**-4.402**	**85.291**
Max Mx	**667**	**3 GENERATED BRITISH BS 5950 1**	**1.793**	**-0.011**	**0.231**	**0.024**	**0.001**	**1745.886**	**456.901**	**-7.005**
Min Mx	**665**	**3 GENERATED BRITISH BS 5950 1**	**1.792**	**-0.019**	**0.231**	**0.015**	**-0.001**	**-1746.1**	**-456.714**	**6.308**
Max My	**562**	**3 GENERATED BRITISH BS 5950 1**	**4.219**	**-9.024**	**-3.287**	**-5.764**	**1.021**	**1010.37**	**1368.467**	**-1166.484**
Min My	**290**	**3 GENERATED BRITISH BS 5950 1**	**3.594**	**-8.291**	**5.902**	**7.512**	**-1.669**	**-246.292**	**-987.402**	**325.413**
Max Mxy	**652**	**3 GENERATED BRITISH BS 5950 1**	**4.231**	**9.012**	**-3.311**	**-5.751**	**-0.984**	**1015.573**	**1365.051**	**1160.553**
Min Mxy	**562**	**3 GENERATED BRITISH BS 5950 1**	**4.219**	**-9.024**	**-3.287**	**-5.764**	**1.021**	**1010.37**	**1368.467**	**-1166.484**

Table 4 shows the summary of maximum, and minimum of principal plane (Angle), Von Mises stress, and Tresca. Each indicates stresses on both top and bottom of each plate element, the determination of stresses acting on each plate were gotten from load combination acting on each plate elements, subsequently analysis was performed using Finite Element Method (FEM).

Table 4.4: Summary of maximum and minimum stresses of principal axis, Von Mises and Tresca

			Principal		Von Mis		Tresca	
	Plate	L/C	Top N/mm2	Bottom N/mm2	Top N/mm2	Bottom N/mm2	Top N/mm2	Bottom N/mm2
Max Principal (top)	562	3 GENERATED BRITISH BS 5950 1	51.168	-3.127	52.801	60.922	54.295	62.611
Min Principal (top)	665	3 GENERATED BRITISH BS 5950 1	-10.945	-41.676	37.424	37.863	41.676	42.138
Max Principal (bottom)	667	3 GENERATED BRITISH BS 5950 1	42.133	10.989	37.855	37.42	42.133	41.671
Min Principal (bottom)	290	3 GENERATED BRITISH BS 5950 1	-1.046	-45.966	45.452	58.061	45.966	62.791
Max Von Mis (Top)	562	3 GENERATED BRITISH BS 5950 1	51.168	-3.127	52.801	60.922	54.295	62.611
Min Von Mis (top)	669	2 LIVE LOAD	-0.058	-0.129	0.112	0.14	0.129	0.159
Max Von Mis (Bottom)	562	3 GENERATED BRITISH BS 5950 1	51.168	-3.127	52.801	60.922	54.295	62.611
Min Von Mis (bottom)	670	2 LIVE LOAD	0.085	-0.128	0.186	0.069	0.213	0.074
Max Tresca (top)	562	3 GENERATED BRITISH BS 5950 1	51.168	-3.127	52.801	60.922	54.295	62.611
Min Tresca (top)	669	2 LIVE LOAD	-0.058	-0.129	0.112	0.14	0.129	0.159
Max Tresca (bottom)	290	3 GENERATED BRITISH BS 5950 1	-1.046	-45.966	45.452	58.061	45.966	62.791
Min Tresca (bottom)	670	2 LIVE LOAD	0.085	-0.128	0.186	0.069	0.213	0.074

Plate 5 indicate the Hydrostatic pressure acting directly toward the wall in green color, and the blue color represent the weight of water acting on the base of the underground water tank. The light green indicate the cantilever retaining wall.

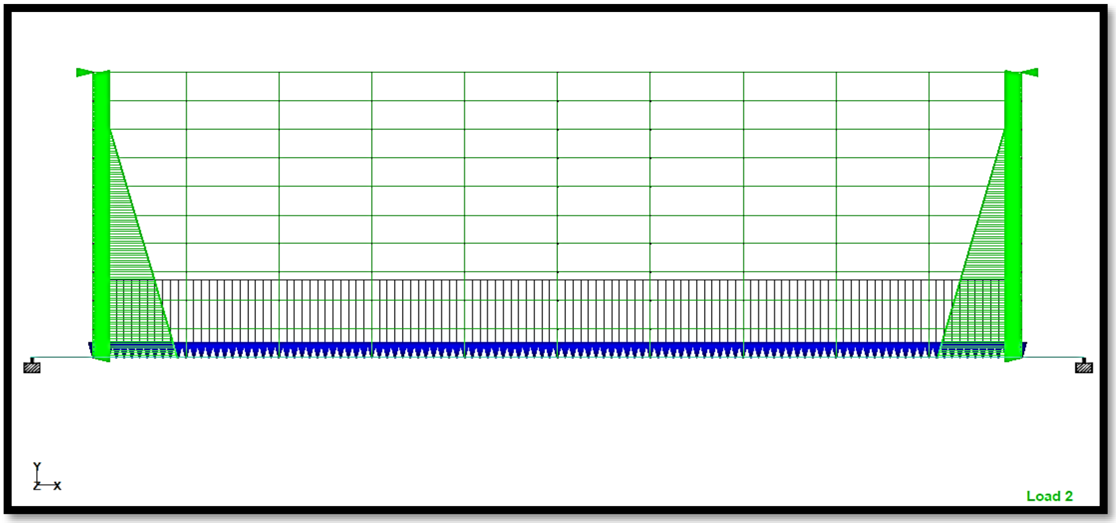


Plate 5: Hydrostatic pressure acting internally in the underground water tank

Plate 6: indicate the Active and Passive pressure diagram in green color, acting externally toward the retaining wall.

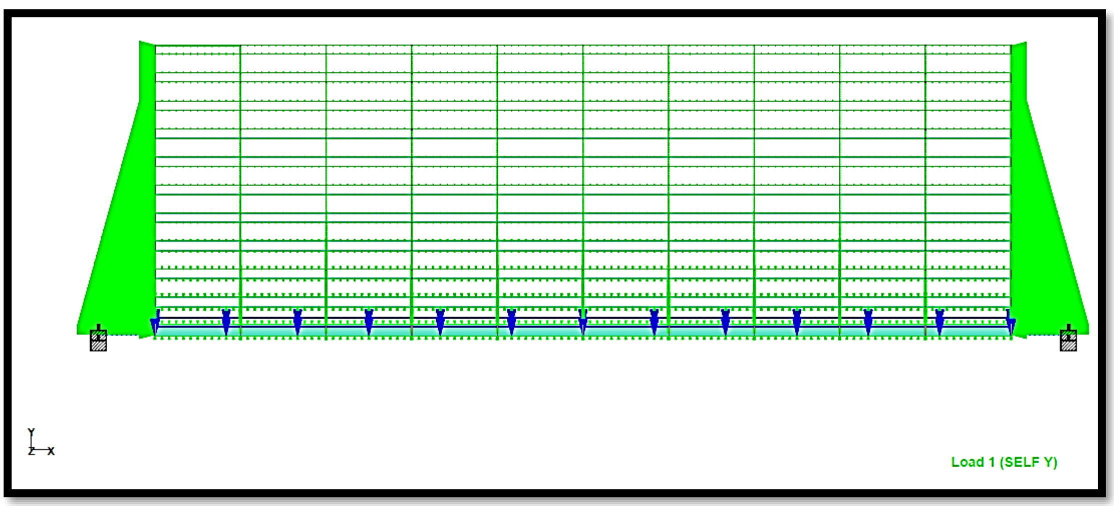


Plate 6: Active and Passive pressure acting externally to the wall

Plate 7 shows the modelling of the underground water tank, while plate 8 also shows the modelling, internal columns and beams of the underground water tank.

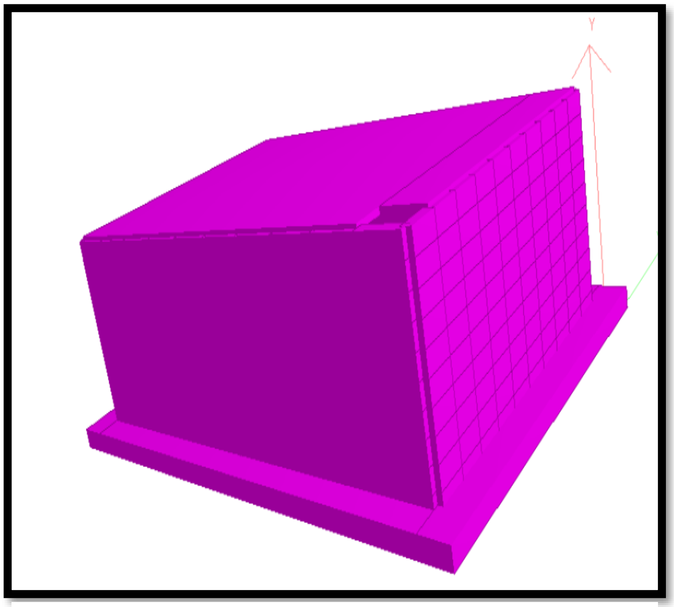


Plate 7: 3D View of underground water tank modelling

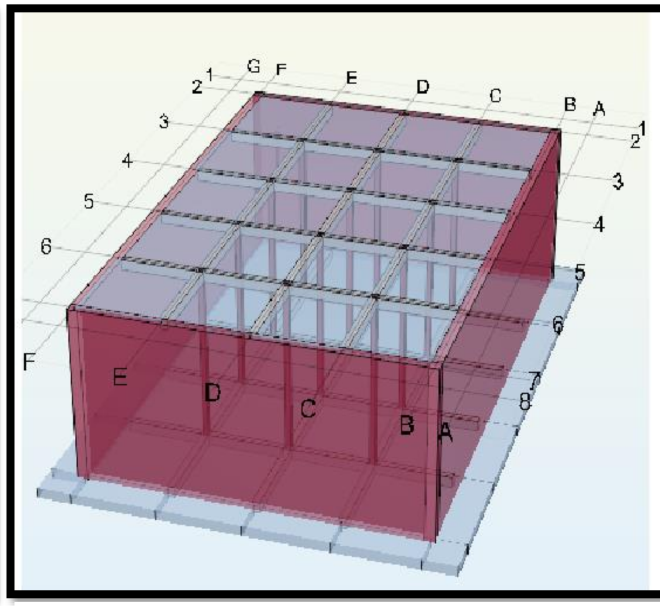


Plate 8: 3D View of both internal columns, and beams

Figure 4 shows the load diagram, shear force, and bending moment diagram for the internal beams of the underground water tank. Figure 5 indicate the column design and details information.

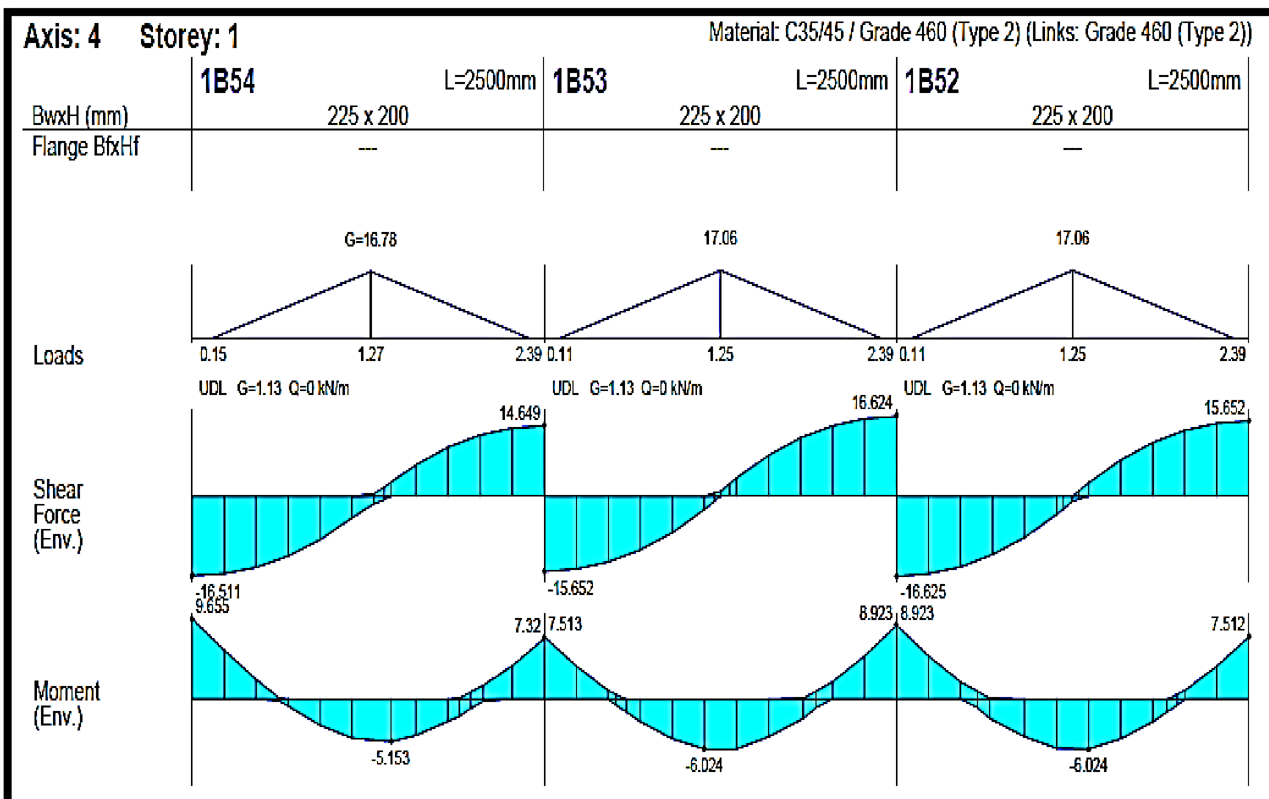
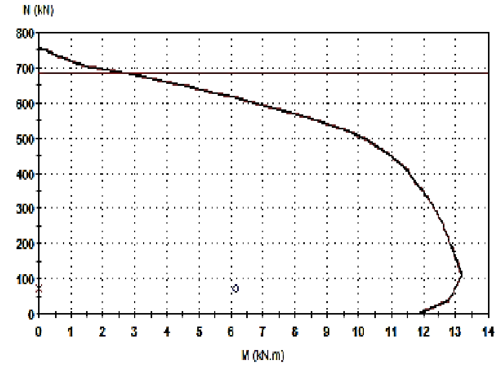


Figure 4.5: Shear force and bending moment diagram

1C1 Storey: 1 (Con.:C35/45 / Steel:Grade 460 (Type 2))

Loadings (Combination):

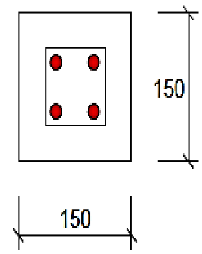
No	N (Bot)	M1 (Bot)	M2 (Bot)	N (Top)	M1 (Top)	M2 (Top)
1	72.0	-0.1	0.1	72.0	0.1	-0.2
2	72.0	-0.1	0.1	72.0	0.1	-0.2
3	72.0	-0.1	0.1	72.0	0.1	-0.2
4	72.0	-0.1	0.1	72.0	0.1	-0.2
5	72.0	-0.1	0.1	72.0	0.1	-0.2
6	72.0	-0.1	0.1	72.0	0.1	-0.2
7	72.0	-0.1	0.1	72.0	0.1	-0.2
8	72.0	-0.1	0.1	72.0	0.1	-0.2
9	72.0	-0.1	0.1	72.0	0.1	-0.2
10	72.0	-0.1	0.1	72.0	0.1	-0.2
11	72.0	-0.1	0.1	72.0	0.1	-0.2
12	61.7	0.0	0.1	61.7	0.1	-0.1
13	61.7	0.0	0.1	61.7	0.1	-0.1
14	61.7	0.0	0.1	61.7	0.1	-0.1
15	61.7	0.0	0.1	61.7	0.1	-0.1



Critical Combination:1 - (G+Q *F)

		Min	Design
N (kN)	72.0	-	72.0
M1 (kN.m)	0.1	0.5	0.0
M2 (kN.m)	-0.2	-0.5	-6.1
N-max (kN)	0.0		

Concrete Cover =30.0 mm



BS8110-Cl.3.8.4.5
N/bhFcu = 0.071
Beta = 0.91

Slender Column...
Le1/b1 = 24.1 > 15.0 !!!
Le2/b2 = 24.1 > 15.0 !!!
M-add(1/2)= 3.1 / 3.1 kN.m

Vd(1/2)= 0.0 / 0.0 kN
vc'(1/2)= 1.50 / 1.50 N/mm2
v (1/2)= 0.00 / 0.00 N/mm2

As (Required): %0.42 95.60 mm2
As (Provided): %3.57 804.25 mm2

4T16

Links = T12-175

Figure 4.6: Underground water tank internal column design details

4.3.1.2 STAAD.Pro V8i (SELECTseries 4) (ELEVATED WATER STEEL TANK)

Table 5 indicates the summary of the reactions on each supports of the stanchion, the selected support is fixed supports, it also indicates the maximum and minimum forces, and moment at X, Y, Z. direction.

Table 4.5: Summary of reactions acting on support

			Horizontal	Vertical	Horizontal	Moment		
	Node	**L/C**	**Fx kN**	**Fy kN**	**Fz kN**	**Mx kNm**	**My kNm**	**Mz kNm**
Max Fx	**7**	**4 GENERATED BRITISH BS 5950 1**	**16.474**	**218.2**	**17.279**	**0.986**	**0.005**	**-0.633**
Min Fx	**9**	**4 GENERATED BRITISH BS 5950 1**	**-13.957**	**173.8**	**12.419**	**0.834**	**- 0.001**	**0.528**
Max Fy	**7**	**4 GENERATED BRITISH BS 5950 1**	**16.474**	**218.2**	**17.279**	**0.986**	**0.005**	**-0.633**
Min Fy	**1**	**3 WIND LOAD**	**-6.78**	**-17.5**	**9.253**	**0.538**	**- 0.005**	**0.073**
Max Fz	**7**	**4 GENERATED BRITISH BS 5950 1**	**16.474**	**218.2**	**17.279**	**0.986**	**0.005**	**-0.633**
Min Fz	**1**	**4 GENERATED BRITISH BS 5950 1**	**12.881**	**185**	**-14.728**	**-0.712**	**- 0.007**	**-0.542**
Max Mx	**729**	**5 GENERATED BRITISH BS 5950 2**	**0.286**	**32.95**	**0.883**	**1.093**	**0**	**-0.124**
Min Mx	**3**	**4 GENERATED BRITISH BS 5950 1**	**-13.189**	**143.6**	**-12.664**	**-0.775**	**0.001**	**0.71**
Max My	**2**	**6 GENERATED BRITISH BS 5950 3**	**-2.274**	**115.3**	**14.516**	**0.53**	**0.019**	**0.019**
Min My	**1**	**5 GENERATED BRITISH BS 5950 2**	**-3.764**	**52.58**	**6.755**	**0.664**	**- 0.015**	**0.12**
Max Mz	**3**	**4 GENERATED BRITISH BS 5950 1**	**-13.189**	**143.6**	**-12.664**	**-0.775**	**0.001**	**0.71**
Min Mz	**4**	**4 GENERATED BRITISH BS 5950 1**	**15.714**	**207.3**	**0.226**	**0.127**	**- 0.006**	**-0.642**

Table 4.6: summary of maximum and minimum Beam end force

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	296	4 GENERATED BRITISH BS 5950 1	68	327.05	0.026	0.024	0	0.026	-0.023
Min Fx	258	4 GENERATED BRITISH BS 5950 1	58	-43.49	0.665	-0.006	0	0.008	1.237
Max Fy	304	4 GENERATED BRITISH BS 5950 1	113	-30.09	186.102	0.01	0	0.003	19.07
Min Fy	334	4 GENERATED BRITISH BS 5950 1	76	-30.05	-186.29	-0.01	0	0.003	19.09
Max Fz	454	4 GENERATED BRITISH BS 5950 1	120	12.741	0.001	8.352	0	-3.491	0
Min Fz	459	4 GENERATED BRITISH BS 5950 1	125	12.719	0.011	-8.368	0	3.497	0.002
Max Mx	661	4 GENERATED BRITISH BS 5950 1	252	-20.5	12.484	0.054	0.155	-0.006	2.326
Min Mx	302	4 GENERATED BRITISH BS 5950 1	65	-19.94	-12.484	-0.054	-0.155	0.023	-3.881
Max My	459	4 GENERATED BRITISH BS 5950 1	125	12.719	0.011	-8.368	0	3.497	0.002
Min My	454	4 GENERATED BRITISH BS 5950 1	120	12.741	0.001	8.352	0	-3.491	0
Max Mz	334	4 GENERATED BRITISH BS 5950 1	71	-30.05	-186.19	-0.01	0	-0.002	112.2
Min Mz	352	4 GENERATED BRITISH BS 5950 1	86	-30.3	-10.414	0.016	0	-0.004	-40.91

Table 4.7: maximum and minimum support displacement

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	rY rad	rZ rad
Max X	**679**	**4 GENERATED BRITISH BS 5950 1**	**548.41**	**-2.424**	**-0.722**	**548.416**	**0**	**0**	**0.03**
Min X	**589**	**4 GENERATED BRITISH BS 5950 1**	**-550.482**	**-2.796**	**-0.776**	**550.49**	**0**	**0**	**-0.03**
Max Y	**220**	**3 WIND LOAD**	**-0.014**	**0.105**	**-0.556**	**0.566**	**0**	**0**	**0**
Min Y	**833**	**4 GENERATED BRITISH BS 5950 1**	**-1.217**	**-221.97**	**-0.887**	**221.979**	**0**	**0**	**0**
Max Z	**490**	**4 GENERATED BRITISH BS 5950 1**	**-1.061**	**-2.449**	**551.193**	**551.199**	**-0.031**	**0**	**0**
Min Z	**382**	**4 GENERATED BRITISH BS 5950 1**	**-1**	**-2.726**	**-552.691**	**552.698**	**0.031**	**0**	**0**
Max rX	**457**	**4 GENERATED BRITISH BS 5950 1**	**-0.948**	**-2.438**	**275.185**	**275.198**	**0.369**	**0**	**0**
Min rX	**349**	**4 GENERATED BRITISH BS 5950 1**	**-0.889**	**-2.713**	**-276.516**	**276.531**	**-0.37**	**0**	**0**
Max rY	**379**	**4 GENERATED BRITISH BS 5950 1**	**-1.038**	**-2.835**	**-243.64**	**243.658**	**0.021**	**0.349**	**0**
Min rY	**385**	**4 GENERATED BRITISH BS 5950 1**	**-0.961**	**-2.614**	**-243.61**	**243.626**	**0.021**	**-0.349**	**0**
Max rZ	**562**	**4 GENERATED BRITISH BS 5950 1**	**-274.043**	**-2.784**	**-0.693**	**274.058**	**0**	**0**	**0.368**
Min rZ	**652**	**4 GENERATED BRITISH BS 5950 1**	**272.204**	**-2.413**	**-0.638**	**272.216**	**0**	**0**	**-0.368**
Max Rst	**382**	**4 GENERATED BRITISH BS 5950 1**	**-1**	**-2.726**	**-552.691**	**552.698**	**0.031**	**0**	**0**

Table 4.8: Maximum and minimum end beam displacement

			Shear		Membrane			Bending Moment		
	Plate	L/C	SQX (local) N/mm2	SQY (local) N/mm2	SX (local) N/mm2	SY (local) N/mm2	SXY (local) N/mm2	Mx kNm/m	My kNm/m	Mxy kNm/m
Max Qx	1037	4 GENERATED BRITISH BS 5950 1	5.352	0.131	6.413	0.858	-0.641	35.53	9.62	-0.14
Min Qx	900	4 GENERATED BRITISH BS 5950 1	-5.352	0.131	6.413	0.528	0.639	35.53	9.62	0.14
Max Qy	1110	4 GENERATED BRITISH BS 5950 1	0.504	6.899	2.884	-6.562	-6.436	-10.9	-40	0.91
Min Qy	983	4 GENERATED BRITISH BS 5950 1	0.651	-6.956	3.583	4.996	-4.919	10.91	40.1	0.8
Max Sx	898	4 GENERATED BRITISH BS 5950 1	5.344	1.104	6.473	-0.095	-0.389	32.43	8.54	-1.88
Min Sx	979	4 GENERATED BRITISH BS 5950 1	0.814	0.925	-3.132	-9.293	-4.374	4.204	4.07	2.4
Max Sy	1221	4 GENERATED BRITISH BS 5950 1	2.27	4.848	4.073	7.782	0.451	-6.9	-26	4.09
Min Sy	1214	4 GENERATED BRITISH BS 5950 1	-0.878	-0.87	-0.012	-12.685	-6.385	-4.3	-4.3	-2.22
Max Sxy	1109	4 GENERATED BRITISH BS 5950 1	-0.504	6.898	2.94	-6.527	6.396	-10.9	-40	-0.91
Min Sxy	1110	4 GENERATED BRITISH BS 5950 1	0.504	6.899	2.884	-6.562	-6.436	-10.9	-40	0.91
Max Mx	900	4 GENERATED BRITISH BS 5950 1	-5.352	0.131	6.413	0.528	0.639	35.53	9.62	0.14
Min Mx	1145	4 GENERATED BRITISH BS 5950 1	5.347	-0.128	6.216	0.901	-0.963	-35.6	-9.6	-0.18
Max My	856	4 GENERATED BRITISH BS 5950 1	0.651	-6.956	3.602	4.511	-4.706	10.91	40.1	0.8
Min My	1110	4 GENERATED BRITISH BS 5950 1	0.504	6.899	2.884	-6.562	-6.436	-10.9	-40	0.91
Max Mxy	992	4 GENERATED BRITISH BS 5950 1	-1.269	-1.128	0.986	-2.312	-2.325	1.206	0.51	9.95
Min Mxy	872	4 GENERATED BRITISH BS 5950 1	1.269	-1.128	1.276	-1.868	1.96	1.205	0.51	-9.95

Table 4.9: maximum and minimum values of shear force, membrane, and bending moment of plate element of the reservoir

				Horizontal	Vertical	Horizontal	Resultant
	Beam	L/C	Node	X mm	Y mm	Z mm	Resultant mm
Max X	501	3 WIND LOAD	167	0.208	0.011	-0.6	0.635
Min X	514	4 GENERATED BRITISH BS 5950 1	180	-1.482	-1.828	-0.611	2.431
Max Y	599	3 WIND LOAD	220	-0.014	0.105	-0.556	0.566
Min Y	564	4 GENERATED BRITISH BS 5950 1	199	-0.833	-5.17	-0.681	5.281
Max Z	621	4 GENERATED BRITISH BS 5950 1	234	-0.993	-4.68	2.078	5.216
Min Z	566	4 GENERATED BRITISH BS 5950 1	201	-0.783	-5.161	-3.365	6.21
Max Rst	566	4 GENERATED BRITISH BS 5950 1	201	-0.783	-5.161	-3.365	6.21

Table 4.10: maximum and minimum values of principal axis, Von Mises, and Tresca on plate element of the reservoir

			Principal		Von Mis		Tresca	
	Plate	L/C	Top N/mm2	Bottom N/mm2	Top N/mm2	Bottom N/mm2	Top N/mm2	Bottom N/mm2
Max Principal (top)	984	4 GENERATED BRITISH BS 5950 1	1073.88	294.137	961.184	953.995	1073.88	1064.37
Min Principal (top)	904	4 GENERATED BRITISH BS 5950 1	-629.825	-656.01	643.314	646.599	656.005	663.027
Max Principal (bottom)	1259	4 GENERATED BRITISH BS 5950 1	661.231	628.175	645.338	641.099	661.231	654.16
Min Principal (bottom)	1110	4 GENERATED BRITISH BS 5950 1	-286.433	-1076.6	965.778	952.63	1076.59	1064.29
Max Von Mis (Top)	1110	4 GENERATED BRITISH BS 5950 1	-286.433	-1076.6	965.778	952.63	1076.59	1064.29
Min Von Mis (top)	960	3 WIND LOAD	-0.001	-0.004	0.003	0.01	0.004	0.012
Max Von Mis (Bottom)	856	4 GENERATED BRITISH BS 5950 1	1073.39	294.097	960.714	954.477	1073.39	1064.88
Min Von Mis (bottom)	1186	3 WIND LOAD	0.005	-0.003	0.007	0.003	0.008	0.004
Max Tresca (top)	1110	4 GENERATED BRITISH BS 5950 1	-286.433	-1076.6	965.778	952.63	1076.59	1064.29
Min Tresca (top)	960	3 WIND LOAD	-0.001	-0.004	0.003	0.01	0.004	0.012
Max Tresca (bottom)	857	4 GENERATED BRITISH BS 5950 1	1073.36	294.045	960.702	954.477	1073.36	1064.9
Min Tresca (bottom)	1186	3 WIND LOAD	0.005	-0.003	0.007	0.003	0.008	0.004

Plate 9 and 10 indicate the modelling of elevated steel tank of 17.5 m high stanchion, and 5m x 5m x 5m reserviour seated on the stanchion. The plate 9 indicate the principal minor stress as a result of hydrostatic pressure acting on the plate element, the plate stress were from the analysis of principal axis, Von Mises, and Tresca. While plate 10 shows the principal minor stress acting in the reservoir.

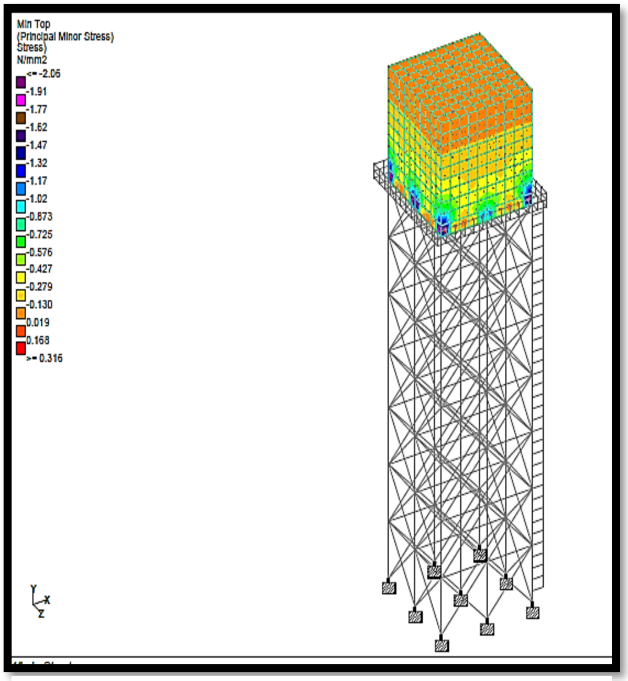


Plate 10: Steel tank modelling and principal minor stress

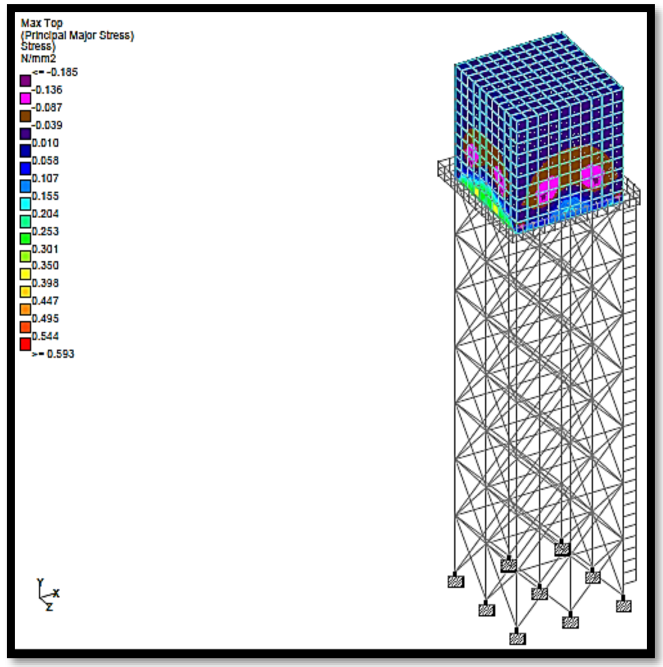


Plate 9: Steel tank modelling and principal minor stress

Plate 10 shows the wind load acting in four directions of the elevated steel tank, at the speed of 55m/sec, while plate 11 indicate the beam stress on each member as a result of loads imposed on the structure.

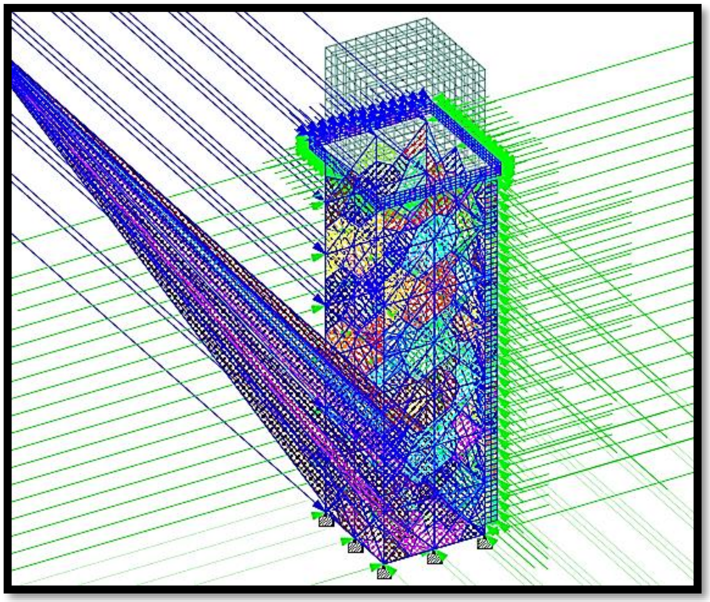


Plate 11: Wind load in action acting in four direction of the elevated tank

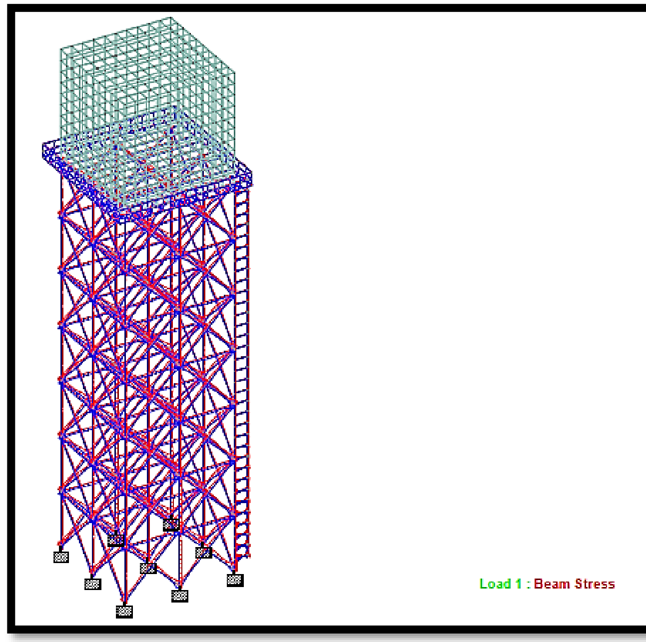


Plate 12: Stress acting on beam

The plates below shows the detailing for the underground water tank. Plate 13 indicate the detailing of the sectional view of shear wall, while plate 14 shows the detaining of the underground top slab, and plate 15 shows the underground detaining of the base slab, plate 16 shows the detailing of the plan view of both the shear wall and column, while plate 17 indicate the detailing of hidden beam,

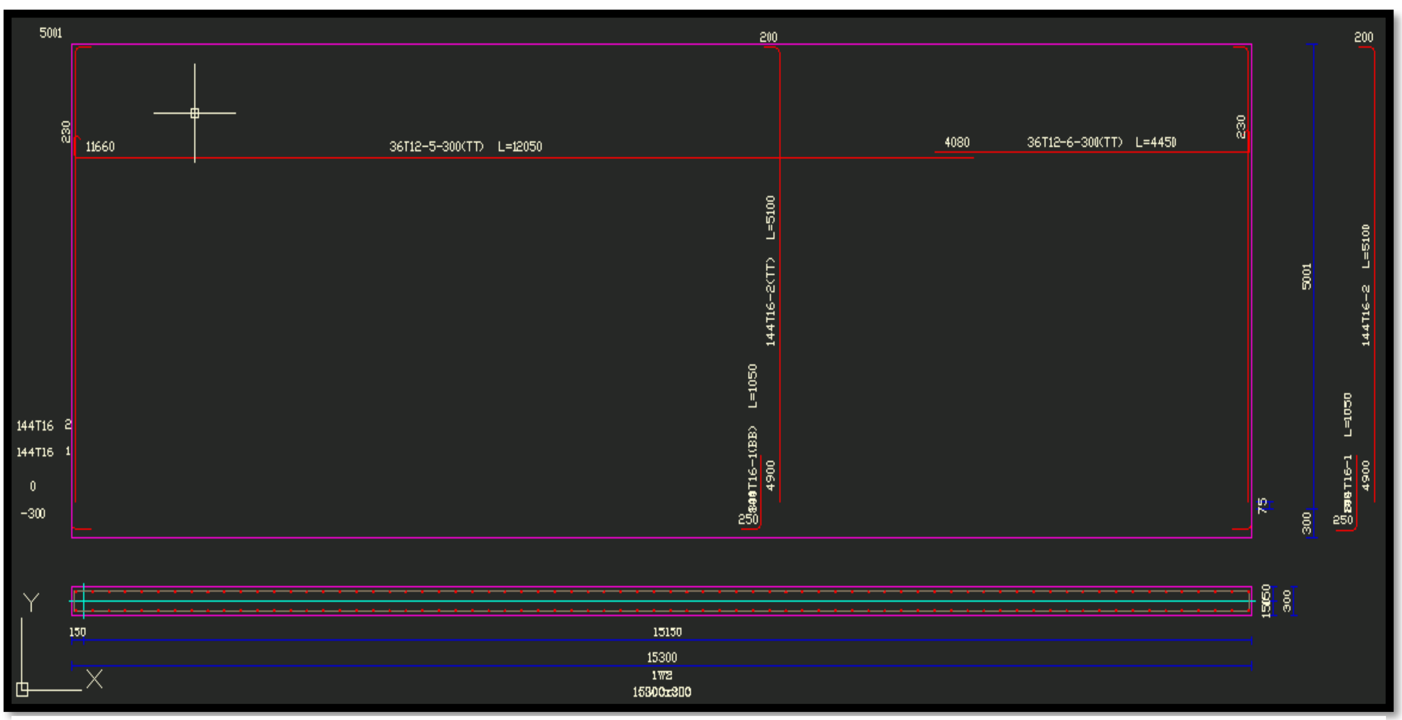


Plate 13: Sectional view of wall detailing

plate 18 indicate the sectional view of the internal column, and plate 19 shows the detailing of elevated steel water tank.

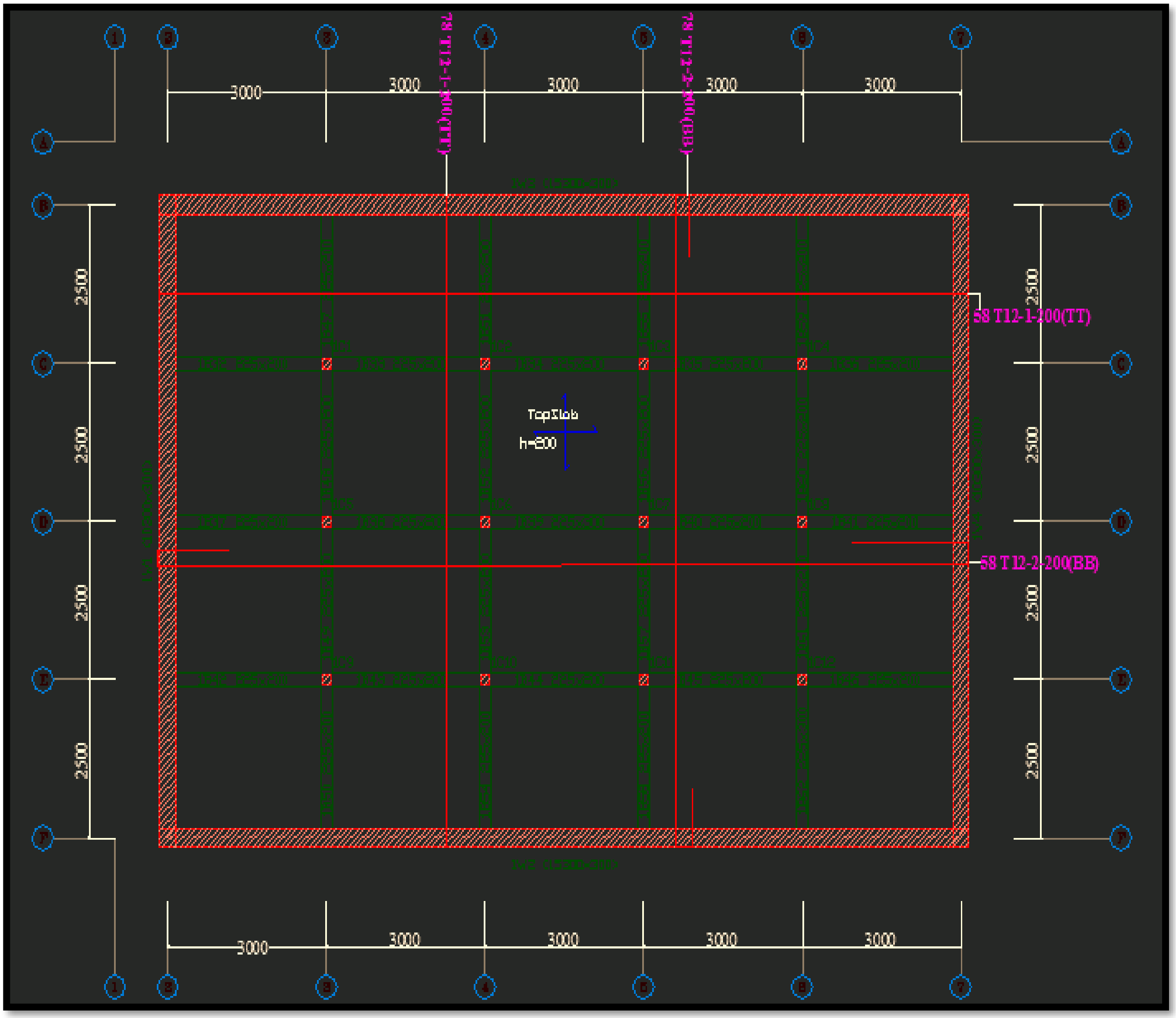


Plate 14: Top slab detailing

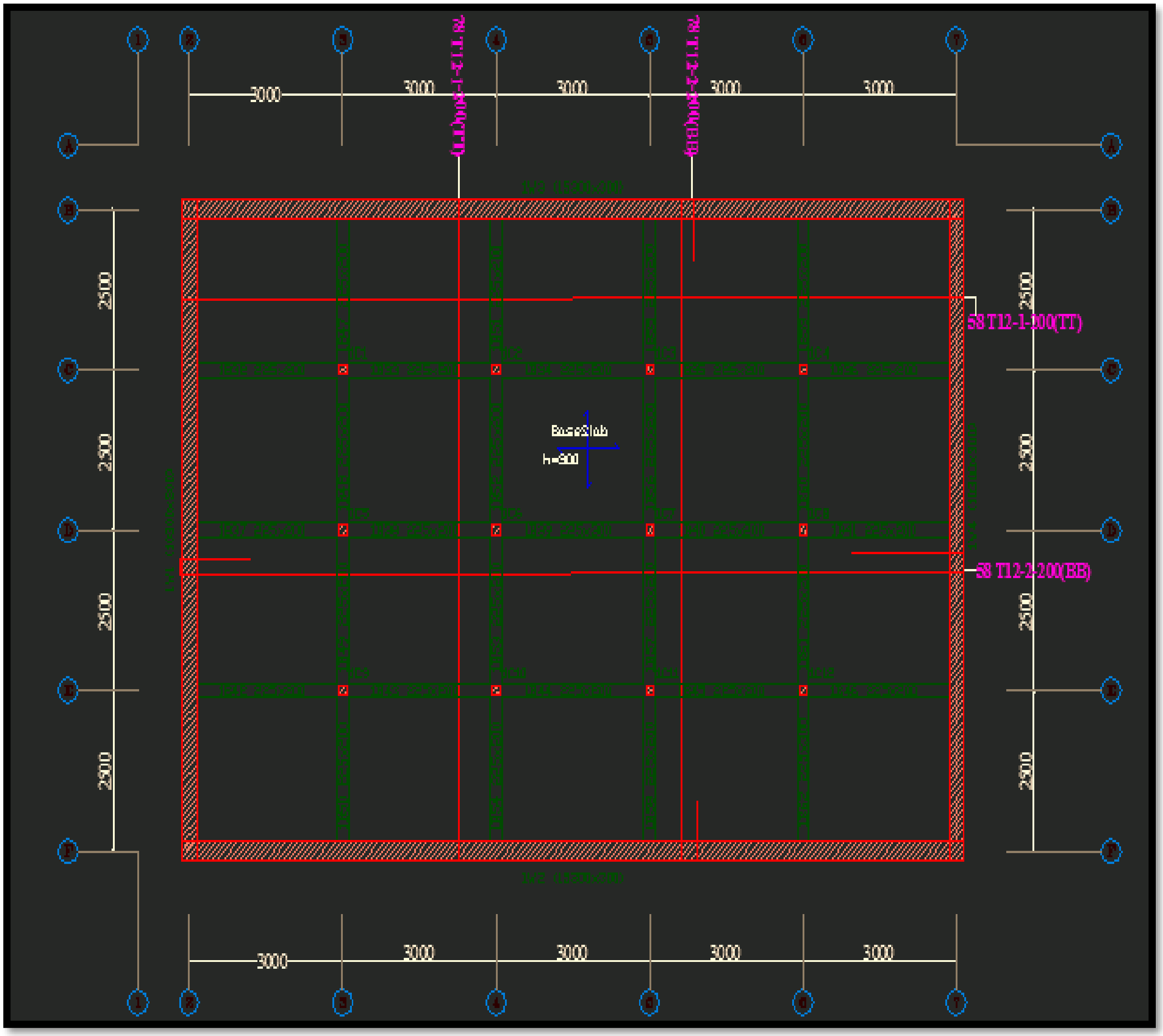


Plate 15: Base Slab detailing

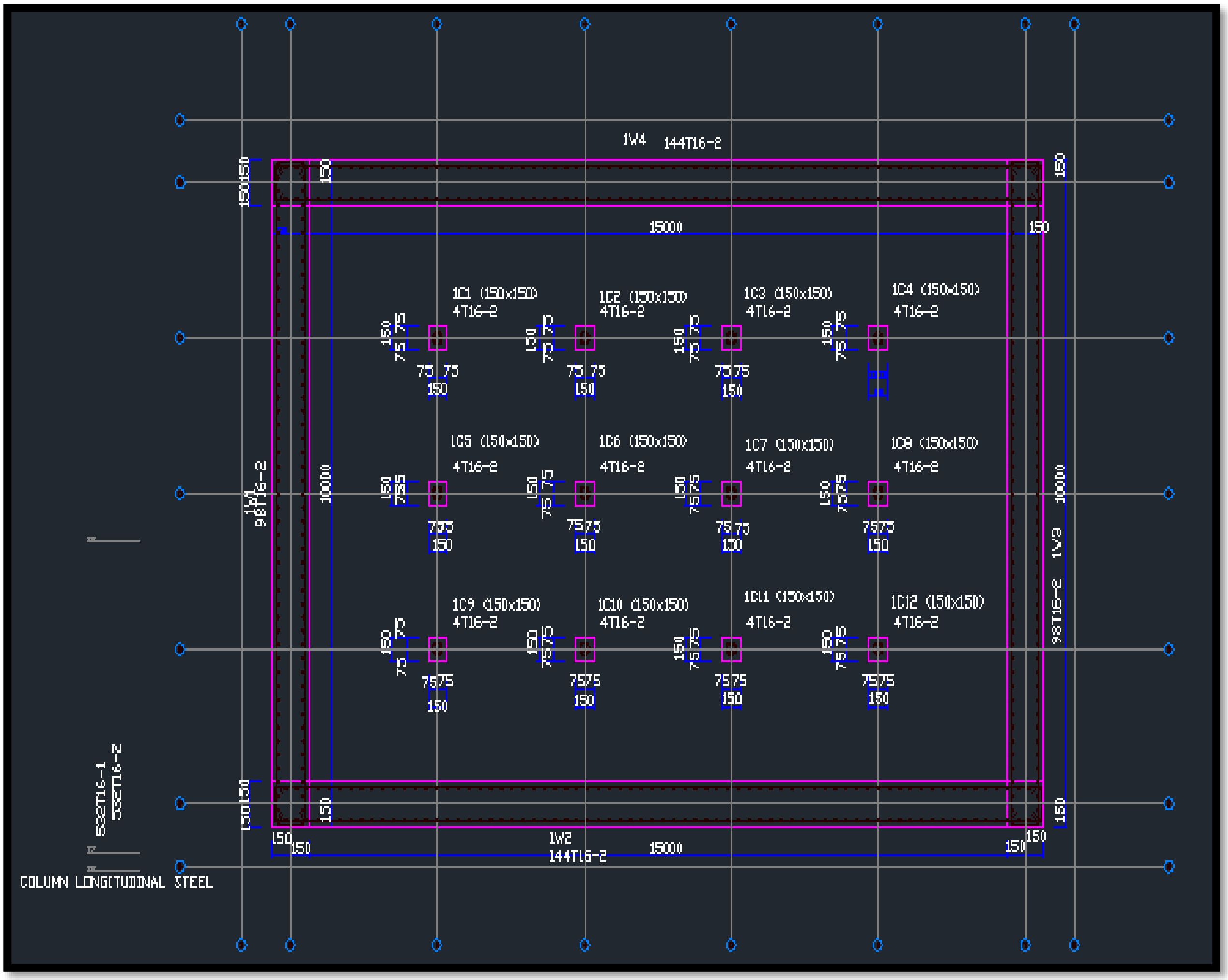


Plate 16: Plan view of wall, and column detailing

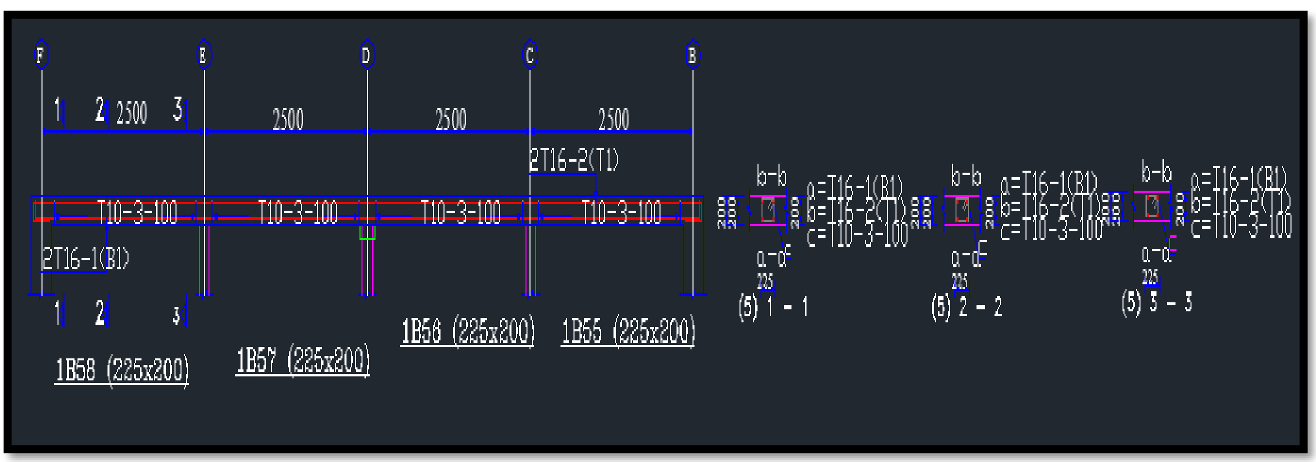


Plate 17: Detailing of hidden beam

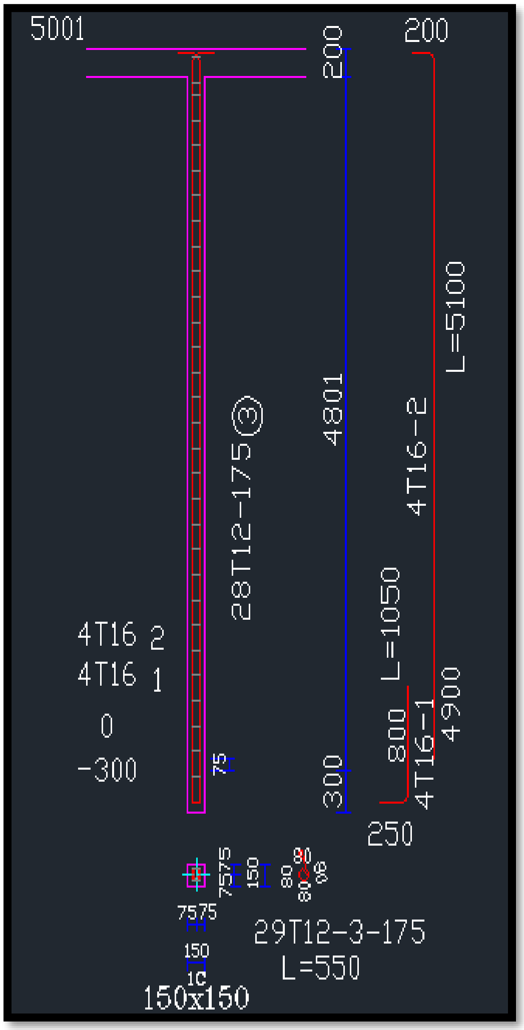


Plate 19: Sectional view of internal column

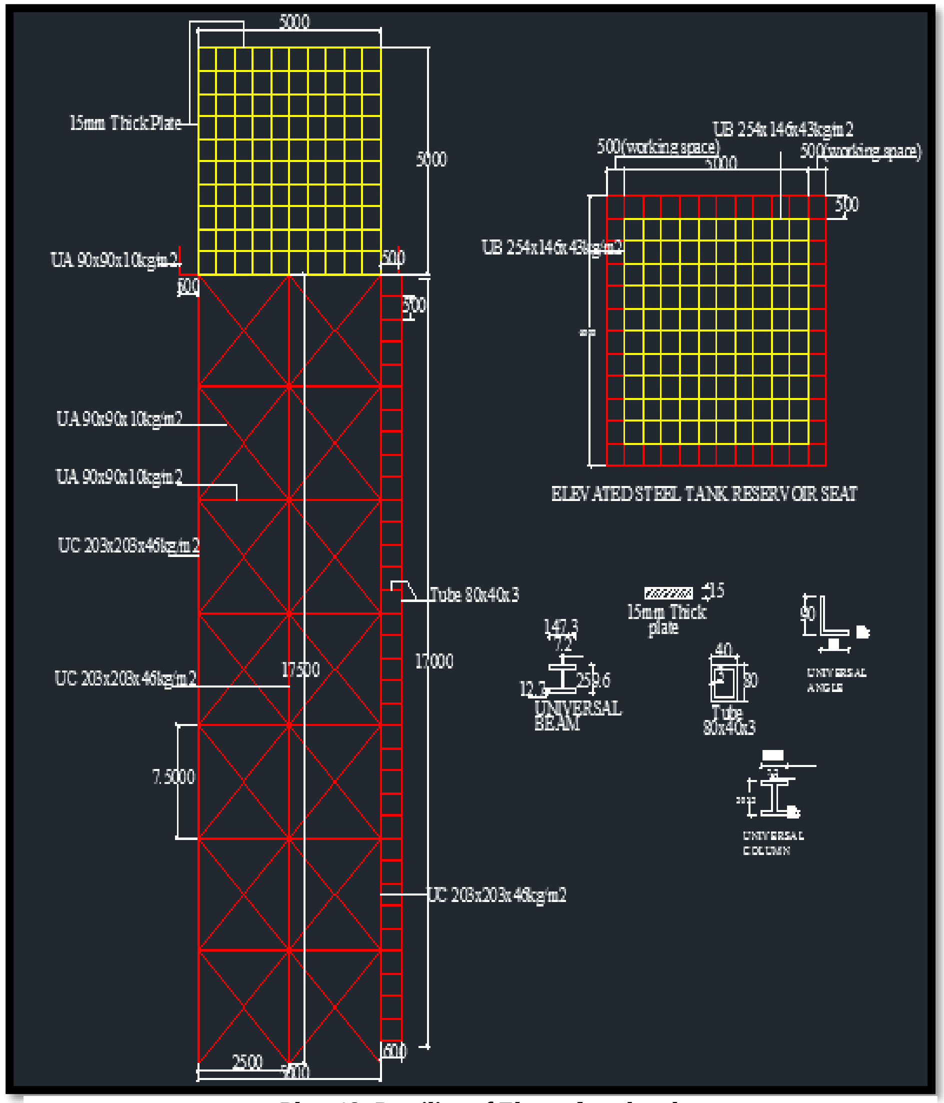


Plate 18: Detailing of Elevated steel tank

4.4 SUMMARY OF MATERIALS

Underground concrete tank

TOTAL VOLUME OF CONCRETE For underground water tank = 254m3

Steel reinforcement

Slab reinforcement both underground top and bottom

Y12 9043.4kg =9.0434tonne

(Base Slab beams reinforcement)

Y20 984KG = 0.984tonne

Y12 465.2KG = 0.4652tonne

Top Slab beams reinforcement

Y10 LINKS = 438.9KG =0.4389tonne

Y16 589.6KG = 0.5896tonne

Column/shear wall reinforcement

Y12 1927.8KG = 1.9278tonne

Y16 5164.0KG = 5.164tonne

TOTAL Y10 = 0.4389tonne

TOTAL Y12 = 9.5086tonne

TOTAL Y16 =0.5896tonne

TOTAL Y20 =0.984tonne

TOTAL TONNAGE OF STEEL =11.5211

ELEVATED STEEL TANK

STEEL TAKE-OFF

PROFILE LENGTH (meter) WEIGHT (KN)

ST UC203X203X46kg/m2	157.50	71.022
ST UA90X90X10kg/m2	751.77	98.754
ST UB254X146X43kg/m2	116.00	48.833
ST TUB80403.0	37.40	1.936

TOTAL WEIGHT = 220.545 (KN)

RETIULATION SYSTEM (Water Pipeline from underground to elevated steel tank)

1. from intake (Underground water tank) to pump

Diameter of pipe: 300.0mm

Length of pipes: 29m

Type of material: concrete pipe

2. from pump to hydrant

Diameter of pipe: 300.0mm

Length of pipes: 53m

Type of material: Ductile Iron

3. from hydrant to last point (immediately after the elevated tank)

Diameter of pipe: 300.0mm

Length of pipes: 1174m

Type of material: Ductile Iron

RETICULATION SYSTEM SUMMARY:

- **2 no. of pump**
- **2 no. of Hydrant**

5 CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

1. 750m³ of underground water tank was designed for, which can accommodate 750,000 litres of treated wastewater, instead of designing for 1,512 m³ of underground water tank, reason been that treated waste water is a continuously reuse action in the university either for flushing of toilet, or washing of cars, it will be more economical to construct 750m³ of underground water tank for a start.
2. In the underground water tank, the hydrostatic pressure acting internally in the reservoir, and active and passive pressure acting externally toward the wall has no impact on the shear wall.
3. The elevated steel tank is proposed to be erected at the highest elevated point on campus so as to attain maximum force of gravity, at the point of discharge to the point of use.

5.2 Recommendation

1. Further research work is recommended for the study of impartation of treated wastewater on elevated steel water.
2. Six (6) numbers of elevated steel water tank of size 125m³, will be recommended for construction in other to capture the design volume of treated waste water in underground water tank (750m³).
3. As population increases, and as demand increases it will be recommended that another 750 m³ of underground water tank, and six (6) numbers of elevated steel tank of 125m³ should be considered for construction.

4. Further research work should be considered for the treatment level of the treated wastewater in the university, and improvement of the quality of the treated wastewater should also be considered for future researcher.

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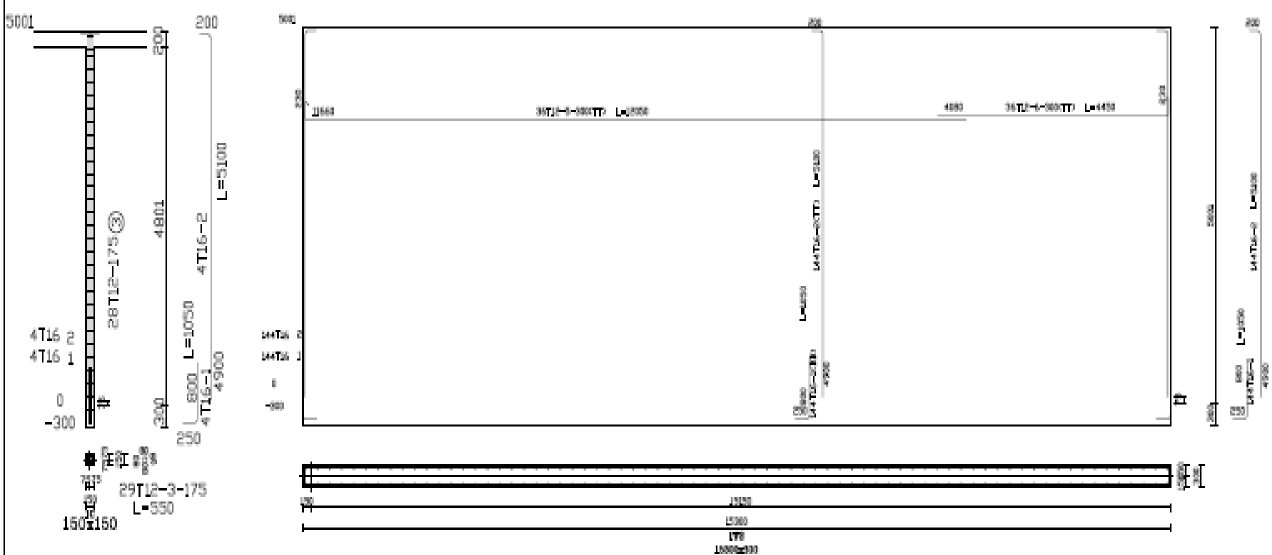
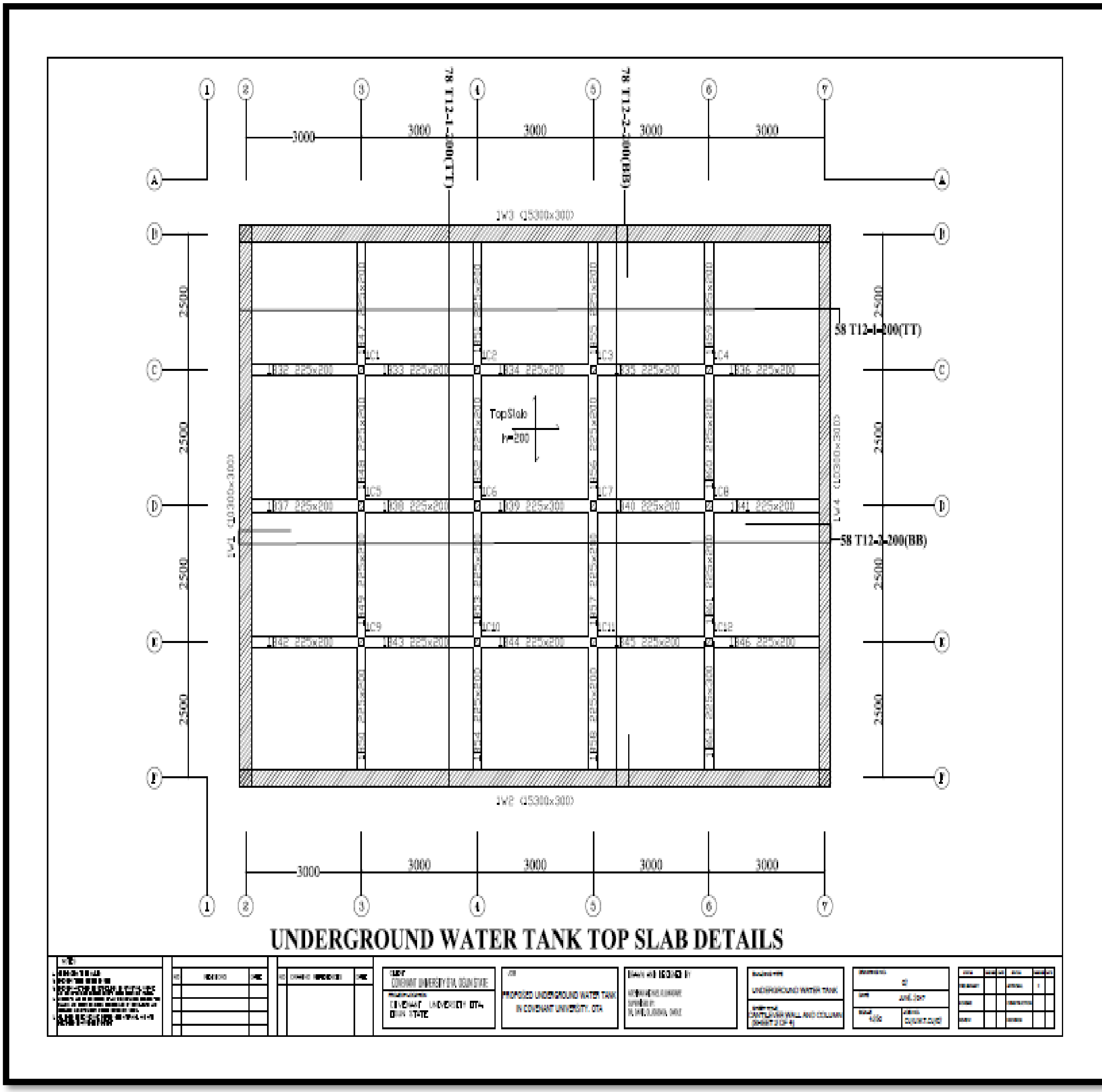
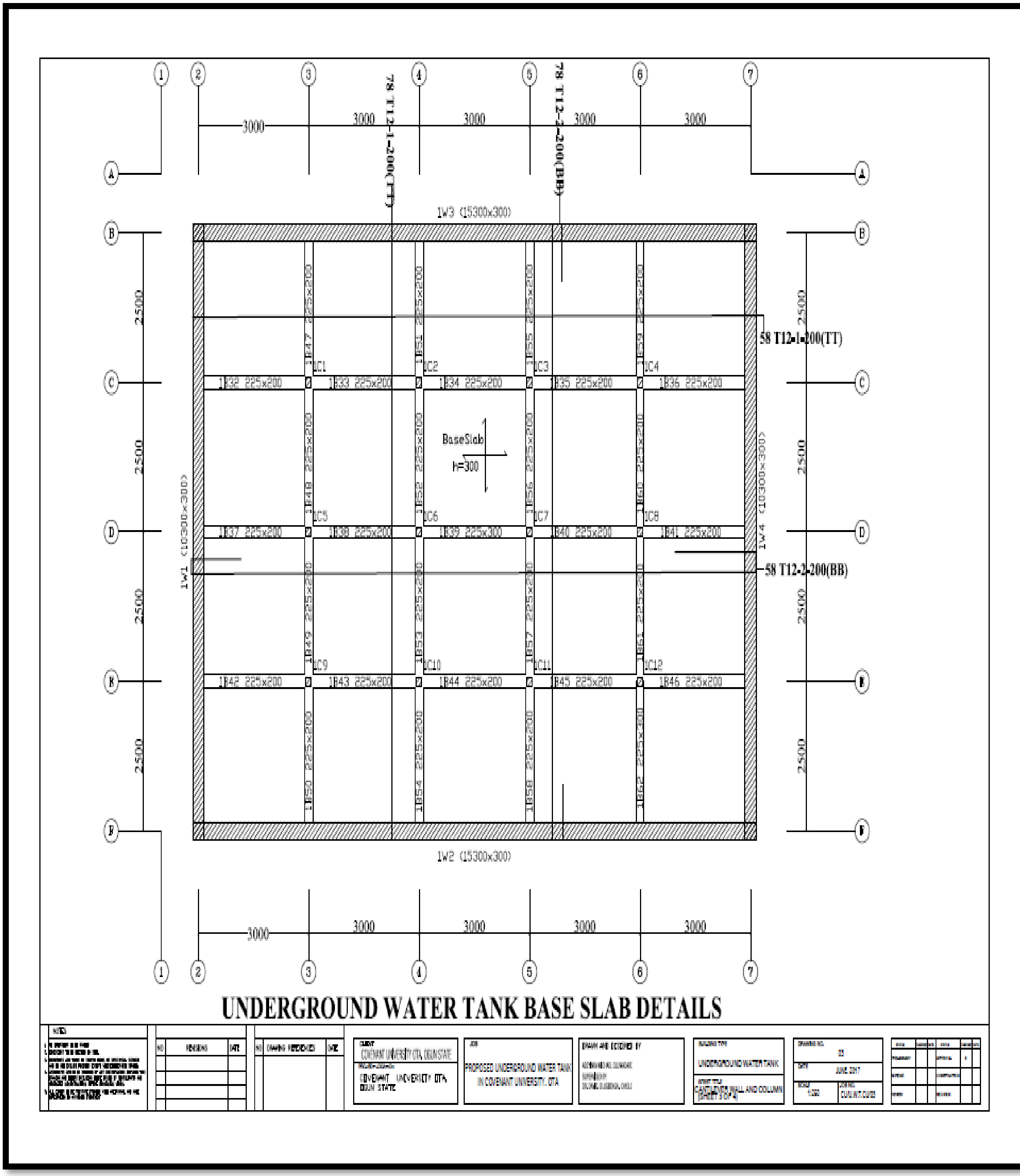
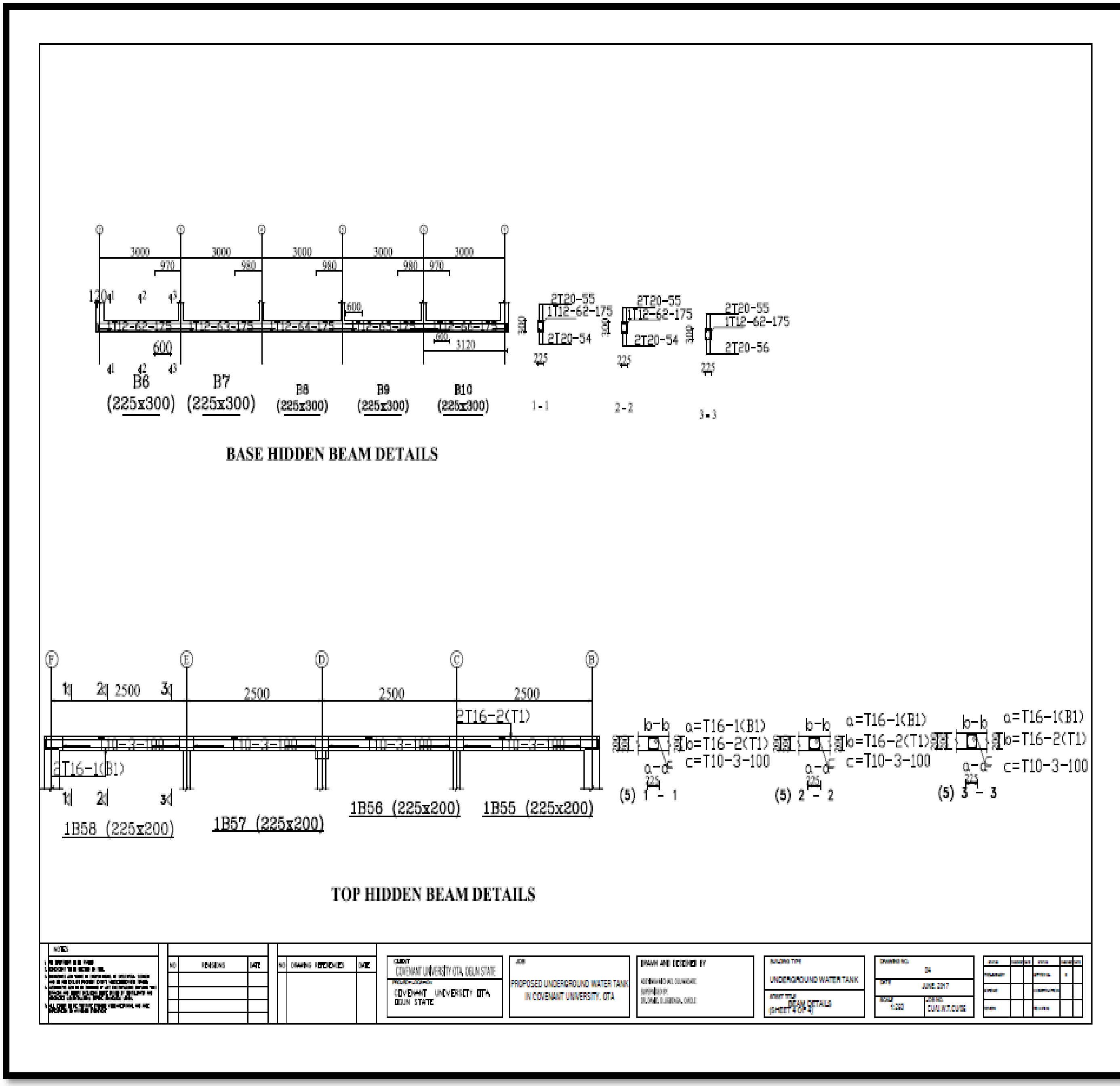
APPENDIX

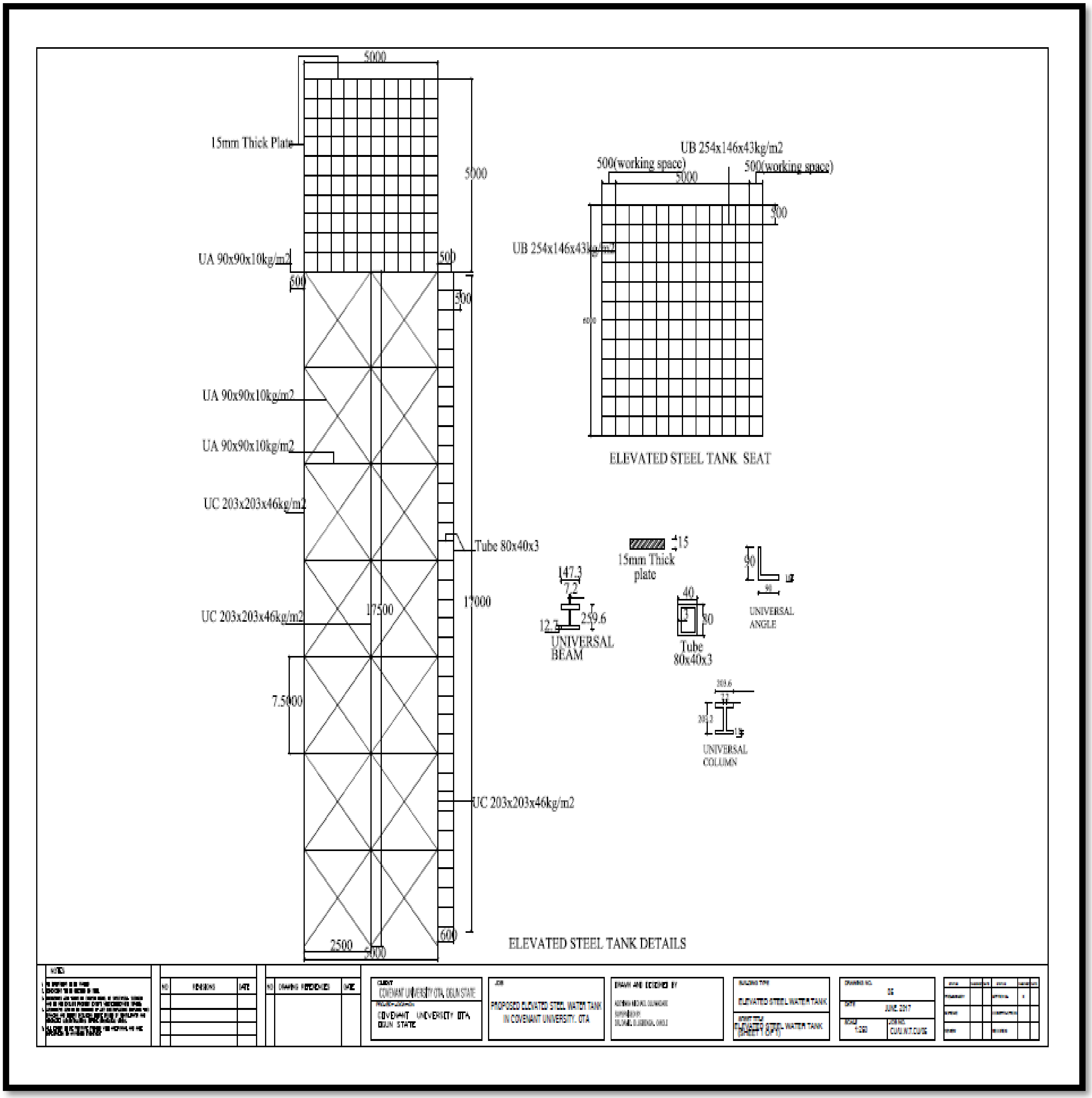


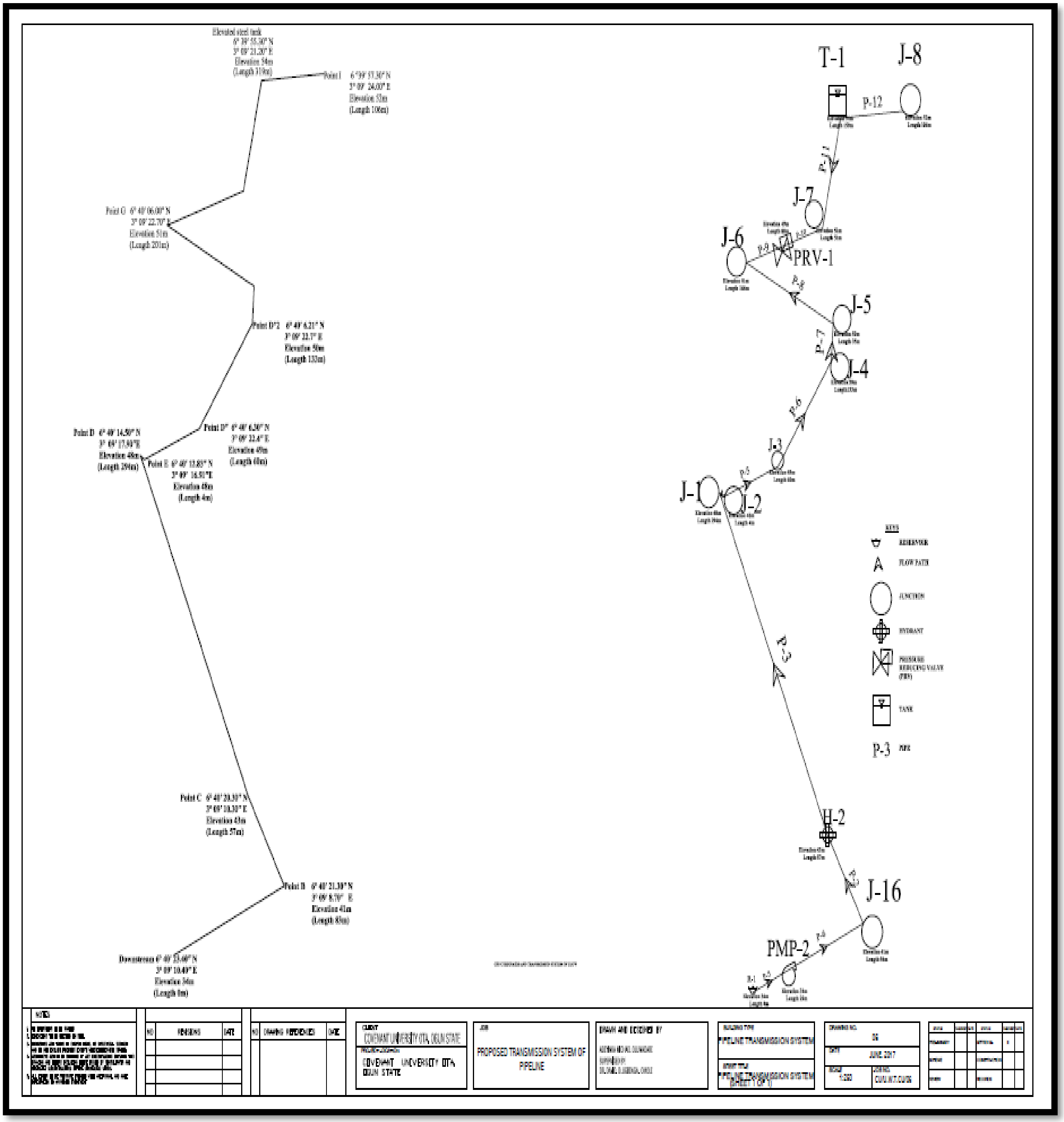
SECTIONAL VIEW OF CANTILEVER WALL AND COLUMN DETAILS


78 T12-1-200(TT)
78 T12-2-200(BB)
1W3 (15300x300)
58 T12-1-200(TT)
58 T12-2-200(BB)
Top Slab
h=200
1W2 (15300x300)
3000
2500
UNDERGROUND WATER TANK TOP SLAB DETAILS


78 T12-1-200(TT)
78 T12-2-200(BB)
1W3 (15300x300)
1W2 (15300x300)
1W1 (10300x300)
1W4 (10300x300)
58 T12-1-200(TT)
58 T12-2-200(BB)
Base Slab
H=300
3000
2500
UNDERGROUND WATER TANK BASE SLAB DETAILS
PROPOSED UNDERGROUND WATER TANK IN COVENANT UNIVERSITY, OTA
COVENANT UNIVERSITY OTA, OGUN STATE
UNDERGROUND WATER TANK
JUNE, 2017


BASE HIDDEN BEAM DETAILS
B6 (225x300)
B7 (225x300)
B8 (225x300)
B9 (225x300)
B10 (225x300)
2T20-55
1T12-62-175
2T20-54
2T20-56
1-1
2-2
3-3
TOP HIDDEN BEAM DETAILS
2T16-2(T1)
2T16-1(B1)
1B58 (225x200)
1B57 (225x200)
1B56 (225x200)
1B55 (225x200)
a=T16-1(B1)
b=T16-2(T1)
c=T10-3-100
PROPOSED UNDERGROUND WATER TANK IN COVENANT UNIVERSITY, OTA
UNDERGROUND WATER TANK
BEAM DETAILS


15mm Thick Plate
UA 90x90x10kg/m2
UA 90x90x10kg/m2
UA 90x90x10kg/m2
UC 203x203x46kg/m2
UC 203x203x46kg/m2
Tube 80x40x3
UC 203x203x46kg/m2
UB 254x146x43kg/m2
500(working space)
500(working space)
UB 254x146x43kg/m2
ELEVATED STEEL TANK SEAT
15mm Thick plate
UNIVERSAL BEAM
Tube 80x40x3
UNIVERSAL ANGLE
UNIVERSAL COLUMN
ELEVATED STEEL TANK DETAILS
COVENANT UNIVERSITY OTA, OGUN STATE
PROPOSED ELEVATED STEEL WATER TANK IN COVENANT UNIVERSITY, OTA
ELEVATED STEEL WATER TANK
JUNE, 2017


Elevated steel tank
Point C
Point D"2
Point D
Point D"
Point E
Point C
Point B
Downstream
T-1
J-8
P-12
P-11
J-7
J-6
PRV-1
P-8
J-5
P-7
J-4
P-6
J-3
P-5
J-1
J-2
P-3
H-2
P-2
J-16
PMP-2
P-4
R-1
P-3
PROPOSED TRANSMISSION SYSTEM OF PIPELINE
PIPELINE TRANSMISSION SYSTEM
JUNE 2017

APPENDIX II

C