STRUCTURAL HEALTH MONITORING OF A LATTICE TOWER

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MEng/SIPET/2018/9244

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ENGINEERING IN CIVIL ENGINEERING (STRUCTURAL ENGINEERING)

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ABSTRACT

Structural health monitoring of a lattice tower is presented. This research was prompted by the requirements of the Nigerian Communications Commission (NCC) that all masts should be checked for their structural health status every five (5) years. However, In the bid to cut down maintenance costs, some telecommunication network providers have adopted tower sharing without checking their structural health status to ensure their capability of bearing extra load from additional equipment, consequently creating an upsurge in the construction and maintenance of telecommunication towers. In this study, a lattice tower with the weakest parameter was selected: a 45m tower, with three (3) legs, erected over nine (9) years and shared by three (3) telecommunications operators in the Federal Capital Territory (FCT), Nigeria. The tower's structural stability and utilization percentages were determined. The auditing of the tower and foundation was also carried out. There were no twisted or missing members on the tower and no visible crack or blister on the three (3) stub columns. The average compressive strengths of the stub columns determined using the Proceq digital Schmidt hammer were 25.1, 25.9 and 25.9 N/mm^2 for legs A, B and C, respectively. From the structural analysis of the lattice tower using the Effective Projected Area (EPA) model, the tower utilization percentage was found to be at 59% after optimization. While results obtained from the STAAD pro. V8i analyses show that the utilization ratios (actual ratio to allowable ratio) of the tower members are less than one ($\leq$ 1) and there was no failed member identified after the structural analysis. The lattice tower can be said to be stable and fit for continuous use. However, the tower paint needs repainting, and it is recommended that structural status be checked whenever additional telecommunication antennas are to be installed on the tower by telecommunications network providers to prevent structural damage and consequent collapse of the tower.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

In the recent past, the number of telecommunication towers has risen astronomically due to licensing of more network providers like Globacom, MTN, Airtel and Etisalat (Okonji, 2013). This is also due to the growing demand for wireless and broadcast communication which has prompted a dramatic rise in construction and maintenance of towers. Failure of such structures is however a major concern (Sharma *et al.*, 2015).

Tower sharing which involves sharing of one tower by two or more network operators has also increased in a bit to reduce maintenance cost. Such towers may need to be strengthened or made taller to support several sets of antennas (GSMA, 2012). Existing towers will have to be assessed to ensure they are capable of withstand extra equipment.

It is therefore extremely important that towers are effectively maintained to ensure continued safety and efficient operation throughout their lifetime. The above statements call for increased awareness on the structural health monitoring of lattice towers in Nigeria.

1.2 Statement of the Research Problem

Failure of towers is generally due to high intensity winds. Several studies have been carried out by considering wind and earthquake loads (Sharma *et al.*, 2015).

Another problem the telecommunications towers is facing is the upkeep of the aging towers along with staying within a maintenance budget that is decreasing (Sullins, 2006).

While new towers can be built taking into consideration the ultimate load-bearing capacity required, existing towers may not have been designed to cater for the additional load requirements of service providers who decide to share (GSMA, 2012).

1.3 Aim and Objectives of the Study

1.3.1 Aim

The aim of this research work is to assess the structural health status of a selected lattice tower.

1.3.2 Objectives

The objectives of the study include the following:

i. to select a lattice tower with weakness parameter based on number of legs, height, years of service and number of operators sharing the tower.

ii. to determine the structural integrity of the selected lattice tower by carrying out tower audit.

iii. to determine the tower loading utilization percentage and the stability using the Effective Projected Area model and the STAAD pro. V8i software respectively.

1.4 Justification of the Study

In recent years, a number of tower failures caused by heavy rains and strong windstorms were recorded in Nigeria as shown in Table 2.1. These failures resulted in great economic loss and loss of lives. On the other hand, the Nigeria Communication Commission (NCC), specified that ‘major inspections (structural health monitoring) be performed at least once in every 5 years for self-supporting towers (NCC, 2009).

In this backdrop, the assessment of structural integrity of the selected lattice tower will help determine stability of the tower. It will further show the possible threat posed by poorly maintained towers and their potential danger to life and properties in their host communities.

1.5 Scope of Study

The scope of study is limited to structural health monitoring of a lattice tower with 3-legs, erected over nine years ago, having a height of 45m and shared by three telecommunication network operators (Glo, Etisalat and Airtel).

Investigation includes thorough physical inspection, non-destructive test on tower's stub column using Schmidt hammer and structural analyses of the entire towers using the Effective Projected Area (EPA) model and STAAD pro. V8i software.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Telecommunications Towers

A telecommunications tower or mast is a combination of steel structures that are designed in order to support radio antennas for telecommunication and broadcasting purposes. The towers used for telecommunication purposes in the public, require elevated antennas to effectively transmit and receive radio communications (Al-jassani and Al-suraifi, 2017).

Bello (2010) defines mast as a freestanding structure which supports antennas at a height where they can transmit and receive radio waves. Telecommunication masts may be of several types, and range in height from 30 to 300 meters or more (Ogbonna *et al.*, 2016). The type of tower used for an application is usually dependent on the design height.

A telecommunication tower is housed in a cell site or base station site. A cell site is a cellular-enabled mobile device site where electronic communications equipment and antennas are placed on a radio mast, tower, or other raised structure to create a cell in a cellular network. Figure 2.1 shows the site layout of a typical telecommunications site.

In order to have optimal network coverage, cell sites are often located in close proximity to the target users; the reason telecom operators also site their masts in residential neighbourhoods (Michael *et al.*, 2013).

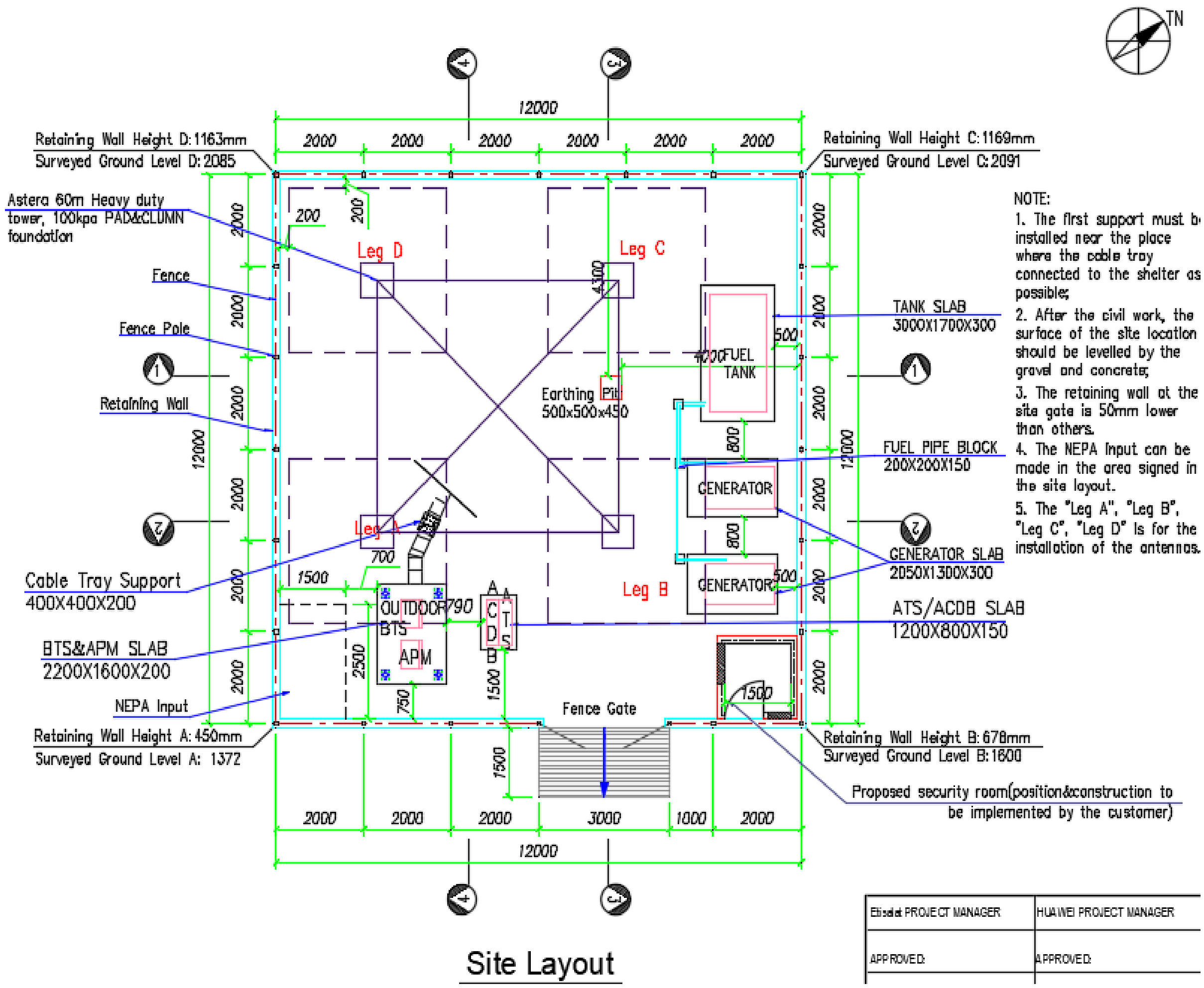


Figure 2.1: Layout of a typical telecommunication site (Source: Etisalat Tower Specification, 2012)

2.2 Classification of Telecommunications Towers

Al-jassani and Al-suraifi (2017), classified telecommunications towers based on various criteria such types of structural action, material sections, numbers of legs, types of weight and capacity, types of shapes and so on. Based on structural action, towers can be classified into three major group namely self-supporting towers, monopoles towers and guyed towers.

Self-supporting towers are supported on ground or on buildings. Though the weight of these towers is more, they require less base area and are suitable in many situations. Most of the television, microwave, power transmission, and flood light towers are self-supporting towers as

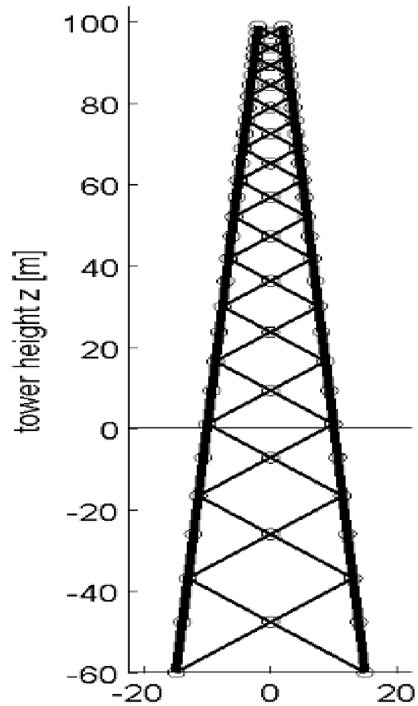


Figure 2.2: Self-supporting tower (Source: Etisalat Tower Specification, 2012)

Monopole towers are single self-supporting pole which are sometimes placed on roofs of high-rise buildings, when number of antennae required is less or height of tower required is less than 9m. They use minimal space and resemble a single tube, require one large foundation, typically not exceed 45 m height and the antennas are mounted on the exterior of the tower, as shown in Figure 2.3.

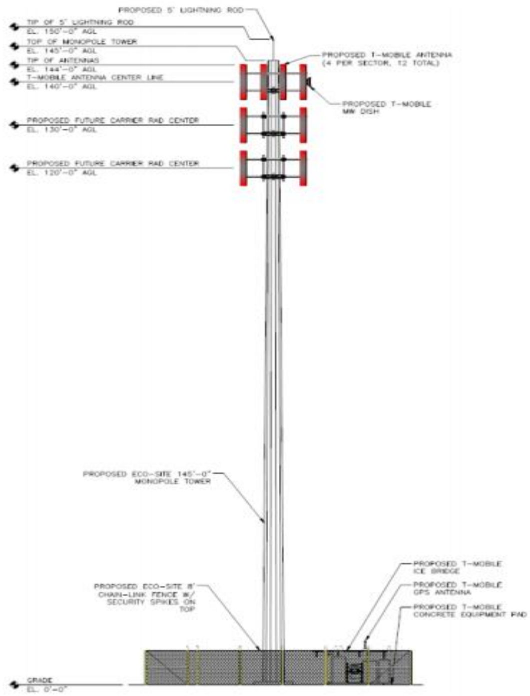


Figure 2.3: Monopole Tower (Source: Etisalat Tower Specification, 2012)

Guyed towers provide height at a much lower material cost than self-supporting towers due to the efficient use of high-strength steel in the guys. Guyed towers are normally guyed in three directions over an anchor radius of typically 2/3 of the tower height and have a triangular lattice section for the central mast. Tubular masts are also used, especially where icing is very heavy and lattice sections would ice up fully. These towers are much lighter than self-supporting type but require a large free space to anchor guy wires. Whenever large open space is available, guyed towers can be provided.

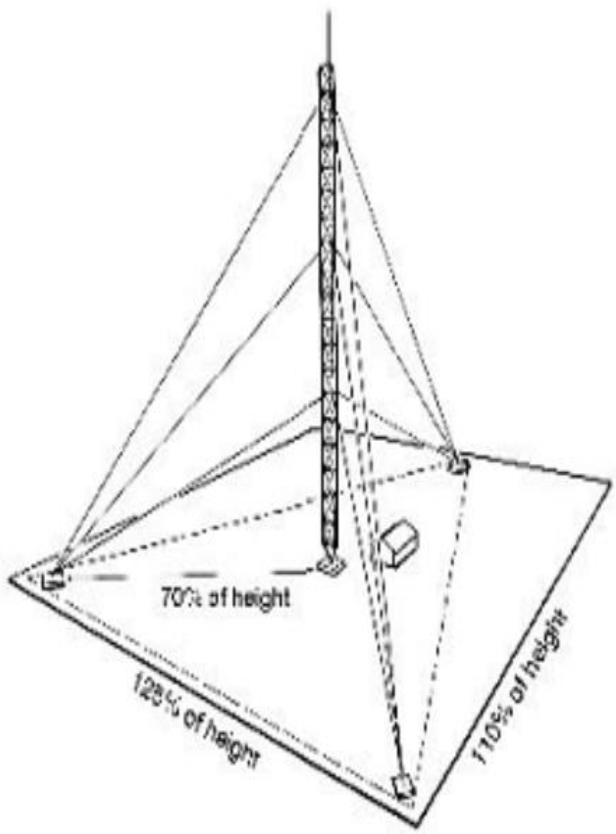


Figure 2.4: Guyed tower (Source: Etisalat Tower Specification, 2012)

2.3 General Requirements of Telecoms Towers

According to Etisalat Tower Specification (2012), for self-supporting latticed tower of modular design, heights can be varied with minimal additional manufacturing. Also, towers will preferably be tapered, with 3-leg and 4-leg variations. Tower members will be made in shapes, sizes and weights to make for easy handling, shipping and local distribution with regular equipment and trucks. Tower shall be designed to be assembled on site by bolts and nuts/washers, without any need for welding, riveting, drilling, or any other form of splicing apart from bolts and nuts.

Each tower will come complete with all accessories which include, but not limited to: Holding down bolts and templates, platforms, ladders, cable supports, radio antenna mountings, microwave antenna mountings, aviation warning light with power cable, lightening spike with copper conductor, insulated grounding cable, naked cables and so on.

2.3.1 Components of telecommunications towers

Telecommunications towers is made of hot dipped galvanized structural steel sections. The sections may be angular sections or tubular sections. Other components include bolts, nuts, raised platform, aviation warning light, paint, and so on.

2.3.1.1 *Structural steel*

Towers will be made in galvanized steel members. As a minimum, Grade 300WA Steel (to SABS 1431) shall be used for the design and manufacture of the tower members. Minimum Yield Strength for standard steel less than 16mm thick should be 235 N/mm^2; for high tensile steel less than 16mm thick should be 355 N/mm^2 and for High tensile steel exceeding 16mm thick should be 345 N/mm^2. Steel sections beyond 35mm thick shall not be utilized in any parts of the towers. Generally, minimum thickness for tower leg members shall be 6mm and for other members (braces) shall be 4mm. Commercial grade steel may be used for the cat ladders and internal platforms.

All steel components for the towers shall be hot-dipped galvanized to the specifications of *ASTM A123*, *SABS SO 1461*, or any internationally acceptable equivalent. All drilling of holes, markings and welding shall be completed for every component prior to hot-dipped galvanization.

Every structural member or fabricated structural sub-assemblies of the tower (except bolts and nuts), shall have a part number clearly marked on it. This part number, which shall have a minimum character of 10mm, will be permanently engraved or stamped on the member prior to galvanization; should be visible after galvanization and painting; and should be positioned on the member to be visible after tower installation.

2.3.1.2 *Bolts and nuts*

All bolts that are M10 or bigger, except Holding down Bolts, shall be Grade 8.8 (high tensile strength). Galvanized flat washers (2mm thick or thicker) must be used on the nut end of the bolt but spring washers are not allowed. Double locking nuts are only required on squeeze type connections, but flat metal-on-flat metal connections do not need double lock nuts. The choice of number of nuts to be adopted for such connections is left to the tower manufacturer.

Bolts that are less than M10 must be stainless steel Grade 304. Such bolts (eg bolts holding Aviation Warning Lamps) must be supplied with double nuts and must allow for a minimum of 5mm of thread to protrude once both nuts are in place. Holding down bolts may be black bolts but the threaded portion that will be exposed above the foundation must be hot dip galvanized.

The grade, type, size, torque, and location of all bolts must be clearly indicated on the tower erection drawings.

2.3.1.3 *Connections*

Tower design should be such that bolts are able to be tightened against flat steel surfaces that bear on each other in such a way that the full design tension for the bolts can be achieved. The joint configuration shall be such that a torque wrench can be used to tighten each bolt without disturbing adjacent bolts. A maximum of only two members shall be connected per individual bolt (except for joint plates and bosom angles).

Sleeve fitting pipe member connections are not recommended on the legs of latticed towers/masts. Where pipe legs are used, drainage holes must be provided in the pipe leg that is flush with the flange plate. Also, the bottom flange of the bottom leg member must allow drainage through the grout if there is a hole in the flange through a 20 mm drainage hole, else, the bottom flange shall contain no holes or be suitably plugged and sealed.

2.3.1.4 ***Ladders and cable runways***

The tower design and manufacture shall include for one access ladder, at least one working platform and rest platforms (spaced not more than 15m along tower height). The access ladder shall be a caged ladder containing stringers and hoops. The ladder, which shall be about 450mm wide (±50mm), shall start from the ground level and reach the full height of the tower, while the hoops and stringers shall start at about 1.5m from the bottom of the tower and terminate at the last working platform.

Cat ladder rungs must be evenly spaced to allow comfortable climbing and will be between

12mm and 16mm diameter thick. Spacing of ladder rungs shall be 250mm (±50 mm). Horizontal safety hoop having a diameter of 700mm (±50mm) must be provided on cat ladders, at spacing not exceeding 1m. Vertical stringers must also be provided to hold the hoops in place and provide adequate protection during climbing. Both sides of the cat ladder will allow for cable runs in such a way that the cables will not impede climbing but will be accessible at any point from the ladder. Cable support systems shall be in angle sections or flat plates and shall allow for cable runs of 300mm wide and 150mm deep. They will allow cable clamps to be attached at 1m spacing, full height of the tower.

2.3.1.5 *Aviation warning lights*

Aviation Warning Light systems, which are to be powered by 220V, 50Hz A.C. power; shall be provided with photo-sensitive day/night switches and conform to ICAO regulations. The lamp is to be protected by a watertight transparent cover mounted in such a manner that an electrical switch will disconnect the power supply to the lamp when the cover is opened Specifications for the design and manufacture of Modular Self- Supporting Lattice Towers for use in Nigeria.

All Aviation light brackets, threaded bolts and nuts shall be fabricated in Stainless Steel grade 304 or better. Bolts' length must allow for a minimum of 5mm of thread to protrude after nuts are in place. Aviation Lights will typically be mounted as scheduled Table 2.1 below:

Table 2.1 Aviation Warning Light Standard

35m, 40m and 45m Towers	Double lights at the top of the tower. Lights should be red and fixed, with Intensity not below 100 Candelas
50m and 60m Towers	Double lights at the top of the tower and three (3) single lights between 25m and 30m height. Lights should be red and flashing, with Intensity not below 1600 Candelas
70m and 80m Towers	Double lights at the top of the tower and three (3) single lights between 37m and 40m height. Lights should be red and flashing, with Intensity not below 1600 Candelas
90m Towers	Double lights at the top of the tower, three (3) single lights between 30m and 35m height and another three (3) single lights between 60m and 65m height. Lights should be red and

	flashing, with Intensity not below 1600 Candelas

2.3.1.6 *Tower grounding and lightening protection*

A Lightening spike made in galvanized steel and with a minimum length of 1200mm shall be designed and supplied with every tower/mast/monopole. The spike may be a 16mm diameter rod or 38mm x 38mm angle section with a sharpened point. The actual length of the spike should be established using the 45^{o} protective angle assumption (that is., all tower members, AWL and antennae are included within a 45^{o} angled cone subtending from the top of the spike).

Provision shall be made for the installation of the lightening spike at the uppermost section of the tower. $70mm^2$ insulated copper cables shall be supplied with the tower for the connection of the lightening spike to the earth ring on ground and for providing grounding points for antennae installed along the height of the tower. Minimum length of continuous insulated 70mm2 copper cable to be supplied with tower shall be 2 x tower height + 10m (example, a 35m tower will be supplied with 80m continuous length of $70mm^2$ insulated copper cable). Alternatively, half of the cables may be the insulated type of continuous length while the remaining half is 3mm x 25mm copper flat bars or 70mm2 bare copper cable of continuous length.

2.3.1.7 *Anchors and templates*

Each tower shall be supplied with an appropriate anchor system complete with template. The template will guide in the installation of the anchor system for accurate placement of tower at a later date. Anchor systems shall generally consist of bolts, nuts and washers. Anchor bolts (which may be galvanized or black bolts) must be black bolts of strength and number, adequate to effectively transfer the tower leg reactions to the bearing structure. Where black bolts are used as anchor bolts, the exposed threaded portion of the bolts must be hot dip galvanized.

2.3.1.8 ***Radio frequency antenna poles and brackets***

Each tower shall be supplied with at least three (3) RF Antenna support poles and brackets. The poles shall be 76mm diameter hollow pipes of 3mm minimum thickness made in hot-dipped galvanized steel and about 2.5m long. Each pole shall be designed to have 2 horizontal beams/brackets, each beam/bracket to be fixed at about 300mm from each end of the pole. Tower suppliers shall design appropriate bracket systems to hold the poles to the beams and the beams to the tower leg using galvanized standard steel sections like angles, U-bolts, threaded rods, plates etc. Provision must be made on the bracket system for adjustments to be made in the beams' lengths to compensate for the taper of the tower and ensure poles are installed vertical if necessary. The poles and brackets shall be designed to effectively transfer the wind load on the panel antenna to the tower legs at a height of 70m under the specified wind and environmental conditions.

2.4 Telecomummication Infrastructure Sharing

Infrastructure sharing is a process where two or more operators share different infrastructure in a particular site as a mechanism for cost reduction, quality of service improvement and rapid network expansion while at same time creating a positive environmental impact with good economic sustainability (Idachaba, 2010). Benefits of telecommunications infrastructure sharing includes savings in capital and operational expenditures, rapid deployment of telecommunications network services and reduction of adverse environmental impact. Infrastructure shared in the telecommunications industry includes tower structure, right of way, ground space, fibre duct, trenches, poles, electric power, antennas, and so on.

Infrastructure sharing can be broadly categorized into three types namely: passive infrastructure sharing, active infrastructure sharing and spectrum sharing (Nosiri *et al*., 2015).

2.4.1 Passive infrastructure sharing

This involves the sharing of non-electronic equipment like site space, tower, mast, poles, and power supply (Ghassan *et al.*, 2007). It is the most common type of telecommunications infrastructure sharing. This method is appropriate mainly in urban centres with limited resource availability, in rural areas that are uneconomical to deploy new infrastructure.

According to the publication of GSMA (2012), passive infrastructure sharing requires the consideration of many technical, practical, and logistical factors although the principle is simple in theory. Any potential impact must be assessed and fully understood before sharing commences to ensure that there are no adverse effects on the operation of the site and the supporting network equipment and systems. Operators must consider items such as load bearing capacity of towers, azimuth angle of different service providers, tilt of the antenna, height of the antenna, before executing the agreement.

2.4.2 Active infrastructure sharing

This type of sharing involves sharing of electronic components and resources such as microwave radio equipment, fibre structure, switching centers, sharing common network both circuit-switched and packet-oriented domains. This method is often serving as lease lines for network redundancies and traffic backhaul services.

2.4.3 Spectrum infrastructure sharing

This is also referred to as spectrum trading. It is a model that has recently come to the fore in the last decade. It involves telecommunications operators leasing their spectrum to one another. As spectrum is a scarce resource that may often be underutilized by one operator in a given area, spectrum sharing remains a viable option for two or more operators.

Spectrum sharing is the logical partitioning of optical spectrum on a submarine cable for different end-users, such that each end-user has its own 'virtual fibre pair. It seeks to address network efficiency concerns by allowing telecommunications companies to leverage on non-linear gains in spectral efficiency. The benefits of spectrum trading provide operators chance to minimize network congestion and carry greater amounts of traffic. It increases flexibility to accommodate shifting demand driven by market changes and removes entry barriers for new operators which results into healthy competition.

2.5 Record of Tower Failures in Nigeria

In the last decade, several tower failures were recorded in Nigeria as shown in Table 2.2. It can be deduced from the table that most of the collapse cases involved towers supported on three legs. This justifies the selection of the three-legged lattice tower for this study.

Table 2.2: Record of tower failures in Nigeria

Date	State	Casualty	Tower Type	Extent of Collapse	Source
May 10, 2013	Lagos	1	3-Legged	Total Collapse	Akoni (2014)
March 19, 2014	Cross River	2	3-Legged	Total Collapse	Kalu (2014)
January 24, 2017	Rivers	3	3-Legged	Total Collapse	Azubuike (2017)
May 7, 2018	Taraba	3	3-Legged	Total Collapse	Chronicle (2018)
June 24, 2019	FCT	Nil	3-Legged	Total Collapse	Ikeji (2019)
June 13,2020	Kano	Nil	Monopole	Total Collapse	On site report
June 14,2020	Sokoto	Nil	3-Legged	Partial Collapse	On site report
March 13, 2021	Cross River	Nil	3-Legged	Total Collapse	On site report
January 7, 2021	Akwa Ibom	Nil	3-Legged	Partial Collapse	Tom (2021)
March 24, 2021	Akwa Ibom	Nil	4-Legged	Total Collapse	Abia (2021)
January 21, 2022	Benue	7	3-Legged	Total Collapse	Dada (2022)

Plate I: Lagos tower collapse (Source: Akoni, 2014)

Plate II: Cross River tower collapse (*Source*: Kalu, 2014)

Plate III: FCT tower collapse (Source: Ikeji, 2019

Plate IV: Sokoto tower collapse (Source: On site picture)

Plate V: Akwa Ibom tower collapse I (Source: Tom, 2021)

Plate VI: Akwa Ibom tower collapse II (Source: Abia, 2021)

2.6 Structural Health Monitoring of Towers

The collapse of transmission towers causes great economic loss and sometimes fatal accidents. The fact that transmission towers collapse during hurricanes or typhoons attracts researchers to accomplish their research on this issue (Siti *et al.*, 2017).

Several authors have contributed theoretical and experimental investigations to the structural health monitoring of steel telecommunication towers. It is fair to mention investigations made by Husain *et al.* (2017) performed research on the appraisal of the spatial distribution of Global System for Mobile Telecommunications (GSM) Infrastructure in Gombe Metropolis, Nigeria. The objectives of the study were to appraise the conformity of existing spatial distribution of GSM masts and base stations to planning standards with a view to developing alternative proposals which will minimize potential harmful effects of GSM masts on residents and contribute to environmental sustainability, while meeting socio-economic objectives of the GSM operators.

Sharma *et al.* (2015) who performed research based on a comparative analysis of steel telecommunication tower subjected to seismic and wind loading. In their research a comparative analysis is being carried out for different heights of towers using different bracing patterns for Wind zones I to VI and Earthquake zones II to V of India. The Gust factor method is used for wind load analysis, modal analysis and response spectrum analysis are used for earthquake loading. The results of displacement at the top of the towers and stresses in the bottom leg of the towers are compared.

Lahodny and Janata (2014) carried out full-scale measurements on one tower and one guyed mast. The measured characteristics, especially the power spectral densities of the wind velocities and the structure response, are compared with theoretical presumptions. The measured structures are situated on different terrains. Subsequently, a practical method for the theoretical evaluation of the structure response to turbulent wind is proposed. The method, based on the spectral analysis approach, considers the contribution of all significant mode shapes. The method can be used for a wide range of towers and masts, especially for those which do not meet EN standards criteria for commonly used equivalent static methods.

Jesumi and Rajendran (2013) modeled five steel lattice towers with different bracing configurations such as the X-B, single diagonal, X-X, K and Y bracings for a given range of height. The heights of the towers are 40m and 50m with a base width of 2m and 5m respectively. The tower of height 40m has 13 panels and the tower of height 50m has 16 panels. 70-72% of the height is provided for the tapered part and 28-30% of the height is provided for the straight part of the tower. The towers have been analyzed for wind loads with STAAD Pro. V8i, to compare the maximum joint displacement of each tower. Optimized design has been carried out to estimate and to compare the weight of each tower. From the results obtained, Y bracing has been found to be the most economical bracing system up to a height of 50m.

Siddesha (2010) presented the analysis of microwave antenna tower with Static and Gust factor method. He compared the towers with angle and square hollow sections. The displacement at the top of the tower was considered the main parameter. The towers with different configurations have also been analyzed by removing one-member present in the regular tower in lower panels. Square sections were found to be most effective for legs as compared to the angle sections. Square hollow sections used in bracing along with the leg members did not show any appreciable reduction of displacement. X-type and M-type bracings in square hollow sections for legs and bracings in the lower first panel of towers showed maximum reduction in displacement as compared to the regular towers with angle sections.

Da Silva *et al.* (2005) presented a paper on an alternative structural analysis modeling strategy for the steel tower design considering all the actual structural forces and moments combining three-dimensional beam and truss finite elements. Comparisons of the two above-mentioned design methods with a third method based on the use of spatial beam finite elements to model the main structure and the bracing system on two actually built steel telecommunication towers (40 and 75m high steel towers) have been described. Generally, in all the cases studied the maximum stress values for the structural tower modeling based on the three investigated methodologies were significantly modified. The lateral displacement values were not significantly changed when the usual truss model, the beam model or the combined beam and truss model were considered.

Albermani *et al*. (2004) that investigated the possibility of strengthening steel truss towers from a restructure and rearrangement of their bracing systems. The adopted solution consisted on the addition of axially rigid systems to intermediate transverse planes of the tower panels.

Kahla (2000) presented a dynamic modelled on the rupture of a cable present in guyed steel towers. The analysis indicated that the guyed steel towers cable rupture, disregarding the wind actions, was one of the most severe critical load hypotheses for the investigated structures.

2.7 Structural Health Monitoring of Towers of a Lattice Tower

In view of the background works carried out in paragraph 2.6, the collapses of tower recorded in the recent past and the prevailing tower sharing by some telecommunication network providers; this research will study the health status of a lattice tower located in FCT, Abuja. This tower is 45m high, supported on 3-legs, erected nine (9) years ago and shared by three telecommunication network providers.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Methodology Concept

The concept shall involve identification and selection, tower auditing and analyzing the tower to determine its structural integrity. To achieve the desired aim of the study, identification of towers supported on 3-legs erected over 5 years and having two or more telecoms' operators hosting their radio antennas on the tower were made. Additionally, a tower of 45m height was selected.

Thereafter, the tower was thoroughly inspected to ascertain the structural integrity of its members and accessories. Subsequently, the tower loading was analysed to determine its stability and percentage utilization. The steps undertaken are presented in Figure 3.1.

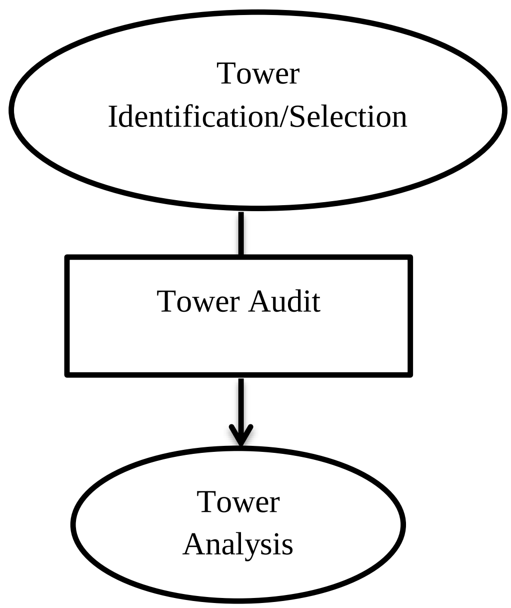


Figure 3.1: Research methodology Chart

3.2 Tower Identification

The tower has been in service for over nine years and was previously used by one network operator (9mobile). However, it was acquired by an infrastructure provider (IHS), who has now leased it to two more telecom operators (Airtel and MTN). This indicates that tower sharing is now taking place on a tower previously erected to be used by a single telecom operator. The tower is a 45m, 3-Legged tower and it is located in Abuja – FCT. 3-legged towers are known not to be as stable as 4-legged towers. Most of the tower collapses are associated with 3-legged towers as shown in Table 2.1.

The relevant documents (Site approved drawing, Soil test report, Tower drawing) were obtained to aid the tower's modelling, design, and analyses as show in the appendix. Details of the lattice tower selected for this research work are presented in Table 3.1.

Table 3.1: Tower identification

S/No	Item	Description
1	Site Identification	B0653 (IHS_ ABJ_0704E)
2	Number of Operators	3
3	Site Location	Plot 7, Unity Hill Estate, Behind Sunny-Ville Estate, Dakwo District, FCT, Abuja, FCT
4	Site Coordinates	Latitude: 8.97312, Longitude: 7.43745
5	Tower Manufacturer	Mast Projects
6	Type of Tower	Medium duty Lattice Tower
7	Tower Design Capacity	12 m^2
8	Years of Service	9 years
9	Tower Height	45m
10	Tower Top Rating	1.2m^2/m spread over the upper 10m of tower
11	Tower legs	3 legs

2

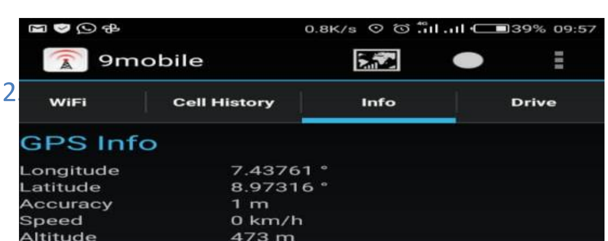


Plate VII: Site Name

Plate VIII: On-site coordinates

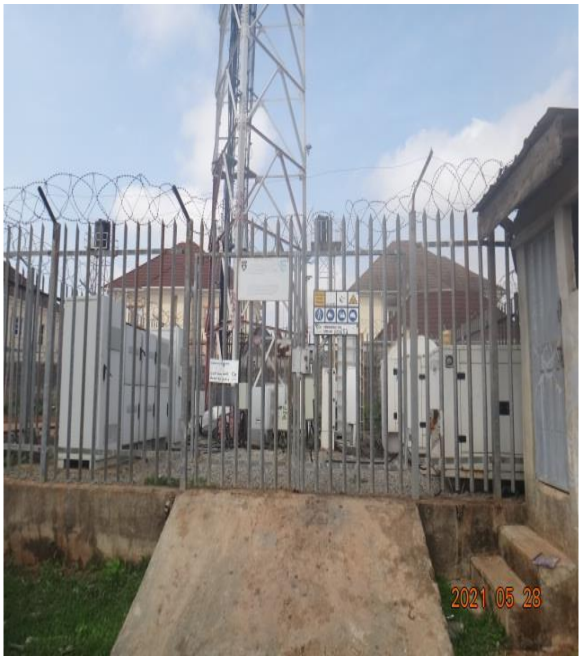


Plate IX: Approach view

Plate X: On Site with a Rigger

3.3 Audit of the Lattice Tower

After tower identification, approval was obtained from 9mobile to visit the selected site for tower audit. Subsequently, a site visit was scheduled. The audit involved carrying non-destructive test on the towers' foundation, taking records of the number of antennas on the tower and inspecting of the tower structural members and accessories. The audit could be grouped into two categories namely the tower foundation and the tower member audit.

3.3.1 Foundation audit using digital Schmidt hammer

A non-destructive test was carried out on the tower stub columns. The stub column is the vertical member which forms part of the tower foundation. It is a reinforced concrete footing through which the tower is anchored. The tower legs are held to the foundation by galvanized hold down bolts.

Lattice towers are usually supported by three or four legs which rest on stub columns. Hence, the non-destructive test was carried out on all the stub columns. The test is carried out on the exposed surfaces of the stub columns above the finished floor level.

The test was carried out using a digital Schmidt hammer (Proceq). The Schmidt hammer or rebound hammer is a mechanical device used to perform quick, non-destructive quality test on concrete. The tower legs were labelled alphabetically from A-C in anticlockwise direction for easy referencing. Also, the exposed stub columns are also checked for the presence of cracks and surface blisters.

Test Procedure

i. Mark up the test points which are at least 200mm apart

ii. Use a grindstone to smoothen the test surface.

iii. Position the concrete test hammer perpendicular to the test surface.

iv. Deploy the impact plunger of the Schmidt hammer by pushing the rebound hammer towards the test surface until the push button springs out.

v. Perform the non-destructive test by pushing rebound hammer against the test surface at moderate speed until the impact is triggered (a loud beep acknowledge impact registration).

vi. The values of the rebound number (R) and the corresponding compressive strength (N/mm^2) are displaced on the digital Schmidt hammer screen.

vii. Repeat the test at seven more points and click "end button" on the display panel of the Schmidt hammer to obtain the average compressive strength in N/mm$^{2.}$ (See figure 3.2).

vi

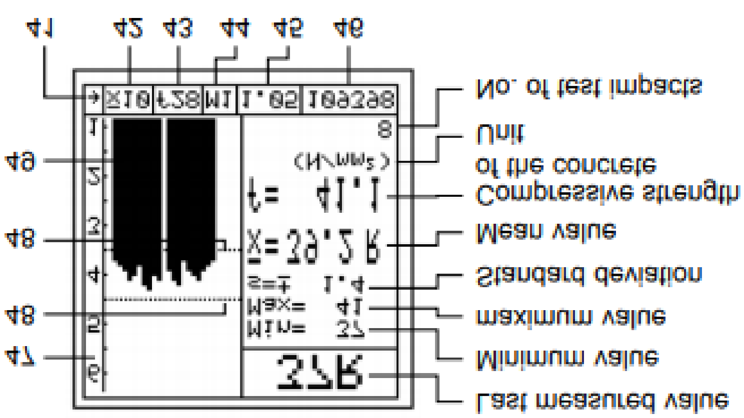


Figure 3.2: Digital Schmidt hammer display screen. (Source: Proceq digi-Schmidt instruction manual, 2000)

Plates XI-XV show some of the tools and procedures used for the foundation audit.

Plate XI: Proceq Digi-Schmidt 2000 **Plate XII**: Hammer and Display Unit

Plate XIII: Marking of test points. as “X”

Plate XIV: Testing of the foundation

Plate XV: Display unit showing readings.

3.3.2 Members audit

The tower audit was done with the support of a professional tower installer called Rigger. A Rigger is a person specialized in erecting towers as well as carrying out maintenance works on the tower. The tower audit involves the thorough inspection of the tower members and bracings, the bolts and nuts conditions at the connections, the state of other tower accessories like the access ladder, rest platforms, paints, aviation warning lights and earth cables. Any defect noted on the tower and recommended for correction. During the tower audit, records of all the telecoms equipment (antennas) installed on the tower are also recorded for use in structural analyses of the tower.

The steps below are taking to record the installed telecommunications equipment.

i. Note the number of legs the tower is supported.

ii. Label each of the tower legs alphabetically in an anticlockwise order.

iii. On each of the tower legs, list out the various types of telecommunication antennas mounted (radio frequency antennas, transmission antennas and remote radio units).

iv. Then record the dimensions of the antennas and heights of installation.

These activities provide cognizance on the state of the tower and the maintenance history of the tower. The data obtained after the audit are compared with the industry laid-down specifications to ascertain the state of the tower. Table 3.2 below shows the tower accessories description while Plates XVI-XXIII show some of the tools and members' audit procedures used.

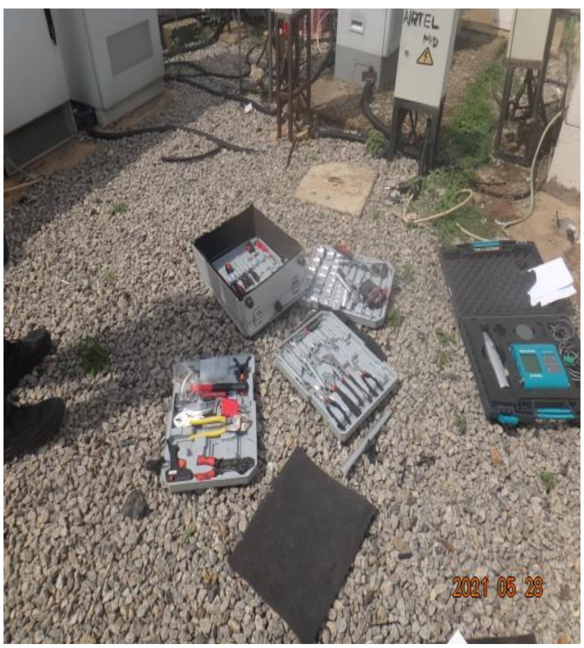


Plate XVI: Toolbox

Plate XVII: Tower legs A, B and C

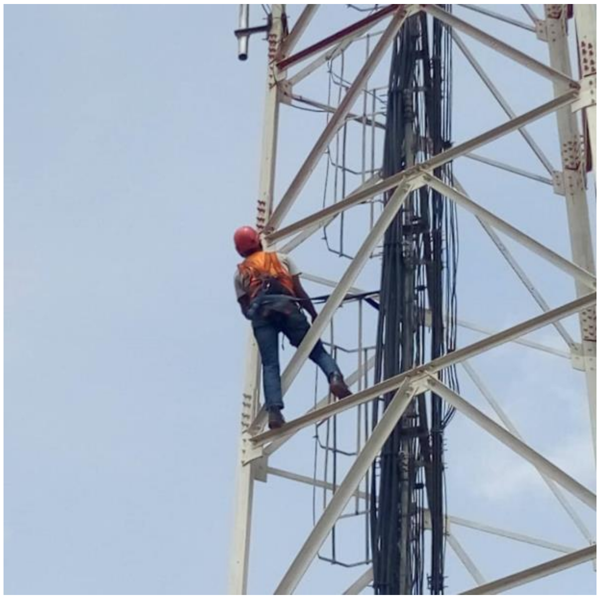


Plate XVIII: Tower physical inspection

Plate XIX: Bolt torquing

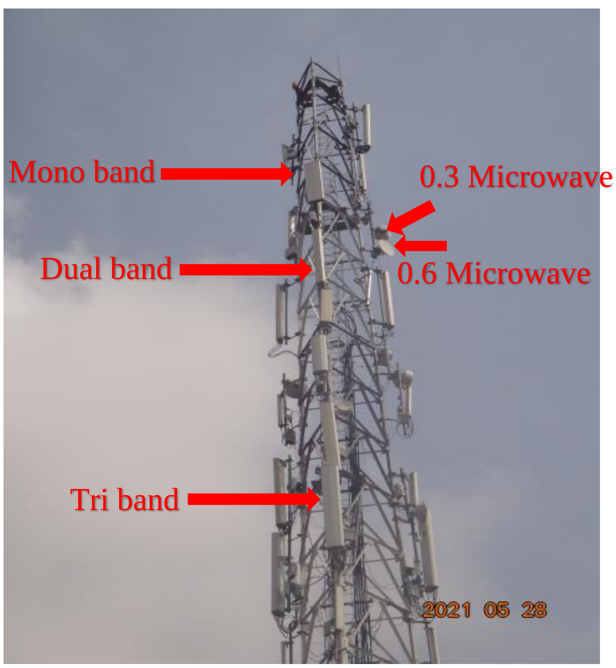


Plate XX: Types of Antennas

Plate XXI: Base Stations of Operators

Table 3.2: Antenna types

Antenna Type	Dimension (mm)	Total Number
Tri-band Antenna	2500 x 300 x 200	3
Dual-band Antenna	1500 x 170 x 150	8
Mono-band	1300 x 150 x 100	11
Radio Remote Unit	480 x 290 x 180	17
Microwave Antenna 1	300 x 150	2
Microwave Antenna 2	600 x 300	7

3.4 Structural Analysis of the Tower

The selected lattice tower is analysed using two methods. The use of the Effective Projected Area model (EPA) and the use of a design software called STAAD Pro. V8i. (Structural Analysis and Designing Program).

3.4.1 Structural analysis using EPA model

The Effective Projected Area (EPA) model is based on the exposed surface areas of the antennas and the tower members. Since the effect of self-weight of the antennas is not significant when compared to the effect of wind forces on the projected areas of the antennas, it is safe to assume that the effect of wind forces alone suffices to give a quick overview of the load-carrying capacity of the tower. The model is computed using the Microsoft Excel.

The spreadsheet idealizes the tower as a single pole and calculates the effect of existing and future loads on the tower using the lever-arm created by the wind load on the antennas with the fulcrum at the base of the tower. Effects of various combinations of antennas loading can also be quickly considered using the spreadsheet.

The computation for the EPA takes into consideration the tower height, tower capacity, tower design wind speed, tower top rating, lever arm, antenna areas and antenna installation heights. The tower design wind speed (Vs) is obtained from the tower assembly drawing tower capacity (TC) and tower top rating (TR) are obtained from the Etisalat tower specification (2012). The antenna areas (A) are obtained from the dimensions (frontal area) of each antenna while each antenna's installation height (Ah) is recorded on site.

The tower lever arm is calculated as shown in equation 3.1.

$$LA = TH - \frac{TR}{2} \tag{3.1}$$

Where:

LA = Tower lever arm (m)
TH = Tower height (m)
TR = Tower top rating (m)

The Effective Projected Area for the antenna is calculated as shown in equation 3.2.

$$EPA = A\left(\frac{Ah}{LA}\right) \tag{3.2}$$

Where:

EPA = Effective Projected Area (m^2)
A = Antenna area (m^2)
A h = Height of antenna installation (m)
LA = Tower lever arm (m)

The spreadsheet sums up the total antennas EPAs installed on the tower. The percentage utilization of the tower capacity resulting from the effect of wind forces on the projected areas of the antennas is computed by relating the summation of EPAs to the original design capacity of the tower.

Tower utilization percentage formula is calculated as shown in equation 3.3.

$$TUP = \left(\frac{\Sigma EPA}{TC}\right) 100 \tag{3.3}$$

Where:

TUP = Tower utilization percentage (%)
ΣEPA = Summation of EPA (m^2)
TC = Tower capacity (m^2)

The tower loading is optimized using the local basic wind speed as provided by the Nigeria Meteorological Agency in figure 3.3. to obtain the optimized tower utilization percentage.

Optimized tower utilization percentage formula is calculated as shown in equation 3.4.

$$OTUP = \left(\frac{Vb}{Vs}\right) TUP \tag{3.4}$$

Where:

OTUP = Optimized tower utilization percentage (%)
TUP = Tower utilization percentage (%)
Vb = Basic wind speed (m/s)
Vs = Tower design wind speed (m/s)

If the tower utilization is below 100%, the tower is assumed to be safe to carry the existing antenna loads. Otherwise, a tower with utilization value above 100% is termed overloaded. Such tower is recommended for load shedding and further structural analysis.

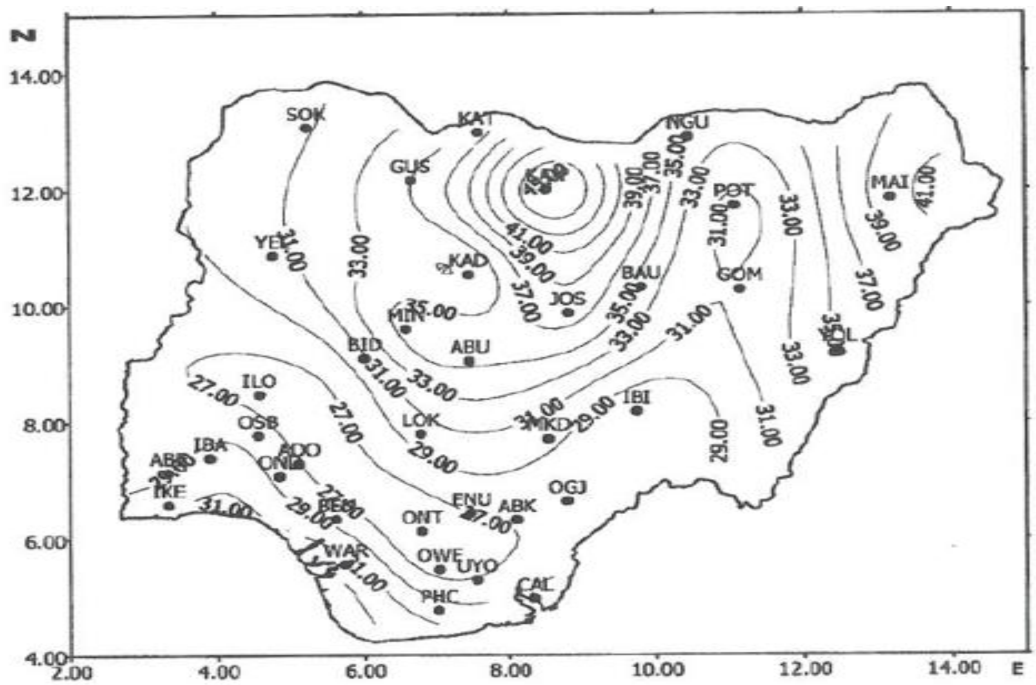


Figure 3.3: Maximum wind flow map for Nigeria (30 years and above) in m/s. (Source: Soboyejo, 1971)

3.4.2 Structural analysis using the STAAD Pro. V8i

The STAAD Pro. V8i software is used for modelling tower and carrying out the structural analysis. The analyses are based on the tower's self-weight, equipment load, wind load on the antennas and wind intensity on the tower members.

It has a friendly user interface. The tower model starts with the setting-out of the structure in a grid system. The dimensions are defined, and subsequently the nodes are connected with beams. The topmost layer is drawn inside the base grid and thereafter elevated in the Y-plane. Once the simple model is drawn, the tower members are defined with material specifications from the tower assembly drawing. Finally, the tower is loaded with calculated loads.

STAAD Pro. V8i can generate quite a large range of outputs. For this research work, the outputs are limited to the stresses on the tower members and safety of the tower. The tower design is based on steel work design guide to BS 5950-1: 2000.

Loadings

There are different types of loads acting on the tower which includes the self-weight of the tower, live load from installed equipment, wind load on the mounted equipment and tower members. The loads acting on the selected lattice tower are derived below.

Self-weight of the tower is automatically generated in STAAD Pro. V8i by using the summed up the weights of all the sections. The weight obtained was distributed downwardly on all the tower members.

Equipment loads or antenna loads on the tower is calculated by calculating the weight of all installed equipment on the tower as shown in Table 3.3. Thereafter, the load is transferred to STAAD Pro. V8i and applied to the tower nodes where the equipment is installed.

Table 3.3: Equipment loading

S/N	Description	Numbers	Length (mm)	Width (mm)	Thickness (mm)	Weight (kg)	Total weight (kg)	Total weight (kN)
1	Tri-band Antenna	3	2500	300	200	25	75	0.75
2	Dual-band Antenna	8	1500	170	150	20	160	1.6
3	Mono-band	11	1300	150	100	10	110	1.1
4	Radio Remote Unit	17	480	290	180	15	255	2.55
5	Microwave Antenna 1	2	300	NA	150	10	20	0.2
6	Microwave Antenna 2	7	600	NA	300	14	98	0.98

Wind pressure on the tower is calculated based on BS 6399-2 1997. It takes into consideration local basic wind speed (V_b) and three multiplying factors (S_1, S_2, S_3) to obtain the design wind speed (Vs). The multiplying factors for topography, height above ground, and structure life represent S_1, S_2, and S_3 respectively. The values for the multiplying factors are obtained from Figure 3.4. Thereafter, the wind pressure (W_k) per node was calculated using equation 3.5.

$$Wk = 0.613\, Vs^2 \qquad (3.5)$$

The wind pressures obtained are applied vertically on tower joints in the STAAD Pro. V8i. model at 2m intervals.

Table 3.4: Wind Pressure Calculation

Height (m)	Abuja Basic wind speed (V_b) (m/s)	Topography multiplying factor (S_1)	Height above ground and wind braking multiplying factor (S_2)	Life of structure (S_3)	Design wind speed (Vs) (m/s)	Wind pressure (W_k) (N/m^2)	Wind pressure (W_k) (KN/m^2)
2	35	1	0.78	1	27.3	456.86277	0.46
4	35	1	0.78	1	27.3	456.86277	0.46
6	35	1	0.79	1	27.65	468.6522925	0.47
8	35	1	0.79	1	27.65	468.6522925	0.47
10	35	1	0.9	1	31.5	608.24925	0.61
12	35	1	0.9	1	31.5	608.24925	0.61
14	35	1	0.9	1	31.5	608.24925	0.61
16	35	1	0.94	1	32.9	663.51733	0.66
18	35	1	0.94	1	32.9	663.51733	0.66
20	35	1	0.96	1	33.6	692.05248	0.69
22	35	1	0.96	1	33.6	692.05248	0.69
24	35	1	0.96	1	33.6	692.05248	0.69
26	35	1	0.96	1	33.6	692.05248	0.69
28	35	1	0.96	1	33.6	692.05248	0.69
30	35	1	1	1	35	750.925	0.75
32	35	1	1	1	35	750.925	0.75
34	35	1	1	1	35	750.925	0.75
36	35	1	1	1	35	750.925	0.75
38	35	1	1	1	35	750.925	0.75
40	35	1	1.03	1	36.05	796.6563325	0.80
42	35	1	1.03	1	36.05	796.6563325	0.80
44	35	1	1.03	1	36.05	796.6563325	0.80
46	35	1	1.03	1	36.05	796.6563325	0.80

Characteristic wind pressure

W_k $0.613 V_s^2$ N/m²
where:

V_s design wind speed in m/s $= V S_1 S_2 S_3$

V basic wind speed in m/s (read from adjoining map)

S_1 multiplying factor relating to topology

S_2 multiplying factor relating to height above ground and wind braking

S_3 multiplying factor related to life of structure

Relation between design wind speed V_s and characteristic wind pressure w_k

V_s (m/s)	w_k (N/m²)
10	61
12	88
14	120
16	157
18	199
20	245
22	297
24	353
26	414
28	481
30	552
32	628
34	709
36	794
38	885
40	981
42	1080
44	1190
46	1300
48	1410
50	1530
52	1660
54	1790
56	1920
58	2060
60	2210
62	2360
64	2510
66	2670
68	2830
70	3000

Values of factor S_1

S_1 may generally always be taken as unity except in the following cases:
On sites adversely affected by very exposed hill slopes and crests where wind acceleration is known to occur: $S_1 = 1.1$
On sites in enclosed steep-sided valleys completely sheltered from winds: $S_1 = 0.9$

Values of factor S_3

S_3 is a probability factor relating the likelihood of the design wind speed being exceeded to the probable life of the structure. A value of unity is recommended for general use and corresponds to an excessive speed occurring once in fifty years.

Values of factors S_2

Structure		Topo-graphical factor	Height of structure h (m) 5	10	15	20	30	40	50	60	80	100	120	140	160	180	200
Cladding etc.		1	0.88	1.00	1.03	1.06	1.09	1.12	1.14	1.15	1.18	1.20	1.22	1.24	1.25	1.26	1.27
		2	0.79	0.93	1.00	1.03	1.07	1.10	1.12	1.14	1.17	1.19	1.21	1.22	1.24	1.25	1.26
		3	0.70	0.78	0.88	0.95	1.01	1.05	1.08	1.10	1.13	1.16	1.18	1.20	1.21	1.23	1.24
		4	0.60	0.67	0.74	0.79	0.90	0.97	1.02	1.05	1.10	1.13	1.15	1.17	1.19	1.20	1.22
Maximum vertical or maximum horizontal dimension	$\ngtr$ 50 m	1	0.83	0.95	0.99	1.01	1.05	1.08	1.10	1.12	1.15	1.17	1.19	1.20	1.22	1.23	1.24
		2	0.74	0.88	0.95	0.98	1.03	1.06	1.08	1.10	1.13	1.16	1.18	1.19	1.21	1.22	1.24
		3	0.65	0.74	0.83	0.90	0.97	1.01	1.04	1.06	1.10	1.12	1.15	1.17	1.18	1.20	1.21
		4	0.55	0.62	0.69	0.75	0.85	0.93	0.98	1.02	1.07	1.10	1.13	1.15	1.17	1.19	1.21
	> 50 m	1	0.78	0.90	0.94	0.96	1.00	1.03	1.06	1.08	1.11	1.13	1.15	1.17	1.19	1.20	1.21
		2	0.70	0.83	0.91	0.94	0.98	1.01	1.04	1.06	1.09	1.12	1.14	1.16	1.18	1.19	1.21
		3	0.60	0.69	0.78	0.85	0.92	0.96	1.00	1.02	1.06	1.09	1.11	1.13	1.15	1.17	1.18
		4	0.50	0.58	0.64	0.70	0.79	0.89	0.94	0.98	1.03	1.07	1.10	1.12	1.14	1.16	1.18

Notes

h is height (in metres) above general level of terrain to top of structure or part of structure. Increase to be made for structures on edge of cliff or steep hill.

Topographical factors

1. open country with no obstructions
2. open country with scattered wind-breaks
3. country with many wind-breaks; small towns; suburbs of large cities
4. city centres and other environments with large and frequent obstructions.

Figure 3.4: Multiplying factor chat. (*Source: Reinforced concrete designer's handbook* 10th ed. by Reynolds and Steedman,1998).

The wind load on the equipment is generated from the force the wind exerts on the projected surface area of the equipment. The force is calculated by multiplying the force coefficient of each antenna which is based on shapes by highest wind pressure by projected area of the antenna. It is obtained using equation 3.6.

$$F = cf.Wk.A \quad (3.6)$$

Where:

F = Force
cf = force coefficient
W_k = wind pressure
A = Area

The force values obtained per equipment are applied perpendicularly to the tower members where the antennas are installed. Table 3.5 shows the forces acting on each type of antenna.

Table 3.5: Wind load on equipment

Description	Length (h) (mm)	Width (b) (mm)	Thickness (a) (mm)	h/b	a/b	Force coefficient (*cf*)	Area (A) (m^2)	Force (F) (KN)
Tri-band Antenna	2500	300	200	8.33	0.67	1.7	0.75	1.02
Dual-band Antenna	1500	170	150	8.82	0.88	1.7	0.26	0.35
Mono-band	1300	150	100	8.67	0.67	1.7	0.20	0.26
Radio Remote Unit	480	290	180	1.66	0.62	1.2	0.14	0.13
Microwave Antenna 1	300	NA	150	NA	NA	1.2	0.07	0.07
Microwave Antenna 2	600	NA	300	NA	NA	1.2	0.28	0.27

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Tower Physical Inspection

The outcome of physical inspection of the lattice tower member and accessories are presented in Table 4.1.

Table 4.1: Tower Physical Inspection

Item	Description
Structural Members	No warped member detected
Access Ladder	Accessible and railings are in good condition
Rest Platforms	Gratings on platforms are not blocked and do not accumulate water or not corroded
Bolts and Nuts	No missing bolts and nuts were observed. Bolts and nuts are properly tightened.
Aviation Warning Light	Aviation warning lights (AWL) are in place and functional
Earthen cables	Copper cables for tower earthen
Antennas	Antennas properly clamped
Tower paint	Faded
Thunder Arrestor	Properly bolted

It was observed from the physical inspection that the tower members and accessories are in good condition with the only exception being the tower paint. The red and white paint of the telecommunications tower is washed-out and needs repainting.

4.2 Tower Foundation Auditing

The average compressive strengths of the tower legs are presented in Table 4.2.

	Rebound Values (R)		
S/N	Leg A	Leg B	Leg C
1	26	28	42
2	27	30	28
3	35	27	35
4	30	25	27
5	32	33	30
6	33	30	31
7	25	28	28
8	25	30	26
Mean Compressive strength X (R)	28.5	29	29
Mean Compressive strength F (N/mm^2)	25.1	25.9	25.9

Table 4.2: Compressive Strength of Stub Columns

The mean compressive strength of the stub columns obtained using the Schmidt hammer are 25.1, 25.9 and 25.9 N/mm^2 for legs A, B and C respectively. These values meet the recommended concrete strength of the foundation (25/19 MPa) as stated in the foundation drawing in Appendix B2. The physical conditions of the stubs are also okay as there was no visible cracks or blisters on them. Furthermore, there were no visible compaction failure around the foundation.

4.3 Tower Analysis using EPA Model

The tower utilization percentage derived from the existing antenna using the EPA model is presented in Table 4.3.

Table 4.3: Tower utilization percentage

Existing Telecommunication Antennas on Tower					
Lever arm LA (TH - TR/2) (m)	Antenna	Exposed Surface (mm)	Area A (m^2)	Height Ah (m)	Effective Projected Area EPA A* Ah/LA (m^2)
40	GSM 1	2500 x 300	0.75	24	0.45
	GSM 1	2500 x 300	0.75	24	0.45
	GSM 1	2500 x 300	0.75	24	0.45
	GSM 2	1500 x 170	0.26	28	0.18
	GSM 2	1500 x 170	0.26	28	0.18
	GSM 2	1500 x 170	0.26	28	0.18
	GSM 2	1500 x 170	0.26	34	0.22
	GSM 2	1500 x 170	0.26	34	0.22
	GSM 2	1500 x 170	0.26	34	0.22
	GSM 2	1500 x 170	0.26	44	0.28
	GSM 2	1500 x 170	0.26	44	0.28
	GSM 3	1300 x 150	0.20	20	0.10
	GSM 3	1300 x 150	0.20	20	0.10
	GSM 3	1300 x 150	0.20	20	0.10
	GSM 3	1300 x 150	0.20	30	0.15
	GSM 3	1300 x 150	0.20	30	0.15
	GSM 3	1300 x 150	0.20	30	0.15
	GSM 3	1300 x 150	0.20	32	0.16
	GSM 3	1300 x 150	0.20	38	0.19
	GSM 3	1300 x 150	0.20	38	0.19
	GSM 3	1300 x 150	0.20	42	0.20
	GSM 3	1300 x 150	0.20	42	0.20
	RRU	480 x 290	0.14	20	0.07
	RRU	480 x 290	0.14	20	0.07
	RRU	480 x 290	0.14	20	0.07
	RRU	480 x 290	0.14	30	0.10
	RRU	480 x 290	0.14	30	0.10
	RRU	480 x 290	0.14	30	0.10
	RRU	480 x 290	0.14	32	0.11
	RRU	480 x 290	0.14	38	0.13
	RRU	480 x 290	0.14	38	0.13
	RRU	480 x 290	0.14	42	0.15
	RRU	480 x 290	0.14	42	0.15
	RRU	480 x 290	0.14	24	0.08
	RRU	480 x 290	0.14	24	0.08
	RRU	480 x 290	0.14	24	0.08
	RRU	480 x 290	0.14	24	0.08
	RRU	480 x 290	0.14	24	0.08
	RRU	480 x 290	0.14	24	0.08
		Sub-Total A			6.46

Table 4.3: Tower utilization percentage continued

Existing Telecommunication Antennas on Tower					
Lever arm LA (TH - TR/2) (m)	Antenna	Exposed Surface (mm)	Area A (m^2)	Height Ah (m)	Effective Projected Area EPA A* Ah/LA (m^2)
#VALUE!	GSM 1	0.60	0.28	16	0.11
	GSM 1	0.60	0.28	26	0.18
	GSM 1	0.30	0.07	28	0.05
	GSM 2	0.60	0.28	32	0.23
	GSM 2	0.60	0.28	32	0.23
	GSM 2	0.60	0.28	33	0.23
	GSM 2	0.60	0.28	37	0.26
	GSM 2	0.60	0.28	38	0.27
	GSM 2	0.30	0.07	39	0.07
Sub-Total B					1.63
Summation of Effective Projected Area					8.09

Tower Height (TH)	45	M
Tower Type	Medium Duty Lattice Tower	
Tower Capacity (TC)	12	m^2
Tower is rated for top (TR)	10	M
Percentage utilization based on EPA (ΣEPA/TC) *100	67.4%	
Tower Design Wind Speed	40	m/s
Abuja Basic Wind Speed	35	m/s
Percentage utilization based on local wind speed (OTUP) (Vb/Vs *100)	59.0%	

The present tower utilization percentage is at 67.4%. However, after optimization of the tower design wind speed with the local basic wind speed the tower utilization percentage is dropped to 59%. The tower loading can be termed satisfactory.

4.4 Tower Analysis using STAAD Pro. V8i

The computation sheets presented as Table 4.1 shows output from the STAAD Pro V8i software. It captures details such as design inputs, tower model, loading animations, tower utilisation ratio and failed member check.

Table 4.4: STAAD Pro computation sheets

Software licensed to	Job No	Sheet No **1**	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Research	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	

Job Information

	Engineer	Checked	Approved
Name:	0.0.0	0.0.0	S.M.A
Date:	26-May-21		

Structure Type	SPACE FRAME

Number of Nodes	141	Highest Node	148
Number of Elements	348	Highest Beam	383

Number of Basic Load Cases	-2
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	DEAD LOAD - TOWER SELF WEIGHT
Primary	2	LIVE LOAD - EQUIPMENT SELF WEIGHT
Primary	3	WIND LOAD WLX
Primary	4	WIND LOAD WLZ
Primary	5	WIND LOAD WLX ANTENNA

Section Properties

Prop	Section	Area (cm^2)	I_{yy} (cm^4)	I_{zz} (cm^4)	J (cm^4)	Material
1	ISA150X150X18	51.000	1.68E+3	442.263	56.570	STEEL
2	ISA150X150X15	43.000	1.45E+3	376.344	32.906	STEEL
3	ISA150X150X12	34.800	1.19E+3	308.001	16.934	STEEL
4	ISA150X150X10	29.200	1.01E+3	260.468	9.833	STEEL
5	ISA120X120X12	27.600	591.465	155.098	13.478	STEEL
6	ISA120X120X10	23.300	504.598	132.540	7.833	STEEL
7	ISA120X120X8	18.800	414.192	107.904	4.028	STEEL
8	ISA100X100X8	15.400	236.028	60.319	3.345	STEEL
9	ISA90X90X8	13.800	169.724	43.580	3.004	STEEL
10	ISA80X80X6	9.290	91.201	23.420	1.130	STEEL
11	ISA70X70X6	8.060	60.196	15.417	0.986	STEEL
12	ISA60X60X5	5.750	31.745	8.071	0.490	STEEL
13	ISA50X50X6	5.680	20.764	5.489	0.698	STEEL
14	ISA20x20x3	1.120	0.634	0.172	0.035	STEEL
15	ISA150x150x10	29.200	1.01E+3	260.468	9.833	STEEL
16	ISA100x100x8	15.400	236.028	60.319	3.345	STEEL
17	ISA200x150x12	40.900	2.05E+3	437.536	19.814	STEEL
18	ISA110x110x12	25.100	460.033	117.653	12.326	STEEL
19	ISA120x120x10	23.300	504.598	132.540	7.833	STEEL
20	ISA100x100x12	22.600	333.243	86.784	11.174	STEEL
21	ISA90x90x12	20.200	238.003	62.579	10.022	STEEL
22	ISA120x120x8	18.800	414.192	107.904	4.028	STEEL

Print Time/Date: 09/06/2021 12:28 STAAD.Pro V8i (SELECTseries 6) 20.07.11.33 Print Run 1 of 18

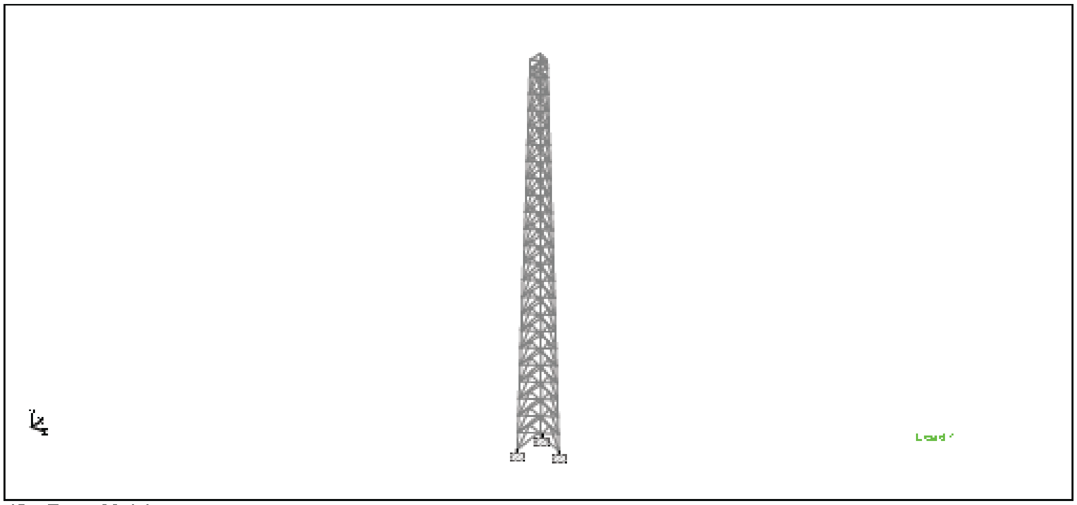
Table 4.4: STAAD Pro computation sheets continued

Section Properties Cont...

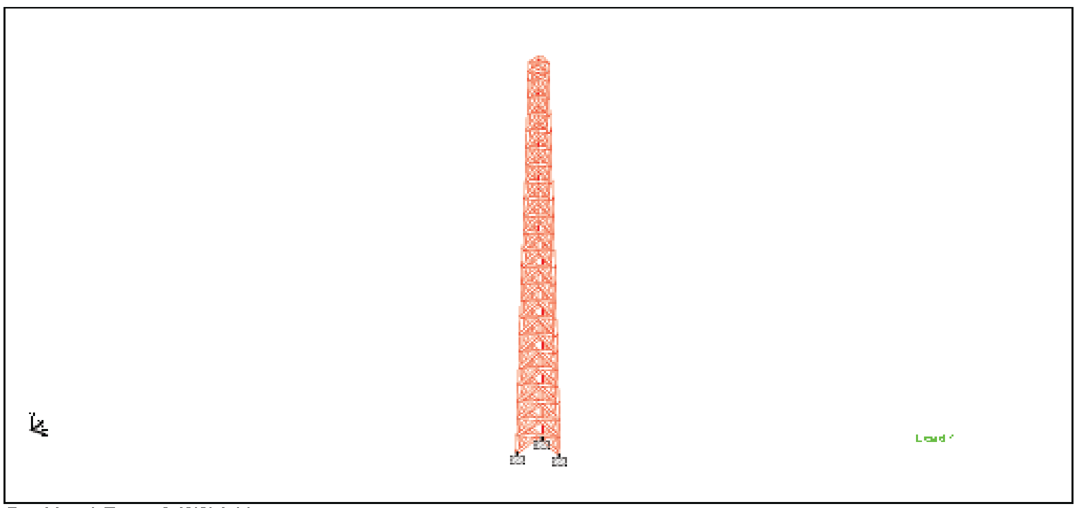
Prop	Section	Area (cm^2)	I_{yy} (cm^4)	I_{zz} (cm^4)	J (cm^4)	Material
23	ISA125x95x8	17.000	335.972	72.076	3.686	STEEL
24	ISA100x100x7	13.700	208.550	54.556	2.247	STEEL
25	ISA100x100x6	11.700	182.269	46.515	1.418	STEEL
26	ISA100x75x6	10.100	128.549	26.746	1.238	STEEL
27	ISA75x75x6	8.660	74.692	19.074	1.058	STEEL
28	ISA65x65x5	6.250	40.755	10.335	0.531	STEEL
29	ISA60x60x4	4.710	25.861	6.771	0.252	STEEL
30	ISA30x30x3	1.730	2.307	0.610	0.053	STEEL
31	ISA90x90x6	10.500	131.495	33.683	1.274	STEEL
32	ISA80x80x6	9.290	91.201	23.420	1.130	STEEL
33	ISA75x75x5	7.270	63.504	16.152	0.615	STEEL
34	ISA70x70x5	6.770	51.254	13.065	0.573	STEEL
35	ISA60x60x5	5.750	31.745	8.071	0.490	STEEL
36	ISA50x50x3	2.950	11.347	2.953	0.089	STEEL
37	ISA45x45x3	2.640	8.196	2.128	0.080	STEEL
38	ISA200x150x10	34.300	1.73E+3	370.155	11.500	STEEL
39	ISA130x130x10	25.100	650.783	166.674	8.500	STEEL
40	ISA130x130x9	22.900	589.885	154.135	6.209	STEEL
41	ISA130x130x8	20.300	532.234	136.463	4.369	STEEL
42	ISA125x95x6	12.900	258.549	55.548	1.562	STEEL
43	ISA40x40x3	2.340	5.679	1.485	0.071	STEEL
44	ISA35x35x3	2.030	3.748	0.978	0.062	STEEL
45	ISA45x45x4	3.470	10.576	2.756	0.188	STEEL
46	ISA50x50x4	3.880	14.695	3.829	0.209	STEEL
47	ISA70x45x5	5.520	31.600	5.360	0.469	STEEL
48	ISA55x55x5	5.270	24.124	6.215	0.448	STEEL
49	ISA75x50x5	6.020	40.283	7.233	0.510	STEEL
50	ISA25x25x3	1.410	1.303	0.338	0.044	STEEL

Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 3	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	



45m Tower Model

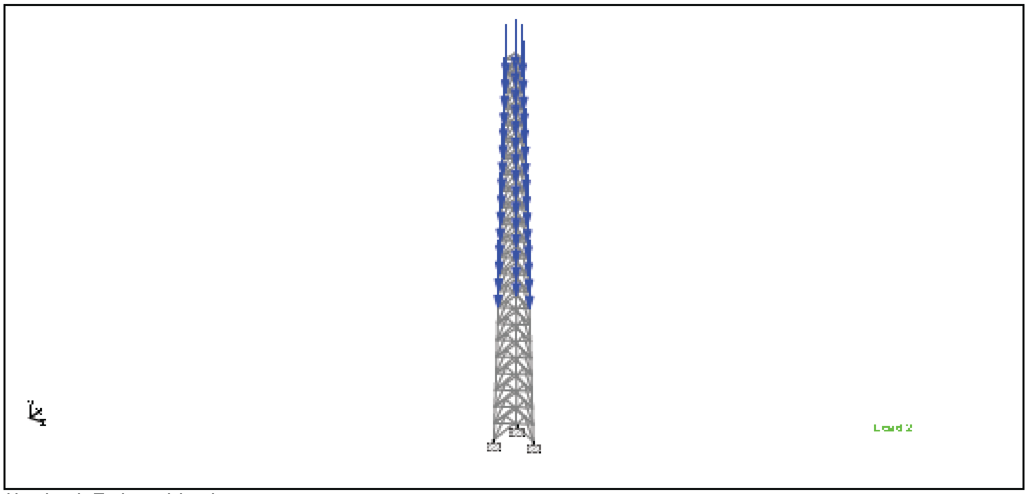


Dead Load_Tower Self Weight

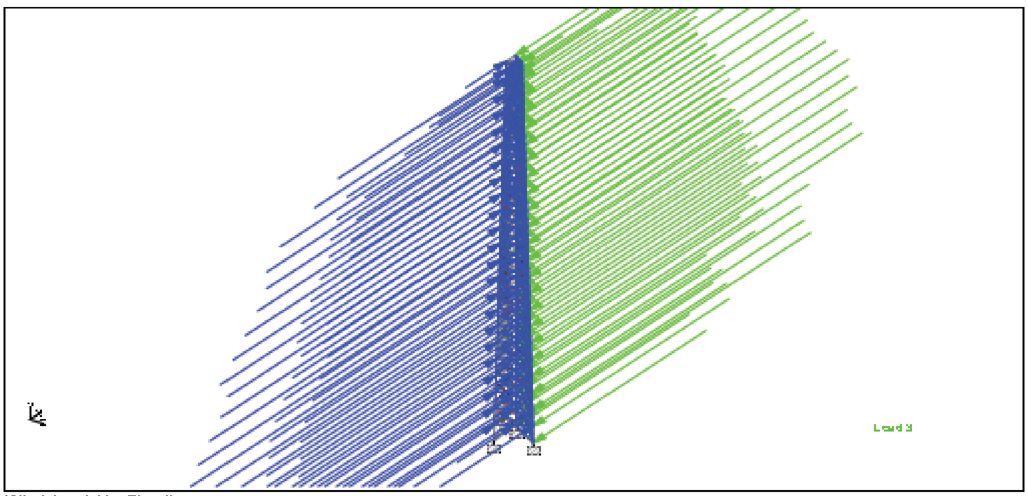
Print Time/Date: [illegible] | STAAD.Pro V8i (SELECTseries 6) 20.07.11.33 | Print Run 3 of 18

Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 4	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	



Live Load_ Equipment Load

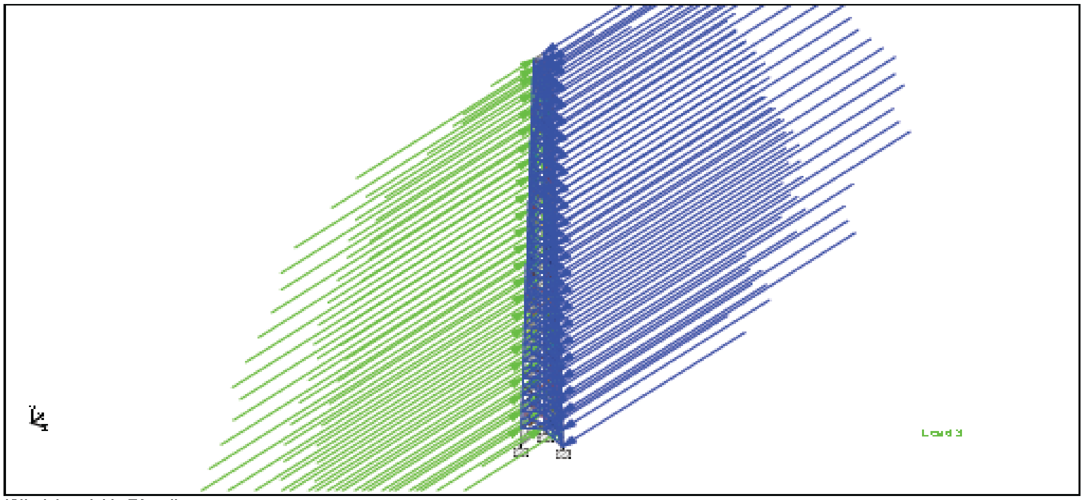


Wind Load_X+ Direction

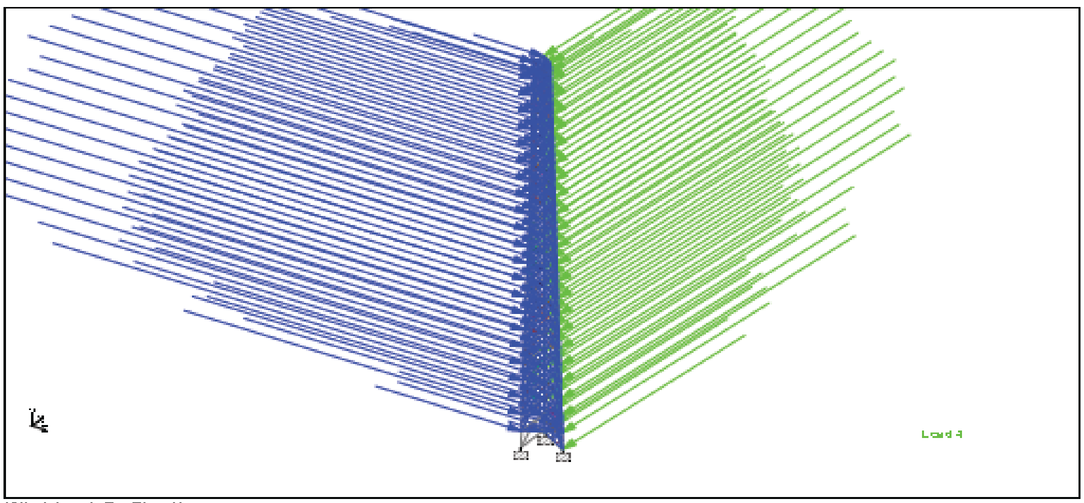
Print Time/Date: 09/06/2021 12:56 STAAD.Pro V8i (SELECTseries 6) 20.07.11.33 Print Run 4 of 18

Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 5	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	



Wind Load_X- Direction

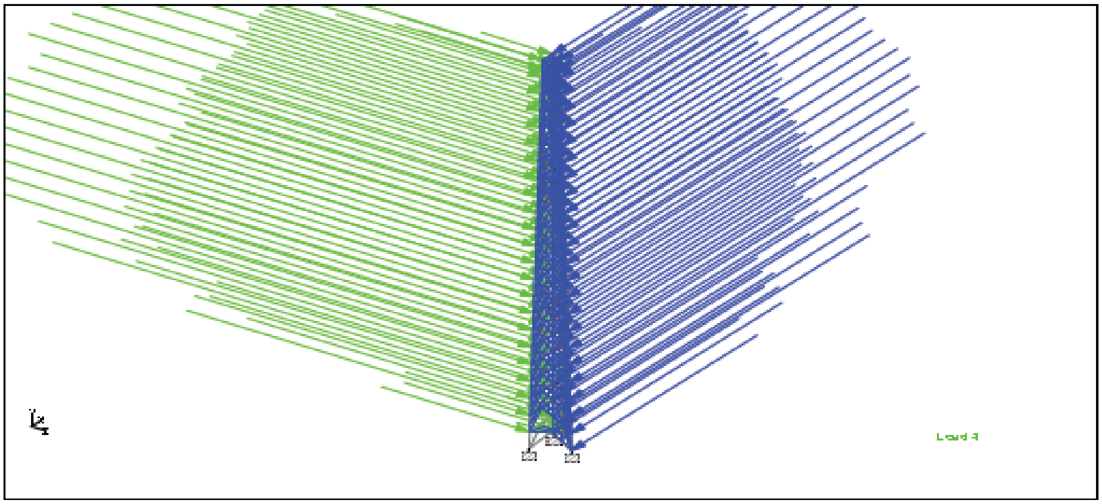


Wind Load_Z+Direction

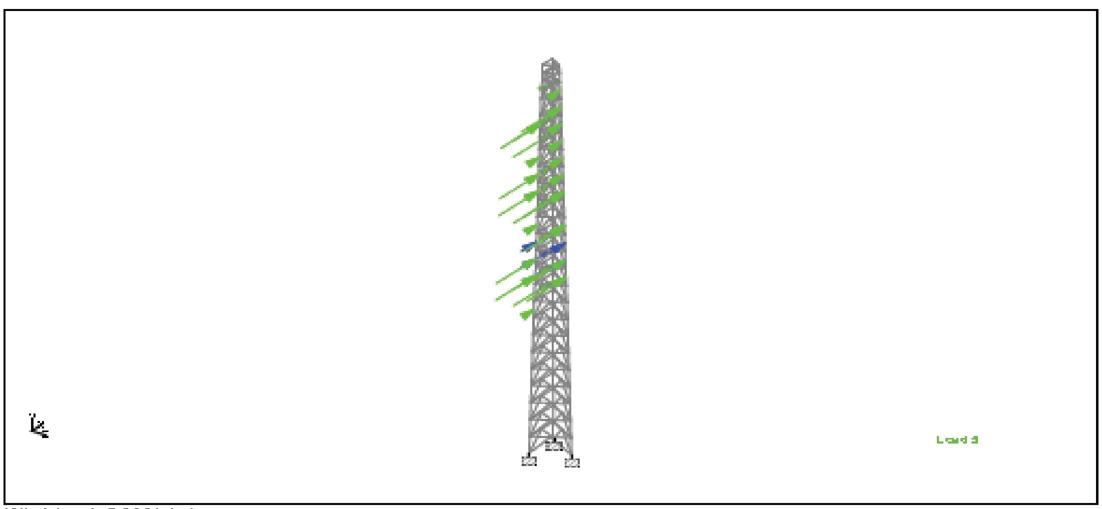
STAAD.Pro V8i (SELECTseries 6) 20.07.11.33

Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 6	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	



Wind Load_Z- Direction

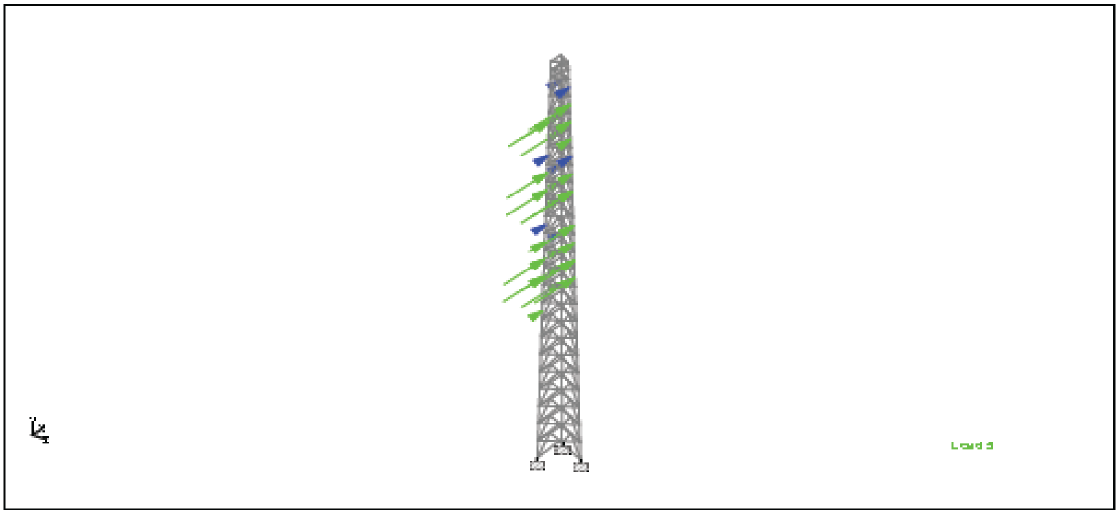


Wind Load_GSM1 Antenna

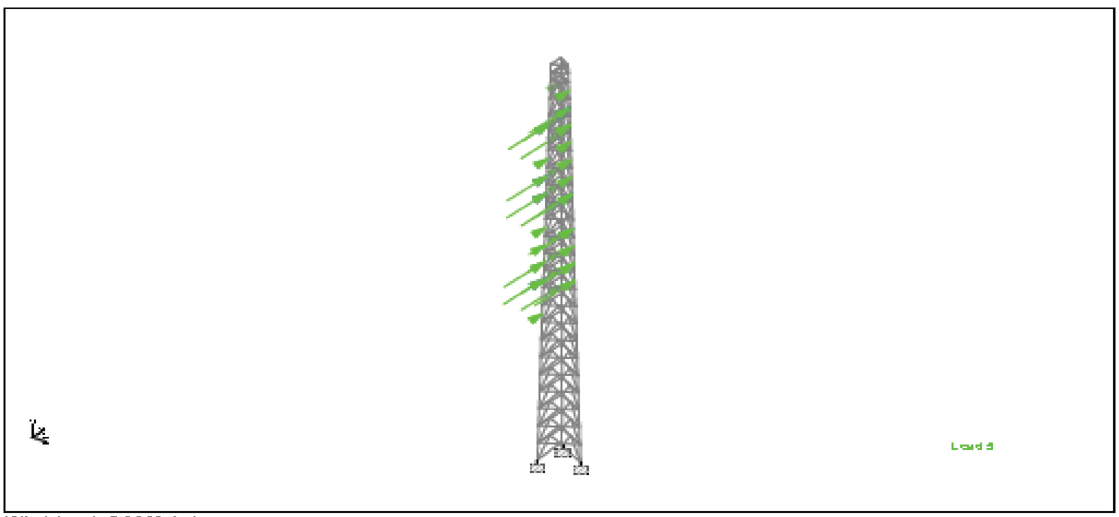
STAAD.Pro V8i (SELECTseries 6) 20.07.11.33

Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 7	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Research	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	



Wind Load_GSM2 Antenna

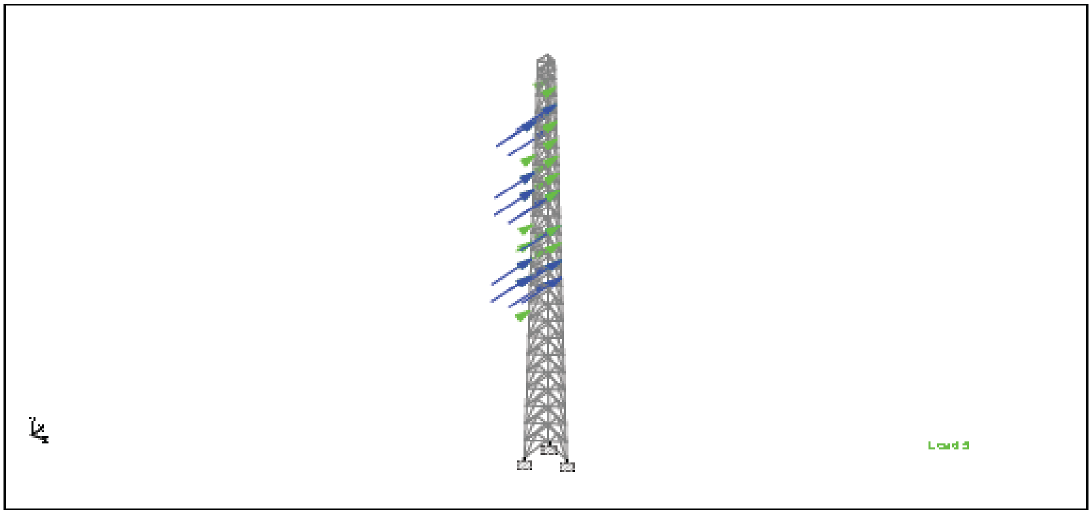


Wind Load_GSM3 Antenna

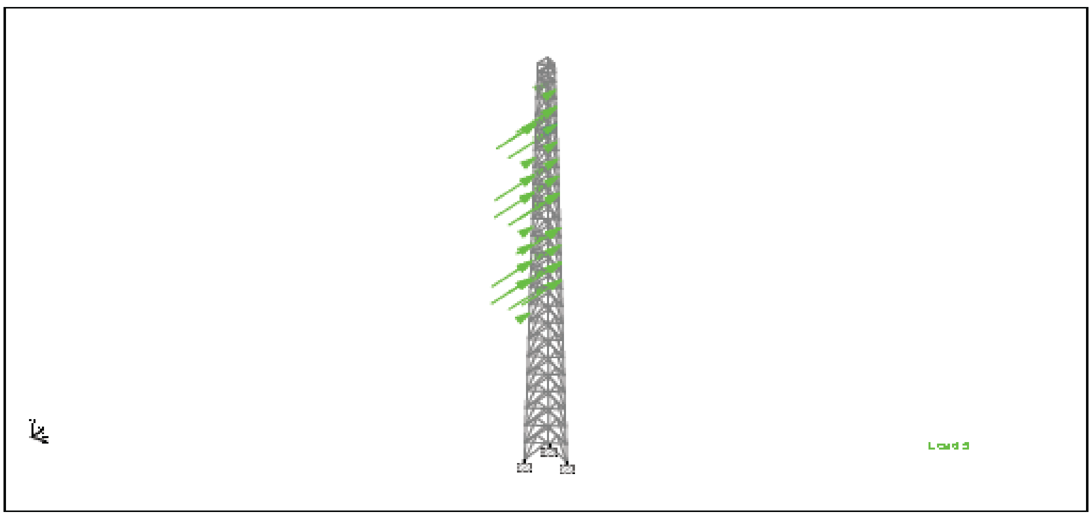
STAAD.Pro V8i (SELECTseries 6) 20.07.11.33

Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 8	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Research	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	



Wind load_RRU

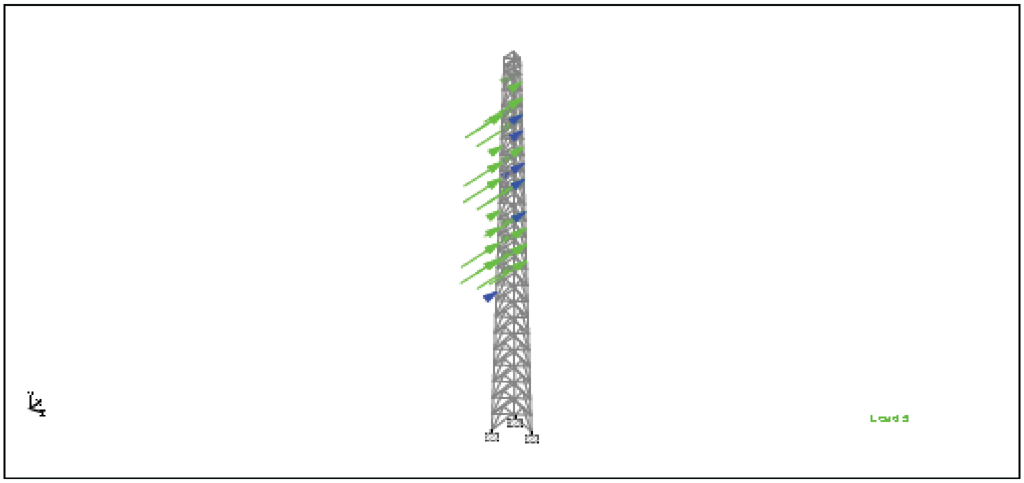


Wind load_MW 1 Antenna

STAAD.Pro V8i (SELECTseries 6) 20.07.11.33

Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 9	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	



Wind Load_MW 2 Antenna

Utilization Ratio

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Ratio (Act./Allow.)	Clause	L/C	Ax (cm^2)	Iz (cm^4)	Iy (cm^4)	Ix (cm^4)
19	ISA50X50X6	ISA20x20x3	0.284	1.000	0.284	BS-4.7 (C)	3	1.120	0.159	0.647	0.034
21	ISA150X150	ISA150x150	0.948	1.000	0.948	BS-4.8.2.2	4	29.200	259.308	1.02E+3	9.733
22	ISA150X150	ISA100x100	0.921	1.000	0.921	BS-4.8.3.3.1	4	15.400	59.766	236.581	3.285
23	ISA150X150	ISA200x150	0.862	1.000	0.862	BS-4.8.3.3.1	4	40.900	434.669	2.05E+3	19.632
24	ISA150X150	ISA110x110	0.995	1.000	0.995	BS-4.8.2.2	4	25.100	116.025	451.661	12.048
25	ISA150X150	ISA120x120	0.991	1.000	0.991	BS-4.8.2.2	4	23.300	130.874	506.264	7.767
26	ISA150X150	ISA100x100	0.964	1.000	0.964	BS-4.8.2.2	4	22.600	85.937	334.090	10.848
27	ISA150X150	ISA90x90x1	0.999	1.000	0.999	BS-4.8.2.2	4	20.200	61.862	238.720	9.696
28	ISA150X150	ISA120x120	0.956	1.000	0.956	BS-4.8.2.2	4	18.800	106.491	415.606	4.011
29	ISA150X150	ISA125x95x	0.954	1.000	0.954	BS-4.8.2.2	4	17.000	71.442	336.605	3.627
30	ISA150X150	ISA100x100	0.941	1.000	0.941	BS-4.8.2.2	4	15.400	59.766	236.581	3.285
31	ISA150X150	ISA100x100	0.957	1.000	0.957	BS-4.8.2.2	4	13.700	53.709	209.396	2.238
32	ISA150X150	ISA100x100	0.993	1.000	0.993	BS-4.8.2.2	4	11.700	45.869	182.915	1.404
33	ISA120X120	ISA100x100	0.861	1.000	0.861	BS-4.8.2.2	4	11.700	45.869	182.915	1.404
34	ISA120X120	ISA100x75x	0.969	1.000	0.969	BS-4.8.3.3.1	5	10.100	26.180	129.114	1.212
35	ISA120X120	ISA75x75x6	0.996	1.000	0.996	BS-4.8.3.3.1	5	8.660	18.713	75.052	1.039
36	ISA120X120	ISA75x75x6	0.851	1.000	0.851	BS-4.8.3.3.1	5	8.660	18.713	75.052	1.039
37	ISA120X120	ISA75x75x6	0.903	1.000	0.903	BS-4.8.3.3.1	5	8.660	18.713	75.052	1.039
38	ISA120X120	ISA65x65x5	0.905	1.000	0.905	BS-4.8.3.3.1	5	6.250	10.081	41.010	0.521
39	ISA100X100	ISA60x60x4	0.940	1.000	0.940	BS-4.8.3.3.1	5	4.710	6.558	26.074	0.251
40	ISA90X90X8	ISA60x60x4	0.663	1.000	0.663	BS-4.8.3.3.1	5	4.710	6.558	26.074	0.251
41	ISA90X90X8	ISA60x60x4	0.999	1.000	0.999	BS-4.8.3.3.1	5	4.710	6.558	26.074	0.251
42	ISA80X80X6	ISA60x60x4	0.844	1.000	0.844	BS-4.8.3.3.1	5	4.710	6.558	26.074	0.251
43	ISA80X80X6	ISA20x20x3	0.986	1.000	0.986	BS-4.8.3.3.1	5	1.120	0.159	0.647	0.034
44	ISA70X70X6	ISA30x30x3	0.906	1.000	0.906	BS-4.8.2.2	5	1.730	0.574	2.342	0.052
45	ISA70X70X6	ISA20x20x3	0.343	1.000	0.343	BS-4.9	5	1.120	0.159	0.647	0.034

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Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 10	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	

Utilization Ratio Cont...

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Ratio (Act./Allow.)	Clause	L/C	Ax (cm^2)	Iz (cm^4)	Iy (cm^4)	Ix (cm^4)
46	ISA150X150	ISA100x100	0.975	1.000	0.975	BS-4.8.3.3.1	4	11.700	45.869	182.915	1.404
47	ISA150X150	ISA100x100	0.933	1.000	0.933	BS-4.8.3.3.1	4	11.700	45.869	182.915	1.404
48	ISA150X150	ISA100x100	0.847	1.000	0.847	BS-4.8.3.3.1	4	11.700	45.869	182.915	1.404
49	ISA150X150	ISA90x90x6	0.965	1.000	0.965	BS-4.8.3.3.1	4	10.500	33.268	131.910	1.260
50	ISA150X150	ISA90x90x6	0.895	1.000	0.895	BS-4.8.3.3.1	4	10.500	33.268	131.910	1.260
51	ISA150X150	ISA100x75x6	0.966	1.000	0.966	BS-4.8.3.3.1	4	10.100	26.180	129.114	1.212
52	ISA150X150	ISA80x80x6	0.982	1.000	0.982	BS-4.8.3.3.1	4	9.290	22.899	91.722	1.115
53	ISA150X150	ISA80x80x6	0.862	1.000	0.862	BS-4.8.3.3.1	4	9.290	22.899	91.722	1.115
54	ISA150X150	ISA75x75x6	0.922	1.000	0.922	BS-4.8.3.3.1	4	8.660	18.713	75.052	1.039
55	ISA120X120	ISA75x75x5	0.935	1.000	0.935	BS-4.8.3.3.1	4	7.270	15.924	63.732	0.606
56	ISA120X120	ISA70x70x5	0.954	1.000	0.954	BS-4.8.3.3.1	4	6.770	12.893	51.426	0.564
57	ISA120X120	ISA65x65x5	0.989	1.000	0.989	BS-4.8.3.3.1	4	6.250	10.081	41.010	0.521
58	ISA120X120	ISA65x65x5	0.833	1.000	0.833	BS-4.8.3.3.1	4	6.250	10.081	41.010	0.521
59	ISA120X120	ISA60x60x5	0.842	1.000	0.842	BS-4.8.3.3.1	4	5.750	7.871	31.944	0.479
60	ISA120X120	ISA60x60x4	0.993	1.000	0.993	BS-4.8.2.2	5	4.710	6.558	26.074	0.251
61	ISA100X100	ISA60x60x4	0.919	1.000	0.919	BS-4.8.2.2	5	4.710	6.558	26.074	0.251
62	ISA90X90X8	ISA50x50x3	0.943	1.000	0.943	BS-4.8.3.3.1	4	2.950	2.891	11.409	0.089
63	ISA90X90X8	ISA45x45x3	0.840	1.000	0.840	BS-4.8.3.3.1	4	2.640	2.072	8.252	0.079
64	ISA80X80X6	ISA60x60x4	0.853	1.000	0.853	BS-4.8.2.2	5	4.710	6.558	26.074	0.251
65	ISA80X80X6	ISA30x30x3	0.746	1.000	0.746	BS-4.8.3.3.1	4	1.730	0.574	2.342	0.052
66	ISA70X70X6	ISA20x20x3	0.819	1.000	0.819	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034
67	ISA70X70X6	ISA20x20x3	0.149	1.000	0.149	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034
68	ISA150X150	ISA200x150	0.808	1.000	0.808	BS-4.8.3.3.1	4	34.300	369.013	1.74E+3	11.433
69	ISA150X150	ISA150x150	0.941	1.000	0.941	BS-4.8.3.3.1	4	29.200	259.308	1.02E+3	9.733
70	ISA150X150	ISA150x150	0.880	1.000	0.880	BS-4.8.3.3.1	4	29.200	259.308	1.02E+3	9.733
71	ISA150X150	ISA150x150	0.793	1.000	0.793	BS-4.8.3.3.1	4	29.200	259.308	1.02E+3	9.733
72	ISA150X150	ISA130x130	0.944	1.000	0.944	BS-4.8.3.3.1	4	25.100	165.783	651.674	8.367
73	ISA150X150	ISA130x130	0.944	1.000	0.944	BS-4.8.3.3.1	4	22.900	152.432	591.589	6.183
74	ISA150X150	ISA130x130	0.953	1.000	0.953	BS-4.8.3.3.1	4	20.300	135.125	533.572	4.331
75	ISA150X150	ISA120x120	0.974	1.000	0.974	BS-4.8.3.3.1	4	18.800	106.491	415.606	4.011
76	ISA150X150	ISA120x120	0.858	1.000	0.858	BS-4.8.3.3.1	4	18.800	106.491	415.606	4.011
77	ISA120X120	ISA125x95x6	0.979	1.000	0.979	BS-4.8.3.3.1	4	17.000	71.442	336.605	3.627
78	ISA120X120	ISA100x100	0.963	1.000	0.963	BS-4.8.3.3.1	4	15.400	59.766	236.581	3.285
79	ISA120X120	ISA125x95x6	0.930	1.000	0.930	BS-4.8.3.3.1	4	12.900	54.742	259.355	1.548
80	ISA120X120	ISA100x100	0.913	1.000	0.913	BS-4.8.3.3.1	4	11.700	45.869	182.915	1.404
81	ISA120X120	ISA90x90x6	0.910	1.000	0.910	BS-4.8.3.3.1	4	10.500	33.268	131.910	1.260
82	ISA120X120	ISA80x80x6	0.956	1.000	0.956	BS-4.8.3.3.1	4	9.290	22.899	91.722	1.115
83	ISA100X100	ISA75x75x6	0.866	1.000	0.866	BS-4.8.3.3.1	4	8.660	18.713	75.052	1.039
84	ISA90X90X8	ISA70x70x5	0.885	1.000	0.885	BS-4.8.3.3.1	4	6.770	12.893	51.426	0.564
85	ISA90X90X8	ISA60x60x5	0.874	1.000	0.874	BS-4.8.3.3.1	4	5.750	7.871	31.944	0.479
86	ISA80X80X6	ISA60x60x4	0.614	1.000	0.614	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
87	ISA80X80X6	ISA60x60x4	0.838	1.000	0.838	BS-4.8.3.3.1	5	4.710	6.558	26.074	0.251
88	ISA70X70X6	ISA40x40x3	0.969	1.000	0.969	BS-4.9	5	2.340	1.435	5.730	0.070
89	ISA70X70X6	ISA20x20x3	0.660	1.000	0.660	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034
90	ISA50X50X6	ISA35x35x3	0.986	1.000	0.986	BS-4.9	3	2.030	0.939	3.787	0.061
91	ISA50X50X6	ISA40x40x3	0.893	1.000	0.893	BS-4.8.3.3.1	3	2.340	1.435	5.730	0.070
92	ISA50X50X6	ISA45x45x3	0.846	1.000	0.846	BS-4.8.3.3.1	4	2.640	2.072	8.252	0.079
93	ISA50X50X6	ISA50x50x3	0.835	1.000	0.835	BS-4.9	4	2.950	2.891	11.409	0.089
94	ISA50X50X6	ISA50x50x3	0.979	1.000	0.979	BS-4.8.3.3.1	4	2.950	2.891	11.409	0.089

STAAD.Pro V8i (SELECTseries 6) 20.07.11.33

Table 4.4: STAAD Pro computation sheets continued

Software licensed to

Job Title 45m Tower Modelling/Analysis

Client M.ENG Project Reseacrh

Job No | Sheet No 11 | Rev

Part

Ref

By 0.0.0 | Date 26-May-21 | Chd 0.0.0

File 45m Tower Modelling and | Date/Time 09-Jun-2021 12:29

Utilization Ratio Cont...

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Ratio (Act./Allow.)	Clause	L/C	Ax (cm^2)	Iz (cm^4)	Iy (cm^4)	Ix (cm^4)
95	ISA50X50X6	ISA45x45x3	0.893	1.000	0.893	BS-4.8.3.3.1	3	2.640	2.072	8.252	0.079
96	ISA50X50X6	ISA45x45x3	0.855	1.000	0.855	BS-4.9	3	2.640	2.072	8.252	0.079
97	ISA50X50X6	ISA45x45x3	0.930	1.000	0.930	BS-4.8.3.3.1	3	2.640	2.072	8.252	0.079
98	ISA50X50X6	ISA45x45x4	0.946	1.000	0.946	BS-4.8.3.3.1	4	3.470	2.681	10.651	0.185
99	ISA50X50X6	ISA45x45x4	0.949	1.000	0.949	BS-4.9	4	3.470	2.681	10.651	0.185
100	ISA50X50X6	ISA50x50x4	0.866	1.000	0.866	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
101	ISA50X50X6	ISA50x50x3	0.821	1.000	0.821	BS-4.8.3.3.1	3	2.950	2.891	11.409	0.089
102	ISA50X50X6	ISA45x45x3	0.970	1.000	0.970	BS-4.9	3	2.640	2.072	8.252	0.079
103	ISA50X50X6	ISA50x50x3	0.901	1.000	0.901	BS-4.8.3.3.1	3	2.950	2.891	11.409	0.089
104	ISA50X50X6	ISA50x50x4	0.932	1.000	0.932	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
105	ISA50X50X6	ISA50x50x3	0.882	1.000	0.882	BS-4.9	3	2.950	2.891	11.409	0.089
106	ISA50X50X6	ISA50x50x3	0.941	1.000	0.941	BS-4.8.3.3.1	3	2.950	2.891	11.409	0.089
107	ISA50X50X6	ISA50x50x4	0.998	1.000	0.998	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
108	ISA50X50X6	ISA50x50x3	0.974	1.000	0.974	BS-4.9	3	2.950	2.891	11.409	0.089
109	ISA50X50X6	ISA45x45x4	0.934	1.000	0.934	BS-4.8.3.3.1	3	3.470	2.681	10.651	0.185
110	ISA50X50X6	ISA60x60x4	0.806	1.000	0.806	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
111	ISA50X50X6	ISA45x45x4	0.952	1.000	0.952	BS-4.9	3	3.470	2.681	10.651	0.185
112	ISA50X50X6	ISA50x50x4	0.834	1.000	0.834	BS-4.8.3.3.1	3	3.880	3.742	14.782	0.207
113	ISA50X50X6	ISA60x60x4	0.703	1.000	0.703	BS-4.9	4	4.710	6.558	26.074	0.251
114	ISA50X50X6	ISA45x45x4	0.962	1.000	0.962	BS-4.9	3	3.470	2.681	10.651	0.185
115	ISA50X50X6	ISA50x50x4	0.842	1.000	0.842	BS-4.8.3.3.1	3	3.880	3.742	14.782	0.207
116	ISA50X50X6	ISA60x60x4	0.959	1.000	0.959	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
117	ISA50X50X6	ISA45x45x4	1.000	1.000	1.000	BS-4.9	3	3.470	2.681	10.651	0.185
118	ISA50X50X6	ISA50x50x4	0.865	1.000	0.865	BS-4.8.3.3.1	3	3.880	3.742	14.782	0.207
119	ISA50X50X6	ISA60x60x4	0.972	1.000	0.972	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
120	ISA50X50X6	ISA50x50x4	0.900	1.000	0.900	BS-4.9	3	3.880	3.742	14.782	0.207
121	ISA50X50X6	ISA50x50x4	0.922	1.000	0.922	BS-4.8.3.3.1	3	3.880	3.742	14.782	0.207
122	ISA50X50X6	ISA70x45x5	0.968	1.000	0.968	BS-4.8.3.3.1	4	5.520	5.172	31.787	0.460
123	ISA50X50X6	ISA50x50x4	0.914	1.000	0.914	BS-4.9	3	3.880	3.742	14.782	0.207
124	ISA50X50X6	ISA60x60x4	0.752	1.000	0.752	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
125	ISA50X50X6	ISA60x60x5	0.890	1.000	0.890	BS-4.8.3.3.1	4	5.750	7.871	31.944	0.479
126	ISA50X50X6	ISA50x50x4	0.986	1.000	0.986	BS-4.9	3	3.880	3.742	14.782	0.207
127	ISA50X50X6	ISA60x60x4	0.811	1.000	0.811	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
128	ISA50X50X6	ISA60x60x5	0.974	1.000	0.974	BS-4.8.3.3.1	4	5.750	7.871	31.944	0.479
129	ISA50X50X6	ISA60x60x4	0.697	1.000	0.697	BS-4.9	3	4.710	6.558	26.074	0.251
130	ISA50X50X6	ISA60x60x4	0.819	1.000	0.819	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
131	ISA50X50X6	ISA65x65x5	0.894	1.000	0.894	BS-4.8.3.3.1	4	6.250	10.081	41.010	0.521
132	ISA50X50X6	ISA70x45x5	0.936	1.000	0.936	BS-4.9	4	5.520	5.172	31.787	0.460
133	ISA50X50X6	ISA70x70x5	0.993	1.000	0.993	BS-4.8.3.3.1	4	6.770	12.893	51.426	0.564
134	ISA50X50X6	ISA60x60x4	0.964	1.000	0.964	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
135	ISA50X50X6	ISA55x55x5	0.997	1.000	0.997	BS-4.9	4	5.270	6.034	24.305	0.439
136	ISA50X50X6	ISA75x75x5	0.901	1.000	0.901	BS-4.8.3.3.1	4	7.270	15.924	63.732	0.606
137	ISA50X50X6	ISA60x60x4	0.967	1.000	0.967	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
138	ISA50X50X6	ISA60x60x5	0.914	1.000	0.914	BS-4.9	4	5.750	7.871	31.944	0.479
139	ISA50X50X6	ISA75x75x5	0.975	1.000	0.975	BS-4.8.3.3.1	4	7.270	15.924	63.732	0.606
140	ISA50X50X6	ISA60x60x4	0.985	1.000	0.985	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
141	ISA50X50X6	ISA60x60x5	0.971	1.000	0.971	BS-4.9	4	5.750	7.871	31.944	0.479
142	ISA50X50X6	ISA75x75x6	0.859	1.000	0.859	BS-4.8.3.3.1	4	8.660	18.713	75.052	1.039
143	ISA50X50X6	ISA55x55x5	0.989	1.000	0.989	BS-4.8.3.3.1	3	5.270	6.034	24.305	0.439

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Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 12	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	

Utilization Ratio Cont...

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Ratio (Act./Allow.)	Clause	L/C	Ax (cm²)	Iz (cm⁴)	Iy (cm⁴)	Ix (cm⁴)
144	ISA50X50X6	ISA55x55x5	0.977	1.000	0.977	BS-4.9	4	5.270	6.034	24.305	0.439
145	ISA50X50X6	ISA75x75x5	0.993	1.000	0.993	BS-4.8.3.3.1	4	7.270	15.924	63.732	0.606
146	ISA50X50X6	ISA60x60x4	0.976	1.000	0.976	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
147	ISA50X50X6	ISA55x55x5	0.976	1.000	0.976	BS-4.9	4	5.270	6.034	24.305	0.439
148	ISA50X50X6	ISA75x75x6	0.861	1.000	0.861	BS-4.8.3.3.1	4	8.660	18.713	75.052	1.039
149	ISA50X50X6	ISA60x60x4	0.969	1.000	0.969	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
150	ISA50X50X6	ISA60x60x4	0.996	1.000	0.996	BS-4.9	4	4.710	6.558	26.074	0.251
151	ISA50X50X6	ISA75x75x6	0.873	1.000	0.873	BS-4.8.3.3.1	4	8.660	18.713	75.052	1.039
152	ISA50X50X6	ISA60x60x4	0.713	1.000	0.713	BS-4.9	3	4.710	6.558	26.074	0.251
153	ISA50X50X6	ISA50x50x4	0.861	1.000	0.861	BS-4.9	3	3.880	3.742	14.782	0.207
154	ISA50X50X6	ISA60x60x4	0.905	1.000	0.905	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
155	ISA50X50X6	ISA40x40x3	0.870	1.000	0.870	BS-4.8.3.3.1	4	2.340	1.435	5.730	0.070
158	ISA50X50X6	ISA40x40x3	0.892	1.000	0.892	BS-4.8.3.3.1	3	2.340	1.435	5.730	0.070
159	ISA50X50X6	ISA45x45x3	0.881	1.000	0.881	BS-4.8.3.3.1	4	2.640	2.072	8.252	0.079
160	ISA50X50X6	ISA45x45x3	0.874	1.000	0.874	BS-4.8.3.3.1	3	2.640	2.072	8.252	0.079
161	ISA50X50X6	ISA40x40x3	0.947	1.000	0.947	BS-4.9	3	2.340	1.435	5.730	0.070
162	ISA50X50X6	ISA45x45x3	0.956	1.000	0.956	BS-4.8.3.3.1	3	2.640	2.072	8.252	0.079
163	ISA50X50X6	ISA50x50x4	0.805	1.000	0.805	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
164	ISA50X50X6	ISA45x45x3	0.983	1.000	0.983	BS-4.8.3.3.1	3	2.640	2.072	8.252	0.079
165	ISA50X50X6	ISA45x45x3	0.905	1.000	0.905	BS-4.9	3	2.640	2.072	8.252	0.079
166	ISA50X50X6	ISA50x50x3	0.949	1.000	0.949	BS-4.8.3.3.1	3	2.950	2.891	11.409	0.089
167	ISA50X50X6	ISA60x60x4	0.703	1.000	0.703	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
168	ISA50X50X6	ISA45x45x4	0.937	1.000	0.937	BS-4.8.3.3.1	3	3.470	2.681	10.651	0.185
169	ISA50X50X6	ISA60x60x4	0.758	1.000	0.758	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
170	ISA50X50X6	ISA45x45x4	0.989	1.000	0.989	BS-4.8.3.3.1	3	3.470	2.681	10.651	0.185
171	ISA50X50X6	ISA60x60x4	0.916	1.000	0.916	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
172	ISA50X50X6	ISA50x50x4	0.934	1.000	0.934	BS-4.8.3.3.1	3	3.880	3.742	14.782	0.207
173	ISA50X50X6	ISA70x45x5	0.974	1.000	0.974	BS-4.8.3.3.1	4	5.520	5.172	31.787	0.460
174	ISA50X50X6	ISA50x50x4	0.941	1.000	0.941	BS-4.8.3.3.1	3	3.880	3.742	14.782	0.207
175	ISA50X50X6	ISA60x60x5	0.883	1.000	0.883	BS-4.8.3.3.1	4	5.750	7.871	31.944	0.479
176	ISA50X50X6	ISA50x50x4	0.985	1.000	0.985	BS-4.8.3.3.1	3	3.880	3.742	14.782	0.207
177	ISA50X50X6	ISA60x60x5	0.917	1.000	0.917	BS-4.8.3.3.1	4	5.750	7.871	31.944	0.479
178	ISA50X50X6	ISA60x60x4	0.720	1.000	0.720	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
179	ISA50X50X6	ISA75x50x5	0.970	1.000	0.970	BS-4.8.3.3.1	4	6.020	7.022	40.494	0.502
180	ISA50X50X6	ISA60x60x4	0.880	1.000	0.880	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
181	ISA50X50X6	ISA65x65x5	0.897	1.000	0.897	BS-4.8.3.3.1	4	6.250	10.081	41.010	0.521
182	ISA50X50X6	ISA60x60x4	0.928	1.000	0.928	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
183	ISA50X50X6	ISA65x65x5	0.999	1.000	0.999	BS-4.8.3.3.1	4	6.250	10.081	41.010	0.521
184	ISA50X50X6	ISA60x60x4	0.953	1.000	0.953	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
185	ISA50X50X6	ISA70x70x5	0.938	1.000	0.938	BS-4.8.3.3.1	4	6.770	12.893	51.426	0.564
186	ISA50X50X6	ISA60x60x4	0.818	1.000	0.818	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
187	ISA50X50X6	ISA60x60x4	0.822	1.000	0.822	BS-4.9	3	4.710	6.558	26.074	0.251
188	ISA50X50X6	ISA60x60x4	0.806	1.000	0.806	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
189	ISA50X50X6	ISA60x60x4	0.817	1.000	0.817	BS-4.9	3	4.710	6.558	26.074	0.251
190	ISA50X50X6	ISA60x60x4	0.832	1.000	0.832	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
191	ISA50X50X6	ISA60x60x4	0.855	1.000	0.855	BS-4.9	3	4.710	6.558	26.074	0.251
192	ISA50X50X6	ISA60x60x4	0.860	1.000	0.860	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
193	ISA50X50X6	ISA60x60x4	0.887	1.000	0.887	BS-4.9	3	4.710	6.558	26.074	0.251
194	ISA50X50X6	ISA60x60x4	0.760	1.000	0.760	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251

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Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 13	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	

Utilization Ratio Cont...

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Ratio (Act./Allow.)	Clause	L/C	Ax (cm^2)	Iz (cm^4)	Iy (cm^4)	Ix (cm^4)
195	ISA50X50X6	ISA50x50x4	0.993	1.000	0.993	BS-4.9	3	3.880	3.742	14.782	0.207
196	ISA50X50X6	ISA60x60x4	0.787	1.000	0.787	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
197	ISA50X50X6	ISA50x50x4	0.999	1.000	0.999	BS-4.9	3	3.880	3.742	14.782	0.207
198	ISA50X50X6	ISA60x60x4	0.881	1.000	0.881	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
199	ISA50X50X6	ISA60x60x4	0.848	1.000	0.848	BS-4.8.3.3.1	3	4.710	6.558	26.074	0.251
200	ISA50X50X6	ISA70x70x5	0.990	1.000	0.990	BS-4.8.3.3.1	4	6.770	12.893	51.426	0.564
201	ISA50X50X6	ISA35x35x3	0.972	1.000	0.972	BS-4.8.3.3.1	3	2.030	0.939	3.787	0.061
202	ISA80X80X6	ISA25x25x3	0.819	1.000	0.819	BS-4.8.3.3.1	3	1.410	0.317	1.324	0.042
203	ISA80X80X6	ISA50x50x4	0.908	1.000	0.908	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
204	ISA80X80X6	ISA20x20x3	0.778	1.000	0.778	BS-4.8.3.3.1	3	1.120	0.159	0.647	0.034
205	ISA80X80X6	ISA50x50x4	0.778	1.000	0.778	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
206	ISA80X80X6	ISA20x20x3	0.735	1.000	0.735	BS-4.9	4	1.120	0.159	0.647	0.034
208	ISA80X80X6	ISA25x25x3	0.680	1.000	0.680	BS-4.9	4	1.410	0.317	1.324	0.042
209	ISA80X80X6	ISA50x50x3	0.897	1.000	0.897	BS-4.8.3.3.1	4	2.950	2.891	11.409	0.089
211	ISA80X80X6	ISA50x50x3	0.834	1.000	0.834	BS-4.8.3.3.1	4	2.950	2.891	11.409	0.089
213	ISA70X70X6	ISA50x50x3	0.837	1.000	0.837	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
214	ISA70X70X6	ISA20x20x3	0.822	1.000	0.822	BS-4.9	4	1.120	0.159	0.647	0.034
215	ISA70X70X6	ISA50x50x3	0.864	1.000	0.864	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
216	ISA70X70X6	ISA20x20x3	0.577	1.000	0.577	BS-4.9	4	1.120	0.159	0.647	0.034
217	ISA70X70X6	ISA50x50x3	0.879	1.000	0.879	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
219	ISA70X70X6	ISA50x50x3	0.911	1.000	0.911	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
221	ISA70X70X6	ISA50x50x3	0.948	1.000	0.948	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
222	ISA70X70X6	ISA20x20x3	0.485	1.000	0.485	BS-4.8.2.2	5	1.120	0.159	0.647	0.034
223	ISA70X70X6	ISA50x50x3	0.922	1.000	0.922	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
224	ISA70X70X6	ISA20x20x3	0.389	1.000	0.389	BS-4.9	4	1.120	0.159	0.647	0.034
225	ISA70X70X6	ISA50x50x3	0.754	1.000	0.754	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
227	ISA70X70X6	ISA45x45x3	0.916	1.000	0.916	BS-4.8.3.3.1	5	2.640	2.072	8.252	0.079
229	ISA70X70X6	ISA45x45x3	0.743	1.000	0.743	BS-4.8.3.3.1	5	2.640	2.072	8.252	0.079
230	ISA70X70X6	ISA20x20x3	0.267	1.000	0.267	BS-4.8.2.2	5	1.120	0.159	0.647	0.034
231	ISA70X70X6	ISA40x40x3	0.963	1.000	0.963	BS-4.8.3.3.1	5	2.340	1.435	5.730	0.070
235	ISA70X70X6	ISA35x35x3	0.872	1.000	0.872	BS-4.8.3.3.1	5	2.030	0.939	3.787	0.061
236	ISA70X70X6	ISA20x20x3	0.349	1.000	0.349	BS-4.9	5	1.120	0.159	0.647	0.034
237	ISA70X70X6	ISA35x35x3	0.845	1.000	0.845	BS-4.8.3.3.1	5	2.030	0.939	3.787	0.061
239	ISA60X60X5	ISA35x35x3	0.776	1.000	0.776	BS-4.8.3.3.1	5	2.030	0.939	3.787	0.061
243	ISA60X60X5	ISA30x30x3	0.821	1.000	0.821	BS-4.8.3.3.1	5	1.730	0.574	2.342	0.052
244	ISA60X60X5	ISA20x20x3	0.086	1.000	0.086	BS-4.8.3.3.1	1	1.120	0.159	0.647	0.034
245	ISA60X60X5	ISA25x25x3	0.550	1.000	0.550	BS-4.8.3.3.1	4	1.410	0.317	1.324	0.042
246	ISA70X70X6	ISA20x20x3	0.082	1.000	0.082	BS-4.8.3.3.1	1	1.120	0.159	0.647	0.034
247	ISA70X70X6	ISA20x20x3	0.124	1.000	0.124	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034
248	ISA70X70X6	ISA20x20x3	0.091	1.000	0.091	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034
249	ISA60X60X5	ISA20x20x3	0.384	1.000	0.384	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034
250	ISA60X60X5	ISA20x20x3	0.054	1.000	0.054	BS-4.8.3.3.1	1	1.120	0.159	0.647	0.034
251	ISA50X50X6	ISA20x20x3	0.677	1.000	0.677	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034
252	ISA80X80X6	ISA50x50x3	0.979	1.000	0.979	BS-4.8.3.3.1	4	2.950	2.891	11.409	0.089
253	ISA80X80X6	ISA25x25x3	0.714	1.000	0.714	BS-4.9	4	1.410	0.317	1.324	0.042
254	ISA70X70X6	ISA20x20x3	0.963	1.000	0.963	BS-4.9	4	1.120	0.159	0.647	0.034
255	ISA70X70X6	ISA20x20x3	0.527	1.000	0.527	BS-4.9	4	1.120	0.159	0.647	0.034
256	ISA70X70X6	ISA20x20x3	0.622	1.000	0.622	BS-4.9	4	1.120	0.159	0.647	0.034
257	ISA70X70X6	ISA20x20x3	0.464	1.000	0.464	BS-4.8.2.2	5	1.120	0.159	0.647	0.034

305	ISA70X70X6	ISA50x50x4	0.912	1.000	0.912	BS-4.8.3.3.1	5	3.880	3.742	14.782	0.207
306	ISA70X70X6	ISA60x60x4	0.678	1.000	0.678	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251

Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 15	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	

Utilization Ratio Cont...

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Ratio (Act./Allow.)	Clause	L/C	Ax (cm^2)	Iz (cm^4)	Iy (cm^4)	Ix (cm^4)
307	ISA70X70X6	ISA60x50x4	0.817	1.000	0.817	BS-4.8.3.3.1	5	3.880	3.742	14.782	0.207
308	ISA70X70X6	ISA60x50x4	0.997	1.000	0.997	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
309	ISA70X70X6	ISA60x50x4	0.816	1.000	0.816	BS-4.8.3.3.1	5	3.880	3.742	14.782	0.207
310	ISA70X70X6	ISA60x50x4	0.946	1.000	0.946	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
311	ISA70X70X6	ISA60x50x4	0.839	1.000	0.839	BS-4.8.3.3.1	5	3.880	3.742	14.782	0.207
312	ISA70X70X6	ISA60x50x4	0.853	1.000	0.853	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
313	ISA70X70X6	ISA60x50x3	0.901	1.000	0.901	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
314	ISA70X70X6	ISA60x50x3	0.930	1.000	0.930	BS-4.8.3.3.1	4	2.950	2.891	11.409	0.089
315	ISA70X70X6	ISA45x45x3	0.907	1.000	0.907	BS-4.8.3.3.1	5	2.640	2.072	8.252	0.079
316	ISA70X70X6	ISA60x50x3	0.828	1.000	0.828	BS-4.8.3.3.1	4	2.950	2.891	11.409	0.089
317	ISA50X50X6	ISA45x45x3	0.830	1.000	0.830	BS-4.9	4	2.640	2.072	8.252	0.079
318	ISA50X50X6	ISA60x50x3	0.931	1.000	0.931	BS-4.8.3.3.1	4	2.950	2.891	11.409	0.089
319	ISA50X50X6	ISA60x50x3	0.960	1.000	0.960	BS-4.9	4	2.950	2.891	11.409	0.089
320	ISA50X50X6	ISA60x50x4	0.810	1.000	0.810	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
321	ISA50X50X6	ISA60x50x4	0.801	1.000	0.801	BS-4.9	4	3.880	3.742	14.782	0.207
322	ISA70X70X6	ISA45x45x3	0.797	1.000	0.797	BS-4.8.3.3.1	5	2.640	2.072	8.252	0.079
323	ISA70X70X6	ISA45x45x3	0.983	1.000	0.983	BS-4.8.3.3.1	4	2.640	2.072	8.252	0.079
324	ISA60X60X5	ISA45x45x3	0.813	1.000	0.813	BS-4.8.3.3.1	5	2.640	2.072	8.252	0.079
325	ISA60X60X5	ISA45x45x3	0.811	1.000	0.811	BS-4.8.3.3.1	4	2.640	2.072	8.252	0.079
326	ISA60X60X5	ISA35x35x3	0.659	1.000	0.659	BS-4.8.3.3.1	5	2.030	0.939	3.787	0.061
327	ISA60X60X5	ISA40x40x3	0.931	1.000	0.931	BS-4.8.3.3.1	4	2.340	1.435	5.730	0.070
328	ISA60X60X5	ISA20x20x3	0.637	1.000	0.637	BS-4.8.3.3.1	5	1.120	0.159	0.647	0.034
329	ISA60X60X5	ISA35x35x3	0.995	1.000	0.995	BS-4.8.3.3.1	4	2.030	0.939	3.787	0.061
330	ISA60X60X5	ISA20x20x3	0.476	1.000	0.476	BS-4.8.3.3.1	5	1.120	0.159	0.647	0.034
331	ISA60X60X5	ISA30x30x3	0.977	1.000	0.977	BS-4.8.3.3.1	4	1.730	0.574	2.342	0.052
332	ISA60X60X5	ISA25x25x3	0.950	1.000	0.950	BS-4.8.3.3.1	4	1.410	0.317	1.324	0.042
333	ISA60X60X5	ISA20x20x3	0.057	1.000	0.057	BS-4.8.3.3.1	1	1.120	0.159	0.647	0.034
334	ISA50X50X6	ISA20x20x3	0.662	1.000	0.662	BS-4.8.3.3.1	3	1.120	0.159	0.647	0.034
335	ISA80X80X6	ISA60x50x3	0.781	1.000	0.781	BS-4.8.2.2	4	2.950	2.891	11.409	0.089
336	ISA80X80X6	ISA90x90x6	0.947	1.000	0.947	BS-4.8.3.3.1	4	10.500	33.268	131.910	1.260
337	ISA80X80X6	ISA80x80x6	0.892	1.000	0.892	BS-4.8.3.3.1	4	9.290	22.899	91.722	1.115
338	ISA80X80X6	ISA60x50x3	0.782	1.000	0.782	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
339	ISA80X80X6	ISA60x50x3	0.824	1.000	0.824	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
340	ISA80X80X6	ISA80x80x6	0.890	1.000	0.890	BS-4.8.3.3.1	4	9.290	22.899	91.722	1.115
341	ISA80X80X6	ISA75x75x6	0.991	1.000	0.991	BS-4.8.3.3.1	4	8.660	18.713	75.052	1.039
342	ISA80X80X6	ISA60x50x3	0.821	1.000	0.821	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
343	ISA80X80X6	ISA75x75x6	0.938	1.000	0.938	BS-4.8.3.3.1	4	8.660	18.713	75.052	1.039
344	ISA80X80X6	ISA60x50x3	0.861	1.000	0.861	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
345	ISA70X70X6	ISA75x75x6	0.898	1.000	0.898	BS-4.8.3.3.1	4	8.660	18.713	75.052	1.039
346	ISA70X70X6	ISA60x50x3	0.890	1.000	0.890	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
347	ISA70X70X6	ISA75x75x5	0.986	1.000	0.986	BS-4.8.3.3.1	4	7.270	15.924	63.732	0.606
348	ISA70X70X6	ISA60x50x3	0.878	1.000	0.878	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
349	ISA70X70X6	ISA75x75x5	0.934	1.000	0.934	BS-4.8.3.3.1	4	7.270	15.924	63.732	0.606
350	ISA70X70X6	ISA60x50x3	0.904	1.000	0.904	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
351	ISA70X70X6	ISA75x75x5	0.883	1.000	0.883	BS-4.8.3.3.1	4	7.270	15.924	63.732	0.606
352	ISA70X70X6	ISA60x50x3	0.936	1.000	0.936	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
353	ISA70X70X6	ISA70x70x5	0.964	1.000	0.964	BS-4.8.3.3.1	4	6.770	12.893	51.426	0.564
354	ISA70X70X6	ISA60x50x3	0.968	1.000	0.968	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
355	ISA70X70X6	ISA70x70x5	0.895	1.000	0.895	BS-4.8.3.3.1	4	6.770	12.893	51.426	0.564

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Table 4.4: STAAD Pro computation sheets continued

Software licensed to	Job No	Sheet No 16	Rev
	Part		
Job Title 45m Tower Modelling/Analysis	Ref		
	By 0.0.0	Date 26-May-21	Chd 0.0.0
Client M.ENG Project Reseacrh	File 45m Tower Modelling and	Date/Time 09-Jun-2021 12:29	

Utilization Ratio Cont...

Beam	Analysis Property	Design Property	Actual Ratio	Allowable Ratio	Ratio (Act./Allow.)	Clause	L/C	Ax (cm^2)	Iz (cm^4)	Iy (cm^4)	Ix (cm^4)
356	ISA70X70X6	ISA50x50x3	0.929	1.000	0.929	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
357	ISA70X70X6	ISA65x65x5	0.996	1.000	0.996	BS-4.8.3.3.1	4	6.250	10.081	41.010	0.521
358	ISA70X70X6	ISA50x50x3	0.823	1.000	0.823	BS-4.8.3.3.1	5	2.950	2.891	11.409	0.089
359	ISA70X70X6	ISA45x45x3	0.936	1.000	0.936	BS-4.8.3.3.1	5	2.640	2.072	8.252	0.079
360	ISA70X70X6	ISA65x65x5	0.928	1.000	0.928	BS-4.8.3.3.1	4	6.250	10.081	41.010	0.521
361	ISA70X70X6	ISA65x65x5	0.857	1.000	0.857	BS-4.8.3.3.1	4	6.250	10.081	41.010	0.521
362	ISA70X70X6	ISA45x45x3	0.800	1.000	0.800	BS-4.8.3.3.1	5	2.640	2.072	8.252	0.079
363	ISA70X70X6	ISA60x60x5	0.960	1.000	0.960	BS-4.8.3.3.1	4	5.750	7.871	31.944	0.479
364	ISA70X70X6	ISA45x45x3	0.786	1.000	0.786	BS-4.8.3.3.1	5	2.640	2.072	8.252	0.079
365	ISA70X70X6	ISA60x60x5	0.833	1.000	0.833	BS-4.8.3.3.1	4	5.750	7.871	31.944	0.479
366	ISA70X70X6	ISA40x40x3	0.917	1.000	0.917	BS-4.8.3.3.1	5	2.340	1.435	5.730	0.070
367	ISA70X70X6	ISA60x60x4	0.895	1.000	0.895	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
368	ISA70X70X6	ISA35x35x3	0.891	1.000	0.891	BS-4.8.3.3.1	5	2.030	0.939	3.787	0.061
369	ISA70X70X6	ISA60x60x4	0.782	1.000	0.782	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
370	ISA70X70X6	ISA35x35x3	0.886	1.000	0.886	BS-4.8.3.3.1	5	2.030	0.939	3.787	0.061
371	ISA60X60X5	ISA35x35x3	0.921	1.000	0.921	BS-4.8.3.3.1	5	2.030	0.939	3.787	0.061
372	ISA60X60X5	ISA60x60x4	0.625	1.000	0.625	BS-4.8.3.3.1	4	4.710	6.558	26.074	0.251
373	ISA60X60X5	ISA50x50x4	0.857	1.000	0.857	BS-4.8.3.3.1	4	3.880	3.742	14.782	0.207
374	ISA60X60X5	ISA35x35x3	0.803	1.000	0.803	BS-4.8.3.3.1	5	2.030	0.939	3.787	0.061
375	ISA60X60X5	ISA35x35x3	0.722	1.000	0.722	BS-4.8.3.3.1	5	2.030	0.939	3.787	0.061
376	ISA60X60X5	ISA50x50x3	0.820	1.000	0.820	BS-4.8.3.3.1	4	2.950	2.891	11.409	0.089
377	ISA60X60X5	ISA20x20x3	0.327	1.000	0.327	BS-4.8.3.3.1	5	1.120	0.159	0.647	0.034
378	ISA60X60X5	ISA40x40x3	0.934	1.000	0.934	BS-4.8.3.3.1	4	2.340	1.435	5.730	0.070
379	ISA60X60X5	ISA20x20x3	0.294	1.000	0.294	BS-4.9	3	1.120	0.159	0.647	0.034
380	ISA60X60X5	ISA20x20x3	0.558	1.000	0.558	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034
381	ISA50X50X6	ISA20x20x3	0.889	1.000	0.889	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034
382	ISA50X50X6	ISA20x20x3	0.153	1.000	0.153	BS-4.8.3.3.1	3	1.120	0.159	0.647	0.034
383	ISA50X50X6	ISA20x20x3	0.392	1.000	0.392	BS-4.8.3.3.1	4	1.120	0.159	0.647	0.034

Failed Members

There is no data of this type.

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From the report generated, the tower members can be said to be stable as the utilization ratio (actual ratio to allowable ratio) of all the tower members are ≤ 1 (less or equal to one) as presented in Table 4.4. The tower member utilization ratio ranged from 0.081 to 1.00.

Also, the tower members profile (Design property) generated due to the present load exerted on the tower are less than the actual tower member profiles (Analysis property). This shows that the tower members are not overstressed. The result shows that no failed member was identified after the analysis.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The deductions from the structural monitoring of the lattice tower are presented below. From the study, the following conclusions can be deduced after auditing of the entire lattice tower:

The tower selected is a 3-Legged, 45m high, erected over 9 years and it is presently shared by three telecommunications operators (MTN, Airtel and 9mobile).

The physical condition of the tower is satisfactory. No cracks on the foundation, and no deformed members however, the tower coating (paint) was found to be worn off, hence would need repainting.

The structural analysis of the tower shows that members are in good standing and within permissible specifications.

In view of paragraphs above, the tower can therefore be considered fit for continuous use.

5.2 Recommendations

To ensure continuous safety of the lattice tower, the following recommendations are proffered:

i. Tower loading and structural analysis must be carried out on the tower whenever new telecommunication antennas are to be installed by network providers to prevent overloading the tower.

ii. Maintenance on the tower members and accessories should be regular to increase early detection of member deterioration. This would reduce the chances of failure and resultant consequences.

iii. The tower should be repainted to the International Civil Aviation Organization (ICAO) stipulations on obstruction painting. The paint shall be red/orange and white non-gloss finish (matt).

5.3 Contribution to Knowledge

This research analysed a 3-legged 45 metre communication tower in Federal Capital Territory, Abuja using Effective Projected Area (EPA) model and STAAD pro. V8i software. The result revealed that the tower utilization percentage was at 59% and the members utilization ratio was between 0.081 to 1.00 (≤ 1). The lattice tower can be said to be stable and fit for continuous use. The approach has been used and can be adopted for structural health monitoring and auditing of other lattice towers. Periodic assessment of communication tower is a requirement by concerned authority. However, it is hardly carried out, despite tower sharing and loading by network providers.

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APPENDICES

Appendix A: NCC Notification Letter on Tower Collapses

NIGERIAN COMMUNICATIONS COMMISSION

EMTS LTD. (9Mobile) CEO'S OFFICE 21 JUL 2020 RECEIVED

NCC/CMED/ISCS/161/VOL.1/8/2020

July 14, 2020

The Managing Director
Emerging Markets Telecommunication Services
Plot 19 Zone L
Fed. Govt Layout, Foreshore Estate
Banana Island, Ikoyi, Lagos.

Dear Sir,

INCREASING CASES OF COLLAPSE OF EMERGING MARKETS TELECOMMUNICATION SERVICES MASTS AND TOWERS ACROSS THE NATION

The Commission has been inundated with reports with respect to concerns regarding the installation of Base Transceiver Station (BTS) sites in its vicinities. These complaints have increased with increasing cases of collapsed Masts and Towers in various states of the Country resulting to loss of lives and properties.

The Commission frowns at and finds this trend very disturbing and hereby directs Emerging Markets Telecommunication Services to take immediate steps to:

1. Ensure structural integrity and reinforcement of both new and existing Masts and Towers
2. Ensure compliance with the Structural Design stipulated in the Guideline for the Technical Specification of Telecommunication Masts and Towers 2009.

Consequently, you are required to:

1. Report to the Commission, within 24 hours, all incidence of BTS towers collapse.
2. Make readily available, records of routine maintenance carried out at the BTS sites for the Commission's inspection at all times;
3. Submit a status report of all collapsed Masts and Towers within the last five (5) years stating the reason for the collapse, actions taken to clear the debris and compensation to victims where necessary;
4. Conduct Structural Integrity Test on all BTS sites especially the ones that are ten (10) years and above.
    a. Submit the Structural Integrity Test schedule before commencement.
    b. Submit the Structural Integrity Test report upon completion detailing amongst other parameters, the load bearing capacity of each BTS site.
5. Provide a copy of the last Third (3rd) Party Insurance cover for all collapsed Masts and Towers (2016 – 2020) as stipulated in the Guideline for Technical Specification of Telecommunication Masts and Towers.

14/07

Page 1 of 2

The Commission expects all tasks will be completed before the 1st of October 2020 and all reports must reach the office of the Executive Vice Chairman by the 15th of October 2020.

Thank you.

Yours faithfully,
PP: Nigerian Communications Commission

Ephraim Nwokenneya
Director, Compliance Monitoring and Enforcement
For: Executive Vice Chairman

Alkasim Umar
Head, Compliance Monitoring

APPENDIX B

Appendix B1: Site layout

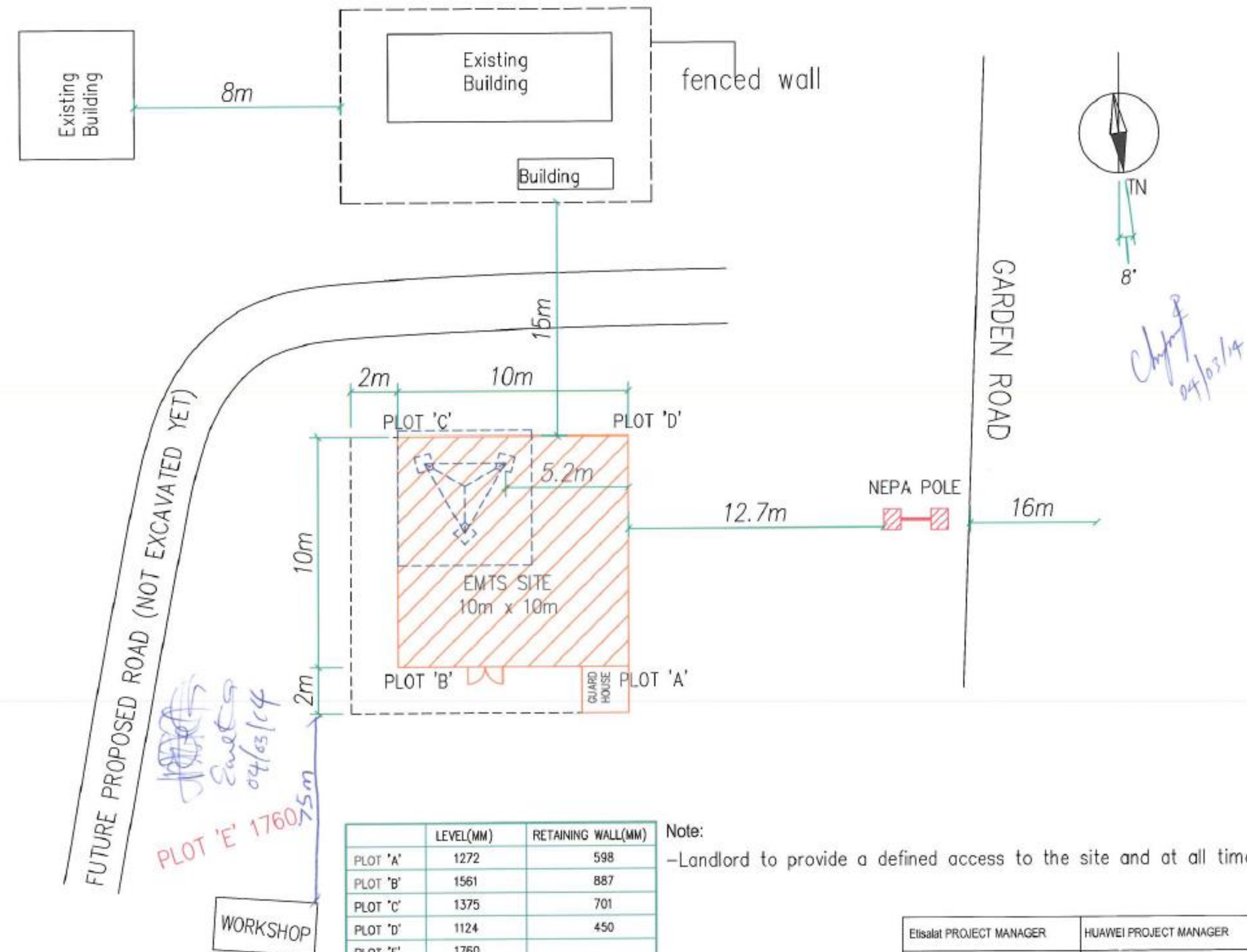
EMTS Copy

DATE: 2014-01-21

Etisalat BTS SITE INFRASTRUCTURE DRAWING

SITE ID:	B0653	SITE NAME:	B0653C
STATE:	ABUJA	CITY/ROAD:	KATAMPE
SITE TYPE:	Greenfield/Outdoor/BTS	SITE SIZE:	10m X 10m
TOWER :	Mast Project/45m/Medium/3-leg	WIND SPEED:	42m/s
FOUNDATION :	150Kpa Raft Foundation	TERRAIN:	URBAN
GENERATOR :	1+1/3phases/13KVA	TANK :	5000L
SITE ADD:	A PIECE OF LAND AT UNITY HILLS GARDEN ESTATE, PLOT 1274, ASO DELIGHT, KATAMPE, FCT ABUJA.		
COORDINATE:	LONGITUDE E: 7.43766° 57	LATITUDE N: 8.97316°	

HUAWEI TECHNOLOGIES CO;LTD.



	LEVEL(MM)	RETAINING WALL(MM)
PLOT 'A'	1272	598
PLOT 'B'	1561	887
PLOT 'C'	1375	701
PLOT 'D'	1124	450
PLOT 'E'	1760	
AVERAGE		659

Note:
-Landlord to provide a defined access to the site and at all time.

Etisalat PROJECT MANAGER	HUAWEI PROJECT MANAGER
APPROVED:	APPROVED:
SIGN:	SIGN:

GENERAL NOTES

1. Do not scale.
2. All dimensions are in mm, unless otherwise specified.
3. All details of existing construction to be confirmed on site. Any discrepancies are to be reported to the Engineer immediately.
4. This drawing to be read in conjunction with all other relevant drawings.
5. All work to be performed according to Etisalat BTS Site Infra-Structure Specification.

Client: Etisalat

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etisalat

Contractor:HUAWEI

HUAWEI

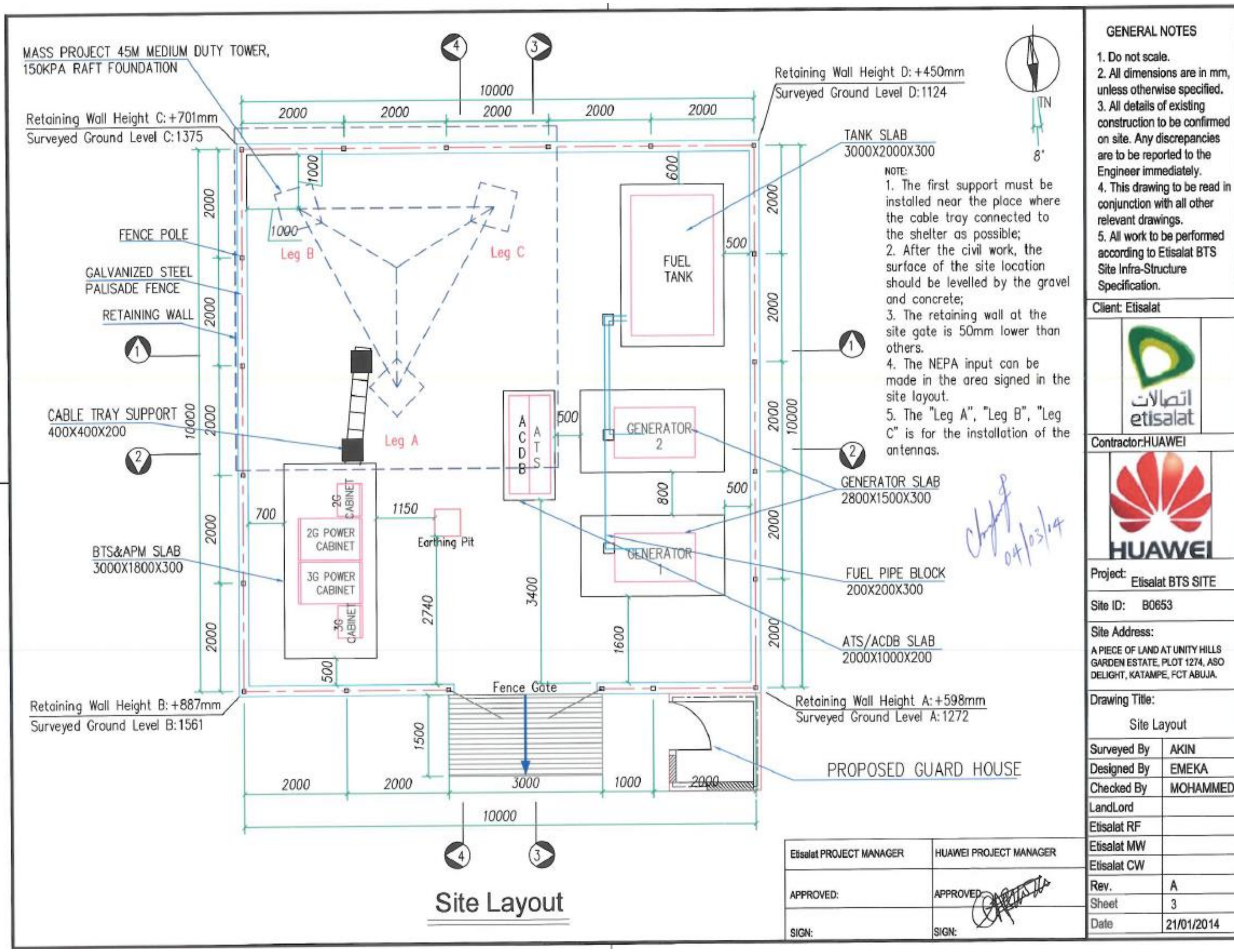
Project: Etisalat BTS SITE

Site ID: B0653

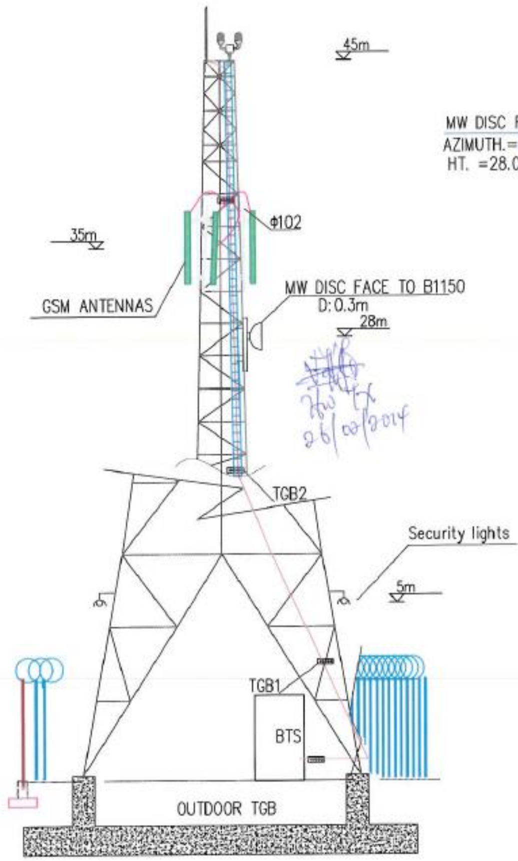
Site Address:
A PIECE OF LAND AT UNITY HILLS GARDEN ESTATE, PLOT 1274, ASO DELIGHT, KATAMPE, FCT ABUJA.

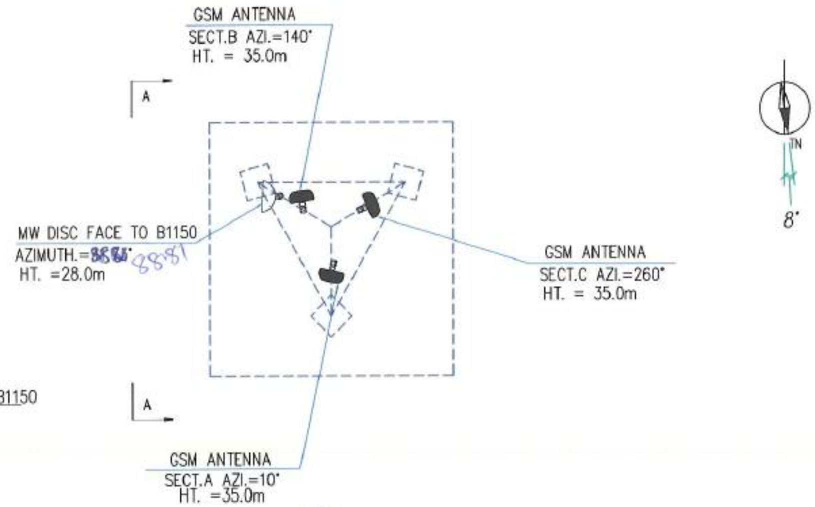
Drawing Title:
Site Locality

Surveyed By	AKIN
Designed By	EMEKA
Checked By	MOHAMMED
LandLord	
Etisalat RF	
Etisalat MW	
Etisalat CW	
Rev.	A
Sheet	2
Date	21/01/2014



MASS PROJECT 45M MEDIUM DUTY TOWER, 150KPA RAFT FOUNDATION
Retaining Wall Height C: +701mm
Surveyed Ground Level C:1375
FENCE POLE
GALVANIZED STEEL PALISADE FENCE
RETAINING WALL
CABLE TRAY SUPPORT 400X400X200
BTS&APM SLAB 3000X1800X300
Retaining Wall Height B: +887mm
Surveyed Ground Level B:1561
Retaining Wall Height D: +450mm
Surveyed Ground Level D:1124
TANK SLAB 3000X2000X300
NOTE:
1. The first support must be installed near the place where the cable tray connected to the shelter as possible;
2. After the civil work, the surface of the site location should be levelled by the gravel and concrete;
3. The retaining wall at the site gate is 50mm lower than others.
4. The NEPA input can be made in the area signed in the site layout.
5. The "Leg A", "Leg B", "Leg C" is for the installation of the antennas.
GENERATOR SLAB 2800X1500X300
FUEL PIPE BLOCK 200X200X300
ATS/ACDB SLAB 2000X1000X200
Retaining Wall Height A: +598mm
Surveyed Ground Level A:1272
PROPOSED GUARD HOUSE
Leg A
Leg B
Leg C
FUEL TANK
GENERATOR 2
GENERATOR 1
ACDB
ATS
2G CABINET
2G POWER CABINET
3G POWER CABINET
3G CABINET
Earthing Pit
Fence Gate
TN
8°
Site Layout
GENERAL NOTES
1. Do not scale.
2. All dimensions are in mm, unless otherwise specified.
3. All details of existing construction to be confirmed on site. Any discrepancies are to be reported to the Engineer immediately.
4. This drawing to be read in conjunction with all other relevant drawings.
5. All work to be performed according to Etisalat BTS Site Infra-Structure Specification.
Client: Etisalat
Contractor:HUAWEI
Project: Etisalat BTS SITE
Site ID: B0653
Site Address: A PIECE OF LAND AT UNITY HILLS GARDEN ESTATE, PLOT 1274, ASO DELIGHT, KATAMPE, FCT ABUJA.
Drawing Title: Site Layout
Surveyed By AKIN
Designed By EMEKA
Checked By MOHAMMED
LandLord
Etisalat RF
Etisalat MW
Etisalat CW
Rev. A
Sheet 3
Date 21/01/2014
Etisalat PROJECT MANAGER
HUAWEI PROJECT MANAGER
APPROVED:
SIGN:





RF configuration

	ITEM	A	B	C	DA	DB	DC	3G(A)	3G(B)	3G(C)
GSM	Electrical Down-tilt(Deg.)	4	4	4	4	4	3			
	Mechanical Down-tilt(Deg.)	0	0	0	0	0	0			
	Feeder cable length(m)	35	35	35	35	35	35			
	Antenna Type	DXXX-824-960/1710-2170/1710-2170-65/65/65-17.5i/17.5i/17i-M/M/M								
	Site Config.	S222/444								

NOTE:

1. Tower grounding bar-1(TGB1) is installed in 1m high of the tower.
2. Tower grounding bar-2(TGB2) is installed in the middle height of the tower, not far from MW dish.
3. Tower grounding bar-3(TGB3) is installed 500mm under the RF antenna.
4. All the TGB are mounted in the cable ladder.
5. Aviation light, MW dish, RF antenna, feeder cable, optical fibre, cable tray must be jointed to TGB.
6. Feeder cable and optical fibre must jointed to outdoor earthing bar before entering minishelter.
7. A low-intensity constant red light is installed on the top of the tower.

Etisalat PROJECT MANAGER	HUAWEI PROJECT MANAGER
APPROVED:	APPROVED:
SIGN:	SIGN:

GENERAL NOTES

1. Do not scale.
2. All dimensions are in mm, unless otherwise specified.
3. All details of existing construction to be confirmed on site. Any discrepancies are to be reported to the Engineer immediately.
4. This drawing to be read in conjunction with all other relevant drawings.
5. All work to be performed according to Etisalat BTS Site Infra-Structure Specification.

Client: Etisalat

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etisalat

Contractor: HUAWEI

HUAWEI

Project: Etisalat BTS SITE

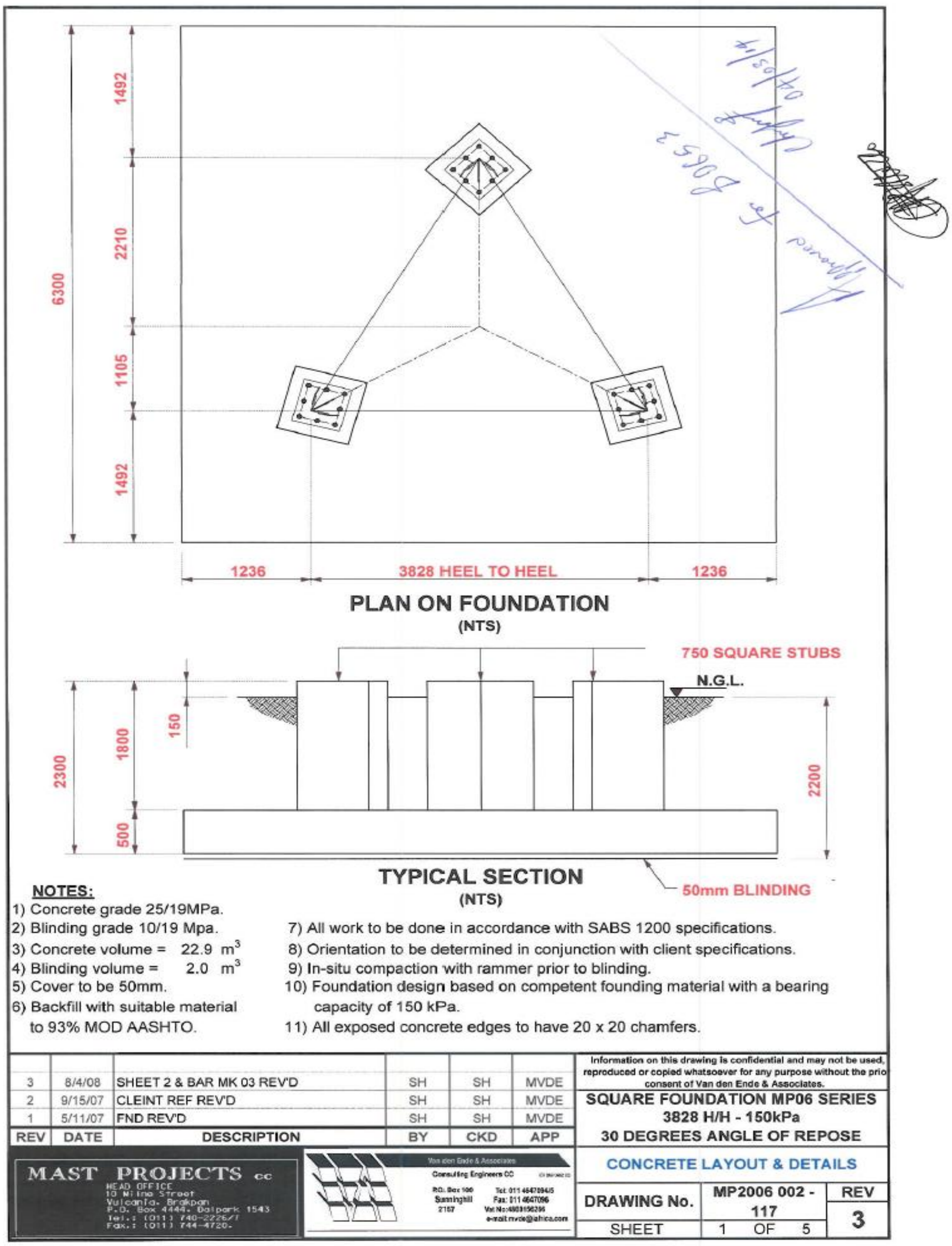
Site ID: B0653

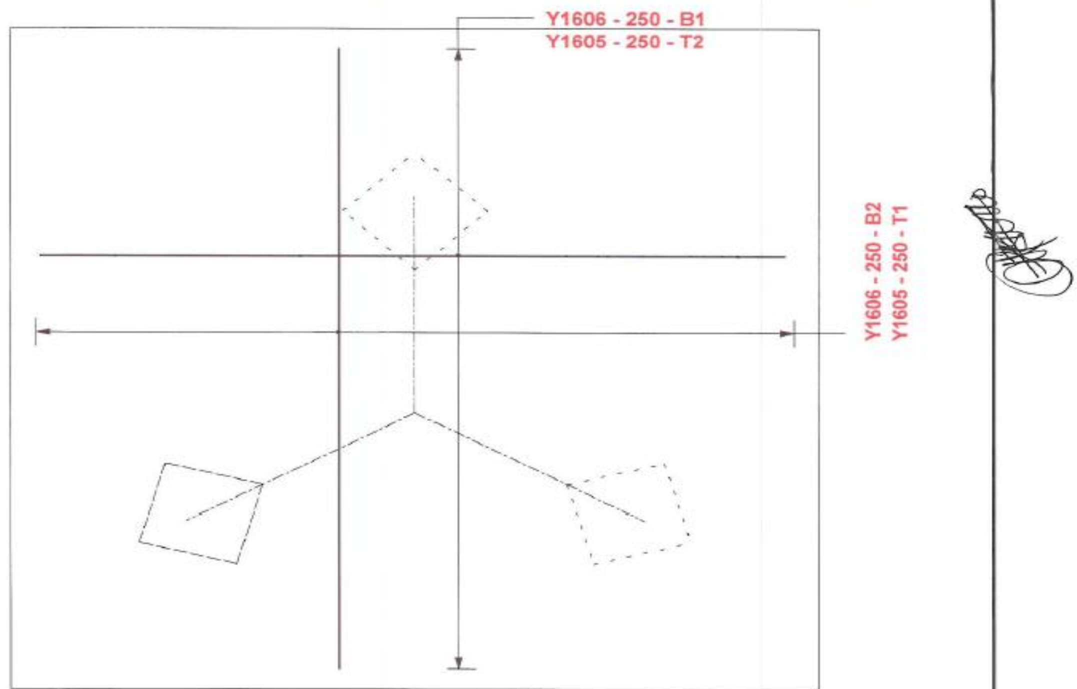
Site Address:
A PIECE OF LAND AT UNITY HILLS GARDEN ESTATE, PLOT 1274, ASO DELIGHT, KATAMPE, FCT ABUJA.

Drawing Title:
Antenna and Feeder Line

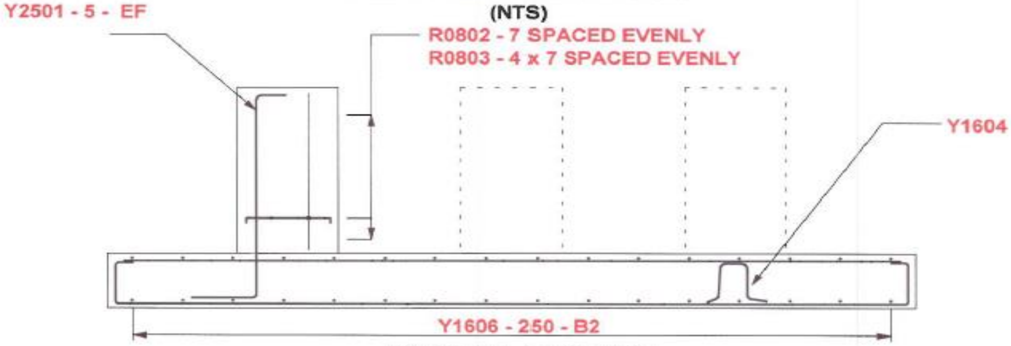
Surveyed By	AKIN
Designed By	EMEKA
Checked By	MOHAMMED
LandLord	
Etisalat RF	
Etisalat MW	
Etisalat CW	
Rev.	A
Sheet	21
Date	21/01/2014

Appendix B2: Foundation drawing





PLAN ON FOUNDATION
(NTS)



TYPICAL SECTION
(NTS)

NOTES:
1) Splice length of rebar to be 50 dia.
2) All work to be done in accordance with SABS 1200 series of specifications.
3) Drawing not to scale - rebar dimension and position indicative only.

REV	DATE	DESCRIPTION	BY	CKD	APP
3	8/4/08	SHEET 2 & BAR MK 03 REV'D	SH	SH	MVDE
2	9/15/07	CLEINT REF REV'D	SH	SH	MVDE
1	5/11/07	FND REV'D	SH	SH	MVDE

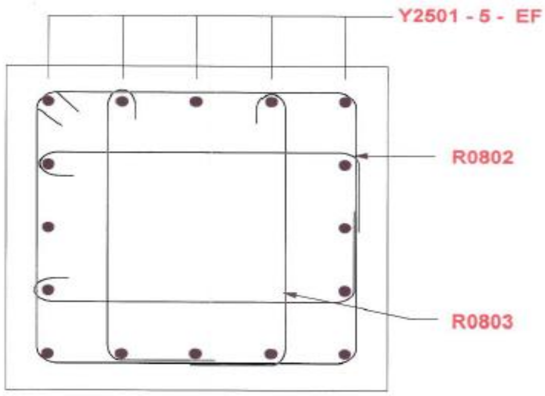
SQUARE FOUNDATION MP06 SERIES
3828 H/H - 150kPa
30 DEGREES ANGLE OF REPOSE

REINFORCING LAYOUT

MAST PROJECTS cc
HEAD OFFICE
10 Milne Street
Vulcania, Brakpan
P.O. Box 4444, Dalpark 1543
Tel.: (011) 740-2226/7
Fax.: (011) 744-4720.

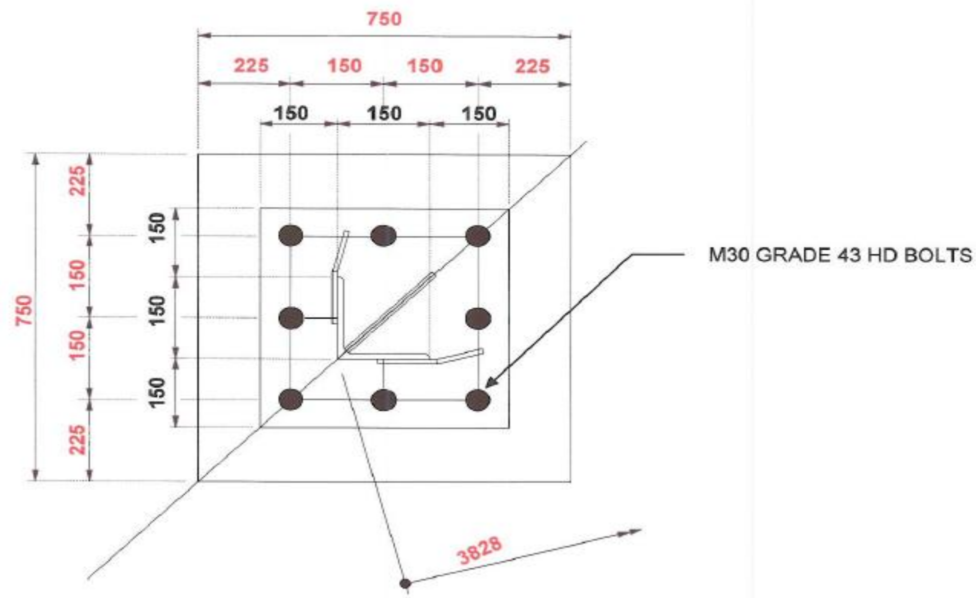
Van den Ende & Associates
Consulting Engineers CC
P.O. Box 100
Sunninghill
2157
Tel: 011 4647094/5
Fax: 011 4647096
Vat No: 4660156266
e-mail: mvda@iafrica.com

DRAWING No.	MP2006 002 - 117	REV	3
SHEET	2 OF 5		



STUB REINFORCING DETAILS

(NTS)



HD BOLT LAYOUT ON STUB

(NTS)

REV	DATE	DESCRIPTION	BY	CKD	APP
3	8/4/08	SHEET 2 & BAR MK 03 REV'D	SH	SH	MVDE
2	9/15/07	CLEINT REF REV'D	SH	SH	MVDE
1	5/11/07	FND REV'D	SH	SH	MVDE

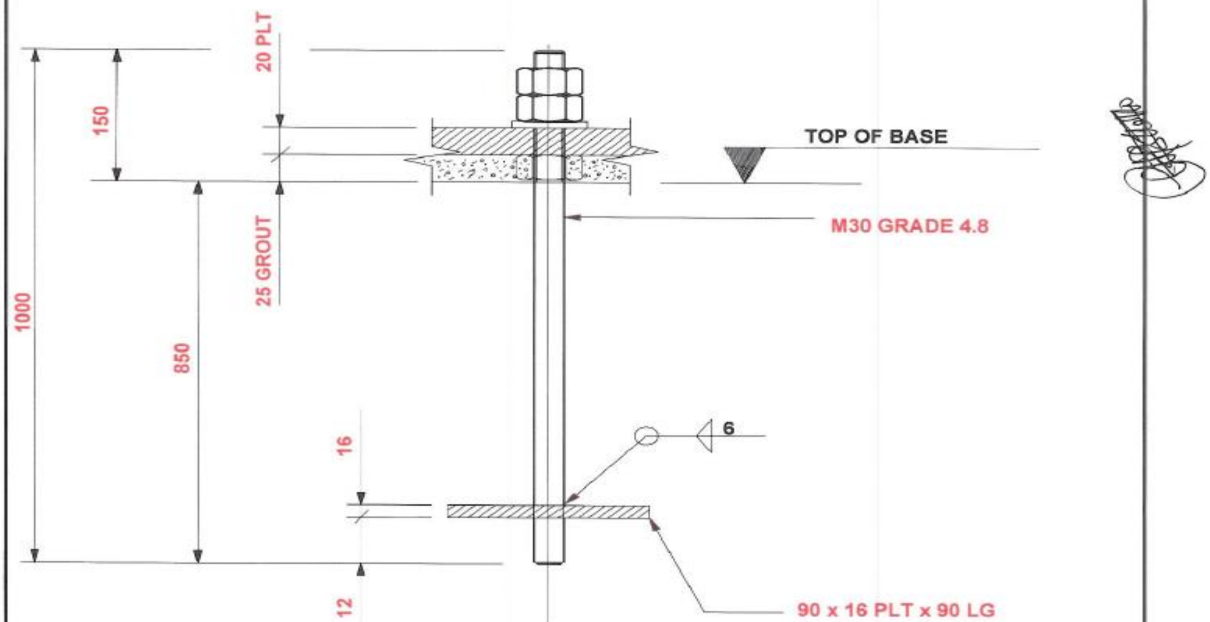
SQUARE FOUNDATION MP06 SERIES
3828 H/H - 150kPa
30 DEGREES ANGLE OF REPOSE

MAST PROJECTS cc
HEAD OFFICE
10 Milne Street
Vulcania, Brakpan
P.O. Box 4444, Dalpark 1543
Tel.: (011) 740-2226/7
Fax.: (011) 744-4720.

Van den Ende & Associates
Consulting Engineers CC
P.O. Box 100
Sunninghill
2157
Tel: 011 4647094/5
Fax: 011 4647096
Vat No:4850156266
e-mail:mvde@iafrica.com

STUB REBAR & HD BOLT LAYOUT

DRAWING No.	MP2006 002 - 117	REV
SHEET	3 OF 5	3



HD BOLTS
24 OFF
(NTS)

NOTES:

1) Steel template to be used for setting out of HD bolts.
2) Grouting under base plate: PRO-STRUCT 531 FIVE STAR grout.
3) All work to be done in accordance with SABS 1200 series of specifications.
4) Corrosion protection to clients specifications.

REV	DATE	DESCRIPTION	BY	CKD	APP
3	8/4/08	SHEET 2 & BAR MK 03 REV'D	SH	SH	MVDE
2	9/15/07	CLEINT REF REV'D	SH	SH	MVDE
1	5/11/07	FND REV'D	SH	SH	MVDE

Information on this drawing is confidential and may not be used, reproduced or copied whatsoever for any purpose without the prior consent of Van den Ende & Associates.

SQUARE FOUNDATION MP06 SERIES
3828 H/H - 150kPa
30 DEGREES ANGLE OF REPOSE

HD BOLT DETAILS

DRAWING No. MP2006 002 - 117 | REV 3
SHEET 4 OF 5

MAST PROJECTS cc
HEAD OFFICE
10 Milne Street
Vulcania, Brakpan
P.O. Box 4444, Dalpark 1543
Tel.: (011) 740-2226/7
Fax.: (011) 744-4720.

Van den Ende & Associates
Consulting Engineers CC
P.O. Box 100
Sunninghill
2157
Tel: 011 4647094/5
Fax: 011 4647096
Vat No: 4850156266
e-mail: mvde@iafrica.com

Appendix B3: Soil test report

PROPOSED ETISALAT GSM MAST

SITE LOCATION: A PIECE OF LAND LOCATED AT UNITY HILLS GARDEN ESTATE, PLOT 1274, ASO DELIGHT, KATAMPA, F.C.T. ABUJA.

SITE I.D: B 0653

اتصالات
etisalat

AND

HUAWEI

REPORT OF SUBSOIL INVESTIGATION FOR HUAWEI TECHNOLOGIES COMPANY LTD.

DATE: JANUARY, 2014

PREPARED BY:
KDF KONSULT LIMITED
3, BALOGUN STREET
OFF AWOLOWO WAY, IKEJA.

EXECUTIVE SUMMARY

ALLOWABLE BEARING PRESSURE

KPA VALUES:

Differential Depth (m)	Allowable bearing Capacity (KN/m^2)
0.00 – 0.25	90
0.25 – 0.50	140
0.50 – 0.75	210
0.75 – 1.00	290
1.00 – 1.25	340
1.25 – 1.50	480
1.50 – 1.75	625
1.75 – 2.00	765

RECOMMENDED FOUNDATION:

Shallow foundation

Shallow foundation is recommended for the proposed tower and ancillary facilities on project site.

GROUND WATER

Groundwater was not encountered in the course of the investigation on the project site. Occasionally during raining season water is trapped within the overburden sediment, If water is encountered in the course of excavation, though it was not encountered in the course of the DCP tests, the allowable bearing pressure stated in this report should be halved.

EXCAVATION

Adequate preparation should be put in place to excavate into cohesive soil.

Excavation support would not be required.

Excavation could easily be achieved using conventional excavating equipments / tools.

1.0 INTRODUCTION

The Contractor, **(HUAWEI TECHNOLOGIES COMPANY LTD)** commissioned **Kdf Konsult Limited** to proceed with subsoil investigations at the proposed **GSM** Cell Site located on **A PIECE OF LAND LOCATED AT UNITY HILLS GARDEN ESTATE, PLOT 1274, ASO DELIGHT, KATAMPA, F.C.T. ABUJA.** This Report is a consequence of the soil investigation and analysis, which is presented in an objective and professional manner.

The purpose of the subsoil investigation and attendant report is as follows:

- Determine the subsoil and surface/groundwater conditions of the designated location.
- Evaluation of the subsoil stratigraphic sequence geotechnical/engineering properties of the soil and the subsequent effects on foundation design and construction.
- Analysis of the data/results of tests carried out on the soil samples obtained and provide recommendations on the fit-for-purpose type of foundation for the proposed structure.

2.0 SITE ACCESSIBILITY

The site is accessible through**, Katampe road, Unity Hills Garden Estate, Plot 1274, Aso Delight, Katampa, F.C.T. Abuja** to mention but a few.

3.0 DESCRIPTION OF WORK

The soil investigation comprised of and carried out in three parts;

- Field Work: Tests (3DCPTs and Test pit), Laboratory Tests and collation of the test results.

3.1 FIELD WORK

The site works were carried out on January 21st, 2014.

The Scope of Work executed involved the performance of 3Nos. Dutch Cone Penetrometer Tests (DCPTs) to a depth of refusal and 1No. Test Pit.

DUTCH CONE PENETROMETER

The apparatus consists of a cylindrical probe, of $1000mm^2$ cross sectional area, and a conic head of apex angle of 60^o. The probe is forced down through the soil at a steady rate of about 20mm/s in the closed position by exerting pressure force on outer sounding tube. If desired the point resistance and the resistance to side friction can be measured separately.

3Nos. static cone penetration test was carried out using a 2.5tons capacity testing equipment (machine). The test involves advancing the cone into the ground slowly at a constant rate and the resistant to penetration measured at predetermined intervals of 0.25m depth. The tests were terminated at depths where the machine anchor legs lifted.

These tests were taken from the existing ground level down to depths of **-2.00m** in Pen 1, Pen 2 and Pen3 respectively.

The cone penetration test results are presented in a graphical form respectively in the Appendix to this Report.

TEST PIT

1No. Test Pit was done by manual excavation, (dimension - 1.50m x 1.50m x 1.00m).

3.2 ANALYSIS OF TEST RESULTS

3.2.1 Geological Description

Available geological record reveals that the investigated area is within the basement complex of Nigeria; it is characterized by crystalline rocks of Precambrian age. Rocks of granitic origin later intruded these rocks

3.2.2 Subsoil Condition

The subsoil indicated from the cone penetration test and trial pit result reveals a simple and uniform occurrence along the entire area investigated. Details of the subsoil characteristics encountered during the Penetrometer test and the trial pit excavation are shown below:

Subsoil Condition based on Dutch Cone Penetrometer Test (DCPT):

Depth (m)	Description of Stratum
0.50 to –2.00	Stiff to hard Cohesive Soil.

Subsoil Condition based on Trial Pit

Depth (m)	Description of Stratum
0.00 to –1.50	Stiff to hard Sandy CLAY.

3.2.3 Groundwater Condition.

Groundwater was not encountered in the course of the investigation on the project site. Occasionally during raining season water is trapped within the overburden sediment, if water is encountered in the course of excavation, though it was not encountered in the course of the DCP tests, the allowable bearing pressure stated in this report should be halved.

3.2.4 Site description and Condition.

The proposed site on which subsoil investigation was carried out in an open piece of land located within a residential environment; buildings and fence around show no sign of distress.

3.2.5 Topography.

The project site has an uneven topography.

3.2.6 Vegetation.

Vegetation on the project site as at the time of geotechnical investigations were mainly grasses and weeds.

3.2.7 Erosion and Flooding.

At the time of investigation the site shows no proneness to erosion and / or flooding under heavy down pour, however adequate drainage should be in place on the project site.

4.0 FOUNDATION DISCUSSION AND RECOMMENDATION

4.1 DESIGN DETAILS

Essentially, the Cell Site facilities/infrastructure requiring foundations that exert any significant loads shall comprise the following:

1. Self-supporting Tower resting on concrete bases.
2. A generator base
3. A shelter base
4. Cell Site location fence, which shall be in block wall or galvanized steel frame. Depending on the specified design, a concrete retaining wall may be required.

Generally it was advised that a minimum bearing design pressure of 50KN/m^2 is required beneath the tower if a shallow foundation is to be adopted.

4.2 DISCUSSIONS

Geotechnical Properties based on Dutch Cone Penetrometer Test (DCPT):

Depth (m)	Geotechnical Properties
0.00 to –2.00	Good to very good geotechnical properties, high shear strength and low compressibility potential.

Geotechnical Properties based on Trial Pit

Depth (m)	Geotechnical Properties
0.00 to –1.50	Good to very good geotechnical properties, high shear strength and low compressibility potential.

GEOTECHNICAL ENGINEERING PARAMETERS

Depth (m)	q_c value for Pen 1 (kg/cm^2)	q_c value for Pen 2 (kg/cm^2)	q_c value for Pen 3 (kg/cm^2
0.00 to –2.00	20 – 171	18 – 168	24 – 175

4.3 RECOMMENDATION

The foundation type to be chosen for a particular structure depends largely on the followings;

- Loads to be transmitted
- Receiving soil strata
- Factor of safety against shear failure of the supporting soil must be adequate.
- Settlement should neither cause any unacceptable damage nor interfere with the function of the structure.

Foundations can be classified as shallow foundation or as deep foundation.

The choice between shallow foundation and deep foundation can be arrived at after careful consideration of the following elements.

1. The magnitude of the transmitted loads from the stratum,
2. The soil nature,
3. The economic aspects of the elements of the foundation work,
4. Problems concerning foundation construction.

4.3.1 Allowable Bearing Pressure between ground surface and -2.00m

Allowable bearing pressure calculated in accordance with theoretical soil mechanics principle for different depths are indicated below:

Depth (m)		Allowable Bearing Pressure
0.00 -0.25	-	90KN/m^2
0.25 -0.50	-	140KN/m^2
0.50 -0.75	-	210KN/m^2
0.75 -1.00	-	290KN/m^2
1.00 -1.25	-	340KN/m^2
1.25 -1.50	-	480KN/m^2
1.50 -1.75	-	625KN/m^2
1.75 -2.00	-	765KN/m^2

4.3.2 Recommended Foundation.

The foundation type to be chosen for a particular structure depends largely on the followings;

- Loads to be transmitted
- Receiving soil strata
- Factor of safety against shear failure of the supporting soil must be adequate.
- Settlement should neither cause any unacceptable damage nor interfere with the function of the structure.

Foundations can be classified as shallow foundation or as deep foundation.

The choice between shallow foundation and deep foundation can be arrived at after careful consideration of the following elements.

5. The magnitude of the transmitted loads from the stratum,
6. The soil nature,
7. The economic aspects of the elements of the foundation work,
8. Problems concerning foundation construction.

Shallow foundation

Shallow foundation is recommended for the proposed tower and ancillary facilities on project site.

4.3.3 Settlement

For the allowable bearing pressure stated above, anticipated total and differential settlement would not exceed 25mm.

4.3.4 General Comment

- Factor of safety value of 3 was used for our shallow foundation analysis.
- The above recommendation is based on the depth of termination of the test, if water is encountered in the course of excavation, though it was not encountered in the course of the DCP tests, the allowable bearing pressure stated in this report should be halved.

- The above recommendation is based on the depth of termination of the test, no geotechnical information of the subsoil beneath -2.00m depth of termination could be determined except borehole/SPT test is carried out.

4.3.5 Excavation.

- Adequate preparation should be put in place to excavate into cohesive soil.
- Excavation support would not be required.
- Excavation could be easily achieved using conventional excavating tools.

4.3.6 General Precaution for Shallow Foundation Construction

It is recommended that the following general guidelines that govern the construction of shallow foundation should be observed when work commences on the site:

- Over excavation beyond the depths stated should not be done.
- Ingress of water into the excavated foundation trench should be prevented if the stated bearing value at the founding depth is to be achieved. A layer of concrete blinding should therefore be provided within a trench once it has been excavated.
- Adequate cover to the concrete should be allowed for the reinforcement bars to protect them from possible effect of corrosion.
- The sides of foundation should be backfilled up to existing ground level as soon as they are cast.
- Pile cap should be deep enough to ensure full transfer of the load from the column to the cap in the punching shear and from the cap of the piles.
- Ground beam should be used to inter-connect the pile or pile cap so as to take care of out-of-balance moment resulting from wind effect at ground level both in normal and punching shear

Note;

- **Our recommendation is for guidance purpose only and it is based on the depth of termination of the Dutch Cone Penetrometer tests (DCPT) carried out on the project site. To confirm the recommendations above and for further information beneath depth of termination of the DCPT, we recommend that at least a -25m borehole / SPT test or geophysical investigation for geotechnical purpose be carried out on the project site.**
- **The recommendations given in this report are based on the assumption that the subsurface materials and conditions do not deviate appreciably from those disclosed.**

5.0 CONCLUSION

Shallow foundation is recommended for the proposed tower and ancillary facilities on project site.

Despite an objective soil investigation and reporting, a poorly designed and/or constructed foundation may lead to structural failure if all other environmental conditions remain constant. Kdf Konsult Limited therefore recommends that the design and construction of all foundation and earthwork be carried out by a competent company in accordance with good and strict engineering practice expected of a professional. The construction contractor shall be guided by reference Code of Practices such as; British Institution CP 2004, 1973: Code of Practice for Foundation and BS 6031: Code of Practice for Earth Works.

FOR: KAYODE OLAOYE

APPENDIX C

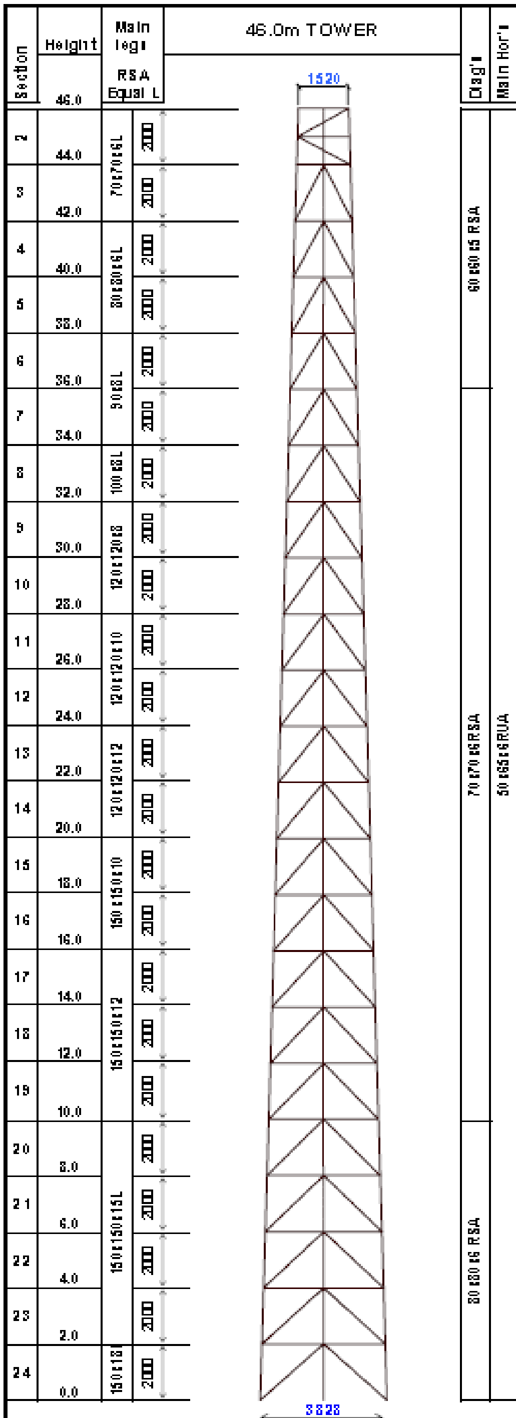
Appendix C: Tower drawing

MAST PROJECTS NIGERIA

46M (42M/S) 3820HH TOWER FOUNDATION TEMPLATES

PACKING LIST

S/NO.	ITEMS/MATERIALS	QUANTITY PER SITE
1	Angle Irons (50 X 50 X 6L X 1810LG)	6Pcs.
2	Angle Irons (50 X 50 X 5L X 1106LG)	3Pcs.
3	Top Plates (375 X 375)	3Pcs.
4	Bottom Plates (375 X 375)	3Pcs.
5	Splice/Connecting Plates (260 X 50 X 5PLT)	6Pcs.
6	M12 X 30 Assembly Bolts & Nuts	54Pcs.
7	M30 Holding Down Bolts	24Pcs.

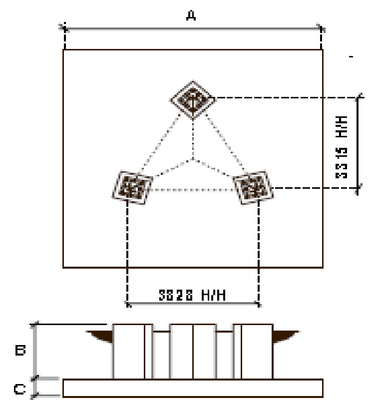


Design Codes:

SABS 0162 Part 1 1991
SABS 0160 Part 1 1998 As amended.

Notes :

1- Mass of tower : 7582 kg
2- Mass of catladder : 920 kg
3- Maximum force (Per leg) : 909 kN
4- Maximum uplift (Per leg) : 890 kN
5- Site altitude : 50 ASL
6- a) Design wind speed : 40 m/s
   b) Survival wind speed : 46.5 m/s
7- Terrain category : 2B
8- Mean wind return : 1:50 Years
9- Artificial base height : 0 m
10- Flatplt areas:
   - Antenna area : 12 sq/m Spread (Cf = 1,0)
   - Feeder, Catladder & Wave guide : 0.3 sq/m/m
   - Tower : 21.9 sq/m
   - Paint area : 195 sq/m
11- Equivalent antenna force : 14.56 kN
12- All steelwork 350WA
13- Bolts Grade 8.8

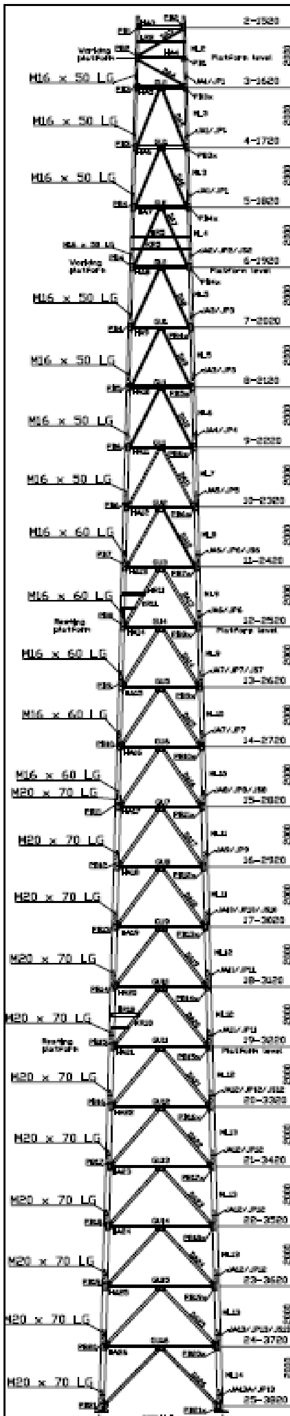


Foundation Criteria:	150 kPa	100 kPa	75 kPa	
1) Concrete grade	25/19	25/19	25/19	MPa
2) Blinding grade	10/19	10/19	10/19	MPa
3) Concrete Volume	25.4	30.9	34.8	m^3
4) Blinding Volume	1.9	2.5	2.8	m^3
5) Excavation Volume	84	66	59	m^3
6) Backfill Volume	58	35	24	m^3
7) Steel	1953	2231	2451	kg
8) Stubs	750	750	750	mm
9) Pmax	150	100	75	kPa
10) Mr	N/A	N/A	N/A	
11) Angle of repose	30	20	10	AOR
12) Dimension A	6100	7000	7500	mm
13) Dimension B	1800	900	600	mm
14) Dimension C	600	600	600	mm
15) Ground Cover	1650	750	450	mm

MAST PROJECTS cc

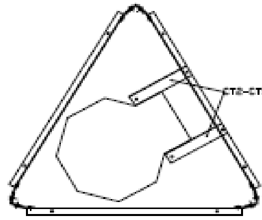
46m Angle Tower (MP06/24/2)

Compiled by:	Compiled for:	Date	Rev
S.H	Mast Projects	28-Jan-08	0

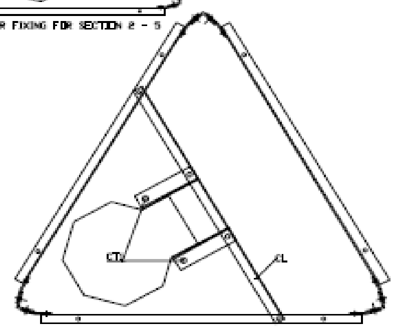


Section	Levels	Members		
Section 2	0/46m – 2/44m	ML2 - 3 HA3 - 3 HA4 - 3 DA3 - 3	DA4 - 3 PB1 - 6 PB2 - 6 LR2 - 3	CT2 - 2
Section 3	2/44m – 4/42m	ML3 - 3 HA5 - 3 DA5 - 6 GU1 - 3	PB3 - 3 PB3x - 3	JA1 - 3 JP1 - 6 CT3 - 2
Section 4	4/42m – 6/40m	ML3 - 3 HA6 - 3 DA6 - 6 GU1 - 3	PB3 - 3 PB3x - 3 CT4 - 2	JA1 - 3 JP1 - 6
Section 5	6/40m – 8/38m	ML4 - 3 HA7 - 3 DA7 - 6 GU1 - 3	PB4 - 3 PB4x - 3 HR5 - 3 LR5 - 3	JA1 - 3 JP1 - 6 CT5 - 2
Section 6	8/38m – 10/36m	ML5 - 3 HA8 - 3 DA8 - 6 GU1 - 3	PB4 - 3 PB4x - 3 CL - 1 JS2 - 6	JA2 - 3 JP2 - 6 CT1 - 2
Section 7	10/36m – 12/34m	ML5 - 3 HA9 - 3 DA9 - 6 GU1 - 3	PB4 - 3 PB4x - 3 CL -1	JA3 - 3 JP3 - 6 CT1 - 2
Section 8	12/34m – 14/32m	ML6 - 3 HA10 - 3 DA10 - 6 GU1 - 3	PB5 - 3 PB5x - 3 CL - 1	JA3 - 3 JP3 - 6 CT1 - 2
Section 9	14/32m – 16/30m	ML7 - 3 HA11 - 3 DA11 - 6 GU1 - 3	PB6 - 3 PB6x - 3 CL - 1	JA4 - 3 JP4 - 6 CT1 - 2
Section 10	16/30m – 18/28m	ML8 - 3 HA12 - 3 DA12 - 6 GU2 - 3	PB6 - 3 PB6x - 3 CL - 1	JA5 - 3 JP5 - 6 CT1 - 2
Section 11	18/28m – 20/26m	ML9 - 3 HA13 - 3 DA13 - 6 GU3 - 3	PB7 - 3 PB7x - 3 CL - 1 JS6 - 6	JA6 - 3 JP6 - 6 CT1 - 2 HR11 - 2 KR11 - 2
Section 12	20/26m – 22/24m	ML9 - 3 HA14 - 3 DA14 - 6 GU4 - 3	PB8 - 3 PB8x - 3 CL - 1	JA6 - 3 JP6 - 6 CT1 - 2
Section 13	22/24m – 24/22m	ML10 - 3 HA15 - 3 DA15 - 6 GU5 - 3	PB9 - 3 PB9x- 3 CL - 1 JS7 - 6	JA7 - 3 JP7 - 6 CT1 - 2
Section 14	24/22m – 26/20m	ML10 - 3 HA16 - 3 DA16 - 6 GU6 - 3	PB10 - 3 PB10x - 3 CL - 1	JA7 - 3 JP7 - 6 CT1 - 2
Section 15	26/20m – 28/18m	ML11 - 3 HA17 - 3 DA17 - 6 GU7 - 3	PB11 - 3 PB11x - 3 CL - 1 JS8 - 6	JA8 - 3 JP8 - 3 JP8x- 3 CT1 - 2
Section 16	28/18m – 30/16m	ML11 - 3 HA18 - 3 DA18 - 6 GU8 - 3	PB12 - 3 PB12x - 3 CL - 1	JA9 - 3 JP9 - 6 CT1 - 2
Section 17	30/16m – 32/14m	ML12 - 3 HA19 - 3 DA19 - 6 GU9 - 3	PB13 - 3 PB13x - 3 CL - 1 JS10 - 6	JA10 - 3 JP10 - 6 CT1 - 2
Section 18	32/14m – 34/12m	ML12 - 3 HA20 - 3 DA20 - 6 GU10 - 3	PB14 - 3 PB14x - 3 CL - 1 HR18 - 2	JA11 - 3 JP11 - 6 CT1 - 2 KR18 - 2
Section 19	34/12m – 36/10m	ML12 - 3 HA21 - 3 DA21- 6 GU11 - 3	PB15 - 3 PB15x - 3 CL - 1	JA11 - 3 JP11 - 6 CT1 - 2
Section 20	36/10m – 38/8m	ML13 - 3 HA22 - 3 DA22 - 6 GU12 - 3	PB16 - 3 PB16x - 3 CL - 1 JS12 - 6	JA12 - 3 JP12 - 6 CT1 - 2
Section 21	38/8m – 40/6m	ML13 - 3 HA23 - 3 DA23 - 6 GU13 - 3	PB17 - 3 PB17x - 3 CL - 1	JA12 - 3 JP12 - 6 CT1 - 2
Section 22	40/6m – 42/4m	ML13 - 3 HA24 - 3 DA24 - 6 GU14 - 3	PB18 - 3 PB18x - 3 CL - 1	JA12 - 3 JP12 - 6 CT1 - 2
Section 23	42/4m – 44/2m	ML13 - 3 HA25 - 3 DA25 - 6 GU15 - 3	PB19 - 3 PB19x - 3 CL - 1	JA12 - 3 JP12 - 6 CT1 - 2
Section 24	44/2m – 46/0m	ML14 - 3 HA26 - 3 DA26 - 6 GU16 - 3 Stubs - 3	PB20 - 3 PB20x - 3 CL - 1 JS13 - 6 JA13A - 3	JA13 - 3 JP13 - 12 CT1 - 2 PB21 - 3 PB21x - 3

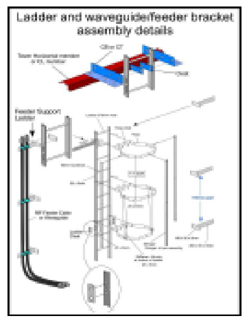
46M – 12m²



CAT LADDER FIXING FOR SECTION 2 – 5



CAT LADDER FIXING FOR SECTION 6 – 24



ERECTION NOTES:

1) VERIFY FOUNDATION SET OUT AND LEVELS
2) VERIFY TOWER STEELWORKS AND ACCESSORIES QUANTITIES
3) TOWER TO BE ERECTED WITH ALL MEMBERS IN ONE SECTION COMPLETE, WITH BOLTS FINGER TIGHT PRIOR TO COMMENCING WITH ERECTION OF NEXT SECTION
4) TOWER TO BE PLUMB, STRAIGHT AND COMPLETELY ERECTED PRIOR TO FINAL FASTENING OF BOLTS, FASTEN BOLTS ON BRACES FROM TOP TO BOTTOM PRIOR TO FASTENING BOLTS OF SPLICES FROM TOP TO BOTTOM
5) BOLTS TO BE TIGHTENED WITH PROGGER SPANNER, TURN OF THE NUT METHOD. IN THE TIGHTENED STATE, THE NUT HEAD WOULD RESIST ROTATION OF A MAN USING FULL EFFORT WITH A PROGGER SPANNER
6) BOLTS ARE TO BE INSERTED AS FOLLOWS:
   6.1) HORIZONTAL BOLTS FROM INSIDE OUT, ie BOLT HEAD TO THE INSIDE OF THE TOWER
   6.2) VERTICAL BOLTS TO BE INSERTED FROM TOPSIDE OF THE HOLE ie NUT TO DOWNSIDE
7) HARDENED WASHERS TO BE USED UNDER ALL NUTS
8) ALL BOLTS TO BE PAINTED WITH DAYMARK PAINTING OR COLD GALVANISE PAINT AFTER TIGHTENING
9) NO HOLES TO BE DRILLED OR MEMBERS MODIFIED WITHOUT CONCENT FROM ENGINEER
10) NO MEMBER TO BE FITTED WITH FORCE
11) NO BOLTS TO BE RE-USED
12) ALL BOLTS 8/8 GRADE
13) GROUT TO BE CEMENTITIOUS FLOWABLE NON-SHRINK GROUT
14) CAT LADDERS STRINGERS AND CAGE TO BE LINED UP PRIOR TO FASTENING OF BOLTS. CAT LADDER TO BE ERECTED FROM BOTTOM TO TOP

DESCRIPTION: 46m, 12m2 THREE LEGGED TOWER GENERAL ARRANGEMENT
CLIENT:
COUNTRY: NIGERIA
DR.NO: GA-46M-3A
MODEL NO: MP0602

Mast PROJECTS

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QUANTITY: 1
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