ESKOM

TRANSMISSION

SPECIFICATION

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TITLE: **TRANSMISSION LINE TOWERS AND LINE CONSTRUCTION**

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COMPILED BY	FUNCTIONAL RESP.	AUTHORIZED BY
PD Appleyard **Eskom Enterprises (Pty.) Ltd. Line Engineering Services**	**H Mohabir** **Tx. Network Operational Engineering Manager**	**J Machinjike** **Transmission Engineering Manager**
DATE:….....	DATE:….....	DATE:….....

This document has been seen and accepted by:

Name	Designation

Note: Concerns queries and comments on this document should be referred to the compiler

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1. Scope

This specification details the requirements for the design, detailing, fabrication, testing, supply, delivery and erection of transmission line towers and foundations, together with the erection of all conductors and associated line hardware and fittings.

2. Definitions

a) The *"Employer"* is the party for whom the *works* are to be executed and in this specification means Eskom and where applicable, includes Eskom's successor in title but not, except with the written content of the *Contractor*, any assignee of Eskom.

b) The *"Contractor"* is the party appointed by the *Employer* to "Provide the Works".

c) The *"Project Manager"* is the person appointed by the *Employer* from time to time to act in the capacity and notified, by name and in writing by the *Employer* to the *Contractor*, as required in "The NEC Engineering and Construction Contract".

d) The *"Supervisor"* is the person appointed by the *Employer* from time to time to act in the capacity and notified, by name and in writing by the *Employer* to the *Contractor*, as required in "The NEC Engineering and Construction Contract".

3. Normative references

The following documents are to be read in conjunction with this specification. In cases of conflict, the provisions of this specification shall take precedence. Unless otherwise stated, the latest revision, edition and amendments shall apply.

ASCE Manual No. 52	Guide for design of steel transmission towers
BS 183:1972	Specification for general purpose galvanised steel wire strand.
BS 443:1982	Specification for testing zinc coatings on steel wire and for quality requirements.
BS 970	Specification for wrought steels for mechanical and allied engineering purposes.
BS EN 287-1:1992	Approval testing of welders for fusion welding. Part 1: Essential variables, range of approval examination and testing, acceptance requirements, re-tests, period of validity. Annexes on steel groups, welders test certificate, procedure specification and job knowledge.
BS EN 288-3:1992	Specification and approval of welding procedures for metallic materials. Part 3: Welding procedure tests for the arc welding of steels.
ECCS	Recommendations for angles in lattice transmission towers, No. 39.
SABS 82:1975	Bending dimensions of bars for concrete reinforcement.
SABS 135:1991	ISO metric bolts, screws and nuts (hexagon and square) (coarse thread free fit series).
SABS 182-5:1979	Zinc-coated steel wires for conductors and stays.
SABS 471:1971	Portland cement (ordinary, rapid-hardening and sulphate-resisting).
SABS 626:1971	Portland blast furnace cement.
SABS 675:1993	Zinc-coated fencing wire.
SABS 471:1971	Hot-dip (galvanised) zinc coatings (other than on continuously zinc-coated sheet and wire). (Appendix C to apply).
SABS 831:1971	Portland cement 15 (ordinary and rapid hardening).

SABS 920:1985	Steel bars for concrete reinforcement.
SABS 1083:1976	Aggregates from natural sources.
SABS 1200-GE:1984	Precast concrete (structural).
SABS 1431:1987	Weldable structural steels.
SABS 1491-1:1989	Portland cement extenders, Part 1: Ground granulated blast furnace slag.
SABS 1491-2:1989	Portland cement extenders, Part 2: Fly ash.
SABS 1491-3:1989	Portland cement extenders, Part 3: Condensed silica fume.
SABS 1466:1988	Portland fly ash cement.
SABS 0100-1:1992	The structural use of concrete. Part 1: Design.
SABS 0100-2:1992	The structural use of concrete, Part 2: Materials and execution of work.
SABS 0144:1978	Detailing of steel reinforcement for concrete.
SABS 0162-1:1993	The structural use of steel, Part 1: Limit-states design of hot-rolled steelwork.
SABS 0162-2:1993	The structural use of steel, Part 2: Limit-states design of cold-formed steelwork.
SABS 0162-3:1993	The structural use of steel, Part 3: Allowable stress design steelwork.
SABS Method 862	Slump of freshly-mixed concrete.
SABS Method 863	Compressive strength of concrete (including making and curing of the test cubes).
ESKCAAB4	Zinc coated earth conductor, guy and stay wire for transmission lines
ESKASABG3	Bush clearance and maintenanace within overhead powerline servitudes.
TRMSCABC9	Design, manufacturing and installation specification for transmission line labels.
TRMASAAJ7	Earthing of transmission lines.
TRMASACB2	Standard for the installation of overhead ground wire with optical fibre (OPGW)
NWS 1074	Guy strand grips for transmission lines.
NWP 3402	Powerlines in the vicinity of aerodromes and hazards to aircraft.

Department of Agriculture Bulletin No. 399 ISBN0621082589, A primer on soil conservation.

Environmental Conservation Act No. 73 of 1989.

Fencing Act No 31 of 1963.

SAISC, South African steel construction handbook.

4. Environmental

4.1 General

4.1.1 Supervision

The *Contractor* shall give or provide all necessary superintendence during the execution of the *works*. The *Contractor* or a competent and authorised appointee approved of in writing by the *Project Manager* (which approval may at any time be withdrawn) shall be on the *works* at all times when work is being performed or when the *Employer* shall reasonably require it. The *Contractor* shall employ only such persons that are competent, efficient and suitably qualified with related experience in the environmental field. The *Employer* shall be at liberty to object to and require the *Contractor* to remove from the *works* any person, who in the *Project Manager's* opinion, misconduct's himself or is incompetent in the proper performances of his duties.

4.1.2 Precautions against damage

a) In accordance with applicable legislation, the *Contractor* shall take all reasonable precautions for the protection of life and property on, or about, or in connection with the *works.*

b) The *Contractor* shall comply strictly with the "Special Conditions" stipulated by the landowners in the negotiated Options.

c) The *Contractor* shall comply with all the conditions specified in the Environmental Management Plan (EMP) during construction. In general, soil disturbance should be kept to a minimum. The disturbance of land contour banks or other erosion control structures shall be avoided.

d) No damage shall be caused to any crops unless both the landowner and the *Supervisor*, prior to the work commencing agree upon the extent of the intended damage.

e) There shall be no littering of the veld. The *Contractor* shall provide suitable containers for any waste.

f) No fires shall be allowed on site under any circumstances.

g) The *Contractor* shall be held liable for all damage arising from actions or negligence on the part of his workforce and any such damage shall be repaired immediately.

h) Any additional agreement concluded between the *Contractor* and a landowner not relating to Providing the Works, must be in writing and a copy made available to the *Supervisor* within 48 hours of such an agreement being concluded.

i) Any environmental incident as specified in the EMP, or accident during construction of the *works* shall be immediately reported to the *Supervisor*.

4.2 Sanitation

The Contractor is to provide portable toilet facilities for the use of his workforce at all work sites. Under no circumstances shall use of the veld be permitted. To prevent the occurrence of measles in cattle, employees may require to be examined for tapeworm and treated, or treated irrespective of whether they are infested or not. Proof of such treatment is to be supplied to the *Supervisor*. The drug "Niclosamide" (Yomesan, Bayer) is freely available and highly effective against tapeworms in humans. It does not however, prevent re-infestation and regular examination and/or treatment is required.

4.3 Wildlife

a) It is illegal to interfere with any wildlife, fauna or flora as stipulated in the Environmental Conservation Act No 73 of 1989.

b) When stipulated in the EMP, two colour bird diverters are to fitted on both earthwires along the indicated spans at 25m intervals.

4.4 Access

a) The *Supervisor* shall, together with a representative of the *Contractor*, negotiate with each landowner the access to reach the servitude and each tower position. The access agreement will be formalised in the form "TPL 004/005 - Property Access Details" and signed by the three parties. The *Contractor* will mark the proposed route and/or a competent representative will accompany the equipment when opening the access. Any deviation from the written agreement shall be closed and re-vegetated immediately.

b) The *Contractor* shall signpost the access roads to the tower positions, immediately after the access has been negotiated.

4.4.1 Use of existing roads

a) Maximum use of both the existing servitudes and the existing roads shall be made. In circumstances where private roads must be used, the condition of the said roads must be recorded prior to use (e.g. photographed) and the condition thereof agreed by the landowner, the *Supervisor* and the *Contractor*.

b) All private roads used for access to the servitude shall be maintained by the *Contractor* and upon completion of the *works*, be left in at least the original condition.

c) Access shall not necessarily be continuous along the line, and the *Contractor* must therefore acquaint himself with the physical access restrictions such as rivers, railways, motorways, mountains, etc. along the line. As far as possible, access roads shall follow the contour in hilly areas, as opposed to winding down steep slopes.

d) Access is to be established by vehicles passing over the same track on natural ground, multiple tracks are not permitted. Access roads shall only be constructed where necessary at watercourses, on steep slopes or where boulders prohibit vehicular traffic.

e) The *Contractor* is to inform the *Supervisor* before entering any of the following areas:

i) Naturally wet areas: vleis, swamps, etc.

ii) Any area after rain.

iii) Any environmentally sensitive area.

f) If access is across running water, the *Contractor* shall take precautions not to impede the natural flow of water. If instructed, the *Contractor* is to stone pitch the crossing point. There shall be no pollution of water. Access across running water and the method of crossing shall be at the approval of the *Supervisor* and the landowner.

g) Where in the opinion of the *Supervisor* and/or *Project Manager*, inordinate and irreparable damage would result from the development of access roads, the *Contractor* shall use alternative construction methods compatible with the access and terrain, as agreed with the *Project Manager.*

h) Existing water diversion berms are to be maintained during construction and upon Completion be repaired as instructed by the *Supervisor.*

i) Where access roads have crossed cultivated farmlands, the lands shall be rehabilitated by ripping to a minimum depth of 600mm.

4.4.2 Construction of new roads

a) Where construction of a new road has been agreed, the road width shall be determined by need, such as equipment size, and shall be no wider than necessary.

b) In areas over 4% sideslope, roads may be constructed to a 4% outslope. The road shall be constructed so that material will not be accumulated in one pile or piles, but distributed as evenly as possible. The material shall be side-cast as construction proceeds, and shall not be side-cast so as to make a barrier on the downhill side. The cut banks shall

not overhang the road cut, and shall if necessary be trimmed back at an angle which would ensure stability of the slope for the duration of the *works*. The sides or shoulders of roads shall not act as a canal or watercourse.

c) Water diversion berms shall be built immediately after the opening of the new access road. In addition, water outlets shall be made at intervals where berms are installed, and suitably stone pitched if instructed by the *Supervisor*.

d) No cutting and filling shall be allowed in areas of 4% sideslope and less.

e) Existing land contours shall not be crossed by vehicles and equipment unless agreed upon, in writing, by the landowner and the *Supervisor.*

f) Existing drainage systems shall not be blocked or altered in any way.

4.4.3 Closure of roads

a) Upon completion, only roads as indicated by the *Supervisor* shall be closed.

b) In areas where no cut or fill has been made, barriers of earth, rocks or other suitable material shall effect closure.

c) In areas 30 % slope and less, the fill of the road shall be placed back into the roadway using equipment that does not work outside the roadcut (e.g. back-hoe). In areas of greater that 30 % slope, the equipment shall break the road shoulder down so that the slope nearly approximates to the original slope of the ground. The cut banks shall be pushed down into the road, and a near normal sideslope shall be re-established and re-vegetated.

d) Replacement of earth shall be at slopes less than the normal angle of repose for the soil type involved.

4.4.4 Construction of water diversion berms

a) Water diversion berms shall be spaced according to the ground slope and actual soil conditions, but no greater than the following:

- Where the track has a slope of less than 2% : 50m apart
- Where the track has a slope of 2% - 10% : 25m apart
- Where the track has a slope of 10% - 15% : 20m apart
- Where the track has a slope of more than 15% : 10m apart

b) Berms shall be suitably compacted to a minimum height of 350mm.

c) The breadth of the water diversion berm shall be 4m at the base, and extend beyond the width of the road for 2m on the outlet side to prevent water flowing back into the road. It shall be angled to a gradient of 1% to enable the water to drain off slowly.

d) Berms are to constructed so that a canal is formed at the upslope side.

e) Where the in-situ material is unsuitable for the construction of water diversion berms, alternative methods of construction must be investigated and proposed by the *Contractor* and submitted to the *Project Manager* for acceptance.

f) Borrow pits - The *Contractor*'s decision as to the location of borrow pits, shall be at the *Supervisor*'s acceptance. The *Contractor* shall be responsible for the rehabilitation and re-vegetation of the borrow pits. It is the *Contractor*'s responsibility to negotiate the royalties for the borrow pits with the landowner.

4.4.5 Levelling at tower sites

a) No levelling at tower sites shall be permitted unless approved by the *Supervisor*.

b) The steep slopes formed by the cutbanks and respective fillings when building the tower platforms are to be trimmed back to an angle that ensures stability of the slope. When the ground is loose, berms are to be built on the top of the slope, 2m long logs spaced evenly must be pegged across the down-slope, re-vegetated with appropriate local grass seeds together with fertiliser.

4.5 Gates

4.5.1 General

a) Attention is drawn to the Fencing Act No. 31 of 1963 as amended, in particular with regard to the leaving open of gates and the dropping of fences for crossing purposes, climbing, and wilful damage or removal of fences.

b) At points where the line crosses any fence in which there is no suitable gate within the extent of the line servitude the *Contractor* is to, on the *Supervisor's* instruction, provide and install a servitude gate as detailed in the relevant drawing. The *Contractor* will mark these crossing points when the tower positions are being pegged.

c) Where applicable game gates are to be installed in accordance with the relevant drawing.

d) All vehicles shall pass through gates when crossing fences, and the *Contractor* shall not be allowed to drop fences temporarily for the purpose of driving over them. No construction work shall be allowed to commence on any section of line, unless all gates in that section have been installed. Installation of gates in fences on major road reserves shall comply with the ordinances of the relevant Provisional Authority. No gates may be installed in National Road and Railway fences.

4.5.2 Installation of gates

a) Care shall be taken that the gates shall be so erected that a gap of no more than 100mm to the ground is left below the gate.

b) Where gates are installed in jackal proof fencing, a suitable reinforced concrete sill as shown on the drawing shall be provided beneath the gate.

c) The original tension is to be maintained in the fence wires.

d) Where required, the *Contractor* shall replace rusted or damaged wire strands on either side of the gate with similar new wiring to prevent the movement of animals. The extent of the replacement shall be on the *Supervisor's* instruction.

4.5.3 Securing of gates

a) The *Contractor* shall ensure that all servitude gates used by him are kept closed and locked at all times.

b) The *Contractor* shall provide locks for all servitude gates, and when the line is taken over these locks shall be recovered by the *Contractor* and replaced by locks supplied by the *Employer.* The *Contractor* shall also ensure that all existing farm gates used by him are kept closed. The *Contractor* shall provide the *Supervisor* with keys for the above locks. No keys shall be provided to landowners to avoid conflict situations between neighbouring landowners.

4.6 Construction - within the servitude

a) All foundation excavations shall be kept covered or barricaded in a manner acceptable to the *Supervisor* to prevent injury to people and livestock. Failure to maintain proper protection of excavations may result in the suspension of excavation work until proper protection has been restored.

b) Material removed from the excavation, which is not suitable or not required for backfill may be spread evenly over or adjacent to the tower position. If in the opinion of the *Supervisor* the excavated material is not suitable for spreading it shall be disposed of as directed by the *Supervisor*. Spreading of subsoil will not be permitted. All excavated soil suitable for backfill will be returned to the excavation by backfilling with the subsoil first and the topsoil last.

c) All other construction waste, nuts, bolts, surplus concrete, etc. shall be removed from the tower sites and servitude. Plastic, litter and conductor offcuts etc. are to be removed immediately from site to avoid injury to farm animals and wildlife.

d) No surplus concrete or concrete washing is allowed to be dumped on the servitude and at tower locations. No concrete washing is allowed in watercourses.

4.7 Camp-sites

a) The *Contractor* will be responsible for negotiating the position of his camp-sites and the conditions under which the camps may be established, with the landowner. The *Contractor* will be responsible for the proper management of the camps. Notwithstanding, it is required that the entire camp is fenced and the gates shall be locked after hours and over weekends. Proper sanitation and cooking facilities are to be provided. The *Contractor* shall ensure that the water used at the camp-sites is of drinkable quality.

b) Litter shall be disposed to an appropriate site.

c) Sewerage and waste-water at the camp-sites have to be removed to an approved sewerage farm.

d) The *Contractor* shall have the diesel tank protected underneath by plastic sheeting and a trench or bund wall around it to avoid ground pollution. In case of ground pollution a certified contractor shall remove the soil to an approved toxic site or the ground treated chemically. In both cases a certificate is to be supplied to the *Project Manager.*

e) The compacted ground shall be rehabilitated by ripping to a minimum depth of 600mm. The site shall be cleaned and left as it was found and to the satisfaction of the *Supervisor* and landowner.

4.8 Batching plants

a) The *Contractor* shall be responsible for negotiating the site of his batching plant (if required) and the conditions under it may be established, with the landowner. The *Contractor* shall be responsible for the proper management of the batching plant.

b) Upon completion of *works*, the ground of the batching plant area shall be rehabilitated and the site cleaned and left as it was found and to the satisfaction of the *Supervisor* and landowner.

c) The use of local water for concrete must first be negotiated with the landowner and the appropriate authorities. Such water is to be analysed and accepted by the *Project Manager* before use.

5 Line survey

5.1 Plans and profiles

The route of the line will be surveyed by the *Employer*, who will provide all necessary route plans and templated profile drawings, on which, tower types and the position thereof will be indicated.

5.2 Marking of route

The line route will be marked by the *Employer* with iron pegs at each angle, and on-line reference pegs along the straights, at approximately 2 000m intervals, and will, in most cases, be inter-visible.

5.3 Survey beacons at bend points

At bend positions, the original iron pegs indicating the centre line of the transmission line route are on no account to be disturbed or removed, as these are required for servitude registration purposes. The *Contractor* is to, during foundation installation, concrete the bend pegs in position.

5.4 Survey by the *Contractor*

a) The pegging of tower positions, and where necessary, the establishing of self supporting tower leg extensions and guy anchor positions for guy towers, shall be carried out by professional land surveyors or registered surveyors.

b) The *Contractor*, on completion of each 20km or suitable section of the line, is to supply records of all distances measured for each individual tower position. These should agree with the profiles, and any discrepancy reported immediately.

c) It is the *Contractor's* responsibility to inform the *Supervisor* immediately, should

i) there is any discrepancy between the topography shown on the profiles and the actual ground;

ii) errors be found, for example where a tower position is physically in “lands” and the profile states "no tower in land";

iii) new features have appeared since the completion of the survey and the production of the profiles, such as roads, telephone or power lines etc. which could create clearance problems;

iv) the *Contractor*, in his opinion, finds that the site chosen is not suitable for a tower position, or the tower type indicated on the profiles is not suitable for the tower position e.g. excessive side slope.

d) It is the *Contractor*'s responsibility to ensure that the surveyor is familiar with the limitations and restrictions of the tower types and construction methods used.

5.5 Pegging by the *Contractor*

5.5.1 Procedure

a) The *Contractor* shall undertake the pegging of the transmission line tower positions along the intended line route. Pegging shall proceed far in advance of foundation nomination and construction.

b) Every tower centre position is to be marked with a steel peg ±1.2m high and painted white. The pegs are to carry a tag showing the tower number, tower type and height. The pegs are to be left in position until the tower is assembled.

5.5.2 Setting out of angle towers

All angle towers must be positioned in such a way that the centre phase conductor is on the centre line of the servitude.

5.5.3 Correct placing of towers

It is the *Contractor*s responsibility to ensure that accepted survey methods are used, and that checks are done to ensure the correct placing of towers.

- **NOTE:** As numerous numbers appear on the profile drawings, the *Contractor* is to ensure that the actual span distances add up to the length of the straight or section of line between two bends. Any distance which are shown from a line point to a tower are to be taken as unchecked.

6. Foundations

6.1 Design

6.1.1 Soil and rock classification

a) **Hard Rock:** hard to very hard solid or moderately fractured continuous rock, and including hard to very hard rock of any other description which meets the strength requirements of clause 6.1.2

b) **Soft Rock:** weathered or decomposed very soft to soft continuous rock, and including rock of any other description which does not satisfy the requirements for classification under clause 6.1.1 a) above.

c) **Type '1' soils:** competent soil with equal or better consistency (strength or toughness) than one would encounter in stiff cohesive soils or dense cohesionless soils above the water table. This soil must have a broad balanced texture (constituent particle sizes) with high average combinations of undrained shear strength and internal angle of friction, with minimum values of 80kN/m² and 30° respectively. The minimum natural specific weight shall not be less than 18kN/m³.

d) **Type '2' soils:** a less competent soil than type "1", with equal or weaker consistency than one would encounter in firm to stiff swelling cohesive soils, or dry poorly graded loose to medium dense cohesionless soils above the water table. The minimum undrained shear strength shall be 40kN/m², and the minimum natural specific weight shall not be less than 16kN/m³.

e) **Type '3' soils:** dry loose cohesionless soil or very soft to soft cohesive soil.

f) **Type '4' soils:** submerged cohesionless and cohesive soils. This includes all soils below the permanent water table, including soils below a re-occurring perched water table, or permeable soils in low-lying areas subjected to confirmed seasonal flooding.

6.1.2 Geotechnical design parameters

Pad and pier, steel grillage, precast concrete, pad and plinth for guyed tower mast supports and dead man anchors.

- **For hard rock**
- The maximum bearing or toe pressure at foundation depth shall be 2 000kPa.
- **For soft rock**
- The maximum bearing or toe pressure at foundation depth shall be 800kPa.

- **For soil**

		Type '1'	Type '2'	Type '3'	Type '4'
Maximum soil bearing pressure	kPa	300	150	100	50
Maximum toe bearing pressure	kPa	375	200	125	65
Frustum angle for suspension towers	degrees	30	20	0	0
Frustum angle for strain towers	degrees	25	15	0	0
Density of backfill	kg/m^3	1800	1600	1400	1000
Density of reinforced concrete	kg/m^3	2400	2400	2400	1500

- **NOTE:** For maximum soil bearing pressure and maximum toe bearing pressure, use the tabled pressure or 80% of the ultimate tested bearing pressure determined from appropriate tests.

6.1.3 Foundation design loads

The ultimate simultaneous tower design loads shall be used for foundation design purposes. The foundation loads thus calculated shall be further factored upwards for foundation design purposes by a load factor equal to 1.2 for lattice steel self-supporting type towers. For guyed towers the guy anchor loads shall be factored by a load factor of 1.3 minimum and the mast plinths loads by a factor of 1.1. The foundations shall in addition be designed for the most critical cases that would result from the occurrence of the maximum permissible tolerance situations as listed in clause 6.2.4.3

6.1.4 Drilled foundations, including piles and rock anchors

Soil /rock design parameters for final design and construction of drilled foundations shall be determined by pile tests, foundation tests or comprehensive soil /rock investigations as described in clause 6.1.5. The *Contractor* is fully responsible for the final foundation designs. As a guide only, "average" parameters are set out below.

i) In type '1' or type '2' soils, a skin friction with a maximum of 80kPa in a type '1' soil, and a maximum of 40kPa in a type '2' soil, may be used. The skin friction values that are used shall not exceed 80% of the ultimate friction determined from appropriate soil tests in accordance with clause 6.1.5.

ii) In soft rock, when non-shrink grout or concrete is utilised, a maximum skin friction of 135kPa may be used in all piles or anchors. A 37° frustum shall be used to check anchor group pull out resistance. The skin friction value shall not exceed 80% of the ultimate friction determined from appropriate rock tests in accordance with clause 6.1.5.

iii) In hard rock, when non-shrink grout or concrete is utilised, a maximum skin friction of 350kPa may be used in anchors with a maximum diameter of 150mm. A 45° frustum shall be used to check anchor group pullout resistance. The skin friction value shall not exceed 80% of the ultimate friction determined from appropriate rock tests in accordance with clause 6.1.5.

iv) The depth of any pile(s) in a pile group in soils, shall be so calculated to resist the uplift force on the pile or pile group. For a type '1' soil, a 30° frustum for suspension towers, and a 25° frustum for angle strain towers may be assumed. Similarly for a type '2' soil, a 20° frustum for suspension towers, and a 15° frustum for angle strain towers may be assumed. Assumed material densities to be as per clause 6.1.2.

v) No horizontal shear resistance on the piles or pile cap shall be assumed for re-compacted excavated soil. The lateral resistance of undisturbed soil shall be ignored in the top 300mm from ground line, and taken as the lesser of 100kPa or 80% of the permissible bearing determined from appropriate tests from 300mm to the bottom of the pile cap. If the pile cap is not capable of restraining the entire horizontal base shear, the piles and pile cap shall be

designed to resist the shears and moments introduced from the pile cap to the individual piles. A soil bearing pressure of 200kPa in type '1' or 100kPa in type '2' soil shall be allowed under the pile cap. End bearing components for compressive loads shall not be considered in soil replacement type piles with a diameter less than 750mm.

6.1.5 Soil and rock tests

a) In addition to the minimum soil/rock investigation requirements, tests shall be carried out by the *Contractor*, if so required by the *Project Manager*, to confirm a soil or rock type classification and shall be conducted in accordance with accepted, good geotechnical engineering practices, and shall include but not be limited to the following:

i) Standard penetration tests or Dutch Cone penetrometer tests.

ii) Visual classification of soils

iii) Determination of present and probable water table level.

iv) Laboratory and/or site tests to determine soil friction angles and cohesion values.

v) Laboratory tests to determine stress-strain modules of soils and rock.

vi) Laboratory and/or site tests to determine soil unit weights.

vii) Laboratory and/or on site tests to determine the soil texture i.e. whether the soil is predominately clay, silt, sand or gravel.

viii) Continuous rock cores with recovery values and drilling times.

The standard penetration tests and recovery of soil samples shall be obtained in each soil strata encountered or at 1.5m intervals whichever is the less. Rock cores shall extend a minimum of 3.5m into sound rock.

b) The soil/rock investigation shall be conducted to recognised standards to ensure that all encountered soil and/or rock strata are identified and delineated by area along the line route. It shall be the *Contractor*'s responsibility to perform adequate soil/rock investigations to the satisfaction of the *Supervisor* to determine the soil/rock suitability at each site.

6.1.6 Foundation systems

6.1.6.1 General

a) Before foundation excavation commences the *Contractor* shall submit to the *Project Manager*, drawings and relevant design calculations of all the proposed foundations intended for use. Acceptance by the *Project Manager* does not relieve the *Contractor* of his responsibility for the adequacy of the design, dimensions and details. The *Contractor* shall be fully responsible for his designs and their satisfactory performance in service. A registered Civil Engineer or Civil Engineering Technologist, duly authorised to do so on behalf of the *Contractor*, shall accept responsibility for all foundation designs and drawings submitted to the *Project Manager,* and shall sign all drawings accordingly. If the *Employer* provides foundation designs and/or drawings, a registered Civil Engineer or Civil Engineering Technologist, acting on behalf of the *Contractor*, shall check and assume responsibility for such designs and/or drawings. All foundation design loads are to be shown on the relevant foundation drawing.

b) No foundation shall be constructed without the *Project Manager* acceptance. All drawing revisions must be submitted to the *Project Manager* before being issued for construction purposes.

c) Only with the specific permission of the *Project Manager,* may more than one design per soil or rock type of any foundation system for a tower type be utilised.

d) The *Project Manager,* for specific applications, may consider proprietary foundation systems not covered by this specification.

e) A ground slope of up to and including 12 degrees to the horizontal in any direction shall be assumed at all foundation positions for design purposes.

6.1.6.2 Pad and pier foundations for self-supporting towers

a) The foundations shall be designed to withstand, with less than 20mm of differential settlement or displacement, the maximum foundation reactions resulting from the withstand loadings stated in the Works Information, with the dead weight of the tower included at unity factor of safety.

b) The foundations shall be designed for the maximum combinations of compression, uplift and horizontal shear forces. In addition, a 650mm maximum projection of the pier and stub above ground level shall be incorporated in the design. The stub only is to be encased in concrete; the tower steel above the diagonal members is not to be encased.

c) All concrete subjected to tension, where the permissible tensile stress is exceeded, shall be adequately reinforced with deformed reinforcing steel bars. The design shall be in accordance with the requirements of SABS 0100. The maximum permissible tensile stress in the concrete shall be 1.75mPa. Piers shall be reinforced for their full length with the reinforcing properly anchored in the pad. The minimum number of longitudinal bars provided in a pier shall be four 12mm diameter bars with a minimum yield stress of 450mPa. The links shall be 8mm diameter mild steel bars at a maximum spacing equal to the smallest lateral dimension of the section, less 100mm.

a) Pads designed with a full 45° core may be utilised. All faces of such a core where the permissible tensile stress in the concrete is exceeded are to be adequately reinforced to prevent the development of tension cracks.

d) The foundation shall be designed to resist the vertical compression load at the bottom of the foundation. The foundation shall be checked to ensure that "punch-through" of the stubs shall not occur. The maximum soil bearing pressure allowed due to the vertical compressive load, plus the mass of the foundation, less the mass of the soil displaced by the foundation, shall not exceed the values specified in clause 6.1.2 for the soil type involved.

e) In addition to the vertical compression and tension loadings, the foundations shall be designed for the overturning moment and resultant soil toe pressure due to the remaining horizontal base shears applied at the top of the foundation, including the maximum foundation projection. The lateral resistance of the backfill on the pier or stub, at any particular section of the pier or stub, shall be calculated by using an effective pressure equal to the backfill soil weight density, multiplied by the depth of that section. The maximum soil toe pressure shall not exceed the value specified in clause 6.1.2 for the soil type involved.

f) The foundation shall be designed to resist the vertical uplift load, by means of the mass of the foundation plus the nett mass of the soil frustum acting from the bottom of the foundation base. Bracing shears may be neglected in the case of suspension towers, but shall be considered in the pier design in the case of strain towers.

g) The structural steelwork shall be firmly keyed into the concrete by means of adhesion between steel and concrete and bolted-on cleats. A maximum of 50% of the maximum leg load, either in tension or compression, may be transferred from the steel stub angle to the concrete utilising a maximum bond stress of 0.8N/mm^2, and neglecting the top 500mm of the pier. The balance of the load shall be transferred by means of bolted-on cleats. The cleats shall be so positioned on the structural steel member, so as to limit punching shear in the concrete due to both tension and compression load cases. When calculating the number and size of cleats required the maximum contact pressure between cleat and concrete shall not exceed 10mPa. The number of cleat bolts required shall be calculated in accordance with clause 7.1.12.4.

h) The least lateral dimension 'd' of a pier shall not be less than the greater of 300mm or L/6, where 'L' is the lesser of the vertical height measured from top of pad level to the top of the concrete pier, or the vertical height measured from founding level to the top of the concrete pier when a pad is not utilised. For circular pier sections, 'd' represents the diameter and for square or rectangular sections 'd' represents the length of the shortest side.

6.1.6.3 Pad and plinth foundations for guyed tower centre supports

a) The mast support foundations for guyed towers shall be designed to withstand, with less than 20mm of settlement, the maximum foundation reactions resulting from the loadings stated in the Works Information, with the dead weight of the tower included at unity factor of safety.

b) The minimum depth of the mast support foundation/s shall be 750mm in type '1' and type '2' soil, and 1000mm in type '3' and type '4' soil. The soil at the bottom of the foundation shall resist all stresses resulting from the vertical compressive loads and toe pressures due to horizontal shears. The mass of the foundation less the mass of the soil displaced by the foundation, shall be included in the vertical load applied. The maximum soil toe pressure shall not exceed the values specified in clause 6.1.2.

c) The foundations shall be designed for the maximum combinations of compression and horizontal shear forces. In addition, a 900mm projection of the plinth above ground level in the case of cross rope suspension type towers, and a 650mm projection in the case of guyed 'V' type towers, shall be incorporated in the design to allow for leg extension increments.

d) All concrete subjected to a tension where the permissible tensile stress is exceeded, shall be adequately reinforced with steel reinforcing bars in compliance with SABS 920. The design shall be in accordance with the requirements of SABS 0100.

e) Anchoring of the tower bases of guyed "V" towers shall be by means of anchor bolts. The maximum shear on anchor bolts shall be $0{,}65f_y$. If the anchor bolts must resist compression loads from the base plate, the compression load shall be resisted by mechanical anchorage, and not by adhesion between steel and concrete, unless deformed bars are utilised for anchor bolts.

6.1.6.4 Drilled foundations

The *Contractor* shall have equipment for, and personnel knowledgeable and experienced in, the evaluation and construction of this type of foundation.

a) General

i) The *Contractor* shall allow for the testing of two separate piles/anchors in each of the soil or rock conditions for which they have been designed. Pile/anchor tests as described in clause 6.1.6.4 e) below, if so required by the *Project Manager*, are to be successfully tested to the *Project Manager's* satisfaction prior to construction of cast-in-situ pile/anchor foundations.

ii) All design clauses in 6.1.3 relating to drilled concrete foundations shall apply.

iii) Piles must be designed to limit ground line vertical deflection, at maximum loadings, to less than 12mm.

iv) The minimum centre to centre spacing of any two piles in a group of piles, shall be three pile diameters of the pile with the larger diameter, unless otherwise accepted by the *Project Manager.*

v) The structural steelwork shall be firmly keyed into the concrete by means of bolted-on cleats. The adhesion between steel and concrete shall not be relied upon to transmit the load to the foundation. The cleats shall be so positioned on the structural steel member, so as to limit punching shear in the concrete due to both tension and compression load cases. When calculating the number and size of cleats required the maximum contact pressure between cleat and concrete shall not exceed 10mPa. The number of cleat bolts required shall be calculated in accordance with clause 7.1.12.4

b) Single cast-in-situ piles

Foundations utilising one cast-in-situ concrete pile will be considered by the *Project Manager* if the following criteria are met:

i) If a pile cap is not utilised, the pile shall have a minimum diameter of 350mm in order that the structural steel attachment of the tower can be accommodated without conflict with the reinforcing steel. Should a pile cap be utilised, the minimum pile diameter shall be 250mm.

ii) The pile shall be constructed vertically, and shall be designed for the maximum combinations of uplift and compression loadings, and the total horizontal base shears associated with the vertical loadings. Total shear applied at the top of the foundation, including the 650mm maximum projection above ground level, is to be included. Lateral load design bending moments shall be calculated taking into account possible plastic soil deformation. Raked piles will be accepted under special conditions only.

iii) The pile shall be designed to ensure that it acts as a rigid pile. Horizontal deflection at the top of the projected pile under ultimate loading shall be limited to 5mm.

iv) The pile shall be reinforced for its entire length, in order to resist the applied axial and bending forces, and sufficient reinforcing hoops shall be provided to support the vertical reinforcing and resist shear forces in the concrete. Reinforcing may be curtailed.

c) Multiple cast-in-situ piles

Foundations utilising multiple cast-in-situ piles of a minimum diameter of 250mm, will be considered by the *Project Manager* if the following criteria are met:

i) A minimum of two vertical piles per leg are used, connected to the structural steelwork by means of a reinforced concrete pile cap. Raked piles will be accepted under special conditions only.

ii) The piles and pile cap shall be designed for the maximum combinations of uplift and compression loadings, and the total horizontal base shears associated with the vertical loadings, including leg shear. Lateral load design bending moments shall be calculated taking into account possible plastic soil deformation.

iii) The piles shall be reinforced for their entire lengths in order to resist the applied axial and bending forces and sufficient reinforcing hoops shall be provided to support the vertical reinforcing. The reinforcement shall extend into the pile cap sufficiently, and shall be suitably anchored to ensure full utilisation of reinforcement from pile cap to pile. The pile cap shall be reinforced to withstand the shear and bending forces applied by the structural steelwork. Reinforcing may be curtailed.

iv) Allowance shall be made for all possible group effects when two or more piles, with a centre to centre spacing of less than three pile diameters, are used in a group.

d) Rock anchors

Foundations utilising grouted rock anchors will be considered by the *Project Manager* if the following criteria are met:

i) A minimum of four vertical rock anchors shall be used and connected to the structural steelwork by means of a reinforced concrete pile/anchor cap. Inclined rock anchors shall not be used without the *Project Manager's* prior acceptance.

ii) The rock anchors shall be designed to resist the full axial forces imparted by the maximum combinations of uplift and compression loadings, and additional axial loads due to the total horizontal base shear. The design shall incorporate a 650mm minimum projection of the foundation above ground level. The rock anchors shall not carry any shear load.

iii) The pile/anchor cap shall be designed to resist the total horizontal base shear. No horizontal shear resistance shall be assumed for re-compacted excavated soil. The base of the pile cap shall be extended to a minimum of 150mm below the top of sound rock over its full area irrespective of horizontal shear resistance requirements.

iv) The rock anchors shall be reinforced for their entire length in order to resist the applied axial forces and the reinforcing extends into the pile cap sufficiently and is suitably anchored to

ensure full utilisation of reinforcement from pile/anchor cap to anchor. The cap shall be reinforced to withstand the shear and bending forces applied by the structural steelwork. The rock anchor reinforcing steel shall be debonded, by a method accepted by the *Project Manager* for a length of 100mm above and 300mm below the pile cap base.

v) Rock anchors shall only be installed in hard rock, or sound competent soft rock. Proposals to utilise rock anchors in materials such as shale etc. must be specifically accepted by the *Project Manager* after a pile/anchor test, as described in clause 6.1.6.4 e) below, has been conducted. An additional test to verify that the pile cap will resist the entire horizontal base shear may also be required if so specified by the *Project Manager.* The lateral pressure on the leading face of the cap in rock, as well as the friction on the two side faces in rock, shall be the lesser of 135kPa or 80% of the permissible value determined from appropriate tests.

vi) The use of grout mixes, including proprietary mixes, must be accepted by the *Project Manager* prior to the use of such. Documented evidence of use in other similar applications, which have been accepted by a recognised authority, shall be submitted as proof of suitability. In-situ rock anchor testing shall be carried out as specified in clause 6.1.6.4 e) below.

vii) Rock anchors with diameter smaller than 85mm shall only be installed in sound competent rock where the holes have uniform diameters, straight sides and special grouts is used (epoxy or similar with 50mPa minimum strength) as approved by the *Project Manager*. In-situ rock anchor testing shall be carried out as specified in clause 6.1.6.4 e) below.

e) Cast-in-situ pile/anchor test requirements

i) Prior to construction of any cast-in-situ pile/anchor foundations, the *Contractor* shall, if so instructed by the *Project Manager*, install in each general soil or rock type encountered, and at any additional locations, a test cast-in-situ pile/anchor for the purpose of verifying the concrete/soil or grout/rock frictional resistance values. The test pile/anchor shall not be part of a final foundation.

ii) The *Contractor* shall prepare the test procedure and supply all equipment and personnel to perform the tests. All pile/anchor tests shall be conducted to failure of the pile/anchor. The pile/anchor test procedure, based on the following requirements, shall be prepared by the *Contractor* and shall be submitted to the *Project Manager* for acceptance prior to the tests.

- The test beam supports shall be placed outside the uplift influence zone of the pile/anchor to be tested and the distance from the outside of the pile/anchor (or pile/anchor group) to the test beam support shall not be less than "r".

$r = (l + c) \tan \varnothing$

where:

l = depth of pile/anchor (or pile/anchor group) with respect to the underside of the pile/anchor cap.

c = depth of pile/anchor cap excavation.

Ø = frustum angle.

- The *Project Manager* may request that the piled/anchor foundation as a whole be tested, but load tests shall generally be carried out on single piles/anchors with or without pile/anchor caps.
- The maximum design load shall be applied to the piled/anchor foundation during the test in appropriate increments to 50%, 75% and 90%, each for a minimum holding period of 5 minutes and finally, 100% for at least half an hour. Successive load increments shall not be applied and the maximum test load shall be held until the rate of movement under the acting load has stabilised at a rate of movement not exceeding 0,5mm in 5 minutes for a pile and 0,2mm in 5 minutes for an anchor.
- The piled/anchor foundation will be considered to have passed provided the total movement does not exceed 5mm during the entire test up to and including the maximum design load. The anchor foundation will be considered to have passed provided the total movement does not exceed 2mm during the entire test up to and including the maximum design load. The residual movement once all load has been removed must be recorded prior to the determination of the failure load.
- Two micrometers shall be placed on either side of the pulling rod, in order to eliminate errors due to rotation of the foundation. The datum frame supports shall also be positioned a similar distance from the test pile/anchor as the test beam supports above. The average reading of these gauges will represent the actual creep. Should this method, for any authentic reason prove impracticable, then a suitable approved alternative method may be used.

iii) Pile/anchor tests shall be conducted in the presence of the *Supervisor*. Upon completion of the pile/anchor test, the pile shall be removed by the *Contractor* for examination, and properly disposed of, or cut-off at least 600mm below ground level and backfilled, or as directed by the *Supervisor*.

iv) Pile/anchor foundations constructed by the *Contractor*, prior to acceptance by the *Project Manager* of the pile/anchor test results, will be subject to modification or replacement by the *Contractor* should the pile/anchor fail the test.

6.1.6.5 Grillage or steel plate type foundations

The *Contractor* shall have equipment for, and personnel knowledgeable and experienced in, the evaluation and installation of this type of foundations.

a) Such a type of foundation shall consist of one or more steel stubs connected to a steel grillage or plate at the base.

b) Grillage and steel plate foundation design parameters

i) The grillage or steel plate shall consist of structural steel members conforming to SABS 1431, or as otherwise accepted by the *Project Manager*, and shall be hot dipped galvanised after fabrication as per SABS 763.

ii) Steelwork for grillage or steel plate type foundations shall, after galvanising, be treated with an acceptable paint or epoxy compound. All damaged protection to the steelwork shall be repaired prior to the commencement of the backfill operation.

iii) If the grillage consists of an open grill, the spaces between the members shall not exceed the minimum plan width of any one such member. The gross area of such a grillage may be used for end bearing and uplift considerations.

iv) The grillage and plate type foundations shall be designed in accordance with similar loading conditions, settlement criteria and soil/rock design parameters, as is applicable to pad and chimney type foundations as per clauses 6.2.1, 6.1.6.1 and 6.1.6.2. If they are to be used as guy anchors, they shall, in addition to the above, satisfy the design and test requirements as per clause 6.1.6.7.

v) The grillage shall be set on a 100mm thick level bed of well-compressed fine gravel or sand to provide an even distribution of load.

vi) In grillage or plate type foundations where horizontal shear loads are not transferred by truss action to the base, special shear members, or concrete covering to the single leg stub may be required, to engage the passive lateral resistance of the adjacent compacted soil. Should such concrete encasement be required, it shall be not less than 75mm thick, and shall extend from a point 150mm above ground level down to 600mm below ground level.

vii) The depth of excavation shall be carefully trimmed to the proper level. Should the required depth of excavation be exceeded, the excavation shall be backfilled to the required level with 10mPa concrete.

viii) Grillage or steel type foundations shall not be used under conditions that indicate aggressive tendencies with respect to exposed steel.

6.1.6.6 Precast concrete type foundations

The *Contractor* shall have equipment for, and personnel knowledgeable and experience in, the evaluation and installation of this type of foundation.

a) Such type of foundation shall consist of one or more steel stubs or links connected to one or more precast concrete units.

b) Precast concrete design parameters

i) Precast concrete units used for foundation purposes shall conform to the requirements of SABS 1200GE, with ordinary steel reinforced members being designed in accordance with the relevant requirements of SABS 0100.

ii) Precast concrete type foundations shall be designed in accordance with similar loading conditions, settlement criteria and soil/rock design parameters, as is applicable to pad and pier type foundations as per clauses 6.2.1, 6.1.6.1 and 6.1.6.2. If they are to be used as guy anchors, they shall in addition to the aforementioned satisfy the design and test requirements as per clause 6.1.6.7.

iii) The precast unit or units shall be set on a 100mm thick level bed of well-compressed fine gravel or sand to provide an even distribution of load.

iv) The depth of excavation shall be carefully trimmed to the proper level. Should the required depth of excavation be exceeded, the excavation shall be backfilled to the required level with 10mPa concrete.

6.1.6.7 Guy anchors

a) General

i) The *Contractor* shall be responsible for the type of anchors chosen and the design thereof. Anchors requiring or relying on post tensioning will not be allowed. The design of guy anchors shall be subject to the *Project Manager* acceptance.

ii) Unless otherwise specified, the anchors shall be capable of resisting a tension as stated in the enquiry/contract documents, and also satisfy the test requirements as described in clause 6.1.6.7 b) below.

iii) Owing to the dissimilarities in anchor performance and conventional foundation performance in uplift conditions, the *Contractor* shall exercise extreme caution in utilising soil / rock parameters stated in clause 6.1.2 for the design of anchors. Full-scale load tests shall be utilised to determine actual soil holding capacities of anchor designs. The depth of dead man type anchors shall be determined with respect to the dead man and not the attachment point.

iv) Concrete anchors shall meet the requirements stated in clause 6.1.7.

v) Steelwork of the guy anchors shall be so selected by the *Contractor* to have the following minimum properties:

All ferrous material representing the final product shall have a minimum Charpy V-notch impact energy of 20 joules at 25°C and a minimum impact energy of 8 joules at -10°C. Ductility of all ferrous material at room temperature shall be sufficient to provide a minimum elongation in a 50mm gauge length, including the fracture, of 18%. Grade 300 WA steel which, when tested, meets the above requirements may be accepted at the *Project Manager's* discretion.

vi) Guy anchors shall be installed in such a manner that the legs of the U-bolt are in the vertical plane.

vii) The total anchor assembly (link plus reinforcing steel) for single in line drilled anchors less than 250mm in diameter shall be hot dip galvanised. The entire link assembly for single in line drilled anchors greater or equal to 250mm in diameter shall be hot dip galvanised. All galvanising shall be in accordance with SABS 763 with a minimum coating weight of 600 grams/m^2. Ultimate permissible anchorage bond stresses shall be reduced by 30% to allow for the galvanising.

viii) For single in line-drilled anchors less than 250mm in diameter, the top 1 000mm of the soil/rock profile at least shall be ignored for anchorage purposes. For single in line drilled anchors greater or equal to 250mm in diameter, the top 500mm of the soil/rock profile at least shall be ignored for anchorage purposes.

b) Cast-in-situ anchor foundation test requirements

i) Prior to the installation of any cast-in-situ anchor foundations, the *Contractor* shall, if so instructed by the *Project Manager*, install in each general soil type encountered and at any additional locations, a test cast-in-situ anchor for the purpose of verifying the concrete/soil frictional resistance values.

ii) The test anchor shall not be part of a final foundation.

iii) The *Contractor* shall prepare the test procedure, and supply all equipment and personnel to perform the test. The anchor test procedure, based on the following requirements, shall be submitted to the *Project Manager* for acceptance prior to the test.

- The test beam supports shall be placed outside the uplift influence zone of the foundation to be tested and the distance from the outside of the anchor foundation to the test beam support shall not be less than "r".

  r = I tan Ø

  where:

  I = depth of anchor (or anchor group)

  Ø = frustum angle.
- The maximum design load shall be applied to the anchor foundation during the test in appropriate increments to 50%, 75% and 90%, each for a minimum holding period of 5 minutes and finally, 100% for at least half an hour. Successive load increments shall not be applied and the maximum test load shall be held until the rate of movement under the acting load has stabilised at a rate of movement not exceeding 2,5mm in 5 minutes. The maximum test load shall also be held until the rate of movement under the applied load has stabilised at a rate of movement not exceeding 2,5mm in 5 minutes. The foundation will be considered to have passed provided the total movement does not exceed 50mm during the entire test period. The residual movement, once all load has been removed, must be recorded at the end of the test.

iv) Anchor tests shall be conducted in the presence of the *Supervisor.*

v) Anchor foundations installed prior to acceptance by the *Project Manager* of the anchor test results, will be subject to modification or replacement by the *Contractor* should the anchor fail the test.

6.1.6.8 Foundations for concrete or steel poles

a) General

i) The *Contractor* shall be responsible for the design of all foundations for pole structures.

ii) The foundations shall be designed to withstand the maximum combinations of induced factored moment, compression and torsion. The dead weight of the pole shall be included at unity factor of safety.

iii) All foundation designs are to be accepted by the *Project Manager* prior to the utilisation of any such design for pole installation purposes.

b) Testing

i) Prior to the construction of any pole foundations, the *Contractor* shall, if instructed by the *Project Manager* install in each general soil type encountered and at any additional locations, test poles for the purpose of carrying out full scale load tests to determine the moment carrying capacity in each soil type.

ii) The test pole and foundation shall not be part of a final foundation.

iii) The *Contractor* shall prepare the test procedure, and supply all equipment and personnel to perform the tests. The tests shall be conducted in the presence of the *Supervisor.*

iv) The pole foundation shall be capable of withstanding the full design moment for 5 minutes with a displacement at ground level of less than 5mm.

v) The test shall be continued to failure of either the pole or the foundation i.e. either a creep rate greater than or equal to 2mm per minute of the pole measured at ground level, or a pole tip deflection greater than or equal to 10° with respect to the original point of intersection of the pole with the ground.

vi) Upon completion of the test, the pole shall be either removed or broken down to at least 600mm below ground level and properly disposed of.

6.1.7 Concrete and grouts

6.1.7.1 General

a) Concrete foundations shall be designed based upon a concrete strength of 25mPa at 28 days.

b) Concrete mix designs shall be proportioned to obtain a minimum required strength of 25mPa at 28 days, and a target strength of 35mpa, with a maximum water cement ratio of 0,59. No individual 28 day concrete test cube result shall fall below 85% of the specified strength. In the absence of any previous statistical data, the mix designs shall be proportioned to attain a characteristic strength of 33mpa at 28 days. Notwithstanding the above requirements, the minimum cement content shall be 340 kg/m^3.

c) Grout mix designs for rock anchors shall be proportioned to attain a minimum strength of 35mPa at 28 days with any expansive additives included. The use of epoxy grouts is to be used only with the *Project Manager's* approval.

d) Water shall be clean and free from all earthy, vegetable or organic matter, acids or alkaline substances in solution or suspension.

6.1.7.2 Cement types

a) Concrete shall be batched utilising common cement types manufactured in accordance with SABS ENV 197-1

b) The minimum cement class used in concrete will be class 32.5

c) CEM I - Class 52.5 and accelerating admixtures shall not normally be utilised for concrete batching. Their use will only be considered by the *Project Manager* in unusual circumstances, in order to expedite tower erection to facilitate conductor stringing. The *Contractor* shall make test cubes and arrange for their testing, to confirm the concrete strength, and obtain acceptance from the *Supervisor* before proceeding with other activities.

d) Site blending will be acceptable provided the following criteria is met:

i) Proportion of Portland Cement and Extenders are within industry norms (i.e. 50% replacement for slag and 30% replacement for Fly Ash).

ii) The cementatious materials can be weighted into the mix with an accuracy of 2% or better. In special cases the *Project Manager* may require that the replacement value indicated in **i)** above be increased.

e) The cement utilised for grout mixes shall be of a "non-shrink" type. Any shrinkage-compensating admixture shall only be used with the *Project Manager*'s acceptance.

f) Cement extenders used must comply to the following SABS specifications:

- Ground granulated blastfurnace slag (slag) – SABS 1491-1
- Fly Ash (FA) SABS 1491-2
- Condense silica fume SABS 1491-3

g) In aggressive environments where concrete is subject to chemical attack, extenders must be considered to improve resistance to chemical attack (refer to SABS 0100 –2).

6.1.7.3 Aggregates

a) Fine and coarse aggregate shall be obtained from sources accepted by the *Project Manager* and shall be assessed in accordance with SABS 1083.

b) Fine aggregate shall be natural sand or other accepted inert material with similar characteristics, composed of clean, hard, strong, durable, uncoated particles. Fine aggregates shall be free from deleterious amounts of soft, flaky or porous particles, loam, soft shale, clay lumps or organic material.

c) Fine aggregates shall be selected from local sources to provide a reasonably uniform grading of the various size fractions. Fine aggregates having a large deficiency or excess of any size fraction, shall be avoided to the extent practicable.

d) Coarse aggregate shall consist of crushed stone, gravel or other accepted inert material of similar characteristics having hard, strong, durable, uncoated pieces free from deleterious substances.

e) Coarse aggregates up to 26,5mm nominal size, may be single-sized stone. Coarse aggregates up to 40mm nominal size, shall be blended consisting of two parts by volume of single-sized 40mm stone to one part by volume of single-sized 20mm stone. The content of fine material (less than 4,75mm) in coarse aggregate shall be less than 10% by mass.

f) The void content of fine or coarse aggregate shall not exceed 48%. Aggregate shall not contain any materials that are reactive with any alkali in the aggregate itself or in the cement, the mixing water or in water in contact with the finished concrete or grout in amounts sufficient to cause excessive localised or general expansion of the concrete or grout.

Notwithstanding the limits on chlorides as per SABS 1083 (BS 882), the acid soluble chloride as NaCl level in aggregate as a percentage by mass shall not exceed the limits given in the following table:

CONCRETE TYPE	COARSE AGGREGATE	FINE AGGREGATE
Reinforced with OPC	0.05%	0.10%
Reinforced with SRPC	0.02%	0.05%

Note: These limits shall be subject to the overall limit for the concrete as mixed.

h) The maximum nominal aggregate size for concrete batching shall be as follows:

- unreinforced concrete: 37,5mm
- reinforced concrete excluding piles:26,5mm
- piles: 19mm
- grout: 10mm

6.1.7.4 Workability

a) Concrete mix designs and batching shall be conducted in a manner to achieve adequate workability, to ensure that the concrete will be dense, without voids of honeycomb.

b) The design mix workability of the concrete, as determined by the “Slump Test”, shall meet the following requirements by application:

- unreinforced concrete: 25mm – 75mm
- reinforced concrete for conventional foundations and pile caps: 50mm – 100mm
- reinforced concrete for cast in-situ piles: 100mm – 150mm
- reinforced concrete for cast in-situ inclined piles/anchors: 150mm – 200mm

c) The consistency of grout mixtures shall be proportioned so that the mixture is pourable. The fine aggregate to cement ratio shall not exceed 3:1 irrespective of workability.

d) Any admixtures proposed by the *Contractor* shall be subject to the *Project Manager's* acceptance.

6.1.8 Reinforcing steel

a) All main reinforcing steel shall conform to SABS 920 Type C, Class 2, Grade II hot rolled deformed bars with a minimum yield stress of 450mPa. The minimum bar size utilised shall be 10mm.

b) All secondary reinforcing for stirrups, hoops and spirals, shall as a minimum conform to SABS 920 Type "A" hot rolled bars of plain cross-section of mild steel with a minimum yield stress of 250mPa.

c) At the *Contractor*'s option or as required by design, Type B or Type C reinforcing steel may be utilised. The minimum bar sizes utilised shall be at least 0,25 times the largest main reinforcing bar, or 0,01 times the average of the cross-sectional dimensions of the concrete with a minimum diameter of 6mm allowed.

6.2 Construction

6.2.1 Soil and rock type nomination

a) The *Contractor* shall be responsible for ensuring that the subsoil at each foundation location is suitable to withstand the design loading which will be imposed upon it by the foundation, and shall be responsible for any subsidence or failure of foundations due to insufficient care having been taken in the examination of the soil, the likely influence of other naturally occurring factors in the immediate and surrounding area of the tower, and the construction of the foundations. The acceptance by the *Supervisor* of foundation installations shall not relieve the *Contractor* of this responsibility.

b) The *Contractor* shall be responsible for the adoption of an acceptable method of soil/rock investigation in the presence of the *Supervisor*, and he shall delegate this work to a competent member or members of his staff who have suitable related qualifications and experience. Unless otherwise indicated in the Works Information, the minimum soil investigation requirement shall be the excavation of a test pit next to each foundation position, to allow for the in-situ inspection of the soil and the assessment thereof. The test pits shall be excavated outside the zone of influence of the appropriate foundation, and shall be taken down to a depth equal to the lesser of the depth of the foundation system to be constructed or 3m. In addition, appropriate soils tests as described in clause 6.1.5 shall be carried out where further clarification is required for the correct identification of a soil category. The soil type foundation nominations based on the aforementioned procedures shall take place well in advance of actual foundation installation, so as not to disrupt construction activities, and to allow for the possibility of having to conduct laboratory tests on suspect soils and/or rocks.

c) Due to the fact that combinations of two or more of the soil or rock classifications as described in clause 6.1.1 could occur at any one foundation position, including rock boulders in a soil matrix, the soil or rock nomination in terms of one of the six classifications in clause 6.1.1 shall then be conservatively based on the load transfer capability in terms of clause 6.1.2 of the soil and/or rock encountered over the depth of influence of the approved foundation system.

For example, a combination of a type '1' soil and soft rock over the depth of influence of an approved type '1' soil foundation design shall be nominated as a type '1' soil condition, and the approved type '1' soil foundation system installed. By following this procedure, the soil or rock nomination at each foundation position must be one of the six classifications as described in clause 6.1.1 and this shall in turn define which system design is to be installed

d) The test pit shall be suitably backfilled immediately after the relevant inspections and tests have been completed.

e) Where site conditions, such as difficult access or environmentally sensitive areas, etc. preclude the excavation of a test pit, alternative soils identification procedures shall be proposed by the

Contractor and acceptance obtained from the *Supervisor.* Should the foundation conditions at the actual foundation location be found to differ from those identified at the corresponding test pit, the *Contractor* shall immediately inform the *Supervisor* and a revised assessment made. The acceptance by the *Supervisor* of the soil type foundation nomination shall not relieve the *Contractor* of this responsibility.

6.2.2 Excavation

a) At each tower or pole position, the *Contractor* shall excavate, construct the appropriate foundation and backfill the excavation as required. Excavation in this instance shall be the removal of soil/rock by any accepted means for the purpose of constructing a particular foundation system, including conventional pad and pier type foundations, spread footings, piles, anchors, grillages, etc.

b) No excavation work, other than for soil investigation, shall be commenced on a section of line until the following conditions have been met:

i) The *Contractor* has submitted a schedule of tower leg ground levels and proposed leg extension lengths to the *Project Manager.*

ii) The *Contractor* has submitted the proposed foundation and soil type schedule to the *Project Manager.*

iii) If drilled cast-in-situ piles or rock anchors are proposed, soil samples and pile/anchor tests have been conducted, if so instructed by the *Project Manager.*

c) Excavations shall be made to the full dimensions required, and shall be finished to the prescribed lines and levels. The bottom or sides of excavations upon or against which concrete is to be poured shall be undisturbed. If, at any point in excavation, the natural material is disturbed or loosened, it shall be filled with 10mPa concrete, including the application of a blinding layer at the base of foundations where these eventualities are likely to occur during the construction process. Soil backfilling will not be accepted.

d) In soil which is incapable of withstanding the design loads which will be imposed upon it by a pad and pier type of foundation, the *Contractor* shall propose a method of increasing the effective bearing area of the foundation. This may entail the installation of a foundation with a larger pad, or other suitable solutions proposed by the *Contractor*. Any such proposal shall be submitted to the *Project Manager* for acceptance prior to excavation.

e) When the material at foundation depth is found to be partly rock or incompressible material, and partly a soil or material that is compressible, all compressible material shall be removed for an additional depth of 200mm and filled with 10mPa concrete.

f) The excavations shall be protected so as to maintain a clean subgrade until the foundation is placed. Any water, sand, mud, silt or other objectionable material which may accumulate in the excavation including the bottom of pile or anchor holes, shall be removed prior to concrete placement.

g) Excavations for cast-in-situ concrete, including pile caps cast against earth, shall be concreted within seventy-two hours after beginning the excavations. In addition to this general requirement, pile and/or anchor holes that are not adequately protected against the elements to the satisfaction of the *Supervisor*, shall be cast on the same day that drilling/excavation has taken place. Excavations that remain unconcreted longer than seventy-two hours may, at the option of the *Supervisor*, be required to be enlarged by 150mm in all dimensions.

h) The excavations shall be kept covered or barricaded in a manner accepted by the *Supervisor* to prevent injury to people or livestock. Failure to maintain proper protection of excavations may result in the suspension of excavation work until proper protection has been restored.

i) The *Contractor* is to notify the *Supervisor* upon completion of the excavation for the foundations. No concrete is to be placed until the excavation, shuttering and reinforcing steel has been inspected and accepted in writing by the *Supervisor.*

6.2.3 Backfilling

a) After completion of foundation construction, the *Contractor* shall backfill each excavation with suitable material. The *Supervisor* shall accept the materials used for backfill, the amounts used and the manner of depositing and compaction of the materials.

b) The material to be utilised for compacted backfill shall be deposited in horizontal layers, having a thickness of not more than 300mm before being compacted. In backfilling, the pad of the foundation shall be covered, first with a 200mm layer of well-graded material containing no pieces larger than 20mm, before any coarse material is deposited.

The material to be compacted shall contain no stones more than 150mm in diameter, and be free from organic material such as trees, brush, scraps, etc.

c) The distribution of materials shall be such that the compacted material will be homogenous to secure the best practicable degree of compaction, impermeability and stability.

d) Prior to and during compaction operations, the backfill materials shall have the optimum moisture content required for the purpose of compaction, impermeability and stability.

e) The material shall be mechanically compacted to a minimum of 90% of the density of the undisturbed material.

f) The surface of the backfill around the foundation shall be carried to such an elevation that water will not accumulate.

g) Material removed from the excavation, which is either not suitable or not required for backfill, shall be spread evenly over or adjacent to the site, or be disposed of as directed by the *Supervisor*. Spreading of subsoil in agricultural areas will not be allowed. Excavated soil suitable for backfill will be returned to the excavation by backfilling with the subsoil first and the top soil last.

h) Where the excavated material is considered to be unsuitable for backfill, such as a material with a high clay content or a sandy material with little variation in particle size, the *Contractor* shall propose a suitable method of soil improvement for consideration and acceptance by the *Supervisor* prior to being implemented. The properties of the soil may be improved by the addition of stabilising agents such as Portland cement in the case of sandy soils and slaked lime in the case of clayey soils. Backfill material stabilised in this way shall be mixed in the ratio of one part cement or lime per ten parts of soil. This material shall be properly mixed, moistened, placed and compacted in the same manner as excavated material.

6.2.4 Concrete foundations

6.2.4.1 Supply of materials

The *Contractor* shall supply all concrete and concrete materials required for construction, including aggregates, cement, water, admixtures (if any), shuttering, reinforcing steel, all embedded steel components and materials for curing concrete.

6.2.4.2 Prior acceptance

a) Well in advance of construction, the *Contractor* shall select the location of aggregate sources for concrete, and obtain representative samples of all aggregates. A representative sample shall consist of a blend of twelve separate samples from each aggregate stockpile. The representative samples shall be divided into two portions, one set of which shall be examined and accepted by the *Supervisor* and maintained on site during concreting operations. The second set which shall be delivered by the *Contractor* to the Portland Cement Institute, or other laboratory accepted by the *Project Manager*, for examination of suitability of the aggregate in accordance with SABS 1083 and preparation of concrete trial mix design in accordance with the requirements of clause 6.1.7. Prior to any concrete placement the *Contractor* shall submit the trial mix designs and results of seven and twenty-eight day test cube strengths to the *Project Manager* for acceptance.

b) If ready-mixed concrete is to be used, the *Contractor* shall obtain, from the ready-mix supplier, aggregate test reports and mix designs that satisfy the requirements of clause 6.1.7 and test cube strength reports of all mix designs and submit to the *Project Manager* for acceptance prior to placement of any concrete. A ready-mix concrete supplier that does not have SABS 979 recognition shall only be used with the *Project Manager's* acceptance, and thereafter only after satisfying the above requirements.

6.2.4.3 Tolerances for concrete construction

The intent of this paragraph is to establish tolerances that are consistent with construction practice, and the effect that permissible deviations will have upon the structural action or operational function of the structure. Where tolerances are not stated for any individual structure or feature, permissible deviations will be interpreted in conformity with the provisions of this paragraph. The *Contractor* shall be responsible for setting out and maintaining concrete excavations, shuttering and structural steelwork within the tolerance limits so as to ensure completed work within the specified tolerances. Concrete work, that exceeds the tolerance limits specified shall be remedied, or removed and replaced.

a) Variation in structure location

- Transverse to centre-line: less than 50mm
- Longitudinal displacement: less than 300mm

b) Variation in relative vertical elevation of structural steelwork (one leg to another)

- less than 5mm

c) Variation in horizontal distance between structural steelwork from that computed

- Adjacent legs: less than 5mm
- Diagonal legs: less than 7mm

d) Rotation - maximum deviation of transverse axis of structure from bisector of interior line angle

- less than 0º 12'

e) Elevation - variation of tower base from centre-line peg

- minus 150mm
- plus 1 000mm

f) Height of concrete foundations above ground level

- min. 150mm
- max. - per design

g) Variation in relative placement of foundation components from those indicated on drawings, including piles, shuttering, structural steelwork

- less than 50mm

h) Tolerances for placing reinforcing steel

- Variation of protective cover: 5mm
- Variation from indicated spacing: 25mm

i) Tolerances for guy anchors

Guy anchors shall be installed such that the attachment point of the anchor is within 250mm of the correct calculated position. The attachment point shall be a minimum of 150mm and a maximum of 650mm above the ground level.

Guy anchors designed for use with anchor rods extending below ground level shall have the anchor rod installed in line with the guy wire slope, within 5% or such lesser tolerance as required by design.

j) Tolerances for pole foundations

Pole foundations shall be constructed such that the pole, and the associated foundation works are within 50mm of the correct calculated position.

6.2.4.4 Workmanship

Concrete shall be proportioned, mixed, placed and finished in such a manner as to be free of honeycomb, segregation and other defects of workmanship.

6.2.4.5 Formwork

a) Forms shall be of wood, metal or other suitable material.

b) The forms shall be mortar-tight and shall be designed, constructed, braced and maintained such that the finished concrete will be to true line and elevation, and will conform to the required dimensions and contours. They shall be designed to withstand the pressure of concrete, the effect of vibration as the concrete is being placed and all loads incidental to the construction operations without distortion or displacement.

c) Where the bottom of the form is inaccessible, provision shall be made for cleaning out extraneous material immediately before placing the concrete.

d) All exposed corners of the concrete shall be chamfered approximately 20mm. A suitable nosing tool may be used for horizontal chamfers only if approved by the *Supervisor.* All form work dimensions shall be checked, and if necessary, corrected before any concrete is placed.

e) All forms shall be treated with a form-release agent accepted by the *Supervisor* before concrete is placed. Any material, which will adhere to, discolour or be deleterious to the concrete, shall not be used.

6.2.4.6 Proportioning of concrete

a) The concrete mix shall consist of ordinary Portland cement, fine aggregate, coarse aggregate and water proportioned in accordance with the mix design accepted by *Project Manager*. Adjustments in these proportions may be directed at any time when found necessary as a result of field tests of the concrete. No change in proportioning shall be made unless instructed by the *Supervisor*. As an alternative to the use of ordinary Portland cement, the *Project Manager* may consider the use of other approved types of cement or blends thereof.

b) No change in the source, character or gradation of materials shall be made without notice to the *Supervisor* and without a revised proportioning mix design being prepared and accepted by the *Project Manager* prior to use of the materials.

c) During the concrete operations, the concrete mixture shall be tested for each batch by the *Contractor* to determine the slump of the fresh concrete in accordance with SABS Method 862. Records of slump tests shall be supplied to the *Supervisor*.

d) Test cubes shall be prepared, in accordance with SABS Method 863 at the initiation of concrete placement of each mix design and every day that concrete is batched thereafter. Test cubes shall only be made out of a concrete batch at the point of discharge. If the *Contractor* does not make use of independent facilities for the crushing of test cubes and the reporting there-on, then suitable on-site facilities for the crushing of test cubes must be provided by the *Contractor*, and the Supervisor shall witness such tests.

Additional test cube sets shall be prepared and crushed as directed by the *Supervisor.* Each set of test cubes shall consist of four cubes.

One to be crushed at seven days, two to be crushed at twenty eight days and one to be held as a spare in the event of a suspect result from one of the other three cubes. The written results of the test cube strength tests shall be immediately forwarded to the *Supervisor* upon receipt.

e) All cement shall be batched by mass. Cement shall be measured to within 2% accuracy.

f) Aggregates may be batched by mass or by volume, provided that volumetric batching equipment is calibrated at the start of concrete operations by weighing a typical discharge. The quantities of aggregate batched shall be measured within 3% accuracy. Adjustments of fine aggregate volumes due to "bulking" shall be accounted for in batching.

g) The amount of moisture in the aggregates shall be determined daily by a method accepted by the *Supervisor*, and the water requirements as per the mix design altered accordingly.

h) Water quantities, including aggregate moisture allowances, shall be determined within 2% accuracy. The use of water meters for dispensing water shall be subject to the *Supervisor's* acceptance.

6.2.4.7 Mixing of concrete

a) Concrete shall be mixed sufficiently to ensure that the various sizes of aggregate are uniformly distributed throughout the mass, and each particle of aggregate is adequately coated with cement paste of uniform consistency. Concrete delivered to site that lacks homogeneity should be mixed for a longer time or discarded, as directed by the *Supervisor.*

b) For mixers of one cubic metre or less, the mixing time shall be not less than ninety seconds after all ingredients have been charged in the mixer. For mixers of larger capacities, minimum-mixing times shall be increased by fifteen seconds for each additional half cubic metre of mixer capacity, or fraction thereof.

c) Concrete delivered to the job site shall be mixed en-route. Mixing shall be rigorously controlled for agitating time, mixing time and overall time upon arrival at the foundation site. Concrete discharge shall be completed within one and one-half hours after introduction of the water to the cement and aggregate.

d) In exceptional cases only, the *Contractor* may at his own risk add water to a concrete mix at the point of delivery. The maximum amount of water that may be added at site is three litres per cubic metre of concrete. At no time shall the water:cement ratio of 0.59 be increased.

e) Non-shrink grout shall be mixed in a suitable mechanical grout mixer/pump accepted by the *Supervisor.*

6.2.4.8 Placement of reinforcing steel

a) After acceptance of the excavation by the *Supervisor*, the *Contractor* shall install all the reinforcing steel required for foundations. Reinforcing steel shall be fabricated and bent in strict accordance with the drawings and SABS 82.

b) Reinforcing steel, before being positioned, shall be thoroughly cleaned of mill scale and any coatings that will destroy or reduce bond.

c) Reinforcing steel shall be accurately positioned and secured against displacement during placing and vibrating of concrete. Reinforcing bars shall be tied at all intersections with no less than No.18 gauge annealed wire. Reinforcing bars shall be lapped forty-five diameters at all splices, unless shown otherwise on the drawings. Reinforcing steel shall be provided and placed as detailed on the drawings. Unless otherwise shown on the drawings, the minimum cover to the main reinforcing bars in a slab, pile cap, chimney, pile or anchor, shall be 50mm. Use of suitable accepted spacers or supports shall be made, to ensure that the minimum concrete cover to the reinforcement is maintained during the placement of concrete.

6.2.4.9 Placement of embedded items

a) The *Contractor* shall install all required embedded items shown on the drawings, prior to placing of concrete. Structural steelwork or holding down bolts shall be accurately positioned and securely held in place during the placement of concrete. The minimum cover to all embedded items, but excluding angle stubs, shall be 150mm. The minimum cover to angle stubs and cleats shall be 75mm unless otherwise shown on the drawings.

b) Angle stubs may be supported on the bottom of excavations by either precast concrete slabs set at the correct level by placing suitable grout or concrete underneath it, or on a previously placed binding layer installed up to the correct level. The precast slab shall be square in plan with a side dimension of 300mm, and a depth of 75mm, and shall be constructed using reinforced concrete with a minimum characteristic strength of 25mPa. The placing of loose rubble, stones, bricks, etc. under the precast slab will not be acceptable.

c) Structural steelwork or anchor bolts shall be embedded such that the top of the concrete of the foundation correctly coincides with the designed level.

d) Earthing requirements are to be as per the latest revision of specification “TRMASAAJ7 – Earthing of Transmission Lines”.

6.2.4.10 Placement of concrete

a) No concrete for foundations shall be placed until each foundation has been inspected and accepted by the *Supervisor.* The foundation at the time of this inspection shall be ready for concrete placement including reinforcing steel, embedded items and any necessary shuttering.

b) All surfaces of the foundation upon or against which concrete is to be placed shall be free from mud and/or loose or disturbed material. A blinding layer of 10mpa concrete not less than 50mm thick is to be installed on all bottom surfaces of a type ‘3’ or type ‘4’ foundations.

c) The surfaces of dry absorptive materials, against which concrete is to be placed, shall be moistened prior to the placing of concrete to prevent moisture being drawn from the fresh concrete.

d) At least two suitable concrete vibrators shall be ready for operation at the site prior to placement of concrete.

e) Freshly mixed concrete shall be handled, transported and deposited in such a manner as to prevent segregation or loss of material. When discharging by chute, the slope of the chute shall be uniform throughout its length and shall not be flatter than 1 in 3 or steeper than 1 in 2. Baffles shall be provided at the end of the chute to ensure a vertical discharge into the foundation. The maximum discharge height shall be three metres, and for heights in excess of this, a tremie pipe shall be used.

f) Placement of concrete shall not commence when the air temperature is below 2°C and rising, or below 5°C and dropping.

g) The temperature of the concrete mixture immediately before placement shall not exceed 32°C. Concrete exceeding this temperature shall be discarded. During hot weather concreting operations, the *Contractor* shall take the temperature of each batch of concrete.

h) No concrete shall be placed which has taken its initial set, regardless of whether the specified one and one-half hour period has elapsed or not. If a retarder, accepted by the *Project Manager*, has been used, the one and one-half hour period may be exceeded provided the concrete has not taken its initial set. The *Contractor* must dispose of waste concrete in a place acceptable to the *Supervisor.*

i) If concrete must be placed under water, a suitable watertight tremie, accepted by the *Supervisor*, of sufficient length to reach the bottom of the excavation shall be used. The tremie shall be free of water when filled with concrete to the bottom of the excavation. The tremie shall be kept full of concrete during the entire placing operation. The discharge end of the tremie must not be lifted out of the freshly placed mass of concrete until placement has been completed.

j) Concrete shall be thoroughly settled and compacted into a dense homogeneous mass throughout the whole depth of each layer being consolidated, using internal vibrators. Excessive vibration, causing segregation, is to be avoided. Concrete vibrators shall not be used to move concrete.

k) The concrete in cast-in-situ piles must be vibrated from the bottom upwards.

l) Unless authorised by the *Supervisor*, the *Contractor* shall not place concrete, unless the *Supervisor* is present during the entire placement operation.

m) When alternative foundations consisting of multiple cast-in-situ piles and pile caps are utilised, the *Contractor* shall at approximately one tower in twenty, open up on two sides of the completed foundation of one leg, the pile cap and top 500mm of the piles, if so instructed by the *Supervisor.* If the foundation is rejected for any reason, the *Contractor* shall open up as many additional foundations as determined by the *Supervisor*, as is necessary to fully assess the problem. Foundations accepted are to be backfilled using 10mPa concrete up to a level at least 150mm above the base of the pile cap.

6.2.4.11 Construction joints

a) In general, foundations shall be placed monolithically. Construction joints are to be avoided. If construction joints cannot be avoided and are accepted by the *Supervisor*, the *Contractor* may be permitted to make a construction joint if the following criteria are met:

i) The concrete is reinforced and the reinforcing steel will develop full bond strength both sides of the construction joint. No construction joints will be allowed in unreinforced concrete.

ii) In single cast-in-situ piles, the construction joint is located one third the depth of the excavation, ±300mm and at least 150mm below the bottom of the structural steelwork or anchor bolts.

iii) In multiple cast-in-situ piles, the construction joint is to be 75mm, and in rock anchors 100mm, above either the base of the pile cap excavation or the top of blinding level. If the piles are constructed after the excavation for the pile cap has taken place, suitable ring shutters of the same diameter of the piles shall be used to construct the above mentioned pile/anchor projections.

b) No construction joints will be allowed in pile caps.

c) At all construction joints, the surfaces of the previously placed and hardened concrete shall be thoroughly cleaned of all foreign matter, and primed with a 15mm thick layer of a wet mix of cement and sand in equal proportions, in the presence of the *Supervisor* before new concrete is placed. The grout coating shall be brushed over the concrete surface to ensure thorough coverage, particularly between the reinforcing bars. The new concrete shall be placed before the grout coating has taken its initial set.

6.2.4.12 Concrete finish

a) The top surface of the foundation shall be at least a wood float finish, and shall be contoured to shed water.

b) All concrete placed against shuttering shall be free from irregularities, fins, rock pockets or other imperfections. Any rock pockets, porous or defective concrete shall be removed to the extent instructed by the *Supervisor* and repaired by filling with concrete, cement mortar or dry packed, as instructed by the *Supervisor.*

c) All exposed concrete shall be shuttered to a minimum of 150mm below ground level.

6.2.4.13 Concrete curing

a) The *Contractor* shall provide means of maintaining concrete in a moist condition for at least seven days after the placement of concrete. Exposed surfaces shall be kept thoroughly wet 24 hours a day for this period.

b) At the *Contractor*'s option, concrete may be cured either by retaining shuttering in place and applying a liquid curing compound which forms a moisture retaining membrane on unshuttered concrete surface, or by removing shuttering and applying a curing compound as described to all exposed concrete surfaces. Curing compounds utilised shall be of a type accepted by the *Project Manager*. Notwithstanding these requirements, formwork shall not be removed until at least 36 hours after the final placement of the concrete against such formwork. The *Contractor* shall remove formwork in such a way that shock and damage to the concrete is avoided.

6.2.4.14 Steelwork

a) All galvanised structural steel at the steel/concrete interface shall be cleaned with a suitable cleaner before painting with two protective coats of paint acceptable to *Project Manager*. This protection shall extend 500mm above and 400mm below the top surface level of the protruding foundation blocks.

b) In the case of concrete foundations, no part of the structural steelwork of the tower shall be buried or come into contact with the soil.

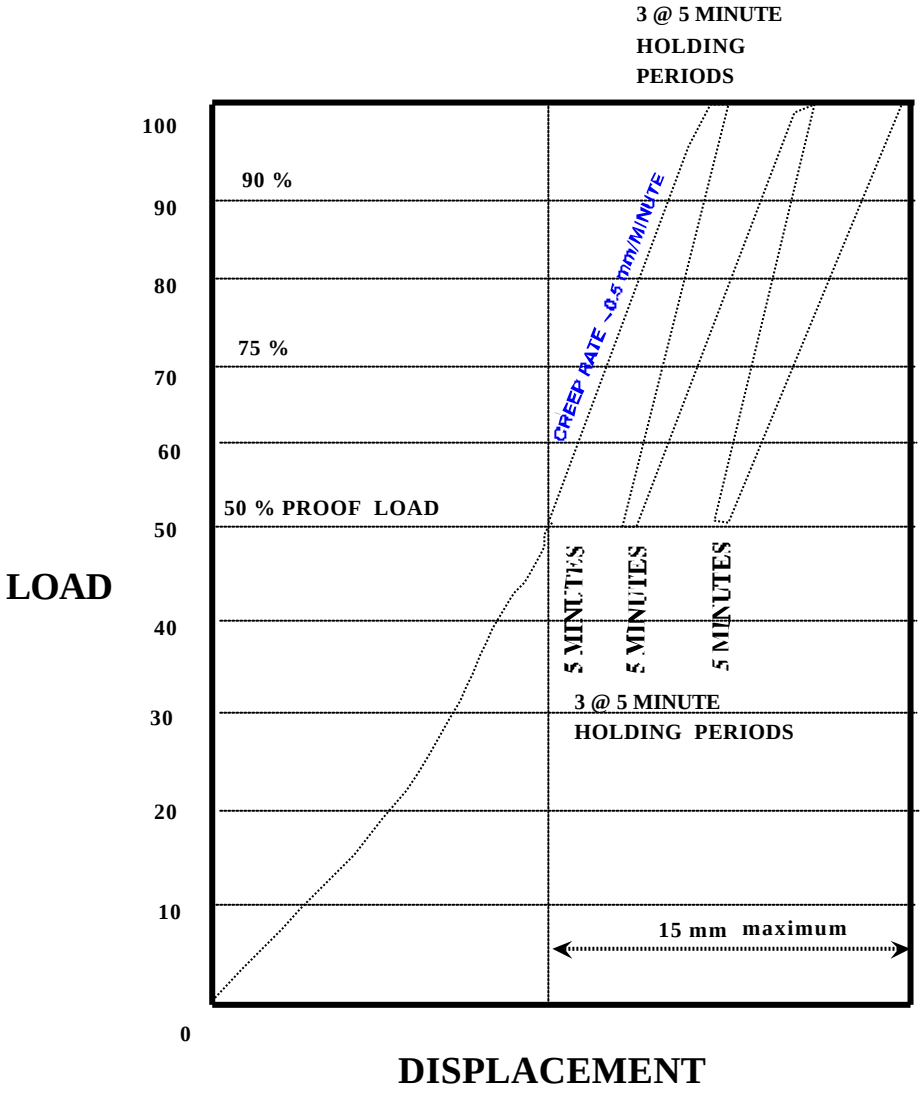
c) Anchors utilising steel extending below ground line shall be galvanised and then painted with two coats of an accepted bitumastic paint, or be encased in concrete with at least 50mm cover. In addition to this requirement, the hot dip galvanised steel guy anchor link plate or bar utilised for the deadman type of anchor foundation, shall be epoxy coated from 300mm below top of concrete level to the top end of the link above ground level. Apply in accordance with the manufacturer's specifications one coat of galvanising epoxy primer followed by one coat of aluminium filled epoxy paint.

6.2.5 Construction proof load tests

6.2.5.1 Guy anchors

a) The *Contractor* shall provide equipment on site, during the installation of the guy anchors, capable of loading the anchor to a load equal to the unfactored foundation reaction for critical loading conditions.

b) Where instructed by the *Supervisor*, the *Contractor* shall apply a construction proof load test equal to the unfactored foundation reaction for critical loading conditions to the completed anchors. The method of the load application shall be subject to the *Project Manager's* acceptance. All anchor tests shall be conducted in the presence of the *Supervisor.*



100 % Proof load = unfactored foundation reaction for critical loading condition

c) The load shall be applied to the anchor in appropriate increments to 50%, 75%, 90% and 100% of the proof test load, and then unloaded to 50% and again loaded to 100% of the proof test load, twice, i.e. during two further cycles of loading. The *Contractor* shall monitor anchor movement along the guy slope. Successive load increments shall not be applied until the rate of creep is less than or equal to 0,5mm/minute. The three cycles of loading from 50% to 100% shall each be of duration of not less than 5 minutes. The anchor shall be considered acceptable if the total creep from 50% to 100% load over 3 cycles is less than 15mm. If the creep exceeds 15mm, the anchor shall be modified or replaced by the *Contractor* and re-tested.

6.2.5.2 Pole foundations

a) The *Contractor* shall provide equipment on site during the construction of the pole foundation capable of loading the pole foundation to two-thirds of the maximum design moment.

b) Where instructed by the *Supervisor*, the *Contractor* shall apply a construction proof load test of two-thirds the maximum design moment to the completed pole.

c) The pole foundation shall be loaded in increments of 50%, 75%, 90% and 100% and then unloaded to 50% in 3 cycles of 50% to 100% of the proof test. If creep exceeds 1mm/minute at ground level, additional load shall be applied until the creep is less than the stated limit. The three 50% loads and three 100% loads shall each be maintained on the pole for 5 minutes. If the creep is less than 1mm/minute, the final creep measurements shall be taken after each holding period. The pole foundation shall be considered acceptable if the total ground level creep from 50% to 100% load over 3 cycles is less than 30mm. If the creep exceeds 30mm, the foundation shall be modified or replaced by the *Contractor* and re-tested.

d) All pole foundation tests shall be conducted in the presence of the *Supervisor.*

7. Towers

7.1 Design

7.1.1 By the *Employer*

a) If the *Employer* provides tower drawings (including but not limited to analysis, member selection, bolt requirements etc.), it shall remain the responsibility of the *Contractor* to verify such drawings to his satisfaction. The *Employer* accepts no responsibility for the completeness, correctness or adequacy of any tower drawings provided.

b) Changes in tower configurations shall be reviewed and accepted by the *Employer* prior to manufacture to ensure acceptability of any changed configuration.

7.1.2 By the *Contractor*

a) The *Contractor* shall be fully responsible for his designs and their satisfactory performance in service. Acceptance by the *Employer* does not relieve the *Contractor* of responsibility for the adequacy of the design, dimensions and details.

b) Where the *Employer* provides general tower configurations, they are as a guide only to the *Contractor*. Electrical clearances, cover angles, minimum phase spacing, tower heights etc., shall be as shown on the conceptual drawings. The *Contractor* is encouraged to improve the towers with respect to mass and aesthetics.

c) Tower test loads will be provided in the Works Information. The towers shall be designed to withstand all the specified loads, and shall be capable of withstanding construction loads during tower erection without special handling equipment.

7.1.3 Design requirements for lattice towers

a) Tower body and leg extensions shall be as specified in the Works Information. The tower body extensions shall be designed in such a way that the leg extensions may be used with either the normal or the extended tower.

b) Guyed towers shall be designed for nominally level ground conditions, whereas self supporting towers shall be designed for all combinations of leg extensions and positions used with standard tower and body extensions. All leg extensions shall be detailed for use in combination with other leg lengths. A common connection plate shall be detailed for all leg diagonals.

c) Stub angles for self-supporting towers shall fit leg extensions for all tower heights.

d) Base assemblies for guyed towers shall fit mast extensions for all tower heights.

e) Unless otherwise specified, when using guyed tower ball and socket fittings, these shall be cast in an acceptable malleable iron or steel. The radius of the hemispherical ball shall be approximately ten percent smaller than the radius of the hemispherical socket.

f) All members shall be capable of withstanding wind induced vibration when assembled and erected as part of a structure.

g) The following miscellaneous requirements shall be incorporated into the tower components.

i) Bolted construction is required and welded joints are not to be used.

ii) Tower members shall have flat surfaces uppermost where practicable. Pockets and depressions likely to hold water shall be avoided and, where unavoidable, shall be properly drained.

iii) Splices in main legs of towers shall be located immediately above bracing members.

iv) Splices shall be provided in all foundations to facilitate the use of stub extensions and to ensure a practical splicing position for repairing main leg failures. The centre of this splice shall be approximately 500mm above ground level.

v) Flat bars, round rods and tubes shall not be used for tower members.

vi) All long members shall be of sufficient section that, after punching or drilling, they will withstand ordinary rough handling during erection.

vii) A minimum of two bolts shall be provided for the connection of any member, including redundants, having a flange width equal to, or greater than 90mm.

viii) The top tension members of all crossarms, and earth conductor peaks on double circuit towers, shall be connected by a minimum of two bolts irrespective of design requirements.

ix) The maximum unsupported horizontal length of members shall not exceed the following:

- For angle section 45 x 45 x 3 = 1 500mm.
- All larger sections shall be governed by the slenderness ratios specified in 7.1.12.3.

x) The design of the lower portion of towers shall be such as to reduce the danger of livestock being caught in the angles between tower members.

On self-supporting towers a flat member, 50mm wide, shall be provided above the intersection of the main leg and the diagonal, such that the open distance along the upper edge of this member is not less than 120mm and not more than 140mm.

The design of the lower portion of the masts on all guyed-V towers will incorporate a steel mesh guard, or other accepted device, of not less than one metre in height and effectively closing the gap between the two mast columns preventing livestock entrapment.

h) Redundant bracing systems shall be arranged so that the secondary forces in any redundant member will be carried to the intersection of a non-redundant member with the leg or any other main member of the tower. When only one redundant member braces a leg or main member at a point, it shall be designed for an axial compressive load of 2,5% of the maximum load in the leg or main member it braces. When two redundant members, in planes normal to each other, are connected to a leg or main member at the same point, they shall be designed for an axial compressive load of 1,5% of the maximum load in the leg or main member they brace.

i) Bracing patterns using triangulated axial force systems are preferred to distribute the forces applied to the structure in a tension/compression fashion according to their geometry and member stiffness'. If "open panels" are used, bending stresses due to unbraced forces shall be considered.

j) A well proven non-linear large deflection computer programme, which takes into account secondary forces due to displacements, shall be used for the analysis of guyed structures.

7.1.4 Tower code numbers and marking

a) New tower designs accepted for manufacture will be allocated a tower code number consisting of three digits, e.g. 422. This number is to be used in conjunction with the tower type letters and tower descriptions given in the schedules to form the titles of the various towers.

- For example:

  Suspension tower type 422 A

  0° - 15 ° Angle strain tower type 422 B

These titles are to be used on all correspondence, drawings, test reports, etc., relating to a particular tower.

b) Each tower member shall be allocated an identifying number by the manufacturer, which shall correspond, to the number on the appropriate tower erection drawing.

c) The tower code number and the tower type letter are to be clearly stamped on every member of the tower as a prefix to the member mark number. All steelwork shall carry a manufacturer's identification marking consisting of a maximum of three letters. This shall be of the same letter height as the number code. Acceptance of the marking shall be obtained prior to usage. These marks shall be stamped before galvanising and be clearly legible after galvanising and erection, e.g.: on back to back members these markings shall be on the flange without stitches.

7.1.5 Tower steel

a) Structural steel for all tower members, including all stubs and cleats embedded in concrete shall conform to SABS 1431 Grade 300 WA or 350 WA, and shall be hot dip galvanised after fabrication.

b) When tower designs utilising a mixture of Grade 300 WA and Grade 350 WA are offered by the *Contractor*, all member sizes designated Grade 350 WA in any one tower design shall be strictly Grade 350 WA. It is the *Contractor*'s responsibility to ensure that only one grade of steel is used for any one-member size on any one tower.

c) Certified mill test reports of the chemical and mechanical properties of the steel for the full quantity required for fabrication shall be obtained from the steel supplier. Copies of these reports shall be retained at the *Contractor*'s works for review.

d) The means of marking and segregating Grade 300 WA and Grade 350 WA steel during receipt, storage and fabrication, shall be supplied to the *Project Manager* for acceptance prior to the first delivery of Grade 350WA steel.

e) The *Contractor* shall cut samples from deliveries of Grade 350 WA steel and conduct mechanical tests upon the samples to ensure that the steel is Grade 350 WA. The frequency of testing shall be subject to acceptance by the *Project Manager*.

f) Only structural shapes included in the latest edition of the "South African Steel Construction Handbook", published by the South African Institute of Steel Construction, shall be used. Availability of shapes selected is the sole responsibility of the *Contractor*.

g) To facilitate the transport of tower members, these shall be limited to a maximum length of 12,5m.

7.1.6 Bolts, nuts and washers

a) Bolts and nuts shall be of mild steel Grade 4.6, and manufactured in accordance with SABS 136, and shall be hot dip galvanised.

b) After galvanising, bolt holes shall be not less than 1,2mm larger in diameter than the corresponding bolt diameter.

c) Bolts of different diameters can be used on the same tower, provided that bolt sizes are not mixed in any one connection or plate. The minimum size of bolt shall be 16mm.

d) The threaded portions of all bolts shall project through the corresponding nuts by an amount not exceeding 15mm and not less than 3mm.

e) No threaded portion of any bolt shall occur within the thickness of the parts bolted together. To ensure this a single washer of suitable thickness shall be placed under the nut.

f) The minimum thickness of washers shall be 3mm and the maximum thickness shall be 6mm.

g) No lock nuts or spring washers shall be used on the tower.

h) Where a pin-type connection is made at the top of masts on guyed structures, it shall be of a type secured by means of a bolt, nut and split pin. The split pin shall be of stainless steel, with a minimum diameter of 20% of the bolt diameter.

7.1.7 Shackles and extension links

a) The *Contractor* is to provide each tower with shackles and extension links for insulator string attachments of a size and strength suitable for attaching the conductor insulator assemblies, and earth conductor hardware assemblies to the tower at the appropriate positions.

b) Shackles, split pins and extension links shall be designed and fabricated according to the relevant specifications.

c) Shackles for insulator string attachments shall be of the correct length, to connect the insulator hardware supplied to the attachment point on the tower.

d) The shackles shall be of the type secured by means of a bolt, nut and split pin. The split pin shall be of stainless steel, with a minimum diameter of 5mm.

e) The orientation shall be as follows:

- Suspension shackle for earth and phase conductors: When viewed on the transverse face, the legs of the shackle are to be in the vertical plane and at right angles to the direction of the line.
- Strain shackle for earth and phase conductors: When viewed on the transverse face, the legs of the shackle are to be in the vertical plane parallel to the direction of the line.

7.1.8 Anti-climbing devices

a) Anti-climbing devices shall be designed for each tower. These are to be attached at a height of approximately 3m, but not less than 2,5m above ground level.

b) Where long leg extensions are used, an anti-climbing device shall be installed on individual legs at a height of not less than 3m and not more than 5m above ground level.

c) Anti-climbing devices shall be formed by stringing onto projecting steel supporting members, fencing wire consisting of 2,5mm double-strand uni-directional twist pattern, galvanised steel barbed wire. Spacing between strands shall not be more than 100mm centres, the first being not more than 100mm from the tower face, and forming an overhang of not less than 500mm beyond the outer face of the tower. This overhang distance shall be maintained at the tower corners. On small anti-climbing devices such as on legs of guyed "V" towers, twin single strand barbed wire may be used.

d) The strands of barbed wire shall be secured at intervals, not exceeding 2m, by spacers formed by pieces of the same barbed wire bound to the strung barbed wire by galvanised binding wire. Where barbed wire other than galvanised steel is specified, the spacers and binding wire shall be compatible.

e) Where the design of the towers is such that they can be climbed on the inner face, a similar anti-climbing device shall extend from the inner face of the tower.

7.1.9 Step bolts

a) One leg of each tower shall be equipped with step bolts at approximately 400mm centres, starting immediately above the anti-climbing devices and extending to the highest crossarm of the tower. The bolts shall be fixed to the main leg members of the tower by means of two hexagonal nuts. The length of the cylindrical section of each step bolt shall not be less than 150mm, as measured from the outside face of the main leg to the bolt head. Holes for step bolts shall be on all leg extensions from ground level up. No step bolts shall be installed below the anti-climbing device except for construction purposes.

b) The bolts shall be uniformly spaced, continuous and in line over gusset plates. Where 20mm tower bolts are used 16mm step bolts may be fitted in a 21,5mm hole, but at connections only. In the connection this bolt shall be ignored when calculating the number of bolts required.

c) In the case of double circuit towers, two diagonally opposite legs shall be equipped with step bolts and shall extend to the underside of the top crossarm.

7.1.10 Tower types

a) Designs must be submitted for each of the tower types called for in the Works Information.

b) Weights shall be given for all towers, including all steelwork, stubs, bolts, nuts, washers, shackles, extension links, anti-climbing device steelwork, mast base assemblies, guys, guy attachment assemblies and guy attachment protection assemblies.

7.1.11 Mass of tower and foundation steelwork

The calculations of mass for angles and other rolled shapes shall be in accordance with the mass per metre listed in the latest edition of the "South African Steel Construction Handbook" published by the South African Institute of Steel Construction. All plate material shall be based on a mass density of 7 850kg/m³. Lengths used to determine mass of members shall be based on the detailed lengths shown on the final, accepted shop drawings and not on the "ordered overall lengths". Material lost from clips, back-cuts, blocks, holes etc., shall not be deducted from the mass of a member or plate. Of the above-calculated mass, 3,5% of the uncoated material shall be used for the mass of the zinc coating (galvanising). The estimated tower mass is to include leg extensions, stubs, bolts, nuts, washers, shackles, anti-climbing device steelwork and galvanising.

7.1.12 Tower member design

7.1.12.1 General

The tower members shall be designed in accordance with ASCE Manual No. 52, "Guide for design of steel transmission towers", or alternatively, ECCS Manual No. 39, "Recommendations for angles in lattice transmission towers", except as limited in this specification.

7.1.12.2 Definitions

- L = The unsupported length of a member, without adjustment for end fixity conditions
- r = Radius of gyration (i, as per SAISC tables)
- fy = Minimum guaranteed yield stress/Maximum allowable design stress.
- ft = Tensile stress
- fb = Bearing stress
- ASCE = American Society of Civil Engineers.

7.1.12.3 Limiting L/r ratios

- Leg members and main chord members in crossarm/bridge and earth conductor peak - 120.
- All other members carrying calculated stress — 200.
- Redundants not carrying calculated stress — 250.

7.1.12.4 Maximum allowable design stresses

- The maximum allowable design stresses for angle shapes shall be as follows:

Steel grade	Member thickness	f_y
300 WA	≤ 25mm	300mPa
350 WA	≤ 16mm	350mPa
350 WA	> 16mm ≤ 25mm	345mPa

- The maximum allowable design stresses for bolts shall be as follows:
- Shear on unthreaded portion of bolt — 250mPa

  On multiple bolt connections allowance must be made, in accordance with either SABS 0162, ASCE Manual No. 52 or ECCS No. 39, for the group effect, which will tend to decrease the permissible shear on the bolts.
- Tension on net area of bolt — 400mPa.

7.1.12.5 Tension design

a) "Tension-only systems" are not permitted. Each member shall be designed for the forces it attracts from the externally applied loads, due to its location and stiffness.

b) If unequal angles are used, they should be connected by the long leg when practicable. When the outstanding leg exceeds the connected leg, the net area shall be determined as for an equal angle based on the connected leg.

7.1.12.6 Bearing design

Bearing on contact area (bolt diameter × material thickness) f_b = 575mPa.

7.1.12.7 Member thickness

a) The outline or main chord members of a tower shall have a minimum thickness of 5mm regardless of bolt size. The minimum thickness of steel sections using 16mm bolts shall be 3mm. When using 20mm to 24mm bolts, the minimum thickness for any member shall be 4mm.

b) Where members of the same size but of different thickness are to be used in the same tower design the difference in thickness shall be more than 1mm.

7.1.12.8 Spacing of bolts

a) Minimum edge distance

The following minimum distances measured from the centre of the hole to an edge shall be maintained:

Bolt diameter	Rolled edge	Sheared edge	Flame cut edge
16mm	23mm	25mm	29mm
20mm	28mm	30mm	35mm
24mm	34mm	36mm	44mm

b) Minimum bolt spacing

Bolt diameter	Spacing
16mm	40mm
20mm	50mm
24mm	60mm

The distance from the centre of a bolt to the face of the outstanding flange of an angle or other member shall be such as to permit the use of a socket spanner for tightening the nut.

7.1.13 Guy strands and guy attachments

7.1.13.1 Guy strands

a) Guy strands used for guyed towers shall be of the same quality as for "Stranding rope for bridges and guys" as described in the latest edition of the Haggie Steel Ropes Limited catalogue, with a "Single strand" design. Furthermore, the guy strand shall conform to the relevant technical requirements specified by the *Employer*. The *Contractor* shall specify the ultimate tensile strength of the strand material selected. Wires shall be hot-dip galvanised before stranding. The individual wires shall be adequately preformed prior to stranding to ensure the wires maintain their respective positions when the strand is cut.

b) The minimum breaking strength of the guy strand selected shall be the greater of:

$$\frac{\text{Maximum guy tension produced by governing transverse load}}{0{,}7}$$

or

$$\frac{\text{Maximum guy tension produced by governing longitudinal load}}{0{,}85}$$

c) In the non-linear analysis of the guyed tower, the actual cross-sectional area and proper modulus of elasticity of the guy strand selected shall be used. The modulus of elasticity shall be taken as 159GPa for steel stranded guy wires.

d) Pre-tensioning of the guy strands will not be permitted in the tower analysis.

7.1.13.2 Guy attachments

a) The guy attachments shall be capable of developing the minimum breaking strength of the guy strand.

b) The thickness and contour of tower and anchor attachment points shall be co-ordinated with the guy attachments, to ensure that excessive bending forces or stress concentrations are not transferred to the guy grips.

c) The grip connecting the guy strand to the anchor shall provide continuous adjustment, parallel to the guy line, of 450mm. Once the tower has been erected, plumbed, and the conductors strung and sagged, the adjustment shall be sealed or locked to avoid the possibility of tampering. The grip connecting the guy strand to the tower may be similar in design, but non-adjustable.

d) Final acceptance shall be obtained from the *Project Manager* for the types of guy attachments selected. Test reports, certifying the results of ultimate strength tests, cycle load tests, vibration tests and impact tests as well as material and fabrication specifications, tests and drawings are to accompany requests for acceptance.

e) The guy attachment link which exits the foundation shall be either a single galvanised steel round bar with a suitable forged eye link or a single galvanised steel plate with suitable attachment holes. Galvanising shall be in accordance with SABS 763, with a minimum coating weight of 600grams/m^2

7.1.14 Design drawings and calculations

7.1.14.1 Before acceptance of the *Contractor's* design

The design drawings shall show the following data and information for each tower type, including all extensions. Two types of towers shall not be combined on a single drawing.

a) A large scale drawing showing tower outline, hardware attachment points, conductor locations and electrical clearances.

b) An outline (single line diagram) of each tower type, drawn accurately to scale and showing all basic design dimensions and design group members.

c) The compression and uplift reactions with corresponding horizontal base shears due to the governing loading conditions for the self-supporting tower, identifying tower height and differential leg extensions used. The compression reactions with corresponding horizontal base shears and guy strand tensions due to the governing loading conditions for the shortest and the tallest guyed structure.

d) A tabulation showing the member size, the member forces, and the governing load cases.

e) All loading and their manner of application, including determination of the wind load on the structure. Wind load on the tower shall be applied at each panel point along the height of the tower.

7.1.14.2 After acceptance of the Contractor's design

Two sets of drawings, together with detailed design calculations, computer analyses, etc., as may be required by *The Employer* for each type of tower and foundation, shall be submitted for acceptance. This shall include a tabulation of the calculations showing the design of each member, i.e. magnitude of compression/tension forces, governing load case, section size, gross and nett cross-sectional areas, unbraced lengths, radius of gyration, slenderness ratios, yield stress or reduced yield stress, compression/tension capacities of member, connection capacity of member in respect to bolt shear and bolt bearing, indication of number of holes deducted from gross cross-sectional area of tension members, bolt size and number of bolts required. After successful tower testing, an acceptable transparency of each drawing, suitable for microfilming, and two prints of each calculation shall be supplied. These shall be provided in all cases, irrespective of copyright agreements.

a) The following drawings are required:

i) Completely dimensioned general arrangement drawing of each tower superstructure and foundation, and of each body and leg extension.

ii) An electrical clearance drawing, indicating clearances from conductors to tower steelwork and conductors to earth conductors, and the cover angle from earth conductors to phase conductors.

iii) If not detailed on the above drawings, the following shall also be provided:

- Erection drawing showing the erection mark of each member, and indicating number and type of bolts and nuts required at each point where members are connected.
- General arrangement and erection drawing of stub-setting templates.
- Drawing showing dimensions of excavations for all foundations.
- General arrangement of earth conductor and phase conductor attachment shackles, chain links, extensions links or other ancillary hardware.
- General arrangement of anti-climbing device.

c) For each tower type, a separate drawing is required showing an unbroken transverse elevation, preferably to a scale of 1:100, to be accommodated on A3 size showing leading dimensions, clearances, main foundation dimensions, etc.

d) To facilitate checking, the *Contractor* shall provide a material list for each type of tower, detailing all items required to complete the tower. The material lists shall be included on the detail drawings.

e) Where the *Employer* obtains the tower copyright, drawings shall be drawn on the *Employer's* titled sheets.

7.1.15 Shop detailing

7.1.15.1 General

a) All tower types and all tower and leg extensions shall be detailed, even though some of the components may not be required.

b) The *Contractor* shall be responsible for the correctness of dimensions and details on the working drawings. The acceptance of the detail drawings shall not relieve the *Contractor* of this responsibility. All bent angles and plates shall be detailed to finished dimensions.

c) Connections shall be detailed in a manner to avoid eccentricity as much as possible. Assembly bolts shall be located as near the centre of gravity of angles as is practicable.

7.1.15.2 Intersection of members

a) All diagonal-bracing members shall be connected at their point of intersection by at least one bolt.

b) Cutting of flanges to interpose members will only be allowed with the *Project Manager's* acceptance.

c) Assembly bolts shall not connect more than three (3) thicknesses of material.

7.1.15.3 Double-angle members

All double-members shall be connected at intervals between end connections by stitch bolts as follows:

i) Tension/compression members: spaced so that the $L/_r$ ratio of one angle between stitch bolts is equal to, or less than the $L/_r$ ratio of the member as a whole, with a maximum length between stitch bolts of 600mm. A minimum of two stitch bolts shall be used between panel points.

ii) Angles with connected legs greater than 100mm shall be stitched at each point with two bolts and a plate.

iii) Angles with connected legs 100mm or less shall be stitched at each point with one bolt and ring spacer.

7.1.15.4 Spacers

a) Spacers shall be provided, as necessary, for all gaps to prevent distortion of structural members.

b) Spacers between tower members, where more than one bolt is involved, shall be one plate of the required thickness. Where a single bolt is involved, the spacer may be made of up to three pieces. The thickness of individual spacers shall be limited to the following standard sizes: 5mm, 8mm and 12mm.

c) Bolts and nuts that bear on sloping faces shall be provided with bevelled washers.

7.1.15.5 Conductor attachment plates

a) All earth conductor attachment plates shall be provided with at least one extra maintenance hole of the same diameter as the attachment hole.

b) All phase conductor attachment plates shall be provided with a least two extra maintenance holes of the same diameter as the attached hole, symmetrically spaced from the attachment hole.

c) For the purpose of determining shackle hole edge distance, these shall be as for "Flame cut edge" as specified in 7.1.12.8

7.2 Fabrication

7.2.1 General

a) All parts of structures shall be fabricated in accordance with the accepted shop drawings, and generally carried out in accordance with SABS 1200H. Workmanship and finish shall be equal to the best modern practice for transmission tower work. Pieces having the same mark shall be interchangeable. Members shall be straight.

b) All parts of the structure shall be neatly finished and free from kinks or twists. All holes, blocks and clips shall be made with sharp tools and shall be clean-cut without torn or ragged edges.

c) Shearing and cutting shall be neatly and accurately done. Cuts shall be clean without drawn or ragged edges. Particular care shall be taken in the edge finish of plates subjected to large bending moments or large bends in fabrication.

d) Redundant material on gusset plates shall be removed.

e) All holes in structural steel less than 18mm thick may be punched to full size unless otherwise noted on the accepted drawings. Holes shown on the drawings as drilled holes, and all holes in structural steel 18mm or more in thickness, shall be drilled or subpunched and reamed. All holes shall be clean cut and without torn or ragged edges. All burrs resulting from reaming or drilling shall be removed. All holes shall be cylindrical and perpendicular to the member. Where

necessary, to avoid distortion of the holes, holes close to the points of bends shall be made after bending. The use of a torch for cutting holes shall not be permitted.

For punching holes to full size, the diameter of the punch shall not be more than 2mm larger than the nominal diameter of the bolt, and the diameter of the die shall not be more than 2mm larger than the diameter of the punch.

f) For subpunching, the diameter of the punch shall be 6mm smaller than the nominal diameter of the bolt, and the diameter of the die shall not be more than 3mm larger than the diameter of the punch. Subpunching for reamed work shall be such that after reaming, no punched surface shall appear in the periphery of the hole.

g) Where holes are reamed or drilled, the diameter of the finished hole shall not be greater than the nominal diameter of the bolt, plus 2mm.

h) All holes shall be spaced accurately in accordance with the drawings and shall be located on the gauge lines. The maximum allowable variation in hole spacing, from that indicated on the drawings for all bolt-holes, shall be 1mm. Misdrilled or mispunched holes may not be refilled by welding.

7.2.2 Bending

a) All forming or bending during fabrication, shall be only done according to methods accepted by the *Project Manager*, such that will prevent embrittlement or loss of strength in the material being worked. The technical requirements for hot and cold forming are as follows:

i) Only the direct resistance heating method shall be used.

ii) The length of the section to be heated shall be clearly marked on the section, and heating equipment set accordingly.

iii) The required bending tool shall be ready on the bending press with checking jigs available at all times.

iv) A dry run shall be made first to check that all systems are operational and that the proper tools are used.

v) Material shall be uniformly heated over the required length, to a temperature of between 750°C to 900°C. Oxidation of the material shall be minimised.

vi) Heated material shall be inserted into the bending press and formed while the temperature is still within the specified range.

vii) Formed material shall be checked immediately to ensure that they have been formed correctly.

viii) Formed material shall be left to cool naturally.

ix) Re-checks shall be made with the appropriate jigs when material is cold.

b) If more than one bend is required on a section, the operation shall be repeated for each bend. Repeated heating of a bend position shall not be allowed.

c) New bends shall not deform the bend previously made.

d) For bending limitations on the flaring of flanges on angle sections, refer to the *Project Manager.* Any other bending of angle sections must be done hot.

e) Cold bending limitations on plates are as follows:

Plate thickness	Maximum deviation angle
Up to 12mm	14°
14 to 22mm	7°

A minimum bend radius of 8mm shall apply for above table. Cold bending is not allowed for plates in excess of 22mm thickness.

7.2.3 Marking

a) Marking shall be done by stamping the marks into the metal with numerals or letters of 10mm minimum height. The marking shall be consistently in the same relative location near the ends on all pieces. No other marking shall be used.

b) All steelwork shall carry a manufacturer's identification marking consisting of a minimum of three letters. This shall be of the same height as the number code. Acceptance of the marking shall be obtained prior to usage.

7.2.4 Galvanising

Galvanising shall be in accordance with SABS 763. All possible care shall be taken to avoid damaging the zinc coating in transit or on site. Any material found to be damaged is to be made good or replaced by the *Contractor*.

7.2.5 Welding

For components of sufficient complexity to require welding, permission must first be obtained from the *Project Manager*. If permission is granted, the *Contractor* shall submit his manufacturing procedure to the *Project Manager* for acceptance before manufacturing commences.

7.2.6 Testing and inspection

a) The *Project Manager* reserves the right to inspect the work, and witness tests at any stage during manufacture.

b) Witnessed tests to SABS 1431 may require samples of steel from the *Contractor*'s stockpile.

c) The *Project Manager* or the SA Bureau of Standards may make tests, to ensure satisfactory quality of the galvanising.

d) Certificates shall be obtained proving compliance with all aspects of material quality, manufacture and galvanising.

7.3 Tower acceptance tests

7.3.1 Prototype assembly and inspection

One tower of each type shall be assembled in the shop to the extent necessary to assure correct fit of all parts and proper field erection. The same procedure shall be followed when the *Employer* supplies copyright tower drawings to the *Contractor*. Two working days notice shall be given for the *Project Manager* to inspect the assembled prototype tower.

7.3.2 Tower

a) If specified, tests shall be made on complete towers at an accepted tower testing facility.

b) These tests shall be made in accordance with International Electromechanical Commission (IEC) Standards, Publication No. 652 and applying the specified test loads for a period of one minute.

c) Upon completion of testing for all specified design loads, the towers shall be tested to destruction, if so instructed by the *Project Manager*.

d) Tensile tests to SABS 1431 shall be carried out on samples of steel taken from members of the tested towers as selected by the *Project Manager*.

7.3.3 Test programme

Two copies of the proposed test programme, including drawings showing the method of testing and the loads to be applied, shall be submitted to the *Project Manager* for acceptance before testing commences.

7.3.4 Test witnesses

The *Project Manager* shall be notified, in writing, at least ten days in advance of the acceptance tests.

Unless the *Employer* specifically waives attendance, no test shall be valid unless witnessed by the *Project Manager*.

7.3.5 Test towers

a) The test towers shall be manufactured at the *Contractor*'s premises and the material and dimensions shall be strictly in accordance with the accepted tower drawings and prototype. When testing guyed towers, the guy strand and guy attachments shall be of the size and type proposed for use in construction. Guyed test towers shall be erected with a working tension in the guys of approximately 10% of the ultimate breaking strength of the guy.

b) No part of any tower tested to destruction may be used on the line.

7.3.6 Tower drawings

During testing, two complete sets of accepted tower drawings shall be kept at the test station on which all modifications made to the tower, before or during testing, shall be clearly marked in red. On completion of testing, the *Employer* shall retain this marked-up set of drawings.

7.3.7 Load application

a) Loads shall be applied at the conductor attachment points. The wind load on the tower shall be applied to at least four representative panel points below the crossarm.

b) Tests shall be made with the tower in a vertical position. Loads shall be applied in such a manner as to avoid impact on the tower. The tower shall be mounted on a rigid foundation and plumbed vertically with a tolerance of 2mm in 1m.

c) The self-supporting towers shall be tested at their maximum design heights. The guyed towers shall be tested at their maximum, and also at their minimum design height, if there are major differences in the member forces for the different height towers.

d) The tower test programme shall include all load cases that have controlled the sizing of main tower members as accepted by the *Project Manager*.

7.3.8 Load measurement

a) All loads shall be measured through a suitable system of strain devices, or the direct application of weights. All systems shall be such that pulley friction is minimised.

b) All strain devices shall be used in accordance with the manufacturer's recommendations. The *Contractor* prior to and following the tests shall provide certified calibration test reports of all load-measuring devices.

c) Tower deflections shall be measured by a procedure accepted by the *Project Manager*. Deflection readings at points specified shall be recorded prior to each load increment, during the period the load increment is on, and after the release of each load increment.

7.3.9 Acceptance

The tower shall be considered acceptable if none of the members or bolts show evidence of permanent deformation. If any member or bolt shows evidence of permanent deformation, the member or connection shall be redesigned and replaced. The test shall be repeated until the tower is capable of withstanding the loads without permanent deformation.

7.3.10 Test reports

a) Within 14 days after testing, the *Contractor* shall supply one copy of the test report covering each test.

b) Test reports shall include the following:

i) General test arrangement.

ii) Loads applied to test tower.

iii) Deflection readings of tower under each load increment.

iv) Photographs of the test tower under final load increment for each design loading, including destruction test.

v) Photographs of all members and connections that fail during the testing sequence, including the destruction test.

vi) Certified mill test reports for main members used in the test towers.

vii) SABS 1431 tensile test reports.

7.4 Tower erection

7.4.1 Tower material handling and storage

a) Tower steel in storage shall be blocked off the ground with a sufficient number of blocks to prevent bending or warping of individual members.

b) Tower steel shall be handled with the use of nylon or fabric slings. The use of unprotected wire rope slings is not permitted.

c) Material shall not be dumped or dropped from trucks, but shall be carefully unloaded and stacked.

d) Material shall not be dragged on the ground.

7.4.2 Assembly and erection of towers

a) The applicable type of tower shall be erected on the completed foundation. In the case of self-supporting tower concrete foundations, towers shall not be erected until the concrete has had at least 14 days in which to cure. In the case of guyed tower concrete foundations and/or anchors, towers shall not be erected until the concrete has had as least 21 days in which to cure.

b) All towers shall be vertical within 2mm in 1 metre in both the transverse and longitudinal directions when erection of the tower is completed, unless a different tolerance is specified.

c) Steel towers shall be assembled and erected so as not to overstress structural members, bolts or foundations. The assemblies shall be erected with the members supported in their proper relative position. Structural assemblies that are not sufficiently rigid to be raised in one piece shall be stiffened by means of temporary bracing.

d) All towers shall be assembled in strict accordance with the drawings. The size and length of all bolts, washers, nuts, ring fills and plate fills shall be as specified on the erection drawings.

e) Contact surfaces of plates at the joints shall be cleaned of foreign materials and dirt before assembly. Wherever possible, bolts shall be installed with threads and nuts to the outside, and bolt heads to the inside of columns and trusses. Surfaces that are horizontal after erection shall have bolt heads down and nuts up.

f) A reasonable amount of drifting will be allowed in the assembly of members, but driving of bolts to correct mismatched holes will not be allowed.

g) If blind or partially blind holes, missed clips, or other minor mis-fabricated steel members are discovered in the field, the *Contractor* shall notify the *Supervisor* and receive his acceptance prior to effecting field repairs.

h) Where drilling, punching or clipping is done in the field, all exposed steel surfaces shall be coated with a heavy layer of zinc-rich paint or an accepted equivalent.

i) Suitable ladders shall be used wherever necessary during erection of towers. Such ladders, and any temporary step bolts shall be removed when erection work is not in progress.

j) After final tightening of all nuts, they shall be fixed in position by punching four indentations symmetrically around the threads with a round pointed centre punch. The nuts and exposed bolt thread shall be painted with an accepted calcium plumbate based galvanised iron primer.

k) After erection, all towers shall be cleaned of all foreign matter or surplus paint.

7.4.3 Erection of guyed towers

a) Provision shall be made for the erection of guyed towers on terrain with various ground slopes.

b) Adjustable guy grips are to be installed to the anchor ends of each guy strand. The total adjustment of the guy grips shall be 450mm, and the guy strands shall be cut to allow a minimum of 300mm tightening adjustment after the tower is erected and the guy strands tensioned.

c) The guy grips shall be installed in strict accordance with the manufacturer's recommendations, to ensure complete holding power of the guy grips.

d) Guy grips of the adjustable U-bolt design shall be carefully tightened to ensure equal loading of the two legs of the U-bolt. Neither nut shall be tightened more than 6mm differentially without equalising the load on the nuts, nor when the desired tension is achieved, the nuts shall be even before locking.

e) The guy strand will be cut to a length that will allow projection to just beyond the bottom of the U-bolt, and tied to obviate opening of the strands, effectively closing the open area of the U-bolt.

f) At the time of tower erection, all guys shall be tensioned to 10% (±2%) of the minimum breaking strength of the guy strand. This shall be the tension in the guy after all fittings have been attached and all rigging used for tensioning the guy has been removed. The *Contractor* shall be responsible for establishing a suitable method of determining installed tensions in the guy strands.

g) Guys shall be tensioned to hold the towers plumb and perpendicular to the line as soon as the towers are erected. Towers shall not be more than 2mm in 1m from vertical in both the transverse and longitudinal direction, and the crossarms shall be perpendicular to the line within 0,3° of arc.

h) The guys shall remain properly tensioned so that the tower remains plumb during, and after conductor stringing and clamping. Conductor stringing operations shall be halted if any guy in a sag section becomes slack during the operation.

i) During erection, if it becomes necessary to leave the guys at reduced tension for longer than twenty-four hours, the *Supervisor* shall be informed immediately.

j) The *Project Manager* shall accept the method of locking the guy grip and guy guard at the anchor end of the guy wire. The guy guard shall not be locked over the guy grip until the *Supervisor* has inspected, and accepted the guy grip installation and the presence of adequate locking.

7.4.4 Tower labels

Tower labels are to be manufactured and installed as in "TRMSCABC9 – Design, manufacturing and installation specification for transmission line labels".

7.4.5 Step bolts and anti-climbing devices

The *Contractor* shall install all step bolts and anti-climbing devices.

8. Stringing

8.1 Material supply

8.1.1 By the *Employer*

a) The *Contractor* is to provide off-loading and secure storage facilities and shall be held responsible for the proper protection and safekeeping of all material until the *completion date*. The *Contractor* shall be held responsible for any loss or damage to material after delivery.

b) The *Contractor* is to verify and confirm the quantities of material supplied by the *Employer.* Conductor use is to be optimised to obviate excessive waste. A nominal amount (dependant on the terrain - max. 3%) of phase and earth conductor will be allowed for sags and jumpers. Off-cuts and waste shall be returned to the *Employer* upon Completion as scrap.

c) All other surplus material shall be returned to the *Employer* upon Completion.

8.1.2 By the *Contractor*

a) The *Contractor* is to estabish the correct quantities of all stringing materials required to Provide the Works.

b) A nominal amount (dependant on the terrain - max. 3%) of phase and earth conductor will be allowed for sags and jumpers. Off-cuts and waste shall be returned to the *Employer* upon Completion as scrap.

8.2 Installation of phase and earth conductors

8.2.1 Crossings, notices and permits

a) Substantial temporary conductor supports shall be used, or equally effective measures taken, to prevent encroachment of statutory clearances, or other clearance requirements stated in the permits, between the conductor being strung and other power or communication lines, roads or railways being crossed.

b) Suitable structures under each phase will be erected to protect all fences from conductor damage during stringing.

c) Temporary changes in poles, fixtures or conductors of lines being crossed will only be carried out if accepted by the *Supervisor.* The *Contractor* shall indicate any changes considered necessary and the *Supervisor* will co-ordinate any changes with the owner of the service.

d) The *Contractor* shall notify the *Supervisor*, at least 30 days in advance, of the time he intends to make crossings of power lines, communication lines, major roads or railways. This notification shall state the location of the crossing to be made, the approximate time of the permit, the length of time that will be required to effect the crossing, and the duration of permit requested.

e) The *Employer* will endeavour to arrange that all crossings be made with the crossed line de-energised. The time of line outages shall be kept to the absolute minimum. All preparatory work shall be done prior to the work permit coming into effect. Upon completion of the work, the *Contractor* shall immediately notify the *Supervisor* that lines are clear and release his working permit.

f) Special scaffolding may be required at certain crossings. If so, the *Supervisor* will instruct the *Contractor* to provide suitable scaffolding and nets

8.2.2 Handling and stringing of conductors

a) All phase and earth conductors shall be tension strung.

b) The equipment and methods used for stringing the conductors shall be such that the conductors will not be damaged. Particular care shall be taken at all times to ensure that the conductors do not become kinked, twisted or abraded in any manner.

c) Stringing shall be done in daylight hours only.

d) The *Contractor* shall make suitable arrangements for temporary staying of towers, and anchoring of conductors when necessary. Conductors may not be anchored to any portion of any tower, except strain towers, and then only at the points designed for conductor attachment. Temporary anchoring to footings and guy anchors will not be permitted. Where temporary anchoring is required, suitable temporary anchors shall be provided. Installation and removal of temporary anchors will be the *Contractor*'s responsibility.

e) Matched conductor drums, marked with the same number followed by the suffix A, B, C etc., shall be used for each pull of multiple conductors per phase to ensure even sag characteristics and a minimum number of joints. The *Contractor* shall select the most suitable sets of matched conductor drums for each stringing position to minimise wastage of conductor. The *Contractor* shall keep an accurate record of the phase and earth conductor drum numbers and their position in the line. On Completion a copy of these records shall be supplied to the *Project Manager*.

f) Where multiple conductors per phase are used, these shall be attached to a single running board and strung simultaneously to ensure matched sags. The individual conductors shall be attached to the running board by auxiliary clamps that will not allow relative movement of strands or layers of wire, and shall not over tension or deform individual wires.

g) Running boards shall pass through blocks smoothly without hanging, catching or causing wide variations in pulling tensions, damage to the blocks or over stressing of towers. The pulling line shall be a non-rotating type, which will not impart twist or torque to the running board or conductors. Swivels shall be used to attach the pulling line and conductors to the running board. Swivels shall be small enough to pass through the blocks without damage to either, and shall have ball bearings and be free turning under load.

h) All conductors shall be strung by the controlled-tension method by means of rubber faced, double-bullwheel-type tension stringing equipment. This equipment must be so designed that there shall be no conduction of the heat generated by the braking action, to the bullwheels. There shall be appropriate mechanical braking on the reels to prevent loose conductor between the reels and the bullwheels, but sufficient tension to pull the conductor in between layers remaining on the reel. Brake controls shall be positive and fail-safe in order to minimise the danger of brake failure.

i) The tension shall be controlled individually on each conductor, and when the desired tension is obtained, the same constant tension shall be held so long as the brakes are left at this setting. Tensions, while pulling, must be sufficient to clear all obstacles safely without damage to the conductor. At no time shall the pulling tension exceed the tension shown on the sag charts. Pulling of more than one drum length of conductor shall be subject to the *Supervisor's* acceptance.

j) Adequate protection shall be provided where there is danger of conductors being damaged by vehicles or other equipment and objects. Conductors shall not be left in contact with the ground, vegetable matter or any conducting or semi-conducting material. Wood lagging or similar material shall be used to protect the conductor when working at ground level.

k) Radio communications shall be used to relay information and instructions between the conductor tensioning station, intermediate check points, mobile stations and the pulling station at all times during a stringing-tensioning operation. An outage of radio communications at any station will require immediate cessation of conductor pulling operations.

l) The placement of tensioning and pulling equipment shall be such that the vertical angle of pull on a crossarm during stringing operations shall not be more than 20°. Conductors shall not be pulled around angles that exceed 20°. With tandem-mounted blocks, the pulling angle shall not exceed 40°.

m) The sheaves shall conform to the conductor manufacturer's recommendation as to diameter, and to size and shape of groove for the size of conductor used. Sheaves shall have a minimum diameter of fifteen times the conductor diameter at the base of the groove. Block surfaces that will be in contact with the conductor shall be coated with neoprene or rubber. This covering shall be kept clean and free of materials that might damage the conductor surface. The conductor sheaves shall have a separate groove for the pulling line. The pulling line shall not run on the rubber covered conductor grooves. The sheaves shall be inspected for damage or contamination before each usage. The *Contractor* shall not use any sheaves rejected by the *Supervisor* due to damage or excessive wear. The Contractor shall immediately remove such sheaves from the site.

n) During stringing operations and before regulating, if it becomes necessary to leave the conductor in the blocks for longer than eighteen hours, the conductor shall be left at reduced tension, and the *Supervisor* immediately notified. The percentage of sag, spans involved, time interval, and correction for creep shall be noted, and records forwarded to the *Supervisor*. In no case shall conductors be left with less than the following clearances:

- cultivated or open country : 6 metres,
- roads and trails: 8 metres,
- railroad tracks: 9 metres.

8.2.3 Joints

a) Before stringing commences, the *Contractor* will be required to compress sample phase and earth conductor mid span joints, as well as phase conductor dead/end assemblies on site in the presence of the *Supervisor*, using the matched and numbered dies and compressors intended to be used on the line during stringing. The length of conductor between any two fittings on the sample shall be not less than 100 times the overall diameter of the conductor.

At an acceptable testing authority a tensile load of about 50% of the breaking load of the conductor shall be applied and the conductor shall be marked in such a way that movement relative to the fitting can easily be detected. Without any subsequent adjustment of the fitting, the load shall be steadily increased to 95% of the breaking load and then reduced to 90% of the breaking load and maintained for 1 min. There shall be no movement of the conductor relative to the fitting due to slip during this period of 1 min and no failure of the fitting. The conductor shall then be loaded to failure, and shall again withstand a minimum load of 95% of the minimum breaking strength of the conductor for it to be deemed acceptable. If the sample fails this test, a further three (3) samples shall be tested and will all be required to pass the above. If any one or more of these samples fail, no stringing shall commence until the *Project Manager* is satisfied that the equipment is acceptable. A copy of the test report shall be forwarded to the *Project Manager,* prior to stringing.

b) As far as possible, complete drum lengths of conductor and earth conductor shall be used to reduce the number of joints. Joints shall not be closer than 15 metres to the nearest suspension tower or 30 metres from the nearest strain tower. Joints shall not be installed in spans crossings

railways, proclaimed roads, power or important communication lines. In no case shall more than one joint be installed in a given span, nor shall a joint be installed in a span dead-ended at both ends. The minimum distance between joints shall be 300 metres.

c) Whenever joints or dead-ends are made, auxiliary erection clamps and hauling devices shall not be placed closer than 8m to the point of joint or dead-end. The auxiliary erection clamps shall not allow relative movement of strands or layers of wire, and shall not birdcage, over tension or deform individual wires.

d) The conductor shall be cut with a ratchet or guillotine cutter to produce a clean cut, retaining the normal strand lay and producing minimum burrs. The aluminium strands shall then be stripped from the steel core by using an acceptable stripper. Under no circumstances shall high tensile hacksaw blades be used to cut conductor.

e) The conductor shall be laid out for a distance of 15 metres and straightened at the ends before preparation for installation of joints or dead-ends. Compression jointing shall be carried out on a clean tarpaulin or jointing trailer. The lay of wires shall be tightened before the first compression is made. The conductor strands shall be cleaned by wire brushing and an accepted non-oxidising paste applied. Compression shall be carefully made so that the completed joint or dead-end is as straight as possible. To minimise distortion, the joint should be rotated 180° between each compression operation, the joint and conductor being fully supported in the same plane as the compression jaws. If, in the opinion of the *Supervisor*, the completed joint or dead-end requires straightening, it shall be straightened on a wooden block by use of a sledgehammer and shaper or wooden mallet.

If, in the opinion of the *Supervisor*, the joint or dead-end has not been satisfactorily straightened or has been damaged in the process, the *Contractor* shall replace it.

f) After compression has been completed, all corners, sharp projections and indentations resulting from compression shall be carefully rounded. All other edges and corners of the fitting that have been damaged shall be carefully rounded to their original radius. Nicked or abraded surfaces shall be carefully smoothed. Tape, tape residue and filler paste shall be removed from fittings and conductors.

g) Sufficient notification must be given to *Supervisor* prior to the installation of compression fittings. Unless previously agreed all joints and dead-ends shall be installed in the presence of the *Supervisor*.

h) Under no circumstances shall compression joint be allowed to pass the travellers.

i) During the progress of the stringing, the *Contractor* shall keep an accurate record of the spans in which conductor and earth conductor joints are made, the date of assembly onto the conductor. A copy of these records shall be supplied to the *Project Manager*.

8.2.4 Preparation of metal to metal contact surfaces

All current carrying connections, contact surfaces, clamps, conductor and terminals shall be prepared as follows:

- wipe the mating surfaces free from grease and dirt (except the bores of compression sleeves);
- apply 1mm thick coating of approved jointing compound to the surfaces using a non-metallic spatula or similar tool;
- scrub all the coated surfaces thoroughly with a wire brush which is new or which has been used solely for this purpose;
- wipe off the jointing compound;
- apply a fresh 1mm thick coating of compound; and
- after a period of not more than one minute make the connection in the normal manner and remove excess extruded compound.

NOTE: No compound squeezed out by clamping pressure shall be used in making further joints. The *Contractor* shall apply such compound as necessary for making the connections by the method outlined above. On bolted connections care shall be taken during the tightening to avoid overstressing the bolts or components of the clamps. A torque wrench shall be used for tightening each bolt to the required torque.

- Tighten all bolts and U-bolts to their specified torque.
- Leave clamps for 24 hours to allow aluminium conductor to expand and contract.
- Check all bolts to ensure that they are still at the required torque.

8.2.5 Conductor repairs

a) Damage caused by the *Contractor* shall be repaired in a manner determined by the *Supervisor.* Damage is any deformity on the surface of the conductor that can be detected by eye or by feel. Damage includes, but is not limited to nicks, scratches, abrasions, kinks, birdcaging, and popped out and broken strands.

b) Depending upon the severity of the damage and the length of damaged section, the repair shall be made by careful smoothing with extra fine sandpaper, covering with preformed repair rods, installing a compression-type repair sleeve, or by cutting and splicing.

c) Kinked, birdcaged or severely damaged sections of conductor shall be cut out. When there is repeated damage in the same span, or in consecutive spans, the entire conductor in such spans shall be replaced.

d) All damage caused by auxiliary erection clamps or other gripping devices shall be repaired or cut out, as instructed by the *Supervisor*, before the conductor is sagged.

e) Preformed repair rods shall be installed if no more than one strand is broken, or nicked deeper than one third of the strand diameter, or when a number of strands are reduced in area not exceeding the area of one strand. Not more than two sets of preformed repair rods shall be installed on any one conductor in any given span.

f) A compression-type repair sleeve shall be installed, if not more than one third of the outer strands of the conductor are damaged over a length of not more than 100mm, or not more than two strands are broken in the outer layer of conductor and the area of any other damaged strands is not reduced by more than 25%.

g) Compression-type repair sleeves shall not be installed on one conductor in a given span if it already contains a conductor splice, conductor dead-end or another compression-type repair sleeve.

h) Damage to the steel strands or aluminium strands, exceeding the stated limits for repair sleeves, shall be cut out and spliced by means of a compression type mid-span joint.

i) Any foreign matter such as pitch, paint and grease placed on the conductor and fittings by the *Contractor* shall be removed by methods approved by the *Supervisor* prior to regulating.

8.2.6 Regulating

a) The *Contractor* shall string all conductors and earth conductors to the appropriate sags and tensions as determined from the conditions specified in the Works Information. The calculation of sag corrections for creep and clamping offsets shall be the responsibility of the *Contractor*, based on charts supplied by the *Project Manager*. Such calculations shall be submitted to, and accepted by the *Project Manager* prior to regulating.

b) Conductors and earth conductors shall be strung to the appropriate sag determined for the actual span length, and the equivalent span of the strain section involved.

c) The ruling/equivalent span of a strain section is given by the formula

$$Le = \sqrt{\frac{\sum L_i 3}{\sum L_i}}$$

where L_i is the length of the individual spans in the strain section. The sag S_e for the equivalent span L_e, is the sag determined from the conditions specified, i.e. appropriate conductor temperature. The correct sag S for any actual span length L in a strain section of equivalent span L_e is then given by:

$$S = (\frac{L}{L_e})^2 \times Se$$

The appropriate conductor temperature to be used for sagging shall be determined by means of a Celsius thermometer inserted in the end of a suitable length of conductor or earth conductor from which a 150mm length has been removed from the centre strand, or other accepted method. The wire with the thermometer inserted shall be hung at crossarm level for at least two hours before the temperature is read.

d) The length of a section of phase and earth conductors to be regulated at any one time shall be limited to that length that will assure attainment of correct sag based upon terrain and obstructions.

e) Where there are a large number of suspension towers between strain towers, regulating of phase and earth conductors shall be done at intervals of 3 to 5 spans. In hilly country the conductors may require to be temporarily anchored one span away from the spans being regulated. The sag spans chosen shall be near each end of the section pulled for single conductor lengths, and near each end and at the middle for double conductor lengths. In addition, the sags shall be checked in all spans over 500 metres. In unusual situations, the *Supervisor* may require additional checks.

f) The *Contractor* shall provide, and maintain in good condition, suitable dynamometers, sag boards or other accepted apparatus for the proper checking of the work. Dynamometers shall read in Newtons and shall be tested and recalibrated at regular intervals. The *Contractor* shall keep dynamometer calibration certificates at the site office.

g) The *Contractor* shall notify the *Supervisor* at least twenty-four hours prior to any planned regulating operation. No regulating shall be done except in his presence, unless otherwise authorised. The *Contractor* shall furnish labour and equipment, for signalling and climbing purposes as requested by the *Supervisor*, to facilitate his inspection of the sag.

h) In pulling up the conductor, caution shall be used to avoid pulling the conductor above sag.

i) The maximum elapsed time from the beginning of the pulling operation to the completion of the regulating operation, shall not exceed seventy two hours, nor shall the maximum elapsed time between the completion of the regulating operation, and the completion of the clamping operation exceed seventy two hours. Conductor remaining in the blocks longer than the established limits shall be subject to inspection and, if damaged, replaced. The *Contractor* shall furnish labour and equipment as requested by the *Supervisor* for this purpose, as well as for inspection in the event of sudden windstorms.

j) No minus regulating tolerance will be allowed. A plus regulating tolerance of 0,01 times the theoretical sag, but not exceeding 150mm will be allowed, provided all conductors in the regulating span assume the same relative position to true sag. Sags of conductors in the same bundle shall not vary more than 35mm relative to one another. Sag variances between phases shall not be apparent to the naked eye.

k) When finally adjusting the sags of conductors and earth conductors, the sag shall be checked with sag boards, or other accepted methods in spans where the levels of the two towers are approximately the same, and the span length is approximately equal to the equivalent span length of the strain section. Upon completion of this regulating operation, as many successive spans as can be observed from the sag board position shall be checked for uniformity of sag.

l) All conductors, except for conductors in sag sections over flat terrain, shall be plumb-marked at each structure for the complete section regulated, before clamping-in or dead-ending of the conductor is begun. Conductors shall be marked with paint crayon or wax pencil - not with metal objects.

m) Insulator strings on three suspension towers adjacent to a new section to be regulated must be clamped to the conductor before temporary anchors are removed and regulating of the new section begins. These insulators shall remain in the plumb position upon completion of regulating of the new section and during plumb-marking.

n) Regulating operations shall be conducted during daylight hours only. Regulating operations shall be suspended at any time, when in the opinion of the *Supervisor,* wind or other adverse weather conditions would prevent satisfactory regulating.

o) Records of temperature, sag and tension for each section regulated shall be kept by the *Contractor*, and a copy supplied to the *Project Manager*.

p) On completion of regulating of a section of the line, the *Contractor* shall measure and record all clearances over roads, powerlines, communication lines, railways etc. along the route. A copy of these records is to be submitted to the *Project Manager*. The *Supervisor* is to be notified immediately of any discrepancy found between the actual clearance and that shown on the profiles.

8.2.7 Clamping of conductors

a) The conductors and earth conductors shall be clamped-in by the *Contractor* after the *Supervisor* has accepted the regulating operation as being in full compliance with the specifications and stringing data. Where offsets are required, the conductors shall be accurately adjusted in accordance with the offset clamping information developed by the *Contractor*.

b) All conductors in a sag section shall normally be clamped-in, beginning at the second structure from the forward end of the pull, and shall progress structure by structure, until the conductors at all structures are clamped-in.

c) The *Contractor* shall exercise extreme care in moving the phase and earth conductor from the stringing blocks to the suspension clamps.

d) Where armour rods or conductor clamps incorporating armour rods are called for, they shall be installed in strict accordance with the manufacturer's recommendations. Armour rods shall be centred in each suspension clamp in such a manner that the clamp is not more than 50mm from the centre of the rods. Variations between the ends of the individual rods shall not exceed 12mm. Aluminium rods shall be handled with the same care as the conductor.

e) Properly calibrated torque wrenches shall be used to tighten suspension clamp and dead-end bolts to the manufacturer's specified torque values. U-bolts shall be drawn up evenly to torque values. Bolts shall not be tightened excessively. Proof of calibration must be submitted to the *Supervisor.*

f) All conductor support assemblies shall be installed such that the insulator string will hang in a vertical plane through points of insulator string attachment to structure, with the structure properly aligned.

8.2.8 Vibration dampers

a) Where vibration dampers are specified, these shall be installed at each suspension and strain point.

b) The number of dampers to be installed per span shall be as recommended by the manufacturer. The spacing from the mouth of the strain clamp or the centre of the suspension clamp shall be in accordance with the manufacturer's recommendations.

c) If the use of armour rods makes it impossible to meet this spacing, the first damper shall be positioned at the end of the armour rods, and any additional dampers shall then be spaced from the first damper. Dampers shall be located within 25mm of their correct position.

d) Vibration dampers shall be installed when clamping the conductor, but only after the conductor has been securely fastened in the conductor support assembly.

e) Stockbridge type vibration dampers shall be installed so that they hang directly under the conductor.

f) The installation of vibration dampers shall be in accordance with the manufacturer's recommendations.

8.2.9 Multi-conductor spacers and spacer dampers

a) On lines employing more than one conductor per phase, spacers or spacer-dampers, shall be installed to separate the individual conductors of each phase.

b) Conductor spacers or spacer dampers shall be installed immediately after clamping the conductors, but in no instance shall conductors be allowed to remain without spacers installed for longer than seventy-two hours after clamping.

c) Notwithstanding the allowed times between stringing, regulating, clamping and fitting of vibration dampers, spacers or spacer dampers, the overall time for these operations shall not exceed six days (144 hours).

d) Conductor spacers or spacer dampers shall be installed within 1 000mm of the positions as specified by the manufacturer.

e) Conductor spacer carts used by the *Contractor* to move his men along the conductor shall be furnished with neoprene or rubber lined wheels to support the carts on the conductors. The carts shall be equipped with an odometer, which shall run on one sub-conductor and indicate distances in metres. The odometer shall be set in such a manner, as to give the distance from the suspension clamp to all cart positions along the span on the centre phase from which all the hardware on the three phases will be aligned perpendicular to the centre line of each span. Spacer-dampers will also be installed perpendicular to the sub-conductors of a phase along the catenary.

8.2.10 Jumpers

a) The jumpers shall be formed to provide the maximum amount of clearance from earthed hardware, and tower steelwork. Their positioning shall comply with the clearances stated under the specified displacements.

b) The *Contractor* shall supply labour and equipment to assist the *Supervisor* in measuring clearances from jumpers to earthed hardware if requested.

c) Jumpers not meeting the required clearances shall be removed and replaced.

8.3 Stringing of OPGW

Refer to “TRMASACB2 – Standard for the installation of overhead ground wire with optical fibre (OPGW)”.

Annex A

Revision information

DATE	REV. NO.	NOTES
9/88	0	• Document originally issued as NWS 1512.
7/92	1	• Text changes.
12/94	2	• Number and format of document changed to comply with requirements of the Eskom Documentation System. (See Eskom Directive ESKADAAA0 and Eskom Procedure ESKPVAAA0). • Text changes made.
12/00	3	• Text changes made.