Islamic Republic of Iran
Vice Presidency for Strategic Planning and Supervision

General Technical Specification and Execution Procedures for Transmission and Subtransmission Networks Electrical Transmission Supports

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CONNTENTS

Technical Specifications of Electrical Transmission Supports

1. General

These specifications present requirements for rating, materials, design, fabrication and testing of transmission lines supports. These structures should be designed, built and tested based on requirements of the last revision of standards and publications mentioned below:

- ACI 318: Building code requirements for structural concrete.
- ASCE 10-97: Design of latticed steel transmission line structures.
- ASTM A36/A36M: Standard specification for carbon structural steel.
- ASTM A82/A82M: Standard specification for steel wire, plain, for concrete reinforcement.
- ASTM A123/A123M: Standard specification for zinc (hot-dip galvanized) coatings on iron and steel products.
- ASTM A143/A143M: Standard practice for safeguarding against embrittlement of hot-dip galvanized structural steel products and procedure for detecting embrittlement.
- ASTM A242/A242M: Standard specification for high-strength low-alloy structural steel.
- ASTM A370: Standard test methods and definitions for mechanical testing of steel product.
- ASTM A384/A384M: Standard practice for safeguarding against warpage and distortion during hot-dip galvanizing of steel assemblies.
- ASTM A385: Standard practice for providing high-quality zinc coatings (hot-dip).
- ASTM A394: Standard specification for steel transmission tower bolts, zinc-coated and bare.
- ASTM A416/A416M: Specification for steel strand, uncoated seven-wire for prestressed concrete.
- ASTM A421/A421M: Standard specification for uncoated stress-relieved steel wire for prestressed concrete.
- ASTM A475: Standard specification for zinc-coated steel wire strand.
- ASTM A529/A529M: Standard specification for high-strength carbon-manganese steel of structural quality.
- ASTM A563: Standard specification for carbon and alloy steel nuts.
- ASTM A572/A572M: Standard specification for high-strength low-alloy columbium -vanadium structural steel.

- ASTM A588/A588M: Standard specification for high-strength low-alloy structural steel with 50 ksi [345 MPa] minimum yield point to 4-in. [100-mm] thick.
- ASTM A606: Standard specification for steel, sheet and strip, high-strength, low-alloy, hot-rolled and cold-rolled, with improved atmospheric corrosion resistance.
- ASTM A615/A615M: Standard specification for deformed and plain carbon-steel bars for concrete reinforcement.
- ASTM A641/A641M: Standard specification for zinc-coated (galvanized) carbon steel wire.
- ASTM A722/A722M: Standard specification for uncoated high-strength steel bar for prestressing concrete.
- ASTM A931: Standard test method for tension testing of wire ropes and strand.
- ASTM A1008/A1008M: Standard specification for steel, sheet, cold-rolled, carbon, structural, high-strength low-alloy, high-strength low-alloy with improved formability, solution hardened, and bake hardenable.
- ASTM A1011/A1011M: Standard specification for steel, sheet and strip, hot-rolled, carbon, Structural, high-strength low-alloy and high-strength low -alloy with improved formability.
- ASTM C31/C31M: Standard practice for making and curing concrete test specimens in the field.
- ASTM C33: Standard Specification for concrete aggregates.
- ASTM C39/C39M: Standard test method for compressive strength of cylindrical concrete specimens.
- ASTM C42/C42M: Standard test method for obtaining and testing drilled cores and sawed beams of concrete.
- ASTM C94/C94M: Standard specification for ready-mixed concrete.
- ASTM C150: Standard specification for portland cement.
- ASTM C172: Standard practice for sampling freshly mixed concrete.
- ASTM C260: Standard specification for air-entraining admixtures for concrete.
- ASTM C330: Standard specification for lightweight aggregates for structural concrete.
- ASTM C403/C403M: Standard test method for time of setting of concrete mixtures by penetration resistance.
- ASTM C494/C494M: Standard specification for chemical admixtures for concrete.
- ASTM C595: Standard specification for blended hydraulic cements.
- ASTM C618: Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete.
- ASTM C935: Standard specification for general requirements for prestressed concrete poles statically cast.
- ASTM C1089: Standard specification for spun cast prestressed concrete poles.
- ASTM E376: Standard practice for measuring coating thickness by magnetic-field or eddy-current (electromagnetic) examination methods.

- ANSI/AWS D1.1/D1.1M: Structural welding code–steel.
- IEC 60652: Loading tests on overhead line structures.
- Iranian concrete code (ABA, standard No. 120).
- Iranian structural welding code (standard No. 228).
- Cement usage, maintenance and storing in sites (Iran standard No. 2761).
- Iran standards for cover and painting of electrical power industries.
- General design criteria for overhead transmission lines (Tavanir).

Other national or international standards are acceptable in the case of client approval and compatibility with above standards.

Contractor should present detailed proposal in such a way that client can evaluate it according to these specifications. While other standards are used by contractor, two copies of them with special differences explanation should be attached to contractor's proposal.

2. Steel Latticed Towers

2.1. Material

Presented specifications for steel materials in this document stands for steel with yielding stress up to 448 MPa (65 ksi) and $F_u/F_y \geq 1.15$, which F_y is yielding stress and F_u is ultimate stress. The F_u/F_y ratio provides enough ductility for structure and prevents brittle failure in elements while they reach to ultimate conditions.

Bolts and nuts materials are based on ASTM A394 and ASTM A563, respectively.

2.2. Material Preparation

2.2.1. Material cutting

Shearing

Materials with straight edges can be cut to a suitable size by a shear. Care must be taken to prevent cracks or other defects at the sheared edge. Limitations of section size and length of the shear must be considered to assure a good cut. Any burrs should be removed if it would be detrimental to the structure or would be a safety hazard.

Oxygen cutting

Curved edges, sections impractical to shear, and edges being prepared for welding may be cut with a burning torch. Care must be taken to prevent cracks or other notch defects forming at the prepared edge and all slog must be removed. Wherever possible, the torch should be mechanically guided. Edges prepared for welding or subject to high stresses should be free from sharp notches.

Sawing

Steel may be sawed with a reciprocating band saw, circular stone saw, or friction saw.

Planning

Sheared or oxygen cut edges may be finished by planning. This is not usually necessary unless closer tolerances, smoother bearing surfaces, or special welding grooves are required.

2.2.2. Bending limitations

The limits on the lightness of a bend in a piece of steel are usually expressed as a ratio of bend inside radius to the thickness of the piece. Some of the factors that affect the limits for a particular plate are the angle and the length of the bend to be made, the mechanical preparation of final rolling of the plate, the preparing of the free edges at the bend line, and the temperature of the metal. Care must be taken to prevent steel from cracking especially at the free ends either during the bending operation or subsequently due to residual stresses.

Cold bending is usually used for simple bends with narrow bend angle. In the process of steel cold forming even though proper precautions are taken to prevent cracking, the resistance to brittle fracture is reduced.

In hot bending the steel should be heated to 760–780 degrees of centigrade. For pieces with normal angle and combined bend, hot forming is required. Pieces with bends in different slopes should be cut and welded. Drawings should include special preparation and welding details.

2.2.3. Hole making

Punched or drilled holes or holes made by oxygen cutting should not be displaced more than 1 mm from their actual positions. Before making holes, method of work and process of quality control should be confirmed.

Punching:

Holes in thinner steel sections may be punched. This method should be applied when the material thickness does not exceed the diameter of the hole. If steel is to be galvanized, precautions against steel embrittlement listed in ASTM A123 and ASTM A143 should be considered. The holes should be smooth and cylindrical. No slag or deformation should be on the holes.

Drilling:
Holes of any diameter may be drilled in plate of any thickness.
Oxygen cutting:
The torch should be machine guided and care should be taken to make the cut edges reasonably smooth and suitable for the stresses transmitted to them. All slag must be removed.

2.3. Minimum Dimensions

Minimum necessary thickness for main legs and crossarms is 5 mm and for other members are 3 mm. Thickness of connection plates should not be less than 5 mm. These dimensions are only for steel section of the member and do not apply to surface coatings.
Bolts diameter should not be less than 12 mm. If bolts with different dimensions are used, their differences in dimension should not be less than 3 mm, regardless to their materials.
Minimum bolts spaces and edges dimensions should not be reduced during rolling or other methods of fabrication. The minimum necessary dimensions of the piece after being made should be according to the drawings.

2.4. Surface Coatings

2.4.1 General

The surface coating protects the base material of corrosion and enhances the appearance of the structure. The structure may be protected using a chemical coating, galvanizing, weathering steels, metallizing or by combinations of these. Surface protection for parts of the structure that are directly embedded in the earth must be given special attention. The original surface coating should be done in an equipped workshop with a suitable quality control plan.
Followings are a number of questions regarding the structure that must be answered before the best coating system is selected:

- Will the structure be exposed to a normal or sever atmosphere including chemical or salt water?
- Will the structure be exposed to wind – borne particles that might abrade the protective coating?
- Will directly embedded structures be immersed in the ground water?
- Are there chemicals or bacteria in the soil or ground water that will significantly increase the corrosion rate?
- Will the coating color provide a fine view in the environment?

2.4.2. Chemical coating (painting)

A large number of commercial coating systems are presently available. Each system has been designed to accomplish a specific function. Manufacturers should investigate and test coatings before using them to assure their function.

If the structure is to be placed into an area in which the environment is particularly corrosive or abrasive, suitable coating are required. The design condition must be carefully evaluated and exotic coating systems which increase cost should not be specified unless they are needed.

Surface preparation

It is necessary to remove burrs and stains from the surface before painting. In order to remove grease and oils, solvents should be used. Sufficient coating must be provided in the site to repair damaged areas on the surface.

Inspection

Coating thickness for evaluation and confirmation should be determined through destructive and nondestructive tests.

The consultant may also specify additional tests to ensure that the coating will perform satisfactorily. These tests might be used to determine adhesion, abrasion resistance, chemical resistance and color retention.

2.4.3. Galvanizing

In this method, base material is protected by applying zinc through hot dip galvanizing according to ASTM A123. Requirements of ASTM A385 and ASTM A384 also should be considered. The final appearance and durability of the zinc coating depend primarily on the quality of the galvanizing process.

All parts of the structural assembly should be made from materials that ensure galvanizing compatibility. The immersion time, the temperature of the bath, and the use of inhibitors will vary with the type of steel. Parts made from steel of different type or from members having large differences in thickness may result in various coating colors, textures, and thickness.

The sizes of the members of structure may be limited by the size of the galvanizing tank. “Double dipping” or dipping one end of the piece and then the other should be used in special situation with the permission of designer. In “Double dipping” the interior of the tubular shape must be inspected.

Proper steel selection and fabrication can decrease the possibility of embrittlement. The related requirements of ASTM A123 and ASTM A153 should be considered.

Surface preparation

The base material can be galvanized satisfactorily only after it has been properly cleaned. An acid bath is used to remove excessive oils, paints, grease, mill scale and rust. Shot or grit blasting may be necessary to remove deeply embedded mill scale or where the surface has inclusions of sand particles that can not be removed by pickling. All welds must be cleaned by hand or blast methods because welding residues are chemically inert and could not be removed in acid bath.

The temperature of the pickling bath and prolonging the immersion in the bath may increase the susceptibility of embrittlement due to hydrogen absorption. Inhibitors that reduce hydrogen absorption should be used in the picking bath. It is imperative that all of the pickling solution be removed from bath inside and outside surface of the part before immersion in the preflux solution.

Zinc coating

After prefluxing, the part is dipped in a molten zinc galvanizing bath. The maximum zinc coating with good quality which can be achieved on steel is 840 gr/m^2.

Table (1) shows minimum average coating thicknesses for different steel pieces. Galvanizing degree is the thickness of coating (μm). Its equivalent quantity in grams per square meters (gr/m^2) is presented in Table (2).

Table (1): Minimum average galvanizing degree for different steel pieces

Piece type	Thickness of steel (mm)				
	<1.6	1.6-3.2	3.2-4.8	4.8-6.4	≥6.4
profiles and plates	45	65	75	85	100
rebar	45	65	75	85	100
pipe	45	45	75	75	75
wire	35	50	60	65	80

Table (2): Coating thickness for each galvanizing degree*

Galvanizing degree	μm	gr/m^2
35	35	245
45	45	320
50	50	355
55	55	390
60	60	425
65	65	460
75	75	530
80	80	565
85	85	600
100	100	705

** Thickness amounts in µm are the galvanizing degree. Third column are calculated from gr/m2=µm*7.067*

Areas damaged during shipment or erection may be repaired by using commercial zinc product designed for this purpose. Some of them are: zinc rich paint, zinc spraying or applying brushed molten zinc.

Inspection

Galvanizing thickness can be determined by variety of nondestructive and destructive tests. The most suitable method is nondestructive tests which were mentioned in ASTM E376. Additional nondestructive examination in the area of the welds may be specified after galvanizing to ensure that there are no cracks.

Coating over galvanizing surface

In the following situations, painting over galvanized surface may be desirable:

- Need for more protection of base material
- Painting to improve appearance
- Reducing light reflection

Precautions must be taken to ensure adherence of the paint coating to the galvanized surface. Adherence may be affected by one or more of the following factors:

- The smoothness of the galvanized surface which does not permit mechanical locking of the coating film.
- Oils, waxes and other contamination on the galvanized surface.
- The difference in thermal expansion on the paint film and the base metal, which may cause cracking and separation.
- Fresh zinc is non adhesive to some paints.

2.4.4. Weathering Steels

The use of weathering steels in steel structures eliminates coating costs. Since good appearance is a major aspect, all parts of the structure should be made from weathering steel. Welding must be compatible with the base steel. Surface preparation will depend on type of paint system and should be done in accordance with consultant's recommendations. It has been reported that paint coating and weathering steels have been found durable than the same coating on ordinary carbon steel.

Weathering steels may be galvanized as described in section 2.4.3.

There are certain environments in which the use of bare, uncoated weathering steels is not recommended because the protective oxide coating will not form properly. These environments include:

- Locations with concentrated corrosive industrial fumes. These locations are recognized by experience. If it is possible, test samples should be done in an open air for one year in the case of consultant's request.
- Environments containing salt water particles.
- Locations where the structure is directly embedded in soil or water.

2.4.5. Metallizing

The structure may be protected against corrosion by coating the base metal using thermal spraying method. Thermal spraying includes flame spraying, electrical spraying and plasma spraying, which should be done in accordance with ANSI/AISC 360.

The base metal must be cleaned, roughened, and be free of any traces. Metal and thickness required depend on the exposure of the structure. The full coating thickness should be applied within 2 hours after surface preparation and at least in two stages.

Sealing and painting should be done to improve corrosion resistance and appearance, and to prevent blisters in sea coast or industrial areas.

Inspection of the metallizing procedure includes checking the abrasives, appearance and profile of the base metal, determining the thickness and adhesion of the metal coating, and inspecting the seal coat.

2.4.6. Protection for direct earth embedment

The base of the structure that is embedded in the earth usually requires special protection. In most cases, a thick film of coal tar epoxy applied over the structure coating will provide adequate protection. The base coating must be properly prepared to receive the coal tar epoxy. If studies indicated that coal tar epoxy is not sufficient to make adequate resist corrosion, cathodic protection may be applied to the embedded portion of the structure.

2.5. Connections

All connections assembled in site should be bolted connections. Welding should be minimum and done before galvanization. If galvanized parts should be welded, special considerations on insulation and recoating in welding point should be taken.

Chords of crossarms, at each end, should be connected with at least two bolts.

The minimum covering of two angles for a member fabrication is twice the width of the smaller flange. The connecting bolts point should be in such a way that the center of gravity of bolts group be as closely as possible to the center of gravity of angles.

In double angles fabrication, the maximum distance between sewing bolts should be 90 cm for tension members and 60 cm for compression members. There should be used a proper washer and/or a filling sheet between two angles in sewing point.

2.6. Tension Members

Tension members with length of less than or equal to 450 cm should be fabricated 3mm smaller than the actual size. For members with length of more than 450 cm, the fabricated length should be 1.5 mm smaller than the actual size in each 300 cm increase in length. Therefore, in tension members there will be one pretension force. If these members are formed by two connected parts, the slip joint should be considered. Using at least 2 bolts are necessary for connecting two parts.

2.7. Climbing Provisions

Each tower should be equipped with step bolts erected on one of tower's main supports. The step bolts stretch from 2.5 m above the ground to the top of tower. Each bolt should bear 130 kg vertical force at its end. The bolts thickness should not be less than 16 mm. The bolts end distance from the body should be at least 10 cm.

For members having the gradient less than 30 degree, there should be considered a concentrated force equal to 130 kg in the point which creates highest stress. The mentioned force should apply to the member with every day stresses (EDS).

2.8. Identification and Sign Plates

Identification and sign plates of electrical transmission line towers should be prepared and erected as followed. The plate quality and its color endurance should be confirmed before installation. Plates can be made of galvanized steel, aluminum or polymer. The weather conditions of the region should be considered while confirming the quality and strength of plates.

2.8.1. Danger Plate

On each tower a plate with 30 cm width and 40 cm height should be installed at 2.5 m height above ground level. Each plate includes "danger sign" and the word "DANGER" which should be written in English and Persian. The plate should be installed in the direction to be seen by most pedestrians.

2.8.2. Support and Line Identification Plate

Identification plate will be installed with the same dimensions of danger plate at 2.5 m above ground level. The tower No., voltage level and the line name should be written on each plate. Also the type of tower (dangling or tension) and the line angle change on tower point should be mentioned. The above identifications can be shown as common and clear abbreviations. Each plate should be installed in such a way to face the next tower with smaller number. If some line information changes, a smaller plate with new line identifications will be installed on the old plate instead of changing the old one.

2.8.3. Aerial Signs Plate

For each ten succeeding supports, aerial sign plates will be installed on a support in two directions back to back at the top point and in line direction. Plate dimensions are 35×70 cm and only the support number should be specified on it.

2.9. Drawings and Documents

2.9.1. Documents to be given by tenderer

- Type and general design of the tower
- Complete type and specifications of the steel
- Completed table of detailed specifications of bolts and nuts
- Completed table of guaranteed weight of tower's different parts and total weight of the steel
- List of codes and standards
- Detailed summary of exceptions in specifications
- List of special tools
- A summary of testing process
- Packaging, shipment, storage, installation and maintenance manuals

Note 1: Steel properties includes its type (ST37, …), supply, the maximum carbon, manganese, sulfur, phosphate and silicon, tension resistance (including yielding stress and ultimate stress), the amount of elongation and the minimum galvanization degree.

Note 2: Bolts and nuts specifications should include their supply, the applied fabrication standard, the used steel, shearing stresses and ultimate tension, the minimum galvanization degree, threaded dimensions and length.

Note 3: Weights of bolts, nuts, connection sheets, galvanization of parts should be considered in the guaranteed weight of different parts of the tower. The final payment will be based on the amount of actual used steel and if the actual weight exceeds the guaranteed weight, payment will be based on the guaranteed weight.

2.9.2. Documents to be given by contractor / supplier

Design, fabrication, packaging, marking, shipment, storage, erection and tests drawings and documents as follow and not limited to the followings shall be submitted:

- Design documents to prove the adequacy of the structure (If using software, concepts of applied programs, assumptions, primary data and results should be attached)
- Shop drawings
- Tests reports and certificates

- Package, shipment and storage details
- Erection and maintenance details
- Time schedules
- Work schedules and monthly progress report
- List of drawings
- List of components

Drawings should consist of:

- The erection point of each member
- Connection details
- Geometric details and the type of construction materials for tower members
- Type of bolts, nuts and washers
- Other special details such as welding, etc.

For this purpose, each member is characterized with an identification number and the number and type of bolts in any connection should be given. The erection drawings consist of the whole structure in which the position and direction of each member will be shown in a larger scale.

Direct connection of members with minimum eccentricity should be always considered in drawing the details of connections. If the designer defines special details for connection, it should be considered according to the presented documents.

Geometric specifications and the type of members' construction materials, bolts, nuts and washers will be presented in separate tables. Samples of tables presenting members' specifications and connection parts are shown in Tables (3) and (4). All dimensions should be considered with 1 mm accuracy in tables and shop drawings.

If a component is reviewed during fabrication process or tower test, it should be mentioned in the explanation column. The total weight of each part of the structure will be gained from the sum of weights relating to members, bolts and nuts (Tables 3,4).

Table (3)

Structural members details

Structure Type: Designer:
Structure Code: Date:

Member: Code:

No.	Type	Code	Material	Dimensions (mm)	Length (mm)	Number	Unit weight (kg)	Total weight (kg)	Explanations
Total Weight:									

Table (4)

Connection members details									
Structure Type: Structure Code:					Designer: Date:				
Member:					Code:				
No.	Type	Code	Material	Dimensions (mm)	Length (mm)	Number	Unit weight (kg)	Total weight (kg)	Explanations
Total Weight:									

2.10. Installation instructions

In this section, installation instructions of latticed steel towers, are presented. If the contractor suggestions are different from these criteria, they should get approval before implementation.

2.10.1. Carrying and storage

Packaging, loading and carrying methods should be explained clearly.

Contractor should prepare a place to store equipments and structures for each part of transmission line considering damage protection and theft. This storage should be used just for project facilities. Contractor is in charge of replacing damaged and lost facilities in case of his fault. All repairs on project facilities should be done by contractor according to supervisor monitoring. Repairs may be done in shop by supervisor request.

After completing installation, contractor should review all the transmission line and towers and check bolts and installed equipments.

Cinder client, request all excessive materials and facilities should be listed by contractor and stored in client storage. Returned facilities should be in sound and good condition. All equipments which are assembling together, should be stored in a same place. Damaged facilities are stored separately.

2.10.2. Tower Assembling and Installation

Tower assembling is performed in horizontal direction part by part. This method reduces assembling problems and makes it more reliable. Special methods of assembling should be indicated in shop drawings clearly.

Contractor should install the towers according to approved drawings. After foundation casting, for type I or II cement, tower should be installed after 10 days and wiring should be done after 28 days. For type III cement, installation and wiring could be started after 3 and 7 days, respectively. In case of using type V cement in high sulphated soils, tower could be installed after 15 day and wiring should be done after 42 days.

- Assembling

Contractor should prevent to damage equipments and galvanized segments. Metal facilities should not be leaved on earth or used as loading or unloading tools. In case of small damages in galvanized equipments and facilities, a galvanizing color with at least 92% fine zinc powder or equivalent color which is verified by consultant could be used.

Segment assembling should be in accordance with the explained details and erection drawings. Bolts should be installed with correct length in all segments and at least 3 threads should be free.

Length of bolts should be declared in shop drawings exactly according to engineer statement. Bolts should be installed with their heads inside the tower or downward unless other consultant statement.

If nuts do not turn around bolts freely, they should be replaced. In the case of wrong size nuts usage, they should be replaced by contractor's charge. However, all bolts should not get tightened until erection completion. Assemblage method is up to contractor.

According to ASTM A394, all nuts should be fastened by a torque wrench and satisfy table (5) limitations. Before starting, supervisor should test torque wrenches and verify their calibrations. This verification will be repeated once every 4 months until the end of project. Maximum acceptable tolerance for torque wrench is ±5%. In the case of using split- ring lock, applied torsion should make the ring completely flat.

Table (5): Minimum applied torsion on nuts for tower erection

Dimension of bolt mm (in)	Minimum torque Kg.m
12 ($1/2$)	6-8
16 ($5/8$)	10-14
20 ($3/4$)	17-21
22 ($7/8$)	17-21
24 (1)	17-21

All excessive material on tower segments such as soil, mud, etc. should be cleaned before erection especially in overlapping length of members. It is important to keep galvanizing cover of members. Bolts should be checked before and after wiring. Before wiring, all bolts should be fastened completely. If supervisor find unsuitable bolts regarding to length or required torque more than 5 percent of total bolts, the contractor should replace or fasten again all the bolts. All the bolts up to 3 meters above ground level should get hammered from nut side to keep them safe.

In on earth assembling, suitable bearings are needed to assure safe erection of elements. In this method all of the bolts should be placed in connections. To prevent any damage and bending of members, temporary elements should be used.

- Erection

Most of towers are symmetric. Therefore no special direction is needed. However, dead-end towers may be asymmetric and need special attention on erecting direction. Contractor should erect towers by approved materials.

If a structural member could not get approval by supervisor, contractor should not use it permanently and should replace it without any excessive cost.

During tower erection, enough attention specially in cold weather should be given to prevent excessive forces and brittle fracture. All works should be done under supervisor approval. Lifting bolts or hangers should not be connected to the middle of the members.

Any erection method which may damage members or whole tower is rejected. Any welding operation in erection phase (except approved conditions by supervisor) is forbidden. In the case of supervisor approval, welding should be done according to related standards.

During erection, it is important to make and keep the tower exactly in its final vertical position. Hangers and other facilities which are used to lift tower should be made of materials that do not damage tower segments and do not bend members.

In order to erect the members in their places, they should not be bent by excessive force. Turn buckles or other equipment should not be used for erection with force. Any damage to the bolt threads during installation should be prevented. Bolt heads and washers should be placed fully stuck to surface of members.

After erection completion, danger plate and arial identification plate should be installed. Vertical axis of support structure should have a deviation less than 0.2% of height in each level.

2.10.3. Site Repairing

If fabrication problems exist in structural members (which could prevent adequate assemblage), they should be reported to supervisor. Contractor should repair these imperfections under supervisor's approval.

If a member contains a hole in drawings which is not performed in fabrication phase, it could be punched or drilled. Welding and making another hole in case of improper hole in a member could be done only by supervisor's letter of approval. Making holes or making a hole greater, in steel or aluminum members, are acceptable just under these criteria:
Resizing up to 1.5 mm for connection bolt holes if they are less than 25 percent of total bolts and up to 3 mm if they are less than 10 percent of total bolts.
Excessive holes in members are not permitted. No member could be made in site except by supervisor letter of approval in each special case.
If there is no other criteria for workshop operation by supervising system, minimum distance between bolts will be 3 times of bolt diameter and minimum distance between bolt and edge of plate will be 1.5 time of bolt diameter.
Contractor should paint all galvanizing cover damages with an accepted galvanizing color.

3. Steel Poles

Section (2) relating to general considerations of steel fabrication will also apply to this section, especially (2.1) for construction materials, (2.2) for metal parts preparation, (2.4) for metal surface coating and (2.8) for signs and specification sheets.

3.1. Fabrication Tolerances

The designer's or manufacturer's method for steel pole fabrication and its parts should satisfy the limits of mentioned tolerances in all conditions. The presented manufacturer's method should be already confirmed by the supervisor.

3.1.1. Body of Pole

The diameter of fabricated body should never be less than the designed diameter in any condition. In body's connections, sections shapes should be coordinated. The length of each section and the total length of the pole after erection should be determined. For a single pole, a decrease of 0.25 percent of the total pole's length is acceptable. Also the exact angles are important for clearance criteria and appearance.

3.1.2. Crossarms

Maximum tolerance is 2.0 cm for crossarm's length, 0.5 percent for crossarm's direction respect to the horizon, 1 percent for rotated crossarm's direction on vertical axis and 1.0 cm for vertical position in pole at connections. Crossarms diameter should never be less than the given diameter in the drawings in any condition.

3.1.2. Slip Joint in Body of Pole

The minimum overlap in slip joint is equal to 1.6 times the interior diameter of the larger section. For compound structures, the effects of tolerances are more critical. An improper overlapping would cause fabrication and utilization problems. Therefore, it is better to perform the assembling in the factory as far as possible. It is necessary to encode the sections with fixed color before connecting; so they could be connected in correct direction and position.

3.1.3. Crossarms Connection and Other Attachments

The position of attachments and connections should be placed correctly for coordinates and direction. Any kind of disconformities can lead to changes in the crossarm's direction and clearances. Having easy erection and preventing time and cost waste for repairs are the results of accuracy in creating holes. Excessive fabrication error in connections would cause eccentricity and would create extra stresses.

3.2. Climbing Provisions

Some measures should be taken to make all parts of pole's structure and other attachments accessible. Fixed or removable steps can be used for this purpose. Steps should be designed in such a way not to deform permanently under one's weight plus the equipment's weight (130 kg in total).
Steps should begin at least from 2.5 m above ground level to prevent pedestrian's accessibility and continue to the pole's top. Steps' distance will be 30-45 cm. Safety distances from electrical parts to one's body should be considered.

3.3. Drawings and Documents

These provisions are in accordance with section (2.9). It is also necessary to define clearly the details and special considerations of welding in shop drawings.

3.4. Executive instructions

In this section, executive instructions for installation of steel poles, are presented. In case of any contractor suggestion which is different from these criteria, they should be approved before implementation.

3.4.1. Handling and Erection

Pole structures should be erected in accordance with the manufacturer's recommendations. The methods of handling and erection and the used equipment should be such that the poles, crossarms, and other components will not be damaged and will not be subjected to loads in excess of those for which they were designed. Special handling instructions, if required, should be fully specified on the erection drawings.

Normally, nylon or polypropylene rope can be used without special padding. Wire rope slings should require padding to prevent damage to the surface of the poles. Wood blocking and cribbing should be used for supporting poles and pole sections during storage and assembly (if poles are assembled on the ground). Bent, twisted, damaged, or misfabricated parts should not be installed until reviewed by qualified personnel. Any field straightening or repair should be approved by the supervisor. No field holes or alterations should be allowed in a pole or accessories unless approval is obtained from the manufacturer.

3.4.2. Slip Joint Assembly

When poles with slip joint sections have assembled, care should be taken to assure correct alignment and orientation. Material, e.g., dirt, gravel, or vegetation, must be removed from the slip joint surface. The two sections should be pulled together using approved procedures to achieve the specified overlap and assure a tight joint. Each section (both male and female) should have marks for proper section assembly, axis orientation and splice overlap.

3.4.3. Bolted Connections Assembly

When pole sections are equipped with flanges, a small angular error in attaching the flanges could result appreciable variation in the alignment of the completed pole. Care should be taken to avoid supplying flanges with a convex connection face.

If flange plates have a gap in excess of 0.8 mm, they should be returned for grinding or other suitable finishing operations. Otherwise, properly designed shims may be installed. All bolts should be installed with proper torque.

3.4.4. Field Tolerances

Normally, the visual inspection is used to control the tolerance. It is essential that this check be made at a time when the sun does not cause an unequal temperature on each side of the pole. The following suggested tolerances may be adjusted if visual considerations are not a critical factor. When poles are set on anchor bolts, the pole should not be displaced horizontally from the specified alignment more than 1% of the height.

Maximum distance between the center of the anchor bolt group and the specified location is 3 Cm. Accuracy of anchor bolt position should be sufficient to allow fitting with the oversize holes in the base plate assembly. The angular variations in the specified location of the anchor bolt group should not exceed 1° for a single pole.

Care should be taken to prevent anchor bolts and threads damage during placing of concrete and erection of the poles. Nuts should operate on bolts threads without extra forcing.

After pole erection, the hold down nuts on the anchor bolts should be secured with a suitable locking device, a second nut, or by applying a predetermined torque value.

4. Concrete Poles

4.1. Design Considerations

Concrete poles should be designed to bear all forces considering prestressing, shipment, erection and other conditions. The above mentioned forces should not damage the section resistance, service capability and the section appearance.

Under the corrosive environment and/or in tension situation, poles should be designed to prevent cracks for service loads with a 10-year return period in sections.

4.2.Materials

4.2.1. Cement

The Portland cement should meet requirements of ASTM C150. Portland cement can be also mixed with hydraulic cement and/or pozzolan according to ASTM C595.

Loading, shipment and unloading should be done carefully and the cement should be protected from rain and humidity. Storing the cement is just allowed in silos. Keeping and storing cement in places with the relative humidity more than 90 % should not last more than 6 weeks in cement bags and more than 3 months in proper silos. Generally, it is necessary to take the measures of Iranian Standard No.2761.

4.2.2. Aggregate

Used aggregates can be either fine aggregates or coarse aggregates and they can be prepared according to ASTM C33 for common aggregates and ASTM C330 for light aggregates; except for the cases mentioned in this section.

Maximum nominal dimension of coarse aggregates should not be more than $\frac{1}{5}$ times of the smallest dimension of a member, $\frac{3}{4}$ times of distances among rebars and/or $\frac{3}{4}$ times of concrete's coating.

Aggregates should be clean and solid without any chemical materials, organic compounds, salt, plaster coatings, clay and other fine materials which affect their cohesion on cement gel. Also aggregates should not have the potential of alkaline reaction.

Aggregates should not seem scaled, needle-like, fragile, inflatable, perforated and should not be made of fine aggregates. The percentage of scaled and needle-like aggregates in coarse aggregates should not exceed 15 %. For used concrete in littoral regions of Persian Gulf and Oman Sea, the maximum water absorption of used aggregates in concrete for coarse aggregates is limited to 2.5 % and for fine aggregates to 3 %.

4.2.3. Water

Consumed water for washing aggregates and curing the concrete should be clean and clear. Waters with lots of materials such as oils, acids, alkaline, salts, saccharin and organic materials should be prevented for their effect on concrete or rebars. The harmful materials of consumed water in concrete should not exceed the maximum allowable amount given in the table (6).

Table (6): Maximum allowable harmful materials in concrete water

Harmful material	Description	Maximum allowable concentration (ppm)
Solid suspense particles	RC in hard environment / Prestressed concrete RC in normal environment	1000 2000
Solved materials	RC in hard environment / Prestressed concrete RC in normal environment	1000 2000
Chloride	RC in hard environment / Prestressed concrete RC in normal environment	500* 1000*
sulphate	RC and Prestressed concrete	1000
Alkaline	(Na_2O+0.658 K_2O)	600

* Also see table (7).

Generally, drinking water is considered satisfactory for curing the concrete. Undrinkable water can be used if it is in accordance with following considerations and table (7).

A. 7-day and 28-day resistances of mortars specimens mixed with undrinkable water are equal at least to 90 % resistances of the similar specimens mixed with distilled water.
B. The time of cement curing with undrinkable water should not be more than 1 hour sooner and 1.5 hour later than the cement curing resulted from distilled water.
C. The health test result of cement mixed with undrinkable water should not be more than the allowable amount related to distilled water.

Table (7): Maximum solvable chloride in concrete water

RC segment	Maximum solvable chloride in concrete water (with respect to cement's weight %)
Prestressed pole	0.06
RC pole in humid condition	0.15
RC pole in dry condition	1.00

PH of consumed water in concrete should neither be less than 5 nor more than 8.5. Concrete mixture plan should be determined on the basis of the water used in the workshop.

4.2.4. Admixtures

Air-entraining admixtures should be used according to ASTM C260. Chemical admixtures should be used according to ASTM C494. Fly ash and other used Pozzolan should meet the requirements of ASTM C618. However, the amount of chloride ion in admixtures should not exceed the amounts given in Table(7).

4.2.5. Steel

Prestressing steel should be according to ASTM A416/A416M, ASTM A421 or ASTM A722/A722M. Longitudinal rebars should be according to ASTM A615/A615M or ASTM A494. Stirrups should meet ASTM A82, ASTM A496 or ASTM A641.
All attachments in the section should resist corrosion. It is not allowable to use aluminum in concrete.

4.3. Compressive Strength of Concrete

Minimum compressive strength of 28-days concrete used in poles is 50 MPa (500 kg/cm^2). The method of determining the compressive strength is based on ASTM C39 or ASTM C42. Test cylinders of compressive strength should be prepared based on ASTM C31 or ASTM C172.

4.4. Cover

The minimum cover for concrete poles produced by static casting is 25 mm and for poles produced by centrifugal method with tube section is 20mm. The end point of prestressing tendons should withdraw 6mm and be filled with water proof construction materials.

4.5. Stirrups

Maximum stirrups distances should be 10 cm. On a distance of 30 Cm and at the two ends on the top and bottom of the pole, maximum distance between stirrups should be 2.5 cm.

4.6. Mixture

Aggregates should be washed and graded and properly mixed with water, cement and admixtures such that the cured concrete would meet the required quality. In this case ASTM C94 should be satisfied.

4.7. Casting

Casting should be done when the formwork is located in a position which be close to the final position (vertical) as far as possible. Special attention should be considered on filling up the whole formwork and putting the concrete below and around all rebars. Rebars should be placed and tightened to prevent movement during casting. Wires used to tighten the stirrups, rebars and tendons should bend as far as possible not to prevent proper casting.

4.8. Curing

Concrete poles should be cured by one of the following methods. One hour after the casting, concrete temperature should be neither more than 40°C nor less than 4°C.

4.8.1. Water Curing

Concrete poles can be cured by either water saturated coating or perforated tube system.

4.8.2. Steam Curing

Steam room should be built in such a way to prevent heat and humidity loss and let the steam rotate around the samples. Steam gates should have such design not to blow steam on samples and formworks directly. Steam curing cycle will be done as follows:

A. After casting and before increasing the concrete temperature, concrete should reach to the initial strength of about 3.5 MPa. It may be done according to ASTM C403. If the ambient temperature decreases to less than 15°C, it should be heated to let concrete temperature stay at casting temperature.
B. Temperature increase in curing container should be uniform and with a rate of 17°C to 33°C per hour. Concrete should be cured in temperatures from 54°C to 74°C to reach its expected strength.
C. Cylindrical samples should be cured in the similar conditions with poles.
D. To record time–temperature relationship during curing process, it is necessary to use recording thermometers from casting process to prestressing.

In addition to the mentioned methods, curing with other methods should be according to the valid standards and it should be confirmed by the client.

4.9. Prestressing

Before initial prestressing, the concrete should reach to the strength more than 35 MPa and 1.67 times the expected maximum stress in the concrete (created in the concrete from prestressing forces immediately after the force transferring and before the loss). The sequence of pulling tendons in post-tensioning should be done in a way to prevent the unwanted temporary stresses.

4.10. Formwork

Formworks should be rigid and stable enough to bear the concrete weight without excessive deflections. Water leakage in the formwork should be removed as far as possible. All formworks should be designed not to damage the concrete while separating from it. All visible concrete edges with angles less than 100 degrees should be round.
Formworks should be cleaned before every usage. New formworks should not have any kind of color or coating which may stick to the pole's surface.

4.11. Surface Polishing

Surface polishing should be done according to the supervisor's suggestions.

4.12. Imperfections

4.12.1. Length

The error in length dimensions should not be more than 50mm or 30mm per each 3m length of pole, whichever is greater.

4.12.2. Section

A. External thickness: deviations of the pole's external thickness in compare to the design dimensions should not exceed more than 6 mm.
B. Wall thickness: in hollow concrete poles, the wall thickness should not be less than 88% of calculated amount or 6mm less than calculated amount, whichever is larger.

4.12.3. Longitudinal Axis Tolerance

Longitudinal axis tolerance should not be more than 6 mm per each 3 m length. This item is applicable to the whole or part of the structure.

4.12.4. Mass

The whole concrete structure's mass should not differ from design value more than 10%.

4.12.5. Rebars and Tendons Placement

A. Longitudinal rebars: longitudinal rebars and tendons tolerance should not be more than 6 mm from the main location for each and 3mm for the center of a group.
B. Stirrups: stirrups should be placed up to 40mm from the main location, except the two ends on the top and bottom of the pole at 30cm distance in which the accuracy to place the stirrups would be 5mm.

4.12.6. Holes

Deviations of hole's thickness for screwing equipments would be limited to 1.5mm. Deviations of spaces among holes would be limited to 3mm for one hole and to 25mm for the central line of the hole group.

4.13. Tests

4.13.1. Concrete Compressive Strength

A. Concrete compressive strength test should be done according to ASTM C39 using standard cylinders. To do so, two samples per $8m^3$ casting with at least two samples per mixture process should be taken.
B. In steam curing conditions, samples should be cured in similar conditions. If poles are cured in normal temperature, it is necessary the samples to be cured according to ASTM C31.
C. The average compressive strength of all cylindrical samples should be more than or equal to required compressive strength. The strength of any sample should not be less than 80% of the required compressive strength of concrete in any condition.
D. If criteria of item (C) could not be followed, some cores should be taken from concrete poles and the compressive strength of them should be determined. This should be done according to ASTM C42. Number of tests will be based on item (A) and its results should satisfy the norms in item (C). If the test results do not meet the least requirements, mentioned poles can be used in other applicable situations.

4.13.2. Loading Test

A. Loading test should be done on a pole with actual dimensions. Poles can be loaded horizontally or vertically. However, ends should be properly stable. It is necessary to apply some arrangements to remove the structure's weight if the test is performing horizontally.
B. Number of tests and test sequence, method of loading, situation, the direction of applied loads and the location of strain gauges should be defined by the client.
C. Contractor should complete and present the report form of the pole's test. These records consist of all recorded results with detailed drawings.

4.14. Rejecting Conditions

Produced poles may be rejected either mentioned technical specifications is not satisfied or for one of the following reasons:

A. A defect showing improper construction materials, concrete mixture and formwork.
B. Surface defects consisting of perforated concrete or showing places with no casting.
C. Existence of damaged and cracked areas which prevent section to meet design requirements.
D. Tendons prestressing loss

Manufacturer should not remove the visible failures without supervisor's permission. Since local fabrication problems or any kind of damaging in shipment is sometimes unavoidable, section repair may be done but it is necessary to obtain the permission of supervising agency to do that.

The repaired sections should be in accordance with the technical specifications and should be confirmed by the supervising agency after getting repaired.

4.15. Drawings and Documents

4.15.1. Documents to be given by tenderer

- Detailed specifications of the concrete support
- Specifications of the concrete (include: supply, 28-day strength, admixtures, etc.)
- Complete specifications of rebars and tendons
- Maximum total weight of concrete support
- List of codes and standards
- Detailed summary of exceptions in specifications
- List of special tools
- Method of prestressing in poles

- A summary of tests methods
- Packaging, shipment, storage, erection and maintenance instructions

4.15.2. Documents to be given by contractor / supplier

Design, fabrication, packaging, marking, shipment, storage, erection and tests drawings and documents which should be delivered are as follow, but not limited to them:

- Design documents to prove the adequacy of the structure (If using software, concepts of applied programs, assumptions, primary data and results should be attached)
- Shop drawings
- Test report and certificates
- Packing, shipment and storage details
- Erection and maintenance details
- Time schedules
- Monthly progress report
- List of drawings
- List of components

Also designer’s presented drawings should include:

A. Dimensions and length
B. Rebars and tendons descriptions and positions
C. Concretes 28-days strength
D. All information relating tendons stress
E. All attached hardware dimensions, positions and descriptions
F. Numbering the poles and other required information

5. Guyed Supports

5.1. Design Considerations

It is necessary for the line designer to determine and review the acceptable methods limits based on local conditions, applicable equipments, and humans' skills. Details relating to structure and other things in relation with safety at fabrication and performance time should be considered while designing the structure. Line designer should consult with erection and maintenance staff and build a proper balance between efficiency and flexibility of the structure and costs using the present experiences. Maximum expected loads resulted from erection and maintenance and their locations should be determined by the line designer.

5.2. Inspection and Maintenance

Guyed structures should be under a clear and scheduled inspection with obvious details just like other transmission line supports. Inspector must complete and present the client's prepared forms on inspecting the structures. It is necessary to consider the following issues for guyed structures in addition to the inspection done for self-supporting structures:

A. Guys' direction and tendency
B. The amount of guys' tension
C. Controlling loose guys

Loose guys usually show the movement of foundations. However, in case of loose guys, the following factors should be considered:

A. Broken guys' strings
B. Anchorage slipping at two ends of guy
C. Existence of slip, crack, bend and break in hardware

5.3. Executive Specifications

In this section, executive specifications for installation of guyed structures, are presented. In case of any suggestion from contractor different from these criteria, they should get approval before implementation.

5.3.1. Construction Considerations

Ease of construction can be enhanced by a number of considerations, both in the design of the structure and in detailing of the connections. Field assembly and erection methods can be influenced by the line design, line route, climatic or seasonal weather conditions, the impact of any environmental restrictions, line route access, schedule requirements, and the availability of critical resources in both manpower and equipment. For example, helicopter might be considered where movement of a large crane is difficult.

Major savings can be made in erection time and cost by quick- connect devices for guy terminations and by taking advantage of the relaxed tolerances permitted by the flexibility of some types of guyed structures. The tolerance limits should be based on the necessary and sufficient performance criteria of the installed structure.

5.3.2. Guyed Poles

5.3.2.1. Erection Methods

It should be noted that guyed poles and H- frames with fixed bases will not have the relaxed erection tolerance of the guyed rigid or masted towers. The location accuracy of the guy anchors is important to the proper functioning of the guyed pole. The design angles of the guys in the vertical and horizontal planes in relation to the pole should be maintained. The deviations from the guy configuration should be approved by the supervisor.

Guyed poles may require two point lifting or other special rigging to prevent excessive deflection and overstress during the lift.

A guyed steel pole with slip type joints should be assembled on the ground with jacking devices. Variations in pole lengths caused by slip lap tolerance can be compensated through placement on the anchor bolts or through embedment length modifications. The jacking force should be less than the maximum design load.

5.3.2.2. Guy Installation

Some designers may require immediate guy installation for guyed poles with fixed base to resist a specified wind loading. Other designers may use guys only to resist applied conductor and ground wire loads. The structure designer should identify to the installer, time of guy installation and any temporary guying required providing structure stability prior to the line completion.

For angle or dead end poles, the guys are usually installed so that the structure is plumb or has a slight negative deflection under the transverse or longitudinal pulls from everyday cable tensions. This can be done in two ways: (1) by adjusting the guy tensions after the line has been strung, (2) by pretensioning the guys against the pole prior to stringing in such a way that the top of the pole has a specified amount of negative deflection.

If guy pretensions are specified, they should be applied by the structural engineer within the construction tolerances.

5.3.3. Guyed Rigid Frames and Latticed Towers

5.3.3.1. Erection Methods

Guyed frames and towers may be erected by any proper method that suits the terrain and access conditions, worker experience, and available equipment.

Vertical loads have negligible effect on the guy tensions. So, adjustment of guy tensions after stringing of tangent structures is not necessary. However, it is necessary to adjust guy tensions after stringing through a guyed angle or dead-end structure.

5.3.3.2. Crane Erection

The guyed structure should, if possible, be tilted up as a complete unit. However, at particularly difficult sites, guyed structures could be erected section by section using temporary guys.

5.3.3.3. Helicopter Erection

Helicopters can be used to lift the entire structure (sometimes complete with insulator assemblies, stringing blocks, and finger lines) from the assembly yard to the site, or to tilt-up the structure assembled on the ground directly on its foundation.

Moving the assembly from the tower site to a flat open assembly yard has the advantages of:

A. Reducing the loss of pieces and elimination of delay due to the such losses.
B. Reducing clearing and grading of the site.
C. Reducing the costs of transport of the assembly workers to the various sites.
D. Reducing assembly costs. Assembling 40 or more structures at one site produces economies when power equipment can be used for bolt tightening, and the guys can be measured, cut, fitted, and attached before the structures are moved.
E. Reducing environmental impact (minimum access road work).

Other items should be considered are as follows:

A. Provisions for attachment of guide members to the structures.
B. Adequacy of helicopter lifting capacity at the site altitude and ambient temperature.
C. Proper consideration of weights, centroids, and lifting points.
D. Whether workers will be allowed on or under a structure during installation.

The greatest efficiency is in savings of cost, time, materials, and impact on the land will be reached when the helicopter is introduced at the start of the design work and planning of construction.

5.3.3.4. Guy Installation

Top ends of the guys have a permanent nonadjustable dead-end fitting and these are attached to the top of the masts or crossarms before erection of the structure. Attaching the guys to the anchors, plumbing of the structure, and then pretensioning of the whole system can be done by at least two different methods.

a) Traditional method

The guys are cut to approximate length (but always slightly longer than needed), permanently attached at their tops to the structure, and attached at their bottoms with temporary grips or other wedge- type devices. The structure is held in approximate plumb position by crane or helicopter while some block and tackle or tensioning device takes up the slack in each guy and holds the structure in place.

Surveying equipment and plumb bobs are used while the structure is brought in to proper alignment by tightening and slackening the guys.

This operation can involve many person- hours, especially if close and rigid specifications have been set regarding the positioning of the tower and the pretension levels.

b) Alternate Method

This method is advantageous if one accepts the fact that relaxed or more liberal than usual tolerances can be applied to the erection of guyed rigid frames and masted towers. Theses relaxed tolerances often will have negligible effect on the strength or performance of the structures. The tolerances are needed to ensure that the structure is vertical.

The human eye cannot detect if a standalone (not in a line) mast or tower is out of plumb by less than about one degree. 0.5 degree has been accepted by some as a limit that would permit the center of the crossarm to be no more than 1% of its height.

In this method, needed guy lengths are calculated. Guys are then cut and three of them fixed to length with simple dead-end fittings, and an adjustable device added to one only. Upon erection of the structure it is moved slightly at the top to permit direct attachment of three of the guys to their anchors and finally the fourth is attached and the desired pretension introduced.

The alternate method requires that the lengths of the three guys and their fitting be accurate to about 0.3% of calculated length, which is a reasonable degree of precision.

5.3.4. Guy to Structure Connection

Method of connecting the guys to structure varies with type of structure. For steel and concrete poles, throughout bolts or buckles are used. In steel poles, an external piece may be welded to pole for guy connection.

5.3.5. Tensioning Devices

Permanent tensioning devices are usually installed only at the lower end of the guys. Guyed structures have traditionally been erected with guys attached at their tops and with temporary fittings and tackle to the anchors while the structure is made almost plumb. Permanent grips are installed and final positioning and pretensioning are done with some from of threaded device.

5.3.6. Erection Tolerances

The erection tolerances have to be specified for the parameters:

a) The vertical alignment of the tower
b) The anchor locations, the anchor rod alignment, and the backfill compaction
c) The precut length of fitted guys.

5.3.6.1. Guyed Poles and H- Frames

Guyed poles should be set in a straight vertical position. The horizontal offset tolerance should be within 75 mm. The vertical tolerance should be within 150 mm from the specified setting depth.

On guyed H- frames, a maximum of 75 mm elevation difference is allowed between the two adjacent poles and a maximum of 50 mm horizontal offset between the two H-frame legs.

Guy anchors can be relocated within 1 m radius of the original design location and the repositioning of the anchor should be documented and reported to the engineer for further analysis.

A tolerance of 10% of the specified guy pretension is considered practical.

5.3.6.2. Guyed Rigid Frames and Masted Towers

The overall verticality of the structure should be based on a limiting requirement that the structure does not appear to be out of plumb to the human eye. An acceptable value is one- half degree.

Thus, for a structure such as the guyed V or the guyed portal, the center point of the crossarm should not be more than $\frac{1}{100}$ of the height from the structure center point on the ground.

Relocating the anchor may cause the guy to load the structure differently from that assumed in design. These changes in structural loading need to be considered before construction begins. The location of the anchor rod should have a tolerance of ±2% of the structure height from the staked location. The anchor rod alignment should be within ±5 degrees to the specified guy angle.

5.3.7. Grouted Anchors

A hole is predrilled at the same angle as the guy. A steel rod is inserted in the hole and is then grouted. The hole size for rock anchors ranges from 1.5 to 3 times the diameter of the rod. Before grouting, the holes should be washed and water allowed standing in the holes overnight. Prior to installation of the anchor bar, the holes are blown clean. Usually the grout is a water- cement mixture with a ratio about 0.4 to 0.45.

Typical ultimate bond stress values between the grout and rock for rock anchors are shown in table8.

It is strongly recommended that core drilling be performed to explore the rock quality, and core testing to determine the rock strength.

Table 8: Typical ultimate bond stresses between grout plug and rock

Rock Type	Ultimate Bond Stress* kPa
Granite and basalt	1700-3100
Dolomite limestone	1400-2100
Soft limestone	1000-1500
Slates and hard shales	800-1400
Soft shales	210-800
Sandstone	800-1700
Concrete	1400-2800

**Bond strength must be confirmed by pullout tests which include time creep tests.*

Grouted anchors in soil are very similar to those installed in rock.

A water- cement grout mixture is inserted by gravity or under pressure. Injecting the grout will increase the capacity of the anchor and is dependent on the soil- grout interface. As with grouted rock anchors, it is recommended that proof testing be conducted after installation.