Entertainment Services and
Technology Association

American National Standard
E1.21 - 2006
Entertainment Technology
Temporary Ground-Supported Overhead Structures Used to Cover the Stage Areas and Support Equipment in the Production of Outdoor Entertainment Events

Rig/2002-2003r6

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The ESTA Technical Standards Program

The ESTA Technical Standards Program was created to serve the ESTA membership and the entertainment industry in technical standards related matters. The goal of the Program is to take a leading role regarding technology within the entertainment industry by creating recommended practices and standards, monitoring standards issues around the world on behalf of our members, and improving communications and safety within the industry. ESTA works closely with the technical standards efforts of other organizations within our industry including USITT, PLASA, and VPLT as well as representing the interests of ESTA members to ANSI, UL, and the NFPA. The Technical Standards Program is accredited by the American National Standards Institute as Accredited Standards Committee E1, Safety and Compatibility of Entertainment Technical Equipment and Practices.

The Technical Standards Committee (TSC) was established by ESTA's Board of Directors to oversee and coordinate the Technical Standards Program. Made up of individuals experienced in standards-making work from throughout our industry, the Committee approves all projects undertaken and assigns them to the appropriate working group. The Technical Standards Committee employs a Technical Standards Manager to coordinate the work of the Committee and its working groups as well as maintain a "Standards Watch" on behalf of members. Working groups include: Camera Cranes, Control Protocols, Electrical Power, Floors, Fog and Smoke, Photometrics, and Rigging.

ESTA encourages active participation in the Technical Standards Program. There are several ways to become involved. If you would like to become a member of an existing working group, as have over two hundred people, you must complete an application which is available from the ESTA office. Your application is subject to approval by the working group and you will be required to actively participate in the work of the group. This includes responding to letter ballots and attending meetings. Membership in ESTA is not a requirement. You can also become involved by requesting that the TSC develop a standard or a recommended practice in an area of concern to you.

The Rigging Working Group, which authored this standard, consists of a cross section of entertainment industry professionals representing manufacturers, consultants, dealers, and end-users. ESTA is committed to developing consensus-based standards and recommended practices in an open setting. Future Rigging Working Group projects will include updating this publication as changes in technology and experience warrant, as well as developing new standards and recommended practices for the benefit of the entertainment industry.

Contents

Appendix A, Commentary (This appendix is informative and contains no mandatory requirements)

Foreword

(This foreword contains no mandatory requirements and is not part of E1.21)

There has been no specific American National Standards that cover temporary stage roofs in the entertainment industry. It should be noted that other ANSI Standards may be relevant, depending on the application and intended use. In an attempt to improve safety and standards in the industry, the Entertainment Services and Technology Association (ESTA) convened a series of meetings to prepare a draft standard.

It has been assumed in the drafting of this standard that the execution of its design provisions are entrusted to appropriately qualified and experienced people, and that the fabrication and use is carried out by qualified and suitably experienced people and organizations.

This standard presents a coordinated set of rules that may serve as a guide to government and other regulatory bodies and municipal authorities responsible for the guarding and inspection of the equipment falling within its scope. The suggestions leading to accident prevention are given both as mandatory and advisory provisions; compliance with both types may be required by employers of their employees.

Safety codes and standards are intended to enhance public safety. Revisions result from committee consideration of factors such as technology advances, new data, and changing environmental and industry needs. Revisions do not imply that previous editions were inadequate.

Compliance with this Standard does not of itself confer immunity from legal obligations.

This document uses annex notes to provide additional reference information about certain specific section requirements, concepts, or intent. Subject matter with a corresponding annex note reference is identified by the asterisk (*) symbol, and the associated reference text is found in Appendix A, Commentary, identified with the referring text section number – e.g. an annex note to section 3.2 will be identified in Appendix A, Commentary as A.3.2. The annex notes are informational only, and do not add or subtract from the mandatory requirements of this standard.

1* Scope

This document establishes a minimum level of design and performance parameters for the design, manufacturing, use and maintenance of temporary ground-supported overhead structures used to cover the stage areas and support equipment in the production of outdoor entertainment events.

The structures within the scope of this standard are ones in which the structural elements are rigid towers, trusses, and space frames. Membrane structures and other structures in which the majority of the structural elements under tension are made of flexible elements such as cable are not included in the scope of this standard. This document offers guidance to ensure the strength and structural reliability of these structures and does not address fire safety and safe egress issues.

2* Definitions

2.1 ASCE: American Society of Civil Engineers.

2.2 Allowable load: Maximum static equivalent load imposed on the structure in addition to the self-weight (i.e. lighting, sound, audio visual equipment, props, scenery, etc.).

2.3 AWS: American Welding Society.

2.4 Base plate: The component or part of the structure that spreads axial load to the on-site supporting material

2.5 Blockage: Any object, whether a part of the structure or part of the payload, that impedes or changes the airflow in and around the structure.

2.6 Buckling: Permanent lateral displacement of a compression member from the original centerline under axial load, usually sudden.

2.7 Competent person: A person who is capable of identifying existing and predictable hazards in the workplace and who is authorized to take prompt corrective measures to eliminate them.

2.8 Components: Parts of a whole.

2.9 Consumable: Supplies that are depleted in the course of their intended use (e.g. welding rod).

2.10 Damage: Condition that adversely affects the intended use of structural component (usually load carrying capacity).

2.11 Dead load: The self-weight of the structure as a whole and all of the necessary components and covering.

2.12 Designer: A person who creates the plans for the structure.

2.13 Diagonal: Elements of the truss or tower module that are at an angle to the main chords.

2.14 Effective wind area: The surface area exposed to wind.

2.15 Incident: Occurrence where damage to one or more structural elements is or may be sustained.

2.16 Live load: The variable load or weight borne by a structure, in addition to its own weight.

2.17 Lock-off: Means of supporting the allowable load of a structure in a fixed position, independent of the lifting device(s).

2.18 Manufacturer: Person or company who fabricates temporary stage roof systems.

2.19 Module: Singular framed structure that is built up entirely from tension and compression members, arranged in panels so as to be stable under load.

2.20 MPH: Miles per hour.

2.21 Orthogonal: Composed of right angles

2.22 Payload: The variable load or weight borne by the structure.

2.23 Ponding: Accumulation of water that does not drain off a surface.

2.24 Qualified person: A person who, by possession of a recognized degree or certificate of professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve problems relating to the subject matter and work.

2.25 Regular service: Normal repetitive use.

2.26 Repetitive use: Components of roof structure assembled and dismantled on multiple occasions.

2.27 Shall: Indicates that the rule is mandatory and must be followed.

2.28 Should: Indicates that the rule is a recommendation, the advisability of which depends on the facts and conditions in each situation.

2.29 Skin: A material cover to a truss structure (usually on a roof system).

2.30 Soleplate: The foundation framing or part, that supports and/or holds the other parts in place.

2.31 Superimposed load: Loads associated with rain, snow, ice, etc.

2.32 Temporary: A period of time that is less than 6 weeks in duration.

2.33 Tower: One or more modules assembled vertically to support primarily axial load usually square or triangular.

2.34 Truss: One or more modules assembled to support load over a distance, generally horizontal, primarily in flexure.

2.35 User: The User is the person or company who assembles or uses the roof structure and as such is responsible for the safe erection, proper use and safe dismantling.

3 Design and Engineering

3.1 Intent

The intent of this section of the standard is to provide the minimum basis on which temporary demountable roof structures shall be designed. This section cites the various standards that should be used in conjunction with this standard.

3.2* Design

3.2.1 Design shall be performed in accordance with established engineering practice.

3.2.2 Temporary demountable roof structures shall be designed to support specified loads in accordance with the referenced standards.

3.2.3 All relevant standards shall be used in the design of the roof structure and shall be dependant on the intended conditions of use. These would include, but are not be limited to, the latest versions of the following standards and documents:

3.2.3.1 ASCE 7, “Minimum Design Loads for Building and Other Structures”

3.2.3.2 ASCE 37, “Design Loads on Structures During Construction”, section 6 only.

3.2.3.3 ANSI E1.2, Entertainment Technology – Design, Manufacture and Use of Aluminum Trusses and Towers

3.2.3.4 ASCE 19 “Structural Applications of Steel Cables for Buildings”.

3.2.3.5 The Aluminum Association, “Specifications & Guidelines for Aluminum Structures”

3.2.3.6 American Institute of Steel Construction (AISC) –”Specifications for Design, Fabrication and erection of Structural Steel Buildings”.

3.2.3.7 American Institute of Steel Construction, “Code of Standard Practice for Steel Buildings and Bridges”

3.2.3.8 American Institute of Steel Construction, “Allowable Stress Design Manual of Steel Construction”

3.2.3.9 American Institute of Steel Construction, “Load and Resistance Factor Design Manual of Steel Construction”

3.2.3.10 IBC, International Building Code.

3.2.4 Welds shall be designed and detailed in accordance with the latest version of the appropriate AWS Standard.

3.2.5 Fasteners shall be designed in accordance with relevant standards.

3.2.6 Concrete work and testing shall conform to all the requirements of American Concrete Institute (ACI) 301, “Specifications for Structural Concrete for Buildings”

3.2.7 All conditions of use considered in the design shall be explicitly outlined in the engineering documentation.

3.2.8 The strength of individual components or assemblies can be established using either Load Factor Resistance Design or Allowable Stress Design methods, or by physical testing.

3.2.9 No increase in allowable stresses for wind or wind in combination with dead loads is permitted.

3.3 Analysis

3.3.1 The analysis of roof structures for the intended load conditions shall be performed by calculation, modeling, physical testing or combination of these methods.

3.3.2 The analysis shall consider the worst combination, application, and configuration of loads and effects possible within the use guidelines. Load combinations shall be determined by referencing ANSI / ASCE 7 or the applicable building code.

3.3.3 Consideration shall be given to overall structural stability and bracing requirements for all applications within the use guidelines.

3.3.4 Consideration shall be given to the effects of eccentricities in element and module connections.

3.3.5 The deflections of the individual structural elements and the overall deflection of the roof structure due to the design loads shall be determined within the structural calculations.

3.3.6 The allowable deflections of the structural elements shall be such to ensure that ponding of rain water does not occur.

3.4 Engineering Documentation

3.4.1 Engineering drawings of the structural elements shall be developed and maintained as well as general arrangement drawings of the roof structure.

3.4.2 Engineering drawings shall include dimensions, components, subassemblies, material types, fastener types and specifications, weld sizes and types, and welding consumables.

3.4.3 Engineering calculations, design notes and/or test results shall be developed and maintained that demonstrate compliance with this standard for the intended load conditions and uses.

3.4.4 The User Information shall contain definitive statements about the Operating Limits of the roof structure including but not limited to the following:

3.4.4.1 Allowable payload

3.4.4.2 Design wind speed

3.4.4.3 Assumed effective wind area inclusive of structure and equipment suspended from or attached to the structure

3.4.4.4 Allowable lateral load

3.4.5 A summary sheet shall be prepared showing all the design loadings and operating parameters of the roof structure and shall be provided with the structural calculations that form part of the engineering documentation.

3.4.6 The engineering documentation shall include:

3.4.6.1 Comment about changes in roof wind pressures when blockage under canopy is changed.

3.4.6.2 Comment about changes in wind pressures on roof coverings if side walls or back drops are added

3.4.6.3 Any specific limitations regarding the addition or roof coverings and/or backdrops.

3.4.7 The proposed guy arrangements, guy forces and hold down requirements shall be reported in the design calculations provided with each roof structure.

3.5 Loadings

3.5.1* Seismic Loading

3.5.1.1 Loading associated with seismic activity for the intended locale shall be considered.

3.5.1.2 A reduction in seismic loading may be permitted consistent with the duration of the intended use.

3.5.2* Wind loading

3.5.2.1 The wind load on all exposed surfaces including but not limited to truss and tower sections, scaffolding, roof skin, back drops, banners, advertisements, and suspended equipment shall be considered.

3.5.2.2 The overall stability and resistance to wind uplift and overturning forces shall be provided by means such as wire guys anchored to ground anchors (or ballast), diagonal braces, ballast applied to the tower sections, self weight of roof top (the dead load) and live loads.

3.5.2.3 The design wind speed for structures as defined by this document shall be 0.75 times the basic wind speed defined in ASCE 7.

3.5.2.4 Where a structure will be erected in an area prone to hurricanes, and precautionary measures can be taken such as dismantling and adequate securing in the event of a hurricane warning, a basic wind speed of 90mph, 3 second gust, shall be allowed per ASCE 37, section 6.2.1.

3.5.2.5 A reduction in effective wind area can be permitted, provided that such elements can be removed in less than 5 minutes. The method of wind monitoring and removal of the equipment shall be clearly defined in the Operations Management Plan. Not withstanding

the above, the structure shall be designed to resist wind forces on all elements associated with the design wind speed of 40mph.

3.5.3 Operations Management Plan

3.5.3.1 The Operations Management Plan shall be prepared by the User and his engineering advisors. Reference shall be made to Clause 5.2.3 of this document.

3.5.3.2 The Operations Management Plan shall be based on sound engineering analysis and the allowable loads as defined in the engineering documentation.

3.5.3.3 The Operations Management Plan shall define the actions to be taken for different parts of the structure and cladding (where applicable) under prescribed loading conditions, with particular regard to wind loads.

3.5.3.4 No action shall be taken that shall reduce the overall lateral stability of the structure.

3.5.4* Load considerations

3.5.4.1 A load case shall be considered when the roof structure is being assembled and no payload is applied.

3.5.4.2 If the allowable wind speed during installation is less than the maximum design wind speed, then this shall be expressly stated in the structural calculations that form part of the engineering documentation.

3.5.4.3 All load combinations shall be considered per ASCE 7.

3.5.4.4 For all load combinations and all stability calculations, a margin of safety against overturning and sliding of not less than 1.5 shall be applied.
(1.5 x overturning moment < 1.0 x restoring moment)

3.5.4.5 Wind shielding from adjacent structures shall not be considered unless demonstrated by sound engineering principles. Additionally, consideration shall be made for site specific wind load increases due to funneling from adjacent structures.

3.5.5* Superimposed loads such as rain, snow, ice, etc

3.5.5.1 All roof structures shall be designed for a minimum superimposed live load of 5 psf (24.4kg/m) uniformly distributed across the whole roof area. This load need not be considered in combination with payload.

3.5.5.2 Measures shall be taken to prevent ponding of the roof covering between the structural members.

3.5.5.3 Temporary demountable roof structures are not generally designed to withstand loads associated with ice and snow. No snow load need be considered if the structure is to be used in a locale where snow is not possible during the envisaged use.

3.6 Lifting Devices

3.6.1 Lifting devices shall be used in accordance with the guidelines and recommendations of the manufacturer.

3.6.2 Where the lifting devices are designed for erection of structure only, lock-off devices shall be used.

3.7* System Erection

3.7.1 Where applicable, the structural adequacy of the towers shall be checked for the following design cases:

3.7.1.1 The towers are being raised from horizontal to vertical

3.7.1.2 The towers are vertical and the roof grid is at low level and is supported by the lifting devices.

3.7.1.3 As above with the roof grid being raised from a low level to a high level.

3.7.1.4 As above, with the grid supported by lock-off devices

3.7.1.5 As above, with the guy wires attached

3.7.2 Consideration shall be taken of the effective length of the tower when determining the structural strength as determined by generally accepted principals of engineering mechanics.

3.7.3 Reference shall be made to American Institute of Steel Construction “Allowable Stress Design Manual of Steel Construction” for factors to determine effective length of compression elements.

3.7.4 An allowance shall be made for sway when determining the structural strength of an unguyed tower. Unguyed towers must be able to sustain a horizontal load at the top of the tower of 0.75% of the vertical load in the tower in either of two orthogonal directions at any one time.

3.7.5 In a structure designed with vertical towers, a sway force can be generated by a lack of verticality. The maximum out of plumb to tower height ratio shall not exceed 0.5% (i.e. a tower shall not be out of plumb by more than 75mm (3 inches) at a tower height of 15 meters (50feet)).

3.7.6 Screw jacks, if used, should be adjusted so that they are in contact with the ground before and after the tower is lifted into position.

3.8* Ground Conditions and Foundations

3.8.1 General

3.8.1.1 Structures shall be supported on foundations of such a size that the allowable bearing pressures and settlements, if defined in the engineering documentation, are not exceeded.

3.8.1.2 In a structure designed with vertical towers, no differential settlement shall be permitted that results in any tower being out of plumb in accordance with 3.7.5.

3.8.1.3 The required capacity and maximum extension of any screw jacks shall be stated in the engineering documentation.

3.8.1.4 Supports shall be positioned far enough apart so that there is no interaction between adjacent foundations, with a minimum distance of 2 horizontal meters (6.5 feet) unless the interaction between foundations is considered.

3.8.1.5 Each tower shall be founded on suitable level bearing strata as defined by the designer.

3.8.2 Tower bases

3.8.2.1 It is essential that the towers be erected so that they are vertical and that all legs of a tower base have equal contact with the surface of the ground.

3.8.2.2 Where adjustable legs such as screw jacks are used, they should be inspected and adjusted, as required, each time the roof is raised or lowered and when the roof is raised or lowered and when the roof has been left in one position for a period of time.

3.8.3 Ground bearing capacity

3.8.3.1 Design calculations should be prepared to show how the loads are transferred to the founding strata.

3.8.3.2 Adequate spreader plates shall be used under the tower bases and screw jacks, as appropriate, to ensure that allowable soil bearing pressures are not exceeded.

3.8.3.3 Soleplates and base plates should be positioned centrally under the load unless indicated otherwise in the design documentation.

3.9* Lateral Stability

3.9.1 General

Correct installation and use of these types of structures is dependent upon close coordination of structure design (as determined by the manufacturer) and installation (as controlled by the User). The structure shall be designed by the manufacturer with means for adequate lateral stability. Design of the lateral stability installation (which is site specific) is the responsibility of the User.

3.9.2 Guy and Cross-bracing Cable Assemblies

Where guy and cross-bracing cable assemblies are used the following clauses shall apply.

3.9.2.1 Guy and cross-bracing cable assemblies shall be provided, where necessary, to transfer the lateral forces that are imposed on the roof structure to the ground.

3.9.2.2 All cable components shall have a safe working load equal or greater than the design loads.

3.9.2.3 The cables must be purpose-made steel cable with purpose-made connectors at each end. Wire rope assemblies shall be constructed in accordance with ASCE 19. Other materials may be allowed subject to compliance with appropriate standards.

3.9.2.4 A means of adjusting the tension in the guy cables shall be provided as part of the assembly.

3.9.2.5 The safe working load of the cable assemblies shall be as defined in the structural calculations.

3.9.2.6 Guy cable assemblies shall be appropriately founded to resist design loads.

3.9.3 Ground Anchors

3.9.3.1 If ground anchors are used, then they shall be designed and installed in accordance with the manufacturer's guidelines and recommendations, taking into consideration the length of time that the structures will be in place and the soil conditions at the location where the roof structure is to be erected.

3.9.3.2 The anchors shall resist the design loads with an appropriate factor of safety against failure.

3.9.4 Ballast Anchors

3.9.4.1 The ground below any ballast shall be level.

3.9.4.2 The amount of ballast shall be determined by a competent person and is site specific. The weight of ballast required at the termination of each guy cable assembly shall be sufficient to resist slippage and uplift of a minimum factor of safety of 1.5. The ballast required is dependant upon a number of factors included but not limited to the force to be resisted, the nature of the bearing surface, the type of ballast used, the angle of the guy cable to the ground, and the coefficient of friction between the ballast and the ground.

3.9.4.3 Consideration shall be given to the reliance of friction for lateral stability in areas of seismic activity.

4 Manufacturing

4.1 Intent

The intent of this section is to ensure that all manufacturers maintain a satisfactory level of quality throughout the manufacturing process and that each and every component is traceable back to the manufacturer in the event of defect.

4.2 Material

Materials used in the manufacturing of structural components shall comply with applicable material standards as listed in section 3.2.3 of this document.

4.3 Fabrication

4.3.1 Fabrication techniques employed shall be approved by the designer of the structure.

4.3.2 Individual fabricators employed in the manufacturing process shall meet applicable standards of qualification.

4.3.3 All welding shall be performed by AWS certified welders.

4.4 Inspection

4.4.1 Individual components of the structure shall be inspected by a competent person during and after fabrication to ensure the component has been built in accordance with design drawings.

4.4.2 Critical component interaction shall be tested after fabrication

4.5 Identification

4.5.1 The manufacturer shall use certified components and materials that are traceable.

4.5.2 The manufacturer shall be responsible for keeping appropriate records relating to the component and material certification.

4.6 Documentation

Manufacturer provided documentation for roof systems shall include but not be limited to the following:

4.6.1 Complete signed and sealed design calculations and drawings of the overall system.

4.6.2 Complete copy of the engineering documentation as outlined in section 3.4 of this document.

4.6.3 Fire certification of the covering material.

4.6.4 Written instruction, including drawings where applicable, for proper use and maintenance of system and individual components including:

4.6.4.1 Recommended preventative maintenance.

4.6.4.2 Erection and dismantling procedures.

4.6.4.3 Inspection guidelines.

4.6.4.4 Emergency contact information.

4.7 Training

Manufacturer shall provide instruction on proper use of the system including but not limited to the following.

4.7.1 Intended use of structure.

4.7.2 Basic initial on-site training

4.7.3 Operations Management Plan

4.7.4 System limitations

5 Use and Care

5.1 Intent

The intent of this section of the standard is to provide the User with the minimum basis on which temporary stage roofs shall be properly implemented and maintained.

5.2* Pre-Use

5.2.1 The User shall designate a competent person or persons to have overall responsibility on site for the roof structure.

5.2.2 The User shall have adequate knowledge of the engineering documentation for the roof structure configuration in use. Any deviations from the original intended use shall necessitate the engagement of a competent engineer to provide engineering guidance.

5.2.3 The User shall prepare proper layout drawings, engineering documentation, and Operations Management Plan as described in section 3.5.3 of this document for each use.

5.2.4 The User shall be responsible to comply with applicable local codes, standards and regulations.

5.2.5 The structure shall be founded on appropriate base material as specified by section 3.8 of this document.

5.2.5.1 Allowable bearing pressure shall be determined using one of the following criteria:

- As defined by local building code;
- As agreed with the authority having jurisdiction;
- In accordance with the guidelines indicated in tables A2 and A3 in the appendix of this document;
- Reference to any suitable soils report for the site.

5.2.6 Sufficient bracing of elements shall be in place during the erection to provide adequate stabilization to prevent buckling or overloading of components.

5.2.7 The User shall develop a risk assessment plan and make all workers aware of the hazards involved with the erection, use and dismantling of the structure.

5.2.8 The User shall coordinate with the client to determine all gravity loads and effective wind area.

5.2.9 It is the responsibility of the User to check the site of the roof structure for underground services before the towers or other load bearing elements are positioned, including ground anchors and ballast points.

5.2.10 Only cable assemblies that have been certified for the required safe working load shall be used.

5.3* During Use

5.3.1 The User shall adhere to the guidelines set forth in the Operations Management Plan, including monitoring of environmental factors (i.e. wind, rain, snow).

5.3.2 The User shall inform all contractors of their responsibilities set forth in the Operations Management Plan.

5.3.3 Adequate safety equipment shall be provided to access the structure.

5.3.4* The User shall be responsible to ensure that the entire roof structure is electrically grounded prior to energizing any electrical component attached to the structure.

5.3.5 Only cable assemblies that have been certified for the required safe working load shall be used.

5.3.6 If the roof is left assembled, then the guy and cross-bracing cable assemblies and anchorages shall be checked by the User before each use and at regular intervals between uses.

5.3.7 The User shall check the adequacy of the ground anchors when the moisture content of the ground changes significantly.

5.4 Post Use

Following each use of the structure, the User shall conduct a complete inspection of each component in accordance with section 6 of this document.

6* User Inspection

6.1 Intent

The intent of this section is to establish minimum required inspection routines and guidelines for the user. While every effort is made to provide a thorough listing of situations and inspection criteria, complete listings are beyond the scope of this standard. Specific advice should be sought by the user for specific inspection routines from the manufacturer or a qualified person.

6.2 Inspection Classifications

6.2.1 Frequent Inspections – Visual inspections with records not required to be kept. Frequent inspections shall be performed in accordance with section 6.4

6.2.2 Periodic Inspections – Visual inspections with records to be kept. Periodic inspections shall be performed in accordance with section 6.5

6.3 Inspection Intervals

6.3.1 Initial Inspection – When purchased or acquired, whether new from the manufacturer or

used, all components shall be inspected in accordance with section 6.4 of this standard but records shall be kept and maintained for the duration of possession. Such action shall establish the basis for the record keeping requirements.

6.3.2 Structure in regular service – A structure and related components in regular service shall be subjected to both Frequent and Periodic Inspections as described in sections 6.4 and 6.5 of this standard.

6.3.3 Structure not in regular service – Frequent inspections shall be performed on all structures and related components not in use for a period of one month or more. Periodic Inspections shall be performed on all truss modules not in service for a period of one year or more.

6.4 Frequent Inspection Procedures

Frequent inspections shall be performed by a competent person on behalf of the user, and shall be conducted prior to each use and immediately after an incident that might in any way have caused damage to any part of the roof structure.

6.5 Periodic Inspection Procedures

Periodic inspections shall be performed by a qualified person on behalf of the owner and shall be conducted at least once each year. Components shall be taken out of service during inspection.

6.6 Records

Records shall be kept on file for each structural component in the structure including the components of the lifting system. These shall be dated and signed by the person conducting the inspection.

6.7 Repair and Removal from Service

6.7.1 If any component shows significant visible damage or is suspected of containing a damaged element, whether visible or not, the component shall be removed from service and marked accordingly. A qualified person shall perform and document an assessment prior to the component being returned to service if appropriate.

6.7.2 Any component deemed damaged beyond repair shall be permanently removed from use or service.

6.7.3 Damaged components shall be permanently marked in a manner that clearly and visibly indicates its condition.

6.7.4 Repairs shall be made by a competent person under the supervision of a qualified person.

Appendix A, Commentary

This commentary is not part of the Standard and contains no mandatory requirements. It offers some explanatory information about the clauses in the standard. The relevant clauses have the same clause number, but without the “A” prefix. The clause numbering here is not continuous because no comments are offered on some of the clauses in the Standard.

Since no mandatory requirements are stated in this commentary, if there is any disagreement between the text of this appendix and the requirements stated in the body of the standard, the requirements in the body of the standard shall prevail.

A.1 Scope

This section of the standard defines the scope of the standard and defines the types of structure that are covered by the standard.

A.2 Definitions

This section provides definitions of the terminology and nomenclature used within this standard.

A.3 Design and Engineering

A.3.2

ANSI E1.2 indicates that a repetitive use factor for aluminum truss and tower sections shall be used in the engineering calculations for the modules are to be used on more than one occasion.

The factor is adopted to account for minor damage that may occur during the transportation and use of the equipment. The factor adopted is 0.85 and this is applied to the allowable loads on each truss or tower module as determined in accordance with the “Specifications and Guidelines for Aluminum Structures” published by the Aluminum Association. The application of this factor effectively reduces the allowable load on the system as a whole by just over 17%.

If the roof structure is made of steel, then the engineer may choose to adopt the same design philosophy and use the same repetitive use factor.

A.3.5.1 Seismic Loading

This standard allows a reduction in seismic loading, consistent with the duration of the intended use. It is important to note that the risk should not be increased if a short duration of use is considered.

A.3.5.2 Wind Loading

Because of their lightweight nature, proper consideration of wind loading on temporary stage roofs is critical to their safe use.

It should be appreciated that the Manufacturer does not generally know the full extent of any backdrops, side walls, banners, suspended equipment, and advertisements at the time that the engineering documentation is prepared.

In the absence of specific information on suspended equipment (with the exception of video and projection screens), the following minimum effective wind areas shall be used:

Main roof structure: An area equal to the width of the roof structure multiplied by 300mm (1 foot)

PA wings: 50% of the vertical area bound by the center lines of the tower, the underside of the supporting structure and the ground.

In the absence of specific information on the tributary wind area of structural elements of the roof structure, then the area shall be assumed to be 0.50 x apparent elevation of truss and tower section.

The wind load on all exposed truss and tower sections, roof skin, back drops, banners, advertisements, and suspended equipment shall be determined in the structural calculations that form part of the engineering documentation for a particular event if these are more onerous than the parameters assumed by the manufacturer.

Unless expressly stated in the design, the overall stability and resistance to wind uplift and overturning forces are provided by a series of wire guys anchored to ground anchors (or ballast), ballast applied to the tower sections, self weight of roof top and a percentage of the payload (operational loads).

ASCE 37 Design Loads for Structures Under Construction indicates that the design wind can be assumed to be 75% of the design wind defined in ASCE 7 Minimum Design Loads for Buildings and Other Structures. This reduction in design wind speed is deemed appropriate for temporary structures that are in place for less than six weeks.

Wind load is proportional to the square of the wind speed and therefore the design wind load is approximately 56% of the full design wind load.

Where temporary structures are to be erected in areas prone to hurricanes, such as Florida where the design wind is in the order of 145 mph, it is unrealistic to design temporary structures in accordance with the above. Hurricanes are wind events that come with adequate warnings. Therefore, it is permitted to design temporary demountable structures to a lower basic design wind speed. These structures can, therefore, be designed for basic wind speeds of 90 mph. This figure is then multiplied by 0.75 as indicated above.

If elements that are attached to the roof structure can be and are removed very quickly, within 5 minutes, then they need not considered in the full engineering documentation.

However, unexpected wind events occur frequently in the US. Therefore, a minimum design wind speed of 40 mph should be used for all roof structures and all elements attached to them. The User shall consider the difficulty and associated risk with the removal of any elements from the roof structure during a wind event. This consideration should be noted in the Operations Management Plan.

There are, therefore, two distinct wind load design cases that should be considered in the engineering documentation. One where the roof structure and all attached components are considered with a design gust wind speed of 40mph and one where the roof structure and all components that cannot be removed in 5 minutes are considered with a design gust wind speed as discussed above.

A.3.5.4 Load Considerations

All roof structures should be designed for a minimum superimposed live load of 5 psf uniformly distributed across the whole roof area. This load is not to be considered in conjunction with the design payload. It has been chosen to ensure that the roof structure is robust. This effectively means that temporary stage roofs would have a minimum design payload. It should be noted that for a typical

60’ x 40’ roof, the minimum design payload is 12000 pounds (5450 kg) uniformly distributed over the plan area of the roof.

A.3.5.5 Superimposed Loads such as Rain, Snow, Ice, etc.

Temporary demountable roof structures are not generally designed to withstand loads associated with ice and snow. However, if it is known that the structure is to be used in an area and at a time of year where snow is possible, then the engineering documentation should include this load case. If snow loading is considered as a load case, then provision for clearing snow from a roof covering could be made in the Operation Management Plan and a reduced value for snow loading may be considered.

A.3.7 System Erection

The coefficients set out in Table 1 are those commonly used to determine the effective height of a tower. Clarification of the terminology in Table 1 follows:

If a point is “held in position, but not restrained in direction”, then it can be considered as “pinned”.

If a point is “held in position and restrained in direction”, then it can be considered as “fixed”.

Table 1 - Factors to Determine Effective Lengths of Towers

Effectively held in position at both ends, but not restrained in direction.	K = 1.0
Effectively held in position at one end, and restrained in direction at both ends.	K = 1.25
Effectively held in position and restrained in direction at one end, and partially restrained in direction but not held in position at the other end.	K = 1.5
Effectively held in position and restrained in direction at one end, but not held in position or restrained at the other end.	K = 2.0

A.3.8 Ground Conditions and Foundations

Designers, Users and Local Authorities should be aware that the performance of soils under short-term loading could be significantly different from that when the soil is loaded for a longer term. Long-term settlement and associated differential settlement are often less significant for temporary demountable structures than for permanent structures. Temporary demountable structures are generally quite flexible and can safely accommodate a larger degree of differential settlement than permanent structures.

The traditional values of allowable bearing pressures may not be appropriate where a roof structure is supported on small soleplates for a short period of time and the loads are relatively small. The allowable bearing pressures for temporary structures may, therefore, be quite different from those associated with permanent buildings.

Where the loads on the ground are relatively small, the normal method of support for roof structures and other temporary demountable structures is to place timber spreaders on the ground and to use proprietary scaffolding screw jacks with steel soleplates. These screw jacks take up any differences in ground level.

Table A2: Indicative values of allowable bearing pressures for foundations of structures in place for less than 31 days

Bearing material	Allowable bearing pressure	
	kN/m²	lbs/ft²
Dense sand	200	4000
Medium dense sand	150	3000
Loose sand	75	1500
Stiff clays	150	3000
Firm clays	75	1500

Table A3: Indicative values of allowable vertical loads on adequate base plates for different bearing materials for structures in place for less than 31 days

Bearing Material	Allowable load (kN)		Allowable load (lbs.)	
	150x150mm	250x250mm	6”x6”	10”x10”
Dense sand	9	27	1850	5500
Medium dense sand	6	18	1225	3670
Loose sand	2	6	410	1225
Stiff clays	5	15	1020	3060
Firm clays	2.5	7.5	510	1530

The values given in Table A2 and Table A3 are indicative and assume that the base plates are placed with a minimum embedment of 150 mm (6”) in undisturbed soil.

Base plates may be placed directly onto certain grassed surfaces underlain by ground of an adequate bearing capacity. Any assessment of the allowable bearing capacity of ground below base plates should be conservative.

In the absence of reliable local or professional engineering knowledge, an allowable bearing pressure not exceeding 50 kN/m2 (1000 lbs/ft2) should be assumed.

The use of timber, plywood sheets or metal plates is generally satisfactory to distribute the loads from the base plate to the founding strata. Concentrated base plate loads should be assumed to spread through a timber spreader at 2 horizontal to 1 vertical along the grain, and 1 to 1 across the grain, unless proven otherwise by calculation.

A.3.9 Lateral Stability

Lateral stability of temporary demountable structures is an important issue that needs to be carefully considered. The amount of ballast shall be determined by a competent person and is site specific.

The amount of ballast required at the termination of each guy rope is dependant upon a number of factors. These include:

- the force to be resisted,
- the nature of the bearing surface,
- the type of ballast used,
- the angle of the guy wire to the ground,
- the coefficient of friction between the ballast and the ground,
- the factor of safety to be adopted.

The minimum factor of safety commonly used against slippage of the ballast on the ground is 1.5.

Table A4: Minimum values of the coefficient of static friction between various types of material used in anchorages.

Minimum value of coefficent of state friction, μ					
Lower load accepting member	Upper load bearing member				
	Plain steel	Painted steel	Concrete	Softwood timber	Hardwood timber
Plain steel	0.15	0.1	0.1	0.2	0.1
Painted steel	0.1	0	0	0.2	0.2
Concrete	0.1	0	0.4	0.4	0.3
Softwood	0.2	0.2	0.4	0.4	0.3
Granular soil	0.3	0.3	0.4	0.3	0.3
Hardwood	0.1	0	0.3	0.3	0.1

The figures in Table A4 are taken from Table 19 of BS 5975 Code of Practice for Falsework. They are assumed to consider that the elements are wet.

The user should consider undertaking tests on site to determine the coefficient of friction between the ballast and the bearing surface.

Notwithstanding the above, the user should determine if the use of ballast to provide lateral stability is permitted in the area where the structure is to be used. For example, it is understood that the use of friction to provide lateral stability is not permitted in California.

A.5.2 Pre-Use

A typical Operations Management Plan to be prepared by the user could follow these guidelines:

Operations Management Plan; items to be included, but not necessarily limited to:

Design wind criteria:

- Basic design wind speed 90 mph, 3 sec gust in accordance with ASCE 7
- Roof to be lowered to stage level at 60 mph, and skins removed
- Sound cabinets to be lowered to stage level at 60 mph, 3 sec gust and laterally restrained
- Scrims on sound wings to be removed at 40 mph, 3 sec gust
- Scrim or back drop to be removed at 20 mph, 3 sec gust
- Wind speeds are measured at 30 feet above ground level

Other documentation

This document shall be read in conjunction with the following documents
• Operating Manual provided by Manufacturer
• BSR E1.21 Entertainment Technology – Temporary Stage Roofs
• Signed and sealed Engineering Report by Manufacturer / Engineer

Monitoring

• The wind speed shall be monitored and records shall be kept on site.
• The wind speed measurements shall be taken at the height of the roof structure above ground, at a location where a true wind speed will be measured.
• A competent, responsible person from Client will be present on site for the whole of the period of the installation.
• A regular liaison with the local airports and weather information centers will be maintained to ascertain if any significant weather events are expected in the immediate vicinity of the roof structures.

Pressures

It should be recognized that the pressure and wind loadings on a structure are proportional to the square of the wind speed

Actions

The following actions will be undertaken by Client personnel on site when the 3 second wind speed gusts approach the following speeds against a background of rising wind speeds

Backdrop

Level 1:	60% of design wind load at 15.5 mph Personnel to be on alert
Level 2:	80% of design wind load at 17.9 mph Personnel to be put on standby to remove the backdrop
Level 3:	100% of design wind load at 20 mph Personnel to remove the backdrop

Sound wing scrims

Level 1:	60% of design wind load at 31 mph Personnel to be on alert
Level 2:	80% of design wind load at 35.8 mph Personnel to be put on standby to remove the scrims
Level 3:	100% of design wind load at 40 mph Personnel to remove the scrims

Main roof grid

Level 1:	60% of design wind load at 46.5 mph Personnel to be on alert
Level 2:	80% of design wind load at 53.7 mph Personnel to be put on standby to lower the roof

Level 3: 100% of design wind load at 60 mph
Personnel to lower roof to stage level and remove skins

Main sound cabinets

Level 1: 60% of design wind load at 46.5 mph
Personnel to be on alert

Level 2: 80% of design wind load at 53.7 mph
Personnel to be put on standby to lower the sound cabinets

Level 3: 100% of design wind load at 60 mph
Personnel to lower the sound cabinets and restrain laterally

The following elements should also be considered when developing the Operations Management Plan for an event:

- Equipment on stage
- Evacuation of the site
- Closure of site to public
- The stage itself (wind can cause uplift on stage decks)
- Mixer tower
- Delay towers
- FOH area

Provide drawings with the Operational Management Plan, a copy of which will be kept on site and at Head Office of Client for ease of reference.

A.5.3 Consistent with A5.2, the relevant portions of the Operations Management Plan must be clearly conveyed to any related contractors on the site. Any of the actions required in the Operations Management Plan may depend on the successful completion and adherence to the plan by these contractors.

A.5.3.4

Clearly, it is essential that the entire roof structure is electrically grounded before energizing any electrical component such as chain motors or lighting equipment that is attached to the structure.

The following grounding guidelines are suggestions only. It is the responsibility of the user to ensure that the all grounding procedures meet the provisions of the National Electrical Code (NEC) or other relevant prevailing codes.

An adequate number of earth rods should be positioned in the ground and be connected to earth clamps on the roof structure itself by suitable wiring.

The surface of the aluminum should be cleaned bare metal with steel wool to remove the oxidization before the earth clamps are fitted.

The User should note that there is generally not a proper or deliberate electrical grounding connection between the main roof structure and the towers where the roof grid is guided up and down the towers with nylon wheels and the guy wires are insulated by round slings.

Any lighting rig or other equipment which is attached to the roof structure should also be electrically grounded.

Additional procedures may be applicable and/or necessary to ensure that grounding of the roof structure meets all applicable codes.

A.6 User Inspection

This part of the standard is consistent with the corresponding section of ANSI E1.2 Entertainment Technology – Design, Manufacture and Use of Aluminum Trusses and Towers.

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