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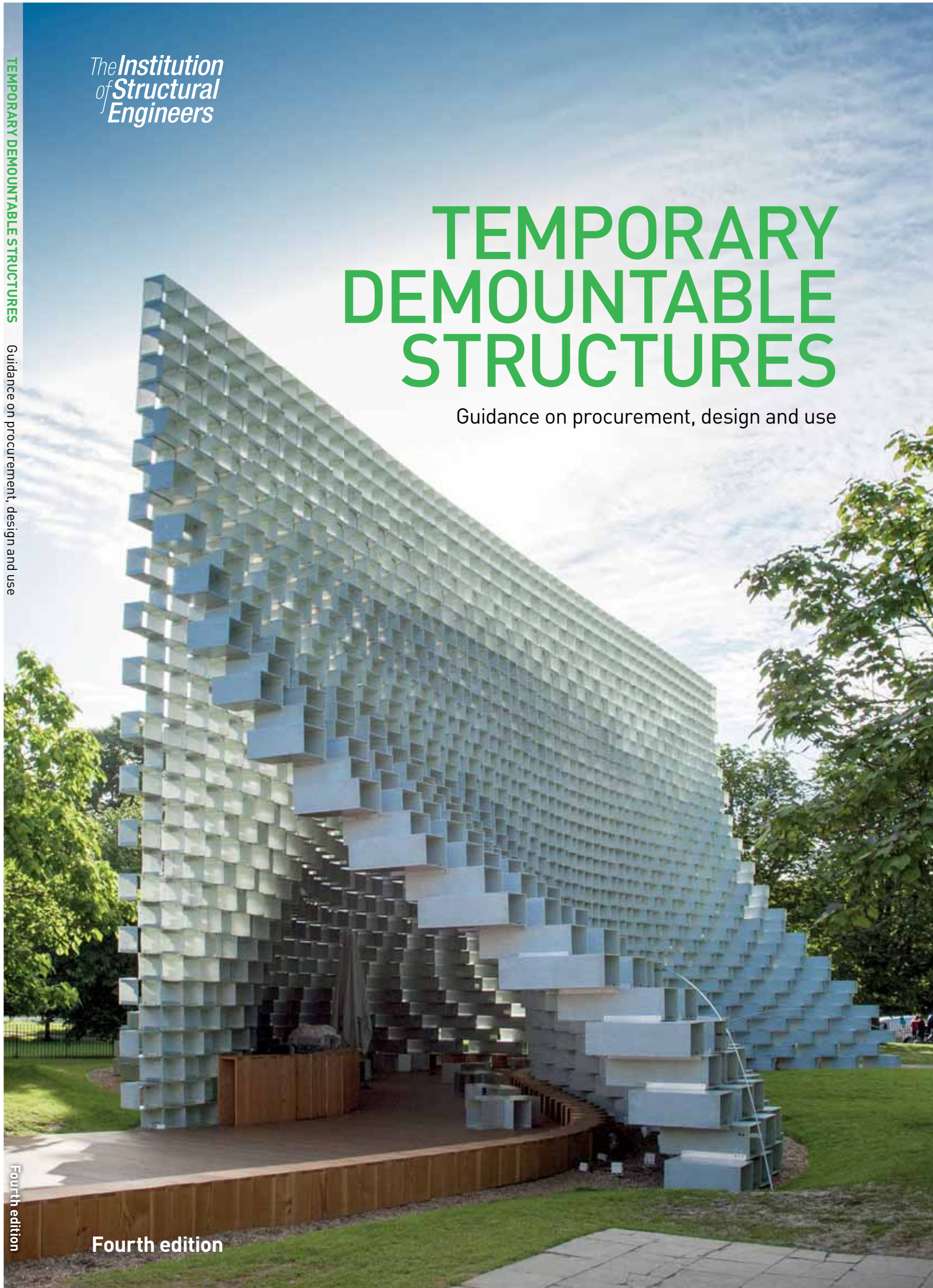
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TEMPORARY DEMOUNTABLE STRUCTURES

Guidance on procurement, design and use

Fourth edition





Temporary demountable structures

Guidance on procurement,
design and use

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Contents

Foreword v

Glossary vi

1 Introduction and scope 1

- 1.1 Introduction 1
- 1.2 Scope and purpose 1
- 1.3 Disclaimer 2
- 1.4 References 2

2 Roles and responsibilities 3

- 2.1 General 3
- 2.2 Responsibilities of Clients 3
 - 2.2.1 Introduction 3
 - 2.2.2 Procurement of structures 3
 - 2.2.3 Information to be provided by the Client 3
 - 2.2.4 Management checklist for the Client 4
- 2.3 Responsibilities of Designers and Contractors 5
 - 2.3.1 Design 5
 - 2.3.2 Method statements 5
 - 2.3.3 Independent erection check and completion certificate 5
 - 2.3.4 Alterations and modifications 6
 - 2.3.5 In-service inspection and maintenance (also see Section 6.3) 6
 - 2.3.6 Component checking and assembly 6
 - 2.3.7 Principal Designer and Principal Contractor 6
- 2.4 Guidance for Enforcing Authorities considering an event licence 6
- 2.5 Document checklist 8
- 2.6 References 8

3 Identification and control of hazards and risks 9

- 3.1 Hazards 9
 - 3.1.1 Design 9
 - 3.1.2 Erection and dismantling 9
 - 3.1.3 Operational 9
- 3.2 Risk assessment 10
- 3.3 Steps to mitigate risks 10
 - 3.3.1 Design 10
 - 3.3.2 Erection and dismantling 11
 - 3.3.3 Operation 11
- 3.4 Crowd behaviour 12
 - 3.4.1 Introduction 12
 - 3.4.2 Crowd density and movement 12
 - 3.4.3 Crowd sightlines 13
 - 3.4.4 Crowd control and crowd management 13
- 3.5 Electrical installations and lightning protection 14
- 3.6 Fire 14
- 3.7 Safety planning 15
 - 3.7.1 Introduction 15
 - 3.7.2 Safety policies 15
 - 3.7.3 Event management plan 15
 - 3.7.4 Safety and supervision during the event 15
- 3.8 References 16

4 Statutory control 18

- 4.1 General 18
- 4.2 Permissioning legislation and procedures 18
 - 4.2.1 Building Regulations 18
 - 4.2.1.1 England and Wales 18
 - 4.2.1.2 Scotland 18
 - 4.2.1.3 Northern Ireland 18
 - 4.2.2 Planning permission 18
 - 4.2.3 Premises licensed for public entertainment (not including sports grounds) 19
 - 4.2.3.1 England and Wales 19
 - 4.2.3.2 Scotland 19
 - 4.2.3.3 Northern Ireland 19
 - 4.2.4 Sports grounds 20
 - 4.2.4.1 Sports grounds safety certification 20
 - 4.2.4.2 Sports grounds prohibition notices 20
 - 4.2.5 Local Acts in England and Wales 21
 - 4.2.6 Fire precautions 21
- 4.3 Occupational health and safety law 21
 - 4.3.1 Health and Safety at Work etc. Act 1974 (and regulations made under it) 21
 - 4.3.2 Construction (Design and Management) Regulations 2015 21
- 4.4 References 22

5 Ground and site conditions 23

- 5.1 Introduction 23
- 5.2 Ground information 23
- 5.3 Basic principles 23
- 5.4 Ground bearing pressures 24
- 5.5 Baseplates (soleplates) and spreaders 24
- 5.6 Uplift and sliding 25
 - 5.6.1 Kentledge 25
 - 5.6.2 Ground anchors 26
- 5.7 Sloping ground 27
- 5.8 Site drainage 27
- 5.9 Inspection 27
- 5.10 References 28

6 Erection, inspection and dismantling 29

- 6.1 Introduction 29
- 6.2 Erection 29
 - 6.2.1 Planning 29
 - 6.2.2 Work on-site 29
 - 6.2.3 Erection check 30
- 6.3 Inspection of components 31
 - 6.3.1 Repeated use of components 31
 - 6.3.2 Scaffolding components 32
 - 6.3.3 Inspection of structural components used repeatedly 33
- 6.4 Dismantling 33
- 6.5 References 33

7	Loading	34	10	Fencing, hoardings and barriers	57
7.1	Introduction	34	10.1	Introduction	57
7.2	Dead loads	34	10.2	Fencing and hoardings	57
7.3	Imposed loads	34	10.2.1	Low-level fencing	57
7.4	Horizontal loads	35	10.2.2	Mesh and block fencing	57
7.5	Barriers and handrails	36	10.2.3	Hoardings	58
7.6	Wind loads	37	10.2.3.1	Steel panel systems	58
7.6.1	Basic principles	37	10.2.3.2	Roadway panel systems	58
7.6.2	Wind load design principle	38	10.3	Front-of-stage barriers	58
7.6.2.1	Existing systems	39	10.3.1	Risk assessments	58
7.6.2.2	New designs	39	10.3.2	Design	60
7.6.3	Wind loading on structures	39	10.3.3	Design loading	61
7.6.3.1	Grandstands	39	10.4	Site conditions/barrier performance	61
7.6.3.2	Stages	39	10.5	Multiple barrier arrangements	62
7.6.3.3	Porous walls (scrims)	40	10.6	Installation and inspection	62
7.7	Resistance to uplift and equilibrium checks	40	10.7	Fencing or hoardings beyond main viewing areas	63
7.8	Operations management for wind effects on structure	40	10.8	References	63
7.8.1	Measurements	41			
7.9	References	41	11	Fabric structures	64
			11.1	Introduction	64
8	Grandstands	43	11.2	Design	64
8.1	Introduction	43	11.2.1	General	64
8.2	Materials	43	11.2.2	Anchors	66
8.3	Design principles	43	11.2.3	Wind loading	66
8.4	Design guidance	45	11.2.4	Flame-retardancy of fabric and materials	66
8.4.1	General	45	11.3	Procurement and use	67
8.4.2	Loading	45	11.3.1	Safety considerations — Client	67
8.5	Connections	46	11.3.2	Safety considerations — Contractor	67
8.6	Loading tests	46	11.4	Erection, inspection and dismantling	68
8.7	Layout criteria (means of escape)	46	11.4.1	Erection	68
8.8	Barriers and handrails	47	11.4.2	Inspection	68
8.8.1	General	47	11.4.3	Dismantling	69
8.8.2	Design	47	11.5	Verification	69
8.9	Demountable standing accommodation	47	11.6	References	69
8.10	Viewing facilities for persons with special needs	47	12	Ancillary and special structures	71
8.10.1	General	47	12.1	Introduction	71
8.10.2	General principles	48	12.2	Design	71
8.10.3	Design requirements — platforms	48	12.2.1	General considerations	71
8.10.4	Design requirements — access ramps	48	12.2.2	Verticality	71
8.10.5	Seating arrangements and capacities	49	12.2.3	Stability	72
8.11	References	49	12.2.4	Overloading	72
			12.2.5	Scaffold	72
			12.2.6	Access	73
9	Stages and similar structures	51	12.3	Masts and towers	73
9.1	Introduction	51	12.4	Catenary wire ropes	73
9.2	General design requirements	51	12.5	Hospitality units	74
9.3	Stage types	51	12.6	High-level decks and platforms	76
9.3.1	Stage floor platforms and associated substructures	51	12.7	References	76
9.3.2	Roofs	52			
9.3.3	Free-standing roof systems	53	Appendix A	Derivation of kentledge — an example	77
9.3.4	Roof systems supported on a stage floor	53			
9.3.5	Roof systems supported within the substructure of a stage floor	54	Appendix B	Management of temporary demountable structures to ensure personal safety in the event of high winds	78
9.3.6	Fully-integrated units that are typically vehicle-based	54			
9.4	Access and egress for non-public use	54	Appendix C	Reference documents	81
9.5	Protection against falling	55	C.1	British Standards	81
9.6	Use of lifting equipment	55	C.2	European Standards	81
9.7	References	56	C.3	American Standards	81
			C.4	Other reference documents	82
			Appendix D	Conversion factors	85
			Appendix E	Sources of further information	86

Foreword

It has been more than 20 years since the first edition of *Temporary demountable structures* was published. The catalyst for its publication was the 1992 collapse of a grandstand at Corsican football club SC Bastia, which resulted in 18 deaths and more than 2300 injuries. Since then, two subsequent editions (1999 and 2007) have been produced. The third edition was identified as a core reference requirement by the London Olympic Organising Committee (LOCOG) for the 2012 Olympic Games; a project that saw the largest number of temporary structures ever used at a single event.

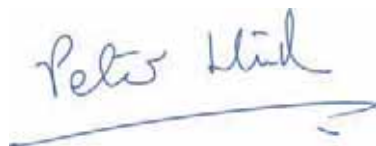
This fourth edition has been prepared to embrace the use of Eurocodes and the Construction (Design and Management) Regulations 2015 (CDM 2015) — and draws on experiences from the 2012 Olympics, where temporary structures were used on an unprecedented scale.

The *Guide* is intended for Clients, Designers, Contractors and suppliers of demountable structures for events. It is also an advisory document for use by Enforcing Authorities.

The Advisory Group on Temporary Structures (AGOTS) consists of representatives from The Institution of Structural Engineers, The Institution of Civil Engineers, Government and the event industry, and is responsible for the development of this fourth edition.

The dedication, enthusiasm, knowledge and experience of the members of AGOTS, in the development of this *Guide* cannot be overstated, and their considerable efforts were fundamental to the production of this edition. I am indebted to Lee Baldwin, the Institution's Head of Publishing, and to Arif Rahman and Vega Vanacore, Secretaries to the Group. The assessment, review and publication have made heavy demands on their busy Institution workloads.

I am also grateful to the HSE for their endorsement (reproduced below) of this fourth edition.



Peter Hind
Chairman, AGOTS
April 2017

"The Health and Safety Executive provided support to the Advisory Group on Temporary Structures in producing this guidance which is aimed at improvements within the entertainments industry. This guidance may go further than the minimum you need to comply with the law with regard to health and safety."

Glossary

Term	Definition
Ballast	see 'Kentledge'.
Bearing material	Material immediately below the superficial layers of topsoil, hardcore or fill etc.
Characteristic load	The principal loads on a structure can be classified as dead load, imposed load and wind load. In some cases, structures may be subject to other loads – such as those due to earthquakes or pressures from retained material. The expected maximum magnitude of each is referred to as the 'characteristic load'.
Client	Person or organisation who procures a demountable structure for use at an event. This may be the owner of the venue, site or building where an event takes place, but is not necessarily the 'Event Organiser'.
Competent persons	People shall be regarded as 'competent' where they have sufficient training and experience to take responsibility for an identified task. It is important that they have a detailed knowledge of the type of structure, and particularly of those matters which are essential for its structural reliability. Competent persons will have an awareness of the limitations of their own experience and knowledge.
Completion certificate	Document prepared by a 'Contractor' to confirm that the appropriate independent erection checks have been carried out and that a temporary structure has been erected in accordance with the design drawings and documentation.
Construction phase plan	Document that records arrangements for managing significant health and safety risks associated with the construction of the project. The basis for communicating those arrangements to individuals involved in the construction phase.
Contractor	An organisation or individual appointed by the 'Client', to supply and erect a structure. Contractors are organisations (or individuals) who directly employ or engage construction workers or manage construction work.
Design check	see 'Independent design check'.
Design (or engineering) documentation	Provided by the 'Designer' of a temporary structure that enable the basis of design to be clearly understood and the design criteria to be verified. They should include drawings, calculations, certificates, statements of loading, risk assessments, 'method statements' and other relevant information.
Design wind speed	Maximum wind speed that a temporary structure is designed to withstand (expressed in gust or mean wind speed).
Designers	Organisations (or individuals) who prepare or modify designs for a building, product or system relating to construction work, or arrange for others to do so. All structures should be properly designed by a competent person. The Designer should be able to offer evidence of their competence. Evidence of the design process being carried out should be available.
Emergency plan	A document that sets out who is responsible for each part of an event and the activities that take place on-site. It will contain clear and simple instructions on what actions are to be taken, and by whom, in the event of an emergency. Clear contact details should also be included.
Enforcing Authority	An organisation which controls the issue of approvals. In the UK, both the Health and Safety Executive (HSE) and Local Authorities enforce CDM 2015. Local Authorities deal with approvals through separate licensing legislation/Building Regulations etc.
Event	A public or private occasion at which spectators are present.
Event management plan	Strategic document for maintaining (before, during and after the event) the optimum status of safety, security and service.
Event Organiser	An individual or organisation that promotes and manages an event. This may not always be the 'Client'.
Grandstand	A large, often roofed structure that can include standing and/or seated accommodation for spectators at sporting or other events. The term 'stand' is commonly used when referring to a 'grandstand' and these terms are used interchangeably in this <i>Guide</i> .
Independent design check	(1) A check of a standard system, which may be based on design or have evolved on an empirical basis, by a suitably qualified engineer having appropriate skill and experience. (2) A 'first principle' check from the original design for complex structural systems. (3) A check of the design of any special or non-standard arrangement of elements supplied for a project, carried out by a suitably qualified engineer having appropriate skill and experience of such design.

Term	Definition
Independent erection check	An inspection of a temporary structure by a 'competent person' made after every erection of the structure. The competent person may be an employee of the supplier of the structure or a person nominated to carry out such inspection by the supplier. Where the erection check is carried out by a member of the erection team, evidence of that person's competence should be made available. The results of this inspection should be recorded on a 'completion certificate'.
Kentledge	Dead weight – normally steel or concrete but could include containers filled with water or granular material. The term 'ballast' is sometimes interchangeable with 'kentledge'.
Local Authority	An organisation which controls the issue of Building Regulations approvals, safety certificates and licences under relevant legislation. In the UK (excl. Northern Ireland) the Local Authority is also the responsible body for planning permission.
Marshal	see 'Steward'.
Method statement	Describes the steps that will be taken from the start to the finish of an activity – with defined responsibilities. There may be method statements for design, erection, checking, operations, health and safety, security, maintenance, dismantling and others, depending upon the scope of an 'event'.
Mobile grandstand	A grandstand, usually with roof and side walls, that is built onto a commercial vehicle chassis (or delivered on one) and that opens out using both manual and powered devices to create a structure of significantly greater volume than when compacted for transport.
Mobile stage	A stage with roof and side walls, that is built onto a commercial vehicle chassis (or delivered on one) and that opens out using both manual and powered devices to create a structure of significantly greater volume than when compacted for transport.
Operational wind speed	Maximum wind speed at which a temporary structure is designed to be safely used (expressed in gust or mean wind speed).
Owner	The owner of the venue, site or building where an 'event' takes place.
Principal Designers	Organisations (or individuals) in control of the pre-construction phase where a project involves more than one 'Contractor'. A 'Client' appoints a Principal Designer. If a Client does not appoint anyone, they must fulfil the duties of this role themselves. In the context of 'events', a Client normally controls the pre-construction phase and therefore retains the Principal Designer role.
Principal Contractors	Organisations (or individuals) in control of the construction phase where a project involves more than one 'Contractor'. A 'Client' appoints a Principal Contractor. If a Client does not appoint anyone, they must fulfil the duties of this role themselves. Similarly to the 'Principal Designer' role, in a production/event setting, a Client may often act as their own Principal Contractor, assisted by their production and site management team.
RAMS	Abbreviation of 'Risk assessments and method statements'.
Risk assessment	Process by which a 'competent person' identifies the hazards associated with the design, construction or operation of a 'temporary demountable structure', determines the level of risk for people constructing or using the structure, and assesses the likelihood and consequences of an incident.
Safe System of Work (SSoW)	Document issued to workers that describes the sequential steps they must take in order to carry out a task safely.
Safety coordinator	Person responsible for implementing a 'safety plan' – a representative of the 'Owner' or 'Event Organiser'. At sporting events covered by a safety certificate, the safety coordinator will be the safety officer.
Safety plan	Document identifying the hazards and associated risks relating to the design, procurement, construction and use of the 'temporary demountable structure' for the proposed 'event', and setting out responsibilities for managing the risks. Under CDM 2015, this information would be required in the provisions which relate to 'construction phase plans'. Safety plans should be subject to continual review and periodic formal revision.
Stage	A structure that includes a performance area. In outdoor locations it will usually have a roof cover, together with associated side and rear walls, and a structural frame above to support sound and lighting equipment. At indoor locations it may have a structural frame above to support sound and lighting equipment.
Steward	A 'competent person' employed for major events by the 'Client' and whose duties are as defined in Section 3 of the <i>Guide to Safety at Sports Grounds</i> . At certain sporting events, a steward is referred to as a 'marshal'.
Structural safety	Refers to the strength, stability and integrity of a structure to withstand the conditions that are likely to be encountered during its lifetime. Structural safety is achieved through the proper procurement, design, construction, use and maintenance of the structure and the application of good engineering practice.
Structure	For the purposes of readability throughout this <i>Guide</i> , the term 'structure' refers to a 'temporary demountable structure' unless otherwise stated. 'Temporary demountable structure' is used only where it is essential to differentiate between these and permanent structures.

Term	Definition
Suitably qualified engineer	A competent and qualified structural or civil engineer (e.g. a Chartered member of The Institution of Structural Engineers or The Institution of Civil Engineers) with appropriate experience in the context of this <i>Guide</i> . In the US and Canada, the equivalent term is 'Professional engineer'.
Temporary demountable structures	Structures which are in place or in use for a short time (generally no more than 28 days) that are designed to be erected and dismantled manually a number of times. They are usually made from lightweight components and are used for a wide variety of functions at public and private events. They include grandstands, hospitality units and fabric structures which may accommodate large numbers of people, and stages (static and mobile) and other supports for performers.
Type approval	Official confirmation that a structure meets the required specifications.

1 Introduction and scope

1.1 Introduction

Temporary demountable structures (largely referred to in this *Guide* as 'structures') are widely used for a variety of functions at public and private events. They may provide viewing facilities (including temporary seating), shelter (fabric structures such as tents and marquees), platforms and supports for performers (such as stages), and media facilities (such as supports for floodlights, loudspeakers, TV cameras, video screens and press boxes). They can be found at exhibitions, sporting events, music festivals and concerts, and other social gatherings. Major events can be attended by thousands, and the integrity of the associated structures is of paramount importance for the safety of all.

Key factors relating to these structures, are that:

- They are often required at short notice
- Timescales for planning, installing and erecting structures before the event — and removing them afterwards — frequently make it necessary for Clients, Designers, Contractors and Local Authority officers to make decisions relatively quickly
- They may need to withstand substantial horizontal, vertical and dynamic loads
- The structural components are often required to be lightweight, rapidly assembled, readily dismantled and reusable

Requirements for a structure can be specified by the owner of the venue where an event is to take place or, more usually, by the organiser of the event. Whoever instructs the Contractor becomes 'the Client' and, as such, should provide a clear written specification to the Contractor.

The fact that a structure is designed for temporary use does not change the overall requirements for safety; the failure of any temporary structure in a crowded space could have devastating effects. Although the time available from concept to use may be limited, it is essential to design structures to suit the specific intended purpose — and to recognise that the key to the safety of the structure lies largely in proper design, control of work practices and careful inspection. From industry experience, a key factor in ensuring safety by design in these structures is to account for operational behavioural aspects within the risk assessment and risk management process.

Structures are usually designed to be easily erected and dismantled, and are capable of adaptation to different situations. This often means that they are relatively lightweight, made from slender components and need to be designed, erected and inspected before use, by competent persons.

Both the Venue Owner and the Event Organiser have responsibilities for the safety of people attending the event, but everybody involved in planning, design, erection and management of a structure has a duty in

relation to the safety of the structure and to the people working on and using the structure.

Contact with Local Authority officers and fire officers may be necessary, to obtain approvals relating to the adequacy of the structure, fire precautions, seating, layout, and entry and exit arrangements.

The achievement of safety requires judgment based on experience and careful evaluation of relevant factors. Each case should be judged on its individual circumstances. It is not merely a matter of the rigid application of Standards. However, the goal is to achieve a level of performance equivalent to Standards. In recent years the traditional structural engineering response to public assembly safety has broadened to include environmental psychology, fire engineering, information systems and management systems. The outcome can be simply expressed as the emergence of the concept of 'crowd management' as opposed to 'crowd control' (Section 3.4.4). Emphasis is placed on public safety as opposed to public order, recognising the need for planned rather than reactive crowd management.

The approach to risk management, including crowd management, should always be one of flexibility and sound judgment. Unjustifiably onerous or inappropriate requirements do not contribute to public safety and in some instances may create risks in themselves. An objective assessment by a competent person is required.

This *Guide* is based on practice in the UK and Europe but the principles described are likely be appropriate for application elsewhere.

1.2 Scope and purpose

This *Guide* provides guidance to all stakeholders in the procurement, design and use of structures; both indoors and outdoors.

Demountable structures considered include:

- Temporary grandstands
- Platforms
- Stage structures
- Viewing facilities
- Barriers
- Towers and masts to support media facilities
- Canopies
- Fabric structures such as tents and marquees

Retractable seating and fairground structures are not considered.

Where a demountable structure is to be used at a sports ground or designated football stadium, local authorities may attach special conditions to certificates controlling its use^{1.1}.

The purpose of the *Guide* is to give the Designer information to assist in achieving the safe and economic design of structures and to encourage their safe and economic erection and use.

To fulfil this aim, it provides information to assist the Designer to evaluate the loads likely to be imposed on the structures. In some cases, an engineering appraisal of the recommended levels of loading will be required, as these may need to be adjusted for the particular circumstances — such as the planned activity or possible misuse.

The *Guide* is also intended for Clients, Event Organisers and venue owners, regulatory and local authorities, as well as Contractors and suppliers of demountable structures. It applies to structures erected for events, whether or not the event is required to be licensed.

It is also intended for competent persons who are responsible for the design, erection, inspection and dismantling of structures.

Structures are usually assembled from readily-connected components which, after dismantling, may be reused many times. However, this *Guide* applies equally to structures that are used only once. A number of proprietary systems exist which should be used in accordance with the manufacturer's instructions and with the approval of the Local Authority.

This *Guide* is concerned with the structural safety and adequacy of structures used for temporary purposes and also with the overall planning and management of events. 'Temporary' is taken here to mean that the structure will not usually be in position or in use for more than 28 days (although this time period is not definitive). However, it may also be used for structures which are not considered to be a permanent feature of the built environment.

Layout, entry, exit and other requirements for crowd safety are covered in general terms only, but information on sources of guidance for such requirements is provided.

1.3 Disclaimer

The Institution of Structural Engineers has produced this publication as guidance and it is only intended as such. It is not intended to provide the definitive approach in all situations. However, it is suggested that any departures should be carefully considered and the reasons for them should be recorded. Readers are advised that although current at the point of publication, references could be superseded at any time. Readers should check the literature for updates.

1.4 References

- 1.1 Sports Grounds Safety Authority. *Alternative Uses of Sports Grounds*. London: SGSA, 2015

2 Roles and responsibilities

2.1 General

The design, erection and dismantling of structures in the UK is subject to the provisions of health and safety law including the *Health and Safety at Work etc. Act 1974*^{2.1} and *The Construction (Design and Management) Regulations 2015*^{2.2} (CDM 2015).

The Regulations define the following parties as having statutory duties:

- Client
- Principal Designer
- Designers
- Principal Contractor
- Contractors
- Workers

The primary roles and responsibilities of each party as defined under CDM 2015 are given in Figure 2.1. Reference should also be made to *CDM 2015 and the entertainment industry*^{2.3}.

The general requirements for health and safety relating to these structures are the same as those for permanent structures; a demountable structure should be part of a safe and healthy environment for those using it, and should not give rise to risks to the health or safety of users, nor to those involved with erection, maintenance or dismantling of the structure. It is the responsibility of all those working with such structures to exercise care in their work and in all matters relating to the safety of the people who may be using them. These roles and their duties can be integrated into the overall safety management process for the event/production. Organisations and/or individuals may have more than one role; e.g. by being both a Designer and a Contractor. It is important that roles and responsibilities are clearly understood. It may be helpful to create a record of these.

The Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)^{2.4} place duties on individuals and companies who own, operate or have control over lifting equipment. This includes all businesses and organisations whose employees use lifting equipment — whether owned by them or not. In most cases, lifting equipment is also 'work equipment', so *The Provision and Use of Work Equipment Regulations 1998*^{2.5} will also apply.

2.2 Responsibilities of Clients

2.2.1 Introduction

The Client should take note of the following:

- It is the Client's responsibility to make suitable arrangements to ensure that construction of the structures they commission (including entrances and exits) is carried out safely and remains safe for their users, including proper protection against the

risks of fire and smoke before, during, and after an event. In the context of event management, a Client will discharge these duties with assistance from their production and site management team

- It is the Client's responsibility to contact the Enforcing Authority to inform them of the proposals for a structure, and to seek advice on responsibilities for enforcement, certificates, licences, or permissions that are required, and any special local regulations that may apply (Section 4)
- When applying for a licence for an event, the Client should notify the Enforcing Authority as to which Contractor/s will be supplying the structures. It is the Client's responsibility to establish what information is required from the Enforcing Authority and then to supply such information to the Enforcing Authority in good time before erection starts

2.2.2 Procurement of structures

When procuring a structure the Client should:

- Obtain written evidence that competent persons are employed to design, erect, inspect and dismantle the structure
- Agree the expected nature and character of spectator activity at the event
- Provide the Contractor with a written technical specification of requirements (such requirements will be specific to the country in which the work is being undertaken)
- Make suitable arrangements for managing the project safely
- Obtain approvals from the relevant Enforcing Authority in good time
- Make sure that an event management plan is available, which includes a plan for dealing with adverse weather conditions — particularly strong winds and heavy rain

2.2.3 Information to be provided by the Client

The Client is legally responsible for providing those involved in construction work (including Designers, Principal Designers and Principal Contractors) with pre-construction information. For projects involving more than one Contractor, a Principal Designer's duties include helping and advising the client on the bringing together of preconstruction information. It is good practice for the Client to provide a written technical specification of requirements for each structure being procured.

This specification should include, *inter alia*, the following:

- Site of event and location of the structure at the site
- Type and details of event, e.g. sport, theatre, festival, conference, concert
- Duration of the event
- Programme for supply of structure, e.g. date required, date by which structural calculations and drawings are required for comment, erection timescale, any limit to working hours

Clients are organisations or individuals for whom a construction project is carried out.	They make suitable arrangements for managing a project. This includes making sure that: • other dutyholders are appointed • sufficient time and resources are allocated • relevant information is prepared and provided to other dutyholders • the Principal Designer and Principal Contractor carry out their duties • welfare facilities are provided
Principal Designers are designers appointed by the client in projects involving more than one contractor. They can be an organisation or an individual with sufficient knowledge, experience and ability to carry out the role.	They plan, manage, monitor and coordinate health and safety in the pre-construction phase of a project. This includes: • identifying, eliminating or controlling foreseeable risks • ensuring designers carry out their duties They prepare and provide relevant information to other dutyholders. They provide relevant information to the Principal Contractor to help them plan, manage, monitor and coordinate health and safety in the construction phase.
Designers are those, who as part of a business, prepare or modify designs for a building, product or system relating to construction work.	They are responsible for preparing or modifying designs, and to eliminate, reduce or control foreseeable risks that may arise during: • construction • the maintenance and use of a building once it is built They provide information to other members of the project team to help them fulfil their duties.
Principal Contractors are contractors appointed by the client to coordinate the construction phase of a project where it involves more than one contractor.	They plan, manage, monitor and coordinate health and safety in the construction phase of a project. This includes: • liaising with the Client and Principal Designer • preparing the construction phase plan • organising cooperation between Contractors and coordinating their work They ensure: • suitable site inductions are provided • reasonable steps are taken to prevent unauthorised access • workers are consulted and engaged in securing their health and safety • welfare facilities are provided
Contractors are those who do the actual construction work and can be either an individual or a company.	They plan, manage and monitor construction work under their control so that it is carried out without risks to health and safety. For projects involving more than one Contractor, they coordinate their activities with others in the project team – in particular, complying with directions given to them by the Principal Designer or Principal Contractor. For single-contractor projects, they prepare a construction phase plan.
Workers are the people who work for, or are under the control of, Contractors on a construction site.	They must: • be consulted about matters which affect their health, safety and welfare • take care of their own health and safety and that of others who may be affected by their actions • report anything they see which is likely to endanger either their own or others' health and safety • cooperate with their employer, fellow workers, Contractors and other dutyholders

Figure 2.1 CDM 2015: Primary roles and responsibilities

- Type of structure/s required, e.g. grandstand, marquee, stage, (with/without roof)
- Size and weight of equipment to be supported by the stage and/or roof
- Accommodation needed on and in the structure, e.g. floor area, number of seats, sightlines, access to stage structure
- Public access routes to site
- Public evacuation times during the event
- Access to site for erection and dismantling
- Ground conditions, e.g. flat or uneven ground, hardstanding, soft ground
- Enforcing Authority contacts (building control, environmental health and fire officers) to ascertain licensing and approvals requirements
- Fire risk factors (Section 3.6)

- Details of any other hazards or risks likely to affect the design, erection or use of the structure

2.2.4 Management checklist for the Client

The following requirements will help Clients ensure that structures are procured and used efficiently and safely:

- Responsibility for design of the structure and its foundations should rest with the Principal Designer/Designer
- Erection, and dismantling after use, should be carried out by competent persons with necessary skills, knowledge, experience and training relevant to the work they are undertaking

- Design, calculations, and drawings or a 'type approval' — together with the independent design check — should be submitted to the Client or the Client's agent
- The structure should be designed by competent persons using accepted engineering principles and should comply with all relevant Standards and guidance (including this *Guide*), and with the specification requirements. Any variation should be subject to a further 'independent design check'
- The Client should ask for sufficient drawings and calculations to satisfy themselves or their Principal Designer that the structure is adequate for the intended purpose
- Evidence of public liability insurance and employer liability cover should be provided by the Contractor and the Client. Evidence of professional indemnity insurance should be supplied by the Designer
- Where appropriate, the structure and its foundations should be protected from vehicular traffic
- Once erected, the structure should be subject to a documented erection check by a competent person, to verify that the structure conforms to the relevant drawings and specified details. The Client, having ultimate responsibility for health and safety, should ensure that the appropriate checks have been both carried out, and recorded on a form (the 'completion certificate') designed for this purpose, by the Contractor
- The Client should carry out (or arrange for others to carry out) periodic inspections, and require the Contractor or other competent person to undertake appropriate repairs and remedial works when necessary, to ensure that the structure is kept fit for use at all appropriate times
- The Client should ensure that an emergency plan is developed that is commensurate with the level of risk associated with the event. Emergency plans should be discussed with the emergency services to ensure an efficient strategic response to a major incident
- The emergency plan should clearly define the roles and responsibilities of all parties. Further information on the preparation of adequate emergency plans can be found from the HSE website^{2,6}

2.3 Responsibilities of Designers and Contractors

2.3.1 Design

All structures should be properly designed by a competent person. The Designer should be able to provide evidence of their competence. The Principal Designer, as defined in CDM 2015^{2,7}, should be appointed by the Client.

Structures should be designed in accordance with the relevant Eurocodes, incorporating the requirements of the relevant National Annex and relevant British Standards (or national Standards) where appropriate. Where existing designs are in accordance with British Standards this should be made clear in the submitted documentation. Eurocodes and superseded British Standards should not be mixed for the same structure.

Structures should be designed in accordance with all relevant and appropriate documentation. Where appropriate, *Dynamic performance requirements for permanent grandstands subject to crowd action*^{2,8} should be considered.

Design documents that cover the key aspects of the design should be provided (Section 2.5). If any of these documents are not applicable this should be clearly stated by the Client/agent or Designer as appropriate.

Independent design checks should be made. Generally, the contractor should liaise with others in the project team to arrange these.

The independent design check should be carried out by a suitably qualified engineer having sufficient skill and experience (and in cases of complex structures, the overall stability may require a fully independent 'first principle' check from the original design). The check may be made on a standard system (which may be based on design or have evolved on an empirical basis), or on the design of any special or non-standard arrangement of elements supplied for a project.

2.3.2 Method statements

Method statements should be drawn up by the Contractor for the erection, dismantling and removal of any structure. They should be submitted to the Client and should include relevant drawings and structural calculations.

The method statements should be specific to the structure and should include the method of founding the structure adequately on the ground.

If there are modifications to the method statements or Safe System of Work documents (SSoWs), these should be communicated to the relevant parties.

Appraisal by any third party should not be used by Contractors as a basis for reducing their own checking procedures.

2.3.3 Independent erection check and completion certificate

The independent erection check is to ensure that the structure has been erected in accordance with the engineering documentation. It should be carried out by a competent person, who may be an employee of the supplier of the structure or a person nominated to carry out such checking by the Contractor. Where the erection check is carried out by a member of the erection team, evidence of that person's competence should be made available.

As a minimum, the check should detail the:

- Type and location of the structure
- Date of the inspection
- Name and position of the competent person making the inspection
- Reference numbers or methods of identifying the design or erection drawings
- Nature of the inspection (physical, visual, etc.)

The erection check documents (also known as 'sign-off documents') should be submitted to the

Client, who in turn should keep them for inspection by the Enforcing Authority.

Procedures for fabric structures are described in Section 12 (see also MUTA's *Best Practice Guide: Safe Use and Operation of Temporary Demountable Fabric Structures*^{2,9}).

2.3.4 Alterations and modifications

Once a completion certificate has been signed and issued, alterations and modifications to the details shown on the design drawings and calculations should be avoided.

If structural modifications are required after the completion certificate has been issued, the following course of action should be followed:

1. A competent person should re-design the structure to take account of the modifications
2. This should then be subjected to an independent design check
3. An erection check should be carried out
4. A new completion certificate should be prepared once the modifications have been made

If structural modifications are required by an Enforcing Authority, written details of the changes required and the reasons for them should be issued to the competent person who is to redesign the structure. The course of action detailed previously should be followed, and method statements and SSoWs should be updated where appropriate, together with any relevant operational changes that may ensue (Section 2.3.2).

In all cases, the structure should comply fully with the design criteria, either before it is used or before the public are admitted.

2.3.5 In-service inspection and maintenance (also see Section 6.3)

Some structures remain in use for considerable periods and particular care may be needed over their long-term condition. Requirements that may apply to permanent structures should be considered.

The structure should be inspected regularly by a competent person to ascertain whether any changes have occurred. This could include significant movement or differential settlement. If significant changes have occurred, a report should be submitted immediately to the Client and/or Contractor and appropriate remedial work undertaken. This may involve repacking and levelling or installing another type of foundation. The Contractor should check that the structure has sufficient redundancy to allow remedial work to proceed without endangering overall stability (Section 6.3).

If heavy rain or flooding occurs, the loadbearing capacity of the ground may be reduced, guy-wires may slacken, and anchorages may be loosened. In strong winds, guy-wires may need regular tightening and anchorages may need to be checked for movement.

Minor damage to the structure may occur while in service. The Designer should be informed of any damage which might affect structural robustness, so

that a decision can be made as to repair or replacement. Provided such damage does not endanger public safety, the damaged components should be clearly marked so they can be easily identified during dismantling, and set aside for repair or rejection.

The design life of a structure may change. If so, a re-design will be necessary and fully implemented on site.

2.3.6 Component checking and assembly

All components should be examined during assembly and dismantling for signs of wear, corrosion, deformation or other damage, and replaced if necessary. For example, metal items with cracked welds, bent or buckled members, or steel items with large amounts of rust should be rejected.

Correct alignment of components is important — they should not be bent, distorted or altered to force them to fit. Particular attention should be given to fastenings and connections. It is essential to provide suitable coverings for bolts and fittings which project into or adjoin public areas (Section 6.2.2).

2.3.7 Principal Designer and Principal Contractor

The Principal Designer has the duty to plan, manage, monitor and coordinate the pre-construction phase of a project involving more than one contractor; for example, the period before the build and breakdown phases of an event. In practice, this duty is likely to continue into the construction phase of an event when further design and/or modification work is carried out, and when gathering information for projects.

The Principal Contractor has the duty to plan, manage and monitor the construction phase of a project involving more than one contractor. In particular, they coordinate matters relating to health and safety during the erection and dismantling of structures.

In the context of event management, a Client may often act as their own Principal Designer and Principal Contractor, assisted by their production and site management team.

2.4 Guidance for Enforcing Authorities considering an event licence

Where an event is required to be licensed, the Enforcing Authority should satisfy themselves that the engineering documentation, including: design calculations, drawings, risk assessments, etc. has been compiled by competent persons.

Design calculations that have been subject to an independent check should help the Enforcing Authority decide whether further checks are required. In the UK, and in accordance with their duties under the *Licensing Act 2003*^{2,10}, a Local Authority will decide, based on the circumstances, whether the information they are presented with is acceptable.

Table 2.1 Document checklist

✓	Document	Prepared by	Section/s within this Guide
Client requirements			
	Statement of what the structure is required to do (the concept)	Client	2.2.3
	Statutory requirements, permissions and licences	Client	2.2.4, 4.1, 4.2
	Other technical requirements (including loading)	Client	2.2.4, 7
Site, location and event			
	Assumed or measured ground bearing capacity	Client	5.4
	Statement of allowable loading for indoor floor on which structure is to be erected	Client	7
	Statement of required superimposed loading on structure	Client	7
	Fire risk assessment for the event	Designer/Contractor	3.6, 4.2.6
	Fire certificates	Client	3.6
	Event management plan	Client/Contractor	2.2.2, 3.3.3, 3.7.3
Design			
	Pre-construction information as defined under CDM 2015	Client	2.1
	Evidence of competence	Designer	2.3.1, 2.3.3
	Detailed design drawings, calculations and statement of the design criteria, with Designer's contact details	Designer	2.4
	Confirmation of design loads	Designer	7
	Relevant information on Standards and Codes, and analysis or design software used	Designer	Appendix C
	Design risk assessment	Designer	3.2
	Maximum leg load on foundations	Designer	5.5
	Slope on which structure can safely be built	Designer	5.7
	Ability of the design to resist anticipated wind load	Designer	7.6
	Ability of superstructure to support suspended equipment, including details of permissible support methods	Designer	12.2.4
	Confirmation of independent design check	Contractor	2.3.1
Erection and dismantling			
	Construction phase plan in accordance with the requirements of CDM 2015	Principal Contractor	3.7.1
	Evidence of competence	Contractor	2.3.1, 2.3.3
	Details of components to be checked at each erection	Designer/Contractor	6.3
	Records of inspection of structural components	Contractor	6.3.3
	Evidence that all lifting equipment is inspected and maintained in accordance with LOLER	Contractor	9.6
	Risk assessment/s for erection and dismantling	Contractor	3.2
	Erection and dismantling method statements	Contractor	2.3.2
	Confirmation of independent erection check	Contractor	2.3.3, 6.2.3
Use			
	Details of methods for assessing wind speeds	Designer/Contractor	7.6
	Details of action required at given wind speeds	Designer/Contractor	7.6
	Completion certificate	Contractor	2.3.3

Where required by the Enforcing Authority, design documentation and technical information should be provided at least 14 days before erection starts, and the Enforcing Authority should respond in writing at least seven days prior to erection. Enforcing Authorities should raise any queries on the design sufficiently far ahead so as to give the Contractor time to deal with any problems.

As part of the licensing process, the Enforcing Authority may also decide to inspect the structure after (and possibly during) erection to verify that:

- It is built in accordance with the approved details
- That it does not obstruct any exit route
- It does not (so far as is reasonably practicable) lend itself to misuse by the public

2.5 Document checklist

Table 2.1 is a checklist of documents that are applicable at the various stages of planning, designing and erecting structures, and the people usually responsible for preparing them. It should be noted that not all these items will apply in every case — particularly for lower-risk projects. Conversely, there may be circumstances where further documentation is necessary.

2.6 References

- 2.1 HM Government (1974). *Health and Safety at Work etc. Act 1974*. Available at: www.legislation.gov.uk/ukpga/1974/37 [Accessed: August 2016]
- 2.2 HM Government (2015). *The Construction (Design and Management) Regulations 2015*. Available at: www.legislation.gov.uk/uksi/2015/51/regulation/4/made [Accessed: August 2016]
- 2.3 Health and Safety Executive (2015). *CDM 2015 and the entertainment industry*. Available at: www.hse.gov.uk/entertainment/cdm-2015/index.htm [Accessed: August 2016]
- 2.4 HM Government (1998). *The Lifting Operations and Lifting Equipment Regulations 1998*. Available at: www.legislation.gov.uk/uksi/1998/2307/made/data.pdf [Accessed: August 2016]
- 2.5 HM Government (1998). *The Provision and Use of Work Equipment Regulations 1998*. Available at: www.legislation.gov.uk/uksi/1998/2306/contents/made [Accessed: January 2017]
- 2.6 Health and Safety Executive (2016). *Planning for incidents and emergencies*. Available at: www.hse.gov.uk/event-safety/incidents-and-emergencies.htm [Accessed: August 2016]
- 2.7 Health and Safety Executive (2016). *Summary of duties under Construction (Design and Management) Regulations 2015 (CDM 2015)*. Available at: www.hse.gov.uk/construction/cdm/2015/summary.htm [Accessed: August 2016]
- 2.8 The Institution of Structural Engineers. *Dynamic performance requirements for permanent grandstands subject to crowd action*. London: IStructE Ltd, 2008
- 2.9 MUTA (2015). *Best Practice Guide: Safe Use and Operation of Temporary Demountable Fabric Structures*. Available at: www.muta.org.uk/MUTAMembers/media/MUTAMembersMedia/PDFs/MUTA-s-Best-Practice-Guide.pdf [Accessed: August 2016]
- 2.10 HM Government (2003). *Licensing Act 2003*. Available at: www.legislation.gov.uk/ukpga/2003/17/contents [Accessed: August 2016]

3 Identification and control of hazards and risks

3.1 Hazards

Hazards are generally defined as circumstances that have the potential to cause harm.

Risks are the likelihood of the hazards being realised.

The process of assessing hazards and risks may be summarised as:

- What if?
- How likely?
- What are the consequences?
- How should they be controlled?

It is only through assessing all the relevant scenarios that the Designer and Contractor can be sure that the risks of accidents have been considered.

This *Guide* recommends that when considering occupancy, means of access and means of escape, Designers and Contractors should familiarise themselves with the environmental and technical infrastructure of the site (or building in which the structure is to be erected) and its management and information systems. In particular, they should identify safety problems by evaluating the hazards and risks and make sure that structures are properly designed with full regard to their surroundings. In all cases, a written risk assessment (including a fire risk assessment detailing how a fire will be controlled) should be completed.

Structural safety and the safety of users should be considered as paramount. The installation of a temporary structure should not compromise the safety of the existing environment.

Security-related hazards should be considered at an early stage to allow suitable mitigation measures to be identified. Early assessment may result in measures that are both easier to adopt and more cost-effective. Readers in the UK are referred to two key publications in this area^{3.1.3.2}. Equivalent publications may exist in other countries. Where these are not available, readers are referred to the UK documents. Further guidance notes may also be available from Enforcing Authorities.

3.1.1 Design

During the design process, hazards may unknowingly be incorporated into a structure. These may create a danger to the people erecting the structure, and to the users, if they are not detected. They are reduced by appropriate quality assurance and design checks. Such hazards may be due to errors on the part of the Designer, e.g. non-compliance with current good practice, failure to appreciate operational requirements, or limitations in current knowledge.

The design team should include competent persons who understand the nature of the use to which the structure will be put. Reference should be made to

BS EN 1990^{3.3}, BS EN 1991^{3.4} and BS EN 1090^{3.5} with regard to:

- Consequence classes
- Execution classes
- Reliability classes
- Production categories
- Service categories

The values used in the structural design should be clearly set out in the engineering documentation.

3.1.2 Erection and dismantling

During erection, hazards may occur for a number of reasons including an unsafe system of work, not following a safe system of erection/deconstruction, human error, time pressure, inadequate lighting, tired or poorly-trained operatives or malfunction of equipment. These may present a danger to operatives erecting the structures and to users, if they are not detected. They are avoided by:

- Appropriate controls built into specifications and erection documents such as method statements
- Training and appropriate supervision of operatives
- Inspection and checking during erection
- The supply of handover documents after first construction
- Final pre-event checks (Section 2.3.3)

These hazards (and controls) are equally applicable during dismantling.

The principal hazards to safety during erection and dismantling include (but are not limited to):

- Non-compliance with design and erection documentation
- Non-compliance with good practice
- Power or equipment failure
- External event e.g. fire, explosion, vehicle impact, weather conditions (particularly wind)
- Damaged or faulty structural members or equipment
- Working at height
- Lifting operations
- Plant movement
- Inadequate training

3.1.3 Operational

When erection is complete and the facility is open to users, a different set of hazards can present themselves. If the facility has been properly designed and erected then the hazards will generally be the result of external influences. Their effect will be significantly reduced by preplanning at all stages. Principal operational hazards include:

Structural

- Unauthorised alterations to the structure
- Overloading, structural failure or collapse
- Vehicle impact

- Structural damage
- Changing ground conditions
- Lack of robustness
- Malicious tampering with the structure

Environmental

- Extreme external environmental events e.g. flood, wind, snow, lightning, earthquake
- Fire or explosion
- Loss of power — leading to systems failures
- Spillage of dangerous substances

Crowd behavior

- Overcrowding and lack of public order

Vandalism or violent criminal behavior

- Excitement, demonstrations or incitement of a crowd

Each hazard should be considered individually and in association with any secondary hazards. For example, an explosion may be followed by fire, power failure, overcrowding at exits and medical emergencies. Several scenarios are possible despite many being highly improbable. The risks associated with a hazard or series of consecutive hazards should be assessed. If it is considered that there is a risk from terrorist activities, specialist advice should be sought by the Client.

3.2 Risk assessment

All employers are required (under *The Management of Health and Safety at Work Regulations 1999*^{3.6} in the UK, the *Occupational Safety and Health Act*^{3.7} in the US and *Canadian enviroOSH Legislation*^{3.8} in Canada/all relevant national regulations) to carry out an assessment to identify hazards and risks that could cause injury to employees or the public. The regulations also require self-employed workers to carry out an assessment of their work practices. When significant changes are made to work procedures, the regulations require these assessments to be reviewed. Where an employer employs five or more people, any significant findings should be recorded and especially vulnerable people should be identified. The risks associated with a hazard depend upon a number of factors, including:

- The probability of an incident and a series of secondary events occurring
- The effectiveness of measures to protect against the hazard and to control an incident
- The direct consequences if an incident occurs, and the indirect consequences thereafter

A proportionate approach to the likelihood of an incident should be adopted. Wherever possible, this should increase protection and reduce consequences.

Assessing the consequences of an adverse incident is both a human and a commercial matter. The fact that disasters are remembered by the names of their location signifies that memories are long. It may take many years for a venue which has been the site of a major incident to recover its popularity and prosperity.

Direct consequences (e.g. death, injury, property damage) are followed by indirect consequences including legal actions — both criminal and civil — that, in turn, result in financial losses, damage to reputations, increased insurance premiums, etc. Recognising that very serious consequences follow any major incident, promotes safe practices.

A number of individuals and organisations may be responsible for assessing risks at different stages of a structure's life; including erection, use and dismantling. For example, the:

- Principal Designer and Designer/s during the design phase
- Principal Contractor and Contractor/s during the erection and dismantling phase
- Event Organiser during an event

Their responsibilities (in the UK) for assessing risks are covered by *The Management of Health and Safety at Work Regulations 1999*, and by various contractual and tortious duties owed to all persons using the structures. In the US and Canada responsibilities are covered by the previously cited documents^{3.7,3.8}.

First, significant hazards for the structure should be identified (e.g. structural collapse, fire, overcrowding) in conjunction with possible consequences (e.g. fatalities, injuries, financial losses). Risks are then assessed in light of the identified hazards. To minimise risk, the likelihood of an incident occurring and the cost of control measures should be evaluated. Reasonably foreseeable hazards should be dealt with by reasonably practicable solutions. Following the assessment the hazard should be removed where possible.

The risk assessment will be unique for each event and is essential in order to identify appropriate risk mitigation measures. The risk assessment should be based on previous experience as far as possible, which means that records of performance should be kept, both for type of event and individual Contractors. Information from people with previous experience of these structures, such as Local Authorities, emergency services, insurers, engineers, Event Organisers and facility managers, may be valuable. Useful guidance on risk assessment and related matters is provided in the *Guide to Safety at Sports Grounds*^{3.9}. Reference should be made to Health and Safety Executive (HSE) assessment guidance and the general principles of prevention in the management regulations and CDM 2015.

It should be appreciated that it is not practicable to provide a generic checklist to cover all structures. The site location and vertical elevation of structures should be included within the risk assessment. Where practicable, structures should be located so as to minimise the risks associated with wind.

3.3 Steps to mitigate risks

3.3.1 Design

The design of temporary structures should generally follow the recommendations in this *Guide* and other relevant documentation.

The Designer's duties listed in Section 9 of the CDM 2015 regulations are:

- When preparing or modifying a design the Designer must take into account the general principles of prevention and any pre-construction information to eliminate, so far as is reasonably practicable, foreseeable risks to the health or safety of any person:
 - carrying out, or liable to be affected by, construction work
 - maintaining or cleaning a structure
 - using a structure designed as a workplace
- If it is not possible to eliminate these risks, the Designer must, so far as is reasonably practicable:
 - take steps to reduce or, if that is not possible, control the risks through the subsequent design process
 - provide information about those risks to the Principal Designer
 - ensure appropriate information is included in the health and safety documentation
- A Designer must take all reasonable steps to provide, with the design, sufficient information about the design, construction or maintenance of the structure, to adequately assist the Client, other Designers and Contractors to comply with their duties under these regulations

Design documentation should be prepared which sets out the design criteria for the structures. The engineering documentation should include a clear summary of the design parameters and operating limits of the structure.

At the design stage, a positive attitude to safety should be adopted; the many potential hazards can be envisaged, the risks assessed and plans made accordingly. In some cases the risk may be so great that another solution is necessary. For example, factors such as continual exposure to prevailing wind, the presence of live overhead electricity cables, risk of flooding or difficulties of access for users, may mean that either an alternative location (within the event site, or possibly an entirely different event site) might be necessary. Hazards that may affect the safety of a structure should be recorded; for use by those with ongoing responsibility for the structure.

Where applicable, vehicle impacts on structures resulting in possible structural damage should be considered during the design, along with secondary effects such as fire, explosion or chemical spillage. Structures, particularly vulnerable parts, should be protected from vehicle impact^{3.10,3.11} or local damage that might lead to disproportionate collapse. Where possible, these hazards must be removed/eliminated (e.g. by traffic control means, controlling vehicle access or using appropriate physical mitigation measures)^{3.12}. Traffic should be separated from pedestrians wherever practicable.

Consideration should be given to reducing the design strength of the structural elements to account for repetitive use.

If the Client or Contractor proposes alternatives to the agreed designs, these should be approved by the Principal Designer. Such changes should be subject to a further independent design check. For standard designs, where the changes are within the scope of the original design, further checks may not be

needed provided that the Contractor has the appropriate quality assurance schemes in place — detailing the methodology of operations, checking inspections and handover certificates.

3.3.2 Erection and dismantling

Erection has its own hazards. Most of these primarily affect site operatives, but some may also affect users of the facility.

Safety margins may be eroded if recommendations in this *Guide* and other relevant documents are not followed. Responsibility for erection should be made very clear, preferably by appropriate wording in the contract. Specifications need to be unambiguous and coordinated with the erection drawings.

All structures should be of sound materials and good construction, i.e. properly put together, and properly founded and supported. Partially erected or dismantled structures (Figure 3.1) may be more vulnerable to the consequences of some hazards, e.g. overloading, vehicle impact or instability due to wind loading.

Methods of quality control for site operations, including site inspections, should be established. Before opening a structure to users, an independent erection check should be carried out by a competent person. This is particularly important if the structure has been erected at short notice.

Reference should also be made to Section 6 of this *Guide*.

3.3.3 Operation

Once erection of a structure is complete and it is accessible to the public, hazards derive from the location, external events and the way in which the operations (not just of the structure but also of the whole event) are managed and controlled. Responsibilities are complex and those involved at various stages may include Clients, Local Authorities, local health authorities and hospitals, emergency services, civil defence authorities and local transport authorities.

The operating limits defined in the engineering documentation should form the basis of an event management plan (Section 3.7.3). This document defines the actions to be taken at certain times. For example, it would define the wind speed at which personnel would be put on standby to remove the wall scrim or equipment attached to a stage roof structure. It would also define the higher wind speed at which these would actually be removed. Guidance on the development of an event management plan is available^{3.13}.

A clear chain of responsibility and command should be specified for each section of the event management plan. This may include matters that relate to the operation and use of a structure. For example, the plan should take account of risks associated with matters such as power supply, overcrowding, vandalism or malicious tampering. Consideration should also be given to implementing search and screening measures for people and their possessions^{3.14} to mitigate the risk of malicious attacks.



Figure 3.1 Site in part-built mode

3.4 Crowd behaviour

3.4.1 Introduction

Crowds may impose significant vertical and horizontal loads on structures (Section 7) and crowd behaviour in emergencies is also important.

Reference should be made to *The Purple Guide to Health, Safety and Welfare at Music and Other Events*^{3.15} for advice on crowd behavior.

Leisure events can attract large numbers of people (Figure 3.2). A crowd may, by its density or mobility, create dangerous conditions in its interaction with the local environment.

Visitors to an event assume that planning for their safety and welfare has taken place.

3.4.2 Crowd density and movement

The density of a crowd determines the amount of free space available to individuals and is a factor used in determining the safe capacity of a venue/site. Where free space is available around each person, even in a very large crowd, people will be comfortable. The critical issue therefore, is usually the local crowd density, rather than the overall capacity of the facility.

If the crowd density increases and involuntary body contact occurs, people cannot move easily and they may become tense. If the tension is further raised, either intentionally via audiovisual stimuli, or by a serious incident such as an explosion, then the collective mood of the crowd changes. It can become very difficult to pass safety information to the crowd in these circumstances.

Management is needed when the behaviour of individuals in the crowd changes^{3.16}. Crowd density



Figure 3.2 Large crowd gathers at Ferrari World, Yas Island, Abu Dhabi

should therefore be considered during the design stage. During the event, there should be an efficient means of controlling the occupancy of local areas.

At different stages during an event, crowds may behave in a variety of ways. They may be:

- Voluntarily ambulatory at access, egress and during an event
- Voluntarily ambulatory because of migration to an area with better sightlines, creating local overcrowding
- Involuntarily ambulatory because of dynamic forces within large crowds
- Non-ambulatory; waiting to enter or leave the event or standing as passive spectators

Ambulatory crowds occur at events where there is frequent movement around the site, e.g. racing meetings, golf tournaments, markets, exhibitions (Figure 3.3). At these events, people attend for relaxation and are usually amenable to instructions given through information and management systems in non-threatening circumstances.

Spectators, particularly at such events, appreciate good access, egress and viewing facilities with no local overcrowding. Because they are not in a highly stimulated state, they respond well to both visual and verbal information systems. They may make several journeys to and from various parts of the site during an event. A temporary grandstand may be emptied and reoccupied frequently.

3.4.3 Crowd sightlines

Sightlines have a critical effect on crowd behaviour. Poor sightlines can lead to seated spectators standing and becoming agitated because they cannot see. This can lead to adverse crowd behaviour. Standing up in a seatway is not in itself dangerous, but it may lead to people standing on

seats, which is particularly hazardous. In grandstands that are not fully occupied, audience migration may also occur over seatways, which can lead to injury.

It is particularly important therefore, that proper consideration is given at the design stage to providing good sightlines. Guidance is available from BS EN 13200-1^{3.17} and the Sports Grounds Safety Authority publications — including Chapter 12 of the *Guide to Safety at Sports Grounds*.

3.4.4 Crowd control and crowd management

'Crowd control' implies that crowds are intrinsically dangerous. They are not: they can become dangerous through insufficient or inappropriate provision for their requirements. A physical response by stewards can then become necessary to secure public safety.

By contrast, 'crowd management' is the business of recognising, analysing and meeting the requirements of crowds, with a combination of forward planning, risk assessment, engineering response, visually intrusive and clearly audible information and alert general management. The aim should be to make crowd control unnecessary by the implementation of good crowd management.

Consideration should be given to the access and egress arrangements for each structure, and how these may affect people occupying them, including provisions for people with disabilities.

Fencing or other means should be adopted to prevent crowd members from climbing structures to gain unauthorised access to vantage points. Access and egress for emergency vehicles should be discussed with the Enforcing Authority.

Unauthorised persons should be kept from the vicinity of (including from being underneath, on top of,



Figure 3.3 Ambulatory crowd

or around) structures, particularly to prevent tampering. The risk assessment for the structure should take this into account, and appropriate steps should be taken; which may range from notices prohibiting entry, to barriers, fencing or complete enclosure. Obscure barriers, fencing or enclosures may make it harder to enforce this, and transparent options should be considered to aid regular visual inspections and the use of CCTV.

In mobility-impaired disabled crowds, spectators take up fixed viewing positions and generally remain at the same location, apart from visits to refreshment facilities, toilets, etc. Although these crowds may similarly appreciate safety and comfort provisions, they may not be so receptive to visual or audible information systems. This may be a result of increased stimulation due to several factors including: high ambient noise levels, excitement generated by the performance and the general effect of being in a crowded, high-energy environment. In such conditions, evacuation information needs to be very intrusive indeed. These crowd conditions can become very difficult to control if public order disturbance occurs.

This *Guide* recommends that Event Organisers consider these aspects when deciding upon the location of the structure and the arrangements for access and egress^{3.16}.

3.5 Electrical installations and lightning protection

All exposed metalwork within a structure that could come into contact with a source of electrical current must be adequately earth bonded^{3.18–3.20}. Consideration should be given by the Designer to the degree of exposure and risk of lightning strike and, where appropriate, the structure should be adequately protected^{3.21}.

Advice on lighting levels for normal and emergency use is outside the scope of this *Guide* and is available elsewhere.

3.6 Fire

Reference should be made to the Enforcing Authority or fire service to determine the implications for the structure. Fire safety arrangements should also be considered during the erection and dismantling phases.

In assessing fire safety, Designers should consider the distinction between life safety provision and provision which protects property. The requirement for proper safety measures will inevitably impact upon the work of a Designer, in particular in the safe and cost-effective choice of materials. However, decisions should always be taken within the context of life safety provision, including safe evacuation from the structure during erection, use and dismantling.

Suitably designed and constructed safe routes from any part of a structure to either a place of safety or a

final exit (means of escape) are essential. There should also be an alternative means of escape of no less a standard. Such means of escape should be integrated into the emergency exit system of the site or building in which it is situated. There should be enough exits to evacuate within a specified time^{3.9,3.22}. The local fire service should be consulted to assist with assessing occupancy factors.

Research has shown that traditional approaches to evacuation have incorrectly assumed that people panic in fire incidents^{3.23}. Far from panicking, people tend to wait inquisitively and watch the fire develop. Furthermore, they dangerously underestimate the rapid spread of a developing fire. Emphasis has therefore shifted to the time taken for crowds to move. This problem may be best dealt with by information and management systems, such as public address systems and effective stewarding, rather than traditional alarm bells or sirens. These systems do not replace traditional engineering methods of providing fire resistance, but are an important complementary feature of safety management.

Other factors may affect the ability of people attempting to evacuate. Inhalation of carbon monoxide, carbon dioxide and cyanide gas, which are readily produced in most fires, can be fatal. Furthermore, smoke irritants from burning organic and inorganic materials cause difficulty in seeing and breathing, and delay evacuation. Choice of materials can therefore be critical to life safety in a rapidly developing fire, even though traditional detection and alarm systems may be in place.

The aim of Designers, Contractors and those responsible for safe management of the structure should be to eliminate:

- Ignition sources, e.g. matches, smoking materials, flame from cooking fuels, flame caused by electrical circuit failure
- Rubbish that will ignite easily, e.g. accumulation of waste paper or wood shavings
- Combustible material that will contribute to a rapidly developing fire and produce toxic gases and dense smoke, e.g. thin untreated wooden sheets or untreated drapes or curtains

Designers and Contractors should consider fire risks which are reasonably foreseeable and should aim to eliminate or reduce these to a level which is considered reasonably practicable. During a fire risk assessment the following checklist may help in identifying materials or activities which might contribute to the development of a serious fire:

- Are structural members made of combustible material likely to affect the safety of people using the structure? If inferior materials are used, evacuation time may be significantly reduced. The use of incombustible construction materials is the primary protection for people against fire^{3.9,3.22}
- Could rubbish accumulate under the structure?
- Could timber, used as decking, risers, soffits or balustrades, make a significant contribution to a developing fire?
- Does any decorative laminate used, have an acceptable resistance to surface spread of flame^{3.24}?

- Has the design and construction provided acceptable travel distances, evacuation times and alternative means of escape^{3,9}?
- Could seating materials contribute to the rapid spread of fire?
- Are curtains, hangings or decorations made of flame-retarded, durably flame-retarded or inherently flame-retarded fabric^{3,25}?
- If a structure is erected indoors, can existing automatic fire detection, fire suppression or fire alarm systems make a significant contribution to fire safety^{3,26,3,27}?
- Does the venue have a general management and stewarding response which is alert to fire hazard?
- If a fire started, could hot gases accumulate beneath the roof?
- Have measures to provide smoke ventilation (to prevent flashover) been considered?
- Can kiosks beneath grandstands be effectively 'fire separated'?
- If kiosks are used as unoccupied storerooms during an event, are fire detection systems in place?
- How (and to where) are the kiosks ventilated?
- Is there any possibility of pyrotechnics being used in a performance?

In addition to these, consideration should be given to the choice of materials — with particular regard to those that might produce toxic gases when subjected to fire conditions or highly elevated temperatures.

The contribution to fire safety provided at a site or indoor venue by the existing infrastructure may vary considerably. Where the contribution is significant it may be possible to relax other requirements. However, Designers and Contractors are cautioned about reliance solely upon management control of the event to reduce life safety risks in fire assessments. Such solutions may be beyond the scope of the Designer or Contractor to verify, e.g. the quality of stewarding.

Flammable gases are not permitted in many public assembly buildings. At outdoor sites, however, they are a popular cooking fuel. Butane and propane — collectively known as liquefied petroleum gas (LPG) — are used extensively. The gas is 1.5 times heavier than air and forms a flammable mixture at between 2% and 10% by volume in air. Temporary hoses and connections may be susceptible to damage and leakage. LPG could represent a significant risk of fire/explosion should it accumulate beneath a structure. It is recommended that the storage or use of LPG should not be permitted beneath demountable grandstands. Furthermore, cooking methods that give rise to serious risk of fire, such as deep fat frying, should not be permitted beneath these structures. Any LPG stored in the vicinity of such a structure should comply with appropriate guidance^{3,28}.

3.7 Safety planning

3.7.1 Introduction

Structures used by large numbers of people do not exist in isolation. They should be designed and

erected with full regard to the local environment and the needs of users. To achieve the safety of the structure and its occupants, it should be designed and erected to coordinate with, and integrate with, the safety framework of the venue or site so that it responds predictably to its particular usage.

The historical engineering response to safety is well understood. However, controlling the planning and supervision of the design, procurement and use of structures at events, is less well known. Preparing and implementing a 'construction phase plan', which identifies the hazards and associated risks relating to the design, procurement and use of the proposed structure within the context of the event, is an effective means of achieving such control.

3.7.2 Safety policies

Safety policies are produced to meet the legal requirements of Section 2 of the *Health and Safety at Work etc. Act 1974*^{3,29}, and guidance on preparing them is available^{3,30,3,31}. Section 3 of the Act provides duties in respect of 'persons other than employees'. This legislation therefore deals with the safety of all people using these structures. At sports grounds the safety of spectators is covered by the *Safety of Sports Grounds Act 1975*^{3,32} and the *Fire Safety and Safety of Places of Sport Act 1987*^{3,33}. The production of a spectator safety policy is often a requirement of safety certificates issued under the 1975 or 1987 Acts.

3.7.3 Event management plan

To create an event management plan, the hazards and associated risks throughout the design, procurement, use and dismantling of a structure should be assessed, and a plan for managing these should be prepared that includes the responsibilities of the various parties (Section 2). The most important aspects of an event management plan are its actions and the management of these actions, i.e. a clear chain of responsibility or command. Individuals should be both identifiable and accountable in respect of their responsibilities for safety matters.

The plan should deal with any special requirements shown on the drawings and other documentation.

Guidance on management and operation of events is given in the *Guide to Safety at Sports Grounds*^{3,9}, *Safety Management*^{3,30}, the *Guide to fire precautions in existing places of entertainment and like premises*^{3,34}, *Events Management*^{3,35}, and the event safety pages of the HSE website^{3,36}.

The degree of risk changes as patterns of behaviour change. The event management plan should be subject to continual review and periodic formal revision. The plan will benefit from input from facility operators and should be periodically reviewed for repeated events. Feedback from debriefing meetings after the event can be very useful in assessing the operational effectiveness of the plan.

3.7.4 Safety and supervision during the event

Good management is essential to provide proper safety for users of these structures. Key aspects that

should be considered in planning supervision during an event include:

- The Client, Event Organiser and safety coordinator should monitor the event and take action as necessary to make sure that structures are used as planned and that safety is not compromised or jeopardised
- Users should not be admitted to a structure until the safety coordinator and Client are satisfied that it has been properly erected and complies fully with the design documentation
- No structural members forming any part of a structure should be removed during use
- The number and distribution of users for which a structure has been designed should not be exceeded
- A sufficient number of stewards should be appointed by the Client to safeguard spectators. They should be appropriately trained beforehand, be under the direction of the Client and safety coordinator, and be briefed on safety and fire drills as well as their specific duties^{3.37,3.38}

A proactive approach to planning is recommended to make sure that risks to safety are reduced to acceptable levels^{3.39,3.40}. This may assist in reducing the risk of incurring liability from a claim under the *Occupiers' Liability Act 1957*^{3.41} and from a claim alleging that the duty of care has been breached.

Security staff should be trained for emergencies, and new and temporary staff given training and instructions. The event management plan, together with drawings of the venue facilities, should be held by the safety coordinator and be readily available to both those in charge and the emergency services.

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4 Statutory control

4.1 General

Legislative controls in the UK can appear complex because the primary legislation controlling public safety can vary depending on the type of venue hosting the event. This section therefore outlines the current legislation most likely to apply to temporary structures.

It should be noted that, in most cases, Clients, Venue Owners and Event Organisers (rather than the suppliers of structures) are principally responsible, in law, for complying with public safety legislation while the structure is in use. It should also be borne in mind that penalties for non-compliance can be severe.

It is therefore recommended that Event Organisers and others involved in the procurement of structures should contact the Local Authority's building control or environmental health office, at the earliest opportunity, to obtain guidance about technical and procedural requirements relating to such structures.

The Local Authority is generally responsible for health and safety regulation during the event. However, where another agency, or indeed another department of the Local Authority is responsible, either the building control officer or the environmental health officer should be able to make sure that enquiries are directed to the appropriate body.

Local Authorities will help to identify what legislation applies in any particular case and exactly what procedural requirements have to be followed by people proposing to erect structures for public use.

A number of factors will determine what legislation applies (Section 4.2). Building control officers (or whichever Local Authority department is responsible for public safety regulation at the venue concerned) will expect to be furnished with information about the structure's proposed use and length of time in operation, in order to advise Venue Owners and Event Organisers on compliance with the relevant statutory requirements.

4.2 Permissioning legislation and procedures

The principal legislation and procedures relevant to all structures are set out in the following subsections.

4.2.1 Building Regulations

4.2.1.1 England and Wales

Building Regulations^{4.1} and their associated amendments, apply to all new buildings erected in England and Wales, save for specific exemptions contained in a schedule attached to the Regulations.

However, many structures will not be subject to control under Building Regulations because:

- They will not be classed as a 'building' for the purposes of the Regulations
- They will be covered by one of the categories for exemption listed in the schedule

For instance, in most cases, an uncovered stand is unlikely to fall within the definition of a 'building' in the Regulations, which is necessary if it is to be subject to control, whereas it is likely that a covered (or part-covered) stand will. Separately, under current provisions, most temporary buildings which will remain on-site for less than 28 days will be exempt under Schedule 2 of the Regulations. In all cases, however, the advice of the Local Authority's building control officer should be sought.

Where either the Building Regulations or local regulations apply, prior notice of the erection of the structure should be given to the Local Authority, together with sufficient details for them to check whether it complies with all of the relevant requirements (including structural stability and fire safety). The Local Authority may also carry out site inspections during erection to make sure that the finished building is compliant. A fee will be charged by the Local Authority for this service. Further guidance can be obtained from the Planning Portal^{4.2}.

4.2.1.2 Scotland

The Building (Scotland) Regulations^{4.3} and their associated amendments, apply to all new buildings in Scotland, except for specific exemptions stated in Regulation 3 (Schedule 1) and Regulation 5 (Schedule 3).

The definition of 'building' in Scotland does not exclude temporary structures, including uncovered stands. Temporary structures either erected or used for a period not exceeding 28 days (or 60 days in any 12 months) are however, exempt.

4.2.1.3 Northern Ireland

The Building Regulations (Northern Ireland)^{4.4} and their associated amendments, apply to all new buildings, except for specific exemptions stated in Part A: Regulation A5. The definition of a 'building' in Northern Ireland includes a temporary building, structure or erection of whatever kind or nature. Temporary structures erected for a period not exceeding 28 days are exempt, as defined in Regulation A5(1) (Schedule 1 Class 4).

4.2.2 Planning permission

It is impossible to summarise here, all the circumstances under which planning permission will be necessary on any given site. However, it is advisable (in England, Scotland and Wales) for the Event Organiser to seek the advice of the Local Authority's planning office prior to the erection of the building or structure. Clearly, planning control will not directly address public safety issues;

however, constraints affecting the siting of the building, permitted hours of use, etc. may alter the number of hazards.

This advice is equally applicable to Northern Ireland. In Northern Ireland 'planning' is the responsibility of the Government of Northern Ireland and is administered by the Planning Service, an agency within the Department of the Environment for Northern Ireland. Further guidance can be obtained from the Planning Portal^{4,5}.

4.2.3 Premises licensed for public entertainment (not including sports grounds)

4.2.3.1 England and Wales

The *Licensing Act 2003*^{4,6} empowers Local Authorities to issue licences in connection with premises used for public entertainment purposes. Temporary demountable structures, including barriers, have no specific mention under the legislation. However, to ensure a premises licence is approved, the licensing authority can attach conditions to the licence.

For Building Regulation control, it should be noted that it is usually the responsibility of Venue Owners and Event Organisers to make the necessary application to the Local Authority. The description of regulated entertainment that needs to be licensed before any premises may be used for such purposes is outlined as follows:

- A performance of a play
- An exhibition of a film
- An indoor sporting event
- The staging of boxing, wrestling or mixed martial arts
- Entertainment of a similar description to those marked with an asterisk (*) below — where the entertainment takes place in the presence of an audience and is provided for the purpose, or for purposes which include the purpose, of entertaining that audience
 - A performance of live music*
 - Any playing of recorded music*
 - A performance of dance*

The definitions of 'entertainment' and 'premises' for licensing purposes are important in determining whether statutory provisions will apply. The definitions as outlined here are precisely given within the Act.

The few exemptions that are made under the Act come under Schedule 1 Part 2 and include:

- The purposes of, or incidental to, a religious meeting or service
- At a place of public religious worship

It is generally held that, if the public (or any section of the public) are allowed to attend any type of entertainment, whether paid-for or otherwise, the entertainment is public. Other considerations, such as whether admission is by ticket or programme (and whether the tickets or programmes have been sold beforehand, been advertised, or are in aid of charity) are immaterial.

As the licence applies to the premises itself, even if the event can be seen as not open to the public, the conditions attached to the premises will remain in force. Private clubs also fall under the Act and as such are regulated in a similar manner.

The term 'premises' includes parks and open spaces, not only buildings.

Under the Act, an application can be made for a Temporary Event Notice (TEN). If successful, an event with fewer than 500 people can take place for no longer than 168 hours (seven days).

If the notice is applied for correctly, there can be no attached conditions by parties such as building control, and although health and safety regulations apply (Section 4.3.1) it might appear that no other permissioning legislation will be in place.

In all cases, contact with the Local Authority and Enforcing Authority should be made, to ascertain the effects of these provisions on the erection of structures for use in connection with public entertainment.

4.2.3.2 Scotland

The *Civic Government (Scotland) Act 1982*^{4,7} empowers Local Authorities to issue licences in connection with premises used for public entertainment purposes (Section 41 of the Act refers) where, on payment or payment of money's worth, members of the public are admitted.

Temporary grandstands and other raised structures (platforms, staging, etc.) are subject to Local Authority approval under Section 89 of the Act. It should be noted that Section 89 does not apply to structures for which a building warrant has been granted.

4.2.3.3 Northern Ireland

The *Local Government (Miscellaneous Provisions) (NI) Order 2002*^{4,8} empowers District Councils to issue licences in connection with premises used for entertainment purposes. Structures used in connection with entertainment will be subject to control under such a licence.

The types of entertainment that need to be licensed before any premises may be used for such purposes are:

- Theatrical performances
- Dancing, singing or music, or any entertainment of a like kind
- Circuses
- Any entertainment which consists of, or includes, any public contest, match, exhibition or display of:
 - boxing, wrestling or mixed martial arts
 - billiards, pool, snooker or any similar game
 - darts
 - any other sport or game prescribed by the Department of the Environment for Northern Ireland
- Machines or equipment for entertainment or amusement, excluding gaming machines
- Equipment for the playing of billiards, pool, snooker or other similar games

Note: Music or singing when part of a religious service is exempt under the Order.

The Order also applies to musical entertainment in the open-air, and similarly identifies the different requirements for indoor and outdoor licences.

The Order stipulates that a licence is required, in relation to the provision of indoor entertainment, at

any place where, on payment of a charge:

- People are admitted for the purposes of entertainment
- Meals or refreshments are supplied to the public

The District Council's building control surveyor will advise on any of these matters, or will otherwise pass on enquiries to the relevant department.

4.2.4 Sports grounds

4.2.4.1 Sports grounds safety certification

The safety of spectators at sports grounds in England, Wales and Scotland is provided for under the *Safety of Sports Grounds Act 1975*^{4.9} or the *Fire Safety and Safety of Places of Sport Act 1987*^{4.10}. The main feature of control under this legislation is the issue of safety certificates which, like entertainment licences, include terms and conditions for spectator safety at such venues. The procedural requirements for erection and use of structures at sports grounds will vary according to which Act applies to the sports ground in question.

Requirements will depend on whether the safety certificate is issued under the provisions of the *Safety of Sports Grounds Act 1975* (generally for larger sports grounds) or the *Fire Safety and Safety of Places of Sport Act 1987* (smaller venues). Where a sports ground has been designated as requiring a safety certificate issued under the provisions of the 1975 Act (normally referred to as 'designated grounds') the certificate will generally prescribe terms and conditions relating to the whole of a sports ground to which spectators have access, and to any structures or equipment that may impact upon the safety of spectators in those areas. A certificate issued under the 1987 Act will provide only for the safety of spectators occupying individual stands which provide covered accommodation for 500 or more spectators at a non-designated sports ground. Such stands are normally referred to as 'regulated stands'.

The erection of structures (or any alterations made to such structures) within the boundaries of a

designated ground, or within a regulated stand, will always require prior notification to the Local Authority.

The erection of structures at non-designated sports grounds, remote from any regulated stand, may not however fall subject to control under either Act (although the Building Regulations may still apply). In such circumstances, the extent of the 'control' over public safety matters that can be exercised by a Local Authority are limited to the use of prohibition notices (Section 4.2.4.2).

The erection of a covered temporary stand at a non-designated sports ground will be subject to control under Building Regulations as outlined in Section 4.2.1. Additionally, if the stand is capable of holding 500 people or more, the Owner (or ground manager, or person in charge of events at the ground) should also contact the certifying Local Authority to clarify whether a safety certificate is required.

Guidance for Local Authorities on the safety certification procedures they should follow at designated sports grounds is available in the *Guide to the safety certification of sports grounds*^{4.11}.

To help simplify matters, Table 4.1 shows the general position, as far as statutory public safety controls affect the erection of temporary grandstands. Event Organisers are advised to confirm, with reference to the Local Authority, whether a submission of details under Building Regulations will be required or whether an application for a new (or an amendment to an existing) safety certificate should be made. For instance, as far as 'designated grounds' are concerned, it should be noted that some association football grounds are designated under the 1975 Act, even though their maximum 'certificated' capacities are less than 10,000.

The equivalent legislation for sports grounds in Northern Ireland is *The Safety of Sports Grounds (Northern Ireland) Order 2006*^{4.12}.

4.2.4.2 Sports grounds prohibition notices

Advice is given to Local Authorities in England, Wales and Scotland in a Department for Culture, Media &

Table 4.1 Temporary grandstands at sports grounds: Building Regulations and safety certificate control

Type of sports ground	Designated sports grounds (most large sporting venues with spectator capacities 10,000+)				Other sports grounds [‡] (including sports grounds with 'regulated stands')			
Duration of grandstand	On-site for less than 28 days		On-site for 28 days or more		On-site for less than 28 days		On-site for 28 days or more	
Type of safety control	Building Regulations	Safety certificate	Building Regulations	Safety certificate	Building Regulations	Safety certificate	Building Regulations	Safety certificate
Uncovered grandstand accommodating <500 spectators	No	Yes	No	Yes	No	No	No	No
Uncovered grandstand accommodating 500+ spectators	No	Yes	No	Yes	No	No	No	No
Covered (or part-covered) grandstand accommodating <500 spectators	No	Yes	Yes	Yes	No	No	Yes	No
Covered (or part-covered) grandstand accommodating 500+ spectators	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Note [‡] This table may also be used to determine whether Building Regulations will apply in the case of other venues where grandstands are used for non-sporting events. For sites other than sports grounds the 'safety certificate' columns can be disregarded.								

Sport circular^{4.13} relating to the use of prohibition notices at sports grounds. This gives Local Authorities emergency powers to prohibit, or limit, the admission of spectators into a temporary structure at a sports ground where the Local Authority consider there to be a risk to public safety. A prohibition notice may be issued for parts of a sports ground not covered by a safety certificate, such as a temporary demountable structure. It should be noted that this may be the only form of control that can be exercised over, for instance, large uncovered temporary grandstands at non-designated sports grounds.

No prior notice needs to be given, by law, to the Local Authority before erecting a temporary grandstand, or similar structure, in a non-designated sports ground. However, in order to avoid the service of a prohibition notice, Venue Owners and Event Organisers should consult the Local Authority before procuring temporary structures for use in any part of a sports ground.

There is no separate legislation for sports grounds currently applicable to Northern Ireland.

4.2.5 Local Acts in England and Wales

In some areas, local legislation (such as County Council Acts) will include public safety provisions which might affect the use of temporary demountable structures. The effect of local Acts in England and Wales is diminishing as they are being either repealed or superseded by national legislation, but reference should again be made to the Local Authority to establish any particular requirements that may apply.

4.2.6 Fire precautions

Reference should be made to the fire service and the Local Authority for the appropriate provisions.

4.3 Occupational health and safety law

The principal UK health and safety legislation relevant to all structures is set out in the following subsections.

4.3.1 Health and Safety at Work etc. Act 1974 (and regulations made under it)

The *Health and Safety at Work etc. Act 1974* ('the Act')^{4.14} and the regulations made under it, apply to employers and the self-employed. The law requires them to do what is reasonably practicable to ensure people's health and safety.

The Act sets out the general duties that employers have towards their employees while at work. The Act also requires employers and the self-employed to protect people other than those at work e.g. volunteer staff and spectators. These people should be protected from risks to their health and safety arising out of, or in connection with, a work activity.

Local Authority environmental health officers will usually be responsible for enforcing the various requirements of the Act and regulations which relate to the use of structures, with The Health and Safety

Executive (HSE) normally enforcing construction work undertaken during erection and dismantling.

Employees similarly have responsibilities for their own health and safety and for the health and safety of others that may be affected by their actions. The HSE or the environmental health department of the Local Authority will be able to advise on the application of this legislation in any particular case.

Designers and Contractors should be aware that Section 6 of the Act places duties on those who design, manufacture or supply articles for use at work, to carry out all testing, research and calculations — to check that they are safe to use.

The Management of Health and Safety at Work Regulations 1999^{4.15} place emphasis on the risk assessment process, using competent persons to advise on health and safety matters and providing adequate training to employees.

Documented health and safety policies and procedures should be maintained, and method statements should be prepared detailing the erection and dismantling operations for temporary structures. There are a number of regulations which relate to construction activities and cover safe working practices for operatives involved in erection and dismantling. Either the HSE or the Local Authority's environmental health officers will be able to give specific advice in this respect.

Equivalent requirements apply in Northern Ireland under the *Health and Safety at Work (Northern Ireland) Order 1978*^{4.16} and the *Management of Health and Safety at Work Regulations (Northern Ireland) 2000*^{4.17}.

Much legislation is applicable to temporary structures as well as to permanent structures, such as *The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013* (RIDDOR)^{4.18}.

4.3.2 Construction (Design and Management) Regulations 2015

The Construction (Design and Management) Regulations 2015^{4.19} (CDM 2015) apply to all temporary demountable structures projects, including those undertaken in the entertainment industry. Reference should be made to these regulations where the roles and responsibilities of Client, Principal Designer and Principal Contractor are defined. A project includes all the planning, design and management tasks associated with construction work e.g. the building, fitting-out, and dismantling of structures for TV, film and theatre productions and live events.

CDM 2015 make the general duties of the *Health and Safety at Work etc. Act 1974* more specific. They complement the general *Management of Health and Safety at Work Regulations 1999*, and integrate health and safety into the management of construction projects.

The aim is for construction health and safety considerations to be treated as an integral part of an event/production's management and development — not as an afterthought. In conjunction with wider measures taken to ensure a safer event/production, the objective of the Regulations is to reduce the risk

of harm to those that build, fit-out, use, maintain and dismantle structures. The key principles are:

- Eliminate or control risks so far as is reasonably practicable
- Ensure work is effectively planned
- Appoint the right people and organisations at the right time
- Make sure everyone has the information, instruction, training and supervision they need to carry out their jobs safely and without damaging health
- Have systems in place to help parties cooperate and communicate with each other and coordinate their work
- Consult workers — with a view to securing effective health, safety and welfare measures

The HSE provides specific CDM 2015 guidance for those working in the entertainment industry^{4.20}.

4.4 References

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- 4.2 Planning Portal (2016). *Building Regulations: When you need approval*. Available at: www.planningportal.co.uk/info/200128/building_control/38/building_regulations [Accessed: August 2016]
- 4.3 HM Government (2004). *The Building (Scotland) Regulations 2004*. Available at: www.legislation.gov.uk/ssi/2004/406/contents/made [Accessed: August 2016]
- 4.4 HM Government (2012). *The Building Regulations (Northern Ireland) 2012*. Available at: <http://www.legislation.gov.uk/nisr/2012/192/contents/made> [Accessed: August 2016]
- 4.5 Planning Portal (2016). *Planning*. Available at: www.planningportal.co.uk/info/200127/planning [Accessed: August 2016]
- 4.6 HM Government (2003). *Licensing Act 2003*. Available at: www.legislation.gov.uk/ukpga/2003/17/contents [Accessed: August 2016]
- 4.7 HM Government (1982). *Civic Government (Scotland) Act 1982*. Available at: www.legislation.gov.uk/ukpga/1982/45/contents [Accessed: October 2016]
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- 4.10 HM Government (1987). *Fire Safety and Safety of Places of Sport Act 1987*. Available at: www.legislation.gov.uk/ukpga/1987/27 [Accessed: October 2016]
- 4.11 Sports Grounds Safety Authority (2014). *Guide to the safety certification of sports grounds*. Available at: www.safetyatsportsgrounds.org.uk/sites/default/files/publications/safety-certification-guidance-2014.pdf London: SGSA, 2014 [Accessed: October 2016]
- 4.12 HM Government (2006). *The Safety of Sports Grounds (Northern Ireland) Order 2006*. Available at: www.legislation.gov.uk/nisi/2006/313/contents [Accessed: October 2016]
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- 4.14 HM Government (1974). *Health and Safety at Work etc. Act 1974*. Available at: www.legislation.gov.uk/ukpga/1974/37 [Accessed: October 2016]
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- 4.16 HM Government (1978). *Health and Safety at Work (Northern Ireland) Order 1978*. Available at: www.legislation.gov.uk/nisi/1978/1039/contents [Accessed: October 2016]
- 4.17 HM Government (2000). *Management of Health and Safety at Work Regulations (Northern Ireland) 2000*. Available at: www.legislation.gov.uk/nisr/2000/388/contents/made [Accessed: October 2016]
- 4.18 HM Government (2013). *The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013*. Available at: www.legislation.gov.uk/UKSI/2013/1471/contents/made [Accessed: October 2016]
- 4.19 HM Government (2015). *The Construction (Design and Management) Regulations 2015*. Available at: www.legislation.gov.uk/ukSI/2015/51/contents/made [Accessed: October 2016]
- 4.20 Health and Safety Executive (2016). *CDM 2015 and the entertainment industry*. Available at: www.hse.gov.uk/entertainment/cdm-2015/index.htm [Accessed: October 2016]

5 Ground and site conditions

5.1 Introduction

Structures are utilised in a wide variety of indoor and outdoor settings. Loadings should be distributed so that any bearing pressures and differential settlements are within acceptable limits.

Event Organisers, Contractors, Designers and Enforcing Authorities should be aware that the performance of the ground can vary significantly, depending on whether the loading is short- or long-term. Long-term settlement and associated 'differential settlement' often has less impact for temporary structures than for permanent structures. Therefore, the allowable bearing pressures on a given type of ground may be different from those associated with permanent buildings. The risk assessment for the structure should take this into account.

The impact of a temporary structure on adjacent slopes, retaining structures and buildings should also be considered, with particular consideration to surcharging.

5.2 Ground information

Clients should give basic information on ground conditions including contamination and water regime. It is likely that the appropriate competent person will be required to determine the allowable bearing capacity for the ground on which structures are founded. Ground information collected for other structures on the site is a good source of foundation design data and may include desk study information for the particular location.

The Client should notify the Contractor of the position of underground services or overhead cables which may present hazards during the erection or use of the structure. If underground services or overhead cables cross the site where the structure is to be erected, the Client should first obtain advice from the service company concerned.

If any doubt exists, and in order to protect its employees, the Contractor or appointed specialist should carry out additional checks such as a Cable Avoidance Tool (CAT) scan of the site area where penetration is planned.

5.3 Basic principles

BS EN 1997-1^{5.1} gives recommendations for the design of buildings and civil engineering works; it does not specifically relate to temporary demountable structures. However, BS EN 1997 may be used as a starting point to assess allowable bearing pressures (with the comments in Section 5.1 being borne in mind).

Structures should be supported on foundations sized such that the bearing pressures do not exceed allowable values. Structures are often supported on steel or aluminium uprights, sometimes on base jacks fitted with steel baseplates. These often sit onto timber 'spreaders' e.g. short lengths of scaffold board or railway sleepers. The spreader plates distribute the point loads so that the allowable bearing capacity of the ground is not exceeded, hence they need to be suitably stiff. The baseplate loads should not cause local crushing of the timber spreaders. Wet/rotten timber is more prone to crushing and such items should be rejected and replaced.

Some large structures, such as multi-storey hospitality buildings, generate high stanchion loads. In these cases a grillage of suitable spreaders is needed to adequately distribute the load to the supporting ground, often effectively acting as a stiff raft foundation. In cases where repeat use of the structure is likely, the provision of permanent concrete pads with holding-down bolts housed within covered manholes, may be appropriate (Figure 5.1).

The greatest risk of foundation failure is 'soft spots' due to peat, unconsolidated fill, cavities, land drains, previous excavations, etc. These may not be apparent at the surface but may be detected by probing, trial pits or small-scale excavation. In all such operations, the hazards posed by underground services should be eliminated.

Unequal settlement could induce high stresses and deformations in the structure. The position of the supports should therefore be set out on-site, and any soft spots which coincide with the support positions should be excavated and replaced with compacted granular fill, or bridged with grillages or other suitable transfer structures.

It should be noted that tower structures are particularly sensitive to differential settlements, which may cause tilting.



Figure 5.1 Permanent base for frequent re-use

5.4 Ground bearing pressures

Determining the allowable bearing pressure involves recognising both ultimate (collapse) and serviceability (allowable movement) limit states.

Structures for outdoor applications are generally loaded for relatively short periods. While it is well known that settlement usually comprises both immediate and longer-term movements, the latter may not need to be taken into account unless the structure will be in use for more than 28 days — in which case a full engineering assessment of the ground should be made.

The ground surface on which structures are positioned may include asphalt or gravel paths, pasture, heaths, sports fields, concrete or bituminous surfaced areas and hardstandings among other types. Before they are accepted for carrying the design loads, the suitability of such surfaces should be visually checked by a competent person, augmented as necessary by a desk study (by excavating trial pits, or by ground investigation involving soil tests or load tests) and taking account of local knowledge.

Particular care should be taken where structures are supported on bituminous, concrete or similar hardstandings. It should be recognised that the thickness of the surface and the thickness and type of the underlying material are critical to the ability of the surface to support load.

Plate bearing tests provide a useful means of estimating allowable bearing pressures. California bearing ratio (CBR) tests are less relevant.

When making any assessment, consideration should be given to current and future weather effects. For example, frozen or dried ground will support higher pressures than the same ground once thawed or saturated by heavy rain.

Overall allowable bearing pressures should never exceed the values in Table 5.1 unless this has been justified by site testing. If test data are not available or if there is doubt about the uniformity of the site conditions, the tabulated pressures may need to be

Table 5.1 Indicative values of allowable short-term bearing pressures

Bearing material	Allowable bearing pressure (kN/m ²)
Dense sand	200
Medium dense sand	150
Loose sand	75
Stiff clays	150
Firm clays	75
Notes These values are considered appropriate for temporary structures in place for up to 28 days. Values for structures in place for periods exceeding 28 days should be derived from an appropriate site investigation and/or from recommendations made in BS EN 1997-1. High water table in granular soils can significantly reduce allowable bearing pressures and increase settlements, i.e. allowable bearing pressure may change with variation of moisture content.	

reviewed and possibly adjusted by a competent person. In the absence of reliable local or professional engineering knowledge, an allowable bearing pressure not exceeding 50kN/m² should be assumed.

Made ground, especially granular materials, can support vertical loads — providing their degree of compaction and location of water table are taken into account. However, its diverse nature requires careful judgement by a competent person to assess its bearing capacities. Peat and organic subsoils (i.e. a depth of topsoil greater than that usually associated with normal grassed areas) are unsuitable for bearing surfaces under any circumstances. Regularly-spaced and equally-loaded timber spreaders may be safely supported on grassed areas such as lawns, heaths, fields, playing fields, etc. provided that the topsoil/grass is not greater than 250mm thick and that the ground is dry, stable and not subject to excessive softening if wetted.

5.5 Baseplates (soleplates) and spreaders

Baseplates (heavy steel plates fixed to substantial column sections, Figure 5.2) and spreaders (timber plates or baulks placed between the steel plates and the supporting ground, Figure 5.3) should be engineered and their size and distribution specified. Design calculations should be prepared to show how the leg loads are transferred to the ground. Experience has shown that the use of either scaffold planks or railway sleeper spreaders are generally satisfactory.

Note that the terms 'baseplate' and 'soleplate' are sometimes used interchangeably, but the latter can also refer to small steel plates normally 150 × 150mm, typically associated with scaffolding systems.

A typical method of support is to place timber spreaders on the ground and to then use scaffolding



Figure 5.2 Frame marquee baseplate



Figure 5.3 Spreader

screw jacks with soleplates to level the structure. Special heavy-duty baseplates are sometimes used; these are larger, stiffer and stronger than conventional scaffold soleplates. They are often associated with hospitality structures or similar, where conventional structural sections are used as the main load-bearing columns.

In certain circumstances, timber spreaders are not required. However, this can only be where good quality concrete, asphalt or other known surfacing can be relied upon to safely support relatively light loadings. Supports should not be founded on ground that has been excavated locally unless the backfill is properly compacted granular material.

Concentrated soleplate/baseplate loads should be assumed to spread through the timber spreader at 2 horizontal to 1 vertical along the grain, and 1 to 1 across the grain unless proven otherwise by calculation. Good quality plywood should be assumed to spread loads at 2 horizontal to 1 vertical in both directions relative to the grain on the surface unless proved otherwise by calculation.

Soleplates and baseplates should be inspected by the Contractor before each use. They should be positioned centrally under the load unless indicated otherwise in the design documentation. Failure to comply with this requirement may result in bearing stresses far in excess of calculated values, leading to

local overstress of the ground and unacceptable differential settlement of the structure.

5.6 Uplift and sliding

The Designer should specify the foundation loads, including any uplift forces and lateral loads, and should demonstrate how this load is transferred through the structure to the ground. As well as ensuring that allowable bearing pressures are not exceeded, adequate resistance to sliding and uplift should be provided. Appropriate safety factors are given in Section 7.

Uplift and sliding forces are generally resisted using either kentledge or ground anchors. Deciding which approach to adopt often depends on the site — for example, it may not be permissible to puncture asphalt or concrete finishes.

5.6.1 Kentledge

Commonly used forms of kentledge include water-filled containers (Figure 5.4), concrete blocks and steel assemblies. The choice of ballast will be influenced by transport considerations, plant and accessibility, and the amount of space available to locate ballast. If water-filled containers are used, adequate steps should be taken to ensure they are not damaged. Damage could result in loss of water and hence reduction in performance of the anchorage, leading to structural instability.

If uplift is to be resisted wholly or partly by the weight of a decking system that the structure is supported on, the Designer must demonstrate that the uplift/sliding forces can be transferred through the deck.

Sliding is resisted by mobilising frictional forces, and guidelines for suitable coefficients of friction are given in Table 5.2. Note that all interfaces need to be checked, i.e. between the soleplate and the plywood spreader, plywood and railway sleeper, sleeper and ground.

Adjacent foundations should be positioned far enough apart to avoid interaction.

The amount of friction generated between the kentledge and the substrate is critical to the stability of the system. The correct value of the coefficient of friction is therefore essential. It should be noted that



Figure 5.4 Water-filled containers as kentledge

Table 5.2 Coefficients of friction

	Wood	Steel	Concrete
Wood	0.4	0.4	0.6
Steel	0.4	0.1	0.2
Concrete	0.6	0.2	0.5
Clay*	0.25	0.2	0.25
Loam*	0.4	0.2	0.4
Sand and gravel	0.65	0.2	0.65
*Minimum stiffness consistency in accordance with BS EN 1997-1.			

when kentledge is placed on grass the coefficient of friction may be very low.

There have been a number of failures of roof structures due to insufficient kentledge being provided^{5.2}. A well known example is the stage collapse at the Indiana State Fair in 2011^{5.3}. It must be appreciated that the effectiveness of kentledge is significantly reduced where the guy-wires are inclined. This, in turn, reduces the resistance of the anchorage markedly.

An example of the derivation of the amount of kentledge required to resist an inclined load is provided in Appendix A.

5.6.2 Ground anchors

Ground anchors or stakes are commonly used to resist uplift in fabric structures, particularly big tops and marquees. They may be used to resist uplift as an alternative to kentledge. The pull-out force that an anchor can withstand depends on the:

- type of ground
- type of anchor/stake
- moisture content of the soil along the length of the anchor/stake
- inclination of the anchor/stake
- depth of the anchor/stake

Stiff to very stiff cohesive soils provide the most resistance to pull-out. Loose, non-cohesive soils such as sand provide the least.

Stakes are driven steel bars, often referred to as 'marquee pegs', which are generally 25mm in diameter, and approx. 800–1500mm in length (Figure 5.5)^{5.4}. These may be plain steel bars, reinforcement bars or 'star bars' which comprise plates welded together to form a star or cruciform in plan. These are either driven vertically through baseplates (typical for marquee construction, Figure 5.6) or installed at an angle and loaded at 45–90° — typical for guys on big tops. Tests have shown there to be no significant difference in pull-out capacity between plain bars and reinforcement bars, although star bars have a greater capacity in cohesive soils due to the larger surface area.

Several types of proprietary ground anchor are available (Figure 5.7). Light- to medium-duty helical anchors and earth anchors are commonly used. Manufacturers of ground anchors usually provide data on safe working loads for various soil types. It should be noted that these allowable loads vary considerably, particularly due to the moisture content of the soil. Ground anchors can be difficult to install



Figure 5.5 Steel stakes

accurately. This can lead to eccentricities which could give rise to bending moments in the structure or in the foundations which need to be accounted for in the design. Ground anchors should be designed by a competent person and installed in accordance with the manufacturers' guidelines and recommendations. Many proprietary anchors can be installed using equipment which calculates the resistance of the anchor during installation, and hence the load-carrying capacity of the anchor.

Given the variability of the effectiveness of ground anchors in different soils, confidence in their capacity should be provided by testing e.g. by means of a forklift truck with a calibrated load cell. Such testing should be in the direction of the force to be resisted by the ground anchor. A minimum of three tests



Figure 5.6 Baseplate with four steel stakes

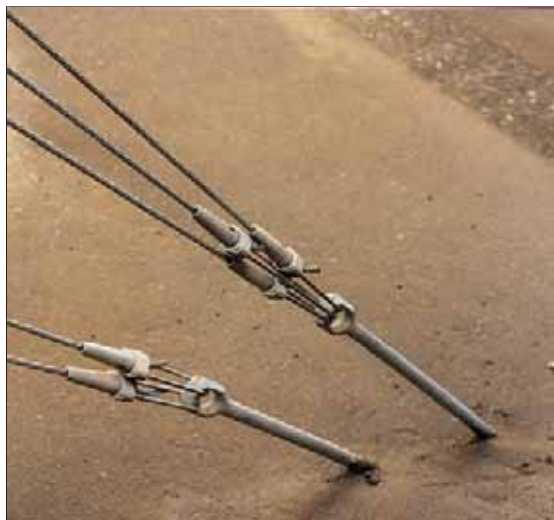


Figure 5.7 Proprietary ground anchor

should be carried out as close as possible to the proposed location of the anchors, and the lowest figure taken. A safety factor of $v = 1.6$ should be applied to the lowest test value in order to determine the load-capacity of the anchor.

Ground anchors should be inspected on a daily basis for any sign of movement, especially after heavy rainfall.

The capacity of ground anchors may reduce significantly after the moisture content of the soil has increased.

5.7 Sloping ground

If a site slopes or is uneven, the ground should be levelled or else the structure must be capable of being modified to deal with the unevenness. Where the ground is not level (or near level, but the foundation bases for the structure cannot be set at an angle) a level base should be provided. This can be achieved either by cutting steps into the ground or by laying timber sleepers up the slope — with timber blocks, shaped to match the slope, fixed to the sleepers to form individual foundations for each upright (Figure 5.8).

It should be noted that the bearing capacity of foundations on a step will reduce, depending on the slope of the surrounding ground. This reduction should be allowed for in design. The stability of the sloping ground should be checked by a competent person.

Care is required in order to obtain full and even contact with the ground. Depressions should be filled and loose material compacted. If the ground is uneven and significant packing is used, care should be taken that stability is maintained.

Where a site slopes, or in order to raise a viewing platform, scaffolding substructures supporting the main structure are often provided. The requirements for spreaders and or grillages etc. described previously are equally relevant to the substructure but the interface between it and the main structure above should be considered. It is essential that the designs of the two elements are fully coordinated so that the

correct load paths (vertical down loads, uplifts and lateral loads) can be maintained and the necessary connections made. It is important that one competent person has overall responsibility for coordinating the various designs.

5.8 Site drainage

The site should be chosen so that it is not prone to flooding, as this could either reduce the load-bearing capacity of the ground or wash away the ground under the supports. The chosen site should not be in an area where water could soften or erode the ground or cause scouring. If such an area cannot be avoided, a suitably hard foundation should be prepared that is sufficiently deep and wide to prevent it being undermined during the period the structure is in use. If the structure is founded underwater, a reduction to the weight of the ballast must be made to take buoyancy into account.

Particular care should be taken when positioning rainwater pipes from roof structures. They should discharge at a suitable distance from the main structural supports.

5.9 Inspection

After the structure has been erected, both it and the ground should be checked regularly to ascertain whether any significant movement, displacement or differential settlement has occurred. A reduction in load-bearing capacity or overloading could cause excessive settlement. Overloading could occur if the rigidity of the structure prevents some of the spreaders from bearing on the soil — leaving the structure to span between supports that are not adjacent to each other. If significant movement is evident, remedial work will be required. This may involve repacking and levelling, or installing another type of foundation. The Contractor undertaking the repacking or levelling should check that the structure has sufficient redundancy (alternate load paths



Figure 5.8 Structure on sloping ground

capable of carrying structure loadings safely to the ground) to allow remedial work to proceed without affecting overall stability.

5.10 References

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- 5.4 *BS EN 13782:2015: Temporary structure. Tents. Safety.* London: BSI, 2015

6 Erection, inspection and dismantling

6.1 Introduction

This section is particularly relevant for Contractors and suppliers and for those who supervise and inspect site work. The Principal Contractor and the Principal Designer, as defined in CDM 2015, should be identified and agreed with the Client.

Reference should be made to BS EN 1090^{6.1}, BS EN 1990^{6.2} and BS EN 1991^{6.3}. Due consideration should be taken of the classes and categories set out in the design (Section 3.1.1)

6.2 Erection

The guidance in this section pertains to temporary structures other than fabric-covered structures — for which, reference should be made to Section 11.

6.2.1 Planning

The critical erection stages should be identified during the design process. To ensure adequate provision against overturning during erection, temporary strutting and/or guying may be necessary. Such requirements should be adequately communicated to the site operatives. A set of risk assessment and method statements (RAMS) which includes the erection method statement — often known as the 'Safe System of Work' (SSoW) document, together with drawings, is recommended for this purpose.

The drawings should be sufficiently detailed to enable the main structural components, including connectors, to be identified and scheduled for delivery to the site. All components should be marked for ease of identification wherever possible (by such means as tags, paint marking or stamping) and in a manner that would not be detrimental to the performance of the component. Deliveries should be organised to allow the erection to proceed in the planned erection sequence. Wherever possible, the drawings should also identify the site location.

The tolerances of assembly should be specified by the Designer. Particular care should be taken to minimise eccentricities at structural joints. Diagonal bracing is often a problem in this respect. Care should be taken in both design and build to ensure that theoretical force lines take into account both the size and bulkiness of connectors and couplers, and the eccentricities caused by off-node connections.

6.2.2 Work on-site

Erection of structure

The structure should be erected safely; in accordance with the RAMS and the design documentation. The RAMS should be produced by

a competent person on behalf of the Contractor in conjunction with the Designer. The Contractor, in conjunction with the Designer where necessary, should prepare and follow a construction sequence included in the erection method statement (SSoW document) which ensures that the structure is stable throughout erection.

All kentledge, ground anchors, guying and other means of support (e.g. Figure 6.1) identified in the RAMS should be properly installed and in the position shown in the engineering documentation. It should be noted that positions shown on drawings may need to be changed for operational reasons. Any changes must be agreed with the Designer. The erection team and site operatives should be aware that by making site-specific judgements and taking decisions with regard to the position of guying and associated anchorages, they are attracting significant design responsibilities. It should be borne in mind that anchorage problems have led to a number of recent failures; perhaps most notably the roof structure at the 2011 Indiana State Fair^{6.4}.

All work at height must be fully assessed and carried out in compliance with the requirements of *The Work at Height Regulations 2005*^{6.5}.

Care should be taken to use the correct component in the correct location and orientation. All components should be carefully aligned. They should not be bent, distorted, or otherwise altered to force a fit. Particular attention should be paid to tightness of connections. The torque applied to bolts and other connectors should be in accordance with the manufacturer's or Designer's recommendations.

Care should also be taken to ensure that all specified ties and bracings have been correctly installed.



Figure 6.1 Heavy-duty substructure arrangement

Site alteration or modifications can only be made via a robust management system employed by the Contractor. Details of this management system should be detailed in the RAMS provided by the Contractor. Reference should also be made to Section 3.1.1 with regard to changes to the design.

Scaffold structures

Where a scaffold (tube and fitting) substructure is required (Figure 6.2), its erection should be carried out in accordance with standards of workmanship given in BS EN 12811-1^{6.6}, BS 5975^{6.7} and the appropriate technical guidance from the National Access and Scaffolding Confederation (NASC).

Putlog couplers (which are intended as positioning devices), wrap-overs, fence couplers and similar items should not be used for structural connections. It is important to recognise the need for meeting the tolerances noted, since it is through poor erection that several collapses have occurred. For modular structures, and system scaffolds, manufacturers' recommendations for tolerances of assembly should be followed.

Bracings and connections

All necessary bracings and other components should be incorporated as assembly progresses. Bracing should be arranged to provide stability at all stages of erection. A check should be carried out to see that the necessary connections are made and that linking components are not strained to achieve engagement. Local instability — that might endanger the complete structure when loading occurs — could arise through omitting or failing to tighten a bolt. Constant emphasis should be placed on the importance of attention to detail.

Safety of operatives

Operatives should be provided with safe systems of work, including details of which parts of the structure

are suitable for the attachment of fall-arrest, work-restraint or work-positioning anchors. These anchors should be clearly specified in the SSoW and identified on the drawing.

Inspection of structures

Inspection is essential to maintain the safety and integrity of a demountable structure. Inspections are required at various stages and these will mainly be the responsibility of the Contractor. The Client, the Principal Contractor, the Principal Designer, the safety coordinator and Local Authority may also make inspections.

During erection, the Contractor should make regular inspections to verify the design assumptions and to check that work is being carried out in accordance with the documentation provided. The initial inspection should concentrate on setting-out and site preparation. Subsequent inspections should check the orientation and location of the components (especially bracing members), the use of temporary supports and the proper installation of the correct connectors, couplers and fittings.

All inspection work should be recorded. Specific reference should be made to remedial measures that have been identified, and to dates agreed for carrying out such work.

The Client should be provided with a full set of erection documentation. Key stages of erection should be highlighted to show where particular safety measures should be taken. The Client's safety coordinator should examine the structure during erection and in subsequent use and any comments should be supplied to the Contractor. The Contractor should carry out any remedial work deemed necessary as a result of these inspections unless they can provide documentary evidence to show that the as-built situation is safe.

Where a Local Authority licence is required, the Local Authority inspector may require a full set of design documents for the assembly and may inspect these at any stage. The inspector may require copies of any documents which formalise earlier inspections.

6.2.3 Erection check

Once erected, the structure should be subject to an erection check by a competent person.

The inspection should be a systematic local check of the complete structure. A drawing and checklist should be available for continuous reference. The inspection should confirm that:

- Members are correctly positioned and connected
- Setting-out is accurate within the tolerance required
- The foundations are adequate, that they are not likely to be disturbed and that they and the lower portion of the supporting structure are not prone to damage by interference, accident, traffic, scour, undermining or any other cause
- Suitable soleplates have been provided, properly levelled and, where necessary, adequately supported. The soleplates should be properly bedded down, with no unacceptable settlement
- The stipulated limits of extension of adjustable components have not been exceeded



Figure 6.2 Scaffold substructure



Figure 6.3 Ground support roof structure with large stage structure below

- All required components: pins, bolts, nuts, clips, etc. are of the correct type, have been correctly inserted and are secure
- Decking, seating and guardrails have been correctly installed and are secure
- Services to the structure do not in themselves create a hazard or impose loadings not catered for in the design

If any significant damage to any elements occurred during erection, this should be noted and the Designer informed, in order that overall stability can be checked.

The inspection should check that the erection conforms to the design documents supplied by the Contractor. Any deviations should be substantiated and supported by additional documentary evidence as required by the management systems in the RAMS (Section 6.2.2). The results of the inspection should be recorded in writing and action taken to correct any faults. On completion of a satisfactory inspection the Client should be informed and confirmation made in writing.

After the structure is completed and inspected, it should be secured to prevent vandalism and malicious tampering. Unauthorised access beneath or on structures should not be permitted. Installation of solid or porous risers may also be considered during the design stage to restrict access to the support structure. Ensuring the area beneath the structure is kept clear and not used as a storage area will assist with any inspections, allowing the area to be checked more efficiently.

It is recommended that a competent person inspect each structure while it is in use; the frequency of the inspection depending on the nature of the event. If a structure remains in use for a reasonable period of

time (for example, for a series of concerts at a festival), it should be inspected before and after each use.

There is an example of an erection checklist in MUTA's Code of Practice^{6.8} which, while written particularly for fabric structures, provides a useful framework for planning inspections of some other types of temporary structure. Figure 6.3 shows an example of a scaffold substructure.

Reference should also be made to relevant guidance from the HSE^{6.9}.

6.3 Inspection of components

6.3.1 Repeated use of components

The repeated use of a structure will inevitably lead to general wear and tear, in addition to damage or distortion that may occur during handling, transportation, assembly and dismantling. The Contractor should regularly inspect all components (erection aids as well as components in the structure itself) for signs of wear, deformation or other damage. Following the procedures set out in Section 6.3.3, the Contractor should inspect components:

- When allocated at the stockyard
- On arrival at site or during unloading
- During assembly
- While in service
- During dismantling
- On arrival back at the stockyard

Since components may be reused many times, particular attention should be given to identifying

damaged or corroded components. Any components whose structural efficiency has been or could be impaired should be rejected. Damage or deterioration may be corrected, if practicable, but if repair is neither practical nor economical, the component should be replaced. Damaged or defective components should be clearly marked and removed from the site as soon as possible.

Spare components should be readily available to allow necessary repairs to be undertaken rapidly. Temporary repairs using makeshift components should be avoided. Typically, damage can include:

- Tube and prefabricated components:
 - Corrosion
 - Cracking
 - Deformation
 - Creasing
 - Split ends
 - Non-flat or non-square ends
 - Weld integrity
- Connectors, couplers, fittings:
 - Deformation
 - Distortion
 - Damaged threads

6.3.2 Scaffolding components

Steel scaffold tube that is corroded to the extent of rust flaking or severe pitting of the surface should be cleaned of all loose material. It should then be measured for external diameter and checked against the minimum requirements of BS EN 39^{6,10}. Particular attention should be paid to the 75mm length at the

tube ends as this is particularly susceptible to corrosion due to damage or overstressing.

Both steel and aluminium tubes should be free from cracks, and should have the ends cut square, smooth and free from burrs. Sections of tube that have been partly sawn, seriously deformed or creased by abuse should be cut out and scrapped. Tubes that have become thin or split at the ends should be shortened by an appropriate amount. Bent tubes should be straightened so that they do not deviate more than 5mm from a straight line in any 2m length.

Fittings should be inspected. They should not be used if they are damaged in such a way that their efficiency is reduced. It is necessary to check that threads are in good condition. Any damage should be corrected by repair or replacement, but if this is not possible, the item should be disposed of.

Baseplates should be checked to ensure weld integrity, that the base is square to the stem, and that the plate is flat.

Prefabricated components should be checked for damage, distortion and weld integrity. Faulty or suspect items should be repaired, checked dimensionally and, if necessary, offered to jigs in order to achieve acceptable fits on future use.

In order to minimise deterioration and accidental damage, all elements should be carefully stored to prevent distortion, and protected to an appropriate extent against deterioration.

Table 6.1 Inspection procedures for structures erected and dismantled repeatedly

Item for inspection	Frequent inspection procedure	Periodic inspection procedure
	Frequent inspections should be performed by a competent person and should be conducted prior to each use and after any incident	Periodic inspections should be performed by a competent person and should be conducted at least once every 12 months. All structural elements should be taken out of service during inspection
	Inspect item for:	Inspect item for:
Main members	• Denting • Bends • Abrasion	• Denting • Bends • Abrasion
Secondary members	• Denting • Bends	• Denting • Bends
Connecting plates	• Flatness • Deformation or excessive wear of holes	• Flatness • Deformation or excessive wear of holes • Corrosion
Pinned connectors	• Deformation	• Excessive abrasion • Deformation of connection pin holes • Method of connection
Welds	• Cracks and abrasion	• Cracks by visual inspection – 100% all welds • Abrasion by visual inspection – 100% all welds • A competent person should undertake dye penetrant testing on any weld that is thought to be defective
Fasteners (proprietary $\frac{1}{4}$ -turn fasteners, bolts, pins)	• Proper grading ○ must be matched • Deformation • Excessive wear	• Proper grading ○ must be matched • No deformation of fasteners • Excessive wear
Geometry of structural element	• Twisting of structural element • Squareness of structural element • Bending of structural element	• Twisting of structural element • Squareness of structural element • Bending of structural element • Sweep • Camber

6.3.3 Inspection of structural components used repeatedly

Here, the minimum required inspection routines and guidelines for the user and/or Owner are set out. It is intended for guidance only and users/Owners should seek advice about specific inspection routines from the manufacturer or a competent person.

The guidelines reflect Standards from the American National Standards Institute (ANSI): ANSI E1.2^{6.11}, ANSI E1.21^{6.12} and British Standards Institution: BS 7905-1^{6.13}, BS 7905-2^{6.14}, BS 7906-1^{6.15} and BS 7906-2^{6.16}. Equipment used for lifting operations may have different inspection requirements.

There are two types of inspection: frequent and periodic, both of which should be carried out following the procedures in Table 6.1. Structures in regular service should be subject to both frequent and periodic inspections.

Periodic inspections are visual inspections for which records are required to be kept. The inspection requirements should be determined by a competent person for all equipment that is new to the Contractor's undertaking, whether purchased new from a manufacturer, manufactured in-house or acquired second-hand. Damaged or unrepairable items should be permanently removed.

Stored structural elements that have been out of service for more than 12 months should be subject to a periodic inspection before further use.

Records for each structural component should be kept and should be signed and dated by the inspector. Inspections and repairs should only be carried out by a competent person.

6.4 Dismantling

The dismantling of a structure is important since its components are likely to be reused. Care should be taken to maintain the safety of the dismantling team and others in the vicinity.

The critical erection stages should have been identified during design. The safest dismantling plan is often to reverse the erection procedure but in any case the correct sequence should be detailed in the RAMS. If temporary guying is used to erect the structure, the Designer must also specify the requirements for dismantling.

The RAMS should detail all measures needed to prevent components from being bent, distorted or overstressed. Minor damage to the structure may have occurred while in service and the damaged components should be clearly marked for ease of identification. During dismantling, the Contractor should examine all components for signs of wear, deformation or other damage. Damaged components, or those with temporary repairs, should be clearly identified for rejection or permanent repair off-site.

6.5 References

- 6.1 *BS EN 1090-1:2009 + A1:2011: Execution of steel structures and aluminium structures. Requirements for conformity assessment of structural components.* London: BSI, 2009
- 6.2 *BS EN 1990:2002 + A1:2005: Eurocode. Basis of structural design.* London: BSI, 2002
- 6.3 *BS EN 1991-1-1:2002: Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings.* London: BSI, 2002
- 6.4 Thornton Tomasetti (2012). *Indiana State Fair Commission, August 13, 2011, Collapse Incident Investigation and Report.* Available at: www.thorntontomasetti.com/projects/indiana_state_fair_commission_collapse_incident/ [Accessed: October 2016]
- 6.5 HM Government (2005). *The Work at Height Regulations 2005.* Available at: www.legislation.gov.uk/uksi/2005/735/contents/made [Accessed: October 2016]
- 6.6 *BS EN 12811-1:2003: Temporary works equipment. Scaffolds. Performance requirements and general design.* London: BSI, 2004
- 6.7 *BS 5975:2008 + A1:2011: Code of practice for temporary works procedures and the permissible stress design of falsework.* London: BSI, 2008
- 6.8 MUTA (2015). *Best Practice Guide: Safe Use and Operation of Temporary Demountable Fabric Structures.* Available at: <http://www.muta.org.uk/MUTAMembers/media/MUTAMembersMedia/PDFs/MUTA-s-Best-Practice-Guide.pdf> [Accessed: October 2016]
- 6.9 Health and Safety Executive (2016). *CDM 2015 and the entertainment industry.* Available at: www.hse.gov.uk/entertainment/cdm-2015/index.htm [Accessed: October 2016]
- 6.10 *BS EN 39:2001: Loose steel tubes for tube and coupler scaffolds. Technical delivery conditions.* London: BSI, 2001
- 6.11 *ANSI E1.2-2012: Entertainment Technology: Design, Manufacture and Use of Aluminum Trusses and Towers.* New York: ANSI, 2012
- 6.12 *ANSI E1.21-2013: Entertainment Technology — Temporary Structures Used for Technical Production of Outdoor Entertainment Events.* New York: ANSI, 2013
- 6.13 *BS 7905-1:2001: Lifting equipment for performance, broadcast and similar applications. Specification for the design and manufacture of above stage equipment (excluding trusses and towers).* London: BSI, 2001
- 6.14 *BS 7905-2:2000: Lifting equipment for performance, broadcast and similar applications. Specification for design and manufacture of aluminium and steel trusses and towers.* London: BSI, 2000
- 6.15 *BS 7906-1:2005: Use of lifting equipment for performance, broadcast and similar applications. Code of practice for installation, use and removal of above stage equipment (excluding trusses and towers).* London: BSI, 2005
- 6.16 *BS 7906-2:2000: Lifting equipment for performance, broadcast and similar applications. Code of practice for use of aluminium and steel trusses and towers.* London: BSI, 2000

7 Loading

7.1 Introduction

This section provides guidance on the various design loading requirements for temporary structures, with particular emphasis on wind loads and the operational management of grandstands, stages and ancillary structures to resist these loads. Operational management details for fabric structures are covered in Section 11.

The loading appropriate for the design comprises dead, imposed, wind and notional horizontal loads (including loads from fall-arrest systems) and may require consideration of dynamic loads from crowds (and, in the case of stage roofs, from moving equipment such as video screens and props). Structures should be designed in accordance with the appropriate National Standards and Codes of Practice. Structures should be capable of resisting all loads imposed by their foreseeable use with adequate safety margins. Those that provide areas for seating/standing should be able to withstand the characteristic actions in accordance with BS EN 1991-1-1^{7.1} — or the loads specified in the appropriate National Standard.

Four main categories of use should also be considered for vertically applied loads (Section 7.3). The actions of horizontal loading should also be considered e.g. handrail and barrier loading; where either the requirement of the *Guide to Safety at Sports Grounds*^{7.2} may be appropriate, or the more standard requirements of the Building Regulations.

The design documents should clearly state the type of imposed loading/category assumed, including if necessary, the maximum number of spectators or participants the structure can accommodate. They should also include the maximum gust wind speed at which the structure remains safe and stable.

7.2 Dead loads

Reference should be made to BS EN 1991-1-1. These result from the self-weight of all fixed elements which form part of the structure.

7.3 Imposed loads

These include loads from spectators, moveable equipment and, where appropriate, snow.

BS EN 1991-1-1 considers various categories of loading appropriate to the type of activity/occupancy for the part of a building or structure. Category C concerns areas where people may congregate. The divisions of this within the Eurocode that are relevant to temporary structures are C2, C3, C4 and C5. The Eurocode gives ranges of imposed loads for these but also gives a recommended value. These ranges are 'nationally determined parameters' and so specific values can be set in National Annexes. The UK has chosen to sub-divide the categories given in the Eurocode. The relevant Eurocode and UK National Annex categories, together with the value/s of imposed loading are given in Table 7.1 (the recommended values from the Eurocode are given in bold numbers).

For stage structures, the imposed loadings will need to be determined, as they are performance-generated. Stage surfaces have to withstand static loads (e.g. the weight of stage sets, equipment, and dynamic loads) caused by people dancing, jumping or moving in a synchronised manner. To ensure that these two conditions are fully considered, the surface should be designed to withstand a minimum vertical static equivalent load

Table 7.1 Imposed uniformly distributed loads (from BS EN 1991-1-1 and UK National Annex)

Category and sub-category of loaded area	Eurocode category UK National Annex sub-category	Vertical loading (kN/m ²)
C2 C21	Areas with fixed seating Assembly areas with fixed seating	3.0–4.0 4.0
C3 C33 C35	Areas without obstacles for moving people Aisles Stairs and landings	3.0–5.0 4.0 4.0
C4 C41	Areas with possible physical activities Dance halls and studios, gymnasias, stages (see Note b from the UK National Annex, below)	4.5–5.0 5.0
C5 C51 C52	Areas susceptible to large crowds Assembly areas without fixed seating (see Notes a and b from the UK National Annex, below) Stages in public assembly areas (see Note b from the UK National Annex, below)	5.0–7.5 5.0 7.5
Notes a For grandstands and stadia, reference should be made to the requirements of the appropriate certifying authority. b For structures that might be susceptible to resonance effects, reference should be made to the National Standard or equivalent documentation.		

Table 7.2 Notional horizontal loads for design of temporary demountable grandstands (as a percentage of vertical imposed load)

Category of spectator activity	Horizontal load (percentage of vertical live load)
Category 1 Nominal potential for spectator movement, which excludes synchronised and periodic crowd movement, such as at: • Lectures/exhibitions • Displays/shows • Minor athletic events • Golf tournaments • Agricultural shows • Military tournaments	6%
Category 2 Potential for spectator movement more vigorous than Category 1. For instance as at: • Major athletics meetings where music accompanies the individual events • Major musical concerts • Rugby or football matches	7.5%
Category 3 Stands with a potential for synchronised and periodic crowd movement and having vertical and horizontal fundamental frequencies which avoid resonance effects, e.g. at most pop concerts where strong musical beats are expected.	10%
Notes a Partial factors for dead and imposed loads for use in the limit state design should correspond to the structural Code of Practice relevant to the material (steel, aluminium, etc.). For notional horizontal loads, the partial factor should be 1.5 for the load combination case with factored values of vertical dead and imposed loads. b The notional horizontal load should be combined with the operational wind load for designing the structural elements, but not in the design against overturning as a result of wind action (Section 7.6). c Synchronised and periodic crowd movements may include dancing, jumping, rhythmic stamping, etc.	

of 5kN/m^2 , and a simultaneous notional load commensurate with the use applied in any one horizontal direction at the stage surface. This value should be a minimum of 5% of the design vertical imposed load (or such higher value taken from Table 7.2 as required by the anticipated activity). This notional load should be applied to the area of stage floor on which the activity takes place. Other parts of the stage floor, including wings and extension platforms used for workers and equipment, should use a value of 2.5% of the vertical load for the notional horizontal load. The values of the design's vertical and horizontal loads used for each area should be clearly defined in the engineering documents and shown on relevant drawings.

However, assuming that the self-weight of the rostra and stage sets does not exceed 2.5kN/m^2 , the design vertical static equivalent load on rostra and stage sets should generally be 2.5kN/m^2 , unless defined otherwise in the engineering documentation. Appropriate risk assessments should be prepared for the rostra and stage sets, and the operating limits clearly defined in the engineering documentation.

Stage floor surfaces should be constructed in such a way as to remove any tripping or undesirable slipping hazards. It is recommended that stages should be designed to carry a point load of 3.6kN over an area $50 \times 50\text{mm}$ without causing any damage to the floor and without causing excessive deflection of the floor panels (e.g. deflection of more than 10mm relative to the adjoining panels).

If moving objects are attached to the structure, an allowance for the dynamic movement of the object should be considered. Unless specific measures are put in place (such as 'soft-start' circuits or other techniques), the allowance should be a 25% increase for electrically-operated equipment and 10% for hand-operated equipment as appropriate.

The quoted values are characteristic values. All roofs, floors and spectator decks should be designed to carry the uniformly distributed load derived using appropriate load factors.

Vertical imposed crowd loads should be taken into account as quasi-static actions. It may also be necessary to consider the dynamic effect of imposed loads, especially for long-span structures and grandstands. It has been demonstrated that groups of people dancing and jumping in unison can generate forces up to 3.5 times their own weight. This means that people jumping in unison can potentially generate forces well in excess of the design load for proprietary stage decks. As such, the use of such decks for a suspended dance floor is not recommended^{7.3,7.4}.

The design of temporary structures to resist earthquakes is not usually required in areas of low seismicity. However, if the Client and/or Enforcing Authority require the structure to be subject to seismic design, the complexity of the design is much higher. Reference should be made to National Standards which may include BS EN 1998-1^{7.5}, ASCE/SEI 7^{7.6}, ASCE/SEI 37^{7.7} and ANSI E1.21^{7.8} or other appropriate and equivalent Standards, as well as relevant guidance documents — including the Institution's *Manual for the seismic design of steel and concrete buildings to Eurocode 8*^{7.9}.

7.4 Horizontal loads

These are either:

- Horizontal loads — wind loading (Section 7.6)
- Horizontal loads — induced by dynamic spectator movement, which depend on the category of spectator action. They are a percentage of the vertical imposed load

- Notional horizontal loads — which take account of the geometric imperfections of frames, such as lack of alignment of vertical members which transfer the loads from the deck to the ground. To ensure robustness, they are 2.5% of the total dead load

Notional horizontal loads and horizontal loads arising from crowd movement are not usually combined.

The horizontal loads which arise due to crowd dynamics should be taken from the appropriate category (Table 7.2), and considered to act at the node points where the vertical imposed loads are transferred to the vertical members. This horizontal load should be applied to the area of the floor on which the activity takes place. These notional horizontal loads should be applied in combination with the operational wind loads.

Lower values of vertical imposed loads may be considered, where appropriate, to determine the horizontal loading. For instance, although structural subframes may be designed for localised crowd loads of 5 kN/m^2 , total crowd numbers may be known and controlled. In this instance it would be conservative to design for 5 kN/m^2 and its associated horizontal load over the whole structure. A lower value (e.g. 3 kN/m^2 throughout) may be more appropriate.

The minimum horizontal load for the performance area of stage decks is 5% of the vertical live load.

7.5 Barriers and handrails

Guidance in this subsection applies to both indoor and outdoor venues.

Loadings for the majority of structural elements acting as a barrier or handrail may be ascertained using Table NA.8 of BS EN 1991-1. The UK National Annex does not provide barrier or handrail loadings for grandstands and stadia. Appropriate loadings for barriers in grandstands are provided here.

Figure 7.1 is a schematic plan view of an elevated seating structure which has an area of standing accommodation to the front edge (shown in greater detail in Figure 7.2). The seating deck will require a perimeter guardrail — elements of which serve various purposes and are subject to different design loadings.

Barrier type A: provide for the safety of individuals moving along a gangway or using a stairway in a direction parallel to the guardrail. Load type A = 2 kN/m .

Barrier type B: provide for the safety of individuals subjected to forces arising from spectators moving in a direction perpendicular to the guardrail direction. Individuals in a gangway or on a stairway can create considerable horizontal forces on this guardrail through pushing or as a consequence of a domino collapse down the gangway or stairway. Load type B = 3 kN/m .

Barrier type C: provide for the safety of individuals entering and exiting seats in the front row. Load type C = 1.5 kN/m .

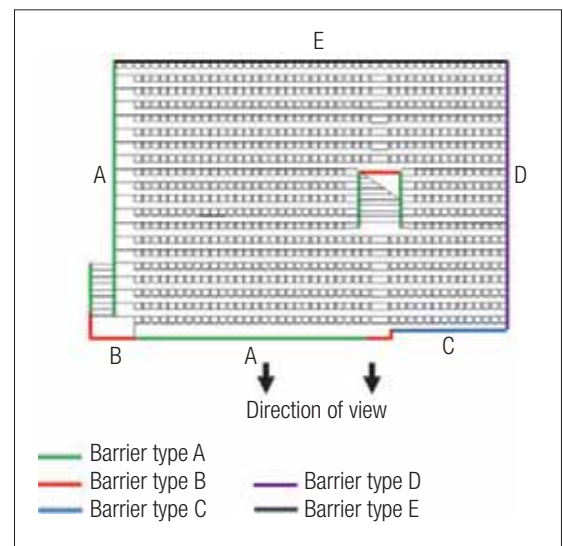


Figure 7.1 Differing requirements for perimeter guardrails on elevated seating structure

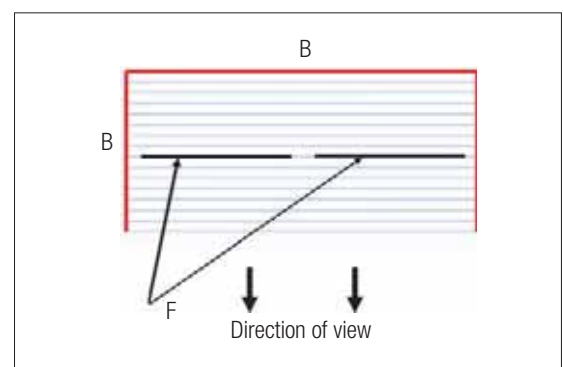


Figure 7.2 Guardrails for standing accommodation

Barrier type D: provide for the safety of an individual occupying a seat adjacent to the guardrail. Load type D = 1 kN/m .

Barrier type E: provide for the safety of individuals at the rear of the stand. Load type E = 1 kN/m .

Barrier type F (Figure 7.2): provide for the safety of spectators occupying a standing area. In this case the barriers should normally be considered as 'crush barriers' of the type associated with areas where overcrowding might occur. The provisions of BS EN 13200-3⁷⁻¹⁰ provide guidance, and BS EN 1991-1-1 together with the appropriate National Annex, should also be consulted. Furthermore, the *Guide to Safety at Sports Grounds* specifies the loading applicable to barriers situated on both horizontal and sloping (terraced) stands.

The characteristic horizontal loading for front-of-stage barriers is 5 kN/m . This loading should be applied at a height of 1 m . The particular requirement for front-of-stage barriers to resist spectator loading should be entrusted to specialist providers.

However, it is recognised that the provision of high-strength barriers normally associated with terraced areas with wide gaps between the runs of barrier (e.g. up to 5 kN/m run) can be difficult to achieve for temporary structures. In this case it is appropriate to provide more runs of lower strength barrier e.g. maximum 2 kN/m at every fourth 400 mm wide step. In all cases where barriers of strength less than that specified by BS EN 1991-1-1, the *Guide to Safety at*

Sports Grounds or Alternative Uses of Sports Grounds^{7.11} are used, these should be the subject of a risk assessment. This may be appropriate at venues which are not sports grounds or at sports events where crowd occupation is of short duration e.g. horse racing, or where the crowd dynamics are known to be more sedate than at a football match for example.

The magnitude of applicable design forces should be assessed after consideration of the geometric arrangement of the structure. The possibility of disorderly egress may need to be considered. The characteristic horizontal loading for side-stage barriers that create the sightline obstruction is 1.25kN/m run of fence. This loading should be applied at a height of 1.5m.

7.6 Wind loads

Some important points relating to wind loads should be borne in mind, including:

- Design documents should clearly state the 'design wind speed' (mean or gust), i.e. the maximum wind speed during which the structure can be safely used
- Reference should be made to the event management plan
- Frequent reference should be made to local weather forecasting services, and site wind speed monitoring should be put in place
- The level of active safety management should then be determined

7.6.1 Basic principles

All structures must be designed to safely resist the loading (forces) applied to them. These forces will include wind forces, as well as those from other applied loading e.g. vertical loads from the dead weight of the structure, live loads from the occupants, and horizontal forces — as described previously.

The requirement to consider hazards from extreme or unusual events is explained in Section 3, where wind is highlighted as a potential hazard both during the erection/dismantling stages and during the operational phase. It is also important to allow for the additional wind forces generated by flagpoles, banners or other cladding/branding items that may be attached to the structure. The Principal Designer and/or Client should be aware that any such unauthorised additions to can have a disproportionate effect on both stability and strength of the frameworks involved.

When the applied forces and framework layouts have been determined, the structure can be analysed to assess what reactions are applied to the ground and what internal forces exist within the components (checks can also be made for deflections and overturning/sliding). Only then can the components and foundations be checked for adequacy.

It is important to realise that the analysis may require several separate checks to be made with different combinations of loading. Design for steel or

aluminium frameworks will require the use of 'material and loading factors' as given by BS EN 1993-1-1^{7.12} or BS EN 1999-1-1^{7.13}. These are used in limit state design and provide the structure with the required degree of safety against failure; these 'safety factors' should not be reduced for temporary structures.

The foundations may be required to provide resistance to uplift, either by way of dead weight alone or by use of friction piles or kentledge (added dead weight). The use of permanent foundations (e.g. concrete pads) will be unlikely unless the structure is used in the same format from year to year. Temporary pad bases will have to provide the reactions to the applied loadings, and in the uplift case they will have to be supplemented by either ground anchors or kentledge. Many loading combinations would need to be considered for completion of a full structural design. General reference should be made to Eurocode 1^{7.1} and the *Manual for the design of building structures to Eurocode 1 and Basis of Structural Design*^{7.14} with regard to load cases and combinations.

The wind loading to be applied in the analysis of permanent structures in the UK is determined by reference to BS EN 1991-1-4^{7.15}. This part of Eurocode 1 is also ideally suited to the design of temporary structures for specific locations and periods of use. Various factors are applied to determine an effective wind speed for the site. This value is used to calculate the dynamic wind pressure.

Physical effects of wind

BRE Digest 520^{7.16} considers the effect of various wind speeds (m/s) on pedestrians, referring to Beaufort scale values (Figure 7.3) as well as commenting on applicable wind speed ranges for short- and long-term exposure in sitting or standing locations (Figure 7.4).

The Beaufort scale values are hourly mean speeds at 10m above ground in 'clean' air. Gusts can be expected to be considerably higher. When considering Beaufort scales B4 and B5, note that it is unlikely that outdoor seating and spectator stands would be occupied in these kinds of conditions. However, these wind speeds would not necessarily be sufficient to cause abandonment of all types of event. For B7 conditions, gust speeds would almost certainly exceed 25m/s at 10m above ground.

Weather forecasting

UK weather forecasts usually give mean wind speeds in mph up to 'gale force' (Beaufort scale B8) which indicates mean wind speeds of 17.2m/s and above. Beyond that level, they normally warn of 'possible structural damage' and give predicted wind gust speeds. The Met Office can provide two-, five- and seven-day forecasts for specific locations throughout the UK. In all cases the forecast speeds are those expected to apply at 10m above ground level in open, level terrain. It is advisable not to place sole reliance on internet forecasts. Reference should be made to site-specific forecasts whenever available — particularly for large venues with multiple structures.

Experience in North America for example, which is more prone to sudden violent storms than the UK, is that the change in wind gust speed from insignificantly low to very high can take place in a few

Beaufort scale	Description	Mean wind speed range		Effects
		(m/s)	(mph)	
B0	Calm	0–0.2	0–0.5	No noticeable wind, smoke rises vertically
B1	Light air	0.3–1.5	0.7–3.4	Direction of wind shown by smoke drift but not wind vanes
B2	Light breeze	1.6–3.3	3.6–7.4	Wind felt on face, leaves rustle
B3	Gentle breeze	3.4–5.4	7.6–12.1	Wind extends light flag, leaves in constant motion
B4	Moderate breeze	5.5–7.9	12.3–17.7	Raises dust and loose paper; hair disarranged, clothing flaps
B5	Fresh breeze	8.0–10.7	17.9–24.0	Small trees in leaf begin to sway; limit of agreeable wind on land
B6	Strong breeze	10.8–13.8	24.2–30.9	Umbrellas used with difficulty; force of the wind felt on the body; wind noisy, frequent blinking
B7	Near gale	13.9–17.1	31.1–38.3	Inconvenience felt when walking; difficult to walk steadily; hair blown straight
B8	Gale	17.2–20.7	38.5–46.4	Generally impedes progress; walking difficult to control; great difficulty with balance in gusts
B9	Strong gale	20.8–24.4	46.6–54.7	People blown over by gusts; slight structural damage
B10	Storm	24.5–28.4	54.9–63.6	Seldom experienced inland; trees uprooted, significant structural damage
B11	Violent storm	28.5–32.2	63.8–72.1	Very rarely experienced; accompanied by widespread structural damage
B12	Hurricane	> 32.3	> 72.4	Countryside devastated; winds of this force only occur in hurricanes and tornadoes

Figure 7.3 Beaufort scale of wind effects on land (wind speeds at height of 10m above ground level)

minutes. In general, the weather producing these conditions is monitored in short-term forecasts used by aviation and other industries.

Interpreting weather data is far more complex than simply looking at projected wind speeds and the 'coloured maps' widely available on the internet. The practice should be undertaken by a properly trained and competent person.

7.6.2 Wind load design principle

There are a number of factors that can affect the wind loads on a temporary structure. These are considered by the Designer when working with Codes and other references on the derivation of an appropriate design wind speed for a permanent building. However, it is considered appropriate to allow an alternative approach to design against wind

loads for temporary structures. This may be accomplished by setting a threshold of maximum wind speed for the design of the structure, in combination with site monitoring of wind speed and providing an agreed action plan or method statement if the threshold is exceeded. Two principal cases are considered appropriate:

- Where the structure is empty (unloaded by crowd or imposed equipment). The critical case is likely to be stability against overturning under maximum likely wind action
- Where the structure is occupied (or equipment is in place). It will be appropriate to assume a suitable wind speed at which the structure is evacuated/ not allowed to be used (Fig.7.4) and to design for a suitably reduced wind action in conjunction with other appropriate actions

Activity	Lawson comfort criteria	
	Tolerable	Unacceptable
Roads and car parks, business walking, fast walking from A to B	10.7 m/s (B5) > 2%	10.7 m/s (B5) > 6%
People at work, workers around buildings	7.9 m/s (B5) > 2%	10.7 m/s (B5) > 2%
Pedestrian strolling, slow walking with occasional stops, shopping, short-term standing e.g. at bus stops	5.4 m/s (B3) > 6%	7.9 m/s (B4) > 4%
Long-term sitting – in open-air cafes, parks, etc. for periods of more than about 10 minutes	3.3 m/s (B2) > 6%	5.4 m/s (B3) > 6%
Entrances and exits of buildings or areas where there is a risk of sudden exposure to wind	3.3 m/s (B2) > 4%	5.4 m/s (B3) > 6%
Covered areas – pedestrian seating areas under cover, places of high cultural significance	3.3 m/s (B2) > 4%	5.4 m/s (B3) > 1%

Figure 7.4 Lawson comfort criteria and threshold wind speeds

Any design where the wind speed affecting the structure is less than that which would be derived for a permanent structure in the same location must be accompanied by a wind management plan and suitable means to operate the plan. Where factors such as probability, time of year or length of operation are introduced, the design will immediately bring into play the need for a suitable wind plan (Section 7.8).

7.6.2.1 Existing systems

Some older existing temporary structure systems will have been designed to CP3: Chapter V-2:1972. This allowed a partial factor of 0.77 to be applied to the effective wind speed — hence reducing the wind speed to take account of the reduced probability of full storm conditions during the relatively short period the structure was exposed. CP3 (and BS 6399) have been officially withdrawn for some time, and should not be used in new analyses. Eurocode 1 allows partial factors to be used by taking account of seasonal variations in wind speeds and, if necessary, by altering a probability factor to accept a greater than usual degree of risk that the design wind speed may be exceeded. This should only be done in the full knowledge of a comprehensive risk assessment. BRE Digest 483^{7.17} which refers to stages, gives useful information with respect to the Seasonal Factor, S_b , which may be used to cater for specific times of usage on-site e.g. for one-, two- or four-month periods at different times of the year. This may be used for other structures as long as the necessary care is taken.

7.6.2.2 New designs

Two options can be considered:

Option A: Design for the maximum likely wind speeds to be experienced in the geographical area in which the structure is to be used. This may be feasible for certain, crane-erected, structural frameworks where considerable dead load will be in place to counteract the effects of wind, but it is unlikely to be economical for lighter structures where hand erection and speed of delivery is paramount.

Option B: Design for a maximum operational wind gust speed that is less than that derived from Option A, and is in accordance with the Client requirements (Table 2.1). The value chosen should be considered to be the effective wind speed, V_e , and used to calculate dynamic wind pressure, q , in the normal manner.

If using Option B then an effective wind speed is usually chosen in a range from 18m/s to 25m/s depending on the level of commercial resilience required for the event. A limit of 25m/s would usually be considered appropriate — not causing too much conservatism or be too likely to trigger the action plan. However, there is a distinct possibility of this value being exceeded in quite a large range of UK venues throughout the year and that wind is often very unpredictable — particularly outside the UK, and especially in countries such as the United States and Canada.

It should also be recognised that on a site containing many differing types of structure, the operational wind speed for the event is likely to be set by the weakest structure present, and that this may have commercial implications.

7.6.3 Wind loading on structures

In the absence of more specific information from tests, the pressure coefficients given in the relevant design Codes should be used when designing for wind loading. In locations where unpredictable wind events are common — such as those caused by convective weather systems — special precautions and pre-warning measures may be essential.

Permeability of the structure needs to be carefully considered — particularly with open framework structures. It is prudent to assume that these structures will be clad with scrims/debris netting or banners unless it is confirmed to the contrary.

It is critical that the extent of any banners and cladding is clearly defined in the structural calculations. It should be appreciated that adding banners, cladding etc. can significantly increase the wind loading on a structure and therefore increase the risk of overturning or collapse.

Critical factors to consider are:

- Will it be possible to evacuate the public and staff safely from the site, especially if strong winds occur during the event?
- If the maximum gust speed is exceeded, then the possibility of structural failure must be considered
- Will load-reducing measures e.g. removal of cladding and other removable elements that contribute to wind loading, be possible?
- Should additional bracing or kentledge be considered?
- Is there a danger from wind-blown debris?
- Are exclusion zones practical? These are notoriously difficult to determine due to the uncertainty over the travel distance of displaced items

7.6.3.1 Grandstands

As spectator occupancy is difficult to predict, heavier imposed loads may well be required to counteract wind overturning moments. If the stands are shown to be susceptible to overturning when empty, they should either be anchored down or procedures should be in place to allow removal of cladding etc. to reduce wind loading in times of high wind. Exclusion zones should only be considered as a last resort.

In the absence of test data the degree of blockage should be apportioned conservatively. It is recommended that degrees of blockage in the following ranges should be considered, depending on judgement and knowledge of the actual component dimensions:

- Solid riser stands: 90–100%
- Open riser stands: 50–75%

The effects of security netting or sheeting and other forms of cladding should also be considered.

Design guidance for grandstands for loads other than wind loads is given in Section 8.

7.6.3.2 Stages

With their relatively large superstructure face area, stages almost always have to be managed structures. The wind case is critical, meaning that Option B in Section 7.6.2.2 is typically adopted.

There have been several cases where major failures of temporary stages have been initiated by wind, resulting in fatalities^{7.18}. Great care must be taken when considering the effects of wind.

Some concern has been expressed regarding the stability of loose-laid stage decks which may be dislodged by wind forces (suction/uplift). Research carried out by The Building Research Establishment is presented in BRE Digest 483. This should form the basis of any new deck designs and act as an aid to checking existing systems.

7.6.3.3 Porous walls (scrims)

BS EN 1991-1-1 indicates that the gross area of a porous wall (a scrim for example) shall be used where the solidity is above 80% (80% solid and 20% void when viewed on elevation), i.e. no account should be taken of the voids at a solidity of 80% or greater. Where solidity is below 80%, a different approach should be used and is dependent on the dimensions of the solid and void elements.

Due consideration of the effect on porosity from surface water, ice and debris should also be given.

7.7 Resistance to uplift and equilibrium checks

Reference should also be made to BS EN 1990^{7.19}.

The action likely to cause the overturning of a structure will often be the applied wind force, but other disturbing actions — such as horizontal forces associated with sway loading from spectators or performers — will also have to be considered in the design analysis.

All structures should possess an adequate factor of safety (1.5) against overturning and sliding.

Often, the most severe conditions will be where wind loading acts on an empty structure. However, sufficient checks should be made using realistic loading assumptions, e.g. a cantilever portion of a grandstand subject to overcrowding.

These particular equilibrium cases are described in Table 7.3 but may not be comprehensive for every structure.

Table 7.3 Load factors for uplift and equilibrium checks

Case 1: Wind on empty structure		
Load	Condition	Load factor
Wind	Unfavourable	1.5
Dead	Unfavourable	1.1
Dead (including kentledge)	Favourable	0.9
Case 2: Crowd load on cantilever		
Load	Condition	Load factor
Imposed (crowd)	Unfavourable	1.5
Imposed (crowd)	Favourable	0
Dead	Unfavourable	1.1
Dead (including kentledge)	Favourable	0.9

If, by following the equilibrium analysis, a negative reaction is found at a support, some form of ground anchor will be needed (Section 5.6).

Unless the structure's adjoining sub-frames are very rigidly connected, or the bracing system is continuous throughout, it is unlikely that the whole framework will act as one. If the results from analysis of load cases show that tension exists in the supporting legs (i.e. negative reactions at the pinned base feet) then either ground anchors or kentledge should be provided (Section 5).

It should be noted that assemblies of buildings — temporary, permanent or a mixture of the two — can create circumstances where wind acceleration occurs and design loads may be exceeded^{7.20}. Clusters of structures may require advice from specialists.

7.8 Operations management for wind effects on structure

Here, the requirements for adopting an operational maximum gust wind speed (Option B in Section 7.6.2.2) are described.

The operational maximum gust speed should be taken as a three-second gust measured at 10m above ground level.

Ensuring the safe operation of facilities up to a maximum gust wind speed requires continuous measurement while people are on or around the structure. There should be a management plan defining the procedures and actions to be put in place, should the operational maximum gust wind speed be exceeded. An example is provided as Appendix B.

It is suggested that such plans should include two levels of warning to ensure that people on or around the structure are not put at risk. The thresholds for Levels 1 and 2 should be determined with an understanding of how much time is reasonably anticipated to implement the required action. The following should be reviewed by the Designer:

- **Level 1:** When monitoring registers a gust wind speed in excess of 75% of the operational maximum gust speed in conjunction with an increasing general trend of recorded wind speeds, staff should be put on alert that action may be required. If erection is still in progress, consideration should be given to delaying further erection
- **Level 2:** When monitoring registers a gust wind speed in excess of 90% of the operational maximum gust speed, in conjunction with an increasing trend in the wind speed records, the operational procedures defined in the management plan should be implemented and the site secured against access by the public

If an isolated gust speed is recorded in excess of 90% of the operational maximum gust speed against a background of a generally falling level of wind speed, a further period of monitoring may be appropriate before implementation of the management plan.

Table 7.4 Relationship between gust wind speed and measurement height (assuming limit of 25m/s at 10m above ground level)

Height (m)	Operational wind speed (m/s)	Level 1 wind speed (m/s)	Level 2 wind speed (m/s)
5	21.5	16.7	19.2
10	25	19.4	22.3
15	26	20.2	23.2
20	26.5	20.6	23.7
30	27.5	21.4	24.6
Notes Level 1 based on 75% of operational maximum gust speed which corresponds to 60% of operational load. Level 2 based on 90% of operational maximum gust speed which corresponds to 80% of operational load.			

7.8.1 Measurements

Wind speed should be measured in 'clean' air avoiding turbulence and shelter from surrounding features. Ideally, this will be achieved by siting an anemometer on a 10m high mast which is located at least 60m from all large obstructions (other structures, trees, etc.). In many cases this will not be possible and the anemometer will need to be fixed to the temporary structure itself. In this case, the anemometer should be mounted at a height of at least $((1.3 \times H) + 1\text{m})$

Where:

H = the maximum height of the structure on which the anemometer is mounted.

Where this is impractical, the Designer should provide a clear statement as to a suitable alternative location. This may include anemometers mounted above the highest structure. Loads on the structures are calculated relative to the threshold wind speed at this elevation, or are conservatively considered to be at the threshold wind speed at all elevations. Alternatively, the anemometer should be positioned as high above the structure as practical and positioned upwind of the structure based on prevailing wind direction.

Sites comprising multiple large structures in close proximity may warrant specialist advice regarding the siting of any measuring devices. Each large structure may require its own anemometer.

Table 7.4 gives the appropriate speeds to be used, assuming a limit of 25m/s has been selected, if measurements are taken at different heights. Intermediate values for heights above 5m may be interpolated.

Where wind speeds have been recorded as a result of a Level 1 action, a copy of the wind speed record should be kept for inspection if required.

An audible and/or visual alarm system should be provided to warn of exceedance of wind speed Levels 1 and 2.

There are various types of wind-measuring device available. Those with separate measuring and display units can be obtained from suppliers to the aviation, crane and marine industries. It is therefore essential to check with the supplier that the device is suitable for the intended purpose.

Reference should also be made to MUTA's *Best Practice Guide*^{7.21}.

7.9 References

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8 Grandstands

8.1 Introduction

The term 'grandstand' is taken to include standing accommodation, seating accommodation, structures which consist of both types, and enclosed hospitality accommodation with viewing balconies or windows.

Temporary demountable grandstands are used at a wide range of events both indoors and outdoors — from minor local events to major international showcases accommodating thousands of spectators. Crowd safety is of paramount importance — particularly with large grandstands where the risks associated with spectator circulation etc. are increased^{8.1}.

The design of a grandstand system to be used generically should be the responsibility of a competent person. The design of the system and supporting engineering documentation, including calculations, drawings, bracing requirements and specifications should be independently checked by a suitably qualified engineer of appropriate skill and experience.

For a standardised structure which is repeatedly erected in exactly the same form at different sites, the original design documentation does not need to be checked every time the structure is erected. Reference should also be made to Section 6.3.1 of this *Guide*.

8.2 Materials

Grandstands incorporate elements from a range of materials including steel, aluminium, timber,

plywoods, textiles, paints and plastic components. Where materials, components and methods of design and construction are not specifically covered by Eurocodes, the Designer should be satisfied that the materials and methods to be employed are such as to ensure sufficient levels of safety, durability, integrity, strength, serviceability and performance. Alternatively, a test assembly should be built to test the structure, component, material or method under consideration. The test assembly should be representative as to materials, workmanship and details of the design and construction for which approval is sought.

Small seating structures may consist of scaffolding while large ones often include standard prefabricated components. Combinations of systems may also be used, e.g. the lower parts of scaffolding create a level platform for a proprietary seating system.

Proprietary grandstands or components from different manufacturers or systems should not be used as part of the same structure unless the Designers of both systems agree they are structurally compatible and specify how they should be connected.

8.3 Design principles

The type of structure under consideration, namely 'temporary demountable grandstands', may be simply described as 'a seating deck of a stepped tiered nature supported by a substructure possessing large numbers of common elements' (Figures 8.1 and 8.2). The scale and complexity of some temporary grandstands is best viewed from the side or rear (Figs 8.1 and 8.3).



Figure 8.1 Temporary stand-alone grandstand



Figure 8.2 Combined roofed grandstand and hospitality unit

A seating place is required to provide a minimum viewing standard, together with a sufficient level of safety. Viewing standards refer to the ability of a spectator to see a predetermined focal point in the activity area. This viewing standard is often referred to as a 'sightline' calculated according to the *Guide to Safety at Sports Grounds*^{8.2}.

The layout and geometry of the spectator deck are required, to provide for the safe ingress and egress of spectators.

Barriers to the perimeter of the structure and within the spectator deck provide protection against falling.

The supporting structure is required to safely resist the static and dynamic forces created by the spectator body, and other dynamic forces — as required by applicable National Standards and as discussed in Section 7.

Criteria concerning sightlines, layout and protection from falling are common to both permanent and

temporary seating decks but the nature of vertical support of these decks is significantly different. Similarly, the ratio of live load to dead load is much higher for temporary structures than permanent.

Demountable framed structures should be designed to form a robust and stable three-dimensional structural arrangement, which will support the design loadings for the required period with an adequate margin of safety. Structural scaffolding or purpose-built modular units may be used to support the seating deck. Components are often designed to be handled by one person. Unnecessary voids created by equipment or temporary structures should be designed out, to assist in keeping the area clear and to aid visual inspection.

The structural integrity should be such that the consequential effects of accidental damage or vandalism should not be disproportionate. By virtue of their lightweight construction and use, temporary structures are often exposed to risks of accidental damage by vehicles, unauthorised removals and



Figure 8.3 Side/rear view of grandstand

alterations, etc. This fact should be carefully considered by the Designer when assessing stability and associated redundancy.

As structures often need to be erected quickly, they are usually of lightweight construction with temporary foundations or supports; they are therefore relatively sensitive to dynamic excitation. As such, this *Guide* addresses the design requirements to cater for both static and dynamic loading and gives recommendations on the appropriate load combinations.

Structures with more conventional structural formats should be designed to normal design requirements (Sections 2 and 7).

The load capacity of each element and its connections, as determined from the relevant National Standards, should not be less than the most unfavourable but realistic factored load which will be experienced by that member.

Overall stability should be checked using the procedures defined in BS EN 1090-1^{8.3}. Where necessary, kentledge and/or anchorage to the ground should be provided, to ensure adequate resistance to overturning, uplift and sliding — with a minimum factor of safety of 1.5.

Structures should possess sufficient transverse and longitudinal stiffness and strength to resist wind loads, notional horizontal loads and dynamic loads induced by spectator movements.

Recognition should also be given to the possibility that only parts of the structure might be subject to imposed spectator loads at any time.

Bracing or stiff frames should be provided regularly on transverse and longitudinal planes and should extend over the full height of the structure.

Bracing should be provided to transmit lateral loads from spectator action, taking account of the nature of the event, and wind loads to both transverse and longitudinal bracing lines. The design of bracing systems should take account of requirements for avoiding disproportionate collapse. The bracing should be designed with sufficient conservatism so that removing up to two adjacent bracing members would not initiate a collapse. Design of the bracing systems should also take into account the dynamic stiffness of the structure and the effects of dynamic loads from spectator movements^{8.4}. Bracing design requirements may be dictated by connection and/or coupler capacities and this possible restriction should be carefully considered. On-site modifications to bracing arrangements specified by the Contractor are not acceptable without accompanying design documentation.

Those responsible for demountable grandstand structures should have an appreciation of crowd behaviour and of the hazards that may arise. Sightlines are particularly important.

General advice on standing decks and layout criteria can be found in Sections 12 and 14 of the *Guide to Safety at Sports Grounds* and BS EN 13200-1^{8.5}.

Temporary structures should meet the safety standards of permanent structures irrespective of

crowd safety measures, and a risk assessment should be undertaken.

The provision of barriers and handrails should comply generally with the requirements of Section 11 of the *Guide to Safety at Sports Grounds*, BS EN 13200-3^{8.6}, BS EN 13200-6^{8.7} or equivalent national requirements.

8.4 Design guidance

8.4.1 General

Grandstands should be designed in accordance with the appropriate Standards and Codes of Practice. Seating structures should be capable of resisting all loads imposed by their foreseeable use, with adequate safety margins. Grandstands that provide either seating or standing accommodation must be able to withstand the characteristic actions in accordance with BS EN 1991-1-1^{8.8} or the loads specified in the appropriate National Standard.

Four main categories of use (Table 7.1) should also be considered. Reference should also be made to Section 3.1.1 and Section 6.

It should be noted that BS EN 1990^{8.9} states that grandstands have a Consequence Class CC3, and therefore Execution Class EXC 3 or EXC 4 are required (as defined in BS EN 1090-2^{8.10}).

8.4.2 Loading

The loadings appropriate for the design of grandstands (dead, imposed, dynamic, wind and notional horizontal) are considered in Section 7.

For structures of unusual configuration, form or location (such as closely-spaced groups of structures or structures in close proximity to one another) the assessment of wind load may require specialist knowledge; where consideration of both quasi-static loadings and dynamic effects may be necessary, along with both overall and localised effects. In combination with the dead, imposed and wind loads, allowance should be made for notional horizontal loads. Grandstands may be relatively flexible structures which can respond dynamically to spectator movements.

Dynamic loads may be particularly significant when any crowd movement (dancing, jumping, rhythmic stamping, etc.) is synchronised and periodic. The dynamic load is thus related to the frequency of the rhythmic activity or the beat frequency and is periodical. Such crowd movement generates both horizontal and vertical loads. If the synchronised movement excites a natural frequency of the structure, resonance will occur which can greatly amplify its response.

Tests on temporary grandstands have indicated that dynamic loads are unlikely to be significant if the crowd movements are not synchronised and not periodic in nature^{8.11,8.12}.

A simple design approach would involve designing the structure to account for spectator activity using the notional horizontal loads given in Table 7.2. The

table is intended to help Designers identify the appropriate category of spectator activity and design approach.

For grandstands which may be subject to synchronised and periodic crowd movements, the simplest approach would be to estimate the vertical and horizontal natural frequencies and to ensure avoidance of significant resonance effects. If this can be achieved, the grandstands can be designed according to the simple design procedure, using notional horizontal loads given under Category 3 of Table 7.2. Evaluation of natural frequencies may be by calculation, measurement or 'type approval'. If it is not possible to avoid the resonance effect in this way, the design will require a rigorous analysis to assess the effect of dynamic loads arising from the anticipated resonance effect.

8.5 Connections

Since the connections are reused many times, they should be subject to a regime of inspection that is recorded. This will normally be visual and checks will be made for:

- Distortion
- Cracking
- Stripping of threads
- Undue play
- Corrosion
- Other undesirable faults

The checks should be made at the time of erection as part of the normal routine. Section 6.3 discusses this in detail.

Connections should be able to transmit the required design forces. Since they are reused, they should have a margin of additional material to compensate for wear. Particular care should be taken over cable and guy-wire terminals. Proper thimbles or eyelets should be used, and shackles, rigging screws and similar fittings may be accompanied by split pins or locking devices to aid retention. Small components are easily lost after several erection and dismantling cycles. The connections should be fully checked by a competent person each time the structure is erected.

Where scaffolding is used for the construction or part-construction of a grandstand to which the public has access, the couplers should be either Class A or Class B to BS EN 74-1^{8.13}. They should also be fitted in a way that will ensure they will perform according to those class specifications, i.e. with correctly torqued securing bolts or correctly driven-home wedges. Low-loadbearing or non-loadbearing fittings should not be used in such structures.

8.6 Loading tests

Load tests are an acceptable way of demonstrating the structural performance of a temporary structure, if not proven by calculation. They should be carried out in accordance with the appropriate material Eurocodes.

The loading system should adequately simulate the magnitude, distribution and duration of the loading and allow the structure to behave in a manner representative of service conditions.

No single test can represent all of the load combinations used in design. As such, a comprehensive series of tests (instigated by a specialist Contractor to prove the adequacy of a standard system to be fabricated in volume) may be appropriate.

In general, load tests should be regarded as a last resort, especially given the short lead times under which the industry operates. It is normally cheaper and quicker to install additional strengthening and stiffness. However, there are instances when the Contractor chooses (or is requested to offer) proof tests to substantiate the frameworks being proposed. Such tests may be necessary when, *inter alia*:

- The Contractor is unable to produce proper calculations or when a framework (or constituent part) is not amenable to reliable calculation
- Verification is required that the dynamic response to spectator movements will be acceptable
- There is doubt as to whether the quality of materials or workmanship is of the required standard
- Materials or design methods are used that are not in accordance with relevant material Standards or Codes of Practice

8.7 Layout criteria (means of escape)

Any escape system from a demountable grandstand should be such that its use is integrated with the site (or building) in which the grandstand is located. There should be enough evenly distributed exits from a structure to evacuate it in an emergency without endangering the lives of spectators. The exits should allow spectators to reach a place of safety (or a final exit) safely, without local overloading of stairs, passageways or routes around the site or building. The aggregate flows of individual escape staircases should be no greater than the intermediate or final exit flows into which they discharge. Practical considerations may allow exceptions to this requirement but if so, a risk assessment of the planned route is necessary.

Staircases or passageways within grandstands should be of even width and should not narrow into funnels so as to cause crowds to compress on their journey to a final exit.

In contrast to a stair, a gangway within seated accommodation is not restricted in length (Figure 8.4). In assessing the risks to spectators on a gangway, the length, going, riser dimensions and width should be considered.

It is recommended that for a gangway pitch exceeding 28°, structural elements that manually assist ascending and descending spectators are provided. If the pitch exceeds 28° and the gangway width exceeds 1400mm, a central handrail that permits spectator crossover is preferred.



Figure 8.4 Gangway

The scale of some grandstands can necessitate vomitories within the seating accommodation that provide for both ascending and descending spectators during ingress and egress. The configuration of any vomitory should be considered when deriving the egress capacity of the grandstand.

Additional guidance is given in BS 9999^{8.14}, BS EN 13200-1 and the *Guide to Safety at Sports Grounds*. Reference should also be made to BS EN 13200-6 and BS EN 13200-7^{8.15}.

Handrails of adequate strength and appropriate height should be provided (Section 8.8). All decking, aisles and steps on grandstands should be made from (or covered with) non-slip materials and have adequate non-slip nosings in a colour that contrasts with the step.

8.8 Barriers and handrails

8.8.1 General

Barriers are necessary at the front and rear of seating blocks and along the side edges of grandstands. With seated audiences or spectators, the seating itself limits the density of the crowd that is able to exert force in any one particular area of barrier. However, in other locations such as the ends of radial gangways, lateral gangways or landings with right angle turns (and to a lesser extent parallel to gangways) crowd loadings will be higher.

8.8.2 Design

Barrier loading requirements for a grandstand are provided in Section 7.5. It should be noted that a temporary grandstand must provide the same level of safety as a permanent grandstand.

Advice on design, construction and maintenance of barriers is given in BS 6180^{8.16}. Where the construction is not specifically covered by the Standard, Designers and Contractors should satisfy themselves that the materials and methods employed will provide durability, integrity and performance at least equal to that recommended.

Where a structure is to be used at a sports ground, specific technical Standards relating to barriers and handrails will apply. Further guidance is given in the *Guide to Safety at Sports Grounds* and BS EN 13200-3.

Front-of-stage barriers are discussed in Section 10.

8.9 Demountable standing accommodation

The accommodation provided shall be considered as Category C5 (sub-category C51) in Table 7.1 of this *Guide*.

The criteria and recommendations given in BS EN 13200-1 and BS EN 13200-3 shall apply with regard to riser and tread geometry, barrier loadings and guardrail configuration.

The crush-barrier configuration may comprise multiple rows of guardrails. The tread and riser geometry will determine the spacing of guardrail type F (crush barriers for standing accommodation, Section 7.5) and the characteristic load requirement should accord with BS EN 13200-3.

In the absence of an appropriate risk assessment, guardrail type B (Section 7.5) is required to resist a characteristic loading of 3kN/m.

Where the nature of the spectator body is considered as a design factor, this should be recorded in the risk assessment associated with the use of the structure.

Further guidance is given in the *Guide to Safety at Sports Grounds* and BS EN 13200-3.

8.10 Viewing facilities for persons with special needs

8.10.1 General

Probably nothing has changed quite so dramatically in venue design in recent years as the focus on the needs of disabled spectators and the requirements for inclusion rather than exclusion.

While the temporary nature of a demountable structure may mean that Building Regulations are not applicable, the person responsible for the event will still have a duty under relevant national legislation e.g. the *Equality Act 2010* in the UK^{8.17}. Under Part 2 of the Act, a provider of goods, facilities, services or premises is required to make 'reasonable adjustment' to ensure facilities do not discriminate against spectators with special needs. This may include avoiding physical barriers to access. Comprehensive guidance on access issues may be found in BS 8300^{8.18}.

Where Building Regulations are applicable, particular reference should also be made to:

- In England and Wales: *The Building Regulations 2010. Approved Document M — Vol. 2*^{8.19}
- In Scotland: Section 4 of *Building Standards technical handbook 2016: non-domestic*^{8.20}
- In Northern Ireland: *Building Regulations (Northern Ireland) 2012 Guidance: Technical Booklet R*^{8.21}

Prefabricated, temporary or demountable grandstands all come under the same criteria as conventional construction and need to satisfy the same criteria for numbers, dispersal and viewing quality for spectators

with special needs. If these criteria cannot be achieved within the grandstand, alternative and satisfactory provisions may be acceptable.

Considering the needs of all spectators is required i.e. in addition to spectators in wheelchairs, the needs of mobility-impaired disabled persons and those with hearing and visual impairments, learning disabilities and cognitive impairments must also be taken into account.

8.10.2 General principles

The design has to start with the location. It is essential that the platform and its occupants do not block the sightlines of other attendees. Failure to address this may result in crushing around the platform.

At events where a standing audience is watching entertainment on a stage at least 1.2m high, an accessible viewing platform height is likely to be between 1.1m and 1.25m. Stages with a platform height of less than 1.2m are usually unsuitable for a standing audience on a level site.

Many disabled people need to have a personal assistant, or simply wish to share the occasion with others. Those accompanying the disabled person may or may not be themselves disabled. Where non-disabled assistants/others are accommodated on the platform, it is essential that there is a management plan to ensure they remain seated if this would interfere with the view of people either sitting on the platform behind them, or standing behind the platform.

The orientation of the view provided should also be considered. Where possible and where appropriate, the platform should face squarely to the entertainment. Oblique angles can be uncomfortable for wheelchair users and other impairment groups, and may reduce the platform capacity if wheelchairs or chairs need to be partially turned. The access ramp has a critical safety function in the event of an evacuation. The ramp and the area it leads to should be treated as an escape route, and be kept clear and safe from the risk of fire.

Consideration should be given to providing a staircase access located away from the access ramp. This enables non-wheelchair users to enter and exit the platform without waiting for wheelchair users on the ramp. In the event of an emergency evacuation, a staircase provides access for emergency personnel while the ramp is being used to evacuate wheelchair users.

8.10.3 Design requirements — platforms

Platform height

Wheelchair users are elevated so their view is not obstructed by spectators standing forward of the platform. The height of a typical platform is not less than 0.75m.

Surface

The surface of the platform should be level and free of bumps and gaps. Scaffold boards or battens are not considered to be a suitable surface, unless overlaid with 18mm plywood, firmly screwed into place.

Edge protection

Given the number of non-disabled people that may be on the platform, barriers should be fitted in accordance with the normal standards for a public venue.

Consideration should be given to avoiding the eyeline height of most seated people and wheelchair users. However, the height of the front barrier should be a minimum of 0.8m.

A toe-board or upstand should be provided at all edges of the platform and sides of the ramp, both to prevent the front wheels of wheelchairs from dropping off the edge, and/or walking/guide stick users misplacing sticks while using the ramp or platform.

Infill

Apart from the usual requirement to position a skirt around the platform to hide the substructure, consideration should be given to providing a 'modesty' screen which would also provide a degree of wind protection. The resultant loads from the wind must be considered in the structural design of the platform.

Signage

Raised platforms provide advantaged viewing. The access points to the platform should be clearly signed to indicate the platform is for the use of disabled spectators, and control measures may require stewards.

Loadings

It is entirely possible that in the event of a stewarding failure, large numbers of people could gain unauthorised access to the platform. Platform surfaces including the ramp should therefore be considered as Category C5 (sub-category C51) in Table 7.1.

8.10.4 Design requirements — access ramps

The failure to supply suitable ramped access is a common problem with the platforms currently available. Key requirements are:

Gradient

Site constraints may impact on ramp gradients. A gradient not exceeding 1:15 is strongly recommended. There should be intermediate level landings to provide rest areas. Flight lengths vary according to the gradient e.g. the longest travel distance between landings should not exceed 8m for a gradient of 1:15, and 10m for a gradient of 1:20. Landings can also be used at changes of direction.

Suitable size

A ramp should have a minimum width of 1.2m. It is not recommended to be any narrower as there is a distinct risk of wheelchair users catching themselves or part of the chair on the handrail system. Thought should be given to whether a ramp is to be used one-way, i.e. one user in one direction at any one time, or two-way, i.e. users passing in both directions. If it is required that wheelchairs pass each other, the ramp should be at least 1.8m wide. The number of users a platform is designed for, will dictate the specific width.

Changes of direction

Given that some wheelchair users may be pushed up the ramp by a non-disabled assistant, or may have

wheelchairs of greater than usual length, any change of direction should have greater dimensions than the width of the ramp. A change of direction must only be accomplished with a level landing. Each leg of the ramp should have a minimum intermediate landing length of 1.8m when measured in the direction of travel from/to that leg.

Ramp surface

Normal plywood is extremely slippery when wet, and conventional paints do little to improve this. Given that a) wheelchair users will be relying on friction between the ramp surface and their wheelchairs, b) other disabled users may find slippery surfaces difficult to use, and c) some users may be assisted by non-disabled people pushing or holding; a non-slip surface is critical to maintain safety. The ramp should be free of gaps and uneven surfaces, ridges, etc.

Edge protection

The ramp should have normal handrails and should have suitable edge protection to prevent wheels slipping off. An upstand of around 75mm in height is sufficient for this.

Visual identification

The ramp edges should be in a contrasting colour to the ramp surface for the benefit of people with impaired vision. The two best contrasting colour combinations for people with one or other form of 'colour-blindness' are black/white and blue/yellow. The use of greens and reds is not recommended.

8.10.5 Seating arrangements and capacities

The optimum seating arrangement is to have a quantity of fold-flat or similar chairs available, and to allocate these as each user arrives. Disabled users should have the option of a companion sitting next to them if they wish. Where gangways are limited it is essential they are not blocked by seats for non-disabled assistants.

Provide seating options both with and without arms, as some disabled users will use the arms of a seat to assist with lowering to, and standing from, a seated position.

Platforms for a single row of wheelchair users

Each wheelchair user should be allowed an area 0.9m wide and 1.35m deep. Assuming that one row of wheelchairs is at the front of a platform, there should be a gangway behind this first row with a width of at least 0.9m.

This dictates that the minimum platform depth for a single row of wheelchairs is 2.25m.

Platforms for a double row of wheelchair users

A platform with two rows of wheelchairs can still operate satisfactorily with a single gangway between the two rows, giving a minimum platform depth of 3.6m.

Capacities

When determining the number of wheelchairs and chairs within a row, widths of 0.9m and 0.5m should be assumed for wheelchairs and folding chairs respectively.

Egress capacity

Rate of egress from a large wheelchair platform accessed via a ramp having multiple changes of

direction, should be considered for the purposes of risk assessment.

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9 Stages and similar structures

9.1 Introduction

This section gives guidance on the design and erection of temporary stages for concerts and similar events. Although not for use by members of the public, their failure could still impact public safety. It should also be borne in mind that stages are a place of work. They typically have the following features:

- A platform raised above ground level to give an audience a better view of the performing act
- Weather protection (for outdoor locations)
- A support structure for lifting equipment

Large numbers of temporary indoor stages are in everyday use for leisure and educational purposes, supplied by a wide range of manufacturers. Many indoor stages are purchased outright and assembled on a repeated basis by the purchaser.

By contrast, there are far fewer outdoor stages and consequently fewer suppliers. Outdoor stages need to meet all the requirements of indoor stages plus the additional factors created by the effects of weather (wind, rain and temperature extremes) and problems from overloading, abuse and lack of maintenance (Section 6). Outdoor stages are typically hired as required and erected by the supply Contractor.

Ancillary and special structures, such as those for supporting lighting equipment, video screens and loudspeakers, are discussed separately in Section 12.

While there are many different proprietary systems available to create stage structures, most can be categorised as one of the following:

- Stage floor platforms and associated substructures
- Free-standing roof systems
- Roof systems that are supported on a stage floor
- Roof systems that are supported within the substructure of a stage floor
- Fully integrated units that are typically vehicle-based ('mobile stages')

Within these categories there is an option that requires guy-wires that terminate outside of the footprint of the stage structure to achieve lateral stability (typically against wind actions) while other designs use similar guy-wires to form tension bracing that anchors within the structure itself. A number of serious structural failures in recent years have been associated with stage roofs reliant on guy-wires anchored externally^{9.1–9.3}. These are typically due to inadequate design, and provision of insufficient kentledge or other forms of restraint (Section 5.6.1 and Appendix A).

There are many similarities between stages designed for either indoor or outdoor use. 'Indoors' is defined as any space in which a stage is erected where it is protected from the effects of the weather. This includes inside marquees and circus tents, for

example. Structures used indoors are generally stage platforms with associated access ramps and stairs. Many of these use 'ground-support' frames to create suspension facilities for loads; typically lights, sound equipment and video screens. These are structurally similar to outdoor stage roof structures, without weatherproof covers.

Structures for indoor use can still be subject to wind pressures (internal pressures). This is particularly relevant in large internal spaces (e.g. exhibition halls) and also in buildings with large dominant openings. The design of structures for indoor use needs to adequately carry any internal wind pressures.

9.2 General design requirements

Design of any staging system is essentially a consideration of the balance between weight, strength, fabrication cost and deployment cost of the individual components. In such a consideration, safety must not be compromised. Design should start from the premise that an appropriate level of safety will be provided. The robustness of the structure should also be considered. Some elements of the design will be more critical than others and some components (or connections between components) will require particularly careful checking each time the structure is erected. Details of items critical to each 'stage type' are outlined in Section 9.3. Reference should also be made to Section 2.2.2 with regard to the Client's responsibility to provide a written technical specification of requirements.

Physical checking of stages is much simpler and more effective if the engineering documentation includes a list of critical items to check, prepared by the structure's Designer (who is unlikely to be the Principal Designer for the event). These critical items should be listed on the check and completion documentation after each phase of the activity. Reference should also be made to the Code of Practice developed by major stage suppliers and the HSE^{9.4}.

9.3 Stage types

9.3.1 Stage floor platforms and associated substructures

The design loadings (both vertical and horizontal) for stage floor platforms and associated substructures are provided in Section 7.

If any of the risk assessments carried out for the event indicate the potential for higher static or dynamic loading to occur, this should be dealt with on a one-off engineering basis, specific to the event. The Client should then be informed in writing by the



Figure 9.1 Rectangular stage system

Contractor as to how the higher loading requirement has been met. Stage floor platforms are usually built either of system scaffolding or of one of the available proprietary systems. Figure 9.1 is an example of a rectangular stage system.

Proprietary stage deck systems often have a method of linking the sections together. Many systems rely on simple bolts between sections and use cut lengths of scaffold tube to provide legs of variable height. Care should be taken to ensure that enough bolts are used to join the sections together; the required quantity being specified by the Designer. It is not acceptable to join adjacent legs with PVC tape, plastic cable ties or other non-structural components.

Products from different manufacturers should not be mixed, even if they appear to be similar, unless the implications have been fully considered by a competent person.

Systems with scaffold tube legs will require diagonal bracing to bring the horizontal loads down to the ground if the sections are used above a particular height. This height is a critical value which should be specified by the Designer in relation to the material from which the scaffold tubes are made. For typical staging modules which are $2.4\text{m} \times 1.2\text{m}$ in plan, using scaffold-grade tubes as unbraced legs, maximum deck heights of 0.9m for aluminium tubes and 1.2m for steel tubes are recommended, provided that there is an adequate moment connection at the top of each leg. These figures are for guidance only. The allowable height depends on the diameter and thickness of the tube, the axial load and the lateral sway load. The design of the leg should be proven by calculation.

For stages built of multiple modules bolted together, it is imperative that each module has its full

complement of legs. In cases where a single tube is used to support the corner of more than one deck panel, specific calculations to show the suitability of the tube — and the effect on the resistance to bending of the deck panel — should be provided. Using a mix of aluminium and steel tubes in the same structure is discouraged. However, the use of aluminium/steel hybrid structures is quite common, and care should be taken in the selection of design parameters if the two materials are deliberately used together.

Many of these systems appear to be very simple but calculations should still be provided. The systems should be subject to the same design rigour and compliance with Standards, as more complex structures.

9.3.2 Roofs

Roofs (and indoor grids) should be designed to support the imposed loads as well as the self-weight of the structure (Figure 9.2). Imposed loads may include:

- Working personnel
- Loads created by wind, rain and snow
- Suspended sound equipment
- Lighting and video equipment
- Anchorages for moving equipment
- Anchorages for personal protective equipment (PPE)

The complete roof, individual components and fixings of the coverings should be capable of resisting any uplift forces caused by the maximum design wind load. Section 7 provides more detail on both loading (general) and resistance to vertical and lateral loads.



Figure 9.2 Curved stage roof

Certain wind conditions cause uplift and/or overturning on most stage structures. The Designer should clearly show the extent of these forces and specify how they are to be dealt with. If kentledge is the chosen option, details should be given of how this is to be attached to the structure. Consideration should be given to the coefficient of friction between the kentledge and the ground where kentledge could possibly slide (Section 5.6 and Appendix A).

During the currency of the third edition of this *Guide* (2007–17) there were several failures of stage roof structures^{9.1–9.3}. Problems identified included:

- Incorrect positioning of anchors (affecting the load transfer to/from the structure)
- Inadequate strength of ground anchors
- Sliding of kentledge (a combination of insufficient weight and too little friction between kentledge and ground surface)
- Inadequate strength of connections between guy-wires and stage roof

Calculations of the uplift forces along the eaves and gable, carried out at the design stage, should show that the fixings for the roof coverings are able to withstand these forces.

Roofs which are supported on masts/towers (and are guyed or braced rather than portalised) may still transfer a bending moment into the tower, due to deflection in the roof (dependent on the lack of fit of the connection between the roof grid and the tower and the relative stiffness of the two). The Designer should highlight the extent of these bending moments and show how they are to be resisted.

Where stability of the roof structure is provided by the use of external guy-wires, particular care should be taken with their positioning and the method of anchorage (Section 5.6).

Where a failure of the structure could cause injury, roofed outdoor structures should be continuously

monitored by a competent person. In practice this means that a representative of the stage supplier should be on-site at all times, particularly when the stage is in use by workers or during a performance. For stages that rely on 'wind management' techniques (Section 7.6.2.2), it is critical that competent personnel are present on-site to ensure that the requirements of the wind management plan are implemented.

Fabric and other sheeting materials used to cover roofs and create walls need to be able to resist the imposed wind forces, fail safely if dislodged by the wind, and be flame-retardant.

9.3.3 Free-standing roof systems

The ability of the roof masts/towers to resist bending forces associated with lateral loads should be carefully considered in the engineering documentation for roof systems with no external guying (Figure 9.3).

9.3.4 Roof systems supported on a stage floor

The majority of 'typical' medium size stages in use in the UK fall into this category (Figure 9.4). In

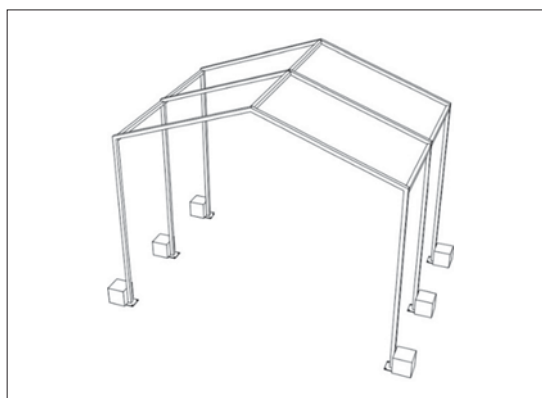


Figure 9.3 Free-standing roof system

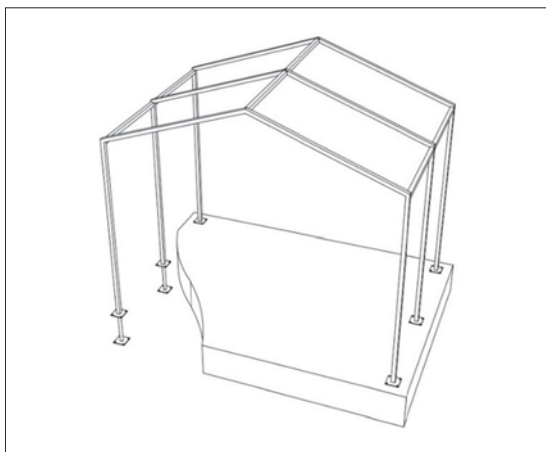


Figure 9.4 Roof system supported on stage floor

In addition to the usual calculations, specific details are required to show how the stage floor surface is designed to resist the downward forces from the roof structure (usually by some form of counter- or under-propping), the upward forces due to wind forces (usually requiring kentledge), plus any lateral forces due to the roof shape. All these forces and actions should be considered in the engineering documentation.

9.3.5 Roof systems supported within the substructure of a stage floor

This is an increasingly common technique (Figure 9.5) used mainly for the larger structures available.

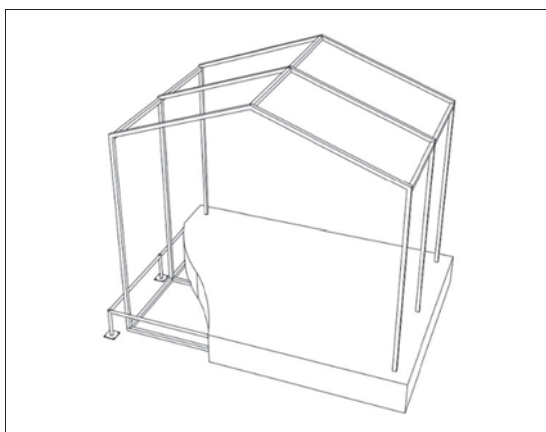


Figure 9.5 Roof system supported within stage floor substructure

The key advantages are:

- The stage substructure levelling system provides a consistent level for the bases of the roof supports

- Some of the self-weight of the stage substructure and decking can be used to replace some or all of the kentledge required to resist uplift

In addition to the loads associated with the stage floor, specific calculations and details should be provided in the engineering documentation to show how the various forces from the roof structure are dealt with by the substructure.

9.3.6 Fully-integrated units that are typically vehicle-based

The use of vehicle-based stages (usually known as 'mobile stages') has become increasingly widespread (Figure 9.6). Generally, they are easy to manage and to check for safety as there are very few loose parts. However, they should comply with the same requirements for floor loading and resistance to wind as any other type of stage, and engineering documentation should be available to verify this.

The Client, Event Organiser and Enforcing Authority should review the engineering documentation for compliance with this *Guide*, relevant Eurocodes, British Standards and CDM Regulations prior to hiring and/or use.

9.4 Access and egress for non-public use

Stages should be provided with adequate access by means of ramps and/or stairways (Figure 9.7a and b). It is good practice to have at least two means of access/egress.

It is recommended that all stairs used for general stage access/egress should comply with Building Regulations^{9.5}.

Guidance on the minimum size of tread and maximum size of riser for stairways used for single person access to work platforms is given in BS EN 1004^{9.6}.

Ramps for equipment access to stages often terminate at the bottom on a truck 'dock'. Designers need to consider the probability of heavy vehicles reversing into the dock structure. Docks should also have a staircase to the ground to facilitate access and egress of crew.

The gradient of any ramp should be gradual enough to enable equipment to be moved safely.



Figure 9.6: Mobile stage



Figure 9.7 Ramp arrangements

Ramps should, if possible, be no longer than 8m between horizontal landing areas. Landing areas should be at least 1m in length in the direction of travel and at least as wide as the access way/ramp. Ramps that are to be used to provide access to a stage for unassisted wheelchair users should have an absolute maximum gradient of 1:15 and should have a horizontal landing for every 0.5m of height change^{9.7–9.9}.

Specific safety measures will be required if the gradient is steeper than 1:5.

The surface of ramps and treads, particularly those which could become wet, should be covered with a slip-resistant material.

Adequate handrails should be provided to all ramps and stairways. Ramps should have suitable rails to restrain equipment on wheels.

- Resist a horizontal load of 0.3kN in any location and applied over an area of 300mm × 300mm

Lack of handrails and inadequate stairs are implicated in many stage-related accidents. There should be a handrail on all edges — except the performance edges — at all times, regardless of height, and at every staircase.

Indoor stages are often built in the same place repeatedly, and at the onset of a performance the light level can change abruptly; from full on, to total blackout almost instantly, increasing the likelihood of a fall. Adequate handrails and clear marking of edges are essential.

Serious accidents have occurred on stages with a narrow gap to an adjacent wall where people have stepped into the gap and become trapped. If gaps are absolutely necessary they should be protected by handrails.

9.5 Protection against falling

The Work at Height Regulations^{9.10} require all Contractors and others in control of work at height to take suitable measures to prevent risk of falling during the erection and dismantling process. These measures should be fully documented in accordance with the requirements of the Regulations.

Once the Contractor passes control of the completed structure to the Client, the Client is required to ensure that measures are in place to prevent falls from height by anyone working during the fit-out. This should include suitable protection to the front edge of the stage floor. This protection should remain in place for as long as possible before the commencement of a performance and reinstated after the performance, before any production-related work activity.

Where protection is provided by handrails, these should be in accordance with BS EN 13374^{9.11} which gives three loading criteria for handrails used in work areas (such as stages and access platforms) where the loads are applied in the most severe location:

- A limiting deflection of 35mm under a 0.3kN point load applied horizontally
- Support a 1.25kN point load applied vertically

As it is unacceptable to most performers to appear behind a handrail, specific measures to protect performers against falling off the front of the stage are required. It has to be appreciated that performers face into very powerful lights, which may dim or go to 'blackout' very suddenly, leaving them temporarily unable to see edge markers.

Measures in regular use include providing:

- A lower 'ledge' below stage floor height. This is particularly suited to high stage floors and may double as a location for sound and lighting equipment
- A tactile strip that provides warning of approach to the edge
- A slight upstand to the front edge

The front edge of stages, physical obstructions and stair edges should be marked with white or luminous tape. For best visibility, white tape should be at least 50mm wide.

9.6 Use of lifting equipment

The Lifting Operations and Lifting Equipment Regulations (LOLER)^{9.12} apply in all premises and

work situations subject to the *Health and Safety at Work etc. Act*^{9.13}. They require companies using lifting equipment to carry out suitable inspections and to manage lifting operations safely. Reference should be made to the Approved Code of Practice^{9.14}.

When sections of structures (typically stage roofs) are being lifted by multiple hoists, adequate provision should be made so that if a hoist fails, the structure will not fall to the ground. One way of achieving this is to use enough hoists or winches so that if one fails the others will safely support the structure being lifted. It is the Contractor's responsibility to appoint a person in charge of the lifting operation (the Appointed Person or 'AP') and to create a suitable 'lift plan'. The AP does not have to be present on-site provided that responsibilities are transferred to a lift supervisor who will be named in the lift plan.

In particular, the positioning of personnel required to monitor and control the movement should be carefully considered in the lift plan. Non-essential personnel should not be in the immediate and surrounding area of the roof structure during raising and lowering.

When any hoist-lifted roof is in use, each hoist should have a mechanical safety device (lock-off) to prevent roof movement in the event of hoist failure, or should meet the requirements of BS 7906-1^{9.15}.

Care should be taken that multiple hoists provide an even lift and that adjustments to the hoisting process can be made to achieve this.

Particular care must be given to the methods used for fixing suspended objects to a structure. Where multiple fixings are used, they should be capable of withstanding progressive collapse in the event of any one fixing's failure. Attention to detail is important and heavy objects should have at least two fixings; either one of which will prevent the object from falling. Falling fittings such as nuts and bolts are a hazard and it is good practice to make regular checks for loose components. Vibration can promote loosening so structures subject to vibration from speakers, wind, or other sources, need careful consideration.

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10 Fencing, hoardings and barriers

10.1 Introduction

Various types of fencing, hoardings and barriers are used for indoor and outdoor events. Front-of-stage barriers are considered in some detail in this section, but commonly-used fencing and hoardings are also discussed. Handrails for grandstands and stages are covered in Sections 7.5, 8.8 and 9.5.

10.2 Fencing and hoardings

All fencing and hoardings should be designed to appropriate Standards. Due consideration should be given to wind loading — in both the engineering documentation and wind management plans.

10.2.1 Low-level fencing

'Pedestrian barrier', 'police barrier', or 'royal barrier' are terms for steel-frame barriers used extensively for street events such as parades and street races where there is a need to very quickly deploy large lengths of barrier to keep crowds separate from the performers. These are usually 1.1m high and come in various lengths from 1.5m–3.5m and can be held in large stacks ready for easy deployment. They are free-standing and supported by flat or arched feet at either end (Figure 10.1a and b). There is also a version with a horizontal hooped base running the full length (Figure 10.1c).

These barriers are useful where there is no direct crowd pressure involved. They are used purely to define 'no go' areas for the public. They should not be considered to have any capacity to resist crowd pressures.

10.2.2 Mesh and block fencing

Mesh panel fencing (typically 3.5m wide × 2m high) consists of a tubular steel frame with an infill of steel wire mesh, supported by the insertion of end uprights into separate block units which may be concrete or heavy plastic (Figure 10.2). The blocks have various holes to allow end fixing or middle fixing. These fences are extensively used at event sites during build periods, where fence lines have to be opened quickly

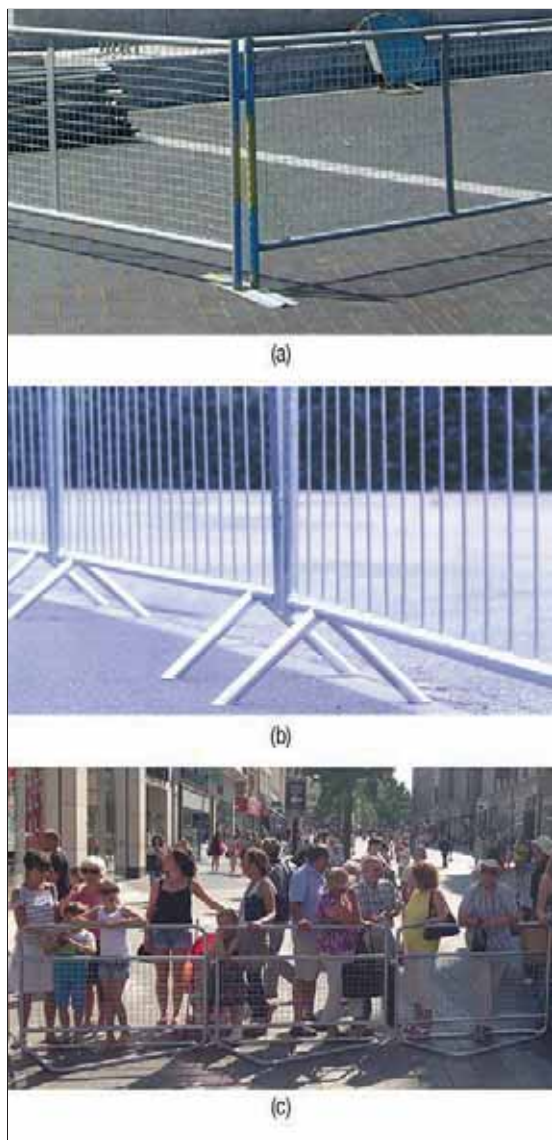


Figure 10.1 Different types of barrier: a) flat foot b) arched foot c) hooped base



Figure 10.2 Mesh panel fencing



Figure 10.3 Rakers situated between panels



Figure 10.4 Steel panel hoarding

or where the site boundary may be changing rapidly. These systems have no structural strength to resist crowds and usually require diagonal braces or struts at right angles to resist wind loading in situations where signs (or other covering) reduce the permeability of the panels. Most contemporary panels used in the UK are 'anti-climb' — having reduced spacing of the vertical elements of the infill mesh.

10.2.3 Hoarding

'Hoarding' is the general description applied by the events industry to panels similar to the mesh panels described previously, with two clear differences. The mesh infill is replaced by a solid steel infill (thin and usually corrugated to resist bending). The exact support arrangements as specified by the manufacturer must be closely followed to achieve the stated capacity. Care must also be taken to ensure that props/struts/rakers etc. (Figure 10.3) are not removed^{10.1}.

It should be noted that the term 'hoarding' has a different meaning in the wider construction industry — often referring to panels built *in-situ* from plywood, and covering a stout timber frame set into concrete.

10.2.3.1 Steel panel systems

These are widely used as the perimeter enclosure for events where there is a wish to control admission. They offer a fairly high degree of security and are formed from a plastic-coated flat steel sheet covering, within a fabricated steel frame. The frames should overlap when bolted together (an essential safety feature to prevent any gaps), and must be secured to the ground. Typical panel size is 3m high x 2.4m wide (Figure 10.4).



Figure 10.5 Roadway panel system used as barriers/hoarding

These robust perimeter hoarding systems (as well as fencing and barriers used for similar purposes) should be designed with lateral loads in mind. Rakers at every join (enabling a substantial length of fence to operate in tension) are essential. In the event of a localised failure, they perform a similar function to motorway crash barriers.

10.2.3.2 Roadway panel systems

Roadway panel systems can be viewed as the 'ultimate' fence system — offering very high loadings (resistant even to vehicle impacts if installed correctly). The panel sizes are similar to those used in steel panel systems. Interconnection between panels is usually by an H-profile sleeve that locates the edges of two adjacent panels. Heavy-duty rakers and extensive ground pinning are essential due to the self-weight of the panels and the potential applied loadings (Figure 10.5).

10.3 Front-of-stage barriers

Front-of-stage barriers have considerable structural strength and should be designed to resist the loads applied by crowds (Section 7). They are used at the front of viewing areas where large crowds are in attendance. There are a number of different systems but they generally consist of 1m steel or aluminium sections. The usual format is an A-frame with built-in steps for stewards to ascend, in order to be able to reach into the crowd (Figure 10.6). These barriers rely on the weight of the crowd on a footplate at the front to maintain stability. They are designed to travel flat and to be erected on-site.

To fulfil their purpose, front-of-stage barriers must be erected and connected strictly in accordance with the manufacturer's instructions and specifications. Reference should be made to the event safety (crowd management) section of the HSE website^{10.2}.

10.3.1 Risk assessments

In order to provide the appropriate arrangements for front-of-stage barriers, it is essential that a full risk assessment is carried out to determine the range and



Figure 10.6 Front-of-stage barrier



Figure 10.7 Finger barriers

nature of the people who will be attending the event. This needs to include; their likely level of excitement, possibility of intoxication, what their normal behaviour might be and their anticipated reaction to unplanned incidents.

A barrier (also referred to as a 'guard' in the Building Regulations and as a 'separating element' in international Standards) is a structural element intended to prevent people from falling, and to retain, stop or guide people. A front-of-stage barrier creates a 'sterile area' (or 'sterile corridor') enabling safe management practices that provide an acceptable level of safety in this critical space.

The area directly in front of the stage barrier is likely to be the most critical. Crowd densities here may be very high. Crowd surges may be experienced, and subsequent dynamic loads on barriers at the front of the stage may be considerable. Fortunately, such surges and loads are generally of short duration. Experience and research suggest that the greatest dangers are not large transient pressures on people, but crowd collapse and subsequent traumatic asphyxiation.

Crowd pressures can reach undesirable levels and individual behaviour can place innocent parties at risk. The function of the barrier is to stand firm; preventing dangerous crowd movement (which could cause collapses) and to enable stewards to monitor the crowd and assist people who may be approaching, or who are in distress. The front-of-stage barrier provides a platform for the stewards — affording them clear sight to more readily identify those in need of assistance, and to more easily pull those in need from the crowd, into the pit area, where they can be escorted away from the direct vicinity of the incident.

Barriers function by using the vertical load of the crowd on the footplate to provide the mass to resist overturning and sliding induced by horizontal loads. Correctly installed front-of-stage barriers should not slide, overturn, lift or collapse. It is often suggested

that some barrier-slide will relieve pressure in the crowd. There is no sound argument for this proposition.

The possibility of lifting is also a consideration where 'finger' barriers are used in order to reduce lateral movement of the crowd and facilitate access to the crowd or stage area (Figure 10.7). Barriers should be designed to resist any lifting as a result of pressure from both sides.

Multiple barrier systems may introduce a measure of control on the crowd density in the area immediately in front of the stage but every barrier layout carries its own set of hazards. Finger barriers create corners where people could be trapped. Multiple barrier systems where two (or sometimes more) lines of barriers are placed further back into the crowd, may help to control the pressures in the immediate front-of-stage area, but these additional systems have to be manned in terms of stewards and medical assistance. Issues such as crowd loading, density, access/egress and means of escape, all have to be considered.

A seated audience does not automatically negate the need for a front-of-stage barrier, particularly in temporary venues or in a venue designed for a specific purpose that differs from the nature of the event being held.

The gradient and condition of the ground towards the stage should be considered in the risk assessment. Particular attention should be given to step changes such as kerb lines, which run across the line of the front-of-stage barrier. Given the reliance on frictional resistance created by the weight of the crowd, any areas where the barrier may need to be raised (packed) to accommodate a change in level should receive careful consideration (and must be clearly separated from areas where the highest crowd pressures are most likely to occur).

It is vital that each particular event is comprehensively assessed in order to determine the level of pressure

likely to be imposed on the barrier. It may be necessary to seek expertise from various disciplines.

The following factors need to be considered:

- The number of people attending the event
- The type of performance — rock concert or formal civic event etc.
- The use of thrusts, B-stages and any other attributes which will affect the crowd response or create crowd movement
- The known history of the performers and promoters — intelligence gathered from other venues and previous tours
- Previous incidents. Factors such as numbers of casualties treated could be indicative of high-energy events
- The crowd profile. Factors affecting how the crowd will respond and how they need to be managed
- The crowd age-range
- The crowd gender
- The volatility of the audience. Are the crowd likely to remain relatively motionless throughout, or will they move around, perhaps pushing forwards to get closer to the stage? Elements within a crowd may engage in disruptive activities such as 'moshing' which may make audience members apprehensive, causing them to try to move away from the centre of activity. It has been demonstrated that extremely volatile crowds can impose loads in excess of the design loading. In such cases, special measures should be taken
- The proposed barrier layout. A straightforward, slightly convex barrier line across the front of the stage, or a complex multiple barrier system with potential different densities for different areas within?
- The nature and condition of the site:
 - Grass (firm or soft ground? Prone to flooding or water-logging?)
 - Hard surface such as asphalt, concrete or gravel
 - Relatively flat or sloping/stepped?

10.3.2 Design

The layout and arrangement of the front-of-stage barrier is a function of stage height, side-stage positions, stewarding arrangements and the venue geometry. Front-of-stage barriers in use in the entertainment industry are purpose-built modular units.

Where barriers are connected to the stage or its components, the design of the stage should take account of the barrier-loading.

Barriers constructed from scaffolding components should not be used.

Figures 10.8 and 10.9 shows how spectators can be packed very tightly against front-of-stage barriers, leading to the risk of asphyxiation or localised injury to the chest region. They also illustrate how the height of individuals in a crowd may vary considerably. Generally, a vertical flat surface provides effective protection across a range of individual heights. It is recommended that the maximum barrier height should be 1.05–1.22m. The barrier should not have sharp edges, gaps or other prominent elements that could cause injury.

The width of the barrier will be defined by the width of the stage. Where necessary, the front-of-stage



Figure 10.8 Crowd pressing onto front-of-stage barrier

barrier should be transformed outside these limits into a sightline obstruction barrier (minimum height 2.4m).

The general principle should be to achieve the widest possible sightline (in an arc from stage right to stage left). If this is provided, a comfortable and safe crowd shape is created. Members of the crowd will not need to push to the front or stage centre to obtain a satisfactory view.

Straight barriers are a standard choice, but convex curvature of the barrier in plan (relative to the audience) may be effective in reducing crowd density.

The sterile area between the stage and the front-of-stage barrier should be provided with a step (or preferably a continuous platform) immediately to



Figure 10.9 Barriers must be suitable for a crowd of varying height

the rear of the barrier that:

- Enables security and rescue services to view the crowd from an elevated position
- Reduces the risk to stewards when lifting and extracting distressed individuals from the audience

A continuous non-slip platform is particularly advantageous at outdoor venues where:

- The ground may create difficult working conditions
- A volatile or large audience is likely to result in significant numbers of spectators requiring assistance

The dimensions of the sterile area will depend on the width of the stage, operational requirements for stewards and medical staff, and the anticipated degree of activity as a result of the profile of the event.

Short barrier panels with no footplates are sometimes used to permit bends in the line of the barrier to allow the required configuration to be achieved. They are completely reliant on load transfer to adjacent sections equipped with footplates, and their use should be minimised. These panels should be clearly identified on the drawings so that their numbers and location can be assessed. They should be kept away from highly pressured areas where possible, and they should be spaced apart — with the largest possible lengths of standard barrier in between.

Gates in barriers, whether opening away from or into the pit, cannot be operated safely when the barrier is subject to any crowd pressure. These gates also rely on adjacent standard sections to carry their loading, but to a greater extent than short panels. This weakens the overall barrier configuration and their use should generally be avoided.

10.3.3 Design loading

Where a footplate is integral with the front-of-stage barrier, the weight of the crowd members may be considered to act as kentledge in resisting overturning and in creating frictional resistance. However, care should be taken regarding the realism of assumptions made, in terms of the number of people required to be packed onto the footplate to generate the required dead load. For example, at events where children account for a significant proportion of the audience, the average weight may be at considerable variance from the assumed standard weight.

The footplate should be sized such that a realistic vertical load from the crowd produces a restoring moment that is greater than the overturning moment by the appropriate factor (Section 7). The crowd will be at its most dense at the barrier, but it is worth noting that this is equivalent to $0.08\text{m}^2/\text{person}$ compared to the average figure of $0.2\text{m}^2/\text{person}$ i.e. five people per m^2 .

Some calculations assume a degree of load-shedding or sharing from overstressed barrier sections to adjacent sections. However, this could only be effective if the extent of the fully-loaded or overstressed sections was extremely localised (see Section 10.3.2 which refers to panels without footplates, and gates in barriers). Pressure over a

wider front would mean that the load would be passed onto an already overloaded section of barrier, which was already looking to shed some of its load. A surge event can act like a wave — spreading out from a point some distance from the front-of-stage barrier — arriving at the barrier across a wide front.

A clear statement should be made in the event management plan, defining the required horizontal design load for the front-of-stage barrier. The capacity of the barrier to resist this load should be confirmed in writing by the barrier supplier or manufacturer, together with any design assumptions or criteria.

Reference should also be made to Section 7.5 of this *Guide*.

10.4 Site conditions/barrier performance

The load resistance of front-of-stage barriers can vary significantly depending on the characteristics of the surface on which they are standing. This site-specific issue requires particular attention. Barrier tests are carried out in controlled conditions, and could be based on assumptions which may not prevail in actuality. Sliding is the most likely failure mode, and under certain site conditions barriers may not be able to sustain the required design loading. It is essential that on-site conditions, the surface on which the barriers will stand, and the profile of the crowd at the event, are taken into consideration.

The area of the footplate and the coefficient of friction between footplate and foundation are the critical components in assessing a barrier's resistance against sliding. Coefficients of friction between materials vary and this factor should be considered in the barrier risk assessment. Reference should be made to Table 5.2 with regard to coefficients of friction between materials. Placing a suitable sheet material to increase frictional resistance or mechanical fixing of the barrier may be essential. Some barrier suppliers recommend the use of rubber matting below the footplate on surfaces such as plastic pitch coverings, asphalt or concrete; although the properties of the rubber matting may not be fully defined. In this case, further questions should be asked of the supplier — to evidence previous uses of this configuration without failure under similar conditions.

It should be appreciated that where a porous outdoor surface might initially be deemed to be satisfactory, ground conditions may be altered by natural or human intervention. In addition to the weather, the provision of water to members of the crowd (essential at high-energy events) inevitably results in spillage which will soften the ground. In extreme situations the ground can turn to mud, causing the barrier to slide. Ground protection using geotextile membranes has been used in the high density vicinity of the barrier to protect the ground surface, but care should be taken to avoid introducing slip or trip hazards.

On greenfield sites, securing barriers into the ground (using steel pins) at locations appropriate to the barrier design, can enhance resistance to sliding. However, extreme care should be taken so

that pinning does not introduce other risks and hazards. The Event Organiser should seek specialist advice and discuss this with the Enforcing Authority. Care must also be taken not to introduce trip hazards in the pit area. Pinning of barriers in prepared pitches in football stadia and other grounds is not usually appropriate given the prevalence of sand within the make-up and the potential for damage to under-soil heating elements, and drainage/irrigation systems.

The introduction of proprietary plastic coverings, made up of interconnected tiles or rolls, to protect the pitch in football and other stadia has resulted in reduced friction coefficients beneath barriers.

10.5 Multiple barrier arrangements

Multiple barrier arrangements allow zones to be created, within which the crowd can be managed^{10.3}.

Complex multiple barrier arrangements are now commonplace, contributing to elaborate stage sets and often with one or more thrusts (Figure 10.10). These arrangements need to be carefully designed — with detailed risk assessments for each section in terms of crowd profile, access, egress and emergency escape, loading density, etc. Using barriers from multiple manufacturers in the same line is discouraged — but where unavoidable, purpose-made connections should be used.

Multiple barrier systems may be more difficult and expensive to construct on open sites and in some cases may not be practicable. If the means of escape requirements are not considered with great care,

multiple barriers can become a system of dangerous pens.

Where multiple barrier systems are installed the arrangements should allow evacuation within a specified time. An analysis should be made of the overall impact upon means of escape when the total population of the site is considered. Zoned barrier arrangements can reduce the incidence of crowd surges and subsequent crushing, provided that a comfort capacity calculation is made and satisfactory management practices are in place.

Management practices for a multiple barrier system need to recognise that moving a spectator hazard further from the stage does not remove the hazard. For evening performances, stage lighting can be beneficial to stewards manning a barrier immediately in front of the stage. The reduction of lighting levels away from the stage needs to be considered for multiple barrier arrangements.

10.6 Installation and inspection

The front-of-stage barrier is the first line of defence for the audience and vital to allow pit stewards to carry out their duties. It is as likely to be exposed to design loadings as any structure on an event site and should be accorded a high level of attention to ensure that all details are correctly completed.

For many events the front-of-stage barrier is necessarily one of the last things to be put in place, but should be installed in good time before crowds begin to gather. This allows for adequate checks (to ensure that barriers have been properly erected in



Figure 10.10 Complex multiple barrier arrangement

accordance with the details and procedures) to be undertaken.

Checks should be made to ensure that all connecting bolts are properly fitted and that any pinning is correctly installed. Rubber matting or other material to improve frictional resistance, where provided, should be checked to ensure that it is correctly located beneath the footplate in accordance with the manufacturer's details and that barriers are located accurately in accordance with the agreed site plan. Where multiple barrier systems are used, this is particularly important in order to prevent 'penned' areas from becoming overloaded.

10.7 Fencing or hoardings beyond main viewing areas

Each specific event layout or stage set-up must be carefully assessed to determine the likely loads imposed by crowds (both during the event and while in transit to/from the viewing area). The *Guide to Safety at Sports Grounds*^{10.4} provides guidance on how crowd pressures vary according to the orientation of the barrier, relative to the crowd movement. Major access and egress routes should be checked.

It is important to manage viewing areas to prevent crowd build-up against obstacles, congestion of exit routes and the potential collapse of fences not specifically designed for crowd loading. Where side-stage fences (to obstruct sightlines) are used, the potential loading needs to be assessed.

In certain circumstances it may be appropriate to adopt a lower loading according to the distance from the viewing area. The first sections might be designed as discussed here, until a point where anticipated crowd build-up is reached. However, where this area also forms part of the exit route, with the crowd moving parallel to the barrier, this assumption cannot be made. Each specific situation must be carefully assessed and any assumptions fully recorded.

There have been collapses of free-standing masonry walls when subjected to crowd pressures. These walls should not form part of an enclosure.

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11 Fabric structures

11.1 Introduction

There are three broad categories of fabric structure: unframed, framed and inflatable. They are used for a variety of functions at events; providing shelter and protection from the weather by enclosing space using a flexible and tensile fabric material. They are usually supported by mechanical means through the use of beams, columns, poles, trusses, ropes or cables. In the case of inflatables, air pressure provides support. Fabric structures should be designed and engineered to withstand appropriate outdoor operational forces such as wind, rain and snow.

Traditional unframed structures commonly known as 'marquees' (Figure 11.1) have central poles or columns, and extensive use is made of guying to stabilise and tension the fabric covering. Modern unframed structures may use timber, steel or aluminium poles or metallic trussing to provide the upwards thrust required to resist the guy tensioning.

Framed structures are the most commonly used, and are typically rectangular on plan. They may be supported by aluminium portal trusses, steel or timber. The fabric covering is typically supported by the framework, which is independently stable (Figures 11.2 and 11.3). Framed canopies using modern tensile fabrics (and erected, for example, over platforms, seating tiers, arenas or stages) require specialist input.

Inflatable structures use an air beam, tubular or cellular wall construction. They rely on either a constant supply of air from an inflation fan, or from being inflated, pressurised and sealed before being covered with a canopy or tensioned cover.

Many inflatable structures use a combination of cellular wall and supporting metal framework — providing both load distribution, and the option for less air pressure in the cellular walls (Figure 11.4).

MUTA is the UK's national trade organisation representing temporary fabric structure Contractors. It operates a self-regulatory scheme which imposes, on its members, a compliance with a Code of Practice which the association enforces through its own inspectorate. The Code is contained within MUTA's *Best Practice Guide: Safe Use and Operation of Temporary Demountable Fabric Structures* which also contains detailed information on all three types of fabric structure^{11.1}.

11.2 Design

11.2.1 General

Fabric structures should be capable of withstanding all forces which they may reasonably be expected to encounter (wind being the most important of these). They should comply with BS EN 13782^{11.2}.

The design of new fabric structures should be carried out by a competent person and subject to an independent check by a suitably qualified engineer of appropriate skill and experience.

For both framed and unframed fabric structures, the stability of the main structure, including any tensioned anchors, should generally be independent of the sheeting fabric. Local tearing of the fabric should not result in the overall collapse of the main structure. The tearing strength and the pattern of seams should be designed to avoid unacceptable propagation of tears across the fabric.

Fabric structures often rely on individual tensioners and anchors for their stability (including anchorage in the ground). Particular attention should therefore be given to the strength and condition of these.



Figure 11.1 Traditional unframed structure



Figure 11.2 Framed fabric structures



Figure 11.3 Interior of framed fabric structure



Figure 11.4 Inflatable structure

Where the fabric behaves purely as cladding and does not provide any real strength or stiffness, the frame can be designed in a similar way to those in any traditional framed structure. However, the flexibility of the structure may be such that the non-linear effects of large displacements may need to be taken into account in the analysis. This is particularly true of large unframed tents supported by a system of guys and poles. These structures also rely entirely on the pre-stress in the system (tension in the guys and compression in the poles) to provide overall stability. This needs to be carefully modelled in the analysis. Pre-tensions in the guys should be defined in the design calculations. It is important that these values are achieved during erection, either by direct load measurement or by accurate length control, within certain specified tolerances.

The design of unusually shaped canopies or tensile fabric structures (in which the fabric contributes to the structural strength or stiffness) requires sophisticated computer analysis for form-finding, stress determination and cutting pattern derivation. Specialist professional advice should be sought.

Care is required in the design and detailing of the stressing devices, cable terminations, tensioning attachments, rigging and stretching screws which enable the system to be adjusted and correctly tensioned. Particular attention should be given to the connections between the fabric and guys, cables or poles. All details should avoid causing local stress concentrations in the fabric.

Given the external wind forces that may be applied to fabric structures, suitable proven fabrics must be used. Rubbing and chaffing should be avoided by providing extra patches or protection to areas where cables/other elements make contact with the fabric.

Fabric which is not sufficiently tensioned or which is in loose contact with other elements may flap in the wind, creating an unpleasant noise and potential damage. This can be avoided through careful structural design. Small panels of fabric may be stretched flat between robust structural elements, but greater stability and stiffness is achieved by providing fabric which has significant curvature in two directions.

Four critical elements may affect public safety:

- Anchorage/kentledge
- Wind loading
- Flame-retardancy
- Overall quality of completed structure

11.2.2 Anchors

Section 5 of this *Guide* provides discussion on ground and site conditions, with Subsection 5.6 focusing on the use of ground anchors and kentledge.

Where ground penetration is not possible, appropriate kentledge can be used to withstand uplift forces. The amount of kentledge required to resist the design load, with the appropriate factor of safety, should be calculated in accordance with the information provided in Section 7. Integral flooring systems can contribute to the kentledge required, but alone are unlikely to meet the full load requirements.

Concrete and similar bases may require specialist bolting systems of an appropriate capacity.

11.2.3 Wind loading

Wind loading on fabric structures is detailed in Section 7.6. It is important to emphasise however, that there have been a number of serious failures of inflatable structures due to insufficient anchorage. The importance of providing this, in order to counteract the significant uplift forces, cannot be over-emphasised. 'Dreamspace V', a very large inflatable sculpture installed in a park in Chester-le-Street, County Durham, UK in 2006, where two people were killed and a further twelve seriously injured, is just one high-profile example^{11.3}.

Further information and examples can be found in Structural-Safety alert SC/10/077^{11.4}.

11.2.4 Flame-retardancy of fabric and materials

General

Newly-manufactured membranes and fabrics should be of inherently flame-retarded fabric or durably flame-retarded fabric when tested to BS 7837^{11.5}.

Other sheet materials should be Class 1 'surface spread of flame' in accordance with BS 476-7^{11.6}. Materials should be free of flaming molten droplet characteristics and should not readily support combustion.

All fabric structure panels should be clearly labelled with the following (minimum) information:

- Name of operator
- Name of proofer/coater manufacturer
- Year of first use
- Flame-retardancy standard applicable to fabric

Textile floor coverings

Floor coverings used in fabric structures may be reusable (e.g. coir or synthetic matting) or disposable (e.g. lightweight polypropylene carpets).

Some floor coverings may react in fire to produce large amounts of heat and smoke, although the rate of surface spread of flame may be relatively slow.

The environment may also have a significant effect on the burning behaviour of materials, as wind can cause a fire to spread more rapidly. It can also blow smoke into escape routes — adversely affecting the means of escape. A similar situation may occur where a lack of adequate ventilation causes smoke to be concentrated in a particular area.

The most appropriate fire test for reusable floor coverings is BS 4790^{11.7}. Such flooring should comply with the low radius of effect of ignition in Table 1 of BS 5287^{11.8}.

Disposable floor covering, which is through necessity lightweight, may not meet the performance specification in BS 5287. Nevertheless, such material may be accepted for a single use inside a fabric structure, provided that it falls within one of the classifications in BS 5287 and that the flame spread time does not exceed 52mm/minute.

Materials for marquee lining drapes

All unattached lining drape materials should comply with Type B performance of BS 5867-2^{11.9}.

Linings may be suspended using ropes constructed from man-made or natural fibres and may be laced together using the same materials. Linings should only be used if constructed from an appropriately (preferably inherently) flame-retardant material. If materials requiring flame-retardancy re-treatment are used, e.g. cotton or wool, this process should be carried out according to manufacturers' instructions and a record kept accordingly.

11.3 Procurement and use

As part of the event planning process, the responsibilities of the Contractor and the Client should be clearly identified and agreed, along with an erection and dismantling schedule with adequate timescale for those operations to be carried out properly and safely. These will normally be set out in the contract and should be standardised. Contractors should make Clients aware of their safety responsibilities.

11.3.1 Safety considerations — Client

The following factors should be considered by the Client when selecting a site and operating a fabric structure.

Site plan

For larger events, it is recommended that an outline plan of all the structures on the site should be prepared by the Client, showing the position of all entrances and exits, plant, vehicles, etc. It should be kept up-to-date on-site and be readily available for review.

The plan should be agreed by the Local Authority (following consultation with the fire service) with regard to occupancy, use, position and other factors relevant to safety. It should not be altered without reference to the Local Authority. The Contractor should be provided with the latest iteration of the plan.

The Client should ensure that the needs and convenience of the disabled are taken into account when designing the event, and ensure that the Contractor is advised of all such requirements from the outset.

Fire safety

Reference should be made to the fire service and Local Authority for the appropriate provisions. These will include, but not be limited to, issues pertaining to access routes, appropriate portable firefighting equipment, access to hydrants and other water supplies. Other issues to consider include:

- Proximity of adjacent buildings, other temporary structures, vegetation and other fire risks in relation to the spread of fire
- Dangerous, combustible or toxic gases or products such as aerosols, explosives or fireworks. These should not be stored in a fabric structure
- Areas underneath stages and platforms should not be used for storage, and rubbish should not be allowed to accumulate there. Such areas should be inspected daily to ensure conformity

Loads

No additional loads should be attached to or suspended from the structure without reference to and approval from the Contractor.

Safety plan

The Client should have access to a reliable local weather forecast and the means to contact the Contractor for maintenance assistance should forecasted conditions dictate the need. The Client should also consider the topography of the site and time of year, and consult with the Contractor as to the necessity of a maintenance team being on-site throughout.

Erection

Nobody other than the Contractor's staff or people under the Contractor's supervision should be admitted to the structure or surrounding area until it is deemed structurally complete and safe.

No alterations to a completed structure should be made without the express authority of the Contractor.

Access and egress

Access and egress routes for the public, emergency vehicles and equipment should be kept free from obstruction at all times. During occupation, the structure's exit doors should not be locked. Where there are no doors, flap exits of 'quick release' design should be provided (and where such arrangements are in place, active management of the exit route by stewards should be considered).

Underground and overhead cables

The location of any underground services must be identified by the Client and clearly marked before any ground penetration operation. If any doubt exists, in order to protect its employees, the Contractor or their appointed specialist should carry out additional checks such as a Cable Avoidance Tool (CAT) scan of the area where penetration is planned.

Overhead power cables represent a particular threat. When carrying out work on-site it should be remembered that electricity is capable of arcing from high voltage lines. Wherever possible, locating fabric structures within 6m of such cables should be avoided. If in doubt, further specialist advice should be sought from the relevant power authority.

Other services

A telephone to call emergency services should be available. Emergency lighting should be provided for structures used during hours of darkness to maintain an adequate level of lighting in the event of a power failure.

11.3.2 Safety considerations — Contractor

Access and egress

Fabric structures intended to hold more than 50 people should have at least two suitable exits. Exits should be distributed as evenly as possible around the structure to provide genuine alternative routes from various directions. The maximum distance of travel from any part of a structure to a final exit should not normally exceed 24m.

In exceptional circumstances (and where structures are wider than 48m) it is possible for the travel

distance to be extended if adequate fire precautions are in place. Sufficient exits should also be provided to enable an appropriate evacuation procedure. As a guideline, an evacuation period of two minutes should be aimed for.

Entrance and exit ramps for the general public should not have a gradient steeper than 1:12 and should be surfaced with a suitable slip-resistant material.

All doors on an exit route should open outwards and, where exit doors have to be secured against intruders, they should be fitted with panic bolts or latches to comply with BS EN 1125^{11.10}. Where there are no doors, flap exits of quick release design should be provided.

All emergency exit doors and flap exits should be provided with exit signs conforming with BS 5499-10^{11.11}. Responsibility for providing exit signs is a matter of agreement between Contractor and Client.

Stakes and ropes

Stakes and ropes near exits and walkways should be clearly marked or fenced-off to prevent members of the public from walking into or tripping over them.

Wind loading

The Contractor should advise the Client of the maximum in-service wind speed (expressed in both m/s and mph) for the structure to enable a safety management plan to be activated accordingly. The Contractor should advise if this maximum wind speed is a 'gust' or 'mean' wind speed.

Services

The Contractor, notwithstanding the responsibility of the Client, should establish the lines of any underground services and take all necessary measures to avoid them when anchorages or similar are being driven into the ground.

Work on electrical installations and appliances should only be carried out by competent persons. Where electrical installations require anything other than a connection through a pre-fitted socket, a qualified electrician is required. All work should be installed, tested and maintained in accordance with the provisions of normative Standards or national guidelines such as BS 7671^{11.12} and BS 7909^{11.13}.

All means of heating other than electrical should be through the use of 'indirect' heaters, i.e. those with an exhaust system, sited externally and ducted by means of flame-retardant hosing. Care must be taken to ensure that exhaust fumes from heaters are prevented from entering the structure and are dispersed safely. Exceptions to this guidance may be permitted by reference to the relevant Local Authority.

Use of naked flames (e.g. effect flames and candles) within a structure requires a full and adequate risk assessment.

Contractors should have access to a reliable local weather forecasting service to determine the level of maintenance necessary during an event.

Contractors should provide an out-of-office emergency telephone number and appropriate response service.

11.4 Erection, inspection and dismantling

11.4.1 Erection

Structures should be erected and dismantled by competent persons. The manufacturer or supplier should provide a method statement for erection and dismantling. The covering fabric and all supporting poles, frames, guys, stakes, anchors, fastenings, etc. should be checked upon delivery to site. Torn or damaged items should not be used.

Stakes and pegs for holding down spreaders, soleplates and cable anchorages are vital to the safety of fabric structures and should be given particular attention. It is essential that the specified number of stakes and pegs are used and that they are fully driven to the necessary depth. Reference should also be made to Section 5.6.2 of this *Guide*.

Temporary props or guys are sometimes required. Specialist lifting, jacking or rigging systems may need to be employed during the erection of larger unframed structures. Competent specialist Contractors should be used for this purpose. In some cases it is advisable to arrange qualified and experienced engineering supervision from specialist firms.

11.4.2 Inspection

After erection and before use, the structure should be thoroughly inspected and approved by the Contractor. The inspection should be based on a checklist and should include, but not be limited to, the following:

- All aspects of the final structure are at a safe distance from power lines and other hazards
- Anchorages are suitable for the purpose and soil conditions, and are holding fast
- All bracing wires, roof and wall bars are in place and adequately tensioned
- All ropes, steel wires and tensioners (including guy-wires) are correctly fitted
- The fabric does not have any significant damage and is correctly tensioned
- All locking pins and bolts are in place and secure
- Structural supports have no significant damage, and are not overstressed
- Eaves connection joints are securely locked home
- Flame-retardant labelling is in place on every panel
- Flooring is evenly laid and securely fixed, with no tripping points
- Timber uprights and ridges are free from splits that are likely to cause failure
- Walls are securely pegged and/or secured
- Suspended loads are evenly distributed, secure and do not overload the structure
- Appropriate emergency exits are in place and are clear from obstruction
- Final all round visual check satisfies that the structure is erected correctly

Adverse weather

Fabric structures are susceptible to the effects of constantly changing climatic conditions and so appropriate management systems should be in place to:

- Monitor and measure the local weather conditions

- Define and deliver a plan to deal with variable loading conditions that can affect (and exceed the safe working parameters of) the structure, e.g. changing ground conditions due to prolonged rain can significantly affect the resistance offered by ground anchorages, and may cause 'ponding' on the fabric
- Take action if required

One of the greatest hazards to fabric structures is wind. Most structures are designed to be safe for use in winds up to a certain strength (speed). The Event Organiser and Contractor should be clear as to the value of this wind speed in accordance with the wind management plan. Further information can be found in Section 7 of this *Guide*.

Fabric structures should be additionally inspected and monitored in the advent of adverse weather, and tensioning systems should be checked and adjusted as necessary. All entrances and exits should be closed and secured. In severe conditions fabric structures may need to be re-approved prior to public entrance.

11.4.3 Dismantling

Care should be taken not to damage or stress poles, ridges, portal frames or other critical components — particularly during handling, lowering or dismantling. Having ensured that the fabric is dry it should, where possible, be carefully folded in the correct way to permit easy unfolding for erection at the next site. Fabric should be stored in a dry, vermin-proof environment. Cables and guys should be carefully coiled and be free of kinks.

11.5 Verification

Design stability calculations should be available, clearly stating the rated maximum service wind speed (gust or mean) in m/s and mph. This should be certified by a suitably qualified engineer of appropriate skill and experience.

Verification of materials and of the competence of Contractors and suppliers may be provided by various means. Under the self-regulatory scheme operated by MUTA in the UK, member companies follow a Code of Practice and Best Practice Guide^{11.1} which emphasises public safety, and permits only the use of fabric and materials with flame-retardant qualities. Under this scheme, members are subject to both site and base inspection, and are obliged to record all fabrics used. Members are issued with a certificate of compliance and it is recommended that this may be accepted as evidence of the satisfactory performance of the Contractor.

Any levelling platform or birdcage scaffold (scaffold grid) supplied by or through a structural or specialist scaffold Contractor should comply with BS EN 12811-4^{11.14} and BS 5975^{11.15}. Loads should be as defined in BS EN 1991-1-1^{11.16} or other documents as agreed by the Client.

A self-check sign-off form should be available which is signed and dated by the site supervisor. Supervisors should have at least two years' field experience. Competence of supervisors can be further evidenced by appropriate vocational

qualifications. MUTA operates a vocational qualification for staff involved in the erection, dismantling and signing-off of fabric structures. This has been established along with a nationally-recognised health and safety course (Structuresafe) and an accreditation card scheme for member's workers in the industry^{11.17}.

11.6 References

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- 11.15** *BS 5975:2008 + A1:2011: Code of practice for temporary works procedures and the permissible stress design of falsework.* London: BSI, 2008
- 11.16** *BS EN 1991-1-1:2002: Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings.* London: BSI, 2002
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12 Ancillary and special structures

12.1 Introduction

As well as grandstands, stages, fencing and fabric structures, a wide variety of other structures are built for sporting and other entertainment events, for many purposes. These structures include those to support loudspeakers and sound-mixing equipment, video screens, camera platforms, display materials, scoreboards and lighting equipment. The requirement for rapid erection and dismantling for touring concerts and events, means that these structures are often constructed of system scaffold or proprietary truss and tower systems (Figure 12.1).

Some of these structures differ from others discussed in this *Guide*, in that during an event they are located in the middle of a venue and are surrounded by the audience. In this case, due care and consideration should be given to audience reaction and movements, and additional safety precautions may be needed.

12.2 Design

12.2.1 General considerations

Structures forming masts, towers or subsidiary structures may be proprietary systems or built from individual components such as scaffold tubes and fittings. The design should be undertaken using:

- Guidance and recommendations from the manufacturers of proprietary systems (when these are based on proper research and design)

- Standard details prepared by a Designer for a standard range of configurations
- Standard details included in national Codes of Practice

All structures should be fully designed by a competent person in accordance with this *Guide* and relevant design Standards. The design must be appropriate for the situation, and the structure should be built strictly in accordance with this design.

As with other temporary structures, an independent design check should be carried out by a suitably qualified engineer of appropriate experience. General guidance on large video screens (Figure 12.2) can be found in *Risk issues associated with large tv/video screens at public events*^{12.1}.

Once constructed, these structures should be inspected on a regular basis by a competent person. Measures should also be taken to prevent trespassers from climbing on, or interfering with, the completed structures.

These types of structure have certain common essential features which strongly influence their safety and integrity and are discussed in the following subsections.

12.2.2 Verticality

Unless specifically designed otherwise, all structures and their vertical supporting members should be as plumb as possible. The maximum out-of-plumb tolerance should be defined in the design documentation or operating manual.



Figure 12.1 Audiovisual support structure

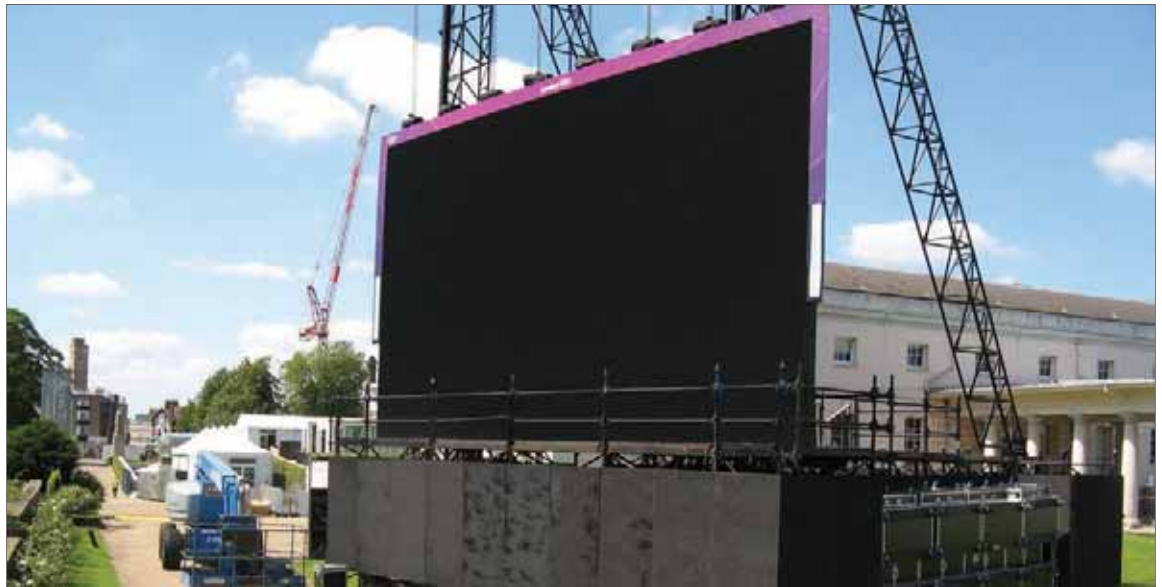


Figure 12.2 Large video screen with support structure

12.2.3 Stability

These structures can be slender and often need effective lateral support. They should be capable of resisting all overturning forces by a suitable factor of safety (Section 7.6). The stability of each structure should be determined by calculation.

Stability can be provided by the following (either individually or operating in combination):

- Having a suitable base area
- Having outriggers or stabilisers to form a suitable base area
- Using guy-wires
- Using kentledge
- Anchoring into the ground

12.2.4 Overloading

The loads applied to a structure should not exceed those considered in the design. Ancillary items such as loudspeakers, signs, banners, flags or cladding, when fixed to the structure, can attract significant wind loads.

Consideration should be given as to how fabric elements are attached to the structure. For example, if a fabric sheet or wall is attached, in-plane loads exist due to the tensions in the fabric.

Special care should be exercised when considering suspended loads. The calculations must account for the transfer of load from wind-loaded elements to the structure. For example, a rigid video screen suspended from its top edge (and not restrained from swaying) will transfer the wind load to the structure at the suspension point — not at its centre of area — thus having an increased load effect on both the structure and overturning, when compared to a screen fixed in such a way that it can't sway. However, reference should be made to the manufacturer's guidelines for the hanging of suspended equipment. Where such guidance is not available, the advice of a suitably competent engineer should be sought. It should be noted that the bending stresses induced by the wind are significantly different depending on whether the equipment is top-hung only, or is restrained from swaying. Note also, that

adding banners/cladding etc. can increase the wind loading significantly (Section 7.6).

A risk assessment should account for the possibility that structures may be climbed by members of the crowd, that other equipment may be tied to or placed against them, and that unplanned impact may occur. These may cause significant overloading.

It is important that the loads acting on the structures are controlled to ensure they are both within the limits set by the design, and that they are not placed so as to cause eccentric forces outside the design parameters.

Loads from lighting, public address equipment, etc. should be documented for each event and checked against the loading allowances assumed by the original Designer. Where public address towers, mixing desks or other structures are located within the audience areas, consideration should be given to the effect of horizontal loading that may be exerted by crowd members. Alternatively, the structures should be surrounded by a barrier adequate to resist the horizontal loading that may be exerted (Section 8.8).

Where barriers are attached to the structure, the resultant worst-case combination of forces should be considered in the design process. It is also important that any horizontal loads are absorbed by bracing attached to the node points. This bracing should be arranged to direct the loads to the ground or to some rigid structure. As the bracing could be carrying compressive loads, its slenderness ratio should also be considered.

12.2.5 Scaffold

In the UK, ancillary and special structures constructed from tube-and-fitting scaffolding should be designed in accordance with BS EN 12811-1^{12.2} or BS 5975^{12.3}, and the appropriate National Access and Scaffolding Confederation (NASC) guidance. Six aspects are important:

- The correct coupler should be used (Section 8.5)
- All connection points at a node should be as close as possible

- The fixing torque on the coupler should be in accordance with the manufacturer's recommendations (values of 40–70Nm are typical)
- Any tube carrying, or likely to carry, significant loads should penetrate the coupler by a minimum of 50mm and be fitted with a check coupler if required
- Any joint made with a bolted coupler depends on the torque applied by an operative, and may therefore be subject to human error. Consequently, all critical couplers and a random sample of non-critical couplers should be checked
- Consideration should be given to using purpose-designed system scaffolds where possible

These types of structure are often built using slender components. It is therefore important that the effective length of any component carrying compressive loads is limited; this limitation being dependent on both the actual length and the degree of end-fixity. In the case of scaffold tubes and couplers, although the coupler can support relatively large moments, it is generally assumed that this forms a pin joint, because of the uncertainty of the coupler-fixing torque.

12.2.6 Access

Ancillary and special structures will often need to be accessed during erection, use and dismantling. This requirement should be considered at the design stage and suitable provision made in the structure (and in the information provided with the structure) to enable safe access.

Workers should only climb heights appropriate to their training and abilities. They should be provided with fall-protection or fall-arrest equipment appropriate to the task.

Access to parts of the structure above ground level should be consistent with current work at height best practice and regulations.

All access should be in accordance with the *Work at Height Directive*^{12.4} and *The Work at Height Regulations 2005*^{12.5}.

12.3 Masts and towers

This section deals with vertical elements (generally known as 'masts' or 'towers') that do not form part of a larger structure (Figures 12.3 and 12.4).

Masts and towers are usually made from prefabricated proprietary truss sections. When used to support equipment such as lights or loudspeakers they are usually restrained laterally by guy-wires or attached to a weighted base. The guying is external to the footprint of the mast/tower.

Towers are typically built with patent system or traditional scaffolding, or by using prefabricated proprietary or patent truss sections with internal guying. They are frequently fitted with high-level platforms for workers and equipment. Rakers, outriggers and stabilisers can be used for stability, but the effective length of these needs to be controlled by the use of suitable bracing. Kentledge



Figure 12.3 Look-out tower

and guys may be employed outside the base area to ensure stability.

If prefabricated mobile access towers are used, then reference should be made to the manufacturer's instructions. Reference should also be made to BS EN 1004^{12.6} and BS EN 1298^{12.7}.

Towers are sometimes used to support lighting, microwave equipment and aërials. People using or inspecting these structures should be alerted to the potential dangers associated with these and any other 'live' equipment.

Barriers should be placed around guy-wires when these are provided on masts. Adequate stewarding should also be in place, to ensure that the guy-wires are not tampered with.

With standard tower/mast units, manufacturers' instructions should be followed at all times. Only equipment designed for the purpose should be used. In particular, equipment designed solely for indoor use, including proprietary load-placement devices, should not be used outdoors. Load-placement devices should not be used as load-supporting devices.

If guy-wires are used to provide lateral stability, account should be made of the vertical component of the force in the guy-wire that acts on the tower/mast.

12.4 Catenary wire ropes

Equipment on event sites often requires electrical cables to be routed between locations. Generally this is best accomplished with underground ducts, surface protection such as heavy rubber mats, or using proprietary systems creating safe conduits within vehicle-proof ramps. Occasionally, the only option is to take cables overhead (Figure 12.5). Any



Figure 12.4 Free-standing 'delay' mast

electrical cable should be suspended/supported from a tensioned steel wire rope (a catenary) in such a manner that no tensile force is applied to the electrical cable (e.g. festooning).

This technique is sometimes employed to take audio cables from the stage to the control position in the middle of the audience (the 'front-of-house' or 'mixer' tower). Great care should be exercised, as the tensile forces generated may be considerable, depending on the length and weight of the cable and the amount of 'sag' permitted.

On no account should catenary wire ropes be used to support loads, especially above the public, unless

calculations have been carried out by a competent person, taking into account the grade of wire required and the effects on the support structures. Specification of the type of steel catenary wire and details of the anchorages should be included in the calculations.

12.5 Hospitality units

Special consideration should be given to the design of hospitality units (Figures 12.6 and 12.7), with particular regard to the mobile nature of spectators and the related dynamic effects on the structure.



Figure 12.5 Catenary wire rope to 'delay' structure



Figure 12.6 Coca-Cola Beatbox Pavilion, London 2012 Olympic Park



Figure 12.7 MegaFon Pavilion, Sochi 2014 Olympic Park

12.6 High-level decks and platforms

In addition to the advice provided elsewhere in this *Guide*, it should be appreciated that some of the high-level structures described in this section will have deck levels at (or close to) the top. There is a significant risk of high-level decks being dislodged by wind, especially if there are partial blockages to the wind below the decks. Due to the increased uplift forces acting at the deck edges, it is good practice to fit handrails or toeboards (or a combination) in such a way that the outer edges of the deck are trapped and cannot uplift. For all other parts of the deck, the self-weight of the deck units — in addition to the required ballast — should be greater than the uplift force with a minimum factor of safety of 1.5. An event management plan should include the procedure to be followed during increasing wind events. The relative deflection between loaded and unloaded areas of deck or platform should be kept to a minimum, and such that a trip hazard is not introduced^{12.8}.

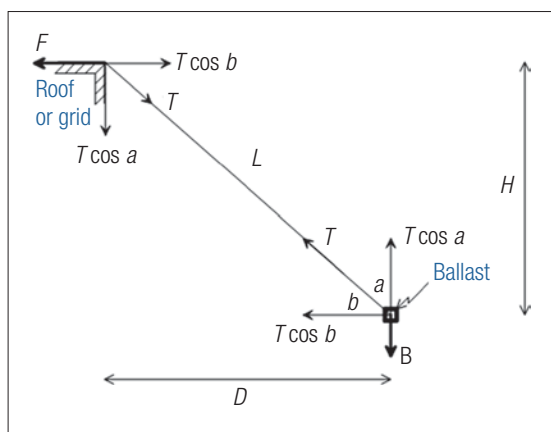
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Appendix A Derivation of kentledge – an example

Guy-wires, ballast and angles of friction

The amount of ballast required can be determined using the following procedures. It is assumed that there are no indentations or mechanical connections between the ballast and the ground, and that overturning of the ballast is not critical. It is also assumed that the ground is level and that the roof is designed to support the vertical component of the tension in the guy-wire, $T \cos a$. Local restraint to lateral forces may be transmitted by static friction between the contact surface of the ground and ballast. When the two are in contact (and transmitting forces) there is a constant relationship between the value of the normal reaction and the force at which frictional lateral restraint is just overcome — so that the ballast slides along the ground. This relationship is known as the 'coefficient of static friction'.



Where:

- F = force to be resisted
- a = angle between guy-wire and vertical
- T = tension in rope
- b = angle between guy-wire and horizontal
- B = ballast required
- L = length of guy-wire
- H = height of top fixing point of guy-wire above ground
- FOS = factor of safety
- D = distance along ground from top fixing point of guy-wire to ballast
- $\cos a = H/L$
- $\cos b = D/L$

Resolving horizontally at grid level:

$$T \cdot \cos b = F \quad \therefore F = T \cdot \cos b \quad \text{or} \quad T = F / \cos b$$

The horizontal component, $T \cos b$, of the tension in the guy-wire must be resisted by friction between the ballast and the ground.

The vertical component, $T \cos a$, of the tension in the guy-wire must be subtracted from the weight of the ballast to find the net vertical force at the ballast.

The frictional force is the net vertical force multiplied by the coefficient of friction, m .

Assume a factor of safety, FOS, against sliding:

$$\begin{aligned} T \cdot \cos b \cdot \text{FOS} &= (B - T \cdot \cos a) \cdot m \\ \therefore (F / \cos b) \cdot \cos b \cdot \text{FOS} &= (B - (F / \cos b) \cdot \cos a) \cdot m \\ \therefore F \cdot \text{FOS} &= B \cdot m - F \cdot \frac{\cos a}{\cos b} \cdot m \\ \therefore F \cdot \text{FOS} + F \cdot \frac{\cos a}{\cos b} \cdot m &= B \cdot m \\ \therefore B &= \frac{F}{m} \cdot \left(\text{FOS} + \frac{\cos a}{\cos b} \cdot m \right) \\ \therefore B &= \frac{F}{m} \cdot \left(\text{FOS} + \frac{(H/L)}{(D/L)} \cdot m \right) \\ \therefore B &= \frac{F}{m} \cdot \left(\text{FOS} + \frac{H}{D} \cdot m \right) \end{aligned}$$

Example 1:

Assume value of coefficient of static friction of 0.4 for the purpose of this example. Assume a factor of safety of 1.5.

Assume that the guy-wires are attached to the edge of the roof 10m above ground and 12m along the ground from the edge of the roof.

Then, substituting into the equation for the weight of ballast:

$$\begin{aligned} B &= \frac{F}{m} \cdot \left(\text{FOS} + \frac{H}{D} \cdot m \right) \\ B &= \frac{F}{0.4} (1.5 + (0.83 \times 0.4)) \\ B &= 4.58F \end{aligned}$$

This shows that the weight of ballast required is 4.58 times the horizontal force at eaves level.

Example 2:

Assume coefficient of friction of 0.4 for the purpose of this example. Assume a factor of safety of 1.5.

Assume that the guy-wires are attached to the edge of the roof 12m above ground and 8m along the ground from the edge of the roof.

Then, substituting into the equation for the weight of ballast:

$$\begin{aligned} B &= \frac{F}{m} \cdot \left(\text{FOS} + \frac{H}{D} \cdot m \right) \\ B &= \frac{F}{0.4} (1.5 + (1.5 \times 0.4)) \\ B &= 5.25F \end{aligned}$$

This shows that the weight of ballast required is 5.25 times the horizontal force at eaves level.

Appendix B Management of temporary demountable structures to ensure personal safety in the event of high winds

Note: this is an example based on a site using several different temporary structures. Management plans for specific sites and structures will require bespoke wording and adjustment. The titles of the various parties may vary from project to project; for instance the 'Site Manager' may be referred to as the 'Principal Contractor' in line with CDM 2015 terminology.

Introduction

This document sets out a management plan for dealing with extreme wind conditions. It aims to identify those parties involved and what actions they need to take.

It has to be recognised that wind speeds are not easy to predict and can vary considerably over short periods; high wind gusts being the principal issue. High winds can, in a similar way to heavy snow falls, be sufficient to cause an event's cancellation but the intangible (and varying) nature of wind can, sometimes erroneously, make such decisions less 'clear-cut'.

Safety during high winds needs to be considered, not just during the event (although this is the most difficult time due to the presence of the public, but also during the erection and dismantling phases.

Because different structures are to be employed, evacuation speeds are recorded for the various structures to allow a sequenced operation to clear the members of the public in the most appropriate manner.

Design considerations

Maximum operational design wind (gust) speeds for three principal types of temporary structure have been determined by suppliers:

Structure	Wind speed
Pole tent	27m/s (60mph)
Hospitality marquee	23m/s (51mph)
Canopy	20m/s (44mph)

A management plan follows, which aims to inform all concerned of their responsibilities under the operational conditions which may arise. Suppliers/ Operators are responsible for monitoring the wind speed conditions and for notifying the General Manager if/when they reach the trigger values relevant to each case. The Suppliers are to provide their own individual operation procedure for use by their Site Foreman.

Note that this may apply to Facility Operators where the structures are provided on a supply-only basis.

Management plan — an example

Personnel

		Abbrev.
Management		
Site Manager (overall responsibility)		SM
General Manager		GM
Operations Manager		OM
Structure Suppliers		
(for each structure)		
Firm	To be named	SUP
Site Foreman	To be named*	SF
Facility Operators		
(for each structure, if appropriate)		
Firm	To be named	FO
Facility Manager	To be named*	FM
Caterer	To be named	CAT
Security		
	Private Security	Security
	Police	Police

*Names and contact details to be given to General Manager as soon as possible (and no later than five days prior to the event).

Operation

	Action
1. During erection and dismantling phases (no public on-site) responsibility rests with the Supplier.	SUP
2. If handover takes place prior to full completion of the structure (and also following the event) then responsibility for staff rests jointly with the Supplier, Facility Operator and Caterer as appropriate.	SUP FO CAT
If the supplier has vacated the site while the Caterer's or Facility Operator's staff are working, then responsibility for these staff rests with their own management. If in doubt about any site conditions, the Caterer/Facility Manager are to liaise with the Operations Manager immediately.	FM CAT OM
Any decision to vacate a structure due to wind (or other) conditions is to be conveyed immediately to the Operations Manager.	SF/FM OM
Suppliers must make arrangements to provide experienced personnel to site — both during erection and during the event itself, as required.	SUP
3. Once the structures are constructed and occupied by either workers or members of the public, the following operational procedure is to be followed:	
a) Site management and/or Suppliers to monitor wind speeds both predicted (through weather forecasts) and actual (via site measurement (anemometer)), if necessary.	FM SUP
b) Suppliers/operators to have a management plan for dealing with the site occupation should wind speeds look likely to approach or exceed safe values.	SUP FO
The plan assumes that a continuous review of wind speed forecast and actual conditions will apply. In particular, when forecasts or irregular monitoring indicate gust wind speeds exceeding 13.4m/s (30mph) regular monitoring of wind speeds is to be implemented.	
The plan will then involve two levels of action:	
Level 1 – when forecasts or regular monitoring indicate gust wind speeds exceeding 15.0m/s (33mph) continuous monitoring is to be implemented and the Operations Manager informed accordingly.	SF OM
Note: 75% value of 20m/s = 15m/s based on lowest rated temporary structure.	
Level 2 – when monitoring registers gust wind speeds in excess of 90% of the operational maximum gust speed, in conjunction with an increasing trend in wind speed records, the operational procedures defined in the Supplier's management plan should be implemented and the site secured against public access and/or cleared of public as necessary. The Site Foreman is to immediately notify the Operations Manager.	SF FO
However, if an isolated gust speed is recorded in excess of 90% of the operational maximum gust speed against a background of generally falling levels of wind speed, a further period of monitoring may be appropriate before implementation of the management plan. This to be decided on-site in consultation with the General Manager.	SF GM
Any decision to evacuate is to be agreed by the Site Manager and Police.	SM Police

4. Notes

The Site Foreman/Facility Manager for each structure, or set of structures, is to keep a copy of the relevant operational procedure on-site at all times. This is to clearly identify the actions to be taken and who is responsible for each.

The document should record the safe operating wind speeds for the structures in question.

It should be recognised that the wind speeds given on the management plan table are 'gust' speeds. Weather forecasts traditionally report mean wind speed values — gust speeds may exceed mean wind speeds by up to 100%.

The various structures have wind speed parameters as listed in the following table.

SF/FM

Wind speed management plan

Wind level		Gust speed m/s mph		Action
1.	Warning 1	15.0 33 (Predicted mean speed would be ≥ 16 mph)		Continuous wind speed monitoring Staff/management on alert
2.	Warning 2			
	Evacuation levels (90%)	18.0 40		Canopy
		20.7 46		Hospitality marquee
		24.3 54		Pole tent
Note To resist the rated wind speed, fabric structures need to be fully sheeted and closed up. If this is the case, suppliers need to build this feature into their wind management strategy.				

Appendix C Reference documents

C.1 British Standards

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BS 5306: Fire extinguishing installations and equipment on premises. London: BSI, 2015

BS 5499-10:2014: Guidance for the selection and use of safety signs and fire safety notices. London: BSI, 2008

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BS 7671:2008 + A3:2015: Requirements for Electrical Installations. IET Wiring Regulations. London: BSI, 2015

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BS EN 1090: 2009 + A1:2011: Execution of steel structures and aluminium structures. London: BSI, 2009

BS EN 1125:2008: Building hardware. Panic exit devices operated by a horizontal bar, for use on escape routes. Requirements and test methods. London: BSI, 2008

BS EN 1298:1996: Mobile access and working towers. Rules and guidelines for the preparation of an instruction manual. London: BSI, 1996

BS EN 1990:2002: Basis of Structural Design. London: BSI, 2002

BS EN 1991: Actions on structures. London: BSI, 2002

BS EN 1993:2005 + A1:2014: Eurocode 3. Design of steel structures. London: BSI, 2007

BS EN 1997:2004 + A1:2013: Eurocode 7. Geotechnical design. London: BSI, 2004

BS EN 1998:2004: Eurocode 8. Design of structures for earthquake resistance. London: BSI, 2004

BS EN 1999:2007 + A2:2013: Eurocode 9: Design of aluminium structures. London: BSI, 2007

BS EN 12811:2003: Temporary works equipment. Scaffolds. London: BSI, 2004

BS EN 13200:2005: Spectator facilities. London: BSI, 2006

BS EN 13374:2013: Temporary edge protection systems. Product specification. Test methods. London: BSI, 2013

BS EN 13782:2015: Temporary structure. Tents. Safety. London: BSI, 2015

BS EN 62305:2011: Protection against lightning. London: BSI, 2011

ISO IWA 14-1:2013: Vehicle security barriers — Part 1: Performance requirement, vehicle impact test method and performance rating. Switzerland: ISO, 2013

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PAS 127:2014: Checkpoint security screening of people and their belongings — Guide. London: BSI, 2014

C.3 American Standards

2015 International Building Code. Washington DC: ICC, 2015

ANSI E1.2-2012: Entertainment Technology: Design, Manufacture and Use of Aluminum Trusses and Towers. New York: ANSI, 2012

C.2 European Standards

BS EN 39:2001: Loose steel tubes for tube and coupler scaffolds. Technical delivery conditions. London: BSI, 2001

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Appendix D Conversion factors

Quantity	From imperial units	To metric units	Multiply by
Mass	lb kip (1000 lb)	kg metric ton (1000 kg)	0.453.592 0.453.592
Mass/unit length	plf	kg/m	1.488.16
Mass/unit area	psf	kg/m ²	4.882.43
Mass density	pcf	kg/m ³	16.018.5
Force	lb kip	N kN	4.448.22 4.448.22
Force/unit length	plf klf	N/m kN/m	14.953.9 14.953.9
Pressure, stress, modulus of elasticity	psf ksf psi ksi	Pa (N/m ²) kPa (kN/m ²) kPa (kN/m ²) MPa (N/mm ²)	47.880.3 47.880.3 6.894.76 6.894.76
Bending moment, torque, moment of force	ft-lb ft-kip	N.m kN.m	1.355.82 1.355.82
Moment of mass	lb ft	kg.m	0.138.255
Moment of inertia	in ⁴	mm ⁴	416.231
Section modulus	in ³	mm ³	16.387.064
Length	mile yard foot foot inch	km m m mm mm	1.609.344 0.914.4 0.304.8 304.8 25.4
Area	square yard square foot square inch	m ² m ² mm ²	0.836.127 0.092.903 645.16
Volume	cubic yard cubic foot cubic foot gallon (US liquid) cubic inch cubic inch	m ³ m ³ L (1000cm ³) L (1000cm ³) cm ³ mm ³	0.764.555 0.836.127 28.316.85 3.785.41 16.387.064 16.387.064
Speed	miles per hour	m/s	0.44704

Appendix E Sources of further information

BRE Ltd

Bucknalls Lane
Watford
WD25 9XX
UK
www.bre.co.uk

Concert Promoters Association

6 St Mark's Road
Henley-on-Thames
Oxfordshire
RG9 1LJ
UK
www.concertpromotersassociation.co.uk/

Core Cities Group

c/o Manchester City Council
Level 5
Manchester Town Hall Extension
Lloyd Street
Manchester
M60 2LA
UK
www.corecities.com/

Department for Communities and Local Government

Fry Building
2 Marsham Street
Westminster
London
SW1P 4DF
UK
www.gov.uk/government/organisations/department-for-communities-and-local-government

Department for Culture, Media and Sport

100 Parliament Street
London
SW1A 2BQ
UK
www.gov.uk/government/organisations/department-for-culture-media-sport

District Surveyors' Association

c/o LABC
3rd Floor
66 South Lambeth Road
London
SW8 1RL
UK
www.labc.co.uk

Health and Safety Executive

Entertainment, Leisure & Consumer Services Sector
Engagement and Policy Directorate
Redgrave Court
Merton Road
Bootle
Merseyside
L20 7HS
UK
www.hse.gov.uk/

Home Office

2 Marsham Street
London
SW1P 4DF
UK
www.gov.uk/government/organisations/home-office

MUTA

Unit 10B
Red House Yard
Gislingham Road
Thornham Magna
Eye
Suffolk
IP23 8HH
UK
www.muta.org.uk

National Access and Scaffolding Confederation

12 Bridewell Place
London
EC4V 6AP
UK
www.nasc.org.uk/

Northern Ireland Environment Agency

Klondyke Building
Cromac Avenue
Gasworks Business Park
Lower Ormeau Road
Belfast
BT7 2JA
UK
www.nidirect.gov.uk/contacts/contacts-az/northern-ireland-environment-agency

Production Services Association

PO Box 2709
Bath
BA1 3YS
UK
www.psa.org.uk

Professional Lighting and Sound Association (PLASA)

Redoubt House
1 Edward Road
Eastbourne
BN23 8AS
UK
www.plasa.org

Security Industry Authority

PO Box 49768
London
WC1V 6WY
UK
www.sia.homeoffice.gov.uk

Sport England

21 Bloomsbury Street
London
WC1B 3HF
UK
www.sportengland.org

sportscotland

Doges
Templeton on the Green
62 Templeton Street
Glasgow
G40 1DA
UK
www.sportscotland.org.uk

Sport Wales

Sophia Gardens
Cardiff
CF11 9SW
UK
www.sportwales.org.uk

Sports Council for Northern Ireland

2a Upper Malone Road
Belfast
BT9 5LA
UK
www.sportni.net

Sports Grounds Safety Authority

East Wing 3rd Floor
Fleetbank House
2-6 Salisbury Square
London
EC4Y 8JX
UK
www.safetyatsportsgrounds.org.uk/

Steel Construction Institute

Silwood Park
Ascot
Berkshire
SL5 7QN
UK
www.steel-sci.org

Temporary Works forum

www.twforum.org.uk/

The Chief Fire Officers' Association

9-11 Pebble Close
Amington
Tamworth
Staffordshire
B77 4RD
UK
www.cfoa.org.uk

The Events Services Association (TESA)

18/19 Moor Street
Chepstow
Monmouthshire
NP16 5DB
UK
www.tesa.org.uk

The Institution of Structural Engineers

International HQ
47-58 Bastwick Street
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EC1V 3PS
UK
www.istructe.org

The Met Office (national)

Fitzroy Road
Exeter
Devon
EX1 3PB
UK
www.metoffice.gov.uk

UK Sport

21 Bloomsbury Street
London
WC1B 3HF
UK
www.uksport.gov.uk



TEMPORARY DEMOUNTABLE STRUCTURES

Guidance on procurement, design and use

Fourth edition

Temporary demountable structures provide a variety of functions at public and private events and may be utilised by large numbers of people. They differ from conventional structures in several ways:

- They are often required at short notice — so Clients, Contractors and Local Authority Officers may have to make decisions quickly
- They may need to withstand substantial horizontal loads (e.g. from wind) and vertical loads (e.g. from crowds)
- Structural components are often lightweight, rapidly erected/dismantled and reusable

An approach to the procurement, design and use of such structures therefore, needs to be one of flexibility and judgement.

This Guide contains essential information on the procurement, design and use of temporary demountable structures, including: grandstands; stages; fabric structures, hospitality units and fencing and barriers. Towers and masts that support media facilities are also included. The Guide is intended for Event Organisers, Venue Owners, Local Authorities, Contractors, Suppliers and 'Competent persons' responsible for the design of such structures. The safety of users is of paramount importance, and guidance is offered on the associated hazards and risks, and on achieving safe structures.

This edition updates and improves on previous editions, to include:

- Extensive reference to current Codes/Standards (including Eurocodes) that have relevance/applicability worldwide
- The ramifications of Construction (Design and Management) Regulations 2015 in the UK
- A number of updates that draw on experiences and lessons learnt from the London 2012 Olympics — where temporary demountable structures were used on an unprecedented scale
- A chapter dedicated to loading — one of the most important aspects of temporary demountable structure design
- Expanded appendices — including an example derivation of kentledge and an example wind management plan

The Guide has been prepared by a group of world-leading experts, who collectively represent the industry, government and influential institutions including The Institution of Structural Engineers.

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