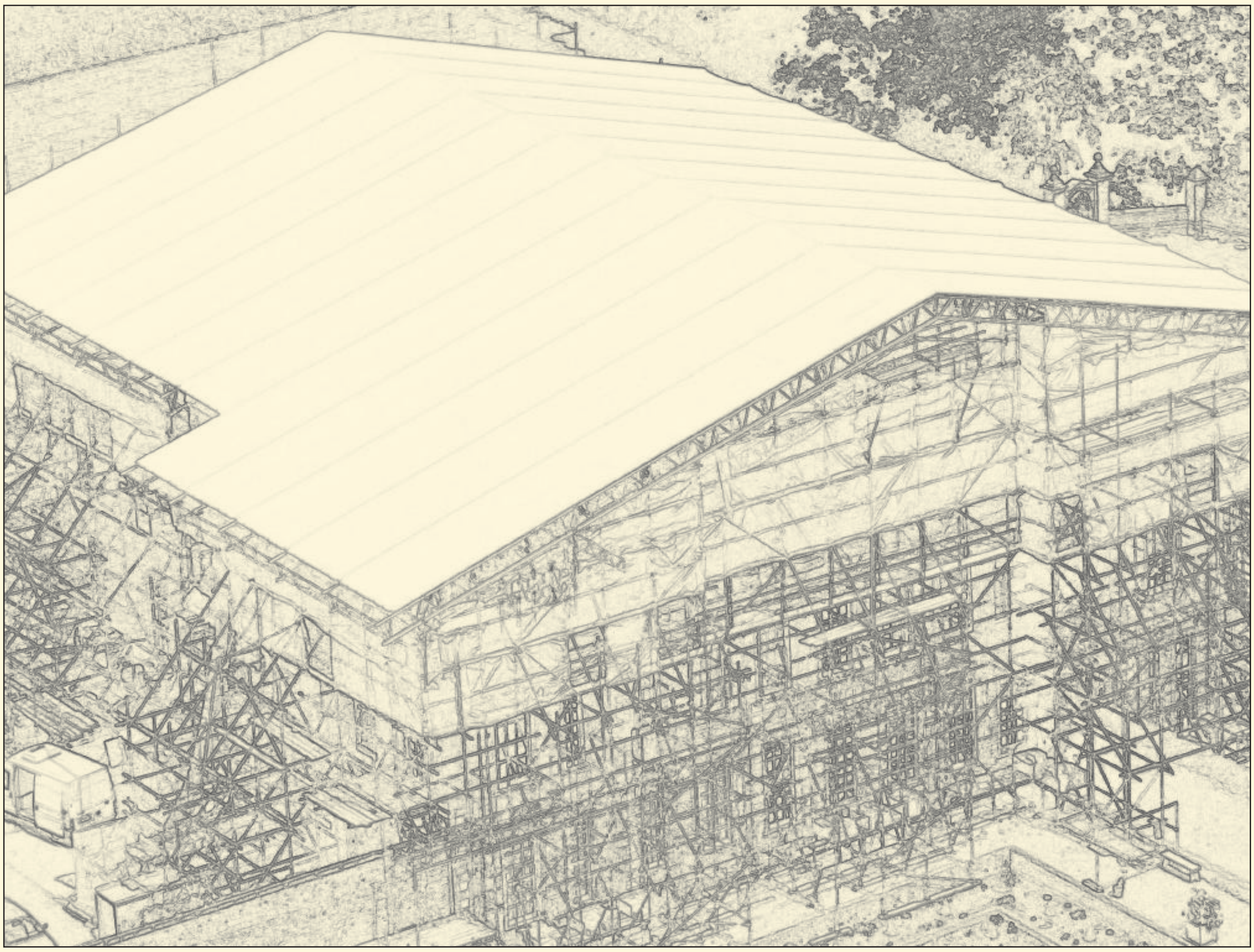
TG9:12

Guide to the design and construction of temporary roofs and buildings

NASC

National Access & Scaffolding Confederation



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1. INTRODUCTION

A temporary roof or building is a sheeted structure designed to provide cover over an area from the effects of weather, dust, etc. It may stand on the ground or on top of a building or be an extension of a scaffold round a building. It may have fully sheeted walls and roof or only a roof or a roof with skirts.

This guide is intended to give design and construction information to the suppliers and erectors of temporary roofs and buildings constructed with scaffolding materials and intended for use by contractors during the building process.

It is not a comprehensive design guide but covers some of the more basic requirements and considerations that should be made to provide an economical, but safe, completed temporary structure.

The usual types of sheeting employed for temporary buildings are as follows:

a) corrugated steel or corrugated aluminium;

b) flexible plastics;

c) flexible plastics covered panels.

For welding screens and other places where there is a fire hazard, corrugated steel sheeting should be used.

For structures with a very limited life, for example: at sports arenas and exhibitions, fixing cords of known breaking strength may be used with flexible sheeting to cater for excessive gust wind speeds.

This guide replaces all previous versions of TG9.

2. SCOPE

This guide is intended for the design and construction of;

- a temporary roof which is supported by an existing building
- a temporary roof which is supported by scaffolding
- a temporary roof which is supported by another temporary construction (for example: a steel frame)
- a complete temporary construction including roof and walls (temporary building).

This guide excludes;

- roofing for stages
- roofing for grandstands
- inflatable structures

Whilst excluded from this guide, these structures will still require specialist design considerations.

3. MANAGEMENT CONSIDERATIONS

A Full Risk Assessment and Method Statement should be prepared for all installations.

The work must be in compliance with Work at Height Regulations.

Where a temporary roof is standing on an existing roof or anchored to building, the principle contractor must ensure that the structure can adequately withstand the additional imposed loads.

Check for hidden services that are likely to cause a problem with loads from standards or kentledge.

Where anchoring to a building is not permitted, ensure that sufficient space is available for buttressing.

The safe method of moving materials to site and to the actual place of installation.

The method of access to the place of the installation for erecting/dismantling and inspection.

Any requirement for water management is to be agreed with client.

Any requirement for snow management is to be agreed with client.

The management and protection for members of the public and the workforce of other contractors.

The choice of covering medium

If Steel sheets are used, then ensure that a safe system of work is practicable.

If rigid panels are used, then ensure that a safe system of work is practicable.

If tracked sheeting is used, then provide adequate safe, working platforms for inserting and removing sheets.

Roof cover

100%

Partial cover – Re-erect or rolling

Sections requiring opening for lowering in of materials etc.

Training of workforce

Ensure that specific training is carried out for the selected roofing system and method of erecting and dismantling.

Job specific design

Working construction design drawing and calculations corresponding to manufacturer's loading data and current codes of practice.

4. TYPES OF CONSTRUCTION

4.1 Structural framework

The most common method of providing temporary roofing is by the use of prefabricated beams manufactured from steel or aluminium alloy.

They are available in various lengths, depths and strengths.

The beams can be joined together by differing methods.

The spacings of the beams may be adjusted to suit the span and loading conditions to give the optimum design.

The roof structure may be constructed in various forms.

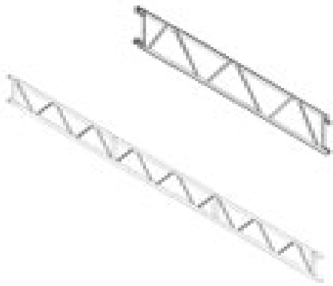


Figure 1

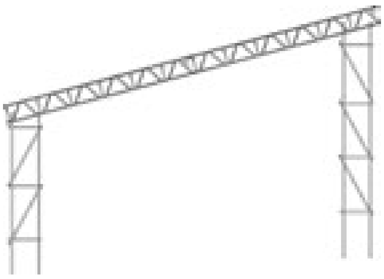


Figure 2
Simple mono-pitched roof

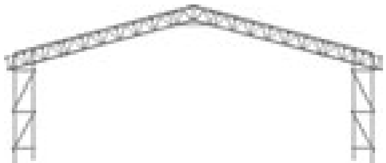


Figure 3
Apex (pitched) roof

Figure 4
Multi-pitched roof

Any of the above types of structure, may be constructed as static structures, mobile or as 'telescopic' arrangements (one roof passing over another)

4.2 Roof covering

A number of covering methods are commonly used;

Rigid / Semi-rigid sheets

- Corrugated Steel or Composite
- Proprietory Panels (also known as Cassettes) with Steel, Aluminium Alloy or plastic sheeting

Flexible Sheeting

- Purpose-made sheeting (PVC, Polythene etc) which may be fixed down to beams by various methods or pulled through and retained by a purpose-made slot in the roof beams (commonly known as 'keder')

4.3 Water management

The roof drainage arrangements should be agreed between the designer and the user. Gutters should have a fall of not less than 1 vertical to 100 horizontal. The rain water pipes should be in agreed locations and tied securely to the structure.

5. COMPONENTS

5.1 Prefabricated beams

5.1.1 Steel beams

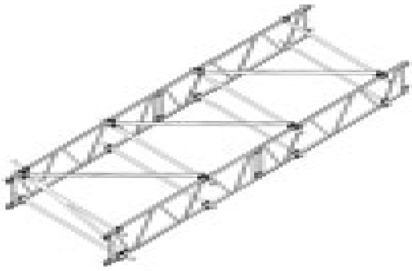


Figure 5

Prefabricated steel beams are generally warren trusses with 48.3mm diameter chords at approximately 600mm centres. They are available in various standard unit lengths and are connected end to end by 2 or 3 bolts and a spigot at each gusset joint.

The load carrying capacity depends mainly on the frequency of restraint to the compression chord. Guidance should be sought from the beam supplier for the actual load carrying capacities. Generally, if chords are tied at the node positions (1.2m approx. intervals) then the maximum bending moment is normally in the range of 12 to 27 kN.m.

It is important that lateral restraint in the form of bracing is provided. Generally this bracing will be required every 5th bay.

Note: depending on the loading conditions, the compression chord may be either top or bottom chord.

It is also important to tie the tension chords together.

Figure 5 illustrates the use of bracing to achieve stability for groups of prefabricated beams. Generally this bracing will be required in every 5th bay.

5.1.2 Aluminium alloy beams

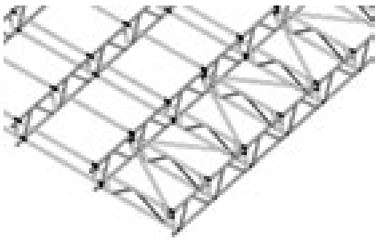


Figure 6 – This is indicative of a system roof

These beams range from 400mm to in excess of 1000mm in depth.

Lacing and bracing may be effected by the use of system components or tube & couplers.

The load carrying capacity largely depends on the frequency and type of restraint to the compression chords.

Guidance should be sought from the supplier/manufacturer for the actual capacities prior to carrying out detail design.

It is important that lateral restraint in the form of bracing is provided. Generally this bracing will be required every 5th bay.

Note depending on the loading conditions, the compression chord may be either top or bottom chord.

It is also important that tension chords are laced together.

Since there is a wide range of this type of beam, with a wide range of properties, it is recommended that the designer **clearly indicates the specific beam used in the design drawing**.

5.2 Covering – Rigid sheeting

5.2.1 Corrugated steel

Corrugated steel sheets are normally placed and fixed in-situ at roof level. The process normally requires 2 men with the appropriate safety measures in place to minimise the risk and consequences of a fall. The gauge thickness of the corrugated steel sheeting should be chosen following careful consideration of the durability required. A thickness of 26 gauge is only recommended for short term requirements, when the sheeting is not going to be re-used. For normal use, the recommended sheeting is 22 gauge or 24 gauge thickness. See Appendix B for further details.

5.2.2 Proprietary sheeting panels – also known as cassettes

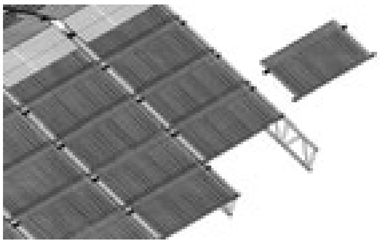


Figure 7

These may be constructed from steel, aluminium alloy or GRP sheet materials, mounted on a framework with a means of secure attachment to the roof trusses.

During erection, the panels should provide the necessary support for the placement of subsequent panels.

The panels may be man-handled into position or lifted by crane depending on the item weight and circumstances.

5.3 Covering – Flexible sheeting

5.3.1 Plastic sheeting supported by proprietary purlins

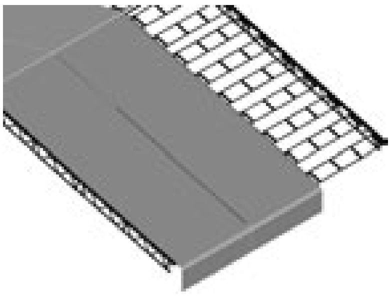


Figure 8

Using this method, the sheets are stretched taut and securely fixed through the sheeting to the roof beams. The purlin frames fitted between the roof beams prevent ponding.

Care should be taken when considering the safe erection of this type of roof covering. It is not normally permissible to walk on the sheeting.

5.3.2 **Plastic sheeting in track** – commonly known as 'keder'

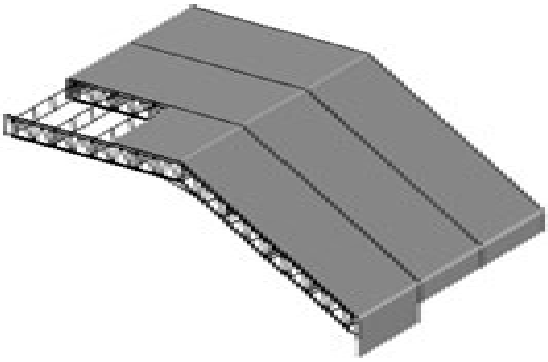


Figure 9

When using this method, channels, which are securely clamped to the truss beam, are provided, either within the truss beam itself or by separate track components.

The sheets are drawn through the slots from one side of the roof to the other.

This method allows the sheet to be fitted without the need to access the roof structure.

In order to prevent ponding, it is essential that the sheets are tensioned at their ends.

It is not normally permissible to walk on the sheeting.

6. DESIGN METHODS

Requirement for structural design

6.1 Basic requirements

All temporary roof and temporary building structures should be individually designed.

The structure should be designed in accordance with recognized engineering principles and should take into account the variability of materials, workmanship, site conditions and construction tolerances.

Temporary works systems should be designed with regard to the ease and safety of erection and dismantling. The designers and suppliers should provide appropriate guidance on the sequence of erection and dismantling of their design.

The designer will be expected to have considered the buildability of the structure and the design should take account of the methods of construction. The designer should also provide the relevant information – with regard to the significant risks involved in its construction.

The layout of the structure should be such that there is a well-defined system for transferring the loads to the ground. When the form of the design has been chosen, the various structural elements and joints should be designed and constructed so that the elements themselves and the rigidity of the joints between them are adequate for their purposes and are used in accordance with the manufacturer's recommendations.

The assembly as a whole should be stable against sliding and sway due to wind forces with a **factor of safety of 1.3** and against overturning with a **factor of safety of 1.2**. Wind loads should be calculated.

The cross fall of the roof should be such that rain water will be readily shed. The lateral thrusts derived from arched or ridged roofs should be taken into consideration in the design and construction. In the case of steeper ridged roofs, ties designed and inserted for this purpose should take the thrust.

The roof drainage arrangements should be agreed between the designer and the user. Gutters should have a fall of not less than 1 vertical to 100 horizontal. The rain water pipes should be in agreed locations and tied securely to the structure.

The load resulting from transverse wind forces may be taken account of by the incorporation of suitably stiff framing and by a means for transferring the local wind loading to it.

The overturning of the structure as a whole may be prevented by ground anchors or kentledge round the perimeter or by guys and anchors.

If the forces in the knee bracing and in the braces to tube and fittings trusses are too large to be resisted by one coupler, then supplementary couplers should be added or the fittings pinned with shear pins. When couplers interfere with the sheeting, a secondary rafter and raised purlins should be added above the truss to carry the sheeting.

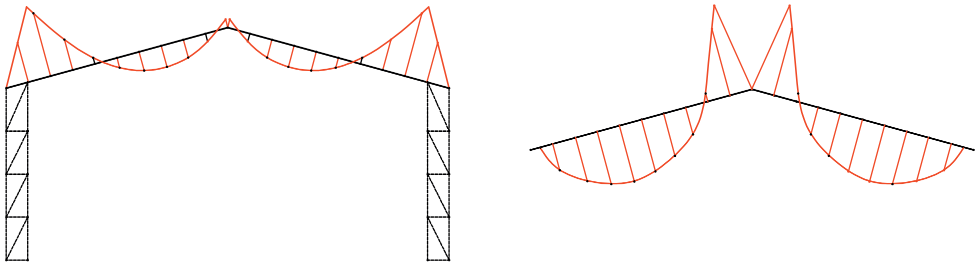
Longitudinal bracing should be inserted in the long walls and transverse bracing in the end walls or end gable. Plan bracing should be inserted in the roof structure.

When the temporary building is an extension to an access scaffolding, the bracing and tying of this access scaffold should be supplemented as necessary. The effect of the horizontal forces on the walls of the building should be considered.

When a temporary building or roof is constructed on the top of an existing building, the anchor points should be suitable to resist the loads imposed upon them.

6.2 Method of design

It is not recommended that the roof structure is designed in isolation from the supporting structure. This can lead to inaccurate assessment of the forces at the ends of the roof trusses. It is preferable, and more accurate, to consider the complete structural arrangement.



a) Total structure model

b) Roof in isolation
assuming ends of roof beams held in position

Figure 10 – Effect of supporting structure on bending moment distribution

The overall roof and the side support scaffolds could be subjected to uplift and joints in the uprights and knee braces may need to be strengthened by lapping. If the scaffolding structure is of insufficient self weight to resist the uplifts, as may be the case in a low height, long span roof, then additional resistance must be provided by anchors, tubes under window heads, kentledge or similar. Overturning and side sway of the total structure must also be considered to determine the worst combinations of loads.

Any untied, free standing structure may need a buttressed scaffold system with anchors at foundation level on any buttress lines and should be the subject of detailed design.

Particular attention should be given to the design and detail of the anchors. Refer to NASC Guidance TG4 (Anchorage systems for scaffolding) and TG16 (Anchoring to the ground).

6.3 Factors of safety

All elements of the structure shall be designed with a factor of safety not less than 1.65.

6.4 Applied loadings

The main conditions of loading which must be considered are:

Dead loads.

Service loads (erection, dismantling etc)

Imposed loads (live loads, lifting, hanging scaffolding etc)

Wind loads.

Snow loads.

To ensure that servicabilty limits are not exceeded, these loads must be considered in the most onerous combinations to produce the worst effect on an element or on the structure as a whole.

Note: these loads should be applied in their true directions;
ie. wind loads should be applied perpendicular to the surface,
gravity loads can only act vertically downwards.

Mobile temporary structures may be subject to an overall uplift due to wind pressure. Consideration should therefore be given to providing kentledge or other means of tying down such structures.

6.4.1 Dead loads

The dead load relates to the self weight of all the components forming the structure. These weights should be obtained from the manufacturers data sheets or brochures.

6.4.2 Service loads

For the effect due to erection and/or dismantling, the structural elements should be designed for two concentrated loads of 1 kN not less than 2m apart, at the most onerous positions.

6.4.3 Imposed loads

The imposed load on the roof covering is any live load that may occur during life of the structure. This could include the effects of gantries, cranes, lighting etc.

Note: The initial design and construction should avoid contained water.
eg. sheets should be sufficiently stretched to prevent excessive sag and ponding to occur.

Where the roof slope is too shallow, natural deflection may allow ponding to develop.

6.4.4 Wind loads

All structures require individual design.

Wind loading should be evaluated using the information available in BS EN 1991-1-4 and take into account the effects of the building shape and wind flow.

See Appendix E for details

6.4.5 Snow loads

If there is little or no risk of snow for the period that the temporary roof or building is to be provided then snow loads may be ignored. However, a minimum vertical loading of 0.1 kN/m2 should be applied.

BS EN 1991-1-3 provides a method of calculating the expected maximum snow loads in the UK.

The snow loading should only be reduced if a practical snow management method has been agreed by Contractor and Client.

See Appendix D for details

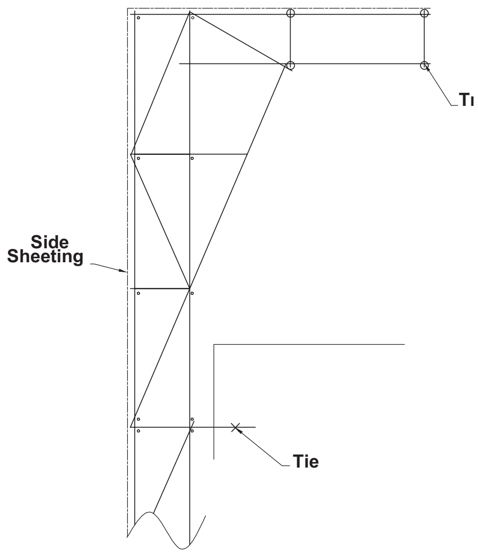
6.4.6 Loading combinations

The designer should consider which of the applied loads would occur within the lifetime of the structure and the probability of any combination of these loads occurring at the same time.

6.5 Special considerations – gable ends

The gable ends of a temporary roof are often overlooked. The gable end will be subjected to significant wind pressures and coefficients, and must therefore be designed.

a) A gable end of a building where a scaffold is built from the ground.



b) A gable end where the supporting scaffold is not available or is unnecessary.

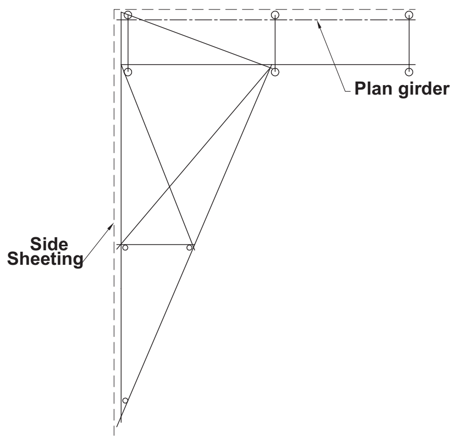


Figure 11 – Gable ends

7. DESIGN & CONSTRUCTION CHECK LISTS

7.1. Design

A) Has a feasibility study been carried out from a site visit?

B) Is the designer fully familiar with the product being used in the design?

C) Is there a full job specific design complete with working drawing and calculations?

D) Is the design compliant with TG9?
(Guide to the design and construction of temporary roofs)

E) Does the design meet with contract requirements, e.g.

- (i) total cover?
- (ii) partial cover?
- (iii) static roof?
- (iv) mobile/rolling roof?
- (v) ability to create openings?

F) Does the design confirm specifications and origin of authorised manufacturer's loading data for components used?

G) Do the proprietary system components used meet with the NASC Code of practice for the hire, sale and use of system scaffolds?

H) Can the designed structure be built/dismantled in accordance with manufacturer's recommended safe system of work ? (User guide)

7.2. Construction

7.2.1 Method statement

State method for:

A) For erecting (and dismantling) by trained operatives ?

B) Raising and lowering equipment ?

C) Movement of men and materials to work face ?

D) Precautions to be taken when weather conditions may prevent safe working ?

E) Erection/dismantling procedures if different from manufacturer's recommendations ?

F) Repositioning of roof (erect/dismantle/move) or mobile ?

G) Rescue procedures ?

7.2.2 Competency of workforce

A) Leading hand should be an advanced scaffolder, and the entire team should have appropriate training and experience for the task.

B) Have scaffolders received manufacturer's training?

C) Proof of training (current methods)? (Record scheme)

7.2.3 Documentation on site

A) Copy of site specific design drawing

B) Current copy of manufacturer's user guide, where appropriate.

C) Copy of site specific method statement & risk assessment

D) Copy of site specific rescue plan

7.2.3 Risk assessment and work at height regulations (WAHR)

A) Has the WAHR hierarchy of avoid, prevent or mitigate falls been used in the risk assessment process for both the design, erection and dismantling of the structure?

A1) AVOID
Can the roof be erected at ground level and lifted into place?

A2) PREVENT
Is it possible/practicable to erect work platforms on 3 sides of the supporting scaffold?

A3) PREVENT
Can the roof be erected bay-by-bay from a work platform and rolled into position?

A4) PREVENT / MITIGATE
Can the roof be erected bay-by-bay from a work platform and walked out?

B) FALL ARREST

If Fall Arrest measures are specified,

B1) Can a work restraint arrangement be used rather than fall arrest?

B2) Are the anchor points adequate, secure and to a specified/approved strength?

B3) Describe the anchor points.

B4) Is minimum practicable lanyard length used ?

B5) Are double lanyards used to ensure worker is attached at all times?

B6) Is there sufficient clearance with no obstructions below the workers at all times to allow the fall arrest to deploy safely?

B7) Are rescue procedures specified to safely rescue a fallen worker?

B8) Is there a statement of P.P.E. equipment to be used?

See Appendix A for safe systems of work

7.2.4 Other Issues

A) Criteria for routine inspection ?

B) Access/egress for inspections ?

C) Maintenance of structure?

D) If corrugated steel sheets is used:

- It must be able to support a person's weight
- It should be secured to prevent displacement of sheets

APPENDIX A: SAFE SYSTEMS OF WORK FOR TEMPORARY ROOFS

With the introduction of the work at height regulations in 2005 (WAHR) have come new duties and responsibilities affecting many aspects of scaffolding and access. The methods employed to build temporary roofs are coming under increasing scrutiny in view of the high risk element involved with all of these structures.

The WAHR Hierarchy

AVOID WORK at HEIGHT	This is unlikely to be an entire solution but there may be scope for reducing the amount of working at height. eg. Assembling sections on the ground and lifting into position.
PREVENT FALL BY COLLECTIVE EQUIPMENT	1. Can the roof be erected entirely from fully guarded platforms? 2. Can the roof be built using MEWPs or independent towers? 3. Can the roof design be chosen where *most* of the work can be carried out from fully guarded platforms, rather than relying on harnesses? eg. A system roof where the covering can be pulled across from the scaffold platforms, rather than a CI roof which has to be worked on in order to install the sheets.
PREVENT FALL BY PERSONAL WORK EQUIPMENT	If harnesses have to be relied on, consider the use of lanyards which would provide work restraint rather than a fall arrest system (ie it stops the person actually reaching an open edge at all). Location and adequacy of anchor points need careful consideration.
MITIGATE THE EFFECT OF FALL BY USING COLLECTIVE MEASURES	eg. Nets below the working areas (if suitable anchor points are available and the nets themselves can be fitted safely)
MITIGATE THE EFFECT OF FALL BY USING PERSONAL MEASURES	This is the ***last resort***, and includes fall arrest lanyards. A detailed, job-specific method statement should be prepared: the risks are high and demand a proportionate level of planning. The location and adequacy of anchor points need careful consideration. The type of lanyard should be suitable eg. twin lanyards for traversing beams (see SG4). Harness inspection regimes should be robust (see HSE leaflet INDG367). Rescue procedure should be in place. Adequate supervision to ensure harnesses are used correctly.

The effect of the Regulations is not to exclude particular methods but they do put pressure on those traditional methods to justify a compliant safe method of building in-situ compared to more modern proprietory systems. This can be demanding.

Four methods for constructing temporary roofs are:

1. Building the roof progressively from a protected platform and rolling out.
2. Building the components on the ground in sections and lifting into position by crane. Whilst this reduces working at height, it also often involves a need to provide working platforms to access the beam lines to connect lifted sections and there can be difficulties weather-proofing joints.
3. Constructing a movable access platform(s) to act as a protected platform for assembly and dismantling.
4. Erecting and dismantling components in-situ from the beams or other roof components.

However, there are other issues that influence the ability to build temporary roofs safely, which include:

- Job specific risk assessment
- A job-specific design aimed at eliminating/reducing the risk of fall and other hazards identified by the risk assessment.
- Scaffolders should be fully trained in the equipment used, with proof of training.
- The designer should be fully familiar with the equipment selected.
- For proprietary temporary roof systems, erection / user guides on the selected method should be provided by the supplier.
- If personal fall arrest is utilised, with twin lanyards, job-specific rescue plan must be provided. Anchor points should be determined for adequacy.
- A materials handling plan should outline the procedure for getting the materials to the workplace, both to the scaffold working platform and their final fixed position on the roof.
- A job specific method statement developed from the above.

SAFE SYSTEMS OF WORK – Methods

a) Proprietary temporary roof systems

The supplier's safe system of work, as stated in the supplier's user's guide, should be followed.

b) Traditional temporary roof with corrugated steel sheeting example

All manual handling and working at height regulations must be complied with.

All materials are to be inspected prior to erection to ensure that they are fit for their intended use.

Upon reaching the desired level of the proposed temporary roof, the leading hand will carry out a visual inspection of the support Scaffold to ensure that it has been erected in accordance with the design drawing.

With the supporting scaffold completely boarded and guardrailed to provide a temporary safe working area, Figure A.1 (a), and additional platform, Figure A.1 (b), is in place for sheeting/repairs etc.

Ensure that there are top and intermediate perimeter guardrails around the roof surface. This will provide edge protection around the entire roof ready for placement of the sheeting.

If a gable-end scaffold is available, raise and place the beams by appropriate methods and assemble the length(s) required.

If a gable-end scaffold is not available, then alternative means should be provided; for example:

- temporary saddle scaffold on roof to assemble beams; or
- raise by mechanical means (eg crane etc); or
- raise beams of correct length from the ground using light lines or similar etc.

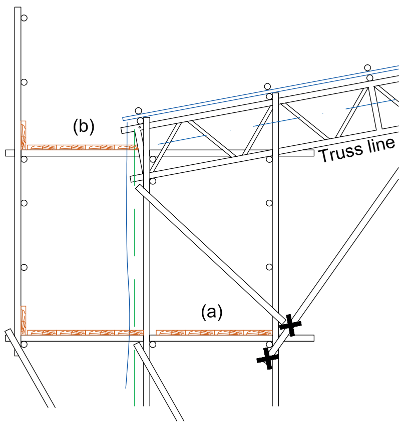


Figure A.1

From the safe working platform (a), secure beams to uprights, or as detailed by the design.

From the platform (a), secure the 1st and 2nd purlins and plan brace this bay.

b) Traditional temporary roof with corrugated steel sheeting example (continued)

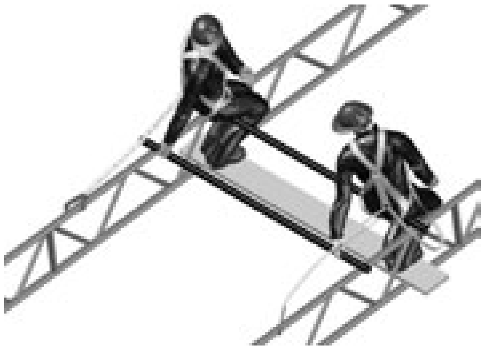


Figure A.2

Using boards placed between the bottom chords of adjacent beams, and using double short lanyards, proceed up the beams fitting the remaining purlins and bracing. Materials can be passed up the structure from a temporary walkway located on top of the purlins that are already in place. This temporary walkway should be complete with an appropriate means of minimising the consequences of a fall.

Note: Provision should be made to prevent temporary boards slipping from the beam and there should be an appropriate procedure in place for moving the boards from each position.

Corrugated steel profile sheets should be hoisted up to the designated loading area, which has been designed to take their weight, and stored in a safe manner. These sheets are normally weighted down to prevent displacement from the scaffold structure.

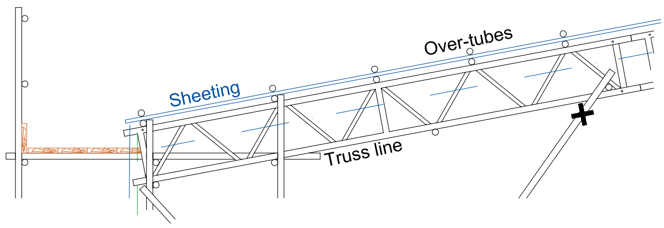


Figure A.3

From platform (b), place the 1st sheeting row and secure with roofing couplers and over-tubes.

Using the secured sheeting as a platform, and the over-tubes as footholds/handholds and anchorage for double lanyards used for work restraint, place the next row of sheets and secure. Repeat until sheeting is completed.

When the temporary roof is complete, the leading hand will sign a hand-over certificate for submission to the principal contractor.

APPENDIX B: OTHER COMPONENTS

Corrugated steel sheeting

B.1 Properties

Pitch of corrugations	Sheet thickness	Unit weight including laps	Approx. I_{NA} per 300mm width	Approx. Z per 300mm width	Bending stress	M.R. per 300mm width
mm	mm (g)	N/m^2	$x\ 10^4 mm^4$	$x\ 10^3 mm^3$	N/mm^2	Nm
76.2	0.5 (26) 0.6 (24) 0.7 (22)	60 75 95	0.819 1.024 1.270	0.855 1.081 1.339	86.9 91.72 96.53	74.3 99.15 129.25

Table B1

References: Steel designers' manual

Max. permissible purlin spacingfor limiting stress and deflection of the sheeting

Pitch of corrugations	Sheet thickness	$0.4kN/m^2$
mm	mm (g)	m
76.2	0.5 (26) 0.6 (24) 0.7 (22)	2.38 2.71 3.03

Table B2

Note: Whilst this table gives the maximum spans that can be obtained when the load is uniformly distributed, consideration should be given to the possibility of localised concentrated loads. The principle source of this form of loading will be from personnel erecting and dismantling the sheeting and from the stacking of material.

If the purlin has a dual role of sheet support and lateral restraint to the beams, the lateral restraint spacings will be considered as the worst case.

B.2 Lapping of corrugated sheets

Generally sheets are overlapped at their ends by a minimum of 150mm, but on exposed sites where there is a higher risk of leakage, end laps should be increased to 230mm or in severe cases 300mm.

When a specification requires a fully watertight roof, it may be necessary to seal the joints with suitable mastic or sealing strip.

Side laps are usually 1 ½ to 2 corrugations wide, and as with end laps, may require some form of mastic or sealant when a watertight roof is specified.

At the edges of the roof where the pressure co-efficient is high, it may be necessary to stitch the side laps together. This can be carried out using either pop rivets, self tapping screws, blind fixings or as a last resort nuts and bolts. These fixings would normally be placed at 450mm c/c.

B.3 Gutterings and downpipes

The drainage arrangements should be agreed between the designer and the user. Early discussion can save a great deal of time and argument, particularly where discharge points need to be varied through the contract.

B.4 Translucent sheeting

Sheets should be *non-fragile* – must be capable of bearing the load imposed by the operatives.

Some contracts may specify the requirement for the provision of natural light whilst also remaining waterproof.

Natural lighting can be achieved using translucent sheeting where the corrugation sizes are compatible with those of the steel sheets.

When using this form of sheeting, either by itself or in conjunction with steel sheeting, it will be necessary to check the following points:

Compatibility with the steel sheeting used for the remainder of the roof.

Durability – Effects from sunlight etc.

Strength – This should be looked at in two ways:

- Span between purlin members – It may be necessary to reduce the spacing between the purlins.
- Fixings – Frequency and type.

All of the above points should be checked with the sheet supplier to ensure that the sheeting is suitable for the specific application.

B.5 Sheeting connectors

Examples of sheeting connectors:

Hook or J bolts.
Roof bolts and screws.
Roofing couplers.

B.5.1 Hook or J bolt

Bolts less than 10mm diameter are not recommended due to their tendency to straighten under wind load oscillation.

Where the bolt passes through the sheeting, it should always be located on the crest of a corrugation. This positioning avoids the possibility of leakage, particularly from a bolt located at the bottom of a corrugation which forms the normal run off flow line.

The hole through the sheet can be waterproofed using either of the following two methods:

(a) Diamond shaped steel washers curved to take up the sheet profile, sandwiching a diamond shaped bitumastic washer on to the sheet face.

or

(b) A proprietary plastic washer with either a loose or captivated nut that forms a seal with the sheet face as the nut is tightened down.

For the safe working load of bolts refer to the manufacturers information as it will vary depending on:
The grade of steel used.
The method of threading.
The method of manufacture.
The thickness of the steel sheet.

It must be borne in mind when designing bolt groups that it is not always the bolts that provide the weak link. In many instances the sheeting is weaker than the bolt and can collapse or tear under load.

B.5.2 Roofing couplers

These couplers enable the roof sheets to be fixed without the need for drilled holes. They connect to the purlin tubes and secure the sheets and overlay tubes.

Figure B.1

B.5.3 Roof bolts and screws

These should be installed in accordance with the recommendations of the sheet manufacturers.

B.5.4 Other forms of connection are possible. For example:

U. Bolts – these again are usually fabricated from M8 or M10 diameter steel rod with either cut or rolled threads. The design load on this type of connector is much higher than the J bolt because the limitation on load carrying capability is now the bar or thread diameter and not the straightening of the hook.

When using this type of connector, it would be the failure of the sheet which would be the deciding factor rather than failure of the bolt.

B.6 Purlins

In temporary roof systems these are usually scaffold tubes which are fixed to the main supporting members (or rafters.)

Where the main supporting member is some form of I beam or lattice structure then in order to reduce the effect of lateral buckling, restraint must be provided. Here the purlin takes on the dual role of a sheet support and lateral restraint member.

The safe bending Moment of Resistance of a new standard scaffold tube 48.3mm dia. x 4mm wall thickness = 0.99 kNm.

In axial compression, the allowable loads should be as shown in NASC TG20, “Guide to good practice for scaffolding with tubes and fittings”.

B.6.1 Purlin connectors

The purlin connector is the final link in the chain before considering the main rafter members.

This particular connector needs to be of the type that will carry the required load but will not interfere with the sheeting line.

Of the scaffold connectors currently on the market, the following fulfil these objectives:

B.6.1.1 Band & plate coupler

This is a combined parallel and right angle coupler.

This coupler will adequately cope with the slip load required to laterally restrain the rafter.

The major load from uplift created by the wind forces will be adequately coped with by this fitting, because the load is at right angles to its normally loaded mode.

Figure B.2

B.6.1.2 Putlog couplers

This is not a fully load bearing coupler, but in accordance with BS 1139 Part 2-1991 must be tested for slip and should be able to sustain a design load of 0.63 kN.

At right angles, normal to the roof surface, this fitting can safely be rated at 1.75 kN.

Figure B.3

APPENDIX C: DESIGN EXAMPLE

General arrangement

Site location Slough
(80km from coast)

Roof span = 22m
Roof length = 28m
Max height = 11m
Roof pitch = 15°
Period = 9 months

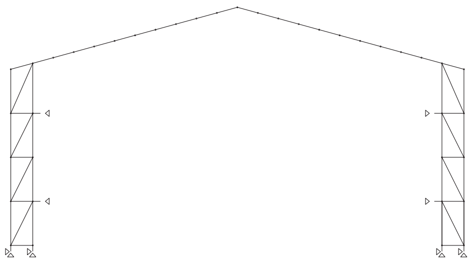


Figure C.1

Design loading

a) Dead loading

Self-Weight of roof structure (from manufacturer's data)
= **0.25 kN/m** run along beam

b) Service loading

Two concentrated load of 1 kN placed 1m each side of ridge.

c) Imposed loading

c.1) Snow loading

Ground snow load	= 0.4 kN/m2 – from BS EN 1991-1-3 (Slough – Zone 2)
Altitude	= 145m
Characteristic snow load	= 0.2 + 0.1 Zone + (145-100)/525 = 0.48 kN/m2
Shape coefficient	= 0.8
Design snow load	= **0.38 kN/m²** **= 0.95 kN/m** @ 2.5m crs

c.2) Wind loadings

Map wind speed, Vb	= 21 m/s – from BS EN 1991-1-4 (Slough)
Altitude	= 145m
Altitude factor, calt	= 1 + 145/1000 = 1.145
Basic wind speed, Vb	= 21 x 1.145 = 24.05 m/s
	C_{prob} = 1.0, C_{dir} = 1.0, C_{season} = 1.0
	T_{wind} (topographical factor) = 1.0
Basic wind pressure, q_b	= 0.613 x V_b^2 / 1000 = 0.35 kN/m²
Combined exposure factor, C_c	= 2.08
Peak wind pressure, qp	= 0.7 x 0.35 x 2.08 = **0.51 kN/m²**

Basic loading cases

Self weight – Case 1

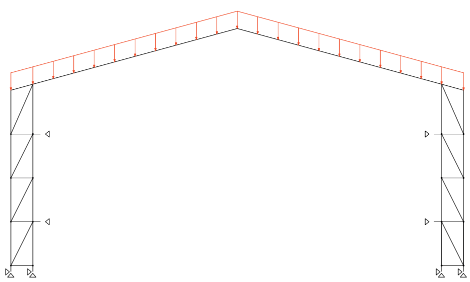


Figure C.2

Snow – Case 2

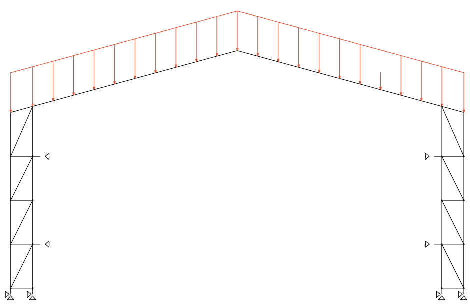


Figure C.3

Normal wind type A – Case 3

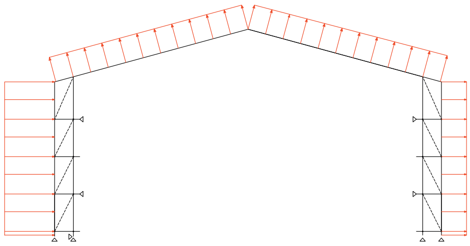


Figure C.4

Normal wind type B – Case 4

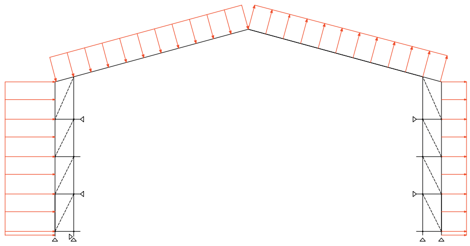


Figure C.5

Internal pressure (+ve) – Case 5

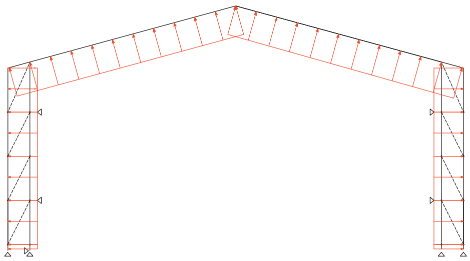


Figure C.6

Internal pressure (-ve) – Case 6

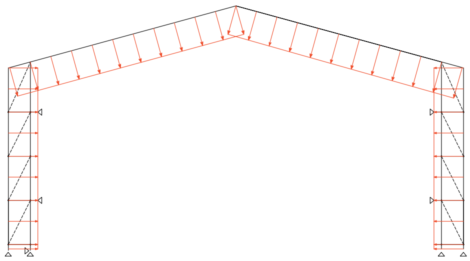


Figure C.7

Design loading cases

self + snow	=	1 + 2
self + wind A	=	1 + 3
self + wind B	=	1 + 4
self + wind A + Internal +ve	=	1 + 3 + 5
self + wind A + Internal –ve	=	1 + 3 + 6
self + wind B + Internal +ve	=	1 + 4 + 5
self + wind B + Internal –ve	=	1 + 4 + 6

for overturning – for design of kentledge etc only (FoS 1.2).

self + wind A	=	1 + 3 x 1.2
self + wind B	=	1 + 4 x 1.2
self + wind A + Internal +ve	=	1 + (3+5) x 1.2
self + wind B + Internal +ve	=	1 + (4+5) x 1.2

APPENDIX D: SNOW LOADING

Snow loading should be taken from BS EN 1991-1-3

Method:

Determine ground snow load or zone
Determine altitude
Determine shape coefficient for roof pitches **not greater than 30° = 0.8**
Combine for design loadings

Useful tips:

For determination of altitude

google earth – can determine altitude anywhere in world;
– may be downloaded from www.google.com

Design snow load, Sd, is given by;

Sk x μ

Where,

Sk = Characteristic ground snow load (kN/m2)

= 0.2 + 0.1 Z + (A-100)/525

Where Z = Zone number from map (Fig. D.1)
or $10\ S_{map} - 2$

S_{map} = Ground snow load at 100m (kN/m2)

A = altitude of the site in metres above sea level

μ = Shape Coefficient

Snow load shape coefficients	
Angle of pitch (α)	**Shape coefficient**
≤ 30°	0.8
$30° < \alpha < 60°$	$0.8 \left(\frac{60 - \alpha}{30} \right)$

10°	0.8
15°	0.8
20°	0.8
25°	0.8
30°	0.8
45°	0.4

Table D.1

Figure D.1 – Basic snow loading, S_{map} (kN/m^2)

APPENDIX E: WIND LOADING

The basic data for the design of structures to resist wind forces are contained in BS EN 1991-1-4 and the UK National Annex to BS EN 1991-1-4. Additional background information is given in PD 6688-1-4. This guide uses a simplified form of the method given in the BS EN that is suitable for the majority of temporary works. The simplification will give comparable or conservative results compared with the BS EN. The designer is not precluded from using the NA and BS EN 1991-1-4 to calculate the wind forces if the situation warrants it.

Although the method of determining wind pressure has changed, the simplified method now recommended has adopted many of the philosophies of the earlier methods.

The simplified method given in this guide applies to:

(1) Temporary structures erected less than 100m high in areas with NO significant topography.

(2) Temporary structures erected less than 50m high in areas of significant topography.

Where a temporary structure is erected between 50m and 100m high in areas of significant topography, the wind pressures should be calculated by reference to the NA to BS EN 1991-1-4.

Information required by falsework designer

The following information is necessary for calculation of the wind forces

(a) Location of site – distances to the edge of town and to the sea.

(b) Topography of site, considered in all directions, e.g. nominally flat, on moderate or steep hill, on moderate or steep escarpment etc.

(c) Altitude of the site (in m above sea level)

(d) Duration of the temporary structure operations and use. (If the structure is expected to be erected for no more than 2 years, a reduction in total wind loading may be applied.)

Peak wind pressure for temporary structures

In order to take account of the temporary nature of a falsework structure erected for a period not exceeding two years, the peak wind pressure may be modified by a temporary works factor (twf) of not less than 0.7 in accordance with the note to Clause 8.2.4.1 of BS EN12812. This value is equivalent to using a probability factor of 0.84 (0.842 = 0.7). Either the twf of 0.7 OR a probability factor of 0.84 may be used, but, they should NOT BOTH be applied in the same wind pressure calculation.

The peak wind pressure is given by:

$$\mathbf{q_p = 0.613 \times C_c \times S_{wind}^2} \qquad N/m^2$$

where q_p is the peak wind pressure (N/m2)

S_{wind} is the wind factor

C_c is the combined exposure factor – see Table E.1

Note: this is a combination of exposure factor, $C_e(z)$ and town correction factor, $C_{e,T}$

The wind factor, S_{wind}, is given by:

$$\mathbf{S_{wind} = T_{wind} \times V_{map} \times (1 + 0.001\,A) \times C_{prob} \times C_{dir} \times C_{season}}$$

where v_{map} is the basic wind speed for the site in m/s – see Fig. E.1

T_{wind} is the topographical factor – see Fig. E.2

A is the altitude of the site (in m above sea level)

C_{prob} is the probability factor

= 1.0 for periods **exceeding 2 years**

= 0.84 for periods **not exceeding 2 years** (providing twf NOT applied)

C_{dir} is the directional factor (normally 1.0)

C_{season} is the seasonal factor (normally 1.0)

Topography factor, T_{wind}

Where the ground is nominally flat, i.e. the average slope is less than 1:20 and at the base of steeper slopes, the value of the topography factor is unity, T_{wind} = 1.00.

Where there are hills or slopes the wind profile changes and the topography, known as "orography" in BS EN 1991-1-4, can become significant. The values for the topography factor T_{wind} for falsework erected up to 50m in height for other conditions of hills or escarpments are shown in Fig. E.2.

Values for topography factor appropriate for the site should be considered for the wind acting in ALL directions, and not just the orientation of the falsework structure.

Displacement height, h_{dis}

The BS EN 1991-1-4 method calculates the wind pressure at a height, z, in metres above ground level.

For a temporary structure erected on the ground the value of z would be taken as the height from the ground to the top of the structure.

When considering the forces on the temporary structure, the value for z should be taken as the actual height of the structure. However, if the temporary structure is erected in an elevated position above the surrounding ground level, for instance at the top of a tall structure, the reference height z, would be measured from the ground, although the actual structure affected by the wind would only be its own storey height.

An allowance can be made for the effect of surrounding general buildings, such as housing or woodlands, by using a height displacement (h_{dis}). The displacement height is the lesser of the value in the following two equations:

	h_{dis}	$= 0.8\ h_{ave}$
or	h_{di}	$= 0.6\ h$
where	h_{dis}	is the displacement height (m)
	h_{ave}	is the average obstruction height in the area (m)
	h	is the height of the considered structure for calculating z.

Where the temporary structure is spaced more than six times the average obstruction height away from the nearest obstruction, the full height of structure is used and hdis = 0.

Values may be interpolated. See Figure E.3.

The effective height of the structure for wind calculations is $z - h_{dis}$

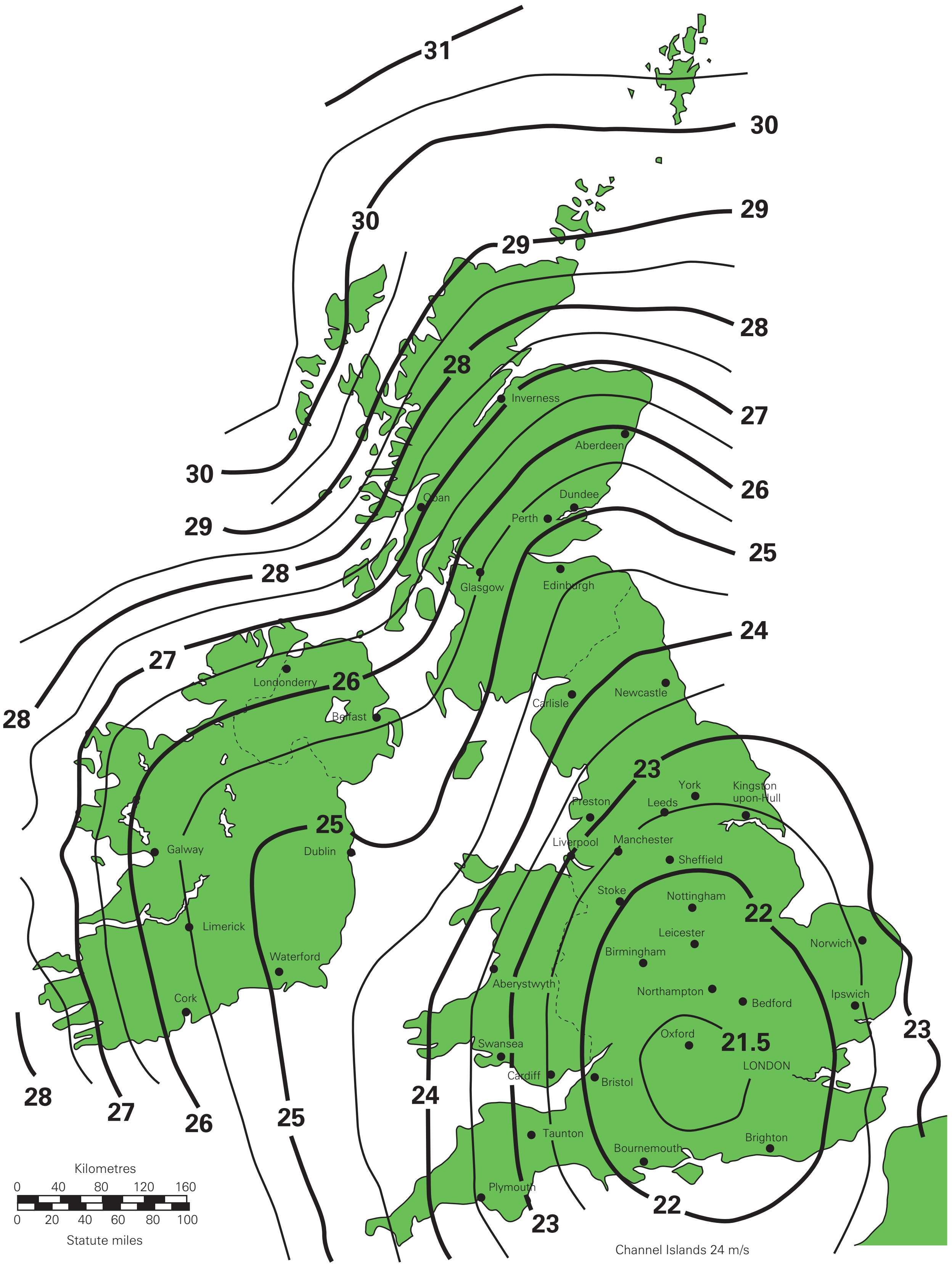


Figure E.1 – Wind speed, V_{map} (m/s)

NASC

Table E1: Combined exposure factor, Cc

Height $Z - h_{dis}$ ** (m)	Site in country or adjacent to sea				Site in town, more than 2 km from the edge of the town		
	Closest distance to the shoreline (km)				Distance to shoreline (km)		
	≤ 0.1	2	10	≥ 100	≥ 2	10	≥ 100
≤ 2	1.90	1.60	1.50	1.40	1.07	1.01	0.94
3	2.15	1.84	1.73	1.62	1.32	1.25	1.17
4	2.31	2.03	1.90	1.78	1.54	1.44	1.35
5	2.43	2.18	2.05	1.90	1.72	1.62	1.50
10	2.82	2.65	2.50	2.32	2.33	2.20	2.04
15	3.07	3.02	2.85	2.67	2.81	2.65	2.48
20	3.20	3.05	2.98	2.78	2.90	2.83	2.64
30	3.42	3.43	3.27	3.04	3.40	3.24	3.01
50	3.68	3.68	3.62	3.39	3.68	3.62	3.39
100	3.98	3.98	3.98	3.80	3.98	3.98	3.80

Notes: (1) Interpolation may be used in this table
(2) Based on Figure NA.7 and Figure NA.8 in the NA to BS EN 1991-1-4

Note: Town values are to be considered if more than 2 km inside the edge of the town.
** for h_{dis} see Figure E.3

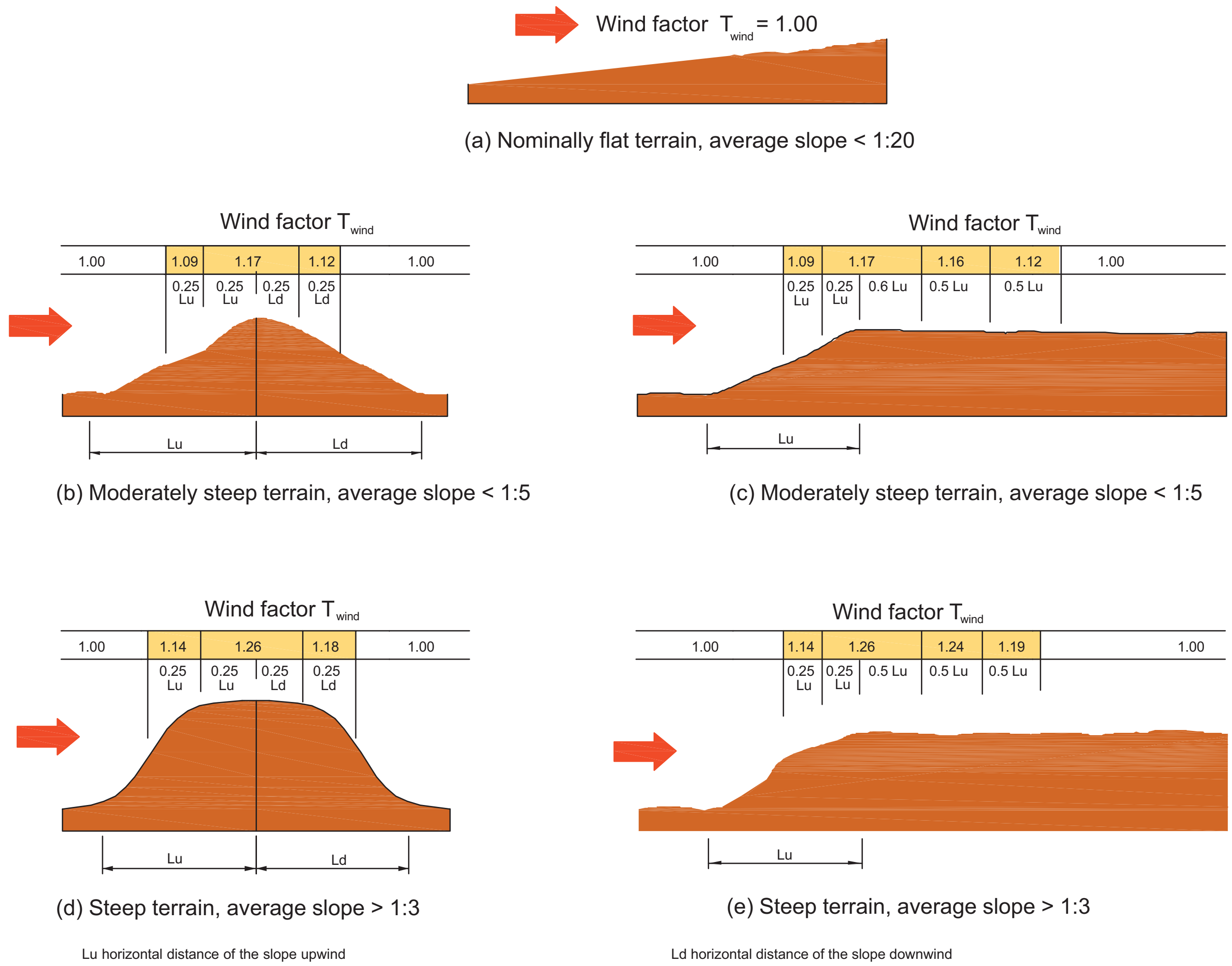


Figure E.2 – Topography factor, T_{wind}

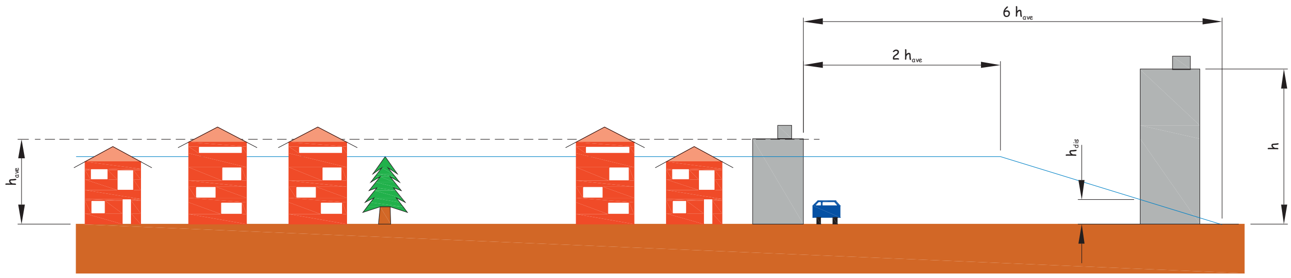


Figure E.3 – Displacement height

External pressure coefficients

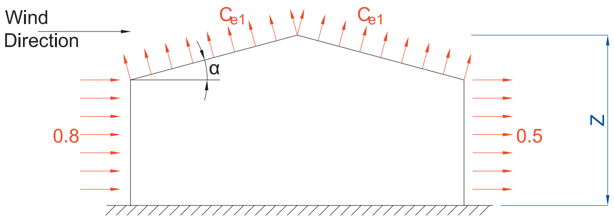


Figure E.4
External pressure coefficients
for duo-pitched roof – Case 1
for C_{e1}, see Fig. E.9

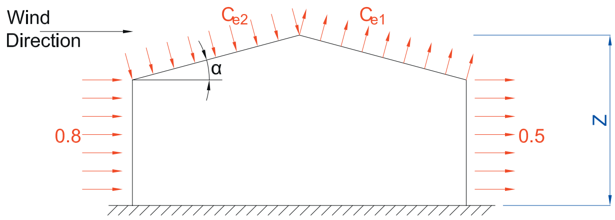


Figure E.5
External pressure coefficients
for duo-pitched roof – Case 2
for C_{e1}, see Fig. E.9
For C_{e2}, see Fig. E.10

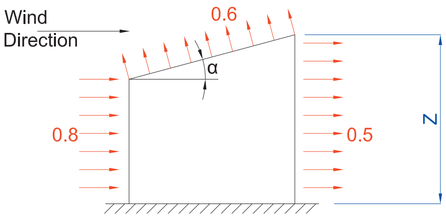


Figure E.6
External pressure coefficients
for mono-pitched roof – Case 1

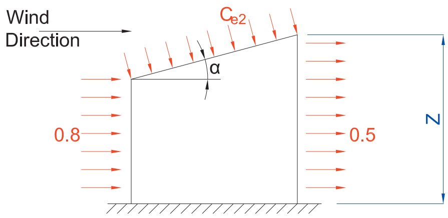


Figure E.7
External pressure coefficients
for mono-pitched roof – Case 2
for C_{e2}, see Fig. E.10

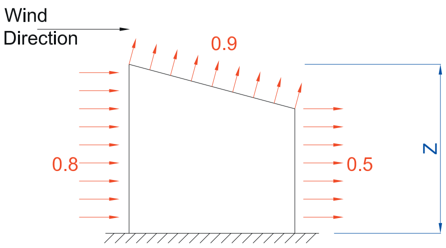
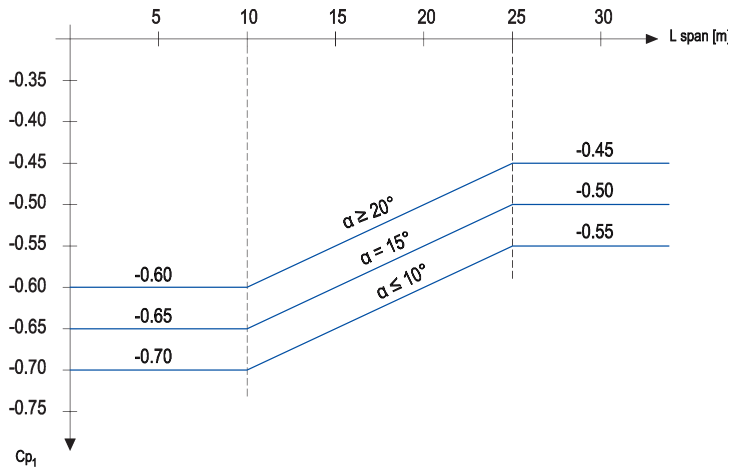


Figure E.8
External pressure coefficients
for mono-pitched roof – Case 3

For External pressure coefficients for other arrangements, refer to BS EN 1991-1-4 and National Annexe eg., canopies, combinations of side sheeting etc

For background to these coefficients, see Appendix F



≤ 10m	C_{e1}	=	$-0.7 + K_a$
10m – 25m	C_{e1}	=	$+0.01 \times Span - 0.8 + K_a$
≥ 25m	C_{e1}	=	$-0.55 + K_a$

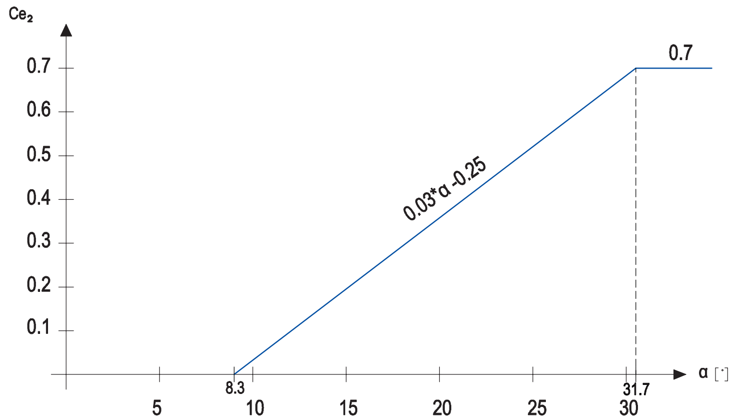
(+ve values are downward pressure)

Where,

$$Ka = \frac{\alpha - 10}{100}$$

α = pitch angle in degrees

Figure. E.9 – External pressure coefficients, C_{e1}



$C_{e2} = 0.03 \times \alpha - 0.25$

(+ve values are downward pressure)

Figure E.10 – External pressure coefficients, C_{e2}

Internal pressure coefficients

Without dominant openings	With dominant openings	
Cpi = +0.2 or -0.3	**Ratio of open area to remainder of area**	
Whichever is the more onerous	2	$C_{pi} = 0.75 \times C_{pe}$
	3	$C_{pi} = 0.90 \times C_{pe}$

Table E.2 – Internal pressure coefficients

Temporary works equipment – Temporary roofing and encapsulation constructions – Performance requirements and general design

Discussions within the working group (CEN/TC53 – WG14) for a pan-European standard, highlighted that a wide variation of pressure coefficients were documented in the member countries.

To make the method of evaluating wind loading uniform, a simplistic approach was required that would satisfy all existing national codes. The coefficients shown in Appendix E have been derived from this exercise.

In order to compare the effects of the proposals with other codes, exhaustive analysis was carried out to a wide range of roof sizes and configurations.

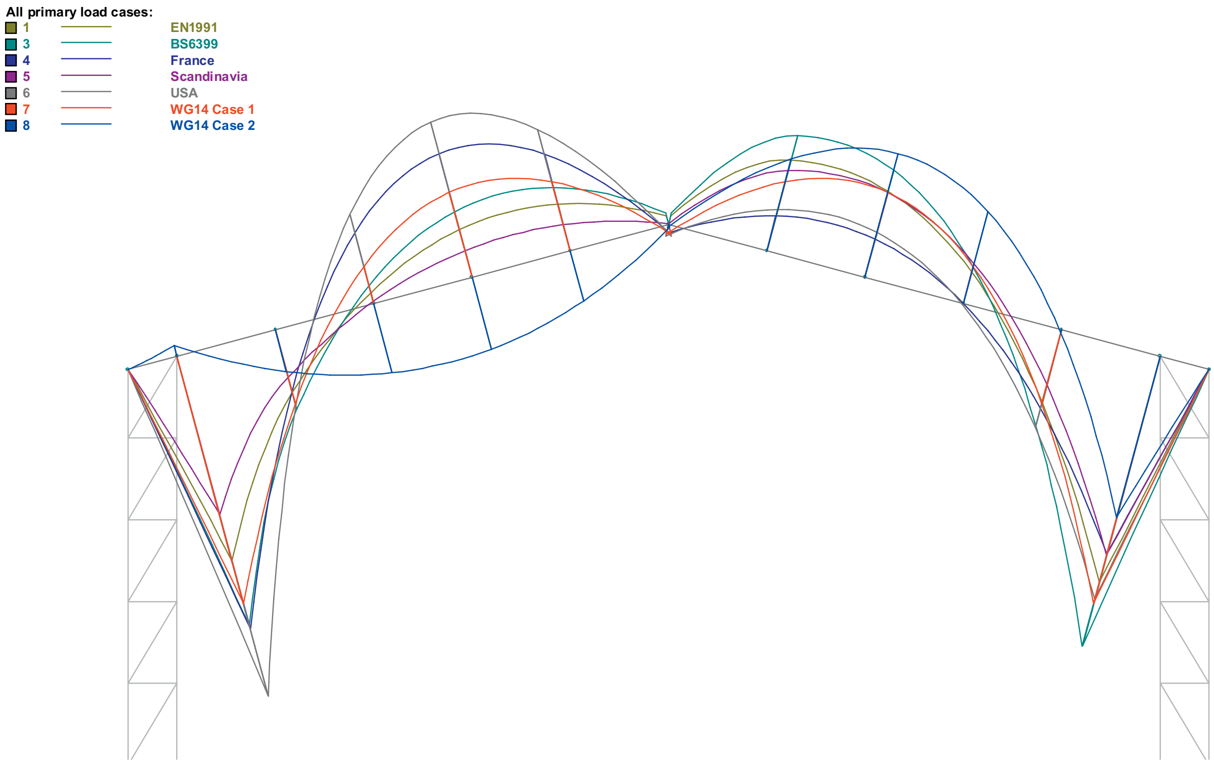


Figure F.1 – Comparison of bending moments induced by coefficients from different codes

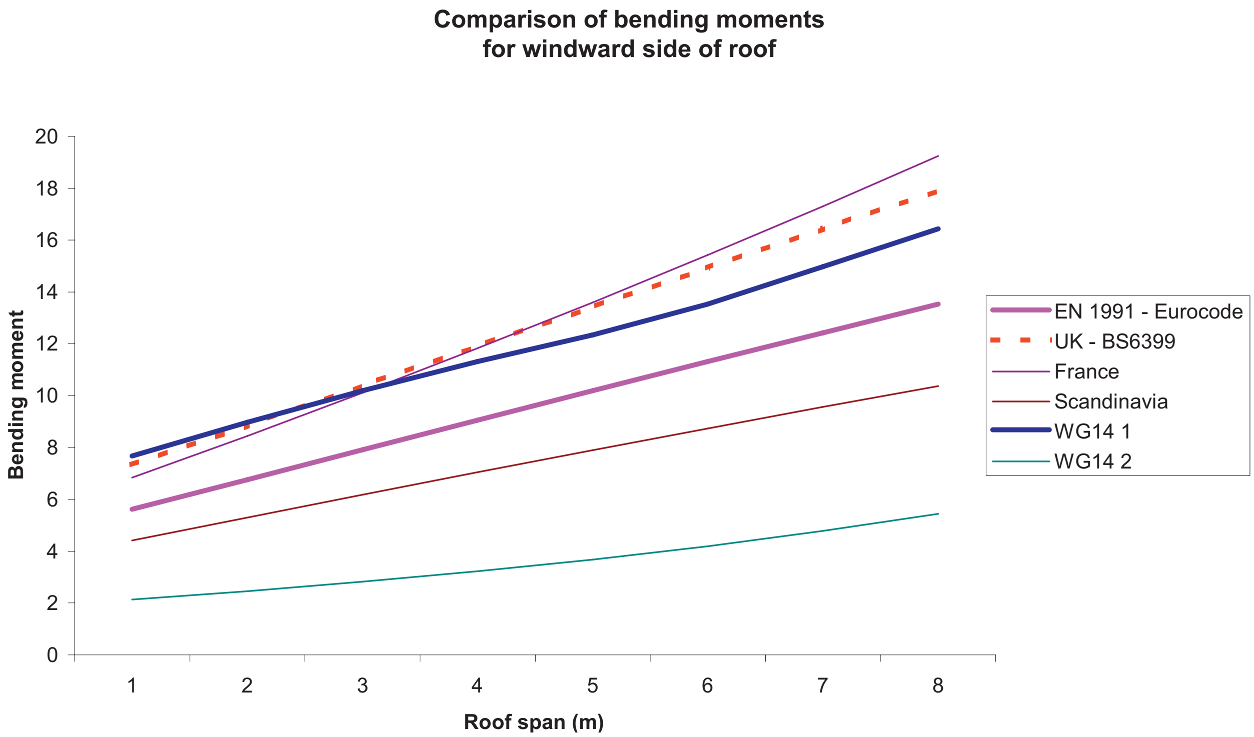


Figure F.2

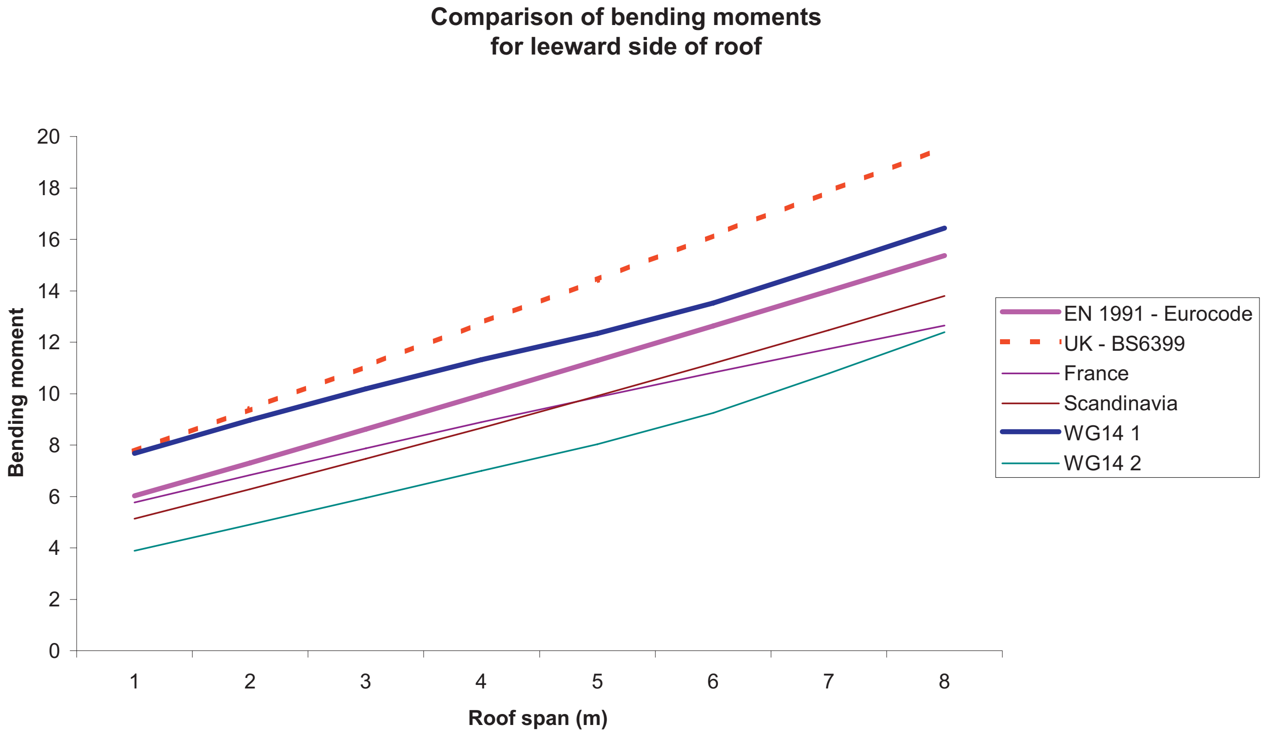


Figure F.3

Although results for the ‘unified’ coefficients on the leeward side tend to yield values less than those specified by BS.6399, they are higher than those specified by BS EN 1991-1-4; ie., conservative.

Note: the BS.6399 results include all design cases for both 0° and 180° wind directions.

APPENDIX G: USEFUL REFERENCES

EN 39	Steel scaffold tube	
EN 74	Steel couplers	
EN 12811	"Scaffolding: Performance requirements and general design"	
BS EN 1991		**Actions on structures**
	Part 1-4:	General actions – Wind actions.
	Part 1-3:	General actions – Snow loads.
BS 5975	Code of practice for temporary works procedures and the permissible stress design of falsework	
NASC TG20	Guide to good practice for scaffolding with tube and fittings.	
NASC TG4	Anchorage systems for scaffolding.	
NASC TG14	Supplementary couplers and check couplers	
NASC TG16	Anchoring to the ground	

NOTES

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