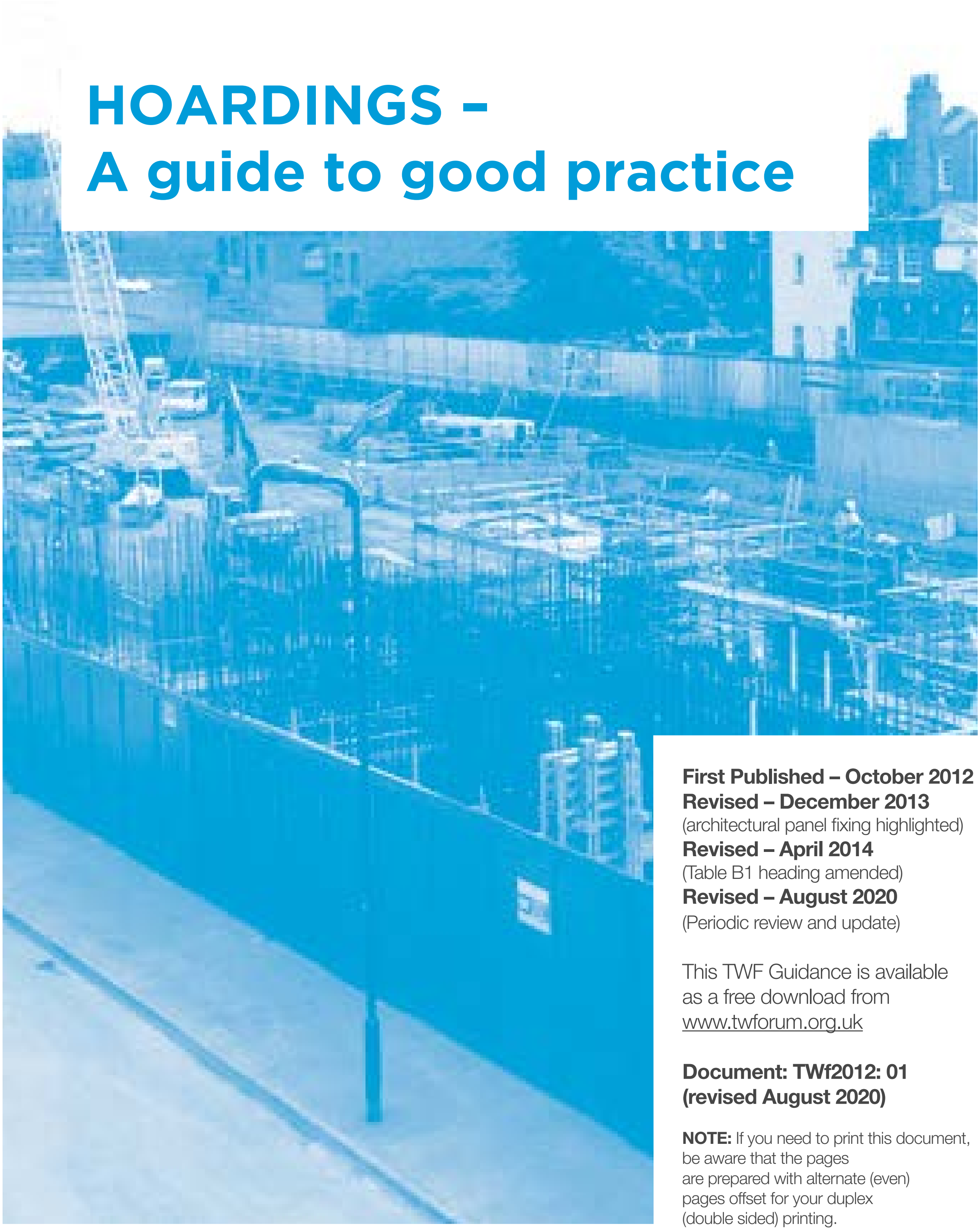
HOARDINGS –
A guide to good practice



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Temporary Works forum

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Synopsis

Site hoardings are common features, particularly in populated areas. However, despite their temporary and incidental nature they are important structures, often of some height, and attracting significant loads. They have been known to collapse and cause both death and injury.

This guidance note is written to assist all parties involved in construction understand the key issues, and to give specific assistance to those specifying, managing, designing and installing these structures.

Hoarding design can be complex and needs engineering judgement. The designer should have a level of competence commensurate with the complexity. All hoarding designs should be independently checked.

Main changes

The main changes made in this guide are:

1. references updated;
2. updated to take into account CDM2015 and BS 5975: 2019;
3. some notes added on the consideration of hoarding duration, shielding factors, wind effects around tall buildings;
4. reduction of passive resistance due to slopes near to post-in-hole hoarding foundations;
5. notes added regarding the use of fixing anchors for hoarding foundations;
6. updated wind probability factor and factors of safety (and example calculation revised accordingly);
7. Appendix F and G added.

General Note:

Users of this document should be aware that BSI has withdrawn all permissible stress codes (with the exception of BS 5975).

This TWf guidance still refers to BS 5268-2: 2002 for permissible stress design as the factors and values used are still considered valid.

BS EN 1995-1-1: 2004 + A1: 2014 is the Eurocode limit state code for timber design.

Foreword

The Temporary Works Forum gratefully acknowledges the contribution made by members of the working party and others in the preparation of this guidance.

The working party recognise that some photographs may show breaches of current safety regulations but the photographs have been retained in the guide to illustrate particular items of interest.

Readers should note that the documents referenced in this Guide and Appendix A are subject to revision from time to time and should therefore ensure that they are in possession of the latest version.

Although guidance is given on different methods of design of post-in-hole foundations, one particular method is recommended with planting depths stated for timber posts for 2.5m high hoardings for three different ground conditions. This does not preclude designers from using sound engineering judgement in their design of alternative solutions.

The two different design methodologies (viz. permissible stress and limit state) may not result in identical solutions and engineering judgement may need to be exercised. Both methods produce 'safe' solutions. However, queries can arise when using one methodology for the design and the other for the design check. (This issue is not exclusive to the design of hoardings.) The TWf advises that the two methodologies should not be mixed; and those involved should agree on which methodology is to adopted.

Disclaimer

Contents

To navigate to page - hover over an item below and 'click'. Return to contents by clicking on the 'Return to the contents' at the bottom of every page.

Scope

This TWf Guidance gives guidance on the information necessary for specifying, procuring and sources of design data for the use of site hoardings. Recommendations for designers on relevant factors to be used and considerations to be incorporated into the design are included.

Proprietary open mesh type fencing products, although used in similar locations to hoardings are not included in this Guide.

The TWf Guidance is not a design code, but is intended to be used in conjunction with the current British Standards and other referenced documents as a guide to good practice in the design of a hoarding. The hoarding designer is not precluded from using other codes and methods of design.

Definitions:

Hoarding – A temporary structure of solid construction, erected to shield the works from others and to prevent any person gaining access.

Principal Contractor's Temporary Works Coordinator (PC's TWC) – competent person who is responsible for the implementation of their organisation's temporary works procedure and checking that other appointed managing contractors who are directly or indirectly in their employ are implementing their procedures

Temporary Works Coordinator (TWC) – competent person with responsibility for the co-ordination of all activities related to their temporary works.

Temporary Works Supervisor (TWS) – competent person who is responsible to and assists the temporary works coordinator

Temporary Works Designer (TWD) – the organisation(s) or person(s) appointed to carry out the design of the temporary works

Temporary Works Design Checker (TWDC) – the organisation(s) or person(s) appointed to carry out the design check of the temporary works

Permanent Works Designer (PWD) – the organisation or person appointed to carry out the design of the permanent works

1.0 Background

The Construction (Design and Management) Regulations 2015 ('CDM2015', Reg. 18) require that the perimeter of a site be 'readily identifiable' or 'fenced off' (depending upon the level of risk posed). Generally, the Principal Contractor (or occasionally the Client) takes measures to prevent unauthorised access onto the site, especially of children. For added security, a solid hoarding is often preferred, as opposed to open-mesh fencing.

Site hoardings are frequently substantial structures: most commonly about 2.4m in height, using a plywood sheet (but increasingly constructed using proprietary steel panels), and hence of solid construction. Hoardings can often be used to enclose the front of shops while alterations are in progress.

This TWf Guidance considers the hoardings erected to construction sites, both in building and civil engineering where examples of hoardings up to 4m high are found. These are all subject to lateral loads of a similar magnitude to those affecting permanent works. Failure may bring fatality or injury and certainly disruption, cost and delay to the project.

Fig 1. Typical site hoarding – site view

1.0 Background – continued

Site hoardings should not be confused with fencing or environmental barriers, although similar components may be used. The standard on solid close-boarded fences (BS 1722-5:2006 + A1: 2018) specifies materials for fences from 1.05m to 1.80m high using either timber or concrete posts.

It gives installation and material requirements but minimal design data. The guidance on environmental barriers (HA 66/95) provides information on noise propagation and attenuation together with guidance on the acoustic performance of different materials.

Use of proprietary open mesh type fencing products, although used in similar locations to hoardings are not included in this Guide. Users should refer to the suppliers/importers data sheets for correct use and design of such products.

Hoardings are frequently used for advertising, by clients and contractors. Whereas painted or poster style adverts do not alter the fundamental design principles, the use of advertising signs that project above the hoarding should receive special attention. There is a separate standard for the design and construction of signs for publicity purposes (BS 559:2009).

TWf is aware of concerns relating to:

- The lack of design guidance for this common site feature, thus leading to unnecessary repeated effort.
- Inadequate, or no hoarding design on some sites.
- Use of inadequate materials, often with inadequate durability.
- Lack of information prior to design.
- Insufficient consideration on inspection and maintenance.

This document is intended to provide guidance on design matters and to indicate minimum levels of provision.

2.0 Responsibility and information

Site hoardings are usually be the responsibility of the Principal Contractor. The task of constructing (and designing) the hoarding will normally either be let to a sub-contractor or be undertaken by the Principal Contractor.

On rarer occasions the hoarding, or its dimensions, may be specified by the Client, but generally the height and detail is left to the Principal Contractor and may be influenced by security needs.

Fig 2. Site hoarding with advertising

As hoardings are a "temporary works" item, the primary source for procedures for their management and control are given in BS 5975: 2019. This includes requirements for the appointment of a Temporary Works Coordinator (TWC and/or PC's TWC) and for the preparation of a register of the temporary works on the site and preparation of design briefs. On most sites, hoardings are likely to be one of the first entries in the register of temporary works. Management procedures would include regular inspections and required maintenance during the life of the hoarding.

For any particular design brief, relevant hazards to its location and use need to be identified and the risks classified; known as "implementation class" in BS 5975: 2019 and the classes are 'very low', 'low', 'medium' and 'high'. As the implementation class increases so does the level of procedure required to control the risks (see BS 5975: 2019, Table 1). Hazards to be considered include the proximity of traffic, services, loadings from wind and/or crowds. The level of design and design checking should be appropriate to the hazards identified, see BS 5975:2019 procedures.

The importance of the preparation of a suitable design brief in controlling the procurement and design for a safe, durable hoarding that is fit for purpose, cannot be stressed too strongly.

Normally a site hoarding is erected for the duration of the construction work. This may involve several stages and can involve different contractors, for example demolition, excavation, construction, fit out. Although each contractor may only expect to be on site for the duration of their own contract, the site hoarding often remains substantially unaltered for the overall construction period. However, due to space constraints, part of the hoarding may need to be modified. The Client therefore has a duty at the start of construction to give a realistic assessment of the critical sequences, modifications and likely overall duration. This expected design life should be communicated to the designer of the hoarding in the design brief.

It is particularly important that the parties responsible for the design brief, the design of the hoarding, and the relevant design checks are made clear and explicit. Whoever designs the hoarding needs to know the layout of the hoarding, the location of the site, the service life, dimensions, below ground obstacles and hazards, geotechnical ground conditions and any restrictions on space (for, say, inclined lateral supports).

If penetrations are to be made into the ground, the engaging party (usually the Principal Contractor) should consider the hazards which may affect effective progress, or which could affect the safety or health of persons. Utilities are the most common hazard in this regard. Information should also be made available by the Client as part of the 'pre-construction information' requirements for the procedures and control measures to be put in place for all temporary works.

3.0 The Design Brief

The likely information to be included in the design brief for any hoarding would be:

- site location:
  - Is the site in a town and more than 2km from the edge of the town?
  - Is it in the country or by the sea? etc.
- expected duration of hoarding, including details, if known, for each stage of relocation.
- required minimum height, and length of hoarding, including dimensioned plan of the site showing the line of the hoarding for each phase, if appropriate, and the required height.
- details of any signage to be attached which may increase dimensions, weight and wind loading. For example on 'prestigious projects' architectural panelling may be specified. The additional weight and recommended fixing methods of such panelling should be specified by the supplier/importer of the panels.

  Note: *The use of impervious panelling on wood based facing materials can change the moisture conditions –* *See Section 5.3*
- details of any specified requirements for hoarding lighting (including any earth bonding requirement), vision panels, decorative treatment, application of advertising, etc.
- ground conditions (relating to strength parameters and any ground contamination). For example, some design methods classify the ground as "Good", Average" or "Poor".
- position of relevant utilities, both buried, surface and overhead (dead, live and about to be energised.).
- access ways required in or through the hoarding; both vehicular and pedestrian.
- details of any permits and/or licences required.
- details of any fire ratings required for the materials to be used.

3.0 The Design Brief – continued

- any space restrictions, for example from existing inclined supports.
- any restrictions on the type of fixings to be used.
- design risk from future operations, for example undermining due to excavations.
- any crowd loading that may be relevant.
- whether vehicle impact loading may be relevant.
- whether in proximity to a railway with likelihood of passing train pressures.
- the category of design check required (See BS 5975: 2019, Table 2).
- the wind factor S_{wind} for the site.

  Note: *If the wind factor is not known, then information on location, altitude above sea level, local topography (i.e. is site more than halfway up a hill or escarpment? how steep is the hill?)*

  Although this might seem a long list, answers to these questions are required before a basic wind design can be carried out. *See also Appendix B*.

  It should be pointed out that, unless it is a very large site, the value of the wind factor S_{wind} is the same for all the temporary works erected on that site.
- any restrictions related to inspection and maintenance.

The design brief should include mention of whether there are any favoured materials already specified and what category of design check is required, to avoid contractual dispute at a later stage.

4.0 Design

4.1 Design life

The anticipated design life of the hoarding affects the loadings to be used in the design and the range/type of suitable materials. Durability of the hoarding is a design consideration.

The service[3] life of a hoarding shall be:

i) as specified by the Client or engaging party (usually the Principal Contractor); or

ii) as agreed with, or specified by the manufacturer (for proprietary hoardings); or

iii) if not specified or agreed elsewhere, 10 years.

Note 1: Consideration should be given to what (if any) appropriate action is to be taken should the intended design life be significantly exceeded (e.g. site being forced to close due to pandemics or bankruptcy).

Note 2: The duration of the hoarding for wind loading considerations (see 4.2.2), normally greater than one year, is not the service life for durability of the materials.

4.2 Design loads

For most hoardings the key design matter is lateral / horizontal loading arising from either the wind and/or impact. Depending on location the impact could be crowd loading and/or vehicular impact. The lateral loads require either a positive connection to the foundations to prevent sliding, or be restrained by sufficient kentledge to resist sliding by friction alone.

The various codes of practice in current use give differing combinations of design loads. To assist designers, these are discussed separately at Section 4.4 of this Guidance. Designers should be particularly aware of the implications of “mix and match” when using different codes.

The various loading that may need to be considered are discussed below:

4.2.1 Minimum notional horizontal load

It is a recommendation of this TWf Guidance that a minimum notional horizontal line load of 0.74 kN/m shall be considered to act on all hoardings. This load is considered to act at a height of 1.2m and may be applied from either side of the hoarding. This load is the “minimum horizontal imposed load” defined in BS 6180: 2011, Table 2.

For areas susceptible to overcrowding associated with wide pavements, shopping malls, retail areas, stadia, or public events a larger value of horizontal load should be considered from the public side. See Section 4.2.3

4.2.2 Wind loading

Although the source of wind loading is BS EN 1991-1-4:2005+A1:2010 and the UK National Annex to that standard, the simplified method given in BS 5975:2019 is generally recommended for hoardings provided due consideration is given to the life of the hoarding. Note though that a wind design in accordance with BS EN 1991-1-4 may provide a more economical design, particularly for very large or very exposed sites.

[3] *similar to the design life of site signage recommended in BS 559:2009*

The wind load varies along the length of the hoarding and increases significantly near corners, openings and free ends. The location of a hoarding will also affect the flow of wind around it. For example the wind on a freestanding hoarding will pass over it and create both pressure and suction forces on the hoarding, whereas when erected in front of a large building the wind is effectively stalled by the building. In the latter case the wind will cause either pressure or suction depending on the direction of the wind. In all cases the wind will accelerate near the edges of hoardings and buildings. To assist designers, guidance and recommendations on factors and sources of wind information are given in Appendix B to this TWf Guidance.

Advertising signs that project above the hoarding locally increase the effective height and increase the wind load. Where the advertising signs are freestanding they have a different wind regime from hoardings as the wind can pass underneath the sign. Such signs should be separately designed (refer to both BS 559 and BS EN 1991-1-4).

It should be noted that certain site hoardings may be erected in areas that are not subjected to wind loads, for example inside buildings or enclosed shopping malls.

Designers should be aware though of the effect on the design of the hoarding should the circumstances alter; examples include:

(a) an internal hoarding to a building suddenly being fully exposed on removal of the curtain wall to the structure.

(b) a hoarding inside a building but adjacent to a roller shutter door.

(c) The designer should exercise caution when considering shielding factors (e.g. from neighbouring buildings or trees) when calculating wind loading as the item offering shielding may not necessary be present for the full life of the hoarding (e.g. a building gets demolished or trees cut down due to disease).

(d) The designer should be aware of accelerated wind effects (‘funnelling’) if a hoarding is to be positioned near tall buildings. BS EN 1991-1-4 provides limited guidance on these effects. Examples are given in the UK National Annex to BS EN 1991-1-4 with further background information in PD 6688-1-4, Clause NA.2.27. An increase in wind velocity and pressure coefficients can be considered where the gap between two tall buildings is relatively small and the air is forced into this narrow gap. Designers may need to seek specialist advice, e.g. Building Research Establishment Publication DG520, ‘Wind microclimate around buildings’; UK Wind Engineering Society; SCOSS Alert, ‘Wind adjacent to tall buildings’.

The designer should also check that the supplier’s fixing recommendations on any architectural panelling and/or signboard can resist the design wind suction forces at the specific location.

4.2.3 Crowd loading

This may be a consideration in populated areas, such as town centres and restricted railway platforms. Information may be specified in local bye-laws, or by the Client. These loads can be significant, particularly if there is a requirement to resist crowd or farm animal crushing loads. The location of the hoarding can be significant, for example in the approaches to a stadium.

Where hoardings are erected in areas identified as susceptible to overcrowding, such as in “retail areas” or where there are “footways or pavements less than 3m wide”, then Table 2 of BS 6180:2011 recommends a lateral line load of 1.5 kN/m applied at a height of 1.1m above the ground level. This increases to 3.0 kN/m for ‘footways greater than 3m width’, ‘adjacent to sunken areas’, for ‘theatres’ and for ‘shopping malls’.

Where overcrowding is considered, the crowd load is considered to apply from the public side only, and replaces the minimum notional horizontal load stated in Section 4.2.1.

Where hoardings are erected in areas adjacent to spectator accommodation, barrier and crush loads may also need to be considered, and reference made to BS EN 13200-3:2018.

Where crowd loading is a consideration, the combination of this load and the wind load is critical. See Section 4.4 of this Guidance.

4.2.4 Face material loading

To ensure the robustness of all hoardings, it is a recommendation of this TWf Guidance that the facing material should be able to resist a uniformly distributed lateral load of 1.5 kN/m2 in the bottom 1.1m of the hoarding. This load is considered in the face material design only, and is not additive with the minimum notional horizontal load stated in Section 4.2.1.

As it is for robustness this load is not considered in conjunction with any other load.

Fig 3. Typical hoarding with vehicle barrier

4.2.5 Vehicle loading

A requirement to design a hoarding to withstand vehicle loading is not reasonable. The relatively lightweight nature of a temporary hoarding designed to resist the dynamics of moving vehicles is not usually economic. This depends in part on the likelihood and the consequences of vehicle penetration, e.g. adjacent excavation behind the hoarding.

It is recommended that if a risk of vehicle impact is considered likely, that separate vehicular barriers or other means are adopted to avoid vehicles impacting with the hoarding.

A space should be left between the vehicle barrier and the hoarding to allow the barrier to move if impacted.

It is noted that the example shown at Figure 3 does not have a space behind the barrier.

4.2.6 Indirect loads from passing trains

Where hoardings are erected close to railway tracks, the velocity pressures arising from passing trains can be significant. If in any doubt, seek advice.

The magnitude of the forces from passing trains is affected by:

- velocity of the passing train (km/hour), usually the maximum line speed,
- aerodynamic shape of the train,
- shape of the hoarding,
- position of the hoarding, its clearance to the tracks and relative height to the track,

To allow for the dynamic effects of the train, a 5m length at the start and end of the hoarding has double the force applied as stated in Clause 6.6.1(5) of BS EN 1991-2:2003,

BS EN 1991-2:2003 at Section 6.6 gives a simple method of evaluating the pressure on vertical surfaces such as hoardings parallel to tracks and on other line side structures.

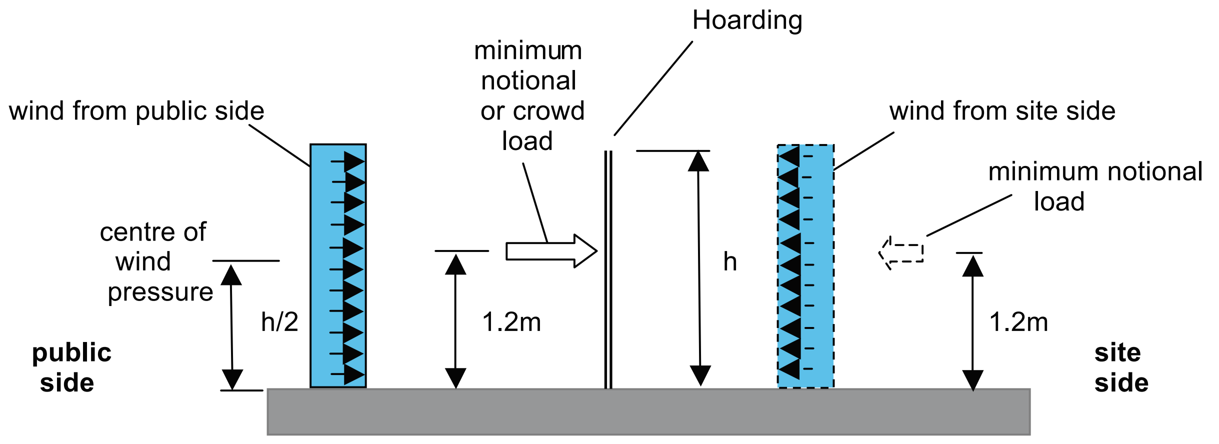
Network Rail issue simple guidelines for calculations when close to railway structures. Further guidance is given in International Union of Railways UIC Code 779-1 relating to the slipstream of passing trains on structures adjacent to the track.

4.3 Design guidance

Prior to the publication of this TWf Guide there was no specific design guidance for hoardings. The documents listed in Appendix A remain useful references. Appendix B gives guidance on calculating the forces arising from the wind and Section 4.8 gives guidance on foundations. A worked example of the design of one particular hoarding arrangement, including the post-in-hole foundation design is given in Appendix E.

Designers will be aware of the two methods of design in current use; either the earlier permissible stress code(s) or limit state (Eurocode) codes. The hoarding working group are aware that there remains many in the industry familiar with permissible stress design, and have therefore included design information to suit both methods. Factors cannot easily be compared between methods because the philosophy is different. Designers should opt for one method or another, but it must be stressed that methods cannot be mixed in a design.

Recognised engineering principles apply to the design of any hoarding. The design wind exerts a pressure on the exposed vertical face, which creates an overturning moment. The wind pressure is considered uniform over the full height of the



Notes: (1) wind can blow from either side.
(2) for combinations of load see Section 4.4

Fig 4 - Design loads on a hoarding

hoarding. It is usually sufficient to consider the worst case as the maximum wind blowing at right angles to the line of the hoarding and is separately considered blowing from either direction. When blowing from the public side the minimum/or crowd lateral load adds to the overturning. See Section 4.4 and Figure 4.

The normal arrangement is for the face material and rails to be fitted above the ground on the public side of the posts. Any overturning caused by the eccentricity of the face material and the rails can reasonably be ignored in the post and foundation design.

Although the face material loading, Section 4.2.4, is considered to apply in the bottom 1.1m of the hoarding for robustness, it is normal practice to consider this load over the full height of the hoarding when designing the face material.

Where a horizontal rail is positioned about 1.1 to 1.2 m above the ground on the public side of the posts, the minimum notional horizontal load or crowd load may be restrained directly by the rail to transfer the load to the posts. Note that the position of this lateral load is a barrier requirement for the public. If the rail is positioned lower or higher, then the minimum notional horizontal load or the crowd load will need to be restrained by the face material, which is in turn restrained by adjacent horizontal rails in bending.

Hoardings erected close to railway lines may be affected by the suction and pressure effects from passing trains. Some guidance is given at Section 4.2.6.

The lateral forces are usually transferred through the face panels to the rails, and then to the posts. To resist an overturning moment, either inclined supports are used, or more conventionally, vertical posts in cantilever from the ground or foundation are used. Hoardings may also be designed with foundation blocks which will be required to resist lateral forces through their self-weight and by friction to prevent sliding.

The designer should consider the particular circumstances and risks involved with the hoarding when undertaking the design. The risk involved from various combinations of load should be considered. See Section 4.4 of this Guidance. The required design combination of load may need to be communicated to the designer in the design brief.

4.4 Load combination factors

The principal load on a hoarding is usually the wind and the minimum notional horizontal line load. This is usually the critical design issue, and the loads from either side are considered in the design. See Figure 4. Where the design brief has identified that the hoarding is susceptible to overcrowding, then crowd loading is to be taken into account. The relevant factors of safety and partial safety factors to be used are given in Section 4.6.

There will be occasions when the location of the hoarding requires the effect of passing trains (see 4.2.6) to be considered in the design. In such cases, care is needed to assess the likely combination of loads and for the designer to make engineering judgements, particularly where the load combinations are not specified in the design brief. This Guide only gives limited guidance about the combination of the passing train load with other loads. The combination of wind and crowd load(s) that need to be taken into account will depend on whether the design will be to permissible stress or limit state (Eurocode) code. The recommended loading combination factors to be used in the design of hoardings are given separately on the following pages.

The face material load (Section 4.2.4) is not shown in Table 1 or 2 as it is not considered to act with any other combination of load as it is for robustness.

4.4.1 Permissible stress – combination factors

Table 1 gives the loading combination factors using permissible stress design codes.

Table 1. Load Combination Factors – Crowd and Wind for Permissible Stress Design

Direction		From Public Side				From Site Side		
	Load Case	Maximum Wind	Working Wind	Minimum Notional Load	Crowd Load	Maximum Wind	Working Wind	Minimum Notional Load
NO CROWD	LC1	1.0	0	-	n/a			
	LC2	0	1.0	1.0	n/a			
	LC3					1.0	0	0
	LC4					0	1.0	1.0
WITH CROWD LOAD	LC5	0	1.0		1.0			
	LC6	1.0	0	-	0			
	LC7					1.0	0	0
	LC8					0	1.0	1.0

Notes: (1) *For calculation of maximum and working wind see Appendix B. The minimum notional horizontal load is stated at Section 4.2.1.*

(2) *Where passing trains loads need to be considered, it is recommended that the passing train load be added to the working wind and not to the maximum wind, unless specified otherwise.*

4.4.2 Ultimate limit state - combination factors

Where the design is to limit state (Eurocode), the combinations of loads (known as actions in Euro codes) are stated in Eurocode 0. The design at ultimate needs to consider both strength and stability. The value of the loads are multiplied by a partial safety factor (commonly called gamma factor) to allow for uncertainties. The values of the partial safety factors vary depending on whether they are considered as permanent, variable or accidental loads. The minimum notional horizontal load, crowd loads and wind load are all considered as variable loads. It is noted that no permanent load is normally attributable to hoarding design.

In the unlikely event of a requirement to design a hoarding for impact load (see 4.2.5), the vehicle impact would be considered an accidental load. The value for the partial safety factor for variable loads is given in Section 4.6.3 (a).

To allow for several variable loads to be applied simultaneously, Eurocodes introduce reduction factors to acknowledge that peak values of two or more variable loads are unlikely to occur simultaneously, and therefore introduces a lower value for accompanying variable actions. These reduction factors are commonly called “psi factors ψ”. In order to consider all likely cases, each variable load is considered in turn with no reduction but with other variable loads reduced by a factor ψ_0.

To assist designers of hoardings, the basic loading cases and their combination factors ψ_0 to be considered for crowd and wind load are shown in Table 2. Values for the factors given in Table 2 are taken from Table NA.A1.1 for buildings in the UK NA to BS EN 1990:2002+A1:2005. The loading cases are based on the Equations 6.10, 6.10(a), 6.10(b), 6.11(a) and 6.11(b) of Clause 6.4.3 of the BS EN 1990:2002+A1:2005.

It is noted that when the wind is considered from the site side, the crowd loading is incidental and overturning in that direction need only consider the wind loading and the minimum notional horizontal load. In the rare occasion where crowds might form on the site side of the hoarding, then due consideration would need to be taken. This should have been identified in the design brief.

Where the design brief requires the load from passing trains (see 4.2.6) to be considered, the combination depends on which other variable and/or accidental loads need to be considered. As already stated, each variable load is considered in turn with no reduction but with other variable loads reduced by a factor ψ_0.

Where an accidental load is a requirement in the design, the accidental load is applied unfactored and the variable loads reduced by lower values of combination factor as ψ_1 and/or ψ_2 , to those stated in Table 2. Refer to both BS EN 1990 and the NA to BS EN 1990.

4.4.2 Ultimate limit state - combination factors – continued

Table 2. Load Combination Factors (ψ_0) – Crowd and Wind using Euro Codes for Ultimate Limit State Design

Direction		From Public Side			From Site Side	
	Load Case	Maximum Wind	Minimum Lateral Load	Crowd	Maximum Wind	Minimum Lateral Load
NO CROWD	LC9	1.0	0.7	n/a		
	LC10	0.5	1.0	n/a		
	LC11				1.0	0.7
	LC12				0.5	1.0
WITH CROWD	LC13	1.0	-	0.7		
	LC14	0.5	-	1.0		
	LC15				1.0	0.7
	LC16				0.5	1.0

Notes: *(1) Partial safety factor for variable actions not included – see Section 4.6.3.*
(2) Where accidental load is a considered combination of load, refer to BS EN 1990.
(3) Load combinations from passing trains need separate consideration.

4.5 Post design

The post to a hoarding is designed to resist the worst load combination identified from Section 4.4 applied separately from either direction. The wind and the minimum notional/crowd load generate a combined moment (M_o) and shear force (Q_o) at the ground level (level 0) of the post. The loads are shown diagrammatically in Figure 5(a) and the design representation in Figure 5 (b).

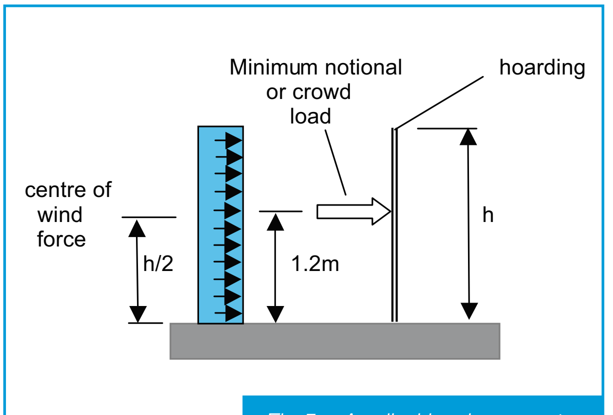


Fig 5a. Applied loads on system

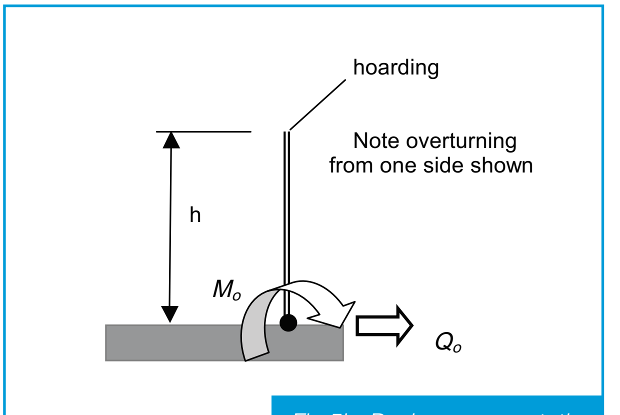


Fig 5b. Design representation

The design moment (in kNm) about the ground level for the post is given by:

$$M_o = \{ \text{(Wind Force)} \times h/2 \} + \{ \text{(minimum notional or crowd load)} \times 1.2 \}$$

Note: *The 1.2 in the equation above is the height in metres of the line of action of the loads and not the factor of safety.*

The design shear load (in kN) applied to the post at ground level is given by:

$$Q_o = \{ \text{Wind Force} + \text{(minimum notional or crowd load)} \}$$

Note: *A worked example using the above information is given in Appendix E.*

4.6 Factors of safety

4.6.1 General

As designers will either be using permissible stress or limit state codes in their design, the recommended factors of safety used in the design of hoardings for materials and for overall stability are given in separate sections. Factors of safety for positional stability are discussed in Section 4.6.4.

An adequate factor of safety should be used when considering the overall stability of the hoarding when subjected to wind and/or crowd loading.

4.6.2 Factors of safety - permissible stress design

(a) Materials

Where the strength of a component cannot be ascertained from the relevant permissible stress code outlined in BS 5975, it is recommended that a minimum factor of safety against structural failure of 2.0 be used.

(b) Overall stability

No part of the hoarding should overturn at any stage during construction or use.

The factor of safety for hoarding overturning when using posts in the ground, with or without concrete surround to the post foundations should be 1.5.

Where overturning is resisted by fixings into a slab, or a carefully controlled weight of kentledge (e.g. concrete block), then the factor of safety on overturning should be 1.5. Where this is not the case (e.g. when the kentledge weight is not carefully controlled such as bags or drums filled with rubble or soil) then the factor of safety on overturning should be increased to 1.67.

4.6.3 Partial safety factors - limit state design - Eurocodes

(a) Materials

The partial safety factor for the material properties and resistance for the ultimate limit state shall be:

γ_m = 1.1 for steel and aluminium

γ_m = 1.2 for all plywood and oriented strand board (OSB)

γ_m = 1.3 for all solid timber either untreated or preservative treated

γ_m = 1.3 for particleboard.

The partial safety factor for loads (actions) in the ultimate limit state depend on whether the loads are permanent or variable, and are further factored on the likelihood of their combined occurrence. See Section 4.4 and Table 2. The recommended values for use in hoardings are:

γ_Q = 1.5 for all variable loads

Note: *Although BS 559:2009 states γ_F = 1.4 for "resistance to wind pressure" it is the recommendation of this TWf Guidance that for hoardings the partial safety factor for wind load, a variable load, be γ_F = 1.5.*

(b) Overall stability

The design moment resisting overturning shall be greater than or equal to the design moment causing overturning. The partial load factor using BS EN 12812 for the ultimate limit state for equilibrium shall be:

γ_F = 1.5 for all destabilising variable actions, e.g. the wind load,

and

γ_F = 0.95 for all stabilising permanent actions resisting overturning due to a carefully controlled weight (e.g. concrete block). Where this is not the case (e.g. when the kentledge weight is not carefully controlled such as bags or drums filled with rubble or soil) then γ_F = 0.9

Note: γ_F = 0 *for all stabilising variable actions.*

Considering the overall stability of foundations in Methods One and Two of this Guide (see 4.8.2) , being prescriptive comply with Eurocode 7[4]. BS EN 1997+A1:2013.

4.6.4 Factors of safety - sliding

Where a hoarding relies on its self-weight and/or fixings to prevent global sliding under the applied lateral loads, the design force (i.e. including the relevant factors of safety) resisting sliding shall be greater than or equal to the applied design lateral load causing sliding.

Table 25 of BS 5975: 2019 gives recommended values of the coefficient of static friction for a limited number of materials. Designers should be aware that frictional restraint does not depend on area of contact, but only on the magnitude of the applied load perpendicular to the friction surface considered. The value of frictional restraint calculated using Table 25 gives the actual value at which the components would slide, without any factor of safety.

[4]BS EN 1997-1:2004 Eurocode 7. Geotechnical Design General Rules at Section 2.1 (4) states "(4) Limit states should be verified by one or a combination of the following: - use of calculations – adoption of prescriptive measures – experimental models and load tests."

It is recommended that for all hoardings designed to permissible stress, the minimum factor of safety on sliding be 1.5. When designing to limit state the relevant favourable and unfavourable factors shall be used; when sliding resistance is the means of restraint the relevant partial safety factors for static coefficient of friction (γ_μ) shall be used.

Where mechanical fixings are used, unless it can be proven that the frictional resistance can be mobilised together with the mechanical restraint, then only one or other means of restraint should be assumed.

4.7 Timber and wood based panel product properties.

4.7.1 General

Timber is a material whose load capacity depends on the duration of the load and its durability on its state/quality. See Section 5.1. A long term load will cause a permanent movement in its fibres, whereas under a short term load, the wood fibre will recover. Hence timber codes introduce a modification factor (K_3) for the duration of load, varying from K_3 = 1.0 for long term, K_3 = 1.4 for one week, K_3 = 1.5 for short term (from Table 7 of BS 5975:2008+A1:2011) and K_3 = 1.75 for very short term loading.

The modification factor (K_{36}) for duration of load used in plywood varies from K_{36} = 0.83 for long term to K_{36} = 1.17 for short and very short term load durations. (from Table 39 of BS 5268-2:2002)

As the wind is the main lateral design load on hoardings (see Appendix B), it is a recommendation of this TWf Guidance that K_3 = 1.75 may be used in the design of timber for freestanding site hoardings and K_{36} = 1.17 for plywood stresses used in the facing material. See also Table 3.

In temporary works where several timber members are spaced not more than 610mm apart and can share the load an additional modification factor of K_8 = 1.1 can be applied. This is not applicable to the use of timber in hoardings where individual members have to take the full load.

A useful guide to the working structural properties of timber and wood based panel products is the '*Formwork – a guide to good practice (3rd Edition)*'. Although written for temporary works use in formwork, often to resist the pressure of concrete on the formwork, the material properties, with certain provisos, discussed in the following paragraphs may be considered suitable for design in hoardings.

The combined modification factor for duration of load and load sharing for timber in hoardings is K3 K8 = 1.75 x 1.0 = 1.75. Recommendations of this TWf guidance are given in the following sections.

4.7.2 Timber

Where the design properties are not specified, it is recommended that the permissible stresses and moduli of elasticity of timber softwood strength class C16, C24 and C27 be taken from Table 3.

Table 3. Permissible stresses and moduli of elasticity for hoarding timber in the wet exposure condition

	Strength class	Bending stress parallel to grain (N/mm^2) (Note 1)	Tensile stress parallel to grain (N/mm^2)	Compressive stress perpendicular to grain (N/mm^2) (Note 2)	Shear stress parallel to grain (N/mm^2) (Note 3)	Modulus of elasticity (N/mm^2) Minimum	Average density (kg/m^3)
Hoardings (Note 4)	C16	7.42	4.48	3.16 (2.44)	1.58	4640	370
	C24	10.50	6.30	3.45 (2.73)	1.68	5760	420
	C27	13.30	8.40	3.59 (2.87)	2.60	6560	450
Modification factors used		K_2 K_3 K_8	K_2 K_3 K_8	K_2 K_3 K_4 K_8 and 1.2	K_2 K_3 K_8 and 1.5	K_2	K_2

Notes: (1) *Values for bending stress may be increased by the depth factor K_7 where the depth of solid timber is less than 300mm.*
(2) *Values for compressive stress allowing for wane are shown in brackets.*
(3) *The shear stress parallel is the maximum value and has been increased by the factor of 1.5 as recommended in BS 5975:2019.*
(4) *Timber is carrying load without load sharing, i.e. K_8 = 1.0.*

When using the stress values in Table 3 the designer should be aware that the following conditions apply:

(a) The timber has been accepted as appropriate to the class concerned, has not been reduced in cross-section and is still in good condition.

(b) The wet exposure condition is assumed. (Factor K_2 allows for the change in stresses and moduli.) Note: In air-conditioned buildings and countries of much lower humidity than the UK the dry condition would be appropriate.

(c) The load duration factor for K_3 has been taken as 1.75.

(d) The bearing length does not exceed 75 mm and there is at least 75 mm of timber each side of any bearing and take-up is not critical. (Factor K_4 allows for this condition.)

(e) The depth factor of K_7 is taken as 1.0 for depth of timber 300 mm. For depths 72mm to 300mm the value is amended using the formula from Clause 2.10.6 of BS 5268-2 as:

$K_7 = (300/\text{depth})^{0.11}$

(For depths of timber up to 72mm, the value of $K_7 = 1.17$).

(f) Values for compressive stress perpendicular to the grain have been increased by a factor of 1.2 for temporary works in agreement with Clause 16.4.2.5 of BS 5975:2019.

(g) The depth-to-breadth ratios of Table 10 in BS 5975:2019 have not been exceeded. Generally, this is a ratio of maximum depth/breadth of 2:1 with no lateral support, reducing to ratio 3:1 where the ends are held in position. For other values refer to BS 5975: 2019.

(h) There is no wane at any point of bearing.

The working structural properties of different sizes of timbers for use in external hoardings, using the stresses in Table 3, are given in Appendix C of this TWf Guide.

The characteristic values of softwood timber species to Service Class 1 for strength classes C16, C24 and C27 for use in limit state design are given in BS EN 338:2016 and partly reproduced in Appendix E.3 of *'Formwork – a guide to good practice (3rd Edition)'*. The relevant modification factors for load and Service Class 3 should be used.

4.7.3 Wood based panel products

The design properties of wood based panel products should be given by the supplier / importer of the products for the grade and thickness to be used.

For common thicknesses of plywood, particleboard and oriented strand board it is recommended that the working structural properties given in Table 15 of *'Formwork – a guide to good practice (3rd Edition)'* be used for hoardings. Where specific trade names are used, working structural properties are given in Table D-W of *'Formwork – a guide to good practice (3rd Edition)'*.

The working properties in Tables 15 and Table D-W recommended are values for wall formwork application with a combined load duration and load sharing factor of $K_{36}\ K_8 = 1.17 \times 1.0 = 1.17$, which is also the value recommended for very short-term load in hoardings. Hence the recommendation that Tables 15 and Table D-W may be used.

Many wood based panels have different properties in the two directions, so orientation of the sheet material should be carefully considered by the designer and communicated to site.

Where designers wish to carry out wood based panel product designs from first principles to establish structural properties, it is recommended that:

- wet (site) condition be used for Service Class 3,
- stress modification factor of $K_{36} = 1.17$,
- moduli modification factor of $K_{36} = 1.43$,
- load sharing factor is not relevant thus $K_8 = 1.00$.

The characteristic values and moduli for many wood based panel products in the Service Class 1 (dry) condition for use in limit state design are given in Appendix E.4, Table E.4 of *'Formwork – a guide to good practice (3rd Edition)'*.

To convert characteristic values given by a supplier for a particular wood based product into permissible stress terms, it is recommended to use the conversion factors given in Table 13 for wall formwork in *'Formwork – a guide to good practice (3rd Edition)'*.

4.8 Foundations

4.8.1 General

The adequate founding of hoardings always requires care and on-site experience given the variability and nature of the ground. Although the design brief, (Section 3.0) will have identified the ground conditions, the designer should take account of expected variations. In common with all below ground work, procedures should be in place to assess any unexpected conditions found during erection, such as sudden changes in ground conditions and/or services. The structural safety of the hoarding relies on its adequate founding.

There are generally three types of foundation used:

- conventional post-in-hole;
- bolted sleeve fabrication; or
- above ground foundation blocks / kentledge.

A worked example of a 2.44m high hoarding design with conventional post-in-hole foundation is given in Appendix E.

An example of a kentledge foundation option has also been provided (see Appendix G).

The post design considered at Section 4.5 will have established the design overturning moment (M_o) about the ground level (level 0) and the shear force (Q_o) at that level. The foundation is then designed, with a suitable factor of safety, to resist the applied moment and shear force.

The point of rotation of the foundation, or fulcrum, depends upon the type of foundation. A bolted foundation at ground level would use the design overturning moment and shear force at that level, but a post-in-hole or ground foundation would rotate about a point within the rigid foundation. The designer would need to take account of this fulcrum point in the design.

A fuller treatise on establishing the fulcrum point for post-in-hole foundations for one method of design is shown at Appendix D.

4.8.2 Conventional 'post-in-hole'

This is very similar to domestic style fencing. The normal construction being that a post is placed in a pre-excavated hole at suitable centres, and while the post is held in position, concrete is placed around the hoarding post. Typical hole sizes are 300 to 450mm diameter or can be square. The concrete should always be placed after the post is inserted and should be well rammed as filling proceeds (See BS 1722-5:2006). An example is shown at Figure 6. This arrangement does allow some drainage of moisture in the post downwards into the ground below, although it may capture some moisture and if the timber is not properly preserved, provide a medium for deterioration over time. If the concrete is placed in the hole first, and the post then inserted, the timber is fully encapsulated and deterioration of the post significantly accelerated.

The type of ground needs to be ascertained prior to design. For example, the design method recommended in this TWf Guidance requires that an engineering judgement of the ground be made with a classification of "Good", "Average" or "Poor". For other design methods excavation and material testing may be required to determine soil type and strength properties.

This guidance relates to upright posts, located centrally in excavated holes with concrete infill to ground level. The depth of post embedment is required to be sufficient to resist the bending moments and shear forces that will be induced in the posts when subject to horizontal loading above ground level.

Having established the design parameters and selected a suitable size of post (Section 4.5) it is considered good practice to then design the post foundation to resist the full capacity of the selected post. Recommended planting depths for 2.5m high hoardings, for two sizes of excavated hole, are shown in Appendix D for the timber post sizes given in Appendix C.

Fig 6. Typical timber post-in-hole hoarding

4.8.2 Conventional post-in-hole foundation - continued

Post stability is achieved by mobilising portions of passive resistance and reverse passive resistance in the soil. These portions form a couple, from which the post cantilevers above ground level. The required depth of embedment is dependent on the resistance characteristics of the soil and the width of the concrete infill. It should be noted that the fulcrum of the ground resistance to the applied overturning moment is within the foundation depth, and not at the ground level.

Enhanced stability may be achieved by casting a concrete slab around the post at ground level to act as a strut.

There are many variations for the design of such foundations, and the subject is covered by organisations in different ways. A full geotechnical design will rarely be justified for a site hoarding and the importance of simple "rule-of-thumb" rules in the design should be encouraged, provided the user has the necessary experience.

There are three methods commonly used in design of embedded posts for hoardings; discussed in the following sections, with the first method the preferred option. Method Three should only be carried out by engineers with an adequate understanding of geotechnical principles.

4.8.2.1 Method One – PD 6547 simplified for lamp posts

This TWf Guidance recommends use of the simplified method given in PD 6547:2004 + A1:2009, (Appendix A) but with a minimum factor of safety of 1.5 applied to the design overturning moment of the post. This method considers and defines 'good', 'average' and 'poor' soil types.

The post is considered to be encased in concrete of a certain diameter (or width) so that the foundation rotates as a solid body with the embedded post about a fulcrum point in the ground. The fulcrum point for the ground resistance is considered to act at a level below the ground level of 0.707 times the planting depth.

Planting depths for 2.5m high hoardings using this method are stated in Appendix D. A full worked example using this method is shown in Appendix E.

4.8.2.2 Method Two - HA 66/95 Section 5 Environmental Barriers

This method assumes that the foundation is fully embedded in well compacted material with a reduction factor for poor surface material. See Appendix A for the reference.

4.8.2.3 Method Three - Geotechnical design from first principles.

For post embedment design from first principles, the following parameters are recommended:

(a) For concrete infill of 600mm width or less, zero active pressure is considered as the soil arches around the infill.

(b) Passive resistance is considered to be mobilised over a width the lesser of either three times that of the concrete infill (3b) or the spacing of the posts, where b is the actual width of the concrete infill. Passive resistance from the upper part of the stress block is ignored to a depth of 1.5b for undrained cohesive soils, or b for drained cohesive and granular soils as recommended in CIRIA SP95.

(c) Where the ground investigation data is available and known by the designer, a minimum factor of safety of 1.5 on passive resistance should generally be used, based on moderately conservative soil parameters.

(d) The factor of safety used in the ground element of the design when using posts in the ground may be reduced further where the prevention or limitation of ground movement and therefore hoarding movement is less important. The recommended minimum factor of safety is 1.2 but should only be used where the designer is confident in the ground conditions and the parameters adopted.

(e) The effect of wall friction or adhesion should be ignored in the calculation (which is conservative), unless the designer is competent to make a proper evaluation of their effects and takes these into account with the chosen factor of safety, which may well need to be greater than the value recommended above.

(f) In granular soils, where there is limited data, an internal angle of friction of 30 deg. should be adopted. Where comprehensive information is available on relative density, soil angularity, etc. a less conservative design value may be used.

(g) Undrained, total stress, shear strength parameters should be used to assess passive resistance in soft normally to lightly over consolidated cohesive soils. In general, undrained, total stress, shear strength parameters may also be used to compute passive resistance in stiff over consolidated cohesive soils. Most design loads are from short-term events such as wind or a collision and are highly unlikely to be sustained long enough for long term drained conditions to apply. Care should, however, be taken when assigning design shear strength values. Because of the fissuring in the clay, the mass shear strength is often significantly lower than measured in the laboratory in hand vane shear tests or in triaxial tests on 38mm or 100mm diameter specimens. In such cases, it is advisable to adopt a maximum design value no greater than 75% of the laboratory measured undrained shear strength. Where it is anticipated that long term softening of the clay may occur, for an example adjacent to an excavation, design checks should also be made using effective stress parameters.

(h) In locations where ground water level varies within the depth of post embedment, the design should assume water at ground level.

(i) Ground level surcharge loads should not be used to enhance passive resistance unless these can be guaranteed to be of a permanent nature.

Note: *Designers should consider the possible reduction of passive soil resistance adjacent to any post foundations. This may be due to the excavation of a service trench near the hoarding line. If a slope has to be excavated adjacent to the hoarding, then the slope should be designed to ensure its own stability. Any adjacent hoarding foundations also need to consider the potential for loss of passive resistance. Further information is provided in Appendix F.*

4.8.3 Bolted (or similar) foundations

The fixing posts can be secured to foundations already prepared. Posts can be bolted to the base. Care is necessary in the selection of corrosion resistant bolt assemblies to ensure the design service life is achieved.

Designers should consider the following when choosing bolts:

a. Mechanical expanding-type anchors can work loose (especially in mass concrete) due to cyclic nature of the loading; resin type fixings may be preferable.

b. Cast-in anchor rods need an allowance for construction tolerance.

c. Bolts should be designed taking into account capacity reduction factors due to close spacing and distance from edge of concrete base.

Proprietary corrosion resistant post sleeves and end plates are available so that the post is kept out of contact with the ground. These items are suitable for a short design life of normal hoardings up to two years, provided there are regular inspections.

4.8.4 Proprietary, above ground, foundation block

These should be verified see (Section 6), for sliding and overturning, against the prevailing site conditions. The weight of each block should be known (marked on the block) and lifting points (or other means for mechanical lifting) provided.

The technical data provided by the supplier, should provide sufficient information to enable its sufficiency, in the particular circumstances.

Typical proprietary hoardings are shown at Figure 7 and Figure 10.

Fig 7. Typical proprietary hoarding with foundation blocks

Fig 8. Typical kentledge block hoarding

4.8.5 Foundation block / kentledge foundation

Resistance to overturning may be provided by either a foundation block or kentledge, see Figure 7. Where this type of foundation is used, the stability in both directions should be carefully considered.

The kentledge may be precast concrete, a purpose made block, or a number of scaffold tubes[5], or a container acting as ballast and filled with sand, soil, rubble or a liquid. Ballast in the form of liquids (e.g. generally water) should be avoided due to the risk of inadvertent or malicious removal. In addition, for long-term hoardings stagnant water can be considered to be a bio-hazard with associated disposal problems.

Whenever using kentledge, see Figure 8, or ballasted containers, see Figure 9, the exact value of overturning resistance is known, and a lower factor of safety can be utilised. See Section 4.6.2(b).

Fig 9. Typical ballasted hoarding

[5]Not only should the number and length of tubes be stated, but whether Type "3" or Type "4" has been assumed because different wall thickness will give a different weight!

5.0 Materials

5.1 Timber

Sustainability of all timber based products should be considered in the procurement process. In the UK, there are two main certification schemes (Forest Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC)) to assure that wood based products originate from sustainable sources.

Painted and treated timber is generally not suitable for recycling. Re-usable plastic sheets (e.g. re-usable PVC manufactured from recycled materials and not single-use PVC) can be considered as an alternative to plywood sheets. PVC products should be certified to ISO 9001. To ensure that the product strength has sufficient resistance to external blows, the minimum thickness of the panel's outside layer should be 2mm. To manage the quality of the product and ensure the strength of the material is controlled, a certified drop ball test should be competed to BS EN ISO 3127:2017 (or equivalent). Full structural properties should be obtained from manufacturers/suppliers.

The minimum quality of timber used in hoardings should be grade C16 (BS EN 338: 2016). Where subject to moisture and possibilities of decay, all hoarding timber should be treated with a wood preservative, preferably supplied pre-treated with a pressure applied wood preservative.

The permissible stresses and moduli of timber for hoardings are given in Table 3 and working structural properties of common timber post and rail timbers are given in Appendix C.

Wood does not deteriorate just because it gets wet. When wood breaks down, it is because an organism is eating it as food. Preservatives work by making the food source inedible to these organisms. Properly preservative-treated wood can have 5 to 10 times the service life of untreated wood. Preserved timber is used for railway sleepers, telegraph poles, marine piles, fences and other outdoor applications.

The durability of wood and wood based products is defined by use classes. BS EN 335-2: 2013, Clauses 4.4 and 4.5. The use classes relevant for hoardings are:

- Class 3.1 Product does not remain wet for long periods; water does not accumulate
- Class 3.2 Product remains wet for long periods; water may accumulate.
- Class 4.1 Product is in direct contact with ground and/or fresh water

Where the ground water is "severe" or in salt water other classes would apply.

Although circumstances will vary, it is foreseeable that a treated wooden hoarding post will rot after about 9 or more years in the ground and surrounded by concrete, giving an expected design life of about 5 years, subject to regular inspections at maximum six monthly intervals. For correct placement of the concrete surround see Section 4.8.2.

Timber will also be used as horizontal rails on to which the facing material can be secured. Care is necessary to avoid water build-up on top surfaces of such rails when using square timbers. Water ponding promotes decay and local rotting of both the rail and/or the facing material.

Certain situations may require fireproofing of the timber. Although this should be included in the design brief (See Section 3) the procurer and/or client may specify particular methods of fire proofing to be incorporated.

5.2 Steel or concrete posts

If a hoarding is required for a considerable period of time then corrosion protection for steel posts should be provided and be regularly inspected.

The use of concrete posts for hoarding is rarely justified. However, the benefits are that they give long service life with little maintenance.

5.3 Facing material

The facing material for hoarding is often a wood based material, such as plywood, wood particleboard (commonly known as chipboard) or Oriented Strand Board (OSB) The face material is normally fitted to span vertically between horizontal rails. See Figure 6.

The structural properties of wood based panel products for use in hoardings is discussed in Section 4.7.3, and the importance of correct orientation of the facing material.

Generally all external hoardings will require a water resistant wood based panel product. Procurers should be aware of the variations in face materials and the various glues and resins used to make the panel. They may not be suitable for long term exposure to the elements. Reference should be made to the manufacturer's specifications and advice on the specific product.

When using wood particleboard, the minimum grade recommended is P7 (EN 12369-1: 2001). None of the grades of particleboard are designed for use in wet conditions where the moisture content is likely to exceed 18%. This limits the use of wood particleboard to short term hoardings in less exposed locations. Particleboard is hygroscopic and its dimensions change in response to humidity. For example, a 1% change in moisture content typically results in a change of 0.4mm per metre length or width of a sheet.

When using oriented strand board (OSB) the minimum grade recommended is OSB/3 (BS EN 310: 1993). OSB has significantly different properties in its two directions and users should be particularly aware of the orientation of the board. OSB, like particleboard is hygroscopic and its dimensions change in response to humidity. For example, a 1% change in moisture content typically results in a change of 0.3mm per metre length or width of a sheet.

For robustness it is suggested that the minimum thickness of a panel of wood or wood based material for an external hoarding should be not less than 16mm.

When using correctly preserved timber for hoarding panels, under normal conditions of use, a life expectancy of the resulting facing panel shall be 15 years (Clause B.3 BS 1722-5:2006). If part of the face is covered, for example by advertising, the change in the moisture conditions on the face reduces significantly the life expectancy.

Certain situations, such as in station environments, underground works, shopping malls, etc. may require fire proofing of the facing materials. Although this should be included in the design brief (See Section 3) the procurer and/or client may specify particular methods of fire proofing to be incorporated. Certain materials may be prohibited from use. In such cases, seek advice.

5.4 Fixings

All fixings shall be considered for durability of the hoarding, and when a long duration is expected, be designed for ease of regular inspection. Nailed connections are to be avoided where joints may become loose under cyclic loading or deteriorate with age.

The frequency of fixings should be increased near to the ends of hoardings - the wind pressure is larger due to the effects of local turbulence of the wind around the ends, see Appendix B.

Typically a hoarding has interface areas of fixings, the face material to the rails, and the rails to the posts. In both cases, the principal load on the fixings is the tension caused by the wind blowing from the opposite side to that which the rails are fitted.

As the face and rails are normally fitted to the public side of the hoarding post, the effects of crowd loading can be ignored in the fixings design. The fixings should be designed for either the full wind force or the working wind plus the minimum notional horizontal load. The worst cases should be considered – see Loading Combinations at Section 4.4.

It is recommended that coach screws, bolts, nuts and washers shall have a protective coating. This could be hot dip galvanised in accordance with BS EN ISO 1461 as recommended for fencing (BS 1722-5, Clause 8) or other suitable protection. The use of stainless steel fixings is rarely justified on a temporary hoarding construction.

Information on the safe loads of nails, screw and bolts are given in Section 6 of BS 5268-2:2002. This includes shear strengths and spacing of nails, use of differing face materials, effects of pre-drilling holes for screws, etc.

The permissible load for a screwed joint is given by the expression:

$$F_{adm} = F \times K_{52} \times K_{53} \times K_{54} \times l \qquad \textit{[Equation 1]}$$

where;

F_{adm} is the permissible load in a screw (in N per mm of penetration)

K_{52} is a modification factor for duration of load

K_{53} is the modification factor for moisture content

K_{54} is a modification factor for screws in line.

l is the threaded point side penetration of the wood screw (in mm)

It is a recommendation of this TWf Guidance that for hoardings the fixings shall be designed for a very short term load, for service Class 3 (wet condition) and with no reduction for line loads.

Hence $K_{52} = 1.25$, $K_{53} = 0.7$ and $K_{54} = 1.00$

The minimum penetration of a screw should be 15mm.

To assist designers, the basic withdrawal load (F) per millimetre of penetration for common sizes of wood screws in pre-drilled holes are shown in Table 4 for different strength classes of timber.

Table 4. Basic Withdrawal Load (F) per millimetre of penetration in N/mm

	Strength Class of timber		
Screw Diameter (mm)	C16	C24	C27
3	10.8	13.1	14.6
3.5	12.2	14.7	16.3
4	13.5	16.3	18.1
4.5	14.7	17.8	19.7
5	15.9	19.2	21.3
5.5	17.1	20.7	22.9
6	18.2	22.1	24.5
7	20.5	24.8	27.5

Notes: *(1) The total withdrawal load should not exceed the tensile strength of the screw.*
(2) Based on Table 67 of BS 5268-2:2002

As an example: The safe tensile capacity of a 5mm wood screw fixing attached onto a section of C16 timber with an expected penetration of 50mm, using Table 4 and Equation 1 would be:

$$F_{adm} = F \times K_{52} \times K_{53} \times K_{54} \times l = 15.9 \times 1.25 \times 0.7 \times 1.00 \times 50 = 696\ \text{N} = 0.696\ \text{kN}$$

Where hoardings are expected to be in position for some time using wood based facing products, the use of screws as fixings can become unsafe, hence the need for regular inspections.

The change in thickness of the panel by prolonged periods of wet and dry with changes in moisture content cause swelling and subsequent shrinkage on drying. This can change the effectiveness of the screw over time.

Where proprietary fittings / connectors are used forming part of the structure supporting a hoarding, they should have a rated safe working load/ characteristic strength in accordance with the requirements of the design.

5.5 Scaffold and Proprietary Equipment

Scaffold and proprietary equipment should be clearly and readily identifiable by shape or size. Where this is not possible they should be marked.

Scaffolding equipment should conform to current recommendations. Useful guidance is given by the National Access and Scaffolding Confederation (NASC) in publications such as TG20:13 and SG4:10. The safe working loads stated for steel scaffold tube and fittings given in TG20:13 may be used for design of hoardings without modification. It is a recommendation of this TWf Guidance that BS EN 39 Type 4 scaffold tubes in the galvanised condition be used in the construction of hoardings.

Information necessary for the design, erection, use, maintenance and dismantling of the proprietary equipment used in the construction of hoardings should be made available. The supplier / manufacturer has a duty in Law to provide data about the product, together with any limitations and requirements affecting the safety of the product. Any particular inspection regimes should be made known to the user.

The recommendations of the supplier should be followed and communicated, as relevant, to the site team. A typical proprietary hoarding incorporating advertising is shown at Figure 10.

If the stability of a proprietary hoarding system is based on tests, the user must ensure that the tests accurately reflect the design loads established from appropriate standards, codes or by using this TWf guidance . The user must also ensure that the proprietary system when erected does not exceed the conditions or arrangements for which the testing was carried out.

6.0 Verification of design

The design of a site hoarding and its foundations should either be to a recognised code, in accordance with fundamental design principles, or in accordance with the design principles outlined in this guidance note.

The design of all hoardings should be checked and a relevant design check certificate be issued. The categories of design check are outlined in BS 5975:2019, Clause 13.7 and listed in Table 2 to that standard. The design check should not be regarded as an onerous task; it is a verification that an independent person (not the actual designer) has carried out a check.

Fig 10. Typical Proprietary Hoarding with Advertising Panels

On a simple hoarding, built to a standard solution, the design would involve ensuring the standard solution was suitable for the site, location and height envisaged, and that the correct data table and/or solution has been used. More complex hoardings would require a greater degree of independence of check.

Where proprietary products are used, the supplier should have already arranged for a structural engineer to certify that the design meets the requirements and a design check certificate issued. Note that the end user would not require to necessarily have access to the suppliers method of verification and certificates. However, it is necessary for the user to ensure that the product is being used as intended, and that the circumstances of use agree with the design assumptions for the hoarding stated in the design brief. An inspection should ensure that the hoarding has been assembled in accordance with the instructions provided.

7.0 Site specific issues

7.1 Workmanship

The quality of workmanship should be to recognised works standards. Operatives assembling and erecting hoardings should be competent and be aware of correct good practice.

Some examples to be considered would include:

- where using timber posts in holes with concrete, remembering to place the post first, and then place the concrete surround,
- ensure the orientation of the facing material is as intended,
- fixings are used as designed,
- more fixings and usually closer post centres near to the ends of hoardings and access openings where the wind loads are larger.

7.2 Inspection in use

All hoardings should be regularly inspected during their working life. At the time of erection of the hoarding the requirement for regular inspection and timings of such inspections should be specified, and is usually a requirement in the initial risk assessment. The maximum period between formal inspections of hoardings should be six months, although in many applications, with fast changing construction processes inspections may require to be more frequent. Additional inspections should be carried out after any exceptional event such as high winds or impact. An inspection plan should be produced and maintenance/replacement carried out as necessary.

It is accepted engineering practice that the design life of a structure can be extended by regular inspections. These more detailed regular inspections should also be agreed at an early stage in the use of the hoarding. Such inspections would be carried out by competent person(s) who have the ability to inspect the critical areas of the structure.

Where the hoarding is designed with diagonal stays, there is always the risk that the stays might be removed by operators, for example to give clearance for a forklift unloading pallets etc. Particular care is required to ensure that such stays are not displaced or removed, making routine observations/inspections more important.

7.3 Access points

Hoardings require openings for access, either personnel and/or vehicular. Site gates with solid panels pick up large wind loads and consideration should be given to use of open mesh panels to reduce the loads; however security concerns have to be addressed.

The gates should be securely fixed when closed and should incorporate a restraint chain or similar to prevent the gate from swinging out beyond the site boundary when not in use.

Particular care is needed in the design of the likely loads on the hoarding posts supporting the gates. When the gates are open there will be loads on to the gate posts acting orthogonal to the hoarding; a different loading case to that when the gates are closed. Often steel square hollow sections are used for gate posts due to the increased strength and stiffness (when compared to timber posts) and facilitate welding of gate hinges to them.

If solid gates are to be used then the weight of the gates and wind loading should be considered for the design of the posts, hinges and any welding. These can act in orthogonal directions depending on whether the gates are open or closed. There are a number of examples where these connection details have failed with a potential to cause serious injury.

APPENDIX A – Design Documents Covering Associated Structures

Part One – British Standards		
1	Eurocodes (BS EN1990-1997)	The Structural Eurocodes cover hoardings (in the sense that they are structures). Several parts of the ENs are required as listed below. Unlikely to be user friendly for this scale of structure.
2	BS EN 1990:2002+A1:2005 – Eurocode – Basis of structural design.	This gives the fundamental formulae and factors used in limit state design. Should be read in conjunction with the UK NA.
3	BS EN 1991-1-4:2005+A1:2010 Eurocode 1: Actions on structures – General actions – Wind Actions	Section 7.4.1 gives information on wind on freestanding walls and returns. Gives design information for wind loads, to be read in conjunction with the NA.
4	BS EN 1991-2:2003 Eurocode 1. Actions on structures. Traffic load on bridges.	Section 6.6 gives information to calculate the dynamic pressure on vertical surfaces parallel to railway tracks.
5	BS 5975:2019 Code of practice for temporary works procedures and the permissible stress design of falsework	Section 2 on procedural control of temporary works Section 17.5.1 Wind loading – details the simplified method of wind loads using BS EN 1991-1-4:2008+A1:2010
6	BS 1722-5:2006+A1:2018 Fencing – Specification for Close Boarded and wooden Pallisade Fences.	Specification for post and rail solid fencing up to 1.80 m high using either concrete or timber posts. Installation guidance included, but no design data.
7	BS EN 335-2:2013 Durability of wood and wood-based panels – definitions of use classes	Gives classes of use in relation to biological agents that attack wood.
8	BS EN 350-2:2016 Durability of wood and wood-based panels – Natural durability of solid wood	Tables on natural durability and treatability of selected wood species.
9	BS 6180:2011 Barriers in and about buildings – code of practice	Gives a range of barrier load options; particularly relevant for hoardings. Values from Table 2 are used in this guidance.
10	BS 5268-2:2002 with AMD 1 (2007) Structural Use of Timber	Permissible stress design code, materials, workmanship and fixings. (Withdrawn in 2010 on publication of limit state BS EN 1995)
11	BS EN 338:2016 Structural Timber – Strength Classes	Characteristic strength classes for softwood and hardwood timber
12	PD 6547:2004 + A1:2009 Guidance on the use of BS EN 40-3-1 and BS EN 40-3-3	Section 6 gives guidance on planting depths for lighting columns by introducing a Ground Factor for Good, Average or Poor conditions.
13	BS EN 13200-3:2018 Spectator Facilities – Part 3: Separating elements - requirements	Design requirements for permanent and temporary separating elements and barriers for spectator events, indoor and outdoor. Includes crush loading and line load values.
14	BS 559:2009 Specification for the design and construction of signs for publicity, decorative and general purposes.	Service life, materials, design, wind and foundation requirements. Includes illuminated signs.

APPENDIX A – Design Documents Covering Associated Structures – continued

Part Two – Other Documents		
15	HA 66/95. Environmental Barriers: Technical Requirements (Vol 10, Section 5 of the Design Manual for Roads and Bridges)	Background only as this does not reflect current codes. Appendix C has simple method of calculating post embedment.
16	National Access and Scaffolding Confederation, TG20/13 Tube and Fitting Scaffolding and Supplement 1	No specific mention of hoardings, but Supplement 1 gives latest method to determine the wind factor S_{wind} used in the calculations.
17	Construction (Design and Management) Regulations 2015	Managing health and safety in construction, Guidance on Regulations, L153 Available (free) from: https://www.hse.gov.uk/pubns/priced/l153.pdf
18	International Union of Railways UIC Code 779-1 Safety of railways	Guidance on slipstream of passing trains on adjacent structures
19	The Concrete Society, Formwork – a guide to good practice: 3rd Edition (2012) – Environmental loads.	Section 4.5 discusses effect of wind on wall formwork both freestanding on the ground and on a suspended slab.
20	Pile Design and Construction Practice, 5th Edition by M.J. Tomlinson & J. Woodward	Pages 327 – 335 give the "Brinch Hansen" method of ultimate resistance of short rigid piles subjected to lateral loads. Needs a spreadsheet to use and time consuming. Needs accurate knowledge of soil parameters.
21	Timber Research and Development Association, GD2 How to calculate the design value of loads using Eurocodes 2006	Although written primarily to assist timber designers to understand Eurocode 5, this document is background reading for limit state design concepts, and explains the notation used in Eurocodes.
22	Wind microclimate around buildings, Building Research Establishment Publication DG520, P Blackmore, 2011	Tall buildings can deflect high-level wind down towards the ground, producing unpleasant and sometimes dangerous wind conditions in adjoining pedestrian areas. Available from https://www.brebookshop.com
23	UK Wind Engineering Society (WES)	A Specialist Knowledge Society of the Institution of Civil Engineers (ICE) that exists to promote cooperation in the advancement and application of knowledge in all aspects of wind engineering.
24	SCOSS Alert, Wind adjacent to tall buildings, Structural-Safety, December 2015	Temporary structures adjacent to tall buildings may be particularly prone to adverse wind effects by virtue of their relative position. Available from: https://www.structural-safety.org/media/386216/scoss-alert-wind-adjacent-to-tall-buildings-december-2015-final-2-.pdf
25	Managing Health & Safety Risks (No. 46): Safety issues in high-rise construction The Structural Engineer, Volume 93, Issue 12, December 2015, IStructE	When very tall buildings are being designed, constructed or modified, a number of standard hazards become exaggerated and require special attention. Available from: https://www.istructe.org/journal/volumes/volume-93-(2015)/issue-12/professional-guidance-managing-health-safety-ri/
26	Temporary works hoardings, DRG 115:2016 (NFDC)	Available from: https://demolition-nfdc.com/download/temporary-works-hoardings/

APPENDIX B – Design Considerations – Wind on Hoardings

B.1 General

Where hoardings are subjected to the wind a full design to BS EN 1991-1-4:2005+A1:2010 and the UK National Annex to that standard is rarely justified.

This TWf Guidance recommends the use of the simplified method given in BS 5975: 2019 provided due consideration is given to the life of the hoarding.

This Appendix outlines the simplified method and gives recommendations on the factors to be used. The use of this simplified method generates conservative values of the wind force on to the hoarding except in extremely onerous site conditions.

B.2 Maximum wind force on hoardings

The calculation of the maximum wind force applied to a hoarding is given by the expression:

$F_W = q_p \times A_{ref} \times c_{p,net} \times \eta$ [Equation B.1]

where;

F_w is the maximum wind force on the structure in N

q_p is the peak velocity pressure in N/m^2 – see B.3

$c_{p,net}$ is the net pressure coefficient – see B.6

A_{ref} is the reference area on which the wind acts in m^2

η is the shielding factor, generally taken as 1.0 for hoardings

For simplicity of calculation, the wind may be considered as blowing only in the directions at right angles to the axis of the hoarding.

B.3 Working wind force on hoardings

A maximum working wind force is considered in permissible stress design, see Section 4.4 and Table 1, is assessed as the maximum velocity pressure during which operations can take place.

In the UK this is normally limited to a wind of Beaufort Scale 6 and represents a velocity pressure of 200 N/m^2.

Note: *At this wind pressure, standing upright unaided is difficult.*

The calculation of the maximum working wind force applied to a hoarding is given by the expression:

$F_{Work} = 200 \times A_{ref} \times c_{p,net} \times \eta$ [Equation B.2]

Where;

F_{work} is the maximum working wind force on the structure in N

$c_{p,net}$ is the net pressure coefficient – see B.6

A_{ref} is the reference area on which the wind acts in m^2

η is the shielding factor, generally taken as 1.0 for hoardings

B.4 Calculation of the peak velocity pressure

The peak velocity pressure, formerly called dynamic pressure, for hoardings is given by:

$q_p = 0.613 \times c^2_{prob} \times C_{ef} \times S^2_{wind}$ [Equation B.3]

Where;

q_p is the peak velocity pressure (N/m2)

c_{prob} is the probability factor for hoardings erected:

longer than one year's use $c_{prob} = 1.00$

C_{ef} is the combined exposure factor - See B.5

S_{wind} is the wind factor – See either BS 5975:2019, Clause 17.5.1.3, or Formwork Guide, Clause 4.5.1.6

The basic values of wind velocity in BS EN 1991-1-4 assume a mean return period of 50 years.

To take account of a structure being erected for a shorter period, and therefore less likely to be exposed to the peak wind, a probability factor c_{prob} is introduced. (BS EN 1991-1-6: 2005, Table 3.1). This TWf Guidance recommends that the normal duration of a hoarding is greater than one year, giving a return period of 50 years, unless specified otherwise in the design brief.

Users should be aware of the risk of using a lower probability factor in consideration of the site hoarding whenever there is a likelihood of delays and the construction time being extended – if in any doubt, then the design brief should specify a value of $c_{prob} = 1.00$

The peak velocity pressure is considered to act over the whole area of the hoarding.

Table B.1. Combined exposure factor, C_{ef}

Hoarding Height (m)	Site in country and adjacent to sea				Site in town, more than 2km from the edge of town		
	Closest distance to the shoreline (km)				Distance to shoreline (km)		
	≤ 0.1	2	10	≥ 100	2	10	≥ 100
≤ 2.0	1.90	1.60	1.50	1.40	1.07	1.01	0.94
2.5	2.03	1.72	1.62	1.51	1.20	1.13	1.06
3.0	2.15	1.84	1.73	1.62	1.32	1.25	1.17
3.5	2.23	1.94	1.82	1.70	1.43	1.35	1.26
4.0	2.31	2.03	1.90	1.78	1.54	1.44	1.35

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

B.5 Combined exposure factor (C_{ef})

The exposure of the site affects the wind velocity, being higher by the sea, than in a town. Table B.1 gives values of a combined exposure factor C_{ef} and includes the relevant correction factor for towns.

A town is considered if the site is situated more than 2 km inside the edge of the town with separations between buildings/trees less than 20 obstacle heights apart. If you have an open area of more than 20 obstacle heights in front of the structure, then the wind picks up speed across the opening and you are 'in the country'! Where a town is by the sea or a lake, the first 2 km from the sea or lake are considered as country and adjacent to the sea.

B.6 The net pressure coefficient $c_{p,net}$

The force applied to a structure by a given peak velocity pressure depends on the shape of the structure and how the wind is constrained to flow around it. Depending on the shape, the wind speed increases and decreases in different regions giving areas of higher and lower pressure, and therefore of differing force. These differences are taken into account using the net pressure coefficient ($c_{p,net}$). The term net pressure coefficient is the summation of the pressure on the windward side plus the drag on the leeward side of the hoarding; the term is effectively interchangeable with the term force coefficient. This TWf Guidance refers to 'net pressure coefficients'.

The net pressure coefficients ($c_{p,net}$) for freestanding hoardings erected on or near the ground should be taken from Table B.2. To cater for the increased wind force near the ends of hoardings, four zones have been assumed. The zones near to the ends of the hoarding are considered to have a larger value of net pressure coefficient. This is shown diagrammatically in Figure B.1. Where the hoarding returns around a corner the wind regime changes and values for returns greater than the hoarding height are shown in Table B.2 This method is similar to the design of permanent walls in BS EN 1991-1-4.

Table B.2. Net pressure coefficients for freestanding hoardings erected on the ground $c_{p,net}$

ZONE Considered	Without returns			With return corner of length > h
	Ratio $\frac{l}{h} = \frac{\text{effective length}}{\text{hoarding height}}$			
	≤3	5	≥10	
A	2.3	2.9	3.4	2.1
B	1.4	1.8	2.1	1.8
C	1.2	1.4	1.7	1.4
D	1.2	1.2	1.2	1.2

Notes: *(1) The hoarding is impervious (solid) and erected on or near the ground level.*
(2) Effective length/height is the combined dimension of hoarding that creates a continuous barrier to the wind.
(3) The location of zones is illustrated in Figure B.1.
(4) Values for hoardings may be interpolated provided the solidity ratio is between 0.8 and 1.0 (solid).

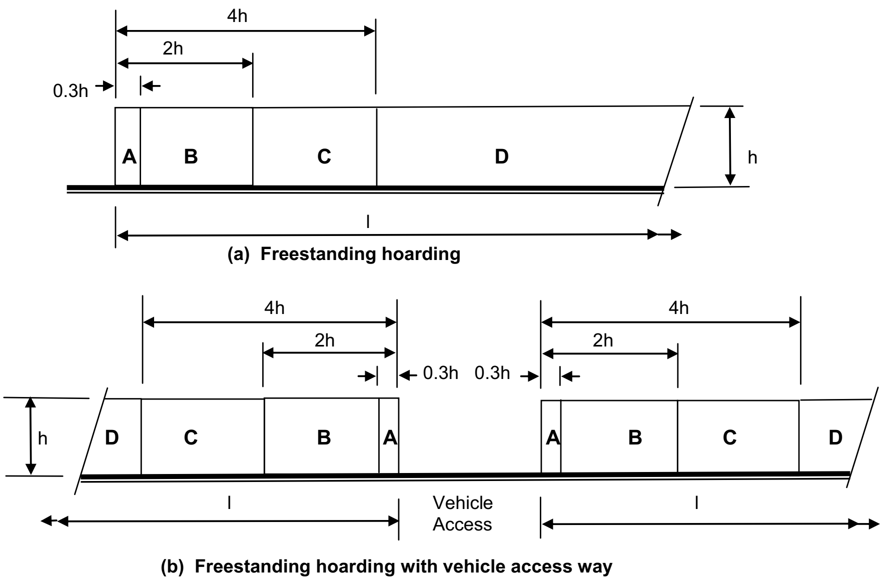


Figure B.1 Key to zones for hoardings

To simplify the design, engineering judgement may be used to rationalise the net pressure coefficients in the Zones. When considering the face material fixing then critical Zone A should be used for the areas adjacent to the hoarding end.

Where there are vehicular wide access ways through the hoarding it would be prudent to design the hoarding as separate structures, i.e. the access way creates two "ends" in the hoarding. See Figure B.1 (b). Where pedestrian access doorways are included in a hoarding structure, engineering judgement can be used and the hoarding considered as a continuous solid structure with relevant net pressure coefficients related to the doorway zone.

Where a hoarding is erected in front of a large building, then the wind is stalled. The wind blowing onto the hoarding creates a pressure. Where the hoarding is connected to the building the wind force is resisted by the existing building. Where the wind blows from behind the building a suction (drag) force is generated on the hoarding, pulling it away from the building. The magnitude of the forces is also affected by how close the hoarding is erected in front of the building. Effectively the hoarding will be subjected to similar wind forces to that of the permanent building; parts of the hoardings becoming the external wall of the building. The values of external pressure coefficients for vertical walls of rectangular buildings are given in Table NA.4 of the NA to BS EN 1991-1-4:2005+A1:2010. The sign convention is that a coefficient shown as a negative value indicates it is a suction (drag) value. Any fixing to the building and the floor/ pavement needs to be designed to transfer this force. The components of the hoarding also need to resist the suction force.

Where hoardings are erected in floors of multi storey buildings, the wind is able to pass around and possibly below the hoarding, and different wind conditions and coefficients apply. Some guidance is given in Section 4.5.1.12 of 'Formwork – A guide to good practice (3rd Edition)'.

APPENDIX C – Working Structural Properties of Timber for Hoardings

Table C1. Softwood : Hoarding Application

Permissible Stresses	Strength Class	Basic Size – square			Basic Size - rectangular						
		Rail	Post		Rail		Post				
		75 x 75	100 x 100	150 x 150	100 x 50	100 x 75	75 x 100	100 x 125	75 x 150	75 x 225	100 x 200
Moment of Resistance f Z K_7 K_8 (kNm)	C16	0.538	1.274	4.069	0.299	0.702	0.945	1.934	2.02	4.448	4.769
	C24	0.761	1.802	5.758	0.423	0.993	1.338	2.737	2.859	6.294	6.749
	C27[4]	0.964	2.283	7.293	0.536	1.258	1.695	3.466	3.621	7.973	8.549
Shear Load q A K_8 (kN)	C16	5.46	9.91	22.15	4.80	7.36	7.36	12.36	11.00	16.69	19.92
	C24	5.81	10.54	23.55	5.11	7.82	7.82	13.15	11.69	17.74	21.19
	C27[4]	8.99	16.31	36.44	7.90	12.11	12.11	20.34	18.10	27.46	32.79
Bending Stiffness EI (kN/m²)	C16	10.39	34.23	170.93	3.89	14.00	25.41	66.45	84.87	296.44	278.11
	C24	12.90	42.49	212.18	4.83	17.38	31.54	82.48	105.36	368.00	345.24
	C27[4]	14.69	48.40	241.65	5.51	19.79	35.92	93.94	119.99	419.11	393.19
Bearing Stress (kN/m²)	C16	3,160 (2,440 with wane)									
	C24	3,450 (2,730 with wane)									
	C27[4]	3,590 (2,870 with wane)									

Notes: *(1) Assumes sawn softwood structural timber is used.*

(2) Structural properties of timber are based on the permissible stresses and moduli from Table 3 appropriate for hoarding applications in the UK.

(3) The section sizes are the commonly available target sizes stated in Table NA.2 of BS EN 336: 2003 See Table C2. (It is noted that there is no National Annex in BS EN 336: 2013).

(4) In the UK the target sizes stated are commonly available in strength classes C16 and C24.

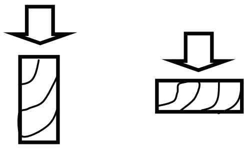
(5) The timber has been accepted as appropriate to the class concerned, has not been reduced in cross section and is still in good condition.

(6) The load duration factor (K_3) has been taken as 1.75 for hoardings based on very short term loading.

(7) There is an assumed minimum 75mm of end bearing where using rails. Where wane is permitted in the grading, use the values for bearing shown in the brackets.

(8) Maximum permitted shear stress values have been increased by a factor of 1.5 in accordance with BS 5975:2019, Clause 16.4.2.8. The values for basic stress parallel to the grain given may be increased by a factor of 1.5 to give the permissible shear stress for timber in temporary works applications. This factor was first introduced in BS 5975:1982. It is noted that this additional factor should not be confused with the 1.5 factor to convert average stress to maximum shear stress on parabolic distributions.

The orientation of rectangular timber members is important, and Table C1 gives values for rectangular timber for both the “strong” and “weak” way around for the smaller sizes commonly used as the horizontal rails. For example the 100 x 75 mm timber when used as a structural beam is assumed to have the 100mm side vertical (Strong); it is considerably weaker when used “on the flat”. In hoardings the principle design load is the lateral wind or crowd load and the rails are generally fitted with the long side vertically, but loaded horizontally, i.e. with the 75mm side horizontal (i.e. in the Weak direction). See sketch.



Strong **Weak**

It is assumed that constructional sawn softwood is used. The EN convention is that the width is stated first, and depth second.

The size of timber is normally based on its size measured at 20% moisture content, and the European standard for coniferous and poplar structural timber, BS EN 336, assumes that the thickness and width of a piece of timber can be increased by 0.25% for every 1% of moisture content greater than 20% up to 30%, and decrease by 0.25% for every 1% of moisture content lower than 20% moisture content. These values are typical without regard to the species of softwood timber.

Table C2. Geometric Properties and Depth Factor for Timbers

Nominal Size	Units	Basic Size – square			Basic Size - rectangular						
		Rail	Post		Rail		Post				
		75 x 75	100 x 100	150 x 150	100 x 50	100 x 75	75 x 100	100 x 125	75 x 150	75 x 225	100 x 200
Finished Size	mm	72 x 72	97 x 97	145 x 145	97 x 47	97 x 72	72 x 97	97 x 121	72 x 145	72 x 220	97 x 195
Area (A)	mm^2	5,184	9,409	21,025	4,559	6,984	6,984	11,737	10,440	15,840	18,915
Section Modulus (Z)	mm^3	62.2 x 10^3	152.1 x 10^3	508.1 x 10^3	35.7 x 10^3	83.8 x 10^3	112.9 x 10^3	236.7 x 10^3	252.3 x 10^3	580.8 x 10^3	614.7 x 10^3
Moment of Inertia (I)	mm^4	2.24 x 10^6	7.38 x 10^6	36.8 x 10^6	0.84 x 10^6	3.02 x 10^6	5.48 x 10^6	14.32 x 10^6	18.29 x 10^6	63.89 x 10^6	59.94 x 10^6
Depth Factor	K_7	1.165	1.128	1.079	1.128	1.128	1.128	1.101	1.079	1.032	1.046
Approxi-mate Weight (kg/m)	C16	1.92	3.48	7.78	1.69	2.58	2.58	4.34	3.86	5.86	7.00
	C24	2.18	3.95	8.83	1.92	2.93	2.93	4.93	4.39	6.65	7.94
	C27	2.33	4.23	9.46	2.05	3.14	3.14	5.28	4.70	7.13	8.51

Notes:
(1) The depth factor (K_7) assumes the timber largest dimension refers when using depth factor formula. See *Section 4.7.2 (e).*
(2) The approximate weight is calculated assuming the mean density based on the finished size stated.
(3) The finished size of timber assumed is the target size finished by planing two opposing faces from Table NA.4 of BS EN 1313-1:1997 (It is noted that there is no National Annex in BS EN 1313-1:2010).

APPENDIX D – Post planting depths for hoardings using PD 6547

D.1 General method

The TWf Guidance at Section 4.8.2 recommended the use of the simplified method given in Section 6 of PD 6547:2004+A1:2009 for calculating the planting depth of timber hoarding posts. The designer will have established the post centres, and calculated the design overturning moment (M_o) and shear force (Q_o) for the post, see Section 4.5, and will also have selected the optimum size of post. The working structural properties of common timber post sizes are stated in Appendix C.

The method assumes that the overturning moment on the hoarding is resisted by a rigid block of concrete that rotates about a fulcrum point in the ground, as illustrated in Figure D1. The fulcrum point for the ground resistance is considered to act at a level below the ground level of 0.707 x planting depth. The ground resistance moment (M_g) is given by the equation:

$$\mathbf{M}_g = \frac{G \times D \times P^3}{10}$$

[Equation D1]

Where;

M_g is the ground resistance moment (in kNm)

G is the Ground Factor (in kN/m²) (see Table D1)

D is the minimum effective width of the concreted foundation in metres

P is the planting depth of the post from ground level in metres.

The planting depth (P) varies depending on the ground conditions and the diameter of the effective post hole (D). The three ground conditions used in the method are stated in Table D1. In hoarding design, the effective post hole considered is the width of the concreted hole that provides the ground restraint - typically between 300 to 400mm wide holes are excavated, filled with the post and then concreted. It is noted that these holes could be dug as square, or be circular if augered.

The effect of the applied loads and the design representation are illustrated in Figure D1. The design needs to take account of the overall factor of safety on stability (minimum 1.5 see Section 4.8.2.1), hence the post is stable if the following criteria is met:

$$M_g \geq \{ M_o + (0.707 \times Q_o \times P) \} \times 1.5$$

[Equation D2]

Where;

M_g is the ground resistance moment (in kNm) from Equation D1

M_o is the critical overturning moment about the ground level from the applied wind and minimum / crowd overturning moment (in kNm). See Section 4.5

Q_o is the critical horizontal shear force at ground level from the applied wind

and minimum notional / crowd loading (in kN) See Section 4.5

P is the planting depth of the post from ground level in metres.

1.5 is the minimum factor of safety on overturning of the foundation. See 4.8.2.1

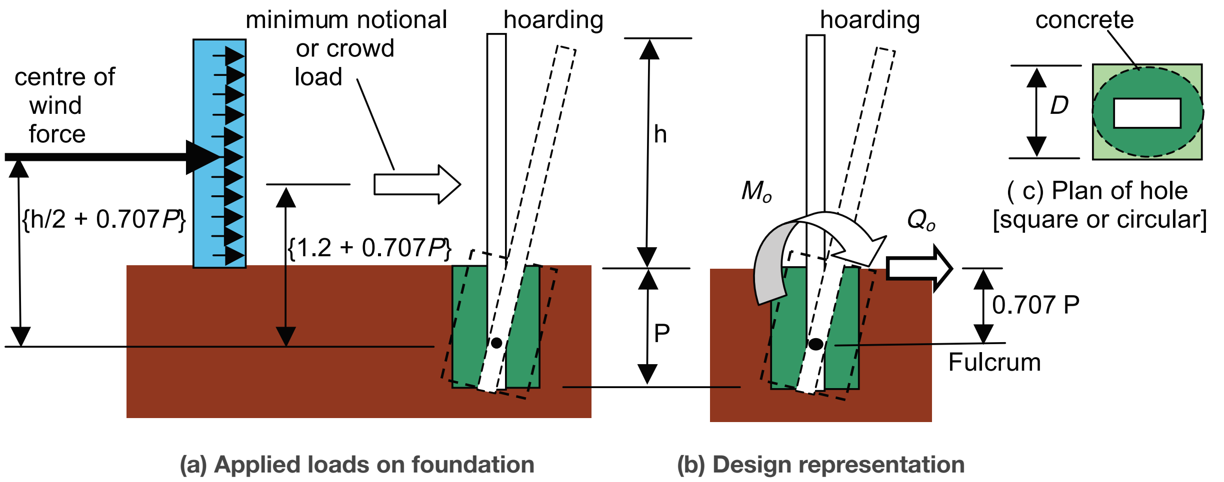


Fig D1 - Post foundation

Note: *Figure D1 assumes that full passive resistance of the soil can be mobilised. Appendix F provides guidance on where this is not the case.*

Table D1. Ground classification

Classification	Quality of the ground	G (kN/m2)
Good	Compact, well graded sand and gravel, hard clay, well-graded fine and coarse sand, decomposed granite rock and soil. Good soils drain well.	630
Average	Compact fine sand, medium clay, compacted well-drained sandy loam, loose coarse sand and gravel. Average soils drain sufficiently well that water does not stand on the surface.	390
Poor	Soft clay, clay loam, poorly compacted sands, clays containing a large amount of silt and vegetable matter, and made-up ground. Includes site placed backfill unless fully compacted. Poor soils are normally wet and have poor drainage.	230

Equations D1 and D2 cannot be solved to generate a simple formula for establishing the planting depth (P) for all cases of post. The designer will be aware of the moments, shear force and ground conditions, and by varying values of D can carry out an iterative trial and error calculation to establish a planting depth that satisfies Equation D2.

The three ground conditions used in the method, and the ground factor (G) used in Equation D1 are stated in Table D1.

D.2 Post planting depth for hoardings up to 2.5m high

Inspection of Figure 4 shows that if the hoarding height were h = 2.44m, then the centre of wind force and the lateral minimum/crowd loading are almost coincidental. As the most common hoarding size is based on a single 8’-0” wood based sheet material placed vertically, i.e. 2.44m, then it is possible to reconcile Equations D1 and D2 and create tables of planting depths.

Tables D2 states the minimum planting depths for timber posts used on up to 2.5m high hoardings based on the moment capacity of the post size stated in Appendix C assuming a 300mm width of effective concreted hole.

Table D2. Planting depth (mm) for hoardings less than 2.5m high using a 300mm wide hole

Ground Condition	Timber Hoarding Post											
	100 x 100		150 x 150		100 x 125		75 x 150		75 x 225		100 x 200	
	C16	C24	C16	C24	C16	C24	C16	C24	C16	C24	C16	C24
Good	500	600	800	900	600	700	600	700	800	950	850	950
Average	600	700	950	n/a	700	800	750	850	1000	n/a	1000	n/a
Poor	750	850	n/a	n/a	850	1000	900	1000	n/a	n/a	n/a	n/a

Notes: *(1) Assumes timber post is surrounded by concrete of effective width 300 mm.*
(2) Factor of safety of 1.5 applied to the post moment – see 4.8.2.1
(3) Ground condition as appropriate – see Table D1
(4) Notation n/a indicates that ground resistance not sufficient for loaded condition.

Where the effective hole width increases to 400mm, the planting depth is reduced, and Table D3 states the minimum planting depths for timber posts used on hoardings up to 2.5m.

Table D3. Planting depth (mm) for hoardings less than 2.5m high using a 400mm wide hole

Ground Condition	Timber Hoarding Post											
	100 x 100		150 x 150		100 x 125		75 x 150		75 x 225		100 x 200	
	C16	C24	C16	C24	C16	C24	C16	C24	C16	C24	C16	C24
Good	450	550	700	800	550	600	550	650	750	850	750	850
Average	550	650	850	950	650	750	650	750	900	1000	900	1000
Poor	650	750	1000	n/a	800	900	800	900	n/a	n/a	n/a	n/a

Notes: *(1) Assumes timber post is surrounded by concrete of effective width 400 mm.*
(2) Factor of safety of 1.5 applied to the post moment – see 4.8.2.1.
(3) Ground condition as appropriate – see Table D1
(4) Notation n/a indicates that ground resistance not sufficient for loaded condition.

Where the effective hole width increases to 500mm, the planting depth is further reduced, and Table D4 states the minimum planting depths for timber posts used on hoardings up to 2.5m.

Table D4. Planting depth (mm) for hoardings less than 2.5m high using a 500mm wide hole

Ground Condition	Timber Hoarding Post											
	100 x 100		150 x 150		100 x 125		75 x 150		75 x 225		100 x 200	
	C16	C24	C16	C24	C16	C24	C16	C24	C16	C24	C16	C24
Good	450	500	650	750	500	600	500	600	700	750	700	800
Average	500	600	800	900	600	650	600	700	800	900	850	950
Poor	600	700	950	1050	750	800	750	850	1000	1100	1000	n/a

Notes: *(1) Assumes timber post is surrounded by concrete of effective width 400 mm.*
(2) Factor of safety of 1.5 applied to the post moment – see 4.8.2.1.
(3) Ground condition as appropriate – see Table D1
(4) Notation n/a indicates that ground resistance not sufficient for loaded condition.

Where hoardings are shorter than 2.5m, say less than 1.75m in height, the resulting planting depths given in Tables D2, D3 and D4 are unlikely to be economical, and a separate design calculation would give a more reasonable planting depth.

Where hoardings are taller than 2.5m or ground conditions are not as classified in Table D1, or hole effective widths (D) differ from that stated, then a separate foundation design should be carried out as described at Section D1. Note that the basic design method using PD 6547 is also explained in detail in the worked example at Appendix E.

APPENDIX E – Worked Example of Hoarding Design – Post-in-hole

E.1 Introduction

It is proposed to design a timber hoarding with the post embedded in the ground using the recommendations of the TWF Guidance on Hoardings. The design will be to permissible stress codes. The foundation design will use the simplified method to determine planting depth given in PD 6547.

The calculations in the example are not necessarily complete for the entire hoarding, but demonstrate the recommended approach to the design. The source of the information and/or equations used is stated; these would not normally be included provided the actual documents used in the calculations are listed, with relevant dates, as E.3 below.

E.2 Design Brief

The project requires a freestanding site hoarding. The design brief, supplied by site, requirements are:-

- Site Location: Liverpool. The site is located in town, approximately 6 km from the sea.
- Topography: flat townscape, no hills.
- Site altitude = 55m

  Height of Hoarding required: 2.44m (i.e. one 8'-0" sheet)
- Length of hoarding: 20m + 20m
- In plan the hoarding will be L–shaped with both ends butting up to an existing chain-link fence.
- The site is adjacent to a normal width pavement adjacent to an existing road. Site have advised there is nominal public pedestrian movements.
- No specific crowd loading is stated.
- Site have advised there are no services in the area where the hoarding is to be located.
- The ground has been described as 100mm of topsoil overlying firm to stiff clay. There is no ground water. The top soil will be stripped prior to installing the hoarding.
- The hoarding will be in place for approximately 18 months. Hence, use c_{prob} = 1.0.
- The preferred facing material for the hoarding is Oriented Strand Board (OSB).
- Site have 75 x 225 C24 constructional sawn timber posts available.

E.3. Documents used

TWf2012:01 Hoardings – A guide to good practice – August 2020

PD 6547:2004 + A1:2009 Guidance on the use of BS EN 40-3-1 and BS EN 40-3-3

BS 5975:2019 Code of practice for temporary works procedures and the permissible stress design of falsework

Ordnance Survey Mapping

Appendix E. Worked Example – continued

Calculation	Source / Output
E.4 Loading **E.4.1 Minimum notional horizontal load** As crowd loading not considered significant in the design brief, the minimum notional horizontal load applied to hoarding is 0.74 kN/m acting 1.2m above the base. (4.2.1)	Hoardings 4.2.1 Minimum notional horizontal load 0.74 kN/m
E.4.2 Wind loading Site post code: - Liverpool From Ordnance Survey Map site Altitude = 55m and the site is not topographically significant (i.e. flat area). Site is approximately 6km from the coast. The site is located in town.	
Fundamental basic wind velocity for Liverpool $v_{b,map}$ = 23m/s	BS 5975 Figure 8
Topographical factor T_{wind} = 1.0	BS 5975 Figure 9
Altitude stated in brief A = 55m	
Wind factor $S_{wind} = T_{wind} \times v_{b,map} \times (1 + (A/1000))$ $= 1.0 \times 23 \times (1 + (55/1000))$ $= 24.27$m/s	S_{wind} 24.27 m/s
Probability factor for period less than two years c_{prob} = 1.0	Hoardings B.4
Combined exposure factor for Site in town and stated about 6km from sea. Hence interpolating in table for 6km distance from sea gives for hoarding height of approximately 2.5m a C_{ef} = 1.165.	Hoardings Table B.1
Peak velocity pressure $q_P = 0.613\ c^2_{prob}\ C_{ef}\ S^2_{wind}$ $= 0.613 \times 1.0^2 \times 1.165 \times 24.27^2$ = 421 N/m² = 0.421 kN/m²	Hoardings B.4 q_p=0.421 kN/m²
Net pressure coefficients ($c_{p,net}$): To simplify the design, the design assumes each end of the hoarding as freestanding and ignore the return corner Ratio of effective length/ height= l / h = 20 / 2.44 = 8.2 As the hoarding is solid, the values of $c_{p,net}$ for each zone may be linearly interpolated from Table B.2 Zone A $c_{p,net}$ = 3.2 Zone B $c_{p,net}$ = 2.0 Zone C $c_{p,net}$ = 1.6 Zone D $c_{p,net}$ = 1.2	Hoardings Table B.2
Design philosophy - The ratio of length/height is 8.2h, and as overall length is about (2 x 4h), Zone D is not applicable in this example. Hence design the first 10m (4h) of the hoarding from end or return for $c_{p,net}$ for Zone B. Zone A is excluded in the post and rail calculations as the end post supports less face area of the hoarding. The connections are designed for Zone A. For simplicity Zone C is ignored. **Note to calculations:** If the hoarding is longer than 8h, then additional calculations for Zones C and D, using the methods shown, may be justified for economy.	Hoardings B.6
Net pressure coefficient for Zone B is $c_{p.net}$ = 2.0	$c_{p,net}$ = 2.0

Appendix E. Worked Example – E.4.2 continued

Calculation	Source / Output
Maximum wind force $F_W = q_p \times A_{ref} \times c_{p,net} \times \eta$ The reference area on which the wind acts in m² is 2.44 x 1 m² per metre The shielding factor η is assumed 1.0 Hence F_w = 0.421 x (2.44 x 1.0) x 2.0 x 1.0 = 2.055 kN/metre run Force acts at half height, i.e. 2.44/2 = 1.22m above ground	Hoardings B.2 Maximum Wind Force 2.055 kN/m
Working wind force $F_{Work} = 200 \times A_{ref} \times c_{p,net} \times \eta$ Hence F_{Work} = 200 x (2.4 4 x 1.0) x 2.0 x 1.0 = 976 N/m = 0.98 kN/metre	Hoardings B.3 Working Wind 0.98 kN/m
E.4.3 Face material loading Design panels for robustness as a local area loading of 1.5 kN/m². For simplicity of design this value is considered over the full height of the panel. The overturning effect of the self-weight of the face material, fitted to the public side of the posts, is ignored. **Note to calculations:** This adds about 3% to the overall overturning effect, and because it acts in opposite direction to the crowd load is a stabilising load!	Hoardings 4.2.4 Hoardings 4.4
E.5 Hoarding design **E.5.1 Load combinations** As there is no specific crowd load stated in the design brief (E.2), consider the worst combination cases of either LC1, LC2 or LC3, LC4. Consider overturning moment about base per metre run of hoarding	Hoardings Table 1
LC1 100% maximum wind = 2.055 x (2.44/2) = 2.51 kNm / m run **LC2** 100% working wind + 100% minimum notional horizontal load (100% x 0.98 x (2.44/2)) + (100% 0.74 x 1.2) = 2.08 kNm / m run **LC3** = LC1 = 100% maximum wind = 2.51 kNm / m run **LC4** = LC2 = 2.08 kNm / m run Design on overturning moment M_o = 2.51 kNm / m run This is in both directions as LC1 = LC3	Overturning Moment 2.51 kNm/m
Consider shear force in base from loading cases per metre run of hoarding LC1 = LC3 maximum wind = 2.055 kN / m run LC2 = LC4 working wind + min. notional horizontal = 0.98 + 0.74 = 1.72 kN Maximum shear force per metre is Q_o = 2.055 kN / m run	Shear Force 2.055 kN/m
E.5.2 Timber posts Site intend to use 75 x 225 C24 constructional sawn timber posts as available on site. Check suitability with properties from Appendix C: Permissible moment capacity C24 class is 6.294 kNm Permissible shear load capacity C24 class is 17.74 kN Permissible bearing stress C24 class is 3,450 kN/m² (2,730 kN/m² wane)	Post C24 75 x 225 Hoardings Table C.1

Appendix E. Worked Example – E.5.2 continued

Calculation	Source / Output
Maximum centres of posts due to bending = 6.294 /2.51 = 2.51m Maximum centres of post due to shear = 17.74 / 2.055 = 8.83m (not critical case) **Note to calculations:** The overall factor of safety of overturning of 1.5 mentioned in Section 4.5.2 (b) is NOT considered in the strength check calculation above as the permissible values of the material strength are used. Although it is used in the foundation check at Section E.6 of this example. Hence maximum post centres limited by bending strength on 75 x 225 C24 posts is 2,510mm centres, say 2.44m c/c (as this suits sheet sizes).	
E.5.3 Horizontal rails Use four horizontal rails. Hence the minimum notional horizontal load occurs between two rails, and midspan of the face material spanning between the rails. Design assumption that worst case is full minimum notional horizontal load on one rail. Maximum centres of rails = 0.8m. **Note to calculations:** The theoretical spacing is (2440 – 100)/ 3 spaces = 780mm Hence, design assumes a worst case of 800mm Try C24 100 x 75 constructional sawn timber used on the flat	
Working structural properties of rail 100 x 75 class C24 used on the flat, i.e. used in the weak direction: Permissible moment capacity C24 is 0.993 kNm Permissible shear load capacity C24 is 7.82 kN Permissible bearing stress C24 is 3,450 kN/m^2 (2,730 kN/m^2 wane)	Hoardings Table C1
The design assumption for worst case for one central rail is either full wind or working wind with min. notional horizontal load applied to a single rail. Wind force is calculated using Force = $q_p \times A_{ref} \times c_{p,net}$ Allowing for continuity factor of 1.1 on udl on face material, the load per metre run on rail is either:- Full wind force is 0.421 x 0.8 x 1.0 x 2.0 x 1.1 = 0.741 kN/m run Working Wind plus minimum notional horizontal load on one rail = (0.2 x 0.8 x 1.0 x 2.0 x 1.1) + 0.74 = 1.092 kN/m run Assuming the rail is simply supported at the posts, the maximum span is $(0.993 \times 8 / 1.092)^{0.5}$ = 2.697 = 2.7m span of rail	Formwork Guide Appendix B Load Case 26
By inspection shear not critical.	
Hence use four C24 100 x 75 timber rails on the flat at about 800mm centres with posts at maximum 2.44m centres is Okay.	Posts at 2.44m

Appendix E. Worked Example – continued

Calculation	Source / Output
E.5.4. Face material By inspection design for worst case loading of either panel robustness loading of 1.5 kN/m^2 (see E.4.3) or the effect of the min. notional horizontal load mid-way between rails. Assuming four rails would give a maximum span c/c of about 0.8m Maximum applied bending moment assuming face material simply supported and not allowing for continuity over the four rails (i.e. fitted as one sheet) for robustness gives = $(1.5 \times 0.8^2 \times 1.0) / 8 = 0.120$ kNm/m width Assuming the minimum notional horizontal line load acts as a point load at midspan and the working wind load is distributed, then the maximum applied bending moment on the face material would be = $(0.74 \times 0.8 / 4) + (0.2 \times 0.8^2 / 8) = 0.148 + 0.016 = 0.164$ kNm/m Checking properties of preferred OSB – the 18mm OSB/3 to EN 310 has stated working property of 0.449 kNm/m or 0.225 kNm/m. Hence this material would be suitable. **Note to calculations:** Although the calculations indicate that the 18mm OSB/3 could be fitted in either orientation, because there are four rails, it would have to be fitted as one continuous vertical sheet.	Hoarding 4.7.3 Formwork Guide Table 15 Face Material 18mm OSB/3
E.5.5 Connections Two connections need to be considered, the face material to the rail, and the rail to the post. Due to increase wind loading at the ends of the hoarding, design the face material and ends of the rail for Zone A pressure coefficients. Note to calculations: For economy screw fixings in other Zones may be considered. The connections are designed for tension, so as fitted on the public side, any crowd loading is ignored, and loading cases LC3 & LC4 considered.	Hoardings 5.5 and Table 1
E.5.5.1 Connection of ply to rails Design wind force (zone A) = $q_p \cdot c_{p.net}$ (zone A) A_{ref} = $0.421 \times 3.2 \times 1.0 \times 1.0 = 1.347$ kN/m^2 Working wind force (zone A) = $0.20 \times 3.2 \times 1.0 \times 1.0 = 0.64$ kN/m^2	Hoardings Table B.2 and Fig B.1 (a)
LC3 Line load Zone A wind = 1.347 kN/m^2 x 0.8m = 1.078 kN/m **LC4** Line load working wind + Min. notional horizontal load = { 0.64 kN/m^2 x 0.8m } + 0.74 kN/m = 1.252 kN/m - governing case	Hoardings Table 1
Try 4mm screws 50mm long at 300mm centres into C24 rails Point side penetration = 50 – 18mm (face thickness) = 32mm (say 30mm) Basic withdrawal load/mm of point side penetration = 16.3 N /mm $K_{52} = 1.25$ (very short term loading) $K_{53} = 0.7$ (Class 3)	Hoardings 5.4 and Table 4
Permissible load per metre = $(30 \times 16.3 \times 1.25 \times 0.7 / 0.300) \times 10^{-3}$ = 1.43kN/m > 1.252 hence Okay Use 4mm screws 50mm long at 300mm centres in pre-drilled holes.	Ply to rails Use 4mm screws 50mm long at 300mm c/c

Appendix E. Worked Example – continued

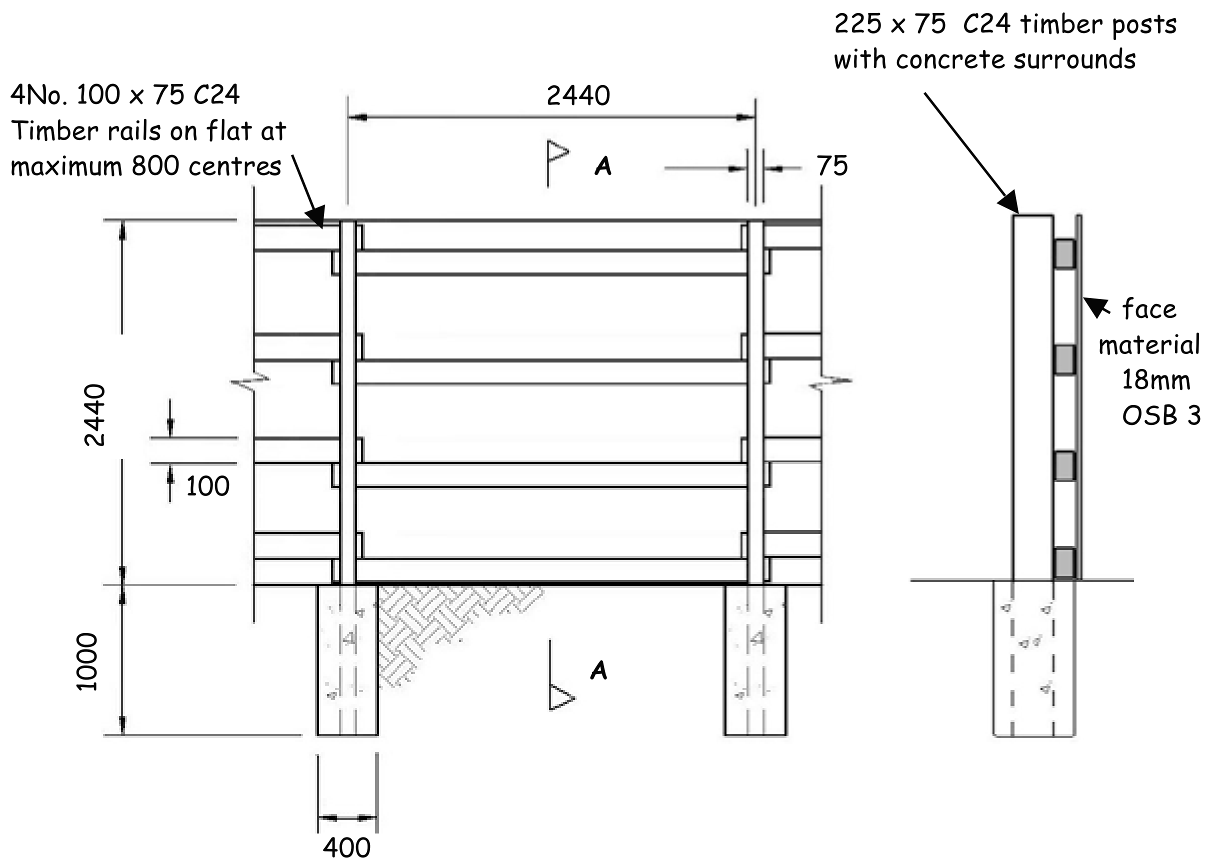
Calculation	Source / Output
E.5.5.2 Connection of rails to post Due to the large centres of the posts (2.44m), the rails span simply supported from post to post, hence: Loaded area per post = 2.44m x 0.8m / 2 = 0.976m^2	
Consider the last span at the end. The hoarding values of $c_{p,net}$ for each zone are Zone A $c_{p,net}$ = 3.2 and Zone B $c_{p,net}$ = 2.0 Hence Averaging for the last 2.6m long rail gives c_{p}, $_{Ave\ A,B\ rail}$ = { (3.2 x 0.30 x 2.44) + (2.0 x (2.44 – (0.3 x 2.44))) } / 2.60 = { 2.342 + 3.416 } / 2.60 = 2.21 Design wind force (end rail) = $q_p \cdot c_{p.\ Ave\ A,B\ rail}\ A_{ref}$ = 0.421 x 2.21 x 0.8 x 1.0 = 0.744 kN/m Working wind force (zone A) = 0.20 x 2.21 x 0.8 x 1.0 = 0.354 kN/m	
LC3 Line load full wind = 0.74 kN/m x (2.44 / 2) = 0.903 kN **LC4** Line load working wind + Min. notional horizontal load = { 0.354 kN/m x (2.44 / 2) } + { 0.74 kN/m x (2.44/2) } = 0.432 + 0.903 = 1.335 - governing case **Note to calculations:** the rails are not continuous past the post, hence in this example the loaded length is halved i.e. 2.44 / 2 Due to practicalities of achieving screw centres at intersection of post and rail try 4No. 5mm screws 100mm long into C24 posts. Point side penetration = 100 – 75mm (rail thickness) = 25mm Basic withdrawal load/mm of point side penetration = 19.2 N/mm K_{52} = 1.25 (very short term loading) K_{53} = 0.7 (Class 3) Permissible load per joint = 4 x 25 x 19.2 x 1.25 x 0.7 x 10^{-3} = 1.68 kN > 1.335 kN hence OK Use 4 No. 5mm screws 100mm long per rail to post connection into pre-drilled holes.	Hoardings 5.5 and Table 4 Rail to post Use 4 No 5mm screws 100mm long
E.6 Foundation design **E.6.1 Planting depth** As the hoarding is 2.44m high then the planting depth tables in Appendix D can be used. For design, assume a concreted hole of width 400mm, hence D = 0.40m. The ground has been described as 100mm of topsoil overlying firm to stiff clay. This is not hard clay, so in consideration of ground classification from Table D.1 assume "average ground". Hence from Appendix D Table D3 the planting depth for C24 75 x 225 posts in average soil is stated as 1000mm. {Note: the planting depth stated in Table D3 is based on the full moment of the post, whereas the supportive calculation in E.6.2 check against the actual moment. Shear force applied} **Note to Calculations:** The following section E.6.2 would not normally be required, but has been completed to illustrate the PD 6547 method as outlined in Appendix D, at Sections D1 and D.2	Hoardings Appendix D Concrete Hole min 400mm Post Planting depth 1000mm

Appendix E. Worked Example – continued

Calculation	Source / Output
E.6.2 Ground resistance calculation for post depth The ground has been classified from Table D.1 as "average ground"	Assume Average
Hence ground factor is $G = 390\text{kN/m}^2$	Table D1
Assume hole for the 75 x 225 post is concreted after post placed in hole such that effective Diameter of hole, D = say 400mm, hence D = 0.40m	
The ground resistance moment, $M_g = G \,.\, D \,.\, P^3 / 10$ where M_g is the ground resistance D is the minimum diameter of the effective item planted P is the planting depth (in m) G is the ground factor (in kN/m^2) Hence $M_g = = 390 \times 0.40 \times P^3 / 10 = 15.60 \times P^3$ kNm per post	Equation D1
The critical overturning moment about the ground level (level 0) identified from the loading combinations at E.5.1 gives Design on overturning moment 2.51 kNm / m run and Maximum shear force of 2.055 kN / m run Hence for posts at 2.44m centres: Critical overturning moment is $M_o = 2.51 \times 2.44 = 6.12$ kNm / post and Critical shear load is $Q_o = 2.055 \times 2.44 = 5.014$ kN / post	
The post is stable provided $M_g \geq \{ M_o + (0.707 \times Q_o \times P) \} \times 1.5$ giving $M_g \geq \{ 6.12 + (0.707 \times 5.014 \times P) \} \times 1.5$ $\geq \{ 9.18 + 5.317 P \}$	Equation D2
Combining the equalities gives $15.60 \times P^3 = 9.18 + 5.317 P$ giving $9.18 = 15.60 P^3 - 5.317 P$ - solved by trial and error gives:	
Try planting depth, $P = 1.0\text{m}$ then $(15.60 \times 1^3) - (5.31 \times 1) = 10.29$ $P = 0.95\text{m}$ then $(15.60 \times 0.95^3) - (5.31 \times 0.95) = 8.33$ Hence Planting Depth of 1.0m is acceptable **Note:** Increasing the depth of the foundation has a greater effect on increasing the resistance of the foundation than increasing its width	Planting depth 1000mm
E.7 Summary Sketch layout shown on next page. Use 75 x 225 C24 constructional sawn timber posts at 2.44m centres. Use four 75 x 100 C24 constructional sawn timber rails on the flat at about 800mm centres. Use 4 No. 5mm screws 100mm long per rail to post connection. Use 4mm screws 50mm long for the ply to rail at 300mm c/centres. Posts are to be embedded in to the ground in 400mm diameter hole 1.0m deep and infilled with mass concrete. Face material assumed as 18mm OSB Grade 3 in vertical 2.44m sheets	

Appendix E. Worked Example – continued

E.8 Sketch of hoarding



REAR ELEVATION OF HOARDING

SECTION A-A

NOTES:

1. Hoarding design for the following loads:-
   - A Maximum peak velocity pressure 0.42 kN/m^2

   or
   - A working wind pressure of 0.2 kN/m^2 in conjunction with a minimum notional horizontal load (pedestrian load) of 0.74 kN/m acting 1.2m above ground.
2. Post embedment is based on firm to stiff clay with the top 100mm of top soil already removed.
3. Concrete surround, minimum 400mm to be placed in hole after the post is positioned.
4. Connections:-
   - Face material to rail connection - 4mm Ø screws 50mm long at 300mm centres
   - Rail to post - 4 No. 5mm Ø screws 100mm long

   Screws to be in pre-drilled holes.

Title: Hoarding example for Liverpool site As TWf Hoarding Guidance	Drawn: A.H.	Sketch No.: SK/001
	Checked: P.F.P/ R.K.F.	Revision: A
	Date: 24/05/20	Status: WORKING

APPENDIX F – Worked Example - Reduction of passive resistance due to sloping ground

There is a reduction of passive resistance due to sloping ground, e.g. where soil has been removed adjacent to a hoarding (see Figures F2 and F3).

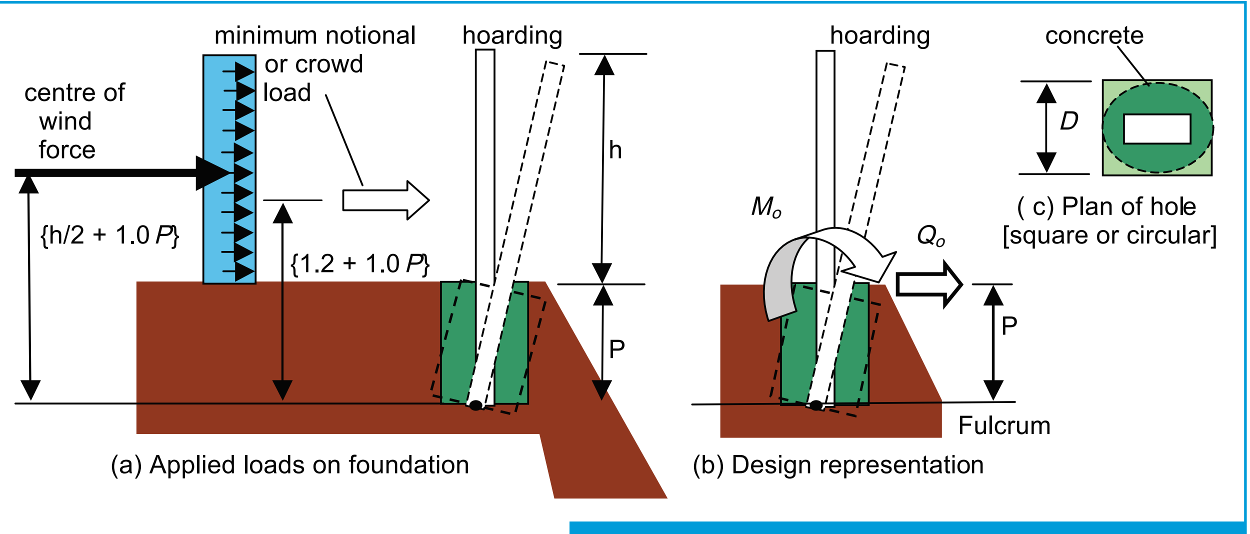


Fig F1 - Reduction of passive resistance due to sloping ground

$$M_g \geq \{ M_o + (0.707 \times Q_o \times P) \} \times 1.5$$

[Equation D2]

From Fig F1(b) for a cut away embankment:

$$M_g \geq \{ M_o + (1.0 \times Q_o \times P) \} \times 1.5$$

[Equation F1]

Note: Gives a 30% increase in the overturning moment

$$M_g = \frac{G \times D \times P^3}{10}$$

[Equation D1]

The 'Ground Classification' (G) in Table D1 should be "downgraded" to account for a cut away embankment. So, if the classification of the ground was originally given as:

- '**Good**' – then reduce to 'Average'
- '**Average**' – then reduce to 'Poor'
- '**Poor**' – not be used in soil initially described as 'Poor'

Fig F2 - Example of soil being removed adjacent to hoarding

Fig F3 -Example of slope failure leading to a failure of the adjacent hoarding (with emergency remedial measures having been taken)

APPENDIX G – Worked example of concrete kentledge block foundation

Assume a triangulated timber frame with the concrete kentledge blocks sat on the frame (see Figure G1). The timber frame is laid on a thin layer of sharp sand on top of the existing soil, to give an even surface. Site restrictions limit the width of the block to less than 1.5m, so assume a block of width, 1.2m.

G.1 Consider overturning

Using the values calculated in Appendix E with posts at 2.44m c/c and an overall factor of safety on overturning of 1.5 (see Section 4.6.2 of this guide):

Overturning moment for load case LC1,

M_o = 2.51 kNm/m x 2.44 m c/c x 1.5
= 9.187 kNm/post

Assuming a block weight of W per post and a restoring lever arm to the centre of the concrete block of 0.6m:

Restoring moment,

M_R = W x 0.6m > 9.187 kNm/post
W > 15.312 kN/post

G.2 Consider sliding

Sliding resistance is provided by friction between the surfaces. Using BS 5975: 2019, Table 25, coefficient of friction (μ) = 0.3 (timber to granular soil).

Using a factor of safety of 1.5 (see Section 4.6.4 of this guide):

Shear per post = 2.055 kN/m x 2.44 m c/c
= 5.014 kN/post

To prevent sliding, the resistance required is
5.014 x 1.5 = 7.521 kN/post

Therefore, minimum W required = 7.521 / 0.3 = 25.070 kN/post

This is the critical case. Hence, 1.0m^3 of mass concrete required per post

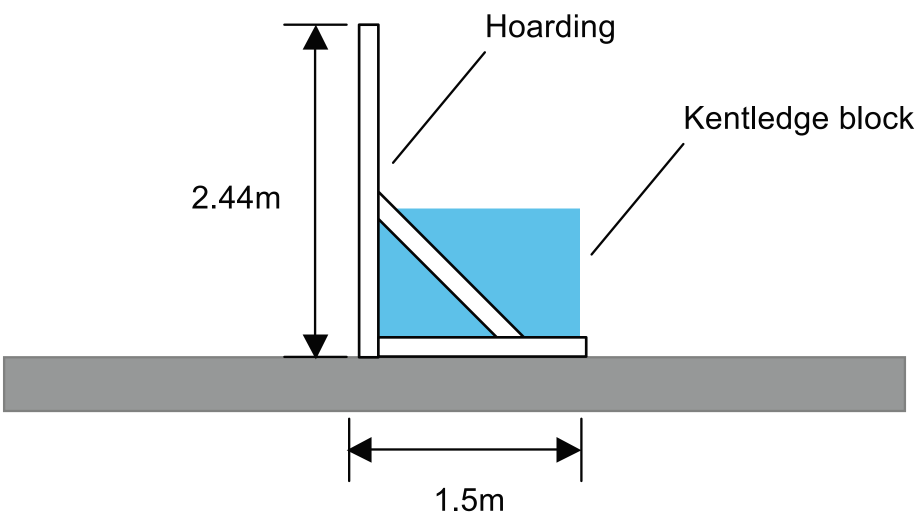


Figure G1 – Kentledge block on a timber frame

Notes:

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