PAS 8812:2016

Temporary works – Application of European Standards in design – Guide

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Foreword

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This PAS is not to be regarded as a British Standard. It will be withdrawn upon publication of its content in, or as, a British Standard.

The PAS process enables a guide to be rapidly developed in order to fulfil an immediate need in industry. A PAS can be considered for further development as a British Standard, or constitute part of the UK input into the development of a European or International Standard.

Relationship with other publications

BSI and HS2 engaged with a number of construction industry stakeholders to identify areas in which it was felt that the industry could benefit from further standardization. This engagement resulted in the development of two BSI PAS publications sponsored by HS2 and the Temporary Works Forum, including this PAS and PAS 8811, *Temporary works – Client procedures – Code of practice* (in preparation), which gives recommendations for UK infrastructure client procedures with respect to temporary works construction projects, from planning through to removal.

A number of other areas were identified as benefitting from standardization. A wider programme of work is underway to develop a further two PASs:

- PAS 8810, *Tunnel design – Design of concrete segmental tunnel linings – Code of practice*, which makes recommendations for the design of concrete segmental tunnel linings. It covers design considerations from project inception through to the end of the service life of the tunnel.
- PAS 8820, *Alkali-activated cementitious material and concrete – Specification*, which specifies requirements for alkali activated cementitious binders for suppliers of alkali-activated binders, ready mixed concrete, engineers and architects, contractors, asset owners and end users.

Where Eurocodes are referenced in this PAS, it is assumed that they will be used in conjunction with the relevant UK national annexes.

Use of this document

During the preparation of this PAS, the steering group has been mindful of the significant improvements in industry practice made as a result of the experience gained following a series of significant temporary works failures in the 1970s that lead to the publication of the Bragg Report [1] and subsequently the development of BS 5975, *Code of practice for temporary works procedures and the permissible stress design of falsework*. Accordingly, the steering group has endeavoured to provide high-level guidance to aid designers who are familiar with previous permissible stress-based codes and the use of equipment and materials rated with a safe working load to make the transition to the current suite of limit state design standards, focusing particularly on the development of guidance on appropriate approaches to partial factors on actions and materials and aspects associated with structural stability.

As a guide, this PAS takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

It has been assumed in the preparation of this PAS that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The guidance in this PAS is presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Spelling conforms to *The Shorter Oxford English Dictionary*. If a word has more than one spelling, the first spelling in the dictionary is used.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a PAS cannot confer immunity from legal obligations.

0 Introduction

0.1 Definition of temporary works

Within the UK construction industry, temporary works are widely understood to comprise: "parts of the works that allow or enable construction of, protect, support or provide access to, the permanent works and which might or might not remain in place at the completion of the works", as defined in BS 5975. This also corresponds to a large degree with the definition of "auxiliary construction works" as defined in BS EN 1991-1-6, *Eurocode 1 – Actions on structures – General actions – Actions during execution*.

0.2 Categories of temporary works

A broad range of structures can be categorized as temporary works. Table 1 sets out the six groups of temporary works identified for the purpose of this PAS. The examples given in Table 1 are intended to be illustrative rather than exhaustive.

Table 1 – Groups of temporary works relevant to this PAS

Group	Sub-group	Examples
Group 1	**Falsework**	Support to a partially completed structure (e.g. in situ and precast concrete, steelwork during assembly) Propping Façade retention Needling Flying shores Gantries/cantilever Service bridges Structures providing stability during construction, alteration or demolition
	Formwork	Vertical (wall and column) Soffits Sloping Arches Cantilever soffits Permanent formwork
	Simple advancing falsework/ formwork	Formwork travellers (horizontal) Climbing formwork (vertical) Advancing/launching formwork
	Access	Tied scaffolds Freestanding scaffolds Gantries Special scaffolds (e.g. underslung scaffolds)
	Protection	Hoardings Protection fans Temporary roofs

Table 1 – Groups of temporary works relevant to this PAS *(continued)*

Group	Sub-group	Examples
Group 2	**Geotechnical**	Trench and excavation support Tower crane bases Piling/crane mats Retaining walls Earthworks Foundations Cofferdams Horizontal and inclined propping Underpinning Ground anchors Haul/site roads
Group 3	**Vehicle and pedestrian bridges and related works**	Temporary bridges Propping trafficked bridges
Group 4	**Underground**	Tunnels/headings Shafts Chambers Tunnelling thrust pits
Group 5	**Marine temporary works**	Temporary quay walls Dolphins Access jetties Floating plant
Group 6	**Other temporary structures**	Bridge launching Heavy lift systems Moving of structures Protection decks Structural support to cranes or other lifting devices Erection gantries Hydraulic equipment Jacking

0.3 Typical features of temporary works and associated risks

The following typical features of temporary works and their conditions of service mean that they tend to be subjected to risks that might not apply to permanent works.

a) They tend to be in place for a relatively short period of time and then removed and potentially reused.

b) Elements and components can be reused numerous times within a project or across several projects throughout their service life, potentially making them vulnerable to misuse on site. As such, their inspection and maintenance history, particularly when there is a risk of fatigue damage, needs to be managed.

c) They might have interfaces with the permanent works, both in terms of the loading that they are subjected to and how they are supported. In some cases, temporary works might be left in place after the completion of the permanent works without necessarily contributing to the resistance or stability of the permanent works.

d) They tend to carry a greater proportion of variable actions than permanent works.

e) Structural systems often have less redundancy and lower stiffness than permanent works and might therefore be vulnerable to accidental loads associated with site activities.

f) They can be particularly susceptible to initial imperfections such as lack of fit, eccentricities, corrosion or damage resulting from previous use.

g) Commonly a relatively short timescale is allocated for their design and procurement.

h) Limited site investigation data might be available when establishing geotechnical parameters.

i) The dominant variable action is typically expected to be encountered at its characteristic value during normal service, whereas in permanent works it would be expected to occur only rarely over the structure's design life.

j) The party that undertakes the design of temporary works is often not involved in the design of the permanent works that they support and might only be involved in a particular aspect of the temporary works and therefore not have a full appreciation of project-wide issues. As such, communication and effective exchange of design data can pose significant challenges and risks unless communication lines and responsibilities are clearly established.

k) The nature of the procurement process for temporary works might bring risks associated with:

   1) assumptions regarding construction sequence;

   2) design interfaces and communication of design assumptions; and

   3) competence of the organization(s) responsible for the safe design, erection, use and removal of the temporary works.

0.4 Continuity in best practice

This PAS recognizes the developments in the field of design and management of temporary works in the UK in the last forty years, in particular those that stemmed from the Bragg Report [1] and subsequently BS 5975, *Code of practice for temporary works procedures and the permissible stress design of falsework*, which has been and remains the reference standard for design of falsework in the UK over the last 30 years.

This PAS together with the companion document PAS 8811 (in preparation) therefore endeavours to provide continuity of good practice during the transition to European Standards through the following approaches.

a) **Application of appropriate procedural controls.** Safe implementation of temporary works is reliant on the application of appropriate procedural controls as introduced in BS 5975 and recommended in PAS 8811. These procedural controls cover the full process, including the selection of appropriate design standards, the development of the initial concept, and the management of operations through the erection and operation phase to final decommissioning.

b) **Appropriate transfer of key data and information.** A key theme identified within the Bragg Report [1] was the need for the appropriate transfer of key data and information across all phases of the design cycle through effective communication between all involved parties, including coordination between the designers of permanent and temporary works.

c) **Continuity in the overall levels of safety.** The overall levels of safety for falsework design embedded in BS 5975 have proved to be necessary and largely successful. This PAS has endeavoured to establish guidance on appropriate partial factors for actions and material properties that do not erode this position.

d) **Design for stability.** The introduction in BS 5975 of the requirement for falsework systems to be designed to resist a notional lateral destabilizing load when considering global and nodal stability has resulted in a significant improvement in the safety of such systems within the UK. The guidance provided in this PAS aims to maintain that legacy and, where relevant, suggests extending its application to other temporary works systems.

0.5 European Standards for temporary works design

The Eurocodes (i.e. BS EN 1990 to BS EN 1999) provide common structural design rules for construction works. Although they focus on the design of permanent works, they give principles and requirements for structural safety, serviceability and durability, which are also relevant to temporary works. However, because of the different features of permanent and temporary works, the application of the Eurocodes to the design of temporary works needs to be considered carefully in order to ensure that levels of reliability and safety that have previously been considered appropriate to the design of temporary works are not compromised.

A great deal of published guidance on the application of the Eurocodes exists in the form of non-contradictory complementary information (NCCI), most of which is equally valid to both permanent and temporary works. However, only a limited amount is available that is specific to the development of temporary works solutions and in particular how to apply a limit state design approach to temporary works.

European product and execution standards written specifically for temporary works have been published alongside the Eurocodes, for example:

a) BS EN 1004, *Mobile access and working towers made of prefabricated elements – Materials, dimensions, design loads, safety and performance requirements*;

b) BS EN 1065, *Adjustable telescopic steel props – Product specifications, design and assessment by calculation and tests*;

c) BS EN 12063, *Execution of special geotechnical work – Sheet pile walls*;

d) BS EN 12810 (all parts), *Façade scaffolds made of prefabricated components*;

e) BS EN 12811 (all parts), *Temporary works equipment*; and

f) BS EN 12812, *Falsework – Performance requirements and general design*.

These European Standards are intended to supplement the Eurocodes and provide additional guidance for those engaged in the design of these categories of temporary works. Generally, they provide simplified approaches that are likely to produce more conservative designs than those resulting from the use of the Eurocodes alone. Although these simplified approaches are likely to be valid for the majority of straightforward applications, they might not be appropriate for complex applications or where there is an interaction with permanent works or geotechnical design.

1 Scope

This PAS gives guidance on the application of European Standards to the design of temporary works in the UK when adopted voluntarily, required by the Public Procurement Directive [2] or stipulated by the client.

NOTE *See also PAS 8811,* Temporary works – Client procedures – Code of practice *(in preparation).*

It covers:

a) interpretation of key design approaches applicable to all temporary works including:
   1) recommendations on suitable partial factors and combinations of actions;
   2) recommendations on appropriate analysis approaches;
   3) stability considerations;
   4) considerations on reuse of equipment, as in the case of proprietary equipment;

b) relationship between the Eurocodes and other European Standards specifically associated with temporary works; and

c) clarification of design requirements for identified groups of temporary works.

The aim of this PAS is to promote consistency in the design approach to temporary works and remove uncertainties for temporary works designers.

It does not cover issues relating to either the procedural control of temporary works covered in BS 5975 or specific requirements related to client procedures, which are covered in PAS 8811 (in preparation).

This PAS highlights issues to be taken into account by the temporary works designer when selecting the most appropriate standards to adopt, in relation to the transfer of key design data and information across all phases of the design cycle. This PAS is for use by practitioners in the field of structural and geotechnical design of temporary works.

This PAS provides non-contradictory complementary information (NCCI) with respect to existing standards and other relevant guidance documents.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 *Where Eurocodes are referenced in the PAS, it is assumed that they will be used in conjunction with the relevant UK national annexes.*

NOTE 2 *A more extensive list of reference publications for temporary works including normative references, informative references and further reading, is provided at Annex A.*

Standards

BS EN 1990, *Eurocode – Basis of structural design*

BS EN 1991 (all parts), *Eurocode 1 – Actions on structures*

BS EN 1992 (all parts), Eurocode 2 – *Design of concrete structures*

BS EN 1993 (all parts), Eurocode 3 – *Design of steel structures*

BS EN 1995 (all parts), *Eurocode 5 – Design of timber structures*

BS EN 1996 (all parts), *Eurocode 6 – Design of masonry structures*

BS EN 1997 (all parts), *Eurocode 7 – Geotechnical design*

BS EN 1999 (all parts), Eurocode 9 – *Design of aluminium structures*

BS 5930, *Code of practice for ground investigations*

BS 5975, *Code of practice for temporary works procedures and the permissible stress design of falsework*

BS 6349 (all parts), *Maritime works*

BS EN 12811-1, *Temporary works equipment – Part 1: Scaffolds – Performance requirements and general design*

BS EN 12812, *Falsework – Performance requirements and general design*

BS EN 13374, *Temporary edge protection systems – Product specification – Test methods*

BS EN ISO 14688 (all parts), *Geotechnical investigation and testing – Identification and classification of soil*

BS EN ISO 14689-1, *Geotechnical investigation and testing – Part 1: Identification and classification of rock – Identification and description*

NA to BS EN 1990, *UK National Annex for Eurocode – Basis of structural design*

NA to BS EN 1991 (all parts), *UK National Annex to Eurocode 1 – Actions on structures*

NA to BS EN 1992 (all parts), *UK National Annex to Eurocode 2 – Design of concrete structures*

NA to BS EN 1993 (all parts), *UK National Annex to Eurocode 3 – Design of steel structures*

NA to BS EN 1995 (all parts), *UK National Annex to Eurocode 5 – Design of timber structures*

NA to BS EN 1996 (all parts), *UK National Annex to Eurocode 6 – Design of masonry structures*

NA to BS EN 1997 (all parts), *UK National Annex to Eurocode 7 – Geotechnical design*

NA to BS EN 1999 (all parts), *UK National Annex to Eurocode 9 – Design of aluminium structures*

Other publications

[NR1] HIGHWAYS ENGLAND. *Design Manual for Roads and Bridges (DMRB)*. Guildford: Highways England.

[NR2] NETWORK RAIL. NR/L2/CIV/003, *Engineering Assurance of Buildings and Civil Engineering works*. London: Network Rail, 2012.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purpose of this PAS, the terms and definitions given in BS 5975, PAS 8811 (in preparation), BS EN 1990 and the following apply.

NOTE *For clarification of some key terms used for the design of temporary works to the Eurocodes, see Annex B.*

3.1.1 European standards in the construction sector

NOTE *The European standardization system comprises design standards (known as "Eurocodes"), product standards and execution standards, which are identified by the Euronorm prefix "EN". The implementation of European Standards in the UK is identified by the prefix "BS EN".*

3.1.1.1 Eurocode

standard that gives structural design provisions for construction works

NOTE *The Eurocodes which are implemented in the UK in conjunction with their National Annexes, include:*

a) *BS EN 1990, Eurocode – Basis of structural design;*
b) *BS EN 1991 (all parts), Eurocode 1 – Actions on structures;*
c) *BS EN 1992 (all parts), Eurocode 2 – Design of concrete structures;*
d) *BS EN 1993 (all parts), Eurocode 3 – Design of steel structures;*
e) *BS EN 1994 (all parts), Eurocode 4 – Design of composite steel and concrete structures;*
f) *BS EN 1995 (all parts), Eurocode 5 – Design of timber structures;*
g) *BS EN 1996 (all parts), Eurocode 6 – Design of masonry structures;*
h) *BS EN 1997 (all parts), Eurocode 7 – Geotechnical design;*
i) *BS EN 1998 (all parts), Eurocode 8 – Design of structures for earthquake resistance; and*
j) *BS EN 1999 (all parts), Eurocode 9 – Design of aluminium structures.*

3.1.1.2 execution standard

standard that specifies requirements for workmanship, fabrication and erection tolerances during the execution of structures

NOTE *For example, BS EN 13670 covers the execution of concrete structures and BS EN 1090-2 covers the execution of steel structures.*

3.1.1.3 product standard

standard that establishes the specification, required physical and mechanical properties, testing methods and classification for constructions materials

NOTE *For example, BS EN 338 covers structural timber, BS EN 10025 covers hot rolled structural steels and BS EN 206 covers concrete mixes.*

3.1.2 equivalent horizontal force

horizontal force applied during the analysis of framed structures (i.e. structures which depend for stability on either direct bracing, upon the stiffness of members in bending, or combination thereof) as a simplifying tool to allow for initial imperfections and potential second order effects

NOTE 1 *This is typically given as a percentage of the vertical actions applied to the structure.*

NOTE 2 *Different design standards use alternative terminology. As an example, BS EN 1993-1-1 calls this force "equivalent horizontal forces", BS EN 1991-1-6 uses both "equivalent horizontal force" and "nominal horizontal force", BS 5975 uses both "notional lateral force" and "horizontal disturbing force".*

3.1.3 safe working load (SWL)

maximum un-factored load that can be safely resisted by a piece of proprietary equipment

3.1.4 supported construction

elements of the permanent works that are supported by the temporary works

3.2 Symbols

For the purpose of this PAS, the following symbols apply.

A	accidental action
A_d	design value of an accidental action
C_d	limiting design value of the corresponding serviceability criterion
c_{prob}	probability factor
c_{season}	seasonal factor
E_d	design value of the effects of actions
$E_{d,dst}$	design value of the effect of destabilizing actions
$E_{d,stb}$	design value of the effect of stabilizing actions
F_d	design value of an action
F_k	characteristic value of an action
F_{rep}	representative value of an action
$G_{dst;d}$	design value of destabilizing permanent vertical actions
G_k	characteristic value of a permanent action
$G_{stb;d}$	design value of stabilizing permanent vertical actions
$G'_{stb;d}$	submerged weight of the column
N_d	design value of the reaction force normal to the surface
P	value of a prestressing action
$Q_{dst;d}$	design value of destabilizing variable vertical actions
$Q_{k,1}$	characteristic value of the leading variable action
$Q_{k,i}$	characteristic value of an accompanying variable action
R_d	design resistance
$S_{dst;d}$	design value of the seepage force in the column
$u_{dst;d}$	design value of the destabilizing total pore water pressure at the bottom of the soil column
X_d	design value of a material or product property
X_k	characteristic value of a material or product property
γ	partial factor
γ_F	general term to identify the partial factor for an action
$\gamma_{f,Ed}$	partial factor to account for uncertainty in the coefficient of friction when calculating the frictional force arising from sliding systems
$\gamma_{f,Rd}$	partial factor to account for uncertainty in the coefficient of friction when calculating the frictional restraint
γ_G	partial factor for permanent actions
$\gamma_{G,inf}$	lower bound partial factor for favourable permanent actions
$\gamma_{G,sup}$	upper bound partial factor for unfavourable permanent actions
γ_M	partial factor for the calculation of the resistances of materials (product of γ_m and γ_{Rd})
γ_m	partial factor for the material property
γ_P	partial factor for prestressing actions
γ_Q	partial factor for variable actions
γ_{Rd}	partial factor for resistance
μ	coefficient of friction
$\sigma_{stb;d}$	design value of stabilizing total vertical stress at the bottom of the soil column
ψ	factor to derive the representative value of a variable action
$\psi_0 \cdot F_k$	combination value of a variable action
$\psi_1 \cdot F_k$	frequent value of a variable action
$\psi_2 \cdot F_k$	quasi-permanent value of a variable action

4 Designing temporary works to the Eurocodes

4.1 Scope of application

Clause **4** provides guidance for the design of all types of temporary works to the Eurocodes.

When temporary works are designed to the Eurocodes, the principles of limit state design, used in conjunction with the partial factor method, apply. Figure 1 gives a general overview of the partial factor method in the Eurocodes for structural design and provides a tool to navigate this clause.

*NOTE Figure 1 does not cover geotechnical design to Eurocodes, which is covered in **6.2**.*

When using alternative approaches, as presented in European product and execution standards or in other technical documents, designers should take account of the basic assumptions of those publications and of the potential complications or conflicts arising from applying them, particularly where an interaction with the phasing of the permanent works is involved.

4.2 Basic requirements

Temporary works should be designed and engineered with the same degree of care and consideration as permanent works so that during their working life they have adequate structural resistance, serviceability, durability and robustness.

*NOTE See BS EN 1990:2002+A1:2005, **2.1** for basic structural requirements.*

Any client-specific requirements to be taken into account during the design of temporary works should be identified in the design brief and, if applicable, the design statement (e.g. *Guidance note: Early focus on temporary works and buildability* [3]).

4.3 Design situations

As part of the design process, all design situations that reflect the service conditions foreseen during the working life of the temporary works should be taken into account.

The following classes of design situation are relevant to temporary works (see BS EN 1990:2002+A1:2005, **3.2**).

a) **Persistent design situation**, where the structure is in its normal configuration during its working life.
b) **Transient design situation**, where the structure is in an unusual configuration for a short period of time [e.g. during execution (construction) stages or when undergoing maintenance, alteration or dismantling].
c) **Accidental design situation**, where the structure is or has been subjected to exceptional conditions (e.g. under impact, explosion or when the structural configuration is changed as a consequence of localized failure).

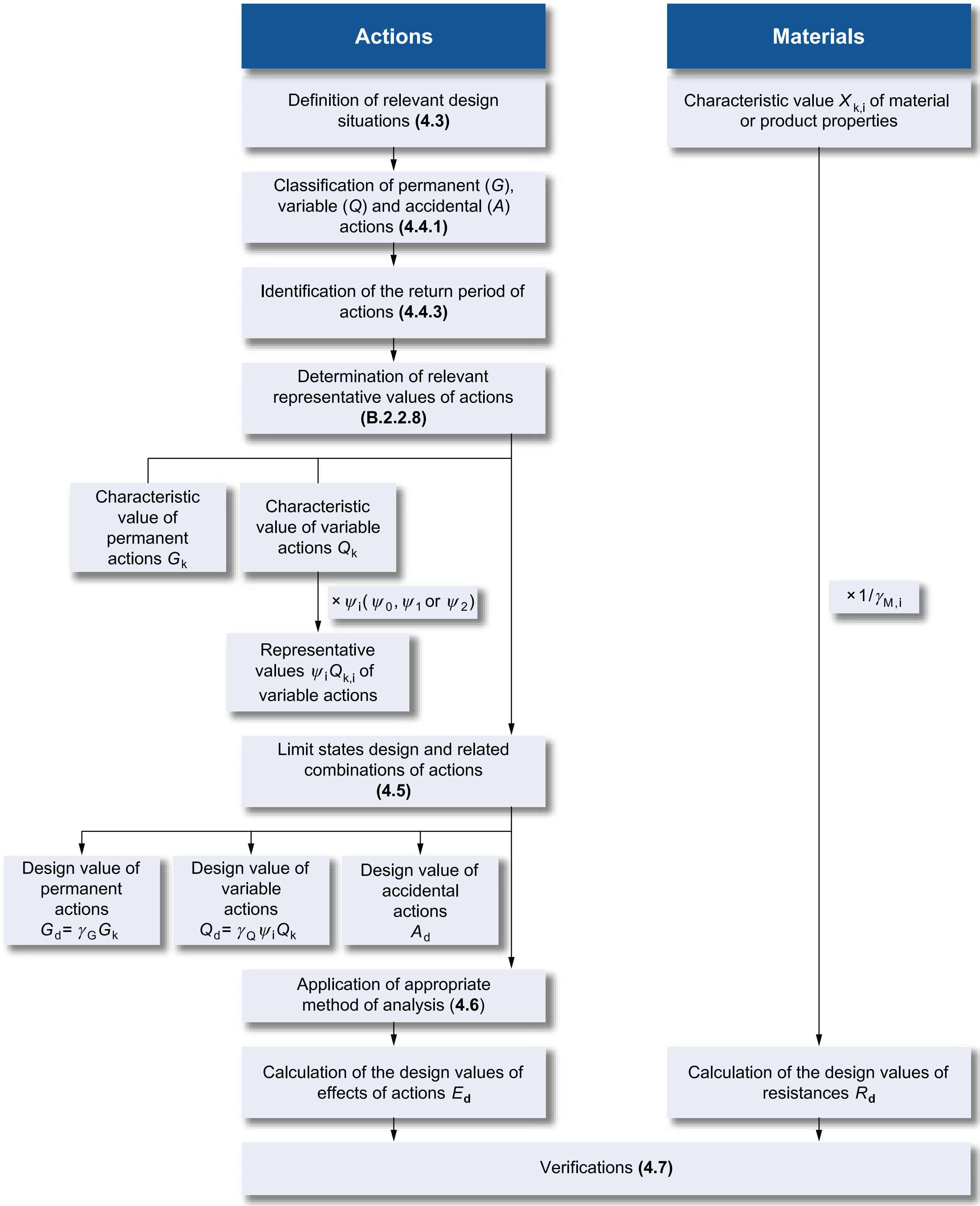
*NOTE See BS EN 1991-1-6:2005, **3.1** for specific guidance on design situations during execution stages.*

In practice, the same combination of actions is used for the verification of both persistent and transient design situations (see **4.5.2.1**).

The relationship between permanent and temporary works can be complex. Permanent structures undergoing construction, maintenance, demolition or alteration should be considered in their temporary condition. Particular attention should be given to the distribution of load effects within both the permanent and temporary works and the potential effect on the stability of the combined system. The effect of the working methods and sequencing of construction activities should also be taken into account.

Where temporary works are to remain in place during a subsequent construction phase, the design information should be communicated to the designers of subsequent phases of the works in order to allow their effects on the structure in terms of stiffness and resistance to be fully considered.

Figure 1 – General overview of the partial factor method in the Eurocodes for structural design



4.4 Actions

4.4.1 Classification of actions

The following three main categories of actions should be taken into account when designing temporary works.

NOTE 1 The specific actions indicated in the three categories below might be treated differently depending on their variability, duration and probability of occurrence. It is important that designers categorize actions appropriately and thus apply the appropriate partial factors to derive the design value of actions.

a) **Permanent actions.** Any action that remains in place over the service life of the structure. These include the self-weight of any structural elements or equipment incorporated into the temporary works, any ancillary elements connected to or forming part of the main temporary works structure (e.g. access ramps and platforms for access and storage of plant and materials, kentledge), earth pressure, groundwater pressure, and long-term effects such as creep, shrinkage and foundation differential settlements.

   NOTE 2 Creep and shrinkage are not normally significant for temporary works design.

b) **Variable actions.** These include supported construction, any actions that vary significantly in magnitude with time, such as associated construction loads (e.g. personnel with hand tools and equipment, formwork and its ancillary equipment), environmental actions, forces from the permanent structure (e.g. prestress effects), and equivalent horizontal force.

   NOTE 3 BS EN 1991-1-6 and BS EN 12812 consider supported construction as a variable action. However, the load that supported construction imposes on temporary works remains and is unlikely to change once in place as acknowledged by BS EN 12812. Therefore, it is important that particular attention is paid to the treatment of supported construction for different limit states. Specific recommendations are given at Annex C.

c) **Accidental actions.** These represent exceptional conditions that the structure would not be expected to cater for under normal service conditions and are usually the result of an extreme event such as impact or explosions.

   *NOTE 4 See **6.6.4** for sources of impact on protection decks.*

4.4.2 Reference standards for actions

Table 2 provides a list of reference standards for typical actions on temporary works. This list includes Eurocodes and other European Standards that provide relevant information.

When using other European Standards, actions should be applied consistently with the assumptions of the standard being used.

NOTE This is particularly important when these European Standards are applied in conjunction with the Eurocodes.

4.4.3 Return periods of actions

4.4.3.1 General

Recommended return periods for the determination of the characteristic values of climatic actions during execution are given in BS EN 1991-1-6:2005, Table 3.1. These values depend on the nominal duration of the design situation being considered.

4.4.3.2 Specific guidance on wind actions

4.4.3.2.1 Basic wind velocity

The characteristic values of the basic wind velocity in BS EN 1991-1-4 are based on wind data with a return period of 50 years. To take account of a temporary structure being erected for a shorter period which is therefore less likely to be exposed to the characteristic wind, a probability factor c_{prob} and a seasonal factor c_{season} may be used.

NOTE 1 The probability factor c_{prob} is introduced in BS EN 1991-1-4:2005+A1:2010, Expression (4.2).

*NOTE 2 The seasonal factor c_{season} is introduced in BS EN 1991-1-4:2005+A1:2010, **4.2**. Values of c_{season} are given in NA to BS EN 1991-1-4:2005+A1:2010, **NA.2.7** for any possible one-, two-, and four-month periods during the year, as well as for the six-month summer and winter periods.*

Table 2 – Typical actions on temporary works and reference standards

Action type	Category	Typical actions on temporary works	Relevant standards
Permanent actions (*G*)	Self-weight	Self-weight of the temporary works, ancillary temporary works	BS EN 1991-1-1
	Earth pressure		BS EN 1991-1-6 BS EN 1997
	Groundwater pressure		BS EN 1997
Variable actions (*Q*)	Construction loads	Group 1: Supported construction	BS EN 1991-1-6 BS EN 1991-1-1 BS EN 12811-1 BS EN 12812 (falsework)
		Group 2: Personnel and hand tools Storage movable items Non-permanent equipment Movable heavy machinery and equipment Storage of materials Accumulation of waste materials	
	Environmental actions	Soil movements of the foundations of the structure and of temporary works	BS EN 1991-1-6 BS EN 1997
		Wind – maximum wind and working wind	BS EN 1991-1-6 BS EN 1991-1-4
		Snow	BS EN 1991-1-6 BS EN 1991-1-3 BS EN 12812
		Water and wave forces	BS EN 12812 BS 5975
		Atmospheric ice	BS EN 1991-1-6 BS EN 1993-3 BS EN 12812 ISO 12494
	Traffic loads		BS EN 1991-2 (bridges)
	Forces from the permanent structure	Prestressing	BS EN 1990 BS EN 1992 to 1999
		Pre-deformations	BS EN 1991-1-6 BS EN 1990 BS EN 1992 to 1999
		Temperature	BS EN 1991-1-6 BS EN 1991-1-5 BS EN 12812
		Shrinkage/hydration effects	BS EN 1991-1-6 BS EN 1992 to 1994
	Friction		BS 5975 BS EN 12812
	Equivalent horizontal force	Additional horizontal load equal to a given percentage of the vertical load	BS EN 1991-1-6 BS EN 12811-1 BS 5975
Accidental actions (*A*)	Accidental actions	Dynamic and impact forces	BS EN 1991-1-6 BS EN 1990 BS EN 1991-1-7

Any reduction to the wind action from its 50-year return period value requires careful consideration and should take into account:

a) the context within which the temporary works are used and the resulting consequences of any failure;

b) the potential total exposure period if a system or elements of it are reused multiple times; and

c) the risk that the initial exposure period might be extended.

This is particularly important when applying c_{season}. Values of c_{season} less than unity should be applied only when there is control over the total exposure period.

*NOTE 3 This recommendation is consistent with BS EN 1991-1-4:2005+A1:2010, **4.2** (3) which recommends that for transportable structures which might be used at any time in the year, c_{season} is taken equal to 1.*

The rationale for any reduction to the wind action should be recorded in the design brief and, if applicable, the design statement.

4.4.3.2.2 Minimum wind speed

NA to BS EN 1991-1-6:2005, **NA.2.5** allows a minimum wind speed to be used in the design of temporary works to be defined on a project-specific basis.

4.5 Limit state design

4.5.1 General criteria

For each critical load case, the design value of the effect of actions should be determined by combining actions that can occur simultaneously.

Where more than one variable action is considered to act simultaneously, the leading variable action should be identified for the purpose of establishing combinations of actions to give the greatest action effect.

NOTE 1 In some cases the choice of leading variable action might not be immediately evident and it might be necessary to treat each variable action in turn as a leading variable action to identify the most onerous for each verification.

In the case of temporary works, although supported construction is classified as a variable action, in practice once in place the load it imposes remains and should be considered as an accompanying variable action with a value of ψ_0 = 1.0 if the recommendations in Annex C are adopted. In which case, another variable action (e.g. other construction loads, wind) should be chosen as the leading variable action (see Figure B.1).

When designing to the Eurocodes, the general expressions for the combination of actions provided by BS EN 1990 should be used at the relevant ultimate limit state (see **4.5.2**) and any applicable serviceability limit states (see **4.5.3**).

*NOTE 2 Some European product and execution standards provide different combinations of actions. In particular, BS EN 12811-1 and BS EN 12812 suggest specific load combinations for scaffolds and falsework systems respectively. For guidance on the scope of application of these load combinations, see **6.1.1** and **6.1.3**.*

Details of the structural configuration, critical load cases and combinations of actions to be applied to the temporary works at different stages of construction and any accidental design situations to be considered should be set out in the design statement.

4.5.2 Combinations of actions for ultimate limit states

4.5.2.1 Persistent and transient design situations

The fundamental combination of actions for ultimate limit state verifications of both persistent and transient design situations is given by BS EN 1990:2002+A1:2005, Equation (6.10):

$$\sum_{j\geq 1} \gamma_{G,j} G_{k,j} \text{"+"} \gamma_P P \text{"+"} \gamma_{Q,1} Q_{k,1} \text{"+"} \sum_{i\geq 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i} \qquad (6.10)$$

where:

$\sum_{j\geq 1} \gamma_{G,j} G_{k,j}$	represents factored permanent actions;
$\gamma_P P$	represents factored prestress;
$\gamma_{Q,1} Q_{k,1}$	represents the factored leading variable action;
$\sum_{i\geq 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i}$	represents factored accompanying variable actions at their combination value.

BS EN 1990 also introduces Equations (6.10a) and (6.10b), which are not equivalent to Equation (6.10) in terms of reliability level. For the design of temporary works, Equation (6.10) should be used in all cases.

NOTE See Designers' Guide to EN 1990 *for background information on Equations (6.10), (6.10a) and (6.10b).*

Values of partial factors γ and ψ factors should be obtained from Annex C.

4.5.2.2 Accidental design situations

The combination of actions for accidental design situations is given by BS EN 1990:2002+A1:2005, Equation (6.11b):

$$\sum_{j\geq 1} G_{k,j}\text{"+"}P\text{"+"}A_d\text{"+"}(\psi_{1,1}\text{ or }\psi_{2,1})Q_{k,1}\text{"+"}\sum_{i\geq 1}\psi_{2,i}Q_{k,i} \quad (6.11b)$$

where:

$\sum_{j\geq 1} G_{k,j}$	represents un-factored permanent actions;
P	represents un-factored prestress;
A_d	represents the design value of the accidental action;
$(\psi_{1,1}$ or $\psi_{2,1})Q_{k,1}$	represents the un-factored main accompanying variable action at its frequent or quasi-permanent value;
$\sum_{i\geq 1} \psi_{2,i}Q_{k,i}$	represents the un-factored accompanying variable actions at their quasi-permanent value.

As well as considering the influence of the design value of the accidental action (A_d), it might be appropriate to take into account any damaged structural members which might need to be removed from the structural analysis.

The choice between $\psi_{1,1}$ and $\psi_{2,1}$ for the main accompanying variable action is given in the National Annex. In the UK, the National Annex to BS EN 1990 suggests the application of $\psi_{1,1}$ for buildings and bridges. $\psi_{1,1}$ should be applied to the main accompanying variable action for the design of temporary works in accidental design situations.

Values of ψ factors should be obtained from Annex C.

4.5.3 Combinations of actions for serviceability limit states

4.5.3.1 General

Serviceability limit state requirements should be agreed on a project-specific basis and based on the performance requirements for the temporary works being designed. The applicable limiting serviceability criteria should be stated in the design brief and, if applicable, the design statement, along with the appropriate combination of actions to be used during the verification.

4.5.3.2 Characteristic combination

In the general context of the Eurocodes, the characteristic combination of actions is used for verifying what the Eurocodes term "irreversible" serviceability limit state checks, which include stress limitations to ensure that yield criteria are satisfied over the full design working life.

The characteristic combination of actions is given by BS EN 1990:2002+A1:2005, Equation (6.14b):

$$\sum_{j\geq 1} G_{k,j}\text{"+"}P\text{"+"}Q_{k,1}\text{"+"}\sum_{i>1}\psi_{0,i}Q_{k,i} \quad (6.14b)$$

where:

$\sum_{j\geq 1} G_{k,j}$	represents un-factored permanent actions;
P	represents un-factored prestress;
$Q_{k,1}$	represents un-factored leading variable action at its characteristic value;
$\sum_{i>1} \psi_{0,i}Q_{k,i}$	represents un-factored accompanying variable actions at their combination value.

***NOTE** The characteristic combination of actions mostly mirrors the combination prescribed for ultimate limit state verifications of persistent and transient design situations (BS EN 1990:2002+A1:2005, Equation (6.10)), the key difference being that no partial factors are applied to the actions. This means that it is an onerous combination in as much as it specifies that all actions are acting at their characteristic or combination value.*

Values of ψ factors should be obtained from Annex C.

4.5.3.3 Frequent combination

In the general context of the Eurocodes, the frequent combination of actions is used for the evaluation of "reversible" serviceability limit states. It is used for crack-width checks for prestressed elements with bonded tendons. It is unlikely that it will be applicable in most temporary works designs.

The frequent combination of actions is given by BS EN 1990:2002+A1:2005, Equation (6.15b):

$$\sum_{j\geq 1} G_{k,j}\text{"+"}P\text{"+"}\psi_{1,1}Q_{k,1}\text{"+"}\sum_{i>1}\psi_{2,i}Q_{k,i} \quad (6.15b)$$

where:

$\sum_{j\geq 1} G_{k,j}$	represents un-factored permanent actions;
P	represents un-factored prestress;
$\psi_{1,1}Q_{k,1}$	represents un-factored leading variable action at its "frequent value";
$\sum_{i>1} \psi_{2,i}Q_{k,i}$	represents un-factored accompanying variable actions at their quasi-permanent value.

Values of ψ factors should be obtained from Annex C.

4.5.3.4 Quasi-permanent combination

In the general context of the Eurocodes, the quasi-permanent combination of actions is used for the evaluation of long-term effects such as creep or shrinkage. It is also used for crack-width checks for reinforced concrete elements. It is unlikely that it will be applicable in most temporary works designs.

The quasi-permanent combination of actions is given by BS EN 1990:2002+A1:2005, Equation (6.16b):

$$\sum_{j\geq 1} G_{k,j} \text{"+"} P \text{"+"} \sum_{i>1} \psi_{2,i} Q_{k,i} \qquad (6.16b)$$

where:

$\sum_{j\geq 1} G_{k,j}$ represents un-factored permanent actions;

P represents un-factored prestress;

$\sum_{i>1} \psi_{2,i} Q_{k,i}$ represents un-factored accompanying variable actions at their quasi-permanent value.

Values of ψ factors should be obtained from Annex C.

4.6 Methods of analysis

4.6.1 Structural analysis to the Eurocodes

The Eurocodes are more explicit in terms of requirements for the approach to analysis than many other design standards. Guidance on analysis is given in Clause **5** of each material-specific Eurocode (i.e. BS EN 1992 for concrete, BS EN 1993 for steel, BS EN 1994 for steel-concrete, BS EN 1995 for timber, BS EN 1996 for masonry and BS EN 1999 for aluminium).

Figure 2 illustrates the analysis options available within the Eurocodes and the related approach to structural verification relevant for temporary works design.

NOTE 1 A key decision in Figure 2 is whether a structure is insensitive to global second order effects. Typically, second order effects are considered if they significantly increase the action effects or significantly modify the structural behaviour. See BS EN 1993-1-1:2005, ***5.2*** *for specific guidance.*

The methods of analysis selected should be appropriate to predict structural behaviour with an acceptable level of accuracy and be appropriate to the limit states considered.

It is anticipated that the majority of temporary works will continue to be designed using first order analysis or simplified second order analysis, which includes second order effects typically by applying a system of equivalent horizontal forces to the initial geometry of the structure. When using first order analysis or simplified second order analysis a minimum equivalent horizontal force of 2.5% of the vertical actions should be applied to all temporary works to ensure lateral stability.

NOTE 2 This recommendation is consistent with BS 5975:2008:+A1:2011, ***19.2.9.1****. The Bragg Report [1] also recognizes the importance of applying a minimum horizontal force to ensure lateral stability (see* ***4.8****).*

NOTE 3 The application of the minimum equivalent horizontal force of 2.5% of the vertical actions is likely to lead to more conservative design solutions than those resulting from a rigorous application of systems of equivalent forces as given in the Eurocodes.

4.6.2 Imperfections

The influence of global and local imperfections such as eccentricities, angular imperfections at joints, bow and sway should be taken into account in the analysis where relevant (see Figure 2 for guidance).

NOTE 1 Typically, the approaches used to consider the effects of imperfections in structural analysis are:

a) *defining the geometry of the structure so that it takes account of the imperfect shape; or*

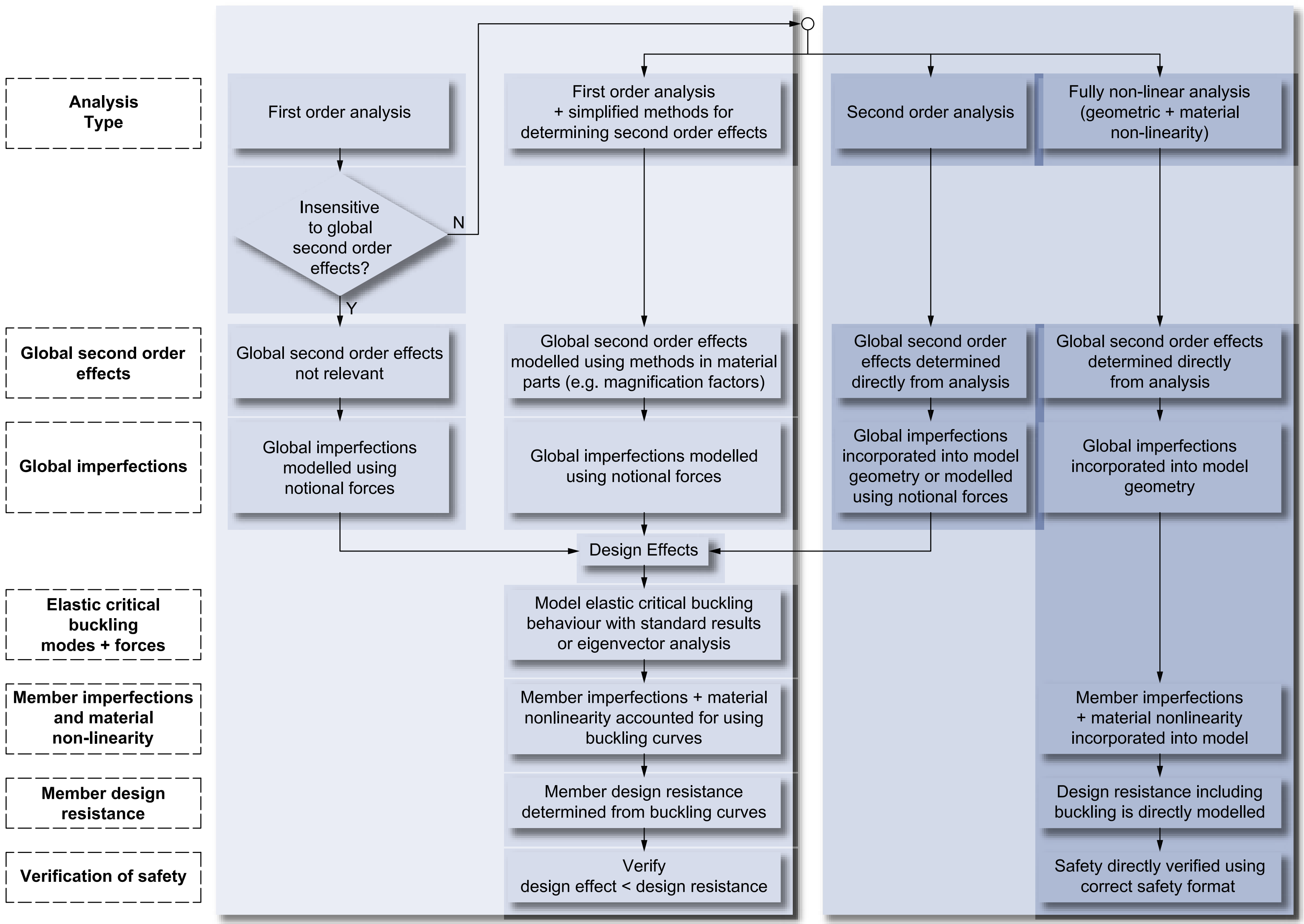
b) *representing the effects of geometric imperfections by introducing systems of equivalent forces.*

NOTE 2 The application of the minimum equivalent horizontal force of 2.5% of the vertical actions as given in ***4.6.1*** *also allows for the effects of initial imperfections within an analysis.*

When designing to the Eurocodes, specific recommendations concerning imperfections are provided in each material-specific part.

Other European Standards (e.g. BS EN 12810 to 12812) can provide supplementary guidance specific to their field of application.

Figure 2 – Methods of structural analysis presented in the Eurocodes and related approach to structural verification



4.7 Verifications

4.7.1 Ultimate limit states

4.7.1.1 General

The Eurocodes require six ultimate limit states to be verified where relevant:

a) EQU, which addresses loss of static equilibrium of the structure or any part of it considered as a rigid body (e.g. overturning);

b) STR, which considers the failure of the structure or structural elements (including those of foundations) where the strength of structural materials governs;

c) GEO, which considers the failure or excessive deformation of the ground where the strength of geotechnical materials are significant in providing resistance;

d) UPL, which addresses loss of equilibrium of the structure or the ground due to uplift by water pressure (buoyancy) or other vertical actions;

e) HYD, which addresses hydraulic heave, internal erosion and piping in the ground caused by hydraulic gradients; and

f) FAT, which considers fatigue-induced failure of the structure or structural members.

4.7.1.2 Loss of equilibrium (EQU)

When considering a limit state of static equilibrium (EQU) it should be verified that:

$$E_{d,dst} \leq E_{d,stb}$$

where:

$E_{d,dst}$ is the design value of the effect of destabilizing actions;

$E_{d,stb}$ is the design value of the effect of stabilizing actions.

4.7.1.3 Failure of structure or ground (STR and GEO)

When considering a limit state of rupture or excessive deformation of a section, member or connection (STR and/or GEO), it should be verified that:

$$E_d \leq R_d$$

where:

E_d is the design value of the effect of actions;

R_d is the design value of the corresponding resistance.

Where geotechnical actions or resistances influence structural design (e.g. spread or piled footings, retaining walls) the STR and GEO limit state verifications should be undertaken in parallel by applying Design Approach 1 in the UK (see **6.2.7.3**).

Where geotechnical actions or resistances do not influence structural design, it is appropriate to undertake a STR limit state verification only.

4.7.1.4 Failure due to uplift (UPL)

When considering a limit state of uplift (UPL) it should be verified that:

$$G_{dst;d} + Q_{dst;d} \leq G_{stb;d} + R_d$$

where:

$G_{dst;d}$ is the design value of destabilizing permanent vertical actions;

$Q_{dst;d}$ is the design value of destabilizing variable vertical actions;

$G_{stb;d}$ is the design value of stabilizing permanent vertical actions;

R_d is the design value of any additional resistance to uplift.

UPL is specific to geotechnical design and is therefore covered in BS EN 1997-1.

4.7.1.5 Failure due to hydraulic heave (HYD)

When considering a limit state of hydraulic heave (HYD) it should be verified that:

$$u_{dst;d} \leq \sigma_{stb;d}$$

or

$$S_{dst;d} \leq G'_{stb;d}$$

where:

$u_{dst;d}$ is the design value of the destabilizing total pore water pressure at the bottom of the soil column;

$\sigma_{stb;d}$ is the design value of stabilizing total vertical stress at the bottom of the soil column;

$S_{dst;d}$ is design value of the seepage force in the column;

$G'_{stb;d}$ is the submerged weight of the same column.

HYD is specific to geotechnical design and is therefore covered in BS EN 1997-1.

4.7.1.6 Failure due to fatigue (FAT)

This limit state deals with fatigue and it is unlikely that it represents a significant concern for temporary works other than temporary bridges reused multiple times.

4.7.2 Serviceability limit states

At serviceability limit state it should be verified that:

$E_d \leq C_d$

where:

E_d is the design value of the effect of actions specified in the serviceability criterion;

C_d is the limiting design value of the corresponding serviceability criterion (see **4.5.3.1**).

4.8 Stability of structural systems

The stability of structural systems and individual elements during service is a fundamental design consideration that is addressed in the Eurocodes and BS 5975.

The consideration of stability during analysis is covered in detail in the individual material-specific Eurocodes.

*NOTE See **4.6.1** on the application of a minimum equivalent horizontal force to temporary works to ensure lateral stability.*

Supplementary guidance on the design and detailing of individual elements is given in Clause **5**.

4.9 Friction

4.9.1 General

Friction forces are the forces that resist movements across a surface under the influence of a normal force. They are generally derived by taking into consideration the normal reaction to the actions applied to the structure and appropriate values of friction coefficients at the sliding interface.

When calculating friction, a distinction should be made between:

a) the design value of the frictional restraint, considered as a resistance (see **4.9.2**); and

b) the design value of the frictional force applied to structural elements as a result of sliding (such as the sub-structure below a sliding bearing), considered as an action (see **4.9.3**).

4.9.2 Frictional restraint

Temporary works often rely on friction to provide lateral stability, particularly during initial assembly.

The design value of the frictional restraint $F_{f,Rd}$ is given by:

$F_{f,Rd} = (\mu/\gamma_{f,Rd}) \cdot N_d$

where:

μ is the coefficient of friction (see **4.9.4**);

$\gamma_{f,Rd}$ is the partial factor to account for uncertainty in the coefficient of friction when calculating the frictional restraint;

*NOTE See **4.9.4.2** for specific guidance on the determination of $\gamma_{f,Rd}$.*

N_d is the design value of the reaction force normal to the surface, which is derived from the design value of the component of the vertically applied forces normal to the sliding surface.

When determining frictional restraint, the partial factors applied to the actions giving rise to N_d should take account of whether the effect of the applied action is stabilizing or destabilizing (i.e. whether it increases or decreases N_d). In cases where the effect of an action is stabilizing, the partial factor used in the calculation of N_d should be less than or equal to 1.0 (see Annex C).

4.9.3 Frictional force arising from sliding systems

The design value of the frictional force $F_{f,Ed}$ is given by:

$F_{f,Ed} = \mu \cdot \gamma_{f,Ed} \cdot N_d$

where:

μ is the coefficient of friction (see **4.9.4**);

$\gamma_{f,Ed}$ is the partial factor to account for uncertainty in the coefficient of friction when calculating the frictional force arising from sliding systems;

*NOTE See **4.9.4.3** for specific guidance on the determination of $\gamma_{f,Ed}$.*

N_d is the design value of the reaction force normal to the surface, which is derived from the design value of the component of the vertically applied forces normal to the sliding surface.

4.9.4 Coefficient of friction μ and its uncertainty

4.9.4.1 General

The coefficient of friction μ can be either the static or dynamic value as appropriate for the design situation considered.

The value of the coefficient of friction μ selected should reflect the combination of materials that form the sliding surface, their state of preparation, lubrication and potential for the ingress of contaminants that might affect the sliding properties during the period of service.

The values of μ adopted for design and any related assumptions in terms of the condition of the sliding surface should be recorded in the design brief and, if applicable, the design statement.

Lower and upper bound values of static coefficients of friction might have to be taken into account depending on whether friction is providing restraint or giving rise to an action arising from a sliding system.

***NOTE** Coefficients of static friction for various combinations of materials are available from a number of sources (e.g. BS EN 12812:2011, Table B.1 or BS 5975:2008+A1:2011, Table 24). Values from BS 5975:2008+A1:2011, Table 24 are given as lower bound values.*

4.9.4.2 Determination of $\gamma_{f,Rd}$

Where lower and upper bound values of static coefficients of friction are explicitly taken into account, values of the partial factors $\gamma_{f,Rd}$ should be equal to 1.0.

Where a single value of the coefficient of friction is considered, values of the partial factor $\gamma_{f,Rd}$ should be agreed and recorded in the design brief and, if applicable, the design statement.

The partial factors applied to actions and to frictional resistance should give an overall factor of safety of not less than 2.0 based on un-factored loads.

***NOTE** This recommendation is consistent with the approach adopted by BS 5975.*

4.9.4.3 Determination of $\gamma_{f,Ed}$

Where lower and upper bound values of static coefficients of friction are explicitly taken into account, values of the partial factor $\gamma_{f,Ed}$ should be equal to 1.0.

Where a single value of the coefficient of friction is considered, values of the partial factor $\gamma_{f,Ed}$ should be greater than 1.0 and should be agreed and recorded in the design brief and, if applicable, the design statement.

4.10 Use of proprietary equipment

A significant proportion of temporary works is supplied in the form of a proprietary product (e.g. formwork panels, props, access stairs, falsework components, hydraulic bracing frames). These may be used in isolation, independent of any other piece of equipment, or as an integral part of a larger whole (and contributed to by other parties). In both cases, their capacity and any restrictions on their usage should be clearly established.

When specifying the use of proprietary equipment that has been given a SWL (see **3.1.3**) rating by its manufacturer, it should be ensured that the equipment is used as intended by the manufacturer and an appropriate level of safety achieved.

When designing structures where there is no significant geotechnical influence, the characteristic combination of actions defined in BS EN 1990:2002+A1:2005, **6.5.3** (and discussed at **4.5.3.2**) can be used to establish nominal load effects within elements for which proprietary equipment is specified. As these load effects result from the application of un-factored actions, the quoted SWL should allow for an appropriate overall factor of safety.

4.11 Off site manufacture

Elements of temporary works systems can be supplied in the form of components manufactured off site. In such cases all issues related to off site manufacture should be taken into account, including handling from factory to final location and the implications for transport, how the components are moved onto and across incomplete structures on site and how they are stabilized until the permanent structure exists.

Health and safety aspects related to all off site manufacture processes should also be taken into account in order to identify, manage, mitigate and eliminate health and safety and other relevant risks.

5 Materials

5.1 General

Properties of materials (including soil and rock) or products should be represented by characteristic values (X_K). Design values of a material or product property (X_d) should either be obtained using the relevant characteristic value X_K in association with material partial factors γ_M (see **B.3.4**), or established directly and recorded in the design statement.

*NOTE General recommendations on material and product properties are given in BS EN 1990:2002+A1:2005, **4.2**.*

Values of material or product properties are given in the material-specific Eurocodes, in the relevant harmonized European technical specifications and other technical documents. Reference standards for different structural materials are listed in Table 3. Guidance on specific design requirements for identified groups of temporary works is given in Clause **6**.

5.2 Design values of material or product properties and resistances

Design values of material or product properties and resistances are typically derived by applying appropriate material partial factors. Values of these partial factors are given in the material-specific Eurocodes as listed in Table 3.

*NOTE For additional information see BS EN 1990:2002+A1:2005, **4.2**.*

5.3 Specific considerations for steel and aluminium

5.3.1 Reuse of prefabricated equipment

A minimum value of the partial material factor $\gamma_M = 1.1$ should be used for proprietary equipment and steel and aluminium elements which might be reused multiple times. Where the relevant Eurocode specifies higher values, those should be used.

NOTE Some European product and execution standards specifically for temporary works (such as BS EN 12811-1 and BS EN 12812) recommend a partial material factor $\gamma_M = 1.1$ for steel and aluminium structures, which is higher than the value given in the Eurocodes. This increased value is intended to take account of the reuse of equipment, increased possibility of bow imperfections, eccentricity and lack of redundancy.

5.3.2 Local stability at load transfer points

In temporary works, where high concentrations of loading can often occur on relatively light members and there is generally less joint rigidity and restraint than in permanent works, the problem of local instability due to web crushing and buckling becomes more critical.

For structural steelwork, web stiffeners should be provided at all loading transfer points including supports, unless calculations are provided to show that such stiffeners are not required for the actual conditions applying and materials used on site.

*NOTE This recommendation is consistent with BS 5975:2008+A1:2011, **J.1**.*

Table 3 – Reference standards for different structural materials

Material	Reference standard			Product and test
	Material properties	Partial factors for materials and resistance	Execution requirements	
Aluminium	BS EN 1999-1-1:2007+A2:2013, Clause **3** BS EN 1999-1-2:2007, Clause **3** BS EN 1999-1-3:2007+A1:2011, Clause **3** BS EN 1999-1-4:2007+A1:2011, Clause **3** BS EN 1999-1-5:2007, Clause **3**	BS EN 1999-1-1:2007+A2:2013, **6.1.3** and **8.1** BS EN 1999-1-4:2007+A1:2011, Clause **2** (cold-formed structural sheeting) BS EN 1999-1-5:2007, **2.1** (shell structures)	—	All product standards indicated in the normative references of BS EN 1999.
Steel	BS EN 1993-1-1:2005+A1:2014, Clause **3** BS EN 1993-1-2:2005, Clause **3** BS EN 1993-1-3:2006, Clause **3** BS EN 1993-1-4:2006, Clause **3** BS EN 1993-1-5:2006, Clause **3** BS EN 1993-1-6:2007, Clause **3** BS EN 1993-1-7:2007, Clause **3** BS EN 1993-1-8:2005, Clause **3** BS EN 1993-1-9:2005, Clause **3** BS EN 1993-1-10:2005, Clause **3** BS EN 1993-1-11:2006, Clause **3** BS EN 1993-1-12:2007, Clause **3** BS EN 1993-2:2006, Clause **3** BS EN 1993-3-1:2006, Clause **3** BS EN 1993-3-2:2006, Clause **3** BS EN 1993-4-1:2007, Clause **3** BS EN 1993-4-2:2007, Clause **3** BS EN 1993-4-3:2007, Clause **3** BS EN 1993-5:2007, Clause **3** BS EN 1993-6:2007, Clause **3**	BS EN 1993-1-1:2005+A1:2014, **6.1** (general) BS EN 1993-1-3:2006, Clause **2**, **8.3**, **8.4**, **8.5** (cold formed members and sheeting) BS EN 1993-1-4:2006, **5.1** (stainless steels) BS EN 1993-1-6:2007, **8.5.2** (shell structures) BS EN 1993-1-11:2006, **2.4** (cables) BS EN 1993-2:2006, **6.1** (bridges) BS EN 1993-3-1:2006, Clause **6** (towers and masts) BS EN 1993-3-2:2006, Clause **6** (chimneys) BS EN 1993-5:2007, Clause **5** (piling) BS EN 1993-6:2007, Clause **6** (cranes)	BS EN 1090	All product standards indicated in the normative references of BS EN 1993.
Concrete	BS EN 1992-1-1:2004+A1:2014, Clause **3** BS EN 1992-2:2005, Clause **3**	BS EN 1992-1-1:2004+A1:2014, **2.4**	BS EN 13670	All product standards indicated in the normative references of BS EN 1992.
Timber	BS EN 1995-1-1:2004+A2:2014, Clause **3** BS EN 1995-2:2004, Clause **3**	BS EN 1995-1-1:2004+A2:2014, **2.4** (general) BS EN 1995-2:2004, **2.4** (bridges)	—	All product standards indicated in the normative references of BS EN 1995.
Masonry	BS EN 1996-1-1:2005+A1:2012, Clause **3**	BS EN 1996-1-1:2005+A1:2012, **2.4.3**	BS EN 1996-2	All product standards indicated in the normative references of BS EN 1996.

NOTE 1 *The UK National Annexes to the standards indicated in this table are also relevant.*

NOTE 2 *This table provides the main reference clauses. For specific cases, other clauses in the standards indicated in this table or other specific standards might also be of relevance.*

NOTE 3 *There is currently no Eurocode dealing with fibre reinforced polymers. Information can be found in the following publications:* EuroComp Design Code and Handbook *[4], BS EN 13706, Revised CUR 96 FRP Composite Structures [5], Manuals of Practice (MOP) #102 [6], BD 90 [7], PAS 8820 (in preparation).*

6 Specific design requirements for identified groups of temporary works

6.1 Group 1 – Falsework, formwork, access and protection

6.1.1 Falsework

6.1.1.1 General

Falsework is one of the few categories of temporary works that has a European Standard specifically applying to it, i.e. BS EN 12812, *Falsework – Performance requirements and general design*.

BS EN 12812 gives performance requirements for specifying and using falsework and gives methods to design falsework to meet those requirements. It does not stand alone, but makes reference to the Eurocodes. Information on structural design is intended to be supplementary to the provisions given in the Eurocodes (see BS EN 12812:2008, Introduction) and includes some modifications, principally to the partial factors (see **6.1.1.4**).

NOTE *BS EN 12812 recognizes the key features of temporary works (see* ***0.3****), and advocates partial material factors that take account of the reuse of equipment, increased possibility of bow imperfections, eccentricity and lack of redundancy.*

General guidance on the application of BS EN 12812 in the UK is provided by BS EN 12812:2008, National Annex.

The design advice given in Clause **4** is compatible with the underlying principles of BS EN 12812.

The high level of safety established in the design of falsework in the UK is largely attributable to three key requirements established by BS 5975:

a) the consistent use of an appropriate level of reliability;
b) the use of procedural controls; and
c) a minimum equivalent horizontal force of 2.5% of the vertical loads applied at the head of falsework.

6.1.1.2 Design checks

For all falsework systems the following four design checks set out in BS 5975:2008+A1:2011, **19.4** should be undertaken:

a) structural strength of the individual members and the connections to transmit the applied forces safely;
b) lateral and nodal stability of individual members and the structure as a whole;
c) overturning of the falsework; and
d) positional stability of the falsework (i.e. sliding).

6.1.1.3 Free-standing and top-restrained falsework systems

A key consideration during the design of falsework is whether the falsework system is free-standing or top-restrained (see BS 5975:2008+A1:2011, **19.3.2**). This has a fundamental influence on the lateral stability and therefore the load carrying capacity of the falsework system.

NOTE *The terms "free-standing" and "top-restrained" are consistent with BS 5975.*

When applying the equivalent horizontal force at the head of falsework:

a) in the case of free-standing falsework, this force should be resisted by the falsework in horizontal shear and taken to suitable restraint;
b) in the case of top-restrained falsework, this force should be resisted at the top by elements of the permanent works which have been designed to provide that resistance.

6.1.1.4 Scope of application of BS EN 12812

The modifications provided by BS EN 12812 should be used only to design lightweight reusable equipment generally fabricated from steel or aluminium.

NOTE 1 *Although BS EN 12812 implies a wide field of application (see BS EN 12812:2008, Introduction, Clause* ***1*** *and* ***3.3****), the majority of its advice applies most directly to the support of concrete and building materials using lightweight reusable equipment generally fabricated from steel or aluminium.*

NOTE 2 *The modifications provided by BS EN 12812 are likely to lead to more conservative design solutions than those resulting from a rigorous application of the Eurocodes.*

NOTE 3 *The overall level of reliability achievable by applying the modifications provided by BS EN 12812 is expected to be broadly in line with previous industry practice using BS 5975.*

6.1.1.5 Design classes

6.1.1.5.1 General

BS EN 12812:2008, Clause **4** identifies two design classes for falsework systems:

a) class A (see BS EN 12812:2008, **4.2**); and

b) class B (see BS EN 12812:2008, **4.3**).

6.1.1.5.2 Class A

BS EN 12812:2008, **4.2** deals with class A falsework. This covers falsework systems for simple construction (such as in situ slabs and beams). The extent of its application is tightly defined in BS EN 12812:2008, **4.2**.

BS EN 12812:2008, **4.2** does not indicate any reference standard to design class A and refers to established good practice. However, it is vital that a quantitative design approach is adopted for any falsework system and BS EN 12812:2008, National Annex recommends that the design rules in BS 5975 are used. Alternatively, class A falsework may be designed following the provisions given for class B falsework systems as appropriate.

6.1.1.5.3 Class B

BS EN 12812:2008, **4.3** deals with class B falsework, which is subdivided into classes B1 and B2. Class B falsework should be designed in accordance with the recommendations given in Table 4.

The key difference between the two subclasses is the degree of simplification used in the design. Class B2 allows a simplified approach, but introduces an additional partial factor on material resistance of γ_R = 1.15 (see BS EN 12812:2008, **9.2.2.1** d) 2)). The design advice given by BS EN 12812 for class B2 falsework can only be directly applied to free-standing, fully braced falsework constructed from steel tube and fitting.

Falsework systems that support bridge deck subject to traffic loads should always be designed to class B1 using the specific guidance given in BS EN 1990:2002+A1:2005, Annex A2.

Table 4 – Guidance and recommendations for the design of class B falsework

	Subclass	
	Class B1	**Class B2**
1. Reference standard for structural design	The design of class B1 falsework should be to the Eurocodes, with the design process and all documentation being to the standard of permanent works design (see BS EN 12812:2008, **NA.4**). BS EN 12812 provides specific supplementary guidance for class B1 on: - differential settlements (see BS EN 12812:2008, **8.3.2**); - design documentation (see BS EN 12812:2008, **9.1.1**, **9.1.2.1** and **9.1.3**); - design value of resistance (see BS EN 12812:2008, **9.2.2.1** d)); - imperfections of tube-based systems (see BS EN 12812:2008, **9.3.3**); - calculation of internal forces (see BS EN 12812:2008, **9.4.1**); and - partial material factors (see BS EN 12812:2008, **9.5.1**) (see also Table 4, partial factors on material properties).	The design of class B2 falsework should be to the Eurocodes where not modified by the following clauses of BS EN 12812:2008: - Clause **5**, Materials; - Clause **6**, Design brief; - Clause **7**, Design requirements; - Clause **8**, Actions and load combination; and - Clause **9**, Structural design (with the exception of subclauses specific to class B1).

Table 4 – Guidance and recommendations for the design of class B falsework *(continued)*

	Subclass	
	Class B1	**Class B2**
2. Actions	Actions should be defined according to the relevant parts of BS EN 1991 and BS EN 1997. Particular attention should be paid to the classification of supported constructions. BS EN 1991-1-6 defines loads from supported construction as variable actions. Specific recommendations for the treatment of supported constructions within the context of EQU and STR limit states are given at **4.4.1** and Annex C.	Actions should be defined in accordance with **BS** EN 12812:2008, Clause **8** and supplemented by the actions defined by the Eurocodes where relevant. The terminology used for the classification of actions defined within BS EN 12812:2008, Clause **8** deviates from that used in the Eurocodes. A key difference is that supported constructions are referred to as "variable persistent imposed actions". This terminology is not consistent with BS EN 1990 and BS EN 1991. However, it serves to acknowledge that, in the case of falsework, actions from supported constructions are unlikely to change once in place. BS EN 12812:2008, **8.2.2.2** recommends that a persistent horizontal load equal to 1% of the vertical load is applied in addition to effects caused by imperfections. This differs from BS 5975:2008+A1:2011, **19.2.4**, which requires a horizontal reaction equal to 1% of the applied vertical forces to be taken into account to allow for erection tolerances.
3. Partial factors on actions	For ultimate limit state verifications the recommended values for partial factors on actions given at **C.4** should be used. Particular attention should be paid to the partial factors relevant to supported construction (see Annex C). For serviceability limit state verifications the recommendations given at **C.5** should be followed.	For ultimate limit state verifications the recommended values for partial factors on actions given in BS EN 12812:2008, **9.2.2.1**b) should be used. For serviceability limit state verifications reference should be made to BS EN 12812:2008, **9.2.2.2**.
4. Partial factors on material properties	Values of partial material factors should be taken from the material-specific Eurocodes (see Clause **5**) but with a minimum value of $\gamma_{M,i}$ = 1.1 for steel and aluminium elements which might be reused multiple times (BS EN 12812:2008, **9.5.1**).	Values of partial material factors should be taken from BS EN 12812:2008, **9.5.1** for steel and aluminium. BS EN 12812:2008, **9.2.2.1**d)2) introduces an additional uncertainty factor of 1.15 to further reduce the design resistance to allow for the simplified approach to structural analysis.
5. Combination of actions	Relevant combinations of actions are presented at **4.5**. Recommended values of ψ factors are provided in Table C.1.	BS EN 12812:2008, **8.5** suggests four load cases where all variable actions other than "flowing water" are considered at their characteristic value simultaneously. The simplistic nature of these load cases is acknowledged in Note 1 to BS EN 12812:2008, **8.5**.

6.1.1.6 Calculation of internal forces

The calculation of internal forces from combined vertical and horizontal loads should take second order effects into account where appropriate (see **4.6.1**). Second order effects can be significant for slender towers and falsework towers that are partially braced, but reduce significantly for squat towers and can be considered to be negligible in fully braced falsework with multiple bays.

NOTE 1 The terms "fully braced" and "partially braced" are consistent with BS 5975.

Traditionally, the calculation of internal forces within falsework structures when applying BS 5975 has used simple elastic analysis with a notional lateral force (or equivalent horizontal force) to take initial imperfections and second order effects into account. This method of analysis is only valid for fully braced falsework where second order effects are not significant. Elastic analysis with an equivalent horizontal force is also a valid method for the design of falsework to the Eurocodes and BS EN 12812.

In all cases, at each phase of construction, falsework systems should be designed to resist the applied vertical loads and an equivalent horizontal force which is the greater of:

a) at least 2.5% of the applied vertical loads; or

b) the most unfavourable combination of imposed horizontal actions plus erection tolerances, where relevant.

*NOTE 2 This recommendation is consistent with BS 5975:2008+A1:2011, **19.2.9.1**.*

General guidance on the treatment of imperfections in structural analysis carried out to the Eurocodes is provided at **4.6.2**. For class B2 falsework the recommendations given by BS EN 12812:2008, **9.3** may be followed.

6.1.1.7 Effective (or buckling) lengths

BS EN 1993 provides limited guidance on values for effective lengths. However, a broad range of guidance is available that deals with aspects of the stability of beams and columns. SCI report P360, *Stability of steel beams and columns* [8] provides guidance for a wide range of common and non-standard restraint conditions that might be encountered.

NOTE See also BS 5975 for information on the effective length of members.

BS EN 1993-1-1:2005, **5.2.2** recommends that if individual stability checks are used to account for second order effects and imperfections, then the effective lengths used reflect the global buckling mode of the structure.

6.1.1.8 Bracing of falsework

Internal brace forces are dependent on externally-applied loads, stiffness of the bracing system, eccentricities of both connections and the point of application of loads, initial member straightness and verticality and second order effects.

NOTE 1 Although the bracing stiffness has traditionally been ignored, in some situations it might need to be taken into account by carrying out a full second order analysis.

Recommendations for node point restraint in compression elements as a result of local sway imperfections are given at BS EN 1993-1-1:2005, **5.3.2** (5). Recommendations for intermediate restraints in braced compression elements as a result of overall bow imperfections are given at BS EN 1993-1-1:2005, **5.3.3**. In the absence of a rigorous analysis, each level of lacing and bracing should resist a minimum equivalent horizontal force equal to 2.5% of the vertical load in the strut in order to achieve nodal stability.

*NOTE 2 This recommendation is consistent with BS 5975:2008+A1:2011, **19.2.9.2**.*

BS EN 12812 gives limited guidance on the calculation of brace forces within falsework. It provides empirical methods for calculating the ideal shear stiffness of the bracing using tube and fittings (see BS EN 12812:2008, **9.4.2.4.1**), timber (see BS EN 12812:2008, **9.4.2.4.2**) and tensioned rods (see BS EN 12812:2008, **9.4.2.4.3**). These provisions cannot be directly applied to any other systems. BS EN 12812:2008, **9.4.2.5.1** provides specific guidance on stiffening of free-standing (fully braced and not top-restrained) lattice towers systems. These subclauses are only relevant to class B2 falsework.

6.1.1.9 Specific guidance on temporary façade retention

Façade retention schemes are temporary structures generally required to support an existing façade and to protect workers and the general public.

Guidance on design of temporary façade retention is provided by CIRIA Report C579, *Retention of Masonry Façade: Best practice guidance* [9]. Further guidance can be found in ICE, *Temporary Works – Principles of design and construction*, Chapter 26 [10].

Wind action is generally the main load to be considered. CIRIA Report C579 [9] recommends a probability factor of c_{prob} = 1.00.

6.1.2 Formwork

6.1.2.1 General

There is no specific European Standard for the design of formwork. In September 2008 the European Standards Committee, CEN/TC 53, for temporary works equipment ruled not to continue work on the preparation of a European Standard for vertical formwork.

Guidance on design of formwork within the UK is provided by the Concrete Society CS30, *Formwork – a guide to good practice* [11]. CS30 covers the philosophy of the design of formwork for walls, columns and soffits. Information is presented in permissible stress terms to maintain compatibility with BS 5975, but data relating to characteristic strength value of timber are presented in CS30, Appendix E [11] to allow designs to be undertaken in accordance with the limit state principles of BS EN 1995.

The design approach and standards adopted should be recorded and justified in the design brief and, if applicable, the design statement.

6.1.2.2 Specific actions on formwork

Characteristic values for concrete pressures on formwork may be calculated using the methods proposed by CIRIA Report R108, *Concrete pressure on formwork* [12]. Due consideration needs to be given to the characteristics of the concrete mix being used and advice on its application using modern concrete mixes and classifications is given in CS30 [11].

All other actions on falsework that need to be taken into account during service conditions should be derived using the relevant Eurocode parts as set out in **4.4.2**.

6.1.2.3 Properties of timber and wood-based products

Timber structures should be designed to BS EN 1995-1-1 and the NA to BS EN 1995-1-1.

Guidance on the application of BS EN 1995-1-1 and NA to BS EN 1995-1-1 is given in PD 6693-1.

Guidance on section sizes, stresses and methods of testing is given by a variety of product standards. Relevant standards are given in the normative references to BS EN 1995-1-1 and NA to BS EN 1995-1-1.

The modification factors for timber and various plywood and oriented strand board (OSB) are given in BS EN 1995-1-1.

Guidance on the evaluation of the characteristic strength of plywood is given in BS EN 789, allowing the supplier/importer to provide the properties applicable for use during design to the Eurocodes.

CS30, Appendix E [11] gives recommendations for appropriate values for material structural properties and characteristic strengths for commonly used wood-based sheet materials. It is important that this information is used when undertaking designs to BS EN 1995-1-1.

NOTE 1 *The guidance in the main body text of CS30 [11] is presented in terms of permissible stress design to be compatible with the design approaches recommended in BS 5975.*

NOTE 2 *The values recommended by CS30 [11] have been approved by a range of trade associations and supply organizations to assist designers.*

CS30, Appendix E [11] also gives recommendations for the modification factors to be applied to basic stresses for use in limit state design.

6.1.3 Access: Scaffolds

6.1.3.1 General

General design criteria for working scaffolds are provided by BS EN 12811-1.

Table 5 lists reference standards for some specific types of scaffold and scaffold components.

Table 5 – Reference standards and other publications for specific types of scaffold and scaffold components

Scaffold/component type	Standard
Prefabricated scaffolds	BS EN 12810
Towers	BS EN 1004
Edge protection systems	BS EN 13374
Steel scaffold tube	BS EN 39
Aluminium scaffold tube	NASC TG20 [13] A)
Scaffold fittings (or couplers)	BS EN 74
Scaffolding with tubes and fittings	NASC TG20 [13] B)
Scaffold boards	BS 2482 C)

A) Gives only general guidance.

B) Gives safe height tables, working values, etc. for basic tube-and-fitting scaffolds.

C) Scaffold boards are not considered under BS EN 1995, but BS 2482 gives the recommended working moment of resistance of boards conforming to the standard.

6.1.3.2 Specific actions on scaffolds

In addition to the self-weight, a scaffold has to withstand specific loads on working areas, access routes and side protection, wind actions and, in the absence of wind, a notional horizontal working load.

Service loads on working areas should be taken from BS EN 12811-1:2003, Table 3 in accordance with the specific load class introduced by BS EN 12811-1:2003, **6.1.3**. Service loads on working areas should be applied as indicated in BS EN 12811-1:2003, **6.2.2**.

Loads on access routes should be taken from BS EN 12811-1:2003, **6.2.4**.

Loads on edge protection should be taken from BS EN 12811-1:2003, **6.2.5**. The specific provisions on edge protection given in BS EN 13374 should also be applied.

There is a potential anomaly when considering temporary edge protection systems. BS EN 13374 introduces three classes of edge protection depending on roof angle and gives different testing requirements. If, however, the edge protection is constructed from tube-and-fitting, the design requirements of BS EN 12811-1 are more onerous in terms of load intensities. More importantly, BS EN 12811-1 introduces the requirement for an upward load on the handrail, which does not exist in BS EN 13374. The approach adopted should be recorded and justified in the design brief and, if applicable, the design statement.

Wind actions should be calculated in accordance with BS EN 1991-1-4 and **4.4.3.2**.

When designing scaffold systems to BS EN 12811-1, BS EN 12811-1:2003, **6.2.7.4.2** requires consideration of the "working wind load" based on a wind velocity pressure of 200 N/m^2 within the service condition (load combination (a) of BS EN 12811-1:2003, **6.2.9.2**).

For mobile access towers of prefabricated materials, e.g. an aluminium tower, the horizontal design pressure to simulate wind is reduced to only 100 N/m^2. This is based on the assumption that the mobile access tower can be quickly dismantled or tied to another structure if high winds are forecast. The use of a working wind pressure of less than 200 N/m^2 should not be extended to other forms of temporary works.

***NOTE** BS EN 12811-1 uses the term "working wind" but does not define its meaning. It is assumed to mean the maximum wind pressure at which operatives could be working on the scaffold or falsework.*

The notional horizontal working load on scaffold is provided by BS EN 12811-1:2003, **6.2.3**.

6.1.3.3 Specific partial factors on actions and resistances

For the ultimate limit state verifications, BS EN 12811-1:2003, **10.3.2.1** introduces partial factors for actions γ_F = 1.50 for both permanent and variable actions and BS EN 12811-1:2003, **10.3.2.2** introduces partial factors for the calculation of the resistances of steel or aluminium components γ_M = 1.10. These values are not aligned to the Eurocodes but have been agreed by CEN Committee TC/53 within the context of the application of BS EN 12811-1.

NOTE The application of a partial load factor of 1.50 on all actions and a partial material factor for steel and aluminium of 1.10 results in a combined global factor of 1.65. This value is consistent with BS 5975 and NASC TG20 [13].

6.1.3.4 Effective lengths of members

Effective lengths of members may be calculated according to appropriate industry guidance.

NOTE See SCI report P360, Stability of steel beams and columns *[8] and BS 5975 for information on the effective length of members.*

6.1.4 Protection: Site hoardings

Site hoardings are temporary structures commonly used on construction sites, but their design is often neglected. Failure in site hoardings can lead to significant injury or even fatality, as well as disruption, cost and delay to the project.

NOTE It is important not to confuse site hoardings with fencing or environmental barriers.

For the design and construction of signs for publicity purposes, BS 559 is the reference standard.

Guidance on the design of site hoardings is provided by TWf2012:01, *Hoardings – a guide to good practice* [14].

6.2 Group 2 – Geotechnical

6.2.1 General

Geotechnical design of temporary works should be carried out in accordance with BS EN 1997-1 and NA+A1:2014 to BS EN 1997-1 in combination with other relevant Eurocode parts, and be appropriate to the geotechnical category (see **6.2.3**).

NOTE 1 Guidance on geotechnical engineering principles, problematic soils and site investigation can be found in the ICE manual of geotechnical engineering, *Volume 1 [15].*

NOTE 2 Guidance on geotechnical design, construction and verification can be found in the ICE manual of geotechnical engineering, *Volume 2 [16].*

Figure 3 gives a general overview of the steps required for geotechnical design to Eurocodes and provides a tool to navigate **6.2**.

Figure 3 – Overview of geotechnical design to the Eurocodes

1	Definition of relevant design situations (**6.2.2**)
2	Identification of the relevant geotechnical category (to be checked and changed, if necessary, at each stage of the investigation, design and construction process) (**6.2.3**)
3	Identification and description of ground conditions (**6.2.4**) – including groundwater control (**6.2.5**) – and derivation of the characteristic values of geotechnical parameters
4	Preparation of the ground investigation report (**6.2.6**)
5	Limit states design at ultimate limit state and serviceability limit state using appropriate partial factors for actions, material properties and resistance in Design Approach 1 (**6.2.7**)
6	Preparation of the geotechnical design report (**6.2.6**)

6.2.2 Design situations

Guidance on design situations for geotechnical design is given in BS EN 1997-1:2004+A1:2013, **2.2**.

6.2.3 Geotechnical categories

To establish geotechnical design requirements, BS EN 1997-1:2004+A1:2013, **2.1** introduces three geotechnical categories reflecting the complexity of the geotechnical design and associated risk, ranging from category 1, for small and relatively simple structures, up to category 3 for the most complex and challenging projects.

Minimum requirements for light and simple structures and small earthworks are not given in NA to BS EN 1997-1 (see NA+A1:2014 to BS EN 1997-1:2004+A1:2013, **NA.2**) and should be agreed with the client and other relevant authorities. Established industry guidance may be used for structures belonging to geotechnical category 1.

A preliminary classification of the temporary works according to geotechnical category should be performed prior to the geotechnical investigations. The geotechnical category should be checked and, if necessary, changed at each stage of the investigation, design and construction process.

6.2.4 Ground conditions

6.2.4.1 Geotechnical parameters

When dealing with geotechnical design of temporary works, the principal risks lie in predicting ground behaviour and dealing with parameter uncertainty.

The identification and description of soil should conform to BS EN ISO 14688-1. The classification of soil should conform to BS EN ISO 14688-2.

The identification and description of rock should conform to BS EN ISO 14689-1.

Information about fill formation and deposits can be found in BRE Report 424, Chapter 2 [17]. Soil properties should be determined in accordance with BS EN 1997-2 and NA to BS EN 1997-2 and BS 5930.

Characteristic soil parameters should be selected in accordance with BS EN 1997-1, based on the results of field and laboratory tests, by a competent person.

***NOTE** Guidance on the process for selecting characteristic values for geotechnical parameters from laboratory and/or field tests is provided in* Decoding Eurocode 7 *[18],* The Designers' Guide to EN 1997-1 *[19] and CIRIA C580,* Embedded retaining walls – guidance for economic design [1] *[20].*

6.2.4.2 Drained and undrained soil conditions

The assessment of whether drained or undrained soil conditions apply over the service life of the temporary work structure is one of the most critical aspects in geotechnical design and requires careful and thorough consideration by the temporary works designers.

Advice on the assessment of drained (long-term) or undrained (short-term) ground behaviour can be found in CIRIA C580 [20] together with guidance on the selection of parameters appropriate for temporary works.

The use of undrained soil conditions during the design of temporary works requires careful consideration as the period for which soil is effectively undrained depends on its permeability, the availability of free water and the geometry of the situation (BS EN 1997-1:2004+A1:2013, **3.3.6**).

As a general guide, CIRIA C580 [20] recommends that undrained conditions are assumed in the short term where the mass in situ permeability of the ground is low (i.e. a coefficient of permeability of the order of 10^{-8} m/s or less). Where the mass in situ permeability is not low, and in coarse grained soils, drained conditions should be assumed in design.

In addition, CIRIA C580 [20] details that undrained (total stress) conditions are commonly assumed in the temporary works for excavations in London Clay for durations of up to six months.

6.2.5 Groundwater

Groundwater control is fundamental in preventing an excavation below the natural water table from flooding.

BS EN 1997-2 and CIRIA C580 [20] provide general information on groundwater measurements in soils and rocks and groundwater control.

Specific guidance on groundwater control is provided by CIRIA C515, *Groundwater control – design and practice* [21].

6.2.6 Reporting

A ground investigation report should be prepared for any significant temporary works as described in BS EN 1997-1:2004+A1:2013, **3.4** to record the results of ground investigations undertaken in accordance with BS EN 1997-2.

A geotechnical design report should be prepared for any significant temporary works as described in BS EN 1997-1:2004+A1:2013, **2.8**.

General guidance on foundation design may be taken from BS 8004, which recommends that a geotechnical feedback report is produced, containing full records of the works constructed, including information on the temporary works required and their effectiveness.

6.2.7 Limit state geotechnical design

6.2.7.1 Actions

Actions applicable during geotechnical design are presented in BS EN 1997-1:2004+A1:2013, **2.4.2**.

6.2.7.2 Partial factors

Table 6 shows the subclauses appropriate to derive partial factors on actions (γ_F), material properties (γ_M) and resistance (γ_R) for different limit states.

BS EN 1997-1:2004+A1:2013, **2.4.7.1** (5) states that less severe values than those recommended at BS EN 1997-1:2004+A1:2013, Annex A may be used for temporary structures or transient design situations, where the likely consequences justify it. However, NA to BS EN 1997-1 does not present these values and recommends that they are agreed with the client and relevant authorities for the specific situation.

[1] This is currently being revised and is expected to be published as CIRIA C760, *Embedded Retaining Walls – Guidance for Design.*

BS EN 1997-1:2004+A1:2013, **2.4.7.1** (4) also recommends that more severe values than those recommended at BS EN 1997-1:2004+A1:2013, Annex A are used in cases of abnormal risk or unusual or exceptionally difficult ground or loading conditions. However, NA to BS EN 1997-1 does not present these values and recommends that they are agreed with the client and relevant authorities for the specific situation.

Where alternative values are adopted, they should be recorded within the design brief and, if applicable, the design statement along with a description of the reason for their adoption.

NOTE CIRIA C580 [20] notes for example that modification to the partial factors for soil parameters cannot be justified on the basis that the retaining wall is temporary. Partial factors for soil parameters are introduced to account for uncertainty in measuring these parameters and are therefore not related to the duration the retaining wall is intended to be operational.

6.2.7.3 Design approach

The manner in which partial factors are applied to actions (or effects of actions), ground properties and resistance in geotechnical design for STR and GEO verifications in persistent and transient design situations (see Equation 6.10 in **4.5.2.1**) depends on the design approach chosen in NA to BS EN 1997. In the UK, Design Approach 1 is used.

NOTE 1 Clarification of the design approaches is provided at BS EN 1997-1:2004+A1:2013, Annex B.

Design Approach 1 requires two separate calculations (see BS EN 1997-1:2004+A1:2013, **2.4.7.3.4.2** (1)) using different sets of partial factors. These two calculations apply partial factors to actions (or equally to effects of actions) and to soil parameters.

*NOTE 2 For the design of axially loaded piles and anchors, see BS EN 1997-1:2004+A1:2013, **2.4.7.3.4.2** (2).*

Table 6 – Partial factors on actions, ground properties and resistance

Limit state	γ_F	γ_M	γ_R
EQU A)	a) For temporary works in general, Table C.2. b) For bridges or other structures and geotechnical works that are subjected to traffic loads: 1) for group 1 and group 2 construction loads: Table C.2; 2) for all other actions: NA to BS EN 1990:2002+A1:2005, **NA.2.3**.	NA+A1:2014 to BS EN 1997-1:2004+A1:2013, **A.2.2**	—
STR and GEO A), B)	a) For temporary works in general, Table C.3 and Table C.4. b) For bridges or other structures and geotechnical works that are subjected to traffic loads: 1) for group 1 and group 2 construction loads, Tables C.3 and C.4; 2) for all other actions: NA to BS EN 1990:2002+A1:2005, **NA.2.3**.	NA+A1:2014 to BS EN 1997-1:2004+A1:2013, **A.3.2**	NA+A1:2014 to BS EN 1997-1:2004+A1:2013, **A.3.3**
UPL	NA+A1:2014 to BS EN 1997-1:2004+A1:2013, **A.4.1**	NA+A1:2014 to BS EN 1997-1:2004+A1:2013, **A.4.2**	
HYD	NA+A1:2014 to BS EN 1997-1:2004+A1:2013, **A.5**	—	

A) There might be cases where the values of γ_F specified are not appropriate (for example for self-weight of water, groundwater pressure and other actions dependent on the level of water). In such cases, guidance is given in NA to BS EN 1997-1, Annex A.

B) See **6.2.7.3** for the application of partial factors in Design Approach 1.

Figure 4 and Figure 5 give a general overview of the application of partial factors in STR/GEO limit states for geotechnical design to the Eurocodes.

Figure 4 – Application of partial factors in Design Approach 1, Combination 1 for STR/GEO, persistent or transient design situations (except axially loaded piles and anchors)

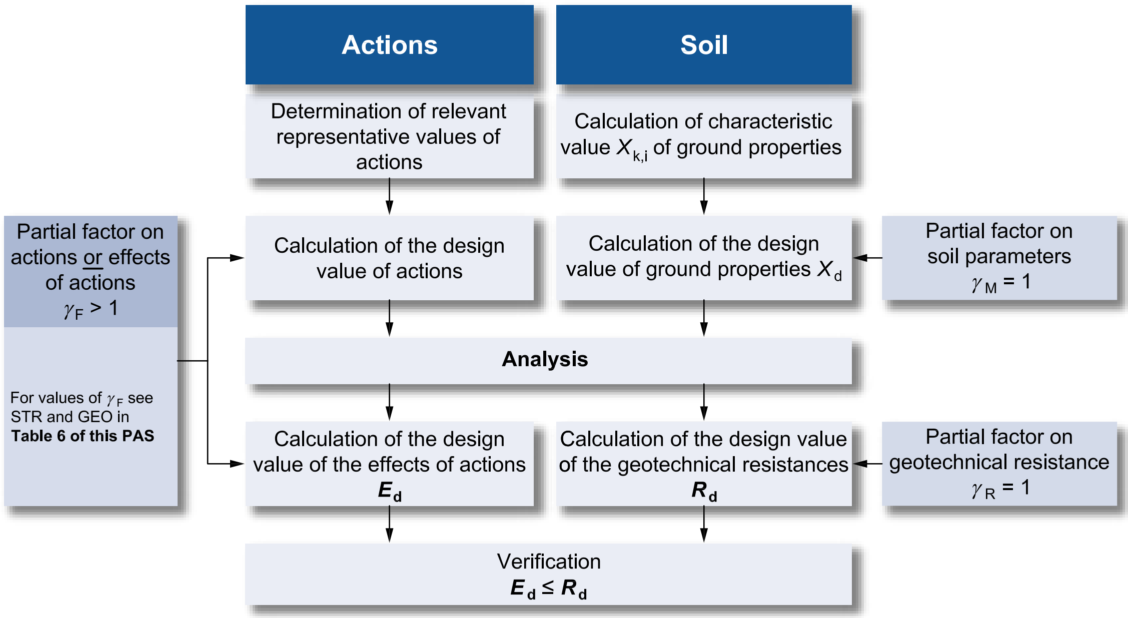
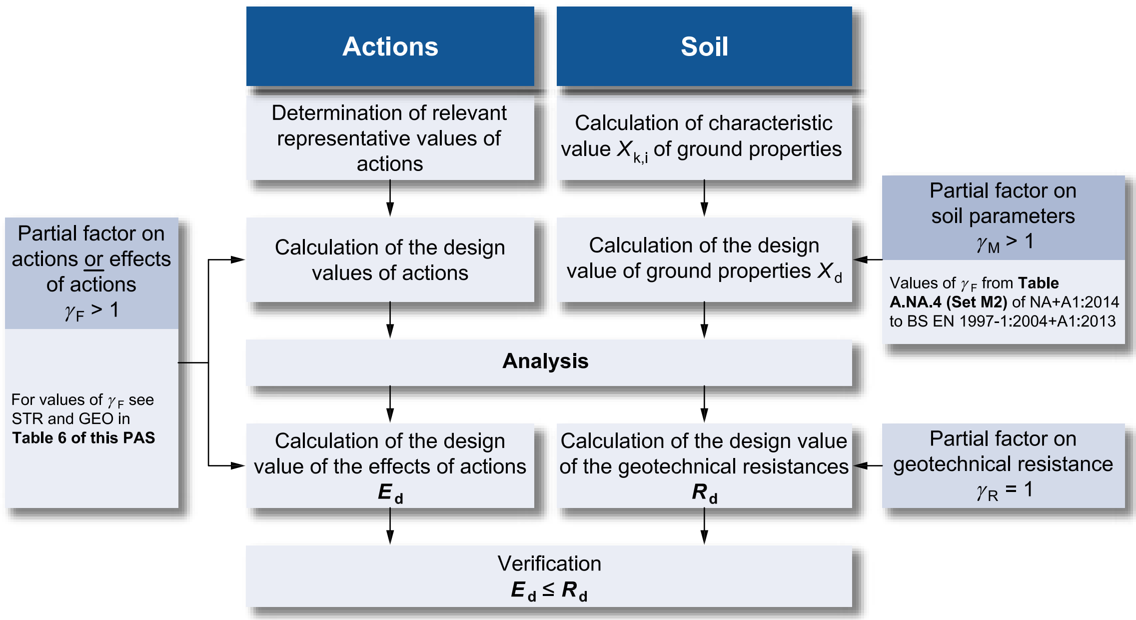


Figure 5 – Application of partial factors in Design Approach 1, Combination 2 for STR/GEO, persistent or transient design situations (except axially loaded piles and anchors)



6.2.8 Crane bases

6.2.8.1 General

Crane bases are temporary foundations which provide the base upon which cranes or other similar construction equipment are erected.

Crane bases should be designed according to BS EN 1997-1 and NA to BS EN 1997-1.

General guidance on foundation design may be taken from BS 8004.

Guidance on the design foundations for tower cranes is also given in CIRIA C654 [22].

***NOTE** The current version of CIRIA C654 mainly focuses on design to British Standards using a permissible stress approach. A new version of CIRIA C654 aligned to the Eurocodes principles and terminology is currently being developed.*

6.2.8.2 Actions

Actions applied to a tower crane foundation need to take into account both the in-service and out-of-service conditions as well as all significant stages during the erection and dismantling of the crane.

CIRIA C654 [22] provides guidance on the actions to consider for both in-service and out-of-service condition.

The current version of CIRIA C654 [22] does not use Eurocodes terminology. For consistency with the Eurocodes, the following distinction should be adopted.

a) In-service actions:
   1) permanent actions: self-weights of the crane components;
   2) variable actions: construction load, weight of the load being lifted, in-service wind loading;
   3) additional actions caused by dynamic effects.
b) Out-of-service actions:
   1) permanent actions: self-weights of the tower crane components;
   2) variable actions: wind loading;
   3) actions during execution, reconfiguration or dismantling operations.

Information on the actions that are required for the design of the temporary foundation should be supplied by crane manufacturers, and varies with the crane type and configuration.

Manufacturers should provide values for all load effects that the crane will apply to the foundation for both in-service and out-of-service conditions and distinguish between permanent and variable action components. Where such a distinction is not made, then an appropriate partial factor on the combined actions should be agreed in consultation with the manufacturer and recorded in the design brief and, if applicable, the design statement.

6.2.9 Working platforms

6.2.9.1 General

Working platforms are temporary structures comprising layers of fill or other materials placed on existing ground that provide a foundation for heavy construction plant. They should have sufficient resistance to ensure that the ground underneath is not overstressed at any time during their service life.

General information about working platforms is provided in BS 8004:2015, **4.9.3**.

Guidance on the design, installation, maintenance, and repair of ground-supported working platforms for tracked plant is given in BRE Report 470 [23], which provides a design method to determine the thickness of the working platform needed to resist punching shear under the tracks.

6.2.9.2 Traffic loading

Traffic loading on working platforms should be assessed on a project-specific basis and recorded in the design brief and, if applicable, the design statement.

Typically, the calculation of traffic loading on a working platform requires consideration of the type of road vehicle or construction plant, which should be assumed to be fully laden and the number of standard axles associated with that vehicle. An example calculation of traffic loading on a working platform is provided by ICE, *Temporary Works: Principles of design and construction* [10].

6.2.9.3 Geosynthetics

Geosynthetic reinforcements incorporated into the construction of granular working platforms can provide beneficial effects that enhance the stability of the working platform.

Guidance on the design of geosynthetics can be found in BRE 470 [23], CIRIA SP123 [24], *Handbook of Geosynthetic Engineering* [25] and in manufacturers' publications.

6.2.10 Piling platforms

Piling platforms are working platforms provided to support the construction equipment used during the installation of piles. If generic loading information is not provided in the design brief and, if applicable, the design statement, the contractor should state the specific plant that the platforms are being designed to accommodate in the design brief and, if applicable, the design statement.

Specific guidance on drilling and foundation equipment is provided in BS EN 16228. Information about the characteristic (unfactored) values of drilling and foundation equipment loading should be provided by the contractor.

6.2.11 Slope stability

The overall stability of cut slopes for temporary excavations and temporary fill slopes should be determined in accordance with BS EN 1997-1:2004+A1:2013, **11.5.1**, which may be supplemented with the guidance given in BS 6031:2009, **7.7** in the case of cut slopes.

The general recommendations of BS 6031:2009, **7.3** and **7.7** on the choice of soil parameters may also be taken into account.

6.2.12 Trenches

6.2.12.1 General

Guidance on the design and construction of temporary excavations, trenches, pits and shafts is given in BS 6031:2009, Clause **3**.

6.2.12.2 Bespoke trench support systems

The design of bespoke trench support systems should be undertaken in accordance with BS EN 1997 and be appropriate to the geotechnical category.

6.2.12.3 Reusable metallic trench lining systems

For the design of reusable metallic trench lining systems (proprietary equipment for trenches), BS EN 13331 may be used.

BS EN 13331-1:2002, Annex A introduces specific partial safety factors $\gamma_F \geq 1.50$ for actions and $\gamma_M = 1.10$ for resistances. These values are not aligned to the partial factors for actions provided by BS EN 1990 and the partial material factors given in BS EN 1993 for steel and BS EN 1999 for aluminium. However, these values are considered appropriate in terms of providing a suitable level of robustness during service.

Recommendations on methods of analysis are provided in BS EN 13331-2:2002, Clause **6**.

6.2.12.4 Hydraulically operated trench support systems

The design of hydraulically operated trench support systems that comprise prefabricated equipment that prop sheeting to the sides of excavations, is covered at BS EN 14653-1:2005, Annex A. This introduces the partial factors $\gamma_F \geq 1.50$ for actions and $\gamma_M = 1.1$ for resistances. These values are not aligned to the partial factors for actions provided by BS EN 1990 and the partial material factors given in BS EN 1993 for steel and BS EN 1999 for aluminium. However, these values are considered appropriate in terms of providing a suitable level of robustness during service.

6.2.13 Retaining structures

Retaining structures include all types of wall and support systems in which structural elements resist load effects imposed by the retained material (from BS EN 1997-1:2004+A1:2013, **9.1.1**).

The structural design of an earth retaining structure should conform to BS EN 1997-1:2004+A1:2013, **9.7.6** and all relevant material-specific Eurocodes.

Guidance on the design of earth retaining structures is given in BS 8002.

Guidance on the selection and design of vertical embedded retaining walls is provided in CIRIA C580, *Embedded retaining walls – guidance for economic design* [20].

6.2.14 Cofferdams

The design of cofferdams should conform to BS EN 1997-1:2004+A1:2013, Clause **9**.

Guidance on the design of different types of cofferdams is given in BS 8002.

Guidance on the design of single and double skin cofferdams can be found in the *ArcelorMittal Piling handbook*, Chapter 9 [26] and CIRIA SP95, *Design and construction of sheet piled cofferdams* [27].

Double-wall sheet pile cofferdams for maritime works should conform to BS 6349-2:2010, **7.8**.

Cellular sheet pile cofferdams for maritime works should conform to BS 6349-2:2010, **7.7**.

Guidance on the design of cellular cofferdams is given in the *ArcelorMittal Piling handbook*, Chapter 10 [26].

6.2.15 Ground anchors

The design of ground anchors should conform to BS EN 1997-1:2004+A1:2013, Clause **8**. General considerations related to design of ground anchors are given in BS EN 1537:2013, Clause **7**.

NOTE A "ground anchor" in BS EN 1537 is termed a "grouted anchor" in BS EN 1997-1.

General information about temporary ground anchors is given in BS EN 1537:2013, **6.3.2**. Guidance on the design of grouted anchors is given in BS 8081.

6.3 Group 3 – Vehicle and pedestrian bridges and related works

6.3.1 General

Temporary bridges, propping trafficked bridges and protection decks should be designed to BS EN 1990:2002+A1:2005, Annex A2 and NA to BS EN 1990 combined with the relevant material-specific Eurocodes as illustrated in Clause **4**.

Traffic actions on highway, railway and footway bridges should be taken from BS EN 1991-2 and NA to BS EN 1991-2. Guidance on the application of BS EN 1991-2 and NA to BS EN 1991-2 is provided by PD 6688-2, *Background to the National Annex to BS EN 1991-2 – Part 2: Traffic loads on bridges*.

Values of partial factors for actions should be taken from BS EN 1990:2002+A1:2005, Annex A2 and NA to BS EN 1990. In addition, Annex C provides recommended values of partial factors to be used for construction loads in temporary works design.

Specific considerations on the temporary propping of trafficked bridges and temporary bridges are addressed in **6.3.2** and **6.3.3**.

6.3.2 Propping trafficked bridges

Propping systems and any associated temporary foundations for supporting trafficked highway bridges and pedestrian bridges used by the general public should be designed in accordance with the requirements of Highways England as contained within the *Design Manual for Roads and Bridges* (DMRB) [NR1] and fulfil the requirements for technical approval as set out in DMRB standard BD 2.

The design of propping systems and any associated temporary foundations for supporting railway bridges should conform to the technical approval processes prescribed in Network Rail standard NR/L2/CIV/003 [NR2].

The installation of a propping system alters the articulation and restraint characteristics of the structure. This should be taken into account during the analysis of the system and the effects on the existing structure assessed for all appropriate limit states.

6.3.3 Temporary bridges

Temporary highway bridges and pedestrian bridges used by the public should be designed in accordance with the requirements of Highways England as contained in the *Design Manual for Roads and Bridges* (DMRB) [NR1] and fulfil the requirements for technical approval as set out in DMRB standard BD 2.

The design of temporary bridges used for construction access only and not open to general highway traffic should take account of the traffic permitted to use the bridge. Temporary bridges which cross over an area accessible to the public (e.g. road, rail, river, canal, towpath, bridleway, footpath) should conform with the requirements for technical approval set out in DMRB standard BD 2 [NR1].

Specific performance criteria for the temporary bridge should be established at the outset of the development of the approval in principle (AIP), design brief and, if applicable, the design statement and recorded in the AIP and design brief and, if applicable, the design statement, along with clarification of the level of design checking that is required.

The general traffic load models given in BS EN 1991-2 should be used. If the characteristics of specific vehicles or combination of vehicles are used for design, then any limitations on the use of the structure should be recorded, monitored and managed during service.

6.4 Group 4 – Underground

Underground excavations include a variety of highly specialized activities ranging from general excavations and retaining structures to more complex methods specifically targeted to tunnelling and ground stabilization processes.

Underground design should be carried out according to the general design principles set out in Clause **4** and the specific guidance on geotechnical design given in **6.2**.

A number of technical documents have been published by the British Tunnelling Society relevant to underground design. Guidance on a wide range of methods and ground stabilization processes is provided by the *Specification for tunnelling* [28], which has recently been updated to reflect current good practice, changes in national standards and the Eurocodes.

Guidance on health and safety practices in tunnel construction is given in BS 6164.

Where guidance given in BS 6164 is in contrast with the Eurocodes, the Eurocodes should take precedence.

Recommendations for the design of civil engineering concrete segmental tunnel linings are given in PAS 8810 (in preparation).

6.5 Group 5 – Marine

Maritime works include a variety of specialized works ranging from cofferdams and mass fill gravity platforms to jetties, floating plant and other complex structures.

The design of marine works should conform to the Eurocodes. This may be supplemented by appropriate guidance specific to the marine environment and conditions as necessary where not addressed within the scope of the Eurocodes (e.g. actions due to waves, icing).

BS 6349 should be used as a primary guidance source as it gives recommendations on general criteria pertinent to the planning, design, construction and maintenance of structures and facilities set in the maritime environment. BS 6349 has recently been revised to align with the Eurocodes.

Another source of information is EAU 2004 [29]. The current edition of EAU 2004 [29] published in 2012 has been revised to align with the Eurocodes.

6.6 Group 6 – Other

6.6.1 General

Group 6 includes specialist erection equipment that is outside the scope of the groups of temporary works given in **6.1** to **6.5**.

Group 6 temporary works are highly safety-critical and their design and operation is generally undertaken by suppliers who have appropriate specialist experience.

An analysis of activities at all stages of the erection, commissioning, operation and decommissioning of the associated equipment and temporary works should be undertaken and recorded in a risk assessment. Mitigation measures and operational constraints and limits should be identified in a construction method statement in order to ensure that all critical activities can be safely monitored and managed.

6.6.2 Bridge launching

The technique of bridge launching is generally used for short- to medium-span structures, where there are a sufficient number of spans to make the process cost-effective or where the nature of the obstacles crossed by the bridge dictates its use. When verifying the equilibrium of the structure (see EQU limit state in **4.7.1.2**), it is vital that upper bound ($\gamma_{G,sup}$) partial factors are applied to any destabilizing effects of permanent actions whilst lower bound partial factors ($\gamma_{G,inf}$) are applied to any stabilizing effects (see partial factors in BS EN 1990:2002+A1:2005, Table A2.2(A)).

For the incremental launching of bridges, the design values for vertical deflections should be defined as indicated in BS EN 1991-1-6:2005, **A2.3** unless alternative, project-specific values are agreed. Any horizontal force due to friction effects should be determined as indicated in BS EN 1991-1-6:2005, **A2.5**.

Often the launching calculations are undertaken early during the design stage and a review should be undertaken to ensure that any design changes that have been incorporated are captured prior to commencing launching operations. Fabrication records should be reviewed to confirm the as built weight of structure. A review of the EQU calculations should be undertaken incorporating this refined data.

6.6.3 Heavy lift systems

A variety of systems to lift heavy loads exist. Their correct application requires an accurate understanding of the components or assemblies to be moved, their lifting points, weight, centre of gravity location, any internal force arising within the element whilst being moved and any additional loads generated during the lifting process and the potential for instability at any stage.

Specific performance criteria for any heavy lift system should be established at the outset of the design and recorded in the design brief and, if applicable, the design statement along with clarification of the level of design checking that is required.

Trials should be undertaken to confirm that the system can be safely installed, operated and decommissioned prior to its use during construction.

Guidance on crane lifting design and heavy transport using self-propelled modular transporters is given in ICE, *Temporary Works, Principles of design and construction*, Chapter 20 [10].

6.6.4 Protection decks

Early understanding of the full functionality of the proposed protection deck is essential if an effective and safe system of work is to be established.

Specific performance criteria for the protection deck should be established at the outset of the design and recorded in the design brief and, if applicable, the design statement along with clarification of the level of design checking that is required. The performance criteria should include, as a minimum:

a) requirements for robustness and redundancy;
b) impact loading and energy absorption from falling equipment and materials (dropped loads); and
c) any other significant project-specific load, depending on operational requirements, such as storage of materials.

Designing or analysing a protection deck for dropped loads can be very complex as parameters such as the weight and shape of objects and the height from which they may fall are highly variable. An analysis of the range of activities which can lead to dropped loads should be undertaken and recorded in a risk assessment. It might prove not to be practical to design a protection deck for the full range of loads identified during the risk assessment process and certain activities might need to be monitored and managed such that no operations or personnel are present below the protection deck.

In the case of a protection deck, the sources of impacts to be explicitly catered for should be identified and therefore treated as variable actions and specified in the design brief and, if applicable, the design statement [see PAS 8811 (in preparation)].

6.6.5 Movable structures and equipment

In the design of temporary works that move themselves or are used to move other structures, restraint systems and/or safety devices should be provided to prevent unintentional or excessive movement.

Annex A (informative)
Reference publications for temporary works

Additional reference publications relating to temporary works are listed in Tables A.1, A.2, A.3 and A.4.

The documents listed at Table A.4 provide useful guidance on the design of temporary works, however some of them might not be fully aligned to the Eurocodes. It is important that temporary works designers understand the assumptions and limitations of those documents and apply them with caution.

Table A.1 – European product and execution standards

BS EN 39	*Loose steel tubes for tube and coupler scaffolds – Technical delivery conditions*
BS EN 74 (all parts)	*Couplers, spigot pins and baseplates for use in falsework and scaffolds*
BS EN 206 (all parts)	*Concrete*
BS EN 338	*Structural timber – Strength classes*
BS EN 789	*Timber structures – Test methods – Determination of mechanical properties of wood based panels*
BS EN 1004	*Mobile access and working towers made of prefabricated elements – Materials, dimensions, design loads, safety and performance requirements*
BS EN 1058	*Wood-based panels – Determination of characteristic 5-percentile values and characteristic mean values*
BS EN 1065	*Adjustable telescopic steel props – Product specifications, design and assessment by calculation and tests*
BS EN 1090 (all parts)	*Execution of steel structures and aluminium structures*
BS EN 1263 (all parts)	*Temporary works equipment – Safety nets*
BS EN 1298	*Mobile access and working towers – Rules and guidelines for the preparation of an instruction manual*
BS EN 1537	*Execution of special geotechnical works – Ground anchors*
BS EN 10025 (all parts)	*Hot rolled products of structural steels*
BS EN 12063	*Execution of special geotechnical work – Sheet pile walls*
BS EN 12369 (all parts)	*Wood-based panels – Characteristic values for structural design*
BS EN 12810 (all parts)	*Façade scaffolds made of prefabricated components*
BS EN 12811 (all parts)	*Temporary works equipment*
BS EN 12812	*Falsework – Performance requirements and general design*
BS EN 12813	*Temporary works equipment – Load bearing towers of prefabricated components – Particular methods of structural design*
BS EN 13001 (all parts)	*Cranes – General design*
BS EN 13331 (all parts)	*Trench lining systems*

Table A.1 – European product and execution standards *(continued)*

BS EN 13374	*Temporary edge protection systems – Product specification – Test methods*
BS EN 13377	*Prefabricated timber formwork beams – Requirements, classification and assessment*
BS EN 13670	*Execution of concrete structures*
BS EN 13706 (all parts)	*Reinforced plastics composites – Specifications for pultruded profiles*
BS EN 14653 (all parts)	*Manually operated hydraulic shoring systems for groundwork support*
BS EN ISO 14688 (all parts)	*Geotechnical investigation and testing – Identification and classification of soil*
BS EN 16031	*Adjustable telescopic aluminium props – Product specifications, design and assessment by calculation and tests*
BS EN 16228 (all parts)	*Drilling and foundation equipment – Safety*

Table A.2 – European design standards

BS EN 1990	*Eurocode – Basis of structural design*
BS EN 1991 (all parts)	*Eurocode 1 – Actions on structures*
BS EN 1992 (all parts)	*Eurocode 2 – Design of concrete structures*
BS EN 1993 (all parts)	*Eurocode 3 – Design of steel structures*
BS EN 1995 (all parts)	*Eurocode 5 – Design of timber structures*
BS EN 1996 (all parts)	*Eurocode 6 – Design of masonry structures*
BS EN 1997 (all parts)	*Eurocode 7 – Geotechnical design*
BS EN 1999 (all parts)	*Eurocode 9 – Design of aluminium structures*
NA to BS EN 1990	*UK National Annex to Eurocode – Basis of structural design*
NA to BS EN 1991 (all parts)	*UK National Annex to Eurocode 1 – Actions on structures*
NA to BS EN 1992 (all parts)	*UK National Annex to Eurocode 2 – Design of concrete structures*
NA to BS EN 1993 (all parts)	*UK National Annex to Eurocode 3 – Design of steel structures*
NA to BS EN 1995 (all parts)	*UK National Annex to Eurocode 5 – Design of timber structures*
NA to BS EN 1996 (all parts)	*UK National Annex to Eurocode 6 – Design of masonry structures*
NA to BS EN 1997 (all parts)	*UK National Annex to Eurocode 7 – Geotechnical design*
NA to BS EN 1999 (all parts)	*UK National Annex to Eurocode 9 – Design of aluminium structures*

Table A.3 – British Standards

BS 559	*Specification for the design and construction of signs for publicity, decorative and general purposes*
BS 1139-1.2	*Metal scaffolding – Part 1.2: Tubes – Specification for aluminium tube*
BS 2482	*Specification for timber scaffold boards*
BS 5975	*Code of practice for temporary works procedures and the permissible stress design of falsework*
BS 6031	*Code of practice for earthworks*
BS 6164	*Code of practice for health and safety in tunnelling in the construction industry*
BS 6187	*Code of practice for full and partial demolition*
BS 6349 (all parts)	*Maritime works*
BS 8002	*Code of practice for earth retaining structures*
BS 8004	*Code of practice for foundations*
BS 8081	*Code of practice for grouted anchors*

Table A.4 – NCCI

BD 2	*Technical Approval of Highway Structures [Design Manual for Roads and Bridges (DMRB)]*
BD 90	*Design of FRP bridges and highway structures*
BRE 470	*Working platforms for tracked plant*
CIRIA Report 97	*Trenching practice*
CIRIA Report R108	*Concrete pressure on formwork*
CIRIA Report C147	*Trenchless and minimum excavation techniques*
CIRIA Report C517	*Temporary propping of deep excavations – Guidance on design*
CIRIA Report C579	*Retention of Masonry Façades – Best Practice Guide*
CIRIA Report C580	*Embedded retaining walls – guidance for economic design*
CIRIA Report C654	*Tower crane stability*
CIRIA Specification SP123	*Soil reinforcement with geotextiles and in manufacturers*
Concrete Society CS30	*Formwork: A guide to good practice*
NASC TG20	*Good practice guidance for tube and fitting scaffolding*
PD 6687-1	*Background paper to the National Annexes to BS EN 1992-1 and BS EN 1992-3*
PD 6687-2	*Recommendations for the design of structures to BS EN 1992-2:2005*
PD 6688-1-1	*Recommendations for the design of structures to BS EN 1991-1-1*

Table A.4 – NCCI *(continued)*

PD 6688-1-2	*Background paper to the UK National Annex to BS EN 1991-1-2*
PD 6688-1-4	*Background information to the National Annex to BS EN 1991-1-4 and additional guidance*
PD 6688-1-7	*Recommendations for the design of structures to BS EN 1991-1-7*
PD 6688-2	*Background to the National Annex to BS EN 1991-2 – Traffic loads on bridges*
PD 6693-1	*Recommendations for the design of timber structures to Eurocode 5: Design of timber structures – General – Common rules and rules for buildings*
PD 6694-1	*Recommendations for the design of structures subject to traffic loading to BS EN 1997-1:2004*
PD 6695-1-9	*Recommendations for the design of structures to BS EN 1993-1-9*
PD 6695-1-10	*Recommendations for the design of structures to BS EN 1993-1-10*
PD 6695-2	*Recommendations for the design of bridges to BS EN 1993*
PD 6696-2	*Background paper to BS EN 1994-2 and the UK National Annex to BS EN 1994-2*
PD 6702-1	*Structural use of aluminium. Recommendations for the design of aluminium structures to BS EN 1999*
SCI Publication P360	*Stability of steel beams and columns*
TRADA Publication	*Timber in excavations*

Annex B (informative) Clarification of key terms and definitions for the design of temporary works to the Eurocodes

B.1 General

The aim of Annex B is to help users to better understand the terms defined in the Eurocodes by providing clarified versions of terms and definitions from BS EN 1990.

Some of the terms presented in this annex might represent a change from traditional UK practice and merit clarification to avoid potential misinterpretation when designing to the Eurocodes and European Standards in general.

The clarifications of definitions provided in this annex are intended to supplement and clarify those given in BS EN 1990.

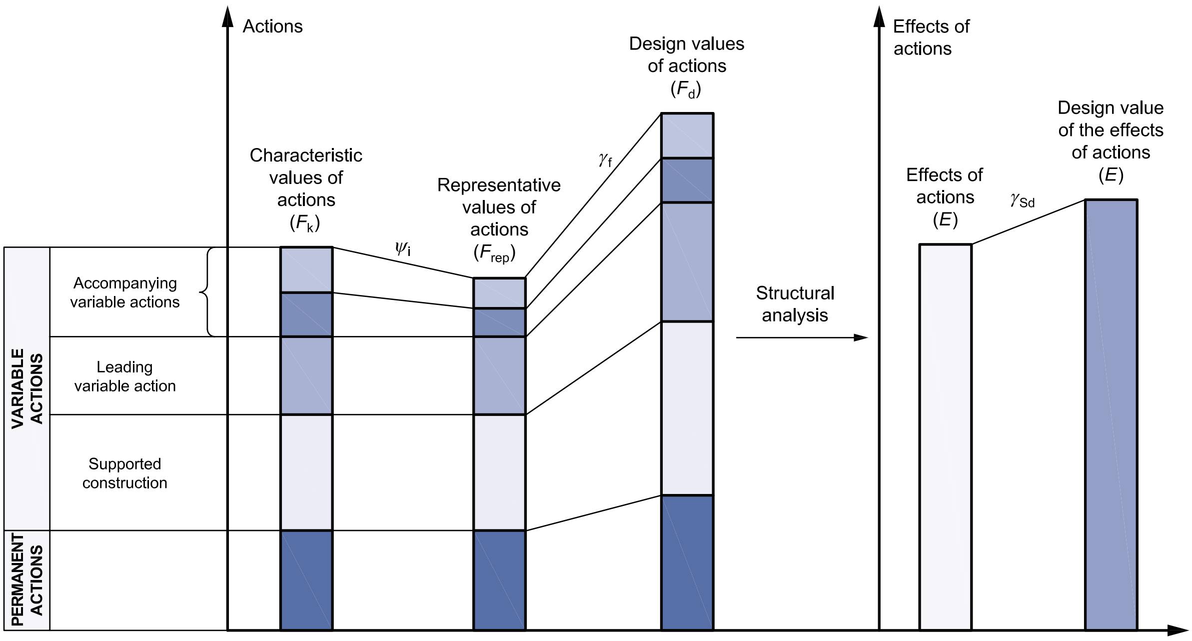
B.2 Actions and effects of actions

B.2.1 General

Figure B.1 provides an overview of the relationship that exists between the terms used to model actions and effects of actions within the context of the Eurocodes. The clarifications of terms and definitions provided are intended to be read in conjunction with Figure B.1. Additional information is given in the *Designers' Guide to EN 1990* [30] and *Understanding key concepts of EN 1990* [31].

***NOTE** Figure B.1 illustrates a general model for the application of partial factors on actions based on persistent and transient design situations at ultimate limit state.*

Figure B.1 – Modelling of actions and effects of actions in persistent and transient design situations at ultimate limit state for temporary works designed to the Eurocodes



B.2.2 Terms relating to actions

B.2.2.1 action (*F*)

set of forces applied to the structure (imposed loads) or imposed deformations or accelerations, caused for example, by temperature changes, moisture variation, uneven settlement or earthquakes (indirect actions)

B.2.2.2 permanent action

any action that remains in place over the service life of the structure

NOTE 1 *For the full definition, see BS EN 1990:2002+A1:2005,* ***1.5.3.3****.*

NOTE 2 *Supported construction is not considered as a permanent action (see* ***3.1.4*** *and* ***4.4.1****).*

B.2.2.3 variable action

action that varies significantly in magnitude with time

NOTE 1 *For the full definition, see BS EN 1990:2002+A1:2005,* ***1.5.3.4****.*

NOTE 2 *Supported construction is considered as a variable action (see* ***3.1.4*** *and* ***4.4.1****).*

B.2.2.4 leading variable action

variable action chosen from all the variable actions that are combined in a specific verification, to give the greatest action effect

B.2.2.5 accompanying variable action

variable action that acts simultaneously with the leading variable action

NOTE *For the full definition, see BS EN 1990:2002+A1:2005,* ***1.5.3.19****.*

B.2.2.6 characteristic value of an action (F_k)

typically a statistical value with a very low probability of being exceeded within a defined reference period

NOTE 1 *For the full definition, see BS EN 1990:2002+A1:2005,* ***1.5.3.14****.*

NOTE 2 *In general the values of actions derived using the various parts of BS EN 1991 are characteristic values, with the exception of accidental actions (see also* ***B.2.7****).*

NOTE 3 *In the absence of statistical data, characteristic loads may be taken to be the maximum working loads for which temporary works are to be designed in combination with other applied actions.*

B.2.2.7 ψ factor

factor less than or equal to 1 that is applied to the characteristic value of a variable action

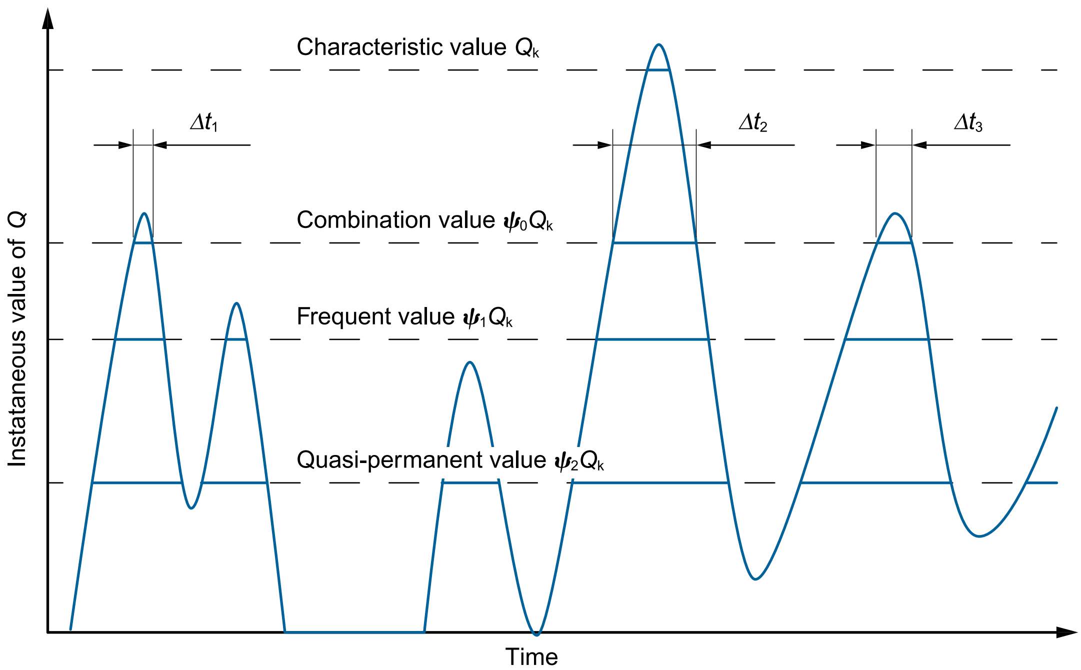
NOTE *Three ψ factors are provided by BS EN 1990:*

a) ψ_0 relates to the combination value of a variable action;

b) ψ_1 relates to the frequent value of a variable action;

c) ψ_2 relates to the quasi-permanent value of a variable action.

Figure B.2 – Four representative values of a variable action



B.2.2.8 representative values of an action (F_{rep})

generic term used to define either the characteristic, combination, frequent or quasi-permanent value of a variable action

NOTE 1 See Figure B.2.

*NOTE 2 For the full definition, see BS EN 1990:2002+A1:2005, **1.5.3.20**.*

B.2.2.9 combination value of a variable action ($\psi_0 \cdot Q_k$)

value given by the product of ψ_0 and the characteristic value of the variable action, used to account for the reduced probability that two variable actions will occur at their characteristic values simultaneously

*NOTE For the full definition, see BS EN 1990:2002+A1:2005, **1.5.3.16**.*

B.2.2.10 frequent value of a variable action ($\psi_1 \cdot Q_k$)

value given by the product of ψ_1 and the characteristic value of the variable action, used to represent typically the value of the action that might be expected to occur on a weekly or monthly basis

*NOTE 1 For the full definition, see BS EN 1990:2002+A1:2005, **1.5.3.17**.*

NOTE 2 It is unlikely that the frequent combination of actions will be applicable in most temporary works designs.

B.2.2.11 quasi-permanent value of a variable action ($\psi_2 \cdot Q_k$)

value given by the product of ψ_2 and the characteristic value of the variable action, used to represent typically the value of the action that might be expected to occur more than 50% of the time

*NOTE 1 For the full definition, see BS EN 1990:2002+A1:2005, **1.5.3.18**.*

NOTE 2 It is unlikely that the quasi-permanent combination of actions will be applicable in most temporary works designs.

B.2.2.12 partial factor γ_F on actions and effects of actions

partial factor which takes account of:

a) the possibility of unfavourable deviations of the action values from the representative values (γ_f);

b) the uncertainty in modelling the effects of actions (γ_{Sd})

NOTE 1 In practice γ_{Sd} tends to be combined with γ_f and applied as a single partial factor γ_F to derive the design value of actions (see Figure B.3).

NOTE 2 The partial factor γ_F is designated γ_G for permanent actions, γ_P for prestressing and γ_Q for variable actions.

NOTE 3 There may be cases where it is appropriate to separate γ_f and γ_{Sd}, for instance when carrying out more sophisticated simulations of actions and effects of actions, or in case of non-linear analysis when the effects of actions are not proportional to the applied actions.

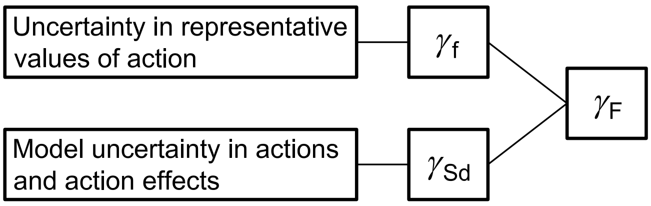
B.2.2.13 design value of an action (F_d)

value obtained by multiplying the representative value of the action by the partial factor γ_F

*NOTE 1 For the full definition, see BS EN 1990:2002+A1:2005, **1.5.3.21**.*

NOTE 2 In the case of accidental actions, the design value is derived directly using BS EN 1991-1-7. Therefore, it is not necessary to apply partial factors to accidental actions.

Figure B.3 – Interaction of partial factors on actions and effects of actions



B.2.2.14 design value of the effects of actions (E_d)

effects of actions (e.g. internal forces: moments, stresses, strains, deflections, rotations) generated as a result of the application of relevant combinations of design values of actions

NOTE *In general* $E_d = \gamma_{Sd} \cdot (E)$*, but in practice* E_d *is usually derived by applying a single partial factor* γ_F *to calculate the design values of the actions used in the structural analysis.*

B.2.2.15 first order effects

action effects calculated without consideration of the effect of structural deformations

B.2.2.16 second order effects

additional action effects due to structural deformations

B.3 Material properties and resistances

B.3.1 General

Figure B.4 provides an overview of the relationship that exists between the terms used to model material properties and resistances within the context of the Eurocodes, to be read in conjunction with the terms and definitions provided. Additional information can be taken from the *Designers' Guide to EN 1990* [30] and "Understanding key concepts of EN 1990" [31].

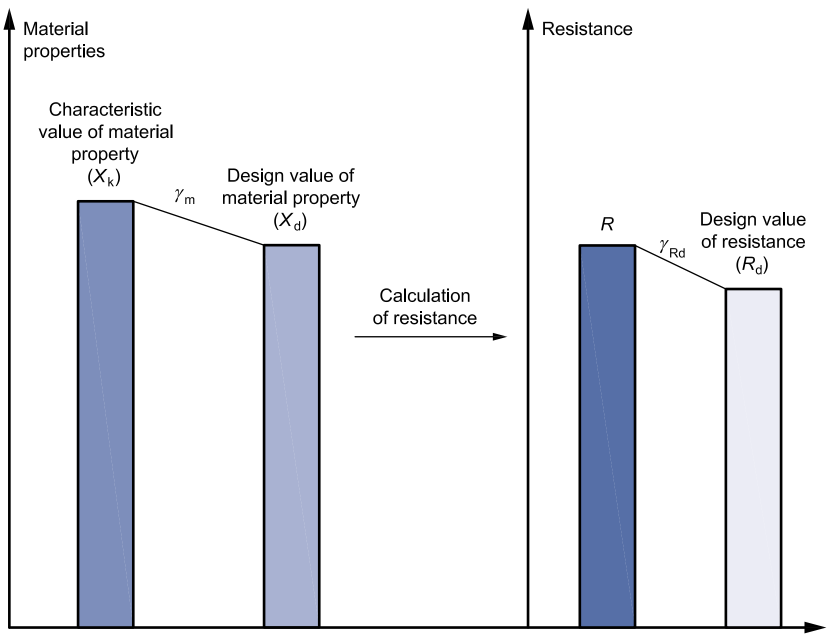
B.3.2 characteristic value of material or product properties (X_k)

statistically derived value of a material or product property having a prescribed level of confidence of being achieved

NOTE 1 *For the full definition, see BS EN 1990:2002+A1:2005,* ***1.5.4.1****.*

NOTE 2 *Where insufficient statistical data are available to establish the characteristic values of a material or product property, nominal or worst credible values may be taken as the characteristic values, or the design value of the property may be established directly.*

Figure B.4 – Modelling of material properties and resistances for temporary works design to the Eurocodes



B.3.3 nominal value

value established on a non-statistical basis, for instance through acquired experience or evaluated based on examination of physical conditions

*NOTE For the full definition, see BS EN 1990:2002+A1:2005, **1.5.2.22**.*

B.3.4 partial factors γ_m on materials and resistance

partial factors which take account of:

a) the possibility of an unfavourable deviation of a material or product property from its characteristic value (γ_m);

b) the uncertainty in the resistance model (γ_{Rd})

NOTE 1 In practice, γ_m tends to be combined with γ_{Rd} and applied as a single partial factor γ_m to the material properties (see Figure B.5).

NOTE 2 There may be cases where it is appropriate to separate γ_m and γ_{Rd}, for instance in geotechnical design.

B.3.5 design value of the material or product property (X_d)

value derived using the characteristic value of the material property divided by the partial factor γ_m

*NOTE For additional information, see BS EN 1990:2002+A1:2005, **6.3.3**.*

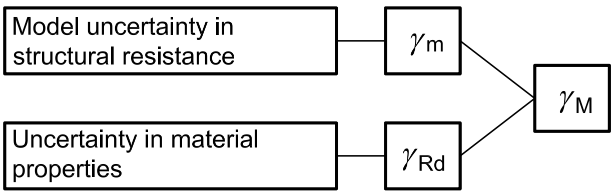
B.3.6 design value of resistance (R_d)

value derived using the design value of the material property (X_d) divided by the partial factor γ_{Rd}

*NOTE 1 For additional information, see BS EN 1990:2002+A1:2005, **6.3.5**.*

NOTE 2 In general $R_d = R / \gamma_{Rd}$ but in practice R_d is generally derived using the characteristic value of the material property (X_k) divided by the partial factor γ_M.

Figure B.5 – Interaction of partial factors on material properties and resistances



Annex C (normative) Combinations of actions and partial factors for the design of temporary works to the Eurocodes

C.1 General

Annex C gives guidance and recommendations on establishing combinations of actions for the design of temporary works to the Eurocodes and gives recommended values of ψ factors and partial factors on actions (γ_F) to be used.

For the design of group 3 temporary works (vehicle and pedestrian bridges and related works) the rules and methods given in BS EN 1990:2002+A1:2005, Annex A2 should take precedence.

An appropriate return period for the determination of characteristic values of environmental actions for the design of temporary works may be derived using BS EN 1991-1-6:2005, Table 3.1 (see **4.3.2**).

C.2 Combinations of actions

Actions and effects of actions that can reasonably occur simultaneously should be included in combinations of actions.

The combinations of actions given in **4.5.2** should be used when verifying ultimate limit states. For geotechnical design, the combinations of actions relevant to Design Approach 1 should be used (see **6.2.7.3**). The combinations of actions given in **4.5.3** should be used when verifying serviceability limit states.

In some cases it might be convenient to group related variable actions and treat them as a single multi-component variable action in terms of establishing the appropriate representative values and partial factors in combinations of actions. This approach is adopted for traffic loads in the case of bridges (see BS EN 1992-1) and may be considered to be applicable to some construction loads where the construction process dictates that they will co-exist (see BS EN 1991-1-6). Any grouping of construction loads should be agreed on a project-specific basis and included in the design brief and, if applicable, the design statement.

C.3 Values of ψ factors

Values of ψ factors to be applied in the combinations of actions for different limit states for the more common variable actions should be taken from Table C.1.

Different values of ψ factors may be determined on a project-specific basis and should be included in the design brief and, if applicable, the design statement.

Construction loads as defined in BS EN 1991-1-6 should be separated into the following groups:

a) group 1: loads due to supported construction; and

b) group 2: loads due to construction activities (e.g. personnel and hand tools, storage movable items).

Table C.1 – Recommended values of ψ factors for temporary works

Variable action	ψ_0 Combination value	ψ_1 Frequent value	ψ_2 Quasi-permanent value
Group 1 construction loads: *Supported construction* A)	1.0	1.0	1.0
Group 2 construction loads B): *personnel and small hand tools/equipment* *storage movable items* *non-permanent equipment* *storage of materials* *accumulation of waste materials* *dynamic/impact forces from equipment/materials*	0.8	0.6	0.5
Environmental actions: *wind*	0.8	0.2	—
Environmental actions: *snow*	0.8	0.5	—
Environmental actions: *thermal actions*	0.6	0.6	0.5
Environmental actions: *water and wave forces* C)			
Environmental actions: *atmospheric ice* C)			
Traffic loads D)			
Forces from the permanent structure: *prestressing* *pre-deformations* *shrinkage/hydration effects*	1.0	1.0	1.0

***NOTE** "—" denotes that the action is not considered in the specific combination of actions.*

A) Once in place the load due to supported constructions does not vary with time and all ψ factors are therefore 1.0.

B) For some actions it might be appropriate to take all ψ factors equal to 1.0, for instance where movable heavy machinery and equipment are considered.

C) These actions are highly dependent on localized environmental conditions and values may be agreed on a project-specific basis.

D) Values of ψ factors for temporary works supporting traffic loads may be taken from NA to BS EN 1990:2002+A1:2005, Annex A2.

C.4 Ultimate limit states

C.4.1 Design values of actions in persistent and transient design situations

The partial factors on actions γ_F for the ultimate limit state in persistent and transient design situations should be taken from Table C.2, Table C.3 and Table C.4. In particular:

a) Table C.2 is relevant only to EQU verifications;

b) Table C.3 is relevant only to STR verifications where there is no significant influence from geotechnical actions or resistances; and

c) Table C.2 and Table C.3 (combined) are relevant for verifications undertaken in accordance with Design Approach 1, where there is an interaction between structural and geotechnical actions and effects.

NOTE 1 *The format of Table C.1, Table C.2 and Table C.3 is consistent with that adopted in BS EN 1990, Annex A1 for buildings and Annex A2 for bridges.*

When using the values given in Table C.2, Table C.3 and Table C.4, the following recommendations apply:

a) In the case of EQU verifications, where the limit state is sensitive to variations in the magnitude or spatial distribution of permanent actions, separate upper and lower characteristic values of permanent actions ($G_{k,sup}$ and $G_{k,inf}$) should be taken into account when evaluating the destabilizing and stabilizing effects of actions respectively ($E_{d,dst}$ and $E_{d,stb}$).

b) In the case of STR and STR/GEO verifications, where the limit state is not sensitive to minor variations in the magnitude or spatial distribution of permanent actions, the characteristic values of all permanent actions arising from one source may be multiplied by either $\gamma_{G,j,sup}$ if the total resulting action effect is unfavourable, or $\gamma_{G,j,inf}$ if the total resulting action effect is favourable.

   NOTE 2 *This simplification in calculation is also known as "single source principle" introduced in BS EN 1990:2002+A1:2005, Note 3 to Table A1.2 (B) and Note 3 to Table A2.4 (B). According to this principle, it is not necessary to apply different partial factors to the favourable and unfavourable parts of a permanent action when arising from a single source. Relevant examples are the action originating from the self-weight of the structure or the water pressure acting on both sides of a retaining wall when the water is from the same hydrogeological formation.*

c) For geotechnical design where Design Approach 1 is applied, a single partial factor (either $\gamma_{G,sup}$ or $\gamma_{G,inf}$) may be applied to the sum of the actions coming from a single source or to the sum of their effects as most appropriate to the modelling approach adopted.

C.4.2 Design values of actions in accidental design situations

The partial factors on actions γ_F for the ultimate limit states in accidental design situations should be taken as equal to 1.0.

C.5 Serviceability limit states

C.5.1 Design values of actions

The partial factors on actions γ_F should be taken as equal to 1.0, except where specified otherwise in BS EN 1992 to BS EN 1999.

Table C.2 – Design values of actions (EQU) (Set A) for persistent and transient design situations

Permanent actions		Leading variable action	Accompanying variable actions
Unfavourable	Favourable		
$\gamma_{G,j,sup} \cdot G_{k,j,sup}$	$\gamma_{G,j,inf} \cdot G_{k,j,inf}$	$\gamma_{Q,1} \cdot Q_{k,1}$	$\gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,1}$

Permanent actions	$\gamma_{G,sup}$ (destabilizing)	$\gamma_{G,inf}$ (stabilizing)
Self-weight of temporary works (including structural elements, fixed equipment and fixed kentledge)	1.35	0.9
Variable actions	$\gamma_{Qi,sup}$ (destabilizing)	$\gamma_{Qi,inf}$ (stabilizing)
Group 1 Construction loads: *supported construction*	1.35 [A)]	0.9 [B)]
Group 2 Construction loads: *personnel and small hand tools/equipment* *storage movable items* *non-permanent equipment* *movable heavy machinery and equipment* *storage of materials* *accumulation of waste materials* *dynamic/impact forces from equipment/materials*	1.5	0
Environmental actions: *wind* *snow* *thermal actions* *water and wave forces* *atmospheric ice*	1.5	0
Traffic loads [C)]		
Forces from the permanent structure [D)]: *pre-deformations* *shrinkage/hydration effects*	1.35	1.0

[A)] The recommended values will result in no reduction in the levels of safety that were achieved by past UK practice and might result in a more conservative approach in some instances. Alternative values may be agreed on a project-specific basis.

[B)] The partial factor applied to stabilizing supported construction should be taken as 0.9 in cases where, once in place, the applied load will not be removed.

[C)] For temporary bridges, the values of partial factors for traffic loads given in NA to BS EN 1990:2002+A1:2005, Table NA.A2.4 (A) should be used.

[D)] Partial factors for prestressing are defined in the material-specific Eurocode parts or may be defined on a project-specific basis.

Table C.3 – Design values of actions (STR) (Set B) for persistent and transient design situations

Permanent actions		Leading variable action	Accompanying variable actions
Unfavourable	Favourable		
$\gamma_{G,j,sup} \cdot G_{k,j,sup}$	$\gamma_{G,j,inf} \cdot G_{k,j,inf}$	$\gamma_{Q,1} \cdot Q_{k,1}$	$\gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,1}$

Permanent actions	$\gamma_{G,j,sup}$	$\gamma_{G,j,inf}$
Self-weight of temporary works (including structural elements, fixed equipment and fixed kentledge)	1.35	1.0
Variable actions	$\gamma_{Qi,unfav}$	$\gamma_{Qi,fav}$
Group 1 Construction loads: *Supported construction*	1.5 [A)]	1.0 [B)]
Group 2 Construction loads: *personnel and small hand tools/equipment* *storage movable items* *non-permanent equipment* *movable heavy machinery and equipment* *storage of materials* *accumulation of waste materials* *dynamic/impact forces from equipment/materials*	1.5	0
Environmental actions: *wind* *snow* *thermal actions* *water and wave forces* *atmospheric ice*	1.5	0
Traffic loads [C)]		
Forces from the permanent structure [D)]: *pre-deformations* *shrinkage/hydration effects*	1.35	1.0

[A)] The partial factor applied to unfavourable supported construction is greater than that used for the permanent works once construction is completed. The recommended value has been established to give a level of safety that is consistent with past UK practice.

[B)] The partial factor applied to favourable supported construction should be taken as 1.0 in cases where, once in place, the applied load will not be removed.

[C)] For temporary bridges the relevant values of partial factors for traffic loads given in NA to BS EN 1990:2002+A1:2005, Table NA.A2.4 (B) should be used.

[D)] Partial factors for prestressing are defined in the material-specific Eurocode parts or may be defined on a project-specific basis.

Table C.4 – Design values of actions (STR/GEO) (Set C) for persistent and transient design situations

Permanent actions		Leading variable action	Accompanying variable actions
Unfavourable	Favourable		
$\gamma_{G,j,sup} \cdot G_{k,j,sup}$	$\gamma_{G,j,inf} \cdot G_{k,j,inf}$	$\gamma_{Q,1} \cdot Q_{k,1}$	$\gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,1}$

Permanent actions	$\gamma_{G,j,sup}$	$\gamma_{G,j,inf}$
Self-weight of temporary works (including structural elements, fixed equipment and fixed kentledge)	1.0	1.0
Variable actions	$\gamma_{Qi,unfav}$	$\gamma_{Qi,fav}$
Group 1 Construction loads: *supported construction*	1.3 [A)]	1.0 [B)]
Group 2 Construction loads: *personnel and small hand tools/equipment* *storage movable items* *non-permanent equipment* *movable heavy machinery and equipment* *storage of materials* *accumulation of waste materials* *dynamic/impact forces from equipment/materials*	1.3	0
Environmental actions: *wind* *snow* *thermal actions* *water and wave forces* *atmospheric ice*	1.3	0
Traffic loads [C)]		
Forces from the permanent structure [D)]: *pre-deformations* *shrinkage/hydration effects*	1.0	1.0

[A)] The partial factor applied to unfavourable supported construction is greater than that used for the permanent works once construction is completed. The recommended value has been established to give a level of safety that is consistent with past UK practice.

[B)] The partial factor applied to favourable supported construction should be taken as 1.0 in cases where, once in place, the applied load will not be removed.

[C)] For temporary bridges the values of partial factors for traffic loads given in NA to BS EN 1990:2002+A1:2005, Table NA.A2.4 (B) should be used.

[D)] Partial factors for prestressing are defined in the material-specific Eurocode parts or may be defined on a project-specific basis.

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