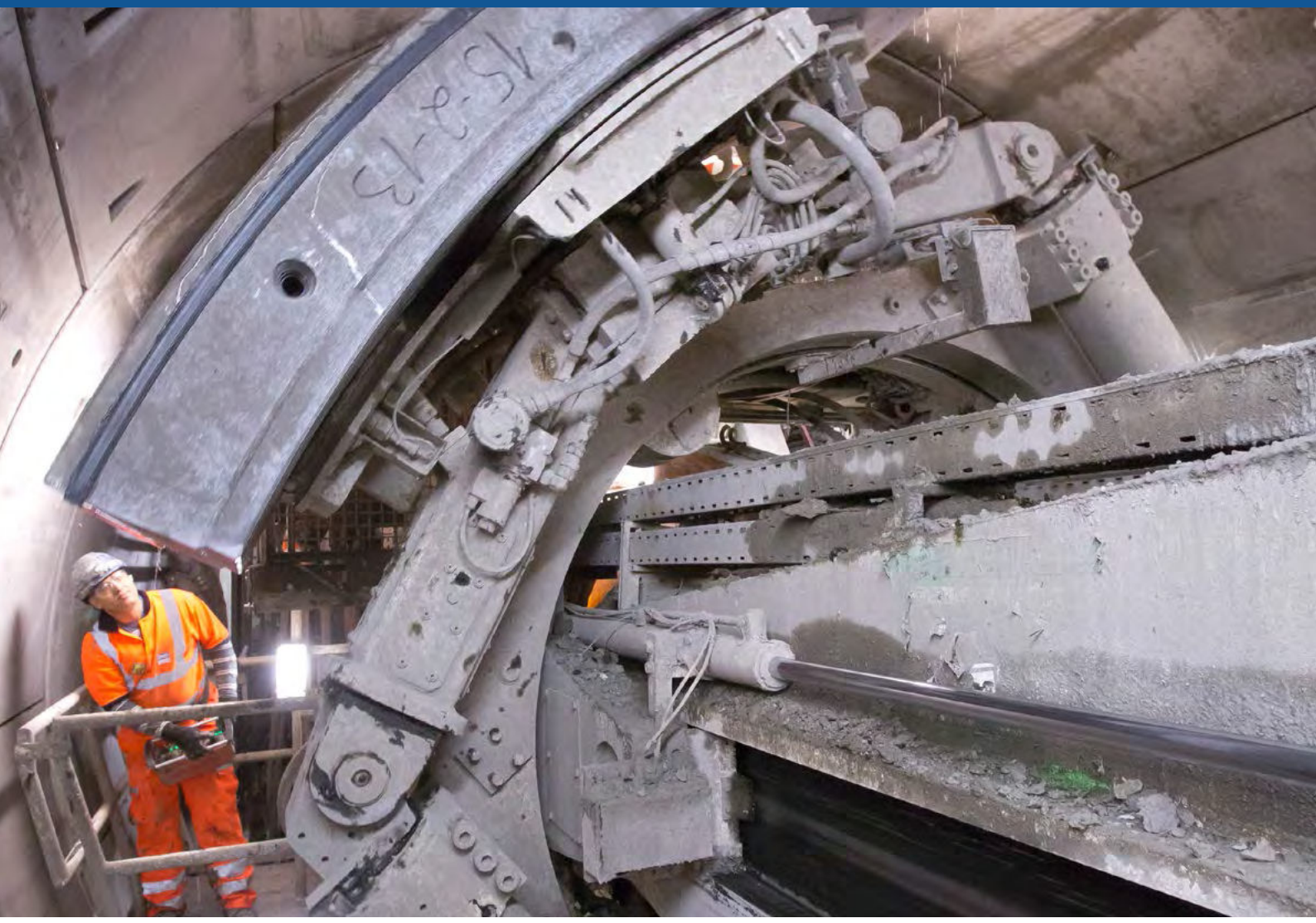
PAS 8810:2016

Tunnel design – Design of concrete segmental tunnel linings – Code of practice



hs2 engine for growth

BRITISH TUNNELLING SOCIETY

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Foreword

This PAS was sponsored by High Speed Two (HS2) Limited and the British Tunnelling Society (BTS). Its development was facilitated by BSI Standards Limited and it was published under licence from The British Standards Institution. It came into effect on 30 April 2016.

Acknowledgement is given to Hyuk-Il Jung, Chris Peaston, Bryan Marsh, Michael Devriendt, Michele Mangione, Eden Almog and Rob Harding of Arup as the technical authors, and the following organizations that were involved in the development of this PAS as members of the steering group:

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Acknowledgement is also given to the members of a wider review panel who were consulted in the development of this PAS.

The PAS process enables a code of practice 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

This PAS is expected to be used in conjunction with BS 6164, which makes recommendations for and gives guidance on health and safety practices in tunnel design and construction.

Use of this document

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 provisions of this PAS are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”. The word “may” is used to express permissibility and the word “can” is used to express possibility, e.g. a consequence of an action or an event.

Commentary, explanation and general informative material is presented in 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 (e.g. "organization" rather than "organisation").

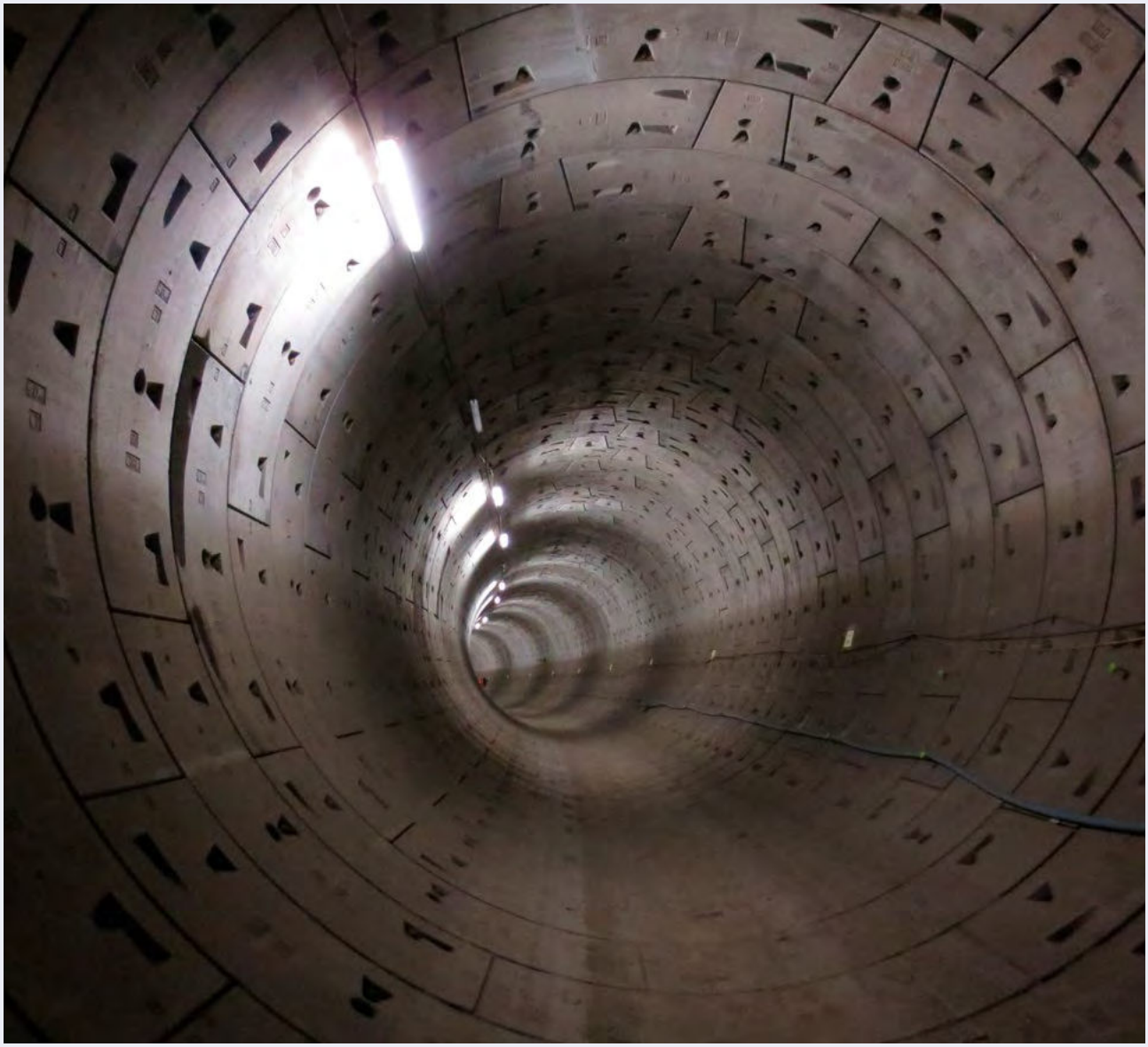
Contractual and legal considerations

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.

Particular attention is drawn to the following specific regulations:

- Construction (Design and Management) Regulations 2015 [1];
- Construction Products Regulations 2013 [2]; and
- Health and Safety at Work etc. Act 1974 [3].



Introduction

HS2 and BSI engaged with a number of construction industry stakeholders to identify areas in which it was felt that the industry could benefit from further standardization.

PAS 8810 was developed specifically to cover the design of segmental tunnel linings, which was identified as an area in which additional standardization was required. Segmental tunnel linings are currently designed with reference to a large number of published general building standards and industry documents, together with several Eurocodes. However, there is no codified or standardized design document that applies specifically to precast concrete segmental tunnel linings, and the volume of relevant standards, guidance and documentation has led to both conflicting guidance and requirements, and the misinterpretation and misapplication of standards. PAS 8810 therefore aims to bring together existing standards and industry documents into a single, usable standardization document while simultaneously reducing unnecessary administration and delay by streamlining, clarifying and standardizing the design process for segmental lining design.

Clauses **4** to **8** cover the more general aspects of tunnel design and do not restrict the designer to a single construction methodology at the conceptual design stage, as a designer would not limit their study only to segmental tunnel lining design. Clauses **9** to **12** provide specific, technical information on precast concrete lining elements for segmental tunnel linings.

At the time of publication, the intention is to standardize further areas of tunnel lining design in the near future including sprayed concrete linings and cast-in-situ linings.

As tunnel construction technology is fast changing, some of the recommendations set out in this PAS might not be fully applicable to a newly-introduced technology that does not exist at the time of this PAS publication.

This PAS is not intended to limit the design flexibility or the adoption of new technology, and, as such, is not intended to be used as a barrier that prevents the adoption of innovative designs.

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

- 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.
- PAS 8812, *Temporary works – Application of European Standards in design – Guide*, which gives guidance on the application of European Standards in the design of temporary works in the UK for practitioners in the fields of structural and geotechnical temporary works design.
- PAS 8820, *Construction materials – 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.

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1 Scope

This PAS 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. At the early stage of the design (e.g. conceptual design stage), the study of the options for the selection of the tunnel lining is not limited to concrete segmental tunnel linings. Thus Clauses **4** to **8** in the PAS are applicable to tunnels with all types of linings. Clauses **9** to **12** give specific recommendations on the design of concrete segmental tunnel linings.

This PAS is for use by design engineers (usually directly employed by the client but this could sometimes be the contractor's designer, for example, in a design and build project) and clients (usually the owner of the tunnel who is responsible for the design and construction of concrete tunnel linings) and contractors.

The PAS sets out detailed design recommendations by referencing existing national standards (BS, BS EN) or internationally-recognized industry standards. Technical requirements from existing standards are referenced, rather than repeated. Specific design recommendations are included only for the design items that are not available from existing standards.

This PAS covers:

1) functional requirements;
2) conceptual design;
3) characterization of ground;
4) materials design and specification;
5) material characterization and testing;
6) limit state design;
7) concrete segmental lining design;
8) concrete segment lining modelling;
9) instrumentation and monitoring; and
10) design management.

This PAS does not cover:

a) sprayed concrete lined tunnels;
b) cast-in-situ concrete lined tunnels;
c) any tunnel lining using material other than concrete, such as spheroidal graphite iron or steel;
d) cut and cover tunnels;
e) drill and blast excavations;
f) hard rock tunnelling;
g) pipe jacking; and
h) project planning and management.

NOTE 1 *Recommendations for health and safety practices in tunnel construction are given in BS 6164.*

NOTE 2 *Requirements for handling ground support elements are given in BS EN 16191.*

2 Normative references

Standards publications

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.

BS 4449, *Steel for the reinforcement of concrete – Weldable reinforcing steel – Bar, coil and decoiled product – Specification*

BS 6164, *Code of practice for health and safety in tunnelling in the construction industry*

BS 6744, *Stainless steel bars for the reinforcement of and use in concrete – Requirements and test methods*

BS 7979, *Specification for limestone fines for use with Portland cement*

BS 8500-1, *Concrete – Complementary British Standard to BS EN 206 – Part 1: Method of specifying and guidance for the specifier*

BS 8500-2, *Concrete – Complementary British Standard to BS EN 206 – Specification for constituent materials and concrete*

BS EN 206:2013, *Concrete – Specification, performance, production and conformity*

BS EN 450-1, *Fly ash for concrete – Part 1: Definition, specifications and conformity criteria*

BS EN 934-2, *Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures – Definitions, requirements, conformity, marking and labelling*

BS EN 1008, *Mixing water for concrete – Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*

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

BS EN 1992-1-1, *Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings*

BS EN 1997-1, *Eurocode 7: Geotechnical design – Part 1: General rules*

BS EN 12110, *Tunnelling machines – Air locks – Safety requirements*

BS EN 12620, *Aggregates for concrete*

BS EN 13055-1, *Lightweight aggregates – Part 1: Lightweight aggregates for concrete, mortar and grout*

BS EN 13263-1, *Silica fume for concrete – Part 1: Definitions, requirements and conformity criteria*

BS EN 13369, *Common rules for precast concrete products*

BS EN 14651, *Test method for metallic fibre concrete – Measuring the flexural tensile strength (limit of proportionality (LOP), residual)*

BS EN 14889-1, *Fibres for concrete – Part 1: Steel fibres – Definitions, specifications and conformity*

BS EN 14889-2, *Fibres for concrete – Part 2: Polymer fibres – Definitions, specifications and conformity*

BS EN 15167-1, *Ground granulated blastfurnace slag for use in concrete, mortar and grout – Part 1: Definitions, specifications and conformity criteria*

BS EN 16191, *Tunnelling machinery – Safety requirements*

BS EN ISO 14688-1, *Geotechnical investigation and testing – Part 1: Identification and classification of soil – Identification and description*

BS EN ISO 14688-2, *Geotechnical investigation and testing – Part 2: Identification and classification of soil – Principles for a classification*

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

BS ISO 13270, *Steel fibres for concrete – Definitions and specifications*

NA to BS EN 1992-1-1, *UK National Annex to Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings*

PAS 1192-2, *Specification for information management for the capital/delivery phase of construction projects using Building Information Modelling*