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Translation

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Design of monoblock concrete sleepers

Conception des traverses monoblocs en béton

Bemessung von Monoblockschwellen aus Beton



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Summary

This document gives the requirements for design of prestressed monoblock concrete sleepers. The primary application is for main-line, standard-gauge (1 435 mm) railways with speeds of up to 300 km/h or axle loads up to 300 kN, but the principles may be valid for other applications. A "standard" design may be considered to be suitable for freight trains of up to 250 kN axle load with 120 km/h maximum speed and passenger trains of up to 180 kN axle load with 300 km/h maximum speed.

This document is intended to support but not replace European Standards on this subject, in particular:

- EN 13230 - Concrete sleepers and bearers (May 2002),
- EN 13146 - Fastening systems (May 2002).

This document represents a State of the Art, at the date of publication, as determined by a UIC expert group and should not be a barrier to further development.

1 - General

1.1 - Scope

This document provides particular design guidance in the following areas:

- service categories for sleeper designs,
- derivation of design loads including dynamic impact factors,
- calculation of design bending moments,
- selection of dimensions.

Advisory information is also provided on current methods of manufacture.

This design guidance is considered to be appropriate in the following fields of application:

- with elastic fastenings,
- on good subsoil,
- with a minimum of 250 mm depth of ballast,
- where there is adequate drainage of ballast and subsoil,
- where there are no mechanical rail joints except glued insulated joints (continuously welded rail),
- where mechanised maintenance is employed.

In circumstances where the above cannot be ensured, a reduced sleeper life and/or additional maintenance may be expected, or the design should be enhanced.

1.2 - Definitions

Q_0	Static axle load of trains
P_d	Design rail-seat load (normal service dynamic loading)
M_{dr+}	Design positive (sagging) bending moment at rail-seat (normal service dynamic loading)
M_{dr-}	Design negative (hogging) bending moment at rail-seat (normal service dynamic loading)
M_{dc-}	Design negative (hogging) bending moment at sleeper centre (normal service dynamic loading)
M_{dc+}	Design positive (sagging) bending moment at sleeper centre (normal service dynamic loading)
γ_p	Factor to apply to dynamic increment to reflect rail-pad attenuation
γ_v	Normal service dynamic increment determining the effect of speed
γ_d	Factor to allow for load distribution between sleepers
γ_r	Partial factor to allow for variation in the sleeper reaction due to support faults
γ_i	Partial factor to allow for irregularity in the longitudinal support of the sleeper
k_1	Impact factor representing exceptional load case
k_2	Impact factor representing accidental load case
I_c	Second moment of area at sleeper centre section
I_r	Second moment of area at rail-seat section

2 - Design criteria

Design criteria to be taken into account for the design of monoblock concrete sleepers are described below.

2.1 - Service categories for sleeper designs

Where the service loading is different, this theoretically permits a different sleeper design. Economies exist where the sleeper is designed specifically for the application, but this is offset against increased manufacture, stocking and management costs.

The following circumstances may lead to a requirement for different design criteria:

- different axle-load or speed categories of line,
- different constraints (e.g. low depth requirement),
- different service load (e.g. curves, on ballasted bridges),
- different track requirements (e.g. expansion joints, etc.).

It is recommended that designs with baseplates should be avoided wherever possible. Where it is necessary to employ these, the basic sleeper design should normally be the same as for direct fastening.

Standardisation of sleeper designs will lead to greater volume and therefore minimum unit cost of production. Decisions on the number of sleeper designs should therefore be guided by economic criteria, taking into account the unit cost of production at the relevant volume levels.

2.2 - Design life and warranty

The sleeper shall be designed for a minimum service life of 40 years. The criteria presented in this document are considered to be consistent with that objective.

The components shall be warranted against defects in materials or manufacture for a minimum period of 5 years. The warranty shall also cover the areas of the design that are the responsibility of the manufacturer. The manufacturer may also propose more stringent design requirements to those presented in this document, for the purposes of providing the warranty.

2.3 - Design loading

Derivation of design loading for concrete sleepers shall take account of:

- the design static axle load of trains,
- dynamic factors, to take account of geometric irregularities in the track structure and vehicles,
- the influence of the track structure in sharing applied axle loads between sleepers and the variability of the track support.

Several load cases may need to be evaluated to determine the worst combination of static and (speed-related) dynamic load.

A "standard" sleeper may be considered as satisfying the load/speed cases shown below:

Axle load/Speed	180 kN	225 kN	250 kN
120 km/h	X	X	X
200 km/h	X	X	
300 km/h	X		

Design based upon assumption of symmetric vertical loading is, in most cases, acceptable, as sufficient factors are included to take account of lateral loading and load transfer on curves. In special circumstances, the purchaser may refine the design to take account of these effects.

Design bending moments in the sleeper are to be derived to account for the following cases:

1. The basic design bending moment, which takes account of static loading plus normal service dynamic loads. No cracking of the sleeper shall occur at this load level.
2. An exceptional load bending moment, which takes account of loads in addition to those in paragraph 1., that are to be expected only a few times in the life of the concrete element (e.g. wheel flats). Any crack formed at this load level shall close on removal of the load.
3. A bending moment relating to accident impact loads. This shall define the ultimate load capacity of the concrete element.

2.3.1 - Static vertical load

The static component of vertical design load (Q_0) can be determined directly from the static axle load of trains (normally the sleeper design load will be expressed per wheel). At the design stage it should be borne in mind that sleepers are expected to last for 40 years or more. If future enhancements to axle load and speed are planned, this may be taken into account in the design.

2.3.2 - Normal service dynamic increment

This accounts (γ_v) for normal dynamic loading resulting from irregularities in the track structure and vehicles. Recommended values are shown below:

- for $V < 200$ km/h: 0,50,
- for $V \geq 200$ km/h: 0,75.

In special circumstances the dynamic factor may be derived from proven empirical relationship, measurement or simulation and may depend on track geometric quality and speed. For speeds up to 200 km/h, the recommended factor is consistent with Standard *EN 13230* (see [Bibliography - page 25](#)). For speeds up to 300 km/h, it is considered that the same factor remains, provided that the necessary geometric tolerances in rail surface and geometric alignment associated with those speeds are maintained. The experience shows that the factor does not increase up to a speed of 300 km/h.

2.3.3 - Resilient rail pads

European Standard *EN 13146* (see [Bibliography - page 25](#)) evaluates the impact attenuation of fastening systems (γ_p) by means of a test to measure the magnitude of impact bending strains in a concrete sleeper. Fastening systems, with their associated rail pads, can be classified according to the reduction of strain to a reference case as follows:

- low attenuation < 15%
- medium attenuation > 15 - 30%
- high attenuation > 30%

These impact-attenuation factors may be applied to design loads. However, it is recommended that the attenuation value measured for the fastening system be reduced by 25% in the normal case to allow for the service condition. This reduction is to apply to exceptional, accidental and normal cases. In order to take advantage of the reductions that may be made in the design load by accounting for the use of resilient rail pads, the purchaser will need to ensure that maintenance standards allow the continued use of rail pads equivalent to or better than those assumed in the design.

Thus dynamic increment factors are to apply as follows:

- low attenuation < 15 % 1,0
- medium attenuation > 15 - 30 % 0,89
- high attenuation > 30 % 0,78

This is used with the normal-service dynamic-load increment to produce a combined dynamic factor, e.g. combined dynamic factor to apply with high-attenuation fastenings at $V = 250$ km/h:

$$= 1 + 0,78 \times 0,75 = 1,59$$

Use of the rail-pad attenuation values to reduce the dynamic impact factor in this way is probably conservative, as there is also likely to be an additional benefit in static load distribution.