Guidance Note 3.03

Bridge bearings

Scope

This Guidance Note provides information on the types of bearings which are normally used in steel bridges. The intention is to provide guidance as to what type of bearings should be used to suit particular bridge forms. Fuller descriptions of some bearing types, with illustrations, are given in Lee [1] and the *Steel Designer's Manual* [2].

In order to select the most appropriate type of bearings it is necessary to consider the articulation of the bridge deck and its overall stability under loading. Information on bridge articulation is given in GN 1.04. Information on the attachment of bearings is given in GN 2.08.

General

In the majority of steel bridges it is convenient to use proprietary bearings, provided appropriate testing and/or design checking procedures can be satisfied. However, steel fabricated bearings can be chosen when the bridge experience uplift situations, for fixed end bearings or where large rotations occur, as in roll-on/roll-off link spans and moveable bridges. Standard bearings have limited rotation capacity, while steel fabricated bearings can be designed to accommodate greater movements and rotations.

Whether bearings are proprietary or fabricated, their design and manufacture must conform to BS EN 1337 [3]. That Standard comprises numerous separate parts, relating to general rules, and rules for individual types of bearings or components of bearings. The task of the bridge designer is to define a schedule of forces and displacements that the bearing is to be designed for - see later comment.

Where bearings have to resist uplift, special bearings normally have to be designed and manufactured. Hence uplift bearings are best avoided if necessary, by modifying the design concept of the bridge. For lightweight structures such as footbridges, consideration should be given to providing separate and robust hold-down devices to prevent dislodgement under accidental impact or theft.

It is now general practice for the designer to make provision for the replacement of the bearings during the lifetime of the bridge and this practice is endorsed in PD 6703 [4]. This usually means that, except for light footbridges, provision for jacking should be designed for and incorporated into the works. Arrangements for fixing by bolting should be such that the bolts can be removed without needing to lift the bridge girders significantly.

Particular attention should be given to the design of supporting concrete plinths to prevent bursting or other types of failure from application of both vertical and horizontal forces.

Types of bearing

Table 1 shows the main types of bearing that are used in steel bridges. Generally, the terminology used in BS EN 1337 is adopted in the Table although not all types of bearing are covered by BS EN 1337.

The most frequently used type of bearing for highway bridges is the proprietary pot bearing, which is able to accommodate rotation and, where required, lateral movement in either longitudinal or transverse directions, or in both directions. Such bearings are particularly suitable for continuous and curved viaducts.

For railway bridges or footbridges, fabricated linear rocker bearings are often suitable at both ends for simply supported spans up to about 20 m. For rail bridges of span greater than 20 m, fabricated roller/rocker bearings can be used at the free end. Line rocker bearings are of benefit in some half-through type rail bridges in resisting transverse rotation at supports (applies to both plate girder type bridges with U-frame action and standard box girders with pin connected floors - see GN1.04 for further comment).

For footbridges and short span road bridges, elastomeric bearings are often used. For short footbridge spans supported by steel columns, bearings may be omitted altogether and replaced by a direct bolted cap plate connection, which allows thermal movements and articulation to be accommodated by flexure of the columns.

Some brief guidance on commonly used bearing types is given below.

Pot bearings

Pot bearings comprise a circular elastomeric disc constrained by a metal housing (forming a cylinder and piston) which allows high pressures to be used such that resistance to articulation is negligible. Free bearings (i.e. allowing horizontal translation) are achieved by incorporating a PTFE/stainless steel interface, usually arranged as shown in Figure 1.

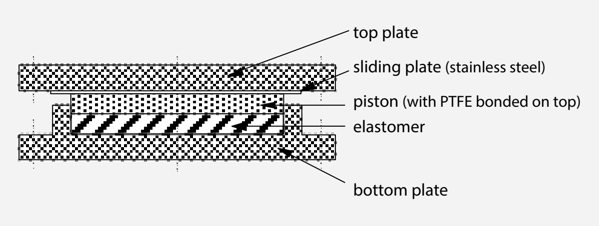

Figure 1 Free-sliding pot bearing

With this arrangement, when movement occurs (due to expansion/contraction) the reaction becomes eccentric to the superstructure above. This eccentricity can be avoided by inverting the entire bearing assembly, but the sliding surface is then vulnerable to collecting debris and should be shrouded by providing a skirt around the bearing (see further comment in Figure 3 of GN 2.08).

The friction on the sliding surface depends on the PTFE interface pressure and is typically 5%.

If the sliding element is omitted, pot bearings provide horizontal restraint. Alternatively, the sliding element may be constrained by guides, creating a unidirectional guided bearing.

Elastomeric bearings

These may be of strip, rectangular or round pad or laminated type (see Figure 2), the latter being available typically up to 1000 kN capacity. Design is governed by SLS requirements, to control excessive distortion of the material.

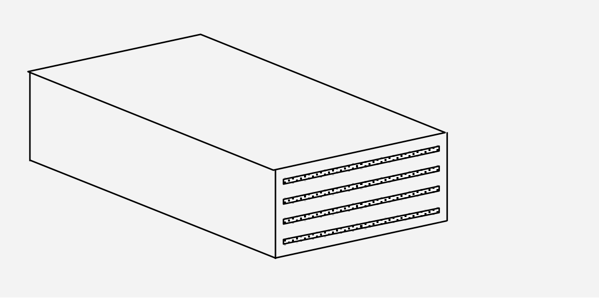

Figure 2 Laminated elastomeric bearing

For loads in excess of 1000 kN, the bearings may become uneconomically large, such that additional spreader plates and stiffening of the steelwork become necessary. Thus, elastomeric bearings are rarely used for steel highway or railway bridges.

Movements and rotations are achieved by deformation of the elastomeric material such that moving parts are completely avoided. See Figure 3.

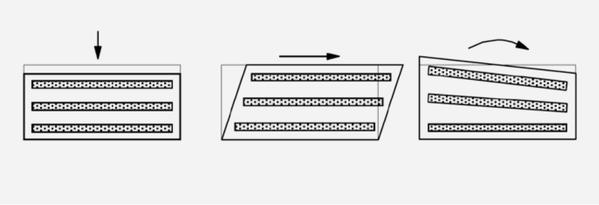

Figure 3 Deformation of elastomeric bearings

It is normal for bearings to require restraining in position by steel keep-strips attached to the steelwork above and the spreader plate below. Movement is restricted to about 40 mm from the mean position. Elastomeric bearings are unsuitable as fixed bearings, unless the forces are small, or horizontal loads are restrained by other means (e.g. dowels).

Linear rocker bearings

Linear rocker bearings can provide an economical solution in that they can be supplied by the steelwork fabricator. As well as economic advantages that this gives, it may also give more assurance that there is a good match between hole positions in bearings, tapered bearing plates and girder flanges, as well as reducing the risk of delay in the procurement process (see further comment overleaf). See Figure 4.

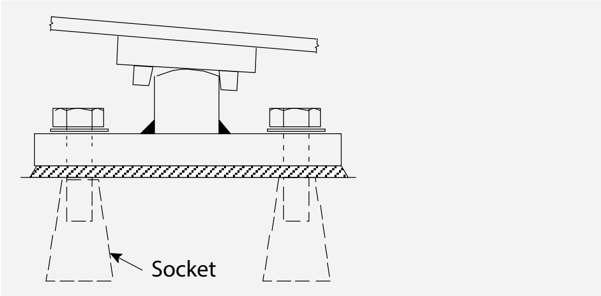

Figure 4 Fabricated line rocker bearing (inclination of girder exaggerated)

The rocker surface is normally machine radiused. The design capacity depends on the radius, as well as on the material properties.

A convenient method of attaching fabricated bearings to the substructure in a way that allows for construction tolerances is to site weld the lower part of the bearing to a larger baseplate that is fixed to the substructure before steelwork erection.

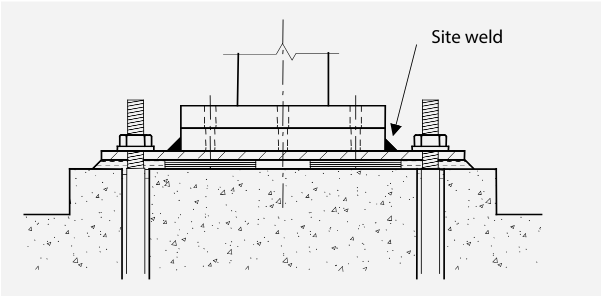

Figure 5 Detail of site welding to baseplate

When designing a linear rocker, the maximum eccentricity of the reaction (due to the restraining torque that the bearing provides) needs to be considered carefully (there is no tensile restraint at the line of contact).

Roller/rocker bearings

These bearings are suitable for situations where only longitudinal movement and articulation occur, and where transverse rotation is to be prevented. In order to reduce bearing height, the upper and lower curved surfaces can be radiused from different axes (see Figure 6), but this arrangement means that under longitudinal movements, the superstructure will tend to lift, creating additional longitudinal forces which must be designed for. This type of bearing is used at the free end of standard box girder rail bridges for spans exceeding 20 m.

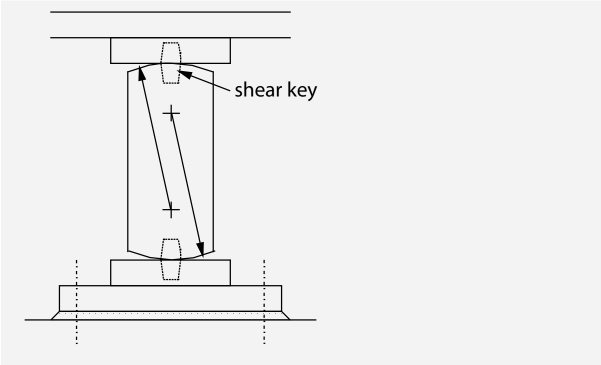

Figure 6 Fabricated rocker bearing

Guides are provided to ensure that the bearings remain normal to the direction of movement and shear keys are provided at each end to transfer lateral loads and prevent crabbing.

Roller bearings

Steel roller bearings usually comprise a single cylindrical roller of high strength or case hardened steel to increase the load capacity and to minimise friction. This type is used where friction is to be minimised and is suitable on leaf piers. It shares the displacement equally between sub- and superstructure.

Guides are provided to ensure against crabbing. However, alignment of the roller axis normal to the direction of the steelwork movement is critical, particularly on long viaducts, where the movement is significant.

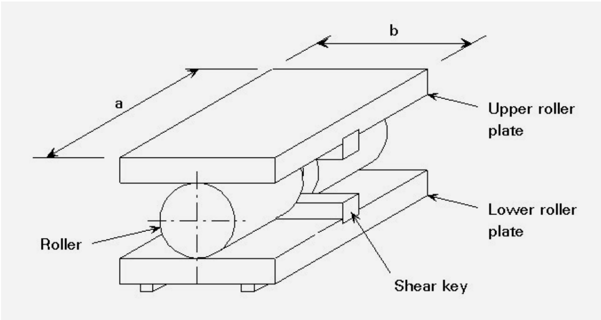

Figure 7 Fabricated roller bearing

It should be noted that some types of high strength steel exposed to the environment under loading for roller bearings may be susceptible to cracking problems and for these reasons the bearing is normally enclosed within an oil-bath.

Roller bearings are now rarely used.

Pin and swing link bearings

These bearings (also known as pendel bearings) are used where the amount of articulation exceeds that of proprietary bearings as in roll-on/roll-off link spans. They are also used in order to resist overturning and/or theft. They are not covered by BS EN 1337.

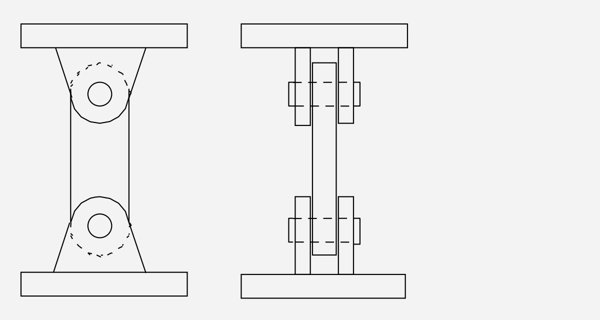

Figure 8 Swing link expansion/uplift bearing

Guide bearings

Occasionally, where lateral loads at a support are large in comparison with the vertical loads, separate guide bearings are used to resist lateral loads only. This situation can arise in long viaducts where lateral forces are only resisted at some supports, or in cable supported bridges. Proprietary sliding plate or pin type guided bearings are available for small loads, but guide bearings are usually purpose-designed.

Specification of bearings

The designer should prepare a bridge bearing schedule for the bearing manufacturer. A typical bearing schedule is given in BS EN 1993-2 but that format is unsuitable, since it provides only for characteristic values of the effects of individual actions and the bearing designer would need to know the appropriate partial factors and combinations of actions, which is outside his responsibility. A different schedule is given in BS EN 1337-1 but even that is not entirely clear about which effects are coexistent or in which design situation they occur. A better schedule is provided in PD 6703 and it is proposed to provide a template schedule in a future revision of BS EN 1990.

See guidance in P406 about determining thermal movement ranges, allowing for tolerance in bearing location.

In the absence of an adequate 'typical' schedule, early discussion between bridge designer and bearing designer is recommended.

The designer should consider with caution the axis convention used in the bearing schedule. The diagrammatic indications given in the footer of Table 1 in BS EN 1337-1 combined with the template bearing schedule imply 'Longitudinal rotation' to be rotation about the longitudinal axis. This conflicts with the traditional British understanding that longitudinal rotation correlates to in plane flexure of a longitudinal beam. The designer should specify the axis convention used on the 'drawing of the support plan' (description as per BS EN 1337-1, i.e. on the bearing articulation drawing) and make this clear to both the supplier and installer.

The design of the bridge including steelwork stiffening, bearing plates and support on the substructures, should be carried out by the designer, assuming either one proprietary make based on catalogue or other information from an approved supplier, or that there are project-specific bearings for which the full details are given in the project documentation. The drawings should then clearly permit the contractor to offer different bearings, provided that all design criteria can be met.

BS EN 1337 contains specification clauses relating to inspection and testing procedures, including the provision of testing procedures for proprietary bearings.

Procurement of proprietary bearings

Whilst the provision of a comprehensive bearing schedule gives a basis for competition between bearing suppliers, it should be noted that the time for gaining approval of selected bearings is often very long. It is all too common for the bearing details to be outstanding after the main body of the steelwork has been fabricated - sometimes even after protective treatment. It is essential to progress bearing procurement as quickly as possible, and to remember that it is false economy to save a little on the cost of the bearings at the expense of delay to the rest of the job.

Robustness

Most bearings, purpose-fabricated or proprietary, are extremely robust and give little trouble in service. The only problems that can be said to occur quite often are contamination of, and hence damage to, sliding surfaces, caused by leakage from the deck washing grit onto the interfaces. This problem can be avoided by careful detailing of bearing attachments and/or the provision of skirts (see Figure 3 of GN 2.08 for an example of a skirt).

There have been some very occasional problems with elastomeric and hardened steel roller or ball bearings caused by high frequency vibration of the bridge structure; the rubber degrades into dust or the steel surfaces develop micro-cracking.

Location plates for railway bridge bearings

It is normal practice for bearings of railway bridges to be positioned on location plates bolted to the abutment, particularly when superstructures are reconstructed on existing abutments during possessions. The lower bearing plate is site welded to the location plate. Location plates offer the following advantages:

- They provide tolerance on the final position of the bearing relative to the abutment.
- Longer holding down bolts may be used to fix the location plates than could be used for the narrower base plates (because of the restricted clearance between the lower bearing plate and the underside of the bridge girder).
- They achieve greater load distribution and therefore reduce bearing stresses on the abutment (this is particularly relevant on brickwork abutments and may enable the depth of sill beams to be reduced).
- The bearing installation period required in a possession can be minimised, because location plates can be installed as soon as the abutment is ready and before the bridge superstructure is erected.

Bearings in integral bridges

In fully integral bridges, there is no translational movement between superstructure and substructure. In some types of integral bridge, line rocker bearings may be provided, to allow relative rotation. Such rocker bearings could be either proprietary or purpose-made; provided that the steelwork is properly protected against corrosion, they should be maintenance-free.

In some types of jointless or semi-integral bridge, sliding bearings might be used, with longitudinal and lateral restraint being provided by earth pressures on the endscreen walls across the end of the superstructure.

References

[1] Lee, DJ, Bridge bearings and expansion joints, 2nd edition, E & FN Spon, 1994.

[2] Matthews, SJ, Bearings and joints, Chapter 28 in the Steel Designers Manual, Blackwell Science (Sixth Edition), 2003.

[3] BS EN 1337 Structural bearings
Part 1 General design rules
Part 2 Sliding elements
Part 3 Elastomeric bearings
Part 4 Roller bearings
Part 5 Pot bearings
Part 6 Rocker bearings
Part 7 Spherical and cylindrical PTFE bearings
Part 8 Guided bearings and restrained bearings
Part 9 Protection
Part 10 Inspection and maintenance
Part 11 Transport, storage and installation

[4] PD 6703 Structural bearings. Guidance on the use of structural bearings, 2009.

[5] Determining design displacements for bridge movement bearings (P406)

Type	Common capacity range (kN)	Supply	Typical friction coefficient or stiffness	Use	Limitations	General comments
Pot	500 - 30,000	Proprietary	0.05	> 20 m span	Rotation capacity 0.01 radians	Widely used
Elastomeric strip	200 - 1,000	Proprietary	4 - 10 kN/mm	Short span > 10 m	Limited translation and rotation	Economic for short spans
Elastomeric pad	10 - 500	Proprietary	0.5 - 5.0 kN/mm	Short spans - light loads	Limited translation and rotation	Useful for light loads
Elastomeric laminated	100 - 1,000	Proprietary	0.5 - 5.9 kN/mm	Short spans	Heavy loads	Widely used
Cylindrical roller	1,000 - 1,500	Proprietary	0.01 (single roller hardened)	Minimal friction	Nil lateral translation or rotation	Little used. Guides essential
Linear rocker	1,000 - 10,000	Fabricated	0.25	Fixed bearings. Rail bridges	High friction. Nil lateral rotation	Large rotation
Cylindrical knuckle	2,000 - 10,000	Fabricated	N/A	Pinned bearings. Base of steel portal	Unsuitable for translation or lateral rotation	Little used
Plane sliding Proprietary	100 - 1000	0.005	Sliding guides with large translation	Small rotation capacity	Suitable very short span (say< 5 m) where	rotation negligible
Spherical sliding	1,000 - 12,000	Proprietary	0.05	> 20 m span	More expensive than pot	Rotation capacity 0.05 radians
Guide	150 - 1,500	Proprietary	0.05	Horizontal load only	Carries no vertical load	Used when guide bearing essential, e.g. end of long viaduct or wide bridge
Pin	10 - 1,000	Fabricated	N/A	Fixed with uplift	Nil translation or lateral rotation	Useful for footbridges for security or uplift
Swing link	10 - 1,000	Fabricated	Control by link length	Guided with uplift	Nil lateral translation or lateral rotation	Useful for footbridges for security or uplift

Table 1 Types of bearings