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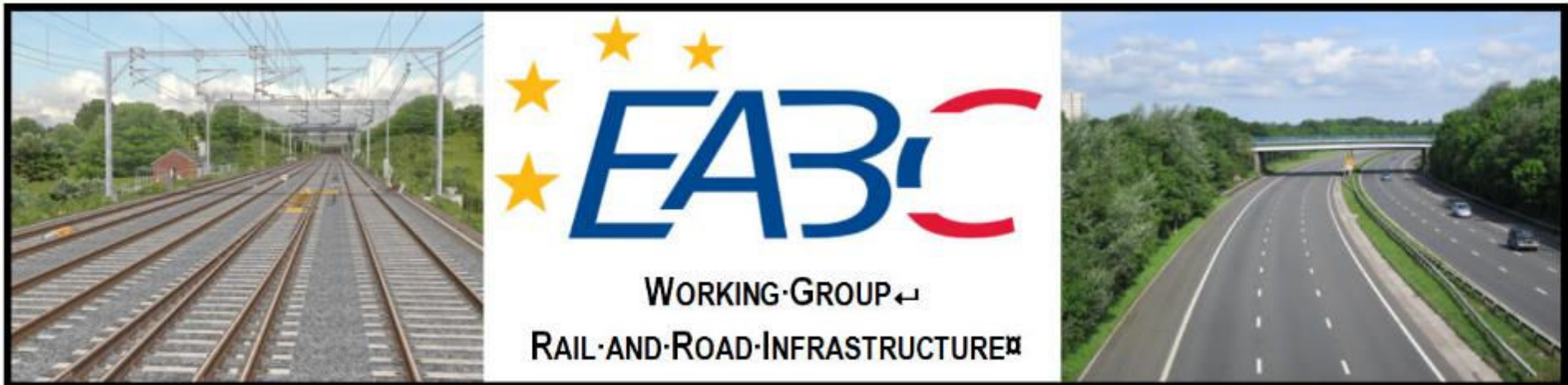
presents

# Railway Bridge Design

Important items for a long life span:  
interaction structure to track  
and bearing selection

By Georg Wolff

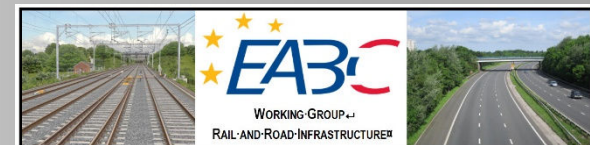
A recommendation of





The European Association for Business and Commerce (EABC) is the European Trade Organisation situated in Bangkok, Thailand, with an objective to contribute to the improvement of trade and investment between the European Union and the Kingdom of Thailand.

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# Introduction of the author:

## Mr. Georg WOLFF

born 1951 in Austria, mechanical engineer  
graduated at Linz/Austria, works in bridge supply  
industry - bearings & joints - since 1970.

Since 1989 expert at  
CEN (European Standards Committee)  
TC 167 for bridge bearings (EN 1337)  
and TC 340 for seismic devices (EN 15129).



Expert at EOTA (European Organisation for Technical Assessment) for ETAG 032 expansion joints.



Expert at ASI (Austrian Standards Institute) at ONK14 Bridges, mirror committee for EUROCODE, European bridge design standard.

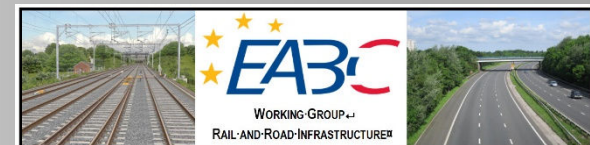


Board member of EABC Thailand (European Chamber of Commerce), registered at the Ministry of Commerce, representing Advantage Austria.

Chair of Working Group  
RAIL & ROAD INFRASTRUCTURE



CEO of Civil Engineering Solutions Pte Ltd  
Singapore and Civil Engineering Solutions  
(Thailand) Co. Ltd.



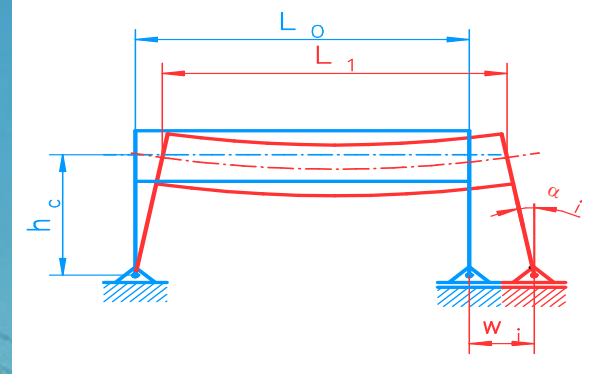
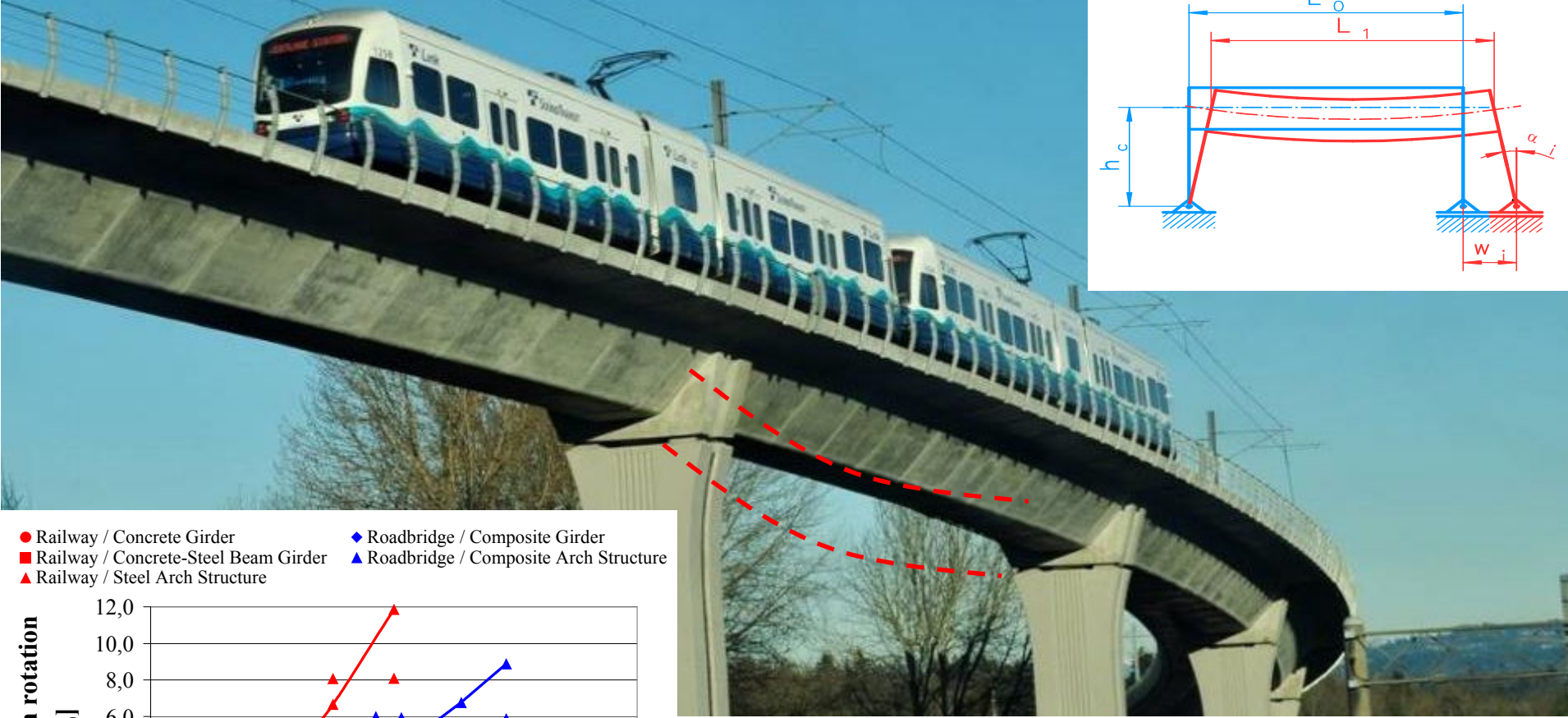
# Railway Bridge Design

Important items for a long life span:

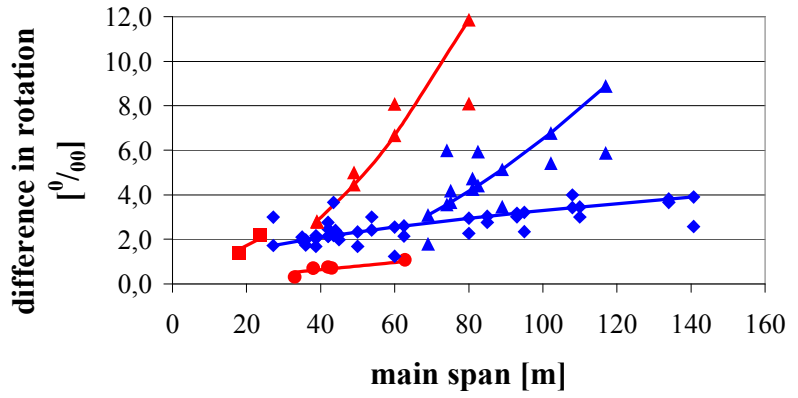
Interaction structure to track  
and bearing selection

There is an interaction between the deck of a railway bridge/viaduct and the track/rail. This can cause serious long-term troubles to train operation if not carefully considered.

# For Railway Bridges special requirements to be considered



- Railway / Concrete Girder
- Railway / Concrete-Steel Beam Girder
- ▲ Railway / Steel Arch Structure
- ◆ Roadbridge / Composite Girder
- ▲ Roadbridge / Composite Arch Structure



- \*Cyclic moving load.
- \*Higher amplitude compare to roads.
- \*Cyclic rotation at bearing point.

The decks of railway bridges and viaducts are not rigid but move in three dimensions!

This can, in particular at the ends of decks, lead to significant stress to the rail!

Such stresses can lead to high maintenance demand at the rails and even to rail fractures due to **FATIGUE!**

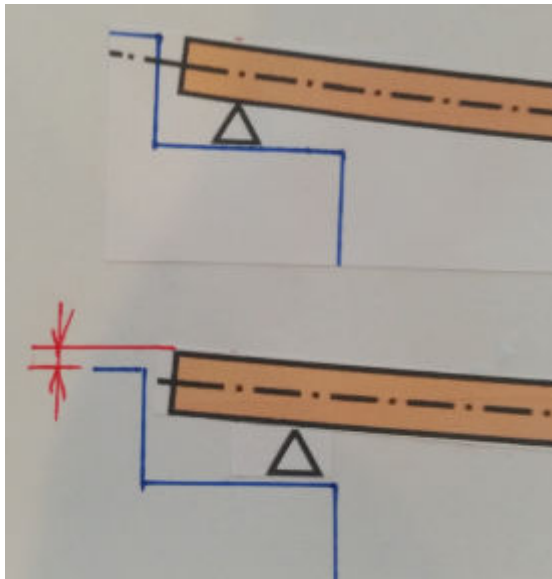
So it is of great importance to limit those effects and to **take them into account** at track design.

It is the responsibility of the structural engineer to make these data available to the planners of the track.

Similarly, track planners are obliged to request this information.

# Vertical Displacement

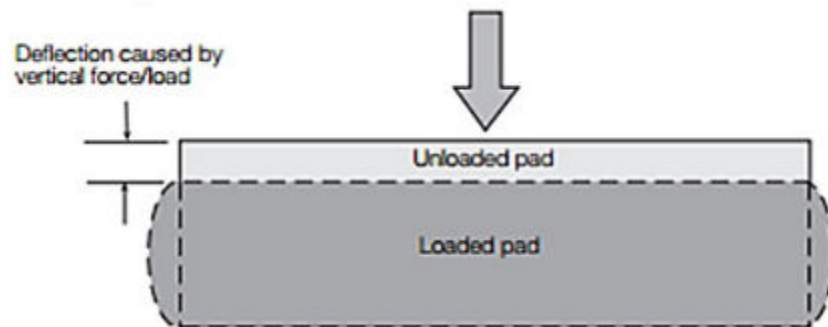
By deflection of the deck due to live loads in dependence of the bearing position



The larger the distance of the bearing to the deck ends, the higher the vertical displacement due to deflection of the deck.

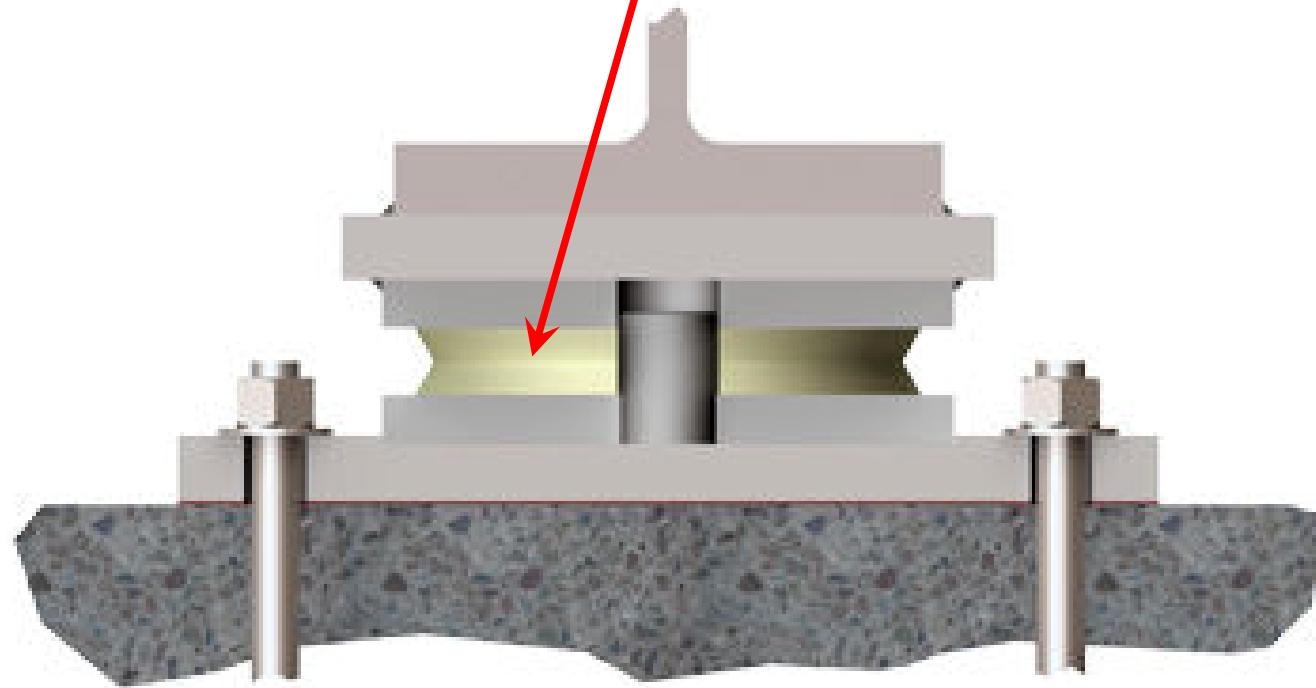
## Vertical Displacement by deflection of the bearing due to insufficient stiffness.

**Reinforced elastomeric bearing.** This bearing acts like a spring. The vertical deflection is reduced by the reinforcement, but it is still there! Traffic loads from trains cause vertical deflections with high fatigue stress for the rails! This deflection can be calculated acc. to EN 1337-3. As the stiffness is reduced by raising temperatures, the maximum allowed modulus of elasticity at high temperature has to be taken into account!



**Elastomeric bearings always cause fatigue bending of the rails!  
They are not suitable for railway bridges!**

**Disc Bearings:** The load bearing PU pad acts like a spring. Traffic loads from trains cause deflections with high fatigue stress for the rails!



**Disc bearings always cause fatigue bending of the rails!  
They are not suitable for railway bridges!**

## Vertical Displacement by deflection of the bearing due to wear.

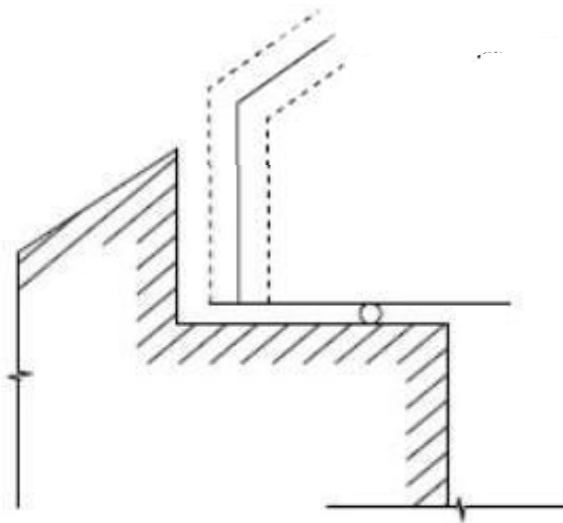
**PTFE sliding bearing.** The PTFE sliding material is worn out due to longitudinal bridge movement. The original thickness of is reduced by the time by 3 to 4 mm.



**If PTFE sliding bearings are used, a 4 mm vertical deflection by the time shall be considered at rail design!**

# Vertical Displacement due to inclined bridge deck with horizontal installed bearings

Bearings are usually designed to sit in a horizontal plane so as to avoid the effect of additional horizontal force. For an inclined bridge deck subject to a longitudinal movement, a sudden jump is induced at the joint and a deformation of the rail induced. To solve this problem, an inclined bearing installation is adopted and the piers should take up the induced horizontal forces.



The effect of inclined bridge deck on joint discontinuity.

**At inclined bridge decks the moveable bearings shall get installed inclined (not horizontally)!**

# Vertical Displacement due to uplift

Conditioned by special designs, such as skewed bridges, junctions and enhancements in certain operation load cases uplift forces (negative vertical loads) may occur. In such cases it must be ensured that an uplift device at the bridge bearing takes over the loads without play (clearance) or with very little play, since otherwise an unscheduled and eccentric loading of the rail and the rail fastening will take place.

If the uplift device shows a play, for sliding bearings the sliding materials shall be fixed in the recess by bonding or bolting, as otherwise an adhesive effect can remove and damage them .

**Uplift devices shall work without play!**

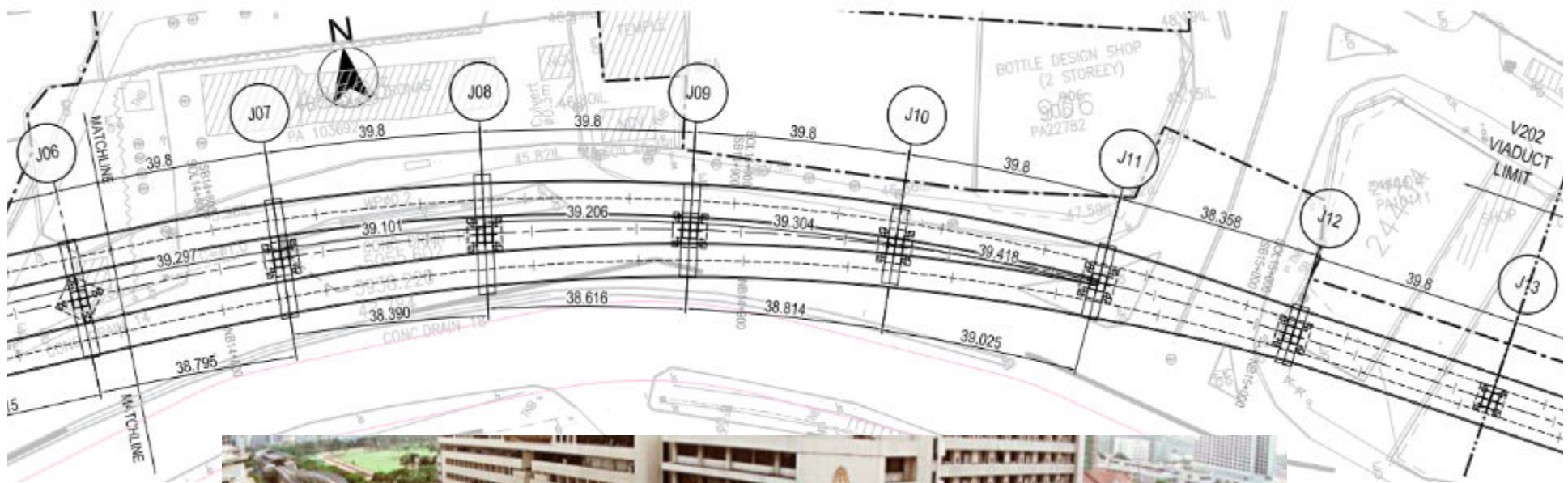
# Horizontal Displacement

## Elastomeric bearings floating arrangement

The arrangement of elastomeric bearings without restraint (unguided) will transfer all horizontal forces to the rail. So the rail has to bear all wind loads. This yields an enormous and inadmissible load to the rails. In case of curved structures centrifugal forces are added and rail and rail fasteners will be overstrained.

Longitudinal forces of acceleration and braking are less difficult as the rail has to transfer them anyhow.

**Floating bearing arrangement  
is unsuitable for railway bridges!**

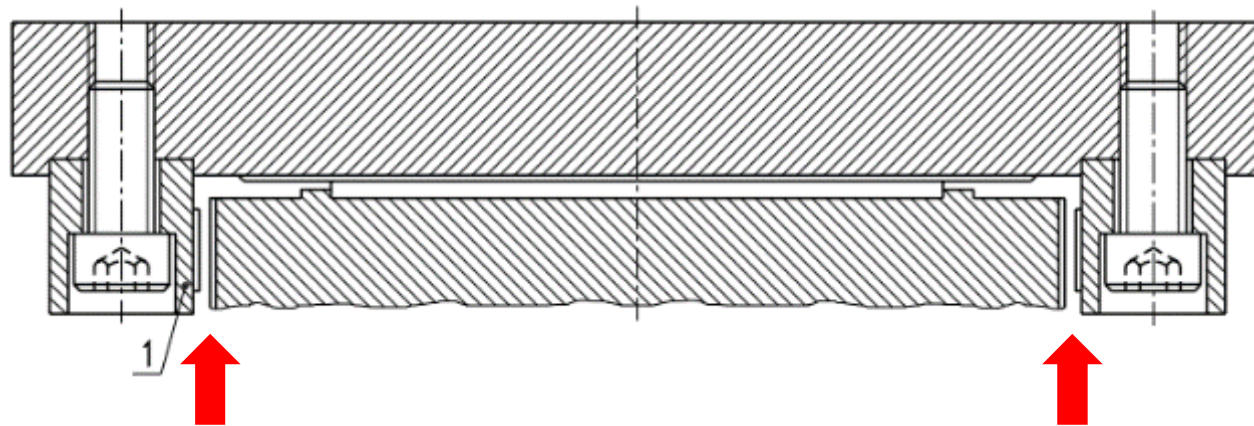


**If viaducts floating on unrestrained elastomeric bearings, the RAIL is bearing the horizontal forces, not the bearing!**

# Horizontal displacement due to inappropriate play in bearing design.

The design of vast majority of bearings is done for road bridges. The various standards for bridge bearings like AASHTO, BS 5400, EN 1337 do not consider the special requirements of railway bridges. They all are drafted for road bridges! For road bridges a narrow play (clearance) for guides and restraints is not of importance. Allowable play is given for new and unused bearings. This is increasing due to wear of sliding materials (e.g. PTFE). So values like 2 mm for a fixed bearing or 5 mm for a guided bearing will be within the limits. But unacceptable for railway bridges!

Due to the play horizontal forces will first go to the rail. And only after the rail suffers an elastic deformation, the bearings guide/restraint will be in contact and take over the forces.



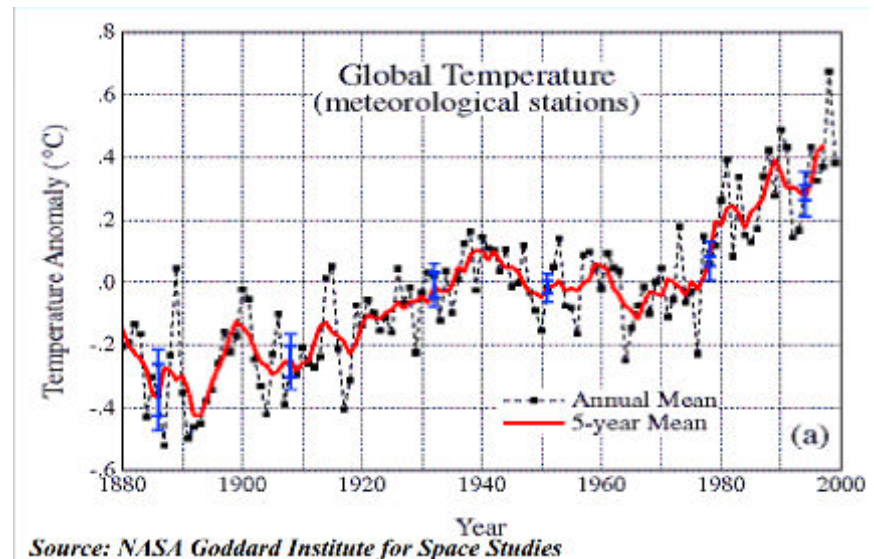
A limitation of play to a small value, e.g. 0.5 mm, is required.

**Railway bridge designer shall limit the bearing play in the tender specs to a measure acceptable for track design.**

# Temperature

Railway bridges shall be designed for a life span of 100 and more years. Available civil engineering standards mostly consider only mean shadow temperatures of the past.

As the railway bridges are often exposed to direct sunlight and provisions for future temperature increase are needed, considering at least +60°C shall be considered for “ULS” bearing operating temperature.



The consideration of a temperature of + 60°C shall be used at the determination of the thermal bridge deck expansion. And also the bridge bearings shall be capable to such operational temperatures as some time they may be exposed to direct sunlight, too.

As this may be a problem for some sliding materials, the property shall be verified by the following test:

A specimen acc. to BS EN1337-2 Fig. D2 with uniform loading of 40 N/mm<sup>2</sup> sliding with an amplitude of 12.7 mm at a ULS temperature of 60°C shall not to deform by more than 3.2 mm in diameter for a period of 100 hours.

**A maximum operating temperature of 60°C shall be considered.**

# Standards

To counter a widespread error, it must be noted that standards are no “approved recipes”. Neither they consider all the circumstances and load cases, nor are they meant to absolve the engineers responsibility.

Before the application of a standard for a project is determined it shall be checked whether it is applicable and valid.

And many information, as the above mentioned interaction of bridge deck and track, will not be covered by any standard.

So e.g. the scope of AASHTO (American Association of State Highway Officials) says very clear „ Provisions are not included for bridges used solely for railway“ . So if such **non-applicable** standards are considered, they need carefully drafted completion.

Another example: Bridge bearings in acc. with BS 5400-9. This standard was withdrawn in 2000 and replaced by BS EN 1337. So its not **valid** anymore.

AREMA (American Railway Engineering & Maintenance-of-Way Association) Manual For Railway Engineering is a private guideline that partially contains very **outdated regulations**.

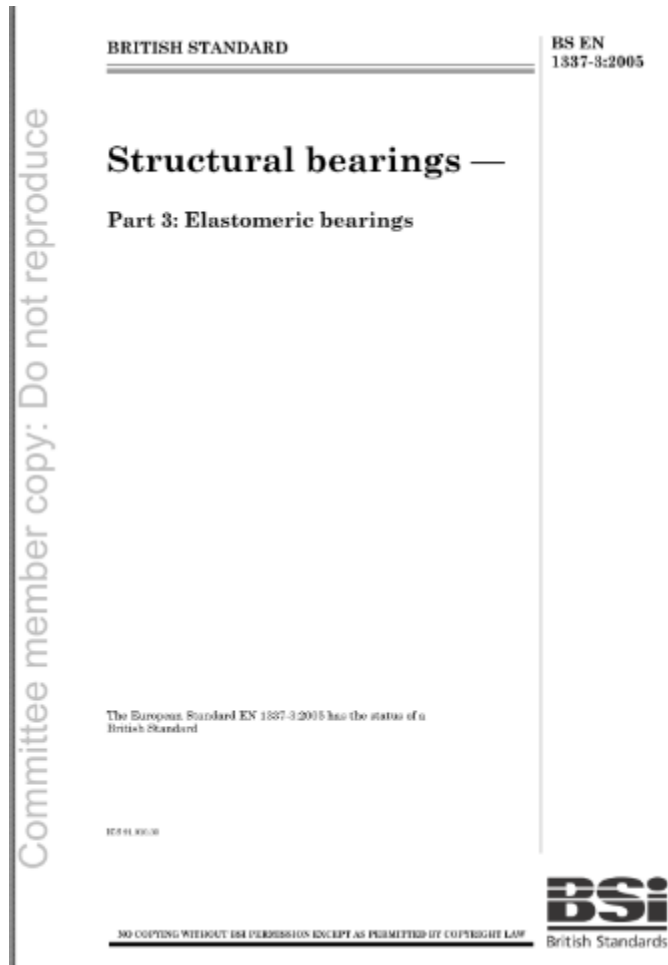


Many national standards can only be used for other countries with difficulties, as they do not provide ways to consider particularities of other countries, for example climatic conditions, national operational reasons, or local building methods.

ISO standards, European standards and European approvals are more easy to use as they got a multinational base.

**Use standards with great care only!**

The only international state-of-the-art standard for bridge bearings is the European Standard EN 1337 structural bearings.



Developed 1989 to 2000  
11 parts  
All approved design of  
bearings included.

No special consideration  
for railway bridges.

CE – marked bearings  
including

**Third party quality control**

This European Standard EN 1337 *Structural bearings* consists of the following 11 Parts:

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*

# Railway Bridge Design

## Bearing Selection

Beside consideration of the interaction between the deck of a railway bridge/viaduct and the track/rail there are the following requirements for state-of-the-art railway bridge bearings:

# Railway Bridge Bearing Requirements

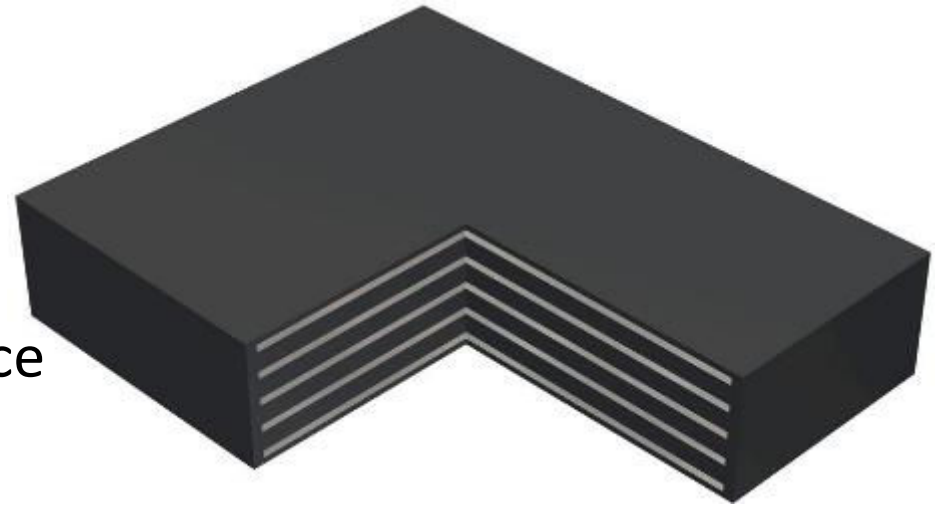
- Long life span
- High loading capacity
- No wear
- Small reaction forces
- Inspectable during service

# Evaluation of all bearing designs on the market showing the performance considering the requirements

✔ passed ✘ failed

# Reinforced Elastomeric Bearing

- ✓ • Long life span
- ✗ • High loading capacity
- ✓ • Free of wear
- ✗ • Small reaction forces
- ✓ • Inspectable during service
- ✗ • Vertical stiffness
- ✓ • Horizontal play
- ✗ • Horizontal load transfer



✗ Applicability for Railway Bridges

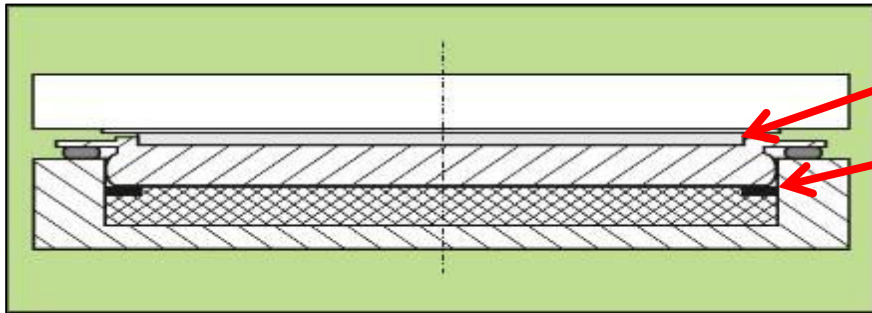
# Pot Bearing + PTFE Pot Sliding Bearing

- ✓ • Long life span
- ✓ • High loading capacity
- ✗ • Free of wear
- ✓ • Small reaction forces
- ✗ • Inspectable during service
- ✓ • Vertical stiffness
- ✗ • Horizontal play
- ✓ • Horizontal load transfer

✗ Applicability for Railway Bridges

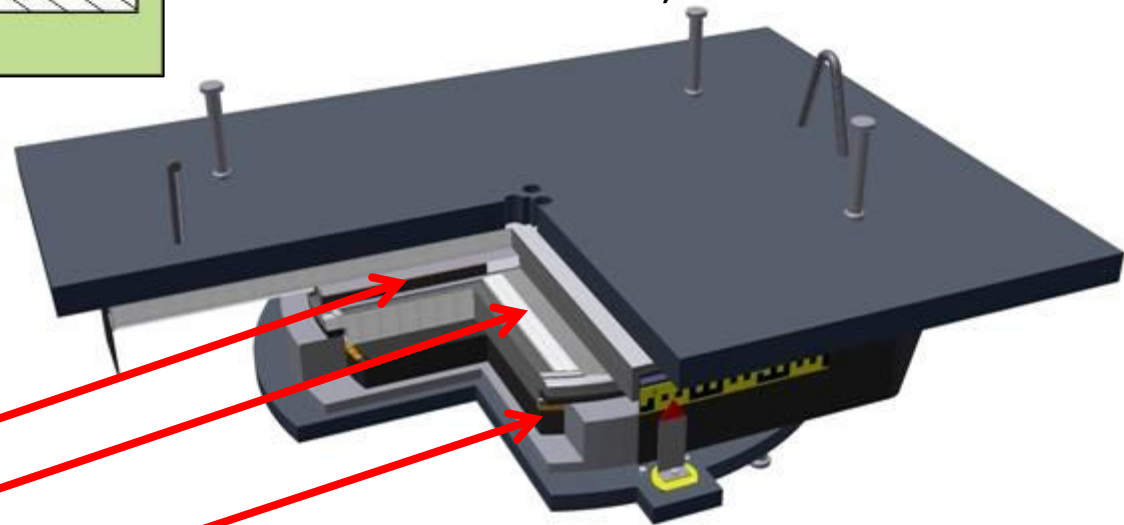
# Pot Bearings got wear and check problem

Pot bearing design needs a play of some millimeter between lid and potwall in order to allow rotation. So horizontal loads will always first be transferred to the rail!



PTFE sliding material WEAR

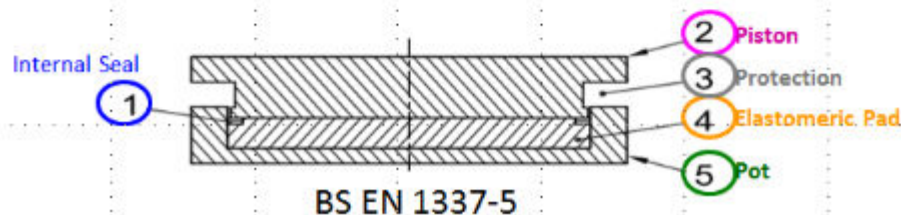
no check of internal seal possible (wear and contact corrosion)



Pot bearing wear part:  
Visible: guide material, PTFE  
Invisible: Internal seal (pot bearing)

# Deutsche Bahn blacklisted pot bearings due to wear and check problem

Pot bearing: wear of internal seal:



Also AREMA does not approve pot bearings for railway bridges.

# POT BEARING TYPICAL LONG TERM DAMAGE



Failure of  
Elastomeric Pad  
Internal Seal

In the case of failure, a sudden loss of bearing height occurs and the bridge will hang on the rails.



# Disc Bearing + PTFE Disc Sliding Bearing

- ✓ • Long life span
- ✓ • High loading capacity
- ✗ • Free of wear
- ✗ • Small reaction forces
- ✗ • Inspectable during service
- ✗ • Vertical stiffness
- ✗ • Horizontal play
- ✓ • Horizontal load transfer

✗ Applicability for Railway Bridges

# Disc Bearing

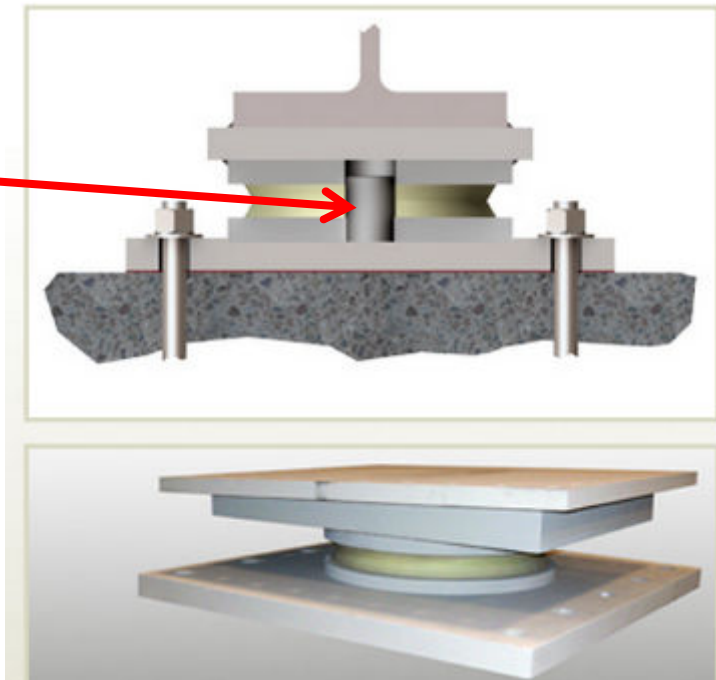
## Hidden Danger for Structural Collapse!

You can never check the central shear pin once the bearing is installed!!!

### Disc Bearing:

Central load bearing shear pin, subject to **fatigue** (!) and **corrosion** not visible after installation. Shear pin needs a play to allow rotation, so horizontal forces will load the rail!

This design, coming from USA, is **blacklisted** in Europe for any kind of bridges. You will not find it in any standard not find any approval. The European Standard Organization CEN recently stated:





Date

2013-09-19

**CEN/TC 167/WG 1 N 424**  
**"Revision of EN 1337"**

## Items to be changed in EN 1337-1

### Add as last sentence in 4.2: (2013-09-19)

Disc bearings designed with internal restraint for horizontal loads are not recommended for bridges as inspections of the element vital for the transfer of the horizontal loads is not possible.

**WARNING** - The use of bearings where load bearing elements subjected to wear, corrosion, ageing and/or fatigue are not inspectable in service should be avoided.



DEUTSCHE BAHN use only elastomeric bearings (for very small structures) and UHMWPE spherical bearings!

What happens, when the central bolt fails at a trains emergency break?



# Steel Roller + Rocker Bearing

- ✘ • Long life span
- ✔ • High loading capacity
- ✘ • Free of wear
- ✘ • Small reaction forces
- ✘ • Inspectable during service
- ✔ • Vertical stiffness
- ✔ • Horizontal play
- ✔ • Horizontal load transfer

✘ Applicability for Railway Bridges

The high loaded contact zone roller/plate (Hertzian Stress) can never be long-time protected against corrosion and cause sudden rupture when overloaded.

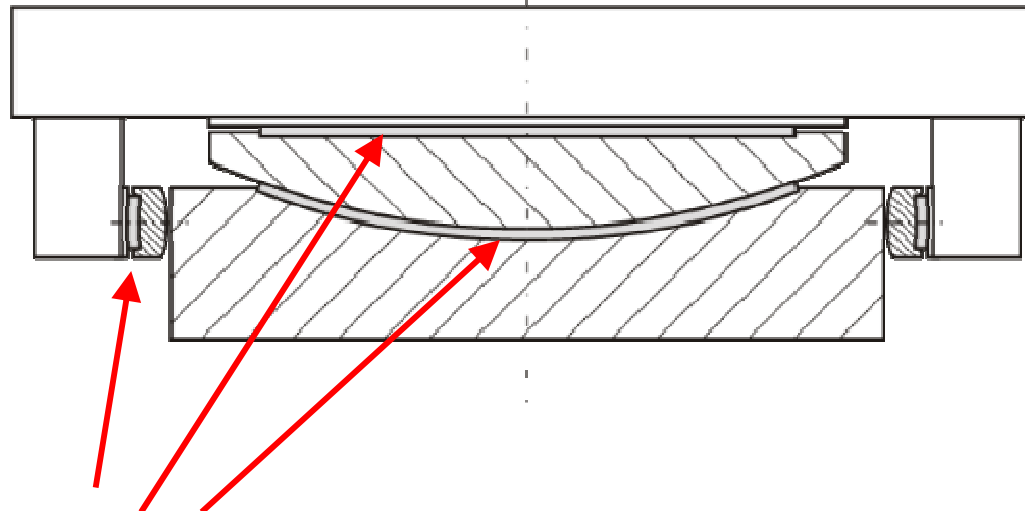


# Spherical PTFE Bearing

- ✘ • Long life span
- ✔ • High loading capacity
- ✘ • Free of wear
- ✔ • Small reaction forces
- ✔ • Inspectable during service
- ✔ • Vertical stiffness
- ✔ • Horizontal play
- ✔ • Horizontal load transfer

✘ Applicability for Railway Bridges

# Typical Design of Spherical PTFE bridge bearing, guided type



Sliding Material PTFE

Due to negative records PTFE bearings are not longer used in European railway bridges. AREMA limits the use to 14 MPa loading.

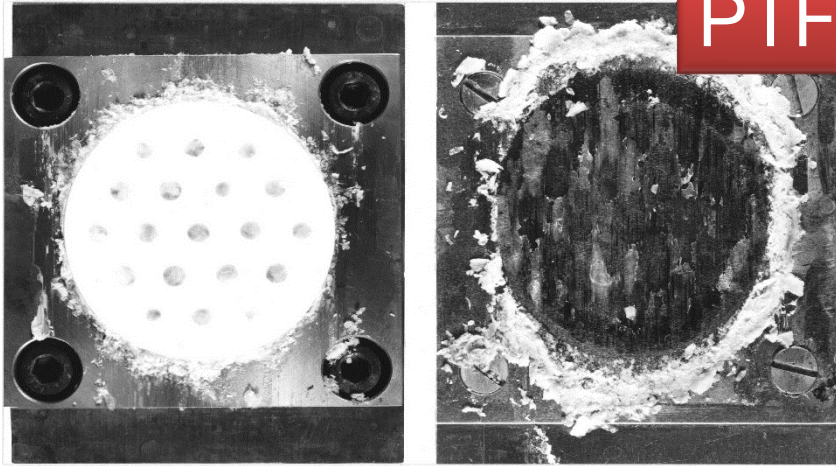
# SLIDING MATERIAL PTFE

Developed in the 50's PTFE (polytetrafluorethylene) was the only long term material transferring high loads with very low friction.

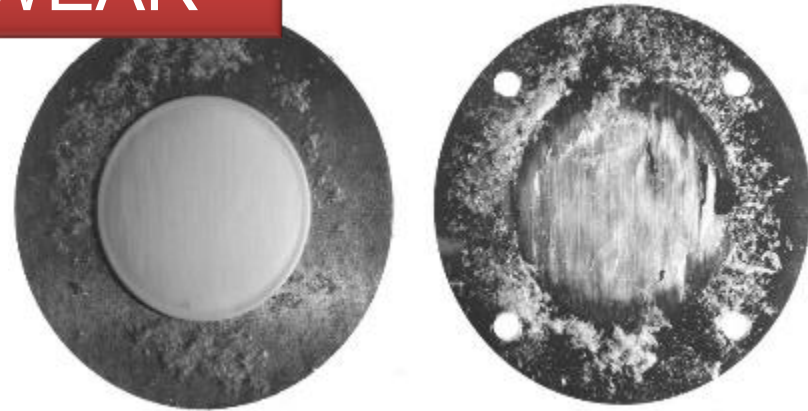


First used in 1960, it quickly became widely used worldwide. The negative long-term effects of creep and wear were neglected as there was no alternative.

# PTFE WEAR



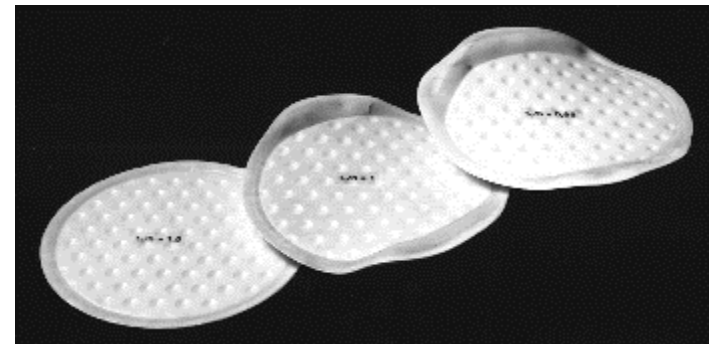
Wear: PTFE test at  $p = 45$  MPa for 20.000 m accumulated slide path



Wear.: PTFE test at  $p = 30$  MPa for 2.000 m accumulated slide path



Due to wear PTFE looses up to 4 mm thickness until the steel recess touches the sliding steel .....



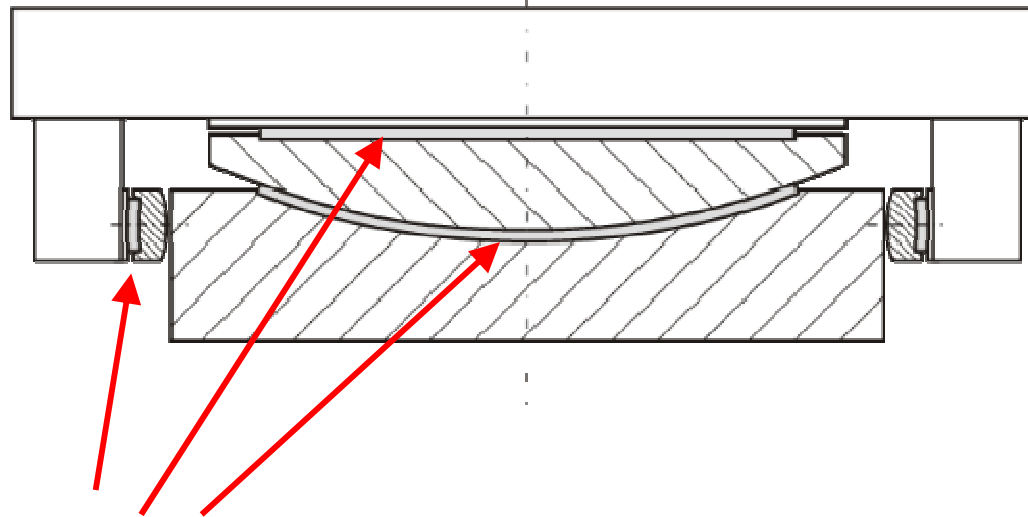
Long term creep of high loaded PTFE

# Spherical UHMWPE Bearing

- ✓ • Long life span
- ✓ ✓ • High loading capacity
- ✓ • Free of wear
- ✓ • Small reaction forces
- ✓ • Inspectable during service
- ✓ • Vertical stiffness
- ✓ • Horizontal play
- ✓ • Horizontal load transfer

## ✓ Applicability for Railway Bridges

# Typical Design of Spherical UHMWPE bridge bearing, guided type



Sliding Material UHMWPE

# SLIDING MATERIAL UHMWPE

Starting 1969 Germany developed the MAGLEV TRAIN (magnetic levitation; Transrapid). Due to high speed vibrations occurred destroying the PTFE bearings within short period.

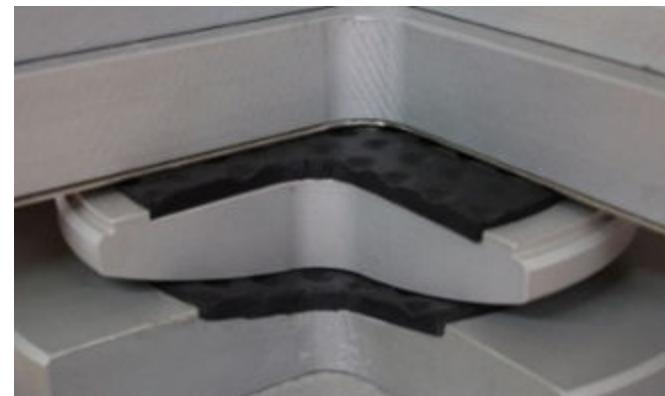


So a group of 3 European bearing manufacturers started the search of better material. And they found UHMWPE (Ultra-high-molecular-weight polyethylene) and developed and tested the formulation until release in 2002 by European Technical Approval (ETA).

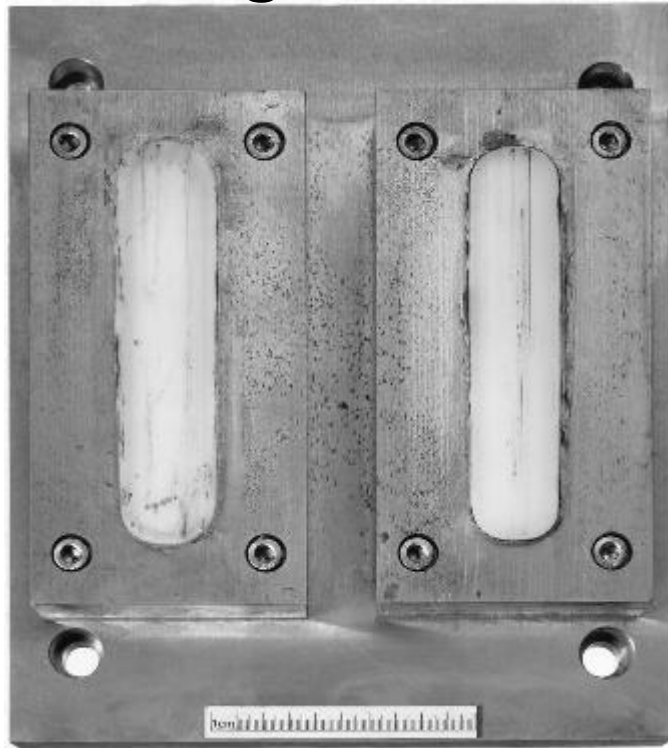
With this material higher loads can be transferred with lower friction and no wear and creep problems!!

This material delivered under the trademark MSM<sup>®</sup> is absolutely resilient and un-destroyable with a life span like stainless steel.

UHMWPE has over 40 years of clinical history as a successful biomaterial for use in hip, knee, and for spine implants.



# Sliding Material UHMWPE

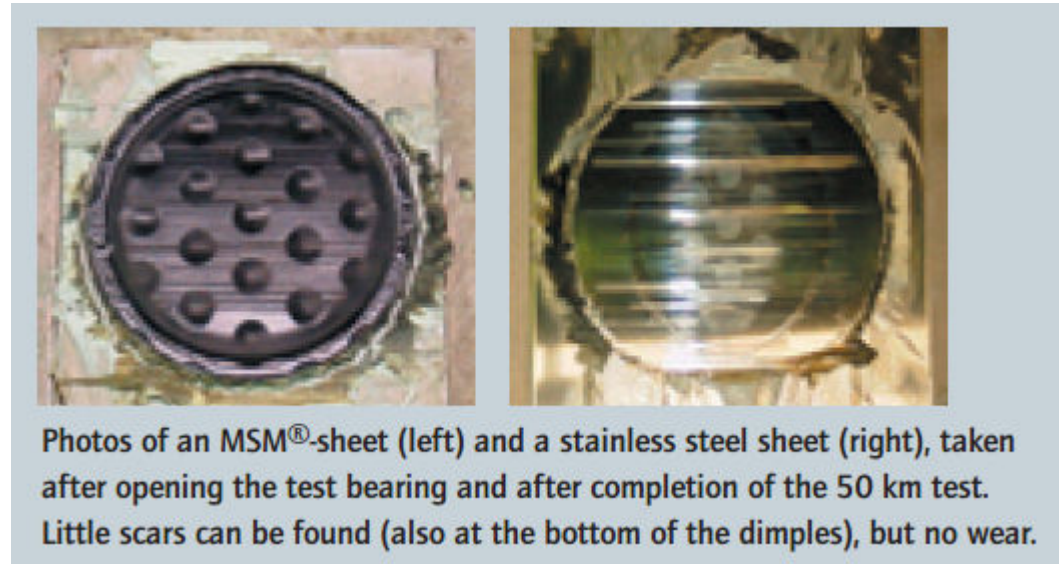


UHMWPE-Gleitlager (Streifen)

**UHMWPE TEST at  $p = 50 \text{ MPa}$ ,  
 $v = 5 \text{ mm/s}$ , after 10.000 meter  
sliding:**

**NO WEAR!!**

NO WEAR



Photos of an MSM<sup>®</sup>-sheet (left) and a stainless steel sheet (right), taken after opening the test bearing and after completion of the 50 km test. Little scars can be found (also at the bottom of the dimples), but no wear.

# Four manufacturers got **European Approval** for **UHMWPE** spherical bearings!

Deutsches Institut für Bautechnik  
Zulassungsstelle für Bauprodukte und Bauarten  
Bautechnisches Prüfamnt

Eine vom Bund und den Ländern  
gemeinsam getragene Anstalt des  
öffentlichen Rechts

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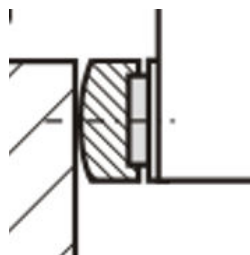
Mitglied der EOTA  
Member of EOTA

## European Technical Approval ETA-06/0131

English translation prepared by DIBt - Original version in German language

Handelsbezeichnung <i>Trade name</i>	MAURER MSM <sup>®</sup> Kalotten- und Zylinderlager <i>MAURER MSM<sup>®</sup> Spherical and Cylindrical Bearing</i>
Zulassungsinhaber <i>Holder of approval</i>	Maurer Söhne GmbH & Co. KG Frankfurter Ring 193 80807 München
Zulassungsgegenstand und Verwendungszweck <i>Generic type and use of construction product</i>	Kalotten- und Zylinderlager mit besonderem Gleitwerkstoff  <i>Spherical and cylindrical bearing with special sliding material</i>
Geltungsdauer: <i>Validity:</i>	vom <i>from</i> 24 May 2013 bis <i>to</i> 24 May 2018 to
Herstellwerke <i>Manufacturing plants</i>	Maurer Söhne GmbH & Co. KG Frankfurter Ring 193 80807 München

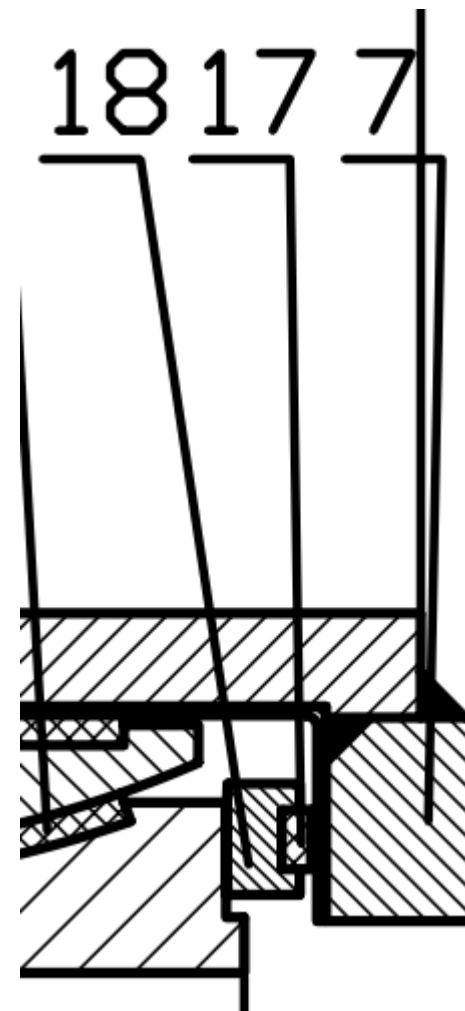
## Guided Bearings



The bearing design allows smallest play for horizontal guides. UHMWPE Spherical bearings have guides designed in acc. with EN1337-2 equipped with:

- UHMWPE sliding material
- Stainless steel sliding surface
- Rock strip to accommodate rotation.

18	2	Rock strip	ASTM A709 Grade 50
17	2	MSM	MSM
7	2	Top guide bar	ASTM A709 Grade 50



# LONG TERM QUALITY

Acc. to AASHTO and AREMA philosophy, the quality is in the hand of the supplier. He has to take responsibility for many years. Quality confirmation is done by load tests with samples from actual production batches. This was also the approach of old (withdrawn) British Standard.

But this is not really helpful when a life span of 100 years is desired for a bridge. Very costly damages mostly occur after many years in service. So in the actual standard EN 1337 - the only up-to-date bearing standard worldwide - a third party quality control is mandatory.

## LONG TERM QUALITY

The European Quality System is mandatory for Bearings in acc. with EN 1337 and such acc. to an European Technical Approval ETA.

First the basic suitability will be closely examined at Initial Type Testing by professionally accredited testing institutes. These tests also consider the effects of long-term conditions such as accumulated sliding paths, aging, fatigue and extreme temperatures. Therefore, cost and time for the Initial Type Testing are very high.

Then, a test plan will be developed for current production, whereby the manufacturer shall furnish proofs of conformity for all components that prove that the materials match with those used at Initial Type Testing.

## LONG TERM QUALITY

An independent and qualified accredited testing institute (notified body) monitors the manufacturer's system the with four unannounced visits per year, where also samples are taken. The samples are carefully examined and compared with the submitted material certificates.

If material data fall under the trade secret of a manufacturer, the accredited testing institute can test yet. In this case certificates will show no parameters.

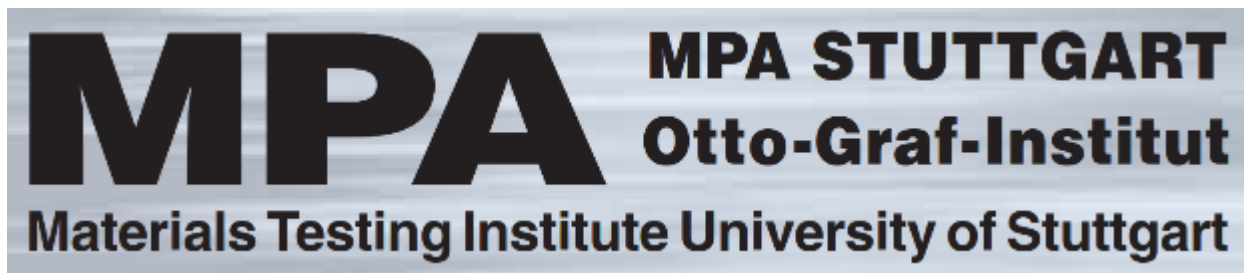
After introduction of this quality management system in Germany over 40 years ago, the level of long-term damage has declined dramatically.

## LONG TERM QUALITY

Finally on the type plates the CE sign is shown, together with the name of the manufacturer and the number of the notified body. The authorization of the notified body, who also issues the suppliers Certificate of Conformity, can be checked on the official web site of the European Union.

<http://ec.europa.eu/growth/tools-databases/nando/index.cfm>

For the UHMWPE Spherical Bearings this is performed by



This is a German governmental institution with the most experienced bridge bearing experts world wide.

# Cost of Bridge Bearings

Some rough figures based on experience values:

The cost of bridge bearings for railway bridges is around 0.9 to 1.3 % of the total building cost (civil engineering without track).

Comparing cost of different design:

- PTFE Pot Sliding Bearing: 100%
- Elastomeric Bearing 70%
- Disc Bearing 80%
- PTFE Spherical Bearing 110%
- UHMWPE Spherical Bearing 90%

# Tender Text

A detailed tender text suggestion may be downloaded from <https://www.dropbox.com/s/aotypgeal7f9m9x/RAILWAY%20BRIDGE%20BEARING%20TENDER%20TEXT%202016.docx?dl=0>

The fundamental features are:

- » All bearings in acc. with EN 1337 or ETA.
- » Elastomeric bearings only up to 10 meter spans.
- » Mechanical bearing design: spherical bearing with UHMWPE sliding material
- » Vertical deflection and play for guides/restraints limited to 0.5 mm

## Contact

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**Thank you for your attention!**

**I will be happy  
answering any questions!**

# Railway Bridge Design

Important items for a long life span:  
interaction structure to track  
and bearing selection

By Georg Wolff

A recommendation of

