Bridge Bearings – a Historical Survey

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(From the German by Barthold Pelzer, Berlin)

INTRODUCTION

In the course of the past two centuries bridge bearings evolved as parts of immense sophistication and complexity in modern bridges. The ever-increasing spans went hand in hand with the rapid growth of the loads to be carried. For reasons of safety it became essential to implement those bearings in the structures arrived at theoretically by structural calculations before.

The first bridge bearings were rather simple objects. In the wake of the railway boom of the nineteenth century, however, they evolved as an independent strand of supporting technology with individual construction characteristics. Products of mechanical engineering such as bolts, pins and rollers were introduced into the realm of bridge construction. "Structures were previously only considered to be rigid and immovable bodies. Now they come to be seen as machines capable of movement."(Lorenz 1990, p.1). Steel bearings developed at this stage were to be virtually the only form far into the twentieth century. It was the development of new materials which finally led to a generational change in bearing technology.

After a brief discussion of the term *bridge bearing* and a description of the pre-industrial beginnings the following will argue how in the nineteenth century the necessity for bearings of a new type arose, which could relate to the physical properties of iron structures under changing temperatures. The sophistication of new technologies to realize advanced bearing conditions will be exemplified with bearings for girder bridges.

THE TERM "BRIDGE BEARING"

The word *bearing* has different technical meanings. The following is based upon a definition of *bearing* as given in a reference work for bearing technology and which in its overall tendency is equivalent to our contemporary concept of a bearing. "Bearings are structural elements, which are arranged between parts of the structure to perform support conditions arrived at by structural calculations. " (Eggert, Kauschke 1996, p.3). *Bridge bearings* accordingly are structural elements performing those functions in bridges. The limits of this functional definition, however, have to be expanded once a historical perspective is assumed. Whereas structural analysis in our contemporary understanding evolved in the last third of the nineteenth century, bridge bearings can be discerned much earlier.

EARLY WOODEN BEARINGS

Bridge bearings according to this definition can already be found in early timber bridges. Simple wooden laths (small sleepers) prevented the timber beams of the load-bearing structure from rotting. The beams serving as a base could be exchanged if required. (**Fig.1**)

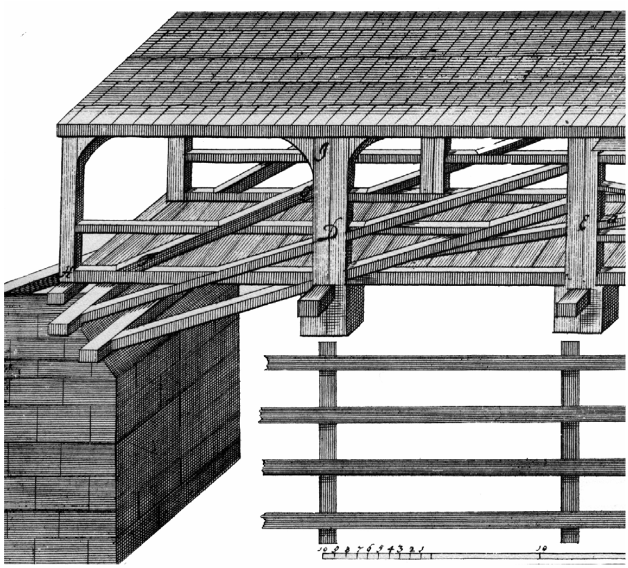

Figure 1. Early timber bridge resting on wooden bearings (Leupold 1726, Tab: XV)

But these beams at the base not only allowed the load to be spread evenly, they also enabled the deflection of the load-bearing structure without edge pressure occurring between bottom chord and masonry substructure. Furthermore the elasticity of wooden bearings absorbed some of the vibrations caused by traffic on the bridge thus less impact being transmitted onto the structure. This welcome property was still being used in the early cast-iron girder railroad bridges that were extremely sensitive to sudden impact. But trains crossing the bridge transmitted increasing weight onto the wooden bearings. These forces could be spread by employing cast-iron plates. In the case of these early iron bridges expansion of the material caused by changing temperatures could be neglected due to their small span. The problem was nevertheless already recognized.

PROBLEMS WITH IRON

The Cause: Temperature

As early as in the seventeenth century it was known that materials reacted to changes in temperature with changing volumes. This was, however, of no consequence to the then existing bridges. For those made of wood tended to be short. If they were composed of more than one beam, changing lengths could be accommodated at the joints. In the case of timber these expansions were rather the result of varying degrees of humidity in the environment than in those of temperature. Bridges composed of stone arches on the other hand were – then as now - not prone to sudden changes in temperature because the mass of the material was very slow to react to temperature changes. Rather than following the short term gradients of day and night, the temperatures of the structure were more significantly related to the oscillations between summer and winter. Cracks and fissures appearing in the course of the cold would close again under warmer conditions.

Louis Vicat (1786—1861) began a pioneering work by scientifically examining the periodical appearance and disappearance of cracks depending on temperature variations on his arched bridge in Souillac (finished in 1824). Although these movements would cause changes in the thrust of the abutment, he did not assume this to seriously threaten the stability of the structure. (Müller 1860, pp.215-6)

As soon as iron became the material for building bridges critical awareness increased. Firstly there was concern about the influence of changing temperature on the strength of the material. Secondly engineers were seriously considering the degree of movement caused by temperature changes and how this would affect the overall stability of the system. These suspicions were not at all unfounded as was demonstrated by early damages occurring in those few iron bridges already constructed. In the case of the Buildwas Brigde crossing the River Severn (erected in 1796) the iron arches were constantly suffering from temperature changes (James 1988, p.159). And the Pont des Arts in Paris, finished in 1803, had complete blocks pushed out by iron rods expanding (Rondelet 1833, p.470). The engineers grew wary.

When *John Rennie the Elder* (1761—1821) had his Southwark Bridge erected between 1813 and 1819, the middle one of the three cast-iron arches spanning 73 metres and the other two 64 metres, he did not take direct precautions to counteract temperature related deformations. His son, however, rigorously observed the effects of temperature changes while the structure was being built. An increase in 25 Kelvin caused a 31 millimetre rise of the arch (Müller 1860, pp.216). The attempt to wedge the complete load-bearing structure between the buttresses to prevent temperature movements caused the abutment masonry to break which had to be rebuilt (James 1988, p.177-8). Later the periodical movements of the arches would repeatedly produce fissures in both the road and the footpath surfaces. Rennie, however, did apparently not envisage any threats to the safety of both the arches and the abutments. Or did he?

The Solution: Movement

What we can observe is that shortly after the completion of Southwark Bridge he was searching for a different solution with a bridge crossing the River Aire in Leeds on the length of but 24 metres. Each of his two proposals from July 1820 – a suspension bridge and a bowstring bridge – was planned, so “that the expansion and contraction are wholly independent of any action on the abutments [...] which are intended to support the perpendicular weight of the superstructure only.“ The freedom of movement of the structural elements was to be ensured by “moveable sectors” (Rennie, p.227). What was actually on Rennie’s mind in mentioning these? Could he have meant sliding bearings? If so, he cannot, however, count as their inventor.

In August of that very year the engineering entrepreneur *Ralph Dodd* (c.1756–1822) completed a bridge spanning only 9 metres crossing the River Chelmer near Springfield presented to the experts as “the most beautiful ever erected in this kingdom, or probably any other“ (F.M. 1820, p.236). And it was certainly worth the attention of engineers: Wrought iron bowstring girders were solely resting on tubular cast-iron pillars rammed into the river banks, both being quite new technologies. And certainly another innovation were the “grooves in the top of those iron columns, on which the whole bridge has room to contract and expand, so necessary in this climate, from the various changes of the atmosphere from heat to cold, as the other iron bridges have suffered materially from this want of precaution“(F.M., p.236). Apparently Chelmer Bridge represents the first instance of sliding bearings having been planned as well as executed. Unfortunately the superstructure was under-designed and soon required additional propping. Finally it had to be rebuilt (James 1980, p.70). Despite all its shortcomings it pointed in new directions for bridge building in particularly with regard to measures coping with temperature changes relayed as loads onto the structure. Whereas Rennie tried to constrain his Southwark Bridge rigidly between its massive pillars and hoped to achieve adequate safety with additional structural mass, Dodd exposed the structural frame so that it could as it were “breathe“. This approach would soon become popular in bridge building. A change of paradigm was announced: an increase of safety by means of increased movability (Lorenz 1990, p.9).

The Method: Bridge bearings

For lager spans arch bridges were still the dominant form in iron bridge building. New constructive details bestowed more freedom of movement to the bridges. In 1822 Joh. Dowell Moxon, a shipowner and merchant from Liverpool, received a patent regarding the “Improvement in the construction of bridges and similar building types“. According to the patent specification, a document not perfectly clear without additional drawings, he suggested for the arches of his bridges something like clamped ribs inserted into each other. Thus arranged, he argued, the bridge was “less subjected to the expansions and contractions due to changing temperatures“(Moxon 1824, p.349). In the mid-1820s the Brothers Leather introduced special bearings into arch-bridge design generally referred to as “hinges“. In the case of multispanning structures, as e. g. the Dunham Bridge (finished in 1832) they separated the single elements of the superstructure structurally, so that each could react independently to changes in temperature. The resulting gaps in the superstructure were covered by apron plates.(**Fig.2**) Five years before, in his bridge crossing the River Lary, James M. Rendel (1799—1856) had similarly used elongated holes to divide the arched superstructure from the buttresses to allow for expansion and contraction. These new structural solutions opened new prospects for building iron arch-bridges round 1830, and ensuring that they can accommodate temperature changes at the same time.

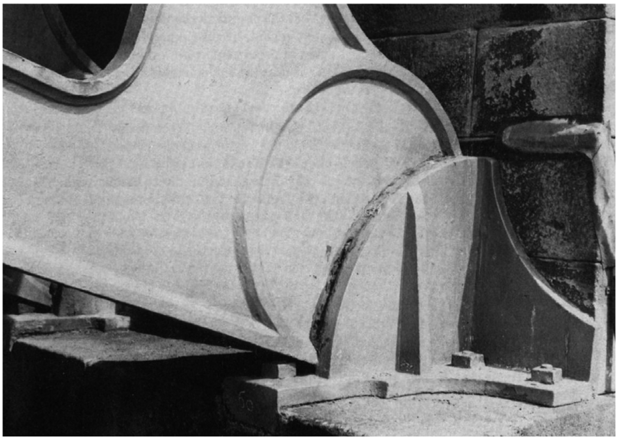

Figure 2. Springing hinge of the Dunham Bridge (Lewis 1978, p.29)

Engineers were similarly inventive in the case of suspension bridges, which were the only feasible solution if conventional structures made from wood, stone or later on cast-iron were ruled out because the spans were too long, the costs were too high or for other reasons. In the early nineteenth century chain- or cable bridges were built with ever-increasing spans, leading to the introduction of shifting saddles which were placed on pylons usually made of stone. It was not merely the changing lengths of the iron suspension cables due to temperature changes necessitating these saddles but also the changing forms of the cables due to the non-uniform live loads moving across the bridge. The support devices ensured that the cables could permanently take the shape necessitated by the load without transmitting significant horizontal forces into the top of the pylon. **Fig.3** shows some solutions of suspension bridges from the early nineteenth century, whose structural organisations were acting as precursors for the bearings later on typically employed in ordinary girder bridges.

DEVELOPING A TECHNOLOGY: THE EXAMPLE OF BEARINGS IN GIRDER BRIDGES

With girder bridges similar developments had as yet not occurred. Their spans were too insignificant and still bridged by either timber or cast-iron beams resting on wooden laths. During the first four decades of the nineteenth century changing this pattern did not seem necessary.

But the conditions for the bearings in girder bridges changed rapidly in the 1840s. The introduction of puddle iron as a building material as well as the invention of new girder systems allowed for wider spans. This meant a rise in the loads the popular wooden bearings had to carry. The impressions they suffered produced level differences which in turn resulted in bigger impacts when loads travelled the bridge. Wooden bearings became inefficient, and the repeated need to replace them proved costly. The main beams for larger bridges were increasingly resting directly upon cast-iron bearing plates. A new generation of bearings for girder bridges evolved, for the era of iron bearings had begun.

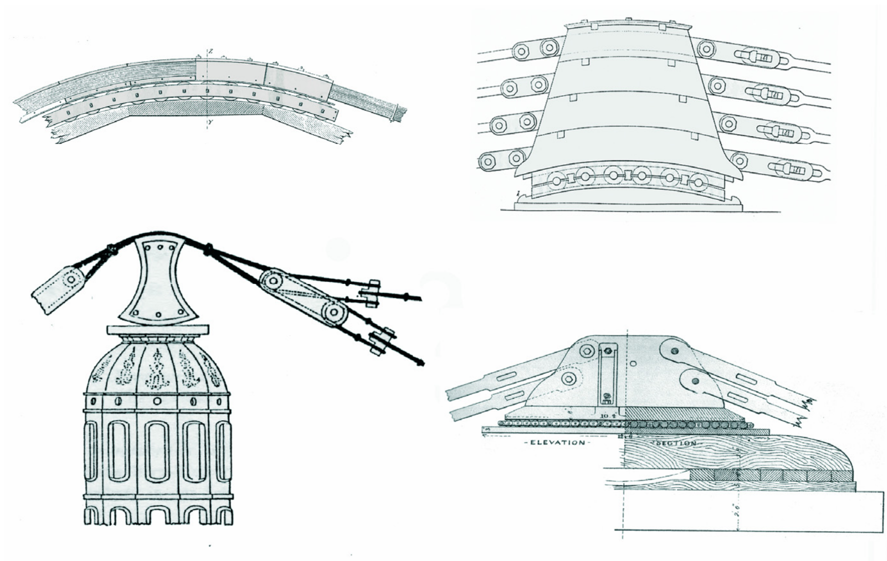

Figure 3. Top left: Dordogne Bridge 1827-28, Top right: Menai Bridge 1819-26, Bottom left: Cubzac Bridge 1827-39 (Mehrtens, 1908); Bottom right: Hungerford Bridge 1841-45 (Anon. 1845)

Plane bearings

The first form of iron bridge bearings was the plane bearing, which meant that its upper and lower part shared a planar area of direct contact. Although the problem of material expanding was familiar from experiences with arched bridges as well as suspended ones, engineers only gradually developed the awareness that girder bridges might require movable bearings as well. Initially all of the girders were often firmly connected to both bearing plate and base. The case of first big lattice girder bridge – the Royal Canal Bridge near Dublin from 1845 – may serve to illustrate the problem: The girders spanning across 42 metres were constrained on both sides to increase the load capacity. The effects of temperature changes on the load-carrying structure were still often underestimated or simply ignored, resulting in deformations in the girders or cracks in the masonry structure of the abutments. On the other hand we can distinguish some simultaneous attempts to achieve free supporting technologies by means of sliding bearings or roller bearings. (**Fig.4**)

Employing rollers helped to diminish the influence of friction working on the construction, an established technology and in bridge construction known from the shifting saddles of suspension bridges. The rule was simple: the bigger the bridge, the higher the number of rollers which were put underneath. The elastic properties of the wood served as a complement, working as both a shock absorber and to allow for rotations at the girder ends.

Plane bearings enjoyed their peak in Conway Bridge (opened in 1848) and Britannia Bridge two years later both built by *Robert Stephenson* (1803—1859). It was not merely the size of the bearings which was extraordinary but they possessed an interesting detail: the upper flange had an additional suspension on both sides with rows consisting of balls made from cannon metal (Anon, 1849, p.346). (**Fig.5**)

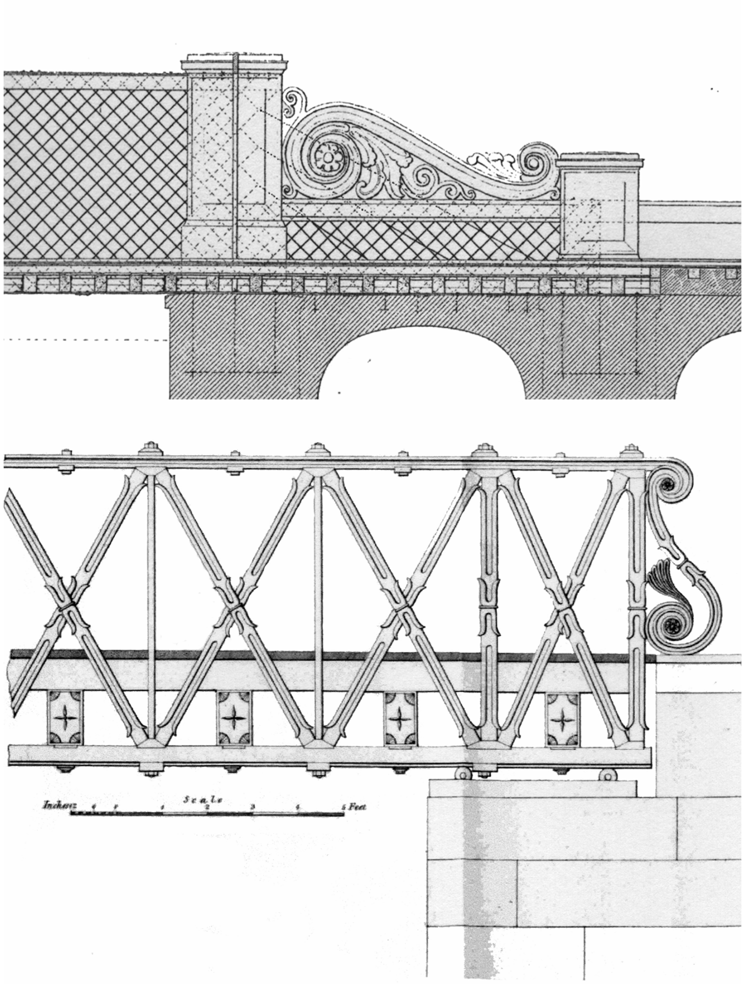

Figure 4. Top: Royal Canal Bridge Dublin 1845, note the indicated ties – all firmly fixed to the base (Pollack 1848), Bottom: Ballysimon Bridge 1846-7, resting on rollers (Osborne 1849)

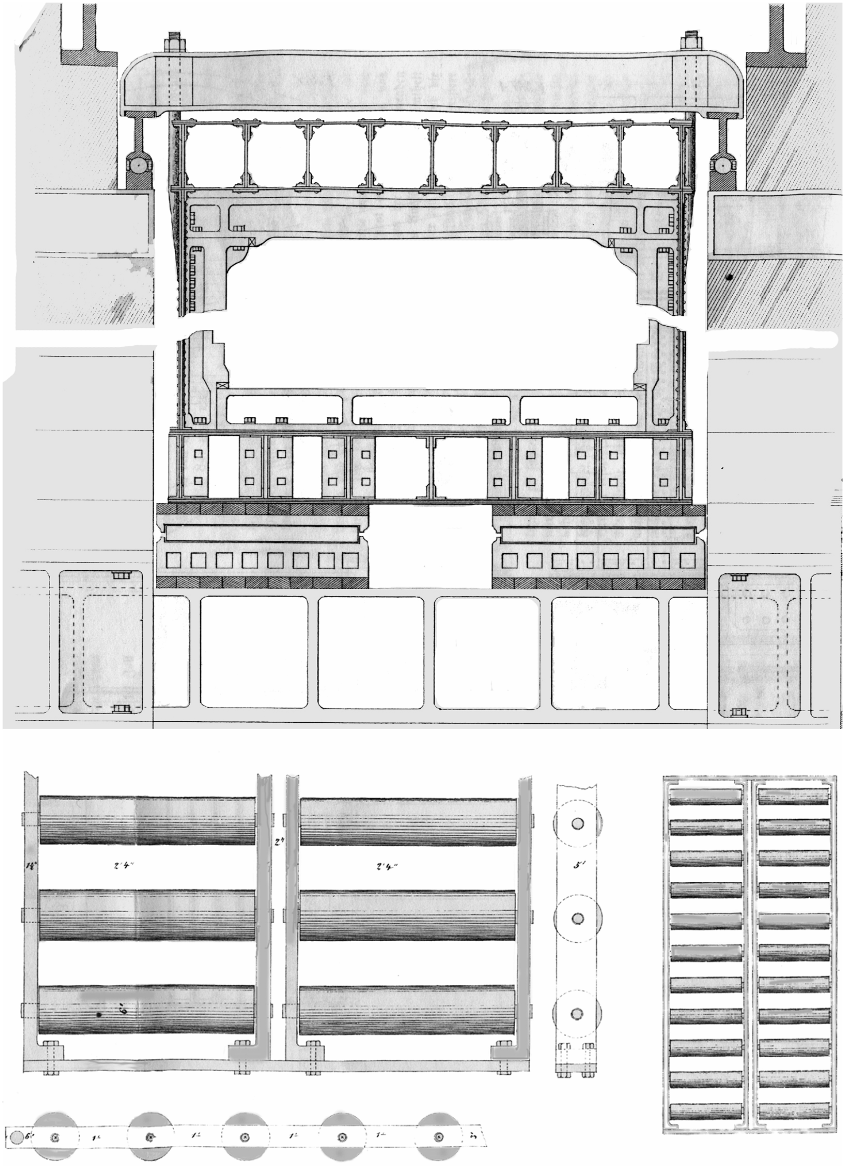

Figure 5. Bearings of the Britannia Bridge (Müller 1960, pl. 88-9)

A substantial disadvantage of plane bearings became visible as soon as the superstructure deflected under load. The bearing area was momentarily reduced to a mere line of support at the edge of the substructure. This did not only affect the structural system of both substructure and bearing, but, depending on the girders, their structural strength, too. (**Fig.6**)

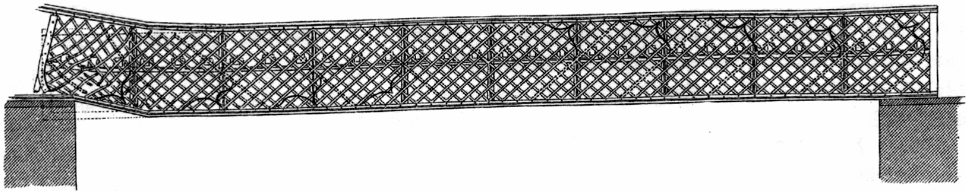

Figure 6. Damage of lattice girder due to plane support (Culmann 1852, p.191)

The problem was well-known, and engineers came up with various solutions. *Carl Lentze* (1801—1883) for example proposed two different methods in the case of his lattice girder bridges built in 1855 in Dirschau and Marienburg: Expecting only minor deformations at the middle bearings of the continuous girder he relied upon the elasticity of the cast-iron bearing plates here. At the end supports which were subject to higher rotation of the girder on the other hand Lentze proposed wooden interlayers (Lentze 1855, p.453). Due to the low durability of the wood, however, steel springs were used as a substitute. A different path was chosen with the Dombruecke (1856—1860) in Cologne crossing the River Rhine, another major project: Here the bearings were to be adjusted so that the rollers facing the opening were exposed under dead weight. In the case of increasing deflection of the superstructure under live loads they were to contribute to the transfer of loads (Anon. 1863, p.347-8).

However, all these were but attempts to combine the increased demands on bridge constructions with an old bearing technology. Plane bearings could no longer satisfy the engineers' desire for constructive clarity. And yet another change occurred. In the middle of the century Great Britain had lost its uncontested supremacy in bridge building technology. In terms of both the theory and the implementation of those concepts Germany was to become increasingly another site for big advances.

Rotating Bearings

By means of a special mechanism rotating bearings allowed for the deflection of the superstructure. Two different solutions shaped the technology: rocker bearings and knuckle bearings. The former were superior with respect to the friction that had to be overcome.

Knuckle bearings originate in the pin-jointed bridges (Kollmar 1919, p.2). These were characterized by either having the complete construction or parts of it coupled by pins in order to decrease secondary stress. Now it was only a small step to use the end pins at the bearings simultaneously as rotating pins. Tied to a sliding part bearings of this kind were being used in Crumlin Viaduct (1853—1857) in southern Wales. The bridge crossing River Guenz (1853) near Guenzburg used them in connection with rollers, this probably being the first implementation of roller bearings in Germany. (**Fig.7**)

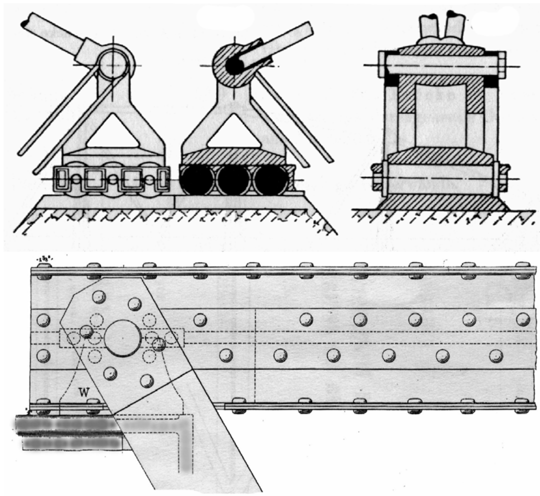

Figure 7. Bearings at pin-jointed bridges; Top: Guenz Bridge (Mehrtens 1900, Fig. 83a), Bottom: Crumlin Viaduct (Malberg 1858, pl.14)

When riveted truss joints came to be state-of-the-art, pins were an established detail of bearing technology and worked as the pivot for so-called knuckle pin bearings. **Fig.8** illustrates typical forms of knuckle bearings which were widely employed in bridge construction far into the twentieth century. And it shows the version that was already used in 1861 in the Brahe pin-jointed bridge near Czersk by *Johann Wilhelm Schwedler* (1823-1892).

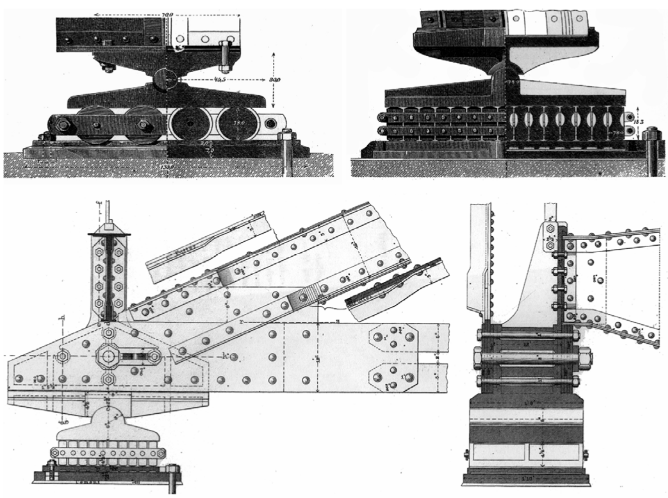

Figure 8. Top Left: Typical knuckle pin bearing, Top Right: Simplified knuckle bearing (Winkler 1875, Fig.380, 381); Bottom: Bearing of the Brahe Bridge (Schwedler 1861, Fig. 6,7)

With the ever-growing size of the superstructures the friction at the knuckle increased causing a displacement of the theoretical bearing pressure. If the friction was to be reduced, the upper and the lower part of the bearing were equipped with different radii. Theoretically this meant that the contact area shrunk to a single line. Instead of sliding friction of the surfaces against each other typical of knuckle bearings now rather a rolling friction arose characterizing rocker bearings.(fig 9) Line rocker bearings had been immaculately implemented by *Johann Ludwig Werder* (1808—1885) in his bridge crossing the River Isar at Grosshesselohe (1851—1857). Werder had already recognized the advantages of high stilts over rollers, since they allowed for more contact area if both had equal length of structure.

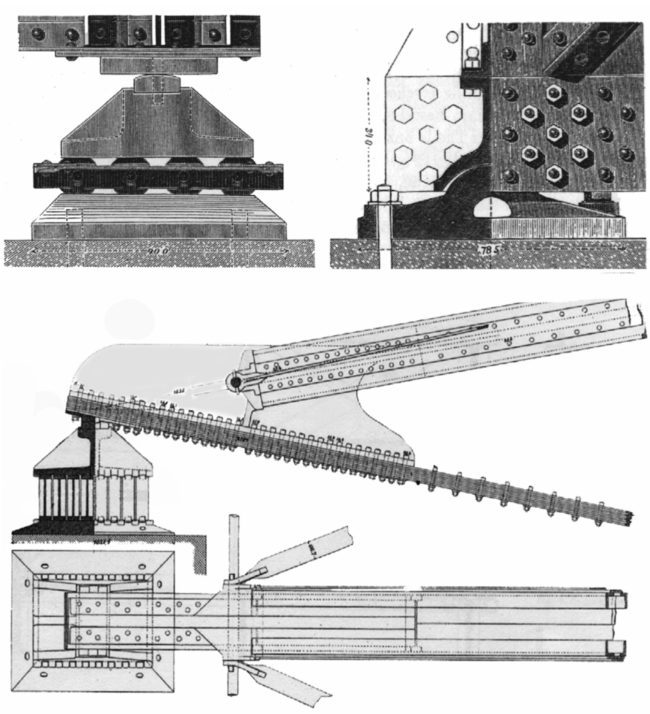

Figure 9. Top: Line rocker bearings with different kind of contact, Left: flat/curved; Right: curved/curved with different radii (Winkler 1875, Fig. 391,393), Bottom: Isar Bridge Bearing, Großhesselohe (Gerber 1859, Fig.10)

The bearing technology available at this time seemed sufficient to deal with the problems arising from temperature changes and low constraint deflection. The superstructures, however, not only increased in length, but in width as well. Bridges with double tracks had become the rule. Temperature related movements and deflections in transversal direction could no longer be ignored. In the case of the bridge crossing the River Moselle near Bullay (1876—1878) an additional pin was to guarantee the transversal deflection at least during construction. (**Fig.10**) In this respect the introduction of the spherical curved sliding bearings was a decisive step forward allowing for rotation of the superstructure in every direction. Bearings of this type could be found in bridges along the railway line between Halle and Guben via Sorau as early as 1871.

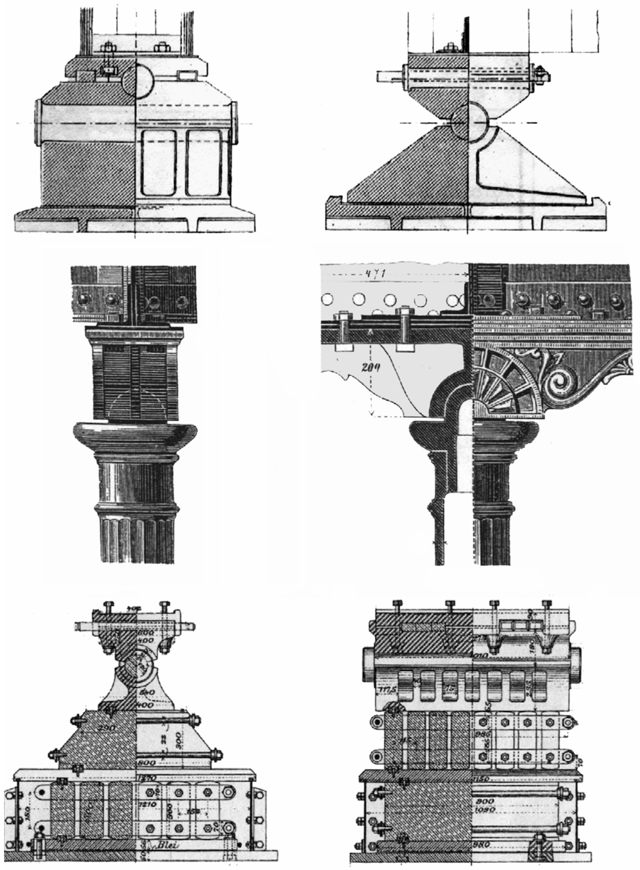

Figure 10. Top: Bearing of the Moselle Bridge, Bullay (Spohn 1884),
Middle: Column head of Halle-Guben-railway structures (Winkler 1875, Fig. 402),
Bottom: Two level stilts of Weichsel Bridge (Anon. 1895, Fig. 14)

The additional row of stilts or rollers which was to accommodate transverse expansion of the superstructure was probably implemented for the first time in the second bridge crossing the River Weichsel near Dirschau in Eastern Prussia (1889—1891). On the other hand this meant increasing the size of the bulky bearings even more. In the case of the Blaues Wunder (1891—1893) near Dresden, in many respects an achievement breaking new ground, engineer *Claus Koepke* (1831—1911) found an elegant solution by implementing a single layer of rollers diagonally, thus able to cope with temperature related movements both in longitudinal and transversal directions. (**Fig.11**)

Koepke employed point rocker bearings as a special form of rocker bearings by using uneven radii for upper and lower part (Bearing design 1891)

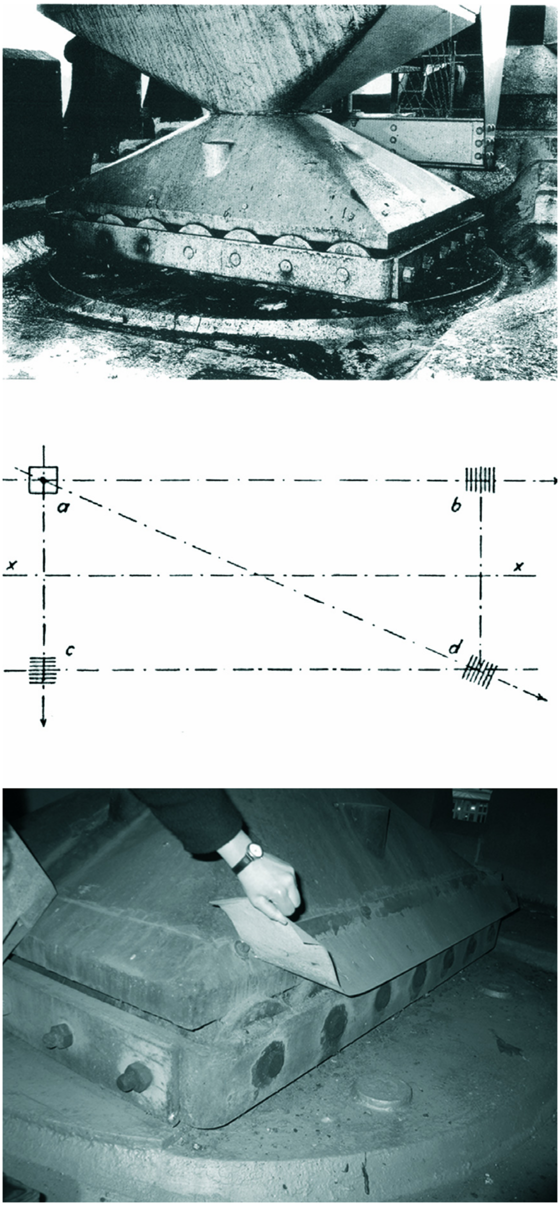

Figure 11. Top: Bearing of Blaues Wunder (Helas 1995, p.58),
Middle: Arrangement of the bearings within the bridge system (Mehrtens 1900, Fig.141),
Bottom: present Condition

Intermediate Solutions

All the bearings mentioned so far suffered from a disadvantage. Especially if two rows of rollers or stilts were being used, these increased the heights of construction considerably producing additional costs. To diminish these heights it was merely necessary to replace the rows of stilts or rollers with that elementary geometrical body permitting shifts in every direction – the sphere.

Ball bearings with freedom of movement in all directions to support bridges were documented in 1922 (Schaper 1922, p.682). *Robert Schoenhoefer* (1878—1954) improved this type in 1940 by developing a multiball bearing, preferring a multitude of small balls to a small number with a large diameter as were previously used. From this he moved on to the multiroller bearing with rollers of a low diameter, sometimes arranged in two rows to permit movability in every direction. There is little indication that these were initially built in any significant numbers. But in conjunction with the rubber pot bearing, which will be discussed later on, this class of bearings was to enjoy a revival in the 1960s as the needle bearing (Eggert 2005, p.21). (**Fig.12**)

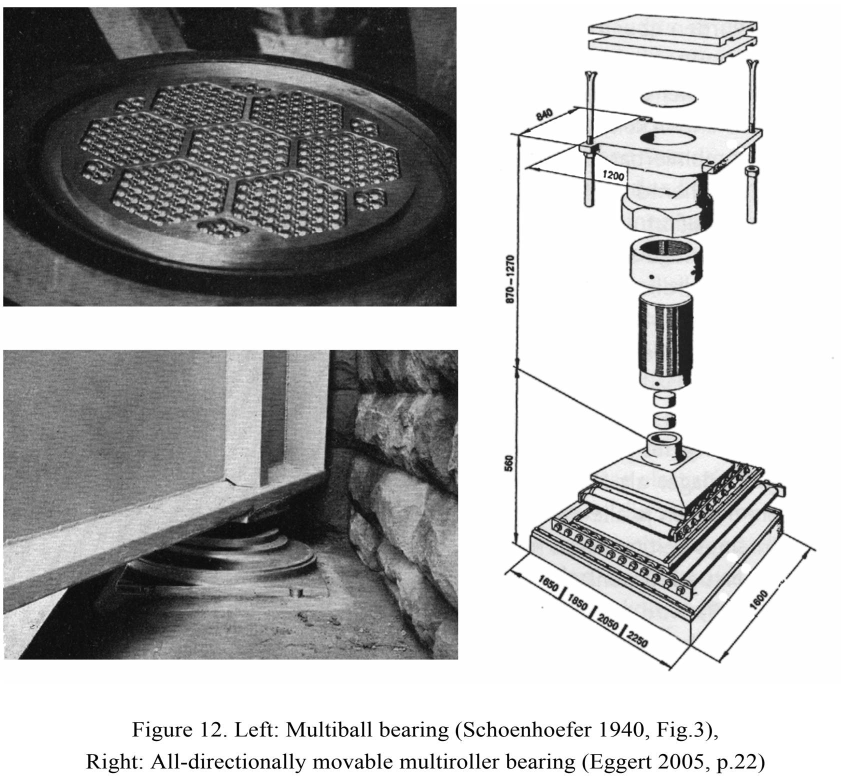

Figure 12. Left: Multiball bearing (Schoenhoefer 1940, Fig.3),
Right: All-directionally movable multiroller bearing (Eggert 2005, p.22)

In a way Schoenhoefer's suggestion to work with a large amount of small rollers was a move away from the general tendency to employ as few rollers as possible regardless of their size. When in Germany in the 1920s federal efforts to standardize bearings were undertaken, those with three or more rollers were ignored from the start. A reliable calculation regarding the distribution of the loads seemed impossible because of the statically indeterminate support system. The double roller bearing was designated to count as the norm, with the single roller bearing being an option for smaller bridges or roof trusses (Karig 1923, p.357). The latter are the most simple form of movable bearings. They require only a small construction depth and they guarantee a quantifiable transfer of load, longitudinal shifts and simultaneously deflections of the superstructure. Due to their simplicity single roller bearings could look back onto a long history. (**Fig.13**) Early types made of steel had already been implemented in 1880 in the Berlin Stadtbahn, the public transport system in the German capital (Anon. 1884, p.230). In the 1930s armoured concrete roller bearings were introduced as were single roller bearings made from stainless steel or with welded applications in the 1960s. Interestingly enough we find very early applications in building construction as well. There were for example cast-iron single roller bearings in the roof of the Valhalla built between 1830 and 1842 near Regensburg in Bavaria.

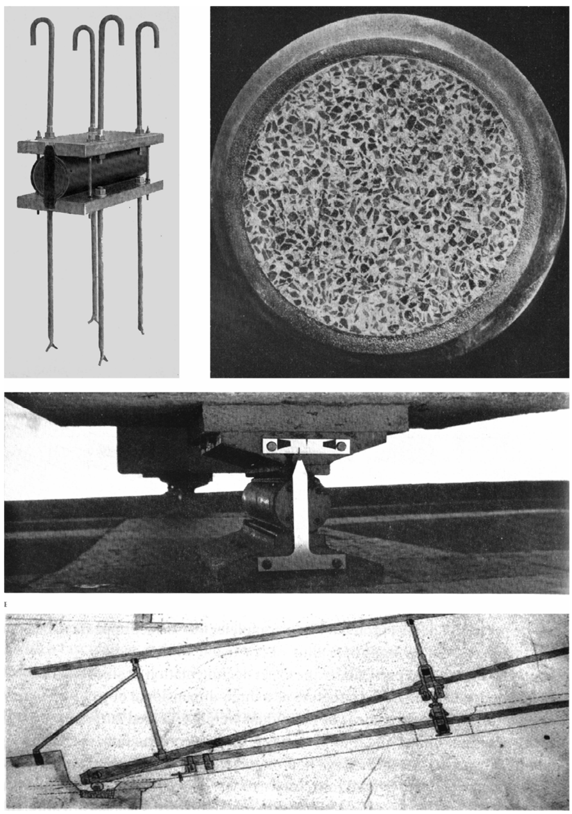

Figure 13. Top: Armoured concrete bearing (Burkhardt 1939, Fig. 17,19);
Middle: Bearing with welded application (Thul 1969, Fig.11);
Bottom: Single roller for Valhalla roof truss (Lorenz, Rhode 2001, Fig.6).

Deformation bearings

In a wider sense complete bridge pillars can count as deformation bearings for their height and their elasticity can yield to movements in the superstructure. In this case pillar and superstructure are connected rigidly. Longitudinal changes in the latter are accommodated by the deflection of the pillars. In the narrower sense, however, deformation bearings are those construction parts, which due to their low natural stiffness are able to accommodate relative movements between superstructure and substructure by deformations.

The most popular form is the rubber – also known as elastomer - bearing. Experiments with lead to counter repetitive movements proved unsuccessful. In the case of "one-off-deformations", however, lead was perfect. It enjoyed great popularity as an interlayer between bearing plate and masonry abutment to ensure smooth bearing pressures and it had been used already in the nineteenth century.

Rubber bearings were made from natural rubber. Thanks to their outstanding capacity to reduce vibrations it did not take long for rubber plates to be appropriated as shock absorbers. The railroad tracks on Britannia Bridge and Conway Bridge were planned to be on mats of 50 millimetres depth "to avoid the effects of vibrations" (Anon. 1846). And few years later, in 1853, the bridge across River Saale near Grizehna contained very early deformation bearings employing the resilient properties of rubber:

"The main girders rest on […] cast-iron base plates […]. These plates are supported by ashlars of sandstone forming the pillars. In order for an even bearing pressure working on them each of these plates is positioned on an half an inch base plate made from vulcanized rubber. These are furthermore to accommodate temperature related expansion of the girders and annihilate any transmission onto the ashlar base and to reduce the intense vibrations caused by railroad trains crossing the bridge." (Targé 1853, p.481)

Only after World War II deformation bearings witnessed substantial distribution, because it took that long to develop appropriate interlayers which prevented the soft rubber mass from bulking. Thus comparatively deep blocks of rubber could be produced, which did not yield too much under load. In 1954 *Eugene Freyssinet* (1879—1962) applied for his idea of having reinforcement mats work as interlayers to be patented (Eggert 2005, p.15) The breakthrough was achieved only when sheets of metal were stuck and glued into the rubber. Although the rubber blocks were equipped with transverse bracing these bearings worked only for small loads lest the bearing areas would be over-sized.

Utilizing rubber for heavy loads was made possible by adapting the sand pot bearing which was already known for centuries. The idea was brilliant in its simplicity with rubber replacing the sand. The enveloping pot blocked the rubber from escaping. Its properties – elasticity and incompressibility – allowed the production of a simple and comparatively cheap deformation bearing for heavy loads which, however, differed from the rubber bearings mentioned before. Rubber pot bearings on their own only allowed for rotational movement of the superstructure. In order to accommodate longitudinal and transversal movements they had to be combined with a sliding or roller part as for example Schoenhoefer's needle bearing. Employing rubber pot bearings is recorded in the case of the elevated "Pariser Strasse" in Duesseldorf (Beyer, Wintergerst 1960, p.228).

Generational Change

The type of the old-fashioned steel bearings had dominated in bridge construction for more than a century – from their introduction in the 1840s up to World War II – first the family of the plane bearings, then those of rotating bearings. They were employed in central Europe even after World War II in repairing the destroyed bridges, because thanks to their sturdiness the old bearings often could be reused.

Commencing with the mid-1950s, however, within a few years, a new generation of bridge bearings was developed replacing the conventional steel bearings almost entirely. Prerequisite for this generational change was the introduction of new materials into bearing technology, first and foremost the rubber bearings already described.

But it was the additional application of the newly synthesized polytetrafluoroethylene (PTFE or Teflon) which completed this new generation. The material's outstanding properties – an extremely smooth surface amongst others – generated the renaissance of sliding bearings as movable bearings. For larger bridges sliding bearings made of steel had been unusable for a long time due to the high amount of friction. The new Teflon allowed for friction coefficients below 0.05 – that is five per cent of the bearing pressure. Similar values had only been possible with roller bearings. But using Teflon the friction coefficient sank with increasing bearing pressure, a wonderful property recommending this type particularly for large bridges. Teflon-based sliding bearings allowed for all-around translation with only a small construction depth. They were anti-corrosive and resistant under high pressure.

To accommodate rotation of the superstructure, Teflon bearings had to be complemented with a rocker part. This was where pot sliding bearings, deformation sliding bearings, and point rocker sliding bearings came from. (**Fig.14**)

It was due to the introduction of Teflon that spherical bearings could be developed accommodating rotations of the superstructure by means of slidings inside a ball joint. (**Fig.15**) The principle of a ball joint had already been realized in the nineteenth century with spherical curved bearings, albeit at the cost of a large amount of friction and a comparatively small area of load transfer (**Fig.10**). The situation changed with the new spherical bearings. The radii of the areas acting together were substantially increased and this meant a considerable improvement of the load transfer. The problem of friction was solved thanks to Teflon. Even today – almost half a century later – there is no alternative to bearings of this kind for large bridge constructions. All these members of this generation are currently still employed.

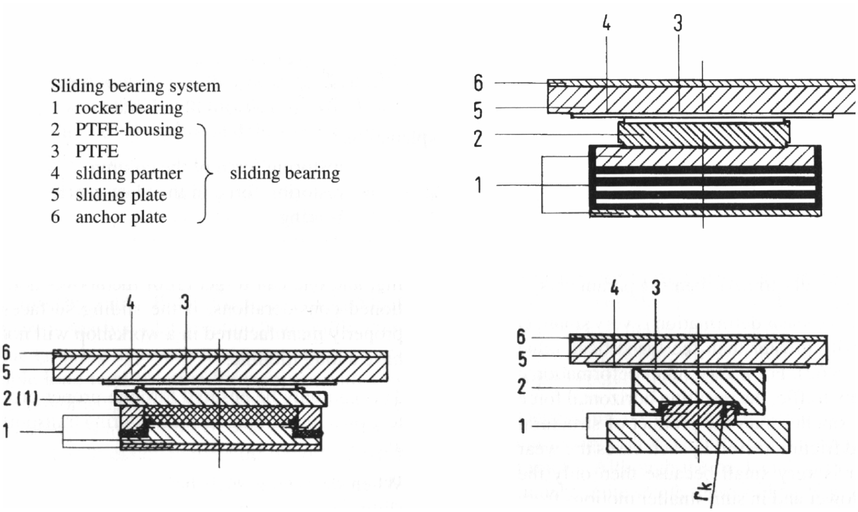

Figure 14. Top: Deformation sliding bearing, Bottom left: Pot sliding bearing, Bottom right: Point rocker sliding bearing (Eggert, Kauschke 2002, p.120)

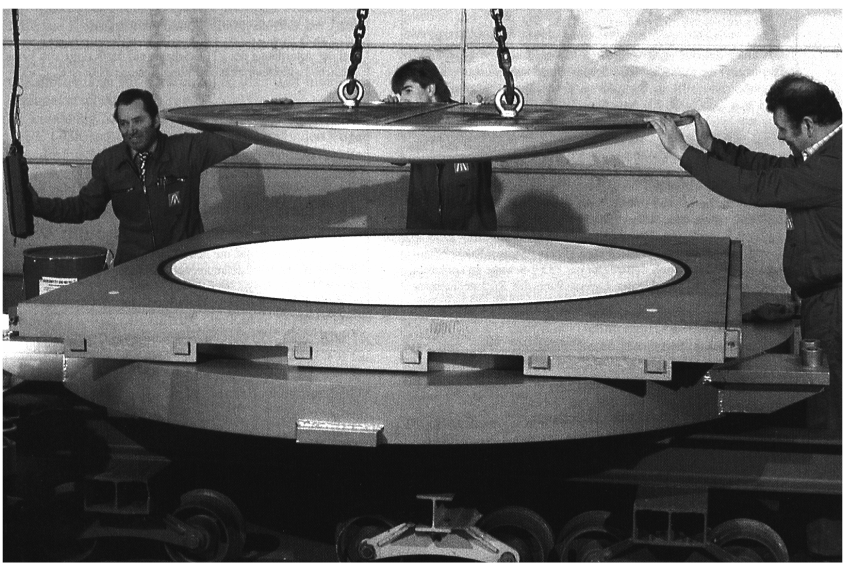

Figure 15. Modern spherical bearing (Kauschke 1989)

RESUMÉE

The history of bridge bearings is that of a minute detail, whose development towards becoming a building part of astonishing sophistication mirrors the technological advances of the last two centuries. The pulse was provided by the building of bridges. The ever-increasing sizes of the constructions required adequate solutions to the new demands. The original tasks were of a relatively simple nature, e.g. to keep the superstructure dry, to distribute the loads evenly or to absorb impacts. Simple wooden laths performed these tasks sufficiently for a long time. Still widely used by the beginning of the nineteenth century they have to be considered as the first generation of bridge bearings.

The entry of the next generation, iron and steel bearings, went hand in hand with the shift to iron as the main material for bridges. Constructive dimensions, shortly before hardly dreamt of, could now be achieved. But these were sizes which also forced the engineers to start thinking in a new fashion, for soon the limits of conventional construction methods showed. Movements in the iron superstructures – particularly due to changing temperatures – were no longer inhibited by increasing the bulk of the structure. Instead they were purposefully accepted. Rollers, balls and pins were established as indispensable parts of bearings within a few years. This second generation reflected a new kind of thinking. The objective was the freedom of movement of the system, first only in longitudal, later on in transversal direction as well: the more the better. In some cases fixed bearing were altogether left away.

The development of this generation had essentially been finished by the close of the nineteenth century. It was to be the main bearing technology for bridges in the course of the first half of the twentieth century. Innovations during this time have to count as intermediate solutions, none of which could establish themselves permanently. The upcoming tendency to build with reinforced concrete generated reinforced concrete bearings, and the introduction of high strength steel was accompanied by as it were high-bred types of bearings. But regardless of the material these intermediate solutions have to be interpreted as belonging to the second generation. Devoid of a construction characteristic original to them, they were attempts to supersede the principles of the old bearings with materials considered either to be superior in quality or because of their cheapness.

It was the application of synthetic materials like rubber and Teflon that gave rise to the third and current generation of bridge bearings. After the phase of movements such as “sliding“, “rolling“ and “rocking“ performed by the predecessors, “deformation“ became another qualitative form to accommodate differences of movement. Thus deformation bearings must count as the type paradigmatic for this generation. With Teflon doing the sliding part they represent a revolutionary step ahead in bearing technology.

And what about the next generation? In retrospect it becomes clear that the two influential generations of bearings of the industrial age evolved in times of economic growth. Precondition for

the iron bearings was the rapid demand for railways, in a similar vein we have to consider the breathtaking extension of the roads for cars after World War II a crucial factor for the development of bearings containing synthetic materials.

Quite possibly a new means of transport will trigger off the necessity for a new generation of bearings. And maybe with new and better materials. Or maybe this will entail a 180° turn, the complete dispensing with bearings, since their installation as well as their maintenance are costly. And so is the exchange of parts, because often the cheap solution is preferred to the durable one which later on has to be installed anyway, but at much higher costs. A complete doing away is technically conceivable. But will that option technically make sense and will it be economically desirable? The future will let us know . . .

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