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SESSION
WORKSHOP NOTES

Session (5-5)
"Anti-Friction Bearings As Used On Movable Bridges", James A. Foster, Jr., Torrington Co., Ct.

Anti-friction bearings have been used on movable bridges for over fifty years. Applications include pillow blocks, flange housings, and dead shaft arrangements. The bearings involved are spherical roller, tapered roller, cylindrical roller and roller thrust bearings. Many of the original bearings are still being used.

The first slide, taken to show the Torrance Avenue bridge in Chicago, shows the three generic types of movable bridges that we will discuss. All of these types have been designed to use anti-friction bearings or have been adapted later to use them.

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The New Haven Railroad bridge over the Cape Cod ship canal at Buzzard's Bay was the first modern movable bridge to use anti-friction bearings. The 544 foot, 2300 ton span, still one of the longest in the world, was opened in June 1935 --- 55 years ago. Eight 22-inch bore cylindrical roller bearings in pillow blocks support the counter weight sheaves at each end of the bridge. The original bearings are still in operation.

The next slide shows a cross-section view of these pillow blocks.

The bearing itself consists of a straight bored inner race, cylindrical rollers 2 1/2 -inches in diameter either 6 1/4 -inches or 8 -inches long in staggered pockets around the inner race, and a spherical O.D. outer race to allow for self alignment. This self aligning is done in a split (two-piece) bronze sleeve with a spherical I.D. and a straight O.D. All of this is installed in the pillow block housing.

The nature of this configuration of a straight roller bearing allows float or expansion of the rollers on the outside of the inner race.

On the inboard side, a piston ring seal carrier locates the bearing inner race against a shoulder on the sheave shaft. On the outboard end a clamp plate holds the bearing against the piston ring seal carrier and the shaft shoulder. Cap screws into tapped holes in the end of the shafts secure the clamp plates.

An end cover is attached to the outer race on the outboard end sealing the bearing from the outside environment and preventing the grease from escaping. In each fixed pillow block, a cylindrical roller double acting thrust bearing is contained in this end cover. The bronze piston rings, mentioned earlier, contact a ring fastened to the outer race on the inboard side of the pillow block.

The next slide shows a picture taken in 1935 prior to shipment and installation of the sixteen pillow blocks. Some of the components mentioned earlier can be identified.

The use of anti-friction bearings on this bridge allowed the designers to reduce motor HP from the 600 HP needed in each tower for bronze bushed pillow blocks to 300 HP. The annual savings in power offsets the initial additional expense of the anti-friction bearings.

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Shortly before World War II, Chicago started to design and build two bascule bridges which were to have roller bearing equipped trunnions. They were the Canal Street bridge and the North State Street bridge --- both completed in 1948. The Canal Street is a conventional "Chicago" type bascule bridge with two leafs --- each supported by two trunnions using radial roller bearings. These spherical O.D. bearings each support approximately 450 tons, although they have a rating of over 1600 tons at 5 R.P.M.

The second of the two bridges to be completed, was the North State Street bridge. It is unique because each leaf is supported on three trunnions. The four center truss trunnion bearings are 25 1/2 - inches in diameter and the eight outer trunnion bearings are 22 1/2- inches in diameter. Each of the two leafs weight 4250 tons, but only two 75 HP motors are required to operate it.

Another of the earlier anti-friction bearing equipped bascule bridges was the Sand Island bridge in Honolulu Harbor, finished in 1962. It was the first bascule bridge to be build in the islands.

The bearing arrangement on this two-leaf bridge is different from most other bridges. Two 440 mm tapered bore spherical roller bearings in special housings, are affixed to each bridge leaf. The "dead" shaft trunnion is tapered to match the bearing bore. Each bearing is held in place on the tapered shaft by a sleeve secured by a clamp plate attached to the end of the shaft by cap screws.

Other bascule bridges using anti-friction bearings are located in Mossdale, California over the San Joaquin River and in Baltimore, Milwaukee, and Seattle.

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The spherical O.D. radial roller bearing used with a separate double acting thrust bearing has proven successful in movable bridge applications for many years. Possibly most of the original bearings are still in use. The Buzzard's Bay Bridge is probably typical. The most recent bridge to use this bearing arrangement is the Peoria and Pekin Union Railroad Bridge over the Illinois River, built in the early 1980s.

However in the 1960s, another type of bearing --- The Spherical Roller Bearing --- was selected for main sheave shafts and bascule trunnions. Conceived in Europe before World War II and first made in the United States in the late 1940s, this type of bearing is most often selected for new bridges today. Barrel shaped rollers in a spherical I.D. outer race allow for internal self alignment as well as some thrust capacity.

Two bridges built during the last five years use spherical roller bearings that are the largest ever made. The Danziger bridge in New Orleans uses eight 800 mm bore bearings in pillow blocks, supporting the four counter weight sheaves. This highway bridge has a lift deck the size of a football field and weighs 2200 tons. The next two slides show pictures taken at the assembly of the pillow blocks. (Incidentally, those of you at the movable bridge conference in Atlanta in November 1988 may have attended a session about this bridge.)

In September of 1989, probably the heaviest vertical lift bridge went into service in Portland, Oregon. In a 72 hour change out, a 516 foot long 4009 ton vertical lift bridge was installed in place of a swing bridge that was a hazard to the commercial shipping on the Willamette River and to the Burlington Northern Railroad crossing it.

Eight 900 mm bore and eight 800 mm bore spherical roller bearings in pillow blocks support the eight counter weight sheaves on the bridge. The 900 mm bore bearings, the largest ever made in the United States and possibly in the world each weigh five tons.

The next slide shows one of these bearings prior to shipment from the factory. Scenes during the erecting follow. The 900 mm bearings are fixed in their housings while the 800 mm bearings are free to float.

The next slide shows the drawing for these housings. Note that the bases are furnished without mounting bolt holes. We designed the cap bolts to be in line with the base bolts so that after the positioning of each cable drum assembly, one cap bolt at a time can be removed and the hole used as a pilot for drilling and reaming the hole for the base bolt.

These large bearings are furnished with a taper bore --- one in twelve --- to fit on a mating tapered shaft. The bearing can be moved into position by tightening the bolts through the clamp plate into the shaft. Greasing the shaft makes this operation possible. The bolts are tightened until the proper amount of diametral clearance is removed from the bearing.

This pillow block housing configuration has been used for bearings from 460 mm bore to 900 mm bore in bridges all over the United States --- both highway and railroad.

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Rolling lift bascule bridges (Scherzer type) are a good application for flange mounted anti-friction bearings.

The next slide shows the flange mounted spherical roller bearings now supporting the leafs of the Indianapolis Boulevard bridge in Gary, Indiana.

The flange housing has a pilot on the back side of the flange (actually the outboard side) that closely fits into a hole in the bridge girder. This locates the housing and the bearing precisely relative to the bridge leaf. The mounting bolts then have no purpose but to attach the housing to the girder. The flange housings are supplied to the job site with pre-drilled undersize mounting holes. At assembly, holes are drilled thru the girder and reamed to size for fitted bolts.

In this application, the housing is partly cut away to fit between stiffening ribs on the bridge girder. In this instance, the "flats" are flush with the pilot diameter.

Many of these flange housing have full circular housings with mounting bolts all around the shaft. For any given bearing size, the housing could be furnished either way.

Bronze piston rings in steel sleeve piston ring carriers keep grease in the bearing and keep out contaminants. In this application, this piston ring carrier serves as a spacer between the bearing and the shaft shoulder. The outboard carrier is held in place by a clamp ring.

The bearing in this application is only a 260 mm bore bearing. However, this flange housed mounting arrangement has been designed and used for bearings as large as 630 mm bore on the Walnut Street bridge in Green Bay, Wisconsin and the State Street bridge in Racine, Wisconsin.

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The remaining basic type of movable bridge is the swing bridge. The pivot position offers another opportunity to move the structure with less effort by using an anti-friction bearing.

All of the bearings in the preceding applications were selected according to the AASHTO and AREA formula where capacity is equal to the formula: C = 3000/5 (NDL). In this formula, the number, length, and diameter of the rollers are multiplied by a constant that assumes only one-fifth of them are load carrying.

A spherical roller thrust bearing used in this position allows all the rollers to be load carrying. Even if the circular track for the bogie rollers is not level, the spherical thrust bearing will have all rollers in contact with the top and bottom races by nature of its internal geometry. The formula for this bearing and application can now read: C = 3000 NDL

The next slide illustrates this in a cross-sectional view of one application. Oil bath lubrication is needed in this application, and is easily maintained. An oil sight gauge shows the internal oil level.

Recently, a 90 year old railroad bridge between Manhattan and the Bronx was rehabilitated using this type of bearing. Nearby in Westport, Connecticut an old highway bridge is now being rebuilt using this type of bearing. Still another is a proposed application in Vermillion Parish in Louisiana.

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As the fiftieth anniversary of the Buzzard's Bay bridge approached, the Corps of Engineers who actually own this bridge hired consultants to recommend any necessary refurbishment.

The next slide shows the proposed sheave bearing arrangement. You will recognize the pillow block on the left as being the original arrangement without the thrust bearing or in other words --- the float arrangement.

However, for the fixed pillow block, we designed a special spherical roller bearing to fit in a sleeve to fit in the original outer housing. By using a spherical roller bearing, no separate thrust bearing would be needed.

The entire proposal was to utilize the original outer housings and replace only the bearings and components.

This proposed refurbishment is an example of what might be done for other bridges built using anti-friction bearings 30 or 40 years ago. In this instance, the spherical roller bearing and straight sleeve on the O.D. were less expensive than replacing the original radial roller bearing and this is not counting the cost of a new thrust bearing.

Unfortunately, this rebuild has not taken place as yet. Following the selection of a contractor by the Corps on a negotiated bid basis, a disappointed contractor protested to the General Accounting Office who directed the Corps to make the award to the protester. At that point, the railroad now operating the bridge took the same protest route and the job is now in limbo.

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Counter weight sheaves for vertical lift bridges are sometimes fitted with anti-friction bearings to operate on fixed or "dead" shafts.

Several types of bearings have been employed.

Radial roller bearings were used on the Wisconsin Avenue bridge in Kaukauna, Wisconsin. The next slide shows this bearing assembly. Each assembly consists of two individual bearings separated by a shaft spacer and an O.D. spacer. Lubrication is done thru the sheave hub into the cavity between the O.D. and I.D. spacers by means of a groove in the O.D. of the outer spacer with three access holes into the cavity.

Auxiliary sheaves on the Willamette bridge used tapered roller bearings. The next slide shows a cross-section view of the sheave arrangement.

The tapered roller bearings selected have the small ends of the rollers inward and contact angles diverging as they approach the axis of rotation. A single cup was used with two separate cones. This arrangement gives the best stability.

The bearings are located next to shoulders on the "dead" shaft and are held in place by conventional bearing locknuts with lockplates. The nuts mate with threads on the shafts and are secured with the lockplates. Sealing is done with conventional pillow block triple labyrinth seals affixed to the "dead" shaft. Groves in the bearing end cover on the auxiliary sheave form the labyrinth.

Recently another arrangement has been proposed for the Carter Road bridge in Cleveland. The next slide shows this arrangement. Two 440 mm spherical roller bearings are used in each sheave. The outer races of each bearing are located next to a center shoulder in the sheave hub. A sleeve between the pillow blocks and the bearing inner race forms a seal riding surface.

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For the last thirty plus years, auxiliary pillow blocks, for line shafts and other positions in the drive train have been spherical roller bearing pillow blocks. The steel housings are similar to commercially available pillow blocks with cast iron housings, but are furnished to the job site without base mounting holes. Similar to the counter weight sheave pillow blocks, the bolt holes are drilled through the housings and supporting structure at the time of assembly and then reamed to size for fitted bolts. Another difference from commercial pillow blocks is a completely solid housing without any pocket cavities in the base.

Sealing of the housings from the outside environment is done by means of triple labyrinth seals --- fitting snugly on the shaft and rotating with it --- mating with grooves in the housing.

The spherical roller bearing is attached to the shaft by a split tapered adapter with adapter nut and lockwasher or lockplate depending on the bearing size.

The bearing seat cavity in the housing is made wider than the bearing width to allow the bearing to float due to temperature fluctuations. As we mentioned earlier, the spherical roller bearing allows internal self alignment and accommodates thrust. A fixed bearing is required in every drive system and this is done by a fixing or stabilizing ring in the housing cavity.

Spherical roller bearing pillow blocks in auxiliary positions on movable bridges have been supplied for shafts of 1 1/2-inches to 14-inches in diameter.

The next slide shows a cut away exploded view of a commercial spherical roller bearing pillow block. Remember that for bridge applications, the bases would be solid when furnished --- no pocket cores or base bolt holes.

Possibly, the reason the spherical roller bearing pillow block is so popular compared to mounted tapered roller bearings and hour glass or concave roller bearings, is that there are several makes of spherical bearings available. From a replacement stand point, in an emergency there would be an almost instantaneous availability of replacement spherical roller bearings.

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From Massachusetts west to Hawaii and from Louisiana north to Minnesota, are movable bridges using anti-friction bearings. At least two of them have been in operation for over fifty years. Several examples have been discussed --- some new, some old, some rebuilds --- covering vertical lift, conventional bascule, rolling lift bascule, and swing bridges. All were designed using anti-friction bearings for anticipated long life, ease of maintenance, and for a savings in needed operating power because smaller sized motors and mechanical equipment can be used.

As we rebuild the infrastructure, many opportunities will arise to refit existing bridges with anti-friction bearings.