APPLICATIONS OF HIGH LOAD MULTIROTATIONAL DISK BEARINGS ON PRECAST CONCRETE BRIDGES

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ABSTRACT

High Load multirotational bearings (HLMRB) have been utilized on precast concrete bridges where the vertical loads and displacements exceed that of conventional elastomeric bearings. Not all HLMRB have performed up to the standards expected by bridge engineers involved in precast concrete designs. The disk bearing however has had an outstanding performance record on precast applications all over the world.

This paper will discuss the development of the disk bearing and review some of the research that has been performed of this innovative device. In addition several case histories will be examined in an effort to demonstrate how disk bearings can make precast concrete a cost effective and superior performance alternative to other bridge construction materials.

Keywords: Bearings, Multirotational, Precast, Concrete, Polyether Urethane, Sliding.

INTRODUCTION

Disk bearings were developed in the late 1960's as a cost effective means to safely transmit the loads, rotations, and translations of a bridge superstructure to the substructure. The primary component of the disk bearing is the load and rotational element, which is comprised of a polyether urethane elastomer. Due to this material's inherent compressive strength, there is no need for confinement of the elastomer, which acts much like a conventional elastomeric bearing.

Now in service for well over 30 years, disk bearings have had an outstanding track record on bridges all over the world. One of the reasons for this success is the simplicity in design, which also allows for ease of inspection and maintenance free performance.

This paper will review the development of the disk bearing and track the evolution of the device to its current design standards. In addition several case histories will be examined on precast concrete bridges, which will detail the design parameters and how disk bearings were able to solve complex structural problems.

In addition some older installations dating back as far as 25 years have been field condition surveyed in order to determine the long-term performance of these devices on concrete bridge applications.

However before examining the disk bearing in detail, it is important to evaluate other types of multirotational bearings and their shortcomings which led to the development of the disk bearing.

CONFINED ELASTOMER BEARINGS

In the 1960's a new generation of compact multirotational bearing devices were developed beginning with the confined elastomer or "pot" type bearing (Fig. 1). While the pot bearing has been successfully installed on numerous structures throughout the world, several problems have surfaced with this concept[1]. One is the ability of the steel pot to withstand the transverse loadings combined with the pressure developed from the elastomer. Another is the fact that satisfactory rotational distribution is not achieved until at least 25% of the bearing capacity in load is applied. This has posed problems especially during erection procedures. Still another problem with the pot concept has been experienced in colder climates. This deals with the rotational element typically manufactured from natural or synthetic rubber. During extreme cold temperatures, coupled with high-design pressures, the rotational element has been known to crystallize which in turn eliminates the rotational capacity of the device. One final problem with confined elastomer bearings worthy of discussion deals with the extremely tight tolerances between the base pot and the piston. If the steel piston is manufactured with a high tolerance relative to the base pot a condition of steel-to-steel contact develops which inhibits the rotational capacity of the bearing device. When the piston is manufactured with a low tolerance relative to the base pot, the sealing ring has difficulty containing the elastomer which under the design pressure acts like that of a fluid (Fig. 2). Numerous cases of this type of failure have resulted in design authorities reverting back to traditional steel bearings.

Fig. 1. Pot Bearing

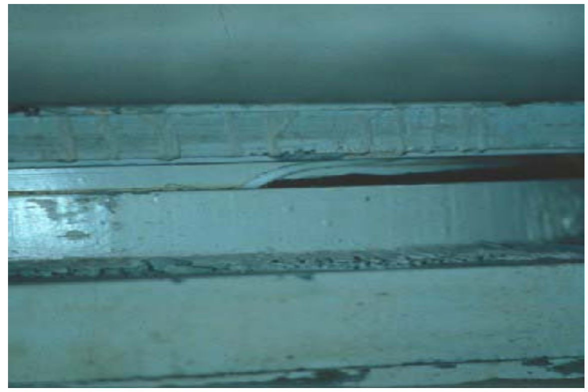

Fig. 2. Failed Pot Bearing

THE DISK BEARING

With these specific problems in mind the disk bearing was developed in the late 1960's. The primary difference of the disk concept to the pot is the use of a polyether urethane rotational element, which due to its high compressive strength requires no need for confinement (Fig. 3). This immediately eliminates the sealing ring problem, which has plagued pot bearings. The urethane material used in the disk remains flexible from –94 to 250°F (-70 to 121 degrees centigrade). Therefore under normal atmospheric conditions there is no problem with the rotational element softening or crystallizing during temperature extremes.

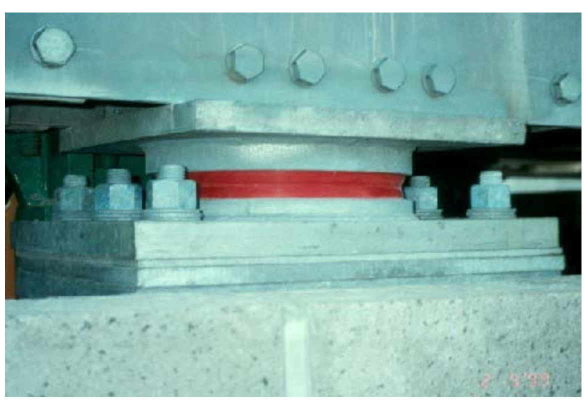

Fig 3. Disk Bearing

The unconfined disk accommodates rotation by the differential deflection of the elastomeric element. The horizontal loads of the structure are transmitted through a shear restriction mechanism. This ball and socket type connection allows the free rotation of the superstructure up to 4% but inhibits shear from being applied to the rotational element. The standard mechanism accommodates a horizontal force of 10% of the vertical capacity of the bearing device. However this can be easily modified for higher horizontal forces conditions that are commonplace with today's longer spans, curved girders and increased awareness of potential seismic activity.

MATERIAL TESTING

In order to demonstrate the feasibility of this bearing concept, the material properties of polyether urethane, the shear-restriction mechanism, and the disc bearing properties have been tested extensively.

Testing conducted by Dupont[2] has shown that polyether urethane has excellent weathering properties when subjected to prolong exposure to seawater, fresh water, ozone and other deleterious chemicals. In addition, extensive load deflection testing has been conducted on the polyether urethane load element demonstrating its ability to accommodate very high loads with a minimal amount of deflection. The deflection is limited by the V notch design in the edge of the disk. This is designed to reduce the shape factor and minimize the overall deflection. The AASHTO[3] maximum allowable pressure on the polyether urethane load element is 5000 psi (34.5 MPa). However the material does not experience plastic deformation until a pressure of 20 times the allowable is applied. This gives the disk bearing an enormous safety factor for vertical loads. In addition because the design load on the polyether urethane material is so low compared to ultimate capacity, the long-term creep of the elastomer is insignificant.

CASE HISTORIES

PASCO KENNEWICK BRIDGE

One of the first major installations of the disk bearings was performed on the Pasco Kennewick Inter City Bridge in the State of Washington (Fig. 4). This landmark structure was the first cable stay bridge built in the 48 continuous states[4]. Its overall length is 2500 ft. (762 meters) and it has a main span of 970 ft. (296 meters). The vertical load capacity of these bearings ranged from 600 to 2800 kips (2670 kN to 12,400 kN). In addition since the concrete deck was continuous, the bridge has a fixed joint at one abutment and an expansion joint at the other abutment designed for 26in. (660 mm) of total movement. Similarly the bearings at that abutment location also had to be designed for 26in. (660 mm) of movement. This type of requirement emphasizes one of the primary advantages of a sliding disk bearing over a comparable elastomeric bearing in that the disk bearing can accommodate this magnitude of displacement and still maintain a very low overall profile. An elastomeric bearing would need to be nearly 60in. (1-½ meters) tall where as the disk bearings were able to fulfill the requirements at the location with an overall height of 6in. (150 mm).

Fig. 4. Pasco Kennewick Bridge

Fig. 5. 25 Year Old Disk Bearing on Pasco Kennewick Bridge

Installed in 1976 the disk bearings have performed well on this picturesque structure. In October of 2001, an inspection of the disk bearings was performed. Other than some cobwebs and typical detritus one would expect to see after 25 years, the bearings are in excellent condition (Fig. 5). The mirror finish on the stainless steel is still evident on the expansion bearings.

I-75 / I-20 INTERCHANGE

One of the largest installations of disk bearings in terms of number of bearings took place in the mid 1980's in Atlanta, Georgia (Fig. 6).

Fig. 6. I-75 / I-20 Interchange in Atlanta

The Georgia Department of Transportation (DOT) undertook the complete rebuilding of this interchange of two major interstate highways in downtown Atlanta to alleviate major traffic congestion in this rapidly growing metropolis. Over 400 disk bearings were installed on the 33 bridges of this interchange starting in 1985. The bearings ranged from 300 to 2600 kips (1330 kN to 11,670 kN) in vertical capacity with a mixture of fixed, multirotational and guided expansion bearings used on these structures.

Prior to the opening to traffic, it was determined that one of the piers supporting a curved concrete box girder was improperly aligned resulting in the disk bearing at that location to be severely rotated during live loading. It was estimated that the polyether urethane disk was rotated 10 times the design value during live load testing. It was assumed by the engineers involved that the disk would have to be replaced once the corrections to the structure were implemented. However, upon inspection it was determined that the disk was undamaged from the unplanned over-rotation test. This further emphasizes the vertical load safety factor of the disk bearing due to the outstanding compressive strength of the polyether urethane material.

Two additional bearings were added to either side of the disk bearing at that location in order to stabilize the structure and prevent this condition of over-rotation from re-occurring.

In August of 2001, an inspection was performed on several of the disk bearings at this interchange. The bearings inspected had been in service for 16 years and were in excellent condition (Fig. 7). One thing that was noticed was rusting that has occurred at field weld locations.

Fig. 7. 16 Year Old Disk Bearing on I-75 / I-20 Interchange

Most design authorities specify corrosion protection systems based on performance in that particular region. Those systems are often quite costly and range from galvanizing or zinc metalizing to elaborate 3 coat epoxy or zinc paint system. The problem lies in that when the bearings are field welded into place, this protection system is ground off to facilitate proper welding to the substructure and/or superstructure. Following the welding procedure a secondary corrosion protection system is usually sprayed or brushed on to the welded surfaces. This secondary system is typically the weak link in the corrosion protection system and is frequently where oxidation will begin. While the corrosion evident on the disk bearings in Atlanta is not adversely affecting the performance of these devices, it is an aesthetic issue and could possibly lead to long-term problems. As a result, specifications should pay particular attention to field welding and field applied corrosion protection systems.

U.S. HIGHWAY 90 AT EAST PASCAGOULA RIVER BRIDGE

The purpose of this project was to replace the existing bridge and alleviate traffic congestion on Highway 90 from Ingalls Access Road to Telephone Road between Pascagoula and Gautier on Mississippi's Gulf Coast. It consisted of work necessary for replacing the drawbridge with a fixed span high-rise bridge and to provide for additional lanes on Highway 90 (Fig. 8).

Fig. 8 U.S. Highway 90

Fig. 9 Disk Bearing Installed on Highyway 90

Thirty-two unidirectional expansion bearings with 250 kip vertical load capacity at the end of the span and 32 fixed bearings with 850 kip vertical load capacity (Fig. 9) at the center piers were utilized on this structure. Steel anchor plates were embedded into the concrete girders and the bearings were field welded to these embedded plates. The expansion bearings were equipped with auxiliary devices to temporarily lock the bearings in the longitudinal direction and prevent the girders from sliding during construction.

The low bidder on this project at $48 million. The contractor selected disk bearings due to the construction durability and low price features. The consulting engineers were convinced that the disk bearings were a superior design at a lower cost and approved their use on this prestigious structure.

Fig. 10 125 Ton Girders being set on disk bearings in Pascagoula, MS

The bridge is a 642 ft. long structure with continuous precast concrete girder spans of 196 ft., 250 ft. and 196 ft (Fig. 10) supported by 4 reinforced concrete piers. The girders translations and rotations are accommodated by 64 disk bearings at piers 13 through 16.

ROUTE 15 – TIOGA COUNTY, PENNSYLVANIA

This bridge is a dual six span structure carrying Route 15 over State Route 2016 and Johnson Creek (Fig. 11). The center spans of this structure are ninety feet above the roadway. A total of sixty AASHTO 28/96" prestressed concrete girders were delivered and erected over an eleven day period. The prestressed beams ranged in length from 100 ft. to 130 ft. (30 m to 40 m) and weighed from 152 kips to 198 kips each.

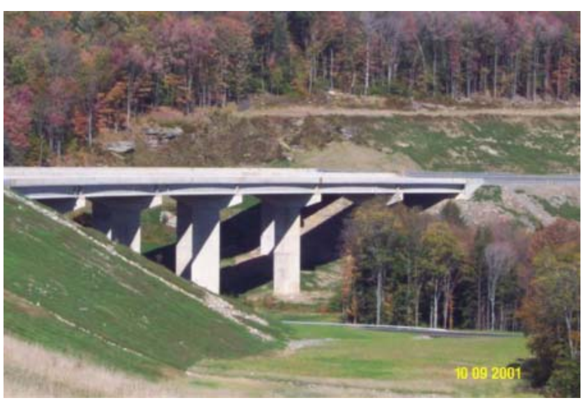

Fig 11 Route 15 Bridge in Blossburg, PA

Fig. 12 Guided disc bearing on Route 15 Bridge

The contractor installed 20 disc bearings at the abutments, 12 unidirectional expansion bearings supporting the interior girders and 8 multirotational expansion bearings supporting the fascia girders.

All bearings had a 300 Kip (1330 kN) vertical load capacity (Fig 12). Steel anchor plates were embedded into the concrete I-beams, and the bearings were bolted in place to these embedded plates.

Guided (unidirectional) bearings were designed for a horizontal load of greater than 20% of the vertical load due to the centrifugal forces developed when traffic passes over the curved bridge structure.

CONCLUSIONS

In the past very little attention has been given to the connection between the superstructure and substructure of bridges and other civil engineering structures. This is evidenced by the types of bearing devices that have been and are currently being employed. While we are more than likely still in the infancy of bearing design and technology, significant advances have been made in the last 25 years. The projects described herein are an attempt to update designers on some of these advances with a goal towards total protection of the structure from the multiplicity of forces in today's complicated designs. Due to the disk bearings unique ability to adapt to a variety of loading conditions, its use with precast concrete bridges will continue to expand.

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