HIGH LOAD MULTI-ROTATIONAL DISK BEARINGS FOR STEEL PLATE GIRDER BRIDGES

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BIOGRAPHY

Ron has a Bachelor of Science Degree in Civil/Structural Engineering from The State University of New York at Buffalo. He has over 40 years of experience in the design, manufacture and testing of high load multi-rotational bearings, seismic isolation devices and bridge deck joint sealing systems. He serves as Chairman of the International Joints and Bearings Research Council and also chairs ASTM Subcommittee D04.32 on Bridges and Structures. He is the Vice Chairman of NSBA Task Group 9 on Bearings. He is also President of R.J. Watson, Inc. which specializes in the design, manufacture and testing of bridge bearing devices and joint sealing systems.

SUMMARY

High load multi-rotational bearings (HLMR) typically consist of pot, spherical or disk bearings. Over the last 20 years disk bearings have been the device of choice for bridge designers due to their long term performance and cost effectiveness. For steel plate girder bridges disk bearings are the common solution to the problem of distributing the loads, movements and rotations to the substructure without damage.

Two high profile projects demonstrate the advantages of disk bearings for a variety of conditions on plate girder bridges. The first is the $4 Billion LaGuardia Airport Rehabilitation Project where 470 disk bearings were supplied for the plate girder bridges in this complex.

The second is the I-480 Valley View Project near Cleveland where the contactor is building a new span between the existing twin spans and then retrofitting the existing plate girder bridges to bring them up to current standards.

In both of these projects the disk bearings we called upon for unusual conditions and were able to meet the challenges of these unique projects.

INTRODUCTION

In 2016 the Public Private Partnership LaGuardia Gateway Partners signed a 35-year lease agreement with the Port Authority of New York and New Jersey and has negotiated the financing to begin the redevelopment of LaGuardia Airport's Central Terminal B in New York City. The members of LaGuardia Gateway Partners are Vantage Airport Group, Skanska Infrastructure Development, and Meridian. The $4B redevelopment is one of the largest infrastructure projects in the U.S. It includes a new 35-gate Terminal B, Central Hall, West Garage, and related roadways and support infrastructure as shown in Figure 1. Skanska USA and Walsh Construction formed a design-build joint venture for this project. HOK and WSP | Parsons Brinkerhoff are its design advisors. Vantage will manage the terminal operations.

Figure 1: LaGuardia Airport Terminal B Redevelopment Rendering

BEARING SELECTION

Since there were numerous bridges on the related roadways and support infrastructure, the designer WSP evaluated all of the bearing candidates and after a thorough investigation, selected disk bearings shown in Figure 2 to support the steel plate girders on this project.

Disk bearings were originally developed back in the early 1970's as a cost effective and superior performance high load multi-rotational alternative to pot or spherical bearings (1). The key to the functionality of the disk bearing is the use of a polyether urethane load and rotational element. Polyether urethanes have exceptional compressive strength and outstanding weathering properties. Additionally, they have a material stability range of -94° to + 248°F so for normal atmospheric conditions the urethane remains functional (2).

An example of long term durability of disk bearings is the Pasco-Kennewick Bridge in the state of Washington. This bridge was built back in the mid 1970's and utilized disk bearings. Over 40 years later the bearings are still in excellent condition. There are numerous other examples but this project is significant in that it was the first cable stayed highway bridge to be constructed in the lower 48 states.

Under the design load the polyurethane load element will deflect approximately 10-15% of the element thickness. This differential deflection gives the bearing the ability to distribute rotations regardless of the direction of orientation. The maximum allowable pressure on the rotational element is limited by AASHTO to 5000 psi (3), however the ultimate strength of this material is on the order of 20 times this load. Therefore, there is an extremely high safety factor for vertical loading. This characteristic is critically important because bearings are frequently overloaded during the girder erection process. The rotation of these bearings transmits very little moment into the substructure and as a result they allow for an efficient foundation design where the superstructure loads are primarily vertical loads on the pedestals.

Figure 2: Unidirectional Disk Bearing

LAGUARDIA BEARING DESIGN

The design of the disk bearings for the LaGuardia project was extremely varied. There were over 470 bearings in total supplied by the manufacturer. The project required several disc bearing variants to be designed with bearings resisting vertical loads ranging from 66 to 2330 kips. The movement requirements for the expansion bearings was typically in the range of 10 inches and under. The sole plates in many cases were beveled to accommodate the super-elevations and in some cases were bi-directional. There were also cases where uplift restraint was required of the bearings.

Uplift bearings, bearings that resist negative vertical loading, are becoming more common especially in seismic zones where earthquake loading is often vertical. The disk bearing can be designed for uplift restraint by modifying the central shear resistance mechanism (SRM) so that it functions much like a trailer hitch on an automobile. This allows the bearing to resist uplift forces while allowing limited rotation as illustrated in Figure 3. If displacement is also required, the uplift bearing can be designed to allow for movement and simultaneous uplift. To accommodate this, typically the bottom section of the guide bar is designed to capture the upper bearing plate. A PTFE/Stainless Steel interface similar to the main sliding surface is situated between these surfaces to allow for smooth operation.

There are many situations that could occur that would cause uplift forces. Some of the more complex cable-stayed designs or designs that include curved girders or even heavily skewed piers can all exhibit a negative vertical load. In addition to uplift forces imposed as a result of the structure's design, another uplift loading condition that has recently become a focus is when a bridge crosses flood-prone bodies of water. We saw this occur during Hurricane Katrina, where sections of Interstate 10 floated away due to the storm surge. One would think that due to the mass of bridges this would not be a problem, but they can become buoyant during flooding.

Thousands of uplift-resisting disk bearings have been supplied on structures all over the world to accommodate these modern design parameters.

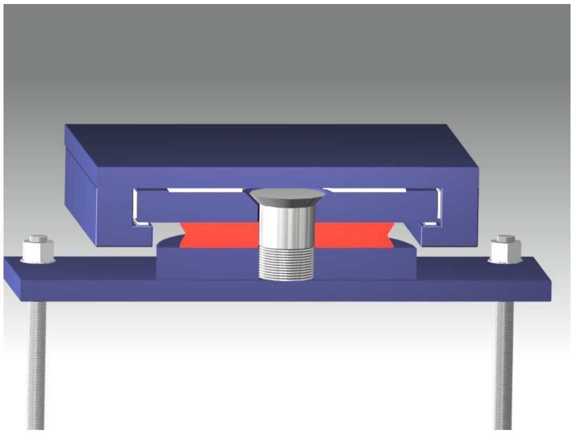

Figure 3: Uplift Expansion Disk Bearing Design

On the LaGuardia Project, the uplift conditions were primarily due to structure geometry. During certain loading conditions there was potential for a negative vertical load to occur. In some locations, uplift bearings were implemented for unforeseen reasons such as earthquakes and/or explosions. The installation of the disk bearings as shown in Figure 4 went smoothly with very few problems in the field with the sizing and fit.

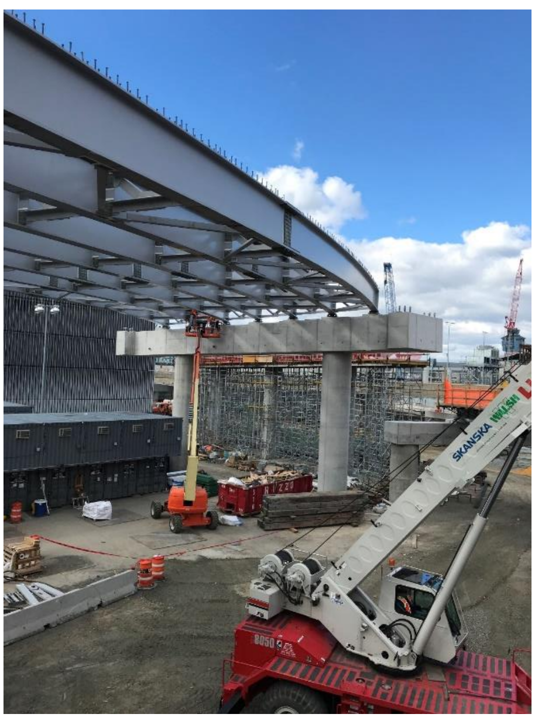

Figure 4: LaGuardia Curved Steel Plate Girders supported by Disk Bearings

VALLEY VIEW BRIDGE PROJECT

In the fall of 2017 the Ohio Department of Transportation awarded a $228 Million Dollar Contract to Walsh Construction for the I-480 viaduct over the Cuyahoga River south of Cleveland connecting the towns of Valley View and Independence, Ohio. This project is unique in that it involves the construction of a new bridge in the center of the existing eastbound and westbound structures. Once the new bridge is complete the existing 40 year old steel plate girders will be retrofitted with new decks. This is also a testimonial that plate girders are long lasting even in a corrosive environment like this. Carrying 180,000 vehicles per day makes the Valley View Bridge the most heavily travelled bridge in the state. Figure 5 shows that the 4155 feet long and 212 feet high bridge is also one of the longest and highest as well. The plan is to have the new bridge open by the fall of 2021 and then switch traffic to that while they retrofit the existing spans. Once finished in 2024 there will be 6 lanes in each direction. This is the largest current project in the state of Ohio and the 4th largest in the state's history. The erection of the new plate girders will be done with a gantry that will span the existing structures.

Figure 5: Existing Valley View Bridge

The design engineer for this project, CH2M-Hill which is now part of Jacobs, did a thorough review of bearing types for this type of structure and selected disk bearings based on their performance on steel plate girder bridges around the country. There were 133 disk bearings manufactured for this 15 span structure. The vertical service loads range from 420 to 1530 kips with fixed, unidirectional and Multidirectional types. The horizontal loads ranged from 15 to 40% of the vertical loads and the rotations were anywhere from 0.018 to 0.025 radians. The movements ranged from 3 to 10 inches except for the hinge bearings which were 470 kip bearings with a 25 inch movement stroke. Figure 6 shows some of the disk bearings ready for installation at the Valley View jobsite and Figure 7 shows one of the disk bearings field welded in place on the new section of the Valley View Bridge.

Figure 6: Disk Bearings ready for installation on the Valley View Jobsite

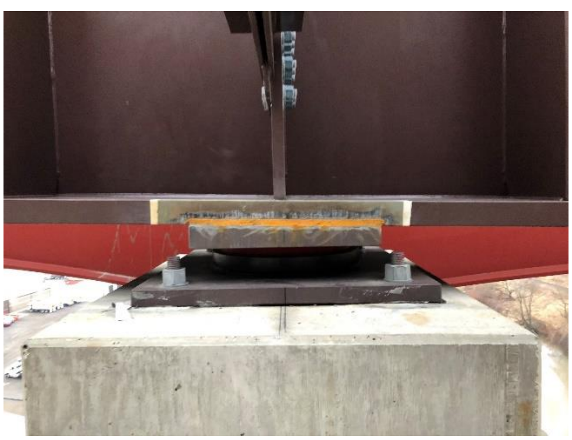

Figure 7: Installed Disk Bearing on the Valley View Bridge

TESTING

The testing performed on the disk bearings for both of these projects conformed to the New York State and Ohio Department of Transportation Specifications. Two bearings from each lot are subjected to a battery of testing including vertical load, rotation, and friction testing. The load and rotation testing are usually performed at the same time. For these tests, the bearing is loaded to 150% of its design capacity while a beveled plate in the test frame imposes a simulated rotation as shown in Figure 8.

Figure 8: Disk Bearing Loaded and Rotated in a test frame.

The bearing is left in this condition for a specified period of time. The load is then removed, and bearing’s components are inspected for damage or defects.

Friction testing is also conducted on full sized, expansion capable bearings. Both static and dynamic friction can be measured by imposing the design vertical load and then through the use of an actuator, simultaneously applying a horizontal load. In most cases, the goal is to achieve a maximum friction force that is no greater than 3% of the imposed vertical load. However, the actual results typically observed when testing a PTFE sliding surface/mirror finish stainless steel interface is on the order of 2%.

INSTALLATION

Installation of disk bearings is no different than any other bearing. They should be installed level and aligned with the girders. Connection details vary from project to project but in the case of the LaGuardia Project, the lower anchor bolts were cast into the substructure and the disk bearings were lowered into place. The bearings were situated on shims and then high-strength grout was pumped/injected under the masonry plate as shown in Figure 9. After the plate girders were set on the bearings and properly aligned, the sole plate is then adjusted for temperature offsetting, and finally welded to the girder. Care should be taken during the welding process so that the temperature of the steel adjacent to the polyurethane disk does not exceed a predetermined temperature.

Figure 9: Disk Bearing Installation on the LaGuardia Project.

CONCLUSIONS

More and more, designers are utilizing HLMR disk bearings to accommodate the loads movements and rotations in their steel plate girder bridge designs. The simplicity of the design, the historical long-term performance, cost effectiveness and overall quality of the device are all primary reasons that these devices are chosen over other options. In both projects cited in this paper, unusual load combinations coupled with uplift conditions necessitated a device with a proven track record to handle these demanding conditions. Disk bearings were selected in both cases. This trend will most likely continue with the designs of bridges becoming more complex and challenging.

REFERENCES

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