Study, Evaluation, and Monitoring of Bridge Bearing in Accelerated Bridge Construction (ABC)

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Abstract

The study starts by going over the several kinds of bridge bearings that are frequently used, such as friction pendulum, pot, and elastomeric bearings. It examines particular difficulties and demands these bearings have in ABC practice, including their quick installation, off-site construction, and compatibility with prefabricated bridge components. By addressing the unique challenges and requirements of bridge bearings, including their evaluation and long-term monitoring, this research contributes to the advancement of accelerated construction techniques, ultimately leading to safer, more efficient, and cost-effective infrastructure solutions.

Keywords: Accelerated Bridge Construction (ABC), bearing types, monitoring, bearing maintenance, durability, advantages and disadvantages of bearings

Introduction

In the infrastructure sector, Accelerated Bridge Construction (ABC) has become more popular as a game-changing method for drastically deducting construction times, avoiding traffic jams, and improving overall productivity. The bridge bearing is an essential part of ABC projects because it affects the lifetime and functionality of the bridge structure. In the framework of ABC, this research offers a thorough assessment and monitoring of bridge bearings, offering insightful analysis and helpful suggestions for engineers and transportation authorities.

Accelerated Bridge Construction (ABC) is a bridge construction method that uses prefabricated, modular bridge components. It can be rapidly assembled and installed. ABC techniques reduce work zone duration and minimize traffic disruptions, and improve safety and quality control, leading to longer-lasting, more resilient bridge structures. ABC requires a comprehensive understanding of the various elements, systems, connections, and materials that make up these accelerated construction methods (Gautam,B et.al., 2019; Khan, M.A., 2015, Xiang, Y.Q. 2018). This research paper explores the load-transferring system mechanism advancements and best practices in bridge bearings to optimize the safety, cost-effectiveness, and long-term viability of accelerated bridge construction initiatives.

One may refer to bearings as the mechanical component of a bridge's construction. The first bridges were constructed with timber, bricks, or large stones. These bridges expand and contract according to temperature differences, however, there aren't many temperature gradients because the bridge material has a large mass. Timber bridges are more sensitive to weather and moisture content than they are to temperature differences. However, since they are built with several joints, they allow for sectionalized movement inside the bridge. Because bridge design and construction have become more sophisticated, bridges are now built using steel, reinforced and prestressed concrete, or composite materials to withstand heavy loads, high traffic volumes, extended lifespans, challenging obstacles, and other factors.

Bearings have been implemented to facilitate the movement of the current generation of bridge constructions. Steel was used to make bridge bearings in the beginning, but due to issues with deterioration, maintenance, flexibility, and durability, other types of bridge bearings have been created to meet various needs and designs. The goal of current research is to further enhance bridge bearings so they can

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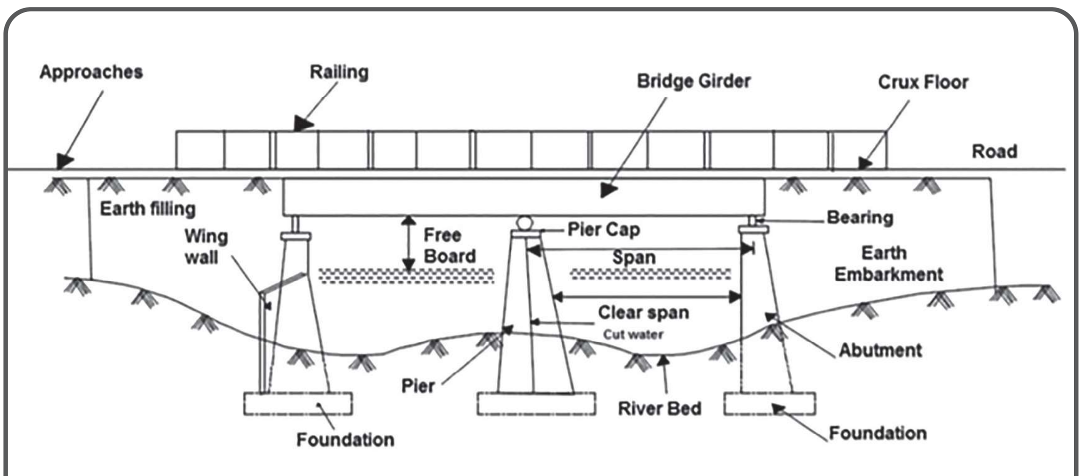
support and transfer more pressures with greater durability throughout a lifespan that is comparable to the bridge's lifespan, all the while enabling cost-effective bridge flexibility.

But not every bridge has a bearing attached to it. Without bearings, integral bridges, slab frame bridges, etc., must be designed so that the structure can support any additional forces and moments resulting from movement limitation. It's also crucial to remember that the bearing-enabled motions of the bridge structure are related to a predefined allowance built into the structure to allow for elongation. The expansion joint is the designation for this consent

Function of Bridge Bearing

Bridge bearings serve as links that transmit forces to the substructures (pier, viaduct, or abutment) from the superstructure (deck) of the bridge. A temperature differential, such as a rise in temperature, causes the bridge's structure to expand or lengthen throughout its length, resulting in structural movements; conversely, a reduction in temperature causes the bridge's length to shrink. When a seismic event occurs, the forces acting on the bridge foundations are transferred to the whole structure, resulting in intense vibrations and movements of the bridge itself (Niemierko, A,2016b). In addition, the bridge's structure flexes and vibrates in response to the stresses of heavy traffic, such as cars and different vehicles. Bridge structure moves due to different reasons like creep, shrinkage, and elastic deformation. Figure 1 below demonstrates the load transfer mechanism.



Component Parts of the Bridge structure

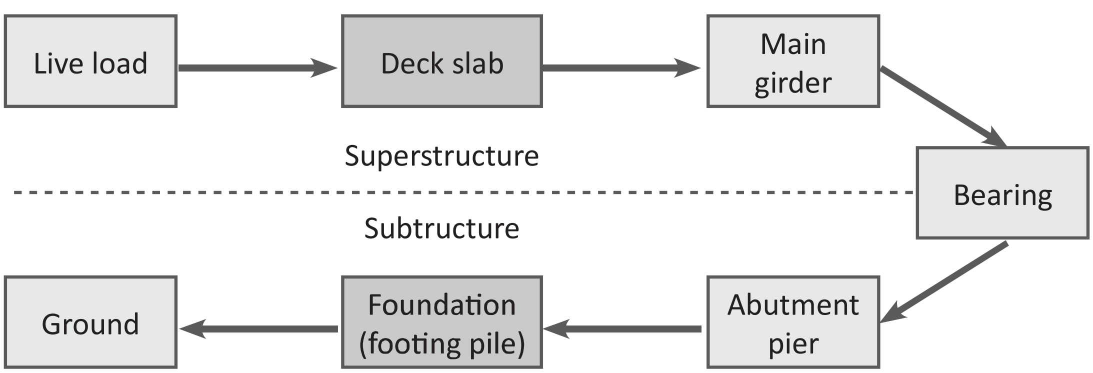


Fig. 1. Live load transfer Mechanism in Bridge

Reasons of Bridge Movement

The following sources can be used to describe bridge movements normally:

- Movements caused by creep and shrinkage
- Motions caused by heavy traffic
- Movements caused by the bridge's structural dead load
- Movements caused by lateral forces, including wind loads, acting on the bridge structure
- Changes in temperature-related movements
- Movements caused by soil pressure acting on abutments; - Movements caused by settlements in supports (both uniform and differential settlements)
- Motions brought on by horizontal loads, including traction force, braking, acceleration, and sliding
- Motions brought on by impact forces, such as cars and other vehicles crashing against bridge structural components(edge beams, kerbs, railings, etc.)
- Motions brought on by seismic activity (earthquakes, tremors)

Considering the aforementioned, it is essential to plan for bridge movement in order to prevent the generation of additional forces and moments when the movement of the bridge is restricted. Bearings allow for these motions in bridges. The following is a summary of a bridge bearing's functions:

Characteristics of Bridge-bearing

- Connects the superstructure of the bridge to the substructure.
- Transfers and accommodates dynamic stresses and vibrations without wearing out or damaging the substructure.
- Facilitates the movement of the bridge structure in response to loads, whether it be translational, vertical, or rotational.
- Regulates the direction and degree of movement in the bridge structure.
- Ensuring that the superstructure of the bridge deforms in a way that prevents the substructure from experiencing significant forces and moments.
- Can modify the bridge's dynamic characteristics.
- Shear on the head of piers, viaducts, or abutments is minimized by bearings.
- Modern bridge bearings are made to absorb and release energy during earthquakes and other seismic events, acting as seismic opponents.

Different types of Bridge Bearing

1. Based on Support Condition
    - Fixed or clamped bearing: it allows rotation but no transverse or longitudinal movement
    - Hinge or pin bearing: It allows rotational movement while at the same time preventing longitudinal movement
    - Movable bearing: It allows both rotational and translational movements
    - Guided bearing: It allows only translational movements
2. **Based on Material used**
    a) Steel Bearing
    - Rocker/Linear bearing
    - Roller bearing
    - Sliding plate bearing
    - Combined roller and rocker bearing

    b) Rubber and Combined bearing
    - Laminated Elastomeric bearing
    - Plain elastomeric bearing
    - Lead rubber bearing
3. **Based on Design**
    - Spherical Bearing
    - Pot Bearing
    - Deformation bearing
    - Elastomeric bearing
    - Disc bearing

- Lifting and measuring bearings
- Incremental Launch Bearing (ILM)
- Special bearing

4. Seismic Isolation Bearing
   - Friction pendulum bearings
   - High damping Rubber bearing (HDR)
   - Lead rubber bearings (LRB)

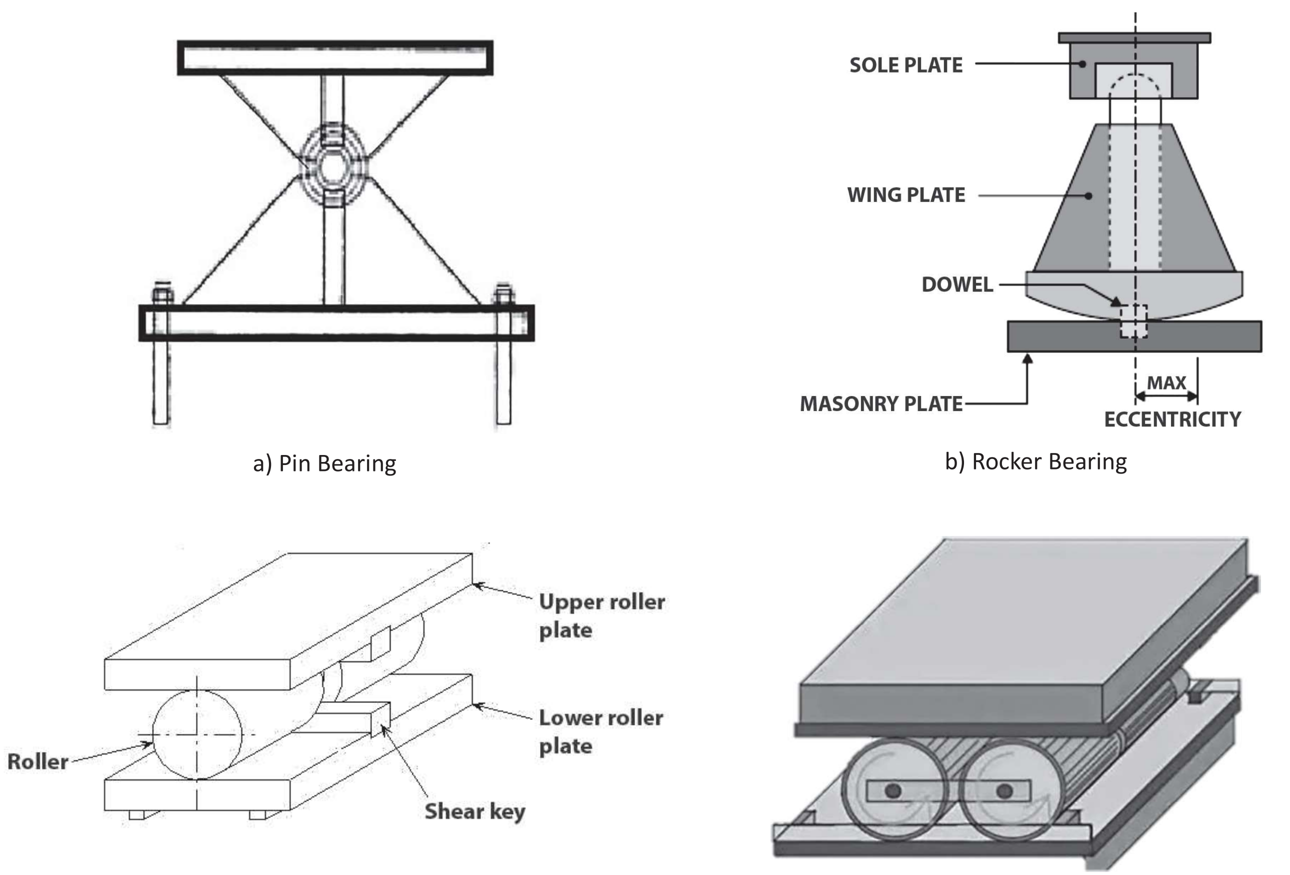
Overview of commonly used Bridge Bearings

1. Steel bearing

The primary bearings are made of steel. The roller bearing (single or multiple), the rocker bearing, the sliding steel bearing, and the combination of the roller and rocker bearing are the most often used types of steel bearings. Different kinds of steel bearings have been developed based on the intended uses. These include the pin/hinged type that allows movement in one direction only and prevents movement in the other, the fixed or clamped type that allows rotation but not transverse or longitudinal movement, the guided type that only allows translation, and the movable type that allows both translation and rotation (Bodewig, A.H. et. Al, 2024). Fig. 2 below shows different kinds of steel below.

Advantages of Steel Bearings

- Steel producers can easily make steel bearings, making them cost-effective choices.
- Installing steel bearings is simple.
- Steel bearings are widely accessible, reasonably priced, and simply available.
- Steel bearings can be utilized in situations when the bearings have a limited area, such as on a single, narrow pier.



a) Pin Bearing

b) Rocker Bearing

c) Roller Bearing

d) Rocker and Roller Bearing

Fig. 2 Steel Bearing (source: internet)

Disadvantages of steel-bearing

- Breakdown in fastening elements (bolts, rivets, and welds) that inhibit shear and uplift
- Certain elements (such as sliding surfaces and pins) need to be lubricated; otherwise, they risk wearing out.
- Excessive wear and partial elevation of steel
- Moving while under a lot of pressure
- Since all of the components that work are composed of steel, there are issues with longevity, rust, and corrosion that limit mobility.
- Steel sliding surface cracking
- The structure, lubricants, and parts of steel bearings collect debris and moisture, which causes the bearings to corrode and freeze.
- Quite high repair expenses

2. Elastomeric Bearings

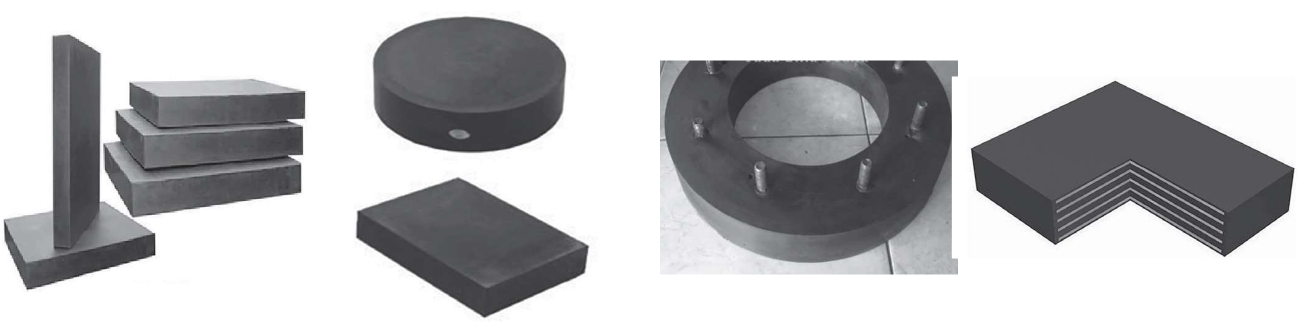
2.1 Background:

An elastomeric bearing facilitates rotation and movement in all directions by elastic deformation, allowing forces to be transferred between components. The form of the elastomeric block might be either round or rectangular. The primary component of an elastomeric block is elastomer, which can be either synthetic or natural rubber. Elastomer can recover its original dimensions and shape when loaded within its elastic range, but it deforms vertically when supporting heavy loads, which causes the rubber to bulge. To maintain the rubber within the permitted elastic range, the deformation must be regulated. Under high vertical loads, the rubber block must be strengthened with horizontal steel plates since excessive distortion might cause sliding. The thickness and quantity of steel plates, which keep the rubber from bulging, are determined by the amount of vertical force the bearing is expected to carry. During the vulcanization process, the steel plates are chemically linked to the rubber in layers. Friction between the superstructure and substructure must also be managed to avoid sliding between the bearings. Restrictive steel plates are included into the elastomer on the top, bottom, and sides of the bearing to achieve this. The bearing is subsequently fastened to the structures using studs, bolts, or pins (Leblouba,M,2022).

Depending on its design and intended use, elastomeric bearings can have a rectangular or circular form. Based on their design, elastomeric bearings can be either laminated elastomeric bearings with steel sheet reinforcement or simple elastomeric pads, which can be shown in Figure 3 below.

2.2 Test strategies

As per BS EN 1337-3, elastomeric bearings undergo various quality assurance tests. In compliance with European standards, testing and controls are performed by bearing manufacturers who are subject to inspection and ongoing oversight by supervisory agencies. The CE label is only applied



a) Plain Rectangular Elastomeric Bearings | b) Laminated elastomeric bearings | c) Circular Elastomeric Bearings | d) Laminated elastomeric bearings

Fig. 3 Different types of Elastomeric Bearings (Source: Internet)

to bearings that meet established quality standards. The following are typical tests carried out on elastomeric bearings:

Short-Term Behavior Tests

- To find the shear modulus G, use the shear modulus test.
- Shear bond determination using a shear strength test.
- Compression test to gauge specimen deformation in accordance with preset compressive stress.
- Rotation behavior under increasing eccentric compressive force of predefined magnitude to detect rotation angle and contact surface loss.

Long-term Behavior Test

- A creep test with a minimum one-month period, a compressive load of 25 MPa, and an ambient temperature of -23°C ± 2°C is used to assess creep in compression.
- To ascertain stress relaxation in shear, conduct a stress relaxation test for a minimum of three months at a pressure of 6 MPa and an ambient temperature of –23°C ± 2°C.

Environment Impact Test

- Heat resistance and accelerated aging test
- Test for salt fog resistance
- The non-slip condition test or adhesive bonding
- Ozone resistance assessment

Dynamic effects behavior: In accordance with BS EN 15129,2009 the anti-seismic device norm, the bearings' behavior in response to dynamic behaviors like impacts, earthquakes, cyclonic winds, etc., is determined.

Advantages of Elastomeric Bearing

- Since reinforcing steels are encased in elastomer, so it the protects against corrosion
- Extended lifespan with minimal maintenance requirements.
- Fit for rotation of big bearings.
- Strong performance in the presence of mild seismic activity.
- Reasonable price.

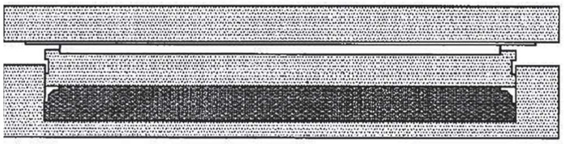
Disadvantage of Elastomeric Bearings

- Dimensioning errors resulting in an excessively short sliding plate, an inadequate amount of elastomeric lamination, and an inadequate quantity of reinforcing steel plate.
- Issues arising from incorrect installation, such as inadequate anchoring and incorrect bearing, substructure, and superstructure connection.
- Defects resulting from substandard product quality, such as rust-eaten steel, insufficient vulcanization, subpar rubber, etc., which cause the rubber to split, slip, or fracture.
- Rubber in the bearing bulging as a result of rotation and compression.
- Shearing strains close to the bearing edge causing delamination from the steel reinforcement.
- Tears during a powerful earthquake, but they are simple to replace in contrast to other kinds of bearings.
- The rubber freezes and becomes rigid in cold weather.
- The rubber's characteristics alter over time due to temperature-related fatigue.

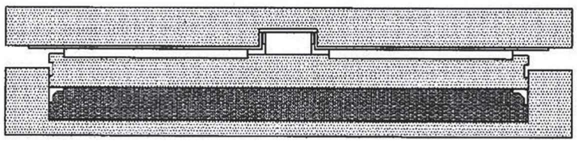
3. Pot Bearings

3.1 Background

Pot bearings can generally withstand higher vertical loads compared to elastomeric bearings, which makes it applicable as launching bearings used during the construction of bridges or lifting bearing used on special bridges that requires lifting of the bridge deck, when needed, and at sea ports for the lifting of cargo containers. Pot bearings allow three-dimensional movements in all directions by sliding and rotation, depending on the design which can be fixed, free sliding, or guided sliding as illustrated below. Pot bearing that slides freely and can move in all directions is unable to support any horizontal load. Pot bearing with central guidance that may move in a single direction and accept horizontal pressures perpendicular to it (S,P..& M,R.,2019). Immovable, fixed pot bearing that can withstand horizontal stresses coming from any angle which are reflected in fig.4 below.



a) Free sliding pot bearing



b) Centrally guided pot bearing

c) Fixed pot bearing

Fig. 4 Different pot Bearings (source: internet)

Advantages of Pot Bearings

- With minimal space needed, they can withstand a significantly high vertical load of up to 30 MN; depending on the design, larger capacities may also be achieved.
- In terms of operation and safety, it is good.
- Because the design is straightforward, production may be automated.
- Produces less elasticity force than other kinds of bearings.
- Distributes stresses evenly throughout the structure as a result of the bearing's hydrostatic pressure.
- When a specific degree of displacement and vertical loading are needed, this is a good technological solution as long as the right sliding mechanisms are used.

Disadvantage of Pot Bearing

- Limited ability to rotate.
- Demands extremely exacting and precise installation.
- Low manufacturing tolerances necessitate extensive manufacturing resources as well as strict quality control throughout the production process.
- Relatively expensive due to the high levels of accuracy, control, and precision needed.
- The elastomer bulging, which reduces rotation ability.

Pot bearings consist of an elastomeric pad enclosed in a steel cylinder or pot, with a steel plate (piston) installed on top. To allow for a sliding plate, a polytetrafluorethylene (PTFE) layer has been added to the piston's surface. Gradient scales can be installed on this sliding plate to track displacement while it is in use. The piston may rotate and tilt around any horizontal axis because the elastomer acts like a viscous fluid when it is under high pressure. The many parts of pot bearings are seen in the Fig. 5

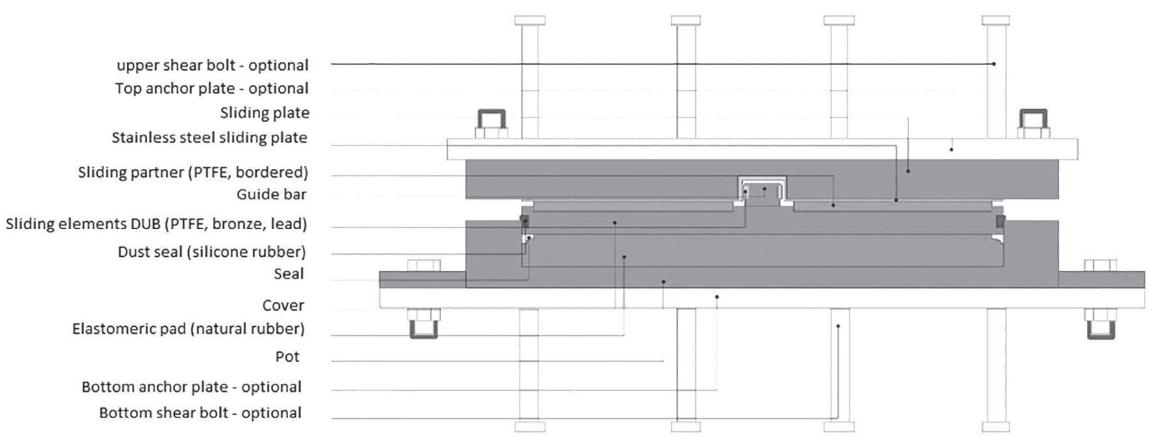


Fig. 5 Components of Pot Bearing (source: mageba.cn)

4. Spherical Bearing

Three-dimensional motions are possible using spherical bearings. They are made to withstand extremely high lateral, vertical, and horizontal loads as well as significant rotational displacements. Similar to pot bearings, their design determines whether they are guided, free-sliding, or fixed. With improved structural features, spherical bearings are intended for use for Incremental launch bearings which is suitable for launching systems used in bridge building; force measurement bearings which is they are used to electronically measure and track forces acting on the structure and uplift protection bearings which are used to handle heavy lifting loads that may arise during a structure's construction or maintenance. Concave and convex plates, mounted on flat sliding surfaces, comprise spherical bearings. The convex plate can be composed of aluminum, brass, chrome, or stainless steel, while the concave plate is composed of smooth-finished steel lined with lubricated dimpled polytetrafluorethylene (PTFE), commonly known as Teflon. Mageba developed a unique type of robo slide which can be reflected in Fig.6. This makes it possible for the convex and concave surfaces to slide past one. The technique allows for rotation in any direction about the horizontal and vertical axes since there is very little friction between the sliding and spherical surfaces. Large tilting degrees are also possible with less resistance and fewer turning moments because of the spherical bearing surfaces (Kumbhar,S.G. et.al.2020)

Advantages of Spherical Bearing

- Installing and replacing spherical bearings is simple.
- Spherical bearings require less maintenance and are reasonably priced given their capabilities.
- Provides more rotational flexibility than pot bearings, making it appropriate for wide and curved bridges that are subject to strong torsion forces and huge turning angles.
- Does not employ rubber or elastomer, thus there are no issues with rubber aging that might impair the bearing's ability to rotate.
- It is appropriate for low temperatures, even down to -50°C.
- Suitable for high-vertical load-supporting structures, generally large displacements from traffic, and quick-bearing movement structures (e.g., high-speed railway bridges).

Disadvantage of Spherical Bearing

- Their high cost can be attributed to their intricate construction.
- PTFE wear.
- The stainless steel sliding plate's corrosion

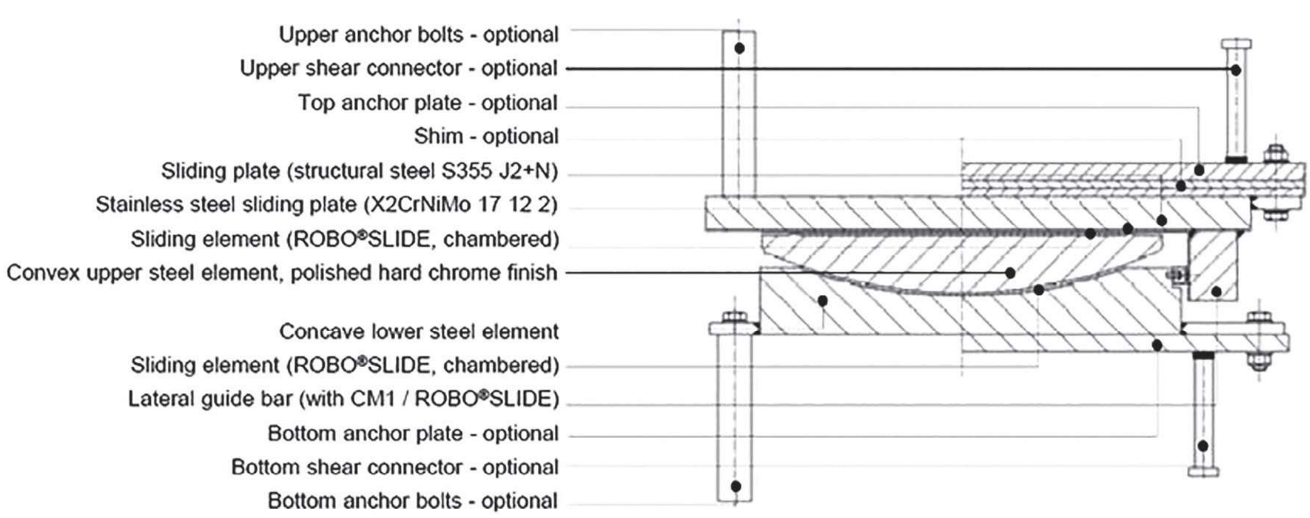


Fig. 6. Components of Spherical Bearings. (Source: mageba.cn)

5. Seismic Isolator Bearing

5.1 Lead Rubber Bearing (LRB)

To offer energy dissipation through damping, a lead core is added to the center of a laminated elastomeric bearing to create a lead rubber bearing. The primary structure consists of steel plates that have been chemically vulcanized to rubber in layers. There may be more than one lead core in an LRB, depending on the design. To make installation easier, doweled plates are affixed to the top and bottom of the steel plates. In addition to providing flexibility, energy dissipation, and damping in the horizontal direction when joined with the lead core, the steel and rubber layers give rigidity, strength, and flexibility in the vertical direction to sustain the weight of the structure they are supporting (Ju, S. et,al, 2020). Lead rubber bearings including laminated rubber bearings can have a rectangular or circular form which is shown in fig. 7 below

Advantage of Lead Rubber Bearing (LRB)

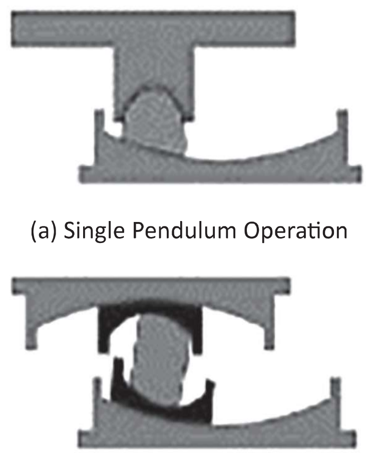
- Effectiveness in dissipating energy
- Stability against seismic loads and isolation of structures through an extension of the natural period
- Economical in terms of seismic safety
- Minimizes the isolated structure's horizontal displacement
- A comparatively longer lifespan with minimal maintenance
- Good re-centering abilities due to its elastic characteristics

Disadvantages of Lead Rubber Bearing (LRB)

- The rubber component aging
- A bearing failure may result from the rubber freezing and stiffening at cold temperatures.
- A large amount of lateral motion might harm the bearing and the supporting structures.

5.2 Frictional Pendulum Bearings

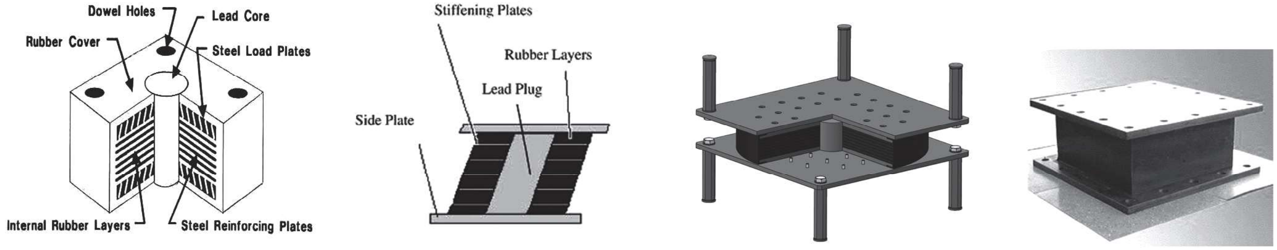
FPB uses the pendulum phenomenon to extend the structure it supports's natural period. Its concave stainless steel surface is moved by an articulated slider, which enables the structure to move in pendulum movements (Peng,T. et.al. 2022). The self-lubricating composite liner, which the producers claim is Teflon or a proprietary equivalent, is applied to the articulated slider which can shown in Fig. 8 below. The concave surface's radius of curvature is the primary determinant of the FPB's natural period.



(a) Single Pendulum Operation

(b) Triple pendulum operation

Fig. 8. Frictional Pendulum Bearing, (Source: Internet)



(a) LRB Components (b) LRB deformation under Loading (c) Circular LRB (d) Rectangle LRB

Fig. 7 Lead Rubber Bearing (LRB), (Source: Internet)

Advantages of Frictional Pendulum

- Effectiveness in re-centering using pendulum movements
- There is no need for bearing restraints since the potential energy of the pendulum serves as a bearing constraint.
- Low coefficient of friction
- There are significant seismic vibrations in the bearings
- Effectiveness in dissipating energy
- Unaffected by variations in temperature
- Able to handle significant displacement
- Superior resilience to torsion
- Strong durability
- Especially appropriate for seismic resistance

Disadvantages of Frictional Bearings

- The bearing radius must be properly designed since the pendulum may be forced out of it by horizontal forces produced by intense seismic activity.
- Needs a significant bearing radius even though it is smaller in height for high forces.
- Technical characteristics and hence potentially costly to build.

5.3 High Damping Rubber Bearings (HDR)

Design Principles

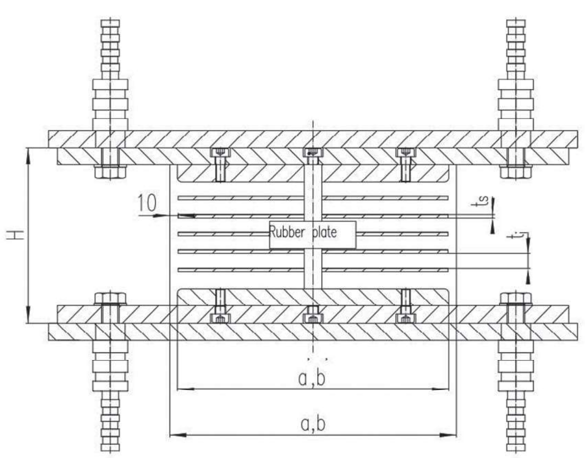
HDRBs consist of multiple layers of high-damping rubber and steel shims. The rubber's inherent damping properties dissipate energy, while the steel layers provide stiffness and support vertical loads. The design must optimize rubber compound composition, layer thickness, and bearing dimensions to ensure effective performance under seismic loads (Park,K.H.et.al.,2023). The different components of HDR bearing can be seen in Fig.9 below

Material Properties

The rubber used in HDRBs exhibits high damping capacity, which is crucial for absorbing seismic energy. The mechanical properties of the rubber, such as shear modulus and damping ratio, are critical parameters influencing the bearing's performance. Steel shims enhance the bearing's vertical load capacity and overall stability.

Seismic Performance

HDRBs are effective in reducing seismic forces and displacements in bridge structures. Their high damping capacity minimizes the energy transmitted to the superstructure, thus protecting the bridge during earthquakes. Studies have demonstrated significant reductions in base shear and improved structural stability with the use of HDRBs.



a,b—Overall width and length of bearing

a',b'—Effective width and length of laminated bearing

t_s—Thickness of steel reinforcing plate

t_l—Thickness of an individual elastomer in a laminated bearing

H—the total nominal thickness of bearing

n—Number of elastomer layers

Fig.9 High Damping Rubber Bearing (HDR), (Source: OVM Company)

Advantages of HDR Bearings

- High-damping rubber bearings offer several benefits for accelerated bridge construction (ABC) projects. Compared to traditional elastomeric bearings, they have higher damping capacity, which can effectively dissipate seismic and other dynamic loads. This can improve the overall structural performance and resilience of the bridge.
- High-damping rubber bearings also have the ability to accommodate larger movements and rotations, making them well-suited for ABC techniques that involve rapid installation and connections. This flexibility can help reduce construction time and traffic disruptions.
- From a constructability standpoint, high-damping rubber bearings are relatively simple to install and do not require specialized equipment or complex connections. This can streamline the ABC process and reduce overall construction costs.

Disadvantages of HDR Bearings

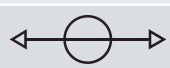
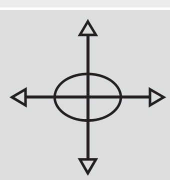
- One potential drawback of high-damping rubber bearings is their higher initial cost compared to traditional elastomeric bearings. The specialized materials and manufacturing process can result in a more expensive solution.
- Additionally, the long-term durability and performance of high-damping rubber bearings in bridge applications may be a concern, as their behavior under sustained loads and environmental factors is not as well-established as traditional bearing types.
- Maintenance and inspection of high-damping rubber bearings may also present challenges, as their internal damping mechanisms can make it more difficult to assess their condition over time. This may require specialized inspection techniques and procedures.

In summary, while high-damping rubber bearings offer advantages in terms of dynamic performance and constructability for ABC projects, their higher costs and potential long-term durability concerns should be carefully considered when evaluating their use in bridge applications.

Articulation Of Bridge Bearing

Articulation is the process of choosing and arranging bearings for use in bridges based on how much they can move. Bridge bearings can be translationally and rotationally coupled, fixed, translational, or moveable. The types of bearings that are employed impact how much the bridge structure moves overall and re-centers (returns to its initial position after movement). The location of the fixed bearings also affects how much the bridge moves and re-centers. Therefore, it is crucial to know which bearings should be permanent or moveable. Although the bridge designer has the last decision on this matter and can draw direction from relevant rules, some workable solutions are shown below in Fig.10, as per Spennteknikk (the bearing manufacturer). Table 1 shows the bearing movement legends and bearing type used.

Table 1: Bearing Description by movement

Legend	Details	Types of Bearing
	Fixed in translation, rotation in all directions	Pin, fixed enclosed (pot, spherical, disc) pin rocker, fixed elastomeric
	Translation in one direction and rotation in all direction	Guided enclosed (pot, spherical, disc), restrained elastomeric
	Translation in one direction, no rotation	Rocker, sliding plate, roller
	Translation and rotation in all directions	Pot, spherical, elastomeric, LRB, FPB, disc

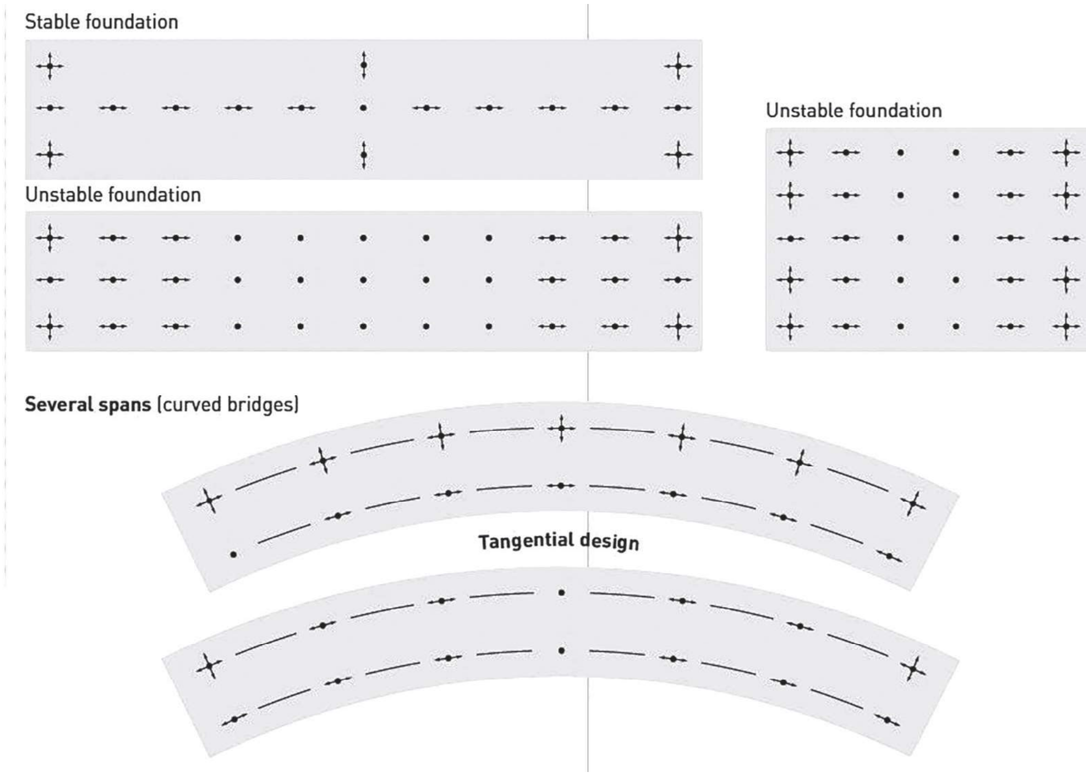


Fig.10: Example of Bearing Articulation (Source: spennteknikk website)

Monitoring of bridge bearings

Bridge bearing monitoring is crucial because it offers insight into how bearings really behave while they are in use. This knowledge is crucial for creating bearings that can withstand heavier loads and require less maintenance and upkeep over time.

Failures may be predicted and avoided by keeping an eye on factors like stresses, deformations, corrosion, fractures, forces, dynamic response, etc. in bridge bearings. It also aids in the preparation of corrective actions required in the event of a failure. Parameters may now be monitored remotely at regular intervals thanks to advancements in structural monitoring systems. The collected data can also be saved and sent via GPRS to computer systems for convenient monitoring. Monitoring systems that integrate thresholds and tolerance limits can activate warning or alarm signals when predefined limits are surpassed (Fu,Y. et.al.,2001).

It's also critical to understand that monitoring systems must be observed, as malfunctions such as sensor deterioration, power outages, temperature fluctuations, etc., might compromise the system's dependability. An integrated monitoring system within the bridge management system is a good one(Cheng,X.X, et.al. 2020). Table 2 below describes about monitoring parameters and instrument.

Inspection methods for bridge bearings

The many types of inspection techniques are displayed in the table below. The techniques utilized to examine cracks in steel buildings are also utilized to examine fractures in steel bearings. The majority of inspection techniques discussed are non-destructive techniques(Aria,M.&Akbari,R.,2013). Table 3 below shows the different methods of bridge-bearing inspections.

Table 2. Monitoring parameters and instruments

Parameter	Measuring Instrument	
Strain	Strain sensors	- Vibrating wire strain gauges - Electrical-resistance wire strain gauges - Interferometry fiber optic strain gauges
Displacement	Displacement transducers	- Capacitive displacement transducers - LVDT (linear variable differential transformer) displacement transducers
Temperature	Temperature sensors, thermistors	- Embedded thermocouple (contact) - Infrared sensors (noncontact)
Forces	Force sensors	- Load cells
Corrosion	Corrosion Sensors	- Electric resistance Sensors - Linear polarization resistance sensors
Dynamic response (acceleration)	Accelerometer	- Piezoelectric accelerometers - Piezo-resistive accelerometers - Capacitive accelerometers - Microelectromechanical system (MEMS) accelerometers
Cracks	Crack sensors, crack-first sensors, strain sensors, LVDT transducers	

Table 3 Method of Bridge Bearing Inspection

Major Problems	Possible cause	Inspection method
- Misalignment, - displacement, - deformation, - damage, - spalling, - movement - condition etc.	- Settlement - Pounding effect - Excessive loading - Seismic activities - Improper installation - Use of poor concrete for piers - and abutments - Improper connections and - Anchorage	- Visual inspection - Taking measurements - Surveying - knocking off adjacent concrete - surfaces in the bearing area, in order to detect hollow spaces
Cracks	- Fatigue - High stress concentration - Excessive loading - Extreme low temperatures - Improper connections and - anchorage - Low bearing capacity	- Visual inspection - Acoustic emissions testing - Corrosion sensors - Computer tomography - Dye penetrant - Coating tolerance thermography - Radiographic testing - Magnetic particle - Ultrasonic through method - Ultrasonic pulse catch - Tensile strength test - Chemical analysis - Charpy impact test - Brinell hardness test - Eddy current - Ultrasonic testing - Robotic inspection

Major Problems	Possible cause	Inspection method
Corrosion	- Exposure to salt, de-icing salts - etc. - Lack of cleaning maintenance - Bird nests, excretes and other - animal activities - Exposure to acidic rainwater, - rainwater, snow etc. - Ineffective expansion joints - Lack or ineffective lubrication - Poor or ineffective corrosion - protection - Bad drainage conditions	- Visual inspection - Section loss monitoring - Coating tolerance thermography

Conclusion

Evaluation of the many literature available demonstrates that bearings are effective in lessening the consequences of the damage that seismic activity causes to the bridge. These bearings reduce forces and moments on the bridge more effectively than others and this research paper has examined the role and performance of bridge bearings within the context of accelerated bridge construction (ABC) techniques. Here are some of the major points that drawn from this study

- The study began by reviewing the ABC rating procedure, and then focused on the state-of-the-art in bridge bearing technologies. It found that high-performance elastomeric bearings are better suited for ABC applications due to their damping characteristics, movement tolerance, and rapid installation.
- The study identified however, based on the type of bridge, usability requirements, site based conditions, different kinds of bearing can use several advantages of high-damping rubber bearings in accelerated bridge construction projects, but also identified several potential drawbacks. Transportation agencies and engineers must carefully weigh these factors when selecting the most appropriate bearing solution for a given ABC undertaking.
- The study, evaluation, and monitoring of bridge bearings within the context of Accelerated Bridge Construction has demonstrated significant advancements and pivotal findings that contribute to the field of civil engineering. Bridge bearings play an essential role in ensuring the stability, durability, and performance of bridges constructed using ABC methodologies.
- Modern bridge bearings exhibit satisfactory performance under earthquake conditions and are vital for ensuring the safety of bridges in earthquake-prone areas.
- Advancements in material science and engineering have led to more sophisticated and resilient bridge bearings, providing better seismic performance.
- Monitoring bridge bearings post-construction is essential for maintaining long-term structural health. This proactive approach ensures the safety of bridge users.
- As ABC methodologies continue to evolve, bridge bearings will remain central to achieving faster, more efficient, and cost-effective bridge construction.

The recommendations and best practices outlined in this study can serve as a valuable resource for transportation agencies, engineers, and researchers actively engaged in the development and implementation of ABC projects.

References

Gautam, B. P., Zhou, Y., Qiu, Z., & Guo, S. (2019). A Semi-Empirical Deflection-Based Method for Crack Width Prediction in Accelerated Construction of Steel Fibrous High-Performance Composite Small Box Girder.

Materials, 12(6), 964. https://doi.org/10.3390/ma12060964

Gautam, B. P., Xiang, Y., Liao, X. H., Qiu, Z., & Guo, S. (2019). Experimental Investigation of a Slip in High-Performance Steel-Concrete Small Box Girder with Different Combinations of Group Studs. Materials, 12(17), 2781. https://doi.org/10.3390/ma12172781

Khan, M.A. (2015), Accelerated Bridge Construction: Best Practices and Techniques; Elsevier/BH: Amsterdam, The Netherlands; Boston, MA, USA, (pp. 13,411-418), ISBN 978-0-12-407224-4.

Xiang, Y.Q.; Zhu, S.; Zhao, Y (2018). Research and development on Accelerated Bridge Construction Technology. China J. Highw. Transp. 31, 1–27.

Niemierko, A. (2016b). Modern bridge bearings and expansion joints for road bridges. Transportation Research Procedia, 14, 4040–4049. https://doi.org/10.1016/j.trpro.2016.05.501

Bodewig, A. H., Pape, F., & Poll, G. (2024). Optimizing stainless steel bearings: Enhancement of stainless steel bearing fatigue life by Low-Temperature Forming. *Metals*, 14(5), 512. https://doi.org/10.3390/met14050512

Leblouba, M. (2022). Stability analysis of elastomeric bearings in bridge structures. Advances in Bridge Engineering, 3(1). https://doi.org/10.1186/s43251-022-00062-1

European Standards. (n.d.). BS EN 1337-3:2005 Structural bearings Elastomeric bearings. https://www.en-standard.eu. https://www.en-standard.eu/bs-en-1337-3-2005-structural-bearings-elastomeric-bearings/

BS EN 15129:2009 Anti-seismic devices. (n.d.). https://www.intertekinform.com/en-us/standards/bs-en-15129-2009-264834_saig_bsi_bsi_612351/

S, P., & M, R. (2019). Investigation and analysis of bridge pot bearing. International Research Journal of Multidisciplinary Technovation, 288–297. https://doi.org/10.34256/irjmtcon39

Kumbhar, S. G., P, E. S., & Desavale, R. (2020). Theoretical and experimental studies to predict vibration responses of defects in spherical roller bearings using dimension theory. Measurement, 161, 107846. https://doi.org/10.1016/j.measurement.2020.107846

Ju, S., Yuantien, C., & Hsieh, W. (2020). Study of lead rubber bearings for Vibration Reduction in High-Tech Factories. *Applied Sciences*, 10(4), 1502. https://doi.org/10.3390/app10041502

Peng, T., Yan, B., & Li, F. (2022). The hysteresis model of the friction pendulum bearing based on the moment balance theory. *Ain Shams Engineering Journal/Ain Shams Engineering Journal, 13(4)*, 101707. https://doi.org/10.1016/j.asej.2022.101707

Park, K. H., Mazda, T., & Kajita, Y. (2023). Research on hysteresis model of high damping rubber bearings considering mechanical properties based on dynamic Loading test. In *Lecture notes in civil engineering* (pp. 1069–1080). https://doi.org/10.1007/978-981-99-4049-3_82

Fu, Y., & DeWolf, J. T. (2001). Monitoring and Analysis of a Bridge with Partially Restrained Bearings. *Journal of Bridge Engineering*, 6(1), 23–29. https://doi.org/10.1061/(asce)1084-0702(2001)6:1(23

Cheng, X. X., B, F., MA, Chen, J. Q., Dong, B., & Wu, G. (2020). Bearing repair and monitoring for Poyanghu Cable-Stayed Bridge. *Advances in Civil Engineering*, 2020, 1–15. https://doi.org/10.1155/2020/8819360

Aria, M., & Akbari, R. (2013). Inspection, condition evaluation and replacement of elastomeric bearings in road bridges. *Structure & Infrastructure Engineering/Structure and Infrastructure Engineering*, 9(9),918–934. https://doi.org/10.1080/15732479.2011.638171