Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 1, No.4, January : 2025

STUDY OF BRIDGE BEARINGS

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Abstract
The bearings are the important part of bridge, it plays an important role in transferring the loads, reducing vibrations, handling expansion and contractions due to thermal stresses. These are mainly divided into two types; those are fixed bearings and expansion bearings. Bearings are of many types such as elastomeric bearings, spherical bearings, pot bearings etc. In this thesis we will learn about bearings, its uses, its types, installation procedures, service life. In this research we will study about functions of bearings, types, movement, installation process and its life. The results suggest that how the life of bearings and what precautions should be taken.
We have also studied Maurer's MSM materials used in Spherical bearings manufactured by Sanfield (India) Ltd.

1 Introduction

A bridge bearing can be defined as a component of a bridge which provides a resting surface between bridge piers and the bridge deck. The purpose of a bearing is to transfer traffic load and self-weight of superstructure to substructure and it also allow controlled movement in both horizontal and vertical direction evolved due to thermal expansion, shrinkage, settlement, or other dynamic forces, and thereby reduce the stresses involved.
Essentially, they act as interfaces between the bridge superstructure and substructure, enabling the bridge to safely accommodate shifts and loads while preventing damage to the structure.
Possible causes of movement are thermal expansion and contraction, creep, shrinkage, or fatigue due to the properties of the material used for the bearing. External sources of movement include the forces due to moving vehicles, settlement of the ground below, thermal expansion, and seismic activity. It also restricts relative motion in specified direction and mitigates friction between two moving parts.

1.1 Until 18th century all the bridges were built with stone, these structures were little affected by environmental changes and any slight movement which may occur were compensated either by deformation of constituent materials or by small displacement at their supports.
But in 19thcentury, with the introduction of Steel and cast iron in the structure bridges they become flexible and there was expansion and contraction due to temperature changes, to deal with that, bearings were introduced, which can withstand movement due to expansion and contraction.

1.2 Bearings form an integral part of a bridge whose main function comprises of transfer of vertical load, connection of superstructure to substructure, allowing movements in vertical and horizontal direction as well as rotation, damping of forces and so on. Out of all the bearings available, flexure bearings rely on elastic properties of a compound used. Some elastic materials do fail after repeated bending even at low loads, but the selection of a quality material to be used as a reinforcement in elastomers can prolong the life of a bearing.

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Fig. Bearing

The motion in the bridges can possibly be due to stresses resulting from temperature changes, seismic action. These bridge bearings are also used to dampen some of the vibrations that are generated due to the movement of vehicles and sometimes due to natural calamities.

1.3 Key Functions of Bridge Bearings:

1. Load Transfer: Bearings transfer vertical, horizontal, and rotational forces from the bridge deck to the substructure, including piers and abutments.
2. Movement Accommodation: Bearings allow for controlled movement of the bridge due to temperature changes, settlement, and other factors (e.g., traffic-induced dynamic loads).
3. Rotation Control: Bearings help the bridge to rotate (especially in curved bridges or those with irregular movements) without excessive stresses on the superstructure or substructure.
4. Vibration Damping: Bearings can help dampen vibrations caused by traffic or other external forces, ensuring long-term stability of the bridge.

1.4 Classification

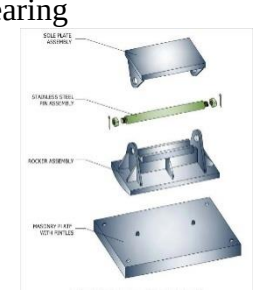
Bearings can be classified based on their design, these types of bearings are used in different types of bridges as per their requirements, and Classification of bearings based on design are as follows:

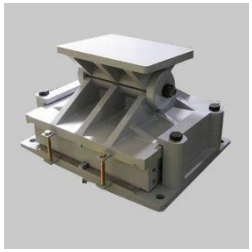
1. Rocker and pin bearings
2. Elastomeric bearings
3. Roller bearings
4. Curved bearings
5. Pot bearings
6. Disk bearings
7. Spherical bearings

Rocker and pin bearings

A rocker bearing is a type of expansion bearing. It consists of pin at the top that permits rotations and a curved surface at the bottom that permits translational movement.

Fig. Rocker and pin bearing





Elastomeric bearings

It consists of elastomer manufactured from synthetic or natural rubber and can take both translation and rotation movements through elastomer deformation.

Materials: Typically made from layers of rubber (natural or synthetic) combined with reinforcing steel plates.

Use: Common in modern bridge construction for their ability to accommodate movement (both translational and rotational) and their durability.

Advantages: Good for small to medium spans, relatively low cost, and simple installation.

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Fig. Elastomeric bearing

Roller bearings

Roller bearings consist of one or more rollers between two parallel steel plates. Single roller bearings facilitate both translational and rotations in longitudinal direction. A group of rollers accommodate only translational in longitudinal direction. Here, rotations are provided by combining rollers with a pin bearing.

Materials: Made of a cylindrical roller that allows the bridge superstructure to roll across a surface.

Use: Typically used where large horizontal movements are anticipated, such as in large movable or expansion bridges.

Advantages: Allows large translational movements.

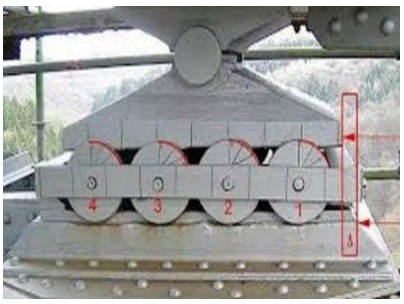

Fig. Roller bearing

Curved bearings

Curved bearings consist of two matching curved plates with one sliding against the other to accommodate rotations. The curved surfaces used can be either cylindrical which allows the rotations about one axis or spherical which allows the bearing to rotate about any axis

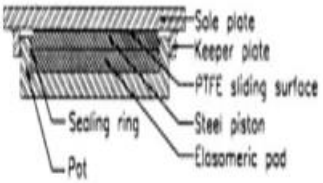

Fig. Curved bearing

Pot bearings

Pot bearings consist of a plain elastomeric disk confined in a shallow ring or a pot. Steel piston that is closely fitted to the steel ring is used to transmit the vertical loads.

Materials: A high-strength elastomer (rubber) is confined within a metal pot-shaped housing.

Use: Suitable for larger bridges and where there are significant loads or movement requirements.

Advantages: Can handle larger forces and movements compared to elastomeric bearings. Often used in combination with sliding bearings.

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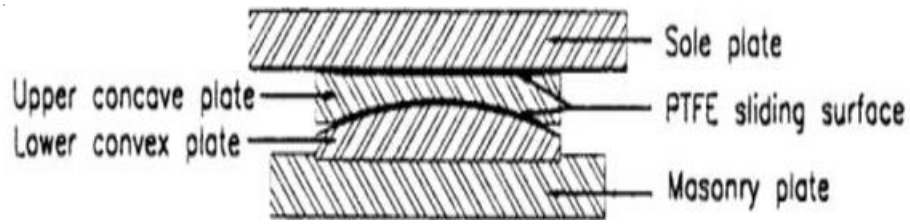


Fig. Pot bearing

Disk bearings

Disk bearing utilizes a hard elastomeric disk to support the vertical loads and a metal key in the centre of the bearing to resist the horizontal loads. The deformation of the elastomers accommodates, rotational movement. A PTFE slider is used to accommodate the translational movement.

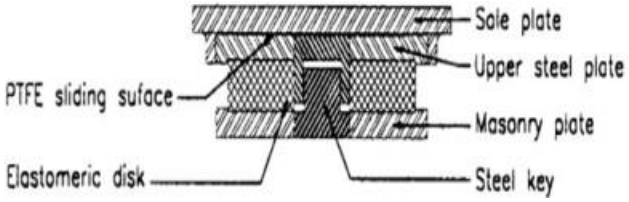


Fig. Disk bearing

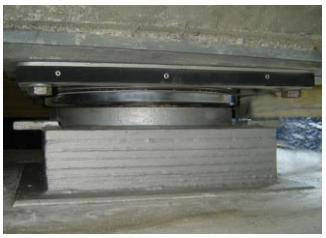
Spherical bearings

It consists of steel plate enclosed with edge sliding guide and stainless-steel panel for sliding controlling, under the stainless-steel panel is a PTFE sheet, which is recessed into the steel to a depth and contains a special lubricant to ensure permanent lubrication of the sliding surfaces.

Materials: A spherical metal surface that allows for both translational and rotational movement.

Use: Often used where there is a combination of horizontal and vertical movement, particularly in complex bridge designs.

Advantages: Provide flexibility for both translation and rotation, making them suitable for bridges subjected to complex forces.



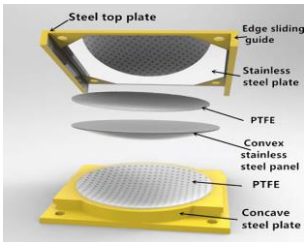


Fig. Spherical bearing

1.5 Factors Affecting the Choice of Bridge Bearings

1. Load Conditions: The magnitude and type of loads (dead load, live load, seismic load, etc.) affect bearing selection.
2. Movement Requirements: Bridges with high thermal expansion, seismic considerations, or other movement needs will require bearings capable of accommodating such movements.
3. Bridge Span: Longer spans tend to require more specialized bearings to accommodate larger movements and forces.
4. Environmental Conditions: Exposure to extreme temperatures, moisture, or aggressive chemicals (e.g., road salts) can influence bearing material choice.
5. Maintenance and Durability: Bearings must be durable and require minimal maintenance over the life of the bridge.
6. Cost: Bearing systems can vary significantly in cost depending on complexity, material, and design requirements.

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1.6 Maurer MSM® Sliding material

Generally, in spherical bearings PTFE material is used, But while researching I found out that Sanfield (India) ltd is manufacturing bearings with higher load capacity and longer life. Those bearings use MSM® material.

MSM® is Maurer's patented high performance sliding material for structural bearings. MSM® stands for MAURER Sliding Material.

Ultra-high molecular polyethylene modified with various additives used in this enhances sliding characteristics. In comparison to usual PTFE, MSM® is characterised by substantially higher durability, twice as high allowable pressure and therefore smaller dimensions as well as lower sliding resistance.

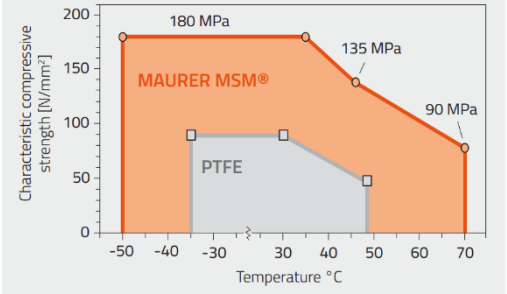
It does not contain regenerated or filling material or any environmentally hazardous component, like fluorine or chlorine, and is insensitive to chemical contamination and ageing.

Characteristics of MSM® Material

- It is particularly suitable for high-speed motion, displaying less wear at a 7.5-fold displacement speed compared to PTFE.
- It can take high loads (in comparison to PTFE double contact pressure).
- It is suitable for use within a temperature range from-50°C to +70°C (whereas PTFE is suitable only from -35°C to+48°C with decreasing load bearing capacity at temperatures above 30°C).
- It causes little friction: The design value of friction is < 1.5%at -5°C, < 2% at -35°C and < 3% at -50°C effective bearing temperature.
- It reaches an extremely long service life (compared to PTFE, 5-fold accumulated sliding displacement without visible signs of wear).
- It can accommodate for concrete setting and evenness deviations due to its elastoplastic behaviour (where as rigid sliding materials may lead to local overstress and wear).

* The compression at ULS shall be at least 1.0 mm.

MSM®	PTFE	MAURER MSM®
Certified sliding distance	10 km	50 km
Certified sliding apeed	2 mm/s	15 mm/s
Design friction	3%	2%
Design life	10 years	50 years



PARAMETER	MSM® SPHERICAL	PTFE POT	ELASTOMERIC
Design pressure on the bearing	128 N/mm²	46 N/mm²	15–30 N/mm²
Size requirement	small	medium	large
Movement	no limitation	no limitation	shear of rubber
Rotation capacity	No limitation	limited	limited
Temperature	-50 °C – +70 °C	-35 °C – +48 °C	-40 °C – +50 °C
Speed	15 mm/s	2 mm/s	Depends on stiffness
Forces caused by a displacement	low	medium	high
Ageing	no ageing	yes	yes
Lifetime expectation	> 50 years	10 – 25 years	10 – 25 years

Fig: MSM vs PTFE

1.7 Common Problems with Bridge Bearings:

1. **Wear and Deformation:** Over time, bearings can wear out due to constant movement, especially if they are not properly lubricated or if the bridge experiences extreme movement.
2. **Corrosion:** Bearings exposed to moisture or de-icing chemicals can corrode, leading to decreased functionality.
3. **Improper Load Distribution:** If a bearing is not properly installed or if the load is unevenly distributed, it may fail prematurely.
4. **Thermal Expansion Issues:** If the bearing is not designed to accommodate expected thermal movements, it may lead to stress fractures or other damage to the bridge.

1.8 Recent Innovations:

- **Smart Bearings:** These bearings incorporate sensors and monitoring devices to track their performance and detect early signs of failure, such as excessive movement or wear.
- **Advanced Materials:** Research into better-performing elastomers, composites, and corrosion-resistant metals is ongoing to extend the lifespan of bridge bearings.

1.9 Service life of bearings

Generally, infrastructure like bridges require large amount of investments, so they are designed for longer lifespan. For designing them for longer lifespan also needs their components also have longer lifespan. So, bearings also need longer lifespan.

Generally assumed life of bearings is 30-50 years, within the life-cycle of bridge bearings may be replaced 2-3 times. Bearings also need maintenance; timely maintenance may increase lifespan of bearings.

Bearing's life may be affected by following factors:

- **Due to external causes**
  - **Leakage in deck joints**

Leakage in deck expansion joint, that may be open or sealed have adverse impact on bridge bearings. Leakage through these joints may allow deck drain to leak through bearings, which causes corrosion in bearing and this will affect rotation and movement of bearings.

  - **Improper bearing orientation**

In guided bearings they allow only one directional movement, if bearings orientation is not correct and as per drawing then there may not be proper movement and thus it may damage bearings due to movement in other direction.

  - **Improper installation**

Improper installation may also lead to bearing damage, loose bolts, improper level of bearing can cause damage as loose bolts may lead in development of shear force, and improper level of bearing may cause in non-uniform load on bearing, which can cause damage in its internal mechanism.

  - **Due to natural hazards**

Natural hazards such as earthquake, heavy rain and fire may damage bearings. Heavy rain can cause corrosion in bearings, fire may damage parts of bearings and due to earthquake, and the movement of bearings would be more than its tolerance that would result in damage.

- **Due to internal causes**
  - **Damage due to load**

Traffic load mainly due to heavy vehicles can cause damage due to wear or overload. Due to movement of vehicles, vibrations and horizontal loads which causes wear in sliding surface of bearings.

  - **Damage due to lack of maintenance**

Lack of maintenance also reduces life of bearings, proper cleaning, painting will reduce risk of corrosion, and thus bearings life would be increased.

  - **Wear and tear of components**

Bearings will wear and tear with time as they always have movement due to traffic and thermal conditions.

2 Objective

As we have studied about major problems in bearings, we have researched in them for finding ways to remove or reduce those problems so the main objective of our research are as follows:

- Defining parameters to choose best bearings.
- Improving bearings life.
- Designing a bearing using staad pro and manual calculation.
- Study of MSM sliding material.

3 Literature review

Wisdot bridge manual (2021) Analysed the types of bearings, their stability, High load multi rotation. It also showed an example for designing steel reinforced elastomeric bearing.

Bridge bearings, Indian railway Institute of civil engineering (2014) analysed the factors for choosing best bearing for the construction of railway bridges, in this various factor like cost, life, design, maintenance has been considered.

Ankit Gupta, Diwakar Prakash Verma, Jagdish Singh Dasouni and Girija Shanker (2014) Design of POT-PTFE bearing is preside by minimum average stress on the PTFE disc, elastomer pad and the plate at which the system is fixed. It's obvious that the maximum stress developed in PTFE disc, elastomer pad and top plate is considerable as a safe design. It is also obvious that the stresses developed in the POT-PTFE bearing is also under critical stress as per the design parameters. This work concludes that the POT PTFE bearing is useful where heavy load is under consideration.

Maurer introduced its Patented MSM® bearings, these bearings are high performance, which can be used on bridges with high-speed limits and heavy load, and also have longer life span.

Rocking and Hinged Bearings: These bearings are designed to permit rotation and are often used in seismic regions to accommodate ground movement without compromising the structural integrity of the bridge. Research by **Takeda et al., 2014** shows that these bearings provide enhanced performance during seismic events by absorbing energy through elastic deformations.

Rubber and Elastomeric Materials: Research on elastomeric bearings emphasizes their resilience to deformation, their ability to return to their original shape after load removal, and their overall longevity. Studies by **Zhou et al., 2011** found that natural rubber-based bearings exhibit excellent fatigue resistance and durability under dynamic loading conditions.

Seismic Design: Research by Lee and Wang, 2012 discusses the importance of seismic isolation in bridge bearing design. Bearings designed to perform under seismic conditions are critical for minimizing the effects of ground movement on the bridge structure. Base isolators and elastomeric bearings with damping features are often used to prevent structural failure during earthquakes.

Smart Bearings for Seismic Monitoring: With advancements in sensor technology, there has been growing interest in using "smart" bearings that can actively monitor the seismic response of a bridge during an earthquake. Research by **Zhu et al., 2020** demonstrates the potential of embedding accelerometers and strain sensors into bearings to provide real-time data for damage detection and post-event analysis.

Dynamic Loading in High-Speed Rail Bridges: Research into bearings for high-speed rail bridges is focusing on minimizing vibrations and ensuring smooth transitions between the superstructure and substructure. **Yoshida et al., 2020** explored the performance of elastomeric bearings under the dynamic loads induced by high-speed trains, which cause high-frequency vibrations and rapid changes in stress. They found that bearings with higher damping properties and optimized geometric design reduce these vibrations, enhancing comfort and reducing wear.

Fatigue Resistance and Longevity: Bearings used in high-speed rail bridges must have excellent fatigue resistance due to the cyclical nature of train loads. **Wang et al., 2015** proposed advanced composite bearings for use in high-speed rail applications, highlighting their improved fatigue resistance and ability to withstand the high-frequency cycling loads experienced in these scenarios.

Hybrid Bearings for High-Speed Rail: Hybrid bearings that combine elastomeric materials with steel or composite components have shown promise for use in high-speed rail bridges. These bearings can be tuned to meet the specific dynamic loading conditions of high-speed trains. **Yu et al., 2021** investigated hybrid bearings with integrated damping systems and their effectiveness in reducing both vertical and lateral vibrations in high-speed rail bridges.

Long-Term Durability and Monitoring: As bridges age, the bearings' long-term durability becomes a major concern. **Jones et al., 2020** investigated the degradation of bearings over time and

emphasized the need for continuous monitoring using sensors embedded in the bearings to track performance metrics such as displacement, temperature, and strain.

5 Research methodology

For researching about bridge bearings, we firstly gained information about bearing, its functions, types, installation procedure, its life and problems faced in them, then we had researched on effects on the bearings after 10-15 years of installation. Then we have listed impacts on those bearings, and compared them with other types of bearings. So that we can find which bearing should be best suited. We have also saw bearing installation step by step and noted how installation is done, type of bearings they are using, what are the causes of improper installation and how to overcome those problems, we also researched about their possible impact on bearings.

We have also studied test results on MSM bearings conducted at National Material Testing Institute of the Stuttgart University of Technology (MPA).

6 Conclusion

Here's some results of MSM bearings

These test results are from a test conducted at National Material Testing Institute of the Stuttgart University of Technology (MPA).

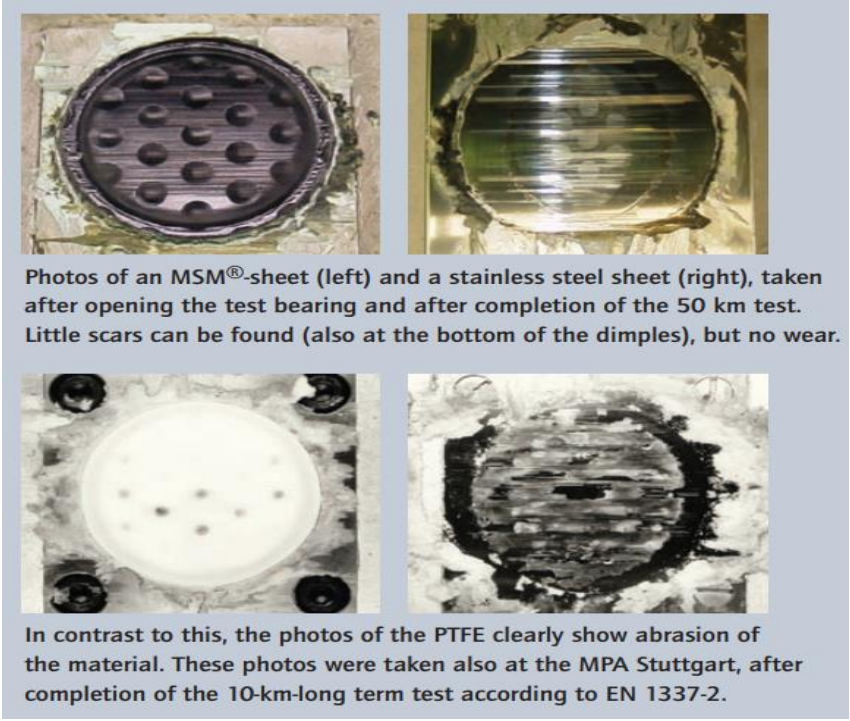


Fig – MSM vs PTFE Test results

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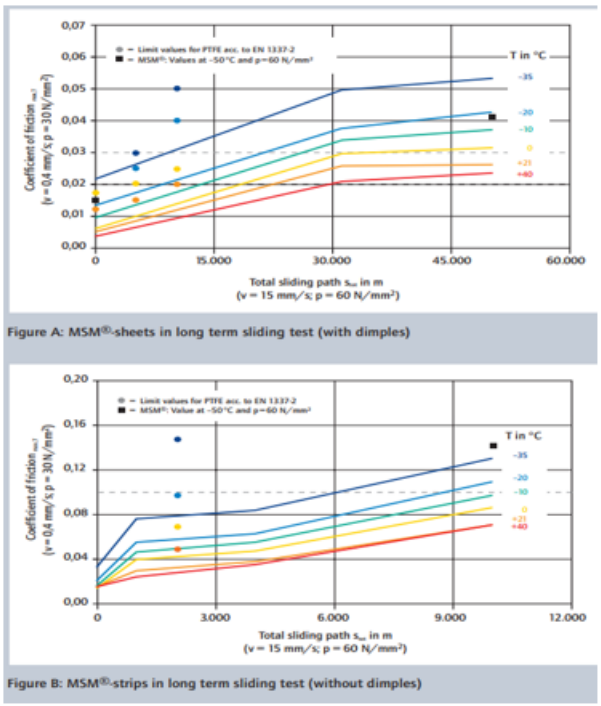

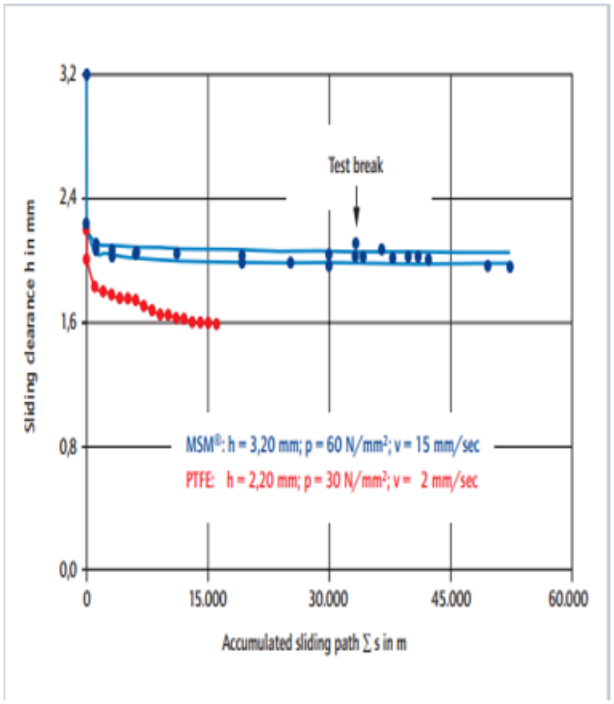

Fig – MSM vs PTFE Test results

In this research we have also find out the measures by which we can increase life of bearings:

- Timely inspection of deck joints, if any leakage found then it should be fixed as soon as possible, especially before rainy seasons.
- Timely inspection of bearings, its pedestal and bolts that has been used to fix them with deck. If there is need of repair that should be done at a time, and if any bearing needs replacement it should be replaced as soon as possible, so that its impact should not be there on the other bearings.
- Orientation and design specification should be rechecked before transferring loads on the bearings.
- Bolts should be tightened propel and there shouldn't be any gap between top plate and pedestal.
- Pedestal should be cured properly.
- There should be checkpoints at the both ends of bridge, so that overloading vehicles can't enter on the bridge.
- Design standards and quality reports of bearings should be checked before installation.
- Timely maintenance of bearings should be done.

Acknowledgement

I would like to express my sincere thanks to **Mrs. Manish Patkar**, for her valuable guidance and support in completing my project.

I would also like to express my gratitude towards **Dr. Ravindra Gautam, Dr. Kashfina Kapadia Memon and Sanfield (India) Ltd.** for giving me this great opportunity to do a project on "**Study of bridge bearings and its types"**. Without their support and suggestions, this project would not have been completed.

Finally, I would like to thank

Mr. Mahesh Rajwani & Ms. Laveena Rajwani

Directors, Sanfield (India) Ltd.

Who helped me a lot in finishing this thesis.

Pragyesh Gour

Permission for using Patented Content

Industrial Engineering Journal
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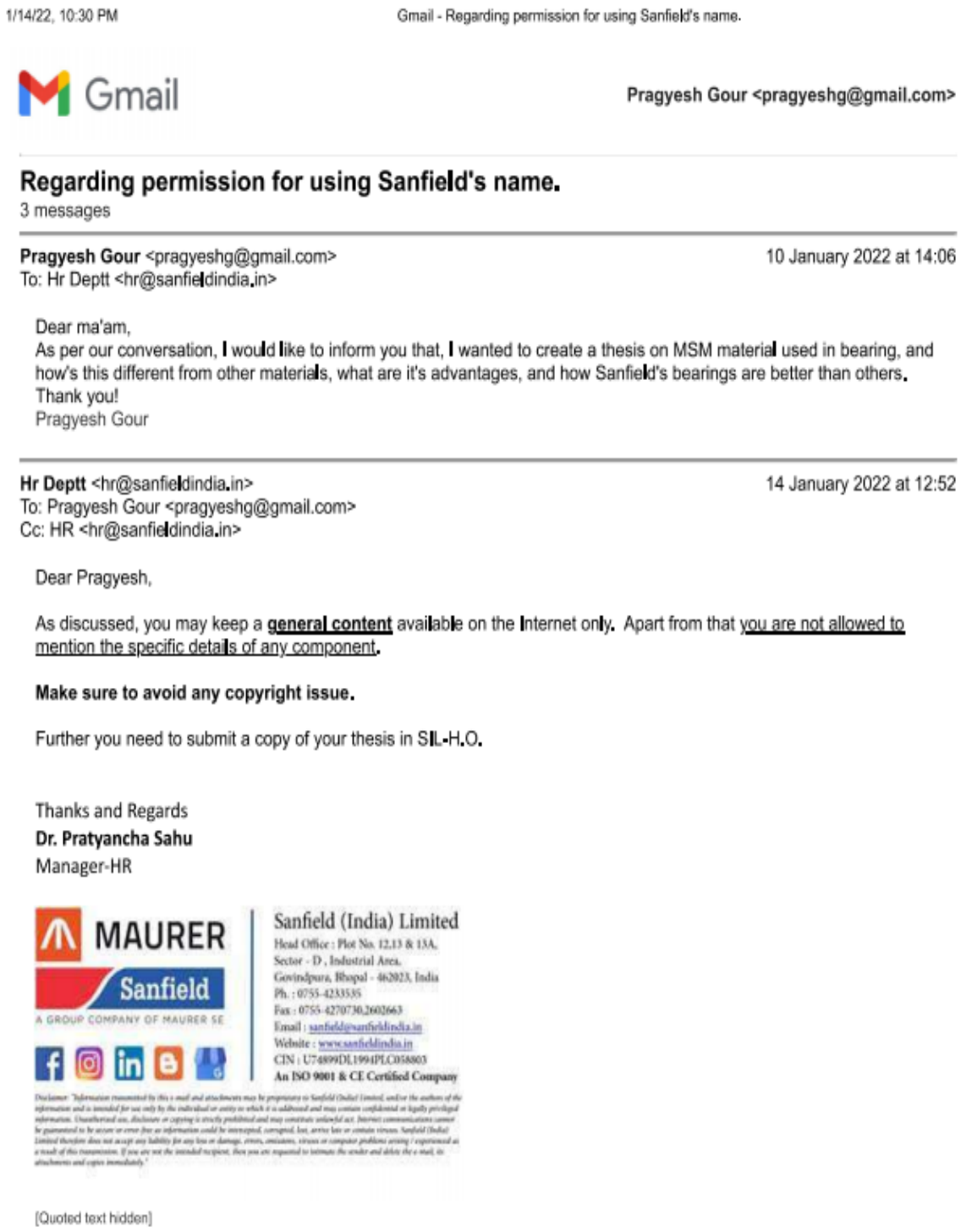

1/14/22, 10:30 PM Gmail - Regarding permission for using Sanfield's name.

Gmail Pragyesh Gour <pragyeshg@gmail.com>

Regarding permission for using Sanfield's name.
3 messages

Pragyesh Gour <pragyeshg@gmail.com> 10 January 2022 at 14:06
To: Hr Deptt <hr@sanfieldindia.in>

Dear ma'am,
As per our conversation, I would like to inform you that, I wanted to create a thesis on MSM material used in bearing, and how's this different from other materials, what are it's advantages, and how Sanfield's bearings are better than others.
Thank you!
Pragyesh Gour

Hr Deptt <hr@sanfieldindia.in> 14 January 2022 at 12:52
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References

1. **Clarke, A., & McDonagh, C. (2010).** Bridge bearings: Design and maintenance considerations. *Engineering Structures*, *32*(3), 1435-1447.
2. **Zhou, M., & Bai, J. (2015).** Recent developments in bridge bearing technology: A review. *Construction and Building Materials*, *74*, 242-256.
3. **Zhang, X., & Wang, L. (2019).** The performance and application of bridge bearings in seismic regions: A comprehensive review. *Journal of Bridge Engineering*,
4. **Kang, Y., & Park, S. (2013).** A study on the durability and performance of elastomeric bearings in bridges. *Journal of Structural Engineering*, *139*(8), 1343-

5. **Li, L., & Liu, Z. (2018).** Research and application of high-performance bridge bearings: Review and perspectives. *Materials Science and Engineering: A, 736*, 85-93.
6. **Huang, Y., & Sun, Q. (2020).** Advances in bridge bearing materials and designs for enhanced durability: A review. *Construction and Building Materials, 250*, 118875.
7. **Gao, S., & Huang, Y. (2017).** A review of the performance of bridge bearings under extreme environmental conditions. *Structural Control and Health Monitoring, 24*(5), e1904.
8. **Sweeney, P., & Kane, M. (2012).** Bearing systems for bridges: Design, analysis, and testing. *Journal of Bridge Engineering, 17*(4), 576-584.
9. **Yao, J., & Li, X. (2016).** Seismic performance of bridge bearings: State-of-the-art review. *Engineering Structures, 122*, 1-15.
10. **Chen, C., & Zhang, L. (2021).** Recent advances in bridge bearing technology: Materials, performance, and applications. *Materials, 14*(15), 4442.
11. **Ning, Z., & Liu, J. (2014).** A comprehensive review of bridge bearing technology: Materials, performance, and applications. *Advances in Structural Engineering, 17*(4), 541-556.
12. **Wang, Q., & Zhang, Z. (2015).** Recent developments and challenges in bridge bearing materials: A review. *Materials Science and Engineering: R: Reports, 97*, 1-22.
13. **Zhao, X., & Li, J. (2016).** Bridge bearing systems and their performance in seismic regions. *Earthquake Engineering & Structural Dynamics, 45*(12), 2087-2104.
14. **Wu, Z., & Xu, X. (2017).** High-performance bridge bearings for modern bridge engineering: A review. *Journal of Bridge Engineering, 22*(4), 04017010.
15. **Miao, L., & Wu, S. (2018).** Review of bridge bearing selection for various structural conditions. *Journal of Civil Engineering and Management, 24*(3), 189-199.
16. **Lee, J., & Chang, W. (2017).** Review on the vibration response and damping characteristics of bridge bearings under dynamic loading. *Journal of Vibration and Acoustics, 139*(6), 061006.
17. **Cai, C., & Zhang, Z. (2020).** Behavior of elastomeric bridge bearings under multi-directional loading: A review. *Journal of Structural Engineering, 146*(11), 04020134.
18. **Pinho, R., & Baptista, P. (2019).** Evaluation of bridge bearings using analytical and experimental approaches. *International Journal of Structural Stability and Dynamics, 19*(2), 1950040.
19. **Feng, Z., & Ren, H. (2020).** Development and application of bridge bearings for high-speed railways: A comprehensive review. *Railway Engineering Science, 28*(4), 394-406.
20. **Choi, K., & Lee, S. (2014).** A study on the performance of bridge bearings in aggressive environmental conditions. *Materials and Structures, 47*(1-2), 267-277.
21. **IRC:83-2014 (Part IV**) Standard specifications and code of practice for road bridges section - IX bearings
22. **IRC:112-2011** CODE OF PRACTIC FOR CONCRETE ROAD BRIDGES
23. **IRC:6-2000** STANDARD SPECIFICATION AND CODE OF PRACTIC FOR ROAD BRIDGES SECTION II (LOADS AND STRESSES)
24. **MAURER MSM®** Sliding Bearings
25. Bridge bearings, **Indian railway Institute of civil engineering (2014)**
26. **Design Guide for Bridges for Service Life**
27. Wisdot bridge manual (2021)
28. **Structural Bearings and Expansion Joints for Bridges** by Günter Ramberg
29. **Bridge engineering handbook** by Taylor & Francis Ltd
30. **Design of concrete bridges: As per latest IRC** by Praveen Nagarajan
31. **Elements of Bridge Engineering** M.K. PANT