# PROTOCOL FOR THE INSPECTION OF BRIDGE BEARINGS

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## 1. Purpose of this Protocol:

Bridge Bearings are a major structural component of most bridges that are in use today.

Historically there has been a trend toward utilizing the services of non professionals to provide maintenance and condition inspections on bridges throughout the Forest Road network. The development of this protocol is intended to provide those individuals conducting bridge inspections on Forest Roads in the Province of British Columbia with a formal approach to understanding and evaluating bridge bearings and providing recommendations for their remediation and repair.

Information gathered and recommendations made during bridge inspections are often the foundation that is used to support engineering certifications and bridge maintenance programs and budgets.

All individuals conducting bridge inspections must be aware of the significance of these components and provide consistent observations and recommendations in order that those who are charged with certifying the safety and maintenance share confidence in the inspection reports.

There are relatively few types of Bridge Bearings commonly found in Forest Road Bridges in British Columbia.

Each type of bearing is prone to one or more "typical" examples of distress, failure or wear and tear as a result of a variety of factors.

An objective of this protocol is to provide the bridge inspector with some visual examples of bridge bearings in good condition along with examples of bearings displaying differing levels of distress accompanied with a description that is intended to quantify the severity of the distress. It will also provide recommendations for any remedial actions that may be required.

Bridge Bearings are a major structural component of most bridges that are in use today. There are several types of bearings in use and they can be affected by a wide variety of circumstances and forces ranging from applied loads, geotechnical conditions, ambient temperature, corrosion and earthquake.

***It must therefore be noted that this protocol is not intended to present the inspectors with every possible type of bridge bearing they may encounter. Nor is it intended to present every possible observation or remedy for the types of bearings that are described.***

***Rather, it is only intended to provide a guideline for the evaluation and remediation of those most common types of bearings expected to be encountered. It remains the responsibility of the inspector using his / her good judgment to understand that what they observe may not represent examples included in this protocol and to use their practical common sense to determine when observed circumstances may indicate that the issue should be referred to others with more experience and or professional qualifications.***

# 2. Description of Bridge Bearings

## 2.1. Definition

2.1.1. Architectural definition of a bearing

A supporting part of a structure.

The area of contact between a bearing member, as a beam and a pier, wall, or other underlying support.

2.1.2. Mechanical definition of a bearing:

The support and guide for a rotating, oscillating, or sliding shaft, pivot, or wheel.

2.1.3. Canadian Highway Bridge Code definition of a bearing:

A structural device that transmits load while allowing either or both, translation or rotation.

All of the above definitions are applicable to bridge bearings as will become evident in the sections that follow.

## 2.2. Location

Bridge Bearings are situated between the bridge foundations and the superstructure.

The bearings are located at top of the foundations, (abutments or piers) and are situated on the underside of the girders (longitudinal stringers or slabs).

## 2.3. Purpose

2.3.1. Secure the superstructure to the foundation

The bridge bearings serve as the connector that affixes the superstructure to the foundations. It is the bridge bearing that limits the movement of the superstructure in relation to the foundations to quantities and directions that have been incorporated into the bridge design.

2.3.2. Transfer loads from superstructure to substructure

Bridge Bearings are responsible for transferring loads resulting from the mass of the superstructure and the forces caused by any applied load such as vehicle traffic and wind force from the superstructure through the foundation and into the underlying ground.

2.3.3. Provide for expansion and contraction of the superstructure on longer bridges

Bridge Bearings are also responsible for allowing the bridge superstructure to expand and contract with ambient temperature fluctuations. As the temperature of any material increases, its volume increases which results in corresponding increases to its dimensions. The opposite occurs as temperatures decrease. The bearings are designed to allow for the longitudinal expansion and contraction of the superstructure without causing damage to the superstructure or the foundations.

2.3.4. Allow for the rotation of the superstructure relative to the foundation

Bridge Bearings are responsible for allowing for rotation caused by deflection of the superstructure when loaded by vehicles.

## 2.4. Significance

Bridge Bearings are considered an important structural component of the substructure or foundation of the bridge. Their functions of securing the superstructure, transferring of loads and restricting movement are crucial to the overall performance of the bridge.

Often problems or abnormalities that are observed in bridge bearings are symptoms of larger problems that may affect the integrity and safety of the entire structure. It is important that bridge inspectors be aware of these components and develops skill in diagnosing problems that may result from the forces acting on them.

# 3. A procedure for inspecting bridge bearings

- Identify the type of bearings in use on the structure.
- Evaluate the current condition of the bearings in comparison to the original installation.
- Determine if there is any deterioration or deformation of the bearings or the adjacent components.
- Identify abnormalities (if present).
- Determine the severity of any abnormalities found.
- Determine the current and potential future implications of any abnormalities found.
- Make recommendations regarding remedial works required.
- Quantify materials required for the remedial works (if any).
- Place a priority value on any remedial works required.
    - **High** - Defects which should be addressed immediately that may endanger users or are compromising the structure (e.g. extensive rot, scour, damage, washouts, etc.)
    - **Moderate** - Defects that affect the strength, durability or life span of the structure in the short term (may be required before next inspection and/or is subject to level of use, e.g. scour, culvert separation or loss of shape)
    - **Low** - Defects that affect long term strength, durability or life span of the structure and could be monitored or replaced subject to level of use.

# 4. Common Bearing Systems Found in Forest Road Bridges

The method whereby bridge superstructure components are fastened to their foundations can be considered as a system. Various systems are utilized depending primarily on the materials specified for the girders and the foundations.

A brief description of the common systems encountered in Forest Road Bridges in BC follows:

### 4.1. Timber Girders on Timber Foundations (treated or untreated)

Bearings used in timber bridge construction typically consist of steel plate formed into a bracket. The bracket is attached to the timber stringer and timber cap by means of bolts or lag screws.

This bracket secures the timber stringer to the pile cap and prevents movement

### 4.2. Steel Girders on Timber Foundations (sills or cribs)

On temporary bridges, steel girders are often resting on timber foundations. These foundations may be composed of logs or squared timbers either as single sills, caps, cribs or bin-wall construction. The timbers may be either untreated, painted or pressure treated materials. Steel Plates welded to the underside of the girders help to spread the anticipated loads over a larger area of the foundation timbers. (See standard Drawing #STD-E-050-32 for typical installation)


Steel Girders on Log Sill Steel Girders on Sawn Timber Sill

## 4.3. Steel Girders on Concrete Lock Block Foundations

Another foundation system in common use consists of steel girders resting on a concrete lock block foundation. Typically there should be a timber, steel or concrete (not shown) cap between the girders and the blocks to spread the loads from each girder to more than one block. The steel or timber cap must be of sufficient strength to spread the anticipated loads across all the supporting blocks. There may be more than one layer or tier of vertically stacked blocks in the foundation. (See standard Drawings # STD-E-050-30, 31 & 32)

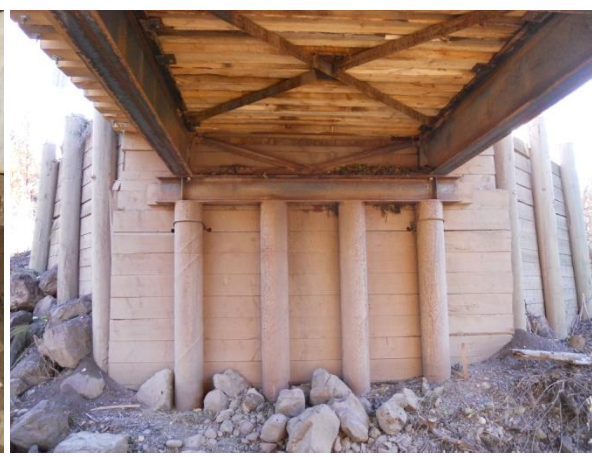
Steel Girders on Timber Sill & Lock Blocks

Steel Girders on Steel Cap & Lock Blocks

## 4.4. Fixed Attachments connecting Steel Girders to Steel Foundations.

Although not a typical installation, under some circumstances steel girders may not be provided with formal bearings. Steel girders may be attached directly to the steel pile tops or a cap beams. In this scenario there is no provision for expansion, contraction or rotation. The steel bearing plates are incorporated to spread the loads from the superstructure over a larger area on the foundation. ***This system for attaching steel girders to their foundations is not encouraged.***

Steel bearing plate welded to girder and pile top.



Steel girders bolted to pile cap beam

### 4.5. Elastomeric Bearings for steel girder bridge applications

Bearings used to connect Steel Girders to Pile Tops or Cap Beams are most likely to be composed of an elastomeric pad situated between steel plates.  The upper steel plates are normally welded to the underside of the girders and the lower steel plates are welded to the upper side of the pile top beam or cap beam.

The upper and lower steel plates are typically bolted together.   (See Standard Bridge Drawings # STD-E-050-10, 20 &21)

Structures will typically have a set of fixed bearings at one end and a set of expansion bearings at the other.  The illustration shown below right is a fixed bearing that allows for no movement while the illustration shown below left shows the plates bolted through a slotted hole that will allow for longitudinal movement originating from expansion and contraction of the superstructure.

Longer bridges composed of multiple spans and piers may have fixed bearings on the piers and expansion bearings on the abutments.  Differing combinations may be encountered depending on the specific circumstances.

These bearings connect the steel girders to the pile tops using a bolted connection that allows for expansion and contraction at one end of the superstructure.


These bearings connect steel girders to a steel pile cap beam

These bearings connect steel girders to a concrete cap beam

## 4.6. Elastomeric Bearing Strips for concrete slab and box girder bridge applications

Concrete slab girders are commonly fixed to their foundations using steel dowels placed in pre-fabricated holes in the concrete components. For connections that are not designed for expansion/contraction, the dowels are grouted into place in both the girder and the foundation. If expansion/contraction is allowed for in the design the dowel is typically grouted into the foundation but all voids between the girder and the dowel are filled with foam filler and the top of the filler is grouted over to prevent the ingress of moisture. (See standard Drawing #STD-E-050-22)

A strip of elastomeric material is placed between the girders and foundation during construction.


Left concrete cap beam with elastomeric material in place (note hole for dowel). Right, girder being installed.


Side view of Concrete Deck Slabs in place on concrete abutment and view under bridge.

## 5. Generic Problems Associated With Bearing Systems

There are several problems that are commonly associated with most bearing systems. A description and recommendation regarding each of these generic problems follows:

### 5.1. Dirt and Debris

The materials used in bridge bearings are susceptible to deterioration and corrosion from the elements. This is often accelerated because of the presence of dirt, dust and debris accumulating on or around them.

**Cause:** Dirt, dust and debris can be deposited during construction, through subsequent use by traffic and wind, or in some cases by flooding.

**Implication:** Allowing dirt and debris to remain in contact with the bearings attracts moisture from rain, run-off or humid air and the moisture promotes deterioration. Consequences include rotting timbers, rusting steel and spalling concrete.

Granular materials left in contact with the bridge bearings can interfere with the designed movement of the components. Rocks in the wrong place can prevent the allowable expansion or rotation from occurring that could ultimately result in deformation or failure of adjacent components. Coarse materials in contact with the bearings can also abrade the smooth surfaces of plates and other materials that are designed to slide.

Example of dirt and debris impeding the function of bearings and promoting deterioration.

**Recommendation:** Dirt, Dust and Debris that has accumulated during construction should be cleaned immediately and prior to placing the structure in service. Materials that accumulate while the structure is in service should be removed as part of a regular maintenance program.

## 5.2. Corrosive Elements

Air and water in combination can be a corrosive element. Their ability to dissolve and transport other elements only adds to the problem. The materials used in bridge bearings are susceptible to corrosion and deterioration.

**Cause:** Corrosive elements include airborne chemicals, (pollution), ice melting chemicals applied to the road surfaces in colder climates and even salt mist found in coastal environments. These elements react with the bridge components causing accelerated deterioration of the materials.

**Implication:** Allowing moisture and its dissolved elements to contact the bearings promotes deterioration. Consequences include rotting timbers, rusting steel and spalling concrete. Water that is allowed to penetrate even small cracks in bridge materials can expand the cracks or even cause breakage as it freezes. The buildup of ice in or adjacent to bearings can also impede movement of the components designed to compensate for expansion, contraction and rotation.

Extreme examples of rusted bearings

**Recommendation:** Water that is observed to be flowing onto the bridge and contacting the bearings should be diverted away from the structure. If corrosive chemicals are utilized for ice melting during winter applications, consideration should be given to avoiding depositing these materials on the bridges. For those applications subject to salt spray or other corrosive elements in the air, consider selecting different materials for the bearings or protective painting etc.

## 5.3. Deformed I-Beam (Web, Flange or Stiffener)

In bearing systems that include steel I-Beam shapes, stiffeners are often ***(but not always)*** designed for steel girders and steel cap beams. The purpose of theses stiffeners is to help support the adjacent web and flanges at those locations of high loading and to prevent destructive deformation of these structural members. The shape of these components is a critical element in the design of the overall structure and must be preserved. The observation of bent flange, web or even stiffener material is indicative of this problem.

Some (***but not all***) designs specify that stiffeners on the girders align with the abutment or pier caps and, or, stiffeners on steel cap beams are designed to align with the girders above and, or, foundation elements below. Wherever possible the inspectors should refer to specific design or as-built drawings for the structure they are inspecting. Some designs do not include stiffeners, or the stiffeners specified do not align with other components. (See MoF Standard Drawings #STD-E-50-20 & 21 for typical alignments)

**Cause:** Deformed steel girder or cap beam web, flange or stiffener is often caused by the application of unplanned loads during fabrication, transportation or installation. Deformation may also be caused by mis-alignment of the girders or caps in relation to the foundations.

**Implication:** Deformation of steel sections may lead to reduced strength of the beam affected and ultimately result in collapse of the I-Beam shape and failure of the structure.

Stiffeners in cap aligned with girders and piles.

Stiffener in Girder aligned with Cap

**Recommendation:** Minor mis-alignment of stiffeners with their adjacent components may not constitute a serious defect. Bent or deformed flanges, webs or stiffeners can be symptoms of a very serious defect that if not addressed may result in failure of the structure. ***In this case measurements of the amount of mis-alignment or deformation are to be taken and the issue referred to a qualified professional for advice and recommendations.***

## 5.4. Loose, Bent, Broken or Missing Fasteners

Bolts, lag screws, dowels, grout and welds are the typical connectors that fasten the bridge components and their bearings together. They are integral in maintaining the components in proper alignment and in firmly attached to the bridge to the ground. Bent, broken or missing connectors are often observed during bridge inspections and those that involve the bridge bearings are discussed below:

**Cause:** Loose, bent, broken or missing fasteners are most likely the result of an installation defect or wear and tear as the structure is stressed during use. Other more serious causes are discussed in subsequent sections of this protocol.

**Implication:** Loose, bent and broken fasteners can ultimately contribute to more serious or even catastrophic failure. All conditions other than appropriately tight and in place should be addressed. Cracked welds, loose, broken or missing bolts and lag screws can no longer perform their function of holding the bridge components in alignment.

Missing lag screw

Broken weld (also a good reason to avoid fixed connections)

**Recommendation:** Typically loose, bent, broken or missing connectors should be tightened or replaced during routine maintenance. ***If significant shifting of the girders relative to the foundations has occurred a more serious problem may be indicated and the services of a qualified professional may be required.***

# 6. Specific Problems Associated With Common Bearing Systems

## 6.1. Plates and brackets for timber construction

There are two typical problems often identified with plate and bracket bearings that are used in timber bridge construction. They are Crushing and Loose or Missing connectors.

### 6.1.1. Crushing

Crushing of the timber components on either side of the steel plate or bracket may be observed. The extent of the crushing and condition of the materials affected will provide indications of the cause and severity of the problem.

Cause: Provided the timber materials at the site of the crushing are sound and dry, minor crushing (<5mm) is possibly due to the bridge components settling into place as they take on load. More severe crushing of sound, dry timber may be caused by providing plates or brackets with too small a bearing area for the compressive strength of the timber materials given the applied loading.

If the timber materials are soft the crushing may be caused by deterioration (rot) of the timber in the vicinity of the steel plate. Moisture can accumulate and linger at these locations that promote the development of fungus in the timber that can drastically reduce the strength of the timber.

Implication: Minor crushing in sound timber is not likely to lead to significant problems. Crushing that is observed in soft materials may lead to further deterioration of the timber components, even in those that have been pressure treated with preservatives. If not addressed progression of deterioration may ultimately lead to catastrophic failure.

Recommendation: Minor crushing in sound material should be noted during inspection and listed as an item to be monitored during subsequent inspections. More significant crushing in sound, dry material may indicate undersized bearing surfaces and should be referred to a Professional Engineer for review.

More severe crushing, especially in soft timber material indicates that destructive fungal attack may have begun. The progress of fiber loss or destruction is very difficult to predict and any rotting timber components should be replaced with new sound components. Consideration should also be given to specifying pressure treated timber components in the replacement. ***Consider closing the structure or restricting load sizes until the repairs are completed.***

### 6.1.2. Loose or missing bolts or lag bolts

Loose or missing bolts or lag bolts may be observed. These fasteners are tasked with keeping the timber components in proper alignment to allow for the designed distribution of forces between the superstructure and the foundation.

Cause: Timber components, whether or not they are pressure treated with preservatives, are subject to constant swelling and shrinking with changes to the relative moisture of the environment surrounding them. These changes in combination with normal vibration of the structure through use can be sufficient to allow fasteners that were tight when installed to loosen and even become displaced over time

Implication: The significance of this problem is dependent on the location of the loose or missing connector and whether or not the components being fastened together have shifted or have potential to shift in their positions as a result. The observation of a single loose bolt on a structure is not likely to be considered a significant defect, but it may be indicative of a trend that could eventually affect the entire structure.

Components that have shifted in their position relative to one another, if left unattended, could lead to catastrophic failure.

Recommendation: All timber structures should be subject to a regular scheduled maintenance program that includes the tightening and replacement of loose or missing fasteners. This should be prescribed during inspections that note loose or missing connectors. ***If significant shifting of the girders relative to the foundations has occurred a more serious problem may be indicated and explored, and the services of a qualified professional may be required.***

## 6.2. Log or Timber Sill Bearing Problems

There are three typical problems often identified with log or timber sill bearings. They are: improper alignment of the girders on the sills, insufficient support under the sill and loose or missing connectors.

### 6.2.1. Improper alignment

Improper alignment of the girders as they rest on the sills may be observed. This is usually evident in the failure of the girder stiffener and bearing plate to line up with the center of the sill.

Cause: This condition is most commonly caused by improper installation. There may also be examples where shifting of the supporting ground or movement of the superstructure has occurred subsequent to installation.

Implication: As detailed in the General Section, mis-aligned components may contribute to early failure of the structure by allowing bending of the flanges, webs or stiffeners in the girders thereby lowering their ability to support the intended loads. Progression of deformation may ultimately lead to structural failure.


Neither the bearing plate nor the stiffener is properly aligned with the sills.

Recommendation: For structures that were improperly installed, the superstructure should be lifted off the foundation and the sills repositioned at the appropriate spacing to allow the plates and stiffeners to center over the sills. The superstructure should then be properly fastened to the sills prior to be put in service. Consider restricting load sizes until repairs are complete. Alternatively it may be possible and easier to add web stiffeners and address securing the bridge without removing it. These solutions will require referral to a Professional for recommendation.

***In circumstances where the foundation or superstructure has shifted during use, the cause must be determined and if necessary referred to a qualified professional for recommendation. Consider restricting load sizes until repairs are complete***.

6.2.2. Insufficient support

Insufficient support may be observed. This is most often indicated by the presence of broken materials or voids under the foundation.

Cause: This condition is most commonly caused by using improper materials or construction techniques. In some instances voids may be caused by erosion and settlement may be caused by thawing soils after the structure has been put in service.

Implication: If the foundation does not provide adequate support for the structure and the loads to be applied, uneven settlement, twisting and bending of the superstructure and ultimately structural failure may result.

Voids under foundations caused by settlement or erosion (those blocks are insufficient)


Broken materials under girders caused by using under sized materials or subsequent deterioration

Recommendation: For structures that were improperly installed, the superstructure should be lifted off the foundation and adequate bearing capacity established in the underlying soils. The sills can then be re-positioned and the superstructure should then be properly fastened to the sills prior to being put in service. ***Consider restricting load sizes until repairs are complete.***

In severe cases where the foundation support has settled or eroded after installation, the cause must be determined and if necessary referred to a qualified professional for recommendations. It is possible that total replacement of the structure may be required.

6.2.3. Loose or missing bolts or lag bolts

Loose or missing bolts or lag bolts may be observed. The function of these fasteners is to secure the bridge girders in alignment with the sills allowing for the designed distribution of forces between the superstructure and the foundation.

Cause: Timber components, whether or not they are pressure treated with preservatives, are subject to constant swelling and shrinking with changes to the relative moisture of the environment surrounding them. These changes in combination with normal vibration of the structure through use can be sufficient to allow fasteners that were tight when installed to loosen and even become displaced over time. Undersized connectors may have been incorporated into the original construction.

Implication: The significance of this problem is dependent on the location of the loose or missing connector and whether or not the components being fastened together have shifted or have potential to shift in their positions as a result. The observation of a single loose bolt on a structure is not likely to be considered a significant defect, but it may be indicative of a trend that could eventually affect the entire structure.

Components that have shifted in their position relative to one another, if left unattended, could lead to catastrophic failure.

Recommendation: All timber structures should be subject to a regular scheduled maintenance program that includes the tightening and replacement of loose or missing fasteners. This should be prescribed during inspections that note loose or missing connectors. ***If significant shifting of the girders relative to the foundations has occurred a more serious problem may be indicated and explored, and the services of a qualified professional may be required.***

## 6.3. Lock Block Foundation Bearing Problems

Problems often observed in relation to Lock Block Foundation Bearings include poor or inadequate foundation soil strength, inadequate or missing cap beam, missing connectors and interference in the function of the cap beams caused by locking keys on the top of the top row of blocks.

### 6.3.1. Poor or inadequate foundation soil strength

The results of poor or inadequate foundation soil strength are observed as uneven settlement of adjacent lock blocks in the foundation wall, or excessive settlement of the entire wall. This is indicated by blocks that are not level, lean inwards or outwards or display other indications that the ground beneath the blocks is not strong enough to carry the experienced loads.

Cause: Typical causes of poor or inadequate foundation soils strength include poor initial preparation of the underlying soils during construction, construction on frozen soils, erosional scour from higher than anticipated stream flows or incursion of ground water into the foundation soils subsequent to construction.

Implication: The significance of this problem is dependent on the severity of the condition of the underlying soils. If minor settlement has occurred and there is no likelihood of subsequent settlement, recommendations for repair may be considerably different than if there is no indication that further settlement will occur. If the foundation does not provide adequate support for the structure and the loads to be applied, uneven settlement, twisting and bending of the superstructure and ultimately structural failure may result.

Components that have shifted in their position relative to one another, if left unattended, could lead to catastrophic failure.

Recommendation: All foundation settlement issues observed must be addressed. If settlement is minor and it can be determined that subsequent settlement is unlikely, repairs may include appropriately sized shims installed to level the superstructure. This recommendation should be reviewed by a Qualified Registered Professional and must be accompanied by listing this issue to be monitored on subsequent inspections.

More significant settlement will indicate that the superstructure should be removed and the foundations re-set on properly prepared foundations. The preparations may include:

- The placement of suitably compacted imported material (e.g. shot rock, angular material, select crush) below the lock block wall.
- Increase of bearing area by laying the blocks on their sides
- Utilizing a poured in place, reinforced concrete pad
- Changing of design to larger spread footings or pile foundation etc.

***All of these options will require referral to a Qualified Registered Professional for determination***.

### 6.3.2. Inadequate or missing cap beams

Inadequate or missing cap beams may be observed. The purpose of the cap beam is to distribute the loads over the entire row or tier of lock blocks for even transfer of the forces into the underlying soils. Lock Blocks are most often fabricated from waste concrete and contain no reinforcing steel and carry no guaranteed strength properties.

Cause: Poor design. Poor construction technique, lack of adequate supervision during construction.

Implication: The significance of this problem is dependent on the bearing capacity of the underlying soils and the quality of materials and quality of installation of the lock blocks. If there is insufficient bearing capacity in the soils, the forces being transferred through a single lock block may be larger than the soil's capacity to resist and result in uneven settlement of the structure. The blocks themselves may fracture under heavy loads. This can eventually lead to racking or twisting of the superstructure and ultimately structural failure.

Left: Inadequate cap does not bear on center block. Right: No cap, only 1 block carries entire load

Fractured lock block.

Recommendation: All lock block foundations require an adequately sized and properly fastened cap beam for the girders to bear on. The soils underneath the lock blocks must be properly compacted during installation to ensure uneven settlement does not occur. If uneven settlement has occurred, repairs are required to be undertaken to address the settlement and may entail the entire structure being removed and a proper base prepared for the lock blocks to bear on. If settlement has not occurred, consideration should be made for designing and installing an appropriately designed cap beam. Fractured or broken blocks should be replaced or otherwise repaired as directed by an engineer.

### 6.3.3. Loose, broken or missing connectors

Loose, broken or missing connectors may be observed. As in all bearing systems, the superstructure must be securely fastened to the substructure. In the case of lock block foundations, ensure that the girders are secured to the cap beam and the cap beam is secured to the lock blocks (most often by drilling holes in the blocks and grouting in redi-rod, mild steel rod or bolts).

Cause, Implication and Recommendations: Refer to section 5.4 above for more information and recommendations.

### 6.3.4. Locking Keys on top of the top row of blocks

Locking keys on top of the top row of blocks interfere with the proper installation / function of the cap beams.

Cause: Lock Blocks can be stacked in tiers to provide a deeper foundation. Key ways in the bottom of these blocks mesh with locking keys on the top of the underlying layer to provide some stability to the installation (like toy Lego blocks). Blocks cast without the locking keys are available and should be used for the top tier.

Implication: The locking keys provide a reduced bearing area for the cap beam. This can result in uneven loading of the blocks due to bending of the beam or crushing or breaking of one or more locking keys. This may progress to uneven settling of the structure that can result in twisting or racking of the superstructure and potentially, structural failure.

Recommendation: Remove the superstructure and replace the top tier of lock blocks with flat surfaced blocks. Re-install the cap beams and superstructure.

## 6.4. Elastomeric Bearings for steel girder bridge applications

### 6.4.1. Deterioration of the Elastomeric Pad

The elastomeric bearing pads in the following images show signs of cracking and are losing their flexibility.

Examples of physical deterioration of elastomeric pads.

Cause: Deterioration of the elastomeric pad is often caused by the presence of corrosive elements and or crushing.

Implication: If left in place, these pads will likely continue to deteriorate and will eventually lose their ability to assist with transferring the expansion/contraction forces and rotational forces from the superstructure into the foundation and may lead to unplanned wear on the bearing plate surfaces. Complete failure of these pads is not likely to result in a catastrophic failure of the structure.

Recommendation: Replace with new. Ensure new pads of appropriate strength and thickness are specified.

### 6.4.2. Deformation of the Elastomeric Pad

The Elastomeric Pads between the bearing plates may appear to be crushing or bulging at the sides.

Examples of crushing (bulging) of the elastomeric pad is evident in these two images

Cause: Deformation of the Elastomeric Pad may have 3 causes. 1.) The strength of the original pad may have been underspecified or incorrect material supplied for construction. 2.) The pads may be subject to loading that was not anticipated during design. 3.) The anchor bolts may have been over tightened not allowing for the clearance as specified on the design drawings.

Implication: If left in place, crushed elastomeric pads may eventually fail to properly transfer rotational forces. This is not likely to result in a catastrophic failure but may eventually lead to un-planned wear on the bearing plates surfaces.

Recommendation: It is recommended for mild cases of deformation that the bearings be noted for monitoring during subsequent inspections. Sever cases of deformation should be analyzed for cause and the pads should be replaced with appropriate new materials.

### 6.4.3. Bent or Sheared bearing bolts

The bolts connecting the upper and lower bearing plates may become bent or in more severe occurrences may shear off entirely.


The bolts securing these bearings to the foundation have been sheared off.

Cause: Bending and shearing of the bolts connecting the upper and lower bearing plates may be the result of several different causes

- The designed expansion/contraction allowance was insufficient to account for the total movement that the superstructure would experience.
- The expansions slots in bearing plates were not properly set during construction.
- The bearings / footings were installed too close together or too far apart.

- The angle of pile cut-off may not match the design slope of the superstructure.
- The soil at one (or more) of the bridge ends is settling or failing causing movement affecting the footings or piles.


Left: Side view of bearing, plates are not parallel causing crushing at the abutment end of the pad.
Right: Same bearing, viewed from under the bridge, note gap on the face and left side.


Left: Same bearing, bolt is at the limit of expansion in the expansion slot
Right: Overview of the same bearing.

In this case the cause of the problems noted in the preceding 4 images is uneven settlement of one spread footing. The uneven settlement is causing a tilt to the support tower that puts unanticipated loading onto the superstructure through the bearing.

<u>Implication:</u> Bent or sheared bearing bolts if not addressed, may lead to more severe damage to other bridge components and may ultimately result in catastrophic failure. For example, the superstructure may, if not secured to the foundation, become shifted off the foundation due to normal vibrations encountered during use.

<u>Recommendation:</u> In order to prescribe appropriate remedial action in response to these types of conditions observed in bridge bearings it is first necessary to determine the root cause of the problem. Solutions range from re-installing the bearings with an increased allowance for expansion and contraction to major retrofit of bridge foundations or approach structures.

Instances of bearing bolts that are bent or not in their appropriate location in the expansion / contraction slots given the ambient temperature during inspection should be noted for monitoring in future inspections.

***It is recommended that any occurrence of sheared bolts or significant shifting of components in relation to each other be referred to a Professional Engineer for advice.***

### 6.4.4. Shifted bearing plates

Conditions that may result in the shearing off of bearing bolts may be severe enough to dislocate the bearing plates.

After the failure of the bolts, the bearing plates on both ends of this bridge have shifted to such an extent that there is now insufficient bearing area.

Cause: In this case it was determined that there were unforeseen geotechnical forces at work in the slopes adjacent to one of the abutments. This unanticipated pressure was causing the foundation to move relative to the superstructure.

Implication: If left un-treated, the geotechnical forces would eventually push the foundations out from under the bridge superstructure.

Recommendation: The solution in this instance is to remove the abutment endfills and address the geotechnical issues in the adjacent slopes. After that is complete, the foundation would be repositioned and the superstructure re-set on its supports with new bearings installed. Consider closing the structure or restricting load sizes.

***It is recommended that any significant occurrence of shifted bearing plates be referred to a professional engineer for advice.***

## 6.5. Elastomeric Bearing Strips for concrete slab bridge applications

Elastomeric Bearing Strip visible at end of precast abutment cap beam

6.5.1. Deterioration - Crushing, Bulging and Shifting.

Due to the relative short span of structures containing this style of bearing, it is unusual to observe problems associated with the elastomeric pad. The pads are often not visible to inspection because of where they are located in the structure.

Cause: Deterioration may be due to improper materials being specified or used for the conditions experienced on site, chemical, environmental etc. On older structures, the material may be deteriorating with age.

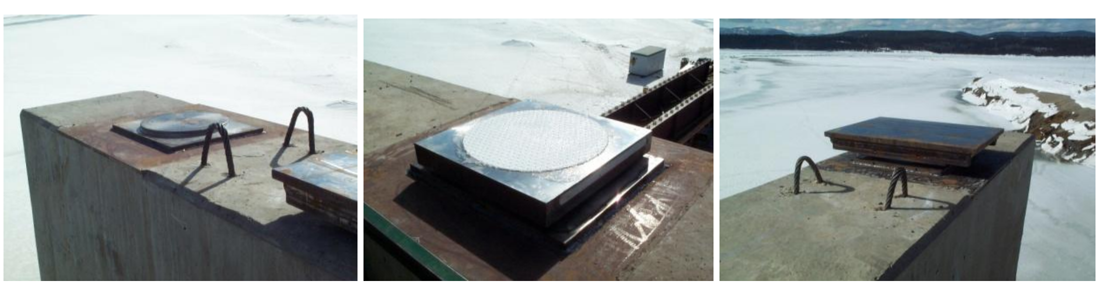
Implication: The bearing material may eventually lose its ability to allow the transfer of movement and rotational forces in the bridge resulting in wear between the girders and the abutment.

Recommendation: If severe deterioration is encountered consider scheduling the replacement of the elastomeric materials.

# 7. Other types of bearings that may occasionally be encountered during inspections

## 7.1. Pot Bearings

The following photographs show a typical pot bearing. These are not commonly used on Forest Road Bridges, but may be encountered on some of the longer span structures.



Pot bearings during assembly.

***If any abnormalities are encountered during the inspection of this style of bearing refer to professional engineer for opinion and recommendations***

## 7.2. Roller Bearings

The following photographs show a typical roller bearing.  These are not commonly found on Forest Road Bridges and are generally restricted to quite large structures.

An example of roller bearings

***If any abnormalities are encountered during the inspection of this style of bearing refer to professional engineer for opinion and recommendations***

## 7.3. Rocker Bearings

The following photographs show a typical rocker bearing.  These are not commonly found on Forest Road Bridges and are generally restricted to quite large structures.

An example of rocker bearings

***If any abnormalities are encountered during the inspection of this style of bearing refer to professional engineer for opinion and recommendations***

## 7.4. Acrow / Bailey Bearings

The following photographs show typical Acrow and Baily Panel Bridge type bearings

Examples of Panel Bridge Bearings

***If any abnormalities are encountered during the inspection of this style of bearing refer to professional engineer for opinion and recommendations***

# APPENDIX A
## LIST OF STANDARD DRAWINGS RELATING TO BRIDGE BEARINGS

| Drawing # | Title |
|---|---|
| STD-EC-030-02 | Standard Steel Girder Bridge With Composite Deck, General Notes – Sheet 2 |
| STD-EC-030-03 | Standard Steel Girder Bridge With Composite Deck General Arrangement |
| STD-EC-040-02 | Standard Steel Girder Bridge With Non-Composite Deck General Notes – Sheet 2 |
| STD-EC-040-03 | Standard Steel Girder Bridge With Non-Composite Deck General Arrangement |
| STD-E-050-10 | Standard Substructure Details Sheet 1 |
| STD-E-050-11 | Standard Substructure Details Sheet 2 |
| STD-E-050-20 | Conceptual Abutment Cap Beam |
| STD-E-050-21 | Conceptual Pier Cap Beam |
| STD-E-050-22 | Conceptual Integral Cap Beam & Wingwall Details |
| STD-E-050-30 | Concrete Cap & Lock Block Abutment Concept |
| STD-E-050-31 | Steel Cap & Lock Block Abutment Concept |
| STD-E-050-32 | Timber Cap & Lock Block Abutment Concept |
| STD-E-050-40 | Conceptual Inverted “T” Abutment Details |
| STD-E-050-50 | Standard Precast Concrete Bridge Abutments for Concrete Bridges,<br>Typical Concrete Cap Beam Details, Sheet 1 |
| STD-E-050-60 | Steel Abutment Cap Beams For Steel Bridges, Steel Cap Beam – 2 Pile/Column System |
| STD-E-050-61 | Steel Abutment Cap Beams For Steel Bridges, Steel Cap Beam – 3 Pile/Column System |
| STD-E-050-62 | Steel Abutment Cap Beams for Steel Bridges, Steel Cap Beam – 4 Pile/Column System |
| STD-E-050-63 | Concrete Abutment Cap Beams For Steel Bridges, Concrete Cap Beam – 2 Pile/Column System |
| STD-E-050-64 | Concrete Abutment Cap Beams For Steel Bridges, Concrete Cap Beam – 3 Pile/Column System |
| STD-E-050-65 | Concrete Abutment Cap Beams For Steel Bridges, Concrete Cap Beam – 4 Pile/Column System |
| STD-EC-070-01 | Standard Precast Reinforced Concrete Slab Bridge, General Notes – Sheet 1 |
| STD-EC-070-02 | Standard Precast Reinforced Concrete Slab Bridge, General Arrangement |
| STD-E-090-01 | Typical All Steel Portable Superstructure, Conceptual General Arrangement Sheet 1 of 2 |
| STD-E-090-02 | Typical All Steel Portable Superstructure, Conceptual General Arrangement Sheet 2 of 2 |
| STD-E-011-02 | Inverted Channel Beam, (Compo-Girder) |