8 HARDWARE

8.1 DEFINITION

Hardware is the generally accepted term used to describe the various bridge components, attachments and devices that are not regarded as main members of the deck, superstructure, substructure or foundations.

8.2 MATERIALS

The principal components of a bridge, e.g. beams, piers, abutments, may have a life exceeding 50 – 80 years with little if any need for maintenance.

Bridge hardware has a shorter life and requires more maintenance than the principal components. Accordingly the design and maintenance of bridge hardware requires careful consideration of initial product selection, maintenance programmes and provision for replacement.

Bridge hardware components use a wide range of materials, all with definite service life. The most common are:

- Steel;
- Plastics – in particular PTFE (poly-tetra-fluoroethylene);
- Rubber;
- Concrete;
- Epoxy-mortar;
- Timber;
- Adhesives.

Function, required life, loading and maintenance requirements of the various components need to be considered at the design stage and when selecting replacements, particularly when considering the type of bearings and joints to be used. Maintenance of bearings and joints can cause major disruption to traffic. They can be costly to replace and they are the components most prone to the debilitating effects of overloads and excessive thermal, shrinkage and creep movement.

All the materials listed above are subject to attack from the external environment.

Steel and timber can be protected by a suitable thickness of good quality protective coating.

Durability of reinforced concrete can be enhanced by suitable coatings (see Section 3.4.3), but primary protection of reinforcement comes from dense, impermeable cover concrete.

There are many types of plastic, some of which are subject to chemical attack, others to radiation such as ultraviolet rays from the sunlight. Most plastics also deform under sustained loads and high temperature.

Rubber may be natural or synthetic (e.g. chloroprene). Both have been used, although the current preference is for natural rubber in bearings. Natural rubber stiffens with age, and requires specific additives to counteract chemical and radiation effects.

Adhesives, used to bond stainless steel or PTFE sliding surfaces to steel backing plates, or steel to rubber in older elastomeric bearings, are also susceptible to ageing and embrittlement. Users should ensure that the correct type is chosen for each application and that the manufacturers' instructions are followed.

Any proposal to replace or modify any bridge hardware element should be submitted to an experienced bridge designer to ensure that the design philosophy and behaviour of the structure are not compromised.

The materials used in the repair of various components should as far as possible be fully compatible with the materials of the original component.

High-pressure water blasters can cause as many problems as they solve. Real care needs to be exercised around bearings and joints when using such equipment, so that water or dirt is not forced into inappropriate places and elastomeric materials are not removed.

8.3 DECK JOINTS

The performance requirement of the deck joint area is dynamically very different from the rest of the bridge deck.

The type of joint used depends on the range of movement and on current practice at the time the bridge was built.

Many older bridges have simple open joints at every support, resulting in minimal movement per joint. These bridges generally do not give joint problems. Bridges of a later era have fewer joints with more movement per joint and often give rise to maintenance problems. The current preference is to eliminate joints if possible and absorb the movements by compression and relaxation of the approach filling.

Open joints allow water and debris to fall through the joint and can be a potential source of deterioration due to corrosion of affected bridge elements. For this reason current practice favours the use of sealed expansion joints. Guidelines for the use and selection of sealed expansion joints is included in United Kingdom Department of Transportation documents BD33/94 and BA26/94.

Features and potential problems common to different joint types are described in Section 8.3.1. In Sections 8.3.2 to 8.3.10 more specific comments are made on various joint types. It is recognised that there are many variations on all these, and the diagrams should be taken as indicative only.

8.3.1 General Problems

Many joints have steel angles protecting the edges of the concrete at the gap. A common problem is loosening of the angles caused by breaking up of the concrete beneath them. This is generally due to insufficient compaction of the concrete under the angle and the presence of air trapped there during concreting. Movement leads to failure of the welds connecting the anchoring bars. When replacing such angles, bleed holes should be drilled in the horizontal legs to release the air during concreting. Sometimes angles or plates are held down by bolts and these frequently need tightening or replacement.
Many joints are susceptible to becoming clogged by debris lodged in the movement gap, and require regular cleaning out. If debris is allowed to build up, movement can be inhibited and superstructure compression forces can cause problems to bearings and substructure elsewhere. The material might also be forced down into the joint seal, thus rupturing it and causing leakage.

Leakage of water and debris through a joint can cause corrosion of steel parts of bearings, holding down bolts and linkage bolts, as well as structural steel main members. The effect on concrete parts can be just as severe, as the water may promote corrosion of reinforcement, as well as unsightly staining of visible surfaces. Corrosion effects are made worse if debris is allowed to build up because it retains the moisture.

Vertical misalignment of the two sides of a joint may lead to damage to the joint itself, which must be repaired. This fault may also indicate a failure in the bearings, which must also be corrected.

Many types of joints incorporate directly or indirectly a nosing of ordinary concrete or an epoxy mortar. Epoxy mortars are relatively cheap but often have a higher compressive strength than the adjacent concrete, and a different expansion coefficient. For these reasons they tend to crack perpendicular to the joint and de-bond, particularly where the traffic loads are greatest and in the region of shrinkage control cracks. A life of 5 – 10 years appears to be usual in a highly trafficked situation, but a longer life has been observed in less-trafficked situations.

Deck joints incorporating steel components at the road surface often appear as a depression in the surface, because commonly used asphaltic binders do not bond satisfactorily to the steel. The joint becomes progressively depressed relative to the running surface on each side as this is built up with successive re-sealing. Impact loads are increased, rideability is decreased, and the joint becomes increasingly noisy. This problem appears to arise because the asphaltic binder used on the deck and on the adjacent roadway is also used on the steel components.

Research shows that the magnitude of creep and shrinkage shortening has often been under-estimated at the design stage, with the consequence that the deck joint provided cannot sustain the movements. The rotational movement of the span ends, induced by traffic loading, also has often been overlooked in the design, and similarly contributes to deterioration or failure of the deck joint.

Poor geometry of the approach roading often leads to high-impact loading at bridge abutment deck joints. A smooth surface profile with the joint finished to the appropriate level and grade is important. Technical literature for the particular joint type should be referred to, but in general the seal element should be set just slightly below the level of the adjacent road surface.

8.3.2 Elastomer In Metal Runners (EMR)

EMR joints are also referred to as strip seals and single seal joints. These joints have a history of good performance on New Zealand road bridges.

An EMR joint consists of an elastomeric membrane fastened to the two sides of the gap, which may have steel angle, aluminium extrusion and/or epoxy nosings. The seal may be clamped, or fastened by shaped anchorage recesses in the nosings.

It is evident that the angle or extrusion used, particularly on the beam side of the joint, must be rigid enough to resist flexing under traffic loads, and the anchorage system must be robust enough to achieve satisfactory performance.

During inspection, all the faults described in Section 8.3.1 should be checked for. If the joint has epoxy nosings, a check should be made for any cracking or de-bonding as this will eventually lead to spalling and break-up of the material.

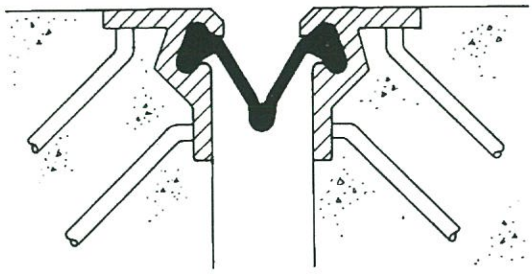


Figure 8.1: Typical elastomer in metal runner joint.

The following points should be considered in the maintenance and repair of EMR joints:

Frequent cleaning of the joint is of vital importance to keep it in good operating condition.

A further aid in preventive maintenance is to avoid chip seals in the immediate vicinity of the joints. Asphaltic concrete is much less prone to releasing aggregate than surface chip seals.

Where damage has already occurred to the membrane, the joint or membrane must be replaced. If the membrane is held in place by bolted proprietary pads, or steel nosings with shaped anchorage recesses, this is a reasonably simple task and causes only minor delays to traffic. But where the sealing membrane needs to be broken out, a new seal installed and new epoxy nosings cast, traffic will be disrupted and the completed repair requires protection by a steel cover plate until curing is complete. The re-casting task can only be carried out in fine weather and when temperatures are above 10°C.

When installing the new membrane care should be take to ensure that:

- Sufficient hog or sag is built into the free section of the membrane to accommodate maximum contraction of the structure during cold weather;
- Sufficient gap is left between the edges of the nosings to allow expansion during hot weather;
- Replacement membranes are chosen on the basis of manufacturer's recommendations to cater for the required movements.

Installation of a strip seal below a sliding plate or finger joint may require a multiple ripple seal (i.e. a membrane which is corrugated to allow for more movement) in order to accommodate the larger movement.

8.3.3 Compression Seals

A compression seal consists of a specially shaped elastomeric seal, generally glued onto the vertical faces of steel angle nosings, and held in compression by them. The seal is a roughly rectangular hollow moulding with internal ribs to assist it to retain its shape. Typical movement range is ±10 mm, but sections allowing greater movement are available.

Inspectors should check for all the faults described in Section 8.3.1. In particular, de-bonding of the seal can occur due to excessive opening of the gap, or if the seal is set too high so that tyres can tear it or load it either directly or through debris lodged in the gap. The seal element should be recessed 3 – 6 mm below the road surface to prevent contact with passing tyres, but shallow enough so that debris does not accumulate.

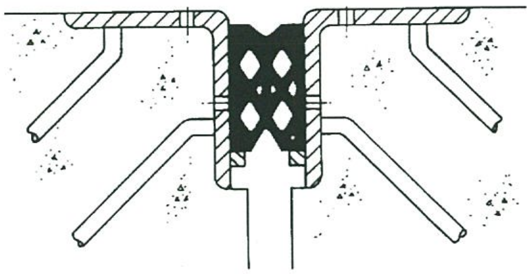


Figure 8.2: Typical compression seal (shown in uncompressed state).

The following points should be considered in the maintenance and repair of compression seals:

As for EMR joints, frequent cleaning out of chips and debris from above the seal will prevent traffic loads being transmitted to it.

If replacement of the seal is required, care should be taken to use a rubber section appropriate to the movement at the joint, and to follow strictly manufacturers' recommendations for application of the adhesive. It is advisable to use the same make and model as specified in the original design, otherwise the seal will probably stand proud of the road surface.

If the angle nosing on a joint of this type needs replacing, it is essential to drill 10 mm bleed holes in the upper surface of the angle to ensure air is released from the replacement concrete (see Section 8.3.1).

When retrofitting other joint types (e.g. sealant filled joints) with a compression seal all traces of bitumen or existing sealants must be removed from the nosing to ensure adhesion.

8.3.4 Open Joints

An open joint is merely a gap, usually protected by steel nosings, with no sealing component. In some cases a channel is provided to collect and discharge any water and debris passing through the joint.

During inspection, all the relevant faults described in Section 8.3.1 should be checked for. The channel, if any, should be checked for blockage and the underlying substructure should be checked for build up of debris.

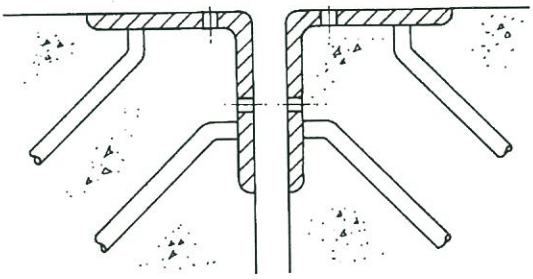


Figure 8.3: Typical open joint.

The following points should be considered in the maintenance and repair of open joints:

Maintenance largely consists of clearing debris carried through the joint onto the channel or the substructure, especially around bearings.

Where possible, install a collector drain to carry water clear of the substructure. In many cases this is not possible because of lack of access.

If the nosings are faulty and need to be broken out, the joint should be replaced with a more suitable type providing a fully sealed joint. Options available would probably include EMR joints or asphaltic plug joints.

8.3.5 Asphaltic Plug Joints

Asphaltic plug joints were developed and have been used in New Zealand for 15 to 20 years. They are becoming increasingly common for retrofitting existing joints to achieve waterproofness and improve rideability. They can cope with small horizontal and rotational movements.

The expansion gap is bridged by a "plug" in a recess in the deck, using aggregate to support the vertical loads of the traffic. The aggregate is bound into a flexible mass with a proprietary, specially formulated bituminous or elastomeric matrix.

The bituminous binder must be soft enough to resist cracking under low temperature, but still be resistant to flow under high-temperature conditions. Materials available cater for a temperature range from –15°C to 35°C.

Asphaltic plug joints are particularly good for short span bridges with limited horizontal movements and limited span end rotations under live load.

The properties of the "plug" cross-section must suit the expected movements, and specialist manufacturer's advice should be obtained.

Defects that occur with this type of joint include:

- De-bonding at the interfaces with the underlying deck slabs and adjacent surfacing, generally caused by the joint being required to cope with movements beyond its capacity. The inspector should check to ascertain if seizure of bearings or another fault at an adjacent expansion joint has caused restriction of movement, transferring all movement to the end where the de-bonding has occurred. Where this is not the case the most common causes of de-bonding are under-design, faulty materials proportioning, or poor surface preparation;
- Excessive depression in the wheel paths, generally caused by incorrect proportioning of aggregate to matrix or by using a matrix unable to cope with high ambient temperatures. In joints skewed to the direction of traffic flow, these deficiencies may also result in "flow" of the joint material along the joint under the traction forces exerted (Figure 8.5);
- Plastic cracking in the joint surface, generally due to the use of a matrix composition unable to cope with low ambient temperatures or to sudden movements such as seismic events or

an excessively lively superstructure. Plastic cracking may also be caused by excessive strain or fatigue from a high number of loading cycles.

The implications of the defects listed above are that excessive deformation of the surface of the joint can cause unacceptable impact loads, particularly from heavy traffic. De-bonding and deep cracking will allow water to get through to the substructure and bearing areas with effects as described in Section 8.3.1 and will also allow progressive break-up of the joint material.

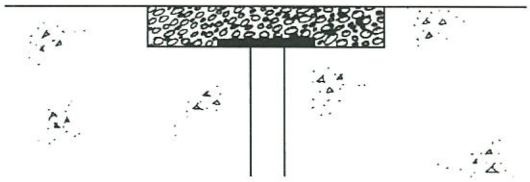


Figure 8.4: Typical asphaltic plug joint.

Figure 8.5: Asphaltic plug joint skewed to the traffic flow showing flow of joint material out of recess due to traction forces.

The following points should be considered in the maintenance and repair of asphaltic plug joints:

Where the joint has failed by debonding or plastic cracking, all movements acting on the joint should be investigated and the suitability of this type of joint for the imposed movements confirmed.

Where the type of joint is unsuited to the situation, the only permanent remedy is total removal of the joint and replacement with new material better designed to cope with the particular needs at that site. Worn joints can be renovated by specialist suppliers by removing the surface and replacing it to the required profile.

A more difficult problem to overcome in retrofitting this type of joint to existing bridges is providing sufficient width and depth of joint to cope with the expected movements. Most existing deck and diaphragm configurations restrict both width and depth availability because relatively thin decks and thin surfacings are used in this country.

Where deck capacity allows, application of an asphaltic concrete overlay on the deck will increase the depth available for the joint.

The failure of some joints of this type is undoubtedly due to the adoption of minimal width and thickness configurations. The joint configuration needs to be critically considered.

8.3.6 Finger Joints

Finger joints are designed to cope with large longitudinal movements. This type of joint was, in the past, employed on long span bridges or bridges where a series of spans have been tied together in such a way as to transfer all thermal movement to a single point.

Inspectors should look for the following defects:

- Bent, broken or misaligned fingers, generally a result of entrapped debris caught in the finger slots or, in the case of misalignment, differential settlement of bearings or failure of holding down bolts. Before effecting any repairs, the causes of the fault should be investigated and remedied;
- Loose, noisy sliding plates, which indicate slackness or a failure in the bolts or other fixing device;
- The membrane seal sometimes mounted below the finger plates may be leaking or blocked with debris.

The implications of water leakage through faulty joints and joint structure are described in Section 8.3.1.

Where no waterproofing element is provided under the joint, the joint's overall performance can be greatly enhanced by adding a sealing element. Where such an element is present, but has failed through rupture or de-bonding, it should be replaced. Alternatively it may be possible to install a drainage channel.

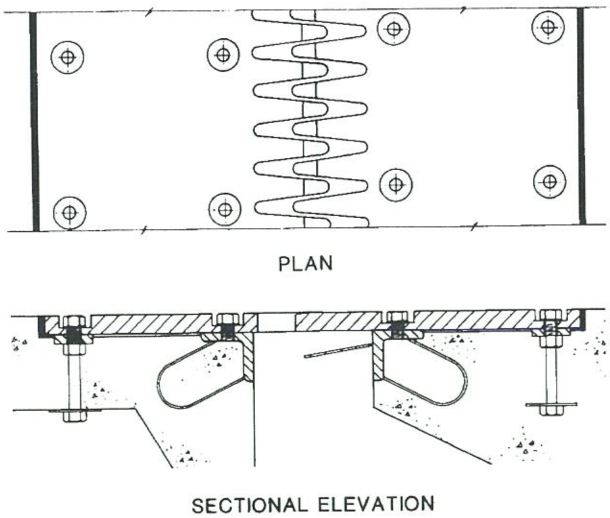


Figure 8.6: Typical finger joint.

8.3.7 Sliding Plate Joints

Sliding plate joints are often used as an alternative to finger joints where moderate to large movements are required. They have the disadvantage that when fully open they provide an irregular surface area that produces a significant bump as traffic passes over them. In general they do not have a seal incorporated. Therefore, although they limit dirt deposition down to the substructure, water leakage does cause problems as described in Section 8.3.1.

The performance of this type of joint is often related to the performance of the bearings under the beams. Problems with bearing seizure, excessive deformation and rotation are reflected at the road surface and more particularly in the relative elevation of adjacent joint components.

During inspection, all faults described in Section 8.3.1 should be checked for, and in particular:

- Loose bolts, studs or broken welds which allow the sliding plate to rattle, creating a very noisy joint;
- Vertical misalignment of the sliding plate and the supporting steelwork on the opposing face. This also promotes failure of the fixing bolts or welds;
- Restricted movement caused by sealing chip, particularly if the re-sealed surfaces intrude into the region of the joint.

The following points should be considered in the maintenance and repair of sliding plate joints:

Other than the addition of a sealing strip, where this is not already present, little can be done to enhance the performance of this type of joint.

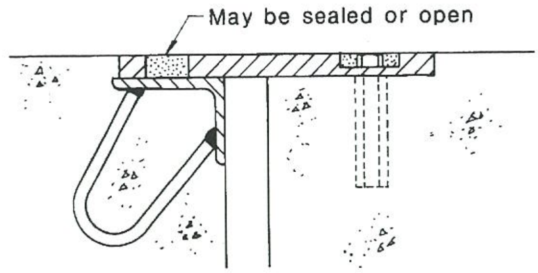


Figure 8.7: Typical sliding plate joint.

If there is any vertical misalignment caused by differential movement between spans, the anchoring mechanism holding the sliding plate to the slab will inevitably fail. This may be caused by span end rotation and/or compression in the bearings under live load. Before repairing such a fault, it is necessary to correct the underlying cause of the differential movement.

Regular maintenance should keep the space next to the edge of the sliding plate clear of sealing chip or other debris.

8.3.8 Sealant Filled Joints

Sealant filled joints are used in areas where movements of only 2-3 mm are expected. The joint consists of an elastomeric compound retained in a formed recess 20-30 mm wide.

Sealant materials are distinguished by application method and include cold poured, hot poured and gun applied. Reputable sealant manufacturers should be consulted before selecting a particular sealant.

Normally the bonding surface is treated with a primer compound to aid bonding.

During inspection, the relevant faults described in Section 8.3.1 should be checked for, but the principal failure in this joint is de-bonding. This is generally due to movement of the structure in excess of the capacity of the joint, or to improper surface preparation, but may also be due to chemical incompatibility with the joint nosing material. Embrittlement and failure of joint materials may also occur.

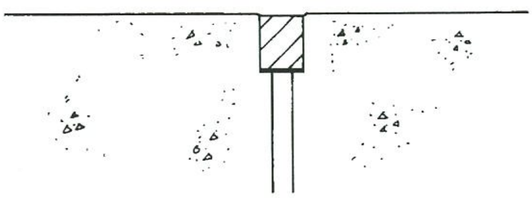


Figure 8.8: Typical sealant filled joint.

The following points should be considered in the maintenance and repair of sealant filled joints:

Where movement has exceeded the capacity of the sealant material, consideration should be given to the use of a different joint system. Compression seals and asphaltic plug joints are potential retrofit options.

In replacing the joint material, take note of the most recent developments in sealant materials. Some systems are now available which have greatly enhanced elastic properties and improved priming coats that will ensure better bond characteristics.

Adhesion is a key factor when reinstalling sealants and critical to this is adequate preparation of the joint surfaces. It is essential to remove all traces of the previous joint material or bitumen as most sealants are sensitive to these materials.

When replacing the sealant, ensure that the surface is kept low enough that tyres do not touch the surface of the compound.

Where a layer of asphaltic concrete is placed over a sealant-filled joint, reflective cracking can be minimised by ensuring that the number of joints is such that the movement accommodated at each joint is small. A narrow strip of suitable membrane should be laid over each joint prior to asphaltic concrete surfacing so that the surfacing is de-bonded over a finite length to provide for elastic deformation of the asphalt under the deck movements.

Regular maintenance should keep the joint clear of chips or other debris.

8.3.9 Multiple Seal Joints

This joint is a development of the single strip seal type, for large movements. The edges of the expansion gap are protected by nosings as for the strip seal. A number of steel spacing members are laid across the width of the bridge in this gap with their tops at road surface level, and resting on longitudinal rails. Between each pair of spacers a strip seal is fastened.

Faults that may develop are:

- Uneven friction on sliding surfaces, leading to uneven gaps between spacers;
- Wear on the sliding surfaces leading to noisy operation;
- Chips and other debris lodged above the seals;
- De-bonding of seals from the spacers, leading to leakage.

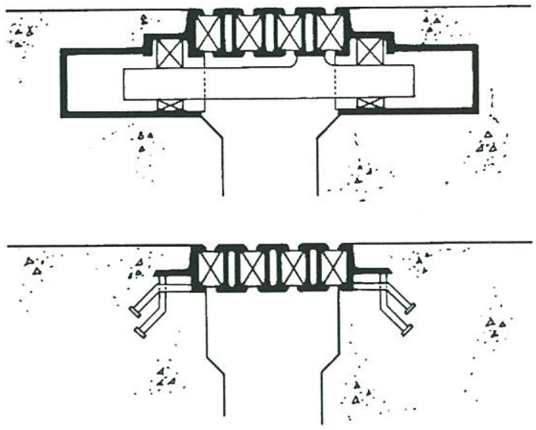


Figure 8.9: Typical multiple seal joint.

The following points should be considered in the maintenance and repair of multiple seal joints:

If replacement of seals is required, the remarks in Section 8.3.2 apply.

If there is uneven wear or friction or noise from sliding surfaces, the sliding medium should be replaced.

Regular maintenance should keep the slots above the seals free of debris.

8.3.10 Reinforced Elastomer Joints

There are two basic variations of this joint type. A reinforced elastomeric plank joint is where the gap is bridged by a reinforced elastomeric plank. An elastomeric sheet seal is where the joint is bridged by a thin elastomeric sheet anchored on either side of the gap by reinforced elastomeric block nosings.

Elastomeric plank joints in particular are very stiff and substantial forces on their anchorages must inevitably develop. The failure and loosening of hold-down bolts can be related to this stiffness.
The joints rely heavily on correct installation. If the joints are installed slightly above carriageway level then problems such as joint element wear, poor rideability and excessive noise generation can be encountered.
Other faults that may develop are:

- Failure of nosings (usually interlinked with the loosening of holding down bolts);
- Chips and other debris lodged in the shaped grooves in the rubber;

- De-bonding of the rubber and steel plates;
- Leakage under the rubber cushion between units butted together;
- Loss of plugs protecting the hold-down bolts.

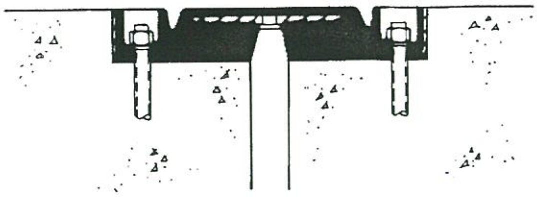


Figure 8.10: Typical reinforced elastomer joint.

The following points should be considered in the maintenance and repair of reinforced elastomer joints:

Bolts should be checked for tightness as a specific task in the maintenance programme.

If the rubber and internal plates have been debonded the cushion will need to be replaced.

Regular maintenance should keep the grooves in the rubber free of debris.

8.4 BEARINGS

The following bearing types cover most of those used in New Zealand bridges. In some situations a purpose-built bearing may be employed but it will generally consist of a modification of one of the types described here or a combination of more than one type.
Bearings transmit superstructure loads to the substructure. They also provide for longitudinal movements and rotation due to live load deflection, expansion and contraction, and small seismic movements. They are vitally important to the efficient functioning of the structure. If they are not kept in good working order, stresses may be induced into the structure that can substantially shorten its service life.

In many bridges, bearings, particularly elastomeric bearings, are not fixed positively to the structure, but depend on friction to prevent progressive displacement.

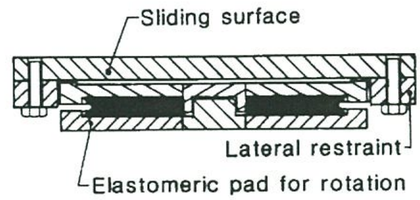
It is desirable that friction effects or the fixing of the bearing components to both the substructure and the superstructure prevent the components parting company or "walking" in a seismic shake.

All bearings need to be protected from sand blasting and grinding operations, and care needs to be exercised when high-pressure water blasting not to drive grit, etc. into places where it will contribute to surface damage.

8.4.1 Sliding Bearings

Sliding bearings are generally of low profile and used in long span structures where significant longitudinal movements occur. They usually consist of a polished stainless steel plate sliding against a PTFE layer bonded to a steel backing plate.

The simple sliding bearing copes only with horizontal movements, but it is usually mounted on a low profile elastomeric pad that copes with any rotational movements. A simple steel-on-steel sliding bearing used on some older bridges is depicted in Figure 8.11 below. This type provides for rotational movement but generally has a high friction coefficient. Other steel on steel sliding bearings are composed simply of flat plates with no specific provision for rotational movement. In some steel sliding bearings, a thick graphite-impregnated sheet is inserted between the plates. A further type of sliding surface used in the past was graphite-impregnated bronze.



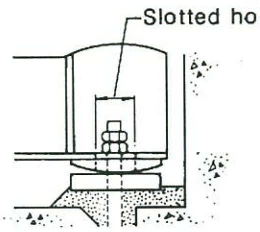


Figure 8.11: Typical sliding bearings: PTFE/stainless steel (top); steel/steel (bottom).

Defects in the sliding component can include:

- Tearing of the PTFE membrane that separates the two stainless steel plates, generally caused by grit or other foreign material trapped between the sliding surfaces;
- Scoring of the stainless steel plates, again caused by contaminants such as grit trapped between the sliding surfaces;
- Misalignment causing binding on the lateral restraint guides. This is generally only a sign of some other problem such as differential settlement of the foundations;

- PTFE “flow” (dimensional change in the thickness of the PTFE membrane), caused by uneven pressure. It is usually the result of misalignment due to differential settlement in the foundations;
- Seizure due to corrosion or to disintegration of the graphite sheet if there is one. This is the main fault that occurs with sliding bearings.

The structural implications of these defects are that a larger force is needed to cause sliding than the designer intended, or that the bearing seizes altogether causing undesirable stresses in both the superstructure and the substructure.

The following points should be considered in the maintenance and repair of sliding bearings:

If PTFE “flow” has occurred, the probable cause will be differential settlement or rotation causing uneven loading on the membrane. Rotational effects will be remedied when the bearing is reset.

Where the PTFE membrane has been deformed or ruptured, the bearing will require full rehabilitation. It is generally inappropriate to attempt this work on site. It will, therefore, be necessary to either replace the bearing with a spare unit or use a temporary bearing while the rehabilitation is carried out under factory conditions. In most cases the stainless steel sliding surfaces will need to be re-polished or, if badly scored, replaced.

Where misalignment has caused bending or cracking of the side guides, these will require straightening and/or re-welding.

If holding down bolts or slide guides are bent or fractured, the cause of the problem should be investigated. Differential settlement or seizure at another point in the structure may have caused the problem. In this case treat the cause first and then repair the bearing fault.

Usually the defects are caused by water or wind-borne grit entering the sliding surface area. The future performance of the bearing may be enhanced by the installation of a protective shroud. When installing a shroud, take care that it is able to cope with the full travel of the bearing.

Where minor corrosion of the base plate and/or top plate only has occurred, and the sliding surfaces are still satisfactory, wire brushing to remove the corrosion product and the application of high-quality protective coatings can be done on site. Under no circumstances should grinding wheels or other grit-producing methods be used to remove the corrosion products, as inevitably some grit will enter the sliding surfaces.

Bearings with metal sliding surfaces should be lubricated.

8.4.2 Rocker Bearings

Rocker bearings provide for rotational movement in the longitudinal direction. They do not allow for any horizontal movement. This type of bearing was used extensively in some older types of steel girder and steel truss bridges. Two common types of rocker bearing are shown in Figure 8.12.

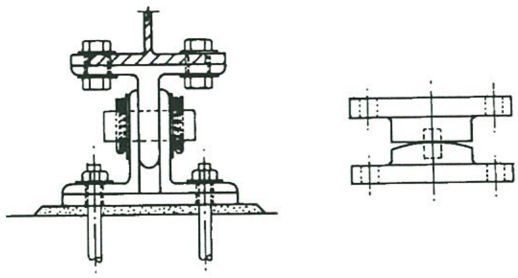


Figure 8.12: Typical rocker bearings.

Typical defects that may be found in inspections are:

- Excessive wear in the key and keyways or pins. This defect is often just a product of age but the condition can be aggravated by dirt and grit carried into the working parts of the bearing by water leaking through faulty deck joints;
- Loose bolts or cracked welds. These are often caused by excessive load brought on by partial seizure of the bearing;
- Corrosion caused by water and dirt build-up in the bearing region due to faulty joint and drainage systems.

The structural implications of the above faults are, again, the introduction of unacceptable stresses into the main members of the structure as described in Section 8.4.

Most of the faults associated with this type of bearing are related to excessive wear and corrosion. Both conditions are aggravated by accumulation of dirt and water in the bearing area. The most common cause of this condition is failure of the deck joint.

The following points should be considered in the maintenance and repair of rocker bearings:

When effecting repairs, any defects in the joint should also be addressed, and the time between the two exercises should be minimised.
If the wear in keys, keyways and pins is not too severe, the bearing should have all corrosion product removed and be treated with a high-quality protective coating.

If the bearing is so badly worn or corroded as to require replacement, replacement with a more modern type of bearing such as a low profile elastomeric pad should be considered.

Any damaged bolts should be replaced and any loose bolts re-tightened to the recommended torque.

All bearings should be lubricated.

8.4.3 Spherical Bearings

This type of bearing is not often found in New Zealand bridges. It allows for rotation in all directions by using spherical bearing surfaces, one of which is polished stainless steel, and one PTFE, similar to sliding bearings. Where longitudinal movements must also be accommodated, this bearing type is modified by inclusion of a sliding component.

Typical defects found in these bearings are similar to those found in sliding bearings:

- Torn sliding membranes, generally caused by dirt entering the sliding surface area. This type of bearing is particularly prone to entrapped dirt and water if it involves a concave bottom plate;
- Corrosion and scoring of the stainless steel plates;
- Loose bolts or fixing devices.

The structural implications of these faults are the same as those for most bearing defects. They will tend to restrict the design movement capacity of the bearing and transfer the resulting stresses into the main structural members of the bridge and to other bearings.

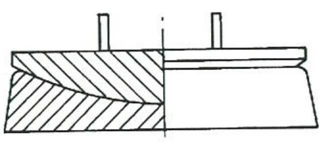


Figure 8.13: Typical spherical bearing.

The following points should be considered in the maintenance and repair of sliding bearings:

Damaged units should be replaced by a more satisfactory bearing such as a low profile elastomeric pad. If the decision is made to repair the original unit, it must be done under factory conditions.

Any loose bolts should be re-tightened or replaced as necessary.

Where no significant damage is apparent the bearing performance and durability can be enhanced by application of a protective shroud to prevent water and wind-borne dirt and grit gaining access to the sliding surface area.

8.4.4 Pot Bearings

A pot bearing consists of an elastomeric pad confined in a pot base. It allows for rotation in all directions. Load is transferred to the elastomeric pad by a steel plate free to move within the pot with minimal clearance. It may be used as an anchorage against horizontal forces (pot stay) or be combined with a sliding surface.

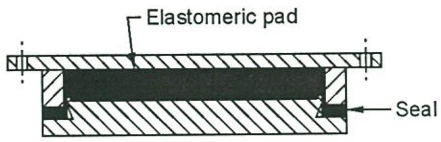


Figure 8.14: Typical pot bearing with sliding surface.

Faults that occur with this type of bearing are:

- The elastomeric pad may suffer compressive rupture at one edge if the bearing has been subjected to more than its designed rotation;
- Shear of bolts caused by horizontal movements for which this type of bearing is not designed;
- Corrosion of the baseplates, pots and fixing bolts, generally caused by leakage through faulty deck joints, possibly causing seizure of the bearing.

The structural implications of the second fault are excessive forces transferred into other parts of the structure and the cause is generally failure of a bearing or joint elsewhere in the structure.

The following points should be considered in the maintenance and repair of pot bearings:

Loose or damaged bolts should be re-tightened or replaced as necessary.

Compressive rupture of the elastomer is generally the result of excessive rotation. Before replacing the pad, the cause of this phenomenon should be investigated. It may be the result of differential settlement or rotation of the foundations. If so, and if it is reasonable to assume differential settlement or rotation has now stabilised, the superstructure should be jacked back up to its original height and the new bearing installed on a raised pad, making suitable provision for rotations that may have occurred.

Corrosion of the base plates, bolts and pots is generally the result of water leakage through faulty joints. The bearing should be removed, the metal components sand blasted, then painted with a high-quality protective coating. Once the bearing is repaired the faulty deck joint causing the problem should be repaired without delay.

8.4.5 Elastomeric Pad and Strip Bearings

This type of bearing is the most commonly used at present. The bearing is designed to cope with rotational and horizontal movements in all directions. The bearing is either a single rubber layer, or is laminated from thin steel plates separated by rubber layers bonded together by vulcanising. Some elastomeric bearings contain one or more lead cylinders embedded within the rubber and steel plates. They look the same in service as conventional elastomeric bearings. Thicker outer plates are designed to accept locating dowels or bolts, and may be either external or, more usually, enclosed in rubber. The edges of the plates are also enclosed by rubber.

In some earlier types of this bearing, the plates and rubber layers were glued making them more vulnerable to de-bonding and corrosion, particularly as the plate edges were not usually covered by rubber.

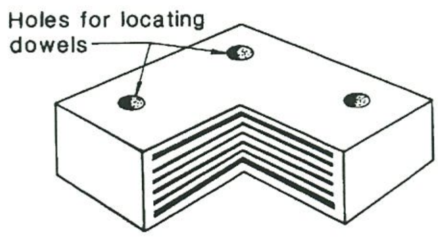


Figure 8.15: Typical elastomeric bearing.

Faults which occur with elastomeric bearings are:

- Shear failure in the form of delamination of the steel plates and layers of rubber, caused by excessive vertical stresses, horizontal movements or seismic forces;
- Rupture of the protective rubber sheathing, caused by excessive horizontal movements and/or excessive compression or rotation;
- Corrosion of the baseplates and/or the laminated steel plates, usually caused by leakage from defective joints;
- Excessive compression due to decomposition of the rubber in older models of this type of bearing.

Elastomeric strips are commonly used under double hollow core units and similar forms of construction. The performance of this type of bearing is generally satisfactory but they should be inspected for excessive compression in particular.

The structural implications of the above faults are the same as described for other bearing types. They can induce unacceptable stresses into the main members of the structure and fail to support effectively the vertical loads and transmit these through to the substructure.

Shear failure in this type of bearing occurs only when the bearing design parameters for horizontal movement are exceeded. This sometimes occurs because the bearing was installed when the bridge superstructure was not midway between its fully expanded and fully contracted travel. In this case it will inevitably exceed its design shear loads at one end of the thermal cycle. It may also occur in prestressed concrete bridges with continuous or interlinked spans due to insufficient allowance having been made for long term creep shortening.

The following points should be considered in the maintenance and repair of elastomeric pad and sliding bearings:

Where any significant damage such as delamination, rupture of rubber cover layer, or perishing of the rubber has occurred for whatever reason, the only remedy available is replacement of the pad.

Where the base plates or top plates have corroded, the corrosion product should be removed by wire brushing, the parts given a high-quality protective coating of paint and the cause of the defect remedied by repair of the defective deck joint.

8.4.6 Roller Bearings

Single roller bearings allow both rotation and longitudinal movements of the supported beams, but multiple roller bearings require specific provision to allow rotation as well, which complicates the details. Neither type is now in common use.

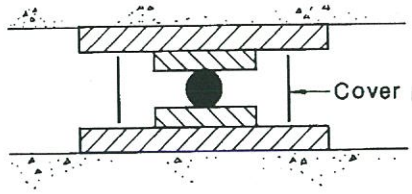


Figure 8.16: Typical roller bearing.

Defects often found include:

- Seizure of the bearing caused by accumulated dirt, debris, corrosion, loss of lubrication or misalignment;
- Corrosion of the steel baseplates, rollers, bolts, pins and guide devices;
- Shear of the bolts or other fixing devices.

The structural implications of the above faults are that they can introduce high stresses into the main support members of the structure and can lead to failure elsewhere.

The following points should be considered in the maintenance and repair of roller bearings:

Regular attention to lubrication is essential.

If minor corrosion has occurred, wire brushing and new protective coating is sufficient.

If seizure has occurred, dismantling in a workshop will be required. If undamaged, the bearing may be re-used.

If the bearing components are severely corroded or flats are worn on the rollers, the unit should be replaced. In this case consideration should be given to replacing it with a more modern unit. If the horizontal movement is large, a sliding bearing could be used, preferably with a low profile elastomeric pad mounted under the sliding bearing base plate to accommodate rotation. If the horizontal movement is small, an elastomeric pad bearing may satisfy both horizontal and rotational movement demands.

8.5 HOLDING DOWN BOLTS

Holding down (HD) bolts in this context are used to fix the superstructure to the substructure. They are generally located within the diaphragm on concrete structures, and through the beam flanges on steel structures.

In older bridges, HD bolts provided horizontal restraint against earthquake movement as well as vertical restraint, but in current designs the two functions are usually separated.

In concrete structures they often pass through ducts which will allow for some horizontal movement in the longitudinal direction.

It should be noted that current design criteria do not require the superstructure to be specifically held down, except where the dead load is small and likely to be reversed, for example at a joint between two cantilevers. Where there is no holding down device, horizontal restraint is achieved by some other means such as shear keys.

Faults that occur with HD bolts are:

- Loose nuts caused by repetitive movement cycles of the superstructure;
- Bending and shear failures caused by excessive horizontal movements;
- Corrosion, generally caused by leakage from defective deck joints or exposure in an aggressive environment;
- Cracking of superstructure or substructure concrete caused by excessive horizontal movements or jamming of the HD bolts in their movement slots.

The structural implications of these faults are that the superstructure may not be effectively tied down to the substructure, and horizontal restraint may not be effective. In the event of a significant seismic shake, a span could be pulled off the supporting pier or abutment.

The following points should be considered in the maintenance and repair of holding down bolts:

Where HD bolts on a concrete bridge have bent, it is often the result of post-tensioning of the superstructure after the bolts have been installed. In this case, where insufficient allowance for movement has been made in the HD bolt ducts passing through the diaphragm, high stresses can be induced in the diaphragm area. The only effective remedy for this condition is to cut the existing HD bolts and drill in new bolts from the deck level. The new bolts should be grouted into the abutment or pier caps with "non-shrink" grout and tightened down into recesses cut in the deck.

Sufficient compressible filler should be placed above the bolts to allow for bearing compression, and secondary concrete poured in the recesses to protect the bolt heads. Where the pier or abutment cap concrete has cracked in the embedment region of the bolt, the concrete should be broken out and patch repaired. If the cracking is not too severe, the cracks should be repaired by epoxy injection.

Corrosion of exposed sections of the bolts is generally the result of leakage of deck drainage through defective joints. The exposed section of the bolt should be cleaned of all corrosion product and protected by coatings of paint. The defective joint should be repaired without delay.

8.6 SEISMIC RESTRAINT DEVICES

Seismic restraint devices are used to resist larger movements from earthquake events. They may include such items as span linkage bolts to control longitudinal movements, keys and/or cleats to resist lateral movement and in older bridges holding down bolts to resist movements in all directions.

Where bolts are used to link spans and to tie end spans to the abutment backwalls, the bolts generally pass through the diaphragms, are fitted with shock-absorbing rubber pads and are fitted in such a way that the independent components of the structure can move up to 100 mm before the device applies restraint.

Where bolted cleats are used to resist lateral horizontal movements, they are generally bolted to the substructure, and rubber pads ensure the forces are evenly distributed.

In some concrete structures lateral restraint is achieved by casting keyways in the substructure and keys as an integral part of the superstructure, or by upstands on the substructure bearing against the outer beams.

Faults that can occur with these devices include:

- Span linkage bolts installed too tightly to allow for normal thermal movements in the superstructure. This defect can transfer unacceptable loads to bearings and holding down bolts. Where the bolts should have allowed for large relative movement, a significant seismic event could lead to a span coming off its support seating elsewhere in the structure. Alternatively, the linkage bolts may have been designed to restrict relative movement to a magnitude that can be accommodated by the bearings and expansion joints;
- Misalignment causing seizure of the device, preventing normal thermal movement. This is often a sign of other problems such as differential settlement of the foundations or bearing failure;
- Corrosion of metal parts, generally caused by leakage through faulty joints or exposure in an aggressive environment;
- Cracked or spalled concrete keys and keyways, generally caused by misalignment faults. The underlying cause of the misalignment must be investigated.
- Bent cleats and sheared bolts, which may also be the result of misalignment due to differential settlement of foundations or bearing failure.

Most of the above faults will prevent the various components of the structure from moving as designed, causing excessive stress which will result in damage to other members of the bridge.

The following points should be considered in the maintenance and repair of seismic restraint devices:

Where span linkage bolts have been installed too tightly, it is generally sufficient to slacken them to allow the required movement. However, it is prudent to investigate if this condition has already led to excessive strain in other areas. The linkage may have been designed to restrict relative movement to a magnitude that can be accommodated by the bearings and expansion joints. It is therefore advisable to check with the design office before adjusting linkages.

If superstructure is misaligned, check that the seismic device is not cracked or bent and that the fixing devices are not damaged. If damage has occurred, replacement rather than repair is usually recommended as these devices are designed to cope with severe stresses during a significant seismic event and any weakening can detract from their ability to restrain the structure during such an event.

Galvanised hardware within a kilometre of the sea should be washed down with clean water from time to time to prevent build-up of salts. In severe environments galvanised steelwork should be given some protection compatible with the associated elastomeric pads.

8.7 PEDESTRIAN AND TRAFFIC BARRIERS

Pedestrian barriers (handrails) provide security for pedestrians using the structure and are not designed to withstand vehicular impact. Pedestrians may be protected from vehicles by a traffic barrier separating the carriageway from the footway. Where no separate barrier is provided, vehicles are generally confined to the carriageway by a kerb and a combined pedestrian/traffic barrier at the outer edge of the footpath.

Traffic barriers are specifically designed to confine traffic to the bridge carriageway. The system commonly used in New Zealand is W-section guardrail mounted on steel posts on the bridge deck and bolted to wooden posts on the approaches. Other types of non-rigid barrier (e.g. thrie beam) and rigid barrier (solid concrete or steel post and rail) are also used.

The design principle for W-section guardrail is that, under an extreme vehicle impact, the holding down bolts fail or the wooden posts break off, allowing the rail to deflect outwards and resist the forces by ribbon tension. For other types of non-rigid barrier, the supporting posts bend under impact to allow ribbon tension to be developed. The height of the W-section guardrail and other non-rigid barriers relative to the road surface must be in accordance with Transit requirements (see Section 6.3.5) If it is too low, vehicles may overturn, rather than being re-directed along the rail. For the same reason all W-section guardrail post packing-out blocks must be in place so that when a post bends under impact the rail will be raised rather than lowered. The W section guardrail or other non-rigid barrier must be effectively anchored at each end in order to develop tension. Rigid barriers do not deflect under vehicle impact.

Defects that can occur with non-rigid barriers include:

- Rot in timber handrails, caused by loss of protective coatings and fungi attack;
- Corrosion of steel components including bolts on both handrails and traffic barriers, caused by loss of protective coatings.
- Loosening of components by excessive movement, impact or vandalism;
- Misalignment, often leading to shear failures caused by failure of bearings or differential settlement of foundations (see Section 6.3);
- Impact damage.

These defects place road users and pedestrians in danger and repairs should be carried out without delay.

The following points should be considered in the maintenance and repair of handrails and traffic barriers:

(a) Timber Handrails

Where damaged by impact, rot or severe weathering, they should be replaced.

Where the damage is restricted to weathering of protective coatings, the timber should be sanded back and a full protective coating system applied from primer through to topcoats.

Any corroded straps or bolts should be replaced or cleaned of all corrosion products and an appropriate protective coating applied.

(b) Steel Handrails

Damage generally consists of loss of protective coatings with subsequent corrosion, and/or loose fixing devices. All loose paint and rust should be removed by grit blasting and a full good quality protective coating system applied.

Damaged bolts or other fixing devices should be replaced.

(c) Non-Rigid Traffic Barriers

In most instances damage will be from vehicular impact. The damaged rail sections should be replaced using new bolts in both the splice areas and the fixing system to the posts. Bent posts should be replaced, using new holding down bolts. For W-section guardrail, these bolts have a special necked section designed to fail at a specific loading. If the barrier rail has suffered a severe impact, they may have been weakened and should not be re-used.

Non-rigid barriers are usually hot dip galvanised. If this sacrificial coating is defective the rail should be replaced and the defective section refurbished and kept for future replacement tasks.

(d) Rigid Traffic Barriers

For rigid concrete barriers, damage from vehicular impact may occur to the face of the barrier. Severe damage should be repaired as for other concrete elements. For rigid steel barriers, damage from vehicular impact may occur to post and rail elements and connections. Severely damaged elements should be replaced using new bolts. Corrosion protection may also be damaged by vehicle impact and should be repaired.

8.8 SERVICES SUPPORTS AND ACCESS ATTACHMENTS

Services supports are generally brackets carrying service lines in ducts on the outer sections of deck soffits. Where service lines are located beneath the cover slabs on footways or inside box girders, the supports may be saddles mounted on the floor of the box girder or the deck surface beneath footways. Usually the brackets will be of steel, bolted to the underside of the deck.

While the items are technically the responsibility of the service utility concerned, the bridge owner has an interest in ensuring that they are kept in good condition.

Access attachments can range from full walkways in larger structures to eyebolts embedded in the deck soffit on smaller structures.

Faults that can often be found with these items are:

- Corrosion of steel brackets caused by loss of protective coatings;
- Loose bolts, generally as a result of inadequately applied torque when installed;
- Misalignment of the service line due to damage to footways caused by differential settlement or abnormal movements in the structure.

The structural implications of these faults are less important than the danger to people using the areas beneath the bridge or the walkways on it. In addition, failure of the service the bridge is carrying can cause considerable disruption to users.

The following points should be considered in the maintenance and repair of services supports and access attachments:

Missing or loose bolts should be replaced and tightened as necessary.

Loss of protective coatings on the brackets may require the brackets to be removed, wire-brushed to remove corrosion products and re-coated.

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