

Superseded

**Technical Specification**

**Transport and Main Roads Specifications  
MRTS90 Modular Bridge Expansion Joints**

**January 2015**

Superseded

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## 1 Introduction

### 1.1 General

This specification sets out the requirements for the design, supply, fabrication, testing, delivery and installation of Modular Bridge Expansion Joints (MBEJ) covering both single and multiple support bar systems. The MBEJ accommodates expansion, contraction and rotation of the bridge superstructure due to temperature and other effects.

This technical specification shall be read in conjunction with MRTS01 *Introduction to Technical Standards*, MRTS50 *Specific Quality System Requirements* and other technical specifications as appropriate.

This specification forms part of the Transport and Main Roads Specifications Manual.

### 1.2 Eligible suppliers

The MBEJ system shall be a proprietary product with proven performance in the field. The MBEJ System Manufacturer shall have at least five years recent experience in the design and supply of MBEJ systems similar to those to be furnished under this specification. All systems required under the Contract shall be provided by the same MBEJ System Manufacturer.

## 2 Definition of terms

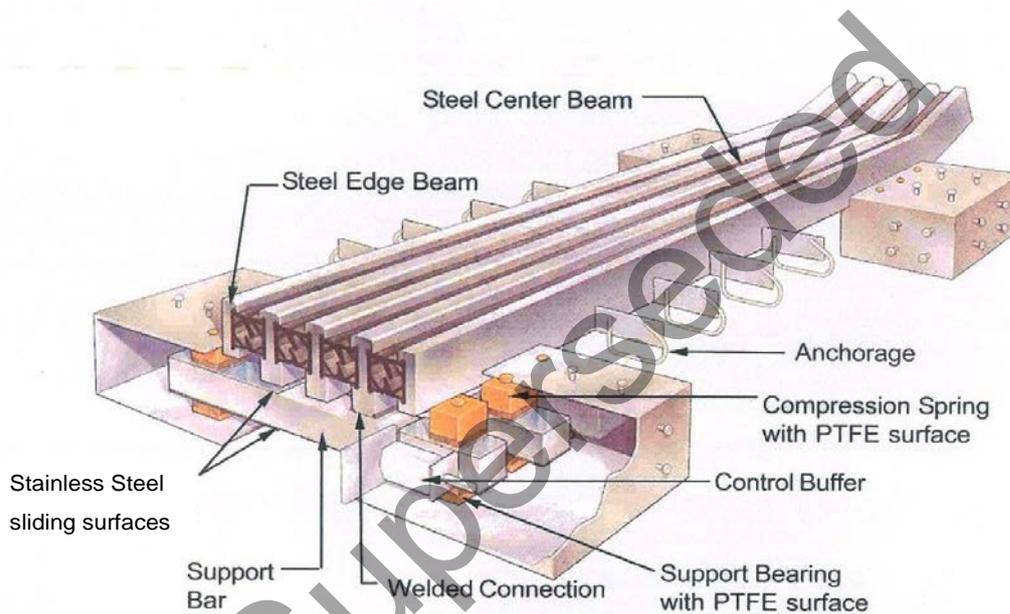
The terms used in this specification shall be as defined in Clause 2 of MRTS01 *Introduction to Technical Specifications*. Further definitions are as defined in Table 2.

**Table 2 – Definition of terms**

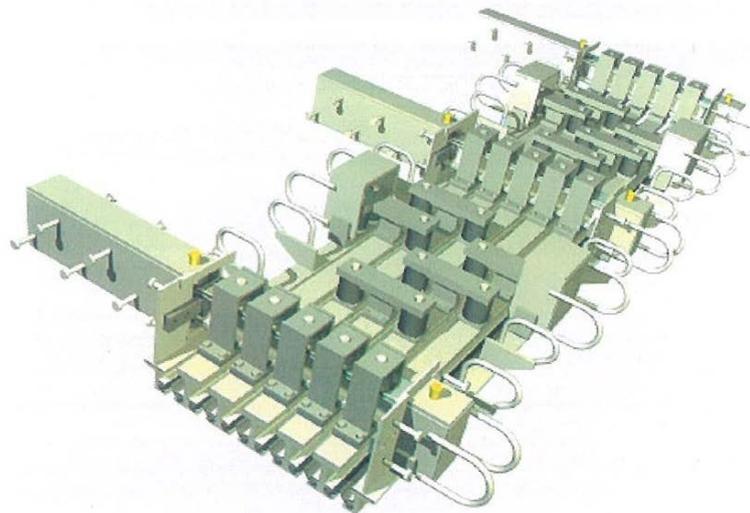
Term	Definition
Dynamic Amplification Factor (DAF)	The factor ( $\chi$ ) by which the static force or stress shall be multiplied to give the total dynamic force or stress. Note that: $\chi = 1 + \alpha$ Where $\alpha$ is the DLA
Dynamic Load Allowance (DLA)	As defined in AS 5100.2
Joint Designer	A senior design engineer engaged by the MBEJ System Manufacturer and nominated by the Contractor and agreed to by the department who shall take the lead role in the design of the MBEJ and who shall certify the design and drawings
MBEJ	Modular Bridge Expansion Joint as described by this specification
MBEJ System Manufacturer	The principal entity that holds the intellectual property in the MBEJ
Modular Joint Drawings	The complete set of drawings prepared for the design, fabrication and installation of the MBEJ
Multiple support bar MBEJ (MSBJ)	Multiple support bar MBEJ have transverse centre beams which are connected to longitudinal support bars. Each support bar supports only one centre beam. The support bars span across the MBEJ opening and slide between elastomeric springs and bearings in support boxes. The support boxes are cast into the concrete on both sides of the MBEJ. A typical multiple support bar MBEJ is shown in Figure 2-A

Term	Definition
NATA	National Association of Testing Authorities (Australia) or internationally equivalent accreditation as provided by NATA's Mutual Recognition Arrangement Partners.
NCHRP	National Cooperative Highway Research Program.
Single support bar MBEJ (SSBJ)	Single support bar MBEJ have transverse centre beams that are attached to support bars using steel yokes and elastomeric springs and bearings. Each support bar supports a number of centre beams. The support bars span across the MBEJ opening and slide between elastomeric springs and bearings in support boxes. The support boxes are cast into the concrete on both sides of the MBEJ and accommodate the required number of support bars. The swivel joint system is a variant of this design. A typical single support bar MBEJ is shown in Figure 2-B.
Swivel Joist System	A special type of single support bar MBEJ system with swivelling single support bars.

**Figure 2-A – Example of a Multiple Support Bar MBEJ System**



**Figure 2-B – Example of a Single Support Bar MBEJ System (shown inverted)**



### 3 Referenced documents

Table 3 lists documents referenced in this technical specification.

**Table 3 – Referenced documents**

Reference	Title
AS 1101.3	Graphical symbols for general engineering – Welding and non-destructive examination.
AS 1627.4	Abrasive Blast Cleaning.
AS 1683.11	Methods of Test for Elastomers – Tension Testing of Vulcanised Rubber.
AS 1683.13	Method of Test for Elastomers – Compression Set of Vulcanised Rubber Under Constant Deflection.
AS 1683.15.1	Method of Test for Elastomers – Internal Rubber Hardness.
AS 1683.15.2	Methods of Test for Elastomers – Durometer Hardness.
AS 1683.23	Method of Test for Elastomers – Rubber – Vulcanised – Determination of Resistance to Liquids.
AS 1683.24	Method of Test for Elastomers – Rubber – Vulcanised – Determination of Resistance to Ozone Cracking – Static Strain Test.
AS 1683.26	Methods of Test for Elastomers – Rubber, Vulcanised or Thermoplastic – Accelerated Ageing and Heat Resistance Tests.
AS 2105	Inorganic Zinc Silicate Paint.
AS 2177	Non-destructive testing – Radiography of welded butt joints in metal
AS 2207	Non-destructive testing – Ultrasonic testing of fusion welded joints in carbon and low alloy steel
AS 2700	Colour Standards for General Purposes.
AS 2702	Acoustics – Methods for the Measurement of Road Traffic Noise.
AS 2812	Welding, brazing and cutting of metals – Glossary of terms.
AS 5100.2	Bridge Design, Part 2: Design loads.
AS 5100.4	Bridge Design, Part 4: Bearings and deck joint.
AS 5100.6	Bridge Design, Part 6: Steel and composite construction.
AS/NZS 1100.501	Technical drawing – Structural engineering drawing.
AS/NZS 1252	High strength steel bolts with associated nuts and washers for structural engineering.
AS/NZS 1554.1	Structural steel welding – Part 1: Welding of steel structures.
AS/NZS 1554.5	Structural steel welding – Part 5: Welding of steel structures subject to high levels of fatigue loading.
AS/NZS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings.
ASTM A240M	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
ASTM C794	Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants.
ASTM D746	Standard Test Method for Brittleness Temperatures of Plastics and Elastomers by Impact.

Reference	Title
ASTM D5973	Standard Specification for Elastomeric Strip Seals with Steel Locking Edge Rails Used in Expansion Joint Sealing.
ISO 9001	AS/NZS ISO 9001 Quality management systems – Requirements.
ISO 13000-1	Requirements and Designation.
NCHRP 402	National Cooperative Highway Research Program – Report 402: <i>Fatigue Design of Modular Bridge Expansion Joint</i> , Transportation Research Board-National Research Council, National Academy Press, Washington, D.C., 1997.
NCHRP 467	National Cooperative Highway Research Program – Report 467: <i>Performance Testing for Modular Bridge Joint Systems</i> , Transportation Research Board-National Research Council, National Academy Press, Washington, D.C., 2002.
WTIA Technical Note 5	<i>Flame Cutting of Steels.</i>
EWINS D J,	Modal Testing: Theory, Practice & Application (2nd Edition), Research Studies Press, Hertfordshire, UK, 1999.

## 4 Quality system requirements

### 4.1 General

The MBEJ System Manufacturer shall operate a quality management system complying with the requirements of ISO 9001. This quality plan shall cover all aspects of the design, fabrication, inspection, testing and installation of the MBEJ.

The MBEJ System Manufacturer's quality plan shall form part of the Contractor's quality plan provided in accordance with the requirements of MRTS50 *Specific Quality System Requirements*.

### 4.2 Hold Points, Witness Points and Milestones

General requirements for Hold Points, Witness Points and Milestones are specified in Clause 5.2 of MRTS01 *Introduction to Technical Specifications*.

The Hold Points, Witness Points and Milestones applicable to this specification are summarised in Table 4.2.

**Table 4.2 – Hold Points, Witness Points and Milestones**

Clause	Hold Point	Witness Point	Milestone
6.14	1. Provision of design prior to fabrication.		Submission of design calculations and drawings (28 days).
7			Submission of shop drawings (10 days).
8.2	2. Material test certificates prior to fabrication.		
8.3		Testing of materials.	Notice of testing of materials (14 days).
9.3		Centre beam dimensional checks.	

Clause	Hold Point	Witness Point	Milestone
9.4.5	3. Corrective action following welding.		
10	4. Certification of materials prior to assembly.		Submission of material certificates (14 days).
11	5. Assembly procedure prior to assembly.	Assembly of the MBEJ. Installation of joint seals.	Submission of assembly procedure (7 days). Notice of installation of joint seals (7 days).
13	6. Transport of MBEJ.		Submission of procedure for transport (7 days).
14	7. Installation of MBEJ.		Submission of procedure for installation including seals and watertightness test (14 days).
16			Submission of as-built drawings (28 days).

#### 4.3 Design and construction procedures

The Contractor shall prepare documented procedures for all design and construction processes in accordance with the quality system requirements of the Contract. The design and/or construction procedures stated below shall be submitted to the Administrator:

- a) details of work to be carried out by shop treatment and work to be carried out by field treatment
- b) fabrication including dimensional control, manufacturing tolerances and details of manufacturing jigs
- c) welding
- d) assembly
- e) repairs and corrections
- f) transport, handling and storage, including measures to prevent distortion and damage to the MBEJ and its protective coating
- g) preparations for work on the site
- h) installation of the MBEJ, and
- i) installation, field jointing and testing for watertightness of the seals.

#### 4.4 Fabrication programme

A fabrication program shall be included in the quality plan. The fabrication program shall include:

- a) the proposed sequence of operations and the proposed time required for fabrication all members and/or parts, which shall be identified by name and mark
- b) the proposed timing for carrying out repairs to the protective treatment at areas in contact with concrete, and
- c) the proposed timing for carrying out protective treatment to the surfaces that are inaccessible in the completed structure and outside of field welds.

#### **4.5 Quality records**

For all MBEJs incorporated in the works, at least the documents listed below shall be included in the quality records:

- a) tender submission
- b) shop drawings
- c) maintenance manual
- d) design documentation
- e) design and construction procedures
- f) NATA laboratory certificates-of-conformance
- g) certification and testing of materials
- h) weld NDE and inspection reports
- i) assembly documentation
- j) certification that the fabricated MBEJ conforms to the design
- k) manufacturer's certification of installation procedures
- l) manufacturer's certification following post-installation inspection
- m) procedures and results of testing the MBEJ for watertightness, and
- n) as-built drawings.

### **5 MBEJ system manufacturer**

#### **5.1 General**

The MBEJ shall be designed, fabricated, inspected, tested and installed by the MBEJ system manufacturer in accordance with the provisions of this specification.

The MBEJ system manufacturer shall provide to the Principal a warranty guaranteeing the quality and performance of the MBEJ for a period of five years, commencing from the date of opening of the bridge on which the MBEJ has been installed or from the date of the Principal's receipt of the warranty, whichever occurs later. At the expiration of this period, an extended warranty which covers the timely supply of replacement parts shall be provided to the Principal. After the expiration of the initial five year warranty period, the cost of such replacements parts will be borne by the Principal.

At appropriate times during the contract period, the MBEJ System Manufacturer shall:

- a) provide evidence that the proposed manufacturing tolerances, specified by the MBEJ System Manufacturer, are adequate for the correct functioning of the MBEJ installed at the location stated on the drawings
- b) supply a maintenance manual which describes all activities necessary to ensure that the life of the MBEJ can be achieved
- c) supply sufficient technical details of materials, components, design and testing to enable the Principal to maintain the MBEJ in the event that the MBEJ system manufacturer can no longer supply components in a timely manner – such information will be regarded by the Principal as being commercial-in-confidence, and
- d) where components of the MBEJ are subject to intellectual property rights, advise the Principal of the holder of these rights, and of any changes to these rights or the holder of these rights.

The MBEJ system manufacturer shall certify that the MBEJ supplied meets the requirements of this Specification with respect to the:

- a) design
- b) conformance of the shop drawings to the design and this specification
- c) materials and components
- d) fabrication and assembly of the MBEJ, including certification that the fabricator has copies of all relevant documents listed in Table 3
- e) installation of the MBEJ, and
- f) the maintenance manual for the MBEJ.

## **5.2 Length of joint**

The joint shall extend the full width of the roadway, without the need for field joints.

## **5.3 Submissions**

The requirements for submission of design, fabrication and installation information is based on Appendix A of NCHRP Report 467.

All offers shall include, as a minimum:

- a) the name and contact details of the MBEJ System Manufacturer
- b) the name, contact details and curriculum vitae of the MBEJ System Manufacturer's agent
- c) names and details of bridges where MBEJ of the MBEJ system type have been installed, together with the movement capability, installation date, and the name, telephone number and facsimile number of the maintaining authority for each bridge
- d) noise test reports of the performance of the MBEJ system under traffic (where available)
- e) an experimental modal analysis study (as per Annexure MRS90.6) conducted on a comparable size and type of dynamically similar MBEJ from the supplier, or a written commitment that the study will be provided if the supplier is successful
- f) evidence of compliance with the fatigue test requirements set out in Appendix B of NCHRP Report 402
- g) results of NCHRP Report 467 testing (where available)
- h) statement of where the proposed materials and fabrication do not comply with this technical specification. This Statement shall include the technical justification for the variations and a clause-by-clause comparison between the specified requirement and the proposed substitution
- i) all MBEJ drawings, regardless of the time of submission, shall be submitted as both hard copies (Size A1) and in electronic format (.DWG, .DXF or .PDF). Electronic copies shall be recorded onto a CD-ROM that shall be labelled with the drawing number(s), sheet number(s) and revision number(s). All drawings shall comply with AS/NZS 1100.501 and dimensions shall be in SI units
- j) four sets of any non-metallic components excluding seals, including four of each type of elastomeric bearing and four of each type of elastomeric springs proposed for use in the MBEJ(s), together with a description denoting which MBEJ type(s) and at what location(s)

each bearing and spring is to be used, and what pre-compression is applied to each bearing and spring, and

- k) the name and address of the proposed fabricator, together with documentation of past experience of the fabricator in complex heavy steel fabrication and pre-qualified weld procedures.

**Note (1):** The Principal will undertake a fabrication shop assessment including inspection of weld procedures, testing, macros, past records of non-conformances and OH&S systems and practices prior to accepting the proposed fabricator.

**Note (2):** The Principal will favour systems that exhibit higher damping characteristics and greater structural stiffness over systems with lower damping characteristics and lower structural stiffness, for both structural performance and environmental noise mitigation.

All submitted documents shall be in the English language. Where it is proposed to submit a primary or supporting document written in a language other than English, a certified English language translation of the document including all text, tables, figures, photographs and appendices from the source document, shall accompany the source document.

## **6 Design requirements**

### **6.1 General**

Detailed design requirements are prescribed in Appendix A to this specification. Appendix A specifies the design loads, various factors to be applied to the loads, the procedures to be followed to satisfy the three limit states of fatigue, strength and serviceability and the requirements of these limit states. The design load shall be the A160 axle specified in AS 5100.2.

For any items not covered in Appendix A, the requirements of AS 5100.4 and AS 5100.6 shall be followed.

### **6.2 General arrangement**

The centre beams shall be continuous over the full width of the carriageway. Field splices in centre beams shall not be used.

The maximum clear gap between the tops of the centre beams shall be 85 mm at the joint opening corresponding to the ultimate limit state.

The spacing between centrelines of the support bars shall not exceed 1500 mm.

MBEJ systems may utilise either positive mechanical control (for example, pantographs, etc.) or elastomeric springs to provide equidistant centre beam spacing. However, where the MBEJ is to be installed at a slope (in the direction of vehicular traffic) exceeding 0.5°, the MBEJ system manufacturer shall demonstrate that the equidistant system proposed is capable of maintaining equal centre beam spacing under all possible operating conditions for the life of the MBEJ.

In service, the MBEJ shall be capable of the movement capacity specified in the Contact at all times.

### **6.3 Design service life**

The following MBEJ components shall be designed to have a minimum 15 year service life and to be replaceable without traffic closures:

- a) compression and control springs, and
- b) support bearings.

The following MBEJ component shall be designed to have a minimum 20 year service life and to be replaceable with either a total road closure not exceeding two hours or not more than two lanes of the bridge at a time closed to traffic:

- a) joint seals.

The following MBEJ components shall be designed to have a minimum 100 year service life:

- a) centre beams, including welded attachments
- b) support bars, including welded attachments, and
- c) support boxes and attachments.

#### **6.4 Limit state requirements**

The nominal yield strength ( $f_y$ ) and nominal tensile strength ( $f_u$ ) shall comply with the following:

- a) the nominal yield strength shall not be less than 250 MPa or greater than 350 MPa for structural steel members, unless otherwise approved by the Principal, and
- b) the nominal tensile strength shall not be less than 830 MPa for bolts and 480 MPa for welds.

The structural design shall be in accordance with the principles of limit state design. The following relationship shall be satisfied:

$$S^* \leq \phi R_{lim} \quad (6.1)$$

Where:

$S^*$  = the design action effect (force, stress, stress range, and so on) for the appropriate limit state

$\phi$  = the capacity reduction factor, and

$R_{lim}$  = the nominal strength, corresponding to  $S^*$ , for the appropriate limit state.

The limit states of fatigue, strength and serviceability shall be checked. The design methodology is prescribed in detail in Appendix A to this specification and is briefly as stated below.

The joint opening and other specific design requirements shall be as stated in Clause 1 of Annexure MRTS90.1.

The axle load and the manner in which it is to be applied are specified in Clause A4 of Appendix A of this specification. The design load shall be obtained by factoring the axle load by various factors (Clause A5 to A9 of Appendix A). The structure shall be analysed and Equation 6.1 verified for each member and detail, as follows:

- a) For the fatigue limit state,  $S^*$  denotes the stress range and  $R^*$  denotes the fatigue resistance for the appropriate Detail Category, for infinite cycles of stress (the cut-off limit stress range)
- b) For the strength limit state,  $S^*$  denotes the bending moments, shears and axial forces and  $R^*$  denotes the section capacity and member capacity, based on the yield stress ( $f_y$ ) or the tensile strength ( $f_u$ ), and
- c) The serviceability limit state requirements deal mainly with noise and damping of vibrations. Clause 6.9 specifies noise level requirements of the MBEJ. The MBEJ system manufacturer shall demonstrate by testing in accordance with Appendix B of this specification that the MBEJ system exhibits damping of at least 5% of critical damping for the first five natural modes.

## 6.5 Design for strength and serviceability

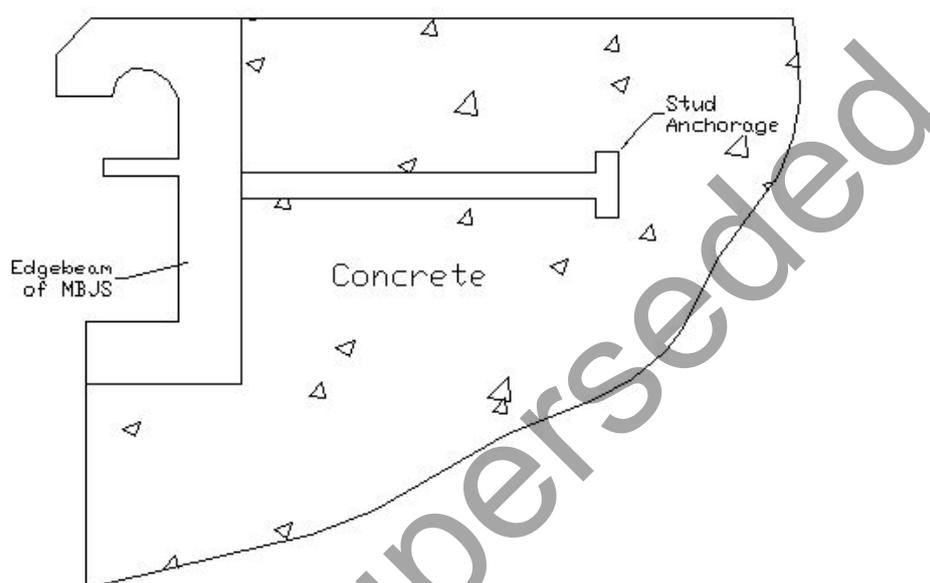
Design of all items for strength and serviceability shall be undertaken in accordance with the requirements of Appendix A to this specification. Structural steel design requirements not covered by this clause shall follow the provisions of AS 5100.6.

## 6.6 Anchorage

### 6.6.1 Edge beams

Where edge beams are not integral with the support boxes, edge beams shall be designed in accordance with Clause 17.4 of AS 5100.4 and detailed in accordance with Figure 6.6.1. Stud anchors that anchor the MBEJ into the concrete shall be 19 mm minimum diameter, 150 mm in length (after welding) and at maximum 300 mm spacing.

**Figure 6.6.1 – Example of edge beam anchorage**



Where edge beams are integral with the support boxes, the edge beam to support box fillet welds along the base of the edge beam shall be assumed to carry not more than 50% of the horizontal component of load.

Where the clear spacing between support boxes exceeds 300 mm, additional anchors conforming to Clause 17.4 of AS 5100.4 shall be provided. Where studs are used, they shall be designed in accordance with the preceding paragraph.

The minimum concrete cover over welded studs, cleats and other fixtures shall be 50 mm but 75 mm is preferred.

### 6.6.2 Support boxes

Horizontal studs that anchor the support box into the concrete shall be 19 mm minimum diameter, 150 mm in length (after welding) and at maximum 300 mm spacing. Vertical studs that anchor the support box into the concrete shall be 13 mm minimum diameter, 75 mm in length (after welding) and at maximum 300 mm spacing.

Alternative forms of anchorage that do not rely upon resistance-welded studs are permitted and shall be designed in accordance with Clause 17.4 of AS 5100.4.

Anchor bars that attach the MBEJ into the concrete shall be designed as follows:

- a) stud welded shear connectors shall only be welded by resistance welding using a welding gun, and
- b) welds holding anchor bars to the MBEJ shall develop the full strength of the bar.

### **6.7 Weld detailing**

All welds in centre beams and support bars shall be full penetration butt welds – Category ‘FP’. All welds attaching anything to centre beams or support bars, within 10 mm of the top or bottom surface, shall be full penetration butt welds – Category ‘FP’. This requirement excludes the welding of stainless steel sliding surfaces. All other welds, except stud welds, shall be Category ‘SP’.

### **6.8 Seals**

The preformed elastomeric joint seals shall resist penetration by material such as aggregate under traffic loading (Reference shall be made to NCHRP Report 467 seal push-out (SPO) test requirement, Clause 4.3).

The preformed elastomeric joint seal retainer profile shall be designed by the MBEJ System Manufacturer to suit the installation situation and to comply with the design requirement herein.

### **6.9 Noise under traffic**

The MBEJ shall not generate excessive noise or vibration under traffic. The MBEJ shall represent “best practice” in achieving minimum noise levels under traffic. The MBEJ System Manufacturer shall include a best practices guide for noise mitigation for the MBEJ.

The average noise of traffic crossing the MBEJ shall not be greater than 6 dB in excess of the traffic noise 30 metres from the joint.

Noise testing shall be carried out in accordance with AS 2702, with measurements taken for drive-by noise performance and underneath the bridge.

### **6.10 Lifting Points**

Suitable handling attachments or lifting points shall be provided to assist in the handling and location of the MBEJ.

### **6.11 Exposed surfaces**

The MBEJ shall provide exposed surfaces that assist in the rejection or reduction of debris accumulation and allow access for clearing of debris if present.

### **6.12 Pedestrian and cyclist requirements**

Where the MBEJ shall be trafficked by pedestrians or cyclists, the MBEJ shall conform to the following additional requirements:

- a) Austroads, Guide To Engineering Practice, Part 13, Pedestrians
- b) Austroads, Guide To Engineering Practice, Part 14, Bicycles, and
- c) any cover plate on the footpath shall have a non-slip surface and not present a trip hazard.

### **6.13 Maintenance**

The design of the MBEJ shall ensure that all performance criteria for the MBEJ are met with minimum maintenance for the design life of the MBEJ.

MBEJs with three or less seals shall be detailed with support boxes with removable tops. The design shall allow for ready access to the MBEJ and provide sufficient space for inspection, maintenance and replacement of MBEJ components as required.

The maintenance manual provided in accordance with Clause 5 shall be delivered to the Principal prior to installation of the MBEJ. The manual shall detail the required inspection and maintenance schedule for the MBEJ, together with work procedures required to carry out repairs and/or replacement of each component of the MBEJ.

#### **6.14 Design documentation**

The Contractor shall submit to the Administrator sufficient drawings and detailed design calculations to enable a complete check of the design to be done in accordance with Appendix A to this specification.

The design submission shall be provided to the Administrator not less than 28 days prior to the commencement of fabrication of the MBEJ. **Milestone**

The information submitted shall include but not be limited to the following:

- a) general arrangement
- b) details of all members, support boxes, yokes if any
- c) all dimensional tolerances for fabrication and fatigue categories of all welds
- d) adequate details of all connections to enable the connections to be checked for fatigue (reference shall be made to Clause A12 of Appendix A to this specification)
- e) drawings indicating the force transmission system for the control spring buffers
- f) static and dynamic design calculations for all structural components, including the anchorages, showing that the MBEJ manufactured to the tolerances shown on the drawings shall perform satisfactorily
- g) certification that the materials and fatigue sensitive details proposed for use on the project have been pre-tested and shall meet the requirements as stated in the current product literature, and
- h) any additions or alterations required to the structure to provide for installation.

The safety and integrity of the MBEJ during transport and erection shall not be included in any design check undertaken by the Principal.

All engineering calculations shall be in SI units.

Fabrication of the MBEJ shall not commence until expiration of the 28 day period. **Hold Point 1**

## **7 Shop drawings**

Shop drawings shall be prepared for the fabrication of all members. Shop drawings shall be independently verified by personnel other than those directly involved in the design and drafting of the shop drawings and certified by the Joint Designer.

The details shown on the shop drawings shall be consistent with the Drawings and shall:

- a) include a marking plan which shall show the location and orientation of the MBEJ in the bridge
- b) conform to AS/NZS 1100.501 as appropriate – drawings showing only the cutting dimensions of beams, flanges and the like shall not be considered as shop drawings

- c) include welding and cutting definitions conforming to AS 2812
- d) include welding symbols conforming to AS 1101.3
- e) show complete information regarding the location, type, category, size and extent of all welds and shall clearly distinguish between shop and field welds
- f) clearly indicate any instance where the welding sequence and/or technique must be carefully controlled to minimise shrinkage stresses and distortion
- g) clearly indicate any instance where welding is not permitted
- h) show weld lengths which are the required effective lengths
- i) show identification marks for each MBEJ and separate identification marks for each part of each MBEJ
- j) show all associated bolting, accessories and/or joining details for assemblies
- k) show details of all holes and attachments required for temporary work such as lifting lugs including methods of sealing all such holes after use, and
- l) show instructions for installation.

Four copies of shop drawings certified by the joint designer as complying with this specification shall be submitted to the Administrator at least 10 working days before commencement of fabrication.

#### **Milestone**

## **8 Materials**

### **8.1 General**

All materials shall comply with the provisions of this specification and the specific requirements shown on the Modular Joint Drawings.

### **8.2 Material certificates**

Test certificates for all materials shall be provided in accordance with the requirements of MRTS78 *Fabrication of Structural Steelwork*.

Where materials are supplied to other than Australian Standards, certified documents stating the equivalent grade in an Australian Standard shall be provided.

Fabrication of a component of the MBEJ shall not commence until all relevant material certificates have been obtained and included in the quality records. **Hold Point 2**

### **8.3 Beams, supports and control units**

The centre beams, edge beams, support bars, control arms, and control boxes shall be fabricated from steel. Aluminium components shall not be used. Weld repaired steel shall not be used.

All steel intended for use as centre beams or support bars shall be non-destructively examined prior to cutting to ensure soundness of material **Witness Point**. Unsound material shall not be used in areas to be welded. Notice of such testing shall be provided to the Administrator at least 14 days prior to commencement of testing. **Milestone**

Centre beams, edge beams and support bars shall be checked and corrected for straightness and bowing before use.

### **8.4 Fasteners**

All bolts, nuts, screws and washers shall comply with relevant clauses of MRTS78 *Fabrication of Structural Steelwork*.

## **8.5 Traceability**

A comprehensive system of identification records shall be established and maintained including which items are cut from each piece of material and where each item is used in each member. Records shall be updated daily and a copy shall be forwarded to the Administrator on request.

## **9 Fabrication**

### **9.1 General**

Fabrication shall be carried out in accordance with the requirements of MTRS78 *Fabrication of Structural Steelwork*.

### **9.2 Prototypes**

Prototypes of each set of components of the MBEJ shall be fabricated and checked for dimensional accuracy prior to the remaining fabrication of the MBEJ.

### **9.3 Centre beam dimensional checks**

Dimensional checks shall be performed after completion of welding of the first centre beam for each type of connection. **Witness Point**

Dimensional checks shall verify that:

- a) all centre beams, support bars and other components are in their design planes
- b) centre beams to support bar connections and other components are orthogonal, and
- c) centre beams and support bars are straight.

### **9.4 Fabrication of steelwork**

#### **9.4.1 Tolerances**

Fabrication dimensions shall comply with the tolerances given on the Drawings. Where a tolerance is not otherwise specified it shall be  $\pm 2$  mm. Tolerances shall be such that all parts fit together within the stated tolerances.

Before any marking out or other work is done, all bars and sections shall be made straight and free from twist to achieve the design tolerances. The methods adopted shall be such as to not damage the material.

#### **9.4.2 Cutting**

Cutting may be by flame cutting, sawing or shearing unless otherwise specified. Surfaces produced by such cutting shall be representative of good workmanship, finished square (unless a bevelled edge is called for), true to the required dimensions and free from defects, such as excessive roughness, which would impair the service performance or seriously interfere with subsequent fabrication and protective treatment. Shearing of items over 16 mm thick shall not be carried out when the item is to be galvanised and subject to tensile stresses unless the item is subsequently stress relieved. Distortions caused by shearing shall be removed.

Re-entrant corners shall be smoothly rounded to a radius of 20 mm. Unless shown otherwise on the drawings, all corners on exposed edges shall be rounded to a radius of approximately 1.5 mm, except where such edges are subsequently to be welded. Rolled edges need not be rounded provided the corners have a similar radius.

Any cut surface to be incorporated in a weld shall comply with AS/NZS 1554 and the depth of isolated gouges shall not be greater than 2 mm.

Flame cutting of plates, sections and other components with surfaces which shall be installed in the as-cut condition shall be carried out using procedures produce minimum reduction in properties at the cut surface and shall satisfy the requirements stated below.

Any cut surfaces to be used in the as-cut condition shall have:

- a) a surface roughness (CLA) not greater than 12  $\mu\text{m}$  – WTIA Roughness Class 2 as shown in WTIA Technical Note 5
- b) a depth of isolated gouges not greater than 3 mm provided that such defects are tapered out smoothly for a distance of at least 75 mm on both sides of the defect, and
- c) a surface quality that shall not impair subsequent fabrication and protective coating requirements.

Cut surfaces may be ground to achieve the stated surface roughness criteria. Grinding marks shall be parallel to the direction of the cut. Any flame cut surface may require light surface grinding to achieve a finish suitable for subsequent protective coating requirements.

#### **9.4.3 Drilling**

The diameters of the bolt holes shall be in accordance with the requirements of AS 5100.6 Appendix G. Unless shown otherwise on the drawings, the nominal diameter of a completed hole shall be:

- a) not more than 2 mm larger than the nominal bolt diameter for a bolt not greater than 24 mm in diameter, and
- b) not more than 3 mm larger than the nominal bolt diameter for a bolt greater than 24 mm in diameter.

Holes may be either drilled full-size or reamed to full-size after sub-drilling or sub-punching. Sub-punched and sub-drilled holes shall be smaller in diameter than the nominal diameter of bolts by at least 3 mm. For sub-punched holes, the diameter of the die shall not exceed the diameter of the punch by more than 1 mm. Holes shall be clean cut, without torn or ragged edges. Reamed or drilled holes shall be cylindrical and perpendicular to the face of the member unless otherwise shown on the Drawings. Reaming and drilling shall be done by mechanical means.

Connecting parts shall be assembled and held securely while being reamed or drilled and shall be match-marked before separating the parts.

All burrs shall be removed. If necessary, assembled parts shall be taken apart for removal of burrs caused by drilling and reaming.

#### **9.4.4 Bending**

Bending and forming plates, bars or sections during fabrication shall conform to the steel manufacturer's recommendations and the provision of MRTS78 *Fabrication of Structural Steelwork*.

#### **9.4.5 Welding**

All welding of steel shall be carried out in accordance with the provisions of MRTS78 *Fabrication of Structural Steelwork*.

All Category FP welds shall be 100% visually and 100% non-destructively examined using methods conforming to the requirements of AS 2177 and/or AS 2207 as appropriate. Non-destructive examination using ultrasound shall report the length, depth and height of any defect.

Jigs shall be used to assist the fabrication process during any welding of the centre beams.

Distortion and residual stresses resulting from welding and fabrication may be corrected by mechanical or thermal means in accordance with the provisions of MRTS78 *Fabrication of Structural Steelwork* or, where no such provision is made, in accordance with accepted industry good practice. Procedures for such corrective action shall be submitted to the Administrator prior to its commencement. **Hold Point 3**

#### **9.4.6 Jointing and assembly**

Joints in the component parts of welded members shall be made before the parts are assembled.

Where additional joints are made at locations not shown on the Drawings or joints are moved from the locations shown on the Drawings, details of the position of such joints shall be included in the as-built drawings.

#### **9.4.7 Identification marks**

Each MBEJ shall be marked with durable identification marks and have its total mass clearly marked upon it.

#### **9.4.8 Packing, storing and transporting**

All open joints, ends and projecting parts shall be protected from damage in transit in such a manner as to stiffen the member and prevent distortion.

Special care shall be taken in the packing and methods of support and lifting during handling of all structural steelwork to prevent distortion or damage to the steelwork and its protective coating.

All steel, whether fabricated or not, shall be stored in such a manner that it shall not be bent or damaged and shall be adequately protected against corrosion. Generally, storage at least 200 mm above the ground on platforms, slabs, or other supports under cover shall be satisfactory.

### **9.5 Corrosion protection**

#### **9.5.1 General**

Steel components other than stainless steel shall be coated on all surfaces in accordance with the corrosion protection system specified in Clause 9.5.2.

The finished surface of stainless steel components shall conform to ASTM A204M Grade 316L with 2B – Mill Surface Finish.

#### **9.5.2 Corrosion protection system**

The corrosion protection system shall be applied in accordance with this clause.

The steel surface shall be prepared by abrasive blast cleaning to a Class 3 finish in accordance with AS 1627.4. The finished surface profile height shall be between 25 and 65 microns

The prepared surface shall be coated, within the specified time period, with a two-pack solvent based inorganic zinc silicate primer conforming to the requirements of AS 2105 Type 4 and GPC-C-29/8A. The finished dry film thickness shall be not less than 75 microns.

Following satisfactory curing of the primer, the inorganic zinc primer coating shall be lightly sanded and then jet washed to remove any zinc salts that may have formed.

The primed surface shall be coated with two coats of a two-pack micaceous iron oxide (MIO) pigmented polyamide cured epoxy coating conforming to GPC-C-29/7A. The finished dry film of each coat shall be not less than 125 microns. The colour of the first coat, in accordance with AS 2700, shall be N43 – Pipeline Grey and that of the second coat shall be N44 – Bridge Grey.

Repair of scratched and slightly damaged areas of the inorganic zinc prime coat shall be carried out with either inorganic zinc primer conforming to the above or with an organic zinc primer consisting of a two pack zinc rich polyamide cured epoxy primer conforming to GPC-C-29/16.

### 9.5.3 Alternate corrosion protection system

An alternative corrosion protection system to that stated in Clause 9.5.2 may be considered. Where an alternative is proposed the following shall be provided to the Administrator:

- a) a full description of the proposed corrosion protection system
- b) a full manufacturer's specification for each of the materials included in the proposed corrosion protection system, and
- c) a direct comparison between the requirements of AS/NZS 2312 for Atmospheric Corrosivity Category C: Medium and the proposed corrosion protection system.

### 9.6 Surfaces exposed to traffic

Supports and control boxes exposed to traffic shall have a skid resistant surface treatment and all such parts shall be resistant to attrition and vehicular impact.

### 9.7 Seals

Preformed elastomeric joint seals shall comply with the requirements stated in this clause. Alternatively, seals complying with the requirements of ASTM D5973 may be used. Preformed elastomeric joint seals of the strip seal type shall be made from vulcanised compound having polymerised chloroprene as the only base polymer.

Preformed elastomeric joint seals, including those deemed to comply, shall be tested in accordance with the seal push-out (SPO) test procedure laid down in NCHRP Report 467 and shall successfully pass testing without failure. Documentary evidence shall be provided to verify that the elastomer used in the manufacture of the joint seals has been tested in a laboratory with appropriate NATA registration and that it complies with the requirements stated in Table 9.7.

**Table 9.7 – Elastomer material requirements**

Property	Requirement	Test Method
Tensile strength	13.8 MPa minimum	AS 1683.11 (Dumb-bell test pieces)
Elongation at break	250% minimum	AS 1683.11 (Dumb-bell test pieces)
Hardness	IRHD 59 ± 5	AS 1683.15.1
Ageing		AS 1683.26 (Method A for 72 hours at 100°C)
Change in tensile strength	– 20% to 0	AS 1683.11 (Dumb-bell test pieces)
Change in elongation at break	– 20% to 0	AS 1683.11 (Dumb-bell test pieces)
Change in hardness	IRHD 0 to + 10	AS 1683.15.1

Property	Requirement	Test Method
Resistance to Ozone	No visible cracking	AS 1683.24 (Ozone concentration 100 pphm in air, 20% strain, 100 hrs at 40°C)
Low temperature stiffening (change in hardness)	IRHD 0 to +15	AS 1683.15.1 (After 7 days at – 10°C)
Change in volume in oil	+ 70% maximum	AS 1683.23 (Using Oil No. 3, after 72 hours at 100°C)
Compression set	40% maximum	AS 1683.13 (72 hours at 100°C)
Low temperature brittleness	Not brittle	ASTM D 746 (B) (at – 30°C)

**Note:** The Principal may waive the requirement for testing as above provided that:

- a) the elastomer for the manufacture of the strip seals is supplied by a company which has a third party certified quality assurance system to AS/NZS ISO 9001 for the manufacture and supply of elastomer, and
- b) test certificates, for Type Tests carried out within the last 6 months, are supplied to prove that the elastomer meets the properties specified in Table 9.7
- c) day to day batch quality control on the manufacture of the elastomer is exercised by performing a test which accurately measures the cure characteristics of the elastomer and highlights variations resulting from incorrect ingredients or levels thereof, and
- d) the manufacturer establishes control points and limits on batches that have been Type Tested and uses these control points and limits for subsequent quality control purposes.

The elastomeric strip seals shall be designed to possess the necessary compression, extension and deformation properties to produce the required range of movement, as nominated in the contract and in accordance with AS 5100, whilst remaining watertight.

The seal width shall be sufficient to ensure that it is not damaged or pulled out of the metal retainer at the maximum design gap width.

The material of each seal shall be uniform and homogeneous throughout. Any seal showing imperfections, surface splits, or indentations shall be rejected.

The permissible tolerance in the relaxed width of the seal shall be 0 to + 2 mm.

The longitudinal profile of the seal, required to match the bridge cross section, may be obtained either by bending the seal to the required angle, or by joining straight lengths of seal by means of an adhesive recommended by the manufacturer of the seal. All joining of seal lengths shall be performed in the factory, except that joining of the seals at sharp changes in profile may be performed in the field.

The metal seal retainer shall be curved or joined to match the adjacent curve or join in the seal.

A certificate from the supplier of the seal verifying conformance of the seal with the requirements of the drawings and this specification shall be included in the quality records.

The method of installing the seals shall be in accordance with the recommendations of the seal manufacturer.

### **9.8 Sliding pads, bearings and strips**

Material for sliding pads and strips shall be 100% virgin polytetrafluoroethylene (PTFE) conforming to ISO 13000-1 Grade 1, and etched on the side bonded to the steel.

Sliding pads shall be manufactured from unfilled, dimensionally stabilised, moulded PTFE sheet that is dimpled and lubricated in accordance with Clause 14.2 of AS 5100.4 on the face in contact with the sliding surface.

The sliding strips on the guide faces shall be a durable filled PTFE with fillers being either milled glass fibre (25% maximum) or carbon fibre (25% maximum). Alternatively, sliding strips may be a multi-layered composite material. For example, a three layer composite consisting of a bronze backing strip, a sintered interlocking porous impregnated matrix, and an overlay of PTFE/lead, graphite/lead or similar mixture might be used.

A current Certificate of Compliance verifying that each batch of PTFE material used in the fabrication of the MBEJ complies with this clause shall be included in the quality records.

The PTFE pad for sliding bearings shall have a minimum thickness of 6 mm for pads with any dimension larger than 650 mm, and 4 mm for smaller pads. The pad shall be restrained by adhesive bonding and recessing into the backing material to a depth of half the thickness of the PTFE, to prevent its extrusion. The average adhesion-in-peel strength of the adhesive compound shall not be less than 30 N when tested under standard conditions in accordance with ASTM Test Method C794.

The backing material to the PTFE and the mating surface shall be sufficiently flat and rigid to ensure that the PTFE layer is uniformly loaded. The deviation from flatness of the PTFE pad shall not be more than 0.002 of the pad diameter. The shoulder of the recess in the backing material shall be sharp and square to resist extrusion of the PTFE. There shall be no gap between the inner face of the recess and the edge of the PTFE.

Stresses in the PTFE pad shall not exceed the values specified in AS 5100.4.

The PTFE pad shall be permanently lubricated in accordance with Clause 14.2 of AS 5100.4. The lubricant used shall meet the requirements of Clause 9.9 of this specification.

### **9.9 Lubricant**

The lubricant used for filling the lubrication reservoirs in the dimpled face of the PTFE sliding pad, and for lubrication of the top and bottom surfaces of the elastomeric disc, shall be made from silicone compounds. It shall exhibit the same consistency over a temperature range of - 40°C to + 200°C as it does at room temperature. The lubricant shall be compatible with all the components with which it is in direct contact. The lubricant shall comply with the requirements stated in Table 9.9.

**Table 9.9 – Properties of lubricant**

<b>Property</b>	<b>Requirements</b>	<b>Method of Test</b>
Penetration worked 60 stroke	< 260	ASTM D217
Evaporation – 24 h at 200°C	< 2%	ASTM D972

Test reports showing conformance of the proposed lubricant with the requirement of Table 9.9 shall be included in the quality records.

### **9.10 Springs**

Elastomeric components used above and below support bars and between centre beams and support bars in the MBEJ shall be tested in accordance with the opening movement and vibration (OMV) procedure laid down in NCHRP Report 467 and shall successfully pass 70 hours of continuous testing without failure.

## 10 Certification

At least 14 days prior to the commencement of assembly of the MBEJ, the Contractor shall submit to the Administrator the certification and results of testing, by a NATA registered laboratory, which demonstrates that the materials from which the component parts of the MBEJ, including steel, stainless steel, joint seals, PTFE and elastomeric springs, meet the requirements of this specification.

### **Milestone**

Assembly of the MBEJ shall not commence until expiration of the 14 day period. **Hold Point 4**

## 11 Assembly

At least seven days prior to the commencement of assembly of the MBEJ, the Contractor shall submit to the Administrator its procedure for the assembly of the MBEJ including manufacturing and assembly tolerances. **Milestone** The procedure shall include evidence demonstrating that the tolerances are adequate for the correct functioning of the MBEJ.

Assembly of the MBEJ shall not commence until expiration of the seven day period. **Hold Point 5**

The assembly process shall be fully documented during assembly. **Witness Point**

Documentation of the actual assembly process shall include, but not be limited to, dynamic stiffness and damping testing of the springs and bearings, their preload and fitting procedures in accordance with Appendix B to this specification, and the measured heights of all support box bearings.

Welding during assembly shall comply with the requirements of Clause 9.4.5

Following inspection of the completed MBEJ in accordance with Clause 12, the joints seals shall be installed. **Witness Point** The Contractor shall provide the Administrator with at least seven days prior notice of the pending installation of the joint seals. **Milestone**

## 12 Inspection of completed MBEJ

Suitable facilities for the inspection of the completed MBEJ system by the Administrator prior to delivery shall be provided. The facilities shall allow free access to all sections of the MBEJ system so that a full compliance inspection to the requirements of this specification can be carried out.

An inspection shall take place before the elastomeric seals are installed.

## 13 Transport of MBEJ

At least seven days prior to the commencement of delivery of the MBEJ, the Contractor shall submit to the Administrator its procedure for the transport, handling and storage, including measures to prevent distortion and damage to the MBEJ and its protective coating. **Milestone**

Loading of the MBEJ for delivery shall not commence until expiration of the seven day period.

### **Hold Point 6**

## 14 Installation of MBEJ

A representative of the MBEJ system manufacturer shall be present during the installation of the MBEJ.

At least 14 days prior to the commencement of installation of the MBEJ, the Contractor shall submit to the Administrator its procedure for the installation of the MBEJ including installation, field jointing and testing for watertightness of the seals in accordance with the requirements of Clause 15. **Milestone**

Installation of the MBEJ shall not commence until expiration of the 14 day period. **Hold Point 7**

The MBEJ system manufacturer's representative shall provide certification to the Administrator indicating that the correct installation procedures have been followed. The certification report must indicate that there has been no deleterious leakage of concrete slurry into the support boxes.

## 15 Testing for watertightness

Not less than 14 days after the completion of installation, the MBEJ shall be tested for watertightness. The procedure for testing the MBEJ for watertightness shall conform to that described below.

- a) The roadway section of the MBEJ from kerb to kerb, or barrier rail to barrier rail, shall be covered with water, either ponded or flowing. The depth of water shall be not less than 25 mm above the roadway surface at all points. A water hose delivering approximately four litres of water per minute shall be secured to the inside face of the bridge railing with the water jet trained in a downward position about 150 mm above the footpath, such that there is continuous flow of water across the footpath and down the kerb face of the MBEJ.
- b) The 25 mm depth of water on the roadway and continuous flow across footpaths and kerbs shall be maintained for a period of five hours. At the conclusion of the test, the underside of the MBEJ shall be closely examined for leakage. Seals shall be considered watertight if no obvious wetness is visible on a finger touching a number of under-deck areas. Damp concrete that does not impart wetness to the finger is not to be considered a sign of leakage. Condensation or other moisture may be expected underneath the MBEJ and shall not constitute leakage unless the flow is sufficient to cause continuous dripping at least every 20 seconds or a visible continuous stream of water, and
- c) Any leakage detected shall be the subject of repair measures recommended by the MBEJ system manufacturer. Once such repairs have been completed, an additional water tightness test shall be carried out in accordance with this clause.

As an alternative, the water tightness of the sealing system may be proved by pre-testing in the factory.

## 16 As-built drawings

Two copies of as-built drawings for the fabrication, assembly and installation of the MBEJ shall be submitted to the Administrator not later than 28 days after the completion of installation process.

**Milestone**

## 17 Supplementary requirements

The requirements of MRTS90 *Modular Bridge Expansion Joints* are varied by the supplementary requirements given in Clause 2 of Annexure MRTS90.1

## Appendix A - Design Methodology

### A1 General

Appendix A describes the approach to design of the MBEJ in conjunction with the requirements of fatigue, strength and serviceability as outlined in Clause 6 of this specification.

The provisions of this appendix assume that the MBEJ is perpendicular to the direction of traffic. For a skewed MBEJ, additional considerations shall be necessary as outlined in Clause 1.3 of Annexure MRTS90.1. Such requirements shall include, at least, the transverse movement due to thermal distortion of the skewed deck.

### A2 Notation

If a symbol is not defined locally where it is used, the following general notation shall apply:

Symbol	Notation
$B_c$	= width of centre beam at top
$B_w$	= width of tyre footprint in direction perpendicular to traffic
$f^*$	= design stress range
$f_s$	= Detail Category fatigue strength at cut-off limit (at $10^8$ i.e. infinite number of cycles)
$f_m$	= fatigue Detail Category defined in AS 5100.6, which is the uncorrected fatigue strength (in MPa) at $2 \times 10^6$ cycles
$f_u$	= ultimate tensile strength used in design
$f_y$	= yield stress used in design
$g_c$	= gap between centre beams at appropriate joint opening
$H^*$	= design longitudinal load
$J$	= joint opening at top (clear gap between edge beams)
$L_w$	= length of tyre footprint in direction parallel to traffic
$Q^*$	= design vertical load
$R$	= support reaction
$R_{lim}$	= nominal strength for the appropriate limit state
$S^*$	= design action in general
$T^*$	= design transverse load
$W$	= Wheel load
$\alpha$	= Dynamic Load Allowance defined in AS 5100.2
$\beta$	= distribution factor (fraction of wheel load carried by one centre beam)
$\chi$	= Dynamic Amplification Factor (DAF)
$\eta$	= ratio of longitudinal load to vertical load
$\tau$	= ratio of transverse load to vertical load
$\phi$	= capacity reduction factor
$\gamma$	= load factor

## Subscripts

The above symbols may be qualified by one or more of the following subscripts:

f	=	value at fatigue limit state
s	=	value at serviceability limit state
u	=	value at strength limit state
avg	=	Average
dn	=	downward component
max	=	maximum
min	=	minimum
up	=	upward component

## A3 Expansion joint openings

The expansion joint openings for design for the limit states of fatigue ( $J_f$ ), strength ( $J_u$ ) and serviceability ( $J_s$ ) shall be as stated in Clause 1.1 of Annexure MRTS90.1. The following guideline shall be used in completing Clause 1.1 of Annexure MRTS90.1.

Compute the following MBEJ openings (refer to Figure A3):

- The minimum MBEJ opening at serviceability:  $J_{s,min} = J_i - e_s (T_{max} - T_i) = \text{_____ mm}$
- The maximum MBEJ opening at serviceability:  $J_{s,max} = J_i + c_s + e_s (T_i - T_{min}) = \text{_____ mm}$
- The MBEJ opening for ultimate limit state:  $J_u = J_i + 1.2c_s + 1.25e_s (T_i - T_{min}) \text{_____ mm}$
- MBEJ opening for fatigue limit state#:  $J_f = \text{_____ mm}$

# The MBEJ opening for fatigue design recommended by NCHRP is the mean value:

$$J_f = (J_{s,min} + J_{s,max}) / 2$$

A slightly more conservative value is the “root mean cube”, based on the fact that fatigue damage varies as the 3rd power of the stress and stress due to a concentrated load varies linearly as the span:

$$J_f = \left[ \frac{J_{s,min}^3 + J_{s,max}^3}{2} \right]^{1/3}$$

If detailed temperature records are available, a logical choice is to assess the mean daily temperature experienced by the bridge for most days of the year ( $T_i$ ) and compute the MBEJ opening for fatigue as:

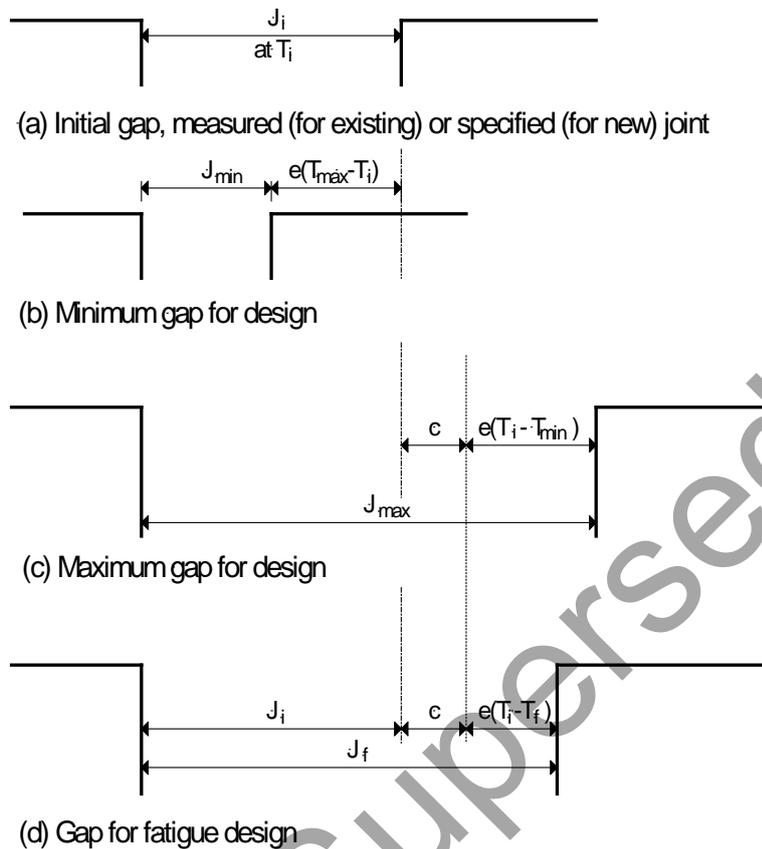
$$J_f = J_i + c_s + e_s (T_i - T_f)$$

Where:

$J_i$	=	Gap at initial condition †
$e_s$	=	Change in width of gap for 1°C change in average bridge temperature
$c_s$	=	Total creep and shrinkage movement until the end of the design life
$T_{max}$	=	Maximum average bridge temperature (refer to AS 5100.2, Clause 17.2)

- $T_{min}$  = Minimum average bridge temperature
- $T_i$  = Expected temperature at initial condition †
- † for a new bridge,  $J_i$  is the gap specified on the drawing for the assumed temperature  $T_i$ ;
- for replacing a joint on an existing bridge,  $J_i$  and  $T_i$  shall be measured at the site

**Figure A3 - Expansion MBEJ movements**

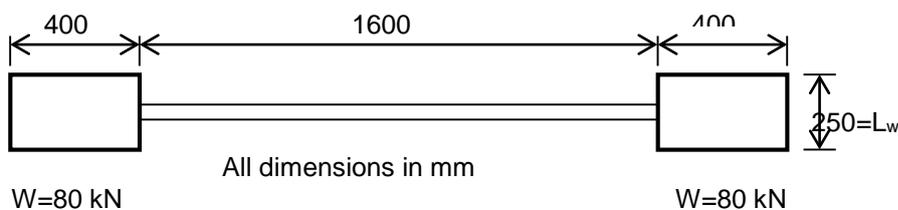


NOTE: The gaps are different for serviceability, ultimate and fatigue design.

**A4 Axle load**

The static axle load is the A160 axle defined in AS 5100.2 and illustrated below for reference. It comprises two wheel loads of 80 kN with contact areas shown in Figure A4.

**Figure A4 – A160 Design axle**



The axle shall be placed anywhere along the centre beam for maximum effects; however, the centre of the wheel need not be closer than 600 mm from the face of the kerb for the fatigue and serviceability limit states and 300 mm for the strength limit states.

## A5 Load factors

The axle load shall be factored by  $\gamma$  for the appropriate limit state under consideration, as follows:

$$\gamma_f = 0.6 \quad \text{for the fatigue limit state} \quad (A.1a)$$

$$\gamma_u = 1.8 \quad \text{for the strength limit state} \quad (A.1b)$$

$$\gamma_s = 1.0 \quad \text{for the serviceability limit state} \quad (A.1c)$$

## A6 Distribution factor

The maximum wheel load carried by one centre beam is  $\beta W$  where the Distribution Factor ( $\beta$ ) is given by:

$$\beta = \frac{B_c + g_c}{L_w} \quad 0.5 \leq \beta \leq 0.8 \quad (A.2)$$

The gap  $g_c$  shall be calculated for the appropriate joint opening ( $J_f$ ,  $J_u$  or  $J_c$ ) depending on the limit state under consideration.

The remaining wheel load is divided equally between the two adjacent centre beams or between a centre beam and edge beam, depending on the position of the wheel.

## A7 Horizontal force factors

Horizontal forces at each wheel shall be applied to the top of the centre beams to account for forces due to traction, braking or acceleration, centrifugal force, etc.

The longitudinal force, in the direction of traffic, is given by  $\eta W$ , where the factor  $\eta$  shall be as stated in Clause 1.2 of Annexure MRTS90.1.

If the MBEJ is located on a curve or significant crossfall, transverse forces shall be applied at the top of the centre beams. The transverse force under each wheel is  $\tau W$ , where the factor  $\tau$  shall be as stated in Clause 1.2 of Annexure MRTS90.1.

If the MBEJ is skewed to the direction of traffic, the forces  $\eta W$  and  $\tau W$  shall be resolved in directions normal and axial to the centre beams, for design of the members.

## A8 Dynamic amplification factor

The static axle load is multiplied by a factor ( $\chi$ ) to account for dynamic effects.

For components not subject to vibrations, such as support boxes and edge beams:

$$\chi_o = 1.6 \quad (A.3)$$

For centre beams, support bars and associated components, the DAF shall be derived by one of the three methods outlined in Clause A10. Further, the DAF comprises an upward component ( $\chi_{up}$ ) and a downward component ( $\chi_{dn}$ ), given by:

$$\chi_{up} = 0.33\chi \quad (A.4a)$$

$$\chi_{dn} = 0.67\chi \quad (A.4b)$$

For computing the stress range for the fatigue limit state, the DAF is:

$$\chi_f = \chi_{up} + \chi_{dn} \quad (A.5)$$

For the strength limit state:

$$\chi_u = \chi_{dn} \quad (A.6)$$

For the serviceability limit state:

$$\chi_s = \chi_{dn} \quad (A.7)$$

## A9 Design loads

The design loads due to each wheel, applied to the top of the critical centre beam, for each limit state, are as stated below.

The vertical design load is:

$$Q^* = \gamma\beta\chi W \quad (A.8)$$

The longitudinal design load, in the direction of traffic, is:

$$H^* = \gamma\beta\eta W \quad (A.9)$$

The transverse design load, if applicable, is:

$$T^* = \gamma\beta\tau W \quad (A.10)$$

The appropriate values of the factors  $\gamma$  and  $\chi$  shall be used, as per Clauses A5 and A8, for the limit state under consideration.

The centre beam shall be analysed as a continuous beam on elastic supports, the spring stiffnesses of which are computed from the properties of the bearings of the support bars.

## A10 Alternative methods for evaluating DAF

Evaluate the dynamic amplification factor by one of the following three methods:

Method 1: Design based on the simple static method recommended in NCHRP Report 402, with the following factors in lieu of the factors recommended by NCHRP:

$$\chi = 2.0 \text{ for Multiple Support Bar Systems} \quad (A.11a)$$

$$\chi = 2.5 \text{ for Single Support Bar Systems} \quad (A.11b)$$

Method 2: Conduct an experimental modal analysis study in accordance with MRTS90 Appendix B, and obtain the maximum overall dynamic amplification factor,  $\chi_{mod}$ . The factors to be used for design are:

$$\chi = 0.67\chi_{mod} \text{ for Multiple Support Bar Systems} \quad (A.12a)$$

$$\chi = 0.50\chi_{mod} \text{ for Single Support Bar Systems} \quad (A.12b)$$

The structural analysis may then be done by the simple static method recommended in NCHRP Report 402.

**Method 3:** Undertake dynamic Finite Element (FE) analysis using a recognised software system for the finite element modelling and post-processing. However, this option will **not** be regarded as definitive unless the FE analysis has been calibrated using experimental modal analysis and strain gauge data as set out in Annexure B. The FE modelling must incorporate multiple axle loading of multiple centre beams. The axle must be stepped over the joint at velocities ranging from 90 km/h to 110 km/h in 5 km/h intervals, unless otherwise specified by the Principal.

## A11 Limit states

### A11.1 General

The procedure for checking the limit states of fatigue, strength and serviceability shall generally comply with AS 5100.6. As a guide to designers not familiar with this Standard, its essential provisions are summarised in the following sections, for items that are expected to be applicable to the design of MBEJs. Nevertheless, all required provisions of AS 5100.6 shall be satisfied.

Equation 6.1 in Clause 6.4 of this specification shall be satisfied for the three limit states. The design actions ( $S^*$ ) are the effects of  $Q^*$ ,  $H^*$  and  $T^*$  specified in Clause A9.

### A11.2 Limit state of fatigue

The action effect is the maximum resultant stress range due to the effects of  $Q^*$ ,  $H^*$  and  $T^*$ .

If normal stresses ( $f_1$  and  $f_2$ ) act in two orthogonal directions, the resultant stress is:

$$f_r = \sqrt{f_1^2 + f_2^2} \quad (A.13)$$

If a normal stress ( $f$ ) is to be combined with a shear stress ( $s$ ), the principal stress is given by:

$$f_p = \frac{f}{2} + \sqrt{\left[\left(\frac{f}{2}\right)^2 + s^2\right]} \quad (A.14)$$

It is emphasised that fatigue stresses at connections shall most often be the critical items rather than stresses in main members. Some of the details and connections that need to be checked are detailed in Clause A12.

The capacity factor for fatigue ( $\phi_f$ ) shall be 1.0.

The resistance shall be the cut-off limit stress ( $f_5$ ) defined in Section 13 of AS 5100.6, which is the resistance for infinite number of stress cycles (effectively  $10^8$  cycles). For certain standard details and connections employed for MBEJs, the fatigue detail categories have been classified in accordance with Table 13.5.1 of AS 5100 and corresponding values of  $f_5$  extracted from Figure 13.6.1 of AS 5100 and the results given in Table A11.2.

**Table A11.2 – Detail classifications for fatigue based on AS 5100.6**

Item	Member or connection	Detail category	Category $f_{rn}$	Illustration No.	Cut-off limit $f_5$ (MPa)
1	Centre beam, support bar	Polished steel bar	180		73
2	Flats for yokes	Rolled products	160	(1)	65
3	Centre beam at bolt hole	Bolted connection	140	(5)	57
4	Sliding plate welded to support bar	Cover plate welded full length, both sides	125	(9)	51
5	Centre beam splice	Butt weld, 100%NDT	112	(16)	45 $\beta_{tf}$ Note 3
6	Centre beam to support bar	Butt weld with extra fillets	90	Note 1	36
7	Yoke to centre beam	Transverse butt weld	90	Note 2	36
8	Connections of yoke members	Shear stress in fillet weld	80	(39)	32
9	Sliding joint between centre beam and support bar	If local or intermittent, longitudinal weld for sliding device	80	(14)	32
10	Attachment for spring equidistancing buffer	Cleat attachments: $t \leq 12$ mm $t > 12$ mm ( $t$ = thickness of cleat)	80 71	(35)(36)	32 29

Note:

- The welded connection between centre beam and support bar is classified as Category C of AASHTO by NCHRP. This is approximately equivalent to Detail Category 90 of AS 5100.6.
- The fatigue category for this connection is assumed equivalent to Category C of AASHTO.
- $\beta_{tf}$  is a "thickness correction factor" defined in AS 5100.6 and given by:

$$\beta_{tf} = \left[ \frac{25}{t_p} \right]^{0.25}$$

where  $t_p$  is the thickness of the plate, i.e. width of the centre beam, in mm.

For details that do not fall into the above categories, an appropriate detail category shall be selected from Table 13.5.1 of AS 5100.6 and if no category is deemed applicable, an authoritative reference shall be submitted to support the value of  $f_5$  adopted.

### A11.3 Limit state of strength

The action effects shall be the bending moment, shear force and axial force due to the effects of  $Q^*_u$ ,  $H^*_u$  and  $T^*_u$ .

The design strength shall be the section capacity and member capacity in bending and shear. Axial forces may also require consideration for skewed MBEJ or where  $T^*_u$  is significant.

The capacity reduction factor ( $\phi_u$ ) shall be as follows:

- 0.9 for structural steel members
- 0.8 for bolted connections
- 0.9 for SP Category complete penetration butt welds
- 0.8 for SP Category fillet welds
- 0.85 for shear stud connectors

For details not included in the above, refer to Table 3.2 of AS 5100.6.

The strength is based on the nominal yield stress ( $f_y$ ) and tensile strength ( $f_u$ ). For materials supplied to Australian Standards, the values in Table 2.1 of AS 5100.6 shall be used. Where materials are supplied to other Standards, such as ASTM, the values in these Standards are acceptable. The minimum values of  $f_y$  specified in Clause 6.4 of this specification shall be complied with.

The section capacity in bending shall satisfy Clause 5.2 of AS 5100.6.

The member capacity of centre beams and support bars shall satisfy Clause 5.6 of AS 5100. The effective lengths of the members shall be as follows:

- For support bars, the length between centres of bearings at joint opening  $J_u$ ;
- For overhanging portions of centre beams, twice the length of the cantilever; and
- For internal spans of centre beams, 0.7 times the span for centre beams welded to support bars and 1.2 times the span for centre beams connected to support bars by yokes.

The shear capacity shall be checked in accordance with Clause 5.10 of AS 5100.6.

Requirements for bolted, pin and welded connections are in Section 12 of AS 5100.6.

#### **A11.4 Limit state of serviceability**

The requirements for noise and vibration, as outlined in relevant portions of this specification, shall comprise the serviceability requirements.

The capacity reduction factor ( $\phi_s$ ) shall be 1.0 for structural steel members.

Capacity of bearings shall be checked for the serviceability limit state.

### **A12 Fatigue limit state details**

#### **A12.1 General**

Calculate the stress ranges causing fatigue by applying the following loads to the MBEJ model:

$$Q^*_f = \gamma_f \beta_f \chi_f W \quad (\text{A.15a})$$

$$H^*_f = \gamma_f \beta_f \eta W \quad (\text{A.15b})$$

$$T^*_f = \gamma_f \beta_f \tau W \text{ if applicable} \quad (\text{A.15c})$$

#### **A12.2 Centre beams**

The longitudinal bending stress due to vertical and horizontal loads  $Q^*_f$  and  $H^*_f$  plus the axial stress due to  $T^*_f$ , if any, shall comply with Item 1 in Table A5.

If centre beams are spliced, the fatigue stress in the butt weld shall be as per Item 5 in Table A5.

If yokes are connected by bolts to the centre beams, the stresses in the centre beams shall be based on the net section at the bolt holes. The stress range in the centre beam at the bolt hole shall be limited as per Item 3 in Table A5.

### **A12.3 Support bars**

Support bars shall be designed for the maximum loads transmitted by their individual centre beams in a multiple bar system, or for the total wheel load transmitted through three centre beams, in a single bar system. Any forces that may arise from deformations of the elastomers and frictional resistance within the MBEJ shall also be considered.

The stress range in the base metal of the support bar shall comply with Item 1 in Table A5.

To enable the support bar to slide smoothly between its support bearings, the support bar may have stainless steel slider plates welded to its top and bottom surfaces. If the welds are for the full length of the support bar, the maximum stress range shall comply with Item 4 in Table A5, whereas if the welding is near the supports only, with Item 9 in Table A5.

### **A12.4 Welded connection between support bar and centre beam**

All dimensions of the weld connecting the centre beam to the support bar in MSBJ systems shall be detailed on the drawing.

The resultant of the vertical and horizontal stresses in the weld, due to the design load, shall be checked for the three effects, a), b) and c), listed below. The A160 axle shall be positioned on the centre beam for the maximum effect in each of the three cases.

- a) Resultant stress at the interface of the weld and soffit of the centre beam;
- b) Resultant stress at the interface of the weld and the top of the support bar; and
- c) Resultant stress at the throat of the weld between the centre beam and the support bar.

Note: The above stresses are designated as stresses due to Type A, Type B and Type C cracking, respectively, in the NCHRP 402 Report and the method given in this reference may be followed for design. The welded connection is classified as AASHTO Category C, which is approximately equivalent to Item 6 in Table A5.

### **A12.5 Yoke and its connections**

#### **A12.5.1 General**

In a single support bar MBEJ system the connection between the centre beam and support bar is through a yoke, which enables a sliding joint. All components of the yoke system shall be designed to resist the fatigue stress cycles generated in the system by application of the loads  $Q^*_f$ ,  $H^*_f$  and  $T^*_f$  in equations A.15a, A.15b and A.15c. If any pre-compression is applied to the yoke bearings it shall be ensured that the pre-compression is not lost due to stress cycles caused by the above loads.

It shall be demonstrated that the yoke system has the ability to resist the horizontal forces together with overturning moments due to application of the above loads, without causing instability or fatigue failure of any component or connection. (Advantage may be taken of the dynamic characteristics of the system, by employing Method 3 of Clause A10, to account for the reduction in longitudinal force experienced by the system due to the short duration of the applied load).

Alternatively, the adequacy of the yoke shall be demonstrated by performance testing.

#### **A12.5.2 Bolted yoke connection**

Where the yoke is connected to the centre beam by bolts, a tensile force ( $Q^*_{up}$ ) shall be applied to the bolts, given by:

$$Q^*_{up} = \gamma_f \beta_f \chi_{up} R \quad (\text{A.16})$$

where  $R$  is the maximum support reaction due to the static A160 axle loads.

The stress range in the bolt due to the force  $Q^*_{up}$  shall not exceed 0.3 times the pre-tension in the bolt.

Only high strength bolts complying with 8.8/TF bolting category of AS 5100 (friction grip connection) are acceptable.

### A12.5.3 Welded yoke connection

Where the yoke members are connected to the centre beam by complete penetration butt welds, the nominal stress range at the welded connection shall be the sum of the longitudinal stress ranges resulting from horizontal and vertical bending of the centre beam. The effects of forces in the yoke need not be added. The stress range at the weld shall comply with Item 7 in Table A5. Fillet welded connections are not acceptable.

### A12.5.4 Welded plates for sliding surfaces

The contact surfaces between the support bar and centre beam may require a special sliding arrangement. If the sliding device is welded to the edges of the centre beam by short lengths of longitudinal fillet welds, the flexural stress range in the centre beam at the weld location shall be limited as per Item 9 in Table A5, whereas for continuous welds it shall comply with Item 9 in Table A5.

### A12.5.5 Spring buffer attachments

Where equidistancing spring buffers are attached to the centre beam by welded cleats, the nominal stress range at the welded connection shall be the sum of the longitudinal stress ranges resulting from horizontal and vertical bending of the centre beam. The effects of forces in the equidistancing buffers due to thermal movements need not be added. The stress range at the weld shall comply with Item 10 in Table A5.

### A12.5.6 Replaceable items

Replaceable items shall be designed for fatigue as follows:

- a) Where a MBEJ of similar type with the same replaceable components (materials, manufacture, design) has sustained 70 hours under the test regime described in NCHRP Report 467, no further design is required, and
- b) For all other cases, the component shall be designed to resist the design number of stress cycles calculated as:

$$n_{sc} = 500,000(N_c + n_e)D_L \quad (\text{A.17})$$

where:

- |          |   |                                                                                                                                                     |
|----------|---|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| $n_{sc}$ | = | the design number of stress cycles caused by the design load                                                                                        |
| $N_c$    | = | the number of centre beams supported on a support bar                                                                                               |
| $n_e$    | = | the number of effective cycles of vibration following excitation and can be derived using the method shown in Appendix B to this specification, and |
| $D_L$    | = | the design life of the component in years.                                                                                                          |

### A12.5.7 Other types of connections

MBEJ designers are free to develop appropriate details and connections. All computations shall be submitted for checking by the Principal. All designs and details shall be treated as Commercial-in-Confidence. Fatigue detail categories that cannot be classified in accordance with AS 5100.6 shall be supported by authoritative references for the cut-off limit stress adopted.

## A13 Strength limit state details

### A13.1 Centre beams

If centre beams are subjected to significant axial force, which may arise if the MBEJ is skewed or the transverse force is significant, their capacity shall be checked for axial load with biaxial bending in accordance with Section 11 of AS 5100.6.

### A13.2 Edge beams

Edge beams shall be adequately anchored into the concrete and the anchors shall be able to resist an ultimate horizontal force 60 kN per metre length of the edge beam.

The section of the edge beam that spans across the openings of the support boxes shall be designed in accordance with Clause A13.3.

### A13.3 Support boxes

The top plate of each support box shall be designed to carry an ultimate load given by:

$$P^* = \gamma_u \chi_o W \quad (\text{A.18})$$

Hence:

$$P^* = 1.8 \times 1.6 \times 80 = 230 \text{ kN}$$

This load may be distributed over an area of  $(L_w+t) \times (B_w+t)$ , where  $t$  is the thickness of the overlying concrete and permanent surfacing layer. Composite action with the overlying structural concrete and the edge beam may be taken into consideration, provided all connections and shear studs are adequately designed for this.

On the three sides of each support box, adequate shear studs shall be provided to transfer the vertical load  $P^*$  and its horizontal components  $\eta P^*$  and  $\tau P^*$  into the surrounding concrete, without assuming any support at the base of the box.

The bottom plate of the support box shall be designed to carry one-third ( $1/3$ ) of the maximum ultimate bearing reaction of the support bar, treated as a uniformly distributed load, by spanning between the three sides of the support box without any support from the underlying concrete. (This requirement is based on the observation that concrete under the support box is often difficult to consolidate and may contain voids).

### A13.4 Connections

All connections, whether by bolts, screws, pins or welds, shall be checked for the strength limit state in accordance with Section 12 of AS 5100.6.

For the strength limit state, assume that the loads  $Q_u^*$ ,  $H_u^*$  and  $T_u^*$  act concurrently. Calculate the stresses due to vertical and horizontal bending of the centrebeam or support bar and the stresses at connections such as welds of yokes or equidistancing buffer cleats. Calculate the resultant stress by

means of equations A.13 or A.14 and show that it is less than the design strength of the weld or parent material, whichever is lower.

## **A14 Serviceability limit state details**

### **A14.1 Structural**

Bolts or screws acting in friction grip mode shall be checked for serviceability loads in accordance with AS 5100.6 Clause 12.5.4, in addition to strength.

Shear connectors shall be designed for the serviceability limit state in order to comply with Section 6 of AS 5100.6.

Reference shall be made to Clause 6.9 of this specification for noise requirements.

Reference shall be made to paragraph (c) of Clause 6.4 of this specification for vibration damping requirements.

### **A14.2 Elastomeric bearings**

The physical properties of the elastomer used (durometer hardness, shear modulus and bulk modulus) shall be reported.

Elastomeric bearings shall be designed to resist serviceability loads and movements, in accordance with AS 5100.4 Clause 12.

The stiffness of the bearings may be either:

- a) Derived by calculation in accordance with Clause 12 of AS 5100.4, if analysis by Method 1 of Clause A5.10 is adopted, or
- b) Obtained by testing in accordance with Clause B2.2 of Appendix B to this specification if analysis by Method 2 or Method 3 is adopted.

The stiffness of the spring supports for the analytical model shall be derived from the combined stiffness of bearings provided for the support bars

## **Appendix B - Outline of Test Procedure for Experimental Modal Analysis**

### **B1 Test description**

The measurement and definition of the natural frequencies and mode shapes of a structure is referred to as Modal Analysis. The general test etiquette and methodology for such analysis is described below (refer also to Ewins D J *Modal Testing: Theory, Practice & Application*). The main aims of the test described in this appendix are to determine the mode shapes, natural frequencies, modal damping and Dynamic Amplification Factor (DAF) for the MBEJ system plus the dynamic compression stiffness and damping factors of the bearings and pre-compression springs, under a simulated load case. Data obtained from an experimental modal analysis shall be used to calibrate any dynamic finite element (FE) method model developed to assist in the fatigue design of the MBEJ. This is seen as being a two-part process. Firstly, the dynamic FE model shall accurately represent the mode shapes and modal frequencies from the experimental study and, secondly, the FE model shall be able to duplicate measured static and dynamic strain gauge results. Matching the dynamic strains may require some adjustment to the applied wheel load. This “adjustment” is in effect an additional “calibration factor”.

### **B2 Measurement of frequency response functions**

#### **B2.1 MBEJ system**

These measurements involve the simultaneous measurement of input force and vibration response. In these tests, force, over the frequency range of interest, shall be imparted to the structure using a suitable shaker or force hammer. The shaker shall be connected to the structure via a force transducer. The vibration response shall then be measured at selected locations using at least one accelerometer attached to the structure with a magnetic base or other suitable attachment method. In the case of in-situ modal testing, the measurements shall only be conducted in the absence of traffic crossing the expansion joint. Where measurements are undertaken on an expansion joint at the place of manufacture, great care shall be exercised to ensure that the boundary conditions closely match those of an installed expansion joint.

A “dynamically similar” modular joint is one in which the design (single support bar or multiple support bar, etc.), bearings, pre-compression springs, centring mechanism and structural steel components are identical to the modular joint proposed in conformance with this specification. However, the spacing of support bars and the number of centre beams does not need to be identical.

The input force and vibration response at each location shall be simultaneously measured using a minimum two-channel FFT analyser. Frequency Response Functions (FRF's) shall then be stored for each measurement.

A minimum of 100 measurement locations are considered necessary to adequately define relevant MBEJ system mode shapes (unless otherwise justified). The extent of measurements shall include at least two bays of the expansion joint (In this context, a “bay” is defined as the space between two consecutive support boxes).

Measurements shall be in three component directions (i.e. vertical, transverse and longitudinal) at each location. Simultaneous measurement at all (minimum 100) locations is not necessary and simultaneous two channel measurements at a time are acceptable (i.e. Channel A – Reference Accelerometer, Channel B – Roving Accelerometer or Force Hammer).

## **B2.2 Bearings and pre-compression springs**

### **B2.2.1 General**

The bearings and pre-compression springs to be tested shall be placed in a suitable test apparatus as described in Clauses B2.2.2, B2.2.3 and B2.2.4.

### **B2.2.2 Test procedure**

The under side of the test bearings shall be supported on a rigid flat surface with a vertical stiffness of at least 10 times that of the test bearings.

The test bearings shall be arranged to support a test mass in a stable manner. For a typical MBEJ, the test mass shall equal a nominal 600 kg per test bearing. (i.e. a 2400 kg test mass supported evenly by four test bearings would be suitable).

### **B2.2.3 Alternative test procedure No. 1**

As an alternative to the test described in Clause B2.2.2, a two mass arrangement may be used. A base mass shall be supported on soft springs upon which the primary mass is mounted via test bearings. The primary suspension mode shall be less than 6 Hz. The dynamic stiffness and damping properties are extracted from the second vertical bounce mode, i.e. out of phase motion of the primary and base mass. Details of the dynamic stiffness property calculations shall be fully documented in the test report.

### **B2.2.4 Alternative test procedure No. 2**

The following test procedure is also available as an alternative:

- a) a suitable rigid mass, i.e. solid steel block (nominal mass to be supported by each bearing assembly, for example, 100 kg) shall be supported in a suitable test frame
- b) the test frame shall be arranged so as to mount the test mass on top of the test linear bearing and below the test top spring – a hydraulic jack or suitable calibrated preload device shall be mounted in series
- c) the nominal design pre-load shall be applied prior to dynamic testing
- d) modal testing of the test mass shall be carried out in sufficient detail to identify the fundamental bounce mode of the test mass suspended between the test bearings
- e) the dynamic stiffness and damping for test bearing set shall be extracted, and
- f) the input force and vibration response at each location shall be simultaneously measured using a minimum two-channel FFT analyser and Frequency Response Functions (FRF's) shall then be stored for each measurement.

The test frame shall be a minimum 10 times stiffer than the combined stiffness of the test bearing set, (i.e. the test frame and preload device shall not significantly contribute to the controlling stiffness of the target bounce mode).

A minimum of four measurement locations are considered necessary to adequately define relevant mode shapes (unless otherwise justified). Measurements shall be in three component directions (i.e. vertical, transverse and longitudinal) at each location.

An example of a typical measurement instrumentation set-up for all dynamic tests is shown as Figure B1.

### **B3 Extraction of modal parameters**

This shall be achieved by processing the FRF measurements with suitable modal analysis software such as SMS STARStruct® or equivalent.

The stages in this process shall be:

- a) the first five vertical modes shall be identified
- b) FRF measurements shall be curve fitted and modal parameters shall be produced (frequency and damping tables, mode shape tables)
- c) the mode shapes shall be animated and displayed
- d) the mode shapes shall be animated and displayed again within the modal software by entering the three dimensional coordinates of all measurement points to produce a line drawing of the structure, and
- e) the resulting residues (from the shape tables above) shall be superimposed on the line drawing and animated for viewing.

### **B4 Analysis and report**

The above resulting Natural Mode Data shall be used in order to determine:

- a) an understanding of the dynamic response of the structure under actual vehicle pass-by excitation; and
- b) an understanding of the dynamic amplification factors, (DAF) which may contribute to the structural failures (eg. weld cracking at centre beam to support bar connection).

In the determination of the DAF, consideration shall be given to:

- the mode shapes involved
- the modal damping for critical modes
- the wheel pass frequency range
- the vehicle speed and axle spacing for multi-axle vehicles
- the structural continuity of the MBEJ system
- the damped natural frequency of the fundamental bounce mode of the test mass for the bearings and the pre-compression springs
- the damping factors associated with the bearing and pre-compression spring modes, and
- the dynamic compression stiffness for the bearings, and the pre-compression springs.

The test report shall detail all test procedures, conclusions and recommendations, including detailed steps used in the determination of the modal parameters.

In the case of in-situ testing, the determination of the DAF range may be assisted by component vibration measurements under traffic excitation, i.e. traffic response vibration tests.

The test report shall detail all test procedures, conclusions and recommendations, including detailed steps used in the determination of the DAF range. The test report shall also provide full size A4 plots (landscape) of representative FRF's for every natural mode identified (magnitude and phase).

Where the DAF assessment produces a probable range of values, the design DAF shall be calculated as follows

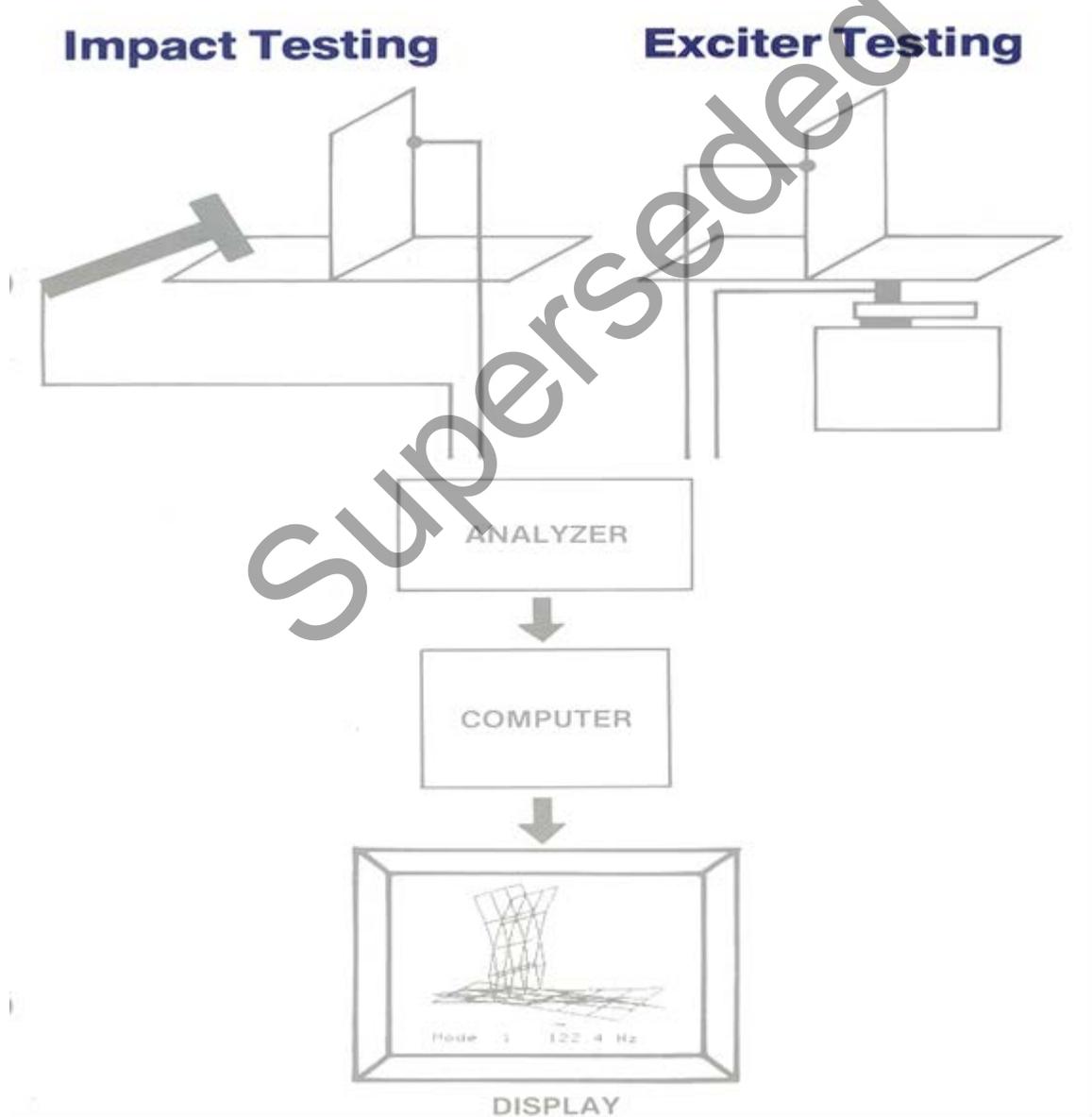
$$\chi_{\text{mod}} = (3\chi_{\text{UB}} + \chi_{\text{LB}}) / 4 \quad (\text{B.1})$$

where  $\chi_{\text{UB}}$  and  $\chi_{\text{LB}}$  are the upper and lower bound values of the DAF.

Animation and display of mode shapes shall be achieved again within the modal software by entering the three dimensional coordinates of all measurement points to produce a line drawing of the structure.

The resulting residues (from the shape tables above) shall then be superimposed on the line drawing and animated for viewing. The main purpose of mode shape animation in these tests is to identify whole body and flexural modes of the MBEJ system and to positively identify the fundamental bounce mode of the bearing test mass.

**Figure B1 – Impact and exciter testing**



## Appendix C – Inclusion for Modular Bridge Expansion Joints (MBEJ)

The following should be included in the Conditions of Tendering, or the Information to be Submitted with Tenders, as appropriate.

The tender shall include, as a minimum:

- a) the name and contact details of the MBEJ System Manufacturer
- b) the name, contact details and curriculum vitae of the MBEJ System Manufacturer's representative
- c) the name, contact details and curriculum vitae of the MBEJ System Manufacturer's Joint Designer
- d) the name and address of the proposed fabricator, together with documentation of past experience of the fabricator in complex heavy steel fabrication and pre-qualified weld procedures
- e) names and details of bridges where joints of the offered MBEJ system type have been installed, together with the movement capability, installation date, and the name, telephone number and facsimile number of the maintaining authority for each bridge
- f) noise test reports of the performance of the MBEJ system under traffic (where available)
- g) an experimental modal analysis study, in accordance with Appendix B to MRTS90 Modular Bridge Expansion Joints, conducted on a comparable size and type of dynamically similar MBEJ, or a written commitment that the study will be provided in accordance with the requirements of that standard
- h) evidence of compliance with the fatigue test specification set out in Appendix B of NCHRP Report 402
- i) results of NCHRP Report 467 testing (where available)
- j) a statement of where the proposed materials and fabrication do not comply with the requirements of MRTS90 Modular Bridge Expansion Joints, including the technical justification for the variations and a clause-by-clause comparison between the specified requirement and the proposed substitution, and
- k) all MBEJ drawings, complying with AS/NZS 1100.501 with dimensions in SI units, as both hard copies and in electronic format.

If so requested by the principal subsequent to the close of tenders, four sets of any non-metallic components including:

- a) each type of elastomeric bearing, and
- b) each type of elastomeric spring,

proposed for use in the MBEJ, together with a description denoting the location where each bearing and spring is to be used and what pre-compression is applied to each bearing and spring shall be provided.

Superseded