

Structures Repair Guidelines

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Table of Contents

1	Introduction.....	5
1.1	The Purpose of the Guidelines	5
1.2	Common Users of the Guidelines.....	5
1.3	Cross Reference	5
1.4	Durability of Repairs	5
2	Steel	6
2.1	General	6
2.2	Repair Methods and Materials	6
2.2.1	Removing rivets and replacing with bolts	6
2.2.2	Patch painting.....	10
2.2.3	Filling voids	11
2.2.4	Sealing interfaces	12
2.2.5	Repairs to corroded flanges and webs of I girders	13
2.2.6	Repairs to stiffeners, bracing connections, and bearings.....	19
2.2.7	Repairs to fatigue damage	26
2.2.8	Repairs to impact damage	34
2.2.9	Repairs to stepways and footway structures	38
2.2.10	Complete replacement of members	48
2.3	References	49
3	Reinforced Concrete.....	50
3.1	General	50
3.2	Repair of Cracks	50
3.2.1	Epoxy injection.....	50
3.2.2	Grouting.....	51
3.2.3	Routing and sealing	51
3.2.4	Drilling and plugging	52
3.2.5	Stitching.....	53
3.2.6	Adding reinforcement	54
3.2.7	Overlays and surface treatment	55
3.2.8	Flexible sealant	56
3.3	Patch Repairs.....	57
3.3.1	Repair with cement-sand mortars	57
3.3.2	Repair with polymer modified cementitious mortars.....	58
3.3.3	Repair with epoxy mortar.....	58

3.4	Recasting with Concrete	59
3.5	Corrosion Repairs	60
3.6	Sprayed Concrete (Shotcreting)	60
3.7	Protective Coatings	61
3.7.1	Coating/repair to prevent chlorides ingress	61
3.7.2	Coating/repair to prevent carbonation	62
4	Masonry.....	63
4.1	General	63
4.2	Crack Repairs	63
4.2.1	Active cracks	63
4.2.2	Inactive cracks	64
4.3	Fretting Repairs	64
4.3.1	Repair of damaged joints.....	64
4.3.2	Repair of damaged masonry units	64
4.4	Repair to Impact Damaged Masonry Units	65
4.5	Other Types of Repairs.....	65
4.5.1	Minor displacement of masonry	65
4.5.2	Sulphate attack	65
4.5.3	Salt water and marine organisms	65
5	Timber.....	66
5.1	General	66
5.2	Repairs Required for Common Defects.....	66
5.2.1	Decay resulting in troughing, pipes, crushing or loss of section	66
5.2.2	Splitting	66
5.2.3	Pile splicing.....	67
5.2.4	Vehicle impact damage.....	67
5.2.5	Weathering – abrasion, cracks, shakes, checks and splits.....	68
5.2.6	Corroded fasteners, missing fasteners and loose connections	68
5.2.7	Termite infestation (white ants).....	68
5.3	Replacement / Strengthening Methods	68
5.3.1	Strengthening of internal girders	68
5.3.2	Replacement of timber piles with new steel trestle	69
5.3.3	Replacement of headstocks, braces and wales, sills, etc	69
5.4	Propping	69
5.4.1	Emergency propping	69
5.4.2	Place / reinstate relieving props	69
5.4.3	Propping for maintenance activities.....	69

5.5 List of Drawings in Appendix A 70

6 Miscellaneous Repairs 71

6.1 General 71

6.2 Repairs to Scour Protection 71

6.3 Replacement of Damaged / Deteriorated Bearing Pads..... 71

6.4 Replacement/ Installation of Road/Pedestrian Traffic Barriers 72

6.5 Track Baulking..... 72

6.6 Bridge Ends 72

6.6.1 Subgrade construction behind abutments and Transition slab 72

6.6.2 Ballast log for transom top underbridge 72

6.6.3 Ballast retention walls..... 72

6.7 Culvert Repairs 72

6.7.1 Repair of steel pipe invert 72

6.7.2 Sleeving of brick culverts 72

6.8 List of Drawings in Appendix B..... 73

7 Typical Examples of Past Repair Work..... 74

8 Appendices 75

1 Introduction

1.1 The Purpose of the Guidelines

The purpose of the guidelines is to provide repair methods for commonly found defects in concrete, masonry, steel, and/or timber structures, which are a part of routine maintenance of Australian Rail Track Corporation (ARTC) assets. Where necessary, the Structures Representative is to seek engineering advice whether a detailed structural design document is required.

1.2 Common Users of the Guidelines

The users of the guidelines are:

- Structures Representative
- Project Engineers/Managers
- Structures Engineers
- Structures Inspectors
- Area Managers
- Infrastructure Workers
- Team Leaders
- Work Group Leaders
- Asset Managers
- Contractors

1.3 Cross Reference

All sections are standalone in this document and therefore sections that are applicable for particular work should be adopted.

1.4 Durability of Repairs

All repairs should have durability equal to or better than the original work/material unless otherwise specified by ARTC. The accessibility of all parts of a repaired structure for inspection, cleaning, or painting should be accomplished by the proper proportioning of repairs and the design of their details. Closed sections, and pockets or depressions that will retain water, should be avoided. Pockets should be provided with effective drain holes or filled with waterproofing materials.

2 Steel

2.1 General

This section should be read in conjunction with AS/NZS 5131: Structural steelwork – Fabrication and erection. The standard provides best practice requirements for fabrication and erection of structural steel members, components and structural assemblies used for load-carrying purposes in bridges, building and other structures.

This section presents methods for repairing defects in steel elements of any structure.

The following minimum requirements apply, Unless Noted Otherwise (UNO), for any strengthening or replacement of steel elements:

- Grade 250 mild steel
- Minimum plate thickness is 8mm
- Minimum diameter of a load carrying fastener is 16mm
- All bolts are Grade 8.8, High Strength Structural (HSS) or swage bolts
- Swage bolts should be used wherever practical to obtain best quality workmanship
- All steel and, bolts, nuts and washers must be either galvanised or painted after installation or otherwise protected against corrosion.

2.2 Repair Methods and Materials

2.2.1 Removing rivets and replacing with bolts

This section covers the removal of existing rivets and replacement with either high strength friction grip bolts or snug tightened bolts.

To remove rivet heads, one of the following two methods can be used:

- cutting using oxy-fuel equipment;
- grinding off all or part of the head/tail.

The following notes are useful to observe for removing of the rivet heads.

Oxy-fuel cutting:

Oxy-fuel cutting can be used in the following circumstances where the head to be removed is adjacent to:

- i. any steel that is to be removed and discarded as part of the repair process;
- ii. intermediate web stiffeners; or
- iii. minor bracing members that are not subject to dynamic or cyclic loading.

Do not allow the oxy flame or molten steel to touch any other steel element except those listed above.

In cases (ii) and (iii) above, where the steel adjacent to the rivet head is to remain in place, take care to avoid or minimise flame effects on that steel, to leave a neat hole for installation of the bolts.

If the use of oxy-fuel cutting cannot be avoided in cases other than those above, take great care to avoid flame effects on the adjacent steel. Any flame affected steel around the hole must be completely removed by reaming prior to installing the bolt.

Grinding:

Use grinding to remove the head, if it is necessary to remove the portion of the head outside the shank diameter.

Take care to avoid creating grooves and indentations in steel that is to remain in place. If such indentations and grooves occur, remove them by grinding the surface smooth after removing the rivet.

Where large numbers of rivets are to be removed, consideration should be given to procuring a grinding bit such as a broaching bit, which when positioned centrally on the domed head will grind away material outside the shank diameter.

The procedure for preparing the hole for the bolt and limitations (in accordance with AS 5100.6 and AS/NZS 5131) are described below:

Prepare the hole to accept the bolt by reaming out the hole to the required diameter, then removing burrs etc. at the edge of the hole and creating a smooth, level surface on both sides for bedding the washer and bolt head. Grinding, wire brushing and scraping may be used.

Use reaming to remove any areas of steel around the hole that have been flame affected during the removal of the rivet.

The hole diameter after reaming must be no more than 2mm larger than the diameter of the bolt not greater than 24mm diameter, and not more than 3mm larger for a bolt of greater than 24mm diameter. For all other holes, both oversize and slotted holes, hardened square plate washers of minimum thickness 10mm, to be installed under both the bolt head and nut as shown in Figure 2 - 1.

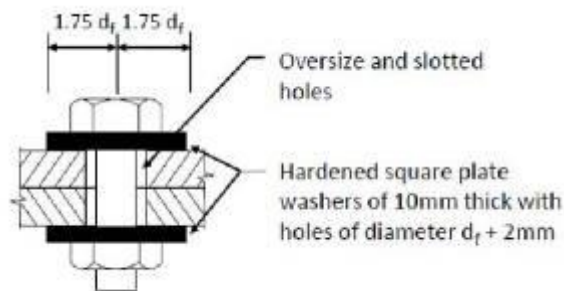


Figure 2 - 1 Replacement of bolts in oversize holes

For the oversize and slotted holes the hole diameter cannot be greater than values provided in Table 2-1.

Table 2 - 1 Limit on oversize or slotted holes

Nominal diameter of fastener, d_r (mm)	Maximum size	
	Oversize hole in diameter (mm)	Slotted hole in length (mm)
16	24	40
20	28	50
22	30	55
24	32	60
27	35	68
30	38	75
36	45	90

The width of slotted hole should not be more than 2mm larger than the bolt diameter.

Limitations on the use of oversize and slotted holes

- i. An oversize hole may be used in any or all plies of bearing-type and friction-type connections.
- ii. A slotted hole may be used only in alternate plies of friction-type and bearing-type connections.

Table 2 - 2 lists the edge distances from the centre of a fastener to the edge of a plate or the flange of a rolled section and pitch distances between the fasteners.

Table 2 - 2 Edge distance and pitch for bolts

Nominal diameter of fastener, d_f (mm)	Minimum Edge Distance (mm)			Maximum edge Distance (mm)	Minimum pitch (mm) $2.5d_f$	Maximum pitch (mm)
	Sheared or hand flame cut edge $1.75d_f$	Rolled plate; machine flame cut, sawn or planed edge $1.5d_f$	Rolled edge of a rolled section $1.25d_f$			
16	28	24	20	100	40	200
20	35	30	25	100	50	200
22	39	33	28	100	55	200
24	42	36	30	100	60	200
27	48	41	34	120	68	200
30	53	45	38	120	75	200
36	63	54	45	120	90	200

For each standard rivet size the minimum size of replacement bolt to give equivalent shear capacity is given in Table 2 - 3. Larger bolts may be used.

Table 2 - 3 Minimum replacement bolt sizes

Rivet size	Bolt size (Grade 8.8 , High Strength Friction Grip)
3/4"	M20
7/8"	M22 or M24
1"	M27 or M30

Preparation of interface for bolting should be as follows:

- i. All oil, dirt, loose scale, loose rust, burrs, fins and any other defects on the surfaces of contact, which will prevent solid seating of the fastener/washer and/or elements in the snug-tight condition, should be removed.
- ii. For a friction-type connection, the contact surfaces should be clean as-rolled surfaces or equivalent, and also need to be free from paint, lacquer, galvanizing or other applied finish.
- iii. For a bearing-type connection, an applied finish on the contact surfaces should be permitted.

Following describes the assembly of a connection involving tensioned bolts

- i. The nut should be placed so that the mark visible after tightening.
- ii. Packing should be provided wherever necessary to ensure that the load-transmitting plies are in effective contact when the connection is tightened to the snug-tight condition. All packing should be steel with a surface condition similar to that of the adjacent plies.
- iii. Snug-tightening and final tensioning of the bolts in a connection should proceed from the stiffest part of the connection towards the free edges. High strength structural bolts that are to be tensioned may be used temporarily during erection to facilitate the assembly; however, if so used, they should not be finally tensioned until all bolts in the connection have been snug-tightened in the correct sequence.

- iv. Re-tensioning of bolts that have been fully tensioned should be avoided, except that if re-tensioning is carried out it should only be permitted once and only where the bolt remains in the same hole in which it was originally tensioned and with the same grip. Re-tensioning of galvanized bolts should not be permitted. Under no circumstances should bolts that have been fully tensioned be reused in another hole. Touching up or re-tensioning of previously tensioned bolts that may have been loosened by the tensioning of adjacent bolts should not be considered as re-tensioning.

Methods of tensioning bolts

The methods of tensioning of bolts involve using of part-turn method, load indicating washer, or a direct-tension indication device.

a) The procedure for tensioning of bolts by the part-turn method involves the following:

- On assembly, all bolts in the connection should be first tightened to a snug-tight condition which is the tightness attained by a few impacts of an impact wrench or by the full effort of a person using a standard podger spanner.
- After completing snug-tightening, location marks should be established to mark the relative position of the bolt and the nut and to control the final nut rotation. Observation of the final nut rotation may be achieved by using marked wrench socket, but location marks should be permanent when required for inspection.
- Bolts should be finally tensioned by rotating the nut by the amount given in Table 2 - 4. During the final tensioning, the component not turned by the wrench should not rotate.
- On completion of tensioning, the bolt/nut shall be punch marked to align against marking on parent metal to indicate during inspections that the nut has not become loose. Any misalignment in punch marks will indicate a loose fastener in need of replacement.
- *The quality of bolt tensioning using this methodology could not be relied upon due to too many variables. Accordingly, it should only be used when it's impractical to use an alternative methodology.*

Table 2 - 4 Nut rotations from the snug-tight condition

Bolt length (underside of head to end of bolt)	Disposition of outer face of bolted parts		
	Both faces normal to bolt axis	One face normal to bolt axis and other sloped	Both faces sloped
Up to and including 4 diameter	1/3 turn	1/2 turn	2/3 turn
Over 4 diameter but not exceeding 8 diameter	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameter	2/3 turn	5/6 turn	1 turn

b) The procedure for tensioning of bolts using Load Indicating (LI) washers

In this method Load Indicating (LI) washers with protrusions and/or coloured dye are used. Note that a single LI washer should be placed under the nut.

On tightening, the gap reduces as the protrusions depress and when the specified gap (usually 0.40mm) is obtained or dye capsule has burst, the bolt tension will not be less than the required minimum.

This gap is measured by means of a feeler gauge, consisting of small bits of steel plates of varying thickness, which can be inserted into the gap.

c) The procedure for tensioning of bolts using a direct-tension indication device involves the following:

- The suitability of the device should be demonstrated by testing a representative sample of not less than three bolts for each diameter and grade of bolt in a calibration device capable

of indicating bolt tension. The calibration test should demonstrate that the device indicates a tension not less than 1.05 times the minimum bolt tension given in Table 2 - 5.

- On assembly, all bolts and nuts in the connection should be first tightened to a snug-tight condition.
- After completing snug-tightening, the bolt should be tensioned to provide the minimum bolt tension specified in Table 2 - 5. This should be indicated by the tension indication device.

Table 2 - 5 Minimum bolt tension

Nominal diameter of bolt (mm)	Minimum bolt tension (kN)
16	95
20	145
22	178
24	210
27	273
30	335
36	490

2.2.2 Patch painting

The procedure for patch painting involves the following:

- Prepare the surface

For normal steel surfaces - Prepare the surfaces for painting in accordance with the recommendations of the paint manufacturer for the paint system to be applied and in accordance with AS/NZS 5131. Hand or power tool cleaning to AS 1627.7 or AS 1627.2 Class 2 is the minimum requirement. That is, when viewed without magnification, the surface should be free from visible oil, grease and dirt, and should be free from most mill scale, rust, paint coatings and foreign matter. Any residual contamination should be firmly adhering without being lifted with a blunt putty knife.

For rough surfaces - Remove sharp ridges and deep narrow grooves or pits from the steel surface by power grinding. Alternatively, for the surface of site fillet welds, fill the surface to a smooth even finish using epoxy resin fillers such as those used for void filling.

Where the depth of the roughness is less than 0.5mm, an adequate and durable paint system can be achieved without the above surface levelling by applying multiple coats of the paint. Each coat is to be no more than the maximum film thickness recommended by the manufacturer. Enough coats are to be applied so that the minimum required dry film thickness (typically 150 micrometres) is achieved at all sharp ridges.

For galvanised surfaces - Prepare the galvanised surface for painting in accordance with the paint manufacturer's recommendations and AS/NZS 5131. Coating manufacturers usually recommend degreasing and abrasion, acid etching or pre-treatment with etch (wash) primers prior to painting. Light abrasive blast cleaning (brush blasting) is the most reliable means of achieving satisfactory coating adhesion. However, where light abrasive blast cleaning is impractical due to the small areas involved, power wire brushing/hard scouring with aluminium oxide impregnated nylon pads to remove the shiny patina on new galvanised steelwork and the white soluble zinc salts on old (weathered) galvanised steelwork is preferred to acid etching or pre-treatment with etch primer.

Caution: majority of aged steel bridges are painted with red lead base paint. Where this is the case refer to Lead Management Procedure COR-PR-030.

ii. Apply the paint

Mix the paint components and apply in accordance with the manufacturer's instructions. The paint should be applied immediately after surface preparation, preferably within 4 hours, and certainly on the same day. The minimum total dry film thickness of the system should not be less than 125 micrometres.

Paint systems suitable for patch painting are listed below. They are typically 2 part epoxy based, high build systems.

- Taubmans Interseal 670HS
- PPG Amerlock 400 GF and Sigmashield 400
- Dulux Luxaprime zinc phosphate
- Carbomastic 15.

2.2.3 Filling voids

When new steel plates or sections are fitted to existing steel as part of repair procedures, voids may be created, usually as a result of the existing steel being heavily corroded or pitted. The voids may need to be filled with epoxy resin for one or both of the following reasons.

- i. To preclude the ingress of air and moisture which would lead to further corrosion, and/or
- ii. To provide a smooth, level surface on to which the new steel elements can be fitted.

Two alternative procedures for applying filling epoxies are described below. In the first, the covering steel member is fitted before the epoxy has hardened and excess epoxy is squeezed out during bolt tightening. Squeezing out excess epoxy ensures the void is completely filled. In the second procedure, the epoxy is trowelled or screeded smooth and flat and allowed to harden prior to fitting the steel member.

The procedure of alternative 1 – New steel elements fitted before epoxy hardens involve the following:

- iii. Prepare the existing steel surface by abrasive blast cleaning to Class 2½ in accordance with AS 1627.4. That is, when viewed without magnification, the surface should be free from visible oil, grease and dirt, and should be free from most mill scale, rust, paint coatings and foreign matter. Any remaining contamination should show only as slight stains in the form of spots or stripes. If abrasive blast cleaning is impractical due to small areas involved then use power tool cleaning to Class 2 in accordance with AS 1627.2.
- iv. Mix the epoxy according to the manufacturer's directions and apply to the steel surface. Trowel and screed into position to the approximate surface required. Ensure that there is a slight excess of epoxy that can be squeezed out when the steel part is fitted. Make sure there is an adequate escape path for excess epoxy.
- v. While the epoxy is still plastic, position the new steel part and install the fixing bolts. Use the tightening of the bolts to bring the steel part into the correct position and squeeze out excess epoxy. Bolts may only be fully tensioned prior to curing if the member would not distort and be forced out of position by such action. If in doubt about the effects of bolt tensioning, wait until the epoxy has cured.
- vi. Clean away excess epoxy and make sure all steel-to-steel interfaces are effectively sealed at the perimeters ready for painting.
- vii. Tension the bolts after the epoxy has cured.

The procedure of alternative 2 – New steel elements fitted after epoxy hardens involve the following:

- i. Prepare the existing steel surface by abrasive blast cleaning to Class 2½ in accordance with AS 1627.4. If abrasive blast cleaning is impractical due to small areas involved then use power tool cleaning to Class 2 in accordance with AS 1627.2.
- ii. Mix the epoxy according to the manufacturer's directions and apply to the steel surfaces. Screed the epoxy to the smooth, flat surface required using a straight edge screed. If necessary to achieve a flat surface, apply the epoxy in two or more coats with each successive coat filling any valleys until the required flatness is achieved.
- iii. Clean away excess epoxy. Ensure that empty bolt holes are not obstructed by epoxy.
- iv. After the epoxy has cured, fit the steel part and fully tension any bolts.
- v. Seal any remaining gaps at interfaces.

The repair materials are described below:

Use high strength, two part epoxy fillers or adhesives. Epoxies should have high strength and non-sag properties if they are to be applied to overhead or vertical surfaces. Select an epoxy with a work time appropriate to the repair being carried out. Recommended products include the following:

- Epirez 8242
- Epirez 633 (moisture tolerant)
- Megapoxy 206

When the procedure of alternative 2 is to be used, choose an epoxy which is suitable for working and screeding.

Comment: Seek advice from recognised manufacturers to select the best epoxy and application procedure for the particular repair.

2.2.4 Sealing interfaces

In repairing steel, gaps may occur at the interface between new and existing steel, often as a result of the existing steel being corroded. In these and similar situations the gaps are to be sealed with a single component polyurethane sealant prior to painting when they are greater than a specified width.

The procedure for sealing interfaces involves the following:

- i. Prior to fitting new steel elements, prepare existing steel surfaces by abrasive blast cleaning to Class 2½ in accordance with AS 1627.4. If abrasive blast cleaning is impractical due to small areas involved then use power tool cleaning to Class 2 in accordance with AS 1627.2.
- ii. Identify areas to be sealed. Interfaces where the gap exceeds 0.5mm or twice the maximum recommended dry film thickness are to be sealed with a single component polyurethane sealant sealing is required whether the concealed steel surfaces are painted or bare steel.
- iii. Break inner seal at extrusion end of cartridge, affix nozzle, cut tip to suit joint size, install in caulking gun and apply in accordance with the manufacturers' instructions.

The repair materials are described below:

Use a single component polyurethane sealant suitable for being painted over with solvent-based paints. Recommended products include the following:

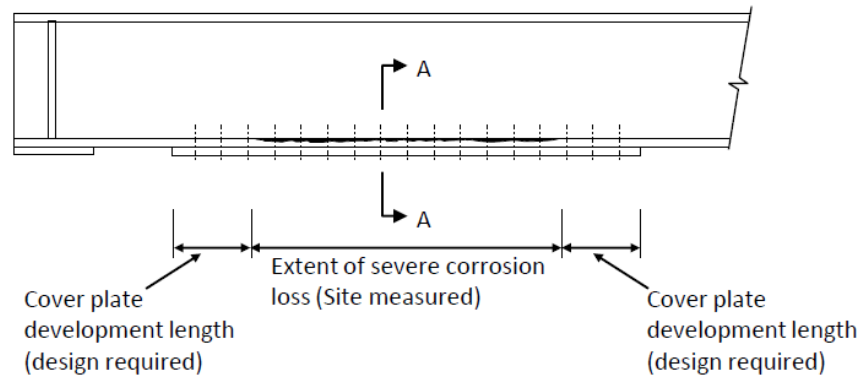
- Epirez 8242
- Epirez 633 (moisture tolerant)
- Epirez D5-070 NS (flexible)
- Dulux Luxepoxy Barrier Coat
- Sikaflex

2.2.5 Repairs to corroded flanges and webs of I girders

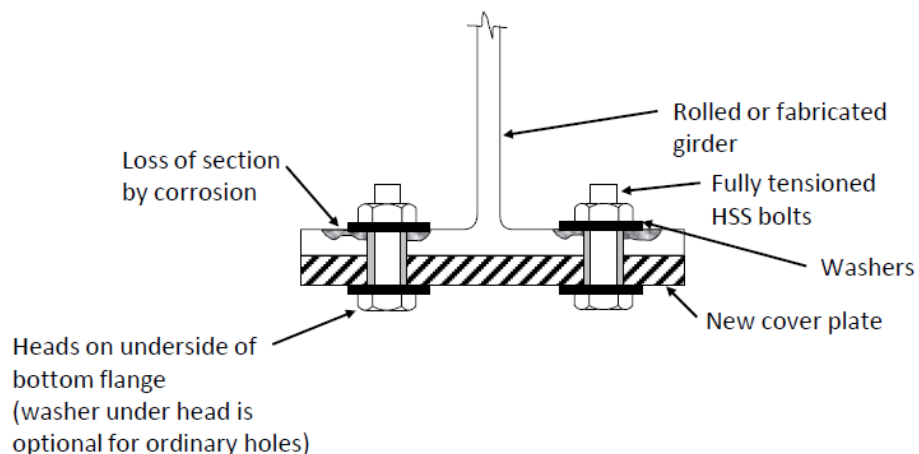
2.2.5.1 Corrosion in flanges of rolled or welded girders

The procedure for repairing flange corrosion in rolled or welded girders involves the following (Refer Figure 2 - 2):

- i. Mark and drill holes in the flange to suit the cover plate.
- ii. Prepare the flange surface for cover plating by removing all loose rust and dirt and by grinding where necessary to create a smooth surface. Fill any deep pitting (>1mm deep) or any area of unevenness to create a flat surface for seating the cover plate.
- iii. Position the cover plate, holding it in place with clamps.
- iv. Fit and tension all bolts.
- v. Seal open interfaces to new steel.
- vi. Prepare for and paint new steelwork and areas of existing steelwork to the extent.



Part Elevation - typical rolled or fabricated girder



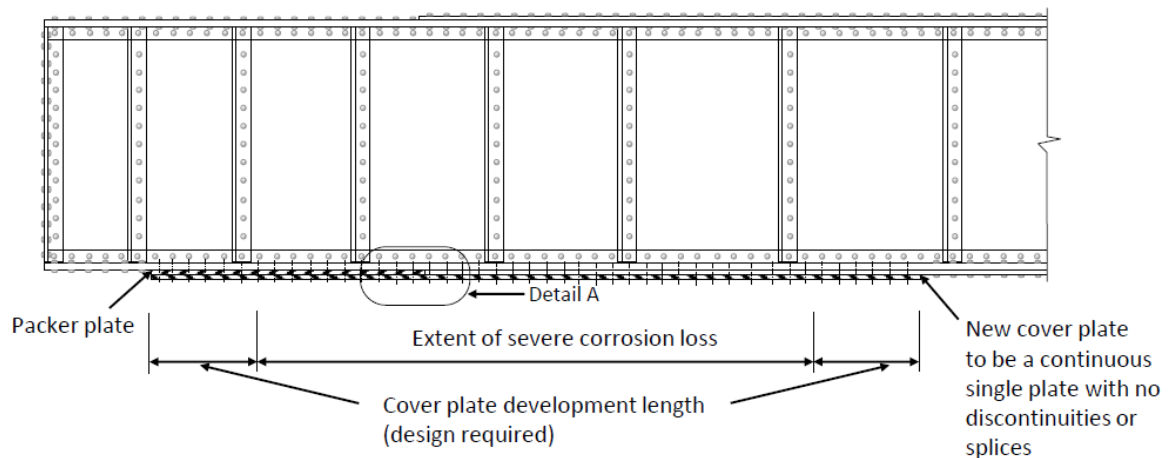
Typical Section A-A

Figure 2 - 2 Repairing flange corrosion in rolled or fabricated girders

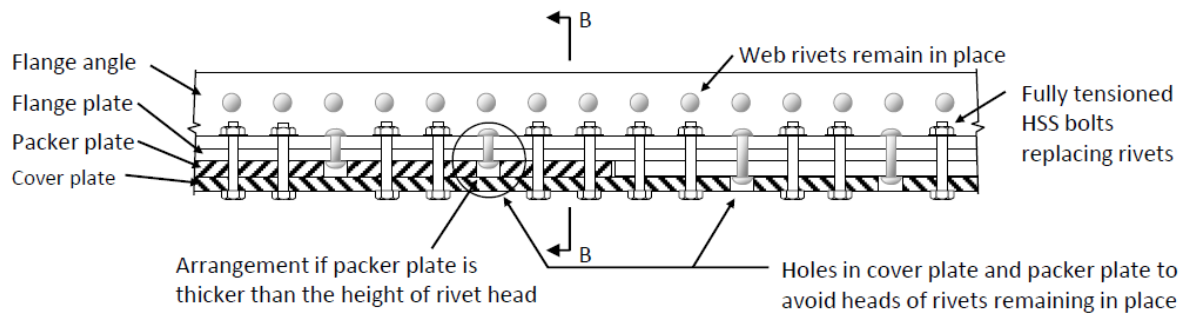
2.2.5.2 Corrosion in flanges of riveted girders

The procedure for repairing flange corrosion in riveted girders involves the following (Refer Figure 2-3):

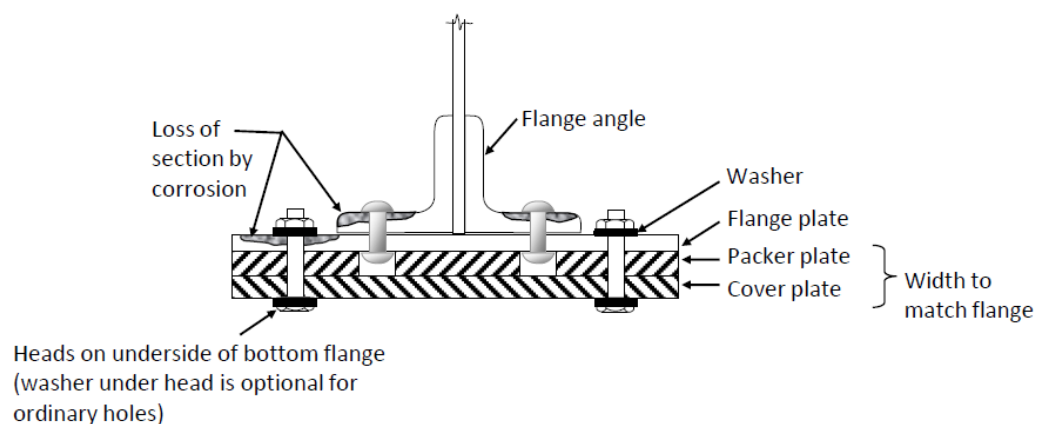
- i. Remove heads of rivets that are to be replaced by bolts. Remove the underside heads for bottom flanges and the topside heads for top flanges. For top flange rivet removal, fit clamps to the underside to prevent rivets falling out.
- ii. Prepare the flange surface for cover plating by removing all loose rust and dirt and by grinding where necessary to create a smooth surface. Fill any deep pitting (>1mm deep) or any area of unevenness to create a flat surface for seating the cover plate.
- iii. Position the packer plates and cover plate, holding them in place with clamps.
- iv. Progressively remove rivets to be replaced and fit and tension replacement bolts. Note that no more than 10% of rivets, evenly distributed along the member, are to be removed at any one time.
- v. Seal open interfaces to new steel where required. Fill exposed rivet head holes on the top flange to prevent collection of water.
- vi. Prepare for and paint new steelwork and areas of existing steelwork to the extent.



Part Elevation
Typical riveted girder



Detail A



Section B-B

Typical Cross section

Figure 2 - 3 Repairing flange corrosion in riveted girders

2.2.5.3 Corrosion in web near bottom flange angles in riveted girders or at cross girder and stringer connections in through and truss spans

The procedure for repairing web corrosion near bottom flange angles in riveted girders involves the following (Refer Figure 2 - 4):

Bolting

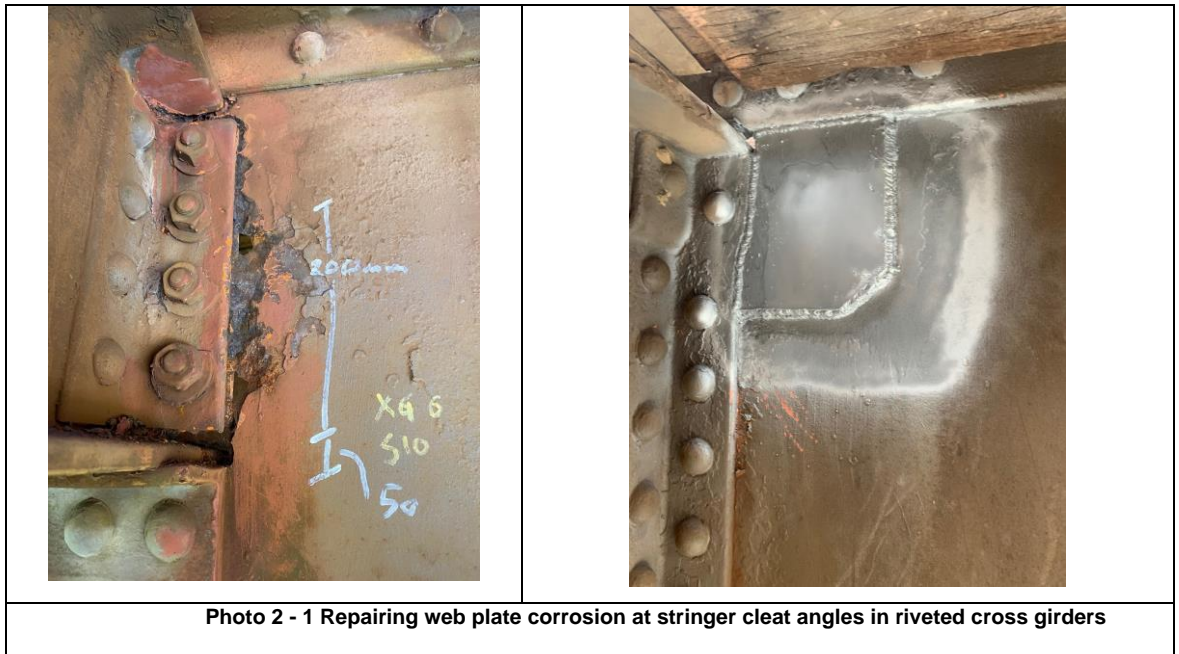
- i. Remove all loose rust from the surface to be plated by mechanical wire brushing and scraping. Scrape or grind smooth the vertical face of flange angles.

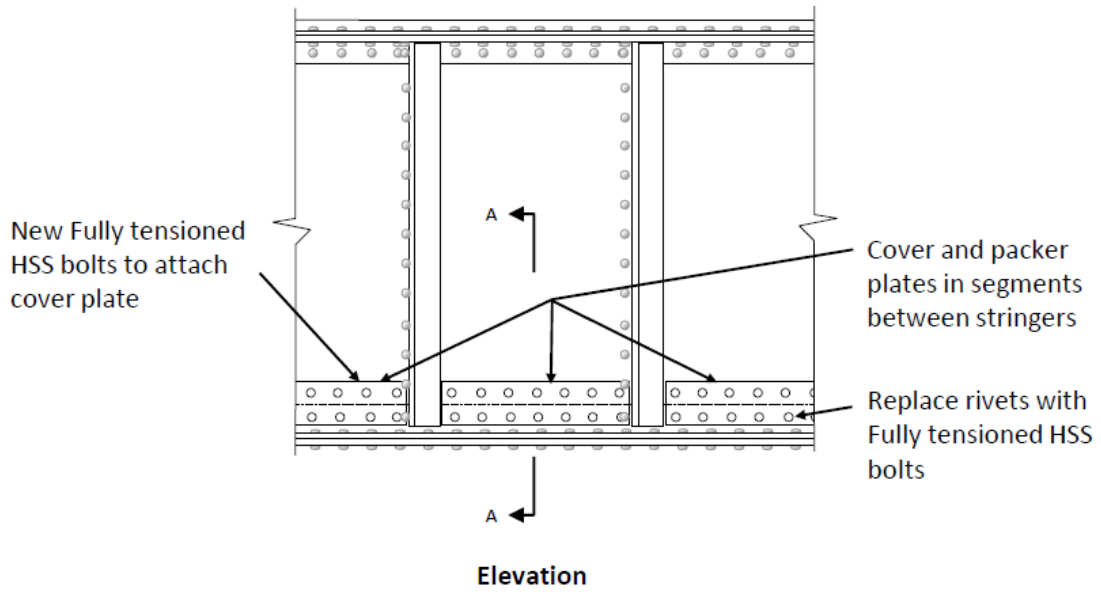
Working on only one panel of web at a time carry out the following:

- ii. Drill holes in the web above flange angle to match the holes in the prefabricated, galvanised cover plate and packer plate.
- iii. Drill holes in the web of cross girder alongside stringer cleat to match the holes in the prefabricated, galvanised cover plate and packer plate.
- iv. Remove the rivets through vertical legs of angles or stringer cleats.
- v. Position the packer plate and fill the void between the packer and the flange or cleat angle.
- vi. Fit the cover plate and, install and tension all bolts. Repeat above steps for each web panel or cross girder web requiring plating.
- vii. Prepare for and patch paint new steelwork and areas of existing steelwork to the extent, including the region of corrosion on the unplated side.

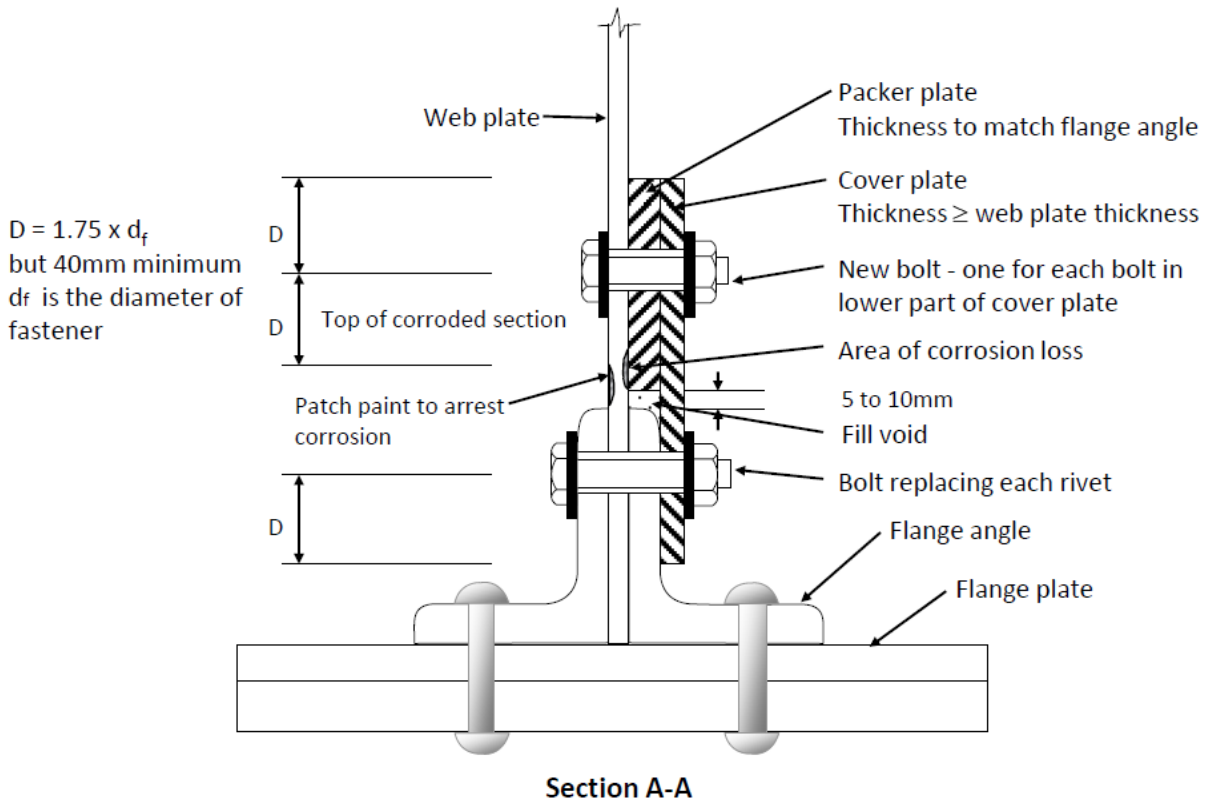
Welding

- i. Welding to cross girder web and flange angles maybe carried out where bolting is not practical, refer Photo 2-1 below.
- ii. Remove all rust, dirt, old paint etc., from the area to be plated by mechanical wire brushing and scraping.
- iii. Prepare correct size cover plates.
- iv. Fill voids and surface pitting with epoxy resin filler over area of web to be covered.
- v. Position cover plate and weld all around on web plate.
- vi. Where cover plate is also butted against stringer cleat angle then weld it to edge of angle.
- vii. Where cover plate is also abutted against top and/or bottom flange angles of cross girder then weld it to edge of these angles. Cover plate shall not be welded to stringer.
- viii. Prepare for and patch paint new steelwork and areas of existing steelwork to the extent, including the region of corrosion/perforation on the unplated side and above ends of stringer.





Typical riveted girder panel



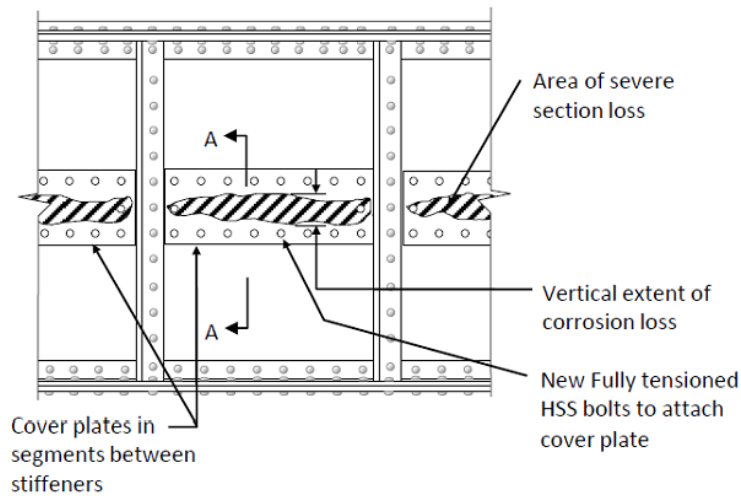
Typical section through cover plate

Figure 2 - 4 Repairing web plate corrosion near bottom flange angles in riveted girders

2.2.5.4 Localised corrosion in webs

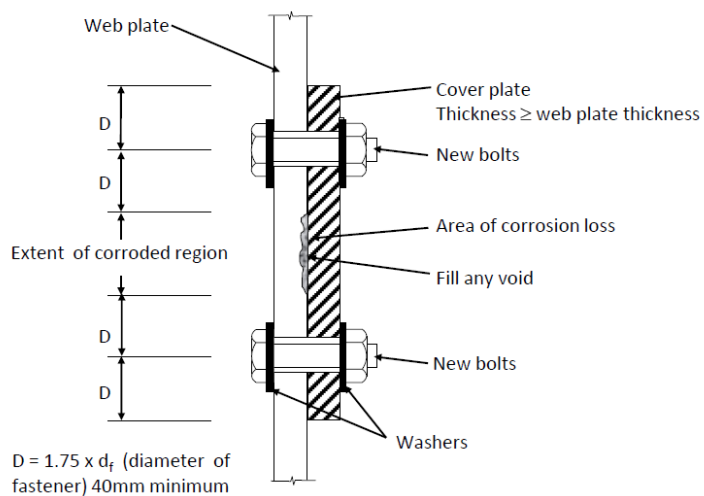
The procedure for repairing webs with localised corrosion involves the following (Refer Figure 2 - 5):

- i. Remove all rust, dirt, old paint etc., from the area to be plated by mechanical wire brushing and scraping.
- ii. Mark and drill bolt holes in the web to match the holes in prefabricated, galvanised cover plates.
- iii. Fill voids and surface pitting with epoxy resin filler over area of web to be covered.
- iv. Position cover plates, and fit and tension bolts.
- v. Seal with epoxy any open interfaces around the perimeter of the cover plates.
- vi. Prepare for and patch paint new steelwork and areas of existing steelwork to the extent.



Elevation

Typical riveted girder panel



Section A-A

Typical section through cover plate

Figure 2 - 5 Repairing webs with localised corrosion

2.2.6 Repairs to stiffeners, bracing connections, and bearings

2.2.6.1 Relieving of corrosion site at the base of intermediate web stiffeners

The procedure involves the following:

- i. Remove any rivets securing the lower portion of the web stiffener that is to be removed.
- ii. Cut off the lower portion of the stiffener to the extent shown on Figure 2 - 6 or Figure 2 – 7 by flame cutting and/or with an angle grinder. Several possible arrangements of web stiffeners are shown on these figures. The appropriate location for the cut is shown in each case.

To avoid accidental creation of heat affected zones (fatigue sites) in the adjacent web and flange, do not use flame cutting to remove portions of intermediate web stiffeners in direct contact with the web or flange. Use an angle grinder to cut these portions. Take care to avoid grinding a groove into the web or flange.

- iii. Dress any flame cut edge to the stiffener by grinding smooth and fit and tension bolts to any holes formerly occupied by rivets.
- iv. Prepare for and patch paint the exposed steel of the web stiffener and the local area of bottom flange and flange angle now exposed.

2.2.6.2 Repairing intermediate and bearing web stiffeners with localised corrosion

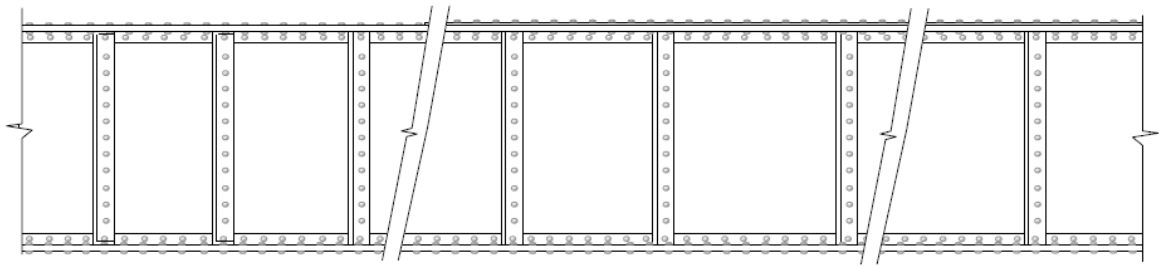
The procedure for the following two cases:

Case A - Corrosion away from end of stiffeners

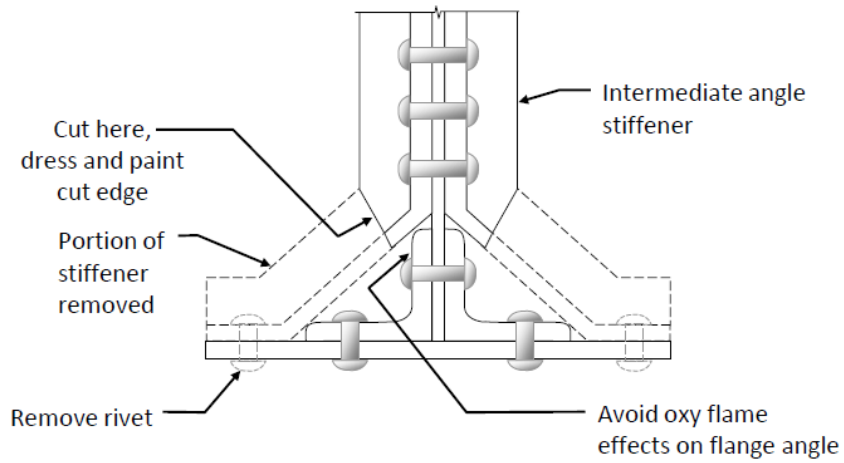
- i. Mark and drill holes in the existing stiffener and web to suit the prefabricated splicing angle.
- ii. If directed, cut away the severely corroded portion of stiffener by flame cutting and by using an angle grinder. Avoid flame effects and grinding of grooves in the web plate. Dress any flame cut edges.
- iii. Clean existing steelwork where new steel is to abut. Fill pitting and depressions so that there is no void between the web and the new stiffener segment.
- iv. Bolt in place the new galvanised stiffener segment, installing new bolts.
- v. Seal any gaps at the interface between new and existing steel.
- vi. Prepare for and patch paint new and existing steel to the extent.

Case B – Corrosion near end of stiffeners

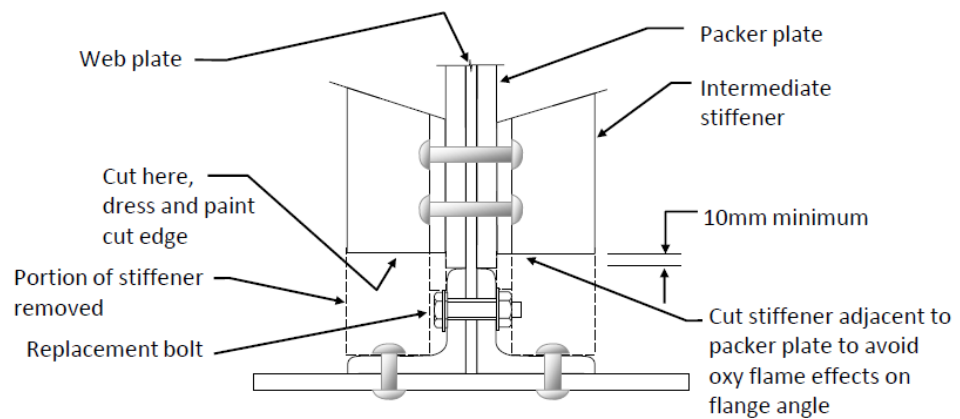
- i. Remove rivets connecting the part of web stiffener to be replaced.
- ii. Cut away the corroded portion of stiffener by flame cutting and by using an angle grinder. Avoid flame effects and grinding grooves in the web plate. Dress any flame cut edges.
- iii. Clean existing steelwork where new steel is to abut. Fill pitting and depressions so that there is no void between the web and the new stiffener segment.
- iv. Fit the prefabricated, galvanised replacement segment of stiffener. Fit only for "bracing connection" stiffeners, otherwise just remove.
- v. Mark and drill bolt holes in the web to match the holes in the splicing angle.
- vi. Fit the prefabricated galvanised splicing angle in accordance with details on these figures.
- vii. Seal any gaps at the interface between new and existing steel.
- viii. Prepare for and patch paint new and existing steel to the extent.



**Part Elevation
Typical riveted girder**



**Intermediate web stiffener
Arrangement A (splayed angle)**



**Intermediate web stiffener
Arrangement B (with packer plate)**

Figure 2 - 6 Relief of corrosion site at the base of intermediate web stiffeners

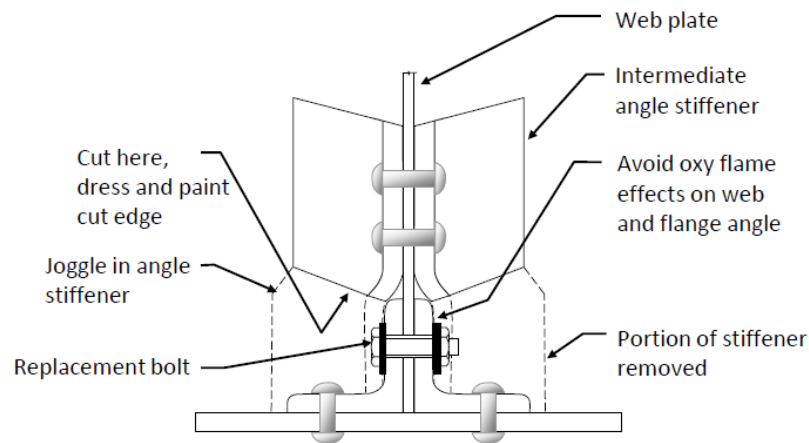


Figure 2 - 7 Relief of corrosion site at the base of intermediate web stiffeners

2.2.6.3 Repairing bearing web stiffeners with localised corrosion at base of outstand leg of stiffener

The procedure involves the following:

- i. Cut away the corroded portion of outstand leg of stiffener by flame cutting and by using an angle grinder. Avoid flame effects in the remaining leg of stiffener. Dress any flame cut edges.
- ii. Clamp new plate with holes drilled to outstand leg. New plate must bear hard on bottom flange.
- iii. Drill existing stiffener and grind smooth all burrs.
- iv. Bolt new plate to existing stiffener.
- v. Prepare for and patch paint new and existing steelwork.

2.2.6.4 Relieving of corrosion site at base of splayed angle bearing end stiffeners

The procedure involves the following:

- i. Remove the section of stiffener by oxy-fuel cutting. Avoid or minimise flame effects on the steel of the girder section.
- ii. Dress the flame cut steel edges by grinding. Clean the area at the base of the stiffener of dirt and debris by power wire brushing, grinding etc.
- iii. Prepare for and patch paint the area.

2.2.6.5 Relieving of corrosion at bottom flange bracing connection

The procedure involves the following:

- i. Install temporary braces as required to compensate for the braces that are to be disconnected.
- ii. Remove rivets as necessary and remove the gusset plate.
- iii. If structurally acceptable, modify members as detailed by flame cutting or with an angle grinder. Avoid flame effects and grinding grooves on the flange and web of main girder.

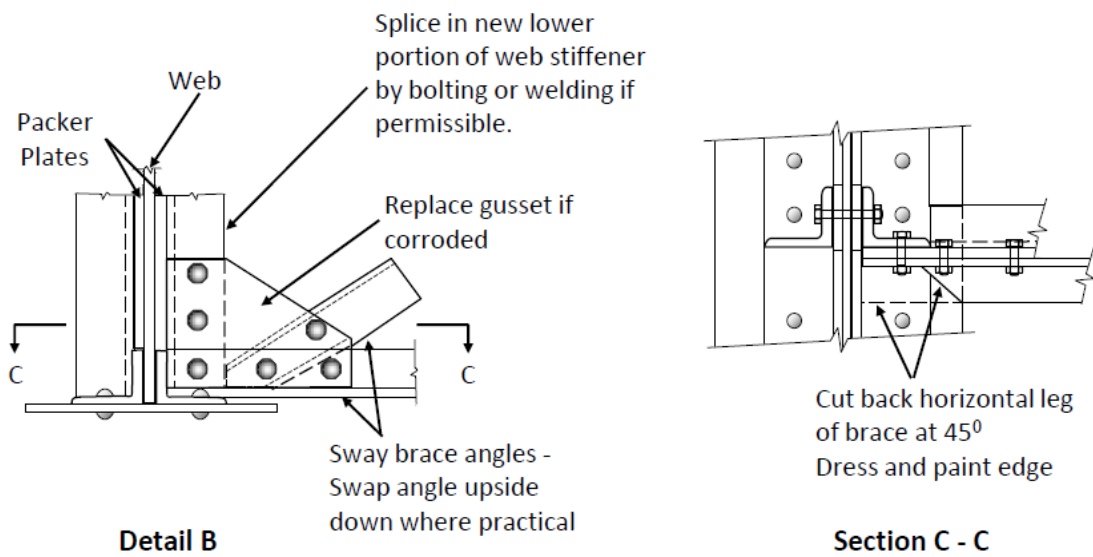
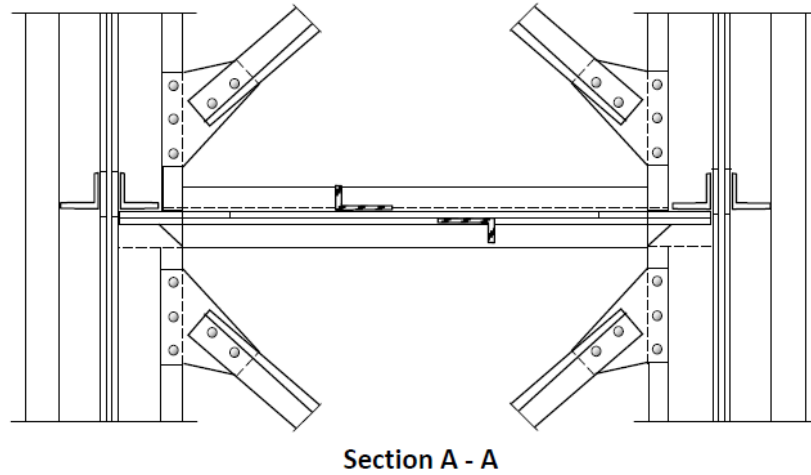
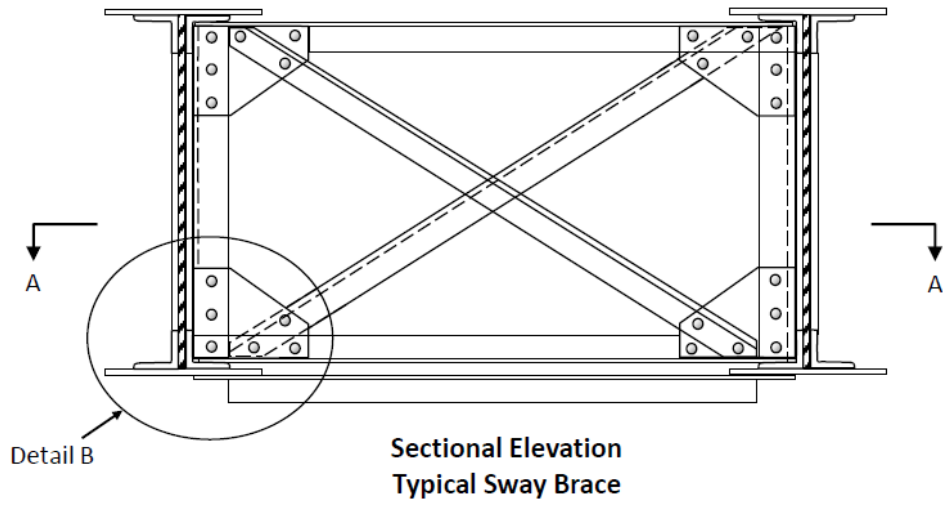


Figure 2 - 8 Repairing corrosion at bottom flange bracing connection

- iv. Completely remove the brace if necessary to avoid these effects. Dress any flame cut edges by grinding.
- v. Repair the web stiffener if required.
- vi. Clean all steel surfaces of loose rust and paint by scraping and power wire brushing.
- vii. Reassemble the connection with a new prefabricated galvanised gusset plate if required. In the process fill voids, including surface pitting. Install new bolts.
- viii. Prepare for and patch paint new and existing steel to the extent.

2.2.6.6 Replacing bearing plates

The procedure involves the following:

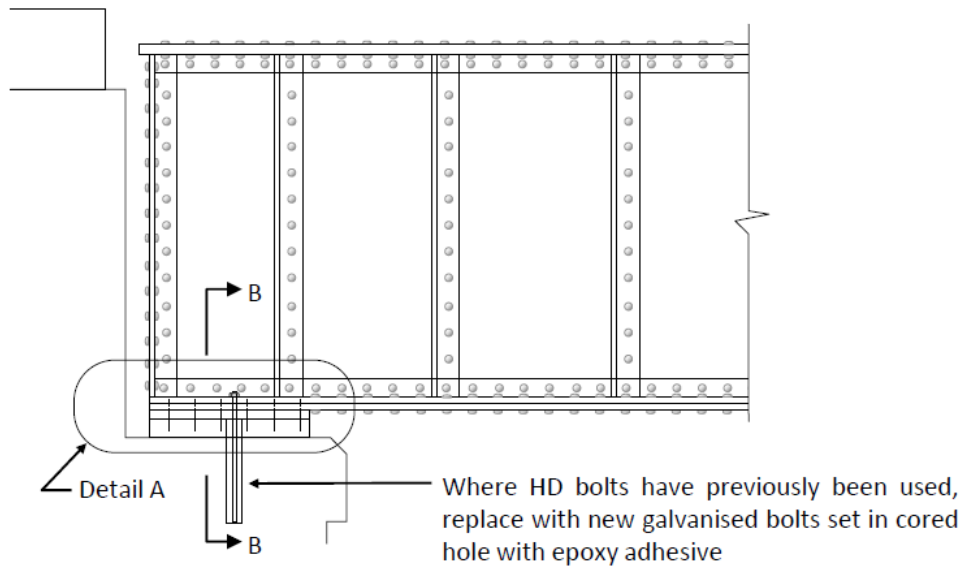
- i. Remove existing attachment bolts between girder and bed plate. If necessary drill out the bolt shank to a larger diameter and tap the hole in the bed plate to suit the new attachment bolt. Refer Figure 2 – 9. Alternative attachment arrangement 2 or 3 shown in Figures 2 - 10 and 2 - 11, could be adopted.
- ii. Raise the girder(s) by jacking the minimum amount required to enable completion of the replacement operation. Raise all girders at one end, simultaneously if necessary, to avoid overstressing cross-connecting members. Lock jacks or pack under the girders to prevent accidental dropping of the girders. If the bridge is to remain open to traffic, restrain the girders longitudinally by blocking against the abutments, unless they are suitably restrained at the remote end bearings.
- iii. Remove rivets connecting the bearing plates and remove the bearing plate.
- iv. Clean the bed plate and underside of the girder flange to remove loose rust, dirt etc. Use wire brushing if possible. Prepare the existing holes for new bolts by reaming, dressing etc.
- v. If the underside of the flange is severely corroded, pitted or uneven, apply an even coat of epoxy filler to the underside of the flange over the bearing plate contact area. Apply sufficient epoxy to fill any pitting voids on the underside of the flange.

Comment: Note that all Holding Down (HD) bolts for bearing plates should have a lock nut (or double nut). Sliding end of the bearing HD bolts should permit sufficient sliding to occur during normal operation of the structure.

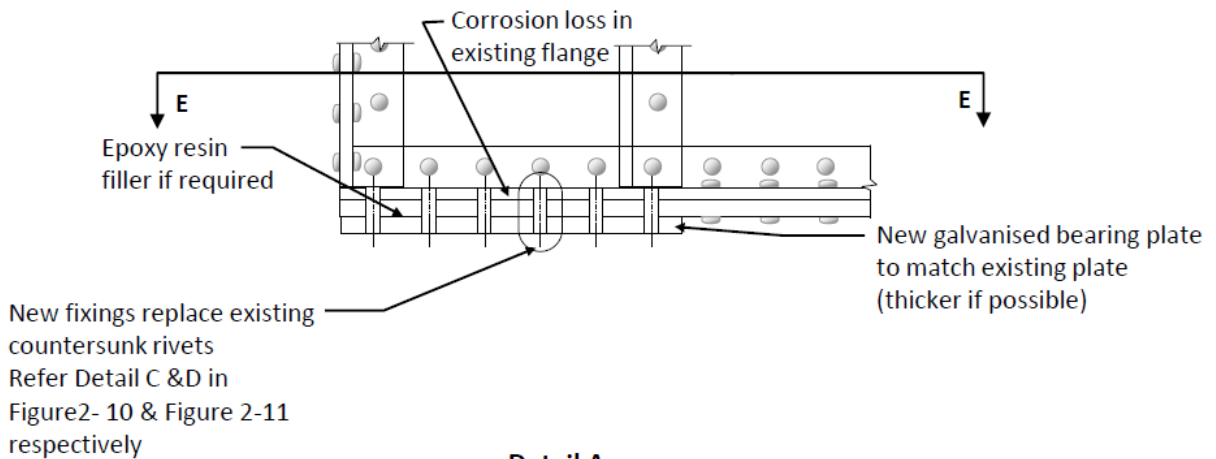
2.2.6.7 Repairing cracked and broken wind brace welded connections

The procedure involves the following:

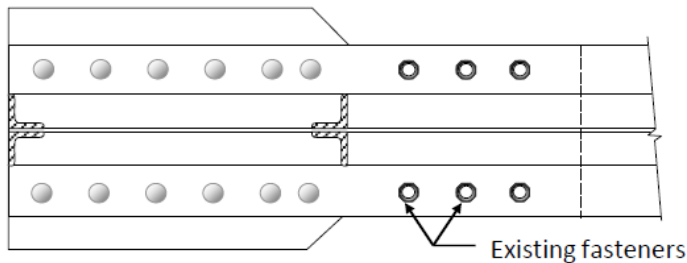
- i. Prepare new gusset plates.
- ii. Remove cracked/broken wind brace member by oxy-fuel cutting. Do not allow the cutting flame to damage the main girder flange. Leave cut area proud if necessary.
- iii. Grind smooth after removing brace member.
- iv. Mark flange for location of bolts.
- v. Drill flange and grind smooth all burrs.
- vi. Mark and drill new wind brace, grinding smooth all burrs.
- vii. Install new wind brace. Fill voids and pitting. Fit new bolts.
- viii. Prepare for and patch paint new and existing steel to the extent.



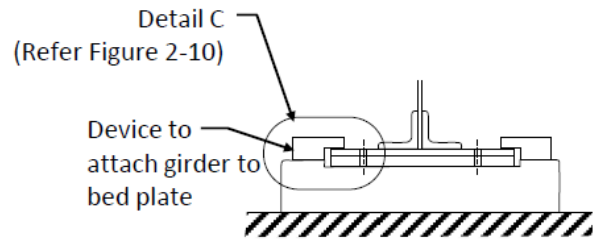
Part Elevation - end of typical riveted girder



Detail A



Section E-E



Section B-B

Figure 2 - 9 Repairs to bearing plates

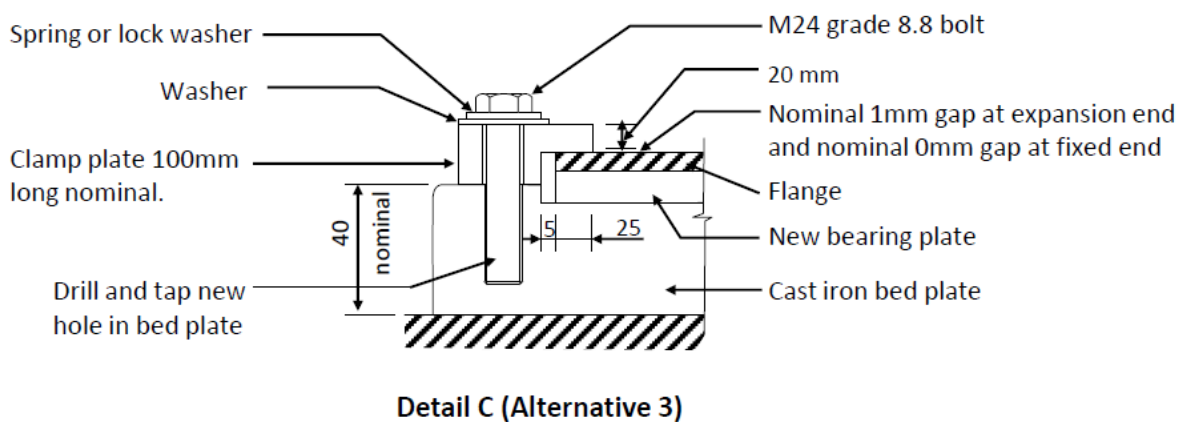
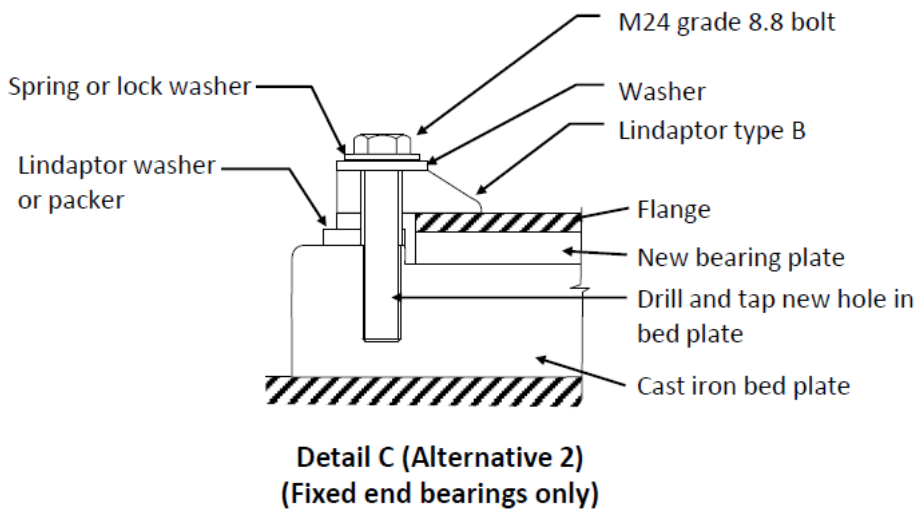
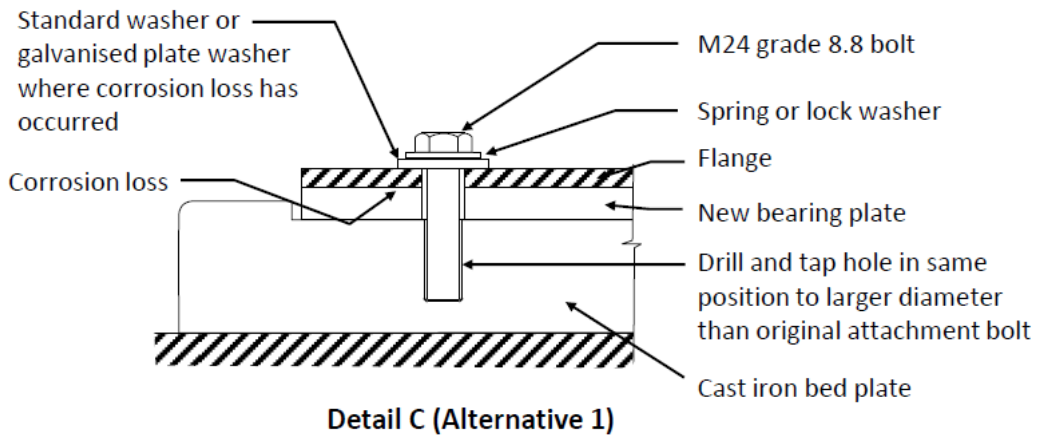


Figure 2 - 10 Repairs to bearing plates

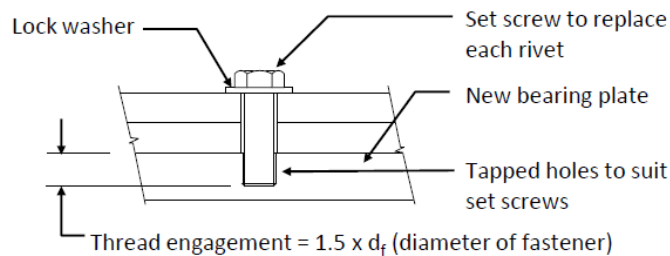
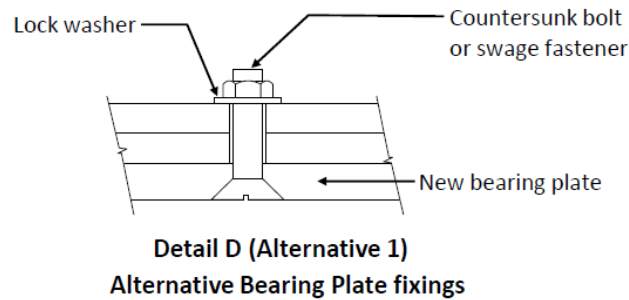


Figure 2 - 11 Repairs to bearing plates

2.2.7 Repairs to fatigue damage

2.2.7.1 Repair of fatigue cracks

The procedure for repairing fatigue cracks involves the following:

- i. Determine the position of the end of the fatigue crack by Magnetic Particle Inspection (MPI), close visual inspection or other suitable means.
- ii. Drill a hole of at least 20mm diameter to intercept the crack. Locate the centre of the hole at the observed crack tip. The preferred hole size is 25 to 26mm to fit an M24 Bolt.
- iii. Use MPI on the inside of the hole to confirm that there are no other cracks around the perimeter of the hole other than the entry crack, i.e. confirm that the tip of the crack has been drilled out.
- iv. Install and fully tension a high strength structural bolt in the hole until the crack is plated over. The bolt is to have standard washers under both head and nut.
- v. Fit new prefabricated, galvanised plate(s) in accordance with the design details. Install and fully tension all bolts including the bolt through the hole at the crack tip.
- vi. Prepare for and patch paint new steelwork and areas of existing steelwork to the extent.
- vii. The crack maybe welded subject to approval by a competent structures engineer.

2.2.7.2 Repair of fatigue cracks at connections

The procedure for repairing fatigue cracks at connections involves the following:

- i. Determine the position of the end of the fatigue crack by MPI, close visual inspection or other suitable means.
- ii. Drill a hole of at least 20mm diameter to intercept the crack. Locate the centre of the hole at the observed crack tip. The preferred hole size is 25 to 26mm to suit an M24 Bolt.
- iii. Drill other holes in the member to suit the brackets to be installed.
- iv. Temporarily support the end of the member under repair.
- v. Disconnect the end of the member by removing rivets etc. as required to fit the new brackets.
- vi. Fit new prefabricated, galvanised brackets in accordance with the design details. Install and fully tension all bolts including the bolt through the hole at the crack tip.
- vii. Prepare for and patch paint new steelwork and areas of existing steelwork to the extent.

Note: Section 2.2.7.3, 2.2.7.4, and 2.2.7.5 are extracts from JRC Scientific and Technical Reports on "Assessment of Existing Steel Structures: Recommendations for Estimation of Remaining Fatigue Life" published in 2008. [Ref.1]

2.2.7.3 Repair of fatigue cracks in welded structures

- i. Welded structures can have fatigue cracks starting from either the weld root or from the weld toe. Fatigue cracks starting from the weld root are much more difficult to identify. Concerning crack propagation, one has to differentiate between a continuously growing process, starting usually at the weld and propagating into secondary or main structural elements and fatigue cracks arresting in low stress areas to relieve the restraint condition. The latter one is in general not that serious compared to the first type of crack propagation.
- ii. The following list gives an overview of typical fatigue failure causes in welded structures:
 - (w-1) poor weld or weld defects (fabrication)
 - (w-2) lack of fusion (fabrication)
 - (w-3) cold cracks (environmental conditions)
 - (w-4) restraint (geometrical imperfection, distortion, out of plane bending)
 - (w-5) vibration (traffic, wind, earthquake – low cycle fatigue, lateral bracing)
 - (w-6) web gaps (e.g. gap between lateral gusset plate and transverse web stiffener)
 - (w-7) geometrical changes (end of cover plate, joints, stiffener, and diaphragms)
 - (w-8) web breathing (repeated web buckling deformation)
- iii. The following listing contains the most important repair and strengthening methods for welded structures:
 - (w-a) removal of crack by grinding
 - (w-b) re-welding
 - (w-c) surface treatments such as Tungsten Inert Gas (TIG) dressing, hammer peening or grinding
 - (w-d) adding plates or Fibre Reinforced Polymer (FRP) strips
 - (w-e) bolted splices using high strength tensioned bolts
 - (w-f) shape improving
 - (w-g) stop holes, for detailed information concerning the hole diameter refer Ref 2.
 - (w-h) modification of the connection detail
- iv. Table 2 – 6 proposes methods to repair fatigue cracks for causes given in this Section (See References 3 and 4).

Table 2 - 6 Repair and strengthening methods for fatigue failures in welded structures

		Repair and strengthening methods							
		grinding	re-welding	surface treatments	adding plates	bolted splices	shape improving	stop holes	Connection modification
Causes of fatigue cracks	weld defects	G	G	N	G	E	G	N	G
	lack of fusion	F	G	G	G	E	E	G	E
	cold cracks	F	G	G	F	E	G	G	E
	restraint	F	F	G	G	E	G	G	E
	vibration	F	F	G	G	F	G	F	E
	web gaps	G	F	G	F	N	N	F	E
	geometrical changes	F	F	F	G	E	N	F	G
	web breathing	N	F	F	F	F	N	G	E
		E: Excellent		G: Good		F: Fair		N: Not good	

2.2.7.4 Repair of fatigue cracks in riveted and bolted structures

- i. The magnitude of stress concentration and tensile stresses is dictated by the geometry of the detail and the fabrication process. Fatigue crack initiation may start from micro-cracks around the rivet hole, resulting from drilling, punching, or riveting process.
- ii. In bearing type connections both stress concentration and residual stresses are responsible for susceptibility to fatigue failure. The major reasons for fatigue cracking in riveted and bolted structures are:
 - (r-1) drilling, punching, or riveting process (micro-cracks due to punching or drilling of the holes or due to poor workmanship during riveting)
 - (r-2) change of geometry (cracks at the holes perpendicular to the main tension stress in net cross section, e.g. end of cover plates, gusset plates, etc.)
 - (r-3) change of geometry (cracks in the gross cross section, e.g. in the tension flange near the web stiffener)
 - (r-4) thin connection plates (too thin gusset plates or other structural members)
 - (r-5) out-of-plane bending, distortion, and restraints
 - (r-6) secondary stresses due to tension rods
 - (r-7) cut-outs, local stress concentration
 - (r-8) frozen or corroded bearings or joints (e.g. cracks from temperature differences or secondary stresses)
 - (r-9) poor structural detail with low fatigue strength and high loading
- iii. The following list contains the most common repair and strengthening methods for riveted and bolted structures. In each case a verification of the efficiency of the chosen method is recommended.

- (r-a) strengthening by means of pre-stressed bolts or injection bolts,
- (r-b) adding new structural members, e.g. filler plates, cover plates or angles
- (r-c) repair-welding (verification of weldability needed)
- (r-d) adding FRP strips
- (r-e) changing the static system
- (r-f) stop holes
- (r-g) repair of the bearing conditions

iv. Table 2 – 7 proposes repair methods in riveted structures in relation to the fatigue failure causes given in this Section.

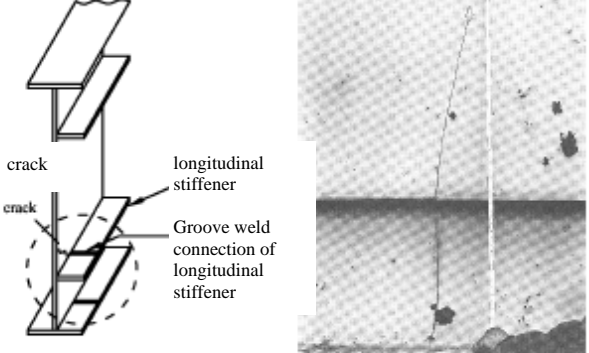
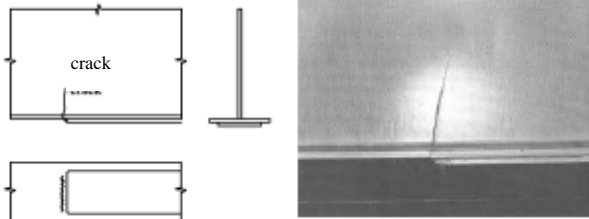
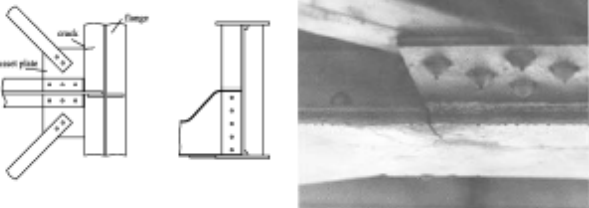
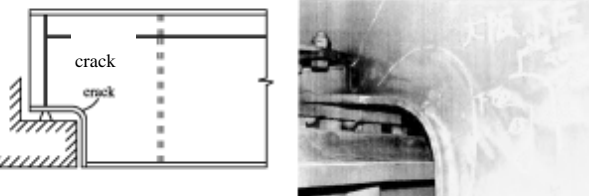
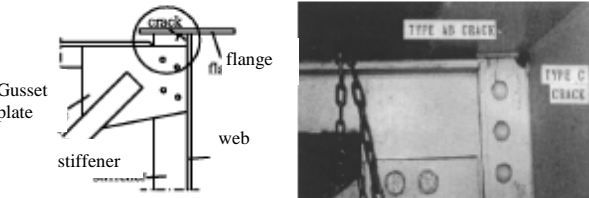
Table 2 - 7 Repair and strengthening methods for riveted and bolted structures

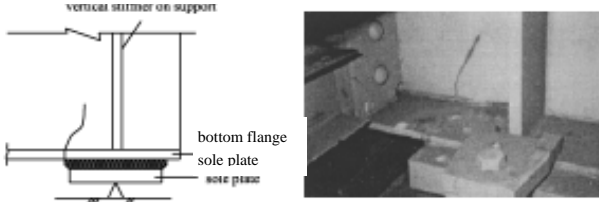

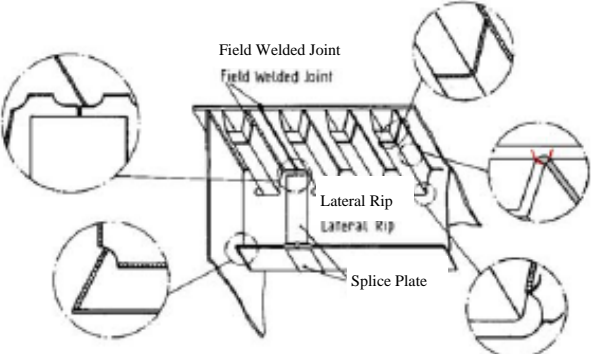
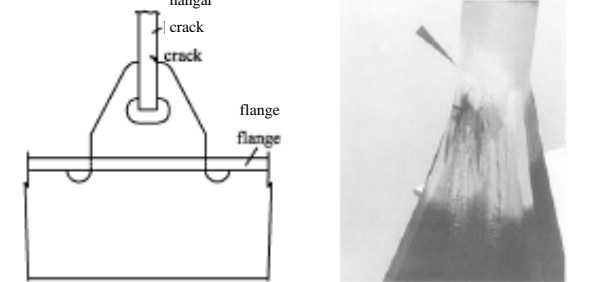
		Repair and strengthening methods						
		Pre-stressed bolts	Adding plates	Repair-welding	FRP strips	Changing static system	Stop holes	Repair bearing
Causes of fatigue cracks	riveting process	G	G	F/N	G	G	-	-
	cracks at holes	E	E	N	F	F	N	-
	cracks in gross cross section	N	E	N	G	F	N	-
	thin connection plates	E	N	N	F	F	N	-
	out of plane bending	N	N	N	G	F	E	-
	secondary stresses	N	N	N	G	-	G	E
	local stress concentration	-	-	-	-	-	F	-
	frozen joints	-	-	N	-	-	-	E
	poor detailing	F	G	-	G	G/F	-	-
E: Excellent		G: Good		F: Fair		N: Not good		- : Not applicable

2.2.7.5 Summary of common fatigue failure and repair/strengthening

Table 2 - 8 summarises the most common fatigue failures in existing welded steel structures together with repair and strengthening methods. See References 3, 4, 5, and 6.

In Table 2 - 8, notations in brackets are related to locations and causes of fatigue cracking mentioned in Section 2.2.7.3 (ii) and repair or strengthening methods mentioned in Section 2.2.7.3 (iii).

Fatigue failure	Repair	Strengthening
<p>Transverse groove welds Cracks in the butt connection groove weld of tension-side longitudinal stiffener or flanges (w1), (w2), (w3)</p> 	<ul style="list-style-type: none"> - adding filler plate or FRP (w-d) - splicing by using bolts (w-e) - re-welding and surface treatments if cracks are small and have not reached the web (w-b) and (w-c) 	<ul style="list-style-type: none"> - adding filler plate or FRP (w-d) - splicing by using bolts (w-e) - re-welding (w-b)
<p>Cover end plates Cracks at transverse front welds at cover plate end (w7), (w1)</p> 	<p>depending on the surface crack length:</p> <ul style="list-style-type: none"> - long cracks $L < 40\text{mm}$: stop holes (w-g) and splicing with bolts (w-e) - short cracks $L < 10\text{mm}$: surface treatments such as TIG (Tungsten Inert Gas) dressing or hammer peening (w-c) 	<ul style="list-style-type: none"> - improving the weld toe detail (w-f) - surface treatments such as grinding and/or peening (w-c) - adding filler plate or FRP (w-d) - shear splices using bolts or injection bolts (w-e)
<p>Gusset plates on flanges Cracks in welded gusset plate joint on flanges (w7), (w1)</p> 	<ul style="list-style-type: none"> - stop holes (w-g) - improving of weld toe detail (w-f) 	<ul style="list-style-type: none"> - improving of weld toe detail (w-f) - surface treatments (w-c)
<p>Coped end of deck plate girder Cracks at the coped end of deck plate girders (w7)</p> 	<ul style="list-style-type: none"> - stop holes (w-g) - full penetration welding (w-b) and surface treatment (w-c) - reinforcement by splice plates (w-e) 	<ul style="list-style-type: none"> - adding bolt connection with rib plates (w-e) - adding plates or FRP (w-d)
<p>Cross bracing connections Fatigue cracks at the cross bracing connection detail on the upper flange (w4), (w1)</p> 	<ul style="list-style-type: none"> - stop holes (w-g) - full penetration welding (w-b) and surface treatment (w-c) 	<ul style="list-style-type: none"> - improve the weld toe detail (w-f) - surface treatments such as grinding and/or peening (w-c) - use symmetrical connections (w-h)

Fatigue failure	Repair	Strengthening
<p>Sole plate connection Fatigue crack in sole plate connection detail at support (w4), (w7)</p> 	<ul style="list-style-type: none"> - adding plates or ribs to the web of the supported girder (w-d) - reinforcement by bolted splices (w-e) - stop holes (w-g) 	<ul style="list-style-type: none"> - adding plates or ribs to the web of the supported girder (w-d) - reinforcement by bolted splices (w-e) - modification of connection detail (w-h)
<p>Cut out web (mouse-hole) Fatigue crack in the web or flange, initiated at the fillet weld toe of the cut out web (w7)</p> 	<ul style="list-style-type: none"> - stop holes (w-g) when crack in the web - adding filler plate or FRP (w-d) 	<ul style="list-style-type: none"> - adding filler plate or FRP (w-d) - increasing the curvature ratios of the cut outs (w-f) - full penetration welding (w-b) and surface treatment (w-c)
<p>Orthotropic deck Orthotropic steel bridge deck, different details with low fatigue strength (w4), (w7), (w1), (w2)</p> 	<ul style="list-style-type: none"> - stop holes (w-g) - adding filler plate or FRP (w-d) 	<ul style="list-style-type: none"> - preventive stop holes (w-g) - strengthening deck plate by thicker steel deck or thicker pavement (w-h) - adding steel plate or FRP strips (w-d)
<p>Hanger and pinned connections Cracks induced by vibration, e.g. by wind or traffic (w4), (w5)</p> 	<ul style="list-style-type: none"> - re-welding of small cracks followed by surface treatments (w-b) and (w-c) 	<ul style="list-style-type: none"> - change of the static system or connection detail (w-h) - improvement of weld quality by surface treatment methods (w-c) - increase curvature ratios (w-f)

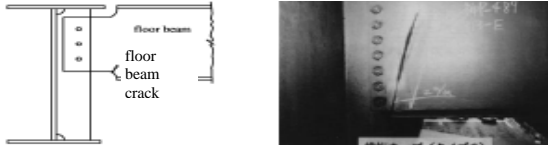
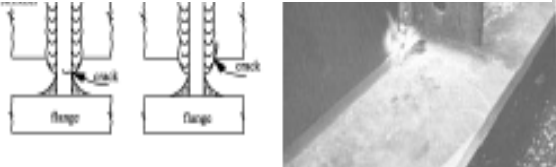
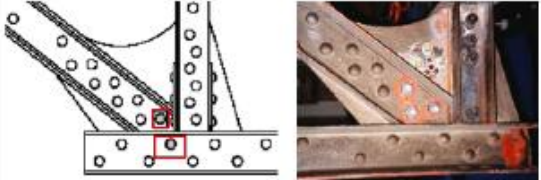



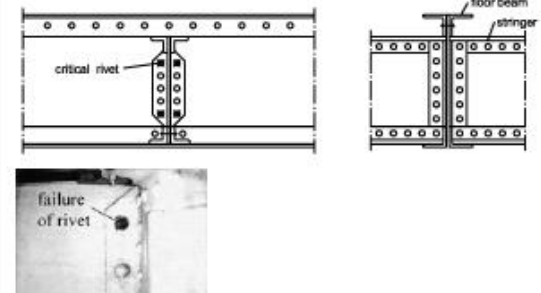
Fatigue failure	Repair	Strengthening
<p>Floor-beam bottom flange Fatigue cracks occurred in the coped web of the end floor-beam (w7)</p>  <p>The diagram shows a cross-section of a floor beam with a coped web. A crack is indicated in the bottom flange. The photograph shows a close-up of a similar crack in a steel beam.</p>	<ul style="list-style-type: none"> - stop holes (w-g) - gouging and re-welding (w-b) 	<ul style="list-style-type: none"> - adding filler plate (w-d) splicing by using HSS tensioned bolts (w-e)
<p>Transverse stiffener web gaps Cracks near the end of a vertical web stiffener (w6), (w1)</p>  <p>The diagram shows two cross-sections of a vertical web stiffener connected to a flange. Cracks are shown at the ends of the stiffeners. The photograph shows a close-up of a crack in a similar stiffener.</p>	<ul style="list-style-type: none"> - stop holes (w-g) - weld toe finishing by TIG-dressing or grinding (w-c) 	<ul style="list-style-type: none"> - prevention out-of-plane distortion of the girder - prevention out-of-plane distortion of the girder web (w-h) - increase flexibility of the connection (w-h)

Table 2 - 8 Typical fatigue failures of welded structures and recommended remedial measures

Table 2 - 8 presents a summary of typical fatigue failures of riveted and bolted structures together with repair and/or strengthening methods. See References 7, 8, and 9.

Notations in brackets are related to above mentioned locations and causes of fatigue cracks (Refer Section 2.2.7.4(ii)) and repair or strengthening methods (Refer Section 2.2.7.4(iii)).

Note that the existing riveted structures should not be welded without detailed verification of the weldability of the used old steel.

Typical fatigue failure	Repair	Strengthening
<p>Gusset plates Cracks in gusset plates due to insufficient thickness (r4)</p> 	<ul style="list-style-type: none"> - short cracks: HSS tensioned bolts (r-a) - long cracks: replace the gusset plate (r-b) 	<ul style="list-style-type: none"> - use bolts in the last 3-4 rivets of the connected truss members (r-a) - drilling of rivet holes to remove micro cracks, caused by riveting process
<p>Ballast sheets Cracks in barrel shaped ballast sheets (r5)</p> 	<ul style="list-style-type: none"> - stop holes as contemporary measure (r-f) - change of the static system by applying the load directly into the cross beams by means of stiff load transfer beams (r-e) 	<ul style="list-style-type: none"> - unload the barrel shaped ballast sheets without horizontal stiffeners by stiff load transfer beams (r-e)
<p>Cross beam –longitudinal beam connection Cracks in a connection between cross beam and longitudinal stringers (r5)</p> 	<ul style="list-style-type: none"> - reduce stiffness by drilling a large hole (r-e) - replace structural member (r-b) 	<ul style="list-style-type: none"> - reduce stiffness by drilling a large hole (r-e) - replace structural member (r-b)
<p>Bearings Cracks due to frozen bearings or joints, because of corrosion or temperature differences (r8) CORROSION OR TEMPERATURE DIFFERENCES (r8)</p> 	<ul style="list-style-type: none"> - stop holes (r-f) - replacement of the cracked member (r-b) - control of the bearings (r-g) 	<ul style="list-style-type: none"> - control corrosion protection (r-g) - control of moveability of bearings and joints (r-g)
<p>Stringer to floor-beam connection Fatigue failure of rivet heads due to local bending</p> 	<ul style="list-style-type: none"> - high strength bolts in the last connection of the connected member or angle of the stringer (r-a) 	<ul style="list-style-type: none"> - replace rivets by high strength bolts (r-a) - adding additional members (r-b) - change static system (r-e)

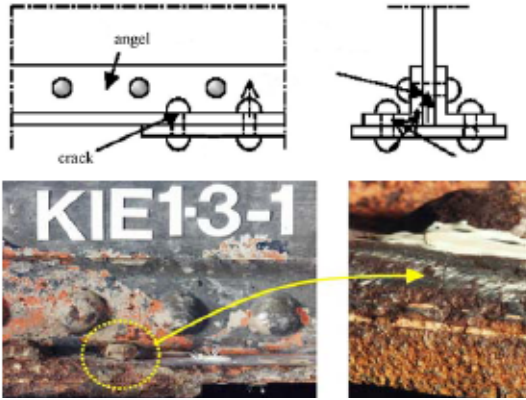
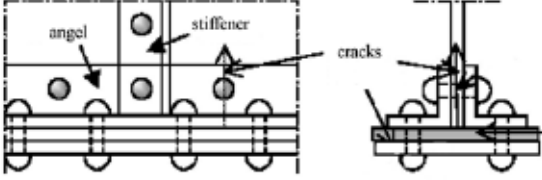
Typical fatigue failure	Repair	Strengthening
<p>Cover plate end Cracks initiating at the holes in net cross section at the end of cover plates due to overload and changes of geometry (r2)</p> 	<ul style="list-style-type: none"> - remove cracked member, add longer cover and filler plate in the tension flange with bolts (r-a) (r-b) 	<ul style="list-style-type: none"> - high strength bolts in the last connection of the upper cover plate (r-a) - adding filler plate and longer cover plate by bolts (r-b) - adding FRP or steel plates (r-d)
<p>Cover plate end Cracks in the flange of the net cross section due to changes of geometry (r3)</p> 	<ul style="list-style-type: none"> - remove cracked member, add longer cover and filler plate in the tension flange with bolts (r-b) 	<ul style="list-style-type: none"> - high strength bolts in the last connection of the upper cover plate (r-a) - adding filler plate and longer cover plate by bolts (r-b) - adding FRP or steel plates (r-d)

Table 2 - 9 Typical fatigue failures of riveted/bolted structures and recommended remedial measures

2.2.8 Repairs to impact damage

Repair solutions can be selected from the following range for impact damage. A combination of repair procedures may result in the best repair solution. Refer Table 2 - 10.

2.2.8.1 Flame straightening

This repair method does not significantly degrade steel properties, but is not generally effective where yielding has exceeded about 1%. It may be considered for the repair of all bent members with the following exceptions:

Do not flame straighten fracture-critical members unless the flame straightened area is fully supplemented by bolted cover plates.

Do not attempt to flame straighten excessively wrinkled plates or plate with excessive kinks. It is nearly impossible to flame straighten this type of damage.

2.2.8.2 Hot mechanical straightening

This is a process where heat is applied to all sides of a bent member, and while the member is still hot it is straightened by applying force. Agencies that use this method restrict the maximum temperature to 640°C. The results of this type of straightening are highly dependent on operator skill. Lack of skill (or care) is frequently indicated by waviness of edges (especially the convex side of the damage) and local indentations due to local hot yielding under jacking loads.

It is believed that flame straightening is a superior method and should be used in lieu of hot mechanical straightening for all primary tension members, where practical. Hot mechanical straightening may be used on primary compression members or secondary members provided the

operators have the skill to produce results that are free of wrinkles, cracks, bulges, and poor alignment.

2.2.8.3 Cold mechanical straightening

Cold mechanical straightening is a process where an accidentally bent member is straightened by applying force. No heat is used. It is believed that a bridge member can be cold straightened once without causing significant degradation, provided the plastic strain is limited to 5% nominal strain.

Cold mechanical straightening should not be applied to member areas that have cracks, nicks, or gouges, or to fracture-critical members. Cold mechanical straightening should not be applied to members with low Charpy impact values.

2.2.8.4 Welding

Welding may be used for several types of repair, including defect or crack repair, welding replacement segments into place, and adding straightening plates by welding. Poorly executed weld repairs in tensile areas can be very dangerous and in some instances may do more harm than good. Fracture-critical members should not be repaired by welding unless fully strengthened by additional bolted material.

The steels to be repaired should be weldable steels.

Do not weld members with low Charpy impact values unless plated in addition.

2.2.8.5 Bolting

Bolting may be used as a repair method or as a supplement to other repair methods. Replacement of a damaged element with a new piece of steel fastened with fully tensioned high-strength bolts is regarded as the safest method of repair. Replacing damaged riveted elements with bolted material may not be excessively difficult and should be considered. Fracture-critical members should be repaired by bolting or repaired by other methods and fully strengthened by adding new bolted material.

2.2.8.6 Partial replacement

In some instances damage will be so serious that partial replacement is necessary. This damage includes excessively wrinkled plates, excessive deformation and bends, tears in member elements, and large cracks.

Partial replacement will normally consists of removing the damaged area and replacement with either a welded insert or a bolted splice insert.

Welded inserts are not recommended for fracture-critical members. Partial replacement by bolting and welding is an acceptable method, provided the longitudinal web weld is located in a compression area.

Partial replacements can be used in conjunction with other repair methods, such as flame straightening. For example, a bent member with a crack could be flame straightened and the crack should be repaired by bolted cover plates.

2.2.8.7 Complete replacement

Complete replacement of a member is normally the most expensive method of repair. If a member is excessively damaged throughout its full length, replacement may be the only alternative. Other less difficult methods of repair should be carefully studied prior to selecting replacement.

Damage Assessment Factors	Repair Methods								
	Flame Straightening	Hot Mechanical Straightening	Cold Mechanical Straightening	Welding	Flame Straightening Supplemented by Bolting	Field Welding Supplemented by Bolting	Bolting	Partial Replacement	Full Replacement
Weldable Steel	✓	✓	✓	✓	✓	✓	✓	✓	✓
Non-Weldable Steel	✓	✓	✓	×	✓	×	✓	✓	✓
Low Charpy Impact Values	✓	×	×	×	✓	×	✓	✓	✓
Adequate Charpy Impact values	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fracture-Critical Member	×	×	×	×	✓	✓	✓	✓	✓
Primary Tension Member	✓	✓*	✓*	✓	✓	✓	✓	✓	✓
Secondary Members	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Compression Members	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tearing and Excessive Wrinkles	×	×	×	×	×	×	×	✓	✓
Primary Tension Member Curvature Strain Meets Guidelines	✓	✓*	✓*	✓	✓	✓	✓	✓	✓
Primary Tension Member Curvature Strain Does Not Meet Guidelines	×	×	×	×	✓	✓	×	✓	✓

Damage Assessment Factors	Repair Methods								
	Flame Straightening	Hot Mechanical Straightening	Cold Mechanical Straightening	Welding	Flame Straightening Supplemented by Bolting	Field Welding Supplemented by Bolting	Bolting	Partial Replacement	Full Replacement
Member Curvature Radius More than Recommended	Member will return to correct position when adjacent members or joints are straightened								
Cracks – Weldable Steel	✓	✗	✗	✓	✓	✓	✓	✓	✓
Non Weldable Steel	✗	✗	✗	✗	✓	✓	✓	✓	✓
Superficial Nicks and Gouges	Grind Defect Smoothly								
Nicks and Gouges Weldable Steel	✗	✗	✗	✓	✗	✗	✓	✓	✓

* Flame Straightening is recommended

Table 2 - 10 Selection of repair method for impact damage

2.2.9 Repairs to stepways and footway structures

2.2.9.1 Repairing steel risers and stringers in stepways

The procedure for repairing steel risers and stringers in stepways involves the following:

Note that stringers with severe corrosion to flanges should be replaced. Where severe corrosion is limited to the web, a web cover plate may be welded in lieu of complete replacement.

Risers with severe corrosion are to be replaced entirely with galvanised steel channels, site welded to stringers.

Case A – Stringers and risers to be replaced

(Only if cost evaluation shows that total stepway renewal is not the cost-effective solution).

- i. Remove precast treads and handrails etc.
- ii. Remove stringers and risers. Remove rivets securing stringers.
- iii. Install new stringers, fabricated to existing steelwork, except use the lower end support detail as shown in Figure 2 - 13. Use splice plates where required to connect stringer segments. Use high strength structural bolts in lieu of rivets.
- iv. Prepare new risers for installation by cutting and trimming flanges at the ends, all as detailed in Figure 2 - 12.
- v. Site weld the new risers to the stringers at positions and levels to suit the precast step units to be used.
- vi. Prepare for and patch paint at the riser connections and other areas of steel. Note the special preparation required for rough surfaces such as site fillet welds. Where galvanised surfaces are to be painted, use the appropriate paint system and surface preparation.
- vii. Refit precast treads and handrails using new galvanised or stainless steel bolts and fittings.

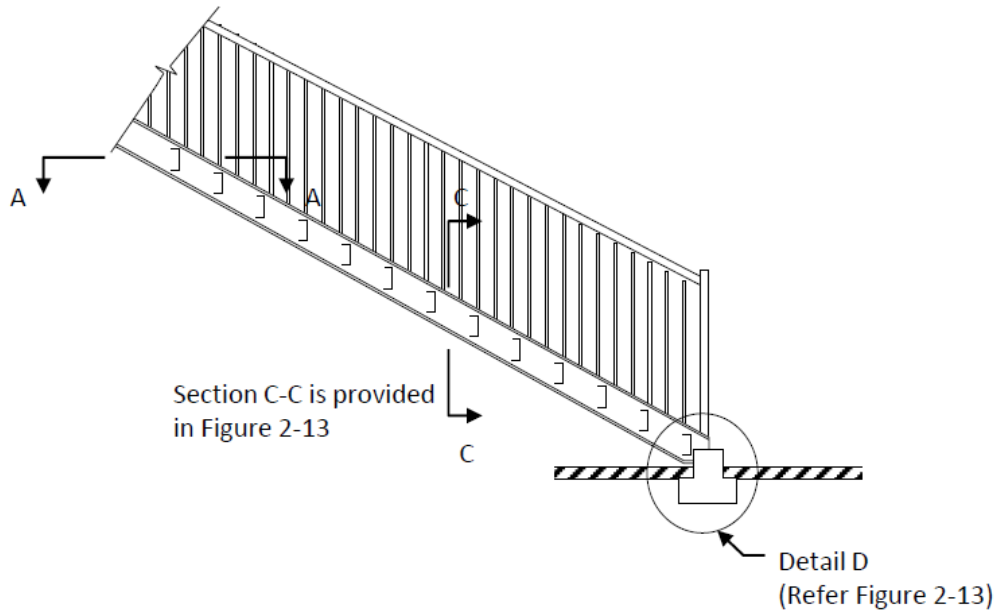
Case B – Risers only to be replaced

- i. Remove precast treads and handrails etc.
- ii. Remove risers to be replaced by oxy-fuel cutting adjacent to the attachment to the stringers. Do not allow the cutting flame to burn or otherwise affect the stringers that are to remain. Remove other attachments supporting risers.
- iii. Grind smooth the face of the stringer web and expose the base metal for welding.
- iv. Prepare new risers for installation by cutting and trimming flanges at the ends, all as detailed in Figure 2 - 12.
- v. Site-weld the new risers to the stringers at positions and levels to suit precast step units to be used.
- vi. Prepare for and patch paint at the riser connections and other areas of steel. Note the special preparation required for rough surfaces such as site fillet welds. Where galvanised surfaces are to be painted, use the appropriate paint system and surface preparation.
- vii. Refit precast treads and handrails using new galvanised or stainless steel bolts and fittings.

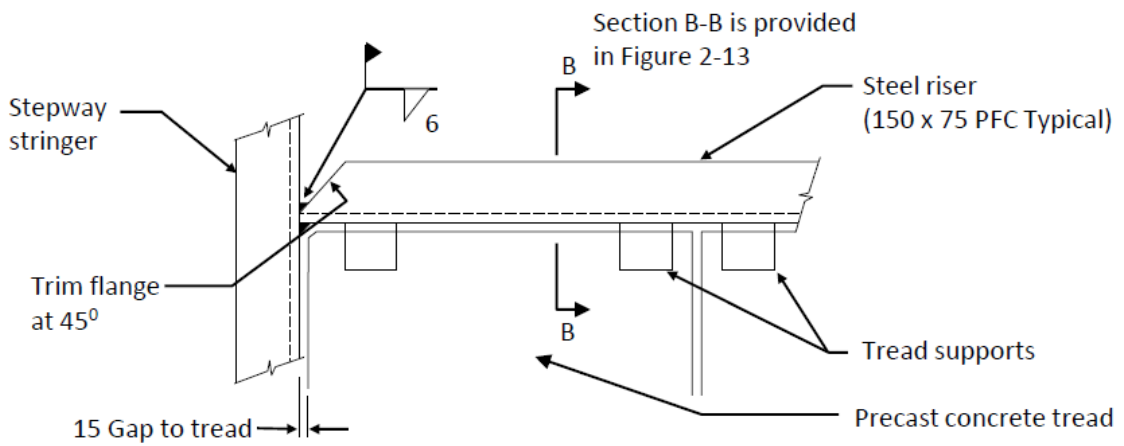
Case C - Risers to be replaced and stringer web to be plated

- i. Remove precast treads and handrails etc.
- ii. Remove risers to be replaced by oxy-fuel cutting adjacent to the attachment to the stringers. Do not allow the cutting flame to burn or otherwise affect the stringers that are to remain. Remove other attachments supporting the risers.
- iii. Grind smooth the inner face of the stringer web to remove any remaining steel from the cross member and any other protrusion that would interfere with the cover plate. Where rivets project through web, provide holes in the cover plate.

- iv. Remove all loose rust from the face of the web to be plated by mechanical wire brushing. Fill all areas of pitting and all depressions with epoxy filler to create a smooth even surface for mounting the cover plate.
- v. Fit prefabricated, galvanised 8mm web cover plates and fix to the stringers by site welding, all in accordance with the details in Figure 2 - 13.
- vi. Prepare new galvanised risers for installation by cutting and trimming flanges at the ends, all as detailed in Figure 2 - 12.
- vii. Site-weld the new risers to the stringers at positions and levels to suit precast step units to be used.
- viii. Prepare for and patch paint at the riser connections and other areas of steel. Note the special preparation required for rough surfaces such as site fillet welds. Where galvanised surfaces are to be painted, use the appropriate paint system and surface preparation.
- ix. Refit precast treads and handrails using new galvanised or stainless steel bolts and fittings.

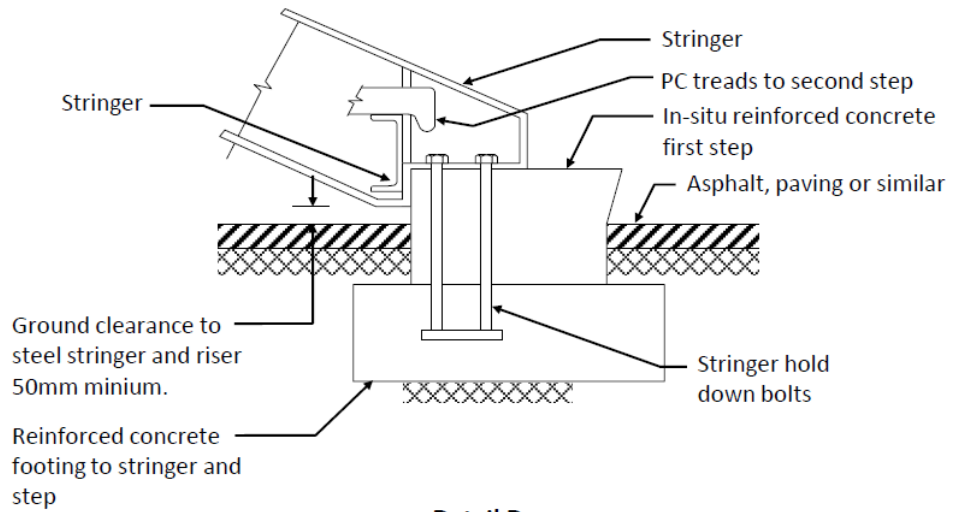


Typical longitudinal section through stepway
(Treads not shown)

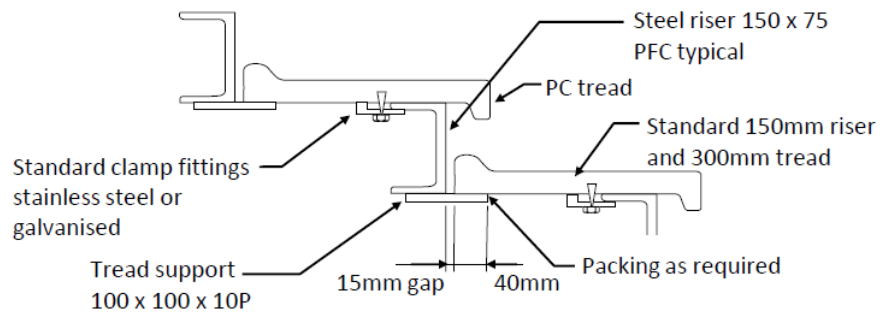


Plan Detail A - A
Riser connection to stringer

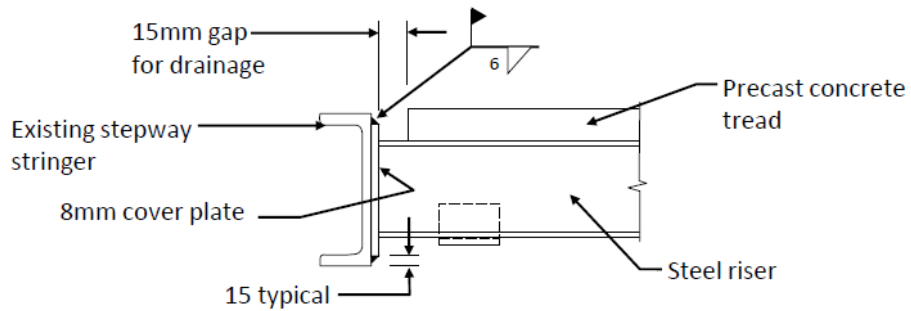
Figure 2 - 12 Repairing steel risers and stringers in stepways



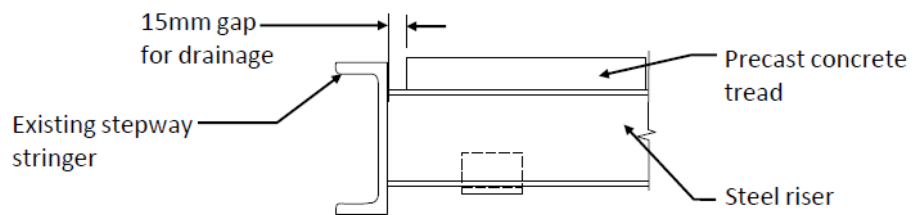
Detail D



Section B-B



Section C-C (where stringer web is plated)



Section C-C (without stringer plating)

Figure 2 - 13 Repairing steel risers and stringers in stepways

2.2.9.2 Repairing corroded angle columns (temporary support available)

The repair involves complete or partial replacement of the column with a galvanised Universal Column (UC) section that is less prone to corrosion damage. Concrete footings with significant damage are to be repaired or rebuilt in conjunction with this repair.

The procedure for repairing corroded angle columns involves the following:

- i. Install temporary supports to allow removal of the column.
- ii. Remove the rivets connecting bracing to the column then remove the column. If the concrete footing is to remain, cut a pocket at the base of the columns to permit oxy-fuel cutting of the steel 50mm below the concrete surface.
- iii. Repair the existing footing or build a new footing in reinforced concrete if required. Drill holes for hold-down bolts.
- iv. Install the new column and complete the base detail as shown in Figure 2 -14. Connect to structure or remainder of column above
- v. Trim bracing members to size and drill new holes for connection to the new bracing cleats.
- vi. Prepare for and patch paint new and existing steel.

2.2.9.3 Repairing corroded 4-angle columns (no temporary support)

The repair involves progressive replacement of each angle of the column, in part or in full. Only one angle is removed from the column at any time. The remaining angles support the dead load of the structure. Partial replacement involves splicing new, galvanised angle segments to the existing steelwork by bolting or, where permissible, welding.

The procedure for repairing corroded 4-angle columns without any temporary support involves the following:

- i. Cut a pocket in the concrete footing around the base of the column as shown in Figure 2 - 16. If welded splices are to be adopted, excavate sufficient depth to expose an uncorroded section of column.
- ii. Drill holes for HD bolts.
- iii. As each of the 4 angle segments is positioned, complete the base connection (HD bolt and base plate or welded splice) and the upper splice connection (bolted or welded). The bolts in the bolted splice connection will need to be removed and reinserted as described for bracing and packing bolts during the procedure.
- iv. Mortar is to be packed under each individual base plate before the next angle is removed to ensure adequate transfer of load.
- v. Fill voids at the heel of splice angles as they are installed. Refer to Section D-D of Figure 2 - 15.
- vi. Seal any open interfaces between individual base plates and at splice angles or at backing bars as required.
- vii. Apply epoxy filler between the angles at the base, profiled as shown in Figure 2 - 17 to promote free drainage of water from column base.
- viii. Prepare for and paint new steelwork and areas of existing steelwork.

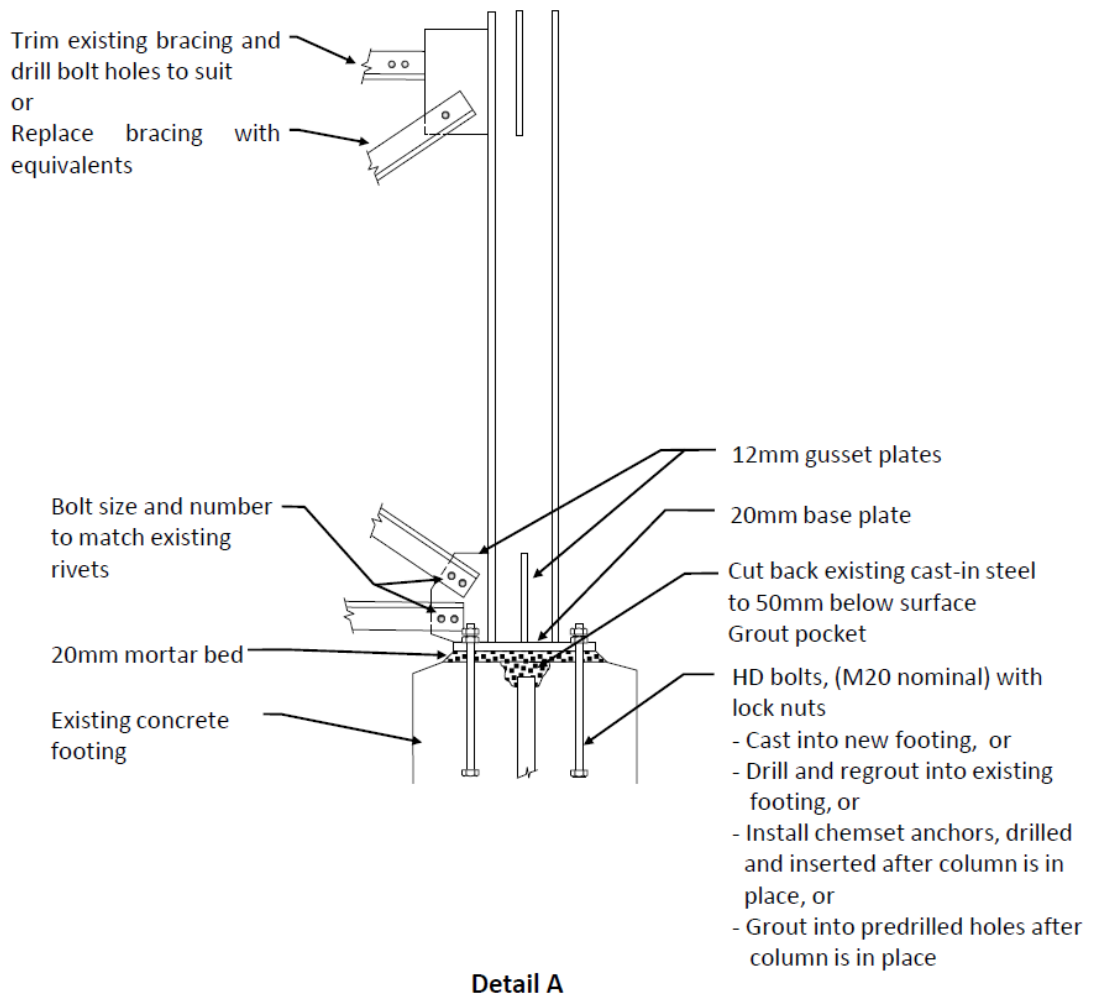
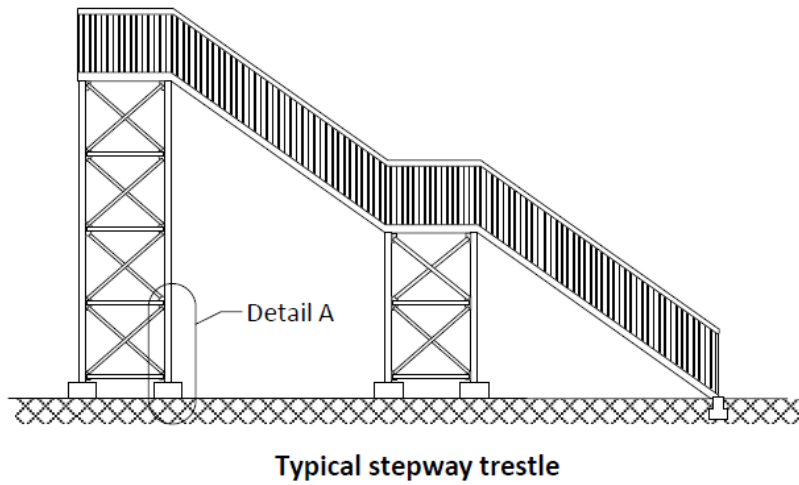
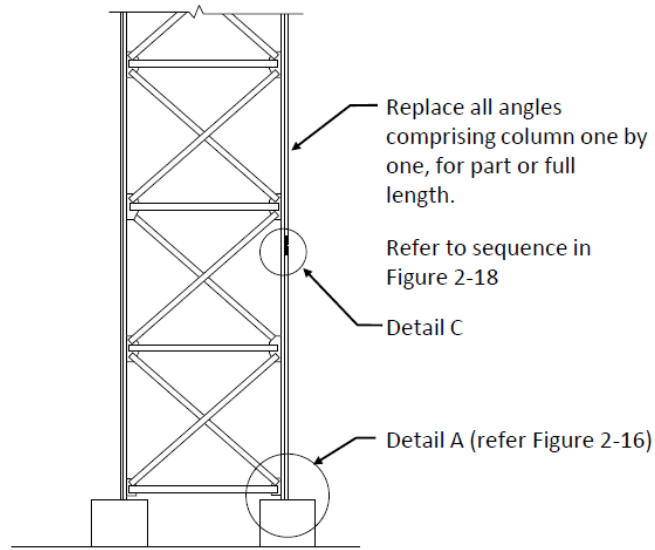
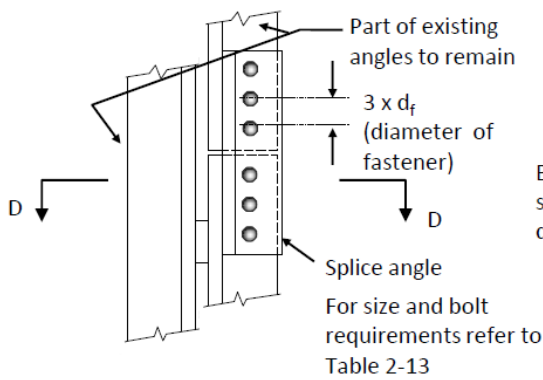


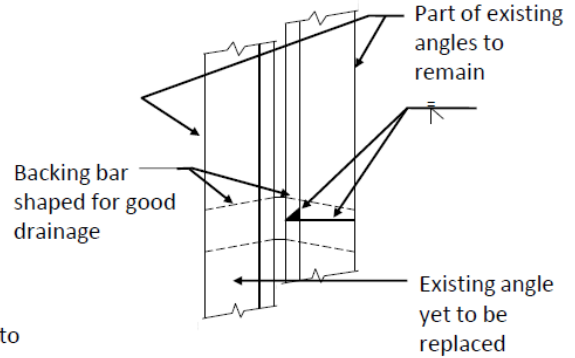
Figure 2 - 14 Repairing corroded angle columns (temporary support available)



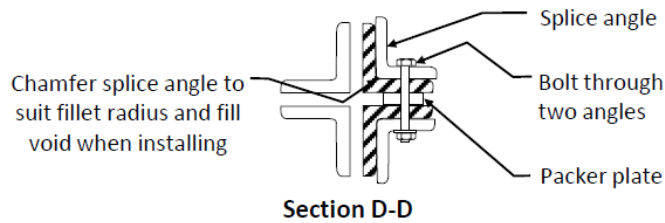
Elevation - Typical trestle with 4-angle column



Detail C - Bolted splice detail

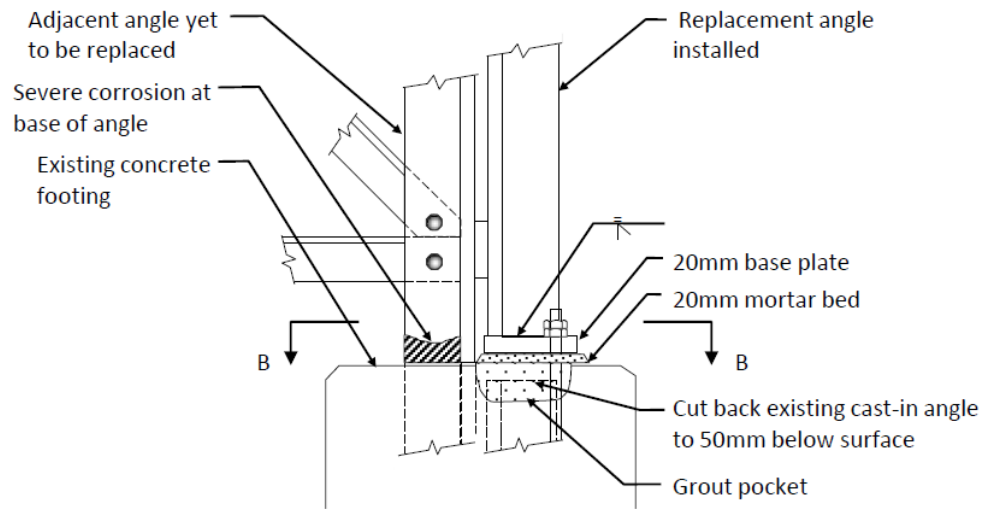


Alternative Detail C - for welded splices

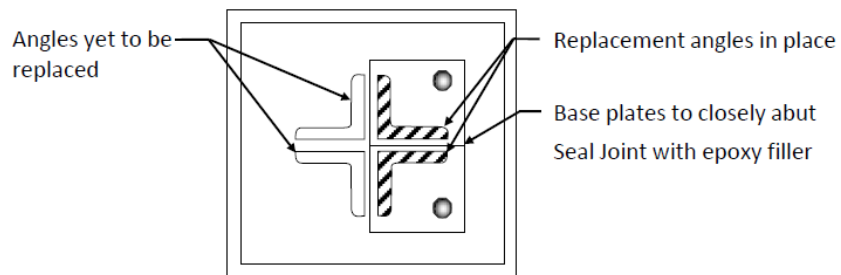


Section D-D

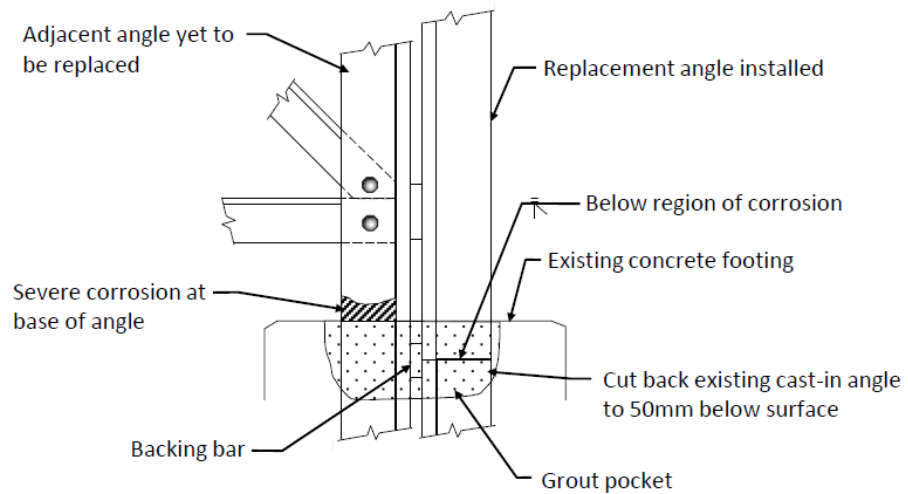
Figure 2 - 15 Repairing corroded 4-angle columns (no temporary support available)



Detail A - Column Base detail



Section B-B



**Alternative Detail A
For welded splices (if steels are weldable)**

Figure 2 - 16 Repairing corroded 4-angle columns (no temporary support available)

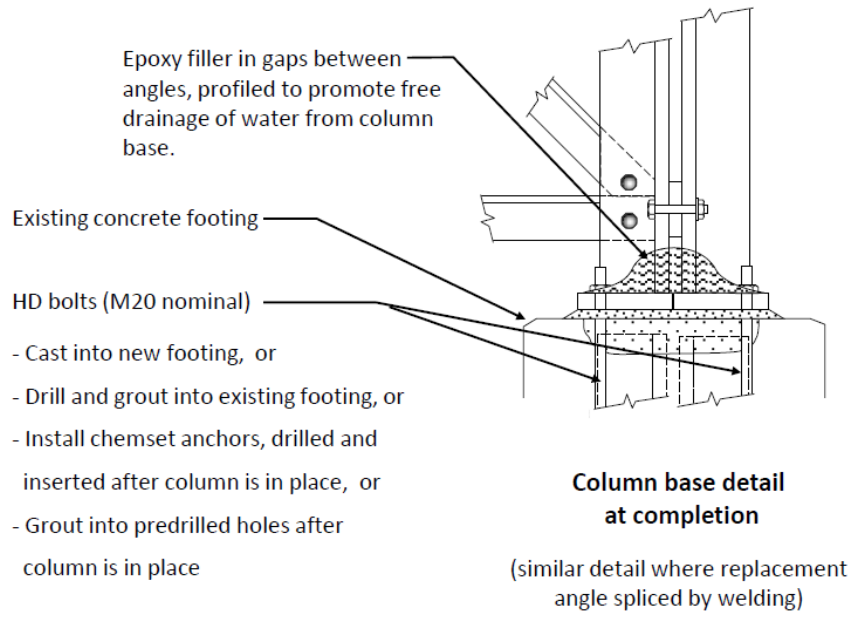
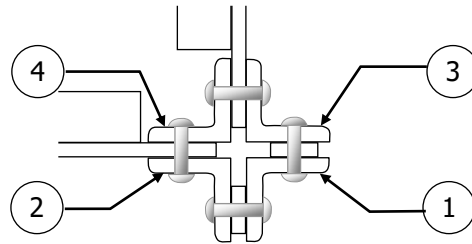
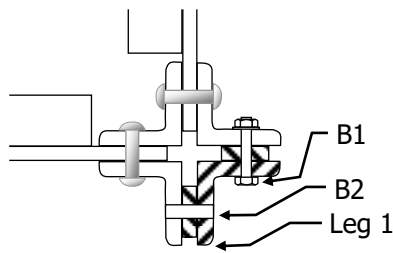


Figure 2 - 17 Repairing corroded 4-angle columns (no temporary support available)

Order of replacement

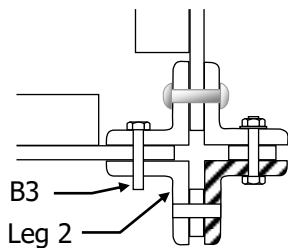


1 Replace outer free leg first

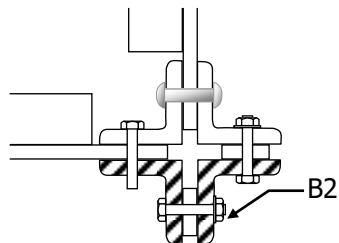


- (a) Remove rivets from positions B1 and B2
- (b) Remove Leg 1 and pack plates
- (c) Install galvanised replacement leg and packs, fitting bolts at position B1 only - fit nuts snug tight only.

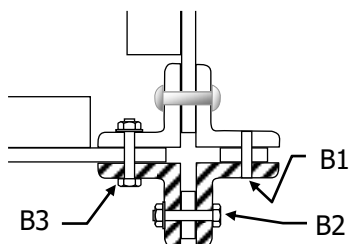
2 Replace Leg 2



- (a) One by one remove rivets at position B3 and immediately replace with bolt as shown. Do not fit nuts.

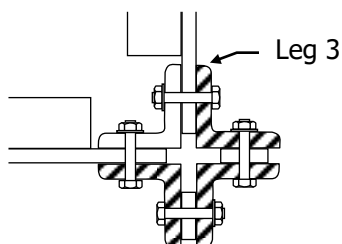


- (b) After all rivets have been replaced remove Leg 2, sliding off bolt shanks. Fit replacement Leg 2 and install bolts at position B2



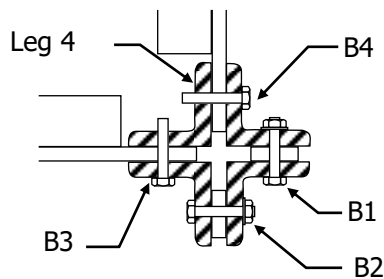
- (c) One by one remove bolts at position B3 and insert from other side and fit nuts (snug tight). After all bolts have been reversed, remove bolts from position B1.

3 Replace Leg 3 using the same procedure as for Leg 2.



4

Replace Leg 4.



- (a) Remove nuts at positions B3 and B4.
- (b) Remove Leg 4, oxy cutting as required to allow legs to slide off bolt shanks. Alternatively bolts may be retracted at one position at a time only sufficient to allow removal of leg (extreme care is required).
- (c) Install galvanised replacement Leg 4 and complete all bolted connections.
- (d) Tension all bolts

Figure 2 - 18 Illustrations to show repairing angles one by one

2.2.10 Complete replacement of members

The procedure for replacing members or elements of riveted members involves the following:

- i. Determine the size, shape and layout dimension for bolt holes by careful measurement on site.
- ii. Fabricate and galvanise the replacement member or elements.
- iii. Fit any temporary bracing or support members required.
- iv. Unbolt connecting bolts or remove connecting rivets. Remove the member or component.
- v. Prepare the area of interface to the new member or element by cleaning, grinding and painting if required.
- vi. Fit the new member or element and complete the bolted connections.
- vii. Prepare for and patch paint new and existing steelwork to the extent.

2.3 References

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3 Reinforced Concrete

3.1 General

This section presents methods for repairing common types of defects and damage to concrete elements in any structure. Techniques that require special equipment and expertise such as cathodic protection, chloride removal, and re-alkalisation have been excluded.

The repair methods presented in this section are for minor and routine nature of repairs for reinforced concrete deterioration. Any significant deterioration that affects the structure capacity and integrity should not be treated with these repair methods. These require engineering investigation prior to deciding on repair or reconstruction methods in achieving desirable strength.

Repair materials that are given as examples can be replaced with any approved equivalent material with similar material properties.

3.2 Repair of Cracks

There are various types of cracks, however for the purposes of repair they can be classified into two categories:

- i. Dead cracks that are inactive and do not move or propagate
- ii. Live cracks that are subject to movement and propagation due to applied loads and temperature changes.

Dead cracks can be repaired by the methods described in Section 3.2.1 to 3.2.7. Live cracks that are not yet likely to cause any defects in structures' integrity can be repaired by a flexible sealant described in Section 3.2.8.

The purpose of sealing is to prevent water from reaching the reinforcing steel, accelerated weathering of concrete, development of hydrostatic pressure within the crack, staining of concrete surface and causing moisture problems on the far side of the crack.

3.2.1 Epoxy injection

Epoxy injection can be applied to cracks of width between 0.05mm and 5mm. Cracks wider than 5mm generally require grouting, which is described in Section 3.2.2.

The procedure of epoxy injection involves the following:

- i. Clean and remove any contamination such as oil, grease, dirt, and fine particle of concrete from the cracks with water under high pressure or some special effective solvent. Blow out the residual water or solvent in the crack with filtered compressed air free of dust and oil or allow adequate time for air drying.
- ii. Seal cracks at the surface to keep the epoxy from leaking out before it has hardened. The surface can be sealed by brushing an epoxy on the surface of the crack and allowing it to harden. If extremely high injection pressures are needed, cut a 12mm deep x 20mm wide V-groove along the crack, fill with an epoxy and strike off flush with the surface.
- iii. Drill holes into the crack for fitting pipe nipple entry ports for epoxy injection. Spacing of ports varies between 150mm to 500mm generally depending on the width and depth of cracks.
- iv. Mix the epoxy as per manufacturer's instructions.
- v. Inject the epoxy with hydraulic pumps, paint pressure pots or air-activated caulking guns using the appropriate injection pressure for the application.
- vi. After the crack has been sealed, remove the projecting entry ports and fill holes with an epoxy patching compound. If required, remove or even out the surface seals by grinding in order to restore the appearance of the structure. Apply surface coating if it is part of the repair process.

Following are some useful notes to consider for the injection of epoxy:

- If the crack is vertical, commence the injection of epoxy at the lowest entry port until the epoxy exudes from the next port above. Cap the lower port and repeat the process at successfully higher ports till the crack has been completely filled and all ports have been capped.
- For horizontal cracks, carry out the injection from one end of the crack to the other in the same manner. The crack is full only if the pressure can be maintained. If the pressure cannot be maintained, the epoxy is still flowing into the crack or leaking out from somewhere.

Some of the approved epoxy products include the following:

- EPIREZ[®] 123
- Nitofill LV (Fosroc)
- Sikadur[®] – 52.

3.2.2 Grouting

Wide cracks that are inactive may be repaired by filling with Portland cement grout. Grout mixture may contain cement and water or cement plus sand and water depending on the width of the crack. Other admixtures or polymers may be used to improve the properties of the grout, such as bond. The water-cement ratio should be kept as low as practical to maximise strength and minimise shrinkage. Another product that can be used is Sikadur – 53 epoxy grout.

The procedure of grout injection involves the following:

- i. If the crack is contaminated with oil or grease, remove the contamination with detergents. If oil and grease have penetrated into concrete, remove the affected concrete and repair by replacing with fresh concrete.
- ii. Flush out all dust and debris from the crack with high pressure water jets.
- iii. Install grout nipples at intervals along the crack.
- iv. Seal the crack between the nipples with a sealant.
- v. Flush the crack to clean it and test the seal.
- vi. Grout the crack until it is completely filled. Maintain the grout pressure for several minutes to ensure good penetration.
- vii. Remove the nipples and fill holes with cement mortar.

3.2.3 Routing and sealing

Routing and sealing is used for repairing dead cracks that are of no structural significance. The method involves enlarging the crack along its exposed face and filling it with a suitable joint sealant.

This is the simplest and most common technique for crack repair and can be executed with relatively untrained labour. It is suitable for both fine pattern cracks and larger isolated defects, but will not be effective on active cracks and cracks subject to a pronounced hydrostatic pressure.

The sealant material is often an epoxy compound. There are many commercial products available in the market. Thus, the type and grade of sealant most suitable for the specific purpose and conditions of exposure should be selected.

Some of the commercially available materials that can be used for sealing are Sikadur – 31 or Sikadur – 33.

The procedure of routing and sealing involves the following:

- i. Prepare a minimum 6mm wide x 6mm deep V-groove at the surface along the crack using a concrete saw, hand tools or pneumatic tools. (Refer air jet. Allow to dry completely before).
- ii. Clean the groove with an oil free air jet. Allow to dry completely before placing the sealant.
- iii. Apply the sealant as per manufacturer's instructions.

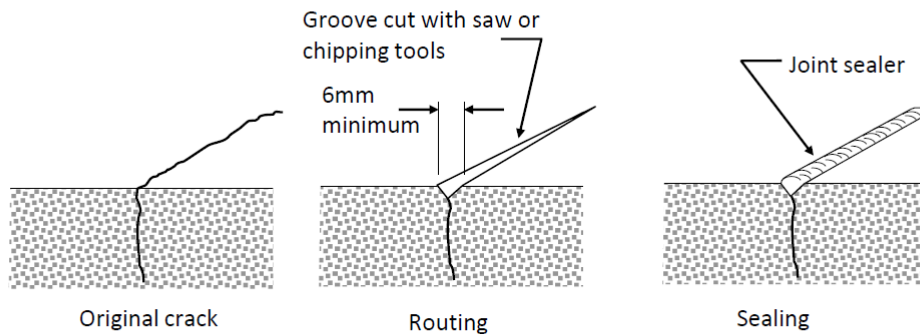


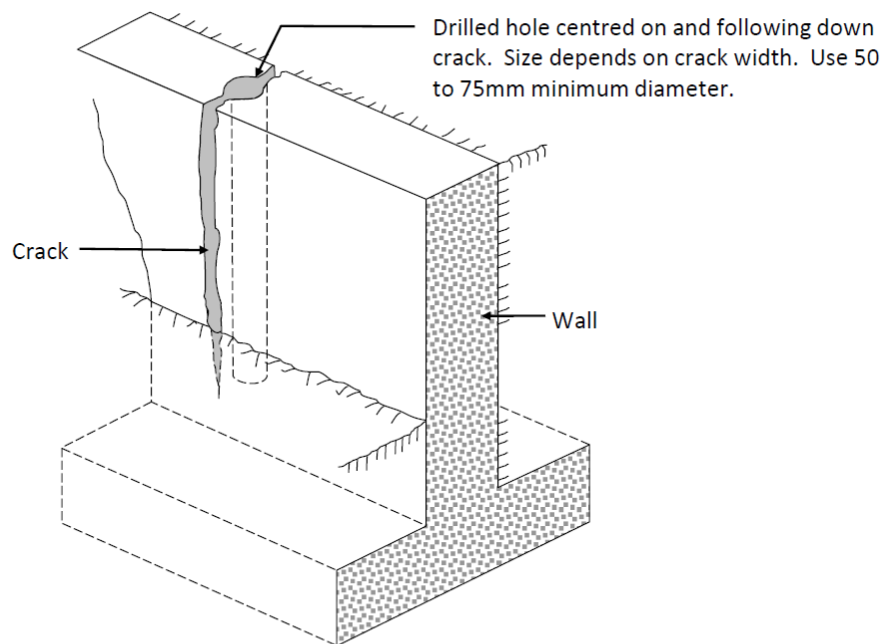
Figure 3 - 1 Routing and sealing

3.2.4 Drilling and plugging

This method is suitable for repairing vertical retaining walls and consists of drilling a hole down the length of the crack and grouting it to form a key. (Refer Figure 3 - 2). The crack must run reasonably straight and the hole must be large enough to intersect the crack along its full length and provide enough section of shear key to structurally take the loads exerted on it. The grout key prevents transverse movement of the sections of concrete wall adjacent to the crack. It will also reduce heavy leakage through the crack and loss of soil from behind the wall.

The grout is made up of cement and sand (1:3) and water. The water-cement ratio should be kept as low as practical to maximise strength and minimise shrinkage. Other admixtures or polymers may be added to improve the properties of the grout.

If water tightness is also required in addition to the structural load transfer, a second hole should be drilled and filled with a resilient material of low modulus, the first hole being grouted. Commercially available resilient products include Sikaflex – PRO, Sikaflex CONSTRUCTION, and Vandex Plug.



Drilling and plugging is a repair method well suited to vertical cracks in retaining walls. The repair material becomes a structural key to resist loads and prevent leakage through the crack.

Figure 3 - 2 Drilling and plugging

The procedure of drilling and plugging involves the following:

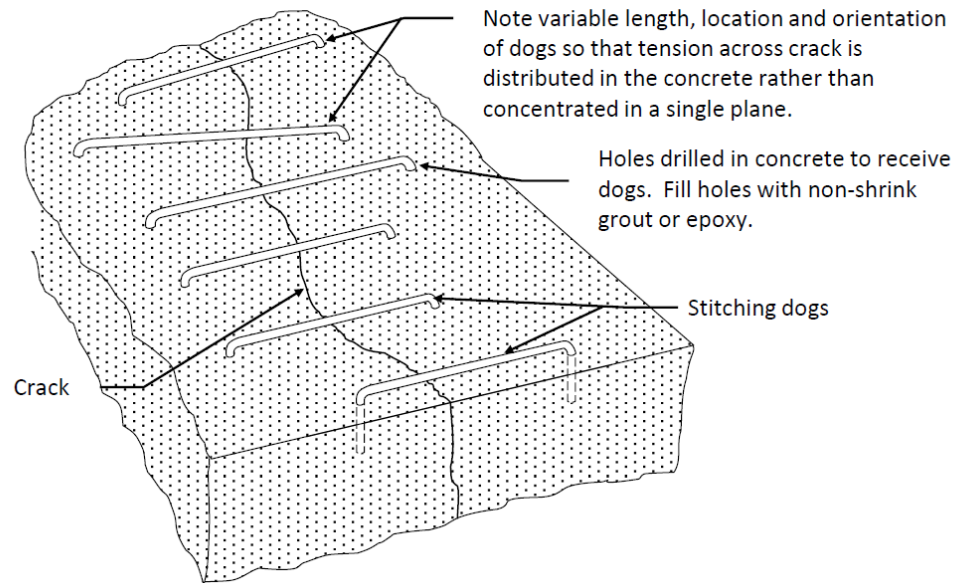
- i. Drill a 50mm to 75mm diameter hole centred on and following the crack.
- ii. Flush the hole and crack with high pressure water jet to remove dust and debris. (Caution: Restrict flushing to the minimum so that backfill soil is not washed into the crack). Allow the crack to damp dry.
- iii. Seal the crack tight on the exposed face. Allow the seal to cure and harden.
- iv. Fill the hole and crack with grout.

3.2.5 Stitching

This method involves drilling holes on both sides of the crack and grouting in stitching dogs (U-shaped metal units with short legs) that span across the crack. (Refer Figure 3 - 3).

Where possible, stitching should be done on both sides of a concrete section so that further movement of the structure would not pry or bend the dogs. This is particularly so in tension members where the dogs must be placed symmetrically. In bending members however the cracks may be stitched on the tension face only.

Stitching will not close a crack but can prevent it from propagating further. If it is required to seal the crack, the sealing should be completed before stitching begins.



Crack repair by stitching restores tensile strength across major cracks. Where there is a water problem, the crack should be made watertight first to protect the stitching dogs from corrosion.

Figure 3 - 3 Repair of crack by stitching

The procedure of stitching involves the following:

- i. If it is required, seal the crack by epoxy injection, grouting, or routing and sealing.
- ii. The stitching dogs should be galvanised steel or stainless steel with minimum 16mm diameter bars.
- iii. The stitching dogs should be variable in length and orientation so that the tension across the crack is not transmitted to a single plane but well distributed in the concrete.
- iv. Drill holes on both sides of the crack accordingly to suit the size and location of the stitching dogs. Spacing of the dogs should be reduced at each end of the crack.
- v. Clean the holes of all dust and debris.
- vi. Anchor legs of the dogs in holes with a non-shrink grout or epoxy resin-based grout system.
- vii. Apply a protective coating on top of the repair covering all stitching dogs. Commercially available protective coating includes Sika Ferrogard 903.

3.2.6 Adding reinforcement

When cracks impair the strength of a concrete structure, the structure can be strengthened by addition of conventional or prestressed reinforcement. The method of fixing such reinforcement will depend on a particular structure, type, and location of the cracks. The damage must be examined and reinforcement designed by a Structural Engineer to resist the forces causing the cracks. (Refer Figure 3 - 4).

Cracked structures may be repaired by epoxy injection and reinforcing bar insertion across the cracks.

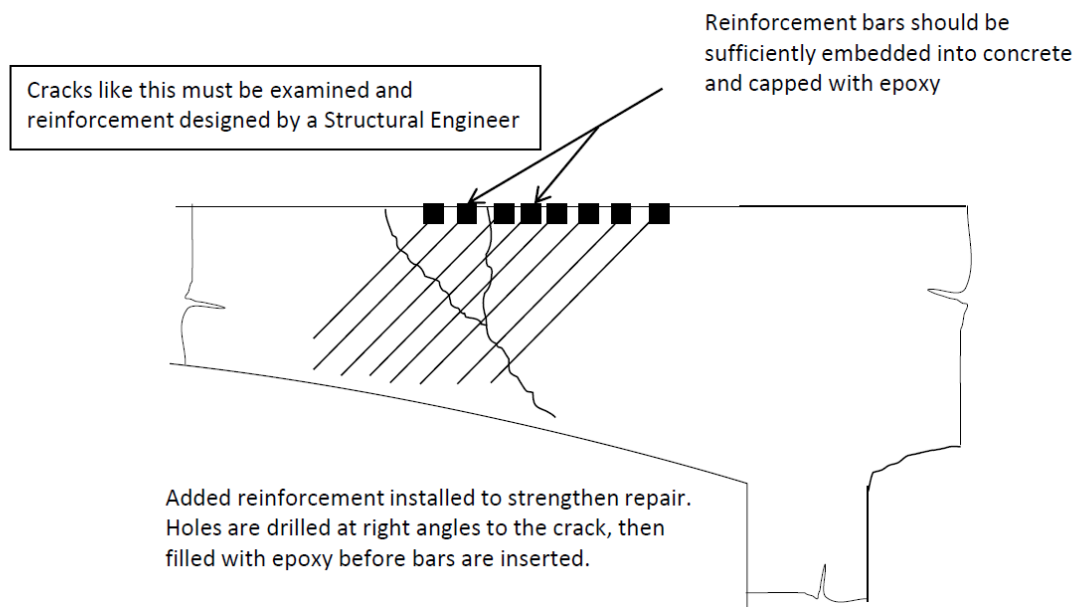


Figure 3 - 4 Adding reinforcement for strengthening

The procedure of adding reinforcement involves the following:

- i. Clean the cracks of dust, debris and contamination. Allow the cracks to dry.
- ii. Seal the cracks at exposed surfaces with an epoxy sealant approximately 3mm thick and 40mm wide. Allow one or two vent holes at the top for escape of air during epoxy injection.
- iii. Drill holes at 45° to the concrete surface and crossing the crack plane at approximately 90°. Use vacuum bits and chucks to prevent dust from clogging the cracks. The holes should extend minimum 450mm on each side of the crack. Number, spacing and location of the holes should be determined by design, taking care to avoid existing reinforcement.
- iv. Fill the holes and cracks with epoxy pumped under low pressure (350 to 550kPa). The epoxy used should have low viscosity and high modulus of elasticity and it should be capable of bonding to concrete and steel in presence of moisture. Holes should be filled with epoxy to part depth sufficient to raise the epoxy level to surface when steel bars are inserted.
- v. Insert reinforcing bars (**typically 16 to 24mm diameter**) making sure the reinforcement are sufficiently embedded into concrete to protect them from the weather and environmental effects.

3.2.7 Overlays and surface treatment

Slabs with numerous fine cracks caused by drying shrinkage or other one-time occurrences can be effectively repaired by the use of protective coatings such as Sikagard – 703W or surface treatments.

Concrete surfaces that are not subjected to wear may be sealed with a low solid, epoxy resin-based system (film forming type) or silane/siloxane based coatings (penetration type) depending on the circumstances of the repair job.

Surfaces subject to traffic such as walkways, parking decks and interior slabs may be sealed with a heavy coat of epoxy resin covered with aggregate to provide skid resistance. The method will close dormant cracks, even if the aggregate is abraded from the surface, because traffic cannot abrade the resin that has penetrated the cracks.

A suitable proprietary repair system should be selected according to the requirements of the job.

The procedure of adding surface treatment involves the following:

- i. Select appropriate repair materials according to the particular job requirements.
- ii. Clean the surface to remove laitance, or contaminants such as grease or oil
- iii. Apply the repair materials strictly according to the supplier's written specifications.

3.2.8 Flexible sealant

Live cracks are treated as movement joints and repaired with flexible sealants.

The sealant is generally installed in a wide recess cut along the crack. The dimensions of the recess (width and depth) depend on the total crack movement and the cyclic movement capability of the joint sealant used. The crack movement should be calculated taking into account the applied loads, shrinkage and temperature variations.

Where aesthetics is not important and surface is not subject to traffic, the sealant may be applied on the surface without making a recess.

The commonly used sealants for movement type of joints are polysulphides, epoxy polysulphides, polyurethanes, silicones and acrylics. They have generally excellent adhesion to concrete, high movement capability of 50% to 100% and require a width/depth ratio of 2:1.

The procedure of repairing recessed seal involves the following:

- i. If the concrete is still uncontaminated, cut a recess along the line of the crack using a power chisel, crack cutter or saw cutting machine. Dimensions of the recess should comply with the requirements of the crack movement and sealant material..
- ii. Clean the recess of dust and debris by wire brushing followed by air-blasting with oil-free compressed air.
- iii. Coat the surfaces of the recess with primer as specified by the sealant manufacturer.
- iv. Place a bond breaker (such as polyethylene strip, pressure sensitive tape or other material that will not bond to the sealant) at the bottom of the recess.
- v. Fill the recess with flexible sealant as per manufacturer's instructions. Where the concrete is carbonated or contaminated with chlorides or has deteriorated due to corrosion of reinforcement, it must be broken out, replaced, and a sealed movement joint formed as detailed below.

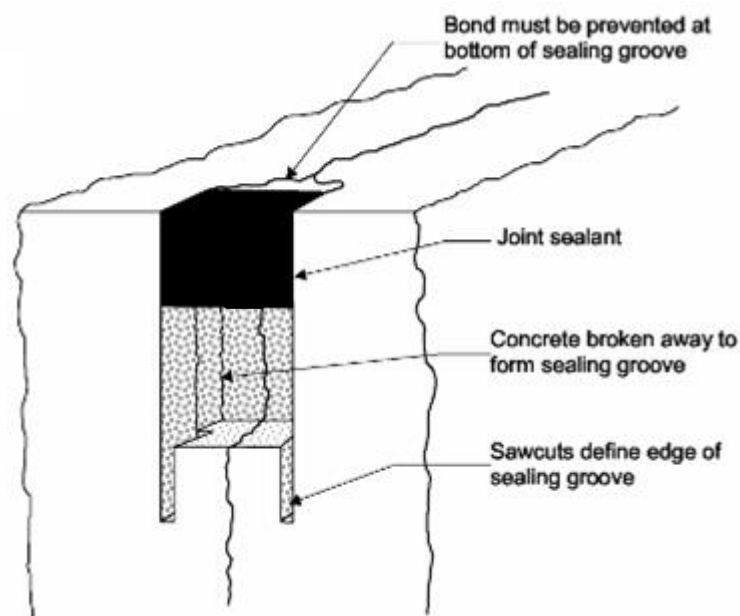
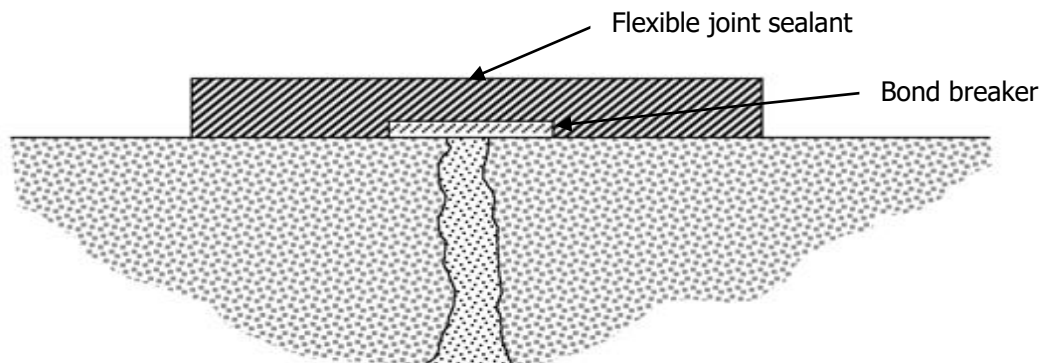


Figure 3 - 5 Flexible joint sealant – recessed seal

The procedure of repairing surface seal involves the following:

- i. Narrow cracks subject to movement, where aesthetics are not important and where the structure is not subject to traffic, may be sealed with a flexible surface seal.
- ii. Apply minimum 60mm wide.

- iii. Clean the concrete surface adjacent to the crack of laitance and contaminants such as grease and oil.
- iv. Coat the concrete surface along the crack in approximately 100mm wide strips with a primer recommended by the sealant manufacturer.
- v. Place a 20mm wide bond breaker strip over the crack.
- vi. Apply minimum 60mm wide and 3mm thick flexible joint sealant over the bond breaker with a trowel.



Flexible surface sealant can be used over narrow crack subject to movement, if appearance is not a consideration. Note bond breaker over the crack itself.

Figure 3 - 6 Flexible joint sealant – surface seal

3.3 Patch Repairs

Patch repairing is employed to restore small areas of otherwise sound concrete damaged by spalling, scaling, honeycombing and impact. Patch repairs are generally trowel applied, require none or minimum formwork and their thickness is limited to a maximum of about 100mm in high build applications.

Depending on the type, location and extent of damage and urgency of repairing, patch repairs may be carried out with Portland cement mortars, latex modified cementitious mortars or epoxy mortars.

If ordinary Portland cement is used in the mortar, the patched surface would tend to be darker than the surrounding concrete. Therefore, a part of the Portland cement should be replaced with white cement to lighten the patch. It is desirable to make a trial patch to achieve matching colour.

Mortar of a consistency suitable for trowelling usually does not contain enough cement paste to coat the old concrete surface or the reinforcement adequately and a bonding coat of cement grout or polymer admixtures must be used. Bonding coats containing polymer admixtures dry quickly and work must be organised so that application of mortar follows the bonding coat within a few minutes.

The following sections describe the procedure involved in repair with the above mentioned materials.

3.3.1 Repair with cement-sand mortars

The procedure of applying cement-sand mortar involves the following:

- i. Remove all damaged, unsound and contaminated concrete and prepare the edges of the patch area.
- ii. Clean concrete substrate and saturate it with water for 24 hours prior to repair.
- iii. Clean the reinforcement if exposed and contaminated with rust.

- iv. Select appropriate patch material and bonding coat for the job. It may be a proprietary pre-packaged formulation or site-mixed preparation. For proprietary products carefully follow the manufacturer's recommendations. For common repair jobs a cement and coarse sand mixture in the ratio of 1:3 by weight is generally adequate. If the patch must match the colour of the surrounding concrete a blend of Portland cement and white cement may be used. Normally, about one-third white cement is sufficient, but the precise proportions can only be determined by a trial.
- v. Prepare the cement-sand mortar by mixing with minimum amount of water. Slump of the mix for shallow patches should not exceed 25mm. To minimise shrinkage, allow the mortar to stand for half an hour after mixing and then re-mix prior to use. Do not re-temper with water.
- vi. Apply the bonding coat to the concrete substrate and to the reinforcement.
- vii. Apply the mortar immediately following the bonding coat. The mortar should be forcibly projected or dashed onto the substrate and placed in layers about 10mm thick. Compact each layer thoroughly over the entire surface using a blunt piece of wood or hammer. Each layer should be cross-scratched to facilitate bonding with the next layer. Generally, there need be no time delays between the layers. For vertical and overhead repairs of considerable thickness, in order to prevent sagging of the mortar, the repair may be limited to about 50mm thickness at one time, and should then be kept moist for a day before applying the successive layer.
- viii. Finish the patch to the texture of the surrounding concrete by using similar form material and hammering with a mallet or by wood floating or steel trowelling as necessary.
- ix. Start curing as soon as possible.

3.3.2 Repair with polymer modified cementitious mortars

The procedure of applying polymer modified cementitious mortar involves the following:

- i. The repair procedure is the same as for cement-sand mortars, except for the details noted below.
- ii. The proportion of polymer admixtures to be added should be as per manufacturer's recommendations.
- iii. The working time of polymer modified mortars is relatively short. Therefore, limit the quantity of mix for a particular job such that it can be placed, compacted and finished within the working time, approximately 20 minutes.
- iv. Soak the concrete substrate with water for one hour before applying bonding coat.
- v. Apply polymer based bonding coat to concrete substrate and reinforcement. Polymer in the bonding coat should be the same as in the repair mortar.
- vi. Place the mortar in the patch without any delay and before the bonding coat can dry. Compact and finish within the working time of the mortar.
- vii. Do not re-work or manipulate the mortar after the latex has coalesced otherwise cracking will occur on drying.
- viii. Curing procedure for polymer modified mortars should follow manufacturer's instructions.

3.3.3 Repair with epoxy mortar

Patch repairs with epoxy mortars require special skills and should be entrusted to personnel experienced in mixing, handling and applying epoxy materials.

The procedure of applying epoxy mortar involves the following:

- i. Do not carry out repairs with epoxy-based materials at low temperatures as it is difficult to get the mixture to harden quickly enough.
- ii. Restrict application of epoxy mortar to thin sections, say not exceeding 20mm.

- iii. Prepare and clean the patch area. The concrete surface should be completely dry.
- iv. Mix the epoxy components and aggregates accurately as recommended by the manufacturer in a high shear mixer, preferably in whole pre-weighed batches as supplied by the manufacturer.
- v. Working time of resin-based materials is very short. Mix the quantities that can be easily placed and finished within the working time. Also, a large batch of resin-hardener mixture has a shorter working life than a small batch.
- vi. Handle the materials cleanly to avoid contamination of both the resin mixtures and the people working with them.
- vii. Prime the concrete substrate (and reinforcement, if exposed) with the same liquid resin mixture as used for the epoxy mortar.
- viii. Apply the mortar with a trowel immediately following the bonding coat and finish the repair before the resin hardens.
- ix. No curing is required for resin mortar patches.

3.4 Recasting with Concrete

Recasting with concrete is required to replace concrete that has been severely damaged and non-removal of which would lead to further deterioration and could impair the strength, stability and functioning of the structure.

Recasting with concrete generally involves removal of deteriorated concrete, cleaning up the substrate and reinforcement, setting up formwork and placement of new concrete. (Refer Figure 3 - 7).

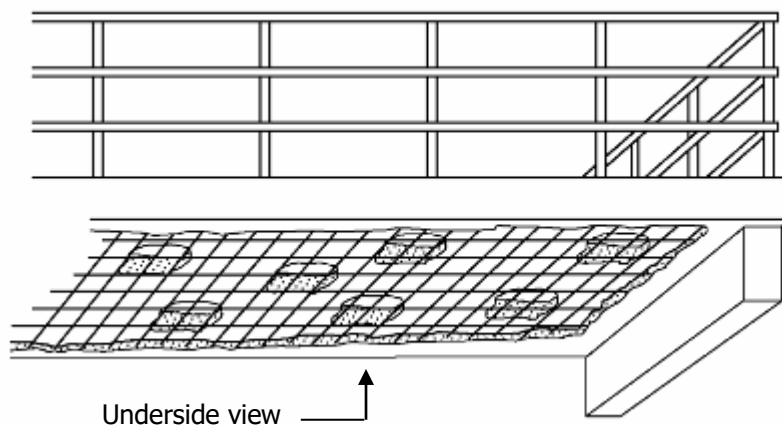


Figure 3 - 7 Holes cut in slab to allow placing of concrete when soffit forms have been fixed

The procedure of recasting with concrete involves the following:

- i. Support the existing structure adequately to safeguard against instability and deformation during repair work.
- ii. Remove all deteriorated or damaged concrete and prepare edges of repair work.
- iii. Examine the reinforcement for loss of section due to corrosion. If cross-sectional area of the reinforcement has reduced by more than 15%, seek engineering advice for extra reinforcement.
- iv. Clean the concrete substrate and reinforcement.
- v. Select a suitable bonding agent for concrete and reinforcement taking into consideration its limited working time available for fixing the formwork and placing the new concrete. If concrete can be placed immediately after applying bonding coat, use either Portland cement

grout or polymer modified cement grout. If delay is expected due to formwork, specially formulated epoxy bonding agents with long working life should be used.

- vi. Apply bonding coat to concrete substrate and reinforcement.
- vii. Fix formwork, if required.
- viii. Place concrete in the forms by a suitable method. Compact well using internal or external vibrators as necessary. Finish unformed surfaces by brooming, wood floating, steel trowelling or any other methods to match the adjacent existing concrete.
- ix. Forms for load bearing structural members should remain in position until at least 80% of the 28 day compressive strength of the new concrete is achieved. (10 days for normal Portland cement, 7 days for high early strength Portland cement). Forms for non-load bearing members may be removed after 2 to 3 days.)
- x. After stripping the formwork, examine the concrete for any blemishes. Repair any defective work using stiff cement mortar having the same proportion of cement and fine aggregate as used in the concrete and bring to an even surface using wooden float.

3.5 Corrosion Repairs

The presence of corrosion in concrete structures is generally known when cracks occur. Extensive corrosion shows up in long cracks running along the reinforcement leading to spalling and delamination or corrosion may be localised due to impact damage, honeycombing or water penetration.

In all cases it is advisable to remove the concrete and examine the extent of corrosion immediately. Where the corrosion is extensive, concrete should be tested for chloride penetration and carbonation.

If it is determined that patch repairing or re-casting with new concrete will be cost effective then the procedures in Section 3.3 and 3.4 should be followed rigorously. The repair should also include cleaning the reinforcement and possibly applying protective treatment. Consideration should be given to the application of a protective coating to the concrete surface to limit further ingress of chlorides and carbonation.

3.6 Sprayed Concrete (Shotcreting)

The procedure of spraying concrete involves the following:

- i. Remove all damaged and unsound concrete from the structure to be repaired. Concrete should be removed so that there is no abrupt change in thickness of repair and any square shoulders should be tapered.
- ii. Clean concrete substrate and exposed reinforcement.
- iii. Fix required fabric reinforcement rigidly to prevent vibration during spraying.
- iv. Fix formwork as required to restrict the boundaries of sprayed concrete. (Refer Figure 3 - 8). Coat the formwork liberally with form release agents compatible with the spray mix.
- v. Protect adjacent buildings, trees, garden, etc. from dust and rebound concrete that would follow during spraying operations, with suitable covers.
- vi. Ensure that local work safety regulations are adhered to.
- vii. Check operation of all spraying equipment before commencing work.
- viii. Wet the substrate with an air/water blast before spraying concrete.
- ix. Apply spray concrete in layers. Build up each layer by making passes of the nozzle over the working area in a pattern of overlapping loops. To minimise rebound, the nozzle should be held nearly perpendicular to the surface being sprayed at a distance of between 0.6m and 1.2m.
- x. Finish the surface by screeding or trowelling if required.
- xi. Commence curing as soon as possible.

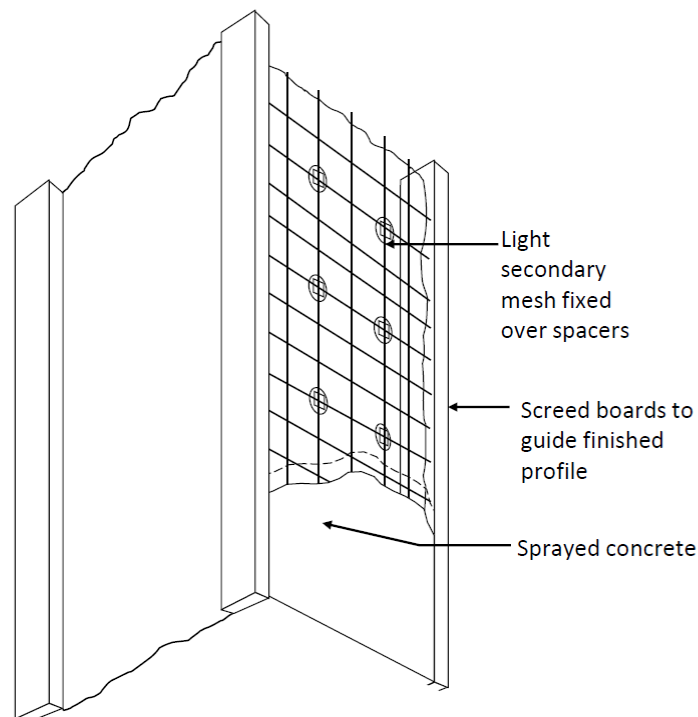


Figure 3 - 8 Sprayed concrete

3.7 Protective Coatings

Protective coatings on surfaces of concrete structures are not exactly repair methods. They are protective or preventive measures applied to inhibit the deterioration process caused by environmental factors such as penetration by moisture, chlorides and carbon dioxide.

Coatings may be applied in any of the following circumstances:

- i. On surfaces of new structures for aesthetics and increased durability.
- ii. On surfaces of the existing structures where tests indicate that chloride ingress and carbonation has occurred in the concrete but as yet no corrosion is evident, in which case application of coatings would help in reducing further deterioration. However, if there are signs of corrosion, application of protective coatings will not stop the corrosion. In this case the deteriorated concrete should be removed and replaced by patch repairing or recasting.
- iii. On surfaces of newly repaired concrete to give extra protection against recurrence of deterioration and to conceal the repair work.

3.7.1 Coating/repair to prevent chlorides ingress

The procedure of applying coating to prevent chlorides ingress involves the following:

- i. Ascertain the profile of chloride penetration into concrete. Determine if the chloride was inherent in the original concrete mix or it has entered later. If there is no corrosion of steel yet, estimate on the basis of chloride profile and age of concrete the time to depassivation of steel.
- ii. Based on this estimate and if the concrete otherwise is in sound condition, decide whether to leave the concrete as it is and re-inspect after an appropriate interval or to take action to limit further chloride ingress. The following techniques can be considered as possible for controlling chloride attack:
 - Silane/siloxane coating

- Cathodic protection
- Chloride extraction and re-alkalisation

Procedure for silane/siloxane coating is given below. The other methods require special technology and should be undertaken only in consultation with the experts in the field.

- iii. Repair surface cracks and spalls if any by appropriate methods.
- iv. Clean the surfaces to be coated of all contaminants. Make good any blowholes and areas of substantial pitting with an approved finishing compound.
- v. Wash down the surfaces with clean water. Allow to dry for 24 hours.
- vi. Mask or protect adjacent areas, paints, sealants, asphalt or coated surface.
- vii. Apply silane/siloxane in at least two flood coats using a low pressure sprayer. Repeat application until correct coverage is achieved as recommended by the manufacturer. (Silane/siloxane is also used as a primer for some protective coating systems. Allow to dry for at least two hours before applying another coating).

3.7.2 Coating/repair to prevent carbonation

- i. Monitor the situation at periodic intervals by phenolphthalein tests by drilling holes and applying phenolphthalein to see colour change to determine the progressive depth of carbonation front. No protective surface treatment is necessary until the carbonation front reaches the steel reinforcement.
- ii. Once the carbonation front reaches the steel, and if the concrete otherwise is in sound condition, any of the following options can be considered to prevent further carbonation:
 - Silane/siloxane primer plus anti-carbonation coating
 - Rendering and painting
 - Cathodic protection
 - Re-alkalisation

Guideline procedure for rendering and painting is given below. Depending on the proprietary materials or coating system selected, exact procedure as recommended by the product manufacturer should be adopted.

- iii. Repair surface cracks and spalls, if any, by appropriate repair methods.
- iv. Clean the surface to be coated of all contaminants. Make good any blowholes and areas of substantial pitting with an approved finishing compound.
- v. Wash down the surfaces with clean water. Thoroughly soak the substrate for one hour. Allow to become damp dry without residual water.
(Instead, a primer may be applied as recommended by the product manufacturer).
- vi. Apply cement-based render with a trowel from "feather edge" to 3mm thickness. Allow to set partly before finishing finally with trowel, or sponge float, as required.
- vii. Cure the render with fine spray of water or a curing material recommended by the manufacturer. The curing material must be compatible with the anti-carbonation coating proposed to be applied. Allow at least 48 hours before top coating.
- viii. Apply the selected protective coating as per manufacturer's recommendations. The coating should be pinhole free. One or two coats may be required as per the product used.

4 Masonry

4.1 General

Repairs for following types of defects are covered in this section:

- Cracks
- Fretting
- Impact Damage
- Other types

4.2 Crack Repairs

For typical repair materials/products refer **Reinforced Concrete in Section 3**.

4.2.1 Active cracks

- i. Repair of cracks not to be sealed permanently involves the following:
 - Clean the crack of loose dust and debris, oil, algae and other contaminants by using high pressure water jets, compressed air (oil free) or vacuum suction. Allow the surfaces of the crack to dry.
 - Prime the crack surfaces with a primer recommended by sealant manufacturer.
 - If the width of crack is more than 5mm insert a tight fitting closed-cell polyethylene foam backer rod into the crack. The backer rod must be pushed to a depth such that the sealant applied will have width to depth ratio of 2:1, or minimum 5mm depth of sealant. (For cracks less than 5 mm do not insert backer rod).
 - Seal the crack by caulking with a flexible sealant flush with the masonry face.

- ii. Repair of cracks to be sealed permanently involves the following:

Either a recessed seal or surface seal as described below can be used:

Recessed Seal

- Cut a recess along the crack using a power chisel or crack cutter. Dimensions of the recess should comply with the requirements of the crack movement and sealant material.
- Clean the recess of dust and debris by wire brushing followed by air-blasting with oil free compressed air.
- Prime the surfaces of the recess with a primer specified by the sealant manufacturer.
- Place a bond breaker strip at the bottom of recess.
- Fill the recess with flexible sealant as per manufacturer's instructions.

Surface Seal

- Narrow cracks subject to significant movement where aesthetics are not important may be sealed with a flexible surface seal.
- Clean the masonry surface adjacent to the crack of dirt, algae, and other contaminants.
- Prime the masonry surface along the crack in approximately 100mm width with a primer specified by the sealant manufacturer.
- Place a 20mm wide bond breaker strip over the crack.
- Apply minimum 60mm wide and 3mm thick flexible joint sealant over the bond breaker with a trowel.

4.2.2 Inactive cracks

Fine cracks can be repaired by epoxy injection. The procedure for repairing wider cracks involves the following:

- i. If cracks run through masonry units and mortar beds, cut out the units and remove joint mortar. Wet the masonry. Allow to dry until it is just damp (no residual water). Install new units, bonding with mortar similar to that in the existing wall. Avoid strong mortar and use a well graded sand to minimise shrinkage. Where the wall is severely exposed, polymer additives may be used in the mortar to increase bond and durability provided the sand used has negligible clay content.

Note that the above procedure for repairing cracked masonry units is also applicable for repairing spalled masonry.

- ii. If cracks run through joints only (that is, masonry units are not affected), rake the joints (on both sides of the walls if accessible) to a minimum depth of 15mm using a square edged tool. Clean the joints of dust and debris with a wire brush or by oil-free air-blasting. Wet the masonry. Allow to dry until it is just damp. Fill and point with mortar not richer than a 1:2:9 mix of cement: lime: sand.

4.3 Fretting Repairs

4.3.1 Repair of damaged joints

The procedure for repairing damage to jointing mortar involves the following:

- i. Where the jointing mortar has been damaged without disturbing the masonry units, rake out all loose and fretting mortar from joints, with a square edged tool. Rake out another 20mm of mortar to make sure that all crystallised salt is removed. Rake the joints in top most 3-4 courses to be repaired first.
- ii. Thoroughly wet the masonry and allow to dry till it is just damp and without any residual water.
- iii. The mortar mix for re-pointing should consist of hydrated lime and washed concrete sand (without any clay content) in the ratio of 1 lime: 4-5 sand. Sand must be free of salts. Only potable water (that is, suitable for drinking) should be used for the mortar.
- iv. Mix dry sand and lime, then slowly add water while still mixing to make a stiff mix. As the lime takes a long time to go off, prepare the mortar some hours in advance of the re-pointing operation and keep it covered with damp bags until used.
- v. Pack joints with the stiff mortar. Ensure that no voids are left, using a pointing tool to ram the mortar into the joint. (Start at the top most joint and work progressively down). Tool off the joint surface to match the original.

4.3.2 Repair of damaged masonry units

The procedure for repairing damaged masonry units involves the following:

- i. Cut out the spalled units to a depth at least 20mm beyond the depth of spalling, or remove the whole units. Remove the jointing mortar also.
- ii. Wash down the broken surfaces to remove dust and debris. Allow the surfaces to dry till it is just damp.
- iii. Set new units (whole or sawn as required) in place of the old with a lime and sand mortar as described in Section 4.3.1 (iii) above.

CAUTION: Before commencing repairs check with the Structures Engineer if the stability of the wall would be adversely affected by removal of the spalled masonry. Remove and replace only a few spalled units at a time as necessary to ensure stability at all times.

4.4 Repair to Impact Damaged Masonry Units

Masonry spalled by accidental impact would require removal and replacement of the spalled units and repair of cracks. Repair procedure for this is the same as for wide cracks.

4.5 Other Types of Repairs

4.5.1 Minor displacement of masonry

Minor displacement of parts of the masonry is not very important. However, large movements may endanger structural stability. It is advisable to find out the cause of all movements and take steps to prevent its continuing or recurring.

When a part of the masonry is displaced horizontally, rake out the joints on that movement has taken place and repoint.

4.5.2 Sulphate attack

Sulphate attack that is affected by dampness is liable to continue unless the masonry can be dried out and kept reasonably dry. The repair therefore should be aimed at investigating the cause of dampness and eliminating it, if possible.

If the damage due to sulphate attack has gone too far, rebuilding may be necessary, in which case use clay bricks of low sulphate content with 1:1:6 or stronger mortar of sulphate-resisting Portland cement.

Rendering that has been damaged by sulphate attack should not be patch repaired. It is best to strip it off and allow the masonry to dry and, preferably, to remain bare. If it is necessary to render again use a weaker mix of sulphate-resisting cement.

4.5.3 Salt water and marine organisms

Repair of masonry damaged by salt water and marine organisms is difficult and thus specialised work should be entrusted to organisations experienced in this field.

Basically, the repair consists of cleaning of the affected masonry by grit and water blasting and protecting the masonry by epoxies or by concrete encasement.

5 Timber

5.1 General

Typical primary members for railway bridges are Grade F22 with a cross-section of 300 x 300mm in NSW. The size of secondary elements generally varies.

Replacement of a member implies that a defective element is replaced with either a like-for-like element or bigger size element. Otherwise, the replacement element needs to be designed by a competent Structural Engineer.

All replacement fasteners for timber connections are of Grade 4.6 mild steel galvanized bolts, nuts, and washers of equivalent or bigger size to the existing fasteners.

iNote that Section 5.4 Propping has some typical details and notes to cover general conditions only due to difficulties in presenting details of temporary supports for various sites with different foundation requirements. For all propping, site conditions should be considered prior to applying a propping system. Adequate drainage should be allowed for the new footing of the propping so that the footing would not be undermined due to poor drainage.

5.2 Repairs Required for Common Defects

The following sections describe the repair methods for commonly found defects in timber structures.

5.2.1 Decay resulting in troughing, piping, crushing or loss of section

When elements are extensively decayed resulting in troughing, piping, crushing, or loss of section (Refer Figure 5 - 1) due to aging or any other means, these elements should be replaced with either like-for-like elements or bigger size elements of similar grade and durability class.

The exception to the above is timber piles, which may be spliced.

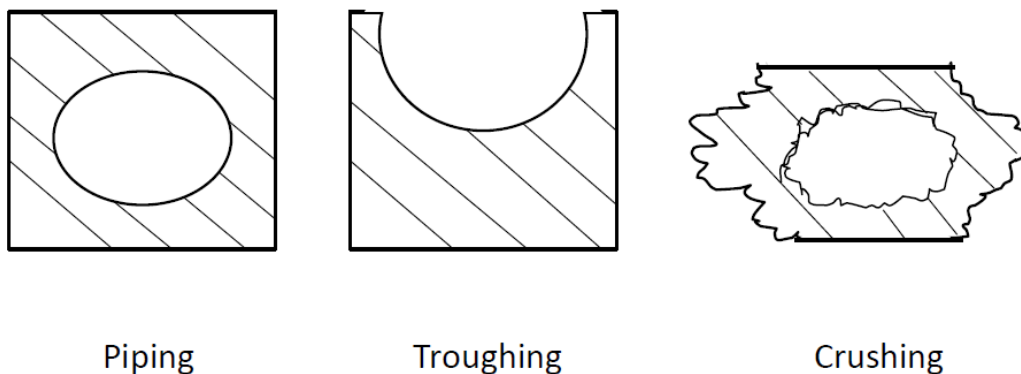


Figure 5 - 1 Common defects in timber

5.2.2 Splitting

Splitting in the timber elements can be repaired with bolting galvanized mild steel large washers (100 x 100 x 12mm thick plates typical) or 100mm wide x 3mm thick metal straps with M24 galvanized bolts in most cases. If bolting is not feasible due to the excessive splitting then the element should be replaced.

The splitting can be in the vertical or horizontal direction of the element. Figure 5 - 2 shows the details of plate bolting to vertical and horizontal splits. Figure 5 - 3 illustrates the details of metal strapping to timber elements.

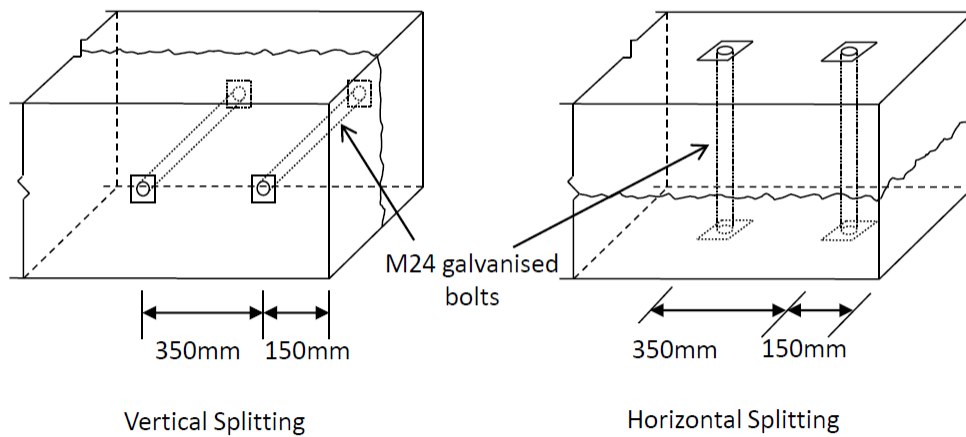


Figure 5 - 2 Mild steel plate bolting to vertical and horizontal splitting in timber elements

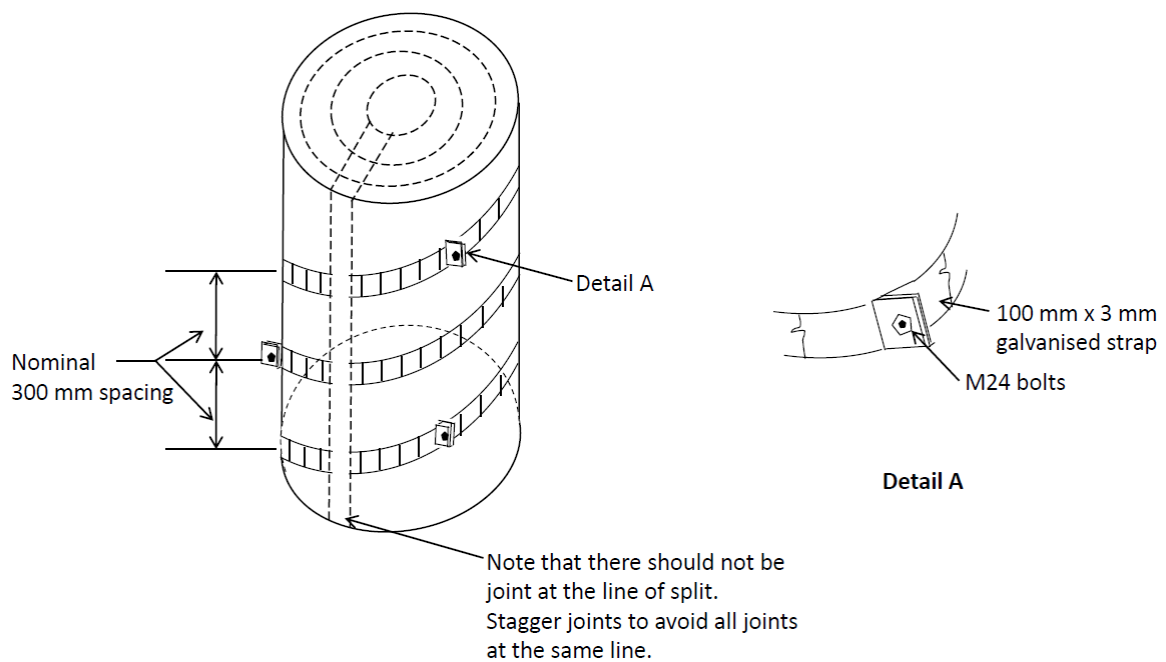


Figure 5 - 3 Metal strapping for split timber elements

5.2.3 Pile splicing

Where the upper part of the pile has defects and the lower part in ground is sound and has adequate ground support, splicing in of a new section of timber pile can be used.

Appendix A shows a splice detail to connect the new upper part of pile to the existing pile.

5.2.4 Vehicle impact damage

Elements that are damaged by vehicle impact are normally replaced otherwise can be repaired as detailed in Sections 5.2.1, 5.2.2, and 5.2.3.

5.2.5 Weathering – abrasion, cracks, shakes, checks and splits

If timber elements have weathered, they are normally repaired with above mentioned methods (Sections 5.2.1, 5.2.2, and 5.2.3) if practical, otherwise they are replaced with like-for-like new elements.

5.2.6 Corroded fasteners, missing fasteners and loose connections

Replace with new fasteners.

5.2.7 Termite infestation (white ants)

Engage a licensed pest controller to eradicate ants. If required, timber elements are replaced with like-for-like new elements.

5.3 Replacement / Strengthening Methods

Replacement of a member implies that a defective element is replaced with either a like-for-like element or bigger size element. Otherwise, the replacement element needs to be designed by a competent Structural Engineer.

5.3.1 Strengthening of internal girders

Figure 5 - 4 shows installation of new additional girders to strengthen the damaged or deteriorated existing timber girders when they cannot be repaired in-situ.

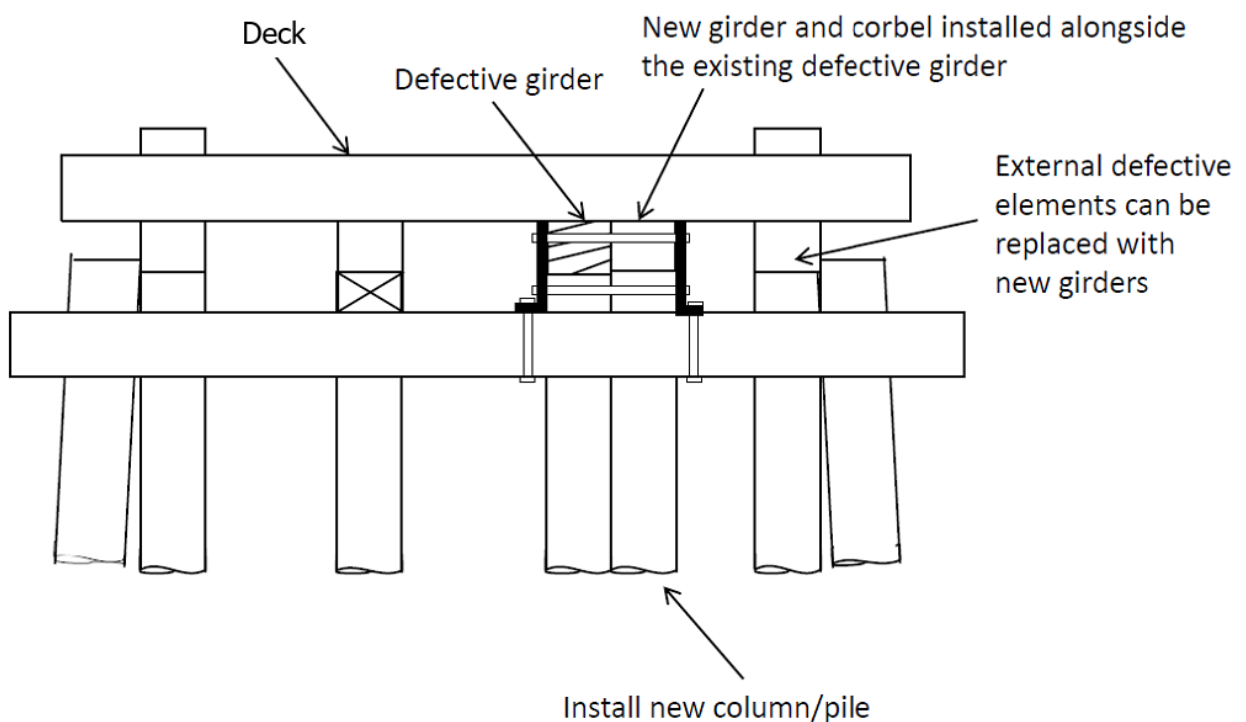


Figure 5 - 4 Installation of additional girders

5.3.2 Replacement of timber piles with new steel trestle

When piles cannot be strengthened, they should be removed and steel trestles installed on a new concrete sill.

Standard drawing in Appendix A shows installation of a new steel trestle to replace the existing deteriorated piles.

5.3.3 Replacement of headstocks, braces and wales, sills, etc

When headstocks, braces, wales, and sills cannot be strengthened then these elements should be replaced with like-for-like new elements.

5.4 Propping

As highlighted in Section 5.4.1, the propping details provided in this section only cover a few typical site situations. Care should be taken when installing props to provide adequate footing and drainage around it.

Circumstances where propping is provided include the following:

- a) To provide emergency support to allow continued use of the bridge
- b) To provide short/medium term relief to deteriorating substructure
- c) To provide temporary support during various maintenance activities, including replacement of elements.

Typical prop size includes 300 x 300mm, Grade F22, recovered timber girders for spans less than 7m. Other types of typical props can include Acro props or steel beams. However, they all must be designed / checked by a Structural Engineer.

5.4.1 Emergency propping

Figure 5 – 5 shows emergency propping arrangements for defective headstocks and girders.

Timber bearing area for props is typically minimum 1m x 1m per post on firm or well compacted ground with nominal 100kPa bearing pressure.

5.4.2 Place / reinstate relieving props

Relieving props are normally used adjacent to log abutments or silled piles where settlements are occurring due to sill deterioration. Propping of the superstructure will reduce load to the defective components and provide extra time before repairs are required. Figure 5 - 6 shows an arrangement of a relieving prop.

5.4.3 Propping for maintenance activities

Propping for maintenance activities should be carried out using timber/steel trestles supported on shallow timber/concrete footing on firm ground.

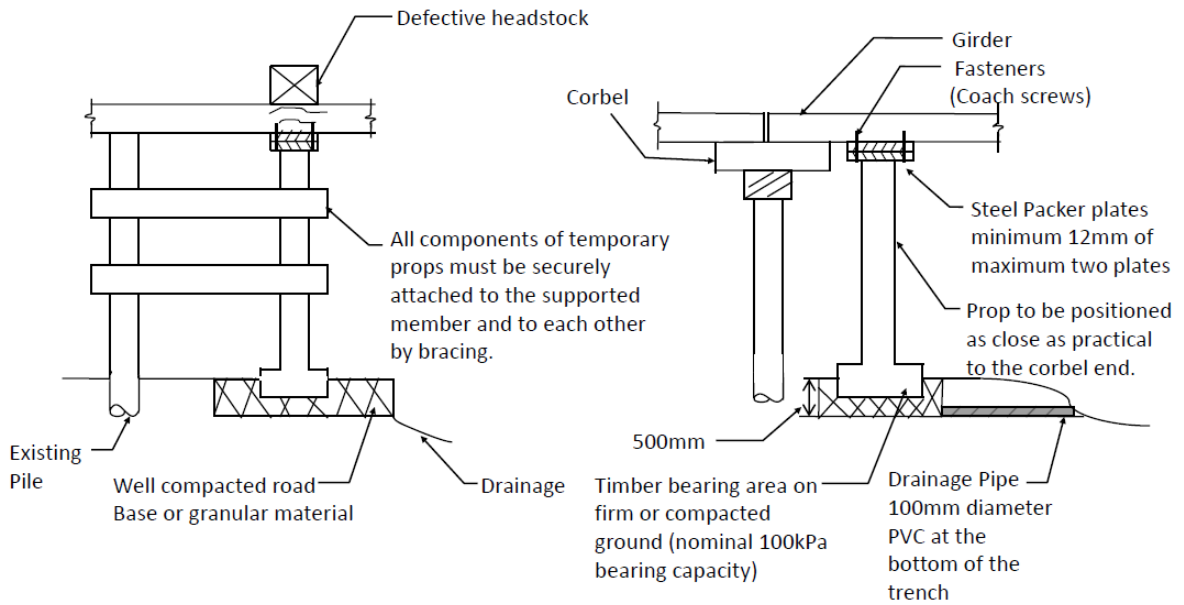


Figure 5 - 5 Emergency propping for defective headstocks and girders

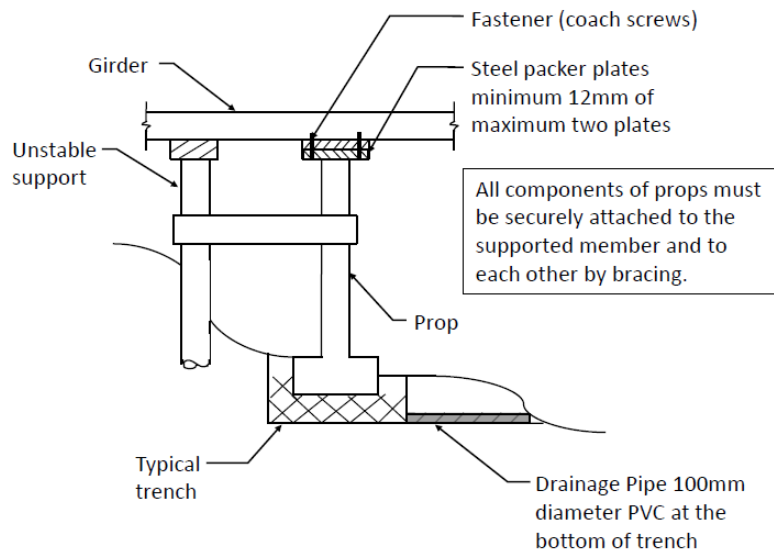


Figure 5 - 6 Relieving Prop Arrangement

5.5 List of Drawings in Appendix A

The following standard drawings are provided in Appendix A:

- i. Pile splicing detail (AA-001)
- ii. Steel trestle on a concrete sill (AA-002)
- iii. Standard protection for span ends at abutments (AA-003)
- iv. Bracings to girder at piers and abutments (AA-004)
- v. Temporary strengthening arrangements (AA-005 Sheets 1 and 2).

6 Miscellaneous Repairs

6.1 General

Structure repairs that are common to all types of materials are covered in this section.

6.2 Repairs to Scour Protection

- Fish net baskets – supply and installed by approved installer. Note that rock bags can easily be cut by knife.
- Reno mattress – supply and installation by approved installer
- Gabion baskets – supply and installation by approved installer
- Concrete slab – unreinforced concrete with or without mesh reinforcement
- Rip – rap mattress – 200 to 300mm rocks.

6.3 Replacement of Damaged / Deteriorated Bearing Pads

Removal of damaged or deteriorated bearing pads in several situations, such as cracking, shattering, crushing, pier/abutment-cracked and shattered, to lift/lower bridge to suit track height and superelevation.

The procedure of replacing bearing pads involves the following:

- i. If bed plates are to be raised with girders, ensure bolts/studs connecting bearing plate to bed plate are in place.
- ii. Remove nuts from Holding Down (HD) bolts or unscrew nuts to allow bed plates to be raised to correct height.
- iii. Raise the girders by jacking the minimum amount required to enable completion of the replacement operation.
- iv. Remove damaged bearing pad.
- v. Assess condition of HD bolts and repair/replace as required.
- vi. Clean concrete/masonry substrate.
- vii. Locate bed plate to correct height.
- viii. Apply bonding coat to concrete/masonry.
- ix. Erect formwork and if necessary, dowel pins in existing work and confine with mesh to suit.
- x. Place new bearing pad material in formwork in accordance with manufacturer's written instructions e.g. Megapoxy H, Megapoxy 206,. Etc.
- xi. Allow time to cure.
- xii. Lower girders and screw up HD bolts.



Poorly formed Bearing Pad - honeycombed



110mm thk Megapoxxy Bearing Pad with 75mm dowels confined by SL81 mesh

6.4 Replacement/ Installation of Road/Pedestrian Traffic Barriers

Fences, safety screens, etc. - patch up first where practical otherwise replace.

6.5 Track Baulking

Track baulking can be carried out in accordance with Drawing No. 207-165 in Appendix B for excavations not greater than 4m wide.

6.6 Bridge Ends

6.6.1 Subgrade construction behind abutments and Transition slab

Refer standard drawings BDS 20 (Page 9 of 11) and, Humes transition slab Drawing No. 11742 – TA – 01 and 11742 – TA – 01 in Appendix B. Refer ARTC CoP Section 9 for specific requirements of transition slab.

6.6.2 Ballast log for transom top underbridge

Refer standard drawings ARTCN2070310001 Sheets 1, 2 and 3 in Appendix B.

6.6.3 Ballast retention walls

Refer standard drawing BDS 20 (Page 11 of 11) in Appendix B.

6.7 Culvert Repairs

6.7.1 Repair of steel pipe invert

Refer standard drawing "Page D1" in Appendix B.

6.7.2 Sleeving of brick culverts

Refer standard drawing ARTCN3090096001 in Appendix B.

6.8 List of Drawings in Appendix B

The following standard drawings provided in Appendix B can be used as required without further engineering input. Drawing numbers are provided in brackets.

- 1) Baulk Rail Installation (No. 207 – 165)
- 2) Ballast retention walls (BDS 20 Page 11 of 11)
- 3) Humes ballast box (transition slab) detail (11742 – TA – 01 and 11742 – TA – 01)
- 4) Ballast log for transom top underbridge (ARTCN2070310001 Sheet 1, 2 and 3)
- 5) Typical detail for repair of steel pipe invert (Page D1)
- 6) Typical sleeving of brick culverts (ARTCN3090096001)
- 7) Delkor rail pad (RF 0.02.192 CL)
- 8) Apron slab for culvert
- 9) Standard - steel trestle for road overbridges (No. CV 0219816)
- 10) Typical 3 or 5 timber trestle renewal – new pile cap (No. CV 0014037)
- 11) Steel walkways and handrails for concrete structures (No. CV 0022997)
- 12) Typical timber underbridge renewal - abutment and wingwall (No. CV 0174890)
- 13) Typical timber underbridge renewal – wingwall type 2 (No. CV 0174896)
- 14) Replacement of concrete treads and landing slabs for standard steel footbridges (No. CV 0191345)

7 Typical Examples of Past Repair Work

Appendix C provides a selection of drawings/sketches of typical repair works undertaken on railway structures.

These drawings/sketches may/may not comply with current traffic and/or design vehicle loadings. Prior to their use they must be verified by a Structural Engineer and if required complete set of detail design document must be sought.

8 Appendices

Appendix A: Drawings relevant for Timber

Appendix B: Drawings relevant for Miscellaneous Items

Appendix C: Typical Examples of Past Repair Work