TMC 302

STRUCTURES REPAIR

Version 2.0

Issued December 2009

Disclaimer
This document was prepared for use on the RailCorp Network only.
RailCorp makes no warranties, express or implied, that compliance with the contents of this document shall be sufficient to ensure safe systems or work or operation. It is the document user’s sole responsibility to ensure that the copy of the document it is viewing is the current version of the document as in use by RailCorp.
RailCorp accepts no liability whatsoever in relation to the use of this document by any party, and RailCorp excludes any liability which arises in any manner by the use of this document.

Copyright
The information in this document is protected by Copyright and no part of this document may be reproduced, altered, stored or transmitted by any person without the prior consent of RailCorp.
Document control

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date of Approval</th>
<th>Summary of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>December 2009</td>
<td>Three Volumes merged into single document. Format change throughout. Minor technical content changes detailed in chapter revisions. Sections on selecting repair actions, repair materials and engineering assessments have been removed from this manual and will be published in a new manual “Structures Assessment”. Sections on deterioration of structures and defect types have been removed from this manual and will be published in next revision of TMC 301 “Structures Examination”.</td>
</tr>
<tr>
<td>1.1</td>
<td>October 2007</td>
<td>Sections on “Health &amp; Safety” deleted – Vol 1 Ch 3; Vol 2 C1-3; Vol 3 C1-2 &amp; C15-2; Vol 1 Appendix 1 inclusion of definitions for ballast kerb &amp; ballast retention wall</td>
</tr>
<tr>
<td>1</td>
<td>October 2006</td>
<td>First issue as a RailCorp document</td>
</tr>
</tbody>
</table>

Summary of changes from previous version

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Current Revision</th>
<th>Summary of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Pages</td>
<td>2.0</td>
<td>Change of format for front page, change history and table of contents</td>
</tr>
<tr>
<td>1.0</td>
<td>2.0</td>
<td>Text from Chapter 1 in Volumes 2 and 3 included; References and Definitions updated; section on Acknowledgements deleted</td>
</tr>
<tr>
<td>2.0</td>
<td>2.0</td>
<td>New chapter – Management requirements</td>
</tr>
<tr>
<td>3.0</td>
<td>2.0</td>
<td>New chapter - Competencies</td>
</tr>
<tr>
<td>4.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 2 Chapter 2); C4-2.2.1: oxy-fuel cutting requirements for BFB’s added; C4-2.2.3: edge distances and bolt spacings included from AS 5100;C4-2.2.4: use of direct-tension indication devices included; C4-3: additional requirements for surface preparation included from AS 1627</td>
</tr>
<tr>
<td>5.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 2 Chapter 3); no changes</td>
</tr>
<tr>
<td>6.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 2 Chapter 4); no changes</td>
</tr>
<tr>
<td>7.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 2 Chapter 5); no changes</td>
</tr>
<tr>
<td>8.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 2 Chapter 6); some content moved to Structures Assessment manual; C8-2: BFB’s added as fracture critical members; C8-4.3: grinding repair procedure added.</td>
</tr>
<tr>
<td>9.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 2 Chapter 7); no changes</td>
</tr>
<tr>
<td>10.0</td>
<td>2.0</td>
<td>New chapter – Painting of steel structures; list of proprietary products updated; management of lead paint deleted as covered in SMS</td>
</tr>
<tr>
<td>11.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 2 Chapter 8); no changes</td>
</tr>
<tr>
<td>12.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 2 Appendix C); no changes</td>
</tr>
<tr>
<td>13.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 3 Chapter 8); some content moved to Structures Assessment manual</td>
</tr>
<tr>
<td>14.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 3 Chapter 9); no changes</td>
</tr>
<tr>
<td>15.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 3 Chapter 10); no changes</td>
</tr>
<tr>
<td>16.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 3 Chapter 11); no changes</td>
</tr>
<tr>
<td>17.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 3 Chapter 12); no changes</td>
</tr>
<tr>
<td>18.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 3 Chapter 13); no changes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>19.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 3 Chapter 14); no changes</td>
</tr>
<tr>
<td>20.0</td>
<td>2.0</td>
<td>Renumbered (formerly Volume 3 Chapter 20); no changes</td>
</tr>
</tbody>
</table>
# Contents

## Chapter 1 Introduction
- Purpose .................................................................................................................. 7
- Who should use this Manual? ..................................................................................... 7
- References ................................................................................................................. 7
- Definitions, abbreviations and acronyms ................................................................. 8
- Nature of the repair procedures ............................................................................... 8
- Aim of the repair procedures ................................................................................... 9
- Sub-procedures ......................................................................................................... 9
- Drawings .................................................................................................................... 9
- Planning repair work ................................................................................................. 10

## Chapter 2 Management requirements .................................................................... 11

## Chapter 3 Competencies ......................................................................................... 12

## Chapter 4 Steel repair sub-procedures .................................................................. 13
- Arresting corrosion (Sub-procedure) ........................................................................ 13
- Removing rivets and replacing with bolts (Sub-procedure) .................................... 14
- Patch painting (including surface preparation) (Sub-procedure) .......................... 17
- Filling voids (Sub-procedure) .................................................................................. 20
- Sealing interfaces (Sub-procedure) ......................................................................... 22

## Chapter 5 Repairing corroded flanges and webs of steel I girders ...................... 23
- Repairing flange corrosion in riveted girders ............................................................ 23
- Repairing flange corrosion in rolled or welded girders ........................................... 26
- Repairing web corrosion near bottom flange angles in riveted girders .................. 28
- Repairing webs with localised corrosion .................................................................. 31
- Repairing corroded bottom flanges of jack arch bridges ....................................... 34

## Chapter 6 Repairing stiffeners, bracing, connections and bearings .................... 39
- Relief of corrosion site at the base of intermediate web stiffeners ......................... 39
- Repairing intermediate and bearing web stiffeners with localised corrosion ......... 42
- Repairing bearing web stiffeners with localised corrosion at base of oustand leg of stiffener . 46
- Relief of corrosion site at the base of splayed angle bearing end stiffeners .......... 47
- Repairing corrosion at bottom flange bracing connection ...................................... 50
- Replacing bearing plates ......................................................................................... 53
- Repairing cracked and broken wind brace welded connections ............................ 58

## Chapter 7 Repairing fatigue damage ...................................................................... 60
- Intercepting fatigue cracks ..................................................................................... 60
- Repairing fatigue cracks at connections of coped I-sections .................................. 61

## Chapter 8 Repairing impact damage to steel structures ....................................... 64
- Description of Defect ............................................................................................... 64
- Engineering Discussion ........................................................................................... 64
- Sub-procedures required .......................................................................................... 64
- Repair procedures .................................................................................................... 65

## Chapter 9 Repairing steel stepways and footways structures ............................... 68
- Repairing steel risers and stringers in stepways ....................................................... 68
- Repairing corroded angle columns (temporary support available) ....................... 73
- Repairing corroded 4-angle columns (no temporary support) ............................. 75

## Chapter 10 Painting of steel structures ................................................................. 83
- Description of action ............................................................................................... 83
- Engineering discussion ........................................................................................... 83
- Procedure ................................................................................................................ 83
- Examples of Proprietary Products ......................................................................... 84
Chapter 11  Complete replacement of steel members................................................................. 86
  C11-1  Replacing members or elements of riveted members ................................................. 86

Chapter 12  Guidelines for welding old steels............................................................................. 87
  C12-1  Background/introduction ............................................................................................. 87
  C12-2  Welding procedures for wrought iron ......................................................................... 87
  C12-3  Welding procedures for mild steel .................................................................................. 87
  C12-4  Welding procedures for structural steel ........................................................................ 88
  C12-5  Weld quality ...................................................................................................................... 88
  C12-6  Quality of repairs .............................................................................................................. 88
  C12-7  Recording of repairs carried out ...................................................................................... 88
  C12-8  Welding process ............................................................................................................... 88
  C12-9  Weld Surface Condition .................................................................................................. 89
  C12-10 Weld Toe Grinding ......................................................................................................... 89
  C12-11 Full Weld Surface Grinding ............................................................................................ 90
  C12-12 Weld Processes and Consumables .................................................................................. 90
  C12-13 Minimum Weld Size ....................................................................................................... 90

Chapter 13  Concrete repair sub-procedures............................................................................. 92
  C13-1  Removing damaged concrete (sub-procedure) ............................................................... 92
  C13-2  Removing concrete at joints (Sub-procedure) ............................................................... 94
  C13-3  Cleaning concrete substrate for patch repairs and re-casting (Sub-procedure) ............. 95
  C13-4  Cleaning Concrete Surface for Overlays ........................................................................ 96
  C13-5  Cleaning reinforcement (Sub-procedure) ...................................................................... 96
  C13-6  Adding reinforcement (Sub-procedure) ......................................................................... 96
  C13-7  Applying bonding coat to concrete (Sub-procedure) ....................................................... 97
  C13-8  Coating reinforcement (Sub-procedure) ........................................................................ 98
  C13-9  Formwork for re-casting concrete (Sub-procedure) ....................................................... 98
  C13-10 Curing (Sub-procedure) ................................................................................................ 99
  C13-11 Surface preparation for external coatings (Sub-procedure) ......................................... 100
  C13-12 Procedure ................................................................................................................... 100

Chapter 14  Repairing cracks in concrete structures ................................................................ 101
  C14-1  Types of cracks .............................................................................................................. 101
  C14-2  Repair methods for cracks ............................................................................................ 101
  C14-3  Cracks that should be repaired ...................................................................................... 101
  C14-4  Epoxy resin injection ..................................................................................................... 102
  C14-5  Grouting ......................................................................................................................... 103
  C14-6  Routing and sealing ....................................................................................................... 103
  C14-7  Drilling and plugging .................................................................................................... 104
  C14-8  Stitching ........................................................................................................................... 105
  C14-9  Adding reinforcement ..................................................................................................... 106
  C14-10 Surface treatments ........................................................................................................ 108
  C14-11 Flexible sealants for live cracks .................................................................................... 109

Chapter 15  Patch repairs of concrete structures ..................................................................... 111
  C15-1  Engineering discussion ................................................................................................. 111
  C15-2  Repair procedure with cement-sand mortars ............................................................... 111
  C15-3  Repair procedure with polymer modified cementitious mortars .................................... 112
  C15-4  Repair procedure with epoxy mortars ......................................................................... 112

Chapter 16  Recasting with concrete.......................................................................................... 113
  C16-1  Engineering discussion ................................................................................................. 113
  C16-2  Concrete mix design ..................................................................................................... 113
  C16-3  Repair procedures ......................................................................................................... 114
  C16-4  Replacing bearing pads ................................................................................................. 115

Chapter 17  Repairs for corrosion in concrete structures .......................................................... 117
Chapter 1  Introduction

C1-1  Purpose

Modern structures are typically designed and built in steel or concrete or a combination of both. RailCorp however is responsible for the maintenance of structures that date back to various eras and which are constructed in steel, wrought iron, concrete and masonry, with a limited number of timber structures.

Many structures within the RailCorp network are constructed in concrete including bridge substructures (piers and abutments), bridge superstructures (girders and deck slabs), tunnel linings, retaining walls, foundations for overhead wiring structures and station platform walls.

Numerous structures within the RailCorp network are constructed in masonry including some bridge substructures (abutments, piers, wingwalls), masonry arch bridges, jack-arch bridge superstructures, tunnels, retaining walls, foundations for overhead wiring structures and station platform walls.

Bridges with masonry substructures are commonly constructed with superstructures comprising steel girders, reinforced concrete slabs or prestressed concrete beams.

A suite of Maintenance Manuals has therefore been prepared, to provide guidance to personnel responsible for the inspection and assessment of structures in service and the undertaking of repair work.

The purpose of this Manual is to describe and detail standard repair procedures for defects commonly found in structures owned and maintained by RailCorp. Both new procedures and those that have been used successfully in the past on the maintenance of structures in the New South Wales rail system are included.

The advantages of adopting standard repair procedures are as follows:

− The standard repair procedures included in this Manual are both structurally sound and practically achievable. Adherence to these procedures will reduce the incidence of inappropriate and ineffective repairs or repairs that have adverse effects on the structure;
− Repairs will be undertaken in a consistent fashion throughout RailCorp, whether carried out by day labour or by contract;
− Engineering input into detailing sound repairs for individual works will be minimised, and duplication of effort in developing repair procedures avoided;
− The cumulative knowledge and experience gained in carrying out repairs can be incorporated in the standard repair procedures. This is an effective means of passing on knowledge.

C1-2  Who should use this Manual?

This Manual should be used by those responsible for:

− determining repair actions
− carrying out repairs
− inspecting and/or certifying completed repair work.

C1-3  References

TMC 301  Structures Examination
TMC 305  Structures Assessment
AS 1252 - 1996  High strength steel bolts with associated nuts and washers for structural engineering
AS 1554.1 – 2004  Structural steel welding – Welding of steel structures
C1-4 Definitions, abbreviations and acronyms

The following terminology is also used in this Manual:

APAS: Australian Paint Approval Scheme
Fracture Critical Member: Tension members or tension components of members whose failure would be expected to result in collapse of the bridge or inability of the bridge to perform its design function.
Tension: Force acting to stretch a structural member
Compression: Force acting to compress a structural member
Flexural Strength: Strength of a structural member in bending
Alkali Aggregate Reaction: Reaction which occurs over time in concrete between the cement paste and aggregates. This reaction can cause expansion of the aggregate, leading to spalling and loss of strength of the concrete.
Site Supervisor: A qualified civil engineer or a competent person with delegated engineering authority for steel repair supervision.

Refer to TMC 301 for “Terms used in bridges and structures”

C1-5 Nature of the repair procedures

The repair procedures are generic in nature. They are methods for repairing common types of defects and damage to structures. They apply to a range of similar situations, with variations in the size, position and arrangement of individual members. As such, it is not possible to completely detail the repair. Additional information such as the size and connections of strengthening elements and their precise position needs to be supplied to enable the repair to be completed.

However, guidelines for the selection of size, position and connections of strengthening elements are given wherever possible to minimise the amount of engineering input required. Such guidelines are often conservative and savings may be made in materials and labour requirements for the repair if the engineering details of the repair are determined by design for the specific case at hand. The savings may be significant and worthwhile if the extent of repair is large.
This manual is limited to repair methods that can be easily carried out by maintenance personnel and general contractors.

Techniques that require special equipment and expertise such as cathodic protection, chloride removal, and re-alkalisation have been excluded. These options are used in circumstances involving extensive deterioration and should be carried out with the assistance of organisations skilled in such work.

Repairs that appear to be difficult and extensive due to severe deterioration and that may require technical investigation and special equipment should be arranged through organisations experienced and skilled in testing and repair of concrete.

**Warning**
The application of the chapters on concrete repairs is limited to reinforced concrete structures only. The methods given herein should not be used for repairing prestressed concrete structures.

This Manual does not cover investigations and remedial measures for foundation movements and hydrological and hydraulic engineering problems such as erosion of stream beds, effects of floods or earthquakes that may be responsible for damage to masonry structures. Reference on these matters should be made to specialist engineers experienced in the particular fields.

The repair of masonry structures generally involves the same issues as for concrete structures.

**C1-6 Aim of the repair procedures**

The aim of the repair procedures is to restore the strength and serviceability of the structure, either to the "as new" condition, or to the condition that is required for current or envisaged use ("fit for purpose").

In developing repair details the normal design practices, as specified in the relevant Australian Standards, are applied. There should be the same level of confidence in the repaired structure as in a new structure. For steel structures, the fatigue life of the repaired structure should not be less than the life that would have remained had the defect not occurred.

Some of the repair procedures aim to restore the original integrity of the member. Other repairs, typically when used in steel structures, aim to compensate for the defect by the attachment of additional structural elements.

A few procedures that are included are not repairs as such, but rather actions that can be taken to reduce or arrest further deterioration of the structure, or make the structure easier to maintain.

**C1-7 Sub-procedures**

Some actions in the repair process are common to more than one repair procedure.

For example, the process of replacing a rivet with a high strength bolt is to be carried out in many of the repair procedures. These actions or sub-procedures are described and detailed in this manual.

Required sub-procedures are referred to in the main repair procedures.

**C1-8 Drawings**

Each repair procedure is detailed on one or more drawings in this Manual. It is envisaged that these drawings, together with the text of the procedure outline and any additional information from an engineering assessment will provide all the engineering detail required by site personnel to implement the repair.

As the drawings often include several alternative details, instructions on which alternative to use may also be required.
C1-9 Planning repair work

Repair work should be planned as follows:

− Carry out detailed damage survey. Indicate location, extent, severity and particulars of the damage.
− Investigate the cause of damage or deterioration by conducting field and laboratory tests as necessary. If corrosion is present establish the cause. Alternatively, determine if it is necessary to engage the services of a specialist consultant to carry out the investigation.
− Assess the strength and stability of the damaged structure.
− Establish the urgency of repairs.
− Examine alternative repair options, materials and methods.
− Assess if the repair work would require track closure, power outage, people and traffic control, flagmen, assistance from police and utility authorities, falsework, temporary structures and health, safety and environmental protection measures.
− Estimate the cost of repairs. Obtain competitive quotations/ tenders if necessary.
− Prepare a project repair report on the basis of the above. Recommend if the repair work be done by day labour, contract or through specialist agencies.
− Organise the repairs.
Chapter 2  Management requirements

Civil Maintenance Engineers are responsible for ensuring that work on structures is carried out by persons with appropriate competencies.

Project managers/supervisors are to ensure that reference to the appropriate procedures from this Manual is included in contract documentation for work by contractors.
### Chapter 3 Competencies

NOTE: These competencies may enable activities to be carried out in other manuals. For a comprehensive list of all activities that are covered by a given competency see Engineering Manual TMC 001 – Civil Technical Competencies and Engineering Authority.

<table>
<thead>
<tr>
<th>To carry out this work</th>
<th>You need these competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain structures</td>
<td>TDT B32 - Maintain structures and their components</td>
</tr>
<tr>
<td>- replace/tighten bolts</td>
<td></td>
</tr>
<tr>
<td>- clean abutments</td>
<td></td>
</tr>
<tr>
<td>- clean weep holes</td>
<td></td>
</tr>
<tr>
<td>- replace bearing plates and pads</td>
<td></td>
</tr>
<tr>
<td>- concrete repair sub-procedures</td>
<td></td>
</tr>
<tr>
<td>- concrete repairs¹</td>
<td></td>
</tr>
<tr>
<td>- masonry repairs¹</td>
<td></td>
</tr>
<tr>
<td>- steel repair sub-procedures</td>
<td></td>
</tr>
<tr>
<td>Maintain structures</td>
<td>TDT B32 - Maintain structures and their components AND Certificate III in Engineering – Fabrication Trade</td>
</tr>
<tr>
<td>- steel repairs</td>
<td></td>
</tr>
<tr>
<td>Repair impact damage to steel structures by grinding²</td>
<td>TDT B32 - Maintain structures and their components AND Certificate III in Engineering – Fabrication Trade</td>
</tr>
<tr>
<td>Repair concrete structures¹</td>
<td>TDT B32 - Maintain structures and their components AND Certificate III or equivalent³</td>
</tr>
<tr>
<td>Repair masonry structures¹</td>
<td>TDT B32 - Maintain structures and their components AND Certificate III or equivalent⁴</td>
</tr>
<tr>
<td>Repair structures using epoxies and grouts</td>
<td>TDT X13 - Mix and place chemical repair products</td>
</tr>
<tr>
<td>Patch painting of steel structures</td>
<td>MEM 8.14A - Apply protective coatings (basic)</td>
</tr>
</tbody>
</table>

Notes

1. Refer to TMC 001 Table 4 for details

2. However, minor grinding may be done by non-boilermaker staff under supervision of the Structures Manager or a site supervisor.

3. Certificate III in Carpentry, Concreting, Civil Construction or equivalent

4. Certificate III in Bricklaying/Blocklaying, Concreting, Civil Construction or equivalent
Chapter 4  Steel repair sub-procedures

C4-1  Arresting corrosion (Sub-procedure)

C4-1.1  Description of action

Any action that will prevent further deterioration and loss of section in steel due to corrosion.

C4-1.2  Engineering discussion

Arresting of corrosion may be the only repair action that is required or possible for a steel structure, or it may be required in conjunction with other repair actions.

The most effective method of arresting corrosion is abrasive blast cleaning followed by the correct application of a high quality paint system and its ongoing maintenance.

If that form of corrosion arrest is appropriate, refer to the sub-procedure for patch painting for information on preparing for and carrying out patch painting. Note that the use of so called "rust converters" prior to painting is not permitted.

In addition to painting, action can be taken to avoid conditions which promote corrosion. Action to avoid collection and entrapment of water may be worthwhile. In some locations, holes may be drilled to allow water to drain away. Voids and depressions which catch water may be filled with epoxy. Epoxy fillers may also be used to profile a surface to promote free drainage of water. Advice on appropriate epoxies should be sought from the recognised manufacturers. Epoxies should be durable, paintable, and should bond adequately to the substrate. Epoxy with some flexibility may be appropriate for the purpose described.

Denso Tape covering of steel elements may be a suitable alternative to painting. Denso tape could be used at the interface between concrete and steel or timber and steel. These locations are typically difficult to protect by painting. The interface between steel beams and other metal elements such as steel decking may be treated similarly.

One advantage of Denso tape is that the amount of surface preparation required is minimal. All that is usually required is the removal of loose rust, dirt, paint etc. from the surfaces. The primers and fillers can then be applied.

Guidance on the appropriate Denso Tape treatment and its correct application should be sought from the manufacturer.

Caution:

Corrosion protection systems such as Denso Tape wrapping and epoxy filling may hide critical defects such as fatigue cracks. Such defects may be difficult to detect during normal inspections and may result in collapse of the structure.

Corrosion protection systems such as these should not be used on fatigue-critical elements unless appropriate procedures to regularly check for and detect cracks are implemented.

C4-1.3  Procedure

- Prepare for and apply Denso Tape, epoxy fillers etc. in accordance with the manufacturer's recommendations.
- Where patch painting is to be used for corrosion arrest, refer to the sub-procedure.

C4-1.4  Materials

Refer to the manufacturers of Denso Tape systems and epoxy resins for advice on suitable materials for each particular case.

C4-1.5  Alternative details
None.

C4-2 Removing rivets and replacing with bolts (Sub-procedure)

C4-2.1 Description of action

This sub-procedure covers the removal of existing rivets and replacement with high strength friction grip bolts and also installation of new high strength bolts. Often the bolts also attach new steel elements.

C4-2.2 Procedure

C4-2.2.1 Remove one head of the rivet

To remove rivet heads use one of three methods:

- cutting using oxy-fuel equipment
- grinding off all or part of the head
- drilling through the centre of the rivet head.

**Oxy-fuel cutting:**

- Because of the possibility of creating heat affected zones in tension regions of main members and adversely affecting their fatigue life, avoid using oxy-fuel cutting to remove the head except where it is adjacent to:
  - any steel that is to be removed and discarded as part of the repair process;
  - intermediate web stiffeners; or
  - minor bracing members that are not subject to dynamic or cyclic loading.

**Caution:**

*No cutting is to be done on broad flange beam spans without prior discussion with the RailCorp Civil Design Section.*

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

For web stiffeners and bracing members, 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:**

- If removing the head by grinding, it is only 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.

**Drilling:**

- Rivet heads may be removed by drilling along the axis of the rivet with a drilling bit larger in diameter than the shank.

C4-2.2.2 Remove the rivet
After the head of the rivet has been removed, force the remaining part out of the hole by punching or using hydraulic rams etc. The rivets are often not easily removed by punching because of deformation of the shaft in slightly misaligned holes.

Alternatively, remove the rivet head and shank and prepare the hole to accept the new bolt in one operation by drilling all the way through the rivet. The drill bit size must be slightly larger than the rivet hole size and must be of a size to suit installation of a high strength bolt.

First drill a small hole through the rivet. Where the remainder of the rivet cannot be removed by the above means, it is permissible to burn a hole through the centre of the shank using oxy-fuel equipment to assist in the removal process. As stated above, extreme care is required to avoid any flame-effects on the surrounding steel. This operation is only to be carried out by experienced operators. Any flame-affected areas of steel must be completely removed by reaming the hole prior to installing the bolt.

The following techniques are suggested for plates of varying thickness:

Option A

Using oxy-acetylene or LPG (LPG preferred option):

For plate thickness combinations of 0mm to 40mm:

- Adjust torch to a neutral flame, using a large gouger: either 48 GB Type 44 or 41, or 64 GB Type 44 or 41.
- Heat head of rivet to required temperature (melting point), ensuring no heat application to adjacent members.
- Carefully flush the rivet head ensuring no gouging to the adjacent member.
- Remove slag using a chipping hammer or chisel.
- Using an appropriate sized punch attempt to knock out the rivet.
- If rivet is keyed in and fails to move flush opposite head (tail) in accordance with the following steps:
  - Heat rivet from one side, using a cutting tip pierce through rivet. If applicable drill a small hole through rivet prior to piercing.
  - Remove slag then punch out rivet.
- If rivet remains keyed in, enlarge pierced hole leaving approximately 3mm of rivet shank. This will ensure scarring of the adjacent member is avoided.
- Punch out remainder of rivet.

For plate thickness combinations of 40mm and greater:

It will be necessary to simultaneously heat the rivet from both sides prior to piercing. From one side in the first instance, or both sides if later necessary.

Note: If scarring occurs it will be necessary to ream the hole before fitting bolts.

Option B

All of the foregoing where applicable except drilling to be used in lieu of piercing.

C4-2.2.3 Prepare the hole for the bolt

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.

The hole diameter after reaming must be no more than 2mm larger than the diameter of the bolt to be installed unless a plate washer is to be installed in accordance with Detail A on Figure 1. In the latter case, the hole diameter may be up to 10mm greater than the bolt diameter.

Use reaming to remove any areas of steel around the hole that have been flame-affected during the removal of the rivet.
The following requirements are extracted from AS 5100 – Bridge design:

The minimum edge distance for new bolt holes in existing or new steel is 1.5 times the nominal diameter of the bolt.

Edge distance is the distance from the nearer edge of a hole to the physical edge of a plate or rolled section, plus half the nominal diameter of the bolt.

The maximum edge distance is 12 times the thickness of the thinnest element being connected, but not more than 150mm.

The minimum spacing between centres of new bolt holes is 2.5 times the nominal diameter of the bolt. The maximum spacing is the lesser of 15 times the thickness of the thinner element being connected or 200 mm.

C4-2.2.4 Install the bolt

Install the replacement bolt in accordance with the following specification.

Table 1 specifies minimum replacement bolt sizes.

The arrangement for oversize holes is shown in Detail A of Fig 1.

The arrangement for blind fasteners is shown in Detail B of Fig.1.

Specification for new or replacement bolts:

- All bolts are to be high strength structural bolts of grade 8.8 to AS 1252 “High strength steel bolts with associated nuts and washers for structural engineering”, fully tensioned to AS 4100 “Steel structures” as a friction joint. Tension is to be controlled by load indicating washers or turn of nut method. Direct-tension indication devices may be used provided they conform to the requirements of AS 4100 Clause 15.2 and they are used strictly in accordance with the manufacturers’ instructions.

- Swage bolts installed in accordance with the manufacturer's instructions, may be used as an alternative.

- All bolts, nuts and washers are to be galvanized.

- Swage bolts, pins and washers are to be galvanised and the steel surface exposed after separation of the pintail is to be painted.

- Nominal maximum hole diameter to be the diameter of the fastener +2mm unless plate washers, as illustrated in Detail A are used, unless otherwise specified for swage bolts.

- For each standard rivet size the minimum size of replacement bolt to give equivalent shear capacity is given in Table 1. Larger bolts may be used.

- For Huck BOM (Blind, Oversize, Mechanically locked) blind fasteners, sufficient room must be available on the blind side to accommodate the expanded head. Refer to Detail B of Figure 1.

<table>
<thead>
<tr>
<th>Rivet size</th>
<th>Bolt size 8.8 T/F</th>
<th>Huck Bolt C50L</th>
<th>Huck-Fit Grade 10.9</th>
<th>Huck BOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;</td>
<td>M20</td>
<td>3/4&quot;</td>
<td>Ø20mm</td>
<td>3/4&quot;</td>
</tr>
<tr>
<td>7/8&quot;</td>
<td>M24</td>
<td>7/8&quot;</td>
<td>Ø22mm</td>
<td>-</td>
</tr>
<tr>
<td>1&quot;</td>
<td>M27</td>
<td>1&quot;</td>
<td>Ø27mm</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1 - Minimum replacement bolt sizes

If Huck bolts are used, the HUCK-FIT fastening system is recommended as the pins are available in standard metric sizes including non-preferred sizes (M20, M22, M24, M27 etc.). The HUCK-FIT system allows fit up and snug tightening of bolts prior to tensioning. Huck bolts are to be installed in accordance with the manufacturer's instructions.

Alternative details:
If there is only access to one side of plates to be bolted, use Huck BOM blind fasteners, installed in accordance with the manufacturer's instructions. Use galvanised BOM fasteners. Make sure there is adequate room for the enlargement of the blind side head (refer to detail B in Fig 1 above).

Note that Huck BOM fasteners are not friction grip connectors and may not be suitable for all situations. Bolt slip may occur to the limit of the hole clearance. Slip can be minimised by drilling close tolerance holes (19 to 20mm for 3/4" as shown in Fig 1).

A similar blind fastener for high strength friction grip applications is available from Huck on special order. It is known as the USBB (Ultra Strength Blind Bolt). Use these fasteners when blind friction grip connections are essential.

![Diagram of blind fastening system](image)

**Figure 1 - Specification for replacement bolts**

### C4-3 Patch painting (including surface preparation) (Sub-procedure)

#### C4-3.1 Description of action

Patch painting is required in conjunction with steel repair as a corrosion protection system for new and existing steel in the vicinity of the repair, and to restore a uniform appearance to a structure.

Patch painting to arrest corrosion may be the only form of repair required.

This sub procedure only covers painting to small areas where hand and power tool preparation is the only feasible method.

Large areas, where the cost of abrasive blast cleaning can be justified, should be painted in accordance with RailCorp’s standard practices as detailed in Chapter 10.

#### C4-3.2 Engineering discussion

##### C4-3.2.1 Paint systems

Paint systems for patch painting should ideally have the following characteristics:

- Formulated to provide good adhesion and protection to poorly prepared steel surfaces (hand or power tool preparation).
- Formulated to bond to sound existing paints of the types typically found on existing steel structures.
- High build, single coat systems to minimise total painting time (i.e. adequate film thickness applied in one coat).
Available in a large range of colours to blend with colour of existing paint and avoid the
necessity for a colour matched top coat.

− Able to bond adequately to galvanised steel.
− Suitable for top coating where a top coat is required.

Leading paint manufacturers have paint systems with most of the above characteristics. One
system specifically developed for this application is a two part surface tolerant epoxy mastic.

ALKYD systems are not suitable for application to galvanised surfaces because the long term bond
cannot be guaranteed.

Where galvanised parts have been fitted as part of the repair and the selected patch paint system
is not suitable for galvanised surfaces, the following options exist:

− Leave the galvanised surface unpainted. Painting is normally only necessary to achieve a
uniform appearance with the rest of the steel; or
− Use different single coat systems for galvanised and ungalvanised surfaces. Systems for
galvanised surfaces are readily available. Galvanised parts can be painted prior to installation; or
− Apply the standard single coat patch paint to ungalvanised surfaces, then apply a suitable top
coat to both galvanised and patch painted surfaces. Top coat systems suitable for such
situations are available; or
− Paint new steel parts instead of galvanising them. Use the patch paint system on site or,
where parts can be prepainted, use the paint system adopted for repainting of bridges. Abrasive blast cleaning is required for the latter.

C4-3.2.2 Surface preparation

Shaded sections below are extracted from AS 1627.2 – Metal finishing – Preparation and pre­
treatment of surfaces – Power tool cleaning and AS 1627.4 - Metal finishing – Preparation and pre­
treatment of surfaces – Abrasive blast cleaning.

Surface preparation by hand and power tool cleaning, such as scraping, wirebrushing, machine­brushing and grinding, is designated by the letters “St”.

The minimum surface preparation for small areas is usually specified by paint manufacturers as
hand or power tool cleaning to preparation grade St 2.

St 2 is thorough hand and power tool cleaning. When viewed without magnification, the surface
shall be free from visible oil, grease and dirt, and from poorly adhering mill scale, rust paint
coatings and foreign matter.

− 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.

− 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 described in Section C4-4.

  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 microns) is achieved at all sharp ridges.

− For galvanised surfaces:
  Prepare the galvanised surface for painting in accordance with the paint manufacturer's
  recommendations. Coating manufacturers usually recommend degreasing and abrasion, acid
etching or pretreatment 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 pretreatment with etch primer.

C4-3.2.3 Hand tool cleaning

Hand tool cleaning is the method of preparing steel surfaces by the use of hand tools, without power assistance. Hand tool cleaning is sometimes carried out initially in order to remove relatively loose contaminants prior to the use of power tools.

The materials and hand tools which may be used include the following:

- Knives, scrapers, chisels and chipping hammers for removing slag, laminated rust scale, chipping old paint, loose rust
- Hand wire brushes, abrasive coated paper and plastic fleece with embedded abrasive for final hand preparation including feathering edges of any firmly adhering coating system.

C4-3.2.4 Power tool cleaning

Power tool cleaning is the method of preparing steel surfaces by the use of power-assisted hand tools, but excluding blast-cleaning.

Acceptable power tools are those driven by either compressed air or electricity.

The types of tool which may be used include the following:

- Chipping hammers and rotary scalers for removal of rough scale, including heavy laminated scale
- Needle guns for welds, recessed work and fasteners
- Sanding machines, sanding discs, rotary wire brushes, rotary abrasive-coated paper wheels, rotary finishing brushes having filaments impregnated with abrasive grit, and plastic fleece with embedded abrasive for removing rust, rust scale and paint
- Power grinders to smooth welds, edges etc prior to general finishing.

Power tool cleaning requires care to prevent excessive roughening of the steel surface. Ridges and burrs contribute to paint failures as sharp edges are often not covered by the specified thickness of paint.

Similarly excessive power wire brushing or discing can also be detrimental to paint adhesion, for instance residual mill scale can easily be burnished to a smooth surface to which paint will poorly adhere.

The use of needle guns should be limited to welds, corners, uneven edges etc as the impact of the needles can cause an unacceptable profile on flat surfaces.

C4-3.3 Procedure

C4-3.3.1 Initial treatment

Before hand and/or power tool cleaning, remove heavy oil or grease by means of a scraper and then, as far as possible, remove further contamination by one or a combination of the following methods:

- Brushing with stiff fibre or wire brushes
- Cleaning with appropriate solvents or solutions (e.g. emulsion or detergent cleaners), followed by rinsing with potable (tap) water. The solvents or solutions may be applied with a stiff fibre or wire brush.
- Treatment with potable water or steam

C4-3.3.2 Hand tool cleaning
Hand tool cleaning should preferably be carried out in the following sequence of operations:
- Use impact hand tools to remove laminated rust and rust scale
- Use impact hand tools to remove all loose weld slag and weld splatter
- Use hand wire brushing, hand abrading, hand scraping or other similar non-impact methods to remove all loose mill scale, all loose or non-adherent rust and all loose paint.

C4-3.3.3 Power tool cleaning

Power tool cleaning should preferably be carried out in the following sequence of operations, modified as necessary if hand tool cleaning is carried out initially:
- Use rotary or impact power tools to remove laminated rust or rust scale to the specified preparation grade
- Use rotary or impact power tools to remove weld slag and weld splatter to the specified preparation grade
- Use power wire brushing, power abrading, power impact or power-assisted rotary tools to remove loose mill scale, loose or non-adherent rust and loose paint to the specified preparation grade. Take care not to burnish the surface.

C4-3.4 Final preparation before painting

Remove any burrs, sharp edges or sharp cuts that have been produced during the cleaning operation.

Immediately before painting, unless otherwise specified, ensure that any remaining sound paint has no residual gloss. Ensure that the edges of any remaining intact paint have been feathered (bevelled) using one of the methods in C4-3.3.2 or C4-3.3.3.

Dry the surface, if necessary, and remove any residual loose matter resulting from the cleaning methods by brushing, vacuum cleaning or a blast of clean, dry compressed air.

C4-3.5 Apply the paint

Mix the components of the 2-part surface-tolerant epoxy mastic paint and apply in accordance with the manufacturer’s instructions. Apply by brush or roller for small areas, spraying for larger areas.

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 150 micrometres (μm).

C4-3.4 Repair materials

Paint systems suitable for patch painting are typically 2 part epoxy based, surface tolerant high build systems.

C4-3.5 Alternative details

None.

C4-4 Filling voids (Sub-procedure)

C4-4.1 Description of action

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

C4-4.2 Engineering discussion
Where the latter is the reason for void filling, the epoxy filler is often structural. It may be required to resist the compressive forces created by the tensioning of bolts or, in the case of bearing plates, transfer bearing forces.

The necessity for void filling depends on the severity of corrosion and uniformity and general profile of the corroded surface (after preparation). If the surface is uniformly pitted so that the surface remains generally flat and steel attachments would not distort when fixed by tensioned bolts, void filling is not necessary. The steel surface would still be able to transfer forces described above. Sealing the steel to steel interfaces, however, may be required - refer to sub-procedure in Section C4.5).

On the other hand, severely corroded surfaces that are uneven normally require filling prior to covering with new steel parts, to prevent distortion of those parts.

Notwithstanding the above, it may be worthwhile applying epoxy fillers to any deeply corroded surface prior to attaching new parts. As well as filling voids, the epoxy acts like a primer paint and also seals the interface between new and existing steel ready for painting. The adhesive quality of epoxies may also be useful in some repairs.

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.

Select the procedure which best suits the repair being carried out. Consider particularly the hardening time for the epoxy.

### C4-4.3 Procedure

#### C4-4.3.1 Alternative 1 - New steel elements fitted before epoxy hardens

- Prepare the existing steel surface by abrasive blast cleaning to Sa 2½. If abrasive blast cleaning is impractical due to small areas involved, power tool clean to preparation grade St 2.
- 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.
- 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.
- Clean away excess epoxy and make sure all steel to steel interfaces are effectively sealed at the perimeters ready for painting.
- Tension the bolts after the epoxy has cured.

#### C4-4.3.2 Alternative 2 - New steel elements fitted after epoxy hardens

- Prepare the existing steel surface by abrasive blast cleaning to Sa 2½. If abrasive blast cleaning is impractical due to small areas involved, power tool clean to preparation grade St 2.
- Mix the epoxy according 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.
- Clean away excess epoxy. Ensure that empty bolt holes are not obstructed by epoxy.
- After the epoxy has cured, fit the steel part and fully tension any bolts.
- Seal any remaining gaps at interfaces in accordance with sub-procedure C4.5.

### C4-4.4 Repair materials
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.

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

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

C4-4.5 Alternative details
Where the thickness of epoxy filler to be applied is significant, a combination of both procedures described above may be used. Use Alternative 2 procedure to apply the bulk of the filler, and leave the surface at or below that required and approximately even. Then use Alternative 1 procedure to fill the remaining dips and valleys in the surface.

C4-5 Sealing interfaces (Sub-procedure)

C4-5.1 Description of action
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.

C4-5.2 Engineering discussion
Paint manufacturers recommend against painting over large gaps.

While the applied paint may initially span these gaps, it may subsequently crack due to drying shrinkage or it may not cure properly because of the excess film thickness. Gaps of width more than twice the maximum recommended film thickness or 0.5mm are to be sealed as described.

C4-5.3 Procedure
- 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, power tool clean to Class 2 in accordance with AS 1627.2.
- 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.
- 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 manufacturer's instructions.

C4-5.4 Materials
Use a single component polyurethane sealant suitable for being painted over with solvent based paints.

C4-5.5 Alternative details
Where voids between steel elements are to be filled, extending the void filling epoxy to the edges of the steel will generally avoid the necessity to seal interfaces as a separate operation.
Chapter 5  Repairing corroded flanges and webs of steel I girders

C5-1  Repairing flange corrosion in riveted girders

C5-1.1  Description of defect
Loss of cross-sectional area of top or bottom flange plates in a riveted plate web girder resulting from significant corrosion.

This repair is also to be used where loss of cross-sectional area of flange angles has occurred.

C5-1.2  Description of repair
Fit a galvanised cover plate, sufficient in nett area to compensate for the lost cross-sectional area.

C5-1.3  Engineering discussion
It will be necessary to carry out an engineering assessment to determine the necessity for, and extent of, cover plating required. The assessment should determine the cover plate section size and the number and location of rivets that are to be replaced by bolts.

As a guide, up to 10% section loss is permissible before the repair is necessary. The nett cross-sectional area of the cover plate should be at least twice the maximum area of corrosion loss. The minimum plate thickness is to be 10mm.

If a significant proportion of the section loss has also occurred in the flange angle(s), the engineering assessment should determine if the angle(s) is capable of transferring shear force to the flanges. If not, the corrosion of the flange angle(s) should first be considered as a separate defect.

Consideration could be given to replacement of the continuous flange angle(s) by flange angle segments between web stiffeners. In this case the nett area of the cover plate must be sufficient to also compensate for the discontinuity of flange angle(s).

In determining the extent of cover plating, the transfer of load (development of stress) into the plate must be considered. Conservative guidelines for the number of fasteners required to develop maximum permissible stress in the plate are detailed below:

The number of bolts in the cover plate must be sufficient to develop the maximum permissible strength in the cover plate.

The number of bolts to achieve the above requirement is given in Table 2, based on the nett area of the cover plate (Acn) in cm² and the bolt size.

<table>
<thead>
<tr>
<th>Bolt size</th>
<th>No. of bolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>M20</td>
<td>5.4 x Acn ÷ 1000</td>
</tr>
<tr>
<td>M22</td>
<td>4.4 x Acn ÷ 1000</td>
</tr>
<tr>
<td>M24</td>
<td>3.7 x Acn ÷ 1000</td>
</tr>
<tr>
<td>M27</td>
<td>2.9 x Acn ÷ 1000</td>
</tr>
</tbody>
</table>

Table 2 - Number of bolts in cover plate

Because only a few fasteners are removed at any one time, theoretically the girder remains at near full strength throughout the repair. Nearly all existing rivets can be replaced by bolts if necessary. Bracing connected by flange rivets must remain adequately connected.

To avoid unnecessary work however, only the minimum number of rivets, as shown by engineering assessment, should be replaced by bolts.

The maximum edge distance and fastener spacing given in C4-2.2.3 should be observed so that the interface to the cover plate is tight and crevice corrosion is avoided.
C5-1.4 Sub-procedures required

- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)
- Filling Voids
- Sealing Interfaces

C5-1.5 Procedure outline

- Remove heads of rivets in accordance with the sub-procedure that are to be replaced by bolts. Remove the under side heads for bottom flanges and the top side heads for top flanges. For top flange rivet removal, fit clamps to the under side to prevent rivets falling out.
- 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 in accordance with sub-procedure for filling voids to create a flat surface for seating the cover plate.
- Position the pack plates and cover plate, holding them in place with clamps.
- Progressively remove rivets to be replaced and fit and tension replacement bolts. No more than 10% of rivets, evenly distributed along member, are to be removed at any one time.
- Seal open interfaces to new steel where required in accordance with the sub-procedure for sealing interfaces. Fill exposed rivet head holes on the top flange in accordance with the sub-procedure for filling voids to prevent collection of water.
- Prepare for and paint new steelwork and areas of existing steelwork to the extent directed, in accordance with the sub-procedure for patch painting.
C5-1.6  Action to avoid or minimise recurrence

- Routine maintenance to remove built-up dirt and debris on the upper surfaces.
- Routine maintenance to the paint system.

C5-1.7  Alternative details

None

C5-1.8  Special considerations and effects of repair.
The engineering assessment may determine that speed restrictions or a track possession is required while this repair is being carried out.

**C5-1.9 Follow up inspections and testing**
- Programmed inspections only.
- Pay particular attention to new steel to steel interfaces to detect early signs of paint system breakdown and steel corrosion.

**C5-1.10 Drawings List**
Figure 2 - Repairing flange corrosion in rivetted girders.

**C5-2 Repairing flange corrosion in rolled or welded girders**

**C5-2.1 Description of defect**
Loss of cross-sectional area of top or bottom flange plates in a welded or rolled girder resulting from significant corrosion.

**C5-2.2 Description of repair**
Fit a galvanised cover plate sufficient in nett area to compensate for the lost cross-sectional area.

**C5-2.3 Engineering discussion**
It is usually necessary to carry out an engineering assessment to determine the necessity for and extent of cover plating required. The assessment should determine the cover plate section size and the number, size and location of connection bolts required.

As a guide, up to 10% section loss is permissible before the repair is necessary. The nett cross-sectional area of the cover plate should be at least twice the maximum area of corrosion loss. The minimum plate thickness is to be 10mm. The nett area of cover plate must also compensate for the existing flange area lost in drilled holes.

In determining the extent of cover plating, the transfer of load (development of stress) into the plate must be considered. Conservative guidelines for the number of fasteners required to develop maximum permissible stress in the plate are detailed below:

- The number of bolts in the cover plate must be sufficient to develop the maximum permissible strength in the cover plate;
- The number of bolts to achieve the above requirement is given in Table 3, based on the nett area of the cover plate (Acm) in cm² and the bolt size.

<table>
<thead>
<tr>
<th>Bolt size</th>
<th>No. of bolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>M20</td>
<td>5.4 x Acm ÷ 1000</td>
</tr>
<tr>
<td>M22</td>
<td>4.4 x Acm ÷ 1000</td>
</tr>
<tr>
<td>M24</td>
<td>3.7 x Acm ÷ 1000</td>
</tr>
<tr>
<td>M27</td>
<td>2.9 x Acm ÷ 1000</td>
</tr>
</tbody>
</table>

*Table 3 - Number of bolts in cover plate*

The strength of the girder is reduced during the repair because of the holes drilled in the flange. Appropriate load and/or speed restrictions must be applied.

The maximum edge distance and fastener spacing given in C4-2.2.3 should be observed so that the interface to the cover plate is tight and crevice corrosion is minimised.

**C5-2.4 Sub-procedures required**
- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)
− Filling Voids
− Sealing Interfaces

C5-2.5 Procedure outline
− Mark and drill holes in the flange to suit the cover plate.
− 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.
− Position the cover plate, holding it in place with clamps.
− Fit and tension all bolts.
− Seal open interfaces to new steel where required.
− Prepare for and patch paint new steelwork and areas of existing steelwork to the extent
  directed.

C5-2.6 Alternative details
None.

C5-2.7 Action to avoid or minimise recurrence
Routine maintenance to remove built-up dirt and debris on the upper surfaces.
Routine maintenance to the paint system.

C5-2.8 Special considerations and effects of repair
The engineering assessment may determine that speed restrictions or a track possession is
required while this repair is being carried out.

C5-2.9 Follow up Inspections and testing
Programmed inspections only.
Pay particular attention to new steel to steel interfaces to detect early signs of paint system
breakdown and steel corrosion.

C5-2.10 Drawings
Figure 3 – Repairing flange corrosion in rolled or fabricated girders.
C5-3 Repairing web corrosion near bottom flange angles in riveted girders

C5-3.1 Description of defect

Severe corrosion of the web of a riveted girder at the junction of the upper toe of the bottom flange angle(s). Loss of web section in plan view results.

C5-3.2 Description of repair

Fit galvanised cover plates over the region of corrosion loss. The cover plates are to be in discrete lengths between web stiffeners.

C5-3.3 Engineering discussion

It is recommended in most cases that an engineering assessment be carried out to determine the necessity of repair and the locations where cover plate segments are required.

In the absence of engineering assessment, the following guidelines should be applied: Cover plate the segment of web between stiffeners where the average loss of web area in the panel in plan view exceeds 15%.

In the engineering assessment, the necessity for a cover plate should be based on the ability of the remaining web area (plan view) to transfer the shear stresses to the flange.

This repair may not be satisfactory at the girder bearing location where stresses additional to shear stresses occur.

It should be recognised that the shear transfer stresses are often low, particularly in the middle half of the span, so considerable section loss may be tolerable. Corrosion arrest may be all that is required. Irrespective of shear transfer stress levels, the web panel should be repaired where section loss exceeds 40%.
Alternative repair details involving site welded cover plates are not normally acceptable, because of the significant reduction in fatigue life that results from welding fitments in this tensile zone.

If a detailed engineering assessment is not carried out, the cover plate should incorporate all rivets through the vertical leg of the flange angle. The upper part of the cover plate should be attached by bolts of the same number and size as the lower part.

An engineering assessment may determine that a reduced number of bolts is adequate for a particular web panel.

C5-3.4 **Sub-procedures required**

- Arresting Corrosion
- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)
- Filling Voids
Figure 4 - Repairing web corrosion near bottom flange angles in riveted girders

C5-3.5 Procedure outline

- 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:

Outside face

Inside face

Pack plate (galvanised) Thickness to match flange angle

Cover plate (galvanised) Thickness ≥ web plate thickness

New bolt - one for each bolt in lower part of cover plate

Area of corrosion loss

Fill void

Bolt replacing each rivet

Flange angle

Flange plate

D = 1.75 x d (dia of fastener)

Patch paint to arrest corrosion

5 to 10mm

Top of corroded section

40mm minimum

Typical elevation of typical riveted girder panel.
Drill holes in the web above flange angle to match the holes in the prefabricated, galvanised cover plate and pack plate.

Remove the rivets through vertical legs of angles.

Position the pack plate and fill the void between the pack and the flange angle.

Fit the cover plate and install and tension all bolts.

Repeat steps 2, 3, 4 and 5 for each web panel requiring plating, then

Prepare for and patch paint new steelwork and areas of existing steelwork to the extent directed, including the region of corrosion on the unplated side.

**Caution:**

Rivets must NOT be removed from more than one panel of web at any one time.

C5-3.6 Alternative details

Cover plates may be fitted to both sides of web to improve appearance by covering the area of web corrosion.

C5-3.7 Action to avoid or minimise recurrence

Routine maintenance of paint system particularly at crevices and steel to steel interfaces.

The repair detail presents a similar situation to the original corrosion prone details so proper maintenance of the paint system is essential to avoid recurrence of the defect.

C5-3.8 Special considerations and effects of repair

The engineering assessment may determine that speed restrictions or a track possession is required while this repair is being carried out.

C5-3.9 Follow up inspections and testing

Programmed inspections only.

Pay particular attention to new steel to steel interfaces to detect early signs of paint system breakdown and steel corrosion.

C5-3.10 Drawings

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

C5-4 Repairing webs with localised corrosion

C5-4.1 Description of defect

Localised severe corrosion of a web leading to significant loss of web section in plan view. Typically this defect occurs where concrete ballast troughs have been in direct contact with the girder web.

C5-4.2 Description of repair

Fit galvanised cover plates over the regions of web where the section loss has occurred. The cover plates are to be in discrete lengths between web stiffeners.

C5-4.3 Engineering discussion

It is recommended that an engineering assessment be carried out to determine the effect of the section loss on the girder shear capacity and hence the necessity of repair and the location, size and bolt arrangement of cover plates.

In the absence of an engineering assessment, the following guidelines may be applied: Segments of web between stiffeners are to be cover plated where the loss of area in sectional view exceeds
10% of the total web area or where the loss of area in plan view exceeds 15%. Guidelines for the size and spacing of attachment bolts are given in Figure 4.

It should be recognised that, where the web thickness is constant for the girder, there is often an excess of shear capacity, particularly near mid span. A considerable loss of section may be tolerable at these locations before the repair is required. The assessment may show that only corrosion arrest is required in some panels where section loss exceeds the above guideline figures.

The engineering check on the reduced shear capacity of the web must, of course, consider web buckling as well as shear stresses.

**Caution:**

*Alternative repair details involving welded cover plates may be permissible if testing indicates that the steel is weldable and welding does not reduce the fatigue life unacceptably.*

Corrosion loss, localised near the mid-height of the girder in panels near mid-span, may be repairable by using welded cover plates, as tensile stresses in these areas are low. Do not weld to web stiffeners.

It is important to note that significant principal tensile stresses occur at mid-height of girders near the span ends as a result of shear forces. Welded cover plates are not normally permitted here because of the adverse effect on fatigue life.

### C5-4.4 Sub-procedures required

- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)
- Filling Voids
- Sealing Interfaces
**Figure 5 – Repairing webs with localised corrosion**

**C5-4.5 Procedure outline**

- Cut back reinforced concrete etc. that is causing corrosion as directed.
- Remove all rust, dirt, adhering concrete, old paint etc. from the area to be plated by mechanical wire brushing and scraping.
− Mark and drill bolt holes in the web to match the holes in prefabricated, galvanised cover plates.
− Fill voids and surface pitting with epoxy resin filler over area of web to be covered.
− Position cover plates and fit and tension bolts. Seal with epoxy any open interfaces around the perimeter of the cover plates.
− Prepare for and patch paint new steelwork and areas of existing steelwork to the extent directed.

C5-4.6 Alternative details
None.

C5-4.7 Action to avoid or minimise recurrence
Remove concrete cast directly against or in close proximity to web. Reconstruct accessways etc. to approved details, e.g. using gridmesh.

Routine maintenance of paint system, particularly at crevices and steel to steel interfaces.

C5-4.8 Special considerations and effects of repair
None

C5-4.9 Follow up inspections and testing
Programmed inspections only.

Pay particular attention to new steel to steel interfaces to detect early signs of paint system breakdown and steel corrosion.

C5-4.10 Drawings
Figure 5 – Repairing webs with localised corrosion.

C5-5 Repairing corroded bottom flanges of jack arch bridges
C5-5.1 Description of defect
Severe corrosion of the bottom flange of jack arch bridge girders resulting in a significant loss of cross-sectional area.

C5-5.2 Description of repair
Fit a galvanised cover plate to the bottom flange sufficient in cross-sectional area to compensate for the loss of cross-sectional area. If the existing steel is weldable, connect the cover plate by welding (Case B). Otherwise use Huck BOM blind fasteners (Case A).

C5-5.3 Engineering discussion
This repair is only effective in restoring full strength if the remainder of the girder section is in good condition. It is difficult to determine the condition of the girders in a jack arch bridge as only the underside of the bottom flange can be readily inspected for loss of section.

An engineering assessment should be carried out to determine:

− the necessity for the repair;
− if the repair is likely to be effective in restoring full strength;
− if the steel is weldable;
− the size and extent of the cover plate and, if bolted connections are to be used, the arrangement of connection bolts.

Use bolted connections if the steel is not weldable or the existing flange edge is severely feathered, precluding welding. Feathered edge to be ground to provide minimum 5mm thickness.
As a guide, the repair should be carried out if loss of bottom flange cross section exceeds 15%. The net area of the cover plate should be at least twice the maximum area of cross-sectional loss, plus the area removed by drilling for fixing bolts. The minimum plate thickness is to be 10mm and the width selected to suit the bolt gauge and edge distance or weld details. Extend the cover plate as close to the bearings as possible (within span/10) so the termination weld is in a region of low stress.

An engineering assessment may show that other details are acceptable.

Where bolted fixings are used, the spacing and edge distances must comply with the requirements in C4-2.2.3.

C5-5.4 Sub-procedures required
- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)
- Filling Voids
- Sealing Interfaces
Epoxy seal

Terminate cover plate in low stress region

Part elevation – Girder in Jack Arch bridge

Typical section

Pocket excavated to accommodate expanded fastener head

Area of corrosion loss filled with epoxy

Seal interface

Cover plate (narrower than flange)

Connection Alternative A
Huck BOM blind fasteners

Connection Alternative B
Welded from below

Figure 6a - Repairing corroded bottom flanges of jack arch bridges
**C5-5.5 Procedure outline**

**C5-5.5.1 Case A - Bolted Cover Plate**

- 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.
- Mark and drill holes in the bottom flange to suit the cover plate. For each hole, excavate a small pocket in the concrete or masonry on the blind side to accommodate the expanded blind side head of the Huck BOM fastener. A suitable grinding bit on power drill can be used (refer to Figure 1).
- Fit the galvanised cover plate and attach with Huck BOM blind fasteners.
- Seal open interfaces to the cover plate where required.
- Prepare for and patch paint new steelwork and areas of existing steelwork to the extent directed.

**C5-5.5.2 Case B - Welded Cover Plate**

- 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.
- Fit the cover plate and hold in place. Weld longitudinally in accordance with the details on Figure 6. Note the alternative welding arrangements detailed - one permitting overhand welding but requiring good access, the other requiring down hand welding, but with restricted access. Epoxy seal transverse joint, no weld.
- Prepare the surface of the fillet weld for painting.
- Prepare for and patch paint new steelwork and areas of existing steelwork to the extent directed.

C5-5.6 Alternative details
Bolted and welded cover plate alternatives are detailed.
For welded cover plate, alternative arrangements for the welding are detailed.

C5-5.7 Action to avoid or minimise recurrence
Routine maintenance.
Check for debris build up and corrosion of cover plate overhangs.

C5-5.8 Special consideration and effects of repair
Traffic restrictions may be required if drilling holes removes a significant amount of cross-sectional area.

C5-5.9 Follow up inspections and testing
None

C5-5.10 Drawings list
Figure 6a - Repairing corroded bottom flanges of jack arch bridges
Figure 6b - Repairing corroded bottom flanges of jack arch bridges.
Chapter 6  Repairing stiffeners, bracing, connections and bearings

C6-1  Relief of corrosion site at the base of intermediate web stiffeners

C6-1.1  Description of defect

Severe corrosion at the base of riveted angle type intermediate web stiffeners and in the adjacent bottom flange where

−  the local corrosion of the web stiffener is not structurally significant, but
−  corrosion and loss of section of the flange is significant or potentially significant.

Corrosion of bearing stiffeners and stiffeners at connections of cross-girders and bracing are not covered by this procedure.

C6-1.2  Description of repair

The repair involves removal of the unnecessary portion of stiffener to result in a detail that can be readily cleaned, painted and maintained to prevent further corrosion but is structurally satisfactory. Intermediate web stiffeners may be terminated 50 to 100mm from the bottom flange and still perform their required function.

C6-1.3  Engineering discussion

The removal of the lower portion of true intermediate web stiffeners is normally structurally acceptable. It is often not acceptable for stiffeners that form part of the connection or force transfer system of cross-girders or bracing.

If the stiffener is to be cut using oxy-fuel equipment, extreme care is required to ensure that there are no flame effects on the web, flange or flange angles. Even small flame strikes can create fatigue initiation sites. The recommended locations for cutting stiffeners have been chosen to minimise the chances of oxy flame effects on the girder.

Where necessary, an angle grinder should be used to cut the segment of stiffener closest to the girder.

If corrosion at the base of the stiffener has already resulted in significant corrosion loss in the flange or flange angle, repair the flange using repair procedure in C5-1 if necessary and appropriate.

C6-1.4  Sub-procedures required

−  Arresting corrosion
−  Removing rivets and replacing with bolts
−  Patch painting (including surface preparation)

C6-1.5  Procedure outline

−  Remove any rivets securing the lower portion of the web stiffener that is to be removed.
−  Cut off the lower portion of the stiffener to the extent shown on Figure 7a or Figure 7b by flame cutting and/or with an angle grinder. Several possible arrangements of web stiffeners are shown on the drawing. 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.

−  Dress any flame cut edge to the stiffener by grinding smooth and fit and tension bolts to any holes formerly occupied by rivets.
−  Prepare for and patch paint the exposed steel of the web stiffener and the local area of bottom flange and flange angle now exposed.
C6-1.6 Alternative details
None.

C6-1.7 Action to avoid or minimise recurrence
Not applicable.

C6-1.8 Special considerations and effects of repair
The removal of the lower portion of web stiffeners as detailed is only permissible in true intermediate web stiffeners performing no other structural functions. Some stiffeners also form part of the connection of cross-girders or bracing. Similarly, the procedure must not be applied to bearing stiffeners.

C6-1.9 Follow up inspection and testing
Programmed inspections only.

C6-1.10 Drawing list
Figure 7a - Relief of corrosion site at the base of intermediate web stiffeners
Figure 7b - Relief of corrosion site at the base of intermediate web stiffeners.
**Intermediate Web stiffener**

**Arrangement A (splayed angle)**

- Web plate
- Intermediate stiffener
- Pack Plate
- Intermediate Web stiffener
- Replacement bolt
- Cut stiffener adjacent to pack plate to avoid oxy flame effects on flange angle
- 10 min
- Portion of stiffener removed
- Cut here, dress and paint cut edge

**Part Elevation**

Typical rivetted girder

- Intermediate angle stiffener
- Cut here, dress and paint cut edge
- Portion of stiffener removed
- Remove rivet
- Avoid oxy flame angle

**Figure 7a - Relief of corrosion site at the base of intermediate web stiffeners**
C6-2 Repairing intermediate and bearing web stiffeners with localised corrosion

C6-2.1 Description of defect
Severe corrosion of web stiffeners over a limited area leading to loss of cross-sectional area in plan view. The repair procedure is intended to cover riveted angle stiffeners but may be adapted to other situations.

C6-2.2 Description of repair
Two cases are covered by this repair procedure:

C6-2.2.1 Case A - Corrosion away from end of stiffeners
If the region of severe corrosion loss is away from both ends of the stiffener, the repair procedure involves lap splicing a new segment of stiffener angle, connected to the existing stiffener above and below by bolting. A sufficient length of uncorroded stiffener must be available above and below to effect the bolted connection.

C6-2.2.2 Case B - Corrosion near end of intermediate stiffener
If the region of severe corrosion loss is at one end of the stiffener only, the repair procedure involves removing the corroded segment of stiffener, fitting a replacement segment and splicing it to the existing stiffener in a similar manner to Case A. A sufficient length of uncorroded stiffener must be available at one end to effect the bolted connection.

C6-2.3 Engineering discussion
Corrosion may occur at the bottom end of web stiffeners because of entrapment of water by the detail. It may occur away from the ends where concrete or timber elements are in close contact with the steel (crevice corrosion). When repairs are carried out, the cause of the corrosion should be eliminated if possible.

The repair procedure addresses corrosion of stiffeners over a localised area. If the web stiffener is severely corroded over its entire length, it can be completely replaced.

If the corrosion is limited to a small non-essential part of the stiffener at the base, the procedure described in C6-1 may be appropriate.
C6-2.3.1 Isolated Web Stiffeners:

Isolated web stiffeners (i.e. those not associated with the connection of bracing or cross-girders etc.) can sustain substantial loss of cross-section before repair is required. As a guide, the repair should be carried out if the loss of section exceeds 30% (evenly spread). If the loss is localised to the outer edge, the repair should be carried out if the section loss exceeds 15%.

An engineering assessment may be carried out to determine if greater section losses are acceptable without repair.

If corrosion loss is acceptable, the sub-procedure for arresting corrosion should be carried out and the cause of corrosion should be eliminated if possible.

C6-2.3.2 Web Stiffeners at Bracing Connections:

Web stiffeners, located at the connections of bracing members, are often an integral part of the system of transferring bracing forces. In such cases the amount of section loss that can be accepted is less. Unless otherwise shown by an engineering assessment, the repair should be carried out if the section loss exceeds 10%.

The repair details require an adequate length of existing stiffener to remain to effect the bolted connection. These remaining sections must have no more than 10% loss of section. Guidelines for the number of bolts to connect the stiffener are given in Table 3 below.

<table>
<thead>
<tr>
<th>Size of outstand leg of stiffener</th>
<th>No. of connecting bolts</th>
<th>Size of connecting bolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 75 x 10</td>
<td>2</td>
<td>M20</td>
</tr>
<tr>
<td>Up to 100 x 10</td>
<td>3</td>
<td>M20</td>
</tr>
<tr>
<td>Up to 125 x 10</td>
<td>3</td>
<td>M24</td>
</tr>
<tr>
<td>Up to 150 x 16</td>
<td>4</td>
<td>M24</td>
</tr>
</tbody>
</table>

Table 3 - Bolt details for stiffener repair

In Case A, the segment of stiffener with excessive corrosion may remain in place provided the corrosion is arrested. Feathered edges to be ground to 5mm minimum thickness.

Connection of the replacement stiffener piece by bolting rather than welding is proposed as the standard repair. Steels of stiffeners are often not weldable and even if weldable, the welding process may create fatigue initiation sites in the web at the new butt welds in the stiffener angle.

Where it can be shown by engineering assessment that the effects on the web of welding the stiffener do not result in an inadequate fatigue life, the welded splice detail shown in Figure 8b may be adopted. Where there is a pack plate between the stiffener and the web, the web is adequately protected and the welded splice detail may be adopted. The stiffener steel must be weldable, as determined by appropriate tests.

Note that the mid-height region of webs is not an area of low tensile stress if there is significant shear stress at the section (resulting in principal tensile stress, e.g. near bearings).

C6-2.4 Sub-procedures required

- Arresting Corrosion
- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)
- Filling Voids
- Sealing Interfaces
Corroded segment may be left in place, or removed. If corroded segment remains in place, arrest corrosion and fit bolts through outstand leg.

**For Case B**

- New bolts through web to be same size and thickness as rivets connecting existing stiffener.
- New angle stiffener lap spliced with existing angle size to be $\geq$ existing stiffener.
- For number and size of bolts in development length refer to Table 7.1.
- Minimum spacing $3 \times d_{f}$ (dia of fastener).

**Detail A: Bolted splice arrangement**

**Figure 8a – Repairing intermediate web stiffeners with localised corrosion**
C6-2.5 Procedure outline

C6-2.5.1 Case A - Corrosion away from end of stiffener
Mark and drill holes in the existing stiffener and web to suit the prefabricated splicing angle. Refer to Figure 8a.

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.

Clean existing steelwork where new steel is to abut. Fill pitting and depressions in the surface so there is no void between the web and the new stiffener segment.

Bolt in place the new galvanised stiffener segment, installing new bolts in accordance with the appropriate part of the sub-procedure for removing rivets and replacing with bolts.

Seal any gaps at the interface between new and existing steel.

Prepare for and patch paint new and existing steel to the extent directed.

C6-2.5.2 Case B - Corrosion near end of stiffener

Remove rivets connecting the part of web stiffener to be removed.

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.

Clean existing steelwork where new steel is to abut. Fill pitting and depressions in the surface so there is no void between the web and the new stiffener segment.

Fit the prefabricated, galvanised replacement segment of stiffener in accordance with the details in Figure 8b. Fit only for “bracing connection” stiffeners, otherwise just remove.

Mark and drill bolt holes in the web to match the holes in the splicing angle.

Fit the prefabricated galvanised splicing angle in accordance with details on the drawing.

Seal any gaps at the interface between new and existing steel.

Prepare for and patch paint new and existing steel to the extent directed.

C6-2.6 Alternative details

None.

C6-2.7 Action to avoid or minimise recurrence

Corrosion at the base of stiffeners can be addressed by stopping the new stiffener segment above the bottom flange (if structurally acceptable) (Case B only). Refer also to the sub-procedure for arresting corrosion.

C6-2.8 Special considerations and effects of repair

None.

C6-2.9 Follow up inspection and testing

Programmed inspections only.

C6-2.10 Drawing list

Figure 8a – Repairing intermediate web stiffeners with localised corrosion

Figure 8b – Repairing intermediate web stiffeners with localised corrosion.

C6-3 Repairs bearing web stiffeners with localised corrosion at base of oustand leg of stiffener

C6-3.1 Description of defect

Severe corrosion and perforation to the outstand leg of riveted angle bearing stiffeners at base, where the remaining leg is in good condition.

C6-3.2 Description of repair
The repair involves the removal of the severely corroded and perforated portion of the outstand leg of bearing stiffener and bolting a new plate to the outstand leg. The new plate must bear hard on bottom flange.

**C6-3.3 Engineering discussion**
See C6-1.3.

**C6-3.4 Procedure outline**
- 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.
- Clamp new plate with holes drilled to outstand leg. New plate must bear hard on bottom flange.
- Drill existing stiffener and grind smooth all burrs.
- Bolt new plate to existing stiffener.
- Prepare for and patch paint new and existing steelwork.

**C6-3.5 Sub-procedure required**
- Arresting corrosion
- Oxy-fuel cutting
- Preparing the hole for the bolt
- Install the bolt
- Patch painting

**C6-4 Relief of corrosion site at the base of splayed angle bearing end stiffeners**

**C6-4.1 Description of defect**
Severe corrosion or conditions conducive to corrosion at the base of a splayed angle bearing stiffener in riveted girders. Refer to Figure 8.

**C6-4.2 Description of repair**
The "repair" involves a modification to the stiffener so that the area can be readily cleaned, painted and maintained to prevent further corrosion.

The modification is to remove a triangular section of the splayed segment of the bearing stiffener.

**C6-4.3 Engineering discussion**
While the removal of the section of stiffener theoretically reduces the girder's bearing capacity, the reduction is only marginal and is not considered significant. Note that the splayed section of stiffener is usually connected by only one rivet. This gives an indication of the small upper limit to the compression load in the stiffener.

The splayed angle bearing stiffeners are significantly less effective than end bearing type stiffeners used in modern practice. If the bearing detail is performing poorly under live load (e.g. excessive flexing of bearing or bed plates etc.) then consideration should be given to replacing the splayed angle bearing stiffener with an end bearing type stiffener.

**C6-4.4 Sub-procedures required**
- Patch Painting (including surface preparation)

**C6-4.5 Procedure outline**
- Remove the section of stiffener as illustrated in Figure 9 by oxy-fuel cutting. Avoid or minimise flame effects on the steel of the girder section.
− 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.
− Prepare for and patch paint the area.

C6-4.6 Alternative details

None.
Figure 9 Relief of corrosion site at base of splayed angle bearing stiffeners

End of typical riveted girder with splayed angle bearing stiffeners

Detail A

Intermediate stiffeners

Splayed angle Bearing stiffeners

Riveted girder

Remove this portion of stiffener

Dress and paint edges

Clean away rust, dirt and debris and paint

© Rail Corporation
Issued December 2009
Page 49 of 125
Version 2.0
UNCONTROLLED WHEN PRINTED
C6-4.7  Action to avoid or minimise recurrence
Corrosion at the base of stiffeners can be addressed by:
− Applying epoxy filler to the area to produce a contour that will readily drain water away, or
− Protecting areas vulnerable to corrosion with denso tape.
Refer to the sub-procedure for arresting corrosion.

C6-4.8  Special considerations and effects of repair
None.

C6-4.9  Follow up inspection and testing
Programmed inspections only.
Pay particular attention to maintenance of the paint system in the vicinity of the bearing.

C6-4.10  Drawing list
Figure 9 Relief of corrosion site at base of splayed angle bearing stiffeners.

C6-5  Repairing corrosion at bottom flange bracing connection

C6-5.1  Description of defect
Severe corrosion in riveted girders at the intersection of bracing, web stiffeners and the bottom flange leading to significant loss of section in one or more of the components.

C6-5.2  Description of repair
The repair involves a replacement of severely corroded elements and possibly adjustment of the detail, in a structurally acceptable manner, to avoid recurrence of the defect.

The repair procedure in C6-2 may be appropriate for the repair of web stiffeners.
Bracing members damaged by corrosion can be replaced.
Where significant corrosion of the bottom flange has occurred, the repair procedure in C6-1 may be required.
Where the loss of section due to corrosion is less than that at which repair is required, the sub-procedure for arresting corrosion may be appropriate.

C6-5.3  Engineering discussion
At the location under consideration, all the elements - the bottom flange, the web stiffeners and web, the braces and connection gusset - may be active parts of the bracing system.

It should be noted that in a sway bracing system, a bending moment will be applied to the web stiffeners if the intersection of the centroids of the horizontal and diagonal braces is not on the web centreline.

As a consequence, changes to the details to avoid further corrosion should not be made in conjunction with the repair without an engineering assessment to determine if the resulting detail will be structurally satisfactory.

The standard repair procedure involves reinstatement of the detail, arrest of corrosion and protection against corrosion by an appropriate means.

To assess the necessity for component repair or replacement, the following guideline should be used: Repair or replace a component if the section loss, uniformly spread, exceeds 10%.

Notwithstanding the need for an engineering assessment, details of a possible modification of a typical connection are shown in Figure 10. The modification to the detail involves cutting back of
the horizontal leg of the brace angle to eliminate the horizontal interface with the flange. If no rivets are removed by this modification it is likely to be structurally acceptable. If the degree of corrosion requires, the web stiffener is to be repaired in accordance with procedure C6-2 and the gusset plate replaced.

If the engineering assessment for the particular case indicates that the proposed modification is not structurally satisfactory, consideration should be given to compensating for the cut away leg of the brace angle by increasing the size and thickness or steel grade of the gusset plate and the number of connecting bolts.

Warning:

Bracing should be removed at only one location at a time and temporary bracing to compensate must be installed if suitable load restrictions are not placed on the structure.

C6-5.4 Sub-procedures required
- Arresting Corrosion
- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)
- Filling Voids
- Sealing Interfaces

C6-5.5 Procedure outline
- Install temporary braces as required to compensate for the braces that are to be disconnected.
- Remove rivets as necessary and remove the gusset plate.
- 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. Completely remove the brace if necessary to avoid these effects.
- Dress any flame cut edges by grinding.
- Repair the web stiffener if required in accordance with procedure C6-2.
- Clean all steel surfaces of loose rust and paint by scraping and power wire brushing.
- Reassemble the connection with a new prefabricated galvanised gusset plate if required. In the process fill voids, including surface pitting, as required. Install new bolts.
- Prepare for and patch paint new and existing steel to the extent directed.

C6-5.6 Alternative details
Consider complete replacement of connected bracing members.

C6-5.7 Action to avoid or minimise recurrence
Included in procedure.

C6-5.8 Special considerations and effects of repair
As stated in C6-5.3, modification to the detail should only be made if an engineering assessment shows that it is structurally satisfactory.

C6-5.9 Follow up inspection and testing
Programmed inspections only.

C6-5.10 Drawing list
Figure 10 - Repairing corrosion at bottom flange bracing connection.
Figure 10 - Repairing corrosion at bottom flange bracing connection
C6-6 Replacing bearing plates
Refer to C15-4 for bearing pad replacement.

C6-6.1 Description of defect
Severe corrosion of bearing plates and attachment bolts in riveted girder bridges.

C6-6.2 Description of repair
The method of repair is to replace the bearing plate with a new galvanised equivalent. The repair procedure describes methods of installing the new bearing plate with a minimum lift of the girder.

C6-6.3 Engineering discussion
Weather conditions and in particular buckling of track in hot weather must be considered before disturbing the bridge.

A severely corroded bearing plate should be replaced.

It may be prudent to replace a severely corroded bearing plate, even if it appears to function properly, to ensure the ongoing performance of the bridge.

Girder attachment bolts should be replaced if they are corroded to the extent that they are unable to restrain the girder against upward movement and/or if they prevent longitudinal movement at the expansion end.

Restore the capacity of the girder to move longitudinally at the expansion end if severe corrosion and obstructions have removed this capacity.

If the repair is to be carried out with the bridge open to traffic, temporary support to the girder including jacks, brackets, struts etc. are to be designed or selected to suit the load that will be applied.

Where screws in tapped holes are used to attach the bearing plate, fabricate the plate from steel of grade 350 or higher. The screws then can be sufficiently tensioned.

C6-6.4 Sub-procedures required
- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)
- Filling Voids
- Sealing Interfaces

C6-6.5 Procedure outline
- 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. Alternative attachment arrangement 2 or 3 shown in Figure 11b is to be adopted, drill and tap new holes in the bed plate to suit.
- 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.
- Remove rivets connecting the bearing plates and remove the bearing plate.
- 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. as required by the sub-procedure for removing rivets.
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.

C6-6.5.1 Preferred Option

- Fit new prefabricated galvanised bearing plate with holes pre-drilled to suit fixed and expansion ends as required. Length of new bearing plate to allow fitting of 3 bolts past bed plate.
- Weld bearing plate to bottom flange. Weld not to extend past bed plate.
- Drill bottom flange and grind smooth all burrs.
- Install new bolts.
- Plug and weld up rivet holes.
- Prepare for patch painting.

See detail D shown in Figure 11c.

C6-6.5.2 Alternative Option

Fit the new, prefabricated, galvanised bearing plate. Fixing bolts are to be in accordance with one of the alternative details shown in Figure 11a. Tighten the fixing bolts.

If epoxy filler was applied, use the bolt tightening to squeeze the epoxy into any voids. Ensure that the bearing plate remains precisely parallel to the girder flange so that it will sit evenly on the bed plate when the girder is lowered.

Ensure that the bearing plate edges and attachment bolt holes align precisely with the guides and bolt holes of the bed plate.

- At the expansion end only apply a liberal layer of lithium disulphide grease to the underside of the bearing plate.
- Lower the girder(s) onto the bed plates, checking for proper fit. If epoxy filler was used, do not lower the girder(s) until the epoxy has cured.
- Fit new attachment bolts in accordance with one of the alternative details shown in Figures 11a, 11b and 11c.

C6-6.6 Alternative details

Several alternative arrangements for securing the new bearing plate and for the attachment bolts are shown in Figures 11a, 11b and 11c.

The use of stainless steel for the new bearing plate and fixing bolts could be considered if the environment is aggressive. Using stainless steel will also avoid the minor problems associated with galvanising zinc entering tapped holes.

For 350 grade bearing plate, a long thread engagement in a tapped hole (1.5 x diameter) is required with high strength bolts to develop adequate tension capacity. Where the thickness of the bearing plate is less than the required thread engagement and cannot be increased, use a high strength structural steel such as Bisalloy 80 for the plate. With this material the thread engagement is to be equal to the screw diameter.

C6-6.7 Action to avoid or minimise recurrence

Routine maintenance to the paint system and to clean dirt and debris from the bearing area. Ensure that longitudinal movement of the expansion end is not prevented.

C6-6.8 Special considerations and effects of repair

None.

C6-6.9 Follow up inspection and testing

Programmed inspections only.
Check all bolts for tightness during routine inspections.

### C6-6.10 Drawing list

- Figure 11a – Repairs to bearing plates
- Figure 11b – Repairs to bearing plates
- Figure 11c – Repairs to bearing plates.
End of typical riveted girder

Epoxy resin filler if required

New fixings replace countersunk rivets
Refer Detail B

Corrosion loss in existing flange

Detail A

Plug and weld up rivet holes

M24 8.8 bolts (galvanised)

Not to extend past bed plate

New galvanised bearing plate

Detail A (Alternative)

New galvanised bearing plate

Section E-E

Figure 11a – Repairs to bearing plates
Alternative girder attachment arrangements

Figure 11b – Repairs to bearing plates
C6-7 Repairing cracked and broken wind brace welded connections

C6-7.1 Description of defect
Cracked and broken wind brace members that have been welded at end and centre (main girder) connections.

C6-7.2 Description of repair
The repair involves removing welded area of wind brace and connecting new wind brace using gusset plates and bolting.

If broken wind brace is in good condition it may be re-used.

C6-7.3 Engineering discussion
In bridges with flat bar wind braces consideration should be given to replacing flat bars with angles.

If flat bars are to be replaced with angles, carry out design check to determine size of angles to be used.

Design new gusset plate to suit and connection bolts.

C6-7.4 Procedure outline
- Prepare new gusset plates.
- 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.
- Grind smooth after removing brace member.
- Mark flange for location of bolts.

Figure 11c – Repairs to bearing plates
- Drill flange and grind smooth all burrs.
- Mark and drill new wind brace, grinding smooth all burrs.
- Install new wind brace.
- Fill voids and pitting.
- Fit new bolts.
- Prepare for patch paint.

**C6-7.5 Sub procedures required**
- Oxy-fuel cutting
- Prepare the hole for the bolts
- Install the bolt

**C6-7.6 Drawing list**

Figure 10 Detail B.
Chapter 7  Repairing fatigue damage
C7-1  Intercepting fatigue cracks
C7-1.1  Description of defect
Fatigue cracks in any steel element.

C7-1.2  Description of action
Drill a hole at the tip of a fatigue crack and install a tensioned bolt in the hole. This procedure is not a repair as such, but a course of action that may delay propagation of fatigue cracks.

C7-1.3  Engineering discussion
Fatigue cracks occur in a properly designed structure when it nears the end of its design life or in poorly designed details where unanticipated high stress levels or fatigue initiation points occur.

The progress of fatigue cracks is not easily halted other than by changing the structural behaviour of the part to dramatically reduce or eliminate the tensile stresses at the crack location (refer to procedure C7-2 for an example.) The precompression of the region near the crack tip by the tensioning of a bolt has been found to inhibit crack propagation.

Warning:
Procedure C7-1 may be used to delay propagation of a fatigue crack, but is unlikely to be a permanent solution.

After carrying out this procedure, the crack site must be regularly monitored to detect new cracks emerging from the hole perimeter. This is particularly important in non-redundant structures where sudden propagation of a crack will lead to collapse.

C7-1.4  Sub-procedures required
None.

C7-1.5  Procedure outline
− Determine the position of the end of the fatigue crack by magnetic particle testing, close visual inspection or other suitable means.
− 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.
− Use magnetic particle testing 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.
− Install and fully tension a high strength galvanised bolt in the hole. The bolt is to have standard washers under both head and nut.

C7-1.6  Alternative details
None.

C7-1.7  Action to avoid or minimise recurrence
Not applicable.

C7-1.8  Special considerations and effects of repair
Do not paint the inside of the hole or the surrounding area as this may hide new cracks forming at the hole edge.
C7-1.9  **Follow up inspection and testing**

As there is no guarantee that the above procedure will be effective in inhibiting the crack propagation, inspections of the defect should continue on the same basis as if the procedure had not been carried out.

C7-1.10  **Drawing list**

Refer to detail B in Figure 12.

C7-2  **Repairing fatigue cracks at connections of coped I-sections**

C7-2.1  **Description of defect**

Fatigue cracks in an I-section web, commencing from the tensile edge adjacent to the point where the flange has been stopped. Refer to the detail in Figure 12.

C7-2.2  **Description of repair**

The repair comprises:

- Drilling a hole at the end of the fatigue crack and subsequently installing a high strength bolt fully tensioned.
- Fitting extended connection brackets that bolts to the girder web. The brackets are to relieve the tensile stresses at the crack and bridge between the connection bolts and the sound portion of the I-sections.

C7-2.3  **Engineering discussion**

Fatigue cracks occur in a properly designed structure when it nears the end of its design life or in poorly designed details where unanticipated high stress levels or fatigue initiation points occur.

A common instance of the latter is the subject of this repair and is illustrated in Figure 12.

Where the flanges of an I-section are curtailed at a distance from the point of effective pinned support, or where there is rotational restraint to the girder end, the bending moment may be significant. With only the web to resist the moment, high levels of stress result. Furthermore, coping of the web or termination of the flange to web weld may create a fatigue initiation site.

Drilling a hole at the fatigue crack tip is only a temporary measure. It may or may not delay further crack propagation.

This repair procedure aims to significantly reduce the tensile stress at the crack site by fitting steel brackets to bridge between the end connection and the sound section of I-girder.

The procedure described and the details shown in Figure 12 are intended to illustrate the principles of the repair rather than any specific case.

A thorough engineering design and the detailing of the steel bracket and its connections are required for each particular case. Note that it may not always be possible to devise a suitable bracket. As a general principle, new brackets should be substantial in section to keep stress levels low.

The design, fabrication and installation effort required by the repair procedure may be substantial. Close consideration should be given to complete replacement of the I-section particularly when the member size and/or length is small.

A bridge possession is normally required to implement this repair as the member is to be disconnected.

C7-2.4  **Sub-procedures required**

Only the principles of the repair are given. Any of the sub-procedures may or may not be required, depending on the designed details.
**C7-2.5**

**Procedure outline**

- Determine the position of the end of the fatigue crack by magnetic particle testing, close visual inspection or other suitable means.
- 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.
- Drill other holes in the member to suit the brackets to be installed.

---

*Figure 12 – Repairing fatigue cracks at connections of coped I sections*
- Temporarily support the end of the member under repair.
- Disconnect the end of the member by removing rivets etc. as required to fit the new brackets.
- 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.
- Prepare for and patch paint new steelwork and areas of existing steelwork to the extent directed.

C7-2.6 Alternative details

None.

C7-2.7 Action to avoid or minimise recurrence

Avoid similar design details in new bridges.

C7-2.8 Special considerations and effects of repair

Depending on the details of the new bracket(s), the fatigue crack may be hidden, preventing ongoing monitoring. The member should be inspected regularly for adequate performance under load.

Note that it may not be possible to design brackets with a long fatigue life.

C7-2.9 Follow up inspection and testing

Programmed inspections to monitor the performance of new connection, the progress of the original crack if possible and check for cracks in the new brackets.

C7-2.10 Drawing list

Figure 12 - Repairing fatigue cracks at connections of coped I sections.
Chapter 8  Repairing impact damage to steel structures

C8-1  Description of Defect
Any damage to bridge elements caused by impact from road or rail vehicles.

C8-2  Engineering Discussion
Steel bridge elements including major components such as girders or truss members and minor components such as bracing members are frequently damaged by vehicle impact. Once the damage has been detected repair of the damaged components must be undertaken.

A range of repair methods is currently available and include:

- Flame straightening
- Hot mechanical straightening
- Cold mechanical straightening
- Welding
- Bolting
- Partial replacement
- Full replacement.

Many of the available repair methods are excluded if the damage has occurred to "Fracture Critical Members" (FCM's).

FCM's are those tension members or tension components of members whose failure would be expected to result in collapse of the bridge or inability of the bridge to perform its design function.

Primary members in tension are FCM's, for example, tension flanges of girders and truss tension members.

Broad flange beam (BFB) spans over roadways are subject to a significant risk of fatigue and/or brittle fracture if damaged by road vehicle impact and shall be considered fracture critical.

The majority of cases of impact damage encountered by RailCorp would be to FCM's.

The applicable range of repairs in most cases will therefore be reduced to full or partial replacement of the damaged member, or flame straightening of the member followed by installation of bolted cover plates to fully replace the damaged section.

C8-3  Sub-procedures required
Repairs to impact damage can involve all of the sub-procedures defined in Chapter 5.

Techniques associated with the following procedures may also be appropriate with minor modification, depending on the form of the impact damage:

- Repairing flange corrosion in riveted girders
- Repairing flange corrosion in rolled or welded girders
- Repairing webs with localised corrosion
- Repairing corroded bottom flanges of jack arch bridges
- Repairing intermediate web stiffeners with localised corrosion
- Repairing corrosion of bottom flange bracing connection
- Intercepting fatigue cracks
- Repairing corroded angle columns (temporary support available)
- Repairing corroded 4-angle columns (no temporary support)
C8-4 Repair procedures

C8-4.1 General

The repair method shall be selected after an assessment of the damage in accordance with TMC 305 – Structures Assessment.

Repair requirements shall be determined from an evaluation of the strength of the damaged member.

Repair solutions can be selected from the following range. A combination of repair procedures may result in the best repair solution.

Straightening procedures need to be done with care to prevent overstraightening (i.e. creating bending in opposite direction) and damage from straightening forces and devices. Also distortions due to yielding must not be confused with those due to restraints from other members.

Further information on the specific repair techniques relating to impact damage is contained in the National Co-operative Highway Research Program Report 271.

C8-4.2 Fracture Critical Members

Fracture critical members shall receive a more rigorous assessment of damage than non fracture critical members. Selection of repair procedures for fracture critical members shall be more conservative than selecting repair procedures for non fracture critical members.

Caution

In general, crack repairs shall be made with bolted cover plates. If other methods are used, such as welding or flame straightening, elements shall be fully strengthened by adding new bolted cover plates. Enough new material shall be added so that the damaged material can be neglected in computing strength.

C8-4.3 Nicks and Gouges

C8-4.3.1 General

Superficial nicks and gouges can be repaired by grinding smooth.

As a guide, superficial nicks or gouges can be taken as those resulting in less than 10% loss of section of the affected element.

More serious damage to weldable steel in compression members and secondary members can be repaired by welding.

Other cases can usually be repaired by adding bolted cover plates.

Requiring partial replacement due to nicks and gouges is rare.

C8-4.3.2 Grinding of Nicks and Gouges

The grinding repair procedure must comply with the following requirements:

- No ground portion is to have a radius less than 100 mm in the longitudinal direction (i.e. along the edge or the surface)
- The ground slope is not to exceed an angle of 1 in 5 to the relevant face or edge
- Any plastic flow is to be removed flush with the face or edge
- Flange edges are to have a minimum radius of 3mm
- Final grinding is to be done in the longitudinal direction and in a manner so as not to cause heat discolouration
− All distorted metal is to be removed
− Grinding is to extend at least 1 mm beyond the damaged surface or end of cracks.
− Use dye penetrant to check for cracks on completion of grinding.

C8-4.4 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 plates with excessive kinks. It is nearly impossible to flame straighten this type of damage.

C8-4.5 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.

C8-4.6 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 shall 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. It is not recommended that twisted or rotated members be cold straightened.

C8-4.7 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 shall not be repaired by welding unless fully strengthened by additional bolted material.

The steels to be repair welded shall be weldable steels.

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

C8-4.8 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 shall be repaired by bolting or repaired by other methods and fully strengthened by adding new bolted material.

C8-4.9 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 consist 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 repaired by bolted cover plates.

**C8-4.10 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 complete replacement.

**C8-4.11 Strength of repair method**

Fracture critical members should be repaired by methods that unquestionably restore full strength. These methods may include bolted splices, partial replacement by bolting, and full replacement. All loading capacities, including service load, overload, and ultimate load, should be fully restored, and the service life should be fully regained.

Non-fracture critical members may be repaired by the same methods used for fracture critical members. However, other less costly methods should also be considered and used as appropriate.

**C8-4.12 Durability of repair**

Durability of repair must be given a high priority. All methods of repair should have durability equal to or better than the original member. The accessibility of all parts of a repaired structure for inspection, cleaning, and painting shall be accomplished by the proper proportioning of repairs and the design of their details. Closed sections, and pockets or depressions that will retain water, shall be avoided. Pockets shall be provided with effective drain holes or filled with waterproofing material.

**C8-4.13 Monitoring of repairs**

Follow up inspection of repairs shall be made on a regular basis. Members that have complete restoration should be inspected with the same frequency as the complete bridge. Member repairs where there is some doubt regarding strength and durability should be inspected at more frequent intervals. Repairs to fracture critical members should receive close consideration with respect to inspection frequency.
Chapter 9  Repairing steel stepways and footways structures

C9-1  Repairing steel risers and stringers in stepways

C9-1.1  Description of defect

Severe corrosion of steel risers and stringers and their connections leading to a significant loss of cross-sectional area and consequent reduction in strength.

C9-1.2  Description of repair

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.

C9-1.3  Engineering discussion

Members should be repaired or replaced when loss of section results in a strength or stiffness reduction below 75% of which is required at any particular location.

A simple design check should be carried out to check the strength loss, but the following guidelines may be applied:

**Risers:** Replace members exhibiting in excess of

- 20% loss in cross-sectional area of both flanges combined, or
- 40% loss in cross-sectional area of the web.

**Stringers:** Replace members exhibiting in excess of 20% loss in cross-sectional area of both flanges combined or 30% loss in cross-sectional area of web plate. Fit cover plates to webs of members exhibiting between 10% and 30% loss in cross-sectional area of the web.

Consideration should be given to complete replacement of all risers or all risers and stringers in stepways where a significant proportion of individual elements would require replacement.

Although bolted connections have generally been used in this manual as the standard for steel repair, site welding is the proposed method of connection of new steel elements in this repair procedure. The locations where welding is required are typically low stress areas in stepways and fatigue is not usually critical as live load stress ranges and cycles are small.

Notwithstanding the above, the weldability of the steel is to be checked by appropriate tests or scientific investigations and all completed welds are to be checked for defects.

Where stringers are to be replaced, adopt the lower end support arrangement illustrated in detail D of Figure 13b to keep the structure clear of the ground.

C9-1.4  Sub-procedures required

- Arresting Corrosion
- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)

C9-1.5  Procedure outline

C9-1.5.1  Case A - Stringers and risers to be replaced

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

- Remove precast treads and handrails etc.
- Remove rivets securing stringers
- Remove stringers and risers
- Install new galvanised stringers, fabricated to existing steelwork, except use the lower end support detail as shown in Figure 13b. Use galvanised splice plates where required to connect stringer segments. Use galvanised bolts in lieu of rivets.

- Prepare new galvanised risers for installation by cutting and trimming flanges at the ends, all as detailed in Figure 13a.

- Site weld the new risers to the stringers at positions and levels to suit the precast step units to be used.

- Prepare for and patch paint at the riser connections and other areas of steel to extent directed. 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 as described in the sub-procedure for patch painting.

- Refit precast treads and handrails using new galvanised or stainless steel bolts and fittings.

C9-1.5.2 Case B - Risers only to be replaced

- Remove precast treads and handrails etc.

- 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.

- Grind smooth the face of the stringer web and expose the base metal for welding.

- Prepare new galvanised risers for installation by cutting and trimming flanges at the ends, all as detailed on in Figure 13a.

- Site weld the new risers to the stringers at positions and levels to suit precast step units to be used.

- Prepare for and patch paint at the riser connections and other areas of steel to extent directed. 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 as described in the sub-procedure for patch painting.

- Refit precast treads and handrails using new galvanised or stainless steel bolts and fittings.

C9-1.5.3 Case C - Risers to be replaced and stringer web to be plated

- Remove precast treads and handrails etc.

- 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.

- 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.

- 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.

- Fit prefabricated, galvanised 8mm web cover plates and fix to the stringers by site welding, all in accordance with the details in Figure 13b.

- Prepare new galvanised risers for installation by cutting and trimming flanges at the ends, all as detailed in Figure 13a.

- Site weld the new risers to the stringers at positions and levels to suit precast step units to be used.

- Prepare for and patch paint at the riser connections and other areas of steel to extent directed. 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 as described in the sub-procedure for patch painting.

- Refit precast treads and handrails using new galvanised or stainless steel bolts and fittings.

C9-1.6 Alternative details
None.

C9-1.7  **Action to avoid or minimise recurrence**
Routine maintenance to remove build up of dirt and debris, particularly at locations of site welds.

C9-1.8  **Special considerations and effects of repair**
None.

C9-1.9  **Follow up inspection and testing**
Programmed inspections only.
Pay particular attention to inspection for corrosion at site welds.

C9-1.10  **Drawing List**
Figure 13a – Repairing steel risers and stringers in stepways
Figure 13b – Repairing steel risers and stringers in stepways.
Figure 13a – Repairing steel risers and stringers in stepways
Ground clearance to steel stringer and riser 50mm min.

Reinforced concrete footing to stringer and step

Asphalt, paving or similar

In-situ reinforced concrete first step

PC treads to second step

Stringer

Stringer hold down bolts

Detail D

Steel riser 150 x 75
PFC typical

PC tread

Standard 150mm riser and 300mm tread

Standard clamp fittings stainless steel or galvanised

Tread support 100 x 100 x 10P

15 gap for drainage

Existing stepway stringer

8mm cover plate (galv)

15 typical

Precast concrete tread

Precast concrete tread

Section B-B

Section C-C (Where stringer web is plated)

Section C-C (without stringer plating)

Figure 13b – Repairing steel risers and stringers in stepways
C9-2 Repairing corroded angle columns (temporary support available)

C9-2.1 Description of defect
Severe corrosion of multiple angle columns resulting in significant loss of cross-sectional area. This procedure covers the case where the structure can be temporarily supported, allowing complete removal of the column.

C9-2.2 Description of repair
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.

C9-2.3 Engineering discussion
An engineering assessment to determine the necessity of the repair and the extent of column replacement should be carried out.

In the absence of an engineering assessment, adopt the following guideline.

Replace columns or segments of columns where the maximum loss of cross-sectional area exceeds 20%.

It should be noted that columns comprising 2 and 4 angles often have a much greater axial load capacity than is required, provided they are adequately braced. On the other hand, columns supporting structures that have had concrete overlay decks added may be highly loaded.

If severe corrosion has occurred over a significant portion of the existing column, complete replacement is recommended. Partial replacement of the lower part of the column should only be adopted if severe corrosion is limited to the lower quarter, with the remainder in good condition and likely to remain so.

The top connection of the replacement column to the supported structure or the remainder of the column must be detailed to ensure proper load transfer.

Where concrete footings to columns have deteriorated significantly and are not repairable, they should be rebuilt in reinforced concrete. The ground bearing area is not to be less than that of the existing footing.

Temporary support must be provided at adjacent columns that become unbraced during the repair. The axial load capacity of such columns is significantly reduced by the disconnection of braces.

Refer to Table 6 for replacement column sizes.

<table>
<thead>
<tr>
<th>UC size</th>
<th>To replace angle size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Leg</td>
</tr>
<tr>
<td>150 UC 23</td>
<td>102 x 108 x 8</td>
</tr>
<tr>
<td>150 UC 30</td>
<td>127 x 127 x 8</td>
</tr>
<tr>
<td>150 UC 37</td>
<td>127 x 127 x 10</td>
</tr>
<tr>
<td>200 UC 46</td>
<td>127 x 127 x 16</td>
</tr>
<tr>
<td>200 UC 60</td>
<td>152 x 152 x 12</td>
</tr>
<tr>
<td>250 UC 73</td>
<td>152 x 152 x 16</td>
</tr>
<tr>
<td>310 UC 97</td>
<td>200 x 200 x 16</td>
</tr>
</tbody>
</table>

Table 6 – Replacement UC sizes

C9-2.4 Sub-procedures required
- Removing Rivets and Replacing with Bolts
− Patch Painting (including surface preparation)

C9-2.5 Procedure Outline
− Install temporary supports to allow removal of the column.
− 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.
− Repair the existing footing or build a new footing in reinforced concrete if required. Drill holes for hold-down bolts.
− Install the new column and complete the base detail as shown in Figure 14. Connect to structure or remainder of column above
− Trim bracing members to size and drill new holes for connection to the new bracing cleats.
− Prepare for and patch paint new and existing steel to the extent directed.

C9-2.6 Alternative details
None.

C9-2.7 Action to avoid or minimise recurrence
The proposed details minimise future corrosion if routine maintenance is carried out.

C9-2.8 Special considerations and effects of repair
None.

C9-2.9 Follow up inspection and testing
Routine inspections only.

C9-2.10 Drawing list
Figure 14 – Repairing corroded angle columns (temporary support available).
C9-3 **Repairing corroded 4-angle columns (no temporary support)**

**C9-3.1 Description of defect**

Severe corrosion of 4-angle column resulting in significant loss of cross-sectional area. This procedure covers the case where the column must continue to carry load during the repair as temporary support of the structure is not possible.
C9-3.2 Description of repair

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.

C9-3.3 Engineering discussion

An engineering assessment to determine the necessity of the repair and the extent of column replacement should be carried out.

In the absence of an engineering assessment, adopt the following guideline:

Replace columns or segments of columns where the maximum loss of cross-sectional area exceeds 20%.

It should be noted that columns comprising 2 and 4 angles often have a much greater axial load capacity than is required, provided they are adequately braced. On the other hand, columns supporting structures that have had concrete overlay decks added may be highly loaded.

It must be recognised that the bracing system interconnecting columns is often essential to achieve the required axial load capacity in the columns. The repair procedure has been devised to ensure that the column under repair remains braced at all times. Only by an engineering assessment of the particular case can it be determined if bracing can be disconnected during the repair.

Where concrete footings to columns have deteriorated significantly and are not repairable, they should be rebuilt in reinforced concrete. The ground bearing area and founding level are not to be less than that of the existing footing.

Bolting is the preferred method of connecting new, galvanised angle segments to existing steelwork. Welded splices, involving full penetration butt welding of the angles, may be used where it can be determined by analysis and testing that existing steels are weldable.

The preferred location for bolted splices is immediately above or below bracing connection points.

C9-3.4 Sub-procedures required

- Arresting Corrosion
- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)
- Filling Voids
- Sealing Interfaces

C9-3.5 Procedure outline

- Cut a pocket in the concrete footing around the base of the column as shown in Figure 15b. If welded splices are to be adopted, excavate sufficient to expose an uncorroded section of column.
- Drill holes for hold-down bolts. Commence the procedure described in detail in Section 9-3.6 to replace the angles (segments) one by one.
- 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.
- Mortar is to be packed under each individual base plate before the next angle is removed to ensure adequate transfer of load.
- Fill voids at the heel of splice angles as they are installed. Refer to Section D of Figure 15a.
- Seal any open interfaces between individual base plates and at splice angles or at backing bars as required.
- Apply epoxy filler between the angles at the base, profiled as shown in Figure 15c to promote free drainage of water from column base.
- Prepare for and patch paint new steelwork and areas of existing steelwork to the extent directed.
Replace all angles comprising column one by one, for part or full length. Refer to sequence in Figure 11.4

Elevation - Typical trestle with 4-angle column

Splice angle
Bolt through two angles
Pack plate

Chamfer splice angle to suit fillet radius and fill void when installing

Part of existing angles to remain

Splice angle. For size and bolt requirements refer to Table 10.2

Part of existing angles to remain

(No temporary support available)
Adjacent angle yet to be replaced

Severe corrosion at base of angle

Existing concrete footing

Galvanised replacement angle installed

20mm base plate

20mm mortar bed

Cut back existing cast-in angle to 50mm below surface

Grout pocket

Detail A - Column Base detail

Angles yet to be replaced

Galvanised replacement angles in place

Base plates to closely abut.

Seal Joint with epoxy filler

Section B-B

Adjacent angle yet to be replaced

Galvanised replacement angle installed

Below region of corrosion

Existing concrete footing

Cut back existing cast-in angle to 50mm below surface

Grout pocket

Alternative Detail A

For welded splices (if steels are weldable)

Figure 15b - Repairing corroded 4-angle columns

(No temporary support available)
Epoxy filler in gaps between angles, profiled to promote free drainage of water from column base.

H.D bolts, galvanised (M20 nom.)
- Cast into new footing, OR
- Drill and grout into existing footing, OR
- Install chemset anchors, drilled and inserted after column is in place, OR
- Grout into predrilled holes after column is in place

Column Base detail at completion
(similar detail where replacement angle spliced by welding)

Figure 15c - Repairing corroded 4-angle columns
(No temporary support available)

<table>
<thead>
<tr>
<th>Angle size</th>
<th>Splice angle</th>
<th>Bolt size</th>
<th>No. of bolts each side</th>
</tr>
</thead>
<tbody>
<tr>
<td>76 x 76 x 10</td>
<td>75 x 75 x 10</td>
<td>M20</td>
<td>3</td>
</tr>
<tr>
<td>89 x 89 x 10</td>
<td>90 x 90 x 10</td>
<td>M20</td>
<td>4</td>
</tr>
<tr>
<td>102 x 102 x 10</td>
<td>100 x 100 x 10</td>
<td>M20</td>
<td>5</td>
</tr>
<tr>
<td>127 x 127 x 12</td>
<td>125 x 125 x 12</td>
<td>M24</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 7 - Splice angle and bolt details

C9.3.6 Procedure for removing angles one-by-one.

Order of replacement

1. Replace outer free leg first
2. Replace Leg 2
3. Remove rivets (refer sub procedure C4.2) from positions B1 and B2
4. Remove Leg 1 and pack plates
5. Install galvanised replacement leg and packs, fitting bolts at position B1 only – fit nuts snug tight only.
One by one remove rivets at position B3 and immediately replace with bolt as shown. Do not fit nuts.

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

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.

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

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

C9-3.7 Alternative details
Details of bolted and welded splice alternatives have been provided.

C9-3.8 Action to avoid or minimise recurrence
Routine maintenance to remove built-up dirt and debris between angles, at the base and at packs etc. fitted between angles.

Epoxy fill between the angles at the base as illustrated in Figure 15c to promote free drainage of water from column base.

C9-3.9 Special considerations and effects of repair
None.

**C9-3.10 Follow up inspection and testing**
Programmed inspections only.

**C9-3.11 Drawing list**
Figure 15a - Repairing corroded 4-angle columns (No temporary support available)
Figure 15b - Repairing corroded 4-angle columns (No temporary support available)
Figure 15c - Repairing corroded 4-angle columns (No temporary support available)
Chapter 10 Painting of steel structures

C10-1 Description of action

Painting of steel components of a range of structures including underbridges, overbridges, footbridges, overhead wiring masts and gantries, and signal gantries.

C10-2 Engineering discussion

The choice of paint system is dependent on whether the steelwork is new or existing and on whether the work is being done in possession or not.

Protective coating can generally be applied to new steelwork in a controlled environment.

For existing steelwork, work is undertaken in the field and is subject to a variety of atmospheric conditions.

As inorganic zinc primers work better without a top coating, organic zinc primers are preferred.

Organic zinc primers are also more tolerant of application conditions e.g. weather, under or over thickness application, and re-coat times.

Surface preparation by blast cleaning is designated by the letters “Sa”. Abrasive may be garnet or steel (note that steel blast can be recycled).

Sa 3 is blast cleaning to visually clean steel. When viewed without magnification, the surface shall be free from visible oil, grease and dirt, and free from mill scale, rust, paint coatings and foreign matter. It shall have a uniform metallic colour.

Sa 2½ is very thorough blast cleaning. When viewed without magnification, the surface shall be free from visible oil, grease and dirt, and from mill scale, rust, paint coatings and foreign matter. Any remaining traces of contamination shall only show as slight stains in the form of spots and stripes.

Sa 2 is thorough blast cleaning. When viewed without magnification, the surface shall be free from visible oil, grease and dirt, and from most of the mill scale, rust, paint coatings and foreign matter. Any residual contamination shall be firmly adhering.

C10-3 Procedure

C10-3.1 New steelwork

C10-3.1.1 Preparation

- Remove visible oil, grease and dirt
- Remove any heavy layers of rust by chipping
- Abrasive blast clean new steel components to Sa 3, with a surface profile height of 25 to 65 micrometres (μm)
- Clean the surface of loose dust and debris.

C10-3.1.2 Coating System

The paint coating system shall consist of a priming coat and one finishing coat as follows:

Priming Coat

(a) The priming coat shall be an organic zinc rich epoxy primer approved under APAS Specification Number 2916, applied to achieve a minimum dry film thickness (DFT) of 75 micrometres;

(b) For primers, no liquid constituents manufactured earlier than 6 months prior to application shall be used;

(c) The priming coat shall be applied before discolouration occurs and in all cases not later than 4 hours after abrasive blast cleaning.
Finishing Coat

(a) After the priming coat has been allowed to dry, it shall be over-coated with a two-pack medium build epoxy micaceous iron oxide (MIO) finish, approved under APAS Specification Number 2973, employing a ‘mist’ coat on the initial pass;

(b) For epoxy MIO coatings no material manufactured earlier than 12 months prior to application shall be used on the steelwork;

(c) The finishing coat shall be applied to a minimum dry film thickness of 200 micrometres.

The total dry film thickness of the system shall be 275 micrometres.

C10-3.2 Existing steelwork – mild deterioration of surface coating

C10-3.3 Preparation

− High-pressure water wash general areas to remove visible oil, grease and dirt
− Power tool clean badly corroded areas to St 2
− Clean the surface of loose dust and debris.

C10-3.3.1 Coating System

− Use a surface-tolerant epoxy mastic paint
− Apply to thickness of 50 to 75μm to areas of spot repairs
− Then apply full coating to dry film thickness of 150 to 200μm.

C10-3.4 Existing steelwork – major deterioration of surface coating

C10-3.4.1 Preparation

− Remove visible oil, grease and dirt
− Remove any heavy layers of rust by chipping
− Abrasive blast clean to Sa 2½ with a surface profile height of 25 to 65μm
− Clean the surface of loose dust and debris.

C10-3.4.2 Coating System

a) Under major time constraints:

Use rapid-cure high-build 2-coat system:

− rapid cure zinc-rich phosphate epoxy primer (75μm DFT)
− rapid cure epoxy MIO top coat (200μm DFT).

b) No time constraint:

Use 2-coat system:

− 2-pack organic zinc-rich epoxy primer (75μm DFT)
− 2-pack epoxy MIO (200μm DFT).

C10-3.5 Existing steelwork – patch painting

Preparation and paint system to comply with the sub-procedure for patch painting in Section C4-3 of this Manual.

C10-4 Examples of Proprietary Products

<table>
<thead>
<tr>
<th>PAINT</th>
<th>PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-pack surface tolerant epoxy mastic</td>
<td>Jotamastic 87 (Jotun Australia P/L Interseal 670HS (International Protective Coatings)</td>
</tr>
<tr>
<td>Description</td>
<td>Options</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2-pack rapid cure zinc phosphate epoxy primer</td>
<td>Amerlock 2K (Ameron Coatings)</td>
</tr>
<tr>
<td></td>
<td>Intercure 200 (International Protective Coatings)</td>
</tr>
<tr>
<td></td>
<td>Amercoat 474 (Ameron Coatings)</td>
</tr>
<tr>
<td>2-pack rapid cure epoxy MIO</td>
<td>Intercure 420 (International Protective Coatings)</td>
</tr>
<tr>
<td></td>
<td>Amercoat 472 (Ameron Coatings)</td>
</tr>
<tr>
<td>2-pack organic zinc-rich epoxy primer</td>
<td>Zincanode 402 (Dulux)</td>
</tr>
<tr>
<td></td>
<td>Amercoat 307 (Ameron Coatings)</td>
</tr>
<tr>
<td></td>
<td>Barrier 80 (Jotun Australia P/L)</td>
</tr>
<tr>
<td>2-pack epoxy MIO</td>
<td>Ferreko No.3 top coat (Dulux)</td>
</tr>
<tr>
<td></td>
<td>Jotacote 910 MIO (Jotun Australia P/L)</td>
</tr>
<tr>
<td></td>
<td>Amercoat 472 (Ameron Coatings)</td>
</tr>
</tbody>
</table>
Chapter 11 Complete replacement of steel members

C11-1 Replacing members or elements of riveted members

C11-1.1 Description of defect
Any impact damage, severe corrosion or fatigue cracking of a member where complete replacement of the member or, in the case of riveted members, one or more components of that member is feasible.

C11-1.2 Description of repair
Complete replacement of the member or element of a riveted member.

C11-1.3 Engineering discussion
An engineering assessment to select the appropriate repair for a defect may determine that the best option is the complete replacement of the members or the element of a riveted member.

C11-1.4 Sub-procedures required
- Removing Rivets and Replacing with Bolts
- Patch Painting (including surface preparation)

C11-1.5 Procedure outline
- Determine the size, shape and layout dimension for bolt holes by careful measurement on site.
- Fabricate and galvanise the replacement member or elements.
- Fit any temporary bracing or support members required.
- Unbolt connecting bolts or remove connecting rivets.
- Remove the member or component.
- Prepare the area of interface to the new member or element by cleaning, grinding and painting if required.
- Fit the new member or element and complete the bolted connections.
- Prepare for and patch paint new and existing steelwork to the extent directed.

C11-1.6 Alternative details
The new member and its connections may differ in detail from the member it replaces provided it has been designed for the appropriate loads and effects and that the capacity of the structure or part of the structure is not reduced.

HUCK BOM blind fasteners may be used where there is access to only one side of the connection.

C11-1.7 Action to avoid or minimise recurrence
None

C11-1.8 Special considerations and effects of repair
None.

C11-1.9 Follow Up inspections and testing
Programmed inspections only.

C11-1.10 Drawing list
None.
Chapter 12 Guidelines for welding old steels

C12-1 Background/introduction

The materials used in railway construction over the past 100 years or so have evolved more or less in step with the changes in the metal fabricating industry and it is important to keep in mind that for the first two thirds of this period welding was not widely used and riveting was the usual method of joining. As a consequence of this the weldability of the materials involved was not a prime consideration and the ease, and in some cases the practicability, of welding can vary considerably. This, of course, makes maintenance very much more complex as riveting is no longer commonly used and where welding is not practicable bolting may be the best solution.

In an actual repair situation it is clear that identification of the material involved is the first and most important step.

It is hoped that in time this information will be available for all bridges in the system.

C12-2 Welding procedures for wrought iron

Since the carbon and sulphur contents of wrought iron are low, it presents no weldability problems in terms of hot or cold cracking, but the presence of slag stringers aligned with the forging direction presents problems. Firstly, whilst butt welds in the X and Y directions are quite feasible, welds on the surface Z direction are not recommended if significant load is to be transmitted as a lamellar tearing type of fracture is likely to occur.

Welding by the MMAW (manual metal arc welding) method is usually recommended using Basic Low Hydrogen electrodes. Note that hydrogen is a concern, but the basic flux is better able to accommodate the slag absorbed into the weld pool. Neither preheat nor post heat is required. Welding procedures and preparations are similar to those used for structural steel but it is recommended that welding speeds be reduced to 50-66% of those used for steel to allow time for slag removal from the weld pool.

Welding procedures and operators should be qualified where possible along the lines of qualification to AS 1554.1: 2004 “Structural steel welding Part 1 - Welding of steel structures”. If wrought iron of suitable section is not available, qualification may be done using Grade 250 structural plate.

Where distortion due to welding is undesirable, then the welding procedure may be combined with a peening procedure to eliminate distortion. See WTIA Technical Note 11 “Commentary on the structural steel welding Standard AS 1554” for details of this procedure.

In cases where it is necessary to make a connection to the surface of a wrought iron member then consideration should be given to replacing a length of the wrought iron by structural steel attached by butt welds to wrought iron or by using a bolting technique.

C12-3 Welding procedures for mild steel

As with wrought iron and structural steel, both the welder and welding procedure should be qualified prior to commencement of work. Again the qualification procedure described in AS 1554.1 should be followed. Since the mild steels are the most difficult of the three materials being discussed, welder qualification on mild steel should be accepted as qualification for procedures within the limits allowed by AS 1554 for wrought iron and structural steel.

Irrespective of the results of chemical analysis, mild steels should be regarded as being at least Weldability Group Number 5 since the sample removed for analysis and the modern analytical methods test only a small area and may not detect segregated areas.

To minimise the risk of HAZ (heat affected zone) hot cracking, weld beads should be kept small and if necessary buttering techniques should be used to reduce the residual stress from welding and the chance of cracking. Low hydrogen basic consumables must be used to counteract the deleterious effects of sulphur and phosphorous into the weld metal.
For those reasons, MMAW basic low hydrogen is the only welding process really suitable for welding these materials. Other welding methods have either too large a HAZ and hot cracking risk, or low tolerance to sulphur and phosphorous absorption to yield satisfactory results.

C12-4 **Welding procedures for structural steel**

Structural steel was developed to overcome the shortcomings of mild steel, i.e. cold cracking, hot cracking, brittle fracture and lamellar tearing. Structural steel is intended for welding.

The procedures for welding such steels are fully described in AS 1554 and the welder and procedure requirements of this standard should be observed fully. Welding consumables should as far as possible conform to the prequalified consumables listed in Table 4.6.1(A) of AS 1554.1 and in repair situations it will generally be found that adherence to the prequalified preparations of Table E1 will provide the optimum solution.

C12-5 **Weld quality**

The quality of the completed weld should be confirmed by visual and non destructive testing. Welds in major members should comply with AS 1554.5: 2004 “Structural steel welding Part 5 - Welding of steel structures subject to high levels of fatigue loading” Section 6 and welds in secondary members to AS 1554.1 Section 6.

C12-6 **Quality of repairs**

Generally, only visual, magnetic particle and ultrasonic examination will be feasible on bridge repairs, but radiographic testing should be used in place of ultrasonic testing where geometry permits and on qualification tests.

C12-7 **Recording of repairs carried out**

A record should be made of each repair carried out and should include at least the following information:

- Bridge identification
- Nature of damage.
- Location and date of samples removed for material identification.
- Metallurgical report number and date.
- Detailed description of defect with photograph if possible.
- Selected repair method.
- Welding procedures together with a copy of WPS (welding procedure specification) and PQR (procedure qualification record).
- Welders used together with qualifications and date.
- Material used, i.e. plate numbers and consumable batch numbers.
- Repair date.
- Visual and NDT test reports.
- Photograph of completed repair (if possible)
- Materials used plates etc, welding consumables, paint and manhours.
- Time and date bridge returned to normal service.

Such records should be kept by the Structures Manager.

C12-8 **Welding process**

Increasing temperature and welding on a member under stress can result in collapse of the structure or excessive distortion of a member. AS 1554.1 in Section 5 indicates that such welding is not permitted unless the question is discussed with the relevant authorities and safety precautions are taken. American Welding Society's AWS D1.1 “Structural Welding Code – Steel” is a little more
specific in Section 11 that sets a limit of 20.7 MPa on members to be repaired. It will therefore be necessary to unload the area to be repaired by the use of appropriate falsework before welding repairs are undertaken in most circumstances.

**Caution**

It is important that all involved with bridge repair be made aware that, whilst welding offers a quick and convenient joining method, unless used very carefully, it can seriously reduce the safety of a structure such as a rail bridge by increasing the danger of fatigue cracking, brittle fracture, and in some cases lamellar tearing.

Compared with bolting or riveting, welding carries with it a number of problems. Firstly in a bolted or riveted structure, the failure of a single member by brittle fracture or fatigue failure is often confined to that member, but in a welded structure the failure will often propagate through the weld to the next member. This was the cause of the numerous sinkings of welded ships during and after World War II when welding was first widely used in ship construction.

Secondly, in fusion welding a region of the HAZ adjacent to the weld is always overheated and in metallurgical terminology "burnt". This burnt region is an incipient crack and is usually regarded as a continuous crack 0.2 mm deep for fracture mechanic calculations. It is therefore clear that replacing riveting or bolting by welding results in a structure very much weaker in fatigue unless the burnt region at the weld toe is ground out. For example, AS 4100 “Steel structures” gives a bolted flange a rating of 140 MPa whilst a welded flange of similar design is rated 63 MPa.

Thirdly, welding used in a repair situation produces both distortion and areas of high tensile residual stress that can seriously reduce the fatigue resistance of a structure. It is almost always futile to simply weld up a fatigue crack or even to use a short doubling plate over the cracked area since rapid recurrence of cracking is inevitable.

Finally, it must always be borne in mind that the bridges of concern were built before the advent of fusion welding and their materials of construction are often not readily amenable to this welding method.

**C12-9 Weld Surface Condition**

Where fatigue cracking is a problem and in some circumstances where brittle fracture could occur, the weld surface profile has a considerable effect on the service life of the joint. For the purpose of this manual we shall simplify the range of surface conditions as follows:

a) as welded

b) weld toe ground

c) weld surface fully ground.

There are other weld surface treatments that offer even greater improvements in performance than b) or c) above but these are probably not required for bridge repairs and will not be discussed further.

**C12-10 Weld Toe Grinding**

As described above any fusion weld in steel or wrought iron contains a virtual crack the full length of the weld toe of around 0.2 mm in depth and the removal of this zone by disk grinding or better still by use of a tungsten carbide burr in a pneumatic pencil grinder will increase the allowable fatigue stress by around 40%. The depth of grinding must be at least 0.5 mm but should not result in the loss of more than 10% of plate thickness.

This procedure requires around 1 manhour/m and is strongly recommended for all repairs on lower flanges. A similar result at lower cost can be achieved by disk grinding but this requires rather more
skill on the part of the operator and it may be difficult to achieve a satisfactory result in a bridge repair situation.

C12-11 Full Weld Surface Grinding

Complete grinding of the weld surface and toe will yield an improvement of about 50% in fatigue performance whilst polishing of the weld surface by burr grinding yields about 80% improvement, but these are expensive and time consuming processes not generally justified on bridges.

The desirable level of weld surface depends naturally upon the stress situation at the repair location. As guidance it is proposed that if Design Branch has not specified other requirements the following be used:

a) Transverse welds on lower flange: Weld toe ground as above. Other criteria as per Table 6.1.2 in AS 1544.5.

b) Longitudinal welds on lower flange and other welds below: web height as per Table 6.1.2 of AS 1554.5.

c) Other welds as per Table 6.2.2 of AS 1554.1.

Where NDT is carried out, the requirements for cases a) and b) shall be Table 6.1.1 in AS 1554.5 and in case c) Table 6.2.1 in AS 1554.1.

C12-12 Weld Processes and Consumables

Usually repair welds are best carried out using the Manual Metal Arc process since this offers a good combination of flexibility and weld metal properties. However, where extensive welding is required the advantages of higher productivity offered by the continuous wire welding processes should be considered.

The continuous wire processes are either flux or gas shielded or self shielded cored wire.

Flux shielding, i.e. submerged arc welding, is generally only used in the downhand and horizontal/vertical positions, although with special equipment it can be used in the horizontal position. Gas shielded processes, i.e. MIG (metal inert gas), GMA (gas metal arc) and TIG (tungsten inert gas) are usually difficult to use in a field repair situation because it is necessary to provide a shelter to prevent the wind upsetting the gas shield.

The self shielded cored wire process is very much more suited to a field repair situation since it is largely immune to the effects of wind and offers excellent productivity and surface profile. Acceptable consumables should meet the requirements of AS 17632 “Welding consumables – Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels – Classification (ISO 17632:2004, MOD)” classification 35, 38 or 42.

Manual metal arc electrodes should be of the basic low hydrogen type to provide the required resistance to HAZ hydrogen cracking in steels of low weldability, good weld metal notch toughness and tolerance to the slag stringer pick up when welding wrought iron. In a repair situation it is best to choose electrodes with 1) low yield strength, 2) good weld metal toughness, 3) smooth running characteristics, and 4) that are supplied in a moisture proof package.

Specific electrodes from different local manufacturers that can be recommended are Cigweld Ferrocraft 61 LT (for reason 1), WIA Austarc 16TC (for reason 3) or Lincoln Jetweld LH-70 (for reasons 2 and 4). It is usually better to use the electrodes familiar to the welder rather than retrain a welder to use an unfamiliar consumable type. Electrodes should only be used if in good condition, i.e. no core wire rusting coating, flaking or laitance and after baking in accordance with the maker's recommendations or those given in WTIA Technical Note 3 “Care and conditioning of arc welding consumables”.

C12-13 Minimum Weld Size

It is important to ensure that the weld size deposited is not less than the values given in AS 1554.1 Table 3.3.5. During welding it is as well to check that the welding current and travel speed are in
accordance with the approved welding procedure. Welding current is best measured by a clamp meter since the meters on welding equipment are seldom reliable. Failing this, the measured size of a fillet weld will usually allow a good estimate of the welding conditions used. See WTIA Technical Note 1 “Weldability of steels” Figure 7.
Chapter 13 Concrete repair sub-procedures

C13-1 Removing damaged concrete (sub-procedure)

C13-1.1 Engineering discussion

Removal of damaged or deteriorated concrete may be necessary in several situations, such as:

- Corrosion of reinforcement leading to cracking, spalling and delamination of concrete.
- Impact damage causing cracks and spalls.
- Construction defects resulting in honeycombing, cracks and scaling.
- Defective joints causing corrosion to reinforcement, cracking of concrete and leaking.
- Repair of old repairs that have broken up.

Regardless of the type of deterioration, all unsound and disintegrated concrete must be removed.

Where reinforcement corrosion is the cause of the problem, concrete must be removed to a depth that includes all the affected reinforcement and goes behind the reinforcement as well so as to give an adequate thickness of cover to the steel in every direction. New concrete that is dense and of high quality will provide sufficient protection against carbonation, unless new carbon dioxide reaches the steel.

Where chloride contamination is the problem, there are more points to consider. If the contamination comes from the original mix, limited concrete removal will not give complete protection to the steel. In this situation coating the reinforcement with epoxy resin should be considered, but if the chloride contamination has come from a salty environment, the depth of concrete that has been contaminated should be determined by testing. The concrete cover should then be removed to a depth where chloride contamination is less than 0.1% of cement. If the salty environment is aggressive, coating the finished concrete surface after the repairs should also be considered.

The extent of concrete removal depends on the extent of damage. It may be localised or widespread. If the damage is due to severe but local corrosion in reinforcement requiring addition of bars, only the damaged area of concrete plus the length needed to bond the new reinforcement needs to be removed.

Concrete may be removed by power tools or by water blasting with or without entrained abrasives. If abrasive is entrained in the water jet, it will also remove most of the rust from the exposed reinforcement.

If concrete is broken out from inside a large area of generally sound concrete, the edges of the area to be repaired should be cut with a perpendicular saw cut at least 15mm deep to avoid a feathered edge finish. The feathered edges of repaired concrete will easily prise off as a result of changes in stress. The face of the saw cut must be roughened slightly (eg. with a needle gun) to help the repair material to bond with it. (see Figs. 16 and 17).
Zone of carbonated concrete

Concrete removed to a depth of at least 20mm beyond reinforcement

20mm sawcut provides a perpendicular edge for the repair

Figure 16 – Removal of deteriorated concrete

Incorrectly installed patch

Correctly installed patch

The feathered edges of the top figure will break down under traffic or will weather off. The broken out area should be at least 20mm deep with the edges at right angles or undercut to the surface.

Figure 17 – Patch repairing

In situations of soffit repairs to beams and slabs, then profile of the removed concrete should be planned to allow escape of air during re-casting. Vent holes may be drilled through the slab for the same purpose.

C13-1.2 Procedure

Before removing any concrete from a load bearing structure carefully consider whether the concrete to be removed is providing essential support for the structure. If yes, support the structure first.
- Ascertain the area of damaged concrete to be removed and repaired. Consider extending the repair area to some line where the boundary of the new work will fit in with a feature of the structure to improve its appearance.

- Mark the repair area with horizontal and vertical lines. Avoid sharp acute angles and re-entrant corners.

- Make perpendicular saw cuts along the lines. The depth of saw cut should be a minimum of 15mm and a maximum 20mm. Take care not to cut through reinforcement bars. For small areas and where saw cutting is not practical, use chipping tools to remove concrete, but ensure that the edges of the repair area are cut perpendicular to the surface.

- Remove the damaged concrete within the saw cut boundaries to the depth required using power tools and/or high pressure water blasting. If removal of material has exposed more than half of the perimeter of the reinforcing bars, remove the concrete further to expose the bars completely with a minimum 20mm clearance behind the bars to ensure encasement and bond.

Exposure of steel reinforcement must also continue along its length until non-corroded steel is reached and continued at least 50mm beyond to show sound rust-free metal.

Corners of the removed concrete at the substrate level should be rounded to obtain good contact between the substrate and patch material.

- Roughen the edges of saw cuts with needle guns.

- Ensure that all weak and flaky concrete is removed throughout the substrate.

C13-2 Removing concrete at joints (Sub-procedure)

C13-2.1 Engineering discussion

Three types of joints are provided in reinforced concrete structures:

- Construction joints
- Contraction joints
- Expansion joints

At construction joints the structure is intended to remain monolithic without movement across the joint. Expansion and contraction joints, however, are provided to allow movement in the structure due to shrinkage, creep and thermal effects.

Depending upon the joint detail, a joint may incorporate continuous reinforcement across it (or, the reinforcement may be stopped on either side of it), dowel bars for shear transfer and water stops and sealants to prevent water penetration. Because of the complexity of detail at the joints, they are difficult to construct and the concrete at a joint may become porous and honeycombed due to lack of compaction. Therefore, it is not surprising that many joints fail resulting in cracking of concrete, corrosion of reinforcement and water penetration.

Construction joints that open and behave as movement joints must be widened and sealed at the external face as soon as they are noticed and before contamination can occur (refer methods for repairing cracks).

A badly deteriorated joint must be repaired by removing the affected concrete and reconstructing the joint.

Removing the concrete 'cover' at a joint is often a matter of removing concrete both on the external surface and the internal joint face and it usually results in removing all the concrete in the immediate vicinity of the joint. The reinforcement, however, must be left in place so that the re-cast concrete can be tied in to the existing concrete.

If the joint incorporates dowel bars, it is often necessary to remove the dowel assembly completely. This means that all the concrete may have to be removed as far as 500mm on either side of the joint.

Repairing dowelled joints that allow movement by removing the concrete on one side only seldom succeeds, because often it is the lack of accurate alignment of the dowels that causes distress in
the joint by not permitting free sliding of the concrete member. In such cases the dowel bars must also be removed and replaced by pre-assembled dowels that are set parallel to each other and in one plane and installed accurately in formwork perpendicular to the joint plane, before the concrete is cast.

C13-2.2 Procedure

− If necessary, support the structure on both sides of the joint before any concrete is removed.
− Ascertain the area of damaged concrete to be removed.
− Mark the repair area with lines running parallel and perpendicular to the joint.
− Make perpendicular saw cuts 15 to 20mm deep along the lines. Take care not to cut through reinforcement bars.
− Remove the damaged concrete between the saw cut and joint to the depth required.
− If the concrete requires removal through the full depth of a slab, the slab should be cut below the saw cut at an angle of approximately 20° to the vertical, sloping towards the joint. To achieve a neat joint on the soffit of the slab, consider making a saw cut on the soffit also offset from the saw cut at the top of slab to give a sloping construction joint. (See Fig. 18).
− Roughen the edges of the saw cut with needle guns.
− Ensure that all weak and flaky concrete is removed.

![Dowel assembly](image)

**Figure 18 - Removing concrete at joints**

C13-3 Cleaning concrete substrate for patch repairs and re-casting (Sub-procedure)

C13-3.1 Engineering discussion

To ensure good adhesion of mortar or new concrete to the parent material, the substrate should be clean and free of dust and loose material.

C13-3.2 Procedure

− After removal of damaged concrete, remove loose particles and dust with high pressure water or vacuum cleaning. Air blowing may be effective, but the compressor should be equipped with a functioning oil trap to prevent contamination of the concrete by oil.
− Do final cleaning immediately before placement of the repair material to ensure that all contamination is eliminated.

All concrete surfaces on which new overlays are to be bonded must be cleaned of dirt, oil, grease, asphalt, tar, laitance and deteriorated concrete. Asphalt or oil particularly interfere with methyl methacrylate polymerisation and therefore must be removed thoroughly. Detergents may remove surface oil contamination. However, oils that have penetrated the surface should be removed by chipping or scarification.
C13-4  Cleaning Concrete Surface for Overlays

C13-4.1  Engineering Discussion

All concrete surfaces on which new overlays are to be bonded must be cleaned of dirt, oil, grease, asphalt, tar, laitance and deteriorated concrete. Asphalt or oil particularly interfere with methyl methacrylate polymerisation and therefore must be removed thoroughly. Detergents may remove surface oil contamination. However, oils that have penetrated the surface should be removed by chipping or scarification.

C13-4.2  Procedure

- Remove tar and asphalt by mechanical means followed by sandblasting.
- Remove all traces of dirt, oil and grease by scrubbing with a proprietary alkaline detergent solution such as sodium metasilicate or trisodium phosphate. Wash with plenty of water to ensure complete removal of the detergent. Dirt alone may be removed by water blasting, with wire brushes or similar mechanical means.
- If oil has penetrated into the surface, remove affected concrete by chipping or scarifying followed by water or sand blasting to remove loose material.
- Remove laitance and deteriorated concrete by water or sand blasting.
- Immediately prior to the application of the overlay material, blow the concrete surface with clean, dry and oil free compressed air to ensure complete removal of all dust and loose particles.

C13-5  Cleaning reinforcement (Sub-procedure)

C13-5.1  Engineering discussion

If the deterioration of concrete has been caused by corrosion of reinforcement, the products of corrosion must be removed before placing the new concrete, otherwise the repair will not be effective. If the damage is due to chloride contamination, it is essential to remove all rust from the steel, as any residual rust will be contaminated with chlorides that could restart the corrosion later.

Water-abrasive blasting is the most effective method for cleaning the reinforcement. The abrasion removes the solid rust and water dissolves the chlorides away. Enough concrete must be cut away on the blind side of the reinforcement to allow room for water-abrasive blasting - the space will be needed for providing concrete cover to the steel.

If the cause of damage is carbonation, rust removal is less critical and it will be sufficient to remove any loose rust that might prevent adhesion of the repair material to the steel.

C13-5.2  Procedure

- Ascertain from test results if chloride contamination has occurred.
- Inspect the reinforcement after the concrete has been removed.
- If deterioration is due to chloride contamination or if the reinforcement is covered with loose corrosion products and has developed pits, use water-abrasive blasting till all the rust is removed and steel has achieved Class 2½ "Near White" surface cleaning to AS1627.4.
- If there is no chloride contamination and the rust is slight and adheres well to the steel, without signs of loose scales and pitting, clean the reinforcement by water blasting only to remove any loose material.

C13-6  Adding reinforcement (Sub-procedure)

C13-6.1  Engineering discussion

If rusting has reduced the cross-sectional area of reinforcement by more than 15%, extra reinforcement must be added before the repair is made good to restore the cross-sectional area to its original value.

C13-6.2  Procedure
− Inspect the exposed reinforcement for damage after the concrete cover has been removed.
− Examine if corrosion has reduced the cross-sectional area of any bars by more than 15%. If it has, measure the length over which such corrosion extends.
− Provide a lapping bar.
− The length of lapping bar required = corroded length + 2 x 25d_b (where d_b = bar diameter).
− Lapping bars shall be of the same diameter as the existing bars.
− Ensure that sufficient concrete is removed to accommodate the lapping bars (See Fig. 19).
− Clean the concrete and the existing reinforcement.
− Attach the lapping bars to existing bars with tie wires or by welding. Ensure that lapping bars have adequate concrete cover all around. If welds are used, remove all weld slag and splatter from the steel and concrete.

![Figure 19 – Adding reinforcement](image)

**C13-7 Applying bonding coat to concrete (Sub-procedure)**

**C13-7.1 Engineering discussion**

Engineering aspects of bonding coats are discussed in TMC 305 – Structures Assessment.

If the selected repair method requires application of a proprietary bonding coat to the concrete substrate, it is essential to read the manufacturer’s instructions for preparation and application of the particular bonding material. These instructions must be strictly followed. Directions given here are for general guidance only.

The working time of different types of bonding coats varies and is often limited. The bonding coat will prevent bonding if it is allowed to dry. It is therefore important to plan the timing for its application beforehand so that the repair can be completed within the allowed working period.

The "wetness" of concrete substrate required prior to application of bonding coats is also different for different bonding materials. Generally, epoxy bonding coats are applied to dry surfaces, but specially formulated resins are available for damp surfaces also. Cementitious bonding coats (whether modified with latex or unmodified) require the substrate to be "pre-wetted", but only just damp at the time of application.

**C13-7.2 Procedure**

− Clean the concrete surface and steel reinforcement in accordance with the sub-procedures.
− When applying unmodified cementitious bonding coat, eg. Portland cement grout, (or repair mortar or concrete), keep the concrete surface wet for 12 to 24 hours prior to starting the repair.
− When applying latex modified Portland cement bonding coat (or repair mortar or concrete), keep the concrete surface wet for at least one hour prior to starting the repair.
− Remove all free water and allow the surface to dry until it is just damp.
− Apply the bonding coat material with a brush or broom working it vigorously into the substrate.
− When applying epoxy based bonding coats, allow the substrate to dry completely (unless the epoxy is formulated for application on damp surface).
− Apply the bonding coat material with a brush or broom working it vigorously into the substrate. Cover only as much of the area of the substrate as can be repaired or overlaid with repair mortar or concrete within the working time of the bonding material.

− Apply the bonding material progressively as the repair work advances.

C13-8  Coating reinforcement (Sub-procedure)

C13-8.1  Engineering discussion

Engineering aspects of coating steel reinforcement are discussed in TMC 305.

Apart from cement slurry, other coatings are generally proprietary products and it is essential to read the manufacturer's instructions for their application. These must be strictly followed.

C13-8.2  Procedure

− Clean the steel reinforcement
− If required, add lapping reinforcement
− Apply the selected bonding coat to the steel bars with a brush, working vigorously to ensure that bars are evenly covered all around
− Remember, the working time of bonding coats is limited. Therefore, follow immediately with the application of the repair material.

C13-9  Formwork for re-casting concrete (Sub-procedure)

C13-9.1  Engineering discussion

Where deteriorated concrete in structural elements is to be replaced, it must be re-cast using appropriate formwork. Often the space for re-casting concrete is very limited, necessitating the use of super-plasticised or pumped concrete and compacting with external vibrators.

Formwork for re-casting repairs must be very rigid and well-supported to prevent the new concrete from sagging away from the old concrete under its own weight, to withstand pumping forces if concrete is to be pumped into forms and to withstand the forces of clamped-on external vibrators.

Heavy gauge steel forms are preferable because as well as being rigid they allow quicker dissipation of the heat of hydration of the fresh concrete, thus reducing the contraction stresses. Formwork should be provided with birdmouth hoppers and openings where appropriate for feeding new concrete and inserting poker vibrators (See Fig. 20). Form releasing agents used should be compatible with the repair materials, particularly epoxy based and latex modified concretes and grouts.
C13-9.2 Procedure

- Pre-assemble the formwork. Use an appropriate form release agent to suit the repair material to be placed.
- Fix the formwork and its supports immediately after applying bonding coats to the concrete substrate and reinforcement.
- Make the forms mortar tight by sealing with building tape or sealants along all joints.
- Clean the forms of all the debris before placing any concrete.
- Place re-casting concrete within the working time of bonding coats (if used).
- Ensure good compaction of concrete using pokers or external vibrators.

C13-10 Curing (Sub-procedure)

C13-10.1 Engineering discussion

All types of cementitious repair need thorough and continuous curing to develop strength and impermeability, and to reduce drying shrinkage to a minimum while bond strength is developing.

Water used for curing shall be free from ingredients harmful to concrete.

Curing procedures for polymer modified and unmodified cementitious materials are different and are discussed in detail in TMC 305. Epoxy based materials are self-curing and do not require external curing.

Curing compounds should not be used with latex modified concretes as the wax or resin in most curing compounds is incompatible with latex.

Curing compounds should also not be used if additional material is to be bonded at a later stage to the surface being cured.

Continuous water curing is always preferable to membrane curing. Curing membranes do not provide any reserve of extra water to make up for any that escapes and are not likely to provide enough curing in the critical early stages. Curing membranes applied after the wet cure, however, can help to slow down drying.
C13-10.2 Procedure for curing latex modified cementitious concretes and mortars
- Complete all surface finishing operations as soon as possible (before formation of the polymer film). Protect the freshly finished surface from rain or damage from other causes.
- As soon as the surface can support it, and prior to formation of the polymer film, cover the surface with a single layer of wet hessian. Place polyethylene film over the wet hessian to prevent moisture loss by evaporation.
- Remove the polyethylene film and hessian after 24 hours. Allow the surface to dry for 3 to 5 days.

C13-10.3 Directions for curing unmodified cementitious concretes and mortars
- Complete all finishing operations before the concrete or mortar starts setting. Protect the freshly finished surface from rain or damage from other causes.
- Keep the concrete moist by light water spray immediately after the initial set, until curing methods are in place.
- Cover with saturated hessian sheets followed by a polyethylene film to prevent moisture loss. Alternatively, the surface may be cured by continuous spraying or flooding with water.
Curing shall be continued for minimum of 4 days in temperate weather and 7 days in hot, dry or windy conditions.

C13-11 Surface preparation for external coatings (Sub-procedure)
C13-11.1 Engineering discussion
Preparation of concrete surfaces is necessary to achieve bonding of film forming coatings and penetration of penetration type coatings.

In new structures, this preparation may only require removal of the oil or wax from release agents and curing compounds that could be sticking to the concrete and prevent adhesion of coatings.

In old structures, apart from repairing any deterioration, surfaces will need to be cleaned of dirt, dust, oil, grease, old paint, moss and algae growth.

The surface also needs to be reasonably dry for the coatings to stick properly and resist peeling and blistering. (However, for cementitious coatings the surfaces have to be pre-soaked with water and should be just damp before application of coating).

Coating materials are available as proprietary products. Manufacturer's instructions regarding surface preparation and application should be carefully studied and followed before undertaking any work.

C13-12 Procedure
- Clean the surfaces to be coated by suitable methods according to the existing condition of the structure. Use high pressure water jets, sandblasting (wet or dry), power operated wire brushes, grinding discs, etc to remove dirt, laitance, weak concrete, corrosion affected concrete and any other deterioration. Remove oil and grease with proprietary alkaline detergents, and moss and algae with fungicidal solutions. Rinse off these solutions with large quantities of water.
- Repair all deterioration in concrete such as cracks, spalls, reinforcement corrosion, etc.
- Fill surface irregularities, blow holes, tie-wire holes and the like with suitable fairing, levelling or sealing coats or mortars.
- Allow the repairs to set and cure.
- Allow the concrete to dry. (For cementitious coatings, however, pre-soak the concrete with water for 24 hours. Remove free water and allow concrete to dry until just damp).
- Immediately prior to the application of primer or final protective coat as required, remove any dust and loose particles with oil free compressed air.
Chapter 14 Repairing cracks in concrete structures

C14-1 Types of cracks

Description of various types of cracks that can occur in concrete structures has been given in TMC 301 “Structures Examination”.

For purposes of repair, however, there are two types of cracks:

- Dead cracks - These are inactive cracks and do not move
- Live cracks - These are subject to movement due to applied loads and temperature changes.

C14-2 Repair methods for cracks

Dead cracks can be repaired by any of the following methods:

- Epoxy injection
- Grouting
- Routing and sealing
- Drilling and plugging
- Stitching
- Adding reinforcement
- Overlays and surface treatments.

Live cracks can be repaired by:

- Flexible sealing.

C14-3 Cracks that should be repaired

Not all cracks are structurally significant. The vast majority are caused by shrinkage or other tension stresses that develop as the structure supports itself and have no influence on strength or durability.

It is important to recognise if cracking is of a size and type that is harmful, and act accordingly.

Generally, fine cracks up to 0.3mm width have no adverse effect when reinforcement cover is adequate. Fine cracking will also heal autogenously as the free cement is exposed to moisture. In this process calcium hydroxide in the cement reacts with carbon dioxide and moisture forming calcium carbonate and calcium hydroxide crystals that tend to seal the crack. Healing will not occur if the crack is subjected to movement or if there is flow of water through it.

Flexural cracks in a bending member do not normally progress beyond the neutral axis and have a reduced width at the tensile reinforcement. In such cases a surface crack width of 0.5mm is usually acceptable. In members protected from driving rain and in the absence of an aggressive marine or industrial environment, even 1mm cracks can be tolerated.

Stable cracks of the size and type described are generally harmless and need not be repaired.

Harmful cracks develop due to such factors as carbonation, chlorination, alkali-aggregate reaction, corrosion, overloading of the structure, foundation movement, insufficient reinforcement and lack of adequate cover. It is important to identify the presence of these causes. All harmful cracks must be repaired.

Longitudinal cracks can expose long lengths of reinforcement to possible sources of contamination and they must always be regarded as potentially dangerous, even if they may not be already the result of rusting.

Cracks due to severe deterioration (as in corrosion and impact damage) that necessitate removal and replacement of concrete will require repair methods other than crack repairs.
Transverse cracks may or may not be serious depending on their width, location and the exposure conditions as described above.

C14-4 Epoxy resin injection

Epoxy resin injection of cracks in concrete is a highly skilled process; its success depends largely on the experience of the operator. It is not a process that should be attempted by a general contractor. The information given below is, therefore, for general guidance only.

C14-4.1 Engineering discussion

Epoxy resin injection is used to restore structural soundness of structures with inactive cracks.

Cracks up to 0.05mm can be bonded and sealed by injecting with a low viscosity epoxy.

Cracks wider than 6mm generally require a mix of epoxy and a mineral filler, or Portland cement grout. The technique generally involves drilling holes at close intervals along the cracks, fitting them with entry ports, and injecting the epoxy resin under pressure.

Some cracks extending downwards from nearly horizontal surfaces may be filled by gravity if the width of crack is more than 0.5mm and depth is less than 300mm. For this, the top surface edges should be chipped or sawn to form a small trough to provide an inlet for the gravity flow of resin into the crack.

Except for certain specialised epoxy resins, the method cannot be used if the cracks are actively leaking. While moist cracks can be injected, water or other contaminants in the crack will reduce the effectiveness of the epoxy repair.

C14-4.2 Repair procedure

− Clean the cracks to remove any contamination (such as oil, grease, dirt, fine particles of concrete) from the cracks with water under high pressure, or a special solvent. Blow out the residual water or solvent in the crack with filtered (dust and oil free) compressed air or allow adequate time for air drying.

  Note: The epoxy system used should be capable of bonding to wet surfaces unless it can be assured that the crack is dry.

− Seal cracks at the surface to keep the epoxy from leaking out before it has gelled. 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.

− Drill holes into the crack for fitting pipe nipple entry ports for epoxy injection. A vacuum chuck and bit are useful in preventing the cracks from being choked with drill dust. Spacing of ports varies between 150mm to 500mm generally depending on the width and depth of the cracks. Establish the first and last entry ports at or near the bottom and top, respectively, of any vertical crack, or at the ends of any horizontal crack in a vertical or horizontal member.

− Mix the epoxy. There are two methods for mixing epoxy, batch or continuous.
  In batch mixing the adhesive components are mixed according to the manufacturer's instructions using a mechanical stirrer.

  Mix only the amount of adhesive that can be used prior to commencement of gelling of the material.

  In the continuous mixing system, the two adhesive components pass through metering and driving pumps prior to passing through an automatic mixing head. The continuous mixing system allows the use of fast setting adhesives that have a short working life.

− Inject the epoxy. Epoxy can be injected with hydraulic pumps, paint pressure pots or air-activated caulking guns. Select the injection pressure carefully. Increased pressure does not necessarily accelerate the rate of injection. In fact, excessive pressure can propagate the existing crack further.
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 successively 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 end 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 some point.

− 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.

C14-5 Grouting

C14-5.1 Engineering discussion

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.

C14-5.2 Repair procedure

− If the surfaces in the crack are 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.
− Flush out all dust and debris from the crack with high pressure water jets.
− Install grout nipples at intervals along the crack.
− Seal the crack between the nipples with a sealant.
− Flush the crack with water to clean it and test the seal.
− Grout the crack until it is completely filled. Maintain the grout pressure for several minutes to ensure good penetration.
− Remove the nipples and fill holes with cement mortar.

C14-6 Routing and sealing

C14-6.1 Engineering discussion

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 unskilled labour. It is suitable for both fine pattern cracks and larger isolated cracks, but will not be effective on active cracks and cracks subject to a pronounced hydrostatic pressure.

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

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

C14-6.2 Repair procedure

− 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 (See Fig. 21).
− Clean the groove with an oil free air jet. Allow to dry completely before placing the sealant.
− Apply the sealant as per manufacturer's instructions.
C14-7 Drilling and plugging

C14-7.1 Engineering discussion

This method is most often used to repair vertical retaining walls and consists of drilling a hole down the length of the crack and grouting it to form a key (See Fig. 22). 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.

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.

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.
Drilled hole centred on and following down crack. Size depends on crack width. Use 50 to 75mm minimum diameter.

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 22 – Drilling and plugging**

**C14-7.2 Repair procedure**
- Drill a 50mm to 75mm diameter hole down the concrete centred on and following the crack.
- Flush the hole and crack with a 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.
- Seal the crack tight on the exposed face. Allow the seal to cure and harden.
- Fill the hole and crack with grout.

**C14-8 Stitching**

Stitching may be used when tensile strength needs to be re-established across major cracks. Stitching also tends to increase stiffness in the structure that may cause cracking elsewhere. This method of repair should therefore be adopted only under the advice of a structural engineer.

**C14-8.1 Engineering discussion**

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 (See Fig. 23).

Where possible, stitching should be done on both sides of a concrete section so that further movement of the structure does 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.

Figure 23 – Repair of crack by stitching

C14-8.2 Repair procedure
- If it is required, seal the crack by epoxy injection, grouting, or routing and sealing.
- 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.
- 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.
- Clean the holes of all dust and debris.
- Anchor legs of the dogs in holes with a non-shrink grout or epoxy resin-based grout system.

C14-9 Adding reinforcement
Adding reinforcement to an existing structure to repair cracks should not be undertaken without the advice of a structural engineer.

C14-9.1 Engineering discussion
When cracks impair the strength of a concrete structure, the structure can be strengthened by the addition of conventional or prestressed reinforcement. The method of fixing such reinforcement will depend on the particular structure and type and location of the cracks. The damage must be examined by a structural engineer and the reinforcement designed to resist the forces causing the cracks.

C14-9.2 Repair procedure with conventional reinforcement
Cracked structures may be repaired by epoxy resin injection and reinforcing bar insertion across the cracks (See Fig. 24).
− Clean the cracks of dust, debris and contamination. Allow the cracks to dry.
− Seal the cracks at exposed surfaces with an epoxy resin sealant approximately 3mm thick and 40mm wide. Allow one or two vent holes at the top for escape of air during epoxy injection.
− Drill 20mm diameter holes at 45o to the concrete surface and crossing the crack plane at approximately 90o. Use vacuum bits and chucks to prevent dust from clogging the cracks. The holes should extend a minimum of 450mm on each side of the crack. The number, spacing and location of the holes should be determined by design, taking care to avoid existing reinforcement.
− Fill the holes and cracks with epoxy pumped under low pressure (350 to 550kPa). The epoxy used should have very low viscosity and high modulus of elasticity and it should be capable of bonding to concrete and steel in the presence of moisture. Holes should be filled with epoxy to part depth sufficient to raise the epoxy level to the surface when steel bars are inserted.
− Insert reinforcing bars (typically 12 or 16mm diameter) into the epoxy filled holes.
− Clean off any overflowing epoxy immediately.

![Added reinforcement installed to strengthen repair. Holes are drilled at right angles to the crack, then filled with epoxy before bars are inserted.](image)

Figure 24 - Adding reinforcement for strengthening (Reference 15)

**C14-9.3 Repair procedure with external prestress steel**

Post-tensioning is often used to strengthen a structure damaged by structural cracking or when the cracks have to be closed. This technique uses prestressing strands or bars to apply a compressive force to negate the tension causing the cracks (See Fig. 25). It requires a thorough design of the prestressing force, detailing of the anchorage system and analysis of the secondary effects on the structure. The task must therefore be carried out by a structural engineer.
To rectify cracking of a slab

To rectify cracking of a beam

External prestressing can close cracks and restore structural strength. Careful analysis of the effects of the tensioning force must be made or the crack may migrate to another position.

Figure 25 - Adding external prestress (Reference 14)

C14-10 Surface treatments

C14-10.1 Engineering discussion

Slabs with numerous fine cracks caused by drying shrinkage or other one-off occurrences can be effectively repaired by the use of protective coatings 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.

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 seal
dormant cracks, even if the aggregate is abraded from the surface, since traffic cannot abrade the resin that has penetrated the cracks.

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

C14-10.2 Repair procedure

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

C14-11 Flexible sealants for live cracks

C14-11.1 Engineering discussion

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 are not important and the surface is not subject to traffic, the sealant may be applied on the surface without making a recess (see repair procedures below).

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

C14-11.2 Repair procedure for a recessed seal

- 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. The dimensions of the recess should comply with the requirements of the crack movement and sealant material (see Fig. 26).
- Clean the recess of dust and debris by wire brushing followed by air-blasting with oil-free compressed air.
- Coat the surfaces of the recess with primer as specified by the sealant manufacturer.
- 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.
- Fill the recess with flexible sealant as per the manufacturer's instructions.

Where the concrete is carbonated or contaminated with chlorides or has deteriorated due to corrosion of the reinforcement, it must be broken out (refer sub-procedure 12-2) and replaced, and a sealed movement joint formed as detailed above.
C14-11.3 Repair procedure for a surface seal

- 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 (see Fig. 27).
- Clean the concrete surface adjacent to the crack of laitance and contaminants such as grease and oil.
- Coat the concrete surface along the crack in approximately 100mm wide strips with a primer recommended 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 using a trowel.

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

Figure 26 - Flexible joint sealant – recessed seal

Figure 27 - Flexible joint sealant – surface seal
Chapter 15 Patch repairs of concrete structures

C15-1 Engineering discussion

Patch repairs are employed to restore small areas of otherwise sound concrete that have been damaged by spalling, scaling, honeycombing and impact. Patch repairs are generally trowel applied, require no 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 the urgency of the repair, patch repairs may be carried out with Portland cement mortars, latex modified cementitious mortars or epoxy mortars. Characteristics of different types of mortars have been given in TMC 306. However, preference should be given to cementitious or latex modified cementitious materials for compatibility with concrete.

If ordinary Portland cement is used in the mortar, the patched surface will 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 a 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.

C15-2 Repair procedure with cement-sand mortars

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

Note: Patch repairs are generally carried out to sound concrete. Repairs for deterioration due to corrosion are treated differently.

− Select the 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.

− Prepare the cement-sand mortar by mixing with the minimum amount of water. The slump of the mix for shallow patches should not exceed 25mm.

To minimise shrinkage in place, allow the mortar to stand for half hour after mixing and then remix prior to use. Do not re-temper with water.

− Apply the bonding coat to the concrete substrate and to the reinforcement.

− 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.

− 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 appropriate.

− Start curing as soon as possible. Follow the sub-procedure.
C15-3  Repair procedure with polymer modified cementitious mortars

- The repair procedure is the same as for cement-sand mortars, except for the details noted below.
- The proportion of polymer admixtures to be added should be as per the manufacturer's recommendations.
- The working time of polymer modified mortars is relatively short. Therefore, limit the quantity of mortar for a particular job such that it can be placed, compacted and finished within the working time - about 20 minutes.
- Soak the concrete substrate with water for one hour before applying bonding coat.
- Apply the polymer based bonding coat to the concrete substrate and reinforcement. The polymer in the bonding coat should be the same as in the repair mortar.
- 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.
- Do not re-work or manipulate the mortar after the latex has coalesced, otherwise cracking will occur on drying.
- Adopt the curing procedure for polymer modified mortars as laid down in the sub-procedure for curing.

C15-4  Repair procedure with epoxy mortars

Patch repairs with epoxy resin mortars require special skills and should be entrusted to personnel experienced in mixing, handling and applying epoxy materials. The following notes are for guidance only.

- Do not carry out repairs with epoxy-based materials at low temperatures as it is difficult to get the mixture to harden quickly enough.
- Restrict the application of epoxy mortar to thin sections, not exceeding 20mm.
- Prepare and clean the patch area. The concrete surface should be completely dry.
- Patching that is thin enough to be appropriate for repair with epoxy mortar is not likely to extend down to the reinforcement, but if it does, clean the reinforcement.
- 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.

The 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.

Handle the materials cleanly to avoid contamination of either the resin mixtures or the people working with them.

- Prime the concrete substrate (and reinforcement, if exposed) with the same liquid resin mixture as used for the epoxy mortar.
- Apply the mortar with a trowel immediately following the bonding coat and finish the repair before the resin hardens.
- No curing is required for resin mortar patches.
Chapter 16 Recasting with concrete

C16-1 Engineering discussion

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. The cause of such damage could be corrosion of reinforcement, fracturing, spalling, delamination, honeycombing or leaking joints.

Recasting with concrete generally involves removal of deteriorated concrete, cleaning up the substrate and reinforcement, setting up formwork and placement of new concrete.

The entire repair scheme must take into consideration the special requirements for this kind of work, that are:

C16-2 Concrete mix design

The concrete mix used for recasting must be capable of producing highly impermeable concrete with adequate workability and low shrinkage.

Ideally the repair mix should be made with the same type of aggregate as the original concrete to minimise thermal stress. It is also usually necessary to use a smaller (10mm) maximum aggregate size for repairs because the space for placing concrete is often restricted. Care should be taken to ensure that aggregate will not react with alkali from the cement, particularly as a cement rich mix will be necessary.

To minimise stresses caused by drying shrinkage, the water:cement ratio should not exceed 0.4. In some situations, it may be helpful to add shrinkage-compensating admixtures to the mix. These admixtures work by causing slight expansion to offset shrinkage and thermal contraction.

The repair concrete should have a high cement-paste content for bonding with old concrete and reinforcement and to provide high alkalinity for the protection of steel. The mix should have a minimum cement content of 410kg per cubic metre of concrete. For the highest concrete quality it is preferable to use both 35:65 SA cement and silica fume in the mix.

The conflicting requirements of low shrinkage and high cement content can be reconciled to some extent by the use of a super plasticiser to give a mix of medium workability (100 to 150mm slump) at a very low total water content.

The grading of aggregate and sand must be chosen to make a dense concrete and to keep bleeding to the absolute minimum, especially for soffit repairs where bleeding can lead to complete separation between old and new concrete.

For small repair jobs concrete may be mixed at site, using a small concrete mixer. On site batching should be avoided. It is preferable to make trial mixes and then pre-batch into convenient sized bags off site with only specified quantities of water and superplasticiser to be added at site. All materials must be weigh batched.

A suggested mix design for small scale repairs is given below. These quantities will make about 0.03 cubic metres of concrete and would fully charge a small mixer.

- Cement
  - Preferred 35:65 SA (Type SA or A acceptable) 13.0 kg
  - Silica fume (If silica fume unavailable, use 13.5kg of cement) 0.5 kg
- 10mm Crushed Aggregate (assumed solid SG 2.7) 36.0 kg
- Sand (assumed with 2% water content) 18.5 kg
- Water (maximum) 5.4 litres
• Superplasticiser (nominal) (dependent upon the brand) 25 ml

The on-site mixer must be rinsed out and charged with the dry components, then 4.5 litres water added, followed by two minutes mixing. Superplasticiser should be added while mixing continuously, and then more water added until the design slump is achieved. A maximum of 0.9 litres of extra water will be needed if the mix design is correct, otherwise the superplasticiser quantity should be reviewed.

Where placement quantities are large enough to justify, pre-mixed concrete from a commercial plant may be used. The mix used should have a minimum cement content of 410kg per cubic metre and a maximum water/cement ratio of 0.40 as specified before.

C16-2.1 Formwork

Requirements of formwork for recasting are discussed in the sub-procedure for formwork.

C16-2.2 Compacting recast concrete

Where concrete is replaced by recasting, it must be made to flow into place to exclude all air voids because the space for placing the concrete and using internal vibrators is often very restricted. The most practical way of achieving good compaction is to place the concrete in small quantities and vibrate it as the work proceeds. External vibrators on the formwork are very effective for inducing flow and compacting concrete in awkward places.

C16-2.3 Placement of concrete

The method of placement depends very much on the individual situation but it should ensure that well compacted concrete completely fills all voids.

Where soffits are recast, holes may be drilled through the slab and concrete placed from above (See Fig. 28). Alternatively, soffit formwork can be extended to provide a series of hoppers at the open sides for feeding superplasticised "flowing" concrete, or the concrete can be pumped to the farthest point of the void through a pipe that is gradually withdrawn as concreting proceeds.

Whichever method is used, any void that is confined on all sides must be filled from the lowest or farthest points to ensure that air is driven out as the concrete advances, and if necessary vent holes or pipes may be provided to allow the escape of the air.

Figure 28 – Holes cut in slab to allow placing of concrete when soffit forms have been fixed

C16-3 Repair procedures

− Support the existing structure adequately to safeguard against instability and deformation during repair work.
− Remove all deteriorated or damaged concrete and prepare the edges of the repair work.
- Examine the reinforcement for loss of section due to corrosion. If cross-sectional area of the reinforcement has reduced by more than 15%, provide extra reinforcement as necessary.
- Clean the concrete substrate and reinforcement.
- Select a suitable bonding agent for concrete and reinforcement, taking into consideration the limited working time available for fixing the formwork and placing the new concrete. If concrete can be placed immediately after applying the 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.
- Apply a bonding coat to concrete substrate and reinforcement.
- Fix formwork, if required.
- Place concrete in the forms by a suitable method. Compact well using either internal or external vibrators as necessary.
- Finish unformed surfaces by brooming, wood floating, steel trowelling or any other method to match the adjacent existing concrete.
- Start curing of concrete.
- Forms for load bearing structural members shall remain in position until at least 80% of the 28 day compressive strength of the new concrete is achieved. (normally 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.
- 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 a wooden float.

C16-4 Replacing bearing pads
C16-4.1 Engineering discussion
Removal of damaged or deteriorated bearing pads may be necessary in several situations, such as:
- Cracking
- Shattering
- Crushing
- Pier/Abutment - cracked and shattered.
- To lift/lower bridge to suit track height and superelevation
Regardless of the type of deterioration, all unsound and disintegrated bearing pads must be removed.

Carry out survey to restore track to correct height and superelevation as required.

Consideration MUST be given to repair/replacement of defective H.D. bolts.

Consideration MUST be given to weather conditions ie buckling of track in hot weather.

If the repair is to be carried out with the bridge open to traffic, provide suitable supports for the girders.

If H.D. bolts need replacing consider drilling new hole in bed plate for new bolt or replace bed plate - chemical anchor for new H.D. bolts.

If bearing pads are to be repaired/replaced under traffic and girders are to be supported from ground, prepare and erect support at least 1 week beforehand to ensure support does not settle under load.

C16-4.2 Procedure outline
– If the bed plates are to be raised with the girders, ensure bolts/studs connecting bearing plate to bed plate are in place.
– Remove nuts from H.D. bolts or unscrew nuts to allow bed plates to be raised to correct height.
– Raise the girders by jacking the minimum amount required to enable completion of the replacement operation (Refer to Section on replacement of bearing plates).
– Remove damaged concrete in bearing pad.
– Assess condition of H.D. bolts and repair/replace as required.
– Clean concrete/masonry substrate.
– Locate bed plate to correct height.
– Apply bonding coat to concrete/masonry.
– Erect formwork.
– Place new bearing pad material in formwork.
– Allow time to cure.
– Lower girders and screw up H.D. bolts.

For steel span underbridges, refer to drawing number CV 0227545 “Standard – Steel Span Underbridges – Replacement of bearing Pads”.
Chapter 17 Repairs for corrosion in concrete structures

The presence of corrosion in concrete structures is generally known to occur 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.

Concrete deteriorated by corrosion must be removed and replaced by patch repairing or recasting with new concrete as necessary. The repair should also include cleaning the reinforcement and protecting it from further corrosion, and finally a protective coating should be applied to the concrete surface to prevent further ingress of chlorides and carbonation.
Chapter 18 Sprayed concrete

C18-1 Engineering Discussion

A description of sprayed concrete is been given in TMC 305. Sprayed concrete is a highly specialised material requiring skilled operators, special mixes, equipment and techniques. For detailed information reference should be made to "Recommended Practice, Sprayed Concrete" published by Concrete Institute of Australia.

Spraying is most suitable when large areas of relatively thin concrete (30 to 60mm) have to be applied, for example: in restoring or increasing the cover over reinforcement, replacing delaminated concrete, linings and coatings on rock faces and tunnel walls, stabilising excavations and encasement of steelwork.

Where sprayed concrete is more than 50mm thick and is to withstand tensile and/or shrinkage and temperature stresses, steel fabric reinforcement should be used. Recommended fabrics are any 100 x 100mm wire spacing or greater. Expanded metal meshes and heavy concentration of small-grid wire mesh are not recommended as they tend to produce rebound problems. Where large diameter bars are provided, exceptional care should be taken in encasing them as they tend to cause voids or rebound inclusions.

Sprayed concrete may be screeded and trowelled to a plane fine-textured finish, but working may impair bonding with the background. Methods of finishing are given in the reference above.

Sprayed concrete employs a relatively dry mix and is often used in thin sections. Proper curing to ensure full hydration of the cement is therefore essential. The surface should be kept continuously wet for at least seven days. If water curing is impractical, approved curing compounds or impermeable sheets (such as polythene) should be used. Curing compounds may be permitted where:

- drying conditions are not severe
- no additional concrete is to be sprayed
- no paint is to be applied
- it is aesthetically acceptable

Due to surface roughness, liquid-membrane curing compounds should be applied at twice the rate required for ordinary concrete work.

C18-2 Repair procedure

It is essential that sprayed concrete work be entrusted to specialist contractors. Accordingly, only brief outlines of repair procedures are given. The repair procedure is:

- 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.
- Clean the concrete substrate and exposed reinforcement.
- Fix required fabric reinforcement rigidly to prevent vibration during spraying.
- Fix formwork as required to restrict the boundaries of sprayed concrete (see Fig. 29). Coat the formwork liberally with a form release agent compatible with the spray mix.
Figure 29 – Sprayed concrete

- Protect adjacent buildings, trees, gardens, etc. from dust and rebound concrete that could ensue during spraying operations, with suitable covers. Ensure that local work safety regulations are adhered to.
- Check the operation of all spraying equipment before commencing work.
- Wet the substrate with an air/water blast before spraying concrete.
- 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.
- Finish the surface by screeding or trowelling if required.
- Commence curing as soon as possible.
Chapter 19 Protective coatings on concrete structures

C19-1 Engineering Discussion

Protective coatings on surfaces of concrete structures are not strictly 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:

− On surfaces of new structures for aesthetic reasons and increased durability.
− On surfaces of 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 ingress. 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.
− On surfaces of newly repaired concrete to give extra protection against recurrence of deterioration and to conceal the repair work.

For whatever reason the coatings are applied, it has to be accepted that they do not last indefinitely and re-coating will be required from time to time as ongoing maintenance. However, in some circumstances coatings could provide a more economic alternative to carrying out repairs.

A large number of proprietary protective coating systems are available. Selection of any coating will depend on the protection required, the soundness of the concrete, ease of application and the cost involved. In all cases, follow the recommendations of the manufacturer for health, safety and handling precautions and application techniques.

Chlorides penetrate into concrete in solution form, i.e. dissolved in water. Therefore, a coating that resists penetration of water will also resist chloride ingress. Silane/siloxane based penetration type coatings, as well as film forming coatings that stick well to the concrete surface and form waterproof skins, are both effective against chloride penetration. However, build up of water vapour behind the film type coatings can cause such coatings to blister and peel off unless their adhesion to concrete is very good.

Carbon dioxide (and other acid gases in industrial environments) penetrate into the concrete mainly as gases and cause carbonation. Silane/siloxane based coatings are vapour permeable and therefore ineffective against carbonation. Rendering and painting is the accepted treatment against carbonation. In this a fine cement-based render is first applied to the affected areas to remove surface imperfections, followed by application of an acrylic based coating that prevents ingress of carbon dioxide.

C19-2 Repair procedure for chloride build up (but no corrosion evident).

− Ascertain the profile of chloride penetration into the concrete. Determine if the chloride was inherent in the original concrete mix or it has entered at a later stage. If there is no corrosion of steel, estimate on the basis of chloride profile and age of concrete the time to depassivation of the steel.
− Based on this estimate, and if the concrete is in otherwise 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 options for controlling chloride attack:
  − Silane/siloxane coating
  − Cathodic protection
  − Chloride extraction and re-alkalisation
The procedure for silane/siloxane coating is given below. The other methods require special technology and should be undertaken only in consultation with experts in the field.
− Repair surface cracks and spalls if any by appropriate methods.
− Clean the surface to be coated of all contaminants. Make good any blowholes and areas of substantial pitting with an approved finishing compound.
− Wash down the surfaces with clean water. Allow to dry for 24 hours.
− Mask or protect adjacent areas, paints, sealants, asphalt or coated surfaces.
− 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).

C19-3 Repair procedure for carbonation (but no corrosion evident)

− Monitor the situation at periodic intervals by phenolphthalein tests to determine the progressive depth of the carbonation front. No protective surface treatment is necessary until the carbonation front reaches the steel reinforcement.
− 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

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

− Repair surface cracks and spalls, if any, by appropriate repair methods.
− Clean the surface to be coated of all contaminants. Make good any blowholes and areas of substantial pitting with an approved finishing compound.
− 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).
− Apply cement-based render with a trowel from “feather edge” to 3mm thickness. Allow to set partly before finishing finally with a trowel, or sponge float, as required.
− Cure the render with a 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.
− Apply the selected protective coating as per the manufacturer’s recommendations. The coating should be pinhole free. One or two coats may be required as per the product used.

Introduction to masonry repairs
Chapter 20 Masonry repair methods

C20-1 General

Methods are outlined below for repairing the following most commonly occurring defects in masonry structures:

- Cracking
- Fretting
- Impact damage
- Corrosion of embedded iron or steel

Other repairs are briefly described under Miscellaneous Repairs (C19-7).

Foundation and waterway repairs are beyond the scope of this Manual and should be referred to geotechnical and hydraulic engineering consultants respectively.

C20-2 Steps in repair work

Refer to C1-9 Planning Repair Work. Basically, the same process should be carried out for repairing masonry structures.

C20-3 Cracking

C20-3.1 Engineering discussion

When the damage results in cracks that are liable to further movement, it is not advisable to make a permanent repair until the movement has stopped. The cracks may be left, but if there is a risk of rain or debris penetrating into the crack, the crack may be sealed temporarily by caulking with a mastic or flexible sealant.

Distinction should also be made between two types of cracks: cracks that run more or less diagonally, following vertical and horizontal mortar joints and cracks that pass straight down through a line of vertical joints and intervening masonry units and mortar beds.

In the first case, cracks through joints can be repaired, if necessary, by repointing.

In the second case, it has to be considered if it is necessary to cut out and replace the cracked units.

In both cases, the decision whether or not to repair cracks will depend mainly on two considerations:

- if the cracks are unsightly;
- if not repaired, whether they are likely to encourage rain penetration.

Fine cracks (up to about 1.5mm wide) are not very conspicuous and can often be ignored. However, if repairs are considered necessary to prevent rain penetration, they can be sealed by low viscosity self-hardening epoxy compounds.

Wider cracks will generally require raking out and repointing of the joints and cutting out the cracked units and replacing them.

C20-3.2 Repair procedure for moving cracks

Reference should also be made to C13-11 Flexible Sealants for Live Cracks.

Cracks that are subject to permanent movement (e.g. due to temperature movements and live loads) should be treated as expansion joints. If they are not unsightly or if there is no danger of water penetration through them, they may be left as they are, otherwise they should be sealed with a flexible sealant of width and depth to suit the expected range of movement.
C20-3.2.1 Non permanent seal

If the expected movements are insignificant or if the crack is not to be sealed permanently implement the following procedure. This is the most common type of repair for movement cracks in masonry:

− Clean the crack of loose dust and debris, oil, algae and other contaminants by using a high pressure water jet, compressed air (oil free) or vacuum suction. Allow the surfaces of the crack to dry;
− Prime the crack surfaces with a primer recommended by the 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 in to a depth such that the sealant applied will have a width to depth ratio of 2:1, or minimum 5mm depth of sealant. For cracks less than 5 mm wide, do not insert a backer rod;
− Seal the crack by caulking with a flexible sealant flush with the masonry face.

C20-3.2.2 Permanent seal

If the expected movements are significant or if the crack is to be sealed permanently, provide a recessed seal or a surface seal as described below.

Recessed Seal

− Cut a recess along the crack using a power chisel or crack cutter. The dimensions of the recess should comply with the requirements of the crack movement and sealant material (C13-11, Fig. 26);
− 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 the manufacturer's instructions.

Surface Seal

Narrow cracks subject to significant movement where aesthetics are not important may be sealed with a flexible surface seal (refer C13-11 Fig. 27).

− Clean the masonry surface adjacent to the crack of dirt, algae, and other contaminants (refer C12.11 Sub-Procedure);
− Prime the masonry surface along the crack over a width of approximately 100mm 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.

C20-3.3 Repair procedure for dead cracks

Fine cracks are best repaired by epoxy resin injection. This method has been fully described in C13-4 Epoxy Resin Injection.

Wider cracks can be repaired as follows:

− If cracks run through masonry units and mortar beds, cut out the units and remove the 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 a negligible clay content.

The above procedure for replacing cracked masonry units is also used for repairing spalled masonry.
If cracks run through joints only (i.e. 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.

C20-4 Fretting
C20-4.1 Engineering discussion
To stop the fretting process permanently, it will be necessary to halt the flow of salt laden water through the wall. If this is not practical, the alternative is to repair or replace the masonry units or jointing mortar that have been damaged.

Application of waterproofing membranes to the exposed surfaces of masonry with a view to stopping water entering from the back face should not be considered. The membrane type of coatings generally blister and peel off under the build up of vapour-pressure from behind. The penetration type of coatings (silane/siloxane) repel the ingress of water from the front, such as rain but, being breathable do not stop water entering from the back face and evaporating from the front face. Thus the wetting and drying process is unchecked and fretting will continue unabated.

If the masonry consists of "soft" lime mortar in the joints, do not replace it with "hard" cement mortar, as it will do more harm than good. As cement mortar is less pervious than lime mortar, more of the salt laden water permeating through the wall will now flow through the bricks or stone. Thus while fretting of the mortar will have been reduced, the rate of fretting of the units will increase.

C20-4.2 Repair procedure for damage to jointing mortar
Repointing of joints is best done in the Winter as lime mortar relies on absorbing carbon dioxide from the air to set. This process takes time and if the temperature is too warm, the mortar will dry out before setting. If working in hot weather, the mortar should be lightly sprayed with water at two to four-hour intervals for a day.

− Where the jointing mortar has been damaged, rake out all loose and fretting mortar from joints with a square edged tool, taking care not to disturb the masonry units. Rake out another 20mm of mortar to make sure that all crystallised salt is removed. Rake the joints in the topmost 3-4 courses to be repaired first;
− Thoroughly wet the masonry and allow to dry till it is just damp and without any residual water;
− The mortar mix for repointing shall 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 water that is suitable for drinking should be used for the mortar;
− 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 repointing operation and keep it covered with damp bags until used;
− Pack the 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 topmost joint and work progressively down). Tool off the joint surface to match the original.

Where extensive repointing is involved, carry out raking and repointing in small sections to avoid instability. For example, work on 3-4 horizontal joints at a time and limit the length of repair to a maximum of 3 metres or ¼ of the length of the wall, whichever is less. Allow at least 24 hours for the mortar to set before raking joints in the next section. Start at the top and work progressively downwards.

C20-4.3 Repair procedure for damage to masonry units
Spalling usually affects only a small proportion of the units in the wall. Replacing the spalled units with new units that would match the rest of the wall is difficult and it may be decided to leave things as they are until complete re-surfacing becomes necessary. However, if matching is not essential, spalling should be repaired as below.
Caution:
Before commencing repairs, check if the stability of the wall would be adversely affected by removal of the spalled masonry. Remove and replace only as few spalled units at a time as necessary to ensure stability at all times.

- 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;
- Wash down the broken surfaces to remove dust and debris. Allow the surfaces to dry until it is just damp;
- Set new units (whole or sawn as required) in place of the old with a lime and sand mortar as described in C19-4.2 above.

**C20-5 Impact damage**

Masonry spalled by accidental impact would require removal and replacement of the spalled units and the repair of cracks. The repair procedure for this is the same as for wide cracks (refer to C19-3.3 above).

**C20-6 Corrosion of embedded iron or steel**

- Open up the masonry to gain access to the steelwork;
- If the corrosion is not too far advanced, thoroughly clean the metal by grit-and/or water-blasting to remove any rust. Apply a corrosion protection system to the steel;
- If the corrosion is well advanced, replace the steelwork either with corrosion protected steel, stainless steel, or reinforced concrete;
- Rebuild the masonry. Apply a protective coating such as silane/siloxane to prevent moisture penetration.

**C20-7 Miscellaneous repairs**

**C20-7.1 Minor displacement of masonry**

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

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

**C20-7.2 Sulphate attack**

Sulphate attack that is abetted 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.

**C20-7.3 Salt water and marine organisms**

Repair of masonry damaged by salt water and marine organisms is difficult and specialised work and 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 epoxy membranes or by concrete encasement.