Guidelines for Resolution of Non-Conformances in Precast Concrete Bridge Elements

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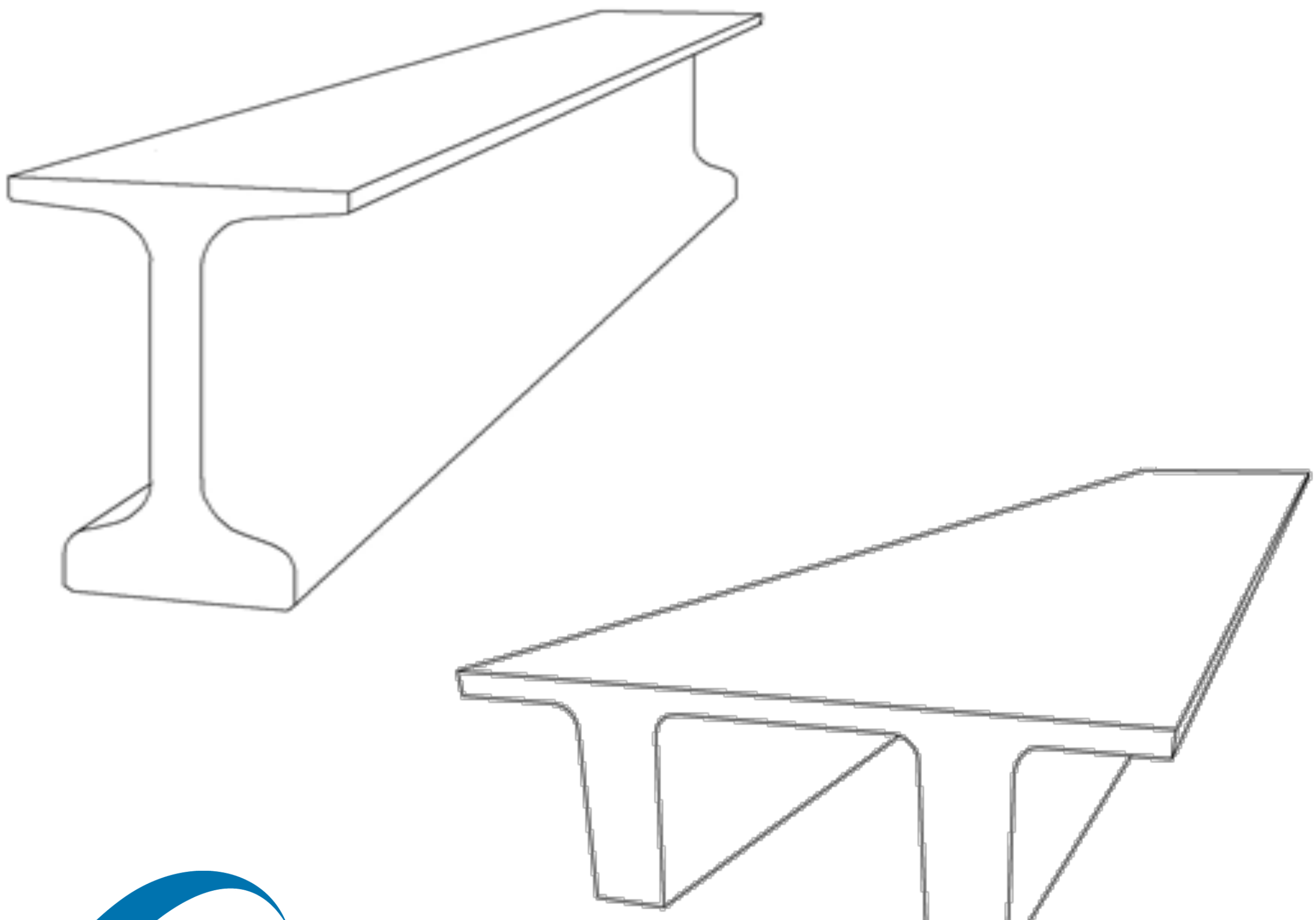
First Edition



PCI NORTHEAST

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Abstract:
These guidelines provide recommendations for the evaluation and repair of non-conformances in precast and prestressed concrete bridge products. The document can serve as a resource for owners, designers, state inspectors, plant production managers, plant quality control Inspectors and plant engineers in reaching informed decisions in addressing non-conformances and repairs.
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By Precast/Prestressed Concrete Institute Northeast
First Edition

This document supersedes the document titled PCINER-01-BMRG – Bridge Member Repair Guidelines dated October 2001

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Contents

Foreword

These guidelines have been prepared by the Precast Prestressed Concrete Institute Northeast Bridge Technical Committee and contain recommendations for resolution of non-conformances in precast concrete bridge elements occurring during production, handling, transportation and erection. These guidelines are a resource document for owners, designers, state inspectors, plant production managers, plant quality control inspectors and plant engineers in reaching informed decisions regarding non-conformances and repairs.

The PCI Northeast would like to acknowledge the members of the Bridge Technical Committee that contributed to the development of these guidelines.

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Section 1: Introduction

Plant-cast prestressed concrete bridge beams and similar products produced in PCI-Certified plants are manufactured in a quality-controlled environment. These facilities meet the minimum standards for processes and equipment. They have trained supervisory and certified quality control staff operating within published procedures that consistently result in high quality products that meet project and customer requirements.

As with any manufacturing process, damage or defects can occur in precast concrete bridge products. Examples include surface voids, spalls, cracks in concrete, and improperly placed or damaged reinforcement and hardware. These fall into one of three categories:

- Products that can be accepted without repair
- Products that can be accepted with repair
- Products that must be rejected

This manual has been prepared to be a resource document to provide a guideline for owners, designers, inspectors, and fabricators in reaching informed decisions regarding repair options. To this end, the engineering considerations related to individual defects are provided. The ultimate value of this guide depends on the sound engineering judgment of qualified individuals who use this document.

How to use this manual

This document is a guideline document that contains recommendations for evaluation and repair of non-conformances. Owners should consider modifying specification language to incorporate these recommendations into contract documents.

The management of non-conformances is a collaborative process between the Owner (or Designer) and the Contractor (or Fabricator). At the beginning of a fabrication process, a fabrication pre-production meeting with all parties involved is recommended. This meeting should establish the process for managing non-conformances and the responsibilities of each party. The following information should be discussed at the pre-production meeting regarding the management of non-conformances:

- Surface finish requirements
  - Description of acceptable surface features
  - Establishment of standard finishing procedures
- Repair procedures
  - Review of PCI Repair Manual
  - Establish acceptable repair materials
  - Establish pre-approved owner repair procedures
  - Establish pre-approved fabricator repair procedures
- Define responsibilities and NCR process
  - Review the Repair Decision Process (flowchart) contained herein

There are other items that should be discussed such as curing methods, handling and storage, etc.

The sections of this manual are organized as described below:

Section 1: Introduction: Contains general information on standard finishing procedures, non-conformances and methods for management of non-conformances. This section also contains significant information on the repair process and the key factors that should be considered in the repair decision process.

Section 2 - Troubleshooting Guide: Contains descriptions, by category, of the defect being considered, with commentary in side-by-side columns:

- Causes - a listing of possible causes of specific types of defects
- Prevention - corresponding corrective actions to aid in preventing each type of defect
- Engineering Effects - a discussion of the engineering implication of the specific type of defect to provide the basis for decisions regarding the option of repair or rejection
- Repair Considerations - suggested repair options based upon the Engineering Effects discussion, with cross-references to Standard Repair Procedures (Section 3).

Section 3 - Standard Repair Procedures: Contains specific instructions to implement repairs for the various types of defects identified.

Section 4 - Selected References: Lists sources for additional information on fabrication, materials, and repairs of precast and prestressed concrete products.

Finishing of Precast Elements

Finishing refers to the process of stripping the element from the forms, cutting of strand extensions, repair of exposed reinforcing coatings, and providing a uniform appearance to surfaces that are to be exposed in the completed structure. The repair procedures outlined in this document are not applicable to the finishing process. The minor surface imperfections described below are not considered defects and are part of the normal casting and finishing process. Items such as small surface voids as described in the finish grades below are a result of the process of placing and consolidating high strength, low slump concrete that is commonly used in modern precast plants. The use of self-consolidating concrete can be used to reduce the number of surface voids; however, finishing will still be required.

Standard finishing processes can be developed and agreed to via the fabrication plant’s Quality System Manual (QSM). The fabricator will work with the Owner’s representative to identify and document the standard finishing process to be performed for typical minor surface imperfections without the necessity of filing, reviewing, and approving a Non-Conformance Report (NCR).

The following finish descriptions, taken from Appendix C of PCI MNL 116, may be used to define specification requirements. The minimum finish grade consistent with a product’s application and the intended use of the structure should be specified.

Grade A Finish

Grade A Finish is for use in special architectural applications and not recommended for bridge products.

Grade B Finish (highly visible)

All air holes over $^1/_4$ inch in size should be filled. Air holes between $^1/_8$ and $^1/_4$ inch in width that occur in high concentration (more than one per 2 square inches) should be filled. Surface blemishes due to holes or dents in forms should be repaired. Discoloration should be permitted at form joints.

This finish is recommended for visually exposed structural members such as fascia beams.

Standard Grade Finish (exposed to view)

Small surface holes caused by air bubbles ("bug-holes"), normal color variations, normal form joint marks, and minor chips and spalls should be considered acceptable.

No air holes (bug holes) larger than ½ inch in any direction should be permitted. Air holes between ¼ and $^3/_8$ inch in width that occur in high concentration (more than one per 2 square inches) should be filled. Large, unsightly surface blemishes or honeycombing should be repaired. The maximum allowable form joint offset should be limited to $^1/_8$ inch. This finish may be used where products are exposed to view but the function of the structure does not require a special finish. The surface should be suitable for an applied textured coating but not necessarily suitable for painting.

This is the recommended finish grade for all structural products that are visible in the completed structure.

Commercial Grade (not exposed to view)

This is essentially an "as cast" finish. Concrete may be produced in forms that impart a texture to the concrete, (e.g., plywood lumber or steel forms with offset joints, dents or holes). The surface may contain air holes (bug holes) and water marks, and there may be some minor chips and spalls. There may be some scaling and/or scouring. There may be patches and streaks of color variation within the surface, and the overall color tone may vary between pieces.

Large fins from joint bleeding should be removed, but small fins may remain. Only "honeycombed" and/or badly spalled areas should be repaired or finished. All faces should have true, well-defined surfaces. The maximum allowable form joint offset should be limited to $^3/_{16}$ in.

This finish is recommended for surfaces of products that are not visible in the completed structure, or when the function of the structure does not require an enhanced surface.

Unformed Surface Finishes

These types of finishes are obtained by screeding and floating with additional hand finishing at projections. Normal color variations, minor indentations, minor chips, and spalls should be permitted. No major imperfections, honeycombing, or defects should be permitted. Where uniformity or other special characteristics of exposed, unformed surface finishes are required, specifications should be clear on the expected results. The Manual for Quality Control for Plants and Production of Structural Precast Concrete Products, Fourth Edition, MNL-116 can be used for guidance on surface finishes.

Exposed Aggregate Finishes for Element Connections

Exposed aggregate finishes are recommended for the surfaces of the elements that are within the connections in closure joints to improve the bond of grouts and concretes used in the connections. An exposed aggregate finish can be created in several ways:

1. A gelatinous retarder can be applied to the formwork in locations where the finish is desired. The hydration reaction of the fresh concrete contacting the retarder is delayed. After form removal, the un-hydrated paste can be washed with water (if epoxy bars are present in the joint).
2. Sand blasting or high pressure water blasting can be applied to the formed surface to expose the aggregate; however, coated bars will need to be protected.

The final finish of an exposed aggregate surface is different than the finish of the top of a composite beam where a certain amplitude is often specified based on design specification provisions. Where joints are detailed with mechanical shear keys, a specific amplitude is not required. The goal of exposed aggregate finish is to expose the stone and remove any surface laitance.

Specifying Surface Finishes

The designer should identify the required surface finishes for all elements based on the recommendations contained in this document. Plans should include a schedule of all element surfaces along with the required surface finish. If the plans do not specify finishes, the recommendations contained herein should be followed.

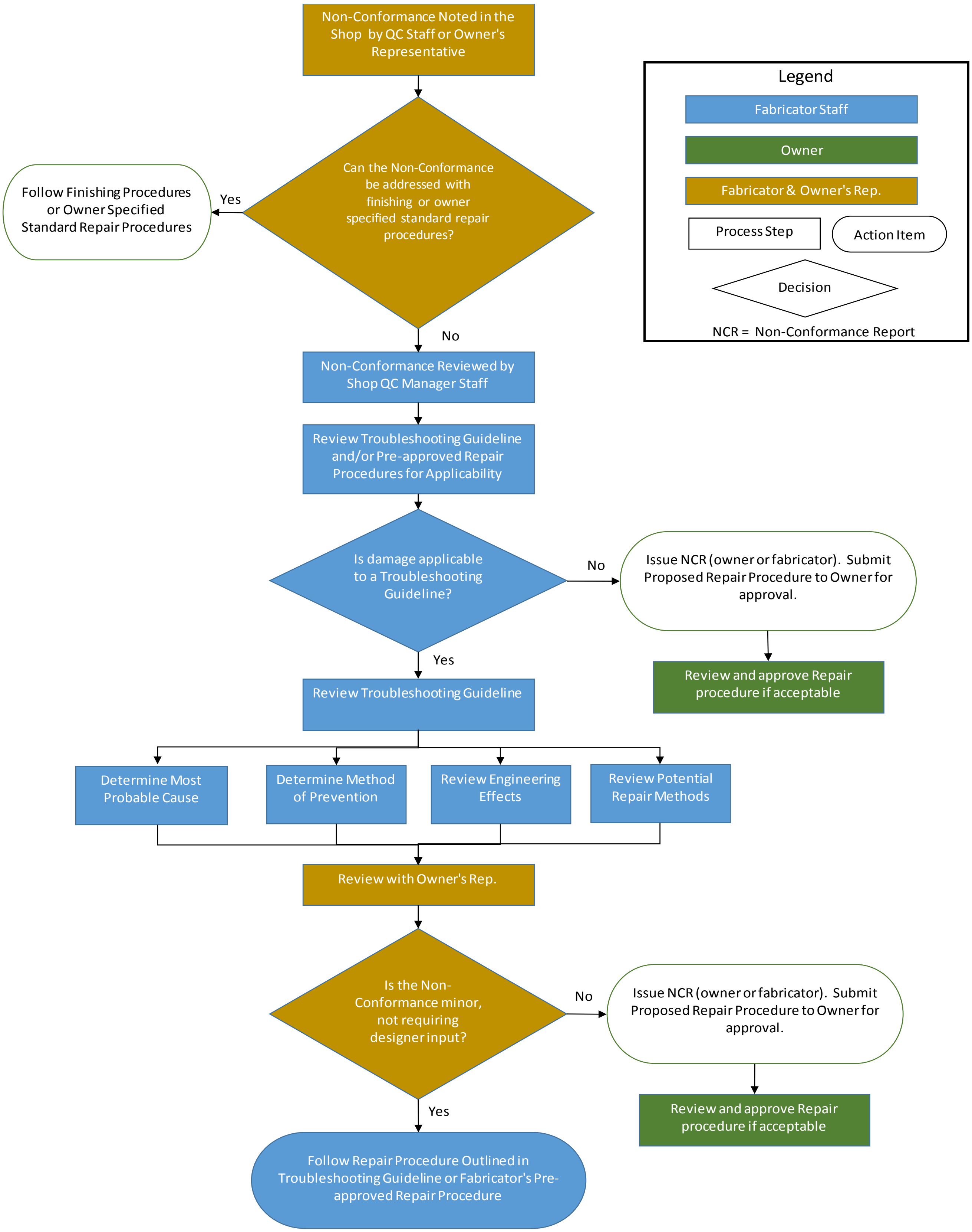
Surface Repairs

Any surface variation that exceeds the limits stated above should be considered a non-conformance and should be treated as described in Section 2.

Repair Decision Process

The evaluation of precast elements should follow a prescribed process where potential non-conformances are systematically reviewed by the fabricator's staff and owner's representative (inspector). The following flow chart is a recommended process that can be used to efficiently manage the disposition of non-conformances and repairs. The goal of troubleshooting should be to resolve the non-conformance as close to the shop floor as possible. Many items may be resolved between the shop QC Manager, plant engineer, and the Owner's inspector. This document also gives guidance on when a non-conformance requires input from the Engineer.

Recommended Decision Process Flowchart



Key Factors in Decisions Regarding No Repair, Repair, or Rejection

Every effort has been made to provide a list of the common types of damage or defects that may occur in precast and prestressed concrete products during production, handling, transportation, and erection (pre-service damage). Other types of defects or damage may occur, however. There may also be other causes for the types of occurrences listed in this guideline, other methods for prevention, and other issues to be considered in the engineering evaluation of the damage. Engineering judgment should be exercised in these situations. In addition, the approaches illustrated in this guideline can be applied to other similar situations that may arise.

Decisions regarding the need for repair or rejection should be established by the owner and included in the contract documents. There is a significant cost impact for the fabricator. If all bidders understand that certain defects will not require repair, or that standard repairs may be applied without the need for excessive review and documentation, the Owner could benefit with lower bids. The converse, of course, is also true. Defining repair requirements also benefits the Owner by reducing the number of time-consuming non-conformances that must be evaluated.

Proper design, detailing, and fabrication techniques are essential for the production of high-quality precast and prestressed concrete products. Some of the many procedures and processes include concrete mix design, mixing and consolidation of concrete, curing of concrete, methods and materials for debonding strands, placement of debonded strands, methods and sequences of detensioning of strands (including special considerations for harped or draped strands), and detailing of anchorage zone reinforcement. Discussion of the important aspects for each of these issues that contribute to defects or damage to elements is beyond the scope of this document. Additional information on these topics may be found in the *PCI Quality Control Manual [1]* and the *PCI Bridge Design Manual (*Section 3, Fabrication) *[2]*.

General Comments on Cracking

When cracks occur, their cause, effect, and possible consequences must be determined. A structural evaluation may be required depending on the nature and location of the crack. The repair guidelines contained herein include recommendations for when a structural evaluation is warranted.

Cracks may occur in sections of prestressed concrete girders where the effects of the prestressing force do not directly act to close such cracks. It should be understood that girders are prestressed in their long, axial direction. Therefore, in general, any cracks that form in the girder that are roughly parallel to the long axis of the member will not close under the effect of prestressing. An example of such cracking is the horizontal and/or diagonal splitting that sometimes occurs at the ends of members (see Section 2, TS #4).

Cracks perpendicular to the long axis of the member can occur prior to transfer of the prestress force when the concrete is not yet prestressed. At this time, the strands and forms provide restraint to dimensional changes in the concrete due to shrinkage and thermal contraction (see Section 2, TS #3). However, when the strands are detensioned, these cracks generally close due to the prestress force.

If the cracks close when the strands are detensioned, or when restraints or other conditions that caused the cracks are resolved prior to de-tensioning, the consequences of the cracking are generally minor or nonexistent. The phenomenon of autogenous healing can result in the concrete "healing" through the crack, reestablishing the tensile capacity of the concrete and restoring it to its un-cracked condition. If allowed to close without tangential displacement, fine cracks in fractured concrete, in the range of 0.004 in. to 0.008 in. wide, will close completely under moist conditions. This is especially true in the presence of compressive pressure across the crack. Cracks with a 0.004 in. width can heal over a period of several days, while cracks 0.008 in. in width can heal over a period of several weeks. This autogenous healing is due to the hydration of previously un-hydrated cement. It has been shown that cracks healed autogenously will perform structurally and long-term like un-cracked concrete.

If the cracks remain open after detensioning, or if they open after detensioning, several scenarios must be considered:

- Will the crack close when subjected to subsequent loads on the structure such as by the addition of a bridge deck?
- Will the crack be protected by a composite deck, or other encasement, from water and salt that may be placed on the deck?
- Is the crack located within the transfer length of the strand, in which case the stress in the strand may be reduced by the presence of the crack?
- Is the crack large enough to permit entry of moisture and oxygen that could promote corrosion of the strands or other reinforcement?

Spalls and Voids

Voids or honeycombs may occur in the casting of precast and prestressed concrete products, especially beams, due to inadequate consolidation of the concrete. Good consolidation results from a good concrete mix design, proper mixing and placing of concrete, appropriate coarse aggregate size, as well as a section that is not overly congested by prestressing strand and mild reinforcing steel. Every effort should be taken to detect voids prior to detensioning so that repairs, if permitted, can be made, then cured and pre-compressed with the adjacent concrete. This action ensures the design performance of the beam and enhances the long-term durability of the repair. Furthermore, the repair of large voids can prevent subsequent damage to the beam from detrimental redistribution of stresses caused by cross-sectional variations during the detensioning process.

Prompt inspection of beams prior to detensioning is very important because delay in transfer of the prestress can lead to damage from cracking. Cracks can occur when beams cool while they are anchored to abutments by the prestressing strands. When inspection detects voids or signs of potential internal voids, measures should be taken during repair investigations to control concrete contraction or shortening of the external prestressing strand due to cooling. Methods for investigating the presence or extent of internal voids include sounding with hammers, using pulse-echo equipment, and probing with wire or by drilling exploratory holes.

Durability of Repairs

The goal of all repairs is to provide an element that has equivalent durability when compared to the adjacent element concrete. The repair procedures contained herein, when constructed correctly, have proven to meet this goal. The presence of a repair should not be cause for a reduction in the element's service life. The materials used for repairs should be of high quality. Important parameters for patching materials include low permeability, high bond strength, resistance to freeze thaw, and strength that is equal to or somewhat greater than the element. Recent studies have been completed on common patching materials that included tests to verify these parameters [5]. This study can be used for the selection of proper patching materials. Some owners maintain approved product lists, and some fabricators also maintain approved product lists. If previous approved by the owner, these materials can be used for the repairs.

Voids discovered following detensioning or spalls caused by handling, transport, and erection of beams are, in almost all situations, repairable. The methods and materials used for repair, however, must be carefully considered to ensure the durability of the finished product in service. The strain compatibility of the repair material with adjacent concrete must be considered from the time of repair through full service loading. The owner/engineer must evaluate the durability, as well as longevity, of the repair from the standpoint of potential future repairs to a beam incorporated into the completed bridge and must consider methods to prevent patches located over traffic from becoming dislodged.

In many instances, the repair of a spall is simply cosmetic (rather than restoration of strength or protection against corrosion of the prestressing or mild steel reinforcement). Consideration should be given to not requiring repair of a spall when the repair will not enhance strength or durability and is located in an area that will be encased by a concrete pour, or will not be readily exposed to view.

Essential Issues to Be Considered In Engineering Evaluation

Condition of cracks under full service load:

1. In general, the preferred condition is that at service-level stresses, precast, prestressed concrete beams will not have open cracks. This is especially true for bottom flanges of beams in positive moment regions. Therefore, an appropriate evaluation of any crack in the bottom of the beam would consider, at service level, that stresses in the vicinity of a crack do not exceed $6\sqrt{f'_c}$ anywhere along the length of the crack.
2. Transverse cracks originating in the top of beams that close upon detensioning or upon placement of a composite slab should not be of concern. Open cracks in a top flange that serves as the riding surface that are observed after detensioning and upon storage on temporary supports at their intended bearing locations should be evaluated.
3. Criteria regarding crack size, as it relates to environmental conditions, are found in *ACI Committee Report ACI 224,* "Control of Cracking in Concrete Structures." For beams used in continuous span applications, negative bending capacity is based on cracked section analysis, both at service and strength levels. Therefore, a crack through the slab and portions of the beam depth are expected. At service level, the crack in the top flange can be expected to be in the range of 0.008 in. to 0.01 inches

The AASHTO LRFD Bridge Design Specifications contains provisions for control of cracking [6]. These provisions are based on an assumed crack width of 0.017 inches for elements exposed to normal conditions and 0.013 inches for elements exposed to more severe conditions such as bridge decks. These criteria should be considered when deciding whether cracks need to be repaired.

Allowable Stresses and Strength:

1. Allowable stresses in the repair and concrete bonded to the repair should not be exceeded at service loads. Allowable stresses in the repair material should be compatible or exceed the design stresses computed for the concrete in the original beam fabrication. Preloading the member prior to making repairs of a void detected after detensioning may be necessary if deemed essential to reducing undesirable stresses in the repair.
2. Allowable stresses at strand release should not be exceeded, considering the reduced section caused by a void.
3. Flexural and shear strength must be adequate near beam ends, considering the lack of fully developed prestressing strands when cracks cross strands or voids expose strands within their transfer length.
4. Bearing stresses must remain within limits at service loads. Consider any reduced bearing area above the bearing device due to a void in the beam at its bearing.

Condition of the crack under dead load of girder alone:

1. If the crack is at the top of a girder whose top flange is to be the riding surface and is exposed to tensile stresses, it should be injected or gravity filled to prevent intrusion of water, since the crack may remain open. Check stresses if the section is changed significantly by the depth of cracking.

Condition of the crack under dead load of girder plus deck slab:

1. If the crack is at the top of the girder and is exposed to tensile stresses under the dead load weight of the beam plus slab, it should be injected to prevent intrusion of water, since the crack may remain open. Check stresses if the section is changed significantly by the depth of cracking.
2. In most cases, the crack will go into compression with the weight of the deck and no repair will be required, unless required by other conditions.
3. An evaluation of the effects of other incidental issues may be required, including the effects that cracking may have on the deck forming system and post-tensioning anchorages.

Note: Full development of exposed mild steel reinforcement can be restored by a properly installed repair procedure. If the strand has lost some or all of its prestress due to a crack or void near the end, however, it cannot be restored at that location. Transfer must occur beyond the location of the void. On the other hand, exposed strand beyond the transfer length can be assumed to have full prestress as though it were never exposed.

Repairable Non-conformances

The standard repair procedures contained herein include recommended repair criteria for the various non-conformances that are typically encountered during the normal fabrication process. Precast concrete units that contain minor defects caused by manufacture or mishandling should be repaired at the manufacturing site. In addition, units that contain minor defects caused by mishandling during shipment or installation should be repaired at the project site.

Non-Repairable Non-conformances

Non-repairable non-conformances may be grounds for rejection of the element. Rejection of a precast element should be considered under the following conditions:

1. When the non-conformances indicate a significant lack of conformance with standard practices and procedures. This includes elements having a significant number of repairable defects indicative of a lack of process management such as proper consolidation of concrete and inadequate handling and storage.
2. A major defect that affects the structural integrity or durability of the unit. This type of defect should be thoroughly evaluated by all parties through a non-conformance report or similar process.

If the producer follows normal procedures and the element still presents many defects, then the design should be reviewed and a design change may be in order. For example, a beam with high release tensile stresses may be more prone to cracking.

Section 2: Troubleshooting Guide

Section 2.1: Prestressed Elements

TS #1: Transverse Cracks Originating at Tops of Beams

TS #2: Vertical and Diagonal Cracks at Bottom of Beams

TS #3: Vertical Through Cracks in Beams

TS #4: Horizontal End Cracks in Webs and Flanges

TS #5: Bottom Flange Cracks at Beam Ends

TS #6: Corner Spalls or Corner Cracks

TS #7: Partially Cracked Top Flanges

TS #8: Random Honeycombing and Voids

TS #9: Random Top Flange Cracks

TS #10: Short Projected Strand or Reinforcing, Missing Projected Strand or Reinforcing

TS #11: Cracks and Honeycombing in Precast, Partial Depth Deck Panels

TS #12: Partially Cracked Top Flanges – NEXT Beams

TS #1: TROUBLE SHOOTING FOR TRANSVERSE CRACKS ORIGINATING AT TOPS OF BEAMS

Description: These cracks are typically perpendicular to the longitudinal axis of the beam and extend across the top of the member, usually visible on both vertical faces, but do not extend to the bottom prestress strands.

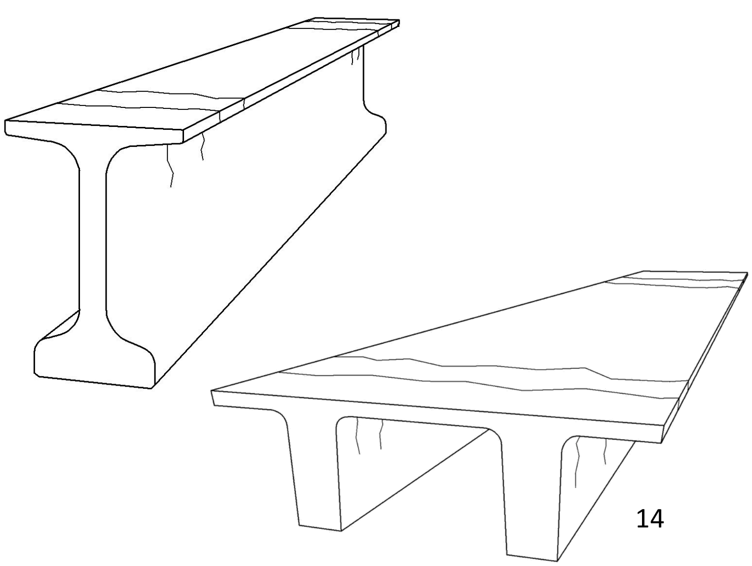
CAUSES

A. Excessive top fiber tension
   1. Release stresses in excess of modulus of rupture of concrete at release
   2. Inadequate top reinforcement
   3. Incorrect placement of top reinforcement
   4. Low release strength
   5. Lack of strand debonding at beam ends or insufficient number of draped strands
   6. Improper location of lifting or dunnage points
   7. Prestress uplift force at mid-span hold-down points exceeds the weight of the beam or exceeds the beam’s top fiber tensile capacity

B. Shrinkage
   1. Shrinkage of beam concrete prior to or during curing
   2. Contraction of beam prior to prestress force release
   3. Contraction of exposed strand in unused portion of the bed

C. Form Expansion with Temperature Rise

D. Excessive Side tension Due To Lateral Displacement During Movement



PREVENTION

A. Reduce Top Fiber Tension
   1. Review/modify design to reduce top tension at release
   2. Provide adequate tensile reinforcement to control cracks or add top prestressing. This option may include lightly tensioned strand (5000 psi+).
   3. Improve inspection prior to concrete placement
   4. Increase release strength
   5. Reduce eccentricity at beam ends by debonding or draping strand pattern, add strands at tops of beams or modify strand pattern to reduce eccentricity
   6. Adjust lifting or dunnage points
   7. Limit uplift force at hold-down points to 75 percent of member weight

B. Improve Production Methods
   1. Minimize Shrinkage
      b. Apply covers rapidly and/or mist spray with water
      c. Adjust concrete mix by reducing cement, adding pozzolans or changing aggregate gradation
      d. Provide uniform heat and humidity
   2. Detension as covers are removed and prevent rapid cool-down of the beam
   3. Prevent exposed strand from cooling differentially with respect to the beam

C. Lengthen Set Time-In Accordance with ASTM C403
   1. Minimize temperature differential between beam, exposed strand, and bed

2. Detension as covers are removed and do not allow section to cool rapidly

D. Provide Lateral Bracing with Strongbacks

TS #1: TROUBLE SHOOTING FOR TRANSVERSE CRACKS ORIGINATING AT TOPS OF BEAMS

Description: These cracks are typically perpendicular to the longitudinal axis of the beam and extend across the top of the member, usually visible on both vertical faces, but do not extend to the bottom prestress strands.

ENGINEERING EFFECTS

1. Cracks that close upon detensioning of the beam, or that will close when the beam is placed upon its designated bearing areas, or can be expected to close when the composite slab is poured, need not be repaired for simple beam applications.

   For beams made continuous for composite dead and live loads, calculations may be required to determine the need for repair. If stresses under service loads do not exceed 3.0 √f'c, it may be presumed that the beam will behave as an un-cracked section, in which case no repairs are necessary. If the stresses exceed 3.0 √f'c, the beam should be repaired by epoxy injection.

2. For cracks that do not close after detensioning, an assessment of the need to repair based on continuity considerations as well as environmental exposure will be required. In the latter regard, ACI Committee 224 report "Control of Cracking in Concrete Structures" states that tolerable crack widths are 0.006-in. for concrete exposed to seawater spray with wetting and drying, 0.007-in. for concrete exposed to de-icing chemicals, and 0.012-in. for concrete exposed to humidity.

REPAIR CONSIDERATIONS

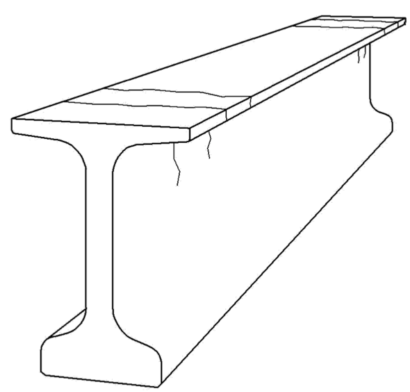
Before Detensioning. No repairs are recommended until after detensioning, as cracks may close.

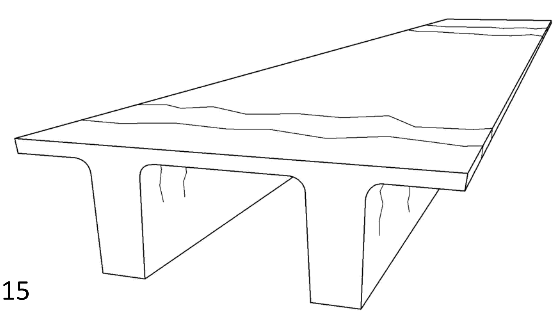
After Detensioning

1. Closed cracks – The decision to repair or not repair should be made in consideration of the Engineering Effects.

2. Cracks over 0.006 in. - If the decision is made that repairs are warranted, the cracks should be epoxy injected in accordance with Standard Repair Procedure #10.

3. The surface of cracks narrower than 0.006-inches should be sealed. See Standard Repair Procedure #14.





TS #2: TROUBLE SHOOTING VERTICAL AND DIAGONAL CRACKS AT BOTTOM OF BEAMS

Description: This crack starts at the bottom of the member and extends upward. In severe cases, crack will extend diagonally toward the mid-height (neutral axis) of the beam.

CAUSE

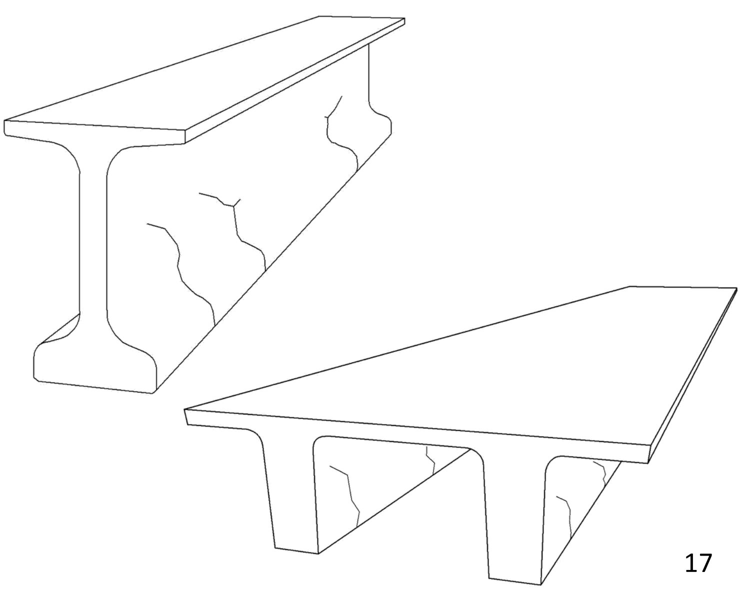
A. Bond of strands
   1. Strand contamination
   2. Incorrect placement of debonding shields
   3. Insufficient vibration of concrete
   4. Excessive debonding termination at one location

B. Shrinkage

C. Detensioning Procedure
   1. Low release strength
   2. Improper detensioning sequence/procedures
   3. Failure to release hold-down mechanism prior to release of horizontal strands

D. Formwork
   1. Indentations or joint offsets in forms
   2. Concrete binding to forms
   3. Bottom plates at beam ends anchored or hung up at bottom (soffit) of form

E. Incorrect Prestress Force
   1. Inadequate prestress strand in design
   2. Under-estimate of prestress losses
   3. Under – tensioning of strand
   4. Incorrect number of strand in bed



PREVENTION

A. Ensure against unintended slip
   1. Inspect strand for cleanliness and absence of lubricants after stressing strand
   2. Verify proper shielding installation
   3. Use internal and external vibration in congested ends of beams
   4. Stagger debonding terminations

B. Improve Production Methods
   1. Apply covers rapidly after concrete pours
   2. Detension as covers are removed
   3. Prevent exposed strand from cooling differentially with respect to the beam
   4. Adjust concrete mix by reducing cement, adding pozzolans or changing aggregate gradation
   5. Provide uniform heat and humidity

C. Use proper detensioning procedure
   1. Ensure proper concrete strength prior to release
   2. Keep prestressed forces balanced while detensioning, using an established procedure
   3. Ensure hold-downs are released prior to detensioning strand and are not binding on the soffit

D. Inspect form condition prior to placing Concrete
   1. Ensure smooth form alignment
   2. Oil forms thoroughly
   3. Ensure any bottom plates will not bind on soffit

E. Apply Correct Prestress Force
   1. Check design calculations
   2. Recompute losses
   3. Compare measured elongation of strand with computed elongation
   4. Check shop drawings

5. Check camber of beam verses calculated camber

TS #2: TROUBLE SHOOTING VERTICAL AND DIAGONAL CRACKS AT BOTTOM OF BEAMS

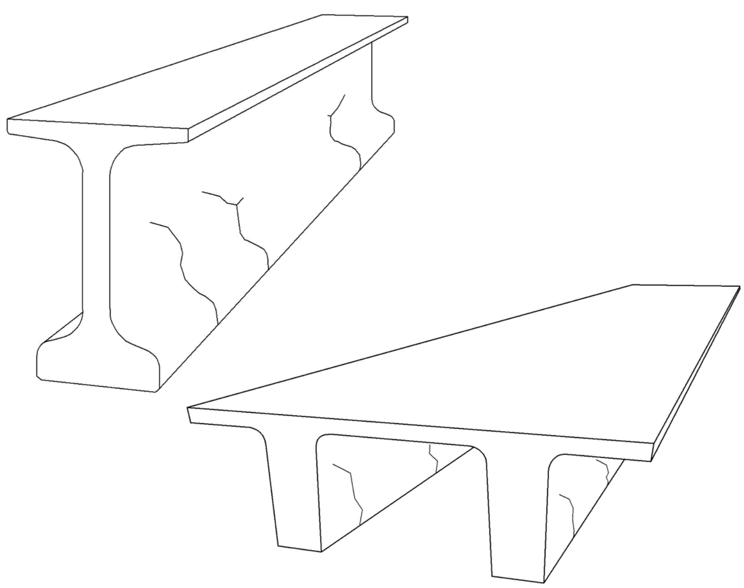
Description: This crack starts at the bottom of the member and extends upward. In severe cases, crack will extend diagonally toward the mid-height (neutral axis) of the beam.

ENGINEERING EFFECTS

1. For vertical cracks that intercept bonded or debonded strand within their respective transfer lengths, it is recommended that the engineer re-compute the moment and shear capacity based on transfer initiating at the point of the crack. If the re-computed capacities are acceptable the beam can be repaired. These cracks should be injected.
2. Vertical cracks that intercept bonded or debonded strand beyond their respective transfer lengths and close to a width less than 0.006-in. after detensioning, need no re-evaluation. Cracks 0.006-in. or greater in width should be referred to the engineer for evaluation, to affirm adequate design.
3. Vertical cracks at any location on the beam that do not intercept strand need no evaluation by the engineer.
4. Diagonal cracks of any size, at any location, require evaluation by the engineer, to determine whether the shear design for the beam is adequate or the accidental loading causing the crack will not be duplicated in service.

REPAIR CONSIDERATIONS

1. It is recommended that cracks not be repaired prior to detensioning as repairs will mask the cause and seriousness of the crack.
2. All cracks less than 0.006-in. in width, after detensioning and deemed acceptable, should be sealed. See Standard Repair Procedure #14. If these cracks are within the transfer zone, an epoxy injection repair should be considered (see below).
3. All cracks 0.006-in. or greater in width, after detensioning and deemed acceptable, should be repaired by epoxy injection in accordance with Standard Repair Procedure #10.



TS #3: TROUBLE SHOOTING VERTICAL THROUGH CRACKS IN BEAMS

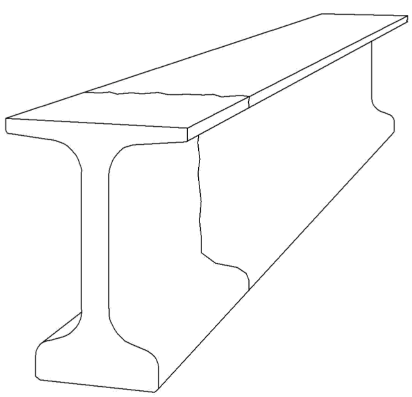
Description: These cracks can develop in beams during the curing process or cool-down period prior to detensioning of strand. This problem is more common to long beams manufactured with higher strength concrete.

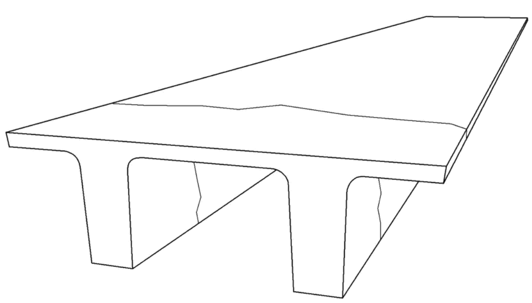
CAUSE

A. Shrinkage
1. Shrinkage of the beam prior to detensioning

B. Temperature Effects
1. Contraction of exposed strand in unused portion of bed
2. Contraction of beam due to cooling prior to transfer of prestress
3. Uneven distribution of heat

C. Production/Formwork
1. Indentations or joint offsets in forms
2. Concrete binding to forms
3. Bottom plate at end of member anchored or restrained in form





PREVENTION

A. Review or modify the mix or modify curing methods to reduce shrinkage
1. Consider change to alternate mix (see note)
2. Apply curing covers rapidly

B. Control Temperature During Production
1. Minimize temperature differential between beam, exposed strand, and bed
2. Detension as covers are removed and do not allow section to cool rapidly
3. Provide uniform heat and humidity during curing

C. Improve production methods
1. Keep forms in good repair; fabricate forms with even, smooth joints
2. Keep forms clean and properly oiled
3. Release restraint of all plates before detensioning

Note: Modifications to mix designs may not be possible in certain situations due to owner pre-qualification requirements for mixes.

Reference:

Zia, Paul, and Caner, Alp, "Cracking in Long-Span Prestressed Concrete AASHTO Girders During Production", Center for Transportation Engineering Studies, North Carolina State University, Raleigh, N.C.

TS#3: TROUBLE SHOOTING VERTICAL THROUGH CRACKS IN BEAMS

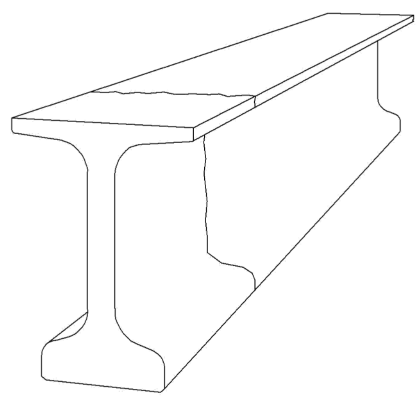
Description: These cracks can develop in beams during the curing process or cool-down period prior to detensioning of strand. This problem is more common to long beams manufactured with higher strength concrete.

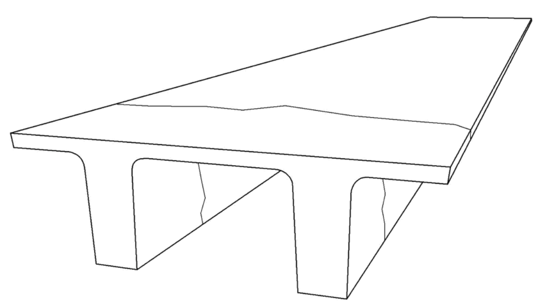
ENGINEERING EFFECTS

1. For cracks falling within the transfer length of bonded or debonded strand, it is recommended that the engineer re-compute the moment and shear capacity based on transfer initiating at the point of the crack. If the re-computed capacities are acceptable the beam can be repaired. These cracks should be injected.
2. For cracks falling beyond the transfer length of bonded or debonded strand that have a width of 0.006 inch or less, after detensioning, no reevaluation is needed. Cracks greater than 0.006 inch should be referred to the engineer for evaluation.
3. Full depth cracks that close after detensioning to a width of less than 0.006-in., or are 0.006-in. or greater and repaired meet the constitutive rules of the modified compression field theory for shear capacity. The subject theory, as a basic given, presumes a full depth crack along the inclined plane of theta degrees. Under full design load if the bottom flange at the pre-existing crack goes into tension, the crack will open along its vertical path until the neutral axis is reached, at which point the crack will turn and extend along the inclined plane, theta. As the compression strut can transmit stress across the vertical portion of the crack, the constitutive rules are not compromised

REPAIR CONSIDERATIONS

1. It is recommended that cracks not be repaired prior to detensioning as repairs will mask the cause and seriousness of the crack.
2. All cracks less than 0.006-in. in width, after detensioning and deemed acceptable, should be sealed. See Repair Procedure #14. If these cracks are within the transfer zone, an epoxy injection repair should be considered (see below).
3. All cracks 0.006-in. in width, after detensioning and deemed acceptable, should be repaired by epoxy injection in accordance with Standard Repair Procedure #10.





TS #4: TROUBLE SHOOTING HORIZONTAL END CRACKS IN WEBS AND FLANGES

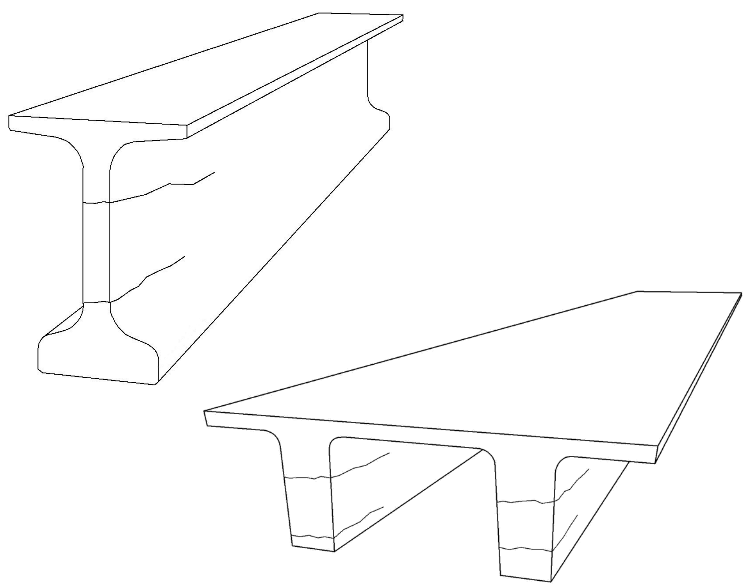
Description: This crack usually begins at the end of the beam and extends across the end of the beam and is visible on both sides.

CAUSE

A. Detensioning
   1. Improper procedures for detensioning strands
   2. Improper detensioning sequence

B. Design
   1. Low release strength specified
   2. Inadequate end vertical reinforcing
   3. Excessive prestress force or concentration of force
   4. Excessive number of debonded strands in the bottom plane and/or lack of confining stirrups
   5. Excessive vertical force from deflected strands

C. Production
   1. Concrete binding in forms
   2. Bottom plates, sleeves or inserts at end of beam
   3. Shrinkage and curing
   4. Improper removal of header or strand caught in header
   5. Settlement of wet concrete below a concentration of strand or mild reinforcing near the top at beam end
   6. For box beams, delayed web pours causing a cold joint



PREVENTION

A. Proper Release Procedure
   1. Heat strand to allow slow elongation (annealing) and avoid sudden release
   2. Keep prestress forces balanced using a pre-stablished procedure (see Note)

B. Improve Design
   1. Establish adequate release strength
   2. Use adequate anchorage zone end reinforcement to control width and length of cracks
   3. Properly space and distribute strand at beam ends
   4. Debonding strands for a short distance is effective in reducing stress concentrations. Debonding of an entire row of strand or debonding the outer strand in a layer are not recommended. Provide confinement reinforcement near beam ends
   5. Fan out deflected strands or combine debonding and deflecting strand

C. Improve Production Technique
   1. Keep forms well oiled
   2. Ensure forms will not interfere with hardware if forms expand or during detensioning
   3. Provide uniform heat and humidity during curing
   4. Separate header from forms before lifting
   5. Improve vibration techniques
   6. Pour webs prior to set of bottom slab of box beams

Note: Balancing of prestress force is key to minimizing the potential for horizontal cracks. See "Release Methodology of Prestress Strands", Kannel J., French C. and Stolurski, H., PCI Journal Vol. 42, No. 1, Jan-Feb. 1997, pp. 42-55

TS #4: TROUBLE SHOOTING HORIZONTAL END CRACKS IN WEBS AND FLANGES

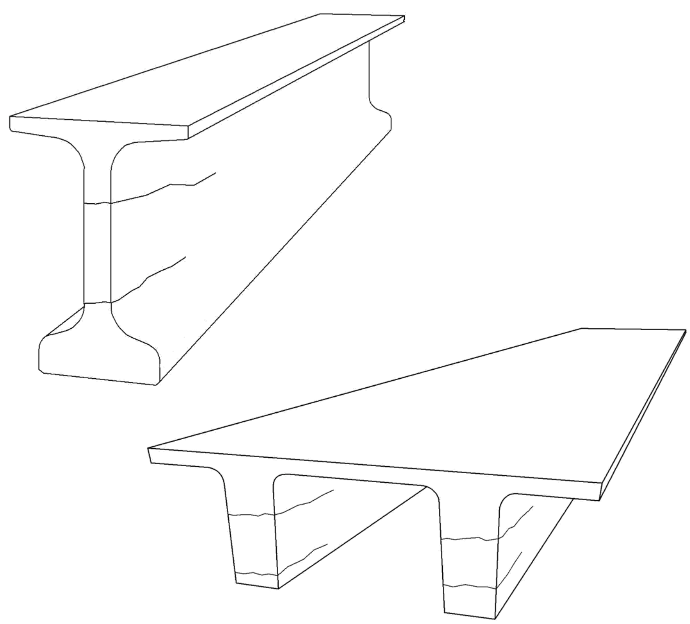
Description: This crack usually begins at the end of the beam and extends across the end of the beam and is visible on both sides.

ENGINEERING EFFECTS

1. Cracks not intercepting strand are not of structural consequence, provided the area of vertical shear reinforcement in the webs meets horizontal shear requirements. After installation of the beams, the cracks would not be expected to grow, given adequate reinforcement against horizontal shear, since the dead load weight of the slab and other dead loads will induce vertical compression in the beams ends.
2. For cracks that intercept or are co-linear with strands, the shear and moment capacity will require re-computation due to a change in location of transfer length of affected strands.
3. Cracks in beam ends under expansion joints, should be considered for epoxy injection to avoid future deterioration from water and salt intrusion. Cracks in box beams, in side-by-side (butted) configurations should be epoxy injected in any case due to potential leakage through grouted joints.
4. In deciding whether to inject cracks or leave them unfilled, ACI Committee 224 report "Control of Cracking in Concrete Structures" states that tolerable crack widths are 0.006-in. for concrete exposed to seawater spray with wetting and drying, 0.007-in. for concrete subject to de-icing chemicals and 0.012-in. for concrete exposed to humidity.

REPAIR CONSIDERATIONS

1. No repairs to beams used in composite construction in accordance with the discussion in ENGINEERING EFFECTS 1.
2. For cracks discussed in ENGINEERING EFFECTS 2:
   a. Cracks that have been verified by the owner to not have diminished the beam capacity below acceptable levels should be injected, in accordance with Standard Repair Procedure #10.
   b. Beams verified by the engineer to have capacity reduced to unacceptable levels will be rejected.
3. Durability concerns, discussed in ENGINEERING EFFECTS 3 and 4 may favor epoxy injection, in accordance with Standard Repair Procedure #10. The surface of cracks narrower than 0.006-inches should be sealed. See Repair Procedure #14.



TS #5: TROUBLE SHOOTING BOTTOM FLANGE CRACKS AT BEAM ENDS

Description: The crack is located at the end of the beam and generally runs parallel to the longitudinal axis.

CAUSE

A. Production
1. Binding in the forms during stripping
2. Indentation in the forms
3. Improper detensioning sequence

B Reinforcement
1. Incorrect placement or omission of confining reinforcement
2. Reinforcement improperly detailed or fabricated
3. Debonding problem
4. Contaminated strand

C. Detensioning
1. Localized differential strains and stresses between the web and flange during detensioning

D. Handling
1. Non-uniform bearing on dunnage or impact while being lowered on dunnage

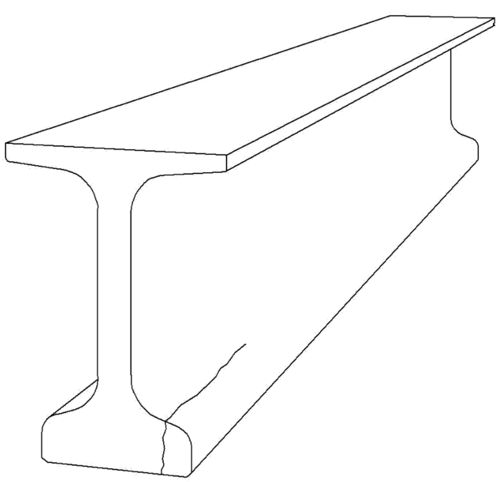
PREVENTION

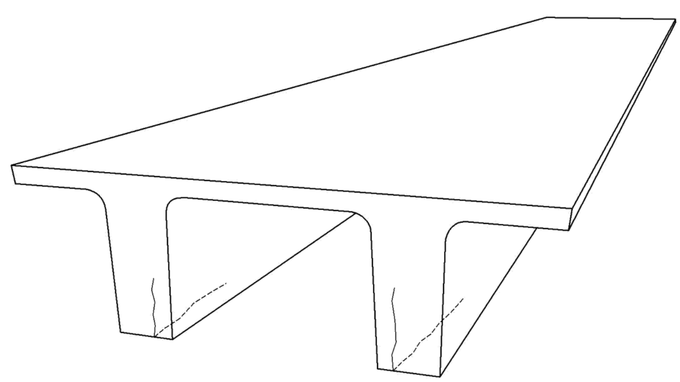
A. Improve Production
1. Keep forms well-oiled and clean
2. Keep forms in good repair
3. Keep forces balanced during detensioning

B. Attention to Reinforcing Details
1. Verify correct placement of reinforcement
2. Scrutinize drawings and fabricated bars to be used
3. Allow for swelling (Hoyer Effect) of detensioned strand that have been debonded by providing confinement reinforcing or relocating debonded strands away from edges of the flange.
4. Inspect strand for contamination and oil residue from manufacturing

C. Detensioning
1. Heat strand to allow slow elongation (annealing) to minimize shock of detensioning

D. Handling
1. Ensure uniform bearing and avoid impacts when handling beams





TS #5: TROUBLE SHOOTING BOTTOM FLANGE CRACKS AT BEAM ENDS

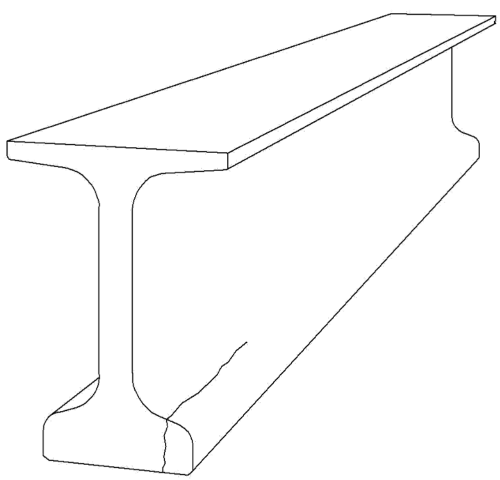
Description: The crack is located at the end of the beam and generally runs parallel to the longitudinal axis.

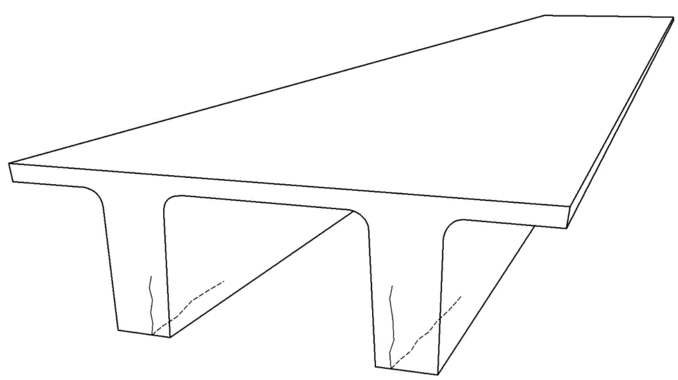
ENGINEERING EFFECTS

1. Cracks co-linear with strands affect the unbonded length and it will be necessary to recompute the shear and moment capacity based on the revised transfer and/or development length location for the strands. Weak axis bending may need checking.
2. In any event, these cracks should be repaired to ensure the integrity of the bearing area and to prevent water and salt intrusion at expansion devices or through grouted shear keys of side-by-side (butted) box beams.

REPAIR CONSIDERATIONS

1. All bottom flange cracks should be epoxy injected in accordance with Standard Repair Procedure #10
2. IN the case of strand involvement, the engineer should be notified to assess conditions prior to repairs.





TS #6: TROUBLE SHOOTING CORNER SPALLS OR CORNER CRACKS

Description: These spalls and cracks can be found at any edge or corner of flanges along the beam

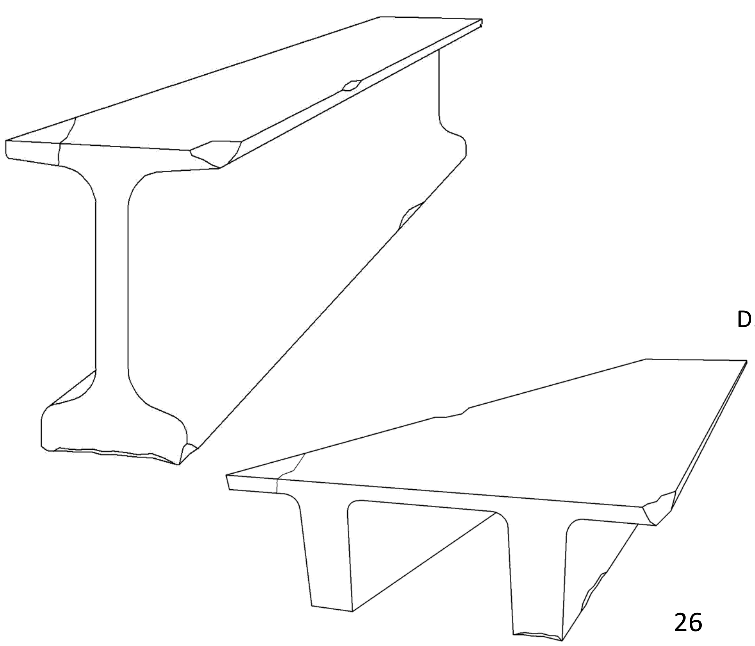
CAUSE

A. Improper Handling
   1. Impacting edges
   2. Uneven dunnage

B. Production
   1. Binding in forms during stripping
   2. Indentation in forms
   3. Inserts hanging up in forms
   4. Sole plates not flush with soffit of forms
   5. Improper shielding of strands
   6. Thermal expansion of forms prior to concrete setting
   7. Improper bulkhead removal
   8. Bleeding of concrete under header

C. Release Procedures
   1. Improper detensioning sequence
   2. Binding in forms during detensioning
   3. Dragging of bottom flange end induced by cambering and shortening at detensioning
   4. Impact and bursting forces from detensioned strand

D. Design
   1. Inadequate edge reinforcement



PREVENTION

A. Care in Handling
   1. Ensure adequate room for transport of beams
   2. Provide uniform dunnage

B. Improve Production Methods
   1. Keep forms clean and well oiled
   2. Keep forms in good condition and ensure all seams are mortar tight
   3. Ensure inserts are free during stripping
   4. Ensure sole plates are flush with soffit prior to concrete pours
   5. Shielding in the bottom row of strands should be minimized and shielding of strands adjacent to the edges of flanges should be avoided
   6. Ensure concrete set prior to starting curing
   7. Keep bulkheads in good condition and well-oiled to avoid the need to pry them loose
   8. Provide mortar-tight header

C. Proper Release Procedures
   1. Keep prestress forces balanced during detensioning
   2. Provide sufficient clearance between forms and beam during detensioning
   3. Provide skid plates, radii, bevels or compressible material for the bottom edge of flanges
   4. Heat strand sufficiently to slowly elongate (annealing) to avoid impact and to mitigate swelling of strand (Hoyer Effect) at release
   5. Ensure all strands are completely severed prior to removal from forms

D. Design
   1. Provide proper reinforcement as close to edges as clearance requirements allow

TS #6: TROUBLE SHOOTING CORNER SPALLS OR CORNER CRACKS

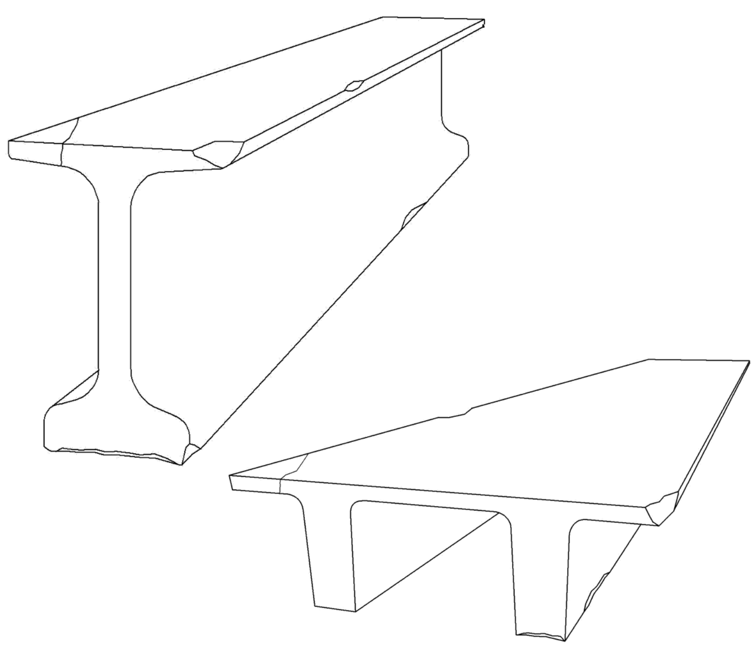
Description: These spalls and cracks can be found at any edge or corner of flanges along the beam

ENGINEERING EFFECTS

1. Corner spalls in top flanges used as the riding surface of the completed bridge require repair to ensure sufficient live load capacity and durability
2. Corner spalls in bearing areas of beams should be repaired to ensure proper bearings as well as to protect strands from water and salt intrusion when beam ends are adjacent to expansion joints.
3. Corner spalls in the bottom flange that may significantly reduce protection from salt and water spray from traffic underneath or leaking grouted joints from above, such as side-by-side boxes and deck bulb-tees, should be repaired.
4. If strands are exposed, the engineering effect should be reviewed by the Engineer.
5. Top flange edges incorporated into slab pours need not be repaired

REPAIR CONSIDERATIONS

1. Where corner spalls are deemed in need of repair, the repairs should be made in accordance with Standard Repair Procedures #3 or #4
2. Corner spalls on edges to be incorporated into composite slab or end diaphragms may not need repair
3. Minor spalls that do not compromise protection from water, salt spray or humidity, or are not exposed to direct view need not be repaired



TS #7: TROUBLE SHOOTING PARTIALLY CRACKED TOP FLANGES

Description: The crack width is usually visible and exhibits a clean break line.

CAUSE

A. Handling
   1. Impacting edges

B. Production
   1. Binding in forms during stripping
   2. Placement of concrete in excessively hot forms
   3. Thermal expansion of forms prior to concrete setting or contraction during cool-down

C. Release Procedures
   1. Improper detensioning sequence
   2. Strands not free from bulkhead

D. Strand Placement
   1. Concentration of prestressing forces at the edges of top flanges

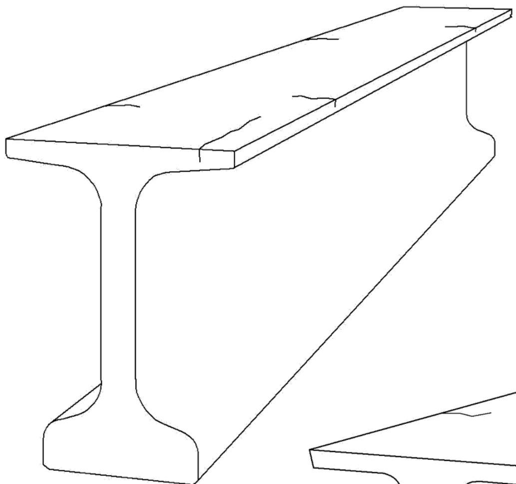
PREVENTION

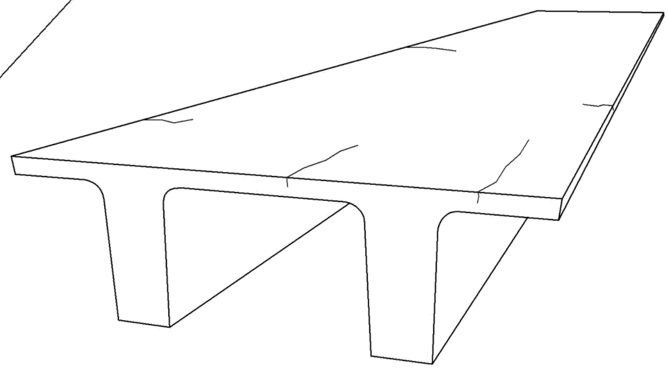
A. Proper Handling
   1. Ensure adequate room for transport of beams

B. Improve Production Methods
   1. Keep forms clean and well oiled. Keep forms in good repair, free of dents and dimples
   2. Ensure forms are cooled to an appropriate temperature prior to placing concrete
   3. Regulate heat during curing and cool-down uniformly

C. Proper Release Procedures
   1. Keep prestress forces balanced during detensioning
   2. Ensure any top strands are completely severed prior to removal from forms
   3. Provide sufficient clearance between forms and beams during detensioning

D. Proper Design Detailing
   1. Avoid placement of prestress near edges of top flange, or if this is unavoidable, add transverse reinforcement to flanges





TS #7: TROUBLE SHOOTING PARTIALLY CRACKED TOP FLANGES

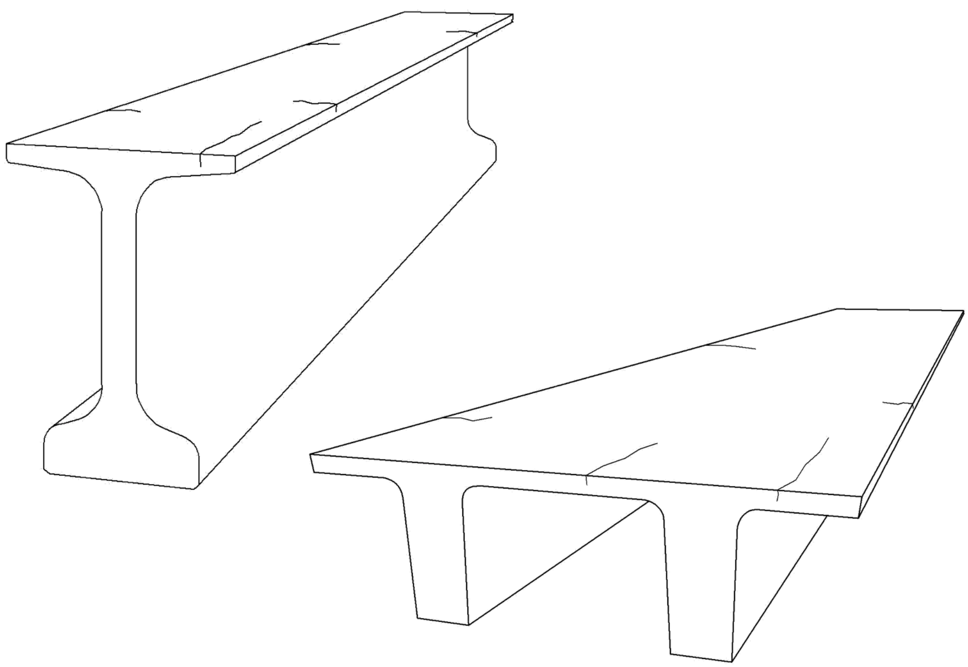
Description: The crack width is usually visible and exhibits a clean break line.

ENGINEERING EFFECTS

1. For beams whose top flange is to be used as the riding surface of the completed bridge, cracks in the top flange can affect durability and live load capacity, if not repaired
2. For beams to receive a cast-in-place slab, repairs may not be warranted

REPAIR CONSIDERATION

1. When the top flange is to be the riding surface, and concrete is displaced, fractured or loose, use Standard Repair Procedure #6. If the crack is clean and no concrete is displaced use Standard Repair Procedures #10.
2. When the top flange is to be encased in a cast-in-place slab, and concrete in the flange is displaced, the engineer should be notified to determine if the flange should be repaired using Standard Repair Procedures #6 or if the displaced concrete can be left and encased in the slab. If the crack is clean and no concrete is displaced, no repairs are warranted.



TS #8: TROUBLE SHOOTING RANDOM HONEYCOMBING AND VOIDS

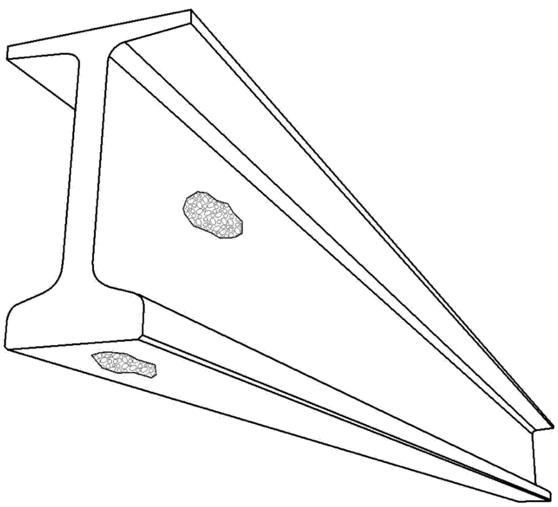
Description: Missing volume of cement paste from around aggregate or voids containing neither paste nor aggregate, in flanges and webs.

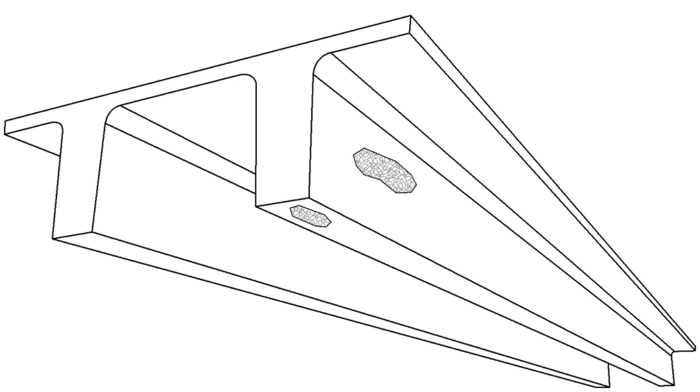
CAUSE

A. Production
1. Inadequate vibration
2. Improper placement of concrete
3. Shifted/misplaced rebar cage

B. Concrete Mix Design
1. Mix too stiff
2. Early set in plasticized concrete
3. Delayed placement of concrete
4. Flash set of concrete in forms

C. Design Details
1. Congested reinforcement





PREVENTION

A. Improved Production Procedures
1. Provide thorough internal and, where warranted, external vibration
2. Start placement away from bulkheads and use vibration to cause the concrete to flow toward bulkheads
3. Verify location of and anchor reinforcement

B. Adjust Mix Design
1. Consider change to alternate mix (see note)
2. Improve delivery time of the concrete
3. Cool forms prior to concrete placement

C. Improve Details
1. Reduce reinforcement congestion to the extent possible
2. Provide clear spacing between reinforcement larger than 1 ½ times the maximum aggregate size

Note: Modifications to mix designs may not be possible in certain situations due to owner pre-qualification requirements for mixes.

TS #8: TROUBLE SHOOTING RANDOM HONEYCOMBING AND VOIDS

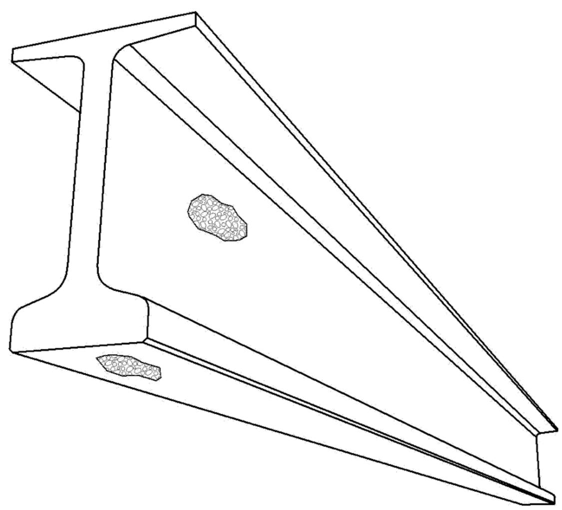
Description: Missing volume of cement paste from around aggregate or voids containing neither paste nor aggregate, in flanges and webs.

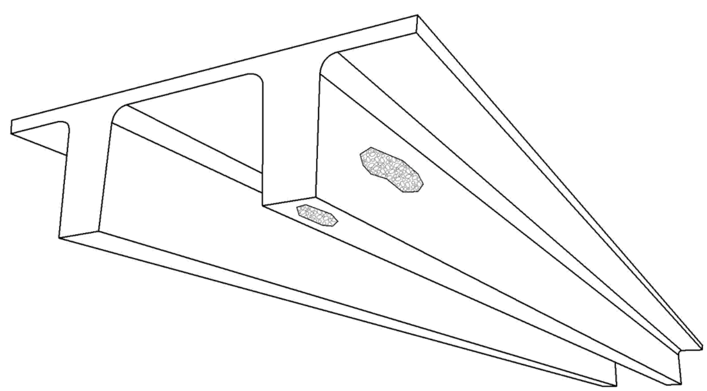
ENGINEERING EFFECTS

1. Honeycombing and voids in bearing areas not only affect the strength and durability of the bearing but, the moment capacity if bond on the strand is impacted. Under modified compression field theory, loss of bond of strand can also affect shear capacity. These areas must be repaired. Honeycombing and voids in other areas of the bottom flange can affect moment capacity, but more likely, only durability.
2. Honeycombing and voids in webs affect shear capacity and must be repaired.
3. Honeycombing and voids in top flanges that will be the riding surface of the bridge affect both moment capacity and durability, requiring repair. Where the top flange is to be encased in a cast-in-place slab, the honeycombing and voids may significantly affect the non-composite strength but not durability.
4. If strands are exposed, the engineering effect should be reviewed by the Engineer.

REPAIR CONSIDERATIONS

1. For conditions discussed in Engineering Effects 1, repair using Standard Repair Procedures #1 or #2, as appropriate.
2. For conditions discussed in Engineering Effects 2, repair using Standard Repair Procedures #5 or #9, as appropriate.
3. For conditions discussed in Engineering Effects 3, if repairs are required, use Standard Repair Procedures #6 or #9, as appropriate.





TS #9 TROUBLE SHOOTING RANDOM TOP FLANGE CRACKS

Description: These cracks are generally oriented longitudinally and are shallow in depth, occurring in a random pattern, often parallel with reinforcement.

CAUSE

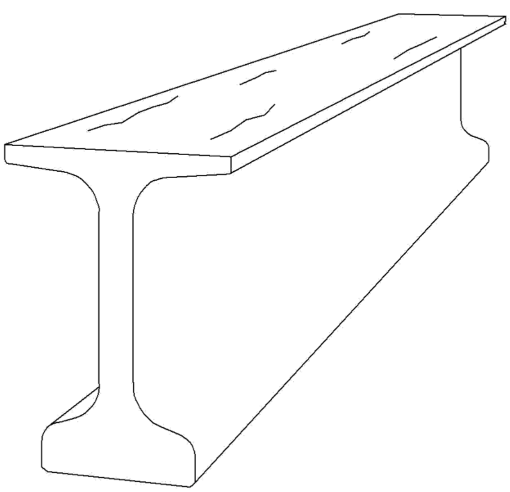
A. Shrinkage
   1. Excess bleed water at the top flange surface
   2. Rapid moisture loss prior to curing
   3. Excessive curing temperature
   4. Delayed start of curing

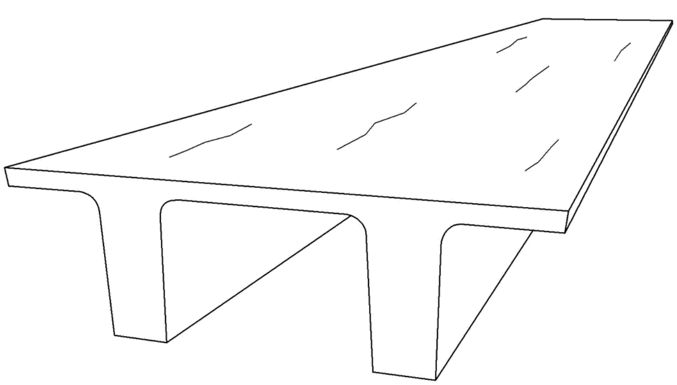
B. Concrete Placement
   1. Settlement of concrete around top reinforcement (subsidence)
   2. Insufficient Vibration

PREVENTION

A. Prevent Shrinkage
   1. Reduce water in mix and or avoid over-working surface finish
   2. Use retardant admixtures cover beams completely and as soon as possible (especially in windy, hot and dry conditions). If necessary, mist-spray exposed top flange surface, with water.
   3. Reduce curing temperature
   4. Determine proper pre-set time to suit curing operations, using ASTM C403. Limit start of curing to 2-3 hours

B. Improve Placement Methods
   1. Allow time for initial settlement, and re-vibrate concrete
   2. Ensure proper vibration to consolidate concrete





TS #9 TROUBLE SHOOTING RANDOM TOP FLANGE CRACKS

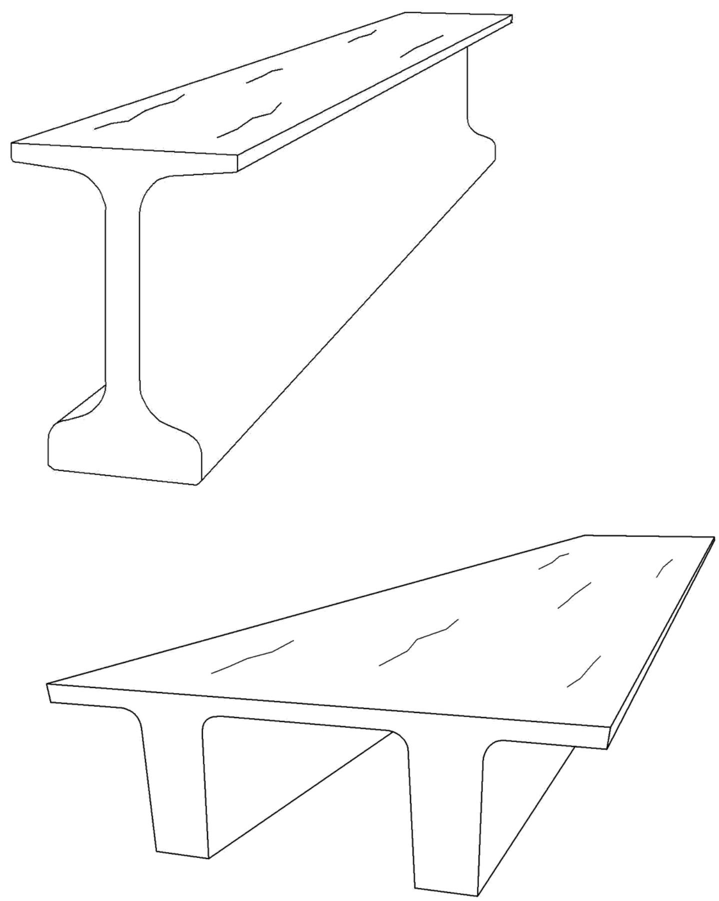
Description: These cracks are generally oriented longitudinally and are shallow in depth, occurring in a random pattern, often parallel with reinforcement.

ENGINEERING EFFECTS

1. Other than concern for durability for top flanges that will become the riding surface of the completed bridge, there are no concerns. These cracks will be covered by the slab in composite construction

REPAIR CONSIDERATIONS

1. Where the top flange will be the riding surface, seal with a low viscosity epoxy or methyl methacrylate product.
2. Where composite construction is used, no repairs are needed.



TS #10 TROUBLE SHOOTING SHORT PROJECTED STRAND OR REINFORCING, MISSING PROJECTED STRAND OR REINFORCING

Description: This type of defect is usually caused by improper production detailing. It is usually limited to projecting strand or reinforcing for continuity connections or horizontal shear reinforcing.

CAUSE

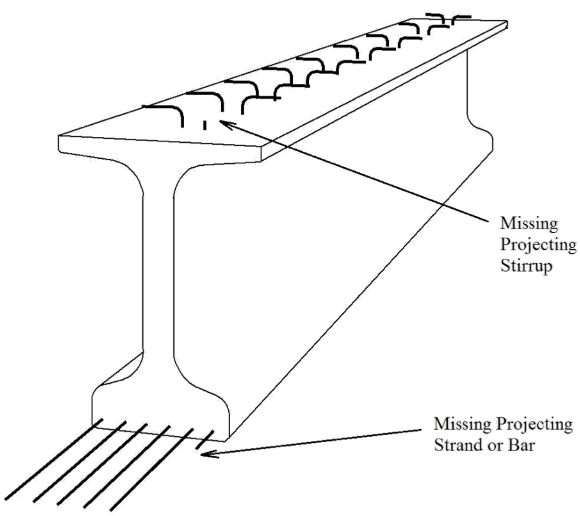
A. Formwork
   1. Bulkhead shift

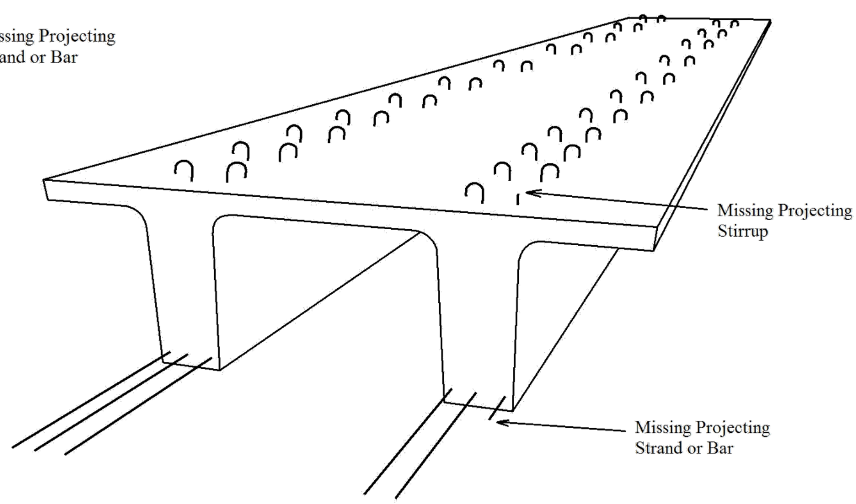
B. Reinforcement
   1. Improper placement
   2. Improper cutting
   3. Improper bending
   4. Incorrect fabrication drawing or design drawing
   5. Shifting during casting
   6. Improper handling

PREVENTION

A. Formwork
   1. Check bulkhead locations and integrity

B. Reinforcement
   1. Re-check reinforcing/strand locations prior to concrete placement
   2. Re-check strand/reinforcing lengths before cutting
   3. Follow CRSI requirements for minimum bending radius
   4. Re-check fabrication and design drawings
   5. Place additional ties on reinforcement
   6. Review shop handling practices



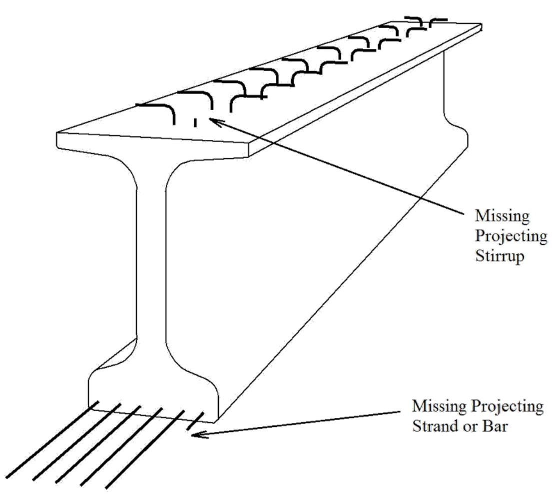


TS #10 TROUBLE SHOOTING SHORT PROJECTED STRAND OR REINFORCING, MISSING PROJECTED STRAND OR REINFORCING

Description: This type of defect is usually caused by improper production detailing. It is usually limited to projecting strand or reinforcing for continuity connections or horizontal shear reinforcing.

ENGINEERING EFFECTS

1. Missing stirrups can materially affect the horizontal shear capacity as well as vertical shear capacity. Calculations may verify no significant reduction in shear capacity. If so, repair may not be necessary.
2. Missing projecting strand will reduce the positive moment restraint capacity at the interior supports of beams made continuous for composite dead and live loads.
3. Where projected strand are to be developed within cast-in-place diaphragms, to ensure adequate longitudinal tension tie capacity for beam vertical shear design may be compromised. Refer to AASHTO LRFD Article 5.8.3.5.



Note 1: Repairs shall not be made without the designer's approval; the following are general guidelines:

Note 2: If acceptable to the owner, a small amount of concrete can be removed and the strand can be repaired as a short projecting strand

REPAIR CONSIDERATIONS

Missing Projected Strand replaced with grouted rebar (see Note 2)

1. This procedure should only be used for repairing up to 25% of the projecting strand.
2. Each missing strand shall be replaced by two #6 rebar grouted adjacent to the missing element with 24" of embedment
3. The grouted rebar shall be as close as practical to the missing element.
4. See Standard Repair Procedure #12

Missing Projected Rebar

1. This procedure should only be used for repairing up to 25% of the projected reinforcing at beam ends.
2. Each missing rebar shall be replaced by an equivalent sized Grade 60 rebar.
3. The embedment shall be sufficient to develop a full lap splice with the internal reinforcing where tension transfer is required.
4. The minimum embedment for other situations shall be based on the chemical adhesive manufacturer's recommendations.
5. See Standard Repair Procedure #12

Short Projecting Rebar

1. Use a mechanical coupler that is approved by the Owner, installed as per the manufacturer's recommendations
2. See Standard Repair Procedure #11.

Short Projecting Strands

1. This procedure can be used for any number of short projecting strands per beam that has sufficient strand remaining that is tightly wound in order to follow this repair procedure; if this can't be met, treat as a missing strand. Saw-cut strand cleanly with a cut off saw and install a self-seating splice chuck with additional piece of strand.
2. See Standard Repair Procedure #11.

TS #11 TROUBLE SHOOTING CRACKS AND HONEYCOMBING IN PRECAST, PARTIAL DEPTH DECK PANELS

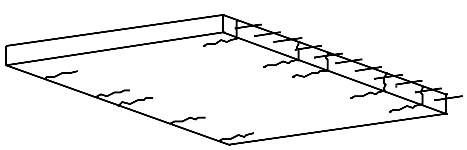
Description: Longitudinal, transverse and diagonal cracks, and honeycombing in panels.

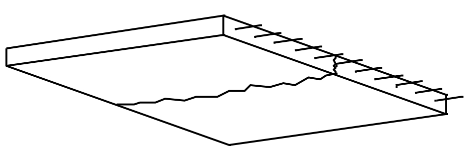
CAUSES

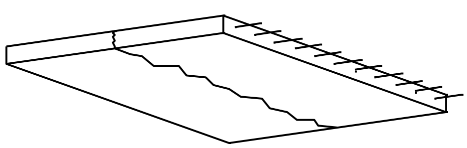
A. Longitudinal cracks running co-linear to strands
   1. Improper detensioning procedures
   2. Excessive prestressing force
   3. Inadequate end reinforcement transverse to strand pattern
   4. Casting concrete in hot forms
   5. Low release strength of concrete

B. Longitudinal cracks not co-linear to strand, transverse cracks or diagonal cracks in panels
   1. Improper handling (impact)
   2. Improper storage
   3. Shrinkage
   4. Improper detensioning procedures
   5. Strand pattern eccentric to panel mid-depth

C. Random Honeycombing
   1. Improper vibration







PREVENTION

A. Longitudinal cracks running co-linear to strand
   1. Keep prestressing forces balanced during detensioning. Heat strand to ensure slow elongation of strand (annealing) during detensioning.
   2. Keep the average prestress force over the end face of panels to 750 psi.
   3. Provide transverse mild reinforcing steel above and below the strand at panel ends.
   4. Cool forms, headers, strand and mild reinforcing, that comes in contact with wet concrete, at or below 90°F.
   5. Increase release strength.

B. Longitudinal cracks not co-linear to strand, transverse cracks or diagonal cracks in panels.
   1. Provide adequate draft for moving panels. Avoid impacts
   2. Keep dunnage level and, uniformly spaced. Provide uniform bearing of panels transverse to strands.
   3. Avoid rapid cooling, after curing has stopped and until detensioning is complete.
   4. Keep prestressing forces balanced during detensioning.
   5. Keep strand placement at mid-depth.

C. Random Honeycombing
   1. Properly vibrate

TS #11 TROUBLE SHOOTING CRACKS AND HONEYCOMBING IN PRECAST, PARTIAL DEPTH DECK PANELS

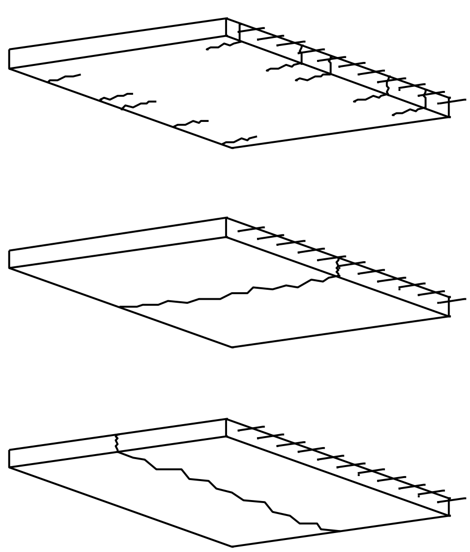
Description: Longitudinal, transverse and diagonal cracks, and honeycombing in panels.

ENGINEERING EFFECTS

1. Cracks co-linear with strand, either extending from the top or bottom face to strands, or through cracks are an indicator of debonding. Experience has shown that even cracks that are partial length of strand will continue to grow full length of strand over time, even after epoxy injection. The owner should be consulted when more than 6 per cent of strand have such cracks. Two consecutive strand having cracks should be cause for rejection.
2. Longitudinal cracks, parallel but not co-linear to strand are of no structural consequence.
3. Transverse and diagonal cracks that cross more than 6 per cent of strand require an assessment by the owner. Because of the relatively short length of panels, compared to the transfer and development length of the strands it is likely that any crack intercepting strands will cause debonding.
4. Honeycombing not more than one-inch deep, in the top or bottom face of panels and not of extensive plan area are of no structural consequence if repaired. Honeycombing deeper than one-inch may compromise strand bond.

REPAIR CONSIDERATIONS

1. Cracks co-linear with strand and extending from one face to the strand, or through cracks co-linear with strand over more than 12 percent of strand should be rejected.
2. Longitudinal cracks parallel to but not co-linear with strand that exceed 0.007 inches in width should be considered for epoxy injection in accordance with Standard Repair Procedure #10.
3. Transverse or diagonal cracks extending over more than 12 percent of strand should be rejected.
4. Honeycombing not exceeding one-inch in depth at either face, of an acceptable plan area, should be repaired in accordance with Standard Repair Procedures #1, #2 or #5.



TS #12 TROUBLE SHOOTING PARTIALLY CRACKED TOP FLANGES – NEXT BEAMS

Description: Crack running parallel to beam centerline along inside face of stem. This crack is expected in obtuse corners of skewed beams adjacent to the interior face of the stem, but can occur in any beam.

CAUSE

A. Detensioning
   1. Release stresses brought on by skew effects. Uneven lift-off of beam stems brought on by skew [8].
   2. Release stresses due to uneven detensioning sequence between beam stems.
   3. Binding in forms during stripping

B. Shrinkage
   1. Shrinkage of top flange concrete restricted by the fixed 2 stem form.

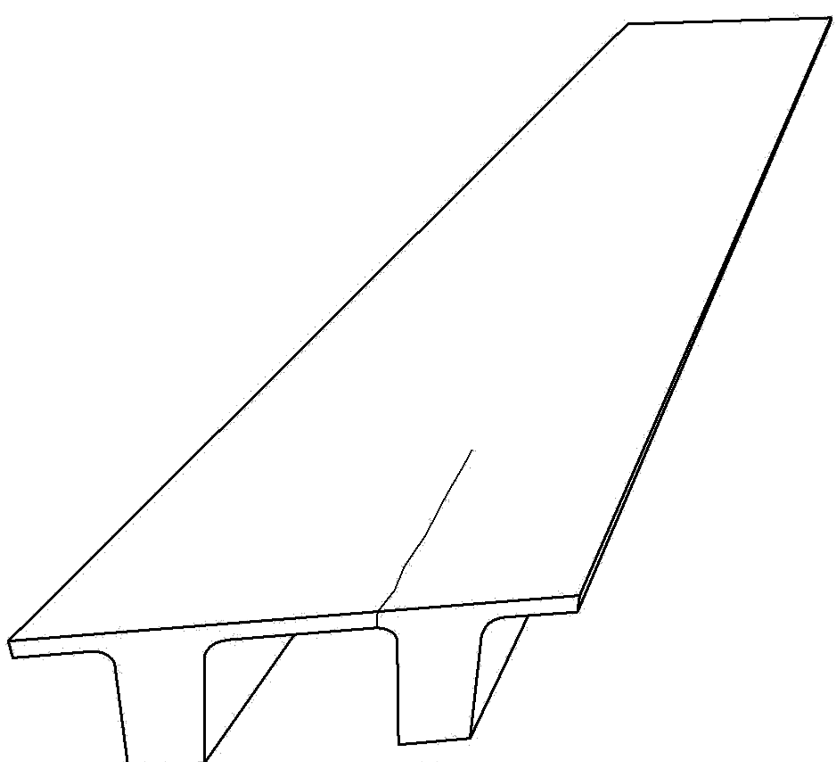
PREVENTION

A. Adjust Reinforcement and detensioning sequence
   1. Verify that additional reinforcing steel that is shown in the current PCI Northeast recommended guide details are being used and installed properly.

      Note: The reinforcement described above was added to the typical details on October 25, 2012.

   2. Release one strand at a time alternating from stem to stem.
   3. Keep forms clean and well oiled. Keep forms in good repair, free of dents and dimples.

B. Modify Fabrication Methods
   1. Avoid rapid cooling, after curing has stopped and until beam is removed from form.

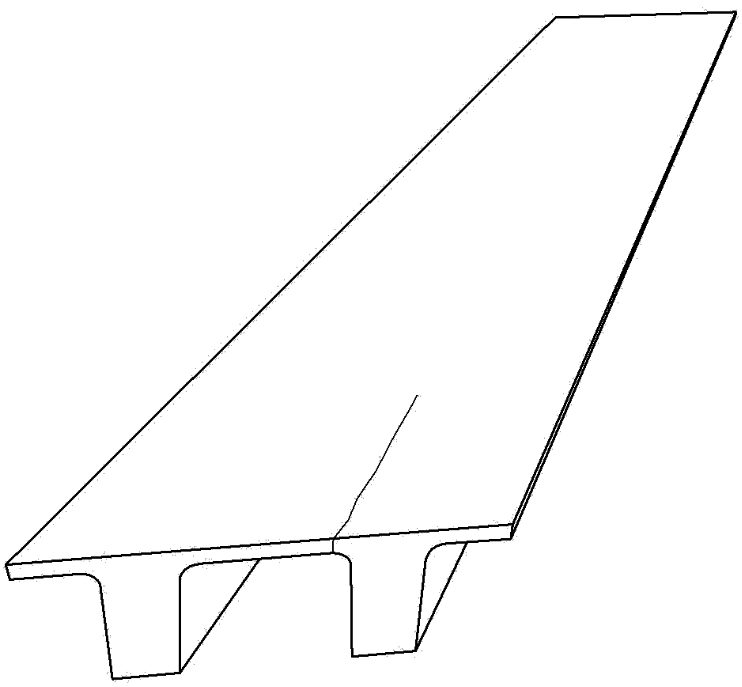


TS #12 TROUBLE SHOOTING PARTIALLY CRACKED TOP FLANGES – NEXT BEAMS

Description — Crack running parallel to beam centerline along inside face of stem. This crack is expected in obtuse corners of skewed beams adjacent to the interior face of the stem, but can occur in any beam.

ENGINEERING EFFECT

1. For beams that will be topped with a composite concrete slab (NEXT F), there are no concerns. These cracks will be covered by the slab in composite construction.
2. For beams whose top flange is to be used as the riding surface of the completed bridge (NEXT D), cracks in the top flange can affect durability, if not repaired.



REPAIR CONSIDERATIONS

1. Where a composite concrete deck is embedded in concrete in the finished structure (integral abutment), no structural repairs are needed.
2. NEXT F: If the crack is exposed on the underside of the finished structure and the bridge is in a corrosive environment:
   - Cracks less than 0.006 inch wide should be ignored (See Note).
   - Cracks greater than or equal to 0.006 inch wide and less than 0.016 inch wide should be sealed with epoxy paste. See Standard Repair Procedure #14.
   - Cracks greater than or equal to 0.016” wide should be sealed using epoxy injection by the pressure injection method. See Standard Repair Procedure #10.
3. NEXT D: Where the top flange will be the riding surface and the crack width is greater than 0.006 inches, the crack at the top surface of the deck can be sealed with a low viscosity epoxy or methyl methacrylate product. See Standard Repair Procedure 14.

Note: The AASHTO LRFD Bridge Design Specifications limits crack widths in Class 2 exposure conditions (bridge decks) to 0.0085 inches (Article 5.7.3.4). Therefore these recommendations are conservative.

Section 2.2: Non-Prestressed Precast Elements

TS #SS1: Corner Spalls

TS #SS2: Cracks

TS #SS3: Honeycombing, Voids, Pour Lines, and Minor Surface Imperfections

TS #SS4: Short Projected Rebar and Missing Projected Rebar

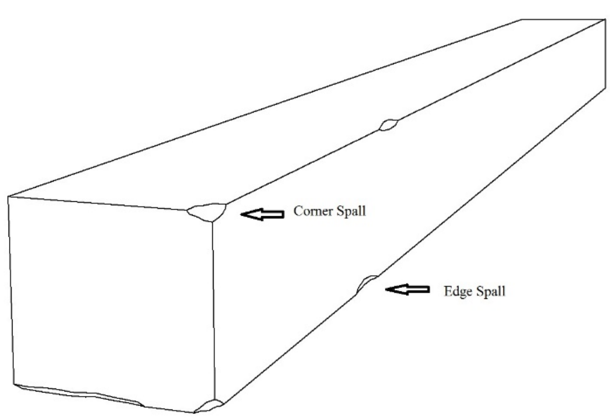
TS #SS5: Missing or Mis-Located Inserts, Voids, or Mis-Located Projecting Rebar

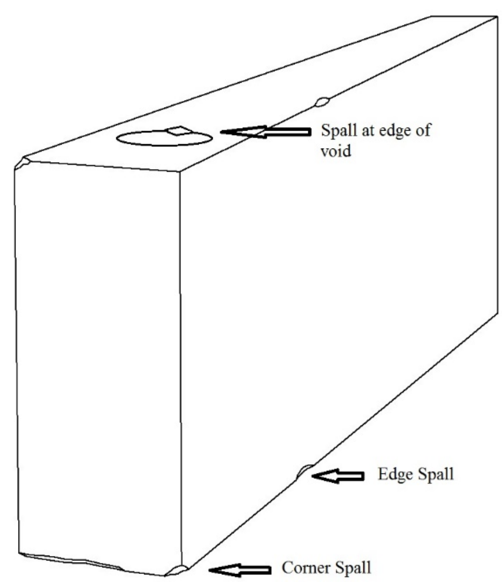
TS #SS1: TROUBLE SHOOTING CORNER SPALLS IN NON-PRESTRESSED PRECAST ELEMENTS

Description These spalls and cracks may be found at any edge or corner of the element

The following elements are covered under this Trouble Shooting Guide: Pier Elements (columns, caps), Abutment and Wall Elements (stems, caps), Foundation elements (footings), or other similar non-prestressed precast elements.

CAUSE	PREVENTION
A. Improper Handling	A. Care in Handling
1. Impacting edges	1. Ensure adequate room for transport of elements
2. Uneven dunnage	2. Provide uniform dunnage. Non-rigid materials such as timber or elastomeric pads are recommended
B. Production	B. Improve Production Methods
1. Binding in forms during stripping	1. Keep forms clean and well oiled
2. Indentation in forms	2. Keep forms in good condition (repair dents, remove projections, and make seams mortar tight)
3. Inserts hanging up in forms	3. Ensure inserts are free during stripping
4. Thermal expansion of forms prior to concrete setting	4. Ensure concrete set prior to starting curing
5. Bleeding of concrete under header	5. Provide mortar-tight header
C. Design	D. Verify Design
1. Inadequate edge reinforcement	1. Provide proper reinforcement as close to edges as clearance requirements allow





TS #SS1: TROUBLE SHOOTING CORNER SPALLS IN NON-PRESTRESSED PRECAST ELEMENTS

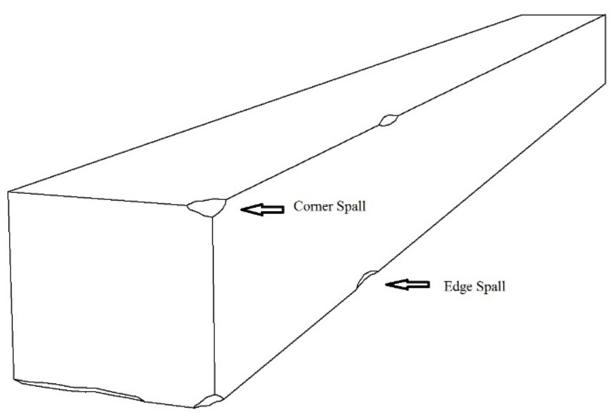
Description These spalls and cracks may be found at any edge or corner of the element

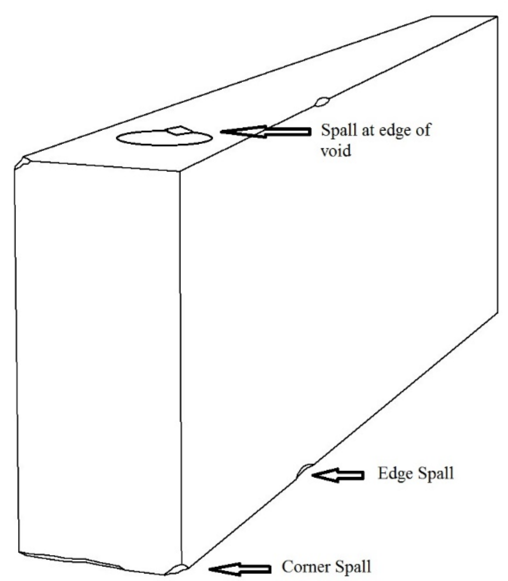
ENGINEERING EFFECTS

1. Corner spalls in beam elements require repair to ensure sufficient load capacity and durability.
2. Corner spalls in bearing areas of beam elements should be repaired to ensure proper bearings.
3. If strands are exposed, the engineering effect should be reviewed by the Engineer.

REPAIR CONSIDERATIONS

1. Spalls in areas that are exposed to the environment in the finished bridge should be repaired.
2. Minor spalls that do not compromise protection from water, salt spray, humidity, or are not exposed to direct view need not be repaired. For example: spalls incorporated into concrete closure pours or grouted joints.
3. Cracks located near corners have the potential to become a spall and should be repaired after removal of cracked concrete.
4. Where corner spalls are deemed in need of repair, the repairs should be made in accordance with Standard Repair Procedure #15.





TS #SS2: TROUBLE SHOOTING FOR CRACKS IN NON-PRESTRESSED PRECAST ELEMENTS

Description These cracks are typically perpendicular to the longitudinal axis of the element and extend across the member, often visible on multiple faces.

The following elements are covered under this Trouble Shooting Guide: Pier Elements (columns, caps), Abutment and Wall Elements (stems, caps), Foundation elements (footings), or other similar non-prestressed precast elements.

CAUSE

A. Shrinkage
   1. Shrinkage of concrete during curing causing friction forces between the element and the form, leading to a build-up of stresses in the element

B. Design
   1. Inadequate temperature and shrinkage reinforcement

2. Form Expansion with Temperature Rise
   1. Thermal expansion of the form causing friction forces between the element and the form, leading to a build-up of stresses in the element.

D. Handling Stresses
   1. High stresses due to inadequate number of pick points or pick point locations.
   2. Removal from form prior to reaching sufficient stripping strength.
   3. Element binding in forms or high suction forces during removal from form.
   4. Uneven dunnage.

PREVENTION

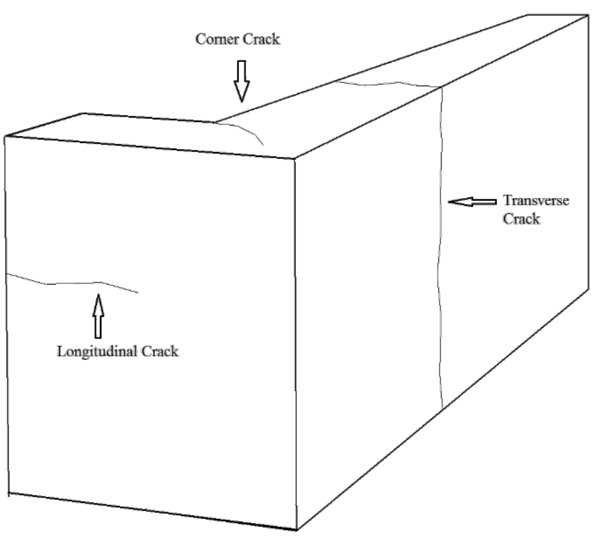
A. Review or modify the mix or modify curing methods to reduce shrinkage
   1. Consider change to alternate mix (see note)
   2. Apply curing covers rapidly

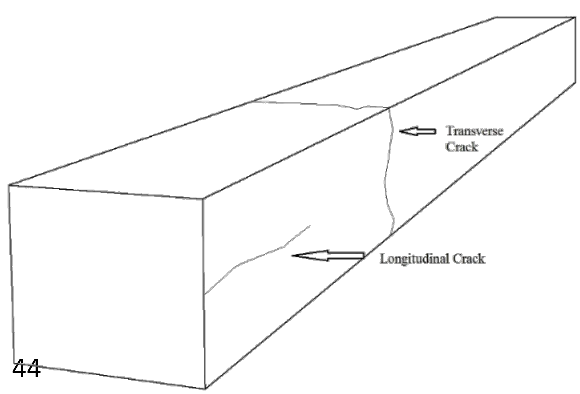
1. Verify Design
   1. Verify that there is adequate temperature and shrinkage reinforcement and that the reinforcement is properly distributed within the element.

C. Lengthen Set Time-In Accordance with ASTM C403
   1. Minimize temperature differential between element and form
   2. Prevent rapid cool-down of the element

3. Improve Handling Methods
   1. Check lifting and handling stresses according to the PCI Design Manual.
   2. Verify concrete strength prior to stripping.
   3. Adjust calculations for stripping. May lead to higher stripping strength requirement.
   4. Check elevation and seating of dunnage. If supported by more than two points, check for gaps in seating points. Avoid stacking elements on top of each other unless dunnage is supported well (concrete slab).

Note: Modifications to mix designs may not be possible in certain situations due to owner pre-qualification requirements for mixes.





TS #SS2: TROUBLE SHOOTING FOR CRACKS IN NON-PRESTRESSED PRECAST ELEMENTS

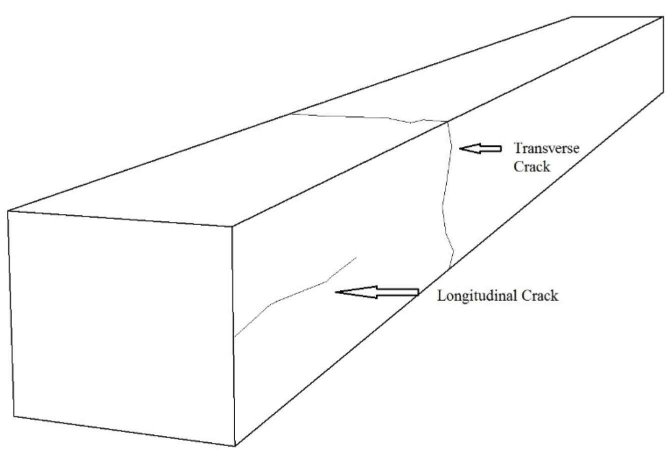
Description These cracks are typically perpendicular to the longitudinal axis of the element and extend across the member, often visible on multiple faces.

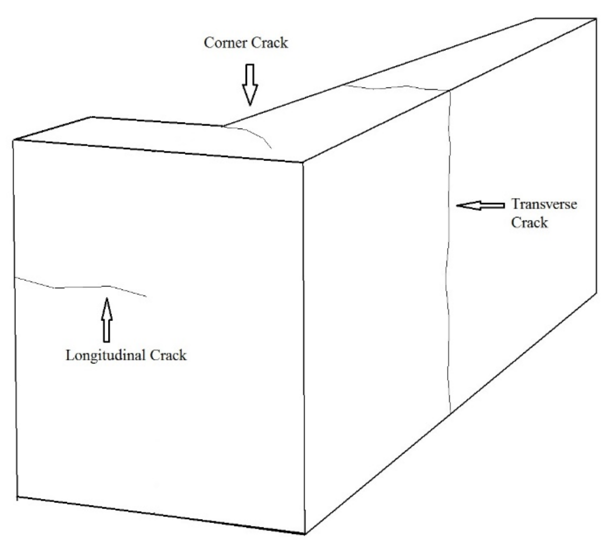
ENGINEERING EFFECTS

1. The design and detailing of reinforcement in the element should be checked in accordance with AASHTO temperature and shrinkage provisions.
2. An assessment of the need to repair as well as environmental exposure will be required. It should be noted that AASHTO provisions are based on an assumed crack width of 0.017-in. with Class 1 Exposure and 0.013-in. for Class 2 Exposure. Class 1 Exposure applies to conditions when cracks can be tolerated due to reduced concerns of appearance and/or corrosion. Class 2 Exposure applies to when there is increased concern of appearance and/or corrosion.
3. ACI Committee 224 report "Control of Cracking in Concrete Structures" states that tolerable crack widths are 0.006-in. for concrete exposed to seawater spray with wetting and drying, 0.007-in. for concrete exposed to de-icing chemicals, and 0.012-in. for concrete exposed to humidity.

REPAIR CONSIDERATIONS

1. Minor cracks that are incorporated into concrete closure pours or grouted joints need not be repaired.
2. If the decision is made that repairs are warranted, the cracks should be epoxy injected, in accordance with Standard Repair Procedure #10.
3. Experience has shown that cracks as narrow as 0.002-in. can be injected successfully. However, the surface of cracks narrower than 0.006-inches should be sealed. See Standard Repair Procedure #14.





TS #SS3: TROUBLE SHOOTING FOR HONEYCOMBING, VOIDS, POUR LINES, AND MINOR SURFACE IMPERFECTIONS IN NON-PRESTRESSED PRECAST ELEMENTS

Description: Missing volume of cement paste from around aggregate or voids containing neither paste nor aggregate. A pour line is a discoloration of the surface concrete between adjacent concrete placements. It is not a cold joint, where the earlier concrete has set prior to placement of the latter concrete.

The following elements are covered under this Trouble Shooting Guide: Pier Elements (columns, caps), Abutment and Wall Elements (stems, caps), Foundation elements (footings), or other similar non-prestressed precast elements.

CAUSE

A. Production
1. Inadequate vibration
2. Improper placement of concrete
3. Shifted/misplaced rebar cage

PREVENTION

A. Improve Production Methods
1. Provide thorough internal vibration and, where warranted, external vibration.
2. Start placement away from bulkheads and use vibration to cause the concrete to flow toward bulkheads.
3. Verify that reinforcing is secured in the forms and located correctly.

CAUSE

B. Concrete Mix Design
1. Inadequate mixing
2. Mix too stiff
3. Early set in plasticized concrete
4. Delayed placement of concrete
5. Flash set of concrete in forms
6. Excessive aggregate size, gap grading, or detrimental shape

PREVENTION

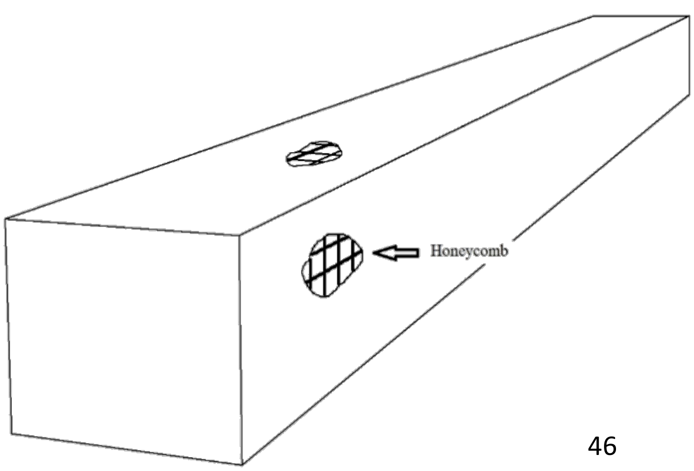
B. Adjust Mix Design
1. Mix concrete thoroughly
2. Adjust mix or additive dosage rates: (add plasticizers, reduce aggregate size, adjust self-consolidating additive dose, etc.).
3. Improve delivery time of the concrete
4. Improve delivery time of the concrete
5. Cool forms prior to concrete placement
6. Consider using smaller and/or different type of aggregate.

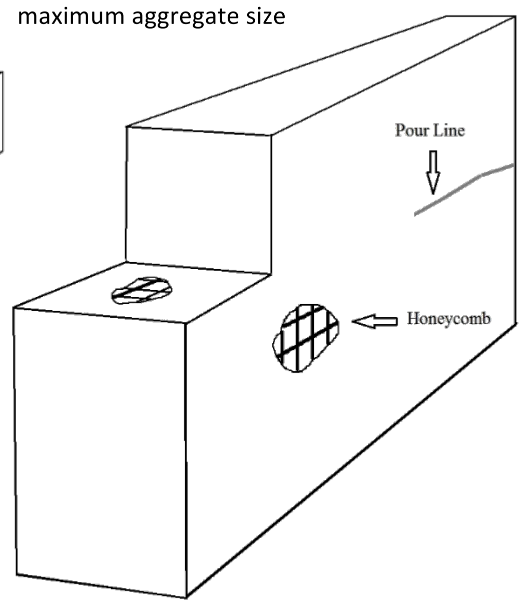
CAUSE

C. Design Details
1. Congested reinforcing.

PREVENTION

C. Improve Details
1. Reduce reinforcement congestion to the extent possible
   Provide clear spacing between reinforcement larger than 1 ½ times the maximum aggregate size





TS #SS3: TROUBLE SHOOTING FOR HONEYCOMBING, VOIDS, POUR LINES, AND MINOR SURFACE IMPERFECTIONS IN NON-PRESTRESSED PRECAST ELEMENTS

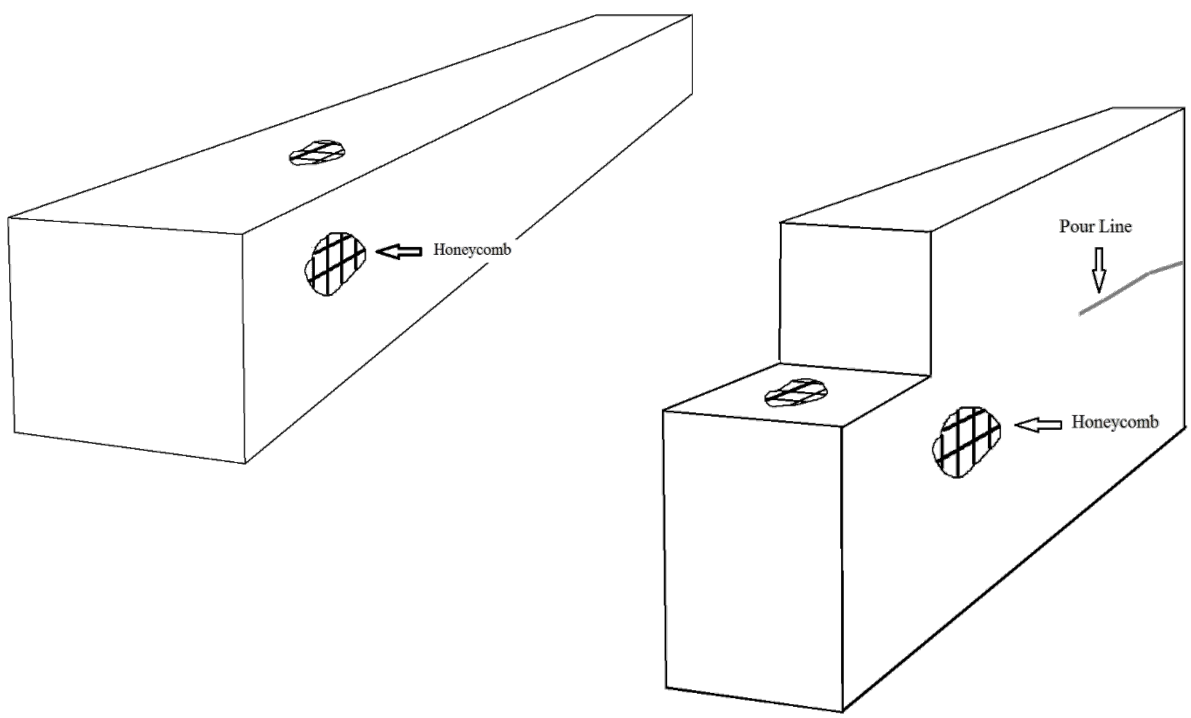
Description – Missing volume of cement paste from around aggregate or voids containing neither paste nor aggregate. A pour line is a discoloration of the surface concrete between adjacent concrete placements. It is not a cold joint, where the earlier concrete has set prior to placement of the latter concrete.

ENGINEERING EFFECTS

1. Honeycombing and voids can affect shear, bending and axial capacity and must be repaired.
2. Where the area is to be encased in a cast-in-place concrete or a grouted joint, the honeycombing will not affect durability. Removal of loose aggregate and concrete prior to the pour will be a sufficient repair in most cases.

REPAIR CONSIDERATIONS

1. Where the area is to be exposed in the final condition, consider matching the color of the patch with the element.
2. If aesthetics are not a consideration, the repair of a pour line is not necessary, otherwise the surface finish should repaired by rubbing, bagging, or dressed (similar to exposed cast-in-place concrete).
3. For other conditions, repair using Standard Repair Procedures #5 or #9, as appropriate.



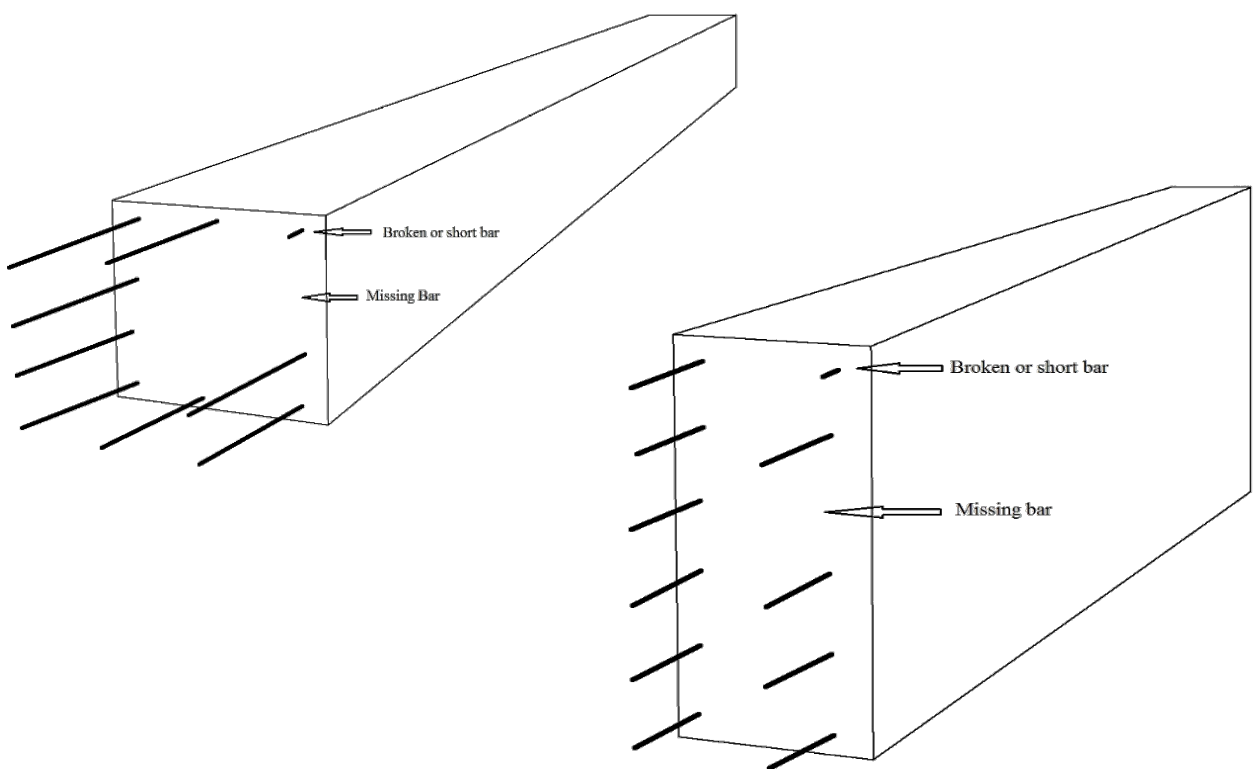
TS #SS4: TROUBLE SHOOTING SHORT PROJECTED REBAR AND MISSING PROJECTED REBAR IN NON-PRESTRESSED PRECAST ELEMENTS

Description

This consists a lack of, or short projecting reinforcing.

The following elements are covered under this Trouble Shooting Guide: Pier Elements (columns, caps), Abutment and Wall Elements (stems, caps), Foundation elements (footings), or other similar non-prestressed precast elements.

CAUSE	PREVENTION
A. Formwork	A. Improve Production Methods
1. Bulkhead shift	1. Check bulkhead locations and integrity
B. Reinforcement Production	B. Improve Production Methods
1. Improper placement	1. Re-check rebar locations prior to concrete placement
2. Improper cutting	2. Re-check rebar lengths before cutting
3. Improper bending	3. Follow CRSI requirements for minimum bending radius
4. Incorrect fabrication drawing or design drawing	4. Re-check fabrication and design drawings
5. Shifting during casting	5. Place additional ties on reinforcement
6. Improper handling	6. Review shop handling practices



TS #SS4: TROUBLE SHOOTING SHORT PROJECTED REBAR AND MISSING PROJECTED REBAR IN NON-PRESTRESSED PRECAST ELEMENTS

Description – This consists a lack of, or short projecting reinforcing.

ENGINEERING EFFECTS

Repairs shall not be made without the designer's approval; the following are general guidelines:

1. Missing projecting reinforcement can materially affect the design of the adjacent connection. If calculations verify no significant reduction in capacity, a repair may not be necessary. If the bar is missing within the element, an engineering assessment of the element is in order. If the bar is required for the design, then rejection of the element is in order.
2. For bars that are to be inserted into grouted sleeves, special care should be taken to ensure that the repaired bar will properly align with the coupler.

REPAIR CONSIDERATIONS

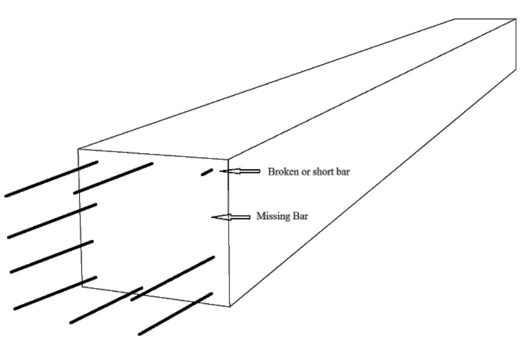
See Below:

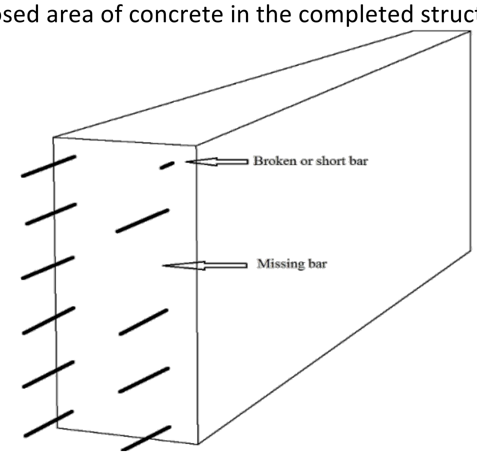
Missing External Projected Rebar with Corresponding Internal Bar Present

1. Drill and Grout New External Bar
    - Each missing external projecting rebar shall be replaced by an equivalent sized Grade 60 rebar. A new bar can be installed by drilling and grouting a new bar using Repair Procedure #12. The embedment shall be sufficient to develop a full lap splice with the internal reinforcing where tension transfer is required.
    - The minimum embedment for other situations shall be based on the chemical adhesive manufacturer's recommendations. See Standard Repair Procedure #12
    - Note that this repair procedure may not be acceptable if the projecting bar is to be spliced with a mechanical coupler in the adjacent element due to potential alignment issues.

Short Projecting Rebar

1. Use a mechanical coupler that is approved by the Owner. Partial removal of the concrete surrounding the bar may be required in order to attach the coupler. Use a coupler that can develop at least 125% of the minimum specified yield strength of the bar. For seismic connections, the coupler may need to develop 100% of the minimum specified tensile strength of the bar.
2. Install bar extension using coupler manufacturer's recommendations. See Standard Repair Procedure #11.
3. If partial removal of concrete is required, two options can be followed:
    - If the removed concrete area is within a closure pour or grouted joint in the completed structure, no repair of the removed concrete is required.
    - If the removed concrete is within the exposed area of concrete in the completed structure, repair the area using Repair Procedure #6.





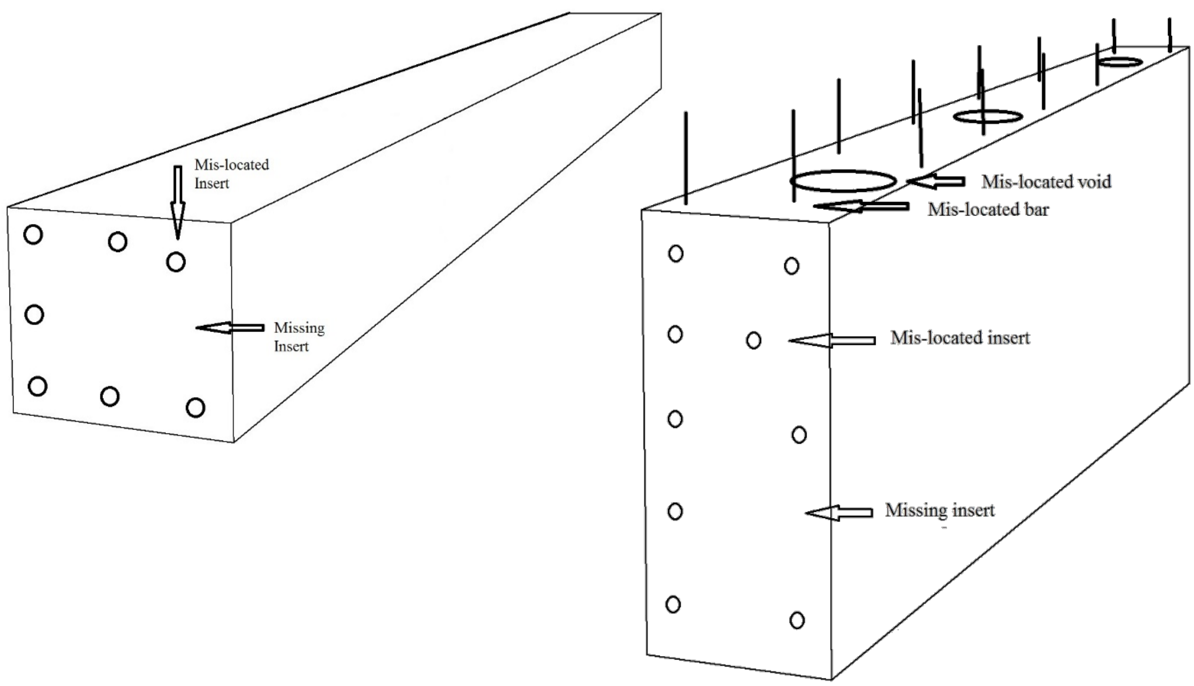
TS #SS5: TROUBLE SHOOTING MISSING OR MIS-LOCATED INSERTS, VOIDS, OR MIS-LOCATED PROJECTING REBAR IN NON-PRESTRESSED PRECAST ELEMENTS

Description

This type of defect consists of missing or mis-located voids and hardware, and mis-located rebar.

The following elements are covered under this Trouble Shooting Guide: Pier Elements (columns, caps), Abutment and Wall Elements (stems, caps), Foundation elements (footings), or other similar non-prestressed precast elements.

CAUSE	PREVENTION
A. Production Oversight	A. Improve Production Methods
1. Bulkhead or template shift	1. Check bulkhead locations and integrity
B. Reinforcement Production	B. Improve Production Methods
1. Improper placement	1. Re-check rebar and void locations prior to concrete placement
2. Incorrect fabrication drawing or design drawing	2. Re-check fabrication and design drawings
3. Shifting during casting	3. Place additional ties on reinforcement



TS #SS5: TROUBLE SHOOTING MISSING OR MIS-LOCATED INSERTS, VOIDS, OR MIS-LOCATED PROJECTING REBAR IN NON-PRESTRESSED PRECAST ELEMENTS

Description — This type of defect consists of missing or mis-located voids and hardware, and mis-located rebar.

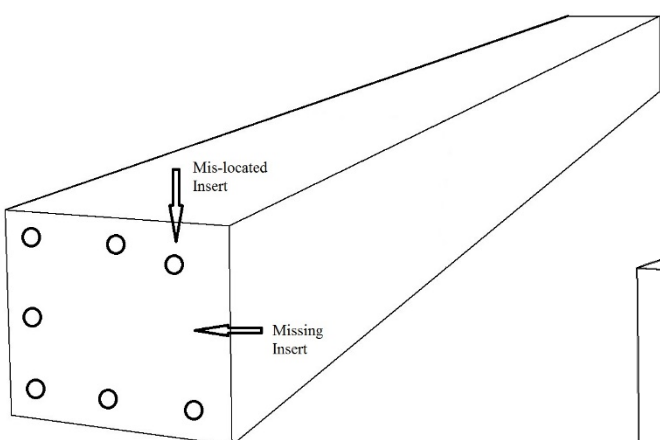
ENGINEERING EFFECTS

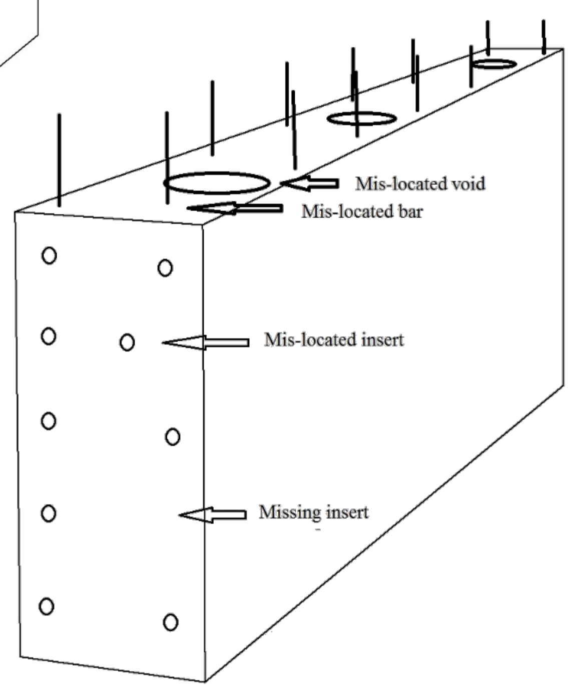
1. Repairs shall not be made without the designer's approval; the following are general guidelines:
2. Mis-located reinforcement or inserts may lead to improper fit-up. Loss of the bar connection can materially affect the design of the adjacent connection. If calculations verify that there is no significant reduction in capacity of the connection, a repair may not be necessary.
3. If the adjacent element has not yet been cast, as-built dimensions may be applied to the shop drawings for the subsequent element provided that the variation does not affect the required structural capacity of the connection.

   The minimum embedment for other situations shall be based on the chemical adhesive manufacturer's recommendations. See Standard Repair Procedure #12

REPAIR CONSIDERATIONS

1. If mis-located inserts and bars cannot be eliminated as stated in Item 1 to the left, consider drilling and grouting a new bar in the correct location, using Standard Repair Procedure #12. The new projecting rebar shall be an equivalent sized Grade 60 rebar. The embedment shall be sufficient to develop a full lap splice with the internal reinforcing where tension transfer is required. If the mis-located rebar location results in insufficient concrete cover, alternate corrosion protection strategies should be considered such as sealers or installation of passive cathodic devices.





Section 2.3: Precast Full Depth Deck Panels

There are several different types of details used for precast full-depth deck panels. Common details include:

1. Full depth shear connector pockets
2. Partial depth (hidden) shear connector pockets
3. Projecting reinforcing used for connections
4. Panels with post-tensioned connections

The graphics contained herein show several different types of details depending on the applicable troubleshooting guideline.

In general, the non-conformances noted in this section are applicable to panels that are precast or prestressed. Non-conformances that are only applicable to prestressed panels are so noted.

TS #FDDP1: Corner Spalls

TS #FDDP2: Cracks

TS #FDDP3: Transverse Cracks

TS #FDDP4: Honeycombing, Voids, and Minor Surface Imperfections

TS #FDDP5: Short Projected Reinforcing and Missing Projected Reinforcing

TS#FDDP6: Missing or Mislocated Inserts, Voids, Ducts or Mislocated Projecting Reinforcing

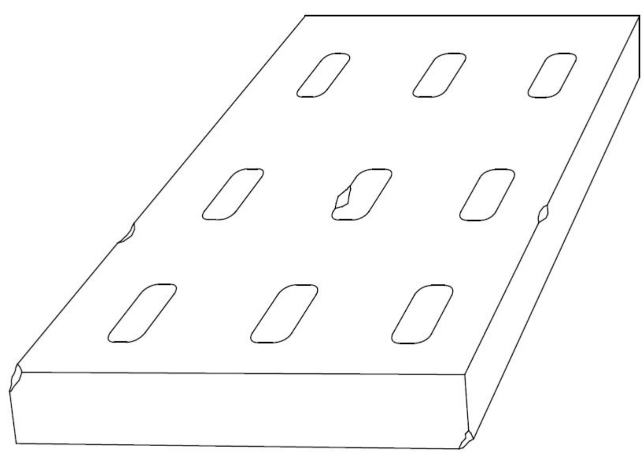
TS #FDDP1: TROUBLE SHOOTING CORNER SPALLS IN PRECAST FULL-DEPTH DECK PANELS

Description These spalls and cracks may be found at any edge or corner of the element

Note: This troubleshooting guide is applicable to both precast and prestressed full-depth deck panels

CAUSE	PREVENTION
A. Design	A. Verify Design
1. Inadequate edge reinforcement	1. Provide proper reinforcement as close to edges as clearance requirements allow
B. Improper Handling	B. Care in Handling
1. Impacting edges	1. Ensure adequate room for transport of elements
2. Uneven dunnage	2. Provide uniform dunnage. Non-rigid materials such as timber or elastomeric pads are recommended
C. Production	C. Improve Production Methods
1. Binding in forms during stripping	1. Keep forms clean and well oiled
2. Indentation in forms	2. Keep forms in good condition (repair dents, remove projections, and make seams mortar tight)
3. Inserts hanging up in forms	3. Ensure inserts are free during stripping
4. Thermal expansion of forms prior to concrete setting	4. Ensure initial concrete set prior to start of curing
5. Bleeding of concrete under header	5. Provide mortar-tight header

Note: One type of deck panel shown, others similar



TS #FDDP1: TROUBLE SHOOTING CORNER SPALLS IN PRECAST FULL-DEPTH DECK PANELS

Description These spalls and cracks may be found at any edge or corner of the element

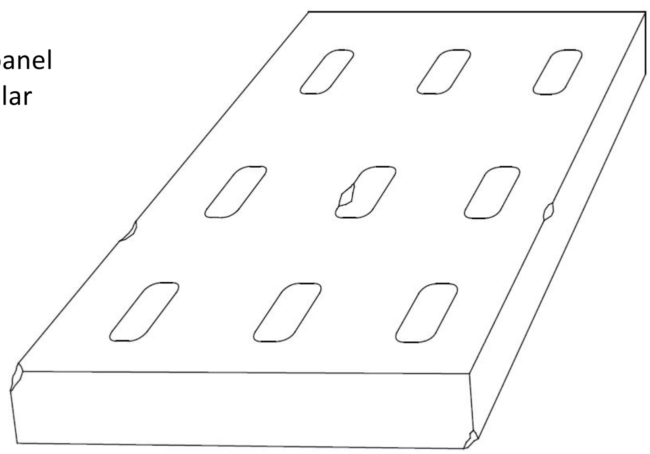
ENGINEERING EFFECTS

1. Spalls in areas of full-depth deck panels that are exposed to the environment in the finished bridge should be repaired.
2. Minor spalls that do not compromise protection of reinforcing from water, salt spray, excessive humidity, or are not exposed to direct view need not be repaired. For example: spalls incorporated into concrete closure pours or grouted joints.

REPAIR CONSIDERATIONS

1. Cracks located near corners have the potential to become a spall and should be repaired after removal of cracked concrete.
2. Where corner spalls are deemed in need of repair, the repairs should be made in accordance with Standard Repair Procedure #15.

Note: One type of deck panel shown, others similar

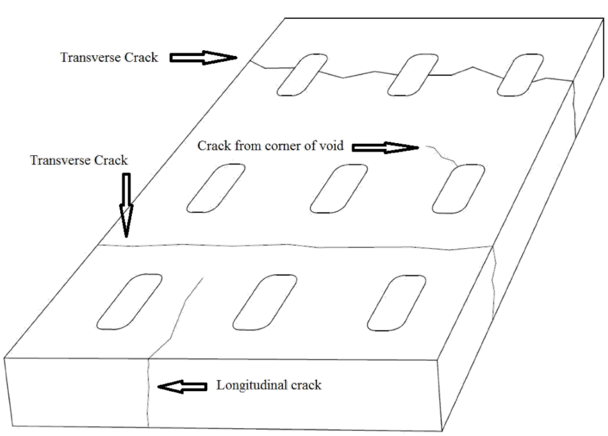


TS #FDDP2: TROUBLE SHOOTING FOR CRACKS IN FULL-DEPTH PRECAST DECK PANELS

Description These cracks are typically perpendicular to the axis of the element and extend partially or entirely across the member, often visible on multiple faces. Other cracks shown below also apply.

Note: This troubleshooting guide is applicable to precast panels designed with mild reinforcing or panels with minor amounts of prestressing for handling. Panels designed with prestressing for strength should be treated similar to a prestressed beam.

CAUSE	PREVENTION
A. <u>Design</u> 1. Inadequate temperature and shrinkage reinforcement	A. <u>Verify Design</u> 1. Verify that there is adequate temperature and shrinkage reinforcement and that the reinforcement is properly distributed within the element
B. <u>Shrinkage</u> 1. Shrinkage of concrete during curing causes friction forces between the element and the form, leading to the build-up of stresses in the element	A. <u>Review or modify the mix or modify curing methods to reduce shrinkage</u> 1. Consider change to alternate mix (see note 2) 2. Apply curing covers rapidly
B. <u>Production/Formwork</u> 1. Thermal expansion of the form causing friction forces between the element and the form, leading to a build-up of stresses in the element 2. Concrete binding to forms 3. Indentations or joint offsets in forms 4. Inserts in forms anchored or restrained by forms	A. <u>Improve Production methods</u> 1. Prevent rapid cool-down of the element 2. Keep forms in good condition; fabricate forms with even smooth joints 3. Keep forms clean and properly oiled 4. Release restraint of all inserts after initial set
C. <u>Handling Stresses</u> 1. High stresses due to inadequate number of pick points or pick point locations 2. Removal from form prior to reaching sufficient stripping strength 3. Element binding in forms or high suction forces during removal from form 4. Uneven dunnage	B. <u>Improve Handling Methods</u> 1. Check lifting and handling stresses according to the PCI Design Manual 2. Verify concrete strength prior to stripping. 3. Adjust calculations for stripping. May lead to higher stripping strength requirement 4. Check elevation and seating of dunnage. If supported by more than two points, check for gaps in seating points. Avoid stacking elements on top of each other unless dunnage is supported well (concrete slab)



Notes: 1. One type of deck panel shown, others similar
2. Modifications to mix designs may not be possible in certain situations due to owner pre-qualification requirements for mixes.

TS #FDDP2: TROUBLE SHOOTING FOR CRACKS IN FULL-DEPTH PRECAST DECK PANELS

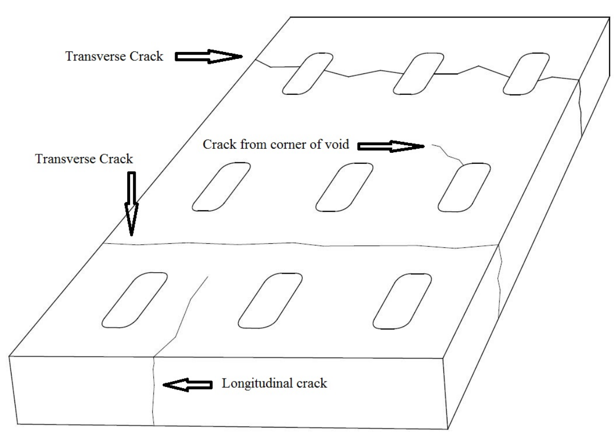
Description These cracks are typically perpendicular to the axis of the element and extend partially or entirely across the member, often visible on multiple faces.

ENGINEERING EFFECTS

1. The design and detailing of reinforcement in the element should be checked in accordance with AASHTO temperature and shrinkage provisions.
2. An assessment of the need to repair as well as environmental exposure will be required. It should be noted that AASHTO provisions are based on an assumed crack width of 0.017-in. with Class 1 Exposure and 0.013-in. for Class 2 Exposure. Class 1 Exposure applies to conditions when cracks can be tolerated due to reduced concerns of appearance and/or corrosion. Class 2 Exposure applies to an increased concern of appearance and/or corrosion.
3. ACI Committee 224 report "Control of Cracking in Concrete Structures" states that tolerable crack widths are 0.006-in. for concrete exposed to seawater spray with wetting and drying, 0.007-in. for concrete exposed to de-icing chemicals, and 0.012-in. for concrete exposed to humidity.
4. Minor cracks that are incorporated into concrete closure pours or grouted joints need not be repaired.

REPAIR CONSIDERATIONS

1. If the decision is made that repairs are warranted, the cracks should be epoxy injected in accordance with Standard Repair Procedure #10.
2. Experience has shown that cracks as narrow as 0.002-in. can be injected successfully. However, the surface of cracks narrower than 0.006-inches should be sealed. See Standard Repair Procedure #14.



Note: One type of deck panel shown, others similar

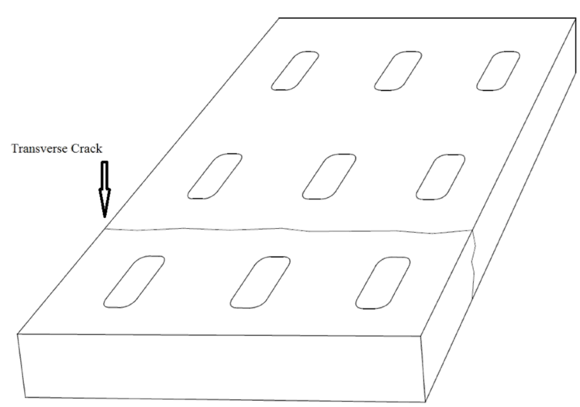
TS #FDDP3: TROUBLE SHOOTING FOR TRANSVERSE CRACKS IN PRESTRESSED FULL-DEPTH DECK PANELS

Description: These cracks are typically perpendicular to the longitudinal axis of the element and extend partially or entirely across the member, often visible on multiple faces.

Notes: This troubleshooting guide is applicable to transverse cracks in precast full-depth deck panels with **prestressing for handling** running perpendicular to the cracks. Panels with prestressing for strength should be treated similar to a prestressed beam.
For other cracks in prestressed deck panels, see TS #FDDP2.

CAUSE	PREVENTION
A. Bond of Strand/Strand Slip	A. Ensure against unintended strand slip
1. Strand Contamination	1. Inspect strand for cleanliness and absence of lubricants after stressing and prior to casting
2. Insufficient vibration of concrete	2. Use internal and external vibration in congested ends of panels
B. Shrinkage prior to detensioning	B. Improve production methods
5. Shrinkage of concrete during curing causing friction forces between the element and the form, leading to a build-up of stresses in the element	1. Apply covers rapidly after concrete pours 2. Detension as covers are removed 3. Prevent exposed strand from cooling differentially with respect to the panel 4. Adjust concrete mix by reducing cement, adding pozzolans or changing aggregate gradation 5. Provide uniform heat and humidity
C. Detensioning Procedure	C. Use proper detensioning procedure
1. Low release strength	1. Ensure proper concrete strength prior to release
2. Improper detensioning sequence/procedures	2. Keep prestressed forces balanced while detensioning, using an established procedure
D. Formwork	D. Inspect form condition prior to casting
1. Indentations or joint offsets in forms	1. Ensure smooth form alignment
2. Concrete binding to forms	2. Oil forms thoroughly
E. Incorrect prestress force	E. Apply correct prestress force
1. Inadequate prestress strand in design	1. Check design calculations and shop drawings
2. Under-estimation of prestress losses	2. Recompute losses
3. Under-tensioning of strand	3. Compare measured elongation of strand with computed elongation
4. Incorrect number of strand in bed	

Note: One type of deck panel shown, others similar



TS #FDDP3: TROUBLE SHOOTING FOR TRANSVERSE CRACKS IN PRESTRESSED FULL-DEPTH DECK PANELS

Description These cracks are typically perpendicular to the longitudinal axis of the element and extend partially or entirely across the member, often visible on multiple faces.

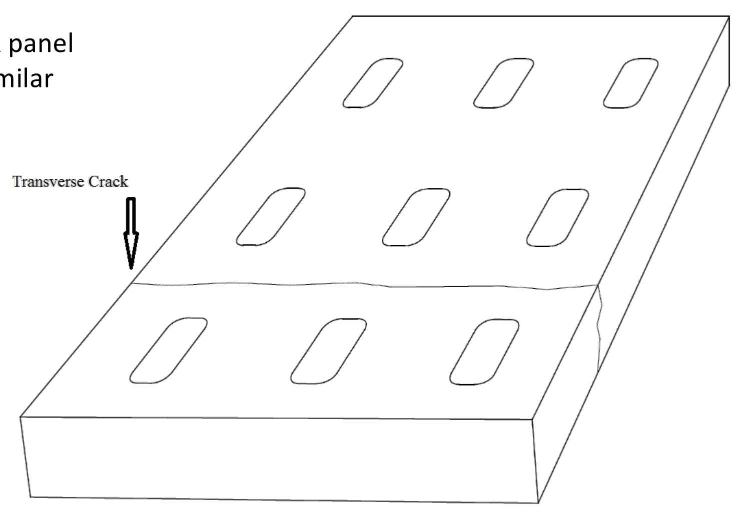
ENGINEERING EFFECTS

1. For vertical cracks that intercept bonded or debonded strand within their respective transfer lengths, it is recommended that the engineer re-compute the moment and shear capacity based on transfer initiating at the point of the crack. If the re-computed capacities are acceptable the panel can be repaired. These cracks should be injected.
2. Vertical cracks that intercept bonded or debonded strand beyond their respective transfer lengths and with a width less than 0.006-in. after detensioning, need no re-evaluation. Cracks 0.006-in. or greater in width should be evaluated to affirm adequate prestress.
3. Vertical cracks at any location on the panel that do not intercept strand need no evaluation by the engineer.

REPAIR CONSIDERATIONS

1. It is recommended that cracks not be repaired prior to detensioning as repairs will mask the cause and seriousness of the crack
2. All cracks less than 0.006-in. in width, after detensioning and deemed acceptable, should be sealed. See Standard Repair Procedure #14. If these cracks are within the transfer zone, an epoxy injection repair should be considered (see Item 3 below).
3. All cracks 0.006-in. or greater in width, after detensioning and deemed acceptable, should be repaired by epoxy injection in accordance with Standard Repair Procedure #10.

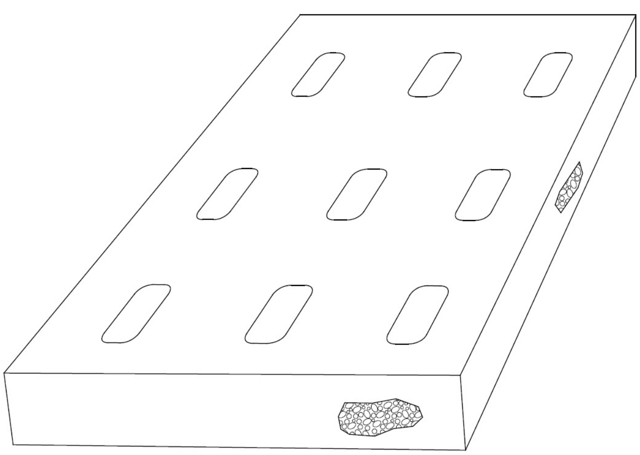
Note: One type of deck panel shown, others similar



TS #FDDP4: TROUBLE SHOOTING FOR HONEYCOMBING, VOIDS, AND MINOR SURFACE IMPERFECTIONS IN PRECAST FULL-DEPTH DECK PANELS

Description Missing volume of cement paste from around aggregate or voids containing neither paste nor aggregate.

CAUSE	PREVENTION
A. <u>Design Details</u>	A. <u>Improve Details</u>
6. Congested reinforcing	1. Reduce reinforcement congestion to the extent possible Provide clear spacing between reinforcement larger than 1 ½ times the maximum aggregate size
B. <u>Production</u>	B. <u>Improve Production Methods</u>
1. Inadequate vibration	1. Provide thorough internal vibration and, where warranted, external vibration
2. Improper placement of concrete	2. Start placement away from bulkheads and use vibration to cause the concrete to flow toward bulkheads
3. Shifted/misplaced reinforcing	3. Verify that reinforcing is secured in the forms and located correctly
C. <u>Concrete Mix Design</u>	C. <u>Adjust Mix</u>
1. Inadequate mixing	1. Mix concrete thoroughly
2. Mix too stiff	2. Adjust mix or additive dosage rates: (add plasticizers, reduce aggregate size, adjust self-consolidating additive dose, etc.)
3. Early set in plasticized concrete	3. Improve delivery time of the concretel forms prior to concrete placement
4. Delayed placement of concrete	4. Consider using smaller and/or different type of aggregate
5. Flash set of concrete in forms	
6. Excessive aggregate size, gap grading, or detrimental shape	



TS #FDDP4: TROUBLE SHOOTING FOR HONEYCOMBING, VOIDS, AND MINOR SURFACE IMPERFECTIONS IN PRECAST FULL-DEPTH DECK PANELS

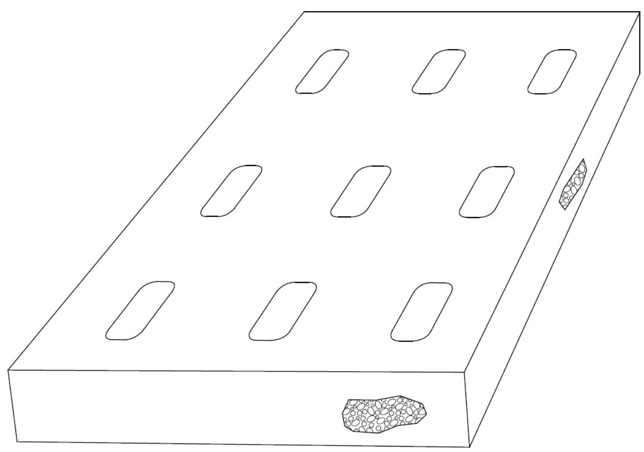
Description Missing volume of cement paste from around aggregate or voids containing neither paste nor aggregate.

ENGINEERING EFFECTS

1. Where the area is to be encased in a cast-in-place concrete or a grouted joint, the honeycombing will not affect durability. Removal of loose aggregate and concrete prior to the pour will be a sufficient repair in most cases.

REPAIR CONSIDERATIONS

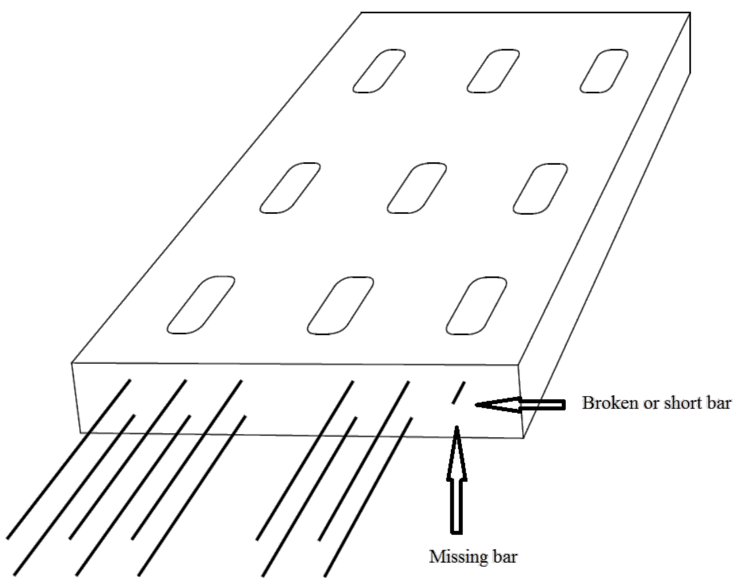
1. For other conditions, repair using Standard Repair Procedures #5 or #9, as appropriate.



TS #FDDP5: TROUBLE SHOOTING SHORT PROJECTED REINFORCING AND MISSING PROJECTED REINFORCING IN PRECAST FULL-DEPTH DECK PANELS

Description This consists of a lack of or short projecting reinforcing.

CAUSE	PREVENTION
A. Formwork	A. Improve Production Methods
1. Bulkhead shift	1. Check bulkhead locations and integrity
	2. Review quality control procedures for pre-pour and adjust as needed
B. Reinforcement Production	B. Improve Production Methods
1. Improper placement	1. Re-check reinforcing locations prior to concrete placement
2. Improper cutting	2. Re-check reinforcing lengths before cutting
3. Improper bending	3. Follow CRSI requirements for minimum bending radius
4. Incorrect fabrication drawing or design drawing	4. Re-check fabrication and design drawings
5. Shifting during casting	5. Place additional ties on reinforcement
6. Improper handling	6. Review quality control procedures for pre-pour and adjust as needed
	7. Review shop handling practices



TS #FDDP5: TROUBLE SHOOTING SHORT PROJECTED REINFORCING AND MISSING PROJECTED REINFORCING IN PRECAST FULL-DEPTH DECK PANELS

Description – This consists of a lack of, or short projecting reinforcing.

ENGINEERING EFFECTS

Repairs shall not be made without the designer's approval; the following are general guidelines:

1. Missing projecting reinforcement can materially affect the design of the adjacent connection. If calculations verify no significant reduction in capacity, a repair may not be necessary. If the bar is missing within the element, an engineering assessment of the element is in order. If the bar is required for the design, then rejection of the element is in order.

REPAIR CONSIDERATIONS

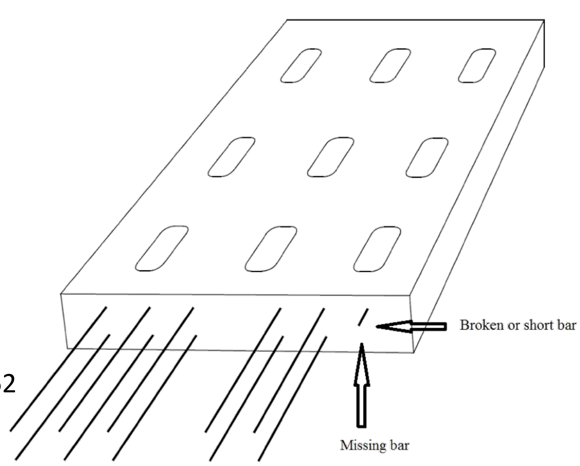
See Below:

Missing External Projected Reinforcing with Corresponding Internal Bar Present

1. Drill and Grout New External Bar
   - Each missing external projecting reinforcing shall be replaced by a bar of equivalent size and grade. A new bar can be installed by drilling and grouting a new bar using Standard Repair Procedure #12. The embedment shall be sufficient to develop a full lap splice with the internal reinforcing where tension transfer is required.
   - The minimum embedment for other situations shall be based on the chemical adhesive manufacturer's recommendations. See Standard Repair Procedure #12
   - Note that this repair procedure may not be acceptable if the projecting bar is to be spliced with a mechanical coupler in the adjacent element due to potential alignment issues.

Short Projecting Reinforcing

1. Use a mechanical coupler that is approved by the Owner. Partial removal of the concrete surrounding the bar may be required in order to attach the coupler. Use a coupler that can develop at least 125% of the minimum specified yield strength of the bar. For seismic connections, the coupler may need to develop 100% of the minimum specified tensile strength of the bar.
2. Install bar extension using coupler manufacturer's recommendations. See Standard Repair Procedure #11.
3. If partial removal of concrete is required, two options can be followed:
   - If the removed concrete area is within a closure pour or grouted joint in the completed structure, no repair of the removed concrete is required.
   - If the removed concrete is within the exposed area of concrete in the completed structure, repair the area using Standard Repair Procedure #6.



TS #FDDP6: TROUBLE SHOOTING MISSING OR MISLOCATED INSERTS, VOIDS, DUCTS OR MISLOCATED PROJECTING REINFORCING IN PRECAST FULL-DEPTH DECK PANELS

Description This type of defect consists of missing or mis-located voids, ducts, hardware, and mis-located reinforcing.

CAUSE

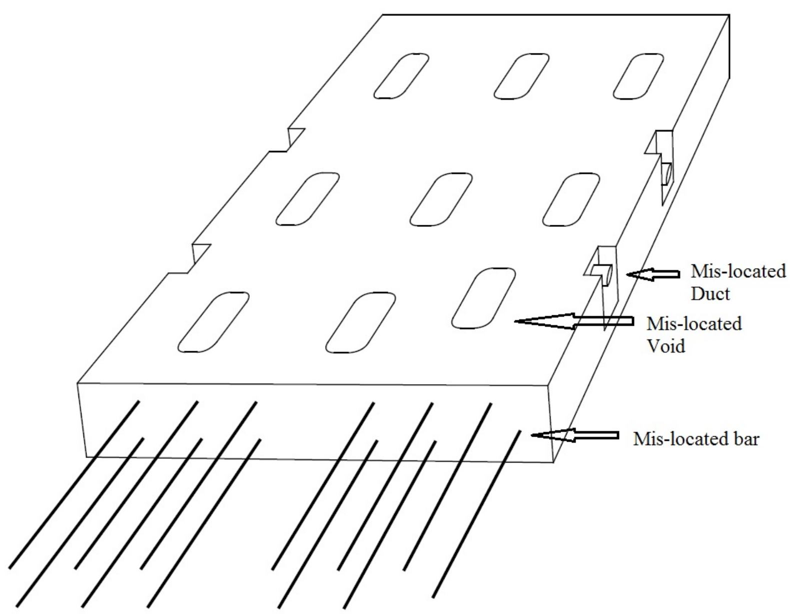
A. <u>Production Oversight</u>
1. Bulkhead or template shift

B. <u>Reinforcing Production</u>
1. Improper placement
2. Incorrect fabrication drawing or design drawing
3. Shifting during casting

PREVENTION

A. <u>Improve Production Methods</u>
1. Check bulkhead locations and integrity
2. Review quality control procedures for pre-pour and adjust as needed

B. <u>Improve Production Methods</u>
1. Re-check reinforcing and void locations prior to concrete placement
2. Re-check fabrication and design drawings
3. Place additional ties on reinforcement



TS #FDDP6: TROUBLE SHOOTING MISSING OR MISLOCATED INSERTS, VOIDS, DUCTS OR MISLOCATED PROJECTING REINFORCING IN PRECAST FULL-DEPTH DECK PANELS

Description — This type of defect consists of missing or mis-located voids, ducts, hardware, and mis-located reinforcing.

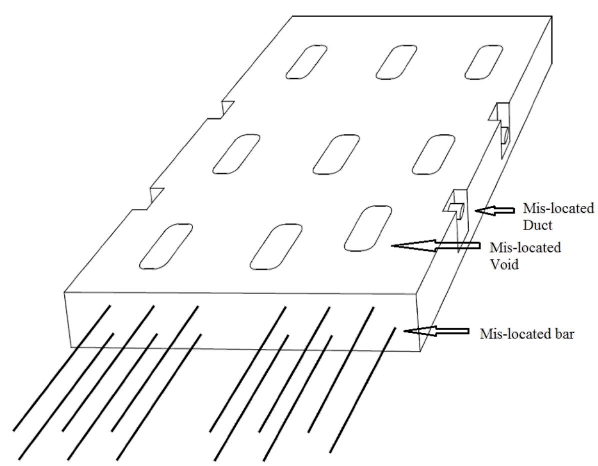
ENGINEERING EFFECTS

Repairs shall not be made without the designer's approval; the following are general guidelines:

1. Mislocated reinforcement or inserts may lead to improper fit-up. Loss of the bar connection can materially affect the design of the adjacent connection. If calculations verify that there is no significant reduction in capacity of the connection, a repair may not be necessary.
2. If the mislocated reinforcing location results in insufficient concrete cover, alternate corrosion protection strategies should be considered such as sealers or installation of passive cathodic devices.
3. The contractor can attempt to determine if a mislocated shear connector void is able to accommodate the required number of shear connectors. If it is feasible to install the connectors within the misaligned void, it may be possible to use the panel.
4. If a post-tensioning duct is slightly misaligned (beyond the specified tolerances), the Contractor can attempt to determine if the misaligned duct can be properly connected and sealed with the duct in the adjacent panel. The Contractor shall also determine if the tendons can be installed in the misaligned duct. If the misaligned duct cannot be used, the panel should be rejected and a new panel cast. If it is determined that the misalignment is acceptable, the Contractor will be responsible for any problems that arise during installation. If the misalignment of the duct results in an eccentricity of the tendon, a review by the Engineer is required.

REPAIR CONSIDERATIONS

1. If mislocated inserts and bars cannot be eliminated as stated in Item 1 to the left, consider drilling and grouting a new bar in the correct location, using Standard Repair Procedure #12. The new projecting reinforcing shall be an equivalent size and grade of reinforcing. The embedment shall be sufficient to develop a full lap splice with the internal reinforcing where tension transfer is required.
2. The minimum embedment for other situations shall be based on the chemical adhesive manufacturer's recommendations. See Standard Repair Procedure #12

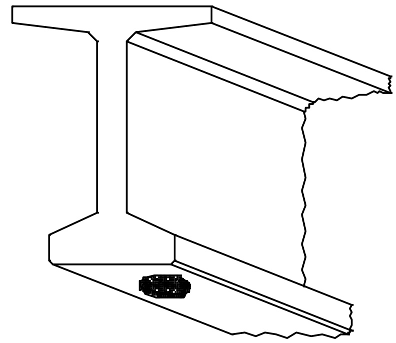


Section 3: Standard Repair Procedures

1. Confined Spalls Inside Bearing Areas
2. Confined Spalls Outside Bearing Areas
3. Non-Confined Bearing Area Spalls
4. Spalls and Voids in the Bottom Flange That Expose Prestressing Strand
5. Honeycombed or Voided Web Areas
6. Damaged Flanges Requiring Removal and Replacement of Concrete
7. Taking Cores and Patching Cored Holes in Girders
8. Misshapen Bearing Recesses
9. Honeycombed Areas Left-in-Place
10. Epoxy Injection of Cracks
11. Short Projecting Mild Reinforcing Bars or Projecting Prestressing Strands
12. Replacement of Missing Projected Mild Steel or Prestressing Strand
13. Missing or Incorrectly Located Diaphragm Inserts
14. Sealing Cracks
15. Edge Spalls in Precast Elements

A suggested reference for guidance on repair methods is the PCI Document entitled *Manual for the Evaluation and Repair of Precast, Prestressed Concrete Bridge Products* [6]. This document contains similar information as this document, however also contains a chapter on Methods of Patching.

STANDARD REPAIR PROCEDURE #1 FOR CONFINED SPALLS INSIDE BEARING AREAS



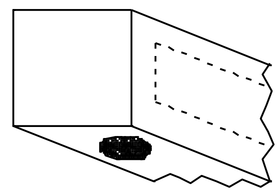
CASE 1: NO STRANDS EXPOSED

A. Remove all loose concrete, taking care to not damage reinforcing or strand.

B. Square all sides of the depression. Take care to not damage any mild reinforcement.

C. Clean the excavated area and reinforcing with a stiff wire brush, blowing away dust, with high pressure air.

D. Repair Option 1 – Fill the voided area using approved polymer modified cementitious, shrinkage-compensated patching material, with a compressive strength equal to or greater than the specified design strength of the beam. Prepackaged patching material is preferred to control quality. Cure properly.



E. Repair Option 2 – Coat surface to be adhered to with an approved bonding agent, following the manufacturer's instructions. Fill the voided area with a high strength, cement based, shrinkage-compensated mortar, following the manufacturer's instructions. Cure properly.

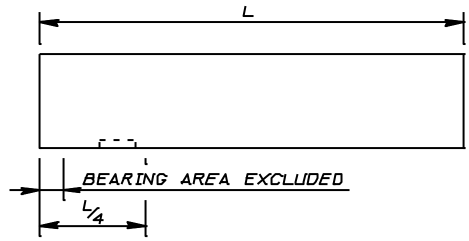
F. Use care to ensure that the repaired area does not project below the bottom of the flange near the bearing area.

NOTE: With the prior approval of the owner/engineer, spalls that involve no more than 20% of the bearing area may be patched, in the presence of the owner's inspector without submitting the repair for formal approval. Repairs of spalls in excess of 20% of the bearing area will require submission of a repair plan to the owner/engineer for approval.

CASE 2: STRANDS EXPOSED

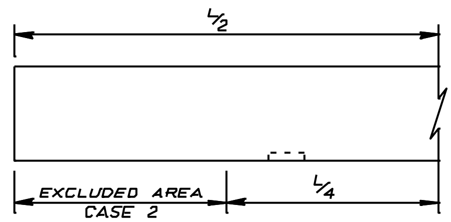
The full extent of strand exposure shall be determined and a repair plan submitted for approval by the owner/engineer, regardless of the size of the spall, as the design capacity may be affected. Generally, if the design capacity is judged to have not been diminished, or diminished an acceptable amount, the repair procedures for Case 1 will remain applicable.

STANDARD REPAIR PROCEDURE #2 FOR CONFINED SPALLLS OUTSIDE BEARING AREAS



CASE 1: No strands exposed; spall located between the end of the beam and the ¼ point.

A. With the prior approval of the owner/engineer, individual spalls or collective multiple spalls not exceeding 10% of the bottom flange plan area, within the defined limits, may be repaired in the presence of the inspector utilizing either repair option specified in Standard Repair Procedure #1.
B. If an individual spall or collective multiple spalls exceed 10% of the bottom flange plan area, a repair plan must be submitted to the owner/engineer for approval.



CASE 2: No Strands Exposed: Spall located between the ¼ point and ½ point of the beam.

A. With the prior approval of the owner/engineer, individual spalls or collective multiple spalls not exceeding 10% of the bottom flange plan area, within the defined limits, may be repaired in the presence of the inspector. The repair options described in Standard Repair Procedure #1 may be used, however an approved shrinkage compensating patch material, with a compressive strength meeting the design strength of the beam, must be used.

CASE 3: Strands Exposed

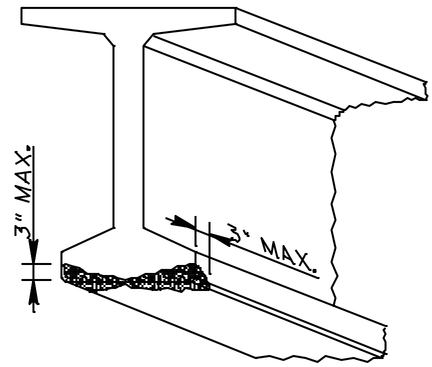
A. Spalls located anywhere on the bottom of the beam flange that exposes strands requires submission of a repair plan for approval by the owner/engineer. The full extent of strand exposure should be identified. Generally, if the design capacity is judged to have not been diminished or diminished an acceptable amount, the repair procedures for Cases 1 & 2, as applicable, may be used.

Note: In cases where the patch is located over vehicular traffic or pedestrian walkways, the patching material must be mechanically anchored either by encapsulating existing reinforcement, be anchored by supplemental reinforcement, or by other anchoring devices.

STANDARD REPAIR PROCEDURE #3 FOR NON-CONFINED BEARING AREA SPALLS

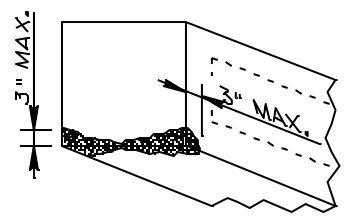
A. Remove all loose concrete.

B. Square interface with existing concrete to be in contact with the patch, to the extent practical. Take care to not damage any mild reinforcement or prestressing strands.



C. Clean the excavated area, blowing away dust.

D. Repair Option 1 – Fill the spall area with approved polymer modified cementitious, shrinkage-compensated patching material, with a compressive strength equal to or greater than the specified design strength of the beam. Pre-packaged patching material is preferred to control quality.

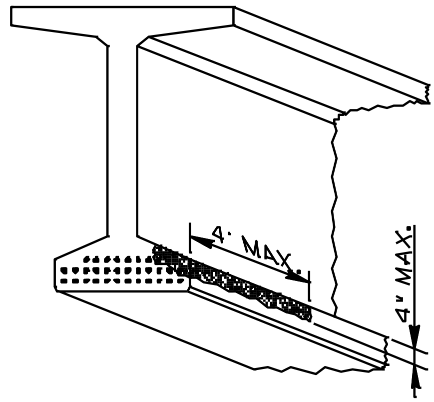


E. Repair Option 2 – Coat surface to be adhered to with an approved bonding agent, following the manufacturer's instructions. Fill the spall area with a high strength, cement based, shrinkage-compensated mortar, following the manufacturer's instructions.

F. In cases where the patch is located over vehicular traffic or pedestrian walkways, the patching material must be mechanically anchored either by encapsulating existing reinforcement, be anchored by supplemental reinforcement, or by other anchoring devices.

NOTE: With the prior approval of the owner/engineer, spalls in the end regions of the beam, within the bounds stated herein, may be patched, in the presence of the owner's inspector without submitting the repair for formal approval. Repairs of spalls larger than shown herein will require submission of a repair plan to the owner/engineer for approval.

STANDARD REPAIR PROCEDURE #4 FOR SPALLS AND VOIDS IN THE BOTTOM FLANGE THAT EXPOSE PRESTRESSING STRAND



Repairs at beam ends should be made after detensioning because any repairs made prior to detensioning will most likely fail due to high transfer stresses.

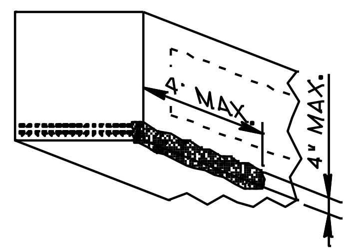
Repairs away from beam ends should be made prior to detensioning so that precompression stresses are induced in the patch material.

A. Remove all loose concrete.

B. Square interfaces with existing concrete to be in contact with the patch.

C. Clean the excavated area, blowing away dust.

   Repair Option 1 – Fill the voided area with approved polymer modified cementitious, shrinkage-compensated patching material, with a compressive strength equal to or greater than the specified design strength of the beam. Prepackaged patching material is preferred to control quality.



D. Repair Option 2 – Coat surface to be adhered to with an approved bonding agent, following the manufacturer's instructions. Fill the voided area with a high strength, cement based, shrinkage-compensated mortar, following the manufacturer's instructions.

E. Detensioning should not occur until the patch reaches the specified compressive release strength.

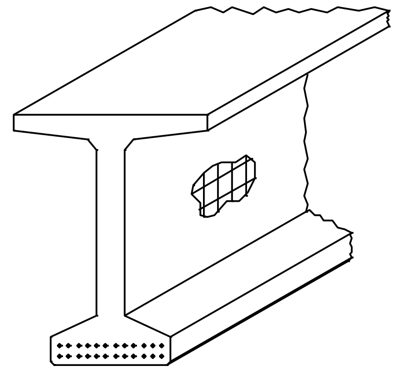
F. For larger spalls of a similar nature and/or involving more strands, the same repair techniques may be employed but must be submitted to the owner/engineer for evaluation and approval.

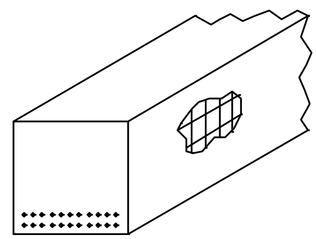
G. For areas with extreme exposure, silane or other sealants may also be applied over the patch area.

NOTES:

1. In cases where the patch is located over vehicular traffic or pedestrian walkways, the patching material must be mechanically anchored either by encapsulating existing reinforcement, be anchored by supplemental reinforcement, or by other anchoring devices.
2. This repair applies only to those voids which do not exceed 4 inches in depth, 4 feet in length and expose no more than 2 strands, and when no more than one spall or void appears in a given section of the girder. A section is defined as ¼ the length of the girder. No two such spalls or voids shall have their closest dimensions nearer than two beam depths apart. With the prior approval of the owner/engineer, this repair may be made, in the presence of the owner's inspector without submitting the repair for formal approval.

STANDARD REPAIR PROCEDURE #5 FOR HONEYCOMBED OR VOIDED WEB AREAS





CASE 1: No strand exposed, but reinforcing exposed

A. Remove all loose concrete with a maximum 15 pound pneumatic chipping hammer.

B. Square all sides of the depression <u>except the top</u> of the void. Bevel the surface as shown in the detail on this sheet.

C. Clean the excavated area, blowing away dust.

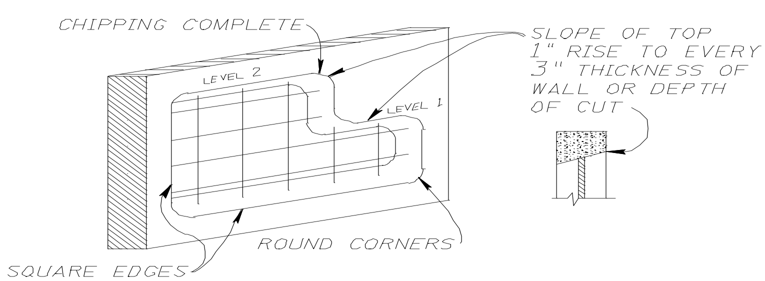
D. Repair Option 1 – Fill the voided area with an approved modified cementitious shrinkage compensated patching material with a compressive strength equal to or greater than the specified design strength of the beam. Prepackaged patching material is preferred to control quality.

E. Repair Option 2 – Coat surface to be adhered with an approved bonding agent, following the manufacturer's instructions. Fill the voided area with a high strength, cement based, shrinkage-compensated mortar, following the manufacturer's instructions.

NOTE: With the prior approval of the owner/engineer, individual areas with a width, measured vertically not greater than 20% of the web depth and a length, measured horizontally not greater than ½ the web depth may be repaired, in the presence of the owner's inspector, without formal submission of a repair plan for approval.

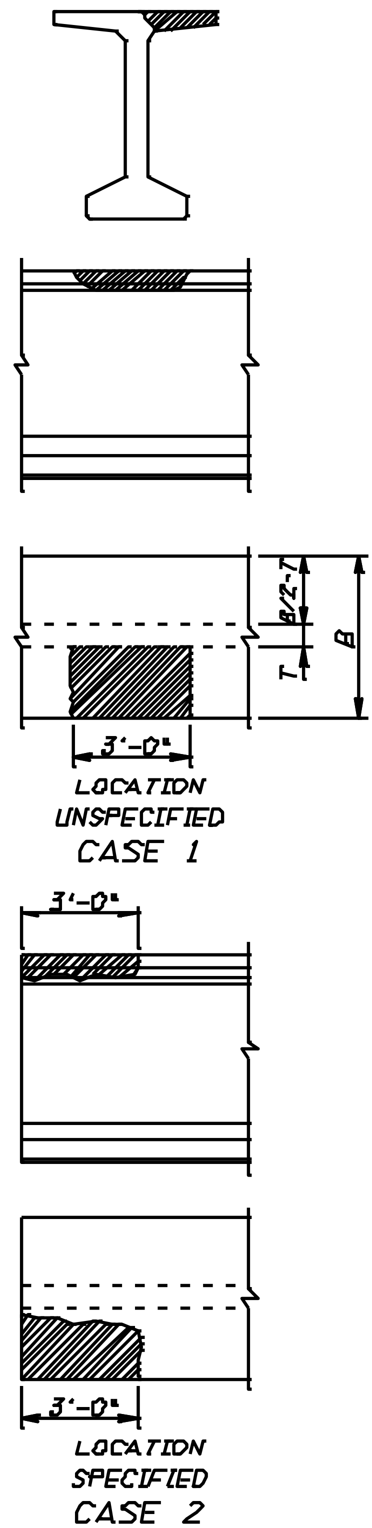
CASE 2: Strands exposed or areas exceeding those defined in Case 1:

A. It may be possible to employ the same repair techniques as above, but a repair plan that indicates the extent of strand exposure must be submitted to the owner/engineer for evaluation and approval.



SPECIAL DETAIL FOR VERTICAL PATCHING

STANDARD REPAIR PROCEDURE #6 FOR DAMAGED FLANGES REQUIRING REMOVAL AND REPLACEMENT OF CONCRETE



Preferably, these repairs should be made prior to detensioning, however, this type damage can occur in handling after detensioning.

CASE 1: The beam will subsequently be topped with a composite structural slab

A. Remove all loose concrete

B. Preserve and thoroughly clean all mild reinforcement. If reinforcement is epoxy coated, touch-up all damaged areas

C. Clean the remaining concrete contact surfaces

D. Repair Option 1 – Re-pour the missing section with approved polymer modified, cementitious, shrinkage compensated patching material, with a compressive and tensile strength equal to or greater than the design strength of the beam. Prepackaged material is preferred for quality control.

E. Repair Option 2 – Coat the surfaces to be adhered to with an approved bonding agent, following the manufacturer's instructions. Re-pour with concrete having a compressive strength equal to or greater than the design strength of the beam. Moist cure in accordance with contract specifications.

CASE 2: The beam flange is the final riding surface or will be overlaid by a non-structural riding surface.

Under these conditions the owner/agent should be consulted as to areas that may be repaired using Standard Repair Procedures.

NOTE: With prior approval of the owner/engineer, areas defined may be repaired in the presence of the owner's inspector without formal submission of a repair plan. Larger area repairs require a formal submission of a repair plan to the owner/engineer for approval.

STANDARD REPAIR PROCEDURE #7 FOR TAKING CORES AND PATCHING CORED HOLES IN GIRDERS

This procedure applies to the sampling by coring and the patching of holes. Cores may be required for situations where the concrete strength of the girder is in question.

A. Obtain cores of the diameter specified by the owner/engineer. The engineer shall determine the location of the core in the member. Preference should be given to areas that will be covered with concrete in the completed structure (i.e. within cast diaphragms, top of top flanges, etc.)

B. Locate and mark all reinforcement and prestressing strand in the vicinity of the core.

C. Core holes, avoiding reinforcing steel and prestressing strands.

D. Coat the cored holes with an approved bonding agent.

E. Patch using an approved high strength non-shrink or polymer modified, cementitious shrinkage compensated prepackage patching material in accordance with the manufacture's recommendations.

F. All work must be witnessed by the owner's inspector.

STANDARD REPAIR PROCEDURE #8 FOR MISSHAPEN BEARING RECESSES

This repair applies to those bearing recesses that are concave, convex, sloping in the wrong direction or dimensionally out of tolerance.

A. Chip out surface to achieve correct profile or to intentionally roughen to accept patching material.

B. Clean bearing recess of all unsound material.

C. Apply a solution of water and latex or other approved bonding agent to the area to be filled.

D. Mix a mortar consisting of 5 parts No. 70 silica sand and 4 parts cement with latex and water to a dry consistency. (For more information on dry consistency, see Section 4) Use of a high strength, non-shrink grout is also acceptable.

E. Apply this mortar mix to produce the specified recess dimensions.

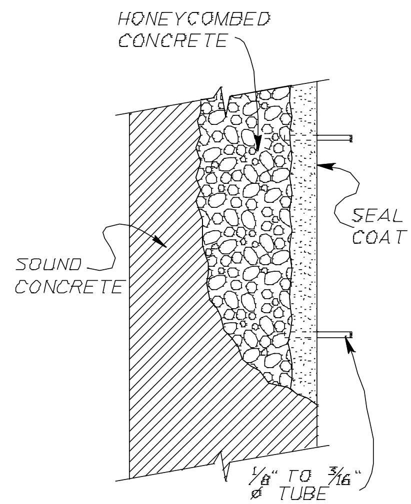
F. Re-check the bearing surface, to ensure that all dimensional tolerances are satisfied as set forth in owner's Standard Specifications.

STANDARD REPAIR PROCEDURE #9 FOR HONEYCOMBED AREAS LEFT-IN-PLACE

NOTE: Repair procedures #1 through #5 cover spalls and voids. They are equally applicable where it is deemed appropriate to remove honeycombed constituents and fill the voids with cementitious materials used for patching. In many cases it is desirable to repair honeycombed areas by filling the voids with pressure injected epoxy resin binders.

A. Chip out ½ to 1 inch of the exposed face of honeycombed area.

B. Apply a seal coat of polymer modified cementitious shrinkage-compensated patching material, having a compressive strength equal to or greater than the design strength of the beam.



C. Insert injection tubes through the freshly applied seal coat such that the tubes penetrate beyond the coating into the honeycombed area (as an alternate to B and C, insert tubes through hole drilled into hardened seal coat and then seal the annular space between holes and tubes.)

D. Inject low viscosity epoxy or Portland cement grout into the honeycombed area, using successive port-to-port injection methods, starting at the lowest tube location, taking care not to entrap air pockets

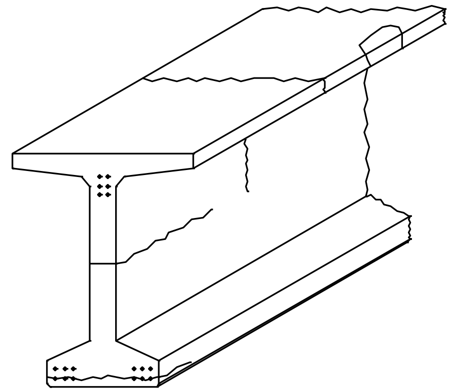
E. Pinch off tubes as injection of its part is completed.

NOTE: Use of Portland cement grout is equally acceptable to epoxy for filling the voids.

NOTE: With prior approval of the owner/engineer, honeycombed voids within the limitations described in standard repair procedures #1 through #5 may be injected with approved epoxy material or Portland cement grout, in the presence of the owner's inspector. For areas greater than the limitations in procedures #1 through #5, formal submission of repair procedures are required.

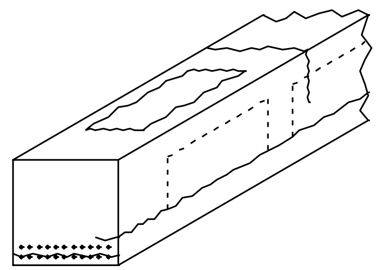
STANDARD REPAIR PROCEDURE #10 FOR EPOXY INJECTION OF CRACKS

This procedure applies to cracks that occur in the precast member with a crack width greater than 0.006 inches.



All workmen engaged in the injection process shall have satisfactorily completed a program of instruction in the specific epoxy injection process to be used.

The specific epoxy resin adhesive used must be approved by the owner/engineer. Surface seal material, used to confine the injected adhesive, must have adequate strength to hold any injection fittings firmly in place and to resist injection pressures and prevent leakage.



Epoxy components shall be mixed in accordance with the manufacturer's recommendations and expended or discarded in accordance with the manufacturer's designated pot life.

Injection equipment used must be capable of delivering the pressure appropriate for the injection requirements.

CASE 1: Cracks accessible and visible from both sides

A. Prepare areas adjacent to the crack, cleaning away dirt, dust, grease, oil and other foreign matter detrimental to the bonding of the injection surface seal system. Corrosives should not be used for cleaning.
B. For cracks of sufficient width to permit entry of loose particles, blow out debris using high pressure air equipment capable of filtering out any oils from the compressor.
C. Apply an appropriate surface seal, to both sides of the crack, allowing sufficient curing time.

D. Install injection ports at intervals not less than eight inches. (Note: The maximum port spacing is a function of crack width and pump pressure and relies on judgement and injection equipment used).

E. For essentially horizontal cracks, begin at either end of the crack. For cracks exhibiting any verticality in orientation, start at the lowest port. Begin and continue injecting epoxy until the adhesive reaches the next port.

STANDARD REPAIR PROCEDURE # 10 FOR EPOXY INJECTION OF CRACKS (CONTINUED)

F. Clamp or otherwise seal off the port and begin injecting through the next port. Do not skip successive ports, in order to avoid entrapment of air which will prevent complete filling of the crack.

G. Perform the injection procedure continuously until the entire crack is filled. If port-to-port travel of the adhesive is not indicated, immediately cease injection and notify the engineer. Determine the cause of problem before continuing.

H. When injection is complete, allow the adhesive to cure the length of time and manner specified by the manufacturer.

I. Remove the surface seal by grinding so that the face of the crack is flush with the adjacent concrete surfaces, with no depressions at the entry ports.

J. If the faces of the beam are not to be subsequently texture coated, apply a color-matching sand and cement mix.

CASE 2: Blind Cracks, Not Visible or Accessible From Both Sides

Use the same procedures described in Case 1 with the exception that port spacing shall not exceed the thickness of the member for through cracks. (Examples are cracks through the web or flanges of box beams.)

NOTE: Sample cores of completed injections may be needed to verify the effectiveness of the procedures used in both Case 1 and 2.

All work should be accomplished in the presence of the owner’s inspector.

STANDARD REPAIR PROCEDURE #11 FOR SHORT PROJECTING MILD REINFORCING BARS OR PROJECTING PRESTRESSING STRANDS

CASE 1: Broken or Short Mild Steel Reinforcement used as Stirrups or End Projections

A. Mechanical Coupler
   An approved coupler may be used, provided enough bar projection remains to install the coupler. The coupler shall be installed according to the manufacturer's recommendations.

B. Welding
   As an alternative to a coupler, welding may be considered. For normally non-weldable grades of reinforcing, such as ASTM A615, welding of the steel should be approached with caution since no specific provisions have been included in the particular ASTM specification to enhance weldability. When nominally non-weldable steel is to be welded, a welding procedure suitable for the chemical composition and intended use of the bar must be prepared. The use of the latest edition of ANSI/AWS D 1.4 is recommended. For weldable grades of mild reinforcement, use of ANSI/AWS D 1.4 negates the need for a separate weld procedure.

   Butt weld the additional segment to achieve the plans projection. All welding must be in conformance with AWS welding procedures for reinforcing steel. Bar preheat should be determined from the carbon content and carbon equivalent (Determined from mill certifications). Welding ground must be placed directly on the reinforcing bar being welded and immediately adjacent to the weld. Grounding through the girder is strictly prohibited.

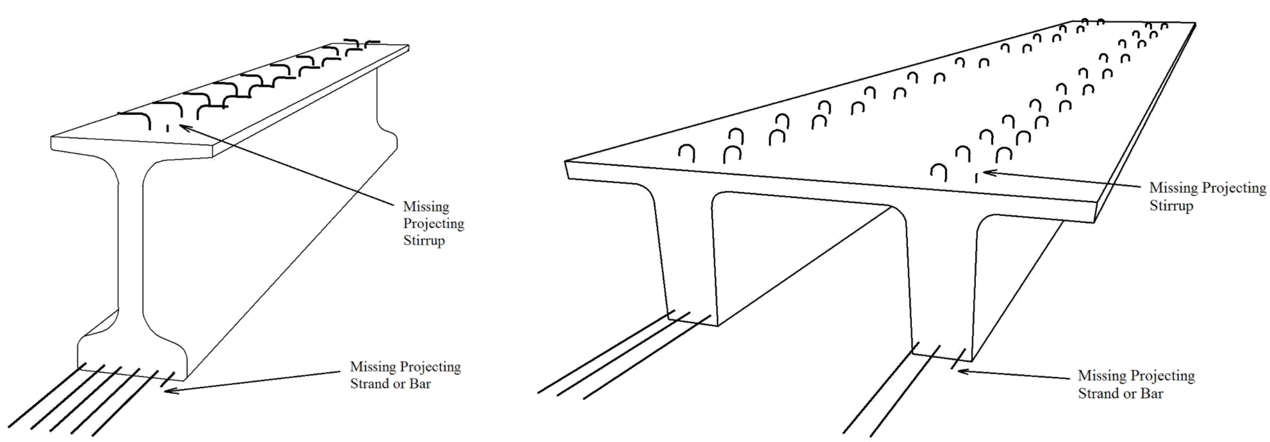
   All work is to be witnessed by the owner's inspector.

CASE 2: Broken or Short Prestressing Strand End Projections

A. Select a proprietary strand coupling device capable of reaching or exceeding the yield strength of the prestressing strand.

B. Cut off strand to a length appropriate for splicing and join the additional length strand required.

NOTE: As an alternate to the repairs outlined in Case 1 and 2, it may be acceptable to drill and grout replacement bar or strand. See Standard Repair Procedure #12.



STANDARD REPAIR PROCEDURE #12 FOR REPLACEMENT OF MISSING PROJECTED MILD STEEL OR PRESTRESSING STRAND

NOTE: Unless otherwise required by the owner/engineer to satisfy design requirements, the following procedure is deemed acceptable.

A. Drill the hole diameter to the oversize dimension suggested by the chemical adhesive manufacturer's recommendation, accounting for the upset lugs. Refer to the Troubleshooting Guide #10 for the required depth of the hole. The hole shall be a minimum of 3" from any beam edge, measured from to the centerline of the bar.

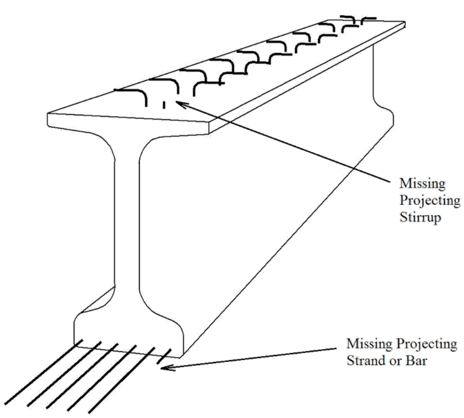
B. After drilling the hole, blow out any residue using filtered compressed air.

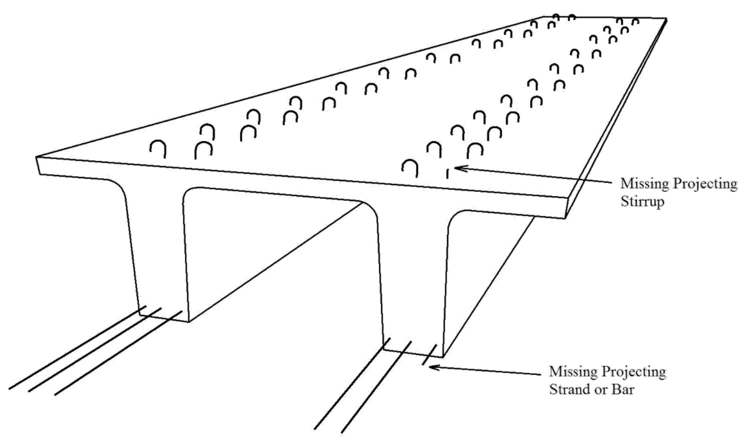
C. Pack the hole with chemical adhesive of the proper viscosity as recommended by the manufacturer of the adhesive, which depends on the orientation of the hole.

D. Rotate and push the bar or strand into the hole until seated at the bottom. <u>Do not drive the bar with percussion tools</u>.

E. The chemical adhesive shall be on the owner/engineer approved products list, for the application intended, or otherwise submitted for approval prior to use.

F. All work should be witnessed by the owner's inspector.





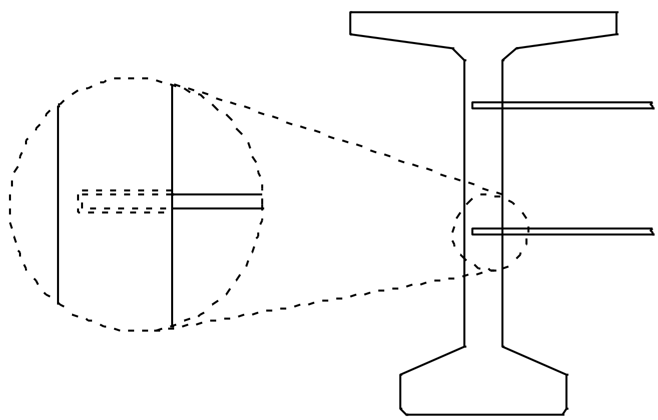
STANDARD REPAIR PROCEDURE #13 FOR MISSING OR INCORRECTLY LOCATED DIAPHRAGM INSERTS

A. Drill hole ¼ - inch greater than the nominal diameter of the bar. The depth of hole should be 1 - inch less than stem width.

B. Fill hole with non-sag chemical adhesive following manufacturer's instructions.

C. Insert rebar and maintain in position until the chemical adhesive cures per manufacturer's instructions.

NOTE: The path of the deflected strand should be determined and marked along the web prior to drilling.



SECTION

STANDARD REPAIR PROCEDURE #14 FOR SEALING CRACKS

CRACKS ON HORIZONTAL SURFACES

NOTE: This repair procedure addresses sealing cracks on horizontal surfaces with a low modulus, high molecular weight methacrylate penetrating sealer and crack filler.

A. Follow the Manufacturer's recommendations for the application of the material.

B. The specific methacrylate sealer material shall be approved by the owner/engineer.

C. Substrate shall be clean, sound and free of surface moisture. Remove dust, laitance, and oils, curing compounds and all other foreign material by mechanical means.

D. Cracks extending through the entire member thickness shall be sealed from the underside to prevent leakage.

E. The methacrylate sealer shall be applied to the surface according to manufacturer's recommendations and allowed to pond over the crack. In some cases it may be necessary to build a temporary dam on either side of the crack to facilitate ponding.

F. The treated surface can become smooth after curing. A dry sand can be broadcast on the partially cured surface if a smooth surface is undesirable.

CRACKS ON VERTICAL SURFACES

NOTE: This repair procedure addresses sealing cracks on vertical surfaces with various materials.

I. EPOXY PASTE:

An epoxy paste applied by hand and worked into cracks can provide an effective moisture seal. This type of repair is typically used to seal individual cracks. The material used shall be approved by the owner/engineer and applied according to manufacturer's recommendations.

A. Surface preparation
   1. Surface to be clean and sound
   2. Surface may be damp or dry
   3. Substrate must be 40 degrees F and rising with preferred temperatures ranging from 40 degrees F to no higher than 80 degrees F

B. Application of the epoxy paste
   1. Prepare the epoxy paste according to the manufacturer's recommendations
   2. Using a thin, flexible, and square ended, plastic or nylon spatula, force the epoxy gel with uniform pressure by squeegee action into the cracks
   3. Finger application to the cracks is permissible, but uniformity in filling of the cracks is best accomplished with the action of a spatula
   4. Allow to set until tack free. Note Well: this is a temperature dependent process and at 40 F and rising the set time will be longer than at 75 degrees F
   5. Lightly hand sand the area to match texture and appearance of adjacent areas not repaired

STANDARD REPAIR PROCEDURE #14 FOR SEALING CRACKS (CONTINUED)

II. SILANE AND SILOXANE SYSTEMS:

A silane or siloxane based water repellents can be applied to the surface surrounding a crack. Experience has shown that the sealers will wick into and seal cracks ≤ 0.013” in width. Multiple applications may be required. This type of repair is typically used on a large network or series of fine cracks. The material used shall be approved by the owner/engineer and applied according to manufacturer’s recommendations.

A. Application of breathable water repellent: silane or siloxane sytems
   1. Power mix materials per manufacturer’s recommendations for the time specified, and periodically thereafter to ensure uniform product
   2. Apply with paint brush, roller or sprayer from the bottom up on vertical surfaces
   3. Apply to saturation per manufacturers recommendations

METHACRYLATE:

A low modulus, high molecular weight methacrylate sealer can be introduced into cracks at any orientation using a vacuum-impregnation process. This type of repair can be used on a series of fine cracks and on individual cracks. The cracks are prepared in a similar fashion to those undergoing an epoxy injection repair. The vacuum-impregnation process is patented by BALVAC, Inc.

STANDARD REPAIR PROCEDURE #15 FOR EDGE SPALLS IN PRECAST ELEMENTS

NOTE: This repair applies only to those voids in precast (including precast elements with prestressing for handling) which do not exceed 4 inches in depth, 4 feet in length. With the prior approval of the owner/engineer, this repair may be made, in the presence of the owner's inspector without submitting a non-conformance report for formal approval.

A. Remove all loose concrete.

B. Square interfaces with existing concrete to be in contact with the patch.

C. Clean the excavated area, blowing away dust.

D. Repair Option 1 – Fill the voided area with approved polymer modified cementitious, shrinkage-compensated patching material, with a compressive strength equal to or greater than the specified design strength of the element. Prepackaged patching material is preferred to control quality.

E. Repair Option 2 – Coat surface to be adhered to with an approved bonding agent, following the manufacturer's instructions. Fill the voided area with a high strength, cement based, shrinkage-compensated mortar, following the manufacturer's instructions.

F. For larger spalls of a similar nature and/or involving reinforcing, the same repair techniques may be employed but must be submitted to the owner/engineer for evaluation and approval.

NOTE: In cases where the patch is located over vehicular traffic or pedestrian walkways, the patching material must be mechanically anchored either by encapsulating existing reinforcement, be anchored by supplemental reinforcement, or by other anchoring devices.

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