

CONCRETE REMOVAL IN REPAIRS INVOLVING CORRODED REINFORCING STEEL—TechNote

Keywords: carbonation; chloride content; concrete removal; corrosion; reinforcing steel; repair; ring anode effect; surface preparation; undercutting.

Introduction

The long-term performance of concrete repair intended to address corrosion of embedded reinforcing steel is influenced by the depth of repair and the condition of the substrate concrete surrounding the repair area. The extent of concrete removal should be adjusted in accordance with the degree and nature of distress affecting the member or structure, while taking into account the concrete condition, the structural design, and the applied loads.

Question

When corroded reinforcing steel is encountered in a repair, should the bar be undercut? How far should the bar be exposed along its length?

Answer

Undercutting is defined as concrete removal all around the circumference of a reinforcing bar to allow it to be encapsulated in repair material (ACI 562). In general, when corroded reinforcing steel is encountered in a repair, it should be undercut, leaving in all directions a clear distance of at least 0.75 in. (19 mm) or 0.25 in. (6 mm) larger than the dimension of the maximum size aggregate in the repair material, whichever is greater (ACI 546R). In addition, concrete removal along the length of reinforcing steel should continue until the bar is free from corrosion products that inhibit bond and no cracks or delamination in the surrounding concrete are visible, extending a minimum of 6 in. (150 mm) (ICRI 310.1R). A licensed design professional (LDP) should review all the relevant information available on the structure (such as condition assessment, design, and loads) prior to specifying that reinforcing steel be undercut in repair areas. Representative field observations by the LDP are recommended during the repair work, especially in cases involving large removals of concrete, removal around multiple reinforcing bars, and removal in highly stressed areas.

Discussion

When a portion of the reinforcing steel is re-embedded in a chloride-free repair material while the other portion remains in contact with existing chloride-contaminated, carbonated concrete, or both, corrosion may be initiated and develop rapidly in areas adjacent to the repair (Fig. 1). This condition is often referred to as the “anodic ring effect” or “halo effect.” To avoid creating an environment where part of the circumference is depassivated and another part is still passive, a combination that will promote accelerated corrosion, it is common practice to completely remove concrete around corroded reinforcing steel when performing repairs.

The size of the repair should be based on both technical and economic considerations. If corroded reinforcement in the repair is exposed and found to have corrosion products that inhibit bond, is not firmly bonded to the surrounding concrete, or more than half of the reinforcement bar is exposed, it is recommended to undercut the affected bar(s) (Fig. 2). This provides optimal conditions for a durable repair, such as all-around clearance for cleaning of reinforcement and a mechanical attachment between the reinforcing bar and the repair material (ACI 546R; ICRI 310.1R). As shown in Fig. 3, a recommended repair practice requires the clear space behind the reinforcing steel should not be less than 0.75 in. (19 mm) or 0.25 in. (6 mm) plus the dimension of the maximum size aggregate in the repair material, whichever is larger (ACI 546R; ICRI 310.1R). In addition, concrete removal along the length of the reinforcing steel

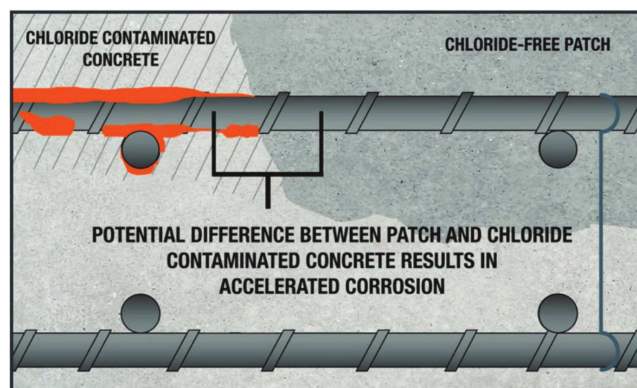


Fig. 1—Anodic ring corrosion in concrete repairs. (Image courtesy of Vector Corrosion Technologies Ltd.)

should continue until there is no further cracking or delamination in the concrete and the reinforcing steel is free from corrosion products that inhibit bond. As a good practice, the repair area should extend a minimum of 6 in. (152 mm) beyond the actual delaminated concrete (**ICRI 310.1R**).

In the decision regarding the extent of concrete to be removed, consideration should be given to the chloride ion concentration, extent of carbonation, or both, in the surrounding concrete. There is a likelihood of continuing corrosion whenever—at the reinforcing steel level—the chloride content exceeds a threshold value or concrete is carbonated. It is difficult to establish a single critical chloride concentration, as it varies depending on the concrete constituents and exposure conditions. However, threshold values as low as 0.20% in acid-soluble chlorides by weight of cement may be enough in some cases to trigger uncoated reinforcing steel corrosion (**ACI 222R**). It is desirable to remove chloride-contaminated concrete, carbonated concrete, or both, around corroded reinforcing steel when performing repairs, although complete removal is not feasible in all situations.

Ideally, any corrosion products on the reinforcing steel that may affect the bond with the repair material should be removed when performing repairs. However, in some situations, it may be difficult to remove corrosion products along the full length or circumference of the contaminated steel (for example, congestion of reinforcement, access limitations, load considerations, or other factors).

When encountering such situations where contaminated concrete, undesirable corrosion products over the reinforcing steel, or both, cannot be removed, it may be possible to reduce the risk of the halo effect by including supplemental corrosion mitigation strategies into the repair design. Supplemental corrosion mitigation strategies that might be considered include galvanic cathodic protection (GCP), impressed current cathodic protection (ICCP), electrochemical chloride extraction (ECE),

and the use of migrating corrosion inhibitors (**ACI 222R**; **ICRI 510.1R**). In some cases of advanced corrosion resulting in section loss, it may be appropriate to replace the concrete along the entire length of the member to ensure a successful long-term repair. Information on the need for replacing bars in case of section loss, which is beyond the scope of this document, can be found in **ACI 364.10T**.

Prior to specifying that reinforcing steel be undercut and the extent of concrete removal in repair areas, an LDP should review the reinforcing steel details, the member geometry, and the applied loads, in addition to the relevant information collected in the condition assessment (corrosion, delamination, spalling, chloride contamination, and carbonation). Undercutting of reinforcing steel can result in buckling of the reinforcement when compressive stresses are present, and the reinforcing steel is insufficiently confined by ties or the surrounding concrete. Buckling of reinforcing steel can

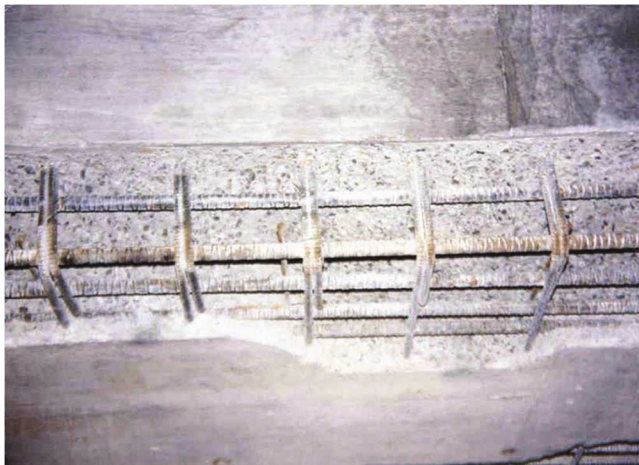


Fig. 2—Typical concrete removal around reinforcing steel.

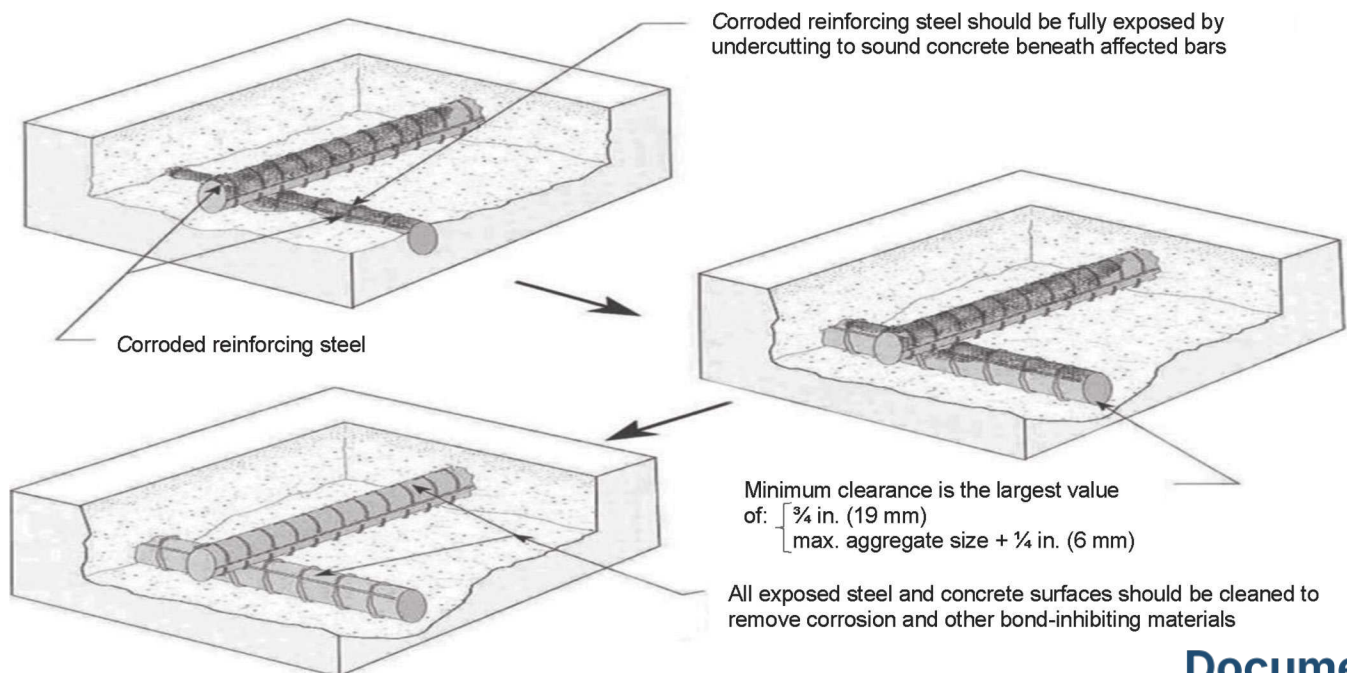


Fig. 3—Removal of concrete from around reinforcing steel (adapted from **ICRI 310.1R**).