

EVALUATION AND MINIMIZATION OF BRUISING IN CONCRETE REPAIR—TECHNOTE

Keywords: bond strength; breaker; bruising; concrete removal; cracking; hammer; microcracking; pulloff test; repair; surface preparation.

Question

What is concrete “bruising,” how is it evaluated, and how can it be minimized?

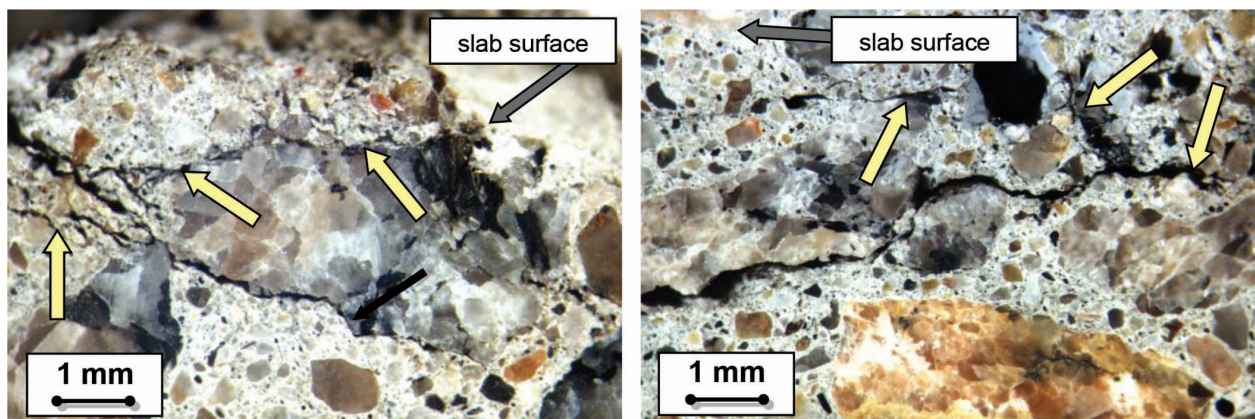
Answer

Bruising refers to damage in a surface layer of remaining substrate concrete that is weakened by fine interconnected cracks caused by the use of high-impact, mechanical methods for concrete removal and surface preparation. The bruised (or fractured) layer left by such surface preparation methods typically extends to a depth of 1/8 to 3/8 in. (3 to 10 mm) or more below the remaining substrate surface and, if not removed, generally results in lower repair bond strengths. Bruising, which can be detected through pulloff testing and petrographic examination, can be effectively minimized by selecting the most appropriate method and equipment for the given application.

Discussion

Concrete repair projects commonly involve the removal of unsound and sound concrete and then preparation of the substrate surface prior to replacement with a repair material. Mechanical removal processes essentially rely upon fracture and/or abrasion of the concrete. Because concrete is a heterogeneous and brittle material, when it is subjected to sufficiently high concentrated impact forces, local brittle fractures occur and the material bursts into pieces, creating splinters and clusters of cracks and microcracks. Obviously, after concrete removal, a fraction of these cracks may extend in the remaining substrate concrete, depending on the nature and intensity of the fracturing process.

The concrete removal/surface preparation process can thus damage the substrate surface, resulting in varying degrees of microcracks and fractures, commonly referred to as bruising (Fig. 1). A bruised surface has a superficial layer weakened by interconnecting microcracks that alters to some degree the quality and mechanical strength of the bond between the existing concrete and the repair material.



a) Slab prepared with a 30-lb jackhammer

b) Slab prepared with a 45-lb jackhammer

Fig. 1—Optical microscope images of concrete core cross sections exhibiting bruising below the surface (adapted from Bissonnette et al. [2006]). (Note: 1 mm = 0.0394 in.; 1 lb = 0.454 kg.)

Concrete can be removed using a variety of methods such as hammering (a wide range of equipment is used in practice, including chipping hammers, jackhammers, and hydraulic hammers), milling, scarifying, scabbling, abrasive blasting, and high-pressure water jetting. Removal of unsound and sound concrete subjects the concrete substrate to a wide range of impact and dynamic loads, and the extent of bruising resulting from the operation will depend on the equipment used and the quality of the concrete. According to [ICRI 310.2R](#), high-impact mechanical methods fracture the cement paste and aggregates. This leaves a layer weakened by interconnecting cracks and loosened aggregates, typically concentrated in the first 1/8 to 3/8 in. (3 to 10 mm) from the surface. The risk and extent of bruising associated with the various types of removal methods increase from those generating diffused impact upon the surface (for example, sandblasting, water jetting, and shotblasting), through those involving moderately concentrated impact (for example, scarifying, scabbling, and rotomilling), to those with the most concentrated impact (hammering). This is illustrated in Fig. 2, with data from test series conducted on experimental concrete slabs, in well-controlled conditions ([Bissonnette et al. 2006](#)). It can be observed on the graph that grinding, sandblasting, scarifying, and water jetting produced virtually no additional damage in comparison with the reference. On the other hand, jackhammering induced significant bruising, with increasing intensity and depth, as the weight of the hammer used gets larger (point tools were used in all cases). In these experiments, the deepest bruising cracking in jackhammered slabs extended below 3/8 in. (10 mm) from the surface, reaching almost 3/4 in. (19 mm) with the heaviest hammer used (45 lb [21 kg]).

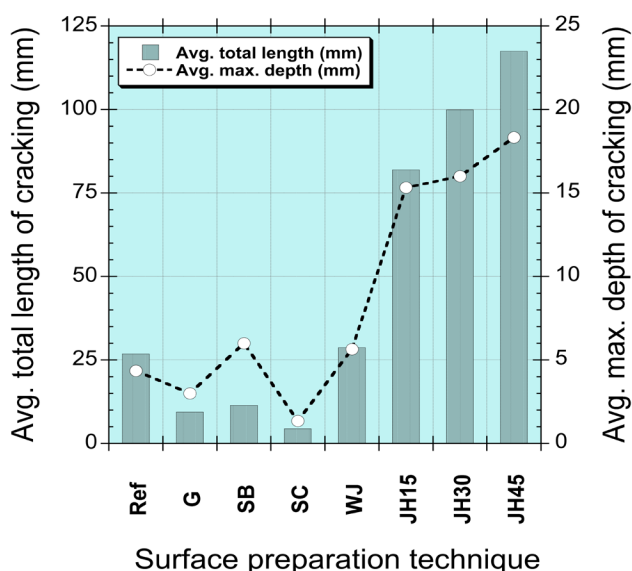


Fig. 2—Average cumulative crack length and average depth of cracking recorded on 100 mm long x 20 mm deep vertical areas below substrate surface, after preparation with different concrete removal techniques (Ref is no treatment; G is grinding; SB is sandblasting; SC is scarifying; WJ is water jetting; JH15 is 15 lb jackhammering; JH30 is 30-lb jackhammering; and JH45 is 45-lb jackhammering) (adapted from Bissonnette et al. [2006]). (Note: 1 mm = 0.0394 in.; 1 lb = 0.454 kg.)

Pulloff testing ([ASTM C1583/C1583M](#)) of the repair can be conducted to determine if the repair bond is affected by bruising ([ICRI 210.3R](#); [ICRI 320.2R](#)). As shown in Fig. 3, bruising translates into a weakened concrete superficial substrate layer and will result in lower pulloff strengths ([Sprinkel 1997](#); [Bissonnette et al. 2006](#)), with failures occurring predominantly in the substrate. If bruising is detected, the depth and extent of the damage to the substrate should be assessed and mitigated. In some cases, the damage may go beyond surface bruising and extend into the concrete mass. The incidence, severity, and depth of bruising can be identified by microscopic examination (such as petrographic examination using [ASTM C856/C856M](#) procedures) of the concrete. Microscopic examination can also be used to assess the effectiveness of remedial actions taken to minimize bruising of the concrete. To identify bruising, a polished surface may need to be magnified up to 20 to 100 times ([Bissonnette et al. 2012](#)), depending on the width of the cracks (Fig. 1).

Bruising can be minimized by selecting the most appropriate concrete removal/surface preparation method and equipment for the given repair application ([Warner et al. 1998](#)) and avoiding whenever possible those that are known to induce significant cracking (Fig. 2 and 3). In this respect, hammering is by far the most aggressive method, especially when breakers are equipped with wide chisel tools ([Courard et al. 2020](#)). When using hammers, selecting the lightest equipment that can yield production rates compatible with the project requirements should be favored. Scabbling, rotomilling, and, to a lesser degree, scarifying can also leave some cracking in the prepared substrate (Fig. 4). Bruising problems can be minimized by using high-pressure water