REMR TECHNICAL NOTE CS-MR-1.12

REMOVAL LIMITS FOR REPAIR OF DAMAGED AND DETERIORATED CONCRETE STRUCTURES

Using hammer and visual inspection to establish removal limit.

PURPOSE: To provide guidance in establishing removal limits for repair of damaged and deteriorated concrete structures.

DEFINING EXTENT OF DAMAGE: The extent of damage to a concrete structure is established and documented through an engineering condition survey. Guidance for conducting an engineering condition survey of concrete structures can be found in TR REMR-CS-1 (Ref a), ACI 201.1R-68 (Ref b), and EM 1110-2-2002 (Ref c). The standard practice for sampling hardened concrete is provided in ASTM C 823-83/CRD-C 26-83 (Ref d and e). Descriptions of nondestructive and laboratory analysis methods that can be employed to evaluate extent of damage are presented in TR REMR-CS-1 and EM 1110-2-2002. Descriptions of nondestructive methods are also presented in TR REMR-CS-10 (Ref f).

An investigation to determine extent of damage will vary in size and approach, depending on the magnitude and importance of damage to the structure's integrity. Typically, an investigation involves a visual inspection of the structure to map areas of observed surface deficiencies, sounding the surface with a hammer or chain to detect delaminated areas, and coring to determine depth of damage. In some cases, ultrasonic pulse velocity testing is employed to aid in locating and mapping areas of damage. A three-dimensional view of damage can be generated from the results of the surface mapping and petrographic examination of cores (ASTM C 856-83/CRD-C 57-83, Ref g and h).

Where corrosion of steel reinforcement is active, a copper-copper sulfate half-cell (ASTM C 876-80, Ref i) can be used to map areas of probable damage. The steel reinforcing can be located with a pachometer and, if the size of the reinforcing bar is known, the depth to the top of bar can be determined. Measurements of total chloride ion content in concrete (AASHTO T260-82, Ref j) can be used to estimate the potential for corrosion with depth.

SETTING REMOVAL LIMIT: Setting removal limits is dependent on the extent of damage, the type repair to be made, and the removal technique. Typically, removal limits are set to fixed dimensions that encompass most of the damaged concrete defined by the condition survey and are adjusted during removal to include remaining areas where damage is more extensive. For resurfacing repairs in which the surface has to be removed and replaced and for spall repairs, removal at the boundaries should produce a 1-in. deep, or greater, cut normal to the surface or undercut to provide a keyed boundary use in some repairs. For repairs requiring less than 1-in. removal, the depth of cut at the boundaries should be the same as the removal depth. For shotcrete repairs, the boundary edge should be slightly tapered into the repair with depth. Concrete should be removed from around reinforcing bars when more than half the perimeter of bar is exposed for 12 in. or more. Removal should provide a minimum clearance of 3/4 in. or the maximum size aggregate plus 1/4 in., whichever is greater.

Some removal techniques, like those used to presplit the concrete (explosive blasting, expansive agents, hydraulic splitters, and other wedging systems), often do not give the desired results when employed in damaged areas because the presplitting plane is controlled by weaknesses within the damaged concrete. For such techniques, the removal limit should be located mainly in sound concrete. Other techniques, such as use of rotary head cutter, water jet blasting, and milling equipment, have significantly lower production rates in sound concrete. The removal limit for these techniques should be set to avoid encompassing substantial quantities of sound concrete that will result in extended removal time and unnecessary cost.

WRITING REMOVAL SPECIFICATIONS: Specifications for the limits for removal work need a clear description of the concrete to be removed to make the contract bid binding. Without a clear description, a bidder may base his bid on a technique and equipment that are inadequate and not economical for the actual work to be done. A contract awarded to this bidder will ultimately lead to a claim for additional compensation based on differing site conditions. On the other hand, all bidders may submit bids that greatly exceed the actual cost of removal based on an assumption of the difficulty of the job. In either situation, unnecessary cost will be borne by the government.

In a description of concrete to be removed, the following items should be considered for inclusion:

a. Age of concrete.

b. Properties of concrete to include average unconfined compressive strength, number of specimens tested, specimen locations, age at time of testing.

c. A description of aggregate contained in concrete that includes type and maximum size.

d. Location, volume, and dimensions of concrete to be removed.

e. Condition of concrete within the removal limits (also include if concrete to be removed contains both damaged and sound concrete because of non-uniformity of extent of damage).

MONITORING FOR LIMITS WHILE REMOVAL IN PROGRESS: It is necessary to monitor the removal effort in progress to ensure that removal has been completed to sound concrete. The funding and time restraints of the repair effort will control the extent to which removal will be monitored. Typically, the monitoring consists of visual inspection of the existing surface combined with impacting the surface with a steel hammer for signs of weakness. An area of footprints, where aggregate has been pulled from the surface, is an indication that the paste is weak and the limit of sound concrete has not been reached. Sound concrete is indicated where the aggregate has been sheared at the surface by the removal mechanism. Fractured aggregate in the surface is also an indication that sound concrete has been reached; however, in this situation, the limit must be extended to remove the fractured aggregate using a less damaging removal technique. Using a steel hammer to impact the surface and observing the resulting surface will help affirm whether sound or weak areas are present.

The removal limit will also have to be adjusted to include delaminated areas that still remain. These areas can be located by sounding the surface with a steel hammer or chain and listening for a drummy sound, indicating delamination. Some repair techniques require the surface to have a certain tensile strength as an indication of sound concrete. To verify that sound concrete has been reached, pullout tests must be conducted. One such pullout test is described in Appendix A of ACI 503R-80 (Ref k); another, in a presentation at the 1987 Annual Convention of ACI (Ref 1).

REFERENCES:

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c. Office, Chief of Engineers, Department of the Army. 1986. "Evaluation and Repair of Concrete Structures," Engineering Manual 1110-2-2002, Washington, DC.

d. American Society for Testing and Materials. 1983. "Examination and Sampling of Hardened Concrete in Constructions," Designation: C 823-83, 1984 Book of ASTM Standards, Section 4, Philadelphia, PA.

e. US Army Engineer Waterways Experiment Station. 1983. "Examination and Sampling of Hardened Concrete in Constructions," Designation: CRD-C 26-83, Handbook for Concrete and Cement, Vicksburg, MS.

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g. American Society for Testing and Materials. 1983. "Petrographic Examination of Hardened Concrete," Designation: C 856-83, 1984 Book of ASTM Standards, Section 4, Philadelphia, PA.

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j. American Association of State Highway and Transportation Officials. 1982. "Sampling and Testing for Total Chloride Ion in Concrete and Raw Materials," Designation: T-260-82, Washington, DC.

k. American Concrete Institute Committee 503. 1980. "Use of Epoxy Compounds with Concrete," ACI 503R-80, ACI Manual of Concrete Practice, Part 5, Detroit, MI.

l. Hindo, K. R. 1987. "In-Place Bond Test of Concrete," Paper Given at 1987 Annual Convention in San Antonio, Texas, American Concrete Institute, Detroit, MI.