Removal and Reuse of Hardened Concrete

Reported by ACI Committee 555

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This report presents information on removal and reuse of hardened concrete. Guidance for assessment of concrete structures for complete or partial demolition is provided. The applicability, advantages, limitations, and safety considerations of various types of concrete removal methods, including hand tools, hand-operated power tools, vehicle-mounted equipment, explosive blasting, drills and saws, nonexplosive demolition agents, mechanical splitters, heating and thermal tools, and hydrodemolition (water-jet blasting), are provided. The available surface removal systems, their probable applications, and advantages and disadvantages of various types of surface removal systems are discussed. Considerations for evaluating and processing waste concrete for production of aggregates suitable for reuses in concrete construction are presented.

Keywords: aggregates; concrete removal; condition survey; demolition; diamond saw; drop hammer; explosive blasting; hardened concrete; hydrodemolition; impact breaker; jet-flame cutter; mechanical spltter; mixture proportion; nonexplosive demolition agent; recycled aggregates; recycled concrete; rotating cutter head; spring-action breaker; thermal lance; water-jet blasting; wrecking ball.

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CHAPTER 1—INTRODUCTION

1.1—Scope

This report provides available information on concrete removal methods with detailed discussions on surface removal. Reuse of removed concrete as concrete aggregate is also addressed. The type and kind of concrete and its location within a structure directly affect the removal methods to be used. Selection of proper tools and equipment are critical for a cost-effective and safe concrete removal project.

1.2—Objective

Driven by cost, need, and limited resources, the technology for concrete removal and reuse is rapidly advancing. Partial removal of critical structural components for repair rather than replacement, geographical constraints, access to structures planned for removal, environmental regulations, and worker and structure safety will continue to effect an evolution of developing methods and equipment.

With safety as a foremost consideration, thorough planning is essential when engaged in a removal project. The scope and type of concrete to be removed should be evaluated and examined in detail to determine the most advantageous system(s). This report provides information on selecting the most appropriate systems.

Concrete reuse is primarily related to a project's location. For example, limited availability of materials in a particular region may result in a cost-effective use of equipment and manpower to remove nearby concrete structures with the intent of reusing the removed materials as a roadway base or as coarse aggregate for concrete. This report is confined to the evaluation and processing of hardened concrete used as concrete coarse aggregates.

Work continues in a number of countries to improve equipment and methods, including the use of robotics. Proceedings from the RILEM Symposium held in October 1993 in Odense, Denmark, and other RILEM publications provide additional information. These publications include: *Demolition and Reuse of Concrete and Masonry* (Kasai 1988), *Demolition and Reuse of Concrete and Masonry* (Lauritzen 1993), "Disaster Planning, Structural Assessment, Demolition and Recycling" (De Pauw and Lauritzen 1993), "Recycling of Demolished Concrete and Masonry" (Hansen 1992), and "Specification for Concrete With Recycled Aggregates" (RILEM Technical Committee 121 1993). The Strategic Highway Research Program (SHRP) in the United States studied problems that have an influence on the removal of concrete for bridges (Vorster et al. 1992).

CHAPTER 2—KINDS OF CONCRETE AND DEGREE OF REMOVAL

2.1—Introduction

This chapter addresses complete and partial removal from different types of structures and assessment of structure considering safety, stability, cost, constructibility, and environmental impact. The complete or partial removal of prestressed, reinforced, and unreinforced concrete structures should be assessed by a competent team experienced in all phases of the concrete removal operation.

One should identify sound concrete and examine what effect the removal may have on remaining concrete and reinforcement when partial removal is undertaken. Most importantly, concrete removal or demolition should be performed under appropriate supervision, regardless of the project size.

2.2—Assessment of concrete structures for complete or partial demolition

2.2.1 *General considerations*—Guidance on performing a condition survey of concrete structures is covered extensively in ACI 201.1R. Listed below are other general items to consider before either partial or complete concrete removal. If the decision to remove concrete is based on economic or reasons other than concrete deterioration, a detailed condition survey might not be necessary.

2.2.1.1 *Safety*—A predemolition survey should be performed to determine if the planned work could cause any structure to collapse. Before to starting work, a survey of the job site should be made to determine the hazards and the safeguards necessary to ensure that work is performed safely. Continually check for hazards due to weakening of the structure.

2.2.1.2 *Environmental impact*—A work plan requiring the removal of a structure, either partially or totally, should address the impact on the surrounding environment. Impacts on the environment include: neighboring tenants and surrounding structures; noise pollution; dust pollution; water runoffs due to work, storms, or both; and other environmental factors such as asbestos and hazardous chemicals. An inventory of potential environmental impacts should be developed and used as a checklist during concrete removal operations.

2.2.1.3 *Plans provided or drawn for assessment documentation*—During the condition survey of the concrete structure, prepare drawings or sketches that reflect existing conditions. These drawings or sketches become part of the condition survey report to provide preremoval documentation.

2.2.1.4 *Complete set of structural and architectural drawings*—In performing a condition survey of concrete structures, the use of as-built structural and architectural drawings is strongly recommended for work plan development. The drawings can be reviewed and evaluated for assessing existing conditions, areas of distress or potential hazards, development of work plans, and concrete removal operations. With accurate and thorough drawings, a work plan can be developed safely and effectively, while minimizing environmental impacts and costly errors. If original drawings are not available or if modifications appear to have been made, spot de-

structive exploration may need to be done to ascertain reinforcement location, size, and condition.

2.2.1.5 *Budgetary and logistic constraints*—Budgetary and logistic constraints should be identified and incorporated into the work plan.

2.2.2 *Evaluation of concrete*

2.2.2.1 *Field documentation (visual examination)*—Refer to ACI 201.1R to develop a checklist for field documentation of the structure. ACI 201.1R provides information on examination of uniformity and rating of distress manifestations.

2.2.2.2 *Detailed examination*

(i) Petrography—The usefulness of any petrographic examination procedure on the objectives of the investigation, proposed or underway, can be determined by a discussion with an experienced petrographer. ASTM C 457 can be used to develop data that will explain why freezing-and-thawing-related damage has occurred. ASTM C 856 gives the following purposes for petrographic examination of concrete:

- Determine, in detail, the condition of concrete in a structure;
- Determine inferior quality, distress, or deterioration of concrete in a structure;
- Determine whether alkali-silica or alkali-carbonate reaction, or cement-aggregate reaction, or reactions between contaminants and the matrix have taken place, and their effects upon the concrete;
- Determine whether the concrete has been subjected to and affected by sulfate attack, other chemical attack, early freezing, or to other harmful effects of freezing and thawing; and
- Determine whether concrete subjected to fire is essentially undamaged or moderately or seriously damaged.

(ii) Nondestructive testing (NDT)—There are numerous nondestructive test methods for estimating strength of concrete, a few of which are listed as follows:

a) Surface hardness methods;
b) Penetration resistance techniques;
c) Pullout tests; and
d) Ultrasonic pulse velocity method.

There are also other nondestructive test methods for determining properties other than strength: a few are listed as follows:

a) Magnetic methods—reinforcement cover and location;
b) Electrical methods—reinforcement corrosion, thickness of concrete pavements, moisture content, and moisture penetration;
c) Radioactive methods—density, voids, composition, and segregation; and
d) Ultrasonic pulse velocity and pulse echo techniques—to determine cracks and voids in mass concrete.

For additional test methods and their application and limitations, refer to ACI 228.1R and ACI SP-82 (Malhotra 1984).

2.2.2.3 *Cause of distress*—In developing removal procedures, consider the cause of distress on the removal process as it may affect the structure's integrity.

2.2.2.4 *Reuse of concrete rubble*—Refer to Chapter 5.

2.2.2.5 *Transport and deposit of waste material*—Very little of the approximately 135 million tons (123 million tonnes) of removed concrete rubble in European communities, United States, and Japan is reused. Due to the declining availability of disposal sites, recycling alternatives should be evaluated as quality aggregate sources.

2.2.3 *Report*

2.2.3.1 *Summary of scope of work*—Define purpose and limitations of preliminary investigation and findings, concrete removal work plan, safety, schedule requirements, environmental aspects, or recycling plan.

2.2.3.2 *Findings*—Describe the structure, its present condition, nature of loading and detrimental elements, original condition of the structure, materials used in construction, and practices used in constructing the structure. Photographs should be used to illustrate the conditions.

2.2.3.3 *Recommendations*—Include complete or partial demolition, salvage, removal methods, safety and environmental considerations, and further investigation or testing as required.

2.2.3.4 *Total estimated cost*—Provide cost estimates for various removal methods, partial or complete concrete removal, reuse, transportation and waste disposal, and additional inspection and testing. Other associated costs should be identified and estimated where practical, including protection of adjacent construction.

2.2.3.5 *Photos and drawings*—Use of drawings illustrating as-built, current conditions and areas of concern (for example, concrete quality, distress, loading, and utilities) is required to demonstrate the need for concrete removal, the logic for the method, and amount of removal recommended. Photographs can illustrate distress manifestations and provide documentation of existing conditions. Where possible, include some means for identifying scale, such as including a ruler or other recognized object like a pencil or coin.

2.2.3.6 *Supporting data in comprehensive form*—To support findings and recommendations, the data developed through visual examination, coring, nondestructive testing, petrography, photographs, drawings, and sketches should be arranged in a comprehensive format that can readily be followed. For example, plans could be labeled with symbols identifying where samples or photos were taken, with each sample or photo containing a brief but concise description. It is essential that the extent of damage be established, regardless of the cause. Whether concrete quality of the remaining structure is sufficient to support a sound repair should be determined.

2.2.4 *Engineering survey*—Before starting any demolition operations, an engineering survey of the structure conducted by a competent individual is required. The purpose of the survey is to determine the condition of the structure so that precautionary measures can be taken, if necessary, to prevent premature collapse or failure of any portion of the structure.

2.2.5 *Health and safety safeguards*—A number of steps should be taken to safeguard the health and safety of workers at the job site. These preparatory operations involve the overall planning of the demolition job, including the methods used to demolish the structure, the necessary equipment, and the measures to perform the work safely. Planning for demolition is as important as actually doing the work.