ACI 229R-13

Report on Controlled Low-Strength Materials

Reported by ACI Committee 229
Report on Controlled Low-Strength Materials

Copyright by the American Concrete Institute, Farmington Hills, MI. All rights reserved. This material may not be reproduced or copied, in whole or part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of ACI.

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at www.concrete.org/committees/errata.asp. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided “as is” without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

Order information: ACI documents are available in print, by download, on CD-ROM, through electronic subscription, or reprint and may be obtained by contacting ACI.

Most ACI standards and committee reports are gathered together in the annually revised ACI Manual of Concrete Practice (MCP).

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org
ISBN: 0-87031-816-0
Report on Controlled Low-Strength Materials
Reported by ACI Committee 229

Thomas A. Fox, Chair

Charles E. Pierce, Secretary

Wayne S. Adaska
Joseph A. Amon
Paul D. Brooks
Timothy S. Folks
Dean M. Golden
Brian H. Green
Morris Huffman
Frank A. Kozeliski
Rudolph N. Kraus
Leo A. Legatski
Frances A. McNeal-Page
Tarun R. Naik
Bruce W. Ramme
Michael D. Serra
Victor H. Smith
Orville R. Werner II
Peter T. Yen

Consulting members
Kurt R. Grabow
Bradley M. Klute
Elizabeth Olenbush
Harry C. Roof

Keywords: aggregates; backfill; compacted fill; controlled density fill; controlled low-strength material; flowable fill; flowable mortar; fly ash; foundation stabilization; low-density material; pipe bedding; plastic soil-cement; preformed foam; soil-cement slurry; trench backfill; unshrinkable fill; void filling.

CONTENTS

CHAPTER 1—INTRODUCTION, p. 2

CHAPTER 2—NOTATION AND DEFINITIONS, p. 2
2.1—Notation, p. 2
2.2—Definitions, p. 2

CHAPTER 3—APPLICATIONS, p. 2
3.1—General, p. 2
3.2—Backfills, p. 2
3.3—Structural fills, p. 3
3.4—Insulating and isolation fills, p. 4
3.5—Thermal-insulation-conductivity fills, p. 4
3.6—Pavement bases, p. 4
3.7—Conduit bedding, p. 4
3.8—Erosion control, p. 5
3.9—Void filling, p. 5
3.10—Nuclear facilities, p. 5
3.11—Bridge reclamation, p. 6

CHAPTER 4—MATERIALS, p. 6
4.1—General, p. 6
4.2—Portland cement, p. 6
4.3—Fly ash, p. 6
4.4—Admixtures, p. 6
4.5—Mineral admixtures and other additives, p. 6
4.6—Water, p. 6
4.7—Aggregates, p. 6
4.8—Non-aggregates, p. 6
4.9—Ponded ash or basin ash, p. 7

CHAPTER 5—PROPERTIES, p. 7
5.1—Introduction, p. 7
5.2—Plastic properties, p. 7
5.3—In-service properties, p. 9

CHAPTER 6—PROPORTIONING, p. 11
6.1—Introduction, p. 11
6.2—Materials, p. 11
6.3—General formulation, p. 11
6.4—Proportioning methods, p. 11
6.5—Evaluation, p. 12
6.6—Adjustments to proportioning, p. 12

CHAPTER 7—MIXING, TRANSPORTING, AND PLACING, p. 12
7.1—General, p. 12

ACI Committee Reports, Guides, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This document is intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. The American Concrete Institute disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom.

Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.
CHAPTER 8—QUALITY CONTROL, p. 13
8.1—General, p. 13
8.2—Sampling of CLSM, p. 14
8.3—Consistency and unit weight, p. 14
8.4—Strength tests, p. 14

CHAPTER 9—LOW-DENSITY CLSM USING PREFORMED FOAM, p. 14
9.1—General, p. 14
9.2—Applications, p. 15
9.3—Materials, p. 16
9.4—Physical properties, p. 17
9.5—Proportioning, p. 18
9.6—Construction, p. 18
9.7—Quality control, p. 19

CHAPTER 10—REFERENCES, p. 19

CHAPTER 1—INTRODUCTION
Controlled low-strength material (CLSM) is a self-consolidating cementitious material used primarily as a backfill as an alternative to compacted fill. Terms used to describe this material include flowable fill, controlled density fill, flowable mortar, plastic soil-cement, and soil-cement slurries.

CLSM is a mixture intended to result in a compressive strength of 1200 psi (8.3 MPa) or less. Most CLSM applications require unconfined compressive strengths of 300 psi (2.1 MPa) or less. Long-term strengths (90 to 180 days) should be targeted to be less than 100 psi (0.7 MPa) for excavation with hand tools. Lower-strength requirements are necessary to allow for future excavation of CLSM.

The term “CLSM” is used to describe a family of mixtures for various applications. CLSM mixtures can also be developed as anticorrosion fills, electrically conductive materials, low-permeability fills, thermal fills, and durable pavement bases. For example, the upper limit of 1200 psi (8.3 MPa) allows use of this material for applications where future excavation is unlikely, such as structural fill under buildings. CLSM is a self-consolidated backfill or fill material that is used in place of compacted earth fill and should not be considered as a type of low-strength concrete. Generally, CLSM mixtures are not designed to resist freezing and thawing, abrasive or erosive forces, or aggressive chemicals. Using recycled materials can maximize recycled material content for sustainable construction. Nonstandard materials that have been tested and found to satisfy the intended application can be used to produce CLSM. Chapter 9 describes low-density (LD) CLSM produced using preformed foam as part of the mixture proportioning. Using preformed foam in LD-CLSM mixtures allows these materials to be produced having unit weights lower than those of typical CLSM. The distinctive properties of LD-CLSM and procedures for mixing it are discussed in Chapter 9.

CLSM typically requires no consolidation or special curing procedures to achieve desired strength and should not be confused with compacted soil-cement, as reported in ACI 230.1R. Long-term compressive strengths for compacted soil-cement often exceed the 1200 psi (8.3 MPa) maximum limit established for CLSM.

Long-term compressive strengths of 50 to 300 psi (0.3 to 2.1 MPa) are low when compared with conventional concrete. In terms of allowable bearing pressure, however—which is a common criterion for measuring the capacity of a soil to support a load—50 to 100 psi (0.3 to 0.7 MPa) strength is equivalent to a well-compacted fill.

Although CLSM generally costs more per cubic yard (cubic meter) than most soil or granular backfill materials, its many advantages often result in lower in-place costs. In fact, for some applications, CLSM is the only reasonable backfill method available (Adaska 1994, 1997; Ramme 1997). Table 1 lists a number of advantages to using CLSM (Smith 1991).

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

\[ E = \text{modulus of elasticity, psi (MPa)} \]

\[ f' = 28\text{-day specified compressive strength of concrete, psi (kPa)} \]

\[ k = \text{coefficient of permeability, in.}/\text{s} (\text{mm}/\text{s}) \]

\[ RE = \text{removability modulus} \]

\[ W = \text{dry mass density, lb/ft}^3 (\text{kg/m}^3) \]

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, “ACI Concrete Terminology,” http://terminology.concrete.org.

CHAPTER 3—APPLICATIONS

3.1—General

The primary application of CLSM is as a structural fill or backfill in place of compacted soil. Because CLSM needs minimal consolidation and can be designed to be fluid, it is useful in areas where placing and compacting fill is difficult. If future excavation is anticipated, the maximum long-term compressive strength should generally not exceed 100 psi (0.7 MPa). The following applications present a range of uses for CLSM (Sullivan 1997).

3.2—Backfills

CLSM can be readily placed into a trench, hole, or other cavity (Fig. 3.2a and 3.2b). Compaction or consolidation equipment is not required; hence, trench width or excavation size can be reduced. Granular or site-excavated backfill, even if compacted or consolidated in the required layer thickness, cannot achieve the uniformity and density of CLSM (Sullivan 1997).

When backfilling against retaining walls, consideration should be given to lateral pressures exerted on the wall by flowable CLSM. Where lateral fluid pressure is a concern,