

Report on Grouting between Foundations and Bases for Support of Equipment and Machinery

Reported by ACI Committee 351



American Concrete Institute®



American Concrete Institute®
Advancing concrete knowledge

First Printing
March 2012

Report on Grouting between Foundations and Bases for Support of Equipment and Machinery

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 978-0-87031-758-3

AVA Documents
Document Sharing Hub

Report on Grouting between Foundations and Bases for Support of Equipment and Machinery

Reported by ACI Committee 351

David Kerins*, Chair

Mukti L. Das*, Secretary

Omesh B. Abhat
Richard P. Bohan
William L. Bounds
William D. Brant*
Michael M. Chehab
Shu-Jin Fang
Fred R. Goodwin
Shraddhakar Harsh
Erick N. Larson
Robert R. McGlohn*
Carl A. Nelson
Richard O'Malley*

Michael A. Paipal*
Ira W. Pearce
Charlie L. Rowan*
William E. Rushing Jr.
Yasser Salem*
Larry W. Schulze
Philip A. Smith*†
Widianto
F. Alan Wiley
Sheng-Chi Wu*

*Members of Subcommittee 351.1 who prepared this report.

†Subcommittee 351.1 Chair.

This report provides an overview of current practices of grouting for support of equipment and machinery. Materials and installation methods are described for epoxy and cementitious-based grouts used as the load-transfer material between equipment bases and their foundations.

Characteristics of placed material, test methods for forecasting long-term performance, qualification of grout materials, foundation design and detailing considerations, and installation procedures are described.

Keywords: bleeding; consistency tests; curing; durability; epoxy grout; cementitious-based grout; equipment grout; formwork (construction); foundations; grout; hydraulic cement grout; inspection; machinery grout; mixing; placing; sand-cement grout; stiffness; strength; tests; volume change.

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.

CONTENTS

Chapter 1—Scope, p. 2

1.1—Scope

Chapter 2—Definitions, p. 2

2.1—Definitions

Chapter 3—Grout, p. 2

3.1—Requirements

3.2—Overview of nonshrink grouts

3.3—Selection

3.4—Common issues

Chapter 4—Nonshrink cementitious grouts, p. 5

4.1—Introduction

4.2—Properties

4.3—Material requirements

4.4—Testing

ACI 351.1R-12 supersedes ACI 351.1R-99 and was adopted and published March 2012.

Copyright © 2012, American Concrete Institute.

All rights reserved including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by electronic or mechanical device, printed, written, or oral, or recording for sound or visual reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietor.

Chapter 5—Nonshrink epoxy grouts, p. 10

- 5.1—Introduction
- 5.2—Properties
- 5.3—Material requirements
- 5.4—Testing

Chapter 6—Design, detailing, and construction, p. 14

- 6.1—Design and detailing considerations for grout
- 6.2—Preparation for grouting
- 6.3—Grout mixing and placing
- 6.4—Curing and protection
- 6.5—Quality control/assurance

Chapter 7—References, p. 21

- 7.1—Referenced standards and reports

CHAPTER 1—SCOPE**1.1—Scope**

This report provides an overview of current practices for grouting to support equipment and machinery. Recommendations are provided for those portions of the grouting operation where a consensus could be developed among knowledgeable manufacturers and users. Various approaches are outlined for areas where opinions differ. Many statements and much of the information contained in this report are based on published manufacturers' data and observations and practical experience by technical representatives and users. There is little current published research available at this time, but the information in this report is the most current information available. This report describes materials and installation methods for grouts used as load-transfer material between machine or equipment bases and their foundations. Characteristics of the placed material, test methods for forecasting their long-term performance, and installation procedures are included. The information may also be appropriate for other types of applications where filling of the space between load-carrying members is required, such as under column baseplates or in joints between precast concrete elements.

Machinery and equipment that have precise tolerances for alignment or require uniform support cannot be placed directly on finished concrete surfaces. Both the concrete surface and the machine base have irregularities that result in alignment difficulties and bearing load concentrations. For this reason, machine bases or soleplates are aligned and leveled by shimming or other means, and the resulting space between the machine base and the foundation is filled with a load-transfer grout material. The load-transfer grout materials most frequently used are nonshrink cementitious grouts and nonshrink epoxy grouts.

CHAPTER 2—DEFINITIONS

ACI provides a comprehensive list of definitions through an online resource "ACI Concrete Terminology" (<http://terminology.concrete.org>). Definitions provided herein complement that resource.

2.1—Definitions

aggregate reduction—reducing the normal four bags of aggregate used with most commercial epoxy grout mixtures to two or three bags.

amine blush—cloudy finish to the surface of an epoxy grout that can inhibit bonding of subsequent applications.

chock—wedge or block for steadying a body and holding it motionless.

cure time—time after setting in which chemical and physical changes in the grout produces long-term durability strength and serviceability.

flowable grout—a cementitious grout consistency with a flow of 125 to 145 by the flow test in accordance with the applicable provisions of the ASTM C1437-07 test method; the flow expressed as a percentage of the original base diameter after five drops of the flow table in 3 seconds.

fluid grout—a cementitious grout consistency with a time of efflux of 10 to 30 seconds when tested by the flow cone procedure of the ASTM C939-10 test method.

grout shoulder—the portion of the grout that extends beyond the base plate toward the edge of the concrete foundation.

plastic grout—a cementitious grout consistency with a flow of 100 to 125 by the flow test in accordance with the applicable provisions of ASTM C1437-07 test method; the flow calculated after five drops of the flow table in 3 seconds.

working time—time in which the grout can be placed without having a detrimental effect on the strength and serviceability of the grout.

CHAPTER 3—GROUT**3.1—Requirements**

After placement and hardening in the space between a machine or equipment base and the foundation, the grout is expected to perform one of the following functions:

- Permanently maintain the original level and alignment of the machinery or equipment and transfer all loads to the foundation when shims and other temporary positioning devices are removed.
- Act together with shims or other alignment devices in the transfer of loads to the foundation.
- Provide only stability support or corrosion protection for shims or other alignment devices that are designed to transfer all loads to the foundation.

The most important requirement for a grout intended to transfer loads to the foundation is the volume-change characteristics that result in complete and permanent filling of the space. Plain grouts consisting of cement, aggregate, and water do not have these characteristics. Other properties of the grout, such as consistency, strength, chemical resistance, temperature resistance, and compatibility with the operating environment are also important. These properties, however, are obtained more easily than the necessary volume-change characteristics.

For most applications, the space between the foundation and the machinery or equipment base can be filled by placing a flowable grout into the space. To maintain

permanent contact with the plate, formulate a grout using special additives. A plain sand-cement grout with a flowable consistency could be placed in the space and may develop adequate strength; however, after placement, the sand-cement grout will lose contact with the plate because of settlement, shrinkage, and bleeding or drying shrinkage. The result will be an incompletely filled space, leaving the equipment resting primarily or completely on the shims or other alignment device.

3.1.1 Volume change characteristics (nonshrink grout)—When dealing with nonshrink grout, define the time at which the initial volume measurement is made. Was it made immediately after the mixing of the grout or after the grout had hardened? This determination of when to make the first measurement depends on the function of the product and its intended use. The function of a nonshrink grout, whether cementitious or epoxy, is to fill the void between the base plate and the foundation completely and permanently without shrinking or separating from either, and to transfer all loads from the base to the concrete foundation (or maintain precise alignment). These requirements demand that the initial measurement be made at the time of the grout placement under the base plate.

To better understand the nonshrink properties of a grout or support for equipment and machinery, a thorough study of ASTM C1107/C1107M-11 should be made. ASTM C1107/C1107M-11 provides the test methodology for the nonshrink characteristics and compressive strength of nonshrink grout. Epoxy grout is briefly discussed in Section 3.2, and Chapter 5 discusses nonshrink epoxy grout.

There are three test methods that are referenced in ASTM C1107/C1107M-11. The first is ASTM C1090-10, "Standard Test Method for Measuring Change in Height of Cylindrical Specimens from Hydraulic-Cement Grout." This procedure measures the height change (volume change) from the time of placement until the grout has hardened and has been put into service.

The second test method is ASTM C827/C827M-08, "Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens of Cementitious Mixtures." This test method measures the height change (volume change) from the time of placement while the grout is still in the plastic state and does not address hardened state expansion or shrinkage.

The third test method is ASTM C109/C109M-11, "Standard Test Method for Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimen)." This test method was designed for testing portland cement mortars made with a specially graded sand. These mortars are extremely stiff and are dry-pack in nature; whereas nonshrink grout varies in consistency from dry-pack to fluid (self-leveling). This test method does not address the variations in consistency. When fabricating procedures for 2 x 2 in. (50 x 50 mm) cubes are used as outlined in this procedure for highly flowable grouts, segregation will occur, indicating a strength that is far below the actual strength of the grout under testing.

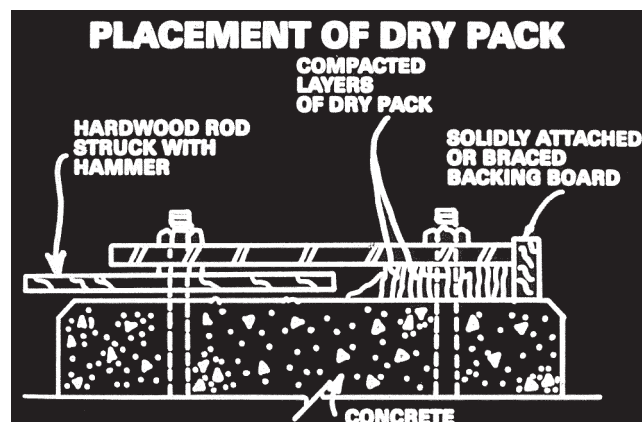


Fig. 3.2.1—Dry-pack placement.

3.2—Overview of nonshrink grouts

Several placement methods and materials have evolved in an attempt to achieve the necessary volume-change characteristics for a material that can be placed between a machine base and the foundation that developed.

3.2.1 Dry-pack (damp-pack)—One of the first methods for permanently filling a space was to force (or dry-pack) a damp, cohesive mixture of sand and cement into the space. The mixture contains only enough water for compaction and hydration but not enough to permit settlement of the grout's constituents. The grout mixture has the consistency of damp sand and is placed in lifts of approximately 1/2 to 3/4 in. (12 to 20 mm) in thickness. Each lift is placed between the base plate and the substrate concrete using a flat-faced wooden or metal tool. The end of the tool not in contact with the grout may be struck with a hammer to increase compaction (Fig. 3.2.1).

This procedure produces a bearing surface that is filled with voids. In most cases, approximately 75 to 80% of the total bearing surface is supporting the load. This low percent of bearing can result in point loading in the bearing area and may cause a foundation failure.

Dry-pack grout as placed produces less-than-optimal bearing, but is a true nonshrink system. The low water content prevents settling in the plastic state, and the compaction between the base plate and foundation during placement produces a positive pressure between the foundation and the base plate and prevents the grout from shrinking during drying in the hardened state.

If properly placed, dry-pack grout is acceptable. It is difficult, however (and in many cases impossible), to achieve proper placement. Dry-packing requires an almost unobstructed space and must be installed by skilled workers.

3.2.2 Gaseous grouts

3.2.2.1 Grouts with aluminum powder—Another early method for making nonshrink grout was to add a small amount (usually 3 to 5 g per 90 lb [44 kg] of cement) of aluminum powder to a plastic or flowable grout. The aluminum powder reacts with the soluble alkalies in the cement to form hydrogen gas. The gas formation causes the grout to increase in volume only while in the plastic state. The expansion is difficult to control due to the difficulty

of blending very small quantities of aluminum powder into the mixture and the sensitivity of the chemical reaction to temperature and soluble alkalis in the mixture. The hydrogen gas is highly compressible and can only produce expansion while the grout is in the plastic state and cannot create a positive pressure between the base plate and the foundation. Therefore, it cannot produce expansion in the hardened state. Grouts that produce gas as their only method of expansion will ultimately shrink as the grout hardens. Aluminum powder grouts are discussed further in Chapter 4. Other grouts with some metallic additives such as magnesium powders have also been used.

3.2.2.2 Air-release system—In the late 1960s, a grout was developed that used specially processed fine carbon. The carbon particles release adsorbed air on contact with the mixing water and cause an increase in volume while the grout is in the plastic state. The material is less temperature-sensitive than aluminum powder and insensitive to the alkali content of the cement used. The air-release system is discussed further in Chapter 4.

3.2.3 Grouts with oxidizing iron aggregate—In the 1930s, an admixture was introduced that contained a graded iron aggregate combined with a water-reducing retarder, an oxidant (or catalyst), and possibly other chemicals. Sufficient volume increase to compensate for settlement shrinkage is caused by the oxidation of the metallic aggregate during the first few days after hardening when blended in the field with cement, fine aggregate, and water. The advantage of metallic catalyzed grout over that of dry-pack grout is that the consistency is more placeable than that of dry-pack grout. Metallic catalyzed grouts have a plastic consistency that can be placed with a lower void ratio than that of a dry-pack grout. This will produce a grout pad with a greater bearing capacity (load-carrying capability). Metal oxidizing grouts are discussed further in Chapter 4.

Metallic catalyzed grout may initially show some plastic shrinkage, but if properly designed, the oxidation of the iron will overcome the initial plastic shrinkage. The expansion that occurs can and will produce a pressure between the underside of the base plate and the foundation. This pressure (expansive force) will offset any drying shrinkage that can occur at a later time.

This is old technology and is generally not in use today. The principal reason is unsightly rust stains on the shoulders of the grout, and the unconfined areas of the grout cause the shoulder of the grout to break up even when the grout that is confined under the base plate is sound.

3.2.4 Grouts with expansive cements—In the late 1960s, grouts were developed that use a system or combination of expansive and other hydraulic cements and additives to compensate for shrinkage. During hydration of these systems, reactions between aluminates and sulfates occur to produce ettringite. Because ettringite has a greater volume than the reacting solid ingredients, the volume of the grout increases. The reaction occurs from the moment mixing water is added and continues at a decreasing rate until some time after the grout hardens. If properly proportioned, it will compensate for shrinkage by inducing a positive pressure

between the base plate and the foundation. This type of grout has been formulated in both metallic and nonmetallic grouts and, when done properly, will meet ASTM C1107/C1107M-11 requirements. Grouts with expansive cement systems are discussed further in Chapter 4.

3.2.5 Epoxy grout—Since the late 1950s, epoxy grouts have been used under machine and equipment bases. Epoxy grouts are usually two-component epoxy adhesive systems mixed with oven-dry aggregate. These epoxy grouts are characterized by high strength and adhesion properties. They are also resistant to attack by many chemicals and are highly resistant to shock and vibratory loads. Epoxy grouts have traditionally shown linear shrinkage; however, manufacturers have various methods to reduce or eliminate shrinkage. Epoxy grouts, when in their development stages in the mid 1950s, were primarily commercially available epoxy resin systems extended with graded silica aggregate. Such mixtures were quite strong but also brittle, resulting in cracking. They were also difficult to place and were inconsistent in performance.

Modifications were made to improve and lessen the tendency to crack. The modifications resulted in formulations with higher creep values. Modern epoxy mixtures are a compromise between crack and creep reduction.

Epoxy grouts do not have a standard test method developed for the purpose of certification as a nonshrink grout. ASTM C1107/C1107M-11 is a standard specification for cementitious grouts for the purpose of certification as a nonshrink grout.

3.3—Selection

3.3.1 General—Both cementitious and epoxy grouts have limitations that must be considered when specifying a grout for a specific project. Two considerations that must be decided on are: 1) the type of load that will be applied to the base plate; and 2) the operating temperature at which the grout must perform. Generally speaking, epoxy grouts can perform at temperatures below 130°F (55°C), whereas cementitious grout can operate at temperatures up to 400°F (200°C).

Many of today's commercially available grouts are well-balanced, preproportioned formulations that provide excellent machine stability with minimal cracking or creep-related problems. The use of preblended, prepackaged grouts usually results in more consistent and predictable performance than can be obtained with field-proportioned epoxy grout. Most manufacturers of preblended grout have quality control programs that result in the production of a uniform product.

The following are general categories in which cementitious and epoxy grouts should be considered. Cementitious grouts are the most versatile as far as consistency, ranging from dry-pack to fluid. A cementitious grout having a fluid consistency will pass through an ASTM C939-10 flow cone in 30 seconds or less. This cementitious grout would be easier to place compared to an epoxy grout.

3.3.2 Static loading—Cementitious grouts are almost always specified for static or non-dynamically loaded equip-

ment foundation systems. Cementitious grouts generally perform better than epoxy grouts in static load systems because cementitious grouts have a lower creep factor.

3.3.3 Dynamic loading—Dynamic systems relate to two different types. Dynamic loads produced by electric motors or other rotating machines (sinusoidal waveform) are generally less harsh than impacting load produced by reciprocating equipment. Cyclic dynamic loads produce horizontal, vertical uplifting, and downward forces on the base plate and grout pad. This can be addressed by either cementitious or epoxy grouts, depending on the size of the load. When a grout is being specified for dynamic loading systems, take into consideration the severity of the shock load to the base plate and, ultimately, to the grout. Epoxy grouts outperform cementitious grouts in dynamic systems because epoxy grouts are less rigid.

3.4—Common issues

Nonshrink grouts are designed to be confined between the base plate and the foundation. Some manufacturers of nonshrink grout allow their products to be used as a patching mortar or overlay. Nonshrink grout used in this way is not addressed in this document. Before using a nonshrink grout as a patching mortar or overlay, the manufacturer of that product should give approval for their application.

One of the major concerns when using a nonshrink grout is hairline cracks in the shoulder of the grout. In most cases, these hairline cracks are cosmetic in nature and do not affect the performance of the grout under the base plate unless located outdoors and subject to weather. If the grout is outside, a good fix is to seal the cracks to prevent water infiltration. A closer examination of these cracks is required to determine if they extend through the full depth of the grout. This could indicate a foundation failure that would require major repair. Cosmetic hairline cracks can be greatly reduced by requiring the grout shoulder to extend no more than 2 to 3 in. (50 to 75 mm) beyond the base plate.

Most designers of base plates assume that the load is transferred uniformly across the base plate. When shims are left in place, the grouts will, in most cases, act together with shims in the load transfer. The proportion of the load carried by the grout, however, depends on many variables such as size, number, and location of shims, and the volume-change characteristics of the grout. Therefore, the participation of the grout cannot be determined accurately. The loads on the supported equipment and the supporting concrete will not be uniform and could result in overstressing of the equipment base plate on the concrete.

Avoid welding to a base plate after grout installation to prevent thermal expansion of the base plate that could result in spalling or cracking of the grout or excessive stress in the anchors.

CHAPTER 4—NONSHRINK CEMENTITIOUS GROUTS

4.1—Introduction

This chapter provides an overview of current practices regarding the use of cementitious grouts to support equipment and machinery.

4.2—Properties

4.2.1 General—The performance of a grout under a machine or equipment base depends on the properties of the grout in both the plastic and hardened states. The most important properties are workability, volume change, strength, stiffness, and durability. The following sections discuss these properties of cementitious grouts and their effect on grout performance.

Cementitious grouts have properties in the plastic and hardened states that make them acceptable for most applications. They are suitable for transfer of large static compressive loads and transfer of many dynamic loads. They are not recommended for dynamic equipment that exerts both vertical and horizontal loads, such as reciprocating gas compressors.

4.2.2 Workability—The workability of a grout while in the plastic state must be adequate to allow placement of the grout under a baseplate. This property is related primarily to the consistency of the grout and its ability to flow and maintain these flow characteristics with time. For example, a non-flowable grout may require rodding to aid in placement under a baseplate, but the grout may still be workable if it has a long working time. On the other hand, a fluid grout may stiffen rapidly but require only a short time to be fully placed. Both of these grouts could have acceptable workability.

4.2.3 Volume change—Except for dry-pack, plain grouts that are mixtures of only cement, aggregate, and water do not have the volume-change characteristics necessary for machine-base grout. After being placed under a plate, a plain grout will generally exhibit significant bleeding, settlement, and drying shrinkage. For use as a machine-base grout, admixtures or special cement systems should be used to compensate for, or prevent, bleeding, settlement, and drying shrinkage.

4.2.3.1 Cementitious grouts with gas generation admixtures—Several admixtures are available to react with the ingredients in fresh grout to generate one or more gases. The gas generation causes the grout to increase in volume while plastic. The expansion stops when the capability for gas liberation is exhausted or the grout has hardened sufficiently to restrain the expansion. The most common gas-generating material used is aluminum powder, which releases hydrogen. If the proper additive dosage is used, it will counteract settlement shrinkage and allow the grout to harden in contact with the baseplate. The expansion that is produced is somewhat greater than would be needed to prevent shrinkage while grout is in plastic state. Because the grout is vertically confined, expansion in excess of settlement shrinkage extends the grout laterally.

Where aluminum powder is used to generate gas, the amount added to a batch is small. Therefore, to obtain uniform dispersion in the mixture, preblend the aluminum powder with the dry cement or use a commercial, preblended grout.

The total expansion of a grout with aluminum powder additive depends on several properties of the grout during various stages of hardening. The rate of gas generation is affected by the temperature of the grout. The total expansion

of the grout is affected by the temperature, the soluble alkali content of the mixed grout, and the rate of hardening of the grout. The restraint provided to the grout as it develops strength limits the amount of expansion.

4.2.3.2 Cementitious grouts with air-release admixtures—Several admixtures are available to react with water to release air. The released air causes the grout to increase in volume while plastic. The expansion stops when the capability for releasing air is exhausted or the grout has hardened sufficiently to restrain the expansion. The most common air-releasing material used is a fine carbon. If the proper dosage is used, it will counteract drying shrinkage and allow the grout to harden in contact with the baseplate. The expansion that is produced is somewhat greater than would be needed to prevent shrinkage while grout is in plastic state. Because the grout is vertically confined, expansion in excess of shrinkage extends the grout laterally. Unlike gas-generating grouts, special methods are not needed for blending fine carbon-based grouts because a much higher portion of admixture is used. Fine carbon admixtures are less sensitive than aluminum powder to temperature and are insensitive to the chemistry of the mixture.

4.2.3.3 Cementitious grouts with metal oxidation admixtures—The addition of metal particles and an oxidant will not prevent drying shrinkage but is designed to cause a compensating increase in volume in the hardened state. The expansion occurs because the oxidation products have a greater volume than the metal particles. The reaction begins after the addition of water and the expansion gradually ceases due to the combination of rigid vertical confinement, the hardening and strength development of the cement matrix, and the diminishing supply of moisture and oxygen.

Machine-base grouts that use this mechanism are usually preblended, which reduces the chance of proportioning errors. Such proportioning errors could affect the rate of expansion. Also, grouts using this mechanism should be used only under rigid bolted confinement. Unconfined areas such as exposed shoulders will disintegrate.

The equipment baseplate should be rigid to withstand the force exerted on the base by the expansion of the grout so that the alignment of the equipment is not affected. These grouts should not be used on equipment subject to thermal movement, such as turbines or compressors, or be placed in contact with post-tensioned or prestressed cables, rods, or bolts due to the corrosive potential of the oxidate.

4.2.3.4 Ettringite formation—The use of expansive cements in grout will result in the expansive formation of ettringite during the plastic and hardened states. If properly formulated, the resulting expansion will compensate for shrinkage and may cause small compressive stresses to develop in grout under confinement.

Machine-base grouts using the expansive cements covered by ASTM C845-04 do not have sufficient expansion unless additives are used to reduce settlement and provide expansion during the plastic state. The standard expansive cements are formulated to compensate for drying shrinkage in ground floor slabs. Drying shrinkage is generally on the order of

0.05%, whereas settlement shrinkage in grout is generally on the order of 1.0%.

As for most types of grout, those that are based on expansive cements may be affected by temperature, water content, and method of curing. Generally, when used for machine bases, expansive cement grouts use other mechanisms, such as thickening agents, to limit the settlement shrinkage to a small enough value that ettringite formation required to overcome it will not cause disruption of the hardened grout.

4.2.3.5 Other mechanisms—Some preblended machine-base grouts are based on proprietary mechanisms for compensating for settlement shrinkage. Several preblended grouts minimize or eliminate shrinkage by using water reducers, combinations of hydraulic cements, thickening agents, or all three additives.

4.2.4 Strength—The strength of a grout must be sufficient to transfer all loads to the foundation. The compressive loads result primarily from the weight of the machine. They may also, however, be due to anchor bolt tensioning and static and dynamic forces resulting from equipment operation. Typically, compressive strengths of cementitious grouts at 28 days are between 5000 and 8000 psi (35 and 55 MPa). Because the bond strength of cementitious grout to steel is relatively low, the grout is not generally used to transfer tensile loads to the foundation.

The compressive strength of most cementitious grouts develops more rapidly than conventional concrete. For most installations using cementitious grouts, the equipment can be placed in service in 3 to 7 days, depending on the design strength requirements and the strength-gain characteristics of the grout, which is mostly temperature driven. If high bearing loads are expected, however, longer waiting periods are required.

4.2.5 Elastic and inelastic properties—The modulus of elasticity of cementitious grouts is typically larger than that of the underlying concrete because of their greater compressive strength. The typical modulus is 3000 to 5000 ksi (20 to 35 GPa).

The creep of cementitious grouts is approximately the same as concrete. The deformation of grout is usually not significant due to the relative thickness of the grout as compared to the foundation. The load-deformation characteristics of hydraulic-cement grouts are not significantly affected by temperatures less than 400°F (200°C).

4.2.6 Durability—Most cementitious grouts have good resistance to freezing and thawing because of their high strength and impermeability. Their resistance to chemicals is usually the same as that of concrete. If adjacent concrete foundations, columns, or floors must be protected from chemical attack, exposed grout shoulders should be given similar protection.

Air entrainment is unnecessary, as the grout is sandwiched between the foundation and the baseplate that protects the grout from water intrusion and the expansive damage that will occur during freezing and thawing.