A Professional's Handbook on Grouting and Concrete Repair

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A Professional's Guide to Grouting and Concrete Repair for:

Architects
Contractors
Engineers
Specifiers
Owners

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PAGE

PREFACE

This handbook, the first of its kind in the industry, was originally published by FIVE STAR PRODUCTS, INC. in 1981 as an aid to owners, engineers, architects, specifiers and contractors involved in the selection, specification and use of nonshrink grouts and concrete repair materials. This latest version is the result of significant industry changes that have occurred since its last publication.

The American Society for Testing and Materials (ASTM), the Corp of Engineers and the American Concrete Institute (ACI), are key organizations responsible for establishing standards and specifications for nonshrink grout and concrete repair. The beneficial work of these organizations is important to industry. Reports, such as "Grouting between Foundations for the Support of Equipment and Machinery" (ACI 351.1R-99), provide an excellent overview for evaluating and selecting nonshrink grouts based on the different expansion mechanisms used by grout manufacturers. Because some of these expansion mechanisms have a significant effect on the successful use of grout products in the field, ACI 351.1R-99 is an important tool for owners, engineers, architects, specifiers and contractors.

However, the nature of some committees within industry organizations is to generate standards and practices around consensus. This is particularly evident with respect to nonshrink grout. Because of this, the term "nonshrink" is one that has often been used loosely and not clearly defined – certain "nonshrink" grouts available in the marketplace actually do exhibit shrinkage when tested by ASTM test methods. Because of this, engineers, architects, specifiers and owners must specify exact performance properties with respect to vertical height change characteristics of grouts, and contractors should understand the importance of the standards and specifications they are given. A successful grout job is the joint responsibility of the engineer, the contractor, *and* the manufacturer. The generic use of the term nonshrink in standards and specifications is insufficient. This handbook, in conjunction with ACI and ASTM standards, can guide the strengthening and use of product specifications to ensure proper selection, specification, and use of precision nonshrink grouts and concrete repair materials.

We wish to acknowledge the assistance of all the owners, engineers, architects and contractors who were of major assistance to us in the development of this Handbook, along with the very knowledgeable and competent engineering and field personnel of Five Star Products, Inc.

GROUTING

INTRODUCTION

A. This section deals with precision nonshrink grout. A precision nonshrink grout does not exhibit any plastic or hardened vertical shrinkage at any time. Precision nonshrink cementitious grouts are designed for static or light dynamic loading, or for high temperature exposure. Precision nonshrink epoxy grouts are designed for heavy dynamic loading from vibration or impact or for applications requiring good chemical resistance.

B. The proper selection and specification of precision nonshrink grout is extremely important. Changes in equipment and machinery packaging, along with the advent of tighter alignment tolerances, have made grout selection a critical issue. Grout cost is incidental when compared to equipment and machinery costs. Developing strong specifications *and* enforcing them, helps to ensure initial, and long term success in the field.

C. PRECISION NONSHRINK CEMENTITIOUS GROUT

1. According to the American Concrete Institute: "The most important requirement for a grout that is intended to transfer loads to a foundation is that it have volume change characteristics that result in **complete** and **permanent** filling of the space." Complete and permanent filling of a space is achieved through the proper selection and specification of a **precision nonshrink grout.** This can be accomplished through the use of ASTM standards developed for evaluating height change characteristics of precision nonshrink cementitious grout:

- **a. ASTM C 827 –** Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens from Cementitious Mixtures
- **b. ASTM C 1090 –** Test Method for Measuring Change in Height of Cylindrical Specimens for Hydraulic-Cement Grout
- **c. ASTM C 1107 –** Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)

2. ASTM C 827 is a test method that evaluates the vertical height change characteristics of nonshrink grout in the plastic state (prior to hardening) where up to 90% of shrinkage can occur. Because of this, ASTM C 827 has been widely and successfully used throughout the industry and should be the starting point for any precision nonshrink grout specification.

3. In 2005, ASTM C 1107 was revised to where specific grades of nonshrink grout (Grades A,B and C) are no longer specified within the standard. Due to this revision, a precision nonshrink grout can no longer be specified using this test method. While ASTM C 1107 does set maximum height change requirements in the plastic state when tested in accordance with ASTM C 827 (4.0%), the standard **no longer sets a minimum requirement for height change in the plastic state.** Therefore, a grout can now exhibit shrinkage in the plastic state and still meet the requirements of ASTM C 1107.

   Due to this revision, the use of ASTM C 827 in any nonshrink grout specification is critical. The specifier must not only reference ASTM C 827, but also set minimum and maximum height change values. Typical values range from 1% (minimum) to 4% (maximum).

4. **All Five Star Precision Nonshrink Cementitious Grouts exhibit no shrinkage at any time (0.0%) when tested in accordance with ASTM C 827 and meet the current version of ASTM C 1107.**

5. Once the issue of height change has been addressed and clarified, other physical properties including flow, working time, versatility, and strength development should be considered. Other special requirements for some projects may include issues pertaining to cement chemistry, such as sulfate resistance, very high temperature resistance (up to 2400°F), or cold weather strength development. No **single** type of grout can address every requirement. **Five Star Products, Inc. manufactures several different precision nonshrink cementitious grouts for both normal and highly specialized applications.**

6. **Air Release**

   1. Cementitious grouts usually contain hydraulic cement, sand (aggregate) and other additives to adjust rheology, working time, strength, and compensate for shrinkage. Additives to compensate for shrinkage include oxidizing iron aggregate, metallic powders (aluminum), along with various types of expansive cements. In the 1960s, U.S. Grout Corp., now known as Five Star Products, Inc. developed and introduced an Air Release System – a major breakthrough in grouting technology. Air Release grouts exhibit controlled expansion prior to hardening and are dimensionally stable in the hardened state.

   2. The Air Release mechanism offers distinct advantages over other expansion mechanisms and results in a consistent high performance grout regardless of job site conditions. **It provides the same height change characteristics at 40°F as it does at 90°F, something aluminum powder-based grouts cannot achieve. Its volume change is independent of moisture availability, something the expansive cement-based and metallic grouts cannot achieve.**

D. PRECISION NONSHRINK EPOXY GROUT

1. Since their inception, epoxy grouts have been promoted as "nonshrink" or evidencing "negligible" shrinkage. Test methods supposedly verifying nonshrink performance date back to the early 1960s, but it is now apparent that these methods are inadequate for epoxy grouts because they do not measure vertical height change. A modification of **ASTM C 827** (Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens from Cementitious Mixtures), which has proven so successful for evaluating nonshrink cementitious grouts, is now being used for epoxy grouts. It shows that **most epoxy grouts can exhibit even greater vertical shrinkage** than the nonprecision cement-based grouts. Loss of Effective Bearing Area (EBA) and failures of epoxy grouts can be directly correlated with plastic shrinkage (vertical height change).
2. **Five Star Products, Inc.** was the first manufacturer to use **ASTM C 827** to demonstrate positive expansion in precision nonshrink epoxy grout. Since no other standards are available for measuring the vertical shrinkage of epoxy grout, specifiers should use **ASTM C 827 (modified)** in evaluating the nonshrink properties of any epoxy grout.
3. Epoxy grouts must be prepackaged, premeasured systems in order to avoid costly failures. Each epoxy system has a unique viscosity requiring a blended aggregate tailored to that system. Using an aggregate that has not been carefully selected invites segregation, poor flow, foaming or frothing, which leads to poor EBA. Field purchasing of aggregates should be avoided since it is impossible to properly match aggregates to the epoxy system without experienced formulators and specialized laboratory facilities. In a field-proportioned system, attempts at measuring may result in improper ratios of all the epoxy components. This can result in a spongy resinous system that will be unable to support the design load.
4. Compared to precision nonshrink cementitious grouts, precision nonshrink epoxy grouts are higher priced, but they have superior properties. When one or more of the following properties are required, use a precision nonshrink epoxy grout.

    a. Proper Support of Equipment
    b. Better Chemical Resistance
    c. Better Dynamic Load Resistance
    d. Higher Compressive Strength
    e. Higher Flexural Strength
    f. Higher Tensile Strength
    g. Higher Bond Strength

CHAPTER 1

SELECTING A CEMENTITIOUS NONSHRINK GROUT

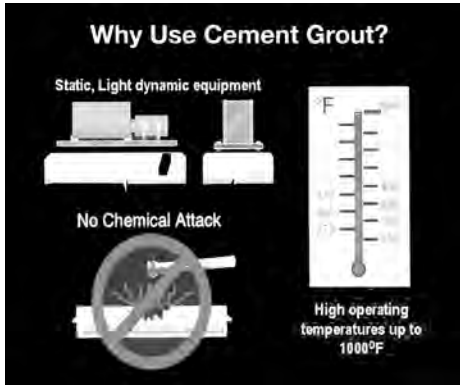
A precision nonshrink grout does not shrink in the plastic state or hardened state. Manufacturers incorporate various additives, including aluminum powders, expansive cements, and other materials, into grout products in an attempt to achieve this.

Aluminum powder-based grout is a common type of cementitious grout. Aluminum powders are often found in "construction grade" grouts. According to ACI in their Committee 351.1R-99 Report; **"Grouting Between Foundations for Support of Equipment and Machinery"**, aluminum powder reacts chemically with the soluble alkalis in the cement to form hydrogen gas. The release of this gas provides expansion of the grout in the plastic state. However, according to ACI, and as is well known in the industry, this expansion is difficult to control because only a very small amount of aluminum powder is used, and expansion depends on the job site temperature as well as on the chemical reaction between the aluminum powder and soluble alkalis. Colder temperatures may slow or stop the reaction, resulting in minimal or no expansion and loss of EBA. Higher temperatures may cause the reaction to occur too quickly, and not allow the grout to settle into place properly before expansion occurs, again, resulting in loss of EBA.

The difficulty for the engineer or specifier is that grout manufacturers using metallic or aluminum powder in their products do not openly acknowledge or publish that information, so it becomes the responsibility of the engineer or specifier to prevent the use of these products in inappropriate applications by:

1. Including statements in specifications disallowing aluminum powder-based grouts.
2. Requiring contractors or grout manufacturers to certify in writing that the grout submitted does not contain aluminum powder or other metals.

Expansive cement grouts rely on the formation and growth of ettringite crystals during the hardened state. Because ettringite occupies a greater volume than the reacting sulfates and aluminates that cause its formation, the grout expands in volume. The formation of ettringite depends on the availability of water/moisture. In the absence of moisture, ettringite formation and growth ceases. Expansive cement grouts require both presaturation of the concrete substrate and a source of moisture to ensure the continued presence of moisture, ettringite growth, and expansion.



Air Release Grouts provide expansion based upon controlled release of air from the additive within the grout. This additive is blended in much larger quantities than aluminum powder and does not rely on a chemical reaction. Rather, the water used

for mixing displaces entrapped air in microscopic air pockets in the additive, causing release of air and expansion. The Air Release mechanism has proven to be the most reliable expansion mechanism in use and is found in all FIVE STAR PRECISION NONSHRINK CEMENTITIOUS GROUTS.

Other categories of grouts include field-proportioned grouts and oxidizing iron aggregate grouts. These materials cannot provide controlled expansion, so they are in very limited use today.

In selecting and specifying cementitious grouts, among the many factors that must be considered are working time, placement requirements, strength development, product field support and proper alignment of equipment.

SELECTING A NONSHRINK EPOXY GROUT

The information that follows provides guidance to architects, engineers, contractors, specifiers and owners on the appropriate application and installation of epoxy grouts. If any one of the following conditions will exist, an epoxy grout should be used.

1. Impact/Dynamic Loading
2. Vibration
3. Chemical Attack

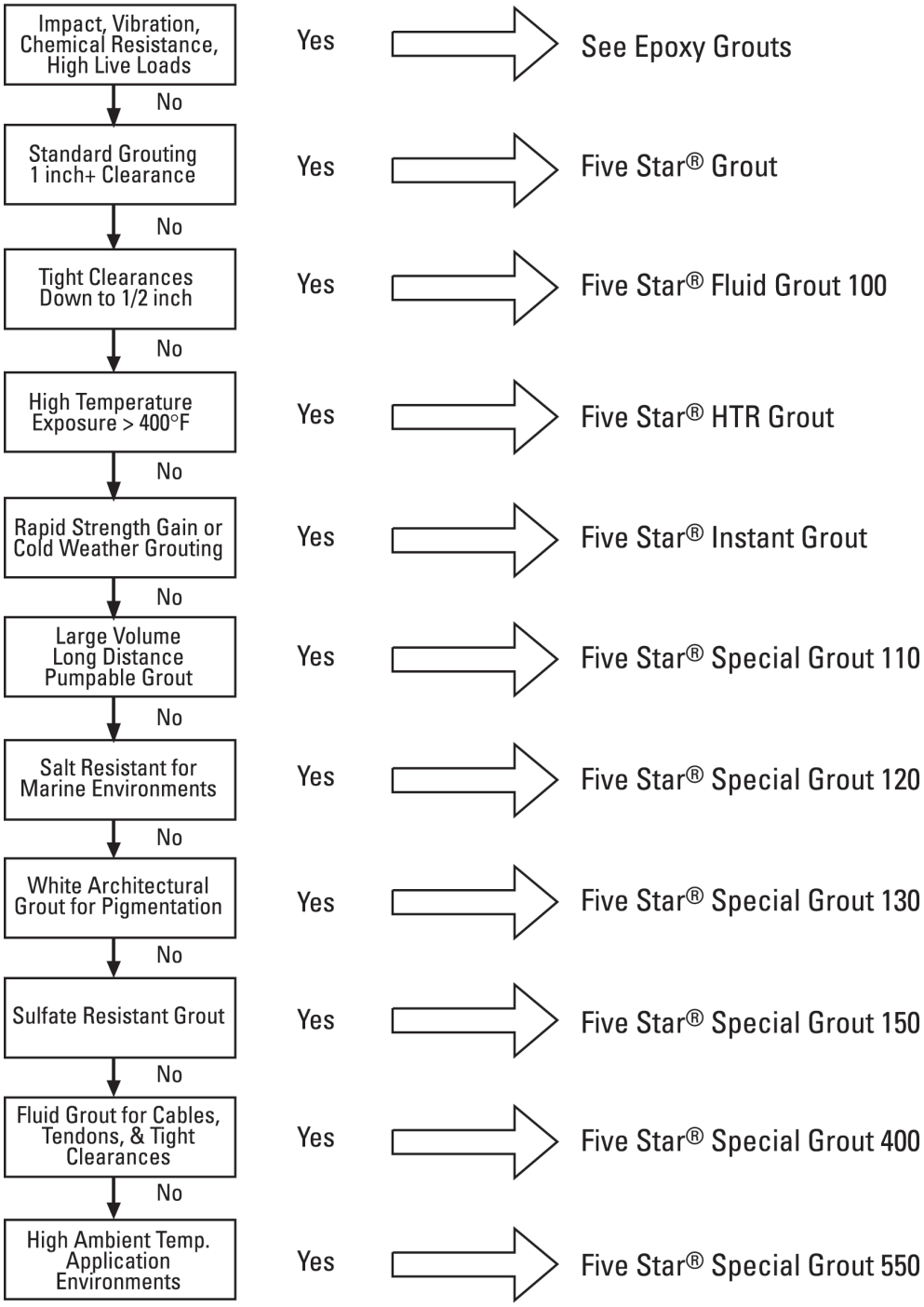
However, additional factors should be considered in choosing *which* epoxy grout to use. No single epoxy grout will meet all of the various requirements which will exist for a given application. Major considerations include:

1. Nonshrink Properties
2. Proper Alignment of Equipment
3. Operating Temperatures
4. Creep Resistance
5. Strengths
    a. Compressive Strength
    b. Bond Strength
    c. Flexural Strength
    d. Tensile Strength
6. Thermal Coefficient of Expansion
7. Dimensions of Grout Placement (in particular, thickness)
8. Exotherm
9. Working Time

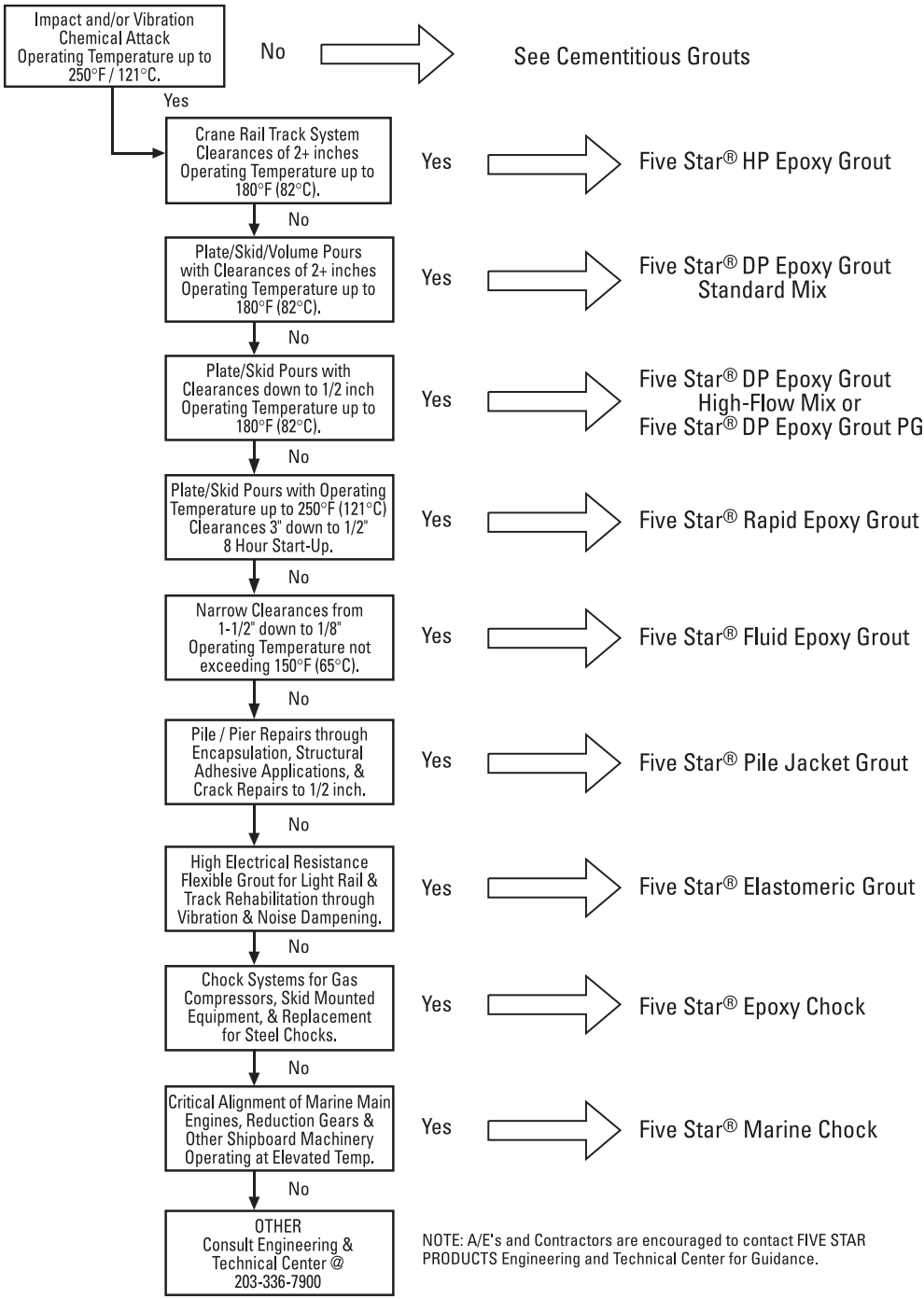
Regardless of the type of epoxy grout selected, it should be nonshrink when tested by the appropriate ASTM methods. **Vertical Height Change should be the ultimate criterion for acceptance.**

The Grout Selection Charts on the following pages are a good starting point. Contact Five Star Products, Inc. by email at info@fivestarproducts.com or call FIVE STAR'S ENGINEERING AND TECHNICAL CENTER at 800-243-2206 for more specific assistance. Additional information can also be found in Five Star Products' DESIGN-A-SPEC documents found on fivestarproducts.com.

Precision Non-Shrink Cementitious Grout Selection Chart



Precision Non-Shrink Epoxy Grout Selection Chart



CHAPTER 2

KEY PERFORMANCE PROPERTIES AND TEST METHODS

1. CEMENTITIOUS GROUTS

The performance requirements of ASTM C 1107, Standard Specification for Packaged Dry, Hydraulic Cement Grout (Nonshrink), include height change and compressive strength characteristics but no longer sets a minimum requirement for plastic height change. Due to this change in ASTM C 1107, a specifier must include minimum and maximum height change requirements under ASTM C 827 to ensure a precision nonshrink grout is specified.

To build a complete specification, height change and compressive strength requirements should be considered along with other key properties that will impact the successful use of a precision nonshrink grout.

The key performance properties and corresponding test methods for a precision nonshrink cementitious grout include:

A. Vertical Height Change / Shrinkage – ASTM C 827, ASTM C 1090, ASTM C 1107
B. Flowability / Consistency / Working Time – ASTM C 1437 (flowable grout), ASTM C 939 (fluid grout)
C. Compressive Strength – ASTM C 109, modified per ASTM C 1107 or ASTM C 942

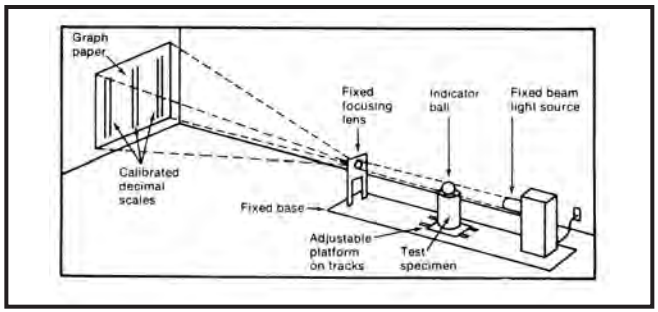
This portion of the Handbook reviews these properties and test methods in detail, along with their significance in evaluating and specifying precision nonshrink cementitious grout.

A. VERTICAL HEIGHT CHANGE

Vertical Height Change is the most critical property with respect to precision nonshrink cementitious grout. A grout that exhibits no shrinkage in the plastic state and is dimensionally stable in the hardened state will **permanently** and **completely** fill a space, in accordance with ACI's definition. In accomplishing this, the grout will provide a high Effective Bearing Area (EBA), permanently maintain alignment of equipment or machinery, and provide proper load transfer to the foundation.

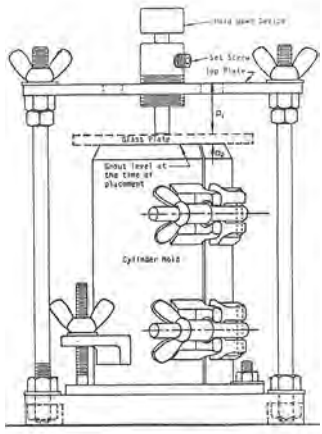
The two current ASTM test methods referred by ASTM C 1107 for height change are ASTM C 827 and ASTM C 1090.

ASTM C 827 measures plastic height change and is required by ASTM C 1107. With a light source behind a cylinder of grout and a focusing lens in front, the change in height is magnified by projection on a screen. Measured over an appropriate period of time, results are reported as a percentage. This test method will often identify where 80% to 90% of shrinkage occurs in cementitious grouts.



ASTM C 827 Test Setup

ASTM C 1090 measures hardened height change. It involves the use of a fixed 3 x 6 inch cylinder of the grout to be tested, a micrometer bridge, and a restraining plate. Measurements are taken with a depth micrometer. This test method, when used in conjunction with ASTM C 827, can ensure proper evaluation of a precision nonshrink cementitious grout. As previously stated, minimum and maximum height change values must be included by the specifier in both ASTM C 827 and ASTM C 1090.



ASTM C 1090 TEST SETUP

B. FLOWABILITY/CONSISTENCY/ WORKING TIME

The flowability / consistency of a grout and its working time are of significant importance to a successful grout installation. Many grout manufacturers offer both flowable and fluid consistency cementitious grouts.

Working time, or the time within which a grout product remains flowable or fluid, is a key indicator of whether a grout can be successfully placed in a particular application. Grouts with working times of 15 to 20 minutes may be acceptable for small footprint, non-critical applications, but may not provide sufficient working time for larger footprint machinery applications without the potential for cold joint development.

Grouts that provide working times of 30 to 45 minutes will provide sufficient working time for most applications and allow a margin of error for any job site

difficulties that delay placement.

The consistency of a grout determines its ability to flow into a confined space or clearance. Most determinations of consistency done in accordance with ASTM C 1437 (Flowable Grouts) or ASTM C 939 (Fluid Grouts), report results immediately after mixing. However, grouts rarely are placed completely and immediately after mixing on job sites. For this reason, it is important to have information on grout consistency not just after mixing (initial test value) but after a specified period of time (delayed test value).

NEVER exceed the maximum water content of cementitious grout to increase flow or retemper the grout. Such a practice is called "overwatering". Overwatering grout will increase shrinkage, reduce strengths, and increase the potential for segregation and cracking. Overwatering is the primary cause for strength reduction issues encountered on job sites.

Placement versatility is another factor in determining the selection or specification of a cementitious grout. Job site applications often vary – a versatile product that has the ability to be poured or pumped into place offers distinct advantages. This versatility allows a contractor to keep just one product on site that can address both placement requirements.

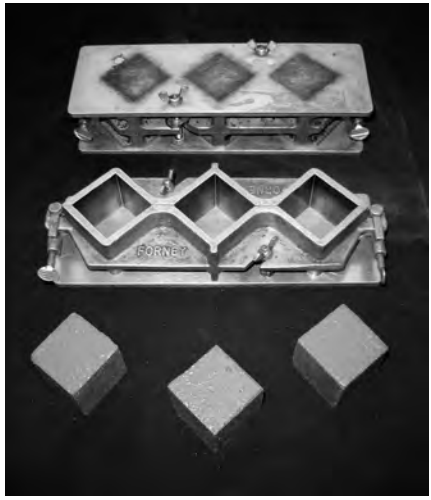
C. COMPRESSIVE STRENGTH

The compressive strength of cementitious grouts is a property that is well defined and understood. ASTM C 1107 specifies strength gain requirements under restraint using applicable portions of ASTM C 109 – Standard Test Method for Compressive Strength of Hydraulic Cement Mortars.

1. ASTM C 942 - the Standard Test Method of Grouts for Preplaced Aggregate Concrete in the Laboratory similarly describes casting retained cubes.

Under ASTM C 109, 2 x 2 inch cube specimens are taken of the mixed grout and cured according to the manufacturer's instructions or other contract requirements.

2. The figure to the right shows cube molds used to cast grout specimens either restrained or unrestrained, along with some cast cubes.



Compressive strength readings are taken at predetermined intervals, usually 1, 7, and 28 days.

Compressive strength requirements will vary from project to project. However, compressive strengths should not be the sole determining factor in selecting or specifying one grout over another. Many assume a cementitious grout with very high compressive strengths to be the best product. This is simply not accurate.

In summary, successful grout selection is the result of two key factors:

1. Proper material specification (precision nonshrink vs. nonshrink)
2. Proper consideration of grout consistency, working time, and versatility.

EXAMPLE:
Contractor X has been given the choice in a specification to use a flowable or fluid grout, and has chosen Grout A, a fluid consistency grout, because it is deemed easier to place than Grout B, a flowable consistency grout.

Grout A has a fluid consistency initially, but after 15 minutes, it loses its fluidity, and at 20 minutes it loses the ability to be placed properly. The potential result can be cold joints or entrapped air under the baseplate, reducing the EBA and leading to future problems such as misalignment or even grout failure.

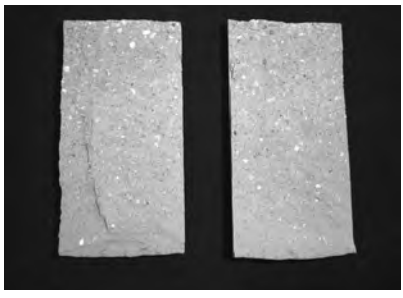
On the other hand, Grout B, a flowable grout, remains placeable for 45 minutes and retains the ability to be placed for that entire time period. Using Grout B, the contractor has sufficient time to place the grout continuously without the development of cold joints or loss of EBA.

Five Star Products, Inc. manufactures precision nonshrink cementitious grouts in flowable, fluid, and dry-pack consistencies that can be poured, pumped or hand-applied. FIVE STAR PRECISION NONSHRINK CEMENTITIOUS GROUTS have long working times and retain their consistency for extended periods, thus ensuring proper and successful field installation. For special applications, including very tight clearances (less than 1/2 inch), high sulfate or high temperature exposure or long distance pumping, Five Star Products, Inc. can provide a successful, time tested solution.

D. OTHER FACTORS AND ISSUES

Segregation is the separation of cement and aggregates within a grout mix. The primary cause for segregation in grout mixes is overwatering. Segregation is evident visually by excessive bubbling or frothing as the aggregate or sand component separates within the grout mix and drops to the bottom.

Segregation can also be observed visually in hardened samples of grout. Cores taken on in-place samples of grout and tested in accordance with ASTM C 39 for purposes of evaluating compressive strength may show a heavy concentration of aggregate in the lower portion of a broken core compared to the top portion. This usually indicates a degree of segregation. Segregation affects every key grout performance property, including loss of compressive strength, increased shrinkage, and potential grout failure.



Quality of a cementitious grout refers to its ability to perform consistently, regardless of where the product is obtained. This is of particular importance on capital projects that utilize large quantities of cementitious

grout. Quality comes from the manufacturer's ability to control the blending and production of the grout, and from the degree of rigor by which manufacturers test their grout prior to shipment. Manufacturer's that have a strict quality assurance program, such as one meeting ISO 9001-2002, can ensure the quality of their products bag to bag and lot to lot. Quality also comes from products with a proven history of use in the particular industry or application under consideration.

Durability refers to the long term performance of a cementitious grout. For instance, a normal Portland cement based grout may perform well at exposure temperatures of 400°F, but will not at 1000°F. Also, cementitious grouts that contain gypsum or expansive cements will not be durable in continuously wet environments, and may actually fail. This failure can be extremely costly, particularly when critical plant equipment has to be shut down for regrouting.

To ensure short term and long term success, engineers and specifiers should carefully evaluate and consider all the necessary factors required for a given application. When in doubt, contact FIVE STAR PRODUCTS ENGINEERING AND TECHNICAL CENTER for product application assistance.

2. EPOXY GROUTS

Although there is no standard specification for an acceptable Nonshrink Epoxy Grout as there is for the cement based grouts discussed above, there are several essential physical and performance properties of Nonshrink Epoxy Grout that are, or should be, of interest to owners, architects, engineers, and contractors. In order of importance, they are:

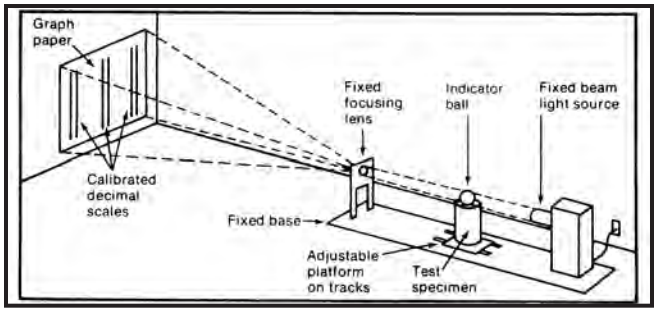
- Proper Support of Equipment
- Vertical Height Change / EBA
- Compressive Strength
- Creep
- Workability
- Quality
- Durability

This portion discusses these properties together with available test methods, their applicability, and their usefulness in evaluating grout performance.

A. VERTICAL HEIGHT CHANGE / EBA

1. Vertical height change is a vital performance property of NONSHRINK epoxy grouts because it is the major factor in determining the EBA. A grout that has positive vertical height change in the plastic state will have a high EBA. But unlike cement grout, there is no standard test for measuring vertical height change in epoxy grout.
2. Five Star Products, Inc. adapted the cement grout test (ASTM C 827-Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens from Cementitious Mixtures) to measure vertical height change in epoxy grout. Over many years of experience, this test has demonstrated its value in verifying the vertical height change and resulting EBA of epoxy grouts. Among the advantages of using the method of ASTM C 827 to measure vertical

height change is that the results are statistically valid. They can be reproduced consistently, thus assuring a sound basis for making judgments about the material's quality.



ASTM C 827 Test Setup

3. Horizontal length change is of little interest in grouting, except for extremely long pours where expansion and contraction joints are needed.
4. To be considered a PRECISION NONSHRINK Grout, the vertical height must NEVER go below the original placement height.

B. COMPRESSIVE STRENGTH

1. The value of an epoxy grout's compressive strength is highly dependent on the details of the test method used to measure it. ASTM C 579 (Compressive Strength of Chemical-Resistant Mortars and Monolithic Surfacings) specifies three different test methods, depending on the maximum aggregate size, and allows two different loading rates. A note in the specification warns that the two loading rates do not give the same values for the compressive strength.
2. In determining whether the compressive strength of an epoxy grout meets its specified requirement, it is of paramount importance that the test method used be the same as that called for in the specification. In comparing the compressive strengths of two epoxy grouts, it is important to be sure that both are measured by the same method. The difference between them when tested by different methods allowed by ASTM C 579 can be as much as 2000 psi (13.8 MPa).

C. CREEP

1. Creep is the deformation of a material under a constant load applied over an extended interval of time. Creep increases with temperature. Because creep acts to reduce the stress in epoxy grout material, it can result in lower anchor bolt torque and consequently cause equipment misalignment and eventual wear in shafts and bearings.
2. Engineers, designers, and other specifiers should know the creep characteristic of any epoxy grout they may be considering for use. Beware of extrapolations from short term tests of only a few days duration. Reliable creep data are based on tests using the method of ASTM C 1181 at a temperature at or above the operating temperature of the grout in service.

3. To be sure that epoxy grout will not creep beyond an acceptable level,
   a. Select an epoxy grout for which long term creep data at or above the operating temperature of the grout in service are available.
   b. Design the installation so that the sum of the compression stresses in the epoxy grout from the weight of the equipment plus that from the anchor bolt torque is not more than 500 psi (3.45 MPa).

D. WORKABILITY

1. Epoxy grouts should be formulated for a flowable or pumpable consistency so as to facilitate placement under all types of baseplates. This is the most versatile consistency and is appropriate for almost all placements.
2. The consistency of epoxy grouts cannot be altered at the job site except by adjusting the amount of aggregate added to the epoxy mix. The manufacturer's limits on the minimum aggregate content must be strictly observed. Failure to do so can cause excessive heat buildup, foam, and segregation leading to loss of EBA and grout failure.
3. To comply with safety and environmental regulations, both the specifier and the field supervisor should prohibit the use of epoxy grouts that are not 100% solids.

E. QUALITY AND DURABILITY

1. Quality is the ability of a material to behave in a predictable manner during placement, and is a critical characteristic of a good epoxy grout. To realize this, epoxy grout must be prepackaged in premeasured units. Field proportioning of partial units of epoxy grout is rarely accurate enough to realize the full potential properties of epoxy grout.
2. Quality of an epoxy grout depends on the manufacturer's ability to control the quality of materials used in the grout, the manufacturing and blending procedures, and the packaging, storage, handling, and shipping. To provide the necessary assurance, the grout manufacturer should have in place a currently certified quality control system conforming to ISO 9001-2000.
3. Durability of epoxy grout can be compromised by too great a difference in the thermal expansion and contraction of epoxy and concrete with changes in temperature. The coefficient of thermal expansion of unfilled epoxy is about 10 times that of concrete, but it can be reduced substantially by the grout manufacturer's design of a proper aggregate blend, another reason for strictly observing the manufacturer's mixing directions. The sketch to the right illustrates what can happen as a result of differential shrinkage. The effect can be minimized by chamfering the epoxy grout, and in extreme instances, chamfering the concrete as well.

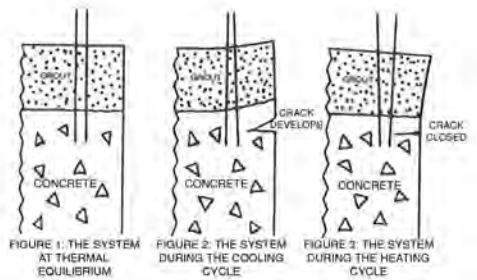


FIGURE 1: THE SYSTEM AT THERMAL EQUILIBRIUM
FIGURE 2: THE SYSTEM DURING THE COOLING CYCLE
FIGURE 3: THE SYSTEM DURING THE HEATING CYCLE

CHAPTER 3

MANUFACTURER'S QUALITY ASSURANCE PROGRAM

Written Quality Assurance programs should be required of all manufacturers of approved grouts. The minimum requirements for a manufacturer's Quality Assurance System should be:

- To maintain records of all the cements, sands, aggregates, resins, hardeners, and other chemicals used in each manufacturing lot of cementitious and epoxy grout.
- To identify all containers of raw materials, intermediates, and finished products with their sources and batch markings, so that all materials can be traced to their sources and verified as meeting the manufacturer's standards.
- To calibrate, at regular intervals, but at least annually, scales used at the manufacturing plant to weigh grout components and packaged products.
- To take regular samples from the manufacturing plant and to verify that they meet their performance requirements, including their nonshrink requirements.
- To maintain test records and to retain them for at least one year beyond the shelf life expiration date; test records for all shipments should be available.

  CAUTION: The value obtained in a compressive strength test depends on the sampling and testing procedure used. Differences in specimen size and shape, conditioning, or loading rate can produce significantly different test results.
- To print instructions for normal mixing and placement conditions, including the minimum and maximum mixing water limits for cementitious grout, on the outside of the bag, pail, or other packaging.
- To post grout manufacturing instructions at the manufacturing plant in a manner available to production operators.
- To provide access to manufacturing sites, upon receipt of adequate notice, by the project engineer or his representative to audit the Quality Assurance System. Manufacturers who cannot comply with this requirement should not be approved as grout sources.

The manufacturer's Quality Assurance System should also ensure that cement based products stored beyond one year in bags (or two years in plastic pails) and epoxy products stored beyond two years are not shipped unless the manufacturer can certify, by retest that the products still meet their applicable performance requirements.

The manufacturer should furnish signed, written certification, when requested, that the product meets its applicable performance requirements, is in accordance with the manufacturer's specifications, conforms to the terms of sale, or meets the project specifications, as applicable. When appropriate, the manufacturer should furnish actual test data. The manufacturer's Quality Assurance System should be audited at regular intervals by an independent auditor and should meet the requirements of ISO 9001-2000.

CHAPTER 4

ESTIMATING, PURCHASING, DELIVERY, AND STORING GROUT

A. ESTIMATING

1. To estimate the quantity of grout required for a job, calculate the volume of the cavity to be filled in cubic feet. Divide the calculated volume by the yield in cubic feet of one unit of grout to calculate how many units will be needed. Add 5% to 10% for waste and spillage, more for smaller jobs, and less for larger ones.
2. The most common shapes of cavities encountered in grouting operations are rectangular solids (for example, the space under a rectangular base plate), solid right cylinders (such as the space under a round, flat-bottomed tank), and hollow right cylinders (like the space between an anchor bolt and its hole). Many other cavity shapes can be divided into some combination of the common shapes for estimating purposes.
3. To find the volume **V** of a rectangular solid in cubic feet, multiply the length **L** in feet times the width **W** in feet times the thickness **T** in feet.

$$V = LWT$$

4. To find the volume **V** of a right cylinder in cubic feet, multiply the square of the diameter **D** in feet times $\pi/4$ times the height **H** in feet.

$$V = 0.785\ D^2H$$

5. To find the volume **V** of a hollow right cylinder in cubic feet, subtract the square of the inside diameter **d** in feet from the square of the outside diameter **D** in feet and multiply that difference times $\pi/4$ times the height **H** in feet.

$$V = 0.785\ (D^2 - d^2)H$$

6. If all dimensions in these equations are in inches, the calculated volume will be in cubic inches. To convert cubic inches to cubic feet, divide by 1728.

B. PURCHASING

1. To compare the cost of grout needed for a job, determine the **cost per cubic foot** for each grout under consideration. To ensure that all prices are directly comparable, requests for quotation should be made in cubic foot units. All cost comparisons must be made on the basis of delivered cost per cubic foot to be meaningful. Grouts must not be compared, bid, or purchased on a weight basis because there is not a constant relationship between weight and volume. The customary unit of volume is the cubic foot, so requesting quotations in cubic foot units allows direct price comparisons.
2. In estimating the quantity of grout that is sold in units other than one cubic foot, divide the manufacturer's yield into the number 1 to determine the actual number of units required for one cubic foot. For example, if a manufacturer's 55-pound unit has a yield of .42 cubic feet, 1 cubic foot /.42 = 2.38 units (bags or pails) per cubic foot.

C. DELIVERY

1. Nonshrink cement-based grout should be delivered palletized and shrink-wrapped, and delivered to the job site in sound, dry packages.
2. Epoxy resin and hardener should be delivered, premeasured, in sealed containers, palletized and shrink-wrapped to prevent shipping damage. Epoxy grout aggregate, delivered as a separate component, should be premeasured, packaged in sealed, dry bags, also palletized and shrink-wrapped to prevent shipping damage.

D. STORAGE

1. Nonshrink cement-based grout should be stored in a dry area in accordance with ACI instructions. The ideal storage temperature is 70°F. Avoid storing cementitious grout below 40°F or above 90°F.
2. Preferably, epoxy grout components should be stored at a temperature between 70°F and 80°F, but never below 60°F nor above 90°F.

E. STORAGE DAMAGE

Immediately remove from the job site any cement-based grout material which becomes damp or otherwise defective. Epoxy grout aggregate that becomes damp or otherwise defective should not be used and should be removed from the job site. Liquid components that are found to be defective should also be removed from the job site.

NONSHRINK GROUT ESTIMATING SHEET

From Premeasured Units

		FIVE STAR	PRODUCT "X"
A.	Cost per Bag Or Unit	_____	_____
B.	Yield per Bag Or Unit (Cubic feet/bag or unit)	_____	_____
C.	Cost per Cubic Foot (A divided by B)	_____	_____
D.	Total Cubic Feet Required (From field estimates)	_____	_____
E.	Total Material Cost (C x D)	_____	_____

To determine material prices in your area, contact your local Five Star Product's sales representative. (For your representative's name and phone number, call FIVE STAR PRODUCTS, INC. Customer Service at 203-336-7900.)

NONSHRINK GROUT COST PER CUBIC FOOT

Instructions:

1. Determine the delivered cost of grout per 100 lbs. (Not all grouts are supplied in 100 lb. bags.)
2. Determine cubic foot yield per 100 lbs.
3. Read the cost per cubic foot of grout in the body of the table. For values not tabulated, use linear interpolation.

COST PER	CUBIC FOOT YIELD PER 100 LB								
100 LB	0.70	0.75	0.78	0.80	0.85	0.90	0.95	0.97	1.00
$20.00	$28.57	$26.67	$25.64	$25.00	$23.53	$22.22	$21.05	$20.62	$20.00
$22.00	$31.43	$29.33	$28.21	$27.50	$25.88	$24.44	$23.16	$22.68	$22.00
$24.00	$34.29	$32.00	$30.77	$30.00	$28.24	$26.67	$25.26	$24.74	$24.00
$26.00	$37.14	$34.67	$33.33	$32.50	$30.59	$28.89	$27.37	$26.80	$26.00
$28.00	$40.00	$37.33	$35.90	$35.00	$32.94	$31.11	$29.47	$28.87	$28.00
$30.00	$42.86	$40.00	$38.46	$37.50	$35.29	$33.33	$31.58	$30.93	$30.00
$32.00	$45.71	$42.67	$41.03	$40.00	$37.65	$35.56	$33.68	$32.99	$32.00
$34.00	$48.57	$45.33	$43.59	$42.50	$40.00	$37.78	$35.79	$35.05	$34.00
$36.00	$51.43	$48.00	$46.15	$45.00	$42.35	$40.00	$37.89	$37.11	$36.00
$38.00	$54.29	$50.67	$48.72	$47.50	$44.71	$42.22	$40.00	$39.18	$38.00
$40.00	$57.14	$53.33	$51.28	$50.00	$47.06	$44.44	$42.11	$41.24	$40.00
$42.00	$60.00	$56.00	$53.85	$52.50	$49.41	$46.67	$44.21	$43.30	$42.00
$44.00	$62.86	$58.67	$56.41	$55.00	$51.76	$48.89	$46.32	$45.36	$44.00
$46.00	$65.71	$61.33	$58.97	$57.50	$54.12	$51.11	$48.42	$47.42	$46.00
$48.00	$68.57	$64.00	$61.54	$60.00	$56.47	$53.33	$50.53	$49.48	$48.00
$50.00	$71.43	$66.67	$64.10	$62.50	$58.82	$55.56	$52.63	$51.55	$50.00
$52.00	$74.29	$69.33	$66.67	$65.00	$61.18	$57.78	$54.74	$53.61	$52.00
$54.00	$77.14	$72.00	$69.23	$67.50	$63.53	$60.00	$56.84	$55.67	$54.00
$56.00	$80.00	$74.67	$71.79	$70.00	$65.88	$62.22	$58.95	$57.73	$56.00
$58.00	$82.86	$77.33	$74.36	$72.50	$68.24	$64.44	$61.05	$59.79	$58.00
$60.00	$85.71	$80.00	$76.92	$75.00	$70.59	$66.67	$63.16	$61.86	$60.00

CHAPTER 5

CEMENTITIOUS GROUT PLACEMENT PROCEDURES

INTRODUCTION

Cementitious grout placement involves proper mixing, placing, finishing, and curing, all of which are critical components of a successful grout installation. Improperly placed grout will often not perform as designed and can lead to potential problems such as grout cracking, equipment misalignment, and even grout failure.

Selecting the type of cementitious grout, pumpable, flowable, fluid, or other, is important and involves a detailed understanding of the application for which the grout is to be used and of which material will provide the best results.

FLUID GROUTS

The industry definition of a fluid grout is one that will pass a specified volume of material through a flow cone in accordance with ASTM C 939 in 30 seconds or less. Fluid grouts are typically easier to place than flowable grouts and can therefore be expected to flow longer distances at normal clearances or to get into tighter clearances. Fluid Grouts must be mixed to a specified consistency, which requires having a flow cone on the jobsite. Without a flow cone available, it is difficult to determine if the grout is mixed with the appropriate amount of water.

FLOWABLE GROUTS

Flowable grout provides sufficient flow to properly grout a majority of applications. Flowable grouts are defined as those having a flow of 125 to 145 when tested on a flow table in accordance with ASTM C 1437- (Standard Test Method for Flow of Hydraulic Cement Mortar). Flowable grouts are typically very versatile. Properly formulated flowable grouts will provide long working times (30 to 45 minutes), can often be extended with coarse aggregate in the field for deep pours, and can be pumped. Some well formulated flowable grouts, such as **FIVE STAR GROUT,** can be mixed in ready mix trucks and pumped long distances. However, it is important to understand that NOT ALL FLOWABLE GROUTS PERFORM EQUALLY. Some flowable grouts, such as those based on aluminum powders, have short working times and, therefore, cannot be mixed in ready mix trucks or pumped.

Flowable grouts are typically packaged in 50 lb or 100 lb bags, and have minimum and maximum water requirements listed on the bag. **NEVER EXCEED THE MAXIMUM WATER REQUIREMENTS AS STATED ON THE PRODUCT PACKAGING. OVERWATERING CAN LEAD TO SEGREGATION, STRENGTH REDUCTION, AND INCREASED GROUT SHRINKAGE, JEOPARDIZING LONG TERM SUCCESS.**

Tight clearance applications (less than 1 inch clearance) or baseplates with shear keys are two applications where fluid grouts have advantages over flowable grouts. When placed properly, fluid grouts will tend to entrap less air in shear key applications, though vent holes should be present in the baseplate to allow the venting of any entrapped air.

Sometimes, mixing to a fluid consistency has been used as a way to speed the placement of grouts with very short working times, which occasionally has led to shrinkage, air entrapment, and segregation. FIVE STAR FLUID GROUT 100 is a fluid grout whose unique formulation produces a grout with excellent workability and without these problems. It can be used where clearances are very tight, as well as for normal clearances.

CAUTION: Take special note that making a normally flowable grout fluid by adding more water than the maximum amount specified can result in aggregate segregating and lower strength from the increased water-cement ratio. There is also a considerable risk that certain flow agents will cause bubbling at the surface, significantly reducing EBA. NEVER add more water than the maximum amount specified on the package.

PUMPABLE GROUTS

Pumpable grouts are either well formulated flowable grouts that provide good pumpability or very specialized grouts that contain pumping aids. Pumpable grouts should be able to be pumped with typical grout pumps or larger pumps, such as concrete pumps. Pumping grouts may involve the addition of coarse aggregate at the jobsite, particularly on large volume placements. Aggregates used for extending cementitious grouts should be clean, washed aggregates of specified size and conform to ASTM C 33. Dirty aggregates or aggregates with a large amount of fines will affect pumpability and strength development.

SAFETY

CAUTION: Cement based grout contains cementitious material and crystalline free silica. The International Agency for Research on Cancer has determined that there is sufficient evidence for the carcinogenicity of inhaled crystalline silica to humans. Take appropriate measures to avoid breathing dust. Avoid contact with eyes and contact with skin. In case of contact with eyes, immediately flush with plenty of water for at least 15 minutes. Call a physician immediately. Wash skin thoroughly after handling. Keep this product out of the reach of children. BEFORE USING, REFER TO THE MATERIAL SAFETY DATA SHEETS, which are available for all Five Star Products at fivestarproducts.com

Take these simple precautions to avoid skin contact with cement powder or freshly mixed grout or mortar:

- Wear rubber boots high enough to keep out cement products. Top of boots should be tight to protect feet.
- Wear rubber gloves to protect hands.
- Wear long pants tucked into boots to protect legs.
- Wear kneepads when finishing concrete to protect knees.
- Wear long-sleeved shirts buttoned at the wrists and neck to protect upper body and arms.
- Wear tight-fitting goggles when handling cement products to protect eyes.
- Do not breathe in the fine dust. Wear a NIOSH approved respirator when opening or dumping bags.

INSTALLATION

A. GENERAL

The general application procedures that follow are appropriate for use under normal conditions:

1. Many grouts are not recommended for placement under a wide range of temperatures. Consult the grout manufacturer's written instructions for placement temperature limitations. At temperatures below 70°F, grout tends to set more slowly than reported on typical product data sheets. At temperatures above 70°F, grout tends to set faster than reported. When grouting is to be done when ambient and mix temperatures are not between the manufacturer's specified temperature range for the grout, usually 40°F to 90°F, follow the additional recommendations in the Hot Weather Grouting and Cold Weather Grouting parts of this section to help maintain the set times and strength gains at or near the 70°F rate.
2. If there are other unusual or difficult conditions (chemical attack, high working temperatures, low clearances, shear keys, etc.), the contractor should consult the owner's engineer and the grout manufacturer's Technical Service Department.
3. All necessary tools and materials should be as close as possible to the area being grouted. Mortar mixer (with rotating blades), wheelbarrow, shovel, water measuring container, and grout should be within easy reach.

B. PLACEMENT

1. Placing NONSHRINK grout is not a difficult process if the engineer and the contractor are aware of the variety of methods available to them. The grout manufacturer can recommend the best grade of grout to use and how to place it. The specifier can make the contractor's job easier by specifying a grout that provides flexibility in placement. Selecting a cement-based grout that can be placed by only one method can increase the cost of grouting.
2. The placement procedures used for grouts are just as critical as selecting the proper grout. The leading grout manufacturers maintain extensive technical service staffs to assist in selecting the proper grout and the applicable placement procedures.
3. This section describes the three most common methods, most other placement techniques being simply variations of the basics. The advantages and disadvantages of each are described to assist the engineer and contractor in choosing the method best suited to their application.

a. Dry Packing

Dry packing requires a grout with a thick consistency. There should be only enough water mixed into the grout so that when a ball of grout is squeezed in a gloved hand, the glove is slightly dampened. Although only a well braced backboard, a tamping rod, and a mallet are required for placement by the dry pack method, and carpentry expense for building and stripping forms is saved, dry packing is not recommended except for very small, accessible placements. Dry packing is labor-intensive and requires a highly skilled worker to ensure that the grout is uniformly compacted under the entire baseplate without cold joints.

b. Pouring

Pouring requires a grout with a flowable or fluid consistency. To place a flowable grout, use forms and a headbox. This method is appropriate for most grouting applications. During the mixing process, a flowable grout, being stiffer than a fluid grout, is less likely to incorporate excess air that later gets trapped under the baseplate. Watertight forms are required for flowable and fluid grout.

To increase the rate of flow from a headbox, manually apply pressure in addition to the hydraulic head by using a plunger. A plunger is a tool, usually fabricated on the job site, made from two pieces of wood nailed together to form a **T**. The stem is the plunger handle and the crossbar, just slightly smaller than the width of the headbox, applies the pressure.

c. Pumping

Grout should be placed by pumping for large or multiple grout installations, particularly when there are obstructions, or when grout must be transported over great distances, or when venting air is not possible. Pumping cement-based grout into place is fast, and can achieve good results. Although it may take somewhat longer to set up the pump and its associated equipment, once done, the pumping method usually produces successful installations. A pumpable grout, needing less water than a fluid grout, contributes to higher strength. Pumping results in fewer air bubbles, and considerably more grout can be placed in a day by the same size crew. As grout installers become more experienced with pumping, it will continue to increase in popularity because of its superior performance characteristics.

PREPARATION

1. CONCRETE

a. The base concrete should have attained its design strength before grouting.

b. Concrete should be sound and all surfaces that will be in contact with the grout should be entirely free of oil, grease, laitance, curing compounds, and other deleterious substances that can prevent cementitious grout from bonding to concrete.

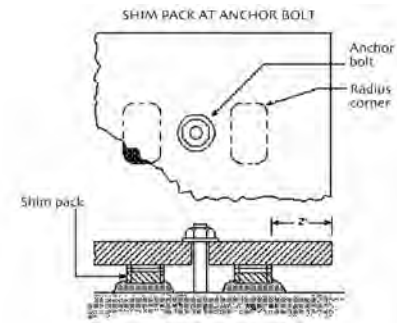
c. Prepare the surfaces by chipping, sandblasting or other mechanical means to ensure a roughened profile. Particular care should be given to the quality of the concrete foundation.

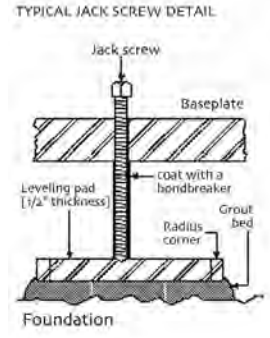
d. Efflorescence may occur on the surface of foundations containing limestone aggregate.

2. BASEPLATES

a. All metal surfaces of equipment bases which are to be in direct contact with the grout should be thoroughly cleaned to bare metal immediately before grouting. NONSHRINK cement-based grout will not bond to grease, oil, paint, primers, or epoxy coatings that are sometimes found on the underside – the contact surface – of the baseplate. These foreign materials should be removed immediately before, or as close as possible to, grouting time.

b. Level and align baseplates according to the project specifications or to the recommendations of the equipment manufacturer. Provide approximately two inches of clearance under leveled baseplates for grouting. For large-volume placements with clearances greater than three inches, grout should be extended with clean, washed coarse aggregate that meets ASTM C 33. Contact the grout manufacturer for the size and amount of coarse aggregate to use for deep pours. The added coarse aggregate helps to manage the heat generated by the hydrating cement and provides dimensional stability. It acts as a heat sink and reduces the temperature rise, helping to reduce the potential for cracking. Special grouts are available to meet the special application requirements of shallow pours, deep pours, or certain problem environments. For long and large volume pours, expansion joints may be considered.





c. Shims, wedges, blocks, and leveling nuts (see the sketch above) are used to support the equipment during alignment and grouting. They can be removed after grouting if the engineer specifies, but they are often left in place. If they are required to be removed, apply two generous coats of paste wax to them, wrap them with polyethylene film, or use some other bond breaker. Shims and wedges that are to remain in place should have generously rounded corners to ensure that they do not act as points of stress concentration. They should be set back from the edge of the baseplate by two inches or more.

d. Before grouting, tighten anchor bolt nuts finger tight only or follow OEM instructions.

3. ANCHOR BOLTS

a. Grout anchor bolts with cementitious grout when the design engineer or the equipment manufacturer so specifies. Anchor bolt holes can be precored when the foundation is poured, or carefully and accurately located and core drilled before the equipment is installed. Anchor bolt holes should be at least 2 inches in diameter for bolts up to 1 inch, and at least 2 inches greater than the bolt for larger sizes. Very deep holes may need to be bigger than this to allow grout to flow all the way to the bottom. Roughen the sides of anchor bolt holes and thoroughly clean all hole and bolt surfaces of oil, greases, loose cement, dust, and other bond-breaking substances. Soak the hole to saturation (8 to 24 hours) with potable water, and remove all free surface water from the holes with oil-free compressed air, sponges, or with a wet/dry vacuum. Refer to Appendix A for more detail.

b. If part of the anchor bolt length is to remain unbonded, protect it with duct tape or a plastic sleeve. Locate and support the anchor bolt in the hole. Mix and pour grout into the hole. Rod the grout well to release any trapped air. When the grout has set, finish the grout surface, and cure the exposed surface as the manufacturer directs.

4. FORMING

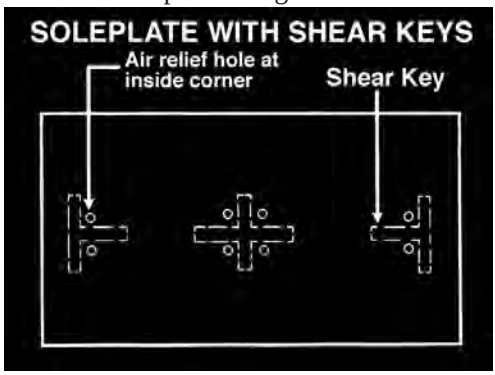
a. Forms are required for all placement methods except dry packing, which requires a well-braced backboard to pack the grout against.

b. Build all forms of sufficiently strong materials, securely anchored and shored

to withstand the considerable pressure forces developed in placing grout.

c. Coat forms with two generous coats of paste wax, form oil, or other approved release agents for easy form removal. Seal forms tightly against existing concrete and vertical wood surfaces. To retain grout within the formwork, seal joints with tape or sealant. Flowable grout can generally be retained by taping, but fluid grout will usually require a water-tight seal.

d. Air vent holes are mandatory for some baseplate designs. Provide vent holes (1/4 to 1/2 inch minimum diameter) in each corner of a baseplate with a perimeter skirt. Baseplates or skids divided into two or more compartments by stiffening cross members, require a vent hole in each corner of every compartment, as shown in the sketch.



5. MIXING

a. FOLLOW DIRECTIONS

Always follow the grout manufacturer's directions when mixing grout. Carefully read all mixing information on the package and in the latest literature. Whenever possible, cement-based grout, as with all mortars, should be mixed in a mortar mixer (a stationary drum with rotating blades) rather than in a concrete mixer (a rotating drum with attached fins) or by hand. If you are in doubt about mixing procedures, consult the grout manufacturer.

b. MIXER TYPE

All leading grout manufacturers recommend using a mortar mixer with moving blades to mix grout. A mortar mixer produces a more thorough and uniform blend of the mixing water into the dry grout mix. For thorough mixing, the mortar mixer should be large enough that a batch of grout occupies less than half the mixer's capacity. Mixing by hand, including the use of an electric drill with a propeller blade, also produces a less thorough blend, takes much more time, and often results in lower strength, lumps, segregation, and less flowability. Hand mixing should be used only when a very small amount of grout is needed.

c. PREPARATION

Have available an adequate number of mortar mixers to support continuous grouting operations, as well as the buckets, buggies,

wheelbarrows, pumps, trowels and other hand tools that will be needed for the job. Locate the equipment and tools as close as possible to the grouting site to take maximum advantage of the available working time.

d. MIXING AND CONSISTENCY

Clean the mortar mixer's drum and blades thoroughly. Rinse the drum and blades with potable water, run the mixer briefly, and empty all excess water. Only then add the measured amount of potable mixing water into the drum. Start with the minimum amount of mixing water specified on the package and in the manufacturer's literature. The consistency of cement-based grout will vary with the amount of water added. Use this flexibility. Always start with the minimum amount of potable water printed on the manufacturer's bag or label. Run the mixer until the surface water has disappeared and a uniform consistency is reached. Mixing should not be for less than three minutes nor for more than five. Only then, add the least amount of additional potable water needed to obtain the desired consistency, and remix. REMEMBER that as the amount of water in the mix goes up, the strength of the grout goes down. NEVER exceed the maximum amount of water specified by the grout manufacturer and printed on the bag or label, and NEVER add an amount of water that will cause segregation of the aggregate. Rarely, a "false set" may occur. Correct this by remixing — without adding more water! NEVER retemper a mix (that is, NEVER add more water after the initial stiffening).

e. CLEAN UP

Clean all equipment and tools with water. An abrasive material such as sand added to the water is helpful in cleaning a mortar mixer.

6. PLACING GROUT

a. GENERAL

1. Check Temperature Conditions

With a thermometer, determine whether the temperatures of the ambient air, the grout, the potable water for mixing, the concrete foundation, and the steel baseplate will be within the manufacture's specified temperature range, commonly between 40°F and 90°F. If not, special hot weather or cold weather procedures will be required.

Checking Temperatures With a Thermometer

2. Working Time

For a given grade of cement-based grout, the working time varies with the temperature. Working time grows shorter as the temperature rises, and grows longer as the temperature falls. Measure the

placement temperature to estimate the time available to place grout. A simple way to determine the working time available under job site conditions is to mix a small sample of grout to the desired consistency, fill a styrofoam drinking cup, and time the interval between mixing and loss of workability.

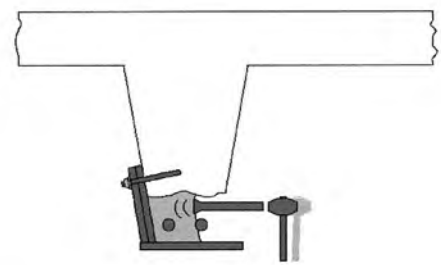
A liquid additive, SUMMERSET, that provides additional working time for Five Star grouts is available from Five Star Products.

3. **Transporting Grout**
   Use a pump, wheelbarrows, buggies, or buckets to transport grout to the placement site.
4. **Eliminating Voids**
   Place grout in a way that assures that all spaces are completely filled and that the grout is in intimate contact with boundary surfaces. Be sure to check whether air vent holes are needed.
5. **Continuous Grouting**
   To avoid cold joints under the baseplate, grout placement should be rapid and continuous. If at all possible, cement-based grouts should

not be placed in lifts or layers. All grouting should take place from one side to the other to avoid trapping air. If grout must be placed through grout holes in the baseplate, cut off the tip of a traffic cone, invert it, and use it as a funnel and headbox. It is important, to avoid trapping air, to place the grout continuously from one hole until full-depth grout has passed the next hole. Only then may grouting continue through a second funnel/headbox through the next grout hole. Leave the first cone full of grout in place as a standpipe at the previous grout hole to maintain contact between the grout and the bottom of the baseplate. Pumping is the preferred placement procedure in this case.

b. DRY PACKING GROUT

Dry packing grout is the placing of zero-slump or near zero-slump grout by ramming into a confined space. It is not recommended except for very small jobs with easy accessibility. Although dry packing avoids the need for formwork, it requires considerable skill on the part of the worker to obtain a uniform degree of grout compression, and therefore, uniform strength in the grout bed. To verify the strength of dry packed grout, test specimens must be packed to the same extent, neither more nor less, as the grout placed in the job.



DRY PACKING

c. POURING GROUT

When a headbox is used and hydraulic head pressure is the means of flowing grout into place, the minimum height of the headbox should be from 1/3 to 1/2 the distance that the grout must flow. Fill the head box to the maximum height and allow the grout to flow down under the baseplate, but refill the headbox before the level reaches the top of the baseplate. The level of grout in the head box must never fall below the top of the baseplate to prevent trapping air under the baseplate. This procedure is repeated until the grout moves completely under the baseplate, pushing air out in front of it, and rising above the bottom of the baseplate on the far side. When the baseplate is long and the headbox is less than the full length of the baseplate, begin grouting at one end of the long side. When the grout front reaches the far side, begin sliding the headbox down the length of the baseplate — keeping pace with the advancing grout front — until the baseplate is completely grouted. To increase the rate of flow from a headbox, manually apply pressure in addition to the hydraulic head by using a plunger. A plunger is a tool, usually fabricated on the job site, made from two pieces of wood nailed together to form a **T**. The stem is the plunger handle and the crossbar, just slightly smaller than the width of the headbox, applies the pressure.

PLUNGING TO ASSIST GROUT FLOW

d. PUMPING GROUT

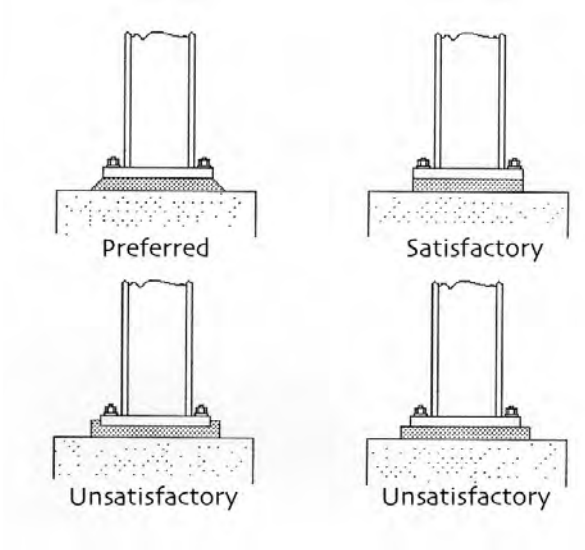
Pumping is the preferred method for placing grout on all large or multiple grouting installations, particularly when there are shear keys, fixators, or other obstructions under the baseplate, or when grout must be placed over great distances, or when it is not possible to vent trapped air. Selecting the appropriate pump to move the grout properly into place is critical. Choose a positive displacement pump, such as a diaphragm or piston pump, rather than a screw pump. The size of the job will dictate the size of the pump required. Pumps vary in size from small ones, delivering 10 to 14 cubic feet per hour, to large ones, compressor-driven, delivering several hundred cubic feet per hour. Rinse the pump, the hose, and the nozzle with potable water. Before grouting, wash a cleansing plug (called a "pig") through the line to ensure that it is open and clear, and follow the pig with a slurry of grout. This will ensure that neither water nor cement are removed from the grout during pumping, and that neither pump nor hose will clog. For large pumping placements, use the grout manufacturer's pumpable grout formulation. Consult the pump manufacturer and the grout manufacturer for specific recommendations. Do not begin placing grout until material of uniform consistency begins flowing from the nozzle. When pumping grout into place, start at the far end of the space to be grouted. As the grout is pumped in, back the nozzle out slowly so that it always remains submerged within the grout. This will prevent air entrapment. Notice that pumping grout into place is the reverse of flowing it into place. When flowing grout through a headbox, grouting begins at the grouter's position and flows away pushing air ahead of it; when pumping, grouting begins at the most distant point and flows toward the grouter, pushing air ahead of it.

PUMPING CEMENTITIOUS GROUT

7. FINISHING SHOULDERS

When the grout has stiffened to the point that it will hold its shape when scored with the point of a trowel, remove the forms and cut the shoulders back at a 45° angle from the bottom edge of the baseplate to the foundation. Finish the grout shoulder with a trowel, float, or brush finish, as desired. Do not allow grout to remain above the bottom edge of the baseplate or in an unchamfered shoulder. In those locations, grout is prone to cracking because of differential expansion when the temperature changes. Sometimes, when anchor bolts are close to the edge of the baseplate, a vertical crack may occur in the grout shoulder. Shoulder cracks rarely propagate

under the baseplate, and do not affect the vertical load-carrying capacity of the grout. For a cosmetic repair, coat the crack with a paste made from the grout and a little water.



GROUT SHOULDER CONFIGURATIONS

8. CURING

a. FOLLOW MANUFACTURER'S DIRECTIONS

Cure cement-based grout as directed by the grout manufacturer in its latest product literature, specifications, and package instructions. For any unusual conditions, consult the grout manufacturer for guidance.

b. WET CURING

In general, and in the absence of manufacturer's directions, begin wet curing immediately after hardening. To prevent rapid surface drying, protect the grout from extreme drying conditions. Cover all exposed grout surfaces with continuously wetted burlap or flannel rags or seal the surface with polyethylene film for a minimum of three days. Special grouts may require more or less wet curing.

c. CURING TEMPERATURE

Maintain the temperature of the baseplate, the concrete foundation, and the grout between 40°F and 90°F during grouting, and for a minimum of 24 hours afterward. Machinery and baseplates will cool faster than the grout at low temperatures and heat up more rapidly than the grout at high temperatures or in direct sunlight. Protect the grout from these conditions during the curing period.

d. CURING COMPOUNDS

As an alternate to the wet curing procedure in **b.**, wet cure for only one day, then immediately coat the exposed surfaces of the grout with curing compound. Apply two coats of white pigmented, resin-based curing compound that meets the requirements of ASTM C 309, Type 2, Class B.

e. ANCHOR BOLT TORQUE
After the grout has cured to its design strength, use a torque wrench to tighten anchor bolt nuts only to the specified torque. NEVER exceed the specified torque. Overtorquing can cause the bolts to stretch beyond their yield point and result in bolt failure.

9. HOT WEATHER GROUTING
High temperatures accelerate the set, decrease working time, and accelerate the strength gain of cement-based products. The procedures below may compensate for these conditions. Refer also to ACI 305R-91 "Hot Weather Concreting".

- **a.** Materials shall be conditioned as necessary so that the mixed grout is between 60°F and 95°F (16°C and 35°C). Due to the mass of palletized material, up to 72 hours of conditioning may be required. [For fast setting grouts, condition to between 60°F and 80°F (16°C and 27°C)].
- **b.** When temperature of mixed grout exceeds 80°F (27°C), normal setting grouts shall be placed within 30 minutes of mixing.
- **c.** All surfaces in contact with grout must be preconditioned and maintained below 95°F (35°C) for a minimum of 24 hours. [90°F (32°C) for fast setting grouts].
- **d.** Cooling of surfaces, materials and equipment can be accomplished by using chilled water for mixing and presoaking concrete and metal surfaces. Shade area from direct sunlight or pour grout when temperatures are decreasing.
- **e.** Wind breaks shall be provided when necessary to prevent rapid evaporation.
- **f.** Grout shall remain shaded, protected with damp rags prior to set, and a wet cure continuously maintained for at least three days. Wet cure must be followed immediately by an approved curing compound that meets the requirements of ASTM C 309.

10. COLD WEATHER GROUTING
Low temperatures delay the set, increase working time and delay the strength development of cement-based products. The procedures below may compensate for these conditions. Refer also to ACI 306R-88, Cold Weather Concreting.

- **a.** Materials shall be conditioned as necessary so that the mixed grout is between 40°F and 80°F (4°C and 27°C). Due to the mass of palletized material, up to 72 hours of conditioning may be required.
- **b.** All surfaces in contact with grout must be preconditioned and maintained at a temperature between 40°F and 90°F (4°C and 32°C) for at least 24 hours.

c. Heating shall be accomplished by indirect exposure. Heated enclosures must be windproof and weatherproof. Combustion heaters must be vented and shall not be permitted to heat and dry the concrete locally. Caution: Exhaust gases may contaminate or cause carbonation within the enclosed environment.

d. The grout temperature shall be maintained above 40°F (4°C) until the grout reaches 1000 psi (6.9 MPa), typically 24 hours, or until it reaches the required strength.

e. Gradually reduce the grout temperature to ambient temperature to avoid thermal shock. [For low temperature conditions to 35°F (2°C), consider the use of FIVE STAR INSTANT GROUT, which must be kept above 35°F until it reaches 1000 psi (6.9 MPa), typically 6 hours, or until it reaches the required strength.]

EPOXY GROUT PLACEMENT PROCEDURES

A. INTRODUCTION

1. The general application procedures outlined below are for use at ambient temperature of 70°F. Temperatures below 70°F tend to slow the set and stiffen the consistency of epoxy grout, and temperatures above 70°F tend to accelerate the set and loosen the consistency of epoxy grout. If grouting is to be done when ambient temperatures are not between 60°F and 90°F, follow the additional recommendations given for Hot Weather Grouting and Cold Weather Grouting for Epoxy Grouts. If other unusual or difficult conditions exist (low clearances, shear keys, etc.), the contractor should consult the owner's engineer and the grout manufacturer's Technical Service Department.

2. All necessary tools and materials should be as close as possible to the area being grouted. Mortar box, mortar mixer (with moving blades), wheelbarrow, hoe, shovels, trowels, and grout components should be within easy reach.

3. If it is desirable that the set times and strength gains are to be maintained at the 70°F rate, the applicable hot weather or cold weather instructions should be reviewed for guidance.

4. It is advised for health and safety reasons that all personnel handling epoxy

material be properly protected. Wearing protective clothing, eye protection (goggles), a respirator, and chemically resistant gloves and boots is necessary. Refer to the manufacturer's Material Safety Data Sheet (MSDS).

B. SURFACE PREPARATION

1. CONCRETE

a. The base concrete should be dry and have attained its design strength before grouting

b. ***DO NOT WET CONCRETE***. All surfaces to be in contact with grout should be dry and entirely free of oil, grease, laitance, curing compounds, frost, and other potential bond-preventing substances.

c. Roughen the surfaces by chipping, sandblasting, or other mechanical means to remove any laitance or weak surface layer.

2. BASEPLATES

a. All metal surfaces of equipment bases which are to be in contact with the grout should be thoroughly cleaned. Sandblasting to an SSPC-SP6 commercial finish will ensure an optimal bond.

b. Level and align the baseplates according to the recommendation of the equipment manufacturer and/or project specifications. For ***most*** conventional epoxy grouts, a **minimum** 2 inch clearance should be provided to facilitate placement. For baseplates wider than three feet, it is imperative to provide an additional one-inch of clearance for each three feet of width. Aggregate is the least costly of all the components of epoxy grout. Grout pours deeper than four inches present the potential for cracking due to excessive internal heat development and subsequent cooling. Deeper pours can be accomplished by using a low exotherm epoxy grout, or pouring in lifts. Embedded rebar acts as a heat sink for curing epoxy. Both methods reduce temperature rise. For placements deeper than four inches, the grout manufacturer should be contacted for detailed procedures.

c. Round shims, wedges, and blocks that are to be removed should be covered with putty, grease, or similar non-bonding material to prevent the grout from adhering. If shims, wedges, or blocks are to remain in place, they should have generously rounded corners (to avoid potential crack development) and be set back at least 2 inches from any plate edge.

3. ANCHOR BOLTS

a. Equipment manufacturers or design engineers often require anchor bolts to be grouted. All surfaces should be thoroughly cleaned of oil, grease, and other deleterious substances and must be dry. Holes must be dried by evaporation, compressed air, or wicking with absorbent rags. Any compressor used to blow out water or other substances from surfaces in contact with the grout must be equipped with an oil trap in the air line to prevent oil from being blown onto the contact surface and preventing the grout from bonding. Refer to Appendix A for more information.

b. If equipment manufacturers or design engineers require anchor bolts to remain isolated, sleeves should be used and filled with a pliable material such as duct seal, putty, silicone rubber molding compound, or other

material specified by the equipment manufacturer. Wrapping bolts in duct tape or foam insulation also works well.

4. SURFACE DRYNESS

All surfaces should be kept completely dry before grouting. Surface must **NOT** be wet.

5. GROUT REMOVAL

Surfaces from which grout is to be removed after placing should be treated with a paste wax or other release agent before placement.

C. FORMING

1. GENERAL

a. Forming or other leak proof containment is always required with epoxy grout. The forms require careful attention to prevent any leakage. If forms are not liquid tight, the grout will leak out and leave voids.

b. Forms must be designed to provide a hydraulic head. If additional hydraulic head is required at the point of placement, headboxes may be used as shown below. Typically, the headbox height should be 1/3 to 1/2 the distance the poured grout must flow. If additional hydraulic head is required at the point of placement, a plunger may be used as shown below.

c. All chamfer edges required in the grouts should be incorporated into the forms because, after hardening, epoxy grout can only be cut or trimmed by grinding.

2. FORM STRENGTH

All forms should be built of materials of adequate strength, securely anchored and shored to withstand liquid head and the forces developed by plunging the grout into place.

3. SEALING AND WAXING FORMS

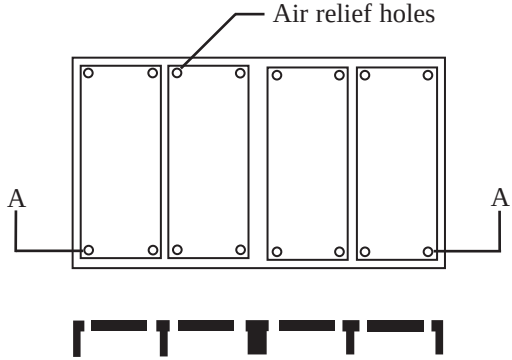
Caulking, such as glazier's putty, butyl rubber caulking, or duct seal should be used to make all joints liquid tight. This particularly applies to the joint between the form and the concrete. All forms may be lined with polyethylene film for easy grout release. Carefully waxing forms with two coats of heavy floor or paste wax, preferably colored, to ensure 100% waxed area is also acceptable.

4. CONTROL OR ISOLATION JOINTS AND REINFORCEMENT

a. Depending upon the application, and as a general rule, control joints may be placed on 4 to 6 foot centers. However, this spacing may (***at the discretion of the design engineer only***) be increased as described in ACI 223-98 (Section 3.4.5). This section of the ACI Manual of Concrete Practice contains control joint information for shrinkage compensating concrete that can be used as a general guide to compensate for thermal expansion differences using epoxy grouts. (There is no shrinkage compensating standard for epoxy grouts as of this writing.) Control joints should extend the full depth and full length from form to form.

b. Joint material can be closed cell styrofoam, thick rubber, thick sheet metal covered with polyethylene, ¼ inch thick steel or wood strips covered with polyethylene tape. Any of these will make removal of the joints relatively easy by preventing the epoxy grout from bonding to them.

c. For pours that are deep (more than 6 inches) or long (more than 6 feet) and under extreme temperature conditions, reinforcing bars should be placed in the grout. To distribute the stresses under these conditions, #6 reinforcing bars should be placed parallel to the equipment frame between the control joints (see diagram below). If wide shoulders or extreme depths are required, consult the grout manufacturer for direction.



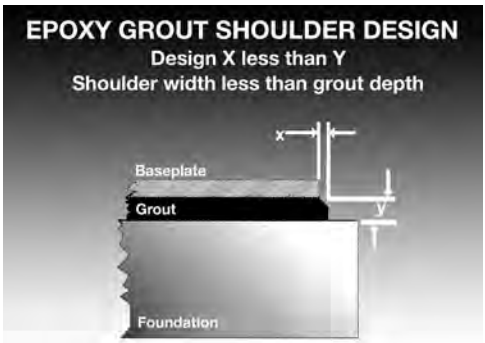
TOP VIEW

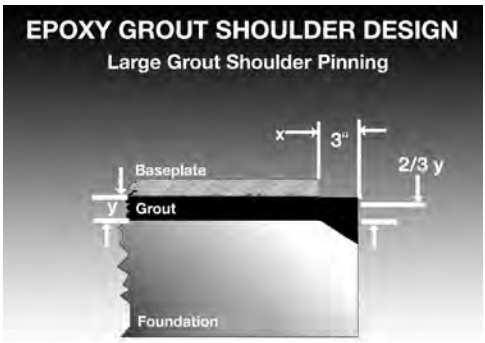
5. AIR RELIEF HOLES

With some base plate designs, air relief holes are mandatory. Baseplates with a skirt around the perimeter should have relief holes (minimum ¼" diameter) in each dead corner. If the plate is sectioned with stiffening members, then relief holes should be provided at the intersections with the skirt (see diagram above for minimum required air relief holes).

6. SHOULDERS

The difference in coefficient of thermal expansion between epoxy grout and concrete induces stresses in shoulders. It is recommended that shoulders not exceed a maximum of 2 to 3 inches. If wide shoulders are mandatory, special anchoring must be provided as shown below and the manufacturer must be contacted for specific instructions.





D. MIXING

1. FOLLOW DIRECTIONS

Grout should be mixed according to the procedures recommended by the manufacturer. Carefully read all mixing information on the packages and the latest literature. If in doubt about the mixing procedures, call the manufacturer.

2. MIXER TYPE

a. Mix in a mechanical mixer at a slow speed (15-20 rpm), using a portable mortar mixer with moving blades (as shown in part three of this section) inside the drum as opposed to a concrete mixer with fixed-in-place fins on a rotating drum. A concrete mixer is not recommended as it will cause air to be entrapped in the mix.

3. MIXING

a. Pour the hardener (Component B) into the epoxy resin (Component A) container and stir by hand or with a variable speed (250 rpm max.) drill and a paddle mixer for two to three minutes until all streaks are eliminated and the mixture is clear. Mixing speed in excess of 250 rpm may entrain air bubbles that reduce EBA.

b. Transfer the mixed liquids to a clean, dry mortar mixer and start it up. Add the aggregate slowly and mix only until the aggregate is completely wetted out. Overmixing results in excess entrapped air and may reduce working time.

c. To maintain proper proportions of resin, hardener and aggregate, always mix full units only. Under no circumstances should partial units be used. For materials prepackaged in one container, such as FIVE STAR RAPID EPOXY GROUT, follow the instructions on manufacturer's label.

4. CONSISTENCY

a. Many years of experience have shown that epoxy grouts and aggregates must be supplied in premeasured quantities to ensure a precision product. Do not vary the ratio of components and **never add solvent to change the consistency.** High temperatures will increase flowability and reduce working time, while cold weather will decrease flowability and extend working time. An ideal balance is developed at 75°F.

b. The only exception to this rule is for the first unit mixed. Because some of the liquids will go to wetting the mixer, about half a 50 lb. bag of aggregate should be withheld from the first batch only. All the following batches should be mixed in accordance with the manufacturer's recommendations with no modifications.

5. CLEANING EQUIPMENT

Equipment and tools must be cleaned before epoxy grout hardens. Hardened epoxy grout can be removed by soaking in appropriate solvent or by grinding. After grouting is completed, or if delays occur, clean mixer, tub, wheelbarrows, tools, etc. with a strong detergent (such as a laundry detergent or trisodium phosphate) and water. Adding some ordinary sand will assist in cleaning a mortar mixer. Organic solvents such as Solvesso, xylol, lacquer thinner, ketones, or similar solvents, as specified by the manufacturer, can also be used for cleaning, but ***FOR SAFETY REASONS***, USE CAUTION WHEN CLEANING POWERED EQUIPMENT WITH HIGHLY VOLATILE SOLVENTS, SUCH AS LACQUER THINNER OR KETONES. KEEP SPARKS AWAY FROM SOLVENTS AND WEAR APPROPRIATE RESPIRATORY PROTECTION.

E. PLACING

1. GENERAL

a. Check Temperature Conditions

Determine if ambient temperature will be between 60°F and 90°F at time of grouting. If not, follow the compensating procedures found in Hot and Cold Weather Epoxy Grouting in parts H and I of this section.

b. Working Time
Temperature affects the consistency of epoxy grout and therefore can affect placement time. Check placement temperature of materials to estimate the time available for placing grout.

c. Transporting Grout
Use power buggies, wheelbarrows, or buckets to transport grout to point of placement.

d. Eliminating Voids
Grout placement should proceed in a manner that will assure that all spaces are filled and that there is intimate contact between the grout and the surfaces to be grouted. The placement should be rapid and continuous to avoid cold joints and to keep voids from forming under the baseplate. All grouting should take place from one side to avoid trapping air. When grouting through grout holes or stand pipes, start placing grout into the next grout hole or stand pipe only when grout from the first hole has reached that next hole.

e. Check for Leaks
Forms must be checked constantly for leaks. All leaks must be sealed immediately or voids will develop.

2. USING A HEADBOX

When hydraulic head pressure is used to flow grout in place, the level of grout in the headbox must never fall below the top of the baseplate, because then air will be trapped. The headbox should be filled to the maximum height (usually 1/3 to 1/2 the pour width) and worked (plunged) down to the top of the baseplate. This procedure is repeated until the grout moves completely under the baseplate, pushing air out in front of it, and rising to the top of the chamfer strip on the far side of the pour.

F. FINISHING

Epoxy grout cannot be trimmed after set. It must be left at final placement level, with all chamfer strips built into forms. To provide a smooth surface, puddle the grout so all aggregate is covered. After initial stiffening, finish with a trowel moistened with low volatility solvent such as diesel oil. All further finishing will require grinding after the grout is completely cured.

G. CURING

1. **FOLLOW INSTRUCTIONS**
   Grout should be cured in accordance with the manufacturer's specifications and recommendations. Read and follow the directions printed on the packaging or on the manufacturer's associated printed material.
2. **FORMS**
   All forms should remain in place until the minimum required strengths are attained.
3. **TEMPERATURE**
   The temperature of the baseplate, supporting concrete foundation and grout should be maintained between a minimum of 60°F and a maximum of 90°F during grouting and for at least 24 hours afterward. See grout manufacturer's literature for curing schedules.
4. **MOIST CURING**
   Water interferes with proper curing of epoxy grouts. ***DO NOT MOIST CURE EPOXY GROUT!***

H. HOT WEATHER GROUTING INSTRUCTIONS FOR EPOXY GROUT

1. **PRECONDITIONING TEMPERATURE**
   All epoxy grout components should be stored in a dry, weatherproof area until all epoxy grout components reach a temperature between 65°F and 80°F. Since aggregate is the major portion of the mix, its temperature will be the most critical in determining final mix temperature.

2. **COOLING AND SHADING**
   Shading or other methods should be used to cool baseplates to below 90°F, Extreme caution should be used because all surfaces in contact with epoxy grout must be completely dry before grouting. Concrete, steel, and forms should be shaded from direct sunlight beginning 24 hours prior to placing grout and kept shaded until at least one day after placement.
3. **MIXING PRECAUTIONS**
   Do not allow mixed resin and hardener to remain without aggregate for more than 3 minutes.

4. TIME OF PLACEMENT

Place the grout in the evening or later when the temperature is dropping. This allows the heat developed during the curing phase to take place during the coolest part of the day.

I. COLD WEATHER GROUTING INSTRUCTIONS FOR EPOXY GROUT

1. PRECONDITIONING TEMPERATURE

All epoxy grout components should be stored in a dry, weatherproof area until all epoxy grout components reach a temperature between 70°F and 80°F. Since aggregate is the major portion of the mix, its temperature will be the most critical in determining final mix temperature.

2. SURFACE CONDITIONS

All surfaces in contact with grout must be maintained at a temperature of at least 60°F for at least 24 hours prior to and at least 48 hours subsequent to grouting. It is economically advantageous to pour and cure the epoxy at temperatures between 65°F and 75°F. Doing so quickens the pace of placement and subsequent curing, thus enabling the equipment to start up sooner. It is important to prevent frost formation on these surfaces.

TENTED, HEATED ENCLOSURE FOR COLD WEATHER GROUTING

3. METHODS

There are many methods of maintaining proper preconditioning, preparation, and curing temperatures. Consult the grout manufacturer for advice on techniques best suited to each application.

CHAPTER 6

TYPICAL CEMENTITIOUS GROUTING APPLICATIONS

The advantages and disadvantages of different placement methods are reviewed for several typical grouting applications:

- A 2 ft x 2 ft baseplate
- A 6 ft x 10 ft baseplate with shear keys
- A waffle baseplate
- Embedded anchors and tie rods
- Precast, pre-stressed applications

The following basic rules are applied in each of the examples:

1. Use the minimum water possible to achieve the required consistency in all placements and do not exceed manufacturer's recommended maximum.
2. Use flowable or fluid grouts and their required watertight formwork where required.
3. If, when using any placement method, the grout extends up the side of the baseplate, cut it back at a 45° angle from the bottom of the baseplate to the foundation. This will avoid cracking of the grout due to possible movement of the baseplate caused by temperature changes, vibration, or other causes.
4. When grout is placed in depths over three inches, consider extending the grout with a course aggregate such as clean, washed 3/8 inch pea gravel that meets the requirements of ASTM C 33. Conditions may vary. Contact the manufacturer for further information.
5. Use grout holes and air relief holes where appropriate.
6. Keep equipment anchors a reasonable distance from the edge of the plate to avoid vertical cracking on the grout.
7. Improper curing, over-finishing, or over-troweling of the grout may result in hairline cracking of the surface.
8. Consult the manufacturer for grouting situations that need clarification.

The typical applications are meant to be guidelines in selecting grouting procedures. Every project, however, is subject to many variables which could require modifications in the selected method. Consult the FIVE STAR PRODUCTS, INC. Engineering and Technical Center for assistance and for any needed clarification.

TYPICAL GROUTING APPLICATIONS
NONSHRINK Cement-Based Grouts

2 ft x 2 ft BASEPLATE
A typical 2 ft x 2 ft baseplate is easily grouted with any one of the methods listed below.

PLACEMENT METHOD	ADVANTAGES	DISADVANTAGES
DRY PACKING AND TROWELABLE	• No Forms • High Strength	• Highly Skilled Personnel Needed • Potential for Cold Joints • Not economical for a Large Number of Plates
POURING	• Fast Placement • Tight Clearances • Consistent Placement	• Watertight Forms Must Be Built • Potential Segregation
PUMPING	• Faster Method • Little Air Entrapment • Considerable Economy for a Large Number of Plates	• Watertight Forms Must Be Built • Equipment Rental • Skilled Personnel Needed • Potential Segregation

Dry packing is often used when a few small plain plates need to be grouted, but ACI 351.1R cautions that "it is difficult…(and in many cases, impossible) to achieve proper placement" by dry packing. In addition, some fluid grouts may exhibit high drying shrinkage and segregation. If a large number of plates are involved, pumping the grout should be considered because of economy and high performance.

STRUCTURAL COLUMNS, AND BEARING PLATES, POLES AND ANCHORS.

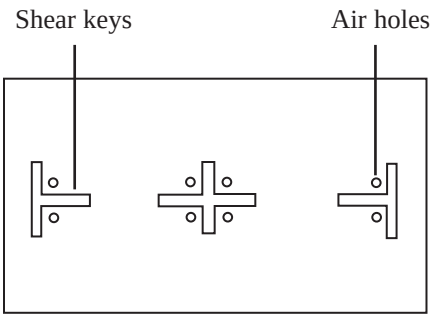
FIVE STAR GROUT can be dry packed, rammed, troweled, poured, or pumped, indoors or out.

TYPICAL GROUTING APPLICATIONS
NONSHRINK Cement-Based Grouts

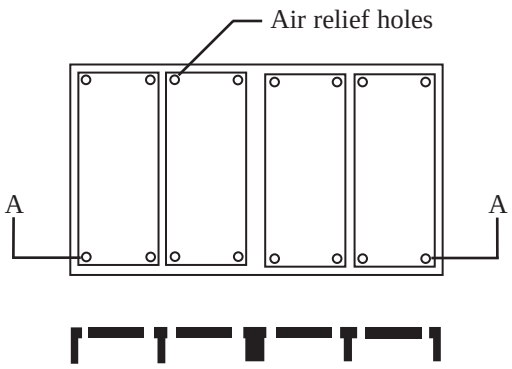
6 ft x 10 ft BASEPLATE with SHEAR KEYS
Often a baseplate with obstructions is encountered. In this example, the obstructions are three shear keys under a 6 ft x 10 ft baseplate.

PLACEMENT METHOD	ADVANTAGES	DISADVANTAGES
DRY PACKING AND TROWELABLE	• NOT RECOMMENDED	
POURING	• Fast Placement • Consistent Placement	• Watertight Forms Must Be Built • Skill Required in Placement • Potential Segregation
PUMPING	• Faster Method • Highest EBA • Lowest Cost	• Watertight Forms Must Be Built • Equipment Rental • Skilled Personnel Needed • Potential Segregation

Dry packing is neither an economical nor an effective procedure for this baseplate configuration. It would be very difficult to obtain a high performance placement. Pouring is worth considering under these conditions. Pumping, however, is the fastest, best performing, and most economical method for grouting this type of plate.



Baseplate with Shear Keys



Section A-A

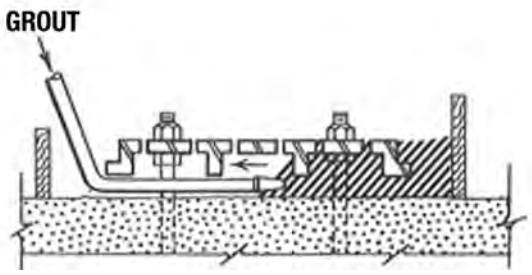
TYPICAL GROUTING APPLICATIONS
NONSHRINK Cement-Based Grouts

WAFFLE BASEPLATE
A waffle plate, or a plate with a skirt around the perimeter, is often encountered in grouting applications. Waffle plates are one of the most difficult types of plates to grout successfully. Adequately sized and located vent holes in each compartment of the plate are required, as are air relief holes in corners. For this configuration, and for those with similar obstructions, close supervision is important to ensure that no air is entrapped.

PLACEMENT METHOD	ADVANTAGES	DISADVANTAGES
DRY PACKING AND TROWELABLE	• NOT RECOMMENDED	
POURING	• Fast Placement • Consistent Placement	• Watertight Forms Must Be Built • Skill Required in Placement • Potential Segregation
PUMPING	• Faster Method • Highest EBA • Lowest Cost	• Watertight Forms Must Be Built • Equipment Rental • Skilled Personnel Needed • Potential Segregation

Dry packing should not be used because of the high probability of entrapping air under the plate. Pouring may be used provided great care is exercised in making sure the grout rises through the air relief holes. The use of a vibrator is recommended. If fluid self-leveling grout falls below any one of the many waffle areas, and loses contact with the plate during the placement, it will entrap air and reduce the EBA.

Pumping through a nozzle (as shown below) is the fastest, best performing, and most economical method for grouting under waffle plates.



Typical Pumping Application

TYPICAL GROUTING APPLICATIONS
NONSHRINK Cement-Based Grouts

EMBEDDED ANCHORS AND BOLTS
In anchoring bolts or anchors in concrete, it is important to remember that a precision NONSHRINK grout must be used to ensure adequate anchoring strength of the embedded item. *When the bolt diameter is one inch or less, the hole diameter should be a minimum of two inches. When the bolt diameter is greater than one inch, the hole diameter should be at least twice the bolt diameter***.** The anchor should be embedded deeply enough so that it will fail before the grout does. Refer to Appendix A for more information on anchor bolt grouting.

PLACEMENT METHOD	ADVANTAGES	DISADVANTAGES
DRY PACKING AND TROWELABLE	• NOT RECOMMENDED	
POURING	• Fast Placement • Little Skill Required • Good for Moderate Embedments with Adequate Clearance (Flowable) • Good for Tight Clearances and Deep Embedments (Fluid)	• Cannot Be Used Horizontally • Potential Segregation
PUMPING	• Good for a Large Number of Anchors • Horizontal Anchors	• Equipment Rental • Skilled Personnel Needed • Potential Segregation

Anchors must be embedded using flowable or fluid grouts only. The grout can often be placed in the hole before the anchor, and then the anchor inserted and rotated repeatedly clockwise, then counterclockwise, or vibrated to ensure proper coverage. Flowable or fluid grout is good for long, deep holes with adequate clearances.

Note that insufficient clearance between the anchor and the hole risks reduced strength and failure to develop a good bond.Grout should be placed either by pouring or by pumping.

Special grouts are formulated for each of the previously discussed applications, including cable grouting. Machinery anchor bolts can be placed before or after the grout is placed in any of the above applications, provided the bolt hole is vibrated before the grout sets. Machinery manufacturers, for various reasons, may have to change the anchoring locations, and setting anchors accurately in the field prior to the arrival of machinery is extremely expensive. When the machinery arrives, the anchor bolt locations can be readily determined, the bolt holes quickly drilled, and a threaded, deformed, or plain anchor, threaded to receive the locking nut, grouted into place.

TYPICAL GROUTING APPLICATIONS
NONSHRINK Cement-Based Grouts

PRECAST OR PRE-STRESSED WORK
Grouting horizontal and vertical joints between precast or pre-stressed panels may be performed by one of the following methods:

PLACEMENT METHOD	ADVANTAGES	DISADVANTAGES
DRY PACKING AND TROWELABLE	• No Forms • High Strength	• Potential for Cold Joints • Skill Required in Placement
POURING	• Fast Placement	• Watertight Forms Required • Potential Segregation
PUMPING	• Fastest Method for Large Number of Joints or Bearing Pads	• Equipment Rental • Hand Pumps for Small Jobs • Mechanical Pumps for Large Projects • Potential Segregation • Watertight Forms Required

CHAPTER 7

TYPICAL INSTALLATIONS BY INDUSTRY CEMENTITIOUS GROUT

TYPICAL INSTALLATIONS BY INDUSTRY

CHEMICAL PROCESSING

POWER

PULP AND PAPER

INFRASTRUCTURE

REFINING

TYPICAL INSTALLATIONS BY INDUSTRY
EPOXY GROUT

POWER

REFINING

PORTS (CRANE RAILS)

PULP AND PAPER

INFRASTRUCTURE
(WATER TREATMENT)

GAS TRANSMISSION

CHAPTER 8
SPECIFICATIONS

1. CEMENTITIOUS GROUT SPECIFICATIONS

The purpose of a specification is to ensure that the type and performance of materials, techniques, and equipment used by a contractor meet the requirements established by the designer and owner. The proper grout should be clearly specified for the particular application.

In specifying a NONSHRINK grout, the specifier faces a particularly difficult situation. Manufacturers today are marketing products claiming they are NONSHRINK or nonmetallic, and they may or may not meet either of these requirements or be NONSHRINK when tested according to pre-approved national test standards such as ASTM C 827 (Standard Test Method for Change in Height in Early Ages of Cylindrical Specimens from Cementitious Mixtures) or ASTM C 1107 (Standard specification for packaged dry hydraulic cement grout NONSHRINK). When a manufacturer has not had a ten to twenty year history of satisfactory performance, the specifier should specifically ask for or obtain independent verification that the products he desires to specify are indeed precision NONSHRINK. These products should be supplied by companies who have many years of experience and rigorous quality control specifications. The manufacturer should mark packages and literature to warranty their products have been tested under the appropriate ASTM standards.

The contractor is in a difficult position if the specifications do not name a grout, or clearly state the type and performance of grout desired for a particular application. Specifications must be clear, not vague, obsolete, or otherwise fail to define the level of performance required.

The designers using ASTM and ACI Standards can ensure a precision NONSHRINK grout is specified. It is important in the selection process for the designer to consult the grout manufacturer on the grout type and performance that is required. The specification writer should work closely with the project designer on each project to ensure both the drawings and specifications clearly state where and what type of NONSHRINK grout is to be used.

In selecting the grout, the specifier should carefully evaluate the performance stated in published literature and should require a quality laboratory's signed test results verifying the NONSHRINK performance and other desired properties.

The cost of grouting is a small portion of the total expense of a construction project, and the material cost of the grout is minor compared to the labor cost for installation. The specifier should be aware that certain grouts, as with other construction products, may have the lower initial cost, but not necessarily the lower lifetime cost. Therefore, the specifier should be governed primarily by performance and history and not only by material cost considerations.
It is essential that all grouts specified be manufactured by a company supported by a technical service organization. It is also important when selecting a grout for the specifier

to give preference to the leading manufacturers who have distribution networks throughout the country to ensure that the grout is readily available.

DESIGN-A-SPEC® (DAS)
Five Star Products, Inc. has developed a standard set of product selection and installation instructions to help architects and engineers expeditiously choose the right Five Star product or an equal for their design applications. The document is designed to enable architects and engineers to follow a procedure that they can use to create a clear set of installation instructions for contractors to follow.

Design-A-Spec®, available to specifiers upon request, provides performance specifications for individual Five Star products. To obtain a copy, go to website at fivestarproducts.com, or call Five Star Products, Inc. at 203-336-7900.

Specifiers who need assistance in selecting a grout can consult FIVE STAR PRODUCTS, INC. Engineering and Technical Center for help with design or field application issues, or contact a field representative.

TYPES OF SPECIFICATIONS
The specifier has four primary types of specifications to choose from in specifying grout. They are, in order of preference:

1. **Proprietary Specification:** Name the specific grout to be used for each specific application, such as "FIVE STAR FLUID GROUT 100 for machinery." Also give the company name and address such as "Manufactured by FIVE STAR PRODUCTS, INC., Shelton, Connecticut."
2. **Or Approved Equal with Identical Properties:** Name a proprietary product with the clause "or approved equal with identical properties" after the name of the product.
3. **Performance Specification:** Specific data and performance requirements are listed.
4. **Open Listing:** Naming three or more competitive grouts.

PROPRIETARY SPECIFICATION
In a proprietary specification there is no question in the mind of the owner, designer, or contractor as to the type and level of performance of the grout required. In addition, no time is lost in the search for, submittal of, or approval of other materials.

OR APPROVED EQUAL WITH IDENTICAL PROPERTIES
When required by the owner or when the specifier thinks there may be a possibility of additional products meeting the required standards, consideration should be given to the use of a specification that reads, for example, "FIVE STAR GROUT or approved equal with identical properties." This has some of the advantages of the above, but it involves the designer, specifier, and contractor in determining if another grout matches the specified grout's performance. It forces the specifier to spend considerable time evaluating other grouts and rejecting those products that do not achieve the desired performance. The "or approved equal" type of specification should be used if the proprietary specification listed above cannot be accepted by the owners.

PERFORMANCE SPECIFICATIONS
The specifier in using a performance type specification faces many issues. Clearly delineating the performance requirements and test standards, such as ASTM C 827 and ASTM C 1107 for NONSHRINK, strength tests, time of setting (initial and/or final), and other desirable properties is required. The specifier should be aware this may mean that many submissions might be received from various manufacturers. The specifier must select from those products believed to meet the criteria established. This opens the specifier and designer to potential liability unless they are experts in the grouting field. The time consumed by the specifier, designer, and owner can be quite extensive.

OPEN LISTING
Naming three or more competitive products is most common in the industry. However, it is essential that the selected competitors offer comparable performance properties. Unless the specifier has taken the time to carefully research the listed grouts to determine if their performance is satisfactory, the grout used will be selected on the basis of cost rather than performance.

COMBINATION SPECIFICATION
Sometimes a specifier is required to use a specification which is a combination of two or more types. When this happens, the specifier may limit liability by specifying a single grout such as FIVE STAR GROUT in a proprietary specification, and then adding a performance specification to eliminate grouts that exhibit shrinkage.

LONG FORM AND SHORT FORM SPECIFICATIONS
There are two forms of specifications: a long form and a short form. Although in many cases, the short form is adequate, the long form may be more appropriate for projects with special requirements. Long form specifications are complete specifications, including sections on General Conditions, Material Specifications, Preparation, Application, Finishing and Curing, and Extreme Weather Conditions. Short Form Specifications are generally limited to a section on Material Specification, but may include such other requirements as the specifier deems necessary.

2. EPOXY GROUT SPECIFICATIONS

Portions of the above discussion of specifications for cementitious grouts apply to specifications for epoxy grout as well. Keep in mind when specifying an epoxy grout that the purpose of the grout is to fill the space to be grouted **completely** and **permanently,** and to transfer the load to concrete. Since their inception, epoxy grouts have been promoted as "nonshrink" or as evidencing "negligible" shrinkage. Test methods supposedly verifying nonshrink performance date back to the early 1960s, but it is now clear that these methods are inadequate for epoxy grouts, because they do not measure vertical height change. A modification of the ASTM C 827 test method shows that most epoxy grouts exhibit even greater vertical shrinkage than the shrinking cement-based grouts. Loss of EBA and failures of epoxy grout can be directly correlated with plastic shrinkage (vertical height change).

Loss of Effective Bearing Area will decrease the area of baseplate actually in contact with the grout, thus reducing the effectiveness of the grout and increases creep in an

epoxy grout. It is generally recommended that the total load on the epoxy grout (dead load plus bolt tension) not exceed 500 psi (3.45 MPa). This design assumes 100% EBA. At 50% EBA the load increases to 1,000 psi (6.9 MPa). Tests indicate that creep increases in direct proportion to the increase in load. In the situation mentioned, creep would approximately double! To prevent such an occurrence, a minimum of 95% EBA should be specified. Because this is one of the most important requirements in an epoxy grout specification, to be reasonably assured of obtaining a 95% EBA, a "NONSHRINK" epoxy grout should be specified. Testing according to ASTM C 827 (Modified) should be an integral part of the specification.

Following are examples of NONSHRINK EPOXY GROUT specifications:

SHORT FORM PROPRIETARY SPECIFICATION

All grouting as called for on the drawings and/or in the specifications shall be performed with FIVE STAR DP EPOXY GROUT as manufactured by Five Star Products, Inc. of Shelton, Connecticut. No substitutions will be approved.

OR APPROVED EQUAL WITH IDENTICAL PROPERTIES SPECIFICATION

All grouting as called for on the drawings and/or in the specifications shall be performed with FIVE STAR DP EPOXY GROUT as manufactured by Five Star Products, Inc. of Shelton, Connecticut, or approved equal with identical properties. The grout must show no shrinkage when tested according to ASTM C 827 (Modified).

PERFORMANCE SPECIFICATION

All grouting as called for on the drawings and/or in the specifications shall be performed with an epoxy grout meeting the performance requirements that follow:

1. Epoxy grout must have a minimum 10-year history of use and meet the following performance requirements. It must be a 100% solids system.
2. **Vertical Height Change**
   The grout shall show no shrinkage (0.0%) and a maximum 4.0% expansion from time of placement when tested according to ASTM C 827 (Modified).
3. **Compressive Strength**
   The grout shall (depending on product selection) show a 7-day compressive strength of at least 13,000 psi (89.7 MPa) when tested according to ASTM C 579, Method B.
4. **Thermal Expansion**
   The grout shall show a maximum coefficient of thermal expansion of 20×10^{-6} in/in/°F (36×10^{-6} mm/mm/°C) when tested according to ASTM C 531.
5. **Creep Resistance**
   The grout shall show creep equal to or less than 4.5×10^{-3} in /in at 140°F (60°C) for one year with a load of 400 psi (2.8 MPa) when tested according to ASTM C 1181.

CHAPTER 9
SHORT FORM SPECIFICATIONS

Five Star® Grout
Performance Specification

A. Nonshrink cementitious grout shall be a preproportioned, prepackaged, precision cement based grout requiring only the addition of potable water. The grout shall not contain metallic aggregate, expansive cement, or gas generating additives such as aluminum powder. The grout shall contain an air release aggregate to generate positive expansion.

B. The manufacturer shall be ISO 9001 certified.

C. Manufacturer shall have at least ten years experience in the manufacture of precision cement-based grouts.

D. The grout material shall meet all the following typical performance criteria when cured at 73°F (23°C): Note 1

1. Early Height Change, ASTM C 827	0.0 to 4.0%
2. Hardened Height Change, ASTM C 1090	0.0 to 0.3%
3. Effective Bearing Area	95%
4. Compressive Strength, ASTM C 942	
28 Days	6500 psi (44.8 MPa)
5. Bond Strength, ASTM C 882	
28 Days	2000 psi (13.8 MPa)
6. Application Temperature	40°F to 90°F (4°C to 32°C)
7. Material Temperature	40°F to 90°F (4°C to 32°C)
8. Meets performance requirements of ASTM C 1107, Grades A, B and C.	
9. Working Time 45 Minutes	

E. The precision nonshrink cementitious grout meeting these criteria is:

Five Star® Grout

as manufactured by Five Star Products, Inc., Shelton, Connecticut 06484, Direct: 203-336-7900.

Note 1 *The data shown above reflect typical results based on laboratory testing under controlled conditions. Reasonable variations from the data shown above may result. Test methods are modified where applicable.*

Five Star® Fluid Grout 100
Performance Specification

A. Nonshrink cementitious grout shall be a preproportioned, prepackaged, precision cement-based grout requiring only the addition of potable water. The manufacturer shall be ISO 9001 certified and have at least 10 years experience in the manufacture of precision cement-based grouts. The manufacturer shall offer technical services and provide a representative at the jobsite if requested.

B. The grout material shall meet all the following typical performance criteria when cured at 73°F (23°C): Note 1

1. Grout shall not contain metallic aggregate, expansive cement, or gas generating additives, such as aluminum powder.
2. Grout shall contain an air release aggregate to generate positive expansion.
3. Early Height Change, ASTM C 827 — 0.0 to 4.0%
4. Hardened Height Change, ASTM C 1090 — 0.0 to 0.3%
5. Effective Bearing Area — 95%
6. Compressive Strength, ASTM C 942
   28 Days — 8000 psi (55.2 MPa)
7. Bond Strength, ASTM C 882
   28 Days — 2000 psi (13.8 MPa)
8. Consistency, ASTM C 939 — 20 to 30 seconds
9. Working Time — 30 minutes
10. Meets performance requirements of ASTM C 1107, Grades A, B and C for 30 minutes at 40°F to 90°F (4°C to 32°C).

C. An acceptable product which meets these criteria is:

Five Star® Fluid Grout 100

as manufactured by Five Star Products, Inc., Shelton, CT [203-336-7900].

Note 1 *The data shown above reflect typical results based on laboratory testing under controlled conditions. Reasonable variations from the data shown above may result in the field. Test methods are modified where applicable.*

Five Star® DP Epoxy Grout Performance Specification

A. Nonshrink epoxy grout shall be a 100% solids, premeasured, prepackaged system containing thermosetting epoxy resins, expansive additives and inert fillers. The manufacturer shall be ISO 9001 certified and have at least 10 years experience in the manufacture of nonshrink epoxy grouts. The manufacturer shall offer technical services and provide a representative at the jobsite upon request.

B. The grout material shall meet all the following typical performance criteria when cured at 73°F (23°C): Note 1

	Standard Mix		**High Flow Mix**	
Aggregate Content	**5 Bags/Unit**		**4 Bags/Unit**	
1. Compressive Strength, ASTM C 579 B Note 2				
	Comp. Strength	Comp. Modulus	Comp. Strength	Comp. Modulus
	psi (MPa)	psi (kPa)	psi (MPa)	psi (kPa)
1 Day	11000 (75.9)	1.5 x 10_6 (10.4)	9000 (62.1)	1.4 x 10_6 (9.7)
7 Days	14000 (96.6)	2.0 x 10_6 (13.8)	13000 (89.7)	1.9 x 10_6 (13.1)
	Post cured @ 140°F (60°C)			
	6500 (113.8)	2.2 x 10_6 (15.2)	14500 (100.0)	2.0 x 10_6 (13.8)
2. Height Change, ASTM C 827, 90°F (32°C)	Positive Expansion		Positive Expansion	
3. Effective Bearing Area (EBA)	95%		95%	
4. Tensile Strength, ASTM C 307,	2100 psi (14.5 MPa)		90°F (32°C) 2000 psi (13.8 MPa)	
5. Creep, ASTM C 1181, 1 Year, 400 psi (2.8 MPa), 140°F (60°C)	3.2 x 10_{-3} in/in (mm/mm)		4.1 x 10_{-3} in/in (mm/mm)	
6. Flexural Strength, ASTM C 580	3800 psi (26.2 MPa)		4000 psi (27.6 MPa)	
7. Bond to Concrete, ASTM C 882	Concrete Failure		Concrete Failure	
8. Coefficient of Expansion, ASTM C 531	17 x 10_{-6} in/in/°F(30 x 10_{-6} mm/mm/°C)		18 x 10_{-6} in/in/°F (32 x 10_{-6} mm/mm/°C)	

C. An acceptable product which meets these criteria is:

Five Star® DP Epoxy Grout

as manufactured by Five Star Products, Inc., Shelton, CT [203-336-7900].

Note 1 *The data shown above reflect typical results based on laboratory testing under controlled conditions. Reasonable variations from the data shown above may result in the field. Test methods are modified where applicable*

Note 2 *Rate of loading 0.25 inches per minute.*

Five Star® Pile Jacket Grout Performance Specification

A. The epoxy grout shall be a 100% solids, premeasured, prepackaged, system containing epoxy resin, hardener, and aggregate with inert filler and graded sand. The manufacturer shall have at least 10 years experience in the manufacture of nonshrink epoxy grouts. The manufacturer shall offer technical services and provide a representative at the jobsite upon request.

B. The manufacturer shall have at least a five year history of ISO certification. The grout shall be manufactured according to ISO 9001 certified procedures for all manufacturing operations.

C. The grout material shall meet all the following typical performance criteria when cured underwater at 73°F (23°C): Note 1

1. Compressive Strength, ASTM C 579 B Note 2	
1 Day	3000 psi (20.7 MPa)
7 Days	7500 psi (51.7 MPa)
2. Tensile Strength, ASTM C 307	
7 Days	2000 psi (13.8 MPa)
3. Bond to Concrete, ASTM C 882	
7 Days	1500 psi (10.3 MPa)
4. Water Absorption, ASTM C 413	0.0%

D. An acceptable product which meets these criteria is:

Five Star® Pile Jacket Grout

as manufactured by Five Star Products, Inc., Shelton, CT [203-336-7900].

Note 1 *The data shown above reflect typical results based on laboratory testing under controlled conditions.*

Reasonable variations from the data shown above may result. Test methods are modified where applicable..

Note 2 *Rate of loading 0.25 inches per minute.*

Five Star® Elastomeric Grout Performance Specification

A. The polyurethane grout shall be a 100% solids, premeasured, prepackaged, system containing polymer, curative, and aggregate with inert filler and graded sand. The manufacturer shall have at least 10 years experience in the manufacture of nonshrink grouts. The manufacturer shall offer technical services and provide a representative at the jobsite upon request.

B. The manufacturer shall have at least a five year history of ISO certification. The grout shall be manufactured according to ISO 9001 certified procedures for all manufacturing operations.

C. The grout material shall meet all the following typical performance criteria when cured at 73°F (23°C): Note 1

1. Shore A Hardness, ASTM D 2240	
Neat	70 ± 10
Filled	85 ± 10
2. Volume Resistivity, ASTM D 257	> 10^{12} Ohm-cm
3. Tensile Properties, ASTM D 638	
Ultimate Tensile Strength	450 psi (3100 kPa)
Elongation	200%
4. Tear Resistance, ASTM D 1004	200 lb/in (35.7 kg/cm)
5. Slant Shear Bond Strength, ASTM C 882	
Concrete (deflection to substrate)	No failure
Steel (deflection to substrate)	No failure
6. Compression Modulus, ASTM D 575B	1 to 12%
7. Compression Set, ASTM D 395	
Incremental Set (third test)	< 1%
8. Dynamic Deflection, ASTM D 2231	No failure
9. Fatigue Resistance, 5 to 250 psi (35 to 1720 kPa)	
16 million cycles at 20 Hz	< 10% deflection
10. Height Change, ASTM C 827	Positive

D. An acceptable product which meets these criteria is:

Five Star® Elastomeric Grout

as manufactured by Five Star Products, Inc., Shelton, CT [203-336-7900].

Note 1 *The data shown above reflect typical results based on laboratory testing under controlled conditions.*

Reasonable variations from the data shown above may result. Test methods are modified where applicable.

CHAPTER 10

CONCRETE REPAIR INTRODUCTION

This section of the Handbook discusses materials available for concrete repairs, their performance, use, and specifications.

Concrete can fail for any of several reasons, ranging from exposure conditions, wearing conditions, and misuse of the structure, to poorly selected ingredients, inadequate mix design and improper placement of mixes. Lack of attention to procedures, inadequate training of skilled people, limited knowledge of materials, the improper selection of the repairing material to be used, and environmental factors like carbonation or degradation from chlorides, are other factors that can contribute to concrete failures.

Contractors often must repair spalled or honeycombed concrete. For large areas or major repairs, various versions of FIVE STAR STRUCTURAL CONCRETE® should be considered to select the proper repair product. All repair surfaces must be free of all oil, grease, laitance, curing compounds, and other harmful substances. The surfaces should be mechanically roughened to assure the bond of the repair material to the existing concrete. Contact the repair material manufacturer for any unusual applications.

When repairing a damaged section of concrete, all these factors have to be taken into account. Recently, manufacturers of concrete products and the Army Corps of Engineers performed considerable research in this area and developed products specifically for the repair of structural concrete. These products have taken into account critical factors such as bonding capability, shrinkage, expansion, strength, thermal compatibility, ease of application, waterproofing, freeze/thaw resistance, chloride ion permeability, and abrasion resistance. FIVE STAR STRUCTURAL CONCRETE® was developed with these criteria in mind.

Sand/cement mixes that have been used in the past should not be used as structural repair products. Such mixes do not provide acceptable performance under the criteria listed.

CEMENTITIOUS CONCRETE REPAIRS EXPLANATION OF PROPERTIES

Because materials will vary by manufacturer, care should be taken to ensure that similar properties and related test methods are properly understood and compared before choosing a product. Below are brief descriptions of the critical physical properties and related test methods. These should be investigated by a Licensed Professional Engineer before deciding upon a concrete repair material. Particular attention should be paid to elevated structures and through deck repairs. It is recommended that a Licensed Professional Engineer approve the application, design, reinforcement, repair procedures, etc.

Length Change - A repair material should not exhibit significant length change in the hardened state. ASTM C 157 is one test method to measure length change. This test should be modified to reflect the manufacturer's curing procedures. Length change should be less than 0.05% for wet expansion or dry shrinkage.

Compressive Strengths - Compressive strength is a basic structural property, and the repair material should at least reach the compressive strength of the concrete being repaired. ASTM C 109 is one test method used to measure compressive strength and should be modified to reflect the manufacturer's recommended curing procedures, according to ASTM C 928 for rapid setting materials.

Bond Strength - Bond Strength is critical property for any structural application, especially for elevated structures. Without adequate bond [2000 psi (13.8 MPa) or greater] to concrete, a repair may break out prematurely and serve no structural purpose. This may result in the failure of a structure. ASTM C 882 is used to test bond strength provided the procedures are modified to the substrate preparation instructions recommended by the manufacturer.

Thermal Coefficient of Expansion - A repair material should exhibit a thermal coefficient of expansion similar to the substrate. The thermal coefficient of expansion of concrete has been reported between 2×10^{-6} and 11×10^{-6} inch per inch per °F. ASTM C 531 is the appropriate test method.

Permeability - The permeability of the repair material is critical because it is a measure of durability. If a material is very permeable to water, then salts and other ingredients will penetrate the repair material, ultimately leading to the deterioration of the repair and surrounding concrete.

Set Time - Set time is a relative measure of and directly proportional to the material working time. ASTM C 266 is the appropriate test for this property.

Yield - Yield (or volume) is a very important feature in purchasing material because buying by the bag or pound can be costly since not all materials with the same bag weight have the same yield.

CRACKING IN CONCRETE

Ever since the first discovery of cementitious mixtures by the Egyptians, there has been cracking in concrete. Some of the world's greatest concrete experts have written volumes of information and given many lectures about the causes of concrete cracking.

There are many ways to describe the types of cracking. In the following, an attempt is made to define most of the various causes of concrete cracking. It is not meant to be the total explanation for any particular crack or the absolute answer to the exact cause, just a series of potential possibilities.

Common types of cracking can be broken down into two force categories. External Forces and Internal Forces:

External Forces:
Static load factors
Horizontal pressures (tension or compression)
Vertical forces causing deflection or positive bending
Excessive dynamic loads (impact or vibration)
Large ambient temperature gradients (changes) which cause shrinkage on cooling and expansion on heating.

Internal Forces:
Plastic shrinkage
Hardened shrinkage
Hardened expansion
Rapid evaporation
Internal heat build-up (addition of coarse aggregate can alleviate this)
High ambient temperatures
Rapid or sudden ambient temperature changes (particularly downward)
High material temperatures
High water temperatures
Freezing
Use of chemical additives
Internal tensile and/or shear stresses
Improper formulation of cementitious mixture
Over watering
Segregation
Internal rebar corrosion
Length of pour
Depth of pour
Mass of pour
Inability of the concrete materials to keep a low heat of hydration
Inability of the concrete materials to dry out and cool off on an even basis
Excessive vibration (over-use of pencil vibrator) during pour
Lack of appropriately located expansion or isolation joints
Improper curing
Improper placement

CHAPTER 11
SELECTING A REPAIR MATERIAL

Repair materials may be classified into three general groups: Cementitious, Polymer and Polymer modified. Cementitious materials are those materials which require the addition only of potable water – they may also be termed "hydraulic materials". Polymer materials are modifying agents to increase flexural strength and other performance properties. Both groups have advantages and disadvantages.

Cement-Based: These generally are prepackaged materials requiring only the addition of potable water. Their physical properties are very similar to those of concrete. As opposed to the polymer types, cementitious products are considered "user-friendly" and users have had considerable experience with them.

The cementitious materials achieve strengths to or greater than the concrete being repaired. Thermal coefficients of expansion are nearly identical to that of concrete. The main disadvantage of most cementitious products is that they don't develop adequate bond strength. Sand/cement mixtures, with or without "bonding" admixtures, and gypsum-based products, exhibit this disadvantage and are usually classified as temporary patches. Of all the properties of cementitious repair materials, bond strength is one of *the* most important requirements.

One product on the market was developed specifically to produce excellent bond strength and the other desirable properties of an ideal repair material. It is called **Five Star Structural Concrete®.**

Polymer Based: These include epoxies, polyesters, and acrylics and are most commonly used where chemical resistance is required. Most of the polymer-based repair materials achieve high strength and good bond to a properly prepared and dry substrate.

There are some disadvantages to these materials:

- They are generally more difficult to work with as compared to cement-based material.
- They exhibit varying degrees of toxicity and flammability and must be used with caution.
- Proportioning the components and mixing are critical to proper curing.

Polymer-Modified: Dispersions of polymers in water have been in use for many years as admixtures to portland cement mortar and concrete. The property improvements from this family of admixtures includes increased bond strength, reduced permeability, increased resistance to freezing and thawing, and increased flexural strength. The specific property improvement to the modified mortar and concrete will vary with the type of latex used. Applications of these materials include floor leveling, concrete patching, and bridge deck overlays.

In addition, all of the polymer based repair materials are more expensive than cement-based materials. Regardless of the type of repair material, an adequate inventory should be kept in stock. Any repair material chosen to be kept in stock *must* have an adequate shelf life. These materials may remain in inventory for months and *must* retain their efficacy. A shelf life of a minimum of 6 months is highly recommended. There are some companies, such as **Five Star Products, Inc.**, who are constantly doing research and development work in this field. Individuals working in this area should keep in touch with **Five Star Products, Inc**. to stay current with the latest developments.

CHAPTER 12

CONCRETE REPAIRS PERFORMANCE PROPERTIES AND TESTS

A. PROPERTIES

The important properties in considering a concrete repair material are

- Length Change
- Bond Strength
- Compressive Strength
- Consistency
- Working Time
- Thermal Coefficient of Expansion
- Durability
- Chloride ion permeability

B. LENGTH CHANGE

1. For concrete repair material, length change (linear shrinkage or expansion) is a critical property. Excessive length change, by shrinkage or expansion, can produce cracks during and after the curing period and result in failure. Cracks also permit the entry of water and harmful substances — such as chlorides, sulfates, oils, and others — that can cause the repair to fail.

2. Use the test method of ASTM C 157 (Standard Test Method for Length Change of Hardened Cement Mortar and Concrete) — or ASTM C 928 for rapid setting materials — to evaluate the length change property of a concrete repair material. Two inch, three inch, or four inch square bars are the most common specimen sizes because many concrete repair materials contain coarse aggregates. Test bars should be cured according to the manufacturer's recommendation. The length change of an acceptable concrete repair material should be within ±0.05% to avoid cracks or excessive stress in the repair.

C. BOND STRENGTH

1. Bond strength is one of the most important — and yet the most under appreciated property of a concrete repair material. By and large, concrete repairs do not fail in compression. They fail because of inadequate bond strength and excessive length change. The entire repair can "pop out" if the bond strength is too low.

2. Although there is no universally recognized standard test for the bond strength of a cementitious repair material to a hardened concrete substrate, a modified version of ASTM C 882 (Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete) has proven useful for this purpose and is widely accepted by the construction industry and by many state highway departments.

3. The modified slant shear procedure of ASTM C 882 consists of casting the concrete repair material directly against a properly prepared substrate without a primer coat. The test specimen is then loaded in compression, producing a shear load on the slanted interface. A minimum strength of 2500 psi (17.3 MPa) in this test will, in most cases, compensate for the cold joint between the repair and the substrate.

D. COMPRESSIVE STRENGTH

1. Except as a way to decide when a concrete repair can be returned to service, compressive strength is a less significant property of a concrete repair material. Bond strength and length change are better criteria for selecting a concrete repair material. That said, most repair jobs require rapid compressive strength development to minimize the time that the structure is out of service.
2. Test concrete repair materials according to ASTM C 109 (Standard Test Method for Compressive Strength of Hydraulic Cement Mortars). The compressive strength of an acceptable rapid setting repair material three hours after adding the mixing water should be at least 2500 psi (17.2 MPa). After 24 hours, it should be at least 4500 psi (31.0 MPa).

E. CONSISTENCY

1. Horizontal repairs can usually be made with repair material of flowable consistency. Repairs to a slightly tilted surface such as a pedestrian ramp or bridge deck will require a repair material of a somewhat thicker consistency (low slump) to be able to maintain the slope without running down to level.
2. Repairs to vertical and overhead surfaces require a material of thick plastic consistency to be capable of placement by troweling. Large repairs can be formed and a flowable repair material poured or pumped into the repair.
   There is no practical test method to determine the optimum consistency for a specific repair job, but where a range of mixing water content is allowed by the directions on the repair material package, experienced workers can generally determine a suitable consistency in relatively short order. However, it is probable that a single grade of concrete repair material will not cover the entire range of consistencies that may be needed in practice.

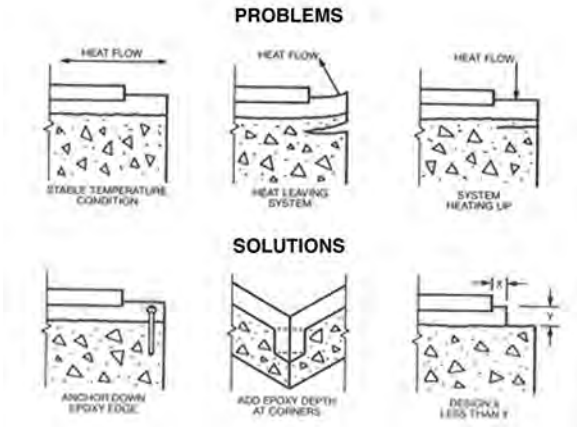
F. WORKING TIME

1. Working time is the elapsed time beginning when the mixing water is added to the concrete repair material and ending when the repair material stiffens to the point that it can no longer be easily worked. Working time is shorter than set time — the time when the repair material can no longer be penetrated by a needle of a particular size and weight as specified in ASTM C 266.
2. There is no reliable field test to determine working time, but workers unfamiliar with fast-setting repair materials should mix a small sample batch following the manufacturer's directions and determine the actual working time under the prevailing environmental conditions.

G. THERMAL COEFFICIENT OF EXPANSION

1. A large difference in the coefficients of thermal expansion between the concrete substrate and the repair material can result in the failure of the repair when it

is subjected to a large change in temperature. Some polymeric repair materials whose coefficients of thermal expansion are greater than three to five times that of the concrete substrate, may be susceptible to such failures. The repair, expanding three to five times as much as the substrate as the temperature rises, and contracting three to five times as much as the substrate as the temperature falls creates substantial stress in the substrate and can lead to tensile failure of the concrete substrate.



2. The coefficient of thermal expansion for most cementitious repair materials is close to that of the concrete substrate, so this failure mode is seldom encountered.
3. The coefficient of thermal expansion can be measured by the test method of ASTM C 531 (Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical Resistant Mortars, Grouts, and Monolithic Surfacings).

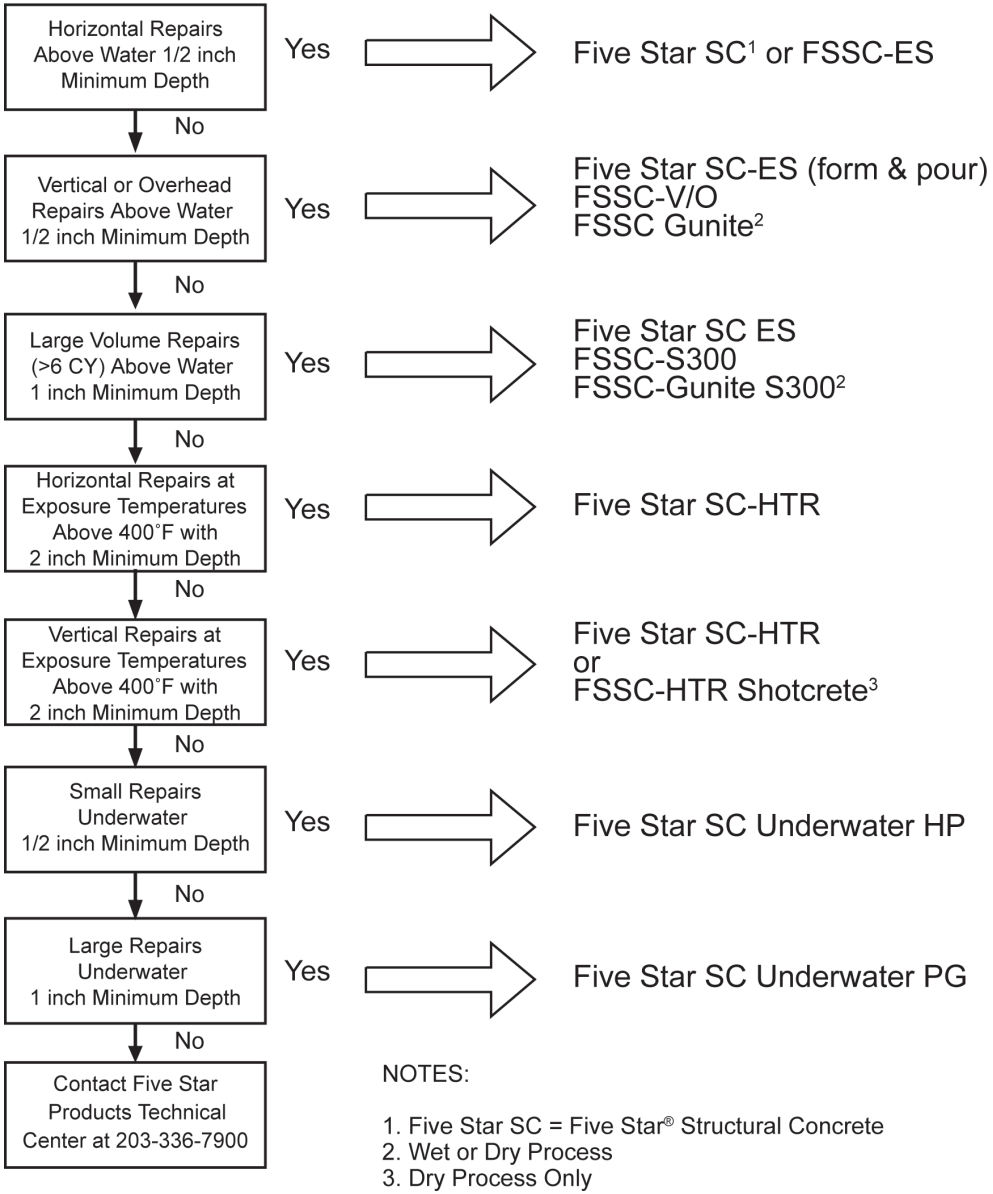
H. DURABILITY

1. Durability is the ability of a concrete repair material to remain in service and protect the substrate over an extended length of time. Durability depends on low absorption, low permeability, and good abrasion resistance in the repair material.
2. A low absorption rate prevents damage to the repair and its deterioration because of freeze/thaw cycling or salt and chemical attack.
3. A low permeability will prevent the transmission of salt and water through the repair to the substrate where they can cause freeze/thaw damage and corrode the reinforcing steel.
4. Good abrasion resistance is important in a repair subject to vehicular traffic to prevent it from being worn away and exposing the substrate.

I. CONCRETE REPAIR MATERIAL SELECTION CHART

Use the Selection Chart on the next page to help select the appropriate concrete repair material for a specific repair application. If your application is not included in the chart, consult the Technical Service Department at Five Star Products, Inc. at (800) 243-2206.

Concrete Repair Selection Chart



NOTES:

1. Five Star SC = Five Star® Structural Concrete
2. Wet or Dry Process
3. Dry Process Only

CHAPTER 13

CONCRETE REPAIRS
MANUFACTURER'S QUALITY ASSURANCE PROGRAM

A. Quality Assurance programs should be required of all manufacturers of approved concrete repair materials. The minimum requirements for a manufacturer's Quality Assurance System are described in **Chapter 3**.

B. The manufacturer's Quality Assurance System should also ensure that cement based products stored beyond one year in bags (or two years in plastic pails) are not shipped unless the manufacturer can certify by retest that the products still meet their applicable performance requirements.

C. The manufacturer should furnish written certification, when requested, that the product meets its applicable performance requirements, is in accordance with the manufacturer's specifications, conforms to the terms of sale, or meets the project specifications, as applicable. When appropriate, the manufacturer should furnish actual test data.

D. The manufacturer's Quality Assurance System should be audited at regular intervals by an independent auditor and should meet the requirements of ISO 9001-2000.

CHAPTER 14

CONCRETE REPAIRS ESTIMATING, PURCHASING, DELIVERING, AND STORING CONCRETE REPAIR MATERIALS

A. ESTIMATING

1. To estimate the quantity of concrete repair material required for a job, calculate the volume of the cavity to be filled in cubic feet. Divide the calculated volume by the yield in cubic feet of one unit of concrete repair material to calculate how many units will be needed. Add 5% to 10% for waste and spillage, more for smaller jobs and less for larger ones.
2. The most common cavity shape encountered in repair operations is a rectangular solid. When the shape of the area to be repaired is irregular or uneven in depth, the average length, width, and depth must be determined by measurement or by estimate. But consider that an irregular shape should be squared off for a durable repair.
3. To find the volume **V** of a rectangular solid in cubic feet (for example, a floor overlay) multiply the length **L** in inches times the width **W** in inches times the thickness **T** in inches.

   V=LWT

   The calculated volume will be in cubic inches. To convert cubic inches to cubic feet, divide by 1728, the number of cubic inches in a cubic foot.

B. PURCHASING

To compare the cost of a concrete repair material needed for a job, determine the cost per cubic foot for each material under consideration. Because concrete repair materials are sold in units that may be of different sizes, and may yield different volumes of concrete for a given weight.[Note 1]

C. DELIVERY

Concrete repair materials should be delivered, premeasured, and packaged in sealed, dry bags, and on stretch-wrapped or shrink-wrapped pallets to prevent shipping damage.

D. STORAGE

1. Concrete repair materials should be stored in a dry location at a temperature near 70°F, but never below 40°F nor above 90°F.
2. Concrete repair materials that become damp or otherwise defective should not be used and should be removed from the job site.
3. Concrete repair materials that are beyond the manufacturer's expiration date should not be used unless the manufacturer has requalified them by actual laboratory retest.

NOTE 1: For Metric: Take U.S. measure in cubic feet and multiply by .03 to determine cubic meters.

CHAPTER 15

PERMANENT CONCRETE REPAIRS

General structural repairs include repairs to walls, piers, pilings, abutments, columns, and industrial and commercial floors.

FIVE STAR STRUCTURAL CONCRETE® has been developed specifically for structural repair of horizontal and formed vertical surfaces. FIVE STAR STRUCTURAL CONCRETE® V/O is specially formulated for repair of vertical and overhead concrete. They both develop excellent bonds and high strengths for tough problems. They also have rapid strength gains so the repaired area can be reopened to use with a minimum delay.

Most of the following procedure is derived from the "Industrial Concrete Repair" section of Five Star Products, Inc. "Design-A-Spec" (DAS) document. It is shown here to illustrate the content of that document. **Architects, engineers, and specifiers are encouraged to refer to the DAS when preparing material specifications for Five Star Products, Inc.'s concrete repair materials.**

A. VERTICAL AND OVERHEAD REPAIRS

The procedures outlined below will suffice for most applications. Snap tie holes and the like are usually filled simply by troweling in a repair material such as FIVE STAR STRUCTURAL CONCRETE or FIVE STAR STRUCTURAL CONCRETE V/O and leveling with the surrounding concrete.

1. SURFACE PREPARATION

Surface preparation is extremely critical in all repair work. In all structural repairs, it is essential to remove from the existing concrete all substances that might prevent the repair from bonding to it. This includes, but is not limited to, form oils, form coatings, curing agents, and similar products. Acid etchers, concrete cleaners, and degreasers may be required to properly clean the surface. All acid, chemical cleaners, and degreasers must be completely removed. The surface to be repaired must not be smooth. It should be roughened by mechanical means such as chipping or sandblasting. All loose and excess material should be removed from the area to be repaired.

CAUTION: Some methods of roughening surfaces can bruise the concrete substrate and cause microcracks under the prepared surface. This can significantly reduce the tensile strength, resulting in failure beneath the bond line.

- Sandblasting, steel shot blasting, and high pressure and ultra high pressure water jetting have a very low risk of generating microcracks.
- Scarifying, needle scaling, and flame blasting have a moderate risk of generating microcracks.
- Scabbling and milling or rotomilling have a high risk of introducing microcracks, and should not be used without the approval of the engineer in charge.

On deep or large repairs, consider using forms, rib lathe, mesh, or reinforcing bars, separately or in combination, depending on the circumstances. Because surface preparation is critical when applying a repair product, it is essential that the contractors and engineers carefully inspect the preparation to ensure that the surfaces are truly cleaned and roughened.

Studies by the American Concrete Institute and the Portland Cement Association show that concrete substrates should be presoaked with potable water to an saturated surface dry (SSD) condition at the time cementitious repair materials are placed. With a dry substrate in hot weather, the repair material may lose water too rapidly for proper hydration to take place. On the other hand, if the substrate is too wet, cement may be washed from the bonding surface.

Under unusual circumstances, the manufacturer of the repair material should be contacted for guidance, but generally, the following procedure should be used:

a. Outline the areas to be repaired with chalk or crayon.
b. Saw cut ½ inch deep along the outline. Chip out the concrete within the saw cut to a minimum depth of ½ inch. Keep all edges as vertical as possible. Avoid feather edges – they tend to dry rapidly, debond, and break up.
c. Add rebar or mesh for deep or large repairs.
d. If rebar is exposed, chip to ¾ inch (or 2 times the maximum aggregate size, whichever is greater) below the rebar.
e. All exposed rebar showing any oxidation should be water or sandblasted.
f. Brush away any debris or dust in the chipped area.
g. Presoak the area to be repaired or use bonding adhesive where appropriate.

2. FORMS

a. Surface preparation should be as outlined above.
b. Forms should be lined with polyethylene or coated with paste wax or form release agent for easy release.

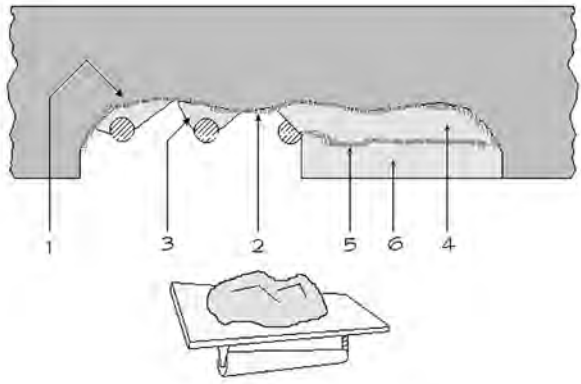
3. MIXING

a. Mix the repair material in a mortar mixer to a trowelable consistency for all applications except those to be poured in place. Mix only the amount of material that can be placed within the working life of the material. For small applications, use a paddle type mixer.
b. For formed areas to be poured, use the repair material mixed to a pourable consistency. Do not exceed maximum water indicated on the packaging. Tap the forms while placing and after placing to eliminate trapped air.
c. During hot weather, adjust set and working times with the admixture provided by the manufacturer.

4. PLACING

a. TROWEL METHOD [For vertical and overhead repair areas with limited reinforcement.]
    1. Apply thin layer of repair material and work firmly into roughened substrate filling all pores and voids. Allow material to begin to stiffen. Follow with application of repair material.

2. Apply repair material in a thick layer, but short of the point of sagging. Roughen each lift for mechanical bond and allow to stiffen before applying next thin layer and subsequent lift. Work repair material firmly into previous lift to ensure bond.
3. Place the repair continuously, repeating the thin layer/thick layer sequence until the void is completely filled.



1. Saturated surface
2. Thin layer of repair material
3. Fill behind reinforcement
4. First layer of repair material
5. Thin layer of repair material
6. Final layer of repair

b. FORM AND POUR METHOD

Leave a small opening or slot at the top of the form to permit the material to be poured into place. The material may be poured directly from the pail or into a small chute inserted in the opening. Consolidate by lightly vibrating the formwork to ensure good contact with the substrate and eliminate bubbles and voids.

> **CAUTION:** Always use care when vibrating. Excessive vibration can cause segregation of the aggregate and spoil the job.

c. PNEUMATICALLY APPLIED REPAIRS

The pneumatically applied repair method (generally called Shotcrete or Gunite) is not covered since the method requires an experienced shotcrete contractor. It is an excellent method to use where very large total areas or overhead installations are involved. It does, however, require an experienced contractor with one or more highly skilled nozzle men. It is an excellent, and the most economical, method to use for repairing very large vertical, or overhead areas. It has the additional advantage of placing a repair at the lowest possible water content (water/cement ratio), resulting in a higher strength repair.

5. CURING
Follow the manufacturer's instructions.

6. FORM REMOVAL
If it was necessary to anchor the forms through the repair, form removal should be delayed until an adequate bond of the repair to the old concrete has developed.

B. HORIZONTAL REPAIRS

This category applies mainly to floors in plants, warehouses, and other industrial and commercial structures.

1. SURFACE PREPARATION
Prepare the surface as previously described in the beginning of this section for VERTICAL AND OVERHEAD REPAIRS.

2. WETTING
Presoak the area to be repaired, and remove any excess (standing) water before placing the repair.

3. MIXING

a. Mix the repair material in a mortar mixer to a pourable consistency for most applications. Mix only the amount of material that can be placed within its working life. For small repairs, hand mix or use a paddle-type mixer.

b. For deep or large repairs, most materials may be extended with coarse aggregate, such as clean, damp pea gravel that meets the requirements of ASTM C 33, to act as a heat sink, provide dimensional stability, and lower the material cost. Consult the manufacturer for the amount of coarse aggregate to add.

c. During hot weather, adjust set and working times with FIVE STAR® SUMMERSET or FIVE STAR® SET EXTENDER, or use ice water to mix the repair material.

4. PLACING

Place the repair material full depth from one side or end of the repair to the other side or end. Puddle lightly to assure full contact with bottom and sides of the repair. Screed the repair level with surrounding concrete and finish as desired.

5. CURING
Follow the manufacturer's recommendations for curing.

C. REPAIRING CONCRETE JOINT EDGES

Joints in concrete floors are often subjected to repeated heavy loads by steel-wheeled or hard rubber-wheeled equipment. With time, the edge of the joint breaks off and the process continues until a large gap or hole exists. These holes should be immediately repaired to avoid hazardous conditions to people and equipment.

Repair material must be chosen to accommodate the type of traffic and loads to which the joint will be exposed. Light impact loadings and pneumatic-tired equipment often will not damage cementitious surfaces as severely as steel wheels.

For most applications, repairs may be made with Five Star Structural Concrete®. For heavy impact loadings or steel wheeled equipment, use one of Five Star's epoxy grouts for the repair. The procedure is as follows:

1. **SURFACE PREPARATION**
   Prepare the surface as previously described in the beginning of this chapter for VERTICAL AND OVERHEAD REPAIRS, but outline the repair area with a vertical saw cut at least 1 inch deep. Chip down so the depth of the repair is at least 2 inches. If chipping exposes reinforcing, chip to a minimum of ¾ inch (or 2 times the maximum aggregate size, whichever is greater) below the steel. If no reinforcing is present or if the repair will be deep or wide, the engineer should design suitable reinforcement to be added before placement.
2. **WETTING**
   If FIVE STAR STRUCTURAL CONCRETE® is being used, presoak the area to be repaired. Remove any standing water before placing the repair. If an epoxy grout is to be used, **do not presoak** and be sure the substrate is dry before placing the repair.
3. **FORMING**
   As the form, use a length of wood board or rigid plastic foam having a thickness equal to the width of the joint. Wrap the form with polyethylene film to serve as a form release. **Do not** use oil, grease, or other release agents that will prevent the joint sealant (used to fill the joint after the repair is complete) from bonding.
4. **MIXING**
   Mix the selected repair material as indicated on the package.
5. **PLACING**
   Place the material full depth from one end to the other end. Consolidate by puddling. Screed off level with surrounding concrete. **IMPORTANT:** Do not permit the repaired side of the joint to be higher or lower than the other side!
6. **FINISHING**
   Finish FIVE STAR STRUCTURAL CONCRETE® with a steel trowel slightly moistened with water (or with solvent or diesel oil if you are using one of the FIVE STAR EPOXY GROUTS.)
7. **CURING**
   As soon as FIVE STAR STRUCTURAL CONCRETE® has hardened, wet cure all exposed surfaces for a minimum of 30 minutes.

CHAPTER 16

CONCRETE PAVEMENT REPAIRS INTRODUCTION

Concrete pavement repairs include bridge decks, highways, dowel bar retrofits, roads, parking garages, and similar applications. All of these require products having certain properties.

The most important properties are **drying shrinkage** and **bond strength.** Excessive length change (linear shrinkage or expansion) can cause a repair failure if the tensile stress in the repair exceeds the tensile strength of the bond to the older material. More repairs have failed because of inadequate bond than from all other causes combined. Products which do not develop a 7-day minimum bond strength of 2,500 psi (17.3 MPa), as measured by ASTM C 882, should be considered questionable for any permanent repair.

Excessive length change can also cause cracks in the repair material itself if the tensile stress in the repair exceeds the materials tensile strength. Cracks permit entry of water and harmful solutions that can lead to failure from freezing or corrosion.

Most repair materials do develop adequate strength. Strength gain should be rapid in order to minimize shutdown time and the resulting inconvenience to the traveling public.

A versatile repair material is formulated to be capable of use at varying consistencies. Flowable-only materials present problems at any areas that are not absolutely level. Flowable repair materials tend to flow toward the low end and require constant troweling to make them conform to the levels of the surrounding concrete. If they start to set while being troweled, undesirable ripples may develop on the surface of the repair.

Most repairs are not done at carefully controlled temperatures. Hot weather presents problems of too rapid set and too short working time. Preferably the repair material manufacturer will have available admixtures to adjust set and working times. These admixtures should be capable of being used in varying amounts and should also be able to be used in the field to meet any job requirement. FIVE STAR PRODUCTS, INC. offers products called SUMMERSET and SET EXTENDER, which will adjust the set time and extend the working time of fast-setting repair materials.

FIVE STAR PRODUCTS, INC. recommends that all specifiers and users upgrade their specifications and projects to permanent FIVE STAR HIGHWAY PATCH to take full advantage of its far superior characteristics. Since all materials will vary by manufacturer, the data shown is based on the typical performance of the top selling brands of each type.

PLACEMENT PROCEDURES

A. EQUIPMENT

All tools, screeds, mixer, potable water, aggregate, and product should be at or near the point of placement before starting to mix and place the repair.

B. SURFACE PREPARATION

1. Outline areas to be repaired with chalk or crayon.
2. Saw cut at least 1/2 inch deep at the outlines. This is to avoid feather edges and their potential for failure. Feather edges dry out rapidly with resulting cracking and debonding. They are also much more susceptible to breakout and abrasion.
3. Chip down at least one inch, but deeper if necessary to reach sound, uncontaminated concrete. If chipping exposes reinforcing bar, chip at least 3/4 inch (or 2 times the maximum aggregate size, whichever is greater) below the reinforcing bar. There may be insufficient reinforcing bar at headers. The engineer should design reinforcing bar cages with top steel approximately (but not less than) 1-1/2 inches below the surface.
4. Keep all outside edges as vertical as possible.
5. Remove all chipped debris and dust using shovels, brooms, oil-free compressed air blowers, or a wet/dry shop vacuum.

C. SUBSTRATE PRESOAKING

Follow the manufacturer's recommendations for presoaking the substrate. **Important: Some products require a wet substrate; others do not.** After presoaking a substrate, be sure that all standing water (puddles) is removed before placing the repair.

D. MIXING

1. If mechanical mixing equipment is used, a mortar mixer (a stationary drum with rotating blades) is recommended for all prepackaged FIVE STAR® products. For larger batch sizes please **consult Appendix D-Recommendations and Procedures for Bulk Mixing** at the end of this book.
2. Wet all tools and the inside of the mixer and pour out all excess water.
3. Measure out a quantity of potable water equal to the maximum called for on the bag or pail times number of bags to be mixed at a time. Pour somewhat less than 85% to 90% into the mixer. Start the mixer. If the product is being extended with clean, washed pea gravel, add the pea gravel last. Aggregate containing larger pieces (over 1/2 inch) should not be put into a mortar mixer. Larger stones tend to wedge under the blades and stall the mixer.
4. If it is necessary to extend the set time or the working time, add SUMMERSET to the water in the mixer before adding the dry repair material. (In many cases, using ice cold water (35°F to 40°F) in the mixer may extend the working time sufficiently).
5. Add the dry repair material into mixer and mix for time indicated on the product bags.
6. After adding the coarse aggregate and mixing as required, add only enough of the remaining 10% to 15% water to obtain desired mix consistency. You can always add more water to a mix, but it can't be removed. Never add more than 100% of the maximum water stated on the bag or pail. Too much water may

cause segregation while too little water may compromise the hydration process. In either case, the product properties will be adversely affected.

E. PLACEMENT

1. Most repair products will be pourable and self-leveling at the maximum recommended water and mixing time. Products should have the capability of being mixed at **varying** water contents to produce consistencies appropriate to the job requirements.
2. Pour the mix into the repair area from the low side and continue pouring across the repair until it is filled. Do not place the repair in lifts. Most repair materials will function best if placed in a single layer. When this is not practical, multiple layers (lifts) can be placed by allowing the previous layer to stiffen somewhat before placing additional lifts. Puddle or rod the first lift to ensure good contact with the substrate.
3. Screed the repair level with surrounding concrete. Float, trowel, or broom to desired finish. Be sure to trowel edges of the repair carefully to ensure that the edges are sealed.

F. CURING

Follow the manufacturer's recommended procedures for curing all repair materials.

CONCLUSION

All of the foregoing assumes that repairing and repair of surfaces in a horizontal plane are the main and only problems associated with bridge decks, highways, dowel bar retrofits, roads, and parking decks. Unprotected surfaces such as piers, columns, and abutments, along with retaining walls, must be protected from water and salt penetration to avoid deterioration. Such areas can be effectively and economically protected by coating with FIVE STAR® WATERPROOFING or FIVE STAR PILE JACKET GROUT. Information about these products is available at **fivestarproducts.com** or from the FIVE STAR PRODUCTS, INC. Engineering and Technical Center at 203-336-7900.

CHAPTER 17

TYPICAL CONCRETE REPAIR APPLICATIONS

WATER TREATMENT

REFINING

HIGHWAYS AND AIRPORT

INFRASTRUCTURE

POWER

CHAPTER 18

SPECIALTY CONCRETE REPAIRS INTRODUCTION

Throughout its history, FIVE STAR PRODUCTS, INC. has prided itself on being able to provide customers with custom designed concrete mixes. Specialty mixes are created in the testing laboratory under the guidance of experienced and dedicated technical personnel. These mixes address special applications going beyond the normal, such as concrete repairs for high temperature processes. FIVE STAR STRUCTURAL CONCRETE® HTR and FIVE STAR STRUCTURAL CONCRETE® HTR SHOTCRETE are unique, high temperature resistant concrete repair materials that gain strength quickly and can be exposed to high temperatures from 1000°F (538°C) to 2400°F (1316°C). Five Star Products, Inc. also custom manufactures salt water resistant concrete repair materials for placement under water, FIVE STAR STRUCTURAL CONCRETE® UNDERWATER HP, FIVE STAR STRUCTURAL CONCRETE® UNDERWATER PG, and FIVE STAR® PILE JACKET GROUT. These products are specifically designed to be placed under water with reduced washout. Each of these products and their properties are explained more fully in the following paragraphs. Specialty repair materials are made to order only. Minimum order sizes apply.

FIVE STAR STRUCTURAL CONCRETE® HTR (FSSC HTR) and **FIVE STAR STRUCTURAL CONCRETE® HTR SHOTCRETE** are both suited for use in high temperature environments where concrete exposure temperatures exceed 400°F (204°C). These products can be exposed to 1000°F (538°C) in three hours and up to 2400°F (1316°C) after a seven-day curing procedure. FSSC HTR can be poured or pumped. It has been applied on floors and walls of coker plants and steel mills, and for repairing kilns and foundries. FSSC HTR SHOTCRETE is a dry process shotcrete available for the same applications.

Typical Properties of FSSC HTR & FSSC HTR SHOTCRETE):

Compressive Strength, ASTM C 109		
	3 Hours	2500 psi (17.3 MPa)
	1 Day	4500 psi (31.1 MPa)
	28 Days	7000 psi (48.3 MPa)
Bond Strength, ASTM C 882		
	1 Day	1500 psi (10.4 MPa)
	7 Days	2500 psi (17.3 MPa)
Thermal Coefficient of Expansion, ASTM C 531		
	5.0×10^{-6} in/in/°F (9.0×10^{-6} mm/mm/°C)	
Set Time, ASTM C 266		
	FSSC HTR	45 minutes
	FSSC HTR SHOTCRETE	20 minutes

FIVE STAR STRUCTURAL CONCRETE® UNDERWATER HP (FSSC UWHP) and **FIVE STAR STRUCTURAL CONCRETE® UNDERWATER PG (FSSC UWPG)** are designed for underwater placement to repair concrete in tidal zones and marine environments. Concrete piles, piers, tanks, dams, seawalls, and other related hydraulic structures are typical repair candidates. FSSC UWHP is a rapid setting, hand pack consistency material suitable for small-volume repairs. It can be placed in as little as ½ inch thickness and as much as several inches in a single application with reduced washout. Saltwater, chloride, and sulfate resistant, this is a one-component material designed for reliability and ease of use. FSSC UWPG is essentially the same product, except in a longer working time, pumpable version for large volume placements. Consult the FIVE STAR PRODUCTS, INC. Engineering and Technical Center (203-336-7900) for more information.

Typical Properties of FSSC UWHP & FSSC UWPG SHOTCRETE):

	FSSC UWHP	FSSC UWPG
Compressive Strength, ASTM C 109		
3 Hours	2000 psi (13.8 MPa)	——
6 Hours	——	2500 psi (17.3 MPa)
1 Day	3000 psi (20.7 MPa)	5000 psi (34.5 MPa)
7 Days	4000 psi (27.6 MPa)	6000 psi (41.4 MPa)
28 Days	5000 psi (34.5 MPa)	7500 psi (51.7 MPa)
Underwater Bond Strength, ASTM C 882		
1 Day	950 psi (6.5 MPa)	1000 psi (6.9 MPa)
7 Days	1150 psi (7.9 MPa)	1500 psi (10.3 MPa)
Length Change, ASTM C 157		
28 Days Wet	+0.02%	+0.02%
Thermal Coefficient of Expansion, ASTM C 531	5.0×10^{-6} in/in/°F (9.0×10^{-6} mm/mm/°C)	

CHAPTER 19

CONCRETE REPAIR SPECIFICATIONS

Repair materials should not be specified based only on requirements for compressive strength and/or rate of strength gain. As mentioned earlier, these materials seldom, if ever, fail as a result of insufficient compressive strength. **They fail because of inadequate bond strength and excessive length change.**

Any specification that does not recognize this will not ensure the use of a product that will give long-lived performance. A proprietary specification can assure the owner and specifier that the desired performance will be achieved. Where a proprietary specification is prohibited, for whatever reason, a performance specification should be written.

The performance specification should include requirements for bond strength, length change, and compressive strength. In order to demonstrate the level of performance expected, the specifier may add the name of a product and manufacturer that meets the performance requirements required.

TYPES OF SHORT FORM SPECIFICATIONS

1. **PROPRIETARY SPECIFICATION**
   All repairs called for in the drawings and specifications shall be made using FIVE STAR STRUCTURAL CONCRETE® as manufactured by FIVE STAR PRODUCTS, INC. of Shelton, Connecticut. No substitutions will be approved.
2. **OR APPROVED EQUAL WITH IDENTICAL PROPERTIES SPECIFICATION**
   All repairs called for in the drawings and specifications shall be made using FIVE STAR STRUCTURAL CONCRETE® as manufactured by FIVE STAR PRODUCTS, INC. of Shelton, Connecticut, or approved equal with identical prop-erties. The repair material must exhibit a minimum bond strength of 2,500 psi (17.3 MPa) in 7 days when tested according to ASTM C 882 (modified) and typical length changes of $\pm$0.05% measured according to ASTM C 157.
3. **PERFORMANCE SPECIFICATION**
   All repairs called for in the drawings and specifications shall be made using a cement based concrete repair material that meets the following performance requirements. [*The specifier must then list the required properties together with acceptable values and the test methods to be used. The names of one or more approved products can also be included*.]

AN EXAMPLE OF A SHORT FORM PERFORMANCE SPECIFICATION

1. All the concrete repair and repairing as called for in the drawings and specifications shall be made using a material meeting the performance requirements that follow. Permanent structural repair material must be a one component system that requires only the addition of water. It must meet the following performance requirements at maximum water content.

A. Bond Strength:	1 Day	2,000 psi (13.8 MPa) min.
ASTM C 882*	7 Days	2,500 psi (17.3 MPa) min.
B. Length Change:	28 Days Dry	-0.05% (max.)
ASTM C 157*	28 Days Wet	+0.03% (max.)
C. Compressive Strength:	3 Hours	2,500 psi (17.3 MPa) min.
ASTM C 109	1 Day	5,000 psi (39.5 MPa) min.
	7 Days	7,000 psi (48.3 MPa) min.
D. Chloride Ion Permeability	28 Days	Very Low

2. A concrete repair material meeting these criteria is
Five Star Structural Concrete®
as manufactured by Five Star Products, Inc., Shelton, Connecticut [203-336-7900].

*Modified: Contact FIVE STAR PRODUCTS, INC. for details

CHAPTER 20

INDUSTRIAL CONCRETE REPAIR SPECIFICATIONS
STANDARD PERFORMANCE SPECIFICATIONS

FIVE STAR STRUCTURAL CONCRETE®
For Permanent Structural Concrete Repair Materials

1.01 PART I – GENERAL

1.02 The work covered by this specification consists of furnishing all permanent structural concrete repair material, equipment and labor required in performing all operations required for the installation of permanent structural concrete repair materials shown in the drawings and specifications. Permanent structural concrete repair materials are used to replace defective or deteriorated concrete and re-establishing the structural capabilities of the original structure.

1.03 REFERENCES

The following codes and standard specifications establish the minimum requirements for concrete repair materials. Referenced test methods, specifications and recommended practices are to be used to verify material properties and identify acceptable practices applicable to permanent structural concrete repair materials:

ASTM C 109	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars
ASTM C 157	Standard Test Method for the Length Change of Hardened Cement Mortars and Concrete
ASTM C 531	Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacing
ASTM C 882	Standard Test Method for Bond Strength of Epoxy-Resin Systems using Concrete
ASTM C 928	Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs

1.04 SUBMITTALS

The Contractor must submit the manufacturer's literature and certified test data to the Engineer prior to installation. The Engineer may choose to buy any submitted material in the open market at the Contractor's expense, without the Contractor or manufacturer's knowledge, and test the material at an independent laboratory to verify compliance with this specification.

1.05 DELIVERY, STORAGE, AND HANDLING

All materials shall be delivered to the jobsite in original, unopened packages, clearly labeled with the manufacturer's identification and printed instructions. All cementitious materials shall be stored and handled in accordance with the recommendations of the manufacturer and the American Concrete Institute.

1.06 PROJECT/SITE CONDITIONS

Refer to the manufacturer's literature or contact the manufacturer directly for any physical or environmental limitations required by the product:

PART II – PRODUCTS

2.01 MANUFACTURERS

The following manufacturers supply materials which meet this specification and will provide field technical service upon request:

Manufacturer	Products
Five Star Products, Inc. Shelton, Connecticut 06484 203-336-7900	Five Star Structural Concrete®

Other manufacturers may submit materials to the Design Engineer for approval following the procedures outlined in Article 1.02

2.02 MATERIALS

Permanent structural concrete repair materials shall be preblended, prepackaged materials requiring only the addition of water, meeting the following performance criteria:

(a) Dimensional Stability – The typical length change after hardening shall be less than ±0.05% when tested according to ASTM C 157 as modified in ASTM C 928.

(b) Bond Strength – The bond between repair materials and concrete shall be at least 2,500 psi (17.2 MPa) in 7 days or the shear strength of the concrete, whichever is less, when tested according to ASTM C 882 as modified in ASTM C 928.

(c) Compressive Strength – The minimum compressive strengths when tested according to ASTM C 109, as modified in ASTM C 928, shall be: 2500 psi (17.3 MPa) at 3 hours, 4500 psi (31.0 MPa) at 24 hours and 6000 psi (41.4 MPa) at 7 days.

(d) Compatibility – The coefficient of thermal expansion shall be less than 6.0 x 10^{-6} in/in/°F (10.8 x 10^{-6} mm/mm/°C) when tested according to ASTM C 531.

PART III – EXECUTION

3.01 EXAMINATION

(a) Inspect concrete surfaces to receive concrete repair and verify they are free of ice, frost, dirt, grease, oil, curing compounds, paints, impregnations, and all loose material or foreign matter likely to affect the bond or performance of the concrete repair material.

(b) Inspect all reinforcing steel for rust, oil, and other deleterious substances that may affect the bond or performance of the repair material.

(c) Confirm that all surfaces are sufficiently rough to ensure good cement bond and that the concrete is structurally sound.

3.02 PREPARATION

(a) Roughen all concrete surfaces requiring additional surface preparation by sandblasting, chipping, or other mechanical means to assure bond. Loose or broken concrete shall be removed.

(b) All grease, oil, dirt, rust, curing compounds, laitance, and other deleterious materials that were identified in the inspection process shall be completely removed from the concrete and/or reinforcing steel.
(c) Forms for repair material shall be built of material with adequate strength to withstand the placement of the material if forms are required.
(d) All concrete surfaces shall be thoroughly saturated and free of standing excess water immediately prior to applying the repair material.

3.03 INSTALLATION

(a) The repair material shall be added to a premeasured amount of water that does not exceed the manufacturer's maximum recommended water content. Retempering the repair material by adding more water after stiffening is not permitted.
(b) Mix and place the repair material according to the manufacturer's specific installation guidelines.
(c) The manufacturer should be contacted for aggregate extension guidelines when applicable.

3.04 CURING

(a) Repair materials shall be cured in accordance with the manufacturer's specifications and recommendations. The method needed to protect the repair material would depend upon temperature, humidity, and wind. Wet burlap or ponding are the preferred curing methods. Consult the manufacturer for appropriate curing schedule.
(b) Equipment and tools shall be cleaned as recommended by the manufacturer.

CHAPTER 21

INFRASTRUCTURE CONCRETE REPAIR SPECIFICATIONS

STANDARD PERFORMANCE SPECIFICATION

FIVE STAR® HIGHWAY PATCH
For Rapid Setting Cement Mortar

PART I – GENERAL

1.01 The work covered by this specification consists of furnishing all rapid setting cement mortar, equipment and labor required in performing all operations required for the installation of rapid setting cement mortar shown on drawings or in the specifications. Rapid setting cement mortar is used to replace defective or deteriorated concrete and re-establishing the structural integrity of the original pavement.

1.02 REFERENCES

The following codes and standard specifications establish the minimum requirements for rapid setting cement mortar. Referenced test methods, specifications and recommended practices are to be used to verify material properties and identify acceptable practices applicable to rapid setting cement mortar:

ASTM C 109	Standard Test Method for Compressive Strength of Hydraulic- Cement Mortars
ASTM C 157	Standard Test Method for the Length Change of Hardened Cement Mortars and Concrete
ASTM C 531	Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacing
ASTM C 882	Standard Test Method for Bond Strength of Epoxy-Resin Systems using Concrete
ASTM C 928	Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs

1.03 SUBMITTALS

The Contractor must submit the manufacturer's literature and certified test data to the Engineer prior to installation. The Engineer may choose to buy any submitted material in the open market at the Contractor's expense, without the Contractor or manufacturer's knowledge, and test the material at an independent laboratory to verify compliance with this specification.

1.04 DELIVERY, STORAGE, AND HANDLING

All materials shall be delivered to the jobsite in original, unopened packages, clearly labeled with the manufacturer's identification and printed instructions. All cementitious materials shall be stored and handled in accordance with the recommendations of the manufacturer and the American Concrete Institute.

1.05 PROJECT/SITE CONDITIONS

Refer to the manufacturer's literature or contact the manufacturer directly for any physical or environmental limitations required by the product:

PART II – PRODUCTS

2.01 MANUFACTURERS

The following manufacturers supply materials which meet this specification and will provide field technical service upon request.

Manufacturer	**Products**
Five Star Products, Inc. Shelton, Connecticut 06484 203-336-7900	Five Star Highway Patch

Other manufacturers may submit materials to the Design Engineer for approval as allowed in Section 1.02.

2.02 MATERIALS

Rapid setting cement mortar shall be preblended, prepackaged materials requiring only the addition of water, and meeting the following performance criteria:

(a) Dimensional Stability – The typical length change after hardening shall be less than ±0.05% when tested according to ASTM C 157 as modified by ASTM C 928.

(b) Bond Strength – The bond between repair materials and concrete shall be at least 2,500 psi (17.2 MPa) in 7 days or the shear strength of the concrete, whichever is less, when tested according to ASTM C 882 as modified in ASTM C 928.

(c) Compressive Strength – The minimum compressive strengths when tested according to ASTM C 109, as modified in ASTM C 928, shall be: 2000 psi (13.8 MPa) at 2 hours, 4500 (31.0 MPa) at 24 hours.

(d) Compatibility – The coefficient of thermal expansion shall be less than 6.0 x 10^{-6} in/in/°F (10.8 x 10^{-5} mm/mm/°C) when tested according to ASTM C 531.

PART III – EXECUTION

3.01 EXAMINATION

(a) Inspect concrete surfaces to receive repair mortar and verify that they are free of ice, frost, dirt grease, oil, curing compounds, paints, impregnations, and all loose material or foreign matter likely to affect the bond or performance of the repair material.

(b) Inspect all reinforcing steel for rust, oil, and other deleterious substances that may affect the bond or performance of the repair material.

(c) Confirm that all surfaces are sufficiently rough to ensure good cement bond that the concrete is structurally sound.

3.02 PREPARATION

(a) Roughen all concrete surfaces requiring additional surface preparation by sandblasting, chipping, or other mechanical means to assure bond. Loose or broken concrete shall be removed.

(b) All grease, oil, dirt, rust, curing compounds, laitance, and other deleterious materials that were identified in the inspection process shall be completely removed from the concrete and/or reinforcing steel.
(c) Forms for repair material shall be built of material with adequate strength to withstand the placement of the material if forms are required.
(d) All concrete surfaces shall be thoroughly saturated and free of standing excess water immediately prior to applying the repair material.

3.03 INSTALLATION

(a) The repair material shall be added to a premeasured amount of water that does not exceed the manufacturer's maximum recommended water content. Retempering the repair material by adding more water after stiffening is not permitted.
(b) Mix and place the repair material according to the manufacturer's specific installation guidelines.
(c) The manufacturer should be contacted for aggregate extension guidelines when applicable.

3.04 CURING

(a) Protect repair material until initial set. Then immediately coat exposed surfaces with an approved coating compound that meets the water retention requirements of ASTM C 309. Alternatively, wet cure for a minimum of three days.
(b) Equipment and tools shall be cleaned as recommended by the manufacturer.

CHAPTER 22

FIVE STAR FOUNDATION SYSTEMS®

INTRODUCTION

Building on currently existing, time tested products, FIVE STAR PRODUCTS, INC. offers customers the materials either to create new equipment foundation systems or to repair existing ones. Equipment installations for diesel or gas compressors, HVAC equipment, turbines, generators, motor and pump assemblies, etc., are generally placed on structural support foundations requiring precision alignment. For this reason, the selection of the material to be used in the design of a strong and sustainable foundation depends on the equipment operating parameters, including, but not limited to, loading (static or dynamic), ambient operating temperature, chemical environment, pour volume, and construction turnaround time.

SELECTING A FOUNDATION SYSTEM

To satisfy the requirements for rebuilding foundations for industrial machinery, and for new installations, FIVE STAR PRODUCTS, INC. offers six different Foundation Systems. Selecting an appropriate foundation system depends on the type of loading (**static:** no movement, or **dynamic:** movement through impact loads or vibration) and on the turnaround time available. Each foundation system is summarized in the following pages, but architects and design engineers are invited to request a CD copy of FIVE STAR PRODUCTS, INC.'s Design-A-Spec™ (DAS), a specification guide that more fully describes them. DAS allows the architect, engineer or specifier to edit each section as necessary and appropriate for an individual application.

MINIMUM DOWNTIME REGROUTING

FIVE STAR FOUNDATION SYSTEM 2 is a very successful method for regrouting compressors and other vibrating equipment. Rather than waiting 7 to 10 days for conventional materials to cure and gain strength, this system, using a high early strength nonshrink epoxy grout, permits the equipment to be back in service within 10 hours at 73°F.

FIVE STAR FOUNDATION SYSTEM 2 can be used to rebuild existing bases or to construct new ones whenever time is critical.

SELECTING A FOUNDATION SYSTEM
USING FIVE STAR® PRECISION NONSHRINK GROUTS

This table is a partial list of machinery and equipment types representing various loading conditions, and the recommended grout component of the FIVE STAR PRODUCTS Foundation Systems material directly under the machinery. Depending on the operating parameters, multiple lift substrate foundation material can be either FIVE STAR STRUCTURAL CONCRETE® ES or FIVE STAR® DP EPOXY GROUT. Contact FIVE STAR PRODUCTS, INC.'s Engineering and Technical Center at 203-336-7900 for assistance in selecting an appropriate Foundation System.

EQUIPMENT GROUT SELECTION CHART

Type of Equipment	Nonshrink Cement Grout	Nonshrink Epoxy Grout	Comments
Fast Turnaround: Static Loads (4 hour start-up) [A]	Five Star Instant Grout	NR	
Fast Turnaround: Dynamic loads: (8 hr. start-up) [A]	NR	FS Rapid Epoxy	
Pump Base Systems	FSG or FSFG [B]	FS DP Epoxy [C]	Design Engineers Choice
TMP & Pulp Refiners	FSG or FSFG [B]	FS DP Epoxy	Design Engineers Choice
Reducers & Drivers	NR	FS DP Epoxy	
Steel Column Baseplates	FSG or FSFG [B]	Not Required	FSFG-100 required for shear keys
Log Chippers	NR	FS DP Epoxy	
Paper Machine Track Baseplates	FSG or FSFG [B]	FS DP Epoxy	Design Engineers Choice
Stamping Process	NR	FS DP Epoxy	
Forced or Induced Draft Fans	NR	FS DP Epoxy	
Debarking Drums	NR	FS DP Epoxy	
Bark Hogs	NR	FS DP Epoxy	
Vibrating Screens	NR	FS DP Epoxy	
Boiler Feedwater Pumps	NR	FS DP Epoxy	
Thick Stock Pumps	NR	FS DP Epoxy	
Lime Kiln	FSG [B]	NR	
Conveyors	FSG or FSFG [B]	Not Required	
Skid Mounted Equip. (static)	FSG or FSFG [B]	Not Required	
Skid Mounted Equip. (dynamic)	NR	FS DP Epoxy [C]	
Reciprocating Compressors	NR	FS DP Epoxy [C]	
Centrifugal Compressors	FSG or FSFG [B]	FS DP Epoxy	Design Engineers Choice
Fan Blower Motors	FSG or FSFG [B]	FS DP Epoxy	Design Engineers Choice
Brine Water Pump	Five Star Special Grout 120	Not Required	
Temperatures ≥ 400˚F (200˚C):			
Coke Drum Rings or Pit	Five Star HTR Grout	NR	
Clinker Cooler	Five Star HTR Grout	NR	
Absorber Vessel	Five Star HTR Grout	NR	
Turbine Generator	FSG or FSFG [B]	FS DP Epoxy	
Winder Baseplates	NR	FS DP Epoxy	
Steel Soleplates			
(1) inch or greater clearance	FSG	FS DP Epoxy	Alternate is FS HP Epoxy
1/2 inch or greater clearance	FSFG [B]	FS Rapid Epoxy	Design Engineers Choice
Storage Tanks [D]	FSG / FSFG [B] / FSG HTR Grout	FS DP or Rapid Epoxy	Consult with FS Technical & Engineering Center

NR = Not Recommended

A. At 73°F (23°C).
B. FSG=Five Star Grout; FSFG=Five Star Fluid Grout 100.
C. Meets API 610 App. L.
D. Grout choice determined by storage material, storage temperature, storage environment, substrate material, clearance to substrate, and pour volume.

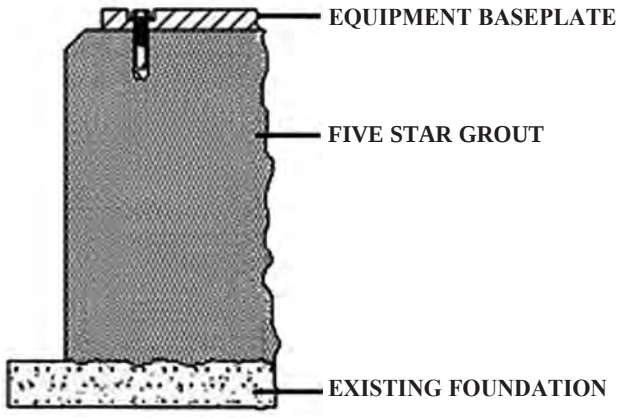
FOUNDATION SYSTEM 1

SINGLE LIFT – CEMENTITIOUS

Key Application Features: New construction, static loads in a non-chemical environment.

DESCRIPTION:
FIVE STAR FOUNDATION SYSTEM 1 consists of FIVE STAR GROUT, a non-metallic, nonshrink grout extended with coarse aggregate up to 100% by weight. This system is used to rebuild foundations and grout equipment in a single application, enabling three day turnarounds. Large mass pours are facilitated by mixing bulk bags in ready mix concrete trucks. The material may be poured or pumped into place.

TURNAROUND TIME: Three days.



LIMITATIONS:
Not recommended for dynamic (impact/vibration) loads, chemical exposure, or high temperature environments exceeding 400°F (204°C). There is no pour volume limit.

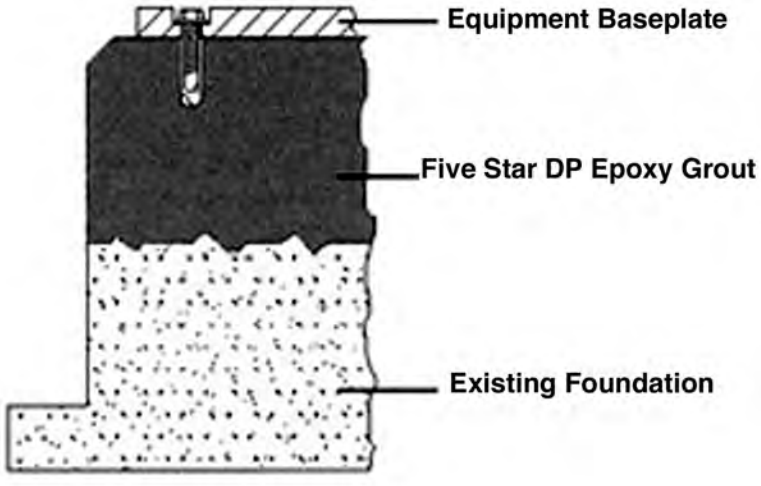
FOUNDATION SYSTEM 2

SINGLE LIFT – EPOXY

Key Application Features: New construction, dynamic loads in a chemical environment.

DESCRIPTION:
FIVE STAR FOUNDATION SYSTEM 2 consists of FIVE STAR DP EPOXY GROUT, an expansive, nonshrink, low exotherm epoxy grout. This system achieves both foundation repairs and equipment grouting in a single application. Its 90 minute working time allows for deep pours to facilitate equipment rebuilds in 10 to 24 hours. FIVE STAR FOUNDATION SYSTEM 2 is ideal for high impact or vibrating machinery and for chemical environments.

TURNAROUND TIME: Ten hours when conditioned to between 75°F (24°C) and 85°F (29°C). Although FIVE STAR DP EPOXY GROUT Epoxy Grout can be poured at temperatures as low as 50°F (10°C), flowability and strength gain are adversely affected by temperatures below 65°F.



LIMITATIONS:
Not recommended for operating temperatures exceeding 180°F (82°C). Pour volume is limited to five cubic yards.

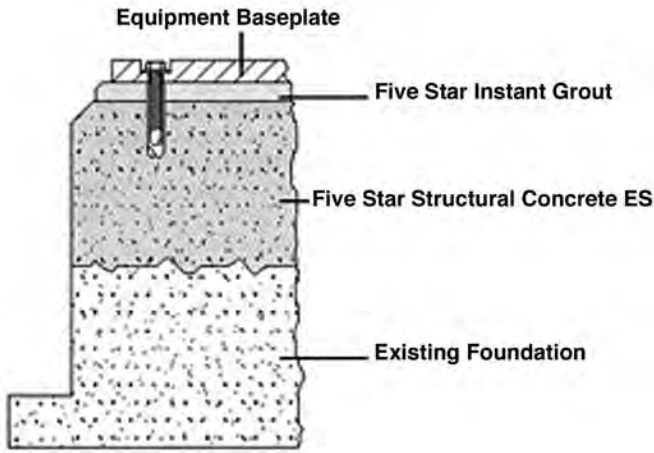
FOUNDATION SYSTEM 3

MULTIPLE LIFT – CEMENTITIOUS

Key Application Features: Fast turnaround repair work, static loads in a non-chemical environment.

DESCRIPTION:
Foundation System 3 consists of FIVE STAR STRUCTURAL CONCRETE ES (Extended Set), concrete foundation repair material, capped with FIVE STAR INSTANT GROUT, a nonshrink machinery grout for equipment support, to complete a total equipment rebuild. FIVE STAR FOUNDATION SYSTEM 3 features one component cementitious repair materials that are capable of aggregate extension up to 100% with adjustable working times. Ideal for small or large rebuilds requiring a fast turnaround. For use with static, nonvibrating equipment.

TURNAROUND TIME: 12 to 36 hours depending on pour ambient temperature conditions.



LIMITATIONS:
Not recommended for dynamic (impact/vibration) loads, chemical exposure, or high temperature environments exceeding 400°F (204°C). Maximum pour volume is six cubic yards.

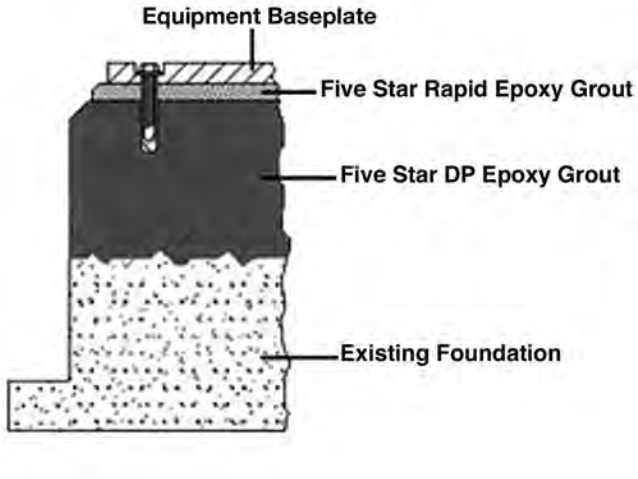
FOUNDATION SYSTEM 4

MULTIPLE LIFT – EPOXY

Key Application Features: Fast turnaround rebuilds, dynamic loads in a chemical environment

DESCRIPTION:
FIVE STAR FOUNDATION SYSTEM 4 consists of FIVE STAR DP EPOXY GROUT as a foundation repair material capped with FIVE STAR RAPID EPOXY GROUT for equipment support. FIVE STAR RAPID EPOXY GROUT, which achieves a 95% Effective Bearing Area (EBA) may be used to maintain precision alignment of equipment at elevated temperatures up to 250°F (121°C). FIVE STAR FOUNDATION SYSTEM 4 is ideal for high impact or vibrating equipment and in chemical environments.

TURNAROUND TIME: 12 hours at ambient temperatures between 65°F (18°C) and 75°F (24°C). Cooler temperatures, as low as 50°F (10°C), will reduce flowability and strength gain while warmer temperatures, up to 90°F (32°C), will increase flowability and strength gain.



LIMITATIONS:
Not recommended for operating temperatures exceeding 250°F (121°C) or in highly corrosive chemical environments. Pour volume is limited to five cubic yards.

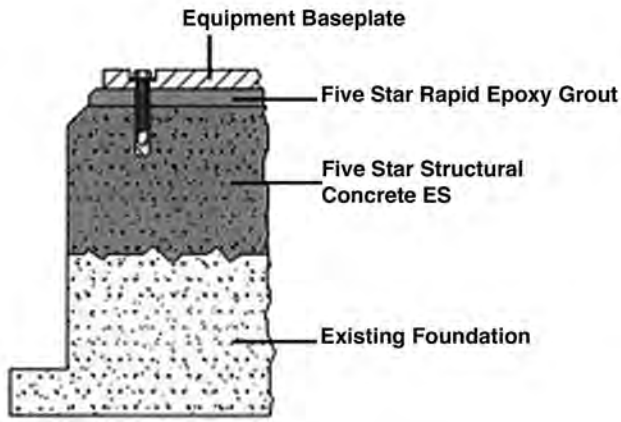
FOUNDATION SYSTEM 5

MULTIPLE LIFT – COMBINATION CEMENTITIOUS AND EPOXY

Key Application Features: High temperature environment, dynamic loads with confined chemical exposure.

DESCRIPTION:
FIVE STAR FOUNDATION SYSTEM 5 consists of FIVE STAR STRUCTURAL CONCRETE ES concrete repair material capped with FIVE STAR RAPID EPOXY GROUT, a NONSHRINK epoxy machinery grout, for equipment support, to complete a total equipment rebuild suitable for chemical environments and dynamic load conditions. FIVE STAR FOUNDATION SYSTEM 5 features a one component cement-based repair material capable of aggregate extension up to 100% with adjustable working times. Capped with a nonshrink expansive epoxy grout, Five Star Foundation System 5 is ideal for small or large foundation repairs and for dynamic loads and vibrating equipment.

TURNAROUND TIME: 12 to 36 hours depending on pour ambient temperature conditions.



LIMITATIONS:
Can be used in a chemical environment provided chemicals are contained or confined to the epoxy grouted area. The maximum pour volume is six cubic yards.

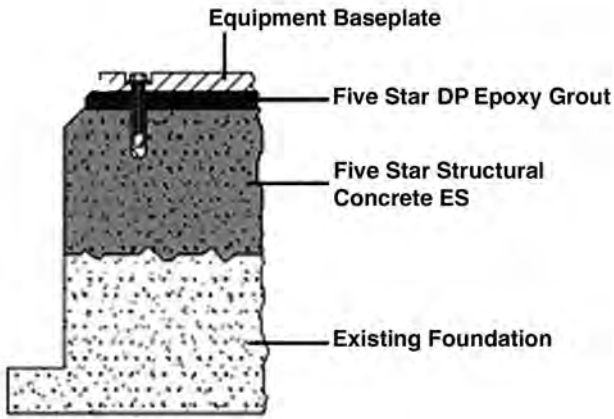
FOUNDATION SYSTEM 6

MULTIPLE LIFT – COMBINATION CEMENTITIOUS AND EPOXY

Key Application Features: Large or small volume applications, dynamic loads with confined chemical exposure, lowest material cost foundation system for dynamic load conditions.

DESCRIPTION:
FIVE STAR FOUNDATION SYSTEM 6 consists of FIVE STAR STRUCTURAL CONCRETE ES, concrete repair material, capped with FIVE STAR HP EPOXY GROUT, a NONSHRINK, expansive epoxy grout for equipment support, to complete a total equipment rebuild suitable for chemical environments and dynamic load conditions. FIVE STAR FOUNDATION SYSTEM 6 features a one component cement based repair material capable of 100% coarse aggregate extension with adjustable working time. Capped with an expansive epoxy grout, FIVE STAR FOUNDATION SYSTEM 6 is ideal for dynamic loads and vibrating equipment, and for small and large foundation repairs.

TURNAROUND TIME: Up to three days depending on ambient cure temperature.



LIMITATIONS:
Not recommended for operating temperatures exceeding 180°F (82°C), or for chemical environments, unless chemicals are contained or confined within the epoxy grouted area. Maximum pour volume is six cubic yards.

TYPICAL INSTALLATION INSTRUCTIONS FOR 48 HOUR TURNAROUND USING FOUNDATION SYSTEM 6

A. FOUNDATION - FIVE STAR STRUCTURAL CONCRETE® ES

1. SURFACE PREPARATION

a. Using mechanical roughening, remove all loose, unsound or cracked concrete. Never use a jackhammer. Bush hammers are not recommended, as they tend to loosen the aggregate in the concrete substrate, possibly resulting in failure under the bond line.

b. Sandblast existing reinforcing bars in the chipped out area.

c. If the base or foundation does not contain reinforcing bars, a "cage" should be assembled and put in place.

d. Wet the existing concrete with saturated rags or sponge foam while forms are being constructed. This will save substrate preconditioning saturation time.

2. FORMING

a. Construct all forms watertight. Wrap forms with polyethylene sheets or treat form with a release agent for easy form removal.

b. Forms must be built and supported to withstand rodding and/or vibration of the rapid setting cementitious material.

3. MIXING

a. A mortar mixer (with moving blades) is recommended for mixing.

b. The mixer should be thoroughly washed out with potable water and all excess water drained out prior to mixing.

c. Water used to mix the FIVE STAR STRUCTURAL CONCRETE ES *must* be potable. Always begin with the minimum amount of water printed on the package. Add the measured amount of water into the mixer. If additional water is required, do not exceed maximum amount on container.

d. Add ingredients to the mortar mixer in the following sequence:

- Potable water
- SUMMERSET, if used in hot weather (cold or ice water is an alternative)
- FIVE STAR STRUCTURAL CONCRETE ES
- Clean, washed coarse aggregate per ASTM C 33

e. Mix for a minimum of five minutes.

f. Add only enough of the remaining water to reach the desired consistency.

g. Do not add more than the maximum amount of water specified on the package.

4. PLACEMENT

a. Placements up to 1 ft deep may require coarse aggregate extension of up to 80% by weight with 3/8 inch clean, washed coarse aggregate, depending on the mass of the pour and on ambient temperature conditions.

b. Placements of 1 ft to 3 ft deep will require coarse aggregate extension of up to 100% by weight of clean, washed coarse aggregate. Mix as directed

under "Mixing", and place in a single lift. Rod or vibrate to ensure proper consolidation and bond with the concrete base. Excessive vibration can cause segregation. Since all pours are not alike, consult the manufacturer for additional details.

c. When using FIVE STAR DP EPOXY GROUT as the grout cap, leave at least 2 inches of clearance between the lift of FIVE STAR STRUCTURAL CONCRETE ES and the baseplate for a pour of up to two feet wide. Generally, 1/2 inch of additional clearance should be allowed for each additional foot of flow distance up to 8 ft for temperatures between 69°F (20.6°C) and 78°F (25.6°C). For temperatures between 55°F (12.8°C) and 68°F (20°C), increase the clearance by 3/4 inch. For temperatures between 79°F (26.1°C) and 90°F (32.2°C), the clearance should be increased by only 1/4 inch as the flowability at higher ambient temperatures is greater. Skid-mounted equipment can be grouted with somewhat smaller clearances.

d. Moist cure FIVE STAR STRUCTURAL CONCRETE ES according to the manufacturer's recommendations to prevent rapid drying. Allow an unfinished rough surface lift of FIVE STAR STRUCTURAL CONCRETE ES to dry after moist curing before installing FIVE STAR DP EPOXY GROUT.

B. GROUT CAP - FIVE STAR DP EPOXY GROUT

1. SURFACE PREPARATION

The lift surface of FIVE STAR STRUCTURAL CONCRETE ES must be *clean* and *dry* before placing FIVE STAR DP EPOXY GROUT. If the FIVE STAR STRUCTURAL CONCRETE ES surface was not rough raked after initial set, it should be mechanically roughened and cleaned before receiving epoxy grout.

2. FORMING

If forms for FIVE STAR STRUCTURAL CONCRETE ES were not carried high enough to permit the placement of FIVE STAR DP EPOXY GROUT, erect a new form to contain the FIVE STAR DP EPOXY GROUT. It must be liquid tight and have chamfer strips built in. Set the height of the chamfer strips at the bottom (contact) surface of the plate or skid.

3. EPOXY CHOICE

a. FIVE STAR DP EPOXY GROUT
Provides an average compressive strength of 6,000 psi (41.4 MPa) in 16 hours, 11,000 psi (75.9 MPa) in 24 hours and increases to 14,000 psi (96.6 MPa) in 7 days.

b. FIVE STAR RAPID EPOXY GROUT – QUICK START UP GROUT:
For a shorter turnaround time, specify FIVE STAR RAPID EPOXY GROUT. This epoxy system provides 8,000 psi (55.2 MPa) in only 8 hours at 73°F (23°C) and increases to 15,000 psi (103.5 MPa) in 7 days.

4. MIXING

a. FIVE STAR DP EPOXY GROUT:

Pour all of Component B (Hardener) into the pail containing Component A (Resin). Mix slowly but thoroughly by hand or low speed mixer to avoid air entrapment. Pour all of the mixed material into a mortar mixer. Add Five Star Epoxy Aggregate one bag at a time. Start the first batch at 4 bags of aggregate instead of 5 bags to wet the mixer. Mix only until all aggregate is wetted and no dry pockets remain. Follow printed instructions ach package.

b. FIVE STAR RAPID EPOXY GROUT

This product is packaged in a seven-gallon pail that contains all three components. Remove the containers of liquid and the bag of aggregate.

Pour the contents of liquid containers into the now empty seven-gallon pail. Mix these liquids with a slow speed (maximum 250 rpm) electric drill, fitted with a mixing paddle, until no streaks of unmixed liquids are obvious. Empty the contents of the aggregate bag into the mixed liquids and continue mixing until all aggregate is wetted and a smooth, pourable grout is obtained. *Do not over mix.* FIVE STAR RAPID EPOXY GROUT is a rapid setting material and must be mixed and placed within 30 minutes at 73°F (23°C). Turn the mixer off before withdrawing the mixing blade to avoid air entrapment.

5. PLACING

Immediately after mixing FIVE STAR DP EPOXY GROUT, place the grout without delay from one side of the form to the other. Additional batches should be mixed and placed quickly to avoid blockages and cold joints.

6. CURING

FIVE STAR DP EPOXY GROUT does not require any curing and will reach 6,000 psi (41.4 MPa) within 16 hours at 75°F (23°C). This is adequate to put most equipment back in operation. Forms may be stripped as soon as FIVE STAR DP EPOXY GROUT has stiffened enough to prevent sagging.

APPENDIX A
ANCHOR BOLT GROUTING - INTRODUCTION

Anchor bolt grouting accounts for a large number of applications relative to both the construction and industrial machinery grouting industry and must be addressed, as it is very important in connection with a successful installation. Precision grouting always includes the need to ensure the installation is completely secured and stable. This is of special concern when the equipment is subjected to dynamic (vibration or impact) loads created during operation.

FIVE STAR PRODUCTS, INC. offers the following general application and installation guidelines to help owners/developers, architects, engineers, specifiers, and contractors engaged in this work to better understand the technical issues associated with the equipment operating environment. These issues, if not properly addressed, can make the difference between a successful or an unsuccessful installation.

FIVE STAR PRODUCTS, INC. highly recommends a visit to our website at fivestarproducts.com to obtain current product information, newly available products, and technical support.

Grout Selection Process

In working with architects, engineers and contractors on grouting applications, the frequency of questions related to grouting generally follow a pattern as noted below and which will be individually addressed in the sections to follow:

1. What type of anchoring grout should be used? Cementitious or epoxy based?
2. What product does Five Star recommend for the application at hand?
3. What size (diameter) should the grout hole be?
4. Is there information available on how to calculate embedded length requirements in *cementitious* based grouts or alternatively, *epoxy* based grouts?
5. Are there guidelines available on how to install these grouts?

Product Recommendation

FIVE STAR PRODUCTS, INC. has several different grout products, each of which has performance and placement characteristics suitable to the application. Because there are many variables that would impact the appropriate selection, and in the interest of helping ensure the correct selection, FIVE STAR PRODUCTS ENGINEERING AND TECHNICAL CENTER (203-336-7900) is available to offer assistance. *However, it is the responsibility of the "Design or Project Engineer" on which product is ultimately selected for any application.* Product warranties are limited to those as stated on each of FIVE STAR PRODUCTS, INC. product data sheets.

Helpful Information

A product selection chart and technical support information on anchoring placement using cementitious or epoxy grout is provided on the following pages to help facilitate the selection and installation process.

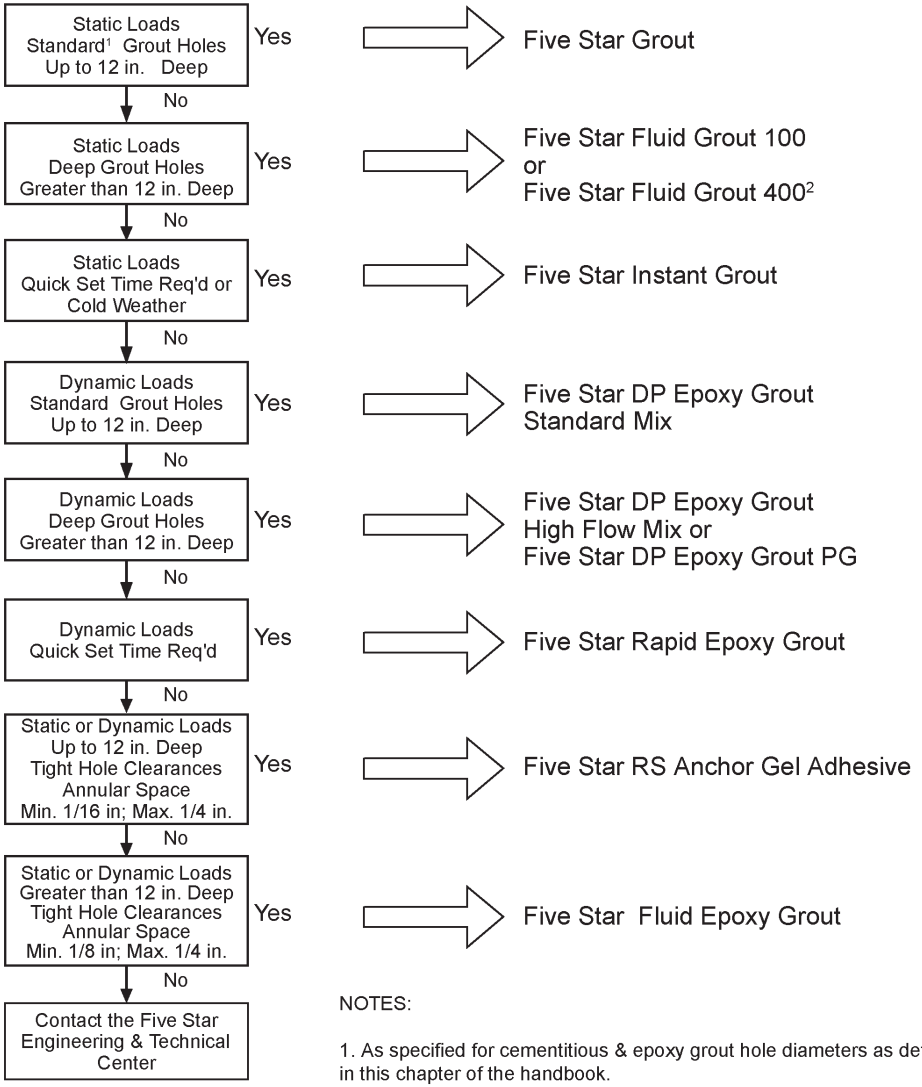
ANCHOR GROUTING WITH FIVE STAR® GROUT

TOTAL LOAD
Pounds at Pullout or Bar Failures

(Designers should allow a factor of safety.)

MODERATE STRENGTH STEEL – YIELD STRENGTH – 80,000 psi			
Bar Diameter	**Plain Bar**	**Reinforcing Bar (Deformed)**	**Threaded Bar**
One Foot Embedment			
1/4"	3,930	3,930	3,930
1/2"	15,700	15,700	15,700
3/4"	28,200	35,400	35,400
1"	37,700	56,500	62,900
Five Foot Embedment			
1"	62,900	62,900	62,900
1-1/2"	141,500	141,500	141,500
2"	252,000	252,000	252,000
3"	565,000	565,000	565,000
Ten Foot Embedment			
1"	62,900	62,900	62,900
2"	252,000	252,000	252,000
3"	565,000	565,000	565,000
4"	1,005,000	1,005,000	1,005,000
HIGH STRENGTH STEEL – YIELD STRENGTH – 135,000 psi			
Ten Foot Embedment			
2"	424,000	424,000	424,000
3"	955,000	955,000	955,000
4"	1,505,000	1,700,000	1,700,000
5"	1,880,000	2,650,000	2,650,000

Anchor Bolt Grout Selection Chart



NOTES:

1. As specified for cementitious & epoxy grout hole diameters as defined in this chapter of the handbook.
2. Five Star® Special Grout 400 is a highly fluid (non-sand based) cable grout that may be considered as an alternative for very deep holes (e.g., rock anchors). Call Five Star Products, Inc., Engineering Technical Center to determine if its use is appropriate.

ANCHOR BOLT GROUTING
CEMENT GROUT

Surface Preparation

Bolts: Free of oil, grease and rust. Preferably sandblasted to a "bright metal" surface condition. [Note 2]

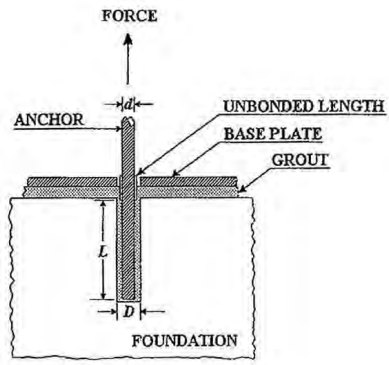
Holes: A. Dry drilled holes shall be cleaned of dust and debris.
B. Wet drilled holes shall be cleaned of drilling slurry.
C. Formed and/or core drilled holes shall be scarified to roughen anchor hole surface.
D. Concrete shall be saturated with water for 24 hours prior to grouting.
E. Standing water shall be removed immediately prior to grouting.

Dimensions

The dimensions called for are designed to eliminate the possibility of a grout failure. A concrete or steel failure is still possible. Therefore, if the concrete is designed to withstand maximum steel tension, the bolt/bar will be the governing design factor. (i.e., failure due to cone mechanism is eliminated due to reinforced concrete or because of baseplate.)

L = Length of Embedment[Note 1]
D = Diameter of Hole
d = Diameter of Bolt/Bar
fy = Yield Strength of Bolt/Bar
C = Bolt/Bar Shape Factor

C = 1.0 for Smooth Bolt/Bar
C = 1.5 for Deformed Bolt/Bar
C = 2.0 for Threaded Bolt/Bar



NOTES:

1. The length of embedment "L" was developed with information provided through ACI 318-99 & ACI 349.2R-97 (design requirements for steel embedments); anchoring in concrete.

2.2. SSPC-SP6: Joint Surface Preparation Standard for Commercial Blast Cleaning; Document Number: NACE No. 3 - per the NATIONAL ASSOCIATION OF CORROSION ENGINEERS, October 1994:

Commercial blast cleaned surface is defined as one in which all oil, grease, dirt, mill scale, rust and old paint have been completely removed from the blast cleaned surface, except that slight streaks, or discolorations caused by rust stain, mill scale oxides, or slight tightly adherent residues of paint or coating may remain. If the surface is pitted, slight residues of rust or paint may remain in the bottom of the pits. The slight discolorations mentioned above are limited to one-third of every square inch.

Length of Embedment

Based on shear/bond strength of 1000psi:

$$1000 \text{ psi}^{\text{Note 3}} \times C \times \pi d L = 1/4\, \pi d^2 f_y$$

Solving for L: minimum $L = f_y d \div [4000 \times C]$

Therefore: With f_y = 80,000 psi (moderate strength steel):

minimum L = 20d for Smooth Bolt/Bar
minimum L = 15d for Deformed Bolt/Bar
minimum L = 10d for Threaded Bolt/Bar

With fy = 135,000psi (high strength steel):

minimum L = 34d for Smooth Bolt/Bar
minimum L = 23d for Deformed Bolt/Bar
minimum L = 16d for Threaded Bolt/Bar

Hole Diameter

The diameters called for are minimum diameters. The requirements will ensure an adequate size bonding surface between grout and concrete. Larger dimensions may ease placement on top or awkward pours.

When bolt diameter $d \leq 1.0$ in, then hole diameter shall be a minimum of 2 in.
When bolt diameter $d > 1.0$ in, then hole diameter shall be a minimum 2d.

NOTES:
3. The value 1000 psi is 1/2 the average bond strength of FIVE STAR PRODUCTS, INC. precision nonshrink cementitious grouts per ASTM C 882 at 28 days and is adjusted upwards to the fully available average bond strength (2000 psi) through "C" above based on anchor bolt surface roughness to ensure concrete cone failure or bolt tension failure BEFORE grout failure occurs. In the application as illustrated with an anchored base plate, only bolt tension failure can occur.

ANCHOR BOLT GROUTING
EPOXY GROUT

Surface Preparation

Bolts: Free of oil, grease and rust. Preferably sandblasted to a "bright metal" [Note 2] surface condition.

Holes: A. Dry drilled holes shall be cleaned of dust and debris.
B. Wet drilled holes shall be cleaned of drilling slurry.
C. Formed and/or core drilled holes shall be scarified to roughen anchor hole surface.
D. Standing water shall be removed and anchor hole surfaces completely dry.

Dimensions

The dimensions called for are designed to eliminate the possibility of a grout failure. A concrete or steel failure is still possible. Therefore, if the concrete is designed to withstand maximum steel tension, the bolt/bar will be the governing design factor. (i.e., failure due to cone mechanism is eliminated due to reinforced concrete or because of baseplate.)

L = Length of Embedment[Note 1] [See diagram on next page]
D = Diameter of Hole
d = Diameter of Bolt/Bar
f_y = Yield Strength of Bolt/Bar
C = Bolt/Bar Shape Factor
S = Factor of Safety

[Epoxy grout bears a different relationship to steel surfaces than cement grout.]

C = 1.5 for Smooth Bolt/Bar
C = 2.0 for Deformed Bolt/Bar
C = 2.5 for Threaded Bolt/Bar

Because of the unique nature of a properly prepared steel surface (in accordance with SSPC-SP6, Steel Structure Painting Council:[Note 2] to bond to epoxy grout in a much stronger fashion than a similar bond to concrete, the value of "C" as shown above is modified to reflect that uniqueness.

NOTES:

1. As the behavior of epoxy based grouts are similar to cementitious based grouts, the length of embedment "L" was developed with information provided through ACI 318-99 & ACI 349.2R-97 (design requirements for steel embedments); anchoring in concrete.

2. SSPC-SP6: Joint Surface Preparation Standard for Commercial Blast Cleaning; Document Number: NACE No. 3 - per the NATIONAL ASSOCIATION OF CORROSION ENGINEERS, October 1994:

Commercial blast cleaned surface is defined as one in which all oil, grease, dirt, mill scale, rust and old paint have been completely removed from the blast cleaned surface, except that slight streaks, or discolorations caused by rust stain, mill scale oxides, or slight tightly adherent residues of paint or coating may remain. If the surface is pitted, slight residues of rust or paint may remain in the bottom of the pits. The slight discolorations mentioned above are limited to one-third of every square inch.

Length of Embedment

Using:

$1000\ psi^{Note\ 1} \times C \times \pi\, d\, L = 1/4\ \pi\, d^2\, f_y$; where $\pi = 3.1415$

Solving for L: minimum $L = f_y d \div [4000 \times C]$

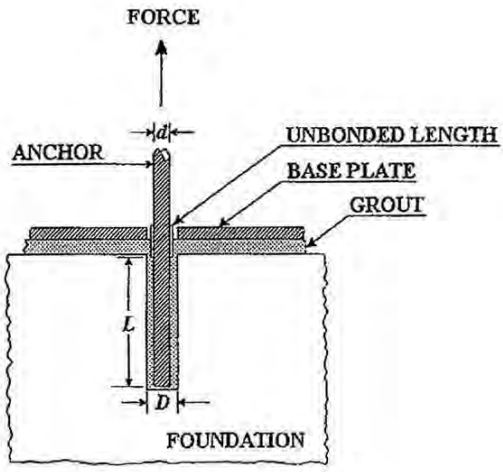
Therefore: With f_y = 135,000 psi (high strength steel):

minimum L = 22.6d for Smooth Bolt/Bar
minimum L = 17.0d for Deformed Bolt/Bar
minimum L = 13.6d for Threaded Bolt/Bar

Hole Diameter

The diameters called for are minimum diameters. The requirements will ensure an adequate size bonding surface between grout and concrete. Larger dimensions may ease placement on deep or awkward pours.

When bolt diameter $d \leq 1^1/_2$ in, the minimum hole diameter shall be $d + 1^1/_2$ in.
When bolt diameter $d > 1^1/_2$ in, the minimum hole diameter shall be $d + 2$ in.



NOTES:

1. The value 1000 psi is 1/2 the average bond strength of FIVE STAR PRODUCTS, INC. precision nonshrink cementitious grouts per ASTM C 882 at 28 days and is adjusted upwards to the fully available average bond strength (2000 psi) through "C" above based on anchor bolt surface roughness to ensure concrete cone failure or bolt tension failure BEFORE grout failure occurs. In the application as illustrated with an anchored base plate, only bolt tension failure can occur.

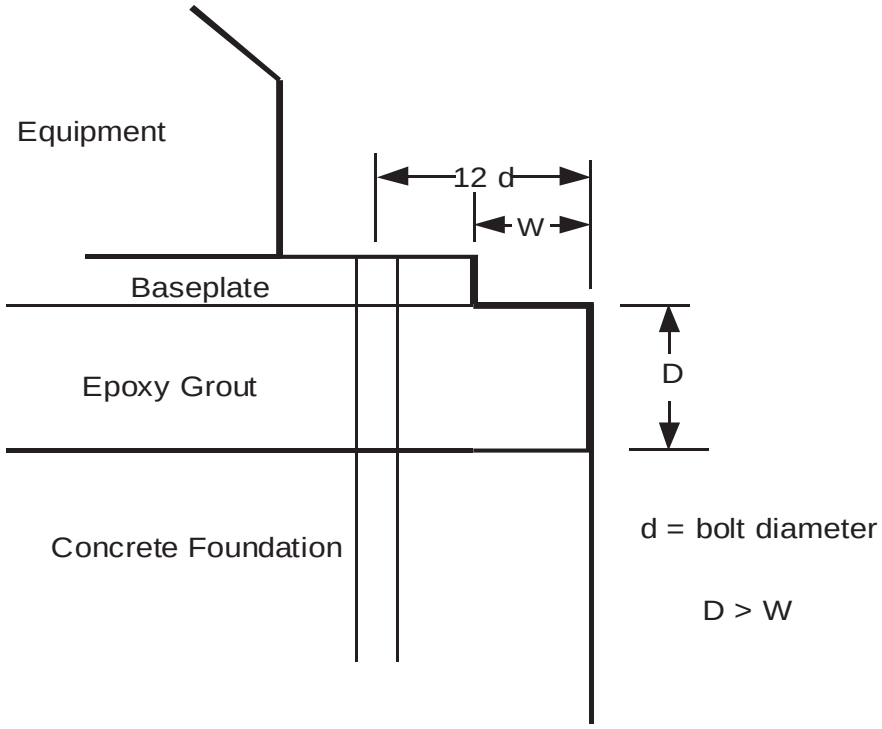
INSTALLATION GUIDELINES
ANCHOR BOLT LOCATION

EDGE DISTANCE AND CENTER TO CENTER DISTANCE

Determining the location of the grout hole relative to the foundation edges is especially important when larger bolts are employed for tensioning *without a baseplate*. Assuming the appropriate embedment length has been established, to assure maximum available resistance to tension loads and avoid concrete cone failure, a ***minimum*** of twelve (12) bolt diameters from any edge and twenty four (24) bolt diameters between bolt center lines is suggested. **The design engineer has the final authority on this.**

AVOIDING EDGE LIFTING

Because of the difference in the coefficients of thermal expansion (COTE) between cementitious and epoxy based concrete, large transient temperature differences (as with equipment operating outdoors during seasonal changes) can cause separation at the outer edges of the bond line between a cementitious substrate and epoxy grout. Therefore, during the equipment foundation design phase, it is recommended that the foundation shoulder width (W) ***always*** be less than the proposed grout clearance depth (D).



Please refer to FIVE STAR PRODUCTS, INC. product specific data sheets (downloadable in Adobe Acrobat® PDF file format) for product information and installation instructions and/or fill out a request form at **fivestarproducts.com** to receive more detailed instructions available through our ***"Design-A-Spec®"*** (DAS) document. The DAS is both a specification and detailed installation instruction document, and is highly recommended for architects, engineers, specifiers, and contractors to help ensure the design, development, and installation of a successful project. Additional information or clarifications may be obtained by contacting the FIVE STAR TECHNICAL AND ENGINEERING CENTER by e-mail through **info@fivestarproducts.com** or by calling (203) 336-7900.

APPENDIX B
GLOSSARY

ACI — American Concrete Institute
PO Box 9094, Farmington Hills MI 48333

ASTM — American Society for Testing Materials
100 Barr Harbor Drive, West Conshohocken PA 19428

DIMENSIONAL STABILITY
Resistance to excessive shrinkage or expansion in the plastic or hardened state.

EFFECTIVE BEARING AREA (EBA)
The portion, expressed as a percent, of the total area of a base plate that is in actual physical contact with the grout beneath it and is available to transfer compressive loads.

GROUT — A mixture of cementitious material and water, with or without aggregate, proportioned to produce a pourable consistency without segregation of the constituents. Also, a mixture of other composition but of similar consistency.

ICRI — concrete industry association devoted to repair and restoration, publishes a magazine and technical guidelines for concrete repair, and co-sponsors the World of Concrete. Worldwide membership include contractors, manufacturers, engineers, distributors, owners and other professionals with a common goal: prolonging the useful life of concrete through quality repair, restoration, and protection.

MACHINE-BASE GROUT
A grout used in the space between plates or between a machinery base and the underlying foundation and which is expected to maintain essentially complete contact with the base and to maintain uniform support.

NONSHRINK GROUT
A hydraulic cement grout that includes a shrinkage-compensating mechanism to produce a volume that, when hardened under stipulated conditions, is greater than or equal to the original installed volume.

PRECISION NONSHRINK GROUT
A grout whose vertical height change is never less than the vertical height at the time of placement and no more than 4.0% in the plastic state and no more than 0.3% in the hardened state. There is no plastic or hardened vertical shrinkage at any time.

APPENDIX C
COMMON CONVERSION FACTORS

Multiply ⇨	***By***	***To Get***
inches [in]	2.54	centimeters [cm]
feet [ft]	0.3048	meters [m]
mils	1000	inches [in]
cubic inches [cu in] [in^3]	16.39	cubic centimeters [cc] [cm^3]
cubic inches [cu in] [in^3]	16.39	millimeters [ml]
cubic feet [cu ft] [ft^3]	28.31	liters [l]
liters [L]	33.81	fluid ounces [fl oz]
cubic feet [cu ft] [ft^3]	7.48	gallons [gal]
cubic feet [cu ft] [ft^3]	1728	cubic inches [cu in] [in^3]
cubic meters [m^3]	35.31	cubic feet [cu ft] [ft^3]
cubic meters [m^3]	1,308	cubic yards [cy] [yd^3]
cubic yards [cy] [yd^3]	27	cubic feet [cu ft] [ft^3]
square feet [sq ft] [ft^2]	144	square inches [sq in] [in^2]
square inches [sq in] [in^2]	6.452	square centimeters [sq cm] [cm^2]
square yards [sq yd] [yd^2]	9	square feet [sq ft] [ft^2]
square meters [sq m] [m^2]	1.196	square yards [sq yd] [yd^2]
square meters [sq m] [m^2]	10.76	square feet [sq ft] [ft^2]
megapascals [MPa]	145.0	pounds/square inch [psi] [lb/in^2]
kilograms/square centimeter	14.22	pounds/square inch [psi] [lb/in^2]
kips/square inch [ksi] [kip/in^2]	6.895	megapascals [MPa]
kips/square inch [ksi] [kip/in^2]	1000	pounds/square inch [psi] [lb/in^2]
pounds (force or weight) [lb]	4.448	newtons [N]
tons (metric tons) [t]	2205	pounds (force or weight) [lb]
ounces (force or weight) [oz]	28.35	grams [g]
degrees Centigrade [°C]	1.8	degrees Fahrenheit -32 [°F]
degrees Fahrenheit -32 [°F]	0.555	degrees Centigrade [°C]
quarts [qt]	0.9466	liters [l]
quarts [qt]	2	pints [pt]
gallons [gal]	4	quarts [qt]
cubic feet of water (at 4°C)	62.43	pounds [lb]
gallons of water	8.33	pounds [lb]
To Get	***By***	⇦ ***Divide***

APPENDIX D
BULK SACK MIXING PROCEDURES

1. Ready-Mix Concrete Truck - Extended

A. Verify working time of grout and water requirements under job site conditions before placement in concrete truck.

B. Mixing drum and mixing blades must be in good operating condition, pre-dampened and excess water removed.

C. First add clean, damp, coarse aggregate meeting the requirements of ASTM C 33 to drum.

D. Add approximately 75% of premeasured potable water to mixing drum as pre-determined by testing. Five gallons of this 75% shall be held back for hopper wash down. Water addition must be adjusted if wet aggregate is used or water is present in the drum.

E. Add grout, with drum turning at a slow speed. Do not exceed half the capacity of drum or add more than 3 bulk bags per truck. Use the 5 gallons (19 liters) of held back water to wash down hopper and drum after loading. Mix thoroughly for approximately five minutes at slow speed to a uniform consistency.

F. Reverse drum to check consistency. Add remaining water as needed, then mix to a uniform consistency. Do not exceed maximum allowable water content as stated on product packaging or add an amount that will cause segregation. Small bags of grout should be available to stiffen consistency if necessary.

G. Position truck as close as possible to pour and promptly discharge from truck. When transporting mixed grout, take care not to allow grout to segregate.

2. Ready-Mix Concrete Truck - Neat

A. Verify working time of grout and water requirements under job site conditions before placement into concrete truck.

B. Mixing drum and mixing blades must be in good operating condition, pre-dampened and excess water removed.

C. Add approximately 75% of premeasured potable water to mixing drum as predetermined by testing. Five gallons of this 75% shall be held back for hopper wash down. Water addition must be adjusted if wet aggregate is used or water is present in the drum.

D. Add grout with drum turning at slow speed. Do not exceed half the capacity of the drum or add more than 3 bulk bags per truck. Use the 5 gallons (19 liters) of held back water to wash down the hopper and drum after loading.

E. Continue mixing at slow speed for 70 – 100 revolutions.

F. Reverse drum to check consistency. Add remaining water as needed, then mix to a uniform consistency. Do not exceed maximum allowable water content as stated on product packaging or add an amount that will cause segregation. Small bags of product should be available to stiffen consistency if necessary.

G. Position truck as close as possible to pour and promptly discharge from truck.

REFERENCES: ACI 351.1R-93 "Grouting for Support of Equipment and Machinery"
PCA 1990 "Cementitious Grouts and Grouting"

APPENDIX E: MIX WATER REQUIREMENTS, MEASURED IN QUARTS

CEMENTITIOUS GROUTS	lbs.	Minimum	Maximum	Notes
Five Star® Grout	50	3.5	5.5	
Five Star® Grout	100	7.0	11.0	
Five Star® High Strength Grout	50	2.25	3.0	
Five Star® High Strength Grout	100	4.50	6.0	
Five Star® Fluid Grout 100	55	4.0	+	To consistency 20 - 30 seconds
Five Star® HTR Grout	50	3.0	3.5	
Five Star® Instant Grout	55	3.0	3.5	
Five Star® Special Grout 110	100	7.0	11.0	
Five Star® Special Grout 120	100	7.0	11.0	
Five Star® Special Grout 150	100	7.0	11.0	
Five Star® Special Grout 400	49	6.0	6.5	Refer to PTI guide spec for modified flow cone
Five Star® Special Grout 550	100	7.0	11.0	
FSP Construction Grout	50	2.5	3.5	
NBEC	55	3.0	4.0	

STRUCTURAL CONCRETE REPAIR	lbs.	Minimum	Maximum	Notes
Five Star® Structural Concrete	50	2.5	3.0	
Five Star® Structural Concrete ES	50	2.5	3.0	
Five Star® Structural Concrete S300	50	2.25	3.0	
Five Star® Structural Concrete V/O	50	3.0	4.0	
Five Star® Structural Concrete Gunite	50	1.75	2.25	
Five Star® Structural Concrete Gunite WP	50	2.25	3.0	
Five Star® Structural Concrete Gunite S300	50	1.75	2.50	
Five Star® Structural Concrete HTR Shotcrete	50	2.50	3.5	
Five Star® Structural Concrete HTR	50	1.75	2.25	
Five Star® Structural Concrete Underwater HP	50	3.0	3.5	
Five Star® Structural Concrete Underwater PG	50	3.0	4.0	

+ Only add that amount of water necessary to achieve a 20-30 second flow / ASTM C 939

APPENDIX E: MIX WATER REQUIREMENTS, MEASURED IN QUARTS

INFRASTRUCTURE/ COMMERCIAL	lbs.	Minimum	Maximum	Notes
Five Star® Concrete Patch	50	2.25	3.0	
Five Star® Vertical Patch	50	2.50	3.0	
Five Star® Rapid Patch	50	2.25	3.0	
Five Star® Highway Patch	50	2.25	3.0	
Five Star® Highway Patch L	50	*	*	* Five Star Polymer Liquid 3 - 4 quarts liquid only
Five Star® Shotcrete	50	1.75	2.5	
Five Star® Shotcrete WP	50	2.25	3.0	
Five Star® Shotcrete WP/FS	50	2.25	3.0	
Five Star® Highway Patch Cement	94	**	**	
Five Star® Fast Set Cement	94	**	**	
Five Star® Fast Set Cement L*	94	***	***	

COATINGS	lbs.	Minimum	Maximum	Notes
Five Star® Waterproofing	50	1.5 + 1.5	2.0 + 2.0	2.0 Water + 2.0 Five Star® Liquid
Five Star® Cement Coat	65	7.0	9.0	
Five Star® AC Coat	16	1.0	1.5	

1) All the products above should be mixed to a recommended consistency.
2) Cement grouts may use less than minimum posted water for hand pack consistency.

** Water requirements for Five Star® Cement Systems are typically based upon project specific mix designs with water-cement ratios ranging from 0.30 to 0.45 (maximum); also available in 2500 lb bulk sacks.

*** In accordance with ACI 301, 4.3.1. for production of latex modified concrete, use 3.5 gallons / per sack of cement of Dow Modifier A latex or equivalent, plus additional water if necessary to adjust slump; not to exceed a water-cement ratio of 0.40; also available in 2500 lb sacks.

Contact Five Star® Technical Services for more information: 203.336.7900

NOTES:

Project Name: Date: Product: Water/Aggregate:	
Project Name: Date: Product: Water/Aggregate:	
Project Name: Date: Product: Water/Aggregate:	
Project Name: Date: Product: Water/Aggregate:	
Project Name: Date: Product: Water/Aggregate:	

NOTES:

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