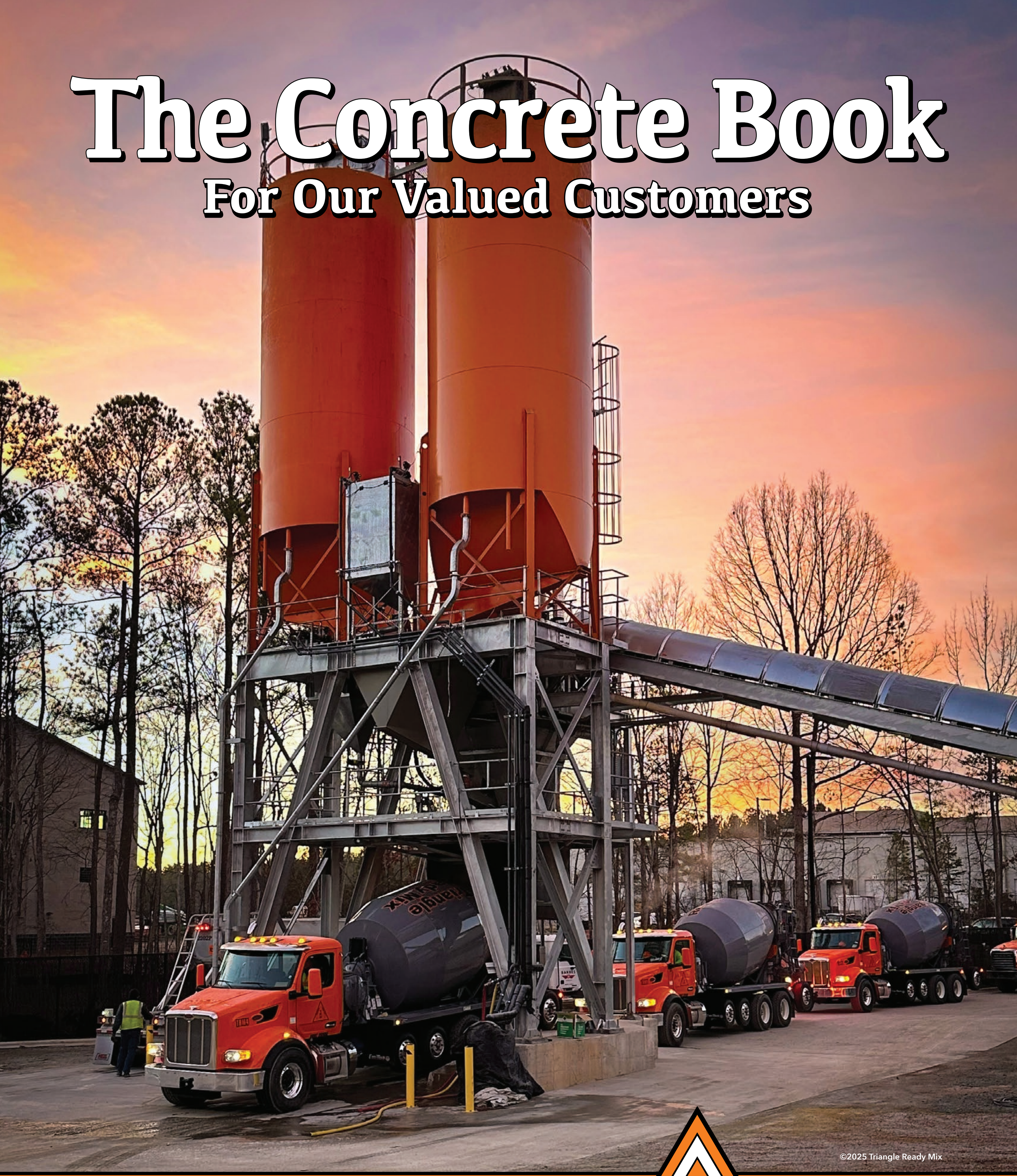
The Concrete Book

For Our Valued Customers



Fifth Edition

TriAngle™
READYMIX
The Contractor's Choice!
an L&L Construction Group company

Table of Contents

Introduction

Thank You for Choosing Triangle Ready Mix . . . 1
The Triangle 5 . . . 2
The Golden Triangle of Service Plan . . . 3
Meet Some of Our Team . . . 4

Section 1: General Information

Concrete 101: The Basics . . . 5
- What is Concrete? . . . 5
- How is Concrete Made? . . . 5
- How is Concrete Tested for Quality? . . . 6
- What are Graded Aggregates? . . . 6

Understanding Pozzolanic & Cementitious Materials . . . 7
- Pozzolanic . . . 7
- Cementitious . . . 7
- Key Differences . . . 7
- Summary . . . 8
- **Infographic: Pozzolanic vs Cementitious** . . . 8

Types of Portland Cement . . . 9
- General Information About Cement . . . 9
- Main Types of Portland Cement . . . 9
- About ASTM C 150 . . . 10
- About ASTM C 595 . . . 10

Fly Ash and Its Use in Concrete Production . . . 11
- About Pozzolans . . . 11
- The Most Common Pozzolan Used in Concrete Production is Fly Ash . . . 11
- What Are the Benefits of Using Fly Ash? . . . 11
- What Are the Drawbacks of Using Fly Ash? . . . 11
- Types of Fly Ash Used in Concrete Production . . . 12
- **Infographic: Pozzolanic vs Cementitious** . . . 12

The Benefits of Inline Aggregate Blending . . . 13
- What is the difference between repose batching and inline blending? . . . 13
- **Graphic: A Typical Repose Batching System** . . . 13
- How does precision inline blending work? . . . 13
- **Graphic: Precision Inline Blending** . . . 14

The Importance of Heated & Chilled Mix Water 14
Why is Heated or Chilled Mix Water Important for Concrete? 14
Benefits of Heated Mix Water 15
Benefits of Chilled Mix Water 15
Graphic: Operation of Typical Mix Water Chillers and Heaters 16
Placing Your Order for Ready Mixed Concrete 16
What is ready mixed concrete? 16
Some basics to keep in mind when ordering ready mixed concrete 17
Responsibilities 18

Section 2: Testing

About Concrete Acceptance Testing 19
The Objective of Concrete Acceptance Testing 19
Testing and Responsibilities 19
Table: Slump Tolerances of ASTM C 94 19
Concrete Slump Testing 20
What is Concrete Slump? 20
How to Perform a Concrete Slump Test 20
Infographic: Steps of Concrete Slump Test 21
Cylinder Compression Testing 22
Understanding Concrete's Compressive Strength 22
What is Cylinder Compression Testing? 22
Why is Cylinder Compression Testing Used? 22
How is Cylinder Compression Testing Performed? 22
Infographic: Calculating Compression Strength 23
What Do Cylinder Compression Test Results Show? 23
Graphic: Cylinder Compression Testing Machine 23
RED FLAG: Low Cylinder Breaks 24
What Are Low Cylinder Breaks? 24
Why Are Low Cylinder Breaks a Concern? 24
Common Causes of Low Cylinder Breaks 24
Conclusion 25
Infographic: Typical Compression Strength Values 25
Understanding Rebound Hammer Testing 26
Assessing Concrete Strength With Rebound Hammer Testing 26
How the Rebound Hammer Test Works 26
Graphic: Rebound Hammer Basic Components 26
Understanding the Rebound Hammer and its Relation to Concrete Strength 26

Graph: Correlation of Hammer Rebound Number to Compressive Strength 27
History & Development 27
Summary 27

Section 3: Additives and Admixtures

About Admixtures for Ready Mixed Concrete 29

What are chemical admixtures for ready mixed concrete? 29
What are some of the most common admixtures? 29

About Synthetic Fiber Concrete Additives 30

Synthetic Fibers in Concrete During Plastic Phase 31
Synthetic Fibers in Hardened Concrete 31
Synthetic Fibers as Secondary Reinforcement 31
Synthetic Fibers Can Be Used for These Applications:. 31
Table: Do Not Use Synthetic Fibers For These Applications 31

Using Superplasticizer Additives in Concrete 32

Advantages of Using Superplasticizer 32
Disadvantages of Using Superplasticizer 32
How Do Plasticizers Differ From Superplasticizers? 33

Air Entraining Admixtures For Concrete 34

History 34
Benefits 34
Infographic: How Air Entrainment Helps Concrete Resist Freeze-Thaw Cycles 34
Drawbacks 35
What is the difference between Entrapped Air and Entrained Air? 35

Section 4: Placement and Curing

Adding Water to Concrete at the Jobsite 37

Why add water at the jobsite? 37
Effect on slump and strength 37
Graph: Effect of Water Addition on Slump and Strength of Concrete 37
What is involved in the process? 37
Infographic: ASTM C 94 Jobsite Water Addition 38

Concrete Surface Dusting: Causes & Prevention 38

What causes concrete surface dusting? 38
Methods to prevent concrete surface dusting. 39
Table: Five Basic Rules to Prevent Dusting 39
Methods for repairing dusting or chalking of concrete 40

Concrete Cracking and Saw Joints ... 40
Common Types of Cracks ... 40
Methods To Minimize Cracking ... 41
Saw Joints ... 41
The Role of Temperature in Concrete Cracking ... 42
What is Heat of Hydration? ... 42
A Temperature Differential Occurs as Heat Dissipates ... 42
Graphic: Expansion & Contraction from Temperature Differential ... 42
What Role Does Temperature Play in Concrete Cracking? ... 43
Managing Concrete Temperature ... 43
Surface Discoloration of Concrete ... 44
About Surface Discoloration ... 44
What Are the Most Common Types of Surface Discoloration? ... 44
What Causes Surface Discoloration? ... 44
Preventing Concrete Surface Discoloration ... 44
Graphic: Five Common Types of Concrete Surface Discoloration ... 45
White Spotting / Efflorescence of Concrete ... 46
What is White Spotting / Efflorescence? ... 46
Methods To Minimize or Prevent Efflorescence ... 46
Sulfate Attack of Concrete ... 48
Types of Sulfate Attack ... 48
Effects of Sulfate Attack on Concrete ... 48
Prevention and Mitigation ... 49
Can Admixtures Help? ... 49
Table: Types of Admixtures & How They Contribute to Enhancing Sulfate Resistance 49
Alkali-Silica Reactivity (ASR) in Concrete ... 50
Key Aspects of Alkali-Silica Reactivity ... 50
Graphic: Effects of ASR on a Concrete Structure ... 50
Can Alkali-Silica Reactivity Be Predicted? ... 50
Infographic: Process of Alkali-Silica Reaction in Concrete ... 51
Prevention and Mitigation ... 51

Section 5: Weather

Essential Tips for Using Concrete in Cold Weather 53

1. The Role of Heated Mix Water 53
2. Admixtures for Cold Weather Concrete 53
3. The Importance of Low Water-Cement Ratio Mixes 54

Key Takeaways 54

Placing Concrete During Cold Weather 54

How does cold weather affect concrete production and placement? 54

Placing Concrete in Cold Weather 55

Table: Recommended Concrete Temperature at Time of Placement 55

Concrete Curing in Hot Weather 56

How does hot weather affect concrete curing? 56

Why take hot weather into consideration? 56

How to manage curing of concrete in hot weather 57

Table: Sample Minimum Curing Period to Achieve 50% of Specified Strength 58

Section 6: Reference

Glossary of Ready Mixed Concrete Terms 59

Thank you for choosing Triangle Ready Mix

Thank you for choosing Triangle Ready Mix as your ready-mixed concrete supplier! Our goal is to provide the finest-quality ready mix concrete, combined with ***unsurpassed*** customer service, to the greater Raleigh, NC area.

Whether your project is large or small, we can accommodate your needs. Triangle Ready Mix boasts a state-of-the-art, technologically advanced concrete blending plant. Located at our facility in Morrisville, this high-volume batch plant outputs precision-blended concrete mixes with extremely high consistency.

You get your concrete the way you want it — the same way ***every time***, and ***on time***.

Less Segregation + Precision blending = Better concrete.

It's simple math!

At Triangle Ready Mix, we blend concrete with a state-of-the art, precision inline blending batch plant. What this means for our customers is that we produce a superior-blended mix with less segregation of materials.

What makes TRM concrete better?

Most concrete producers mix concrete with traditional repose batching plants. While it's a time-honored method, the basic principles of repose batching haven't changed much in almost a century. **We do things differently:**

Triangle Ready Mix utilizes a precision inline blending batch plant. Aggregates are stored in a series of inline bins. Underneath each storage bin is a dedicated weigh belt with a precision weigh scale. These dedicated weigh belts accurately and consistently discharge aggregates onto the collecting conveyor below.

As the collecting conveyor moves, aggregates from the second bin are metered and discharged on top of the first layer of aggregates. In this way, the aggregates are precisely blended in ribboned layers. The aggregates are fully blended before they even enter the truck. As the truck's drum rotates, the mix just keeps getting better. Less segregation means fewer voids, resulting in concrete of superior strength and quality. **It's simply better concrete.**

How our team focuses on YOUR concrete needs:

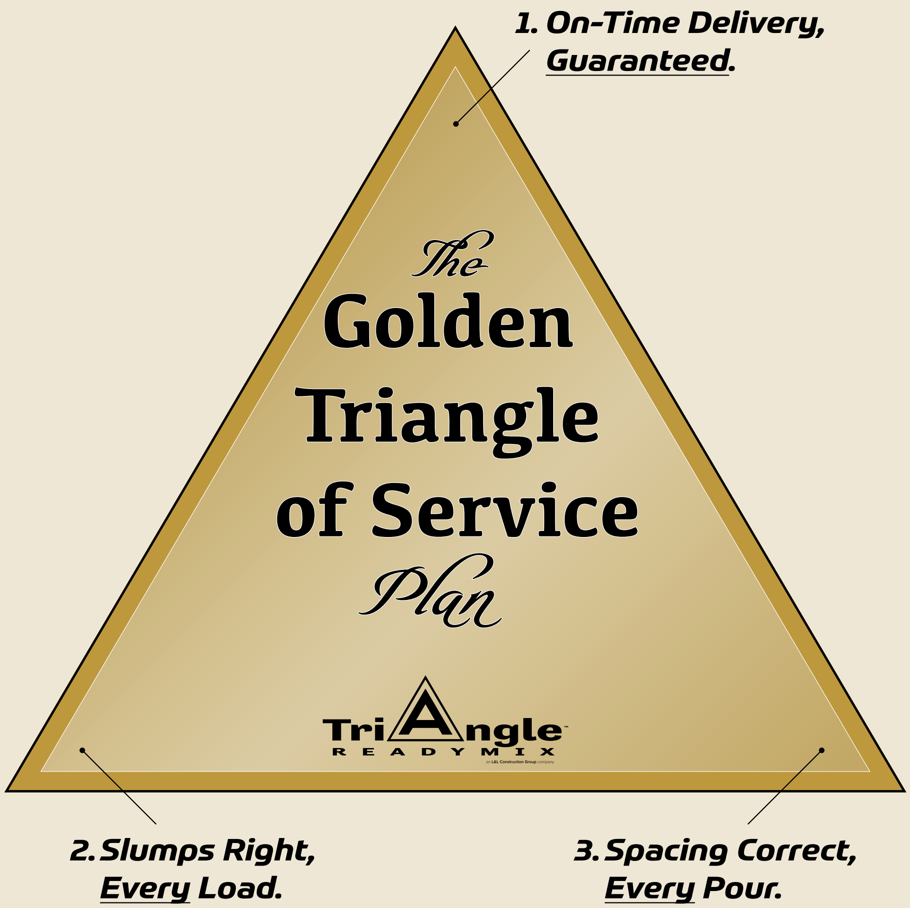
At Triangle Ready Mix, we bring value that you can see in your financials, by minimizing labor and equipment costs with our refined concrete delivery process. Our team of concrete professionals bring daily consistency and focus to meeting your needs. We take the extra steps to review your order by physically visiting every job site the day before, in order to ensure that we have all the details so that we can provide your team with a seamless concrete delivery process.

- We plan daily to ensure that every aspect of your concrete order is done in a fluid and effective manner.
- When we take your concrete order, we deliver — *or we will not take your order!*
- Our field service representatives are seasoned veterans of the ready mix concrete industry. Every day, they are tasked to develop relationships with your team to improve and ensure transparency in all our communications.
- We want your experience of ordering ready mixed concrete from us to be so pristine that you will always choose *"The Contractor's Choice"* — Triangle Ready Mix!

The Triangle 5

Each and every member of our ready mix concrete team adheres to our core process, called the “Triangle Five.” By following these core principles every day, we strive to provide you with the highest quality concrete and the best customer service that you can find in the Triangle!

1. **Safety in ALL we do.** This is a mindset we promote both in the workplace and in our private lives. It is a mindset where we, as individuals, must do the right things, the right way, and at the right time — ***every*** day.
2. **Be on time.** What we are and what we become in life requires that we maintain a presence of urgency and focus. Our success depends on us operating at a higher standard of excellence. Our daily plan involves things that help us all simplify and focus on the mission: Delivering ***your*** concrete on time, and at the right place.
3. **Slump right by sight.** We take the time to get our slump correct — and not by listening to the drum, guessing, or relying on gauges. Our drivers take the time to do it the right way, by visually inspecting the slump of the concrete they’re hauling — ***before*** leaving the plant.
4. **Directions are tight.** We check our directions, and ensure they match the delivery ticket. Triangle Ready Mix drivers make sure they understand the directions, how to get there safely, on time, and at the right job site.
5. **Prompt return flight.** We ask our drivers to follow, without exception, our plan to achieve our daily goals. In order to remain profitable in the ready mix concrete business, we must maintain a level of productivity. Everyone must focus daily on that productivity, as it is the mortar that binds the bricks: Accountability.



How we create an exemplary service experience:

- We just begin when we take your order —
- We ensure that everything is ready on the jobsite the afternoon before you pour.
- Our Field Service Staff checks the following for each order:
  1. We ensure that the address and directions are pinned on our directions.
  2. We inspect the pour site to minimize or eliminate any seen obstacles such as dumpsters, material, open holes or ditches.
  3. We inspect the forms and grade to ensure we have accurate yardage for your pour.
  4. We pin the correct wash out area for your pour.
  5. We contact your superintendent to report any found issues that need attention.
  6. We visit the pour site the following day to ensure quality control, and expedite the pour if it is needed.

What we request from our Golden Triangle customers:

- Accurate — Sure Go orders placed the day before.
- Prompt unloading of our trucks.
- Timely payment of your account.

Publication # 23-07-015

Meet Some of Our Team:

At Triangle Ready Mix, we believe the combined experience of our team provides many added benefits to our customers. From seasoned batch plant operators to staff members with experience in batch plant manufacturing, our team's diverse expertise ensures exceptional quality control.

Our dedicated drivers and knowledgeable dispatchers work together seamlessly to deliver precise, high-quality concrete exactly when and where you need it. Our in-house concrete testing lab ensures that each mix meets rigorous quality standards before it reaches your job site, providing consistency and peace of mind.

With decades of industry experience, we understand the demands of your project and the importance of timing, precision, and reliability. Whether it's a commercial slab, a residential foundation, or a custom mix design, we ensure our expertise adds value, efficiency, and confidence to every pour.

Nelson Loureiro
President. CEO. Visionary.

Keith Mercer
Chief Operating Officer

Dave DeFeo
C.O.O. Business Development

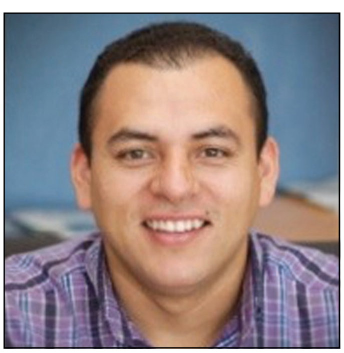
Stephen Apple
V.P. of Business Development

David Moss
V.P. of Customer Relations

Michael Cox
Director of Business Development

Joe Kisselburg
Dir. of Maintenance & Equipment

Tim Brown, Jr.
General Manager



Alberto Nieto
Sales Manager

Sean DeFeo
Quality Control Manager

Anthony Letterman
DOT / Safety / EHS

Concrete 101: The Basics

What is Concrete?

Concrete is a construction material that is made from a combination of coarse aggregates bonded together with a fluid cement that hardens over time. It is one of the most widely used construction materials in the world due to its strength, durability, and versatility. The basic ingredients of concrete are water, cement (typically Portland cement), and aggregate (such as gravel, crushed stone, and sand).

When the cement and water mix, a chemical reaction called hydration occurs. This binds the other ingredients together and forms a solid material. Concrete can be molded into any shape when it's in its fluid, or "plastic," state. This makes concrete an ideal material for a variety of applications such as building foundations, roads, bridges, dams, and more. Concrete is valued for its ability to withstand compression forces, making it suitable for supporting heavy loads. Additionally, concrete can be reinforced with materials like steel bars (rebar) to increase its tensile strength and resistance to cracking.

Concrete and Cement are NOT the same thing. Although the terms are often incorrectly used interchangeably, concrete and cement are two completely different things. Cement — most typically, Portland Cement — is a binding agent used to make concrete. Cement is in a powder form until it is mixed with water (which then begins the hydration process). Concrete is the composite material composed of cement, aggregates, and water. Concrete, when cured, is solid, strong and can last for centuries.

How is Concrete Made?

Concrete is typically made through a mixture process called batching. This is why typical concrete production plants are called "batch plants." Here is a simplified overview of the basic steps involved:

1. **Batching:** The first step is to measure & combine the ingredients in the correct proportions. The main components of concrete are:
   - **Cement:** Usually Portland cement, which is finely ground and acts as the binder.
   - **Coarse Aggregates** such as gravel or crushed stone.
   - **Fine Aggregates** such as sand.
   - **Water:** Used to hydrate the cement and initiate the chemical reaction that causes it to harden.
   - **Admixtures** (optional): These are additional materials added to alter the properties of the concrete, such as accelerating or retarding the setting time, improving workability, or enhancing strength.
2. **Mixing:** Once the ingredients are accurately measured, they are thoroughly mixed together. This can be done using various methods, such as in a rotating drum mixer, a stationary mixer, or a combination of both. The most common method is by the rotating drum of a ready-mixed concrete truck. In all cases, the goal is to achieve a uniform consistency and distribution of materials throughout the mixture.
3. **Transportation:** After mixing, the concrete is transported to the construction site using trucks equipped with rotating drums, or other specialized vehicles.
4. **Placement:** At the construction site, the concrete is poured into forms or molds according to the desired shape and dimensions. It is then leveled and compacted to remove air voids and ensure proper consolidation.
5. **Curing:** Once placed, the concrete must be cured to allow it to gain strength and durability. Curing involves maintaining adequate moisture and temperature conditions for a specified period of time. This can be done by covering the concrete with wet burlap, plastic sheeting, or by applying curing compounds.

Throughout these steps, it's crucial to follow established guidelines and best practices to ensure that the concrete achieves the desired properties and performance characteristics. Properly made and cured concrete can provide long-lasting structural integrity & support.

How is Concrete Tested for Quality?

Concrete quality is typically assessed through tests conducted on samples taken from the batch. These tests evaluate various properties of the concrete to ensure it meets the desired standards and specifications. Some common tests for assessing concrete quality include:

1. **Slump Test:** This test measures the consistency and workability of fresh concrete. A slump cone is filled with freshly mixed concrete, and after the cone is removed, the decrease in height of the concrete specimen is measured. The slump value indicates the degree of fluidity or stiffness of the concrete.
2. **Compressive Strength Test:** Compressive strength is one of the most important properties of concrete. A compressive strength test determines the ability of concrete to withstand compressive loads. Cylindrical or cube-shaped specimens are cast from the concrete batch and cured under specified conditions. These specimens are then subjected to compressive forces in a testing machine until failure occurs. The maximum load at failure divided by the cross-sectional area of the specimen gives the compressive strength of the concrete.
3. **Flexural Strength Test:** This test evaluates the tensile strength of concrete by subjecting beam specimens to bending forces. It is especially important for concrete elements that are subjected to bending stresses, such as beams and slabs.
4. **Durability Tests:** Various tests assess the durability of concrete, including resistance to freezing and thawing cycles, chemical attack, abrasion, and permeability. These tests help ensure that the concrete will withstand environmental conditions and maintain its structural integrity over time.
5. **Density and Unit Weight:** These tests measure the density or unit weight of the concrete, which is important for estimating the structural load-bearing capacity and volume of concrete components.
6. **Air Content Test:** This test measures the volume of air voids in the concrete. Excessive air content can reduce the strength and durability of concrete, especially in freeze-thaw environments.
7. **Temperature Monitoring:** Monitoring the temperature of concrete during mixing, transportation, and placement is important to prevent issues such as excessive heat buildup or cold weather-related problems.

These tests, along with adherence to proper mixing, placement, and curing practices, help ensure that the concrete meets the required quality standards and performs satisfactorily in its intended application. Quality control procedures are often implemented throughout the construction process to monitor and maintain the quality of the concrete.

What are Graded Aggregates?

Graded aggregates in concrete refer to aggregates that have been sorted or classified according to their particle sizes. The process of grading aggregates involves separating them into groups or categories based on specific size ranges. Graded aggregates typically include both coarse and fine aggregates, and they are combined in concrete mixes to achieve the desired properties.

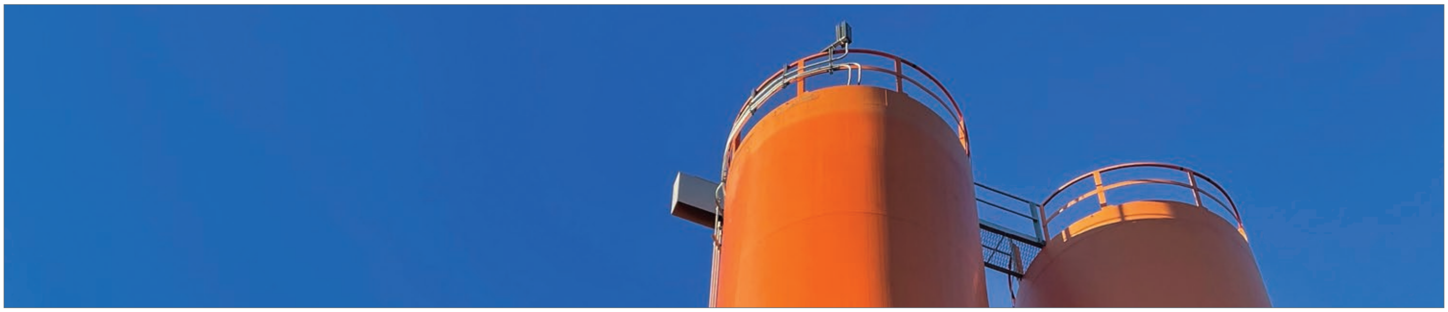
Aggregate grading is important because it influences the workability, strength, and durability of concrete. **Well-graded aggregates have a balanced distribution of particle sizes, helping to minimize voids and improve the packing density within the concrete mix.** This results in better cohesion & reduces the amount of cement paste needed to fill voids, leading to more economical and durable concrete.

Grading of aggregates is typically done according to standardized sieve sizes specified by agencies such as ASTM International (formerly known as the American Society for Testing and Materials). The aggregates are passed through a series of sieves with progressively smaller openings, and the portion of material retained on each sieve is measured to determine the gradation curve. Commonly used grading categories for aggregates include:

- **Coarse Aggregate:** This includes aggregates with particle sizes larger than 4.75 mm (No. 4 sieve size) up to approximately 2 inches in diameter. Coarse aggregates provide bulk and stability to the concrete mix.
- **Fine Aggregate:** Fine aggregates consist of particles smaller than 4.75 mm (No. 4 sieve size) and typically include sand and smaller crushed stones. Fine aggregates fill the voids between coarse aggregates and help to improve workability and cohesiveness.
- **Combined Aggregate Grading:** In concrete mixes, a combination of coarse and fine aggregates is used to achieve the desired grading curve. The specific proportions of coarse and fine aggregates are determined based on factors such as desired strength, workability, and durability requirements.

Graded aggregates play a crucial role in the performance of concrete by influencing its workability, strength, durability, and other properties. Properly graded aggregates contribute to the production of high-quality concrete.

Understanding Pozzolanic & Cementitious Materials



What is the difference between "Pozzolanic" and "Cementitious?"

The terms ***"Pozzolanic"*** and ***"Cementitious"*** refer to different types of chemical reactions that materials undergo in the presence of water and other compounds, particularly in the context of concrete production. The primary pozzolan involved in concrete production is fly ash. The primary cementitious material is, naturally, Portland cement. Typically, as shown in the photo above, ready-mixed concrete plants will have 2 or more silos for storage of both of these materials to use in concrete production.

Pozzolanic:

Definition: Pozzolanic materials are not cementitious by themselves, but they can react chemically with calcium hydroxide ($Ca(OH)_2$) in the presence of water to form cementitious compounds, primarily calcium silicate hydrate (C-S-H), which is responsible for the strength and durability of concrete.

Reaction: The pozzolanic reaction occurs when a pozzolan combines with calcium hydroxide (a byproduct of the hydration of Portland cement) to form additional binder materials.

Examples: Fly ash (Class F), silica fume, natural pozzolans (such as volcanic ash), and metakaolin.

Characteristics:

Pozzolans require an external source of calcium (usually from Portland cement) to activate and contribute to strength development.

They enhance the long-term strength and durability of concrete by consuming excess calcium hydroxide, which can reduce the concrete's vulnerability to chemical attack (such as sulfate attack) and increase resistance to alkali-silica reactions (ASR).

Cementitious:

Definition: Cementitious materials can independently react with water (a process called hydration) to form solid, binding compounds without the need for additional chemicals or activation. These materials possess intrinsic cementing properties.

Reaction: Cementitious materials undergo a direct hydration reaction, where the primary compounds in cement (like tricalcium silicate and dicalcium silicate) react with water to produce calcium silicate hydrate (C-S-H) and calcium hydroxide ($Ca(OH)_2$), providing the initial and ongoing strength in concrete.

Examples: Portland cement, ground granulated blast-furnace slag (GGBFS), and Class C fly ash (which has both cementitious and pozzolanic properties).

Characteristics:

Cementitious materials do not require calcium hydroxide or other compounds to activate; they hydrate with water and begin to harden on their own.

These materials contribute to both early strength gain and long-term performance.

Key Differences:

1. Chemical Activity:

- **Pozzolanic:** Requires calcium hydroxide to react and form cementitious compounds.
- **Cementitious:** Reacts directly with water and hardens independently.

2. Role in Concrete:

- **Pozzolanic materials** enhance long-term durability by consuming calcium hydroxide and forming additional C-S-H, improving the concrete's chemical resistance and strength over time.
- **Cementitious materials** are responsible for the primary strength development in concrete, especially in the early stages.

3. Usage:

- **Pozzolans** are often used to replace a portion of Portland cement in concrete mixes to improve performance and reduce costs or environmental impact.
- **Cementitious materials**, like Portland cement, are the primary binding agents in concrete and are responsible for its initial setting and strength development.

Summary

Cementitious materials can form a solid mass on their own when mixed with water, while pozzolanic materials need an additional source of calcium (like Portland cement) to form similar compounds that contribute to concrete strength and durability.

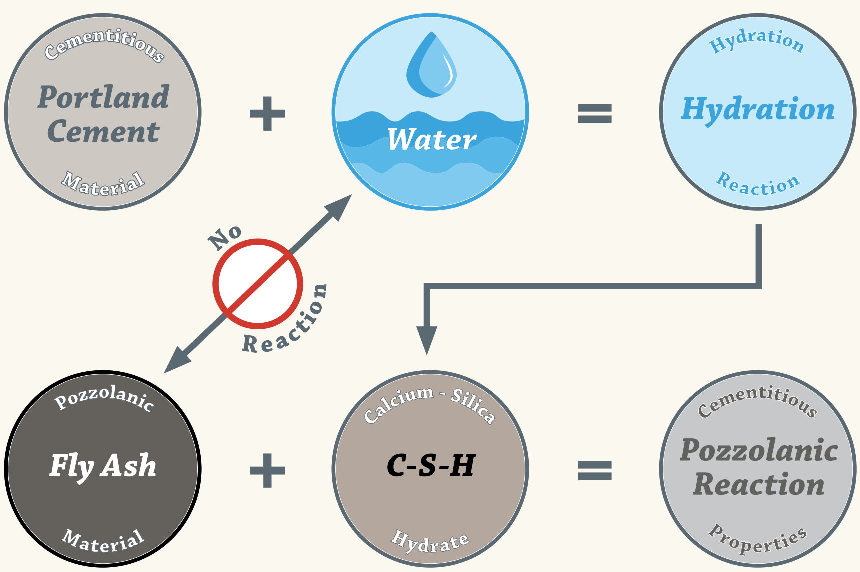
Pozzolanic – vs – Cementitious

Pozzolanic materials are not cementitious by themselves. But, they can react chemically with calcium hydroxide ($Ca(OH)_2$) in the presence of water to form cementitious compounds — primarily calcium silicate hydrate (C-S-H), which is responsible for the strength and durability of concrete.

Types of pozzolanic materials include: Fly ash (Class F), silica fume, natural pozzolans (such as volcanic ash), and metakaolin.

Cementitious materials can independently react with water (a process called hydration) to form solid, binding compounds without the need for additional chemicals or activation. These materials possess intrinsic cementing properties.

Types of cementitious materials include: Portland cement, ground granulated blast-furnace slag (GGBFS), and Class C fly ash (which has both cementitious and pozzolanic properties).



Types of Portland Cement

General Information About Cement:

Hydraulic cement is a type of cement that sets and hardens through a chemical reaction with water, known as hydration, to form a solid mass. Unlike non-hydraulic cements, such as lime-based cements, hydraulic cements have the ability to set and harden underwater or in wet conditions. This property makes them ideal for various construction applications where exposure to moisture is unavoidable.

Hydraulic cements are inorganic substances capable of undergoing a reaction with water in regular environmental conditions, resulting in the formation of a solid and water-resistant substance. Among the widely used types are those primarily composed of calcium silicates, exemplified by Portland cements.

Portland cement is a type of hydraulic cement that is widely used as a key ingredient in concrete, mortar, and other construction materials. It was first produced in the early 19th century by English mason Joseph Aspdin, who named it "Portland" cement because its color resembled the high-quality building stones quarried on the Isle of Portland in Dorset, England.

Main Types of Portland Cement:

Portland cement is categorized into several types based on their chemical composition and performance characteristics. The main types of Portland cement as outlined in ASTM C 150 include:

1. **Type I** (General Purpose): This is the most common type of Portland cement, used for general construction purposes where moderate sulfate resistance is required. It's suitable for most concrete construction, including pavements, reinforced concrete buildings, bridges, tanks, and reservoirs.
2. **Type II** (Moderate Sulfate Resistance): Type II Portland cement offers moderate sulfate resistance, making it suitable for use in concrete exposed to moderate sulfate concentrations in soils or water. It's commonly used in structures where soils or groundwater have moderate sulfate concentrations, such as in some marine environments.

   Type II MH (Moderate Sulfate Resistance and Moderate Heat of Hydration): The "MH" designation stands for "Moderate Heat," indicating that this cement also produces moderate heat during hydration. This property can be beneficial in certain construction applications where controlling the temperature rise in concrete is important. Type II MH cement is suitable for use in various construction projects where moderate sulfate resistance and moderate heat generation are required, such as in structures exposed to moderate sulfate concentrations in soils or water and where temperature control during hydration is necessary.
3. **Type III** (High Early Strength): Type III Portland cement is designed to develop early high strength, allowing for faster formwork removal, early finishing, and faster construction cycles. It's commonly used in precast concrete manufacturing, rapid repair of pavements, and other applications where early strength gain is critical.
4. **Type IV** (Low Heat of Hydration): Type IV Portland cement produces less heat during hydration compared to other types, making it suitable for use in massive concrete structures where controlling temperature rise is important to prevent thermal cracking. It is commonly used in dams, large foundations, and other massive concrete structures.
5. **Type V** (High Sulfate Resistance): Type V Portland cement provides high sulfate resistance, making it suitable for use in concrete exposed to severe sulfate concentrations in soils or water. It's commonly used in structures where soils or groundwater have high sulfate concentrations, such as in some coastal areas or locations with high sulfate content in groundwater.

For blended hydraulic cements, as specified by ASTM C 595, the following nomenclature is used:

6. **Type IL** (Portland - Limestone Cement): Type IL cement is a blend of Portland cement and supplementary cementitious materials (SCMs), specifically limestone (L) and pozzolan (P). The combination of these materials results in a cement with

enhanced performance characteristics. The inclusion of limestone and pozzolan in Type IL cement helps to improve various properties of concrete, such as workability, durability, and sulfate resistance. Limestone is typically added to reduce the carbon footprint of the cement production process, while pozzolan contributes to the cementitious properties and enhances long-term strength and durability. Type IL cement is suitable for use in concrete applications where exposure to sulfate-rich environments is a concern, such as in marine structures, wastewater treatment facilities, and soils with high sulfate content.

7. **Type IS** (Portland - Slag Cement): Type IS cement is a blend of Portland cement and supplementary cementitious materials, specifically slag cement (S) and pozzolan (P). Slag cement is a byproduct of the iron manufacturing process and contributes to the cementitious properties of the blend. Pozzolan, such as fly ash or silica fume, further enhances the cementitious properties and long-term strength of the concrete. Type IS cement offers improved sulfate resistance and reduced heat of hydration compared to conventional Portland cement due to the presence of slag cement and pozzolan. It is suitable for use in concrete applications where exposure to sulfate-rich environments or thermal considerations are a concern.
8. **Type IP** (Portland - Pozzolan Cement): Type IP cement is a blend of Portland cement and supplementary cementitious materials, specifically pozzolan (P) and slag cement (S). Type IP cement offers improved sulfate resistance and reduced heat of hydration compared to conventional Portland cement due to the presence of pozzolan and slag cement.
9. **Type IT** (Ternary Blended Cement): Ternary blended cement is a type of hydraulic cement that is composed of three primary components: Portland cement, supplementary cementitious materials, and a third component. The third component can vary and may include additional cementitious materials, such as limestone, calcined clay, or other pozzolanic materials, or non-cementitious materials like limestone fillers or mineral additives. The selection of the third component depends on the desired properties and performance characteristics of the concrete.

About ASTM C 150:

ASTM C150 is a standard specification for Portland cement, which is published by ASTM International, formerly known as the American Society for Testing and Materials. This specification provides guidelines and requirements for the chemical composition and physical properties of various types of Portland cement. ASTM C150 covers several aspects of Portland cement, including:

- **Chemical Composition:** The standard specifies the minimum and maximum limits for the chemical composition of Portland cement, including the content of calcium oxide (CaO), silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3), and other constituents.
- **Physical Properties:** ASTM C150 defines requirements for various physical properties of Portland cement, such as fineness, setting time, compressive strength, and soundness. These properties are important for determining the performance of the cement in different construction applications.
- **Types of Portland Cement:** The specification distinguishes between different types of Portland cement, such as Type I, Type II, Type III, Type IV, and Type V, based on their chemical composition and performance characteristics.
- **Quality Control:** ASTM C150 provides guidelines for quality control and testing procedures to ensure that Portland cement meets the specified requirements. This includes sampling, testing, and certification procedures that manufacturers must follow to ensure the consistency and quality of their products.

About ASTM C 595:

ASTM C595 is a standard specification published by ASTM International, which outlines the requirements for blended hydraulic cements. Blended hydraulic cements are produced by blending Portland cement with supplementary cementitious materials (SCMs) such as fly ash, slag cement, silica fume, natural pozzolans, or other materials. Key points about ASTM C595 include:

- **Purpose:** The primary purpose of ASTM C595 is to establish requirements for blended hydraulic cements that incorporate supplementary cementitious materials to improve certain properties of concrete, such as durability, workability, and sustainability.
- **Types of Blended Hydraulic Cements:** ASTM C595 specifies several types of blended hydraulic cements, designated as Type IS, Type IP, Type IL, and Type IT. Each type indicates the specific combination of Portland cement and supplementary cementitious materials used in the blend.
- **Chemical and Physical Requirements:** The standard outlines the chemical and physical requirements that blended hydraulic cements must meet, including limits on chemical composition, fineness, setting time, compressive strength, and other properties. These requirements ensure that the blended cements perform satisfactorily in concrete applications.
- **Quality Control:** ASTM C595 provides guidelines for quality control and testing procedures to ensure that blended hydraulic cements meet the specified requirements. This includes sampling, testing, and certification procedures that manufacturers must follow to ensure the consistency and quality of their products.

Fly Ash and Its Use in Concrete Production

About Pozzolans

A pozzolan is a siliceous or siliceous-aluminous material that, when mixed with water and in the presence of calcium hydroxide, reacts chemically to form compounds that have cementitious properties. This reaction, known as the pozzolanic reaction, helps enhance the durability and strength of concrete. Pozzolans can be either natural, such as volcanic ash or clay, or artificial, such as fly ash and silica fume, which are byproducts of industrial processes.

In concrete, pozzolans are commonly used as supplementary cementitious materials (SCMs) to replace a portion of Portland cement. This not only improves the long-term strength and resistance of the concrete to environmental factors like sulfate attack and alkali-silica reactions but also reduces the carbon footprint associated with cement production.

The Most Common Pozzolan Used in Concrete Production is Fly Ash

Fly ash is a byproduct of coal combustion in power plants and is widely used as a supplementary cementitious material (SCM) in concrete. Fly ash is favored not only for its performance benefits but also for its environmental advantages, as it reduces the need for Portland cement, lowering the overall carbon footprint of concrete production. Additionally, using fly ash can improve resistance to chemical attacks, reduce permeability, and enhance the long-term strength of concrete.

What Are the Benefits of Using Fly Ash?

1. **Increased Strength and Durability:** Fly ash contributes to the long-term strength development of concrete. It forms additional cementitious compounds when it reacts with calcium hydroxide, making the concrete stronger over time and enhancing its durability.

2. **Improved Workability:** Fly ash particles are spherical and smooth, helping reduce water demand in concrete mixes. This improves the workability of the concrete, while reducing the need for additional water or chemical admixtures.

3. **Enhanced Resistance to Chemical Attack:** Concrete containing fly ash is more resistant to sulfate attack, alkali-silica reactions (ASR), and chloride-induced corrosion, making it ideal for aggressive environments like seawater, chemical plants, or deicing salts.

4. **Lower Permeability:** Fly ash reduces the permeability of concrete by filling voids in the mix, leading to a denser, less porous structure. This enhances the concrete's resistance to water infiltration and related damage, such as freeze-thaw cycles.

5. **Reduced Heat of Hydration:** Fly ash lowers the heat generated during the cement hydration process, which is particularly beneficial in mass concrete pours, such as dams or large foundations. This helps prevent thermal cracking, improving structural integrity.

What Are the Drawbacks of Using Fly Ash?

While fly ash offers many benefits, there are also some potential drawbacks to its use in concrete. These drawbacks can be mitigated through proper mix design, testing, and quality control measures, but they are important to consider when deciding whether or how much fly ash to use in a specific concrete application.

1. **Slower Strength Gain:** Concrete containing fly ash tends to have a slower initial strength gain compared to concrete made with only Portland cement. This can be an issue in projects requiring early strength development, such as cold weather concreting.

2. **Variability in Quality:** The composition and quality of fly ash can vary depending on the source of the coal and the combustion process. Variations in the chemical makeup or fineness of fly ash can affect the consistency of concrete properties.

3. **Potential for Increased Setting Time:** Fly ash can extend the setting time of concrete, which may be problematic in projects where rapid setting is needed, such as in cold weather or when working under tight time constraints.

4. Availability Issues: The availability of fly ash can be limited in regions where coal-fired power plants are being phased out. As reliance on renewable energy grows, the supply of fly ash may decrease, making it less accessible or more expensive in the future.

5. Potential for Increased Air Entrainment: Fly ash can affect the air-entraining properties of concrete, potentially leading to difficulty in achieving the desired air content, which is important for freeze-thaw resistance in colder climates.

6. Color Variation: Fly ash can cause color variation in concrete, resulting in a darker hue than conventional cement. While this is often a cosmetic issue, it may not be desirable for certain aesthetic applications, such as architectural concrete.

7. Concerns with High Replacement Levels: While replacing a portion of Portland cement with fly ash can improve concrete properties, high levels of fly ash substitution (typically more than 30%) can sometimes lead to issues such as reduced early-age strength, delayed setting, and potential durability concerns if not carefully managed.

Types of Fly Ash Used in Concrete Production

Class F Fly Ash is produced from burning harder, older coal, such as anthracite or bituminous coal. It contains high amounts of silica, alumina, and iron. It has a lower calcium content compared to Class C fly ash.

- **Properties:** Primarily pozzolanic, meaning it requires a source of calcium, such as calcium hydroxide, to react and form cementitious compounds. Provides enhanced resistance to sulfate attack, alkali-silica reaction (ASR), and high durability in aggressive environments.
- **Uses:** Ideal for concrete in harsh chemical environments, such as marine structures, sewer pipes, and areas prone to sulfate soils.

Class C Fly Ash is derived from burning younger, softer coal, such as lignite or sub-bituminous coal. It contains higher amounts of calcium, in addition to silica, alumina, and iron. Its calcium content allows it to exhibit both cementitious and pozzolanic properties.

- **Properties:** Can harden and gain strength on its own when mixed with water, even without an additional source of calcium. Generally sets faster than Class F fly ash, providing early strength gain, but may offer slightly lower resistance to chemical attacks.
- **Uses:** Often used in structural concrete, pavements, and concrete needing higher early strength.

Key Differences:

- **Pozzolanic Activity:** Class F is mainly pozzolanic, requiring calcium hydroxide to become reactive, while Class C can be both pozzolanic and cementitious.
- **Calcium Content:** Class C has a higher calcium content, contributing to its self-cementing properties, whereas Class F has a lower calcium content, making it more dependent on Portland cement or other calcium sources for activation.
- **Sulfate Resistance:** Class F fly ash offers better resistance to sulfate attack, making it preferable for use in environments with aggressive chemicals.

Both types of fly ash can improve concrete's long-term strength, workability, and durability, but the choice between Class F and Class C depends on the specific performance requirements and environmental conditions of the project.

Pozzolanic – vs – Cementitious

The terms "Pozzolanic" and "Cementitious" refer to different types of chemical reactions that materials undergo in the presence of water and other compounds, particularly in the context of concrete production.

Pozzolanic materials are not cementitious by themselves. But, they can react chemically with calcium hydroxide ($Ca(OH)_2$) in the presence of water to form cementitious compounds — primarily calcium silicate hydrate (C-S-H), which is responsible for the strength and durability of concrete.

Class F Fly Ash · **Silica Fume** · **Volcanic Ash**

Types of pozzolanic materials include: Fly ash (Class F), silica fume, natural pozzolans (such as volcanic ash), and metakaolin.

Cementitious materials can independently react with water (a process called hydration) to form solid, binding compounds without the need for additional chemicals or activation. These materials possess intrinsic cementing properties.

Portland Cement · **GGBFS** · **Class C Fly Ash**

Types of cementitious materials include: Portland cement, ground granulated blast-furnace slag (GGBFS), and Class C fly ash (which has both cementitious and pozzolanic properties).

The Benefits of Inline Aggregate Blending

Less Segregation + Precision Blending = Better Concrete. It's Simple Math.

At Triangle Ready Mix, we blend concrete with a state-of-the art, precision inline blending batch plant. What this means for our customers is that we produce a superior-blended mix with less segregation of materials. It's simply **better concrete**.

Most concrete producers mix concrete with traditional repose batching plants. While it's a time-honored method, the basic principles of repose batching haven't changed much in almost a century.

What is the difference between repose batching and inline blending?

To understand the difference, first consider how repose batching works:

1. First, the aggregates are stored in overhead bins

A loud clamshell gate under the first bin opens, allowing the first aggregate to free fall into the weigh hopper below. As the weight begins to reach its set point for the mix design, the clamshell gate closes. Then, it rapidly opens and closes several more times, allowing smaller amounts of the first aggregate to fall through, in an attempt to reach the proper weight.

It's not the most accurate system — nor is it the most consistent.

2. Weigh and repeat

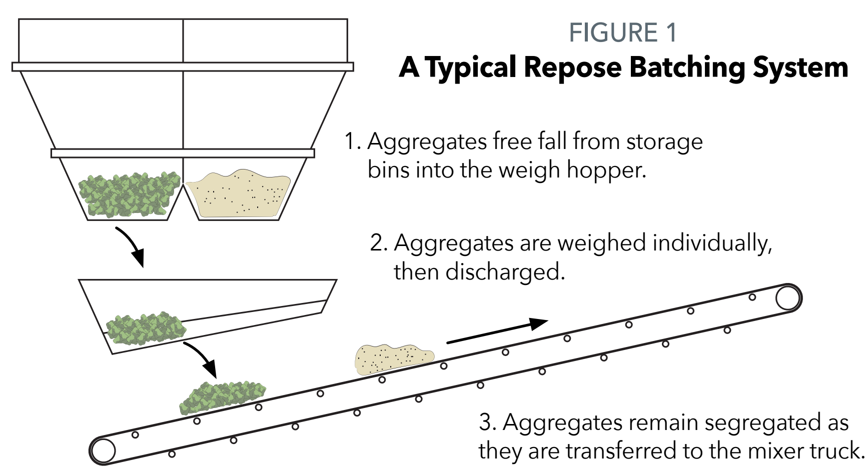
Next, the weigh hopper discharges the weighed first aggregate onto a conveyor belt. With the weigh hopper now empty, the process is repeated for the next aggregate.

3. Material segregation is guaranteed

Weighing and transferring aggregates this way, the materials are segregated when they are loaded into the mixer truck.

The actual mixing only THEN begins.

FIGURE 1
A Typical Repose Batching System

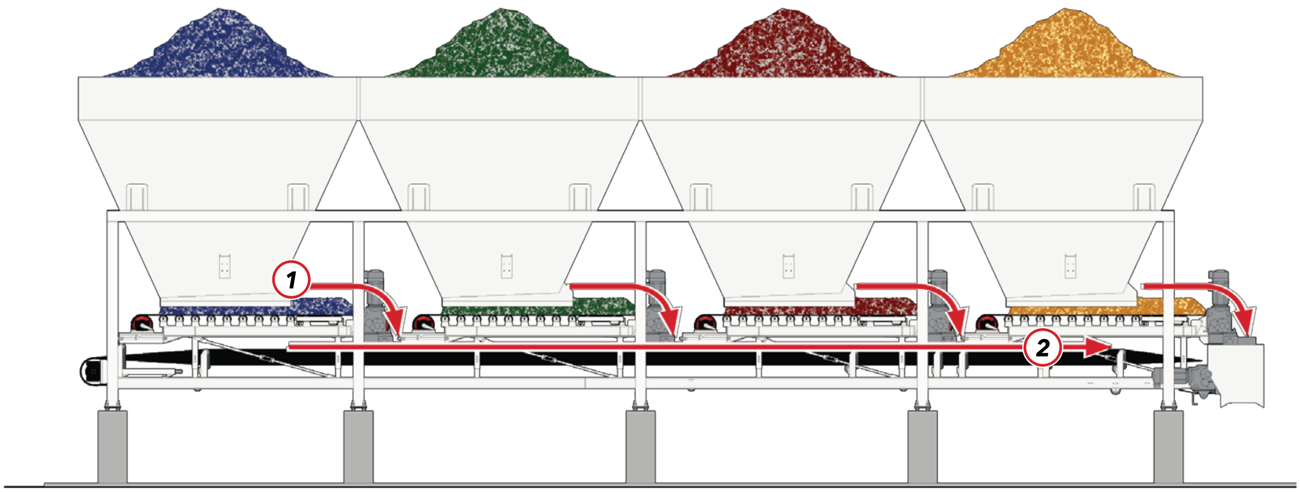


How does precision inline blending work?

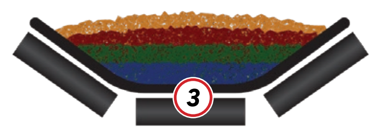
Triangle Ready Mix utilizes a precision inline blending batch plant. Aggregates are stored in a series of inline bins. These bins are easily loaded with a bucket loader from material stockpiles that are only a few feet away.

Underneath each storage bin is a dedicated weigh belt with a precision weigh scale. These dedicated weigh belts accurately and consistently discharge aggregates onto the collecting conveyor below.

FIGURE 2
Precision Inline Aggregate Blending



1. Aggregates are accurately fed from individual weigh belts onto the collector conveyor below.
2. Aggregates are precisely blended in ribboned layers on the conveyor belt.
3. Aggregates fully blended ***– with no segregation –*** before they even enter the truck. The concrete mix just keeps getting better from there.



As the collecting conveyor moves, aggregates from the second bin are metered and discharged on top of the first layer of aggregates. The process continues in the same manner for the remaining aggregates.

In this way, the aggregates are precisely blended in ribboned layers. This precision-blended aggregate mix is discharged from the aggregate blending unit onto a transfer conveyor. The aggregates are fully blended before they even enter the truck.

Water and cement are added. As the truck's drum rotates, the mix just keeps getting better. Less segregation means fewer voids, **resulting in concrete of superior strength and quality**. It's simply better concrete.

Moreover, this system is highly accurate, and extremely consistent. So, the high-quality mix design you order is consistent from one batch to another.

The Importance of Heated & Chilled Mix Water

Why is heated or chilled mix water important for concrete?

Without heated or chilled water, a ready mixed concrete producer faces several limitations that can impact the quality, workability, and performance of the concrete. These limitations are particularly evident in extreme weather conditions, both hot and cold. ***Not*** having heated or chilled water limits a concrete producer's ability to control the temperature of the concrete mix, leading to potential quality issues, project delays, increased costs, and customer dissatisfaction.

Limitations in Cold Weather:

In cold weather, mix water can freeze, making it impossible to mix with cement and aggregates. This can halt production entirely. Cold water slows down the hydration process, leading to delayed setting and curing times. This can extend construction schedules and delay project completion. Concrete mixed with cold water can become stiff and difficult to handle, place, and finish, increasing labor costs and potentially compromising the quality of the finished product. Cold temperatures can lead to uneven strength gain, potentially lowering the concrete's overall strength. Concrete that cools too rapidly during curing can also develop thermal cracks.

Limitations in Hot Weather:

In hot weather, mix water can become too warm, accelerating the hydration process. This can cause the concrete to set too quickly, reducing the time available for proper placement and finishing. High temperatures can lead to rapid evaporation of water from the mix, reducing its workability and making it difficult to achieve a smooth finish. Excessive heat can cause the concrete to expand and then contract as it cools, leading to thermal cracking. High temperatures can cause a rapid initial set, leading to incomplete hydration and potentially reducing the long-term strength and durability of the concrete. Without chilled water, controlling the temperature of the mix becomes difficult, leading to inconsistencies in the final product's quality.

Benefits of Heated Mix Water

Incorporating heated mix water into a ready mixed concrete plant enhances the overall quality and performance of the concrete, especially in cold weather conditions. It ensures consistent workability, accelerates curing times, and prevents freezing issues.

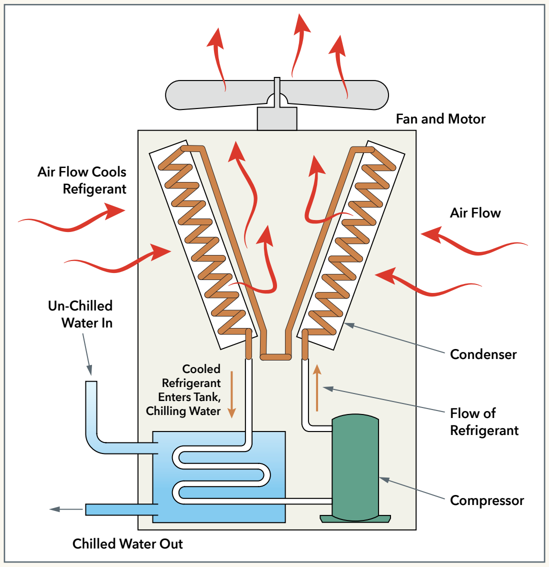
1. **Improved Workability:** Heated water keeps the concrete mix more fluid and workable, making it easier to handle, place, and finish. This is crucial for achieving a smooth, high-quality surface.
2. **Accelerated Setting and Curing:** Warm water speeds up the hydration process, allowing the concrete to set and gain strength more quickly. This can be especially beneficial in cold weather when the setting process naturally slows down.
3. **Consistent Quality:** By maintaining a consistent water temperature, the concrete mix achieves uniform hydration, leading to consistent strength and durability across batches. This uniformity is essential for meeting quality standards and specifications.
4. **Prevention of Freezing:** In cold climates, using heated water prevents the mix water from freezing before or during the mixing process. Frozen water can disrupt the mix and compromise the integrity of the concrete.
5. **Enhanced Strength Development:** Proper curing temperature helps ensure that the concrete reaches its designed strength. Heated water supports the necessary chemical reactions, leading to better long-term performance and structural integrity.
6. **Extended Construction Season:** Heated mix water allows concrete production to continue even in cold weather, extending the construction season and increasing productivity. This can be critical for meeting project deadlines and avoiding costly delays.
7. **Reduced Risk of Thermal Cracking:** Gradual temperature changes during curing are crucial for preventing thermal cracking. Heated water helps manage the temperature differential between the concrete's surface and its core, reducing the risk of cracking.
8. **Improved Admixture Performance:** Some admixtures, such as accelerators or retarders, work more effectively at certain temperatures. Heated water can optimize performance of these admixtures, leading to better control of the concrete's properties.

Benefits of Chilled Mix Water

Incorporating chilled mix water into a ready-mixed concrete plant is crucial for maintaining the quality and workability of concrete in hot weather conditions. It helps prevent premature setting, reduces the risk of thermal cracking, enhances strength and durability, and ensures consistency in the final product.

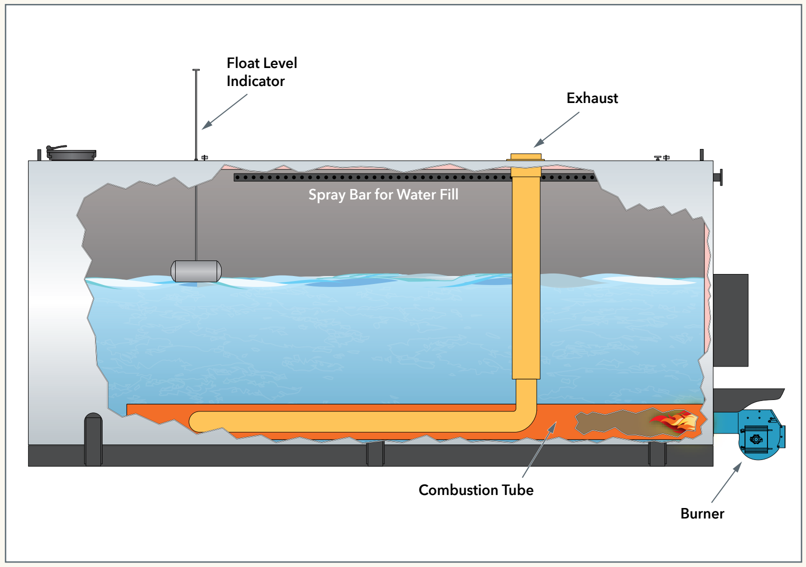
1. **Temperature Control:** Chilled water helps maintain a lower temperature in the concrete mix, which is crucial in hot weather to prevent the mix from becoming too warm and setting too quickly.
2. **Improved Workability:** By reducing the temperature of the mix, chilled water slows down the hydration process, providing more time for workers to place, finish, and cure the concrete properly. This is particularly important for large pours or complex forms.
3. **Prevention of Premature Setting:** In hot conditions, concrete can set too quickly, making it difficult to work with and finish. Chilled water helps control the setting time, ensuring that the concrete remains workable for a longer period.
4. **Reduced Risk of Thermal Cracking:** High temperatures can cause rapid drying and shrinkage, leading to thermal cracking. Chilled water helps maintain a more uniform temperature throughout the concrete, reducing the risk of thermal cracking.
5. **Enhanced Strength and Durability:** Controlling the temperature of the concrete mix helps ensure proper hydration, which is essential for the development of strength and durability. Chilled water supports a more controlled curing process, resulting in a stronger final product.
6. **Consistency in Quality:** By maintaining a consistent mix temperature, chilled water helps produce uniform batches of concrete, ensuring consistent quality and performance across all pours.
7. **Improved Performance of Admixtures:** Certain chemical admixtures used in concrete, such as retarders and plasticizers, perform better at controlled temperatures. Chilled water can optimize the effectiveness of these admixtures.
8. **Increased Productivity:** With chilled water, concrete can be produced and placed even in extreme heat, extending the working time and increasing overall productivity. This can be particularly beneficial for large-scale projects with tight deadlines.
9. **Compliance with Specifications:** Many construction projects have strict specifications for temperature of concrete mix. Using chilled water helps ensure compliance with these requirements, avoiding potential issues with inspectors or project managers.

Figure 1: Operation of Typical Mix Water Chillers and Heaters Used at Concrete Batch Plants



Operation of a Typical Chiller

Compressed refrigerant is circulated through the coils of a condenser. Air flows through the coils, cooling the refrigerant. The refrigerant then decompresses and evaporates, cooling it even further. At this point, it passes through coils in a water holding tank, chilling the water. Chilled water is then drawn from the tank for mixing.



Operation of a Typical Direct-Fired Water Tank

The tank is filled with water via a spray bar near the top of the tank. At the bottom of the tank is a combustion tube. A burner fires into this tube, causing it to heat considerably. Hot burner gases then pass through an exhaust tube that is connected to the combustion chamber. Heat from both the combustion tube and exhaust piping heats the water in the tank. Heated water is then drawn from the tank for mixing.

Placing Your Order For Ready Mixed Concrete

What is ready mixed concrete?

A concrete mix consists of cement, water, and coarse and fine aggregates — such as crushed stone and sand. Many people mistakenly think that cement and concrete are the same thing. They are not. Cement is a powdered ingredient that, when mixed with water, provides the glue that binds the aggregates.

Concrete mixes are blended to gain required properties like workability and strength for a given application. Concrete must have the right consistency — called ***slump*** —to facilitate handling and placement. It must also have adequate strength and durability to withstand applicable loads when cured.

Ready-mixed concrete is delivered in its freshly mixed, unhardened state. The plasticity of this concrete mix lasts several hours depending on the type of mixture and conditions during placement. Normally, concrete sets within two to twelve hours of being mixed. It continues to strengthen for months or even years afterward if it is properly cured during the first few days.

Some basics to keep in mind when ordering ready mixed concrete:

The key to placing an order for ready mixed concrete is to provide all the basic details and keep requirements as simple and relevant as possible. The concrete producer has several mix designs available for various uses, and can assist with choosing the required mixture.

Size of coarse aggregate

It is important to know the nominal maximum size of coarse aggregate, which should be smaller than the narrowest dimension through which concrete is to flow. For example, the thickness of the section and the spacing of the reinforcing steel, if any, are important. For most applications, the nominal maximum size of coarse aggregate is 3/4 or 1 inch.

Slump

Indicate the desired slump of the concrete. A stiffer mixture will have a low slump value. Typical slump range for most applications is 3 to 5 inches. For example, for slip-form construction, a maximum slump of 2 inches is required. A higher slump to a maximum of 7 inches is typical for basement walls. The tolerance on the slump as delivered is ±1 to 1-1/2 inch. Addition of water at the jobsite to increase slump is permitted, provided it is not excessive enough to cause segregation and reduce strength and durability.

Entrained air

When concrete will be exposed to freezing temperatures, air-entrained concrete should be used. In many locations air-entrained concrete is the default option. Clearly state to the concrete producer if you want **non-air-entrained** concrete. Target air content depends on the size of the coarse aggregate. Typical range is 4 to 6% of the concrete volume. Tolerance on air content as delivered is ±1.5%. The concrete supplier is permitted to make an adjustment for air content at the jobsite if, when tested it is lower than the required amount.

Quality level required

The preferred method for ordering concrete is to specify its performance requirements. This generally means the concrete's required strength. When necessary, other performance characteristics may be specified, such as permeability, shrinkage, or durability. Make the producer aware of anticipated exposure and service conditions of the structure. The concrete producer best knows how to proportion, mix, and furnish concrete to meet the desired performance requirements. A minimum strength of 3,500 to 4,000 psi is common.

Another option is to order concrete by specifying it's prescriptive requirements. This is when the purchaser specifies limits on the ingredients in the mixture. In these cases, the purchaser normally accepts responsibility for the concrete's strength and performance. This approach does not allow the concrete producer to have much flexibility on the mixture. Nor does it allow them to accommodate changes that may affect concrete's performance.

Quantity of concrete

Concrete is sold by volume, in cubic yards. The delivered volume is calculated from the measured concrete density or unit weight. One cubic yard of concrete weighs about 4000 pounds. The typical capacity of a truck mixer is 8 to 12 cubic yards.

Order about 4% – 10% more concrete than is estimated from a volumetric calculation of the plan dimensions. This will allow for waste or spillage, over-excavation, spreading of forms, loss of entrained air during placement, settlement of a wet mixture, truck mixer hold-back and change in volume. Hardened concrete volume is 1% to 2% ***less*** than that of the fresh concrete. Re-evaluate these needs during placement, and communicate any changes to the concrete supplier.

Disposal of returned concrete has environmental and economical implications to the ready mixed concrete producer. Make a good estimate of concrete required for the job before placing an order.

Additional Items

A variety of options are available from the concrete producer. Chemical admixtures can accelerate or retard the setting characteristics of concrete to aid in placing and finishing during hot or cold weather. Water reducing admixtures are used to increase slump without adding water to the concrete. Synthetic fibers can reduce the potential for plastic shrinkage cracking. Color additives or special aggregates are also often available.

Scheduling delivery

Schedule the delivery of concrete to accommodate the construction schedule. Inform the producer of the correct address, location, nature of the pour, and an estimated delivery time. Call the ready mixed concrete producer well in advance of the required delivery date. Concrete is a perishable product and the construction crew should be ready for concrete placement when the truck arrives. Notify the producer of any schedule changes or work stoppage immediately.

Ensure that the truck mixer has proper access to the placement location. The concrete truck weighs in excess of 60,000 lbs. and may not be able to maneuver well in certain jobsite conditions.

Responsibilities

Responsibilities of parties involved in the construction process should be addressed at a pre-construction meeting. Key items include:

- The concrete producer is responsible for the concrete slump as specified for a period of 30 minutes after the requested time or the time the truck arrives at the placement site, whichever is later.
- The concrete producer is required to deliver concrete at the requested slump and air content, within the accepted tolerances addressed above, as measured at the point of discharge from the transportation unit.
- When placing procedures can potentially alter the characteristics of the fresh concrete, it is the responsibility of the purchaser to inform the producer of changes to the mixture requirements to accommodate these effects. (***E.g.*** pumping concrete in place.)
- When a job uses more than one type of concrete mixture, it is the purchaser's responsibility to verify the mixture delivered and direct it to the correct placement location.
- The purchaser should check and sign the delivery ticket and document any special occurrences on the ticket.
- The concrete producer cannot be responsible for the quality of concrete when any modification or additions are made to the mixture at the jobsite. These include addition of excessive water, admixtures, fibers or special products, or if the truck has to wait for an extended period before discharging the concrete.
- When strength tests are used for acceptance of concrete, the samples should be obtained at the point of discharge from the transportation unit. The purchaser or his representative should ensure that proper facilities are available for testing at the jobsite and that standard practices are followed. Certified personnel should conduct the tests. Test reports should be forwarded to the producer in a timely manner to ensure that any needed changes are addressed.

CAUTION

Fresh concrete can cause severe chemical burns to skin and eyes. Keep fresh concrete off your skin. When working with concrete use rubber work-boots, gloves, protective eyeglasses, clothing and knee-boards. Do not let concrete or other cement products soak into clothing or rub against your skin. Wash your skin promptly after contact with fresh concrete with clean water. If fresh concrete gets into your eyes, flush immediately and repeatedly with water and consult a doctor immediately. Keep children away from dry cement powder and all freshly mixed concrete.

About Concrete Acceptance Testing

The objective of acceptance testing

The objective of acceptance testing is to ensure that concrete conforms to the requirements of the buyer. Tests are performed on samples of concrete, taken as-delivered to a job site. Acceptance testing includes tests on plastic (unhardened) concrete for slump, air content, density, and temperature. It also includes tests on hardened concrete for strength and durability.

Hardened concrete is tested for acceptance in accordance with standard procedures to determine whether it has the ***potential*** to develop the desired properties. It is not the intent of these test results to reflect the actual properties of concrete in the structure. During construction, numerous variables will influence the properties of in-place concrete. These variables are beyond the control of the ready mixed concrete supplier.

Testing and Responsibilities

The responsibilities of all involved parties for proper sampling, specimen storage, handling, transportation, jobsite sample disposition and laboratory testing should be clearly defined prior to the start of a project. Contractors are legally obligated to facilitate or conduct acceptance testing by jurisdictions that follow model codes like the International Building Code. These model codes in turn refer to the ACI 318 Building Code.

All parties involved should also realize that the results of the testing have substantial implications on the project schedule, cost to participants, and may impact the safety of the structure — and its inhabitants.

Acceptance testing must be conducted by certified technicians. All acceptance testing of concrete must be conducted in accordance with established standards referenced in contract documents. Any deviation from standard procedures is adequate reason for invalidating test results.

Samples

Samples of concrete from concrete delivery vehicles for acceptance tests should be obtained in accordance with ASTM C 172. The sample should be obtained at the end of the truck chute. Two or more portions of concrete as discharged from the middle portion of the load are composited to obtain a sample that is representative of the load.

Slump and Air Content

If the slump and air content measured on the initial sample are ***lower*** than specified, it is permissible to make jobsite adjustments with water or admixtures — followed by adequate mixing.

If slump and air contents are ***higher*** than specified, a retest is made immediately. If the retest fails, then the concrete is considered to have failed the requirements of the specification.

Concrete slump is measured in accordance with ASTM C 143. The tolerance on slump varies by slump level as ordered or specified. Slump tolerances of ASTM C 94 are summarized in **Table 1**.

The air content of concrete is measured in accordance with the pressure method, ASTM C 231 or by the volumetric method, ASTM C 173. These standards are for lightweight concrete or for aggregates with high absorptions. For air-entrained concrete, the tolerance on air content as ordered or specified is ±1.5%.

Table 1: Slump tolerances of ASTM C 94

Specified Slump	Tolerance
Specified as a Maximum Slump	
Less than 3 inch	+ 0 to - 1.5 inch
Greater than 3 inch	+ 0 to - 2.5 inch
Specified as a Nominal Slump	
Less than 2 inch	+ 0.5 to - 0.5 inch
2 – 4 inch	+ 1 to - 1 inch
Greater than 4 inch	+ 1.5 to - 1.5 inch

Density and Yield

For strength tests, ASTM C 94 requires measuring the density of the concrete in accordance with ASTM C 138. This can be done by determining the weight of the air meter container after the sample has been prepared. The minimum container size based on the nominal maximum size of the aggregate in the concrete mixture should be followed. Density measurements can also be correlated with air content measurements and can be an indicator of the water content in the mix.

Temperature

The temperature of concrete is measured in accordance with ASTM C 1064. Temperature is measured to determine conformance to temperature limits in a specification. Temperature testing is required when strength test specimens are prepared.

Hardened Concrete Tests

ASTM C 31 describes the procedures for preparing cylinders and beams for compression and flex strength tests. It describes the procedures for storing specimens at the jobsite, and transporting them to the lab. ASTM C 31 requires maintaining test specimens in a moist condition, in a temperature range of 60 to 80°F in the field. For high strength concrete with a specified strength greater than 5,000 psi, storage temperature limits are tighter at 68 to 78°F. Maintain a record of temperature conditions during field storage of the concrete test specimens. These should not be stored at the jobsite for longer than 48 hrs. Transportation time should not exceed 4 hrs.

The contractor is generally responsible for providing adequate storage facilities at the jobsite for specimens, but it is also the responsibility of the testing technicians and the person certifying test results to ensure that standard procedures are followed during testing.

In the early stages of concrete's development, temperature and moisture affect its quality, which is why deviations from standard protocols should be regarded as grounds for rejecting results as they increase the likelihood of failing tests of acceptable concrete.

Concrete Slump Testing

The concrete slump test is a method used to measure the consistency or workability of freshly mixed concrete. It's a simple and widely used procedure in construction to ensure that the concrete being poured has the desired properties for its intended application.

Different concrete construction projects may require different levels of slump, depending on factors such as the method of placement, weather conditions, and structural requirements.

What is Concrete Slump?

Concrete slump refers to the measure of the consistency or fluidity of freshly mixed concrete. It's a crucial property because it directly influences the ease with which concrete can be handled, placed, and compacted during construction.

When concrete is freshly mixed, it has a certain degree of plasticity, meaning it can be molded and shaped. The slump test measures how easily the concrete flows or slumps under its own weight when placed in a standard slump cone.

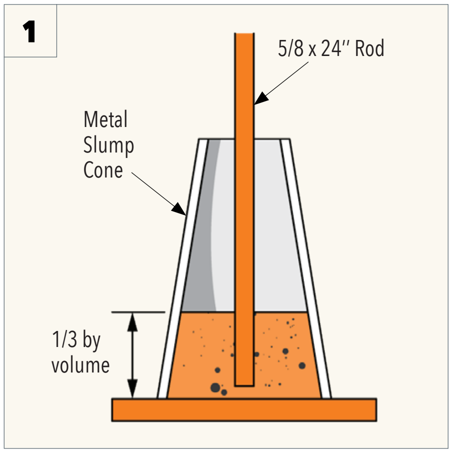
The amount of slump observed in a slump test provides an indication of the workability of the concrete. Higher slumps indicate more workable or fluid concrete, while lower slumps suggest stiffer, less workable concrete.

How to Perform a Concrete Slump Test:

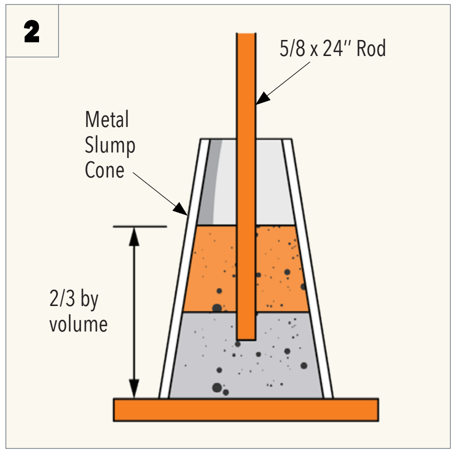
Before performing the test, the equipment needs to be set up. This usually involves a mold in the shape of a truncated cone (often referred to as a slump cone), a base plate, and a tamping rod. Samples of the concrete should be taken at intervals throughout the discharge process from the truck. The metal slump cone used for slump testing is typically made from sheet metal, measuring 4" at the top, 8" at the bottom, and 12" high. The cone should be dampened before use, and place on a non-absorbent surface for the test.

1. **Fill the cone 1/3 by volume.** Fill the slump cone to 1/3 by volume with the sampled concrete. Use the tamping rod to tamp the concrete 25 times, evenly across the entire cross section of the concrete sample.
2. **Fill the cone 2/3 by volume.** Fill the slump cone to 2/3 by volume with the sampled concrete. Use the tamping rod to tamp the second layer 25 times, penetrating into (but not completely through) the first layer.
3. **Fill the cone to overflowing and clean away the excess.** Fill the cone to overflowing. Use the tamping rod to tamp the third layer 25 times, penetrating into (but not completely through) the second layer of the sample. Remove excess concrete from the top of the slump clone. Clean away any concrete overflow from around the base of the cone.

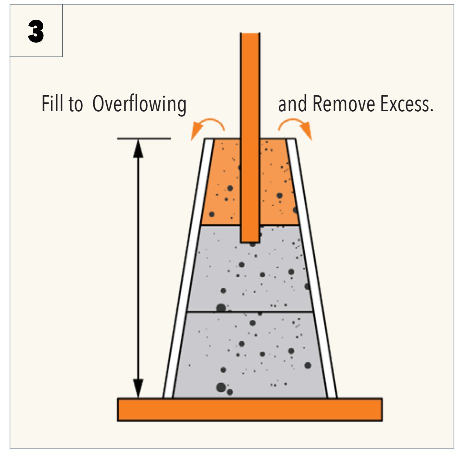
4. **Lift the cone away.** Carefully lift the slump cone away from the concrete sample vertically. Use a slow, even motion and do not jar the concrete or tilt the cone. This action should take no longer than 5–10 seconds.
5. **Measure the slump.** Invert the slump cone and place it next to the slumped concrete sample. Place a straight edge across the top of the cone, and extending over the concrete sample. Measure the amount of slump in inches from the bottom surface of the straight edge to the top of the slumped concrete sample.



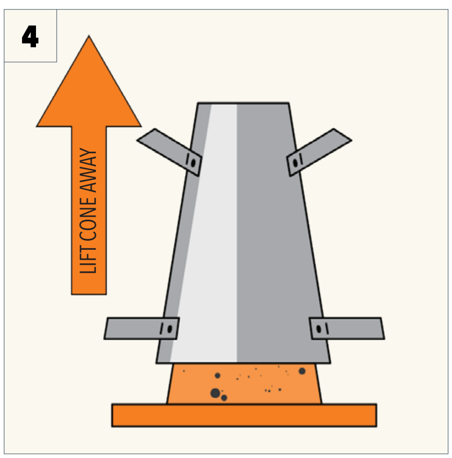
Step 1. Fill the slump cone to 1/3 full by volume. Rod 25 times, evenly across the cross section of the concrete sample. Use a 5/8” diameter x 24” long rod.



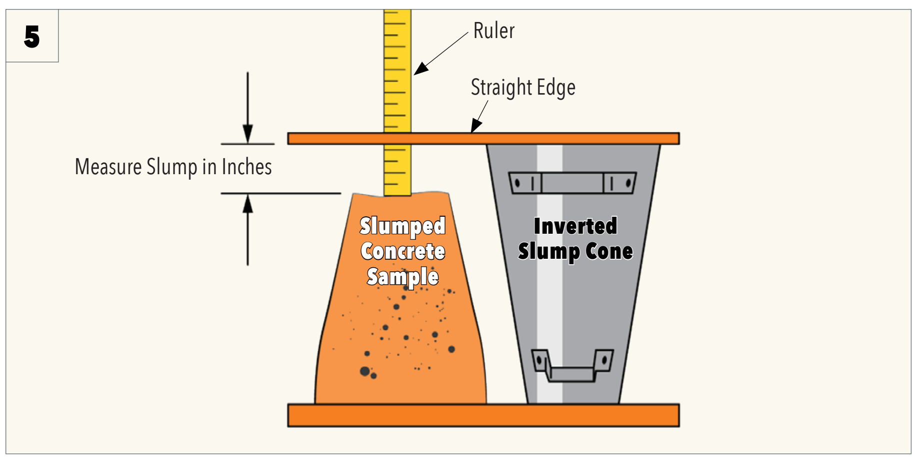
Step 2. Fill the slump cone to 2/3 full by volume. Rod the second layer 25 times, penetrating into (but not completely through) the first layer of the sample.



Step 3. Fill to **overflowing**. Rod the third layer 25 times, penetrating into (but not completely through) the second layer of the sample. Remove excess concrete from the top of the slump clone and clean away any overflow from around the base.



Step 4. Carefully lift the slump cone away vertically, using a slow and even motion. Do not jar the concrete or tilt the cone. This should take no longer than 5–10 seconds.



Step 5. Invert the slump cone and place it next to the slumped concrete sample. Place a straight edge across the top of the cone, and extending over the concrete sample. Measure the amount of slump in inches from the bottom surface of the straight edge to the top of the slumped concrete sample.

Did you know?

The concrete slump test was developed in the 1920s by Duff Abrams, an American researcher in the field of composition and properties of concrete. Abrams was a pioneer in the field of concrete technology and made significant contributions to the understanding of concrete properties and mix design. His work, including the development of the slump test, has had a profound impact on the construction industry by providing a standardized method for assessing the workability of concrete mixes.

Now, over a century later, Duff Abrams’ concrete slump test is used daily in quality control testing of ready-mixed concrete at construction sites all over the country and around the world.

It’s a standard procedure in the construction industry for assessing the workability of concrete mixes before placement. Countries across the globe, regardless of their location or level of industrial development, utilize the slump test as a fundamental tool in quality control during concrete construction projects. The test’s simplicity, effectiveness, and ability to provide valuable insights into the consistency of freshly mixed concrete make it a preferred method for contractors, engineers, and concrete producers worldwide. Additionally, international standards organizations like ASTM International and the International Organization for Standardization (ISO) have established guidelines and specifications for conducting the slump test, further promoting its use on a global scale.

Cylinder Compression Testing

Understanding Concrete's Compressive Strength

Cylinder compression testing is a standard method used in the construction industry to measure the compressive strength of concrete. It is a crucial quality control test that determines if the concrete used in a structure meets the specified strength requirements. Compressive strength is one of the most important properties of concrete, as it directly influences the durability and safety of buildings, bridges, roads, and other structures.

What is Cylinder Compression Testing?

Concrete compressive strength testing is a standardized procedure used to determine the compressive strength of concrete. The test involves casting concrete into cylindrical molds, curing the specimens under controlled conditions, and then subjecting them to a compressive load in a testing machine until they fail. The test measures the maximum compressive force that the concrete can withstand before it fractures, which is expressed in pounds per square inch (psi). The testing process follows specific standards set by organizations like ASTM International (ASTM C39/C39M) and the American Concrete Institute (ACI), ensuring consistency and accuracy in the results.

Why is Cylinder Compression Testing Used?

The primary purpose of cylinder compression testing is to ensure that the concrete mix used in a construction project meets the required compressive strength. This strength is crucial for the following reasons:

1. **Quality Assurance:** Ensures that the concrete can support the loads and stresses it will encounter during its lifespan.
2. **Structural Safety:** Confirms that the concrete meets the design specifications, which helps prevent structural failures.
3. **Compliance with Standards:** Verifies that the concrete mix complies with specifications, building codes, and industry standards.
4. **Performance Monitoring**: Assists engineers in evaluating the performance of concrete over time, especially in critical structures like bridges and high-rise buildings.
5. **Cost Efficiency:** Helps avoid costly repairs or rework by identifying potential issues early in the construction process.

How is Cylinder Compression Testing Performed?

Sampling Fresh Concrete

Concrete is sampled from the delivery truck or directly from the pour site. The sample is taken according to standardized procedures (e.g., ASTM C172) to ensure it accurately represents the batch.

Preparing the Cylinders

Cylinders are usually cast in molds that are 6 inches in diameter and 12 inches in height (or sometimes 4x8 inches for smaller samples). The concrete is poured into the molds in layers, with each layer being compacted using a tamping rod or a vibration table to eliminate air voids. The top surface of the concrete is leveled and smoothed to ensure even contact during testing.

Curing the Cylinders

- Initial Curing: Cylinders are covered and stored in a moist environment (e.g., covered with plastic or damp cloths) at a temperature of about 23°C (73.5°F) for the first 24-48 hours.
- Final Curing: After demolding, the cylinders are submerged in water tanks or placed in a moist room where they continue to cure until the testing age (usually at 28 days).

Testing the Cylinders

- Test Intervals: Cylinders are tested at intervals such as 7 days, 28 days, and sometimes 56 days, depending on requirements.
- Compression Machine: Cylinders are placed in a compression testing machine, which applies gradual force until the cylinder fails.
- Data Collection: The maximum load (force) applied to the cylinder before it fractures is recorded, and the compressive strength is calculated using the formula:

$$\text{Compressive Strength} = \frac{\text{Maximum Load}}{\text{Cross-Sectional Area}}$$

(For a standard 6x12-inch cylinder, the cross-sectional area is 28.27 square inches.)

Interpreting the Results

The compressive strength is compared to the specified design strength. For example, if the project specification is 4,000 psi at 28 days, the cylinder must meet or exceed this value. If the cylinders consistently fail to reach the required strength, it may indicate issues with the concrete mix, curing process, or sampling procedures.

What Do Cylinder Compression Test Results Show?

The results of cylinder compression testing provide valuable information about the quality and performance of the concrete mix. Here are the key insights that can be drawn from the test results:

Compressive Strength: The primary output of the test is the compressive strength value, which indicates the ability of the concrete to withstand axial loads. A higher compressive strength means the concrete can handle more weight and stress.

Mix Quality: Consistently meeting or exceeding the target strength suggests that the concrete mix design is suitable and that quality control measures are effective. If the strength is lower than expected, it could indicate issues such as improper water-cement ratio, poor aggregate quality, or errors in batching.

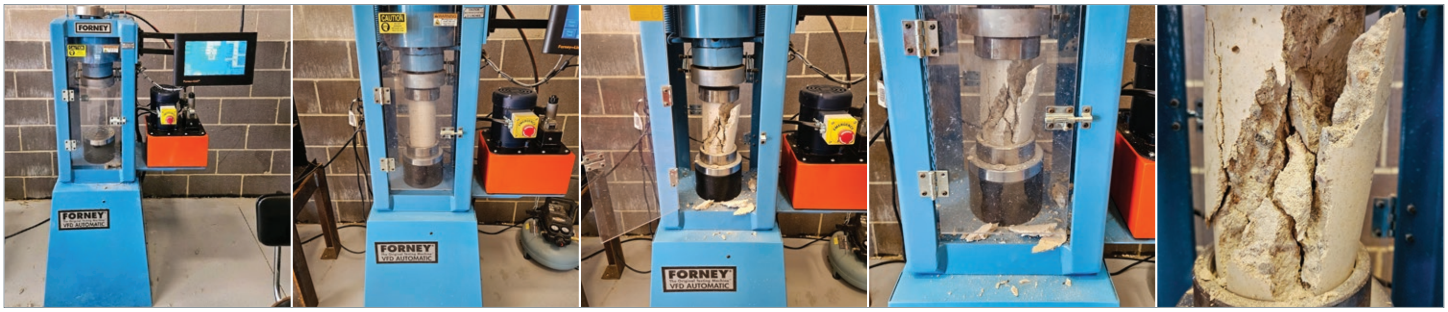
Curing Effectiveness: Proper curing is essential for concrete to achieve its full strength potential. Low test results may point to insufficient curing practices, such as inadequate moisture or temperature control.

Potential Structural Issues: Low compressive strength results could signal potential problems with the structural integrity of the concrete elements. In such cases, additional testing (e.g., core sampling or non-destructive testing) may be necessary to assess the concrete's performance in the field.

Data for Mix Adjustments: Test results can inform adjustments to the concrete mix or construction practices, especially for large-scale projects where consistency is critical.

Figure 1: Cylinder Compression Testing Machine at the Triangle Ready Mix Testing Lab

RED FLAG: Low Cylinder Breaks



Low cylinder breaks are a red flag indicating that the concrete may not be as strong as required, potentially affecting the structure's safety and longevity. In the construction industry, ensuring the quality of concrete is critical, as it forms the backbone of many structures, from buildings and bridges to roads and foundations. One of the primary methods for assessing concrete strength is cylinder compression testing, where concrete specimens are crushed under pressure to measure their compressive strength. However, when these test results fall below the expected values, it can raise significant concerns.

What Are Low Cylinder Breaks?

In concrete testing, a "low cylinder break" occurs when a concrete test cylinder fails to reach the specified compressive strength at a designated testing age, typically 28 days. For example, if a project specifies a compressive strength of 4,000 psi at 28 days, but the test cylinder only achieves 3,500 psi, it is considered a low break.

These breaks serve as an early warning sign that the concrete mix may not meet structural requirements. Since compressive strength is a critical measure of concrete's ability to bear loads, low results can compromise structural integrity & performance of the construction.

Why Are Low Cylinder Breaks a Concern?

Low cylinder breaks are not just about failing to meet specifications—they can have serious implications for the safety, durability, and cost-effectiveness of a project. Here are a few reasons why low breaks are cause for concern:

1. **Structural Safety:** Concrete that does not meet the required strength may not be able to support the loads it was designed to handle, leading to potential structural failures.
2. **Project Delays:** Low breaks often require further investigation & additional testing, which can delay project timelines.
3. **Increased Costs:** Addressing low-strength concrete can be expensive, especially if it involves removing and replacing already-placed concrete or implementing additional reinforcement.
4. **Compliance Issues:** Failing to meet the specified strength can result in non-compliance with building codes and project specifications, potentially leading to legal and contractual complications.

Common Causes of Low Cylinder Breaks

Understanding the root causes of low cylinder breaks is essential for preventing and addressing them. Several factors can contribute to lower-than-expected compressive strength:

Poor Mix Design

Incorrect Proportions: Errors in the ratio of cement, aggregates, water, and admixtures can significantly affect the concrete's strength.

High Water-Cement Ratio: Adding too much water to the mix increases workability but decreases strength by creating more voids within the hardened concrete.

Material Quality

Substandard Materials: Using poor-quality cement, aggregates, or water can compromise concrete strength.

Contaminants: Presence of impurities like dirt, clay, or organic matter in the aggregates can weaken the mix.

Improper Curing

Inadequate Moisture: Concrete needs sufficient moisture to develop strength. Improper curing leads to surface drying & low strength.

Temperature Fluctuations: Extreme temperatures (either too hot or too cold) can adversely affect the hydration process, leading to lower strength development.

Errors in Cylinder Preparation

Improper Sampling: If the sample taken from the concrete batch is not representative, it may lead to inaccurate test results.

Poor Compaction: Inadequate compaction of the concrete in the molds can cause air pockets, reducing the strength of the cylinder.

Delayed Testing: Testing the cylinders before or after the specified time frame (e.g., not exactly at 7, 28, or 56 days) can affect the results.

Testing Errors

Machine Calibration: Using a compression testing machine that is not properly calibrated can produce incorrect strength readings.

Misalignment: If the cylinder is not centered correctly in the testing machine, it can lead to uneven loading and premature failure..

Conclusion

When low cylinder breaks occur, immediate action is needed to identify the cause. This includes retesting cylinders, reviewing the mix design, curing methods, and material quality. Remedial measures like strengthening or replacing concrete may be required. The best way to deal with low cylinder breaks is to prevent them from occurring in the first place. Here are some best practices to follow:

1. **Optimize the Mix Design:** Use a proven mix design that balances strength, workability, and durability. Adjust the water-cement ratio as needed to achieve the desired properties.
2. **Use High-Quality Materials:** Ensure that all materials meet the project specifications and are free from contaminants.
3. **Proper Sampling and Handling:** Follow ASTM standards for sampling and preparing test cylinders to avoid introducing errors.
4. **Monitor Curing Conditions:** Implement proper curing practices to ensure adequate moisture and temperature control during the concrete's early stages.
5. **Routine Quality Control Checks:** Conduct regular tests on concrete batches to catch any issues early, rather than discovering them after the concrete has been placed.

Low cylinder breaks are a critical warning sign that should not be ignored.

They can signal potential problems with the concrete mix, curing, or testing procedures, and addressing them promptly is essential for maintaining the safety, durability, and success of any construction project. By understanding the causes, implications, and solutions associated with low cylinder breaks, construction professionals can take proactive measures to ensure that their concrete structures are built to last.

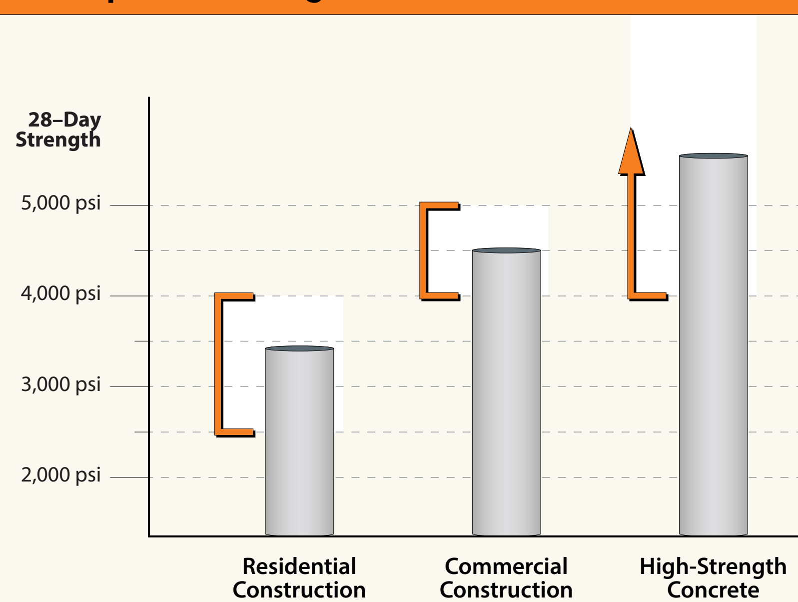
Ultimately, a rigorous approach to quality control, from mix design to testing and curing, is the best defense against low cylinder breaks, safeguarding the structural integrity of your projects and the safety of those who rely on them.

Figure 1: Typical Compression Strength Values

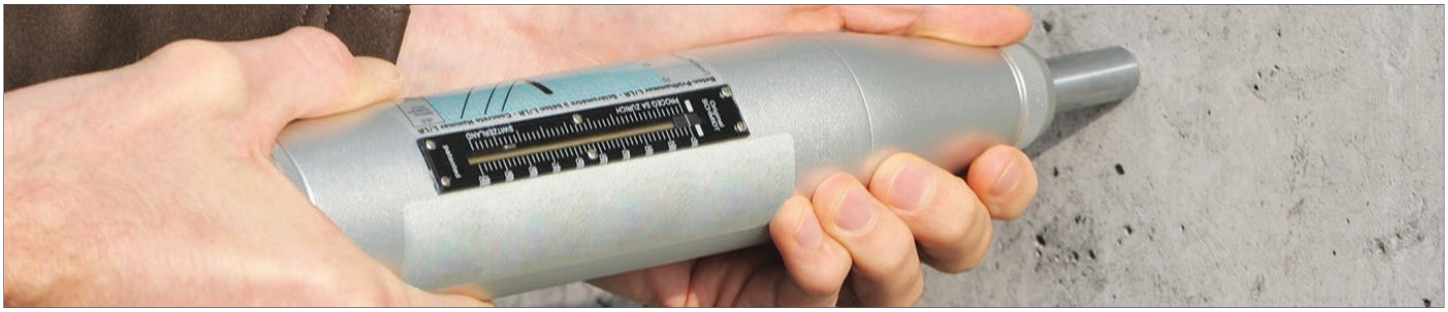
In concrete cylinder testing, the normal breaking point for compressive strength depends on the concrete's design specifications and intended use. Typically, concrete strength is measured at 28 days after pouring, as this is when it reaches the majority of its design strength. Common strength values for general construction applications range from 3,000 psi to 5,000 psi at 28 days:

Residential Construction: 2,500 to 4,000 psi
Commercial Construction: 4,000 to 5,000 psi
High-Strength Concrete: 5,000 psi and above (for applications like bridges or high-rise buildings).

Early tests, such as those at 7 days, are also performed to gauge strength gain, typically achieving about 60-75% of the 28-day target strength. However, these values can vary depending on the specific requirements of the project, environmental factors, and curing conditions.



Understanding Rebound Hammer Testing



Assessing Concrete Strength With Rebound Hammer Testing

The rebound hammer test, also known as the Schmidt hammer test, is a non-destructive test used to assess the compressive strength and surface hardness of concrete. This test provides a quick and simple method for evaluating the condition of concrete, especially for quality control and inspection purposes.

The rebound hammer test is used by civil engineers, construction contractors, quality control technicians, building inspectors, maintenance teams, and concrete producers to quickly assess the surface strength and quality of concrete. It is commonly used for on-site evaluations during construction and inspections of existing structures due to its speed, convenience, and cost-effectiveness.

While the test provides an approximate measure of compressive strength, it is often used as a preliminary tool to determine if further, more in-depth testing is necessary.

How the Rebound Hammer Test Works:

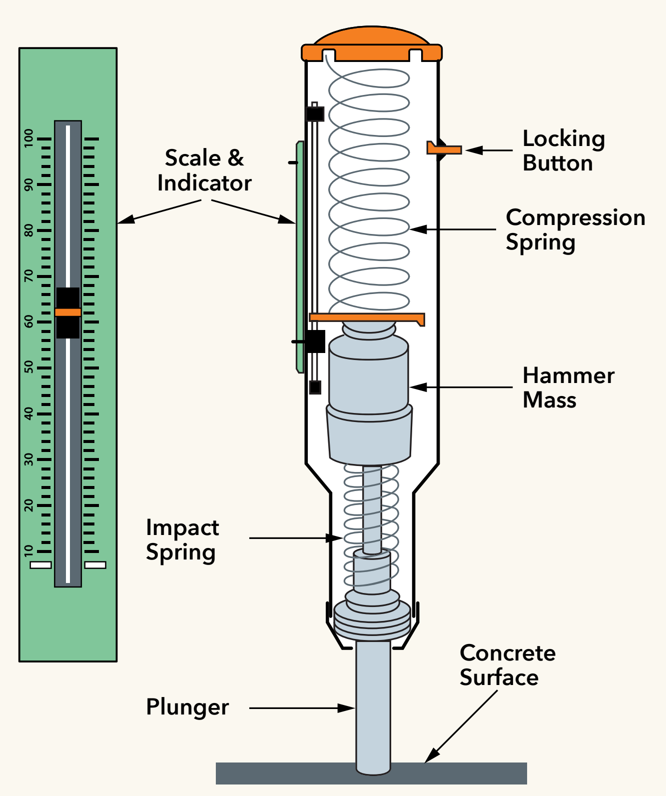
A rebound hammer consists of a spring-loaded mass that strikes the concrete surface with a defined amount of force. The hammer measures the rebound distance of the mass after impact, which correlates with the hardness and strength of the concrete.

In the rebound hammer test, the device's plunger is pressed against the concrete surface, releasing a spring-loaded mass housed within the hammer's internal mechanism. This mass is propelled by a calibrated spring, striking the surface of the concrete with a specific energy.

Upon impact, the mass rebounds, and the hammer measures the rebound distance, known as the rebound number. A scale on the hammer records this rebound number, which correlates with the surface hardness of the concrete.

Higher rebound numbers generally indicate greater compressive strength, while lower numbers suggest reduced strength or potential surface issues like weathering or microcracking. The internal spring mechanism ensures consistent energy release, making the test reliable for quick, non-destructive assessments.

Figure 1: Rebound Hammer Basic Components



Understanding the Rebound Hammer and Its Relation to Concrete Strength

The rebound hammer operates based on the principle of kinetic energy and elasticity. When the hammer strikes the concrete surface, some of its energy is absorbed by the concrete, while the rest is reflected back. The amount of energy that bounces back determines how strong the concrete is.

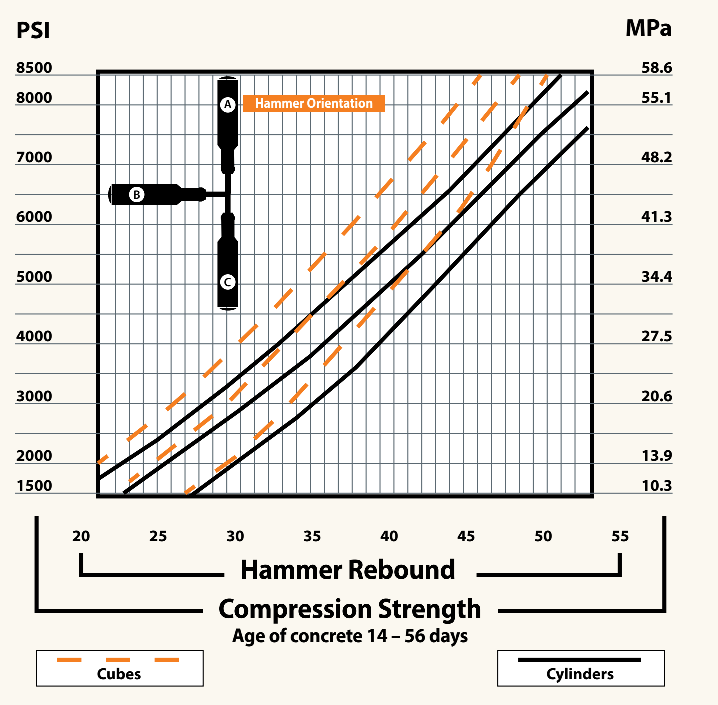
The hammer has a spring mechanism that launches a small mass (the hammer) towards the concrete. When it hits the surface, it compresses the spring and then rebounds. The distance the hammer rebounds back is measured, and this distance is known as the "rebound number."

The rebound number is a crucial factor. A higher rebound number indicates that more energy was reflected back, suggesting the concrete is harder and stronger. Conversely, a lower rebound number means more energy was absorbed, indicating that the concrete may be weaker or more damaged.

While the rebound hammer provides a quick way to assess strength, it does not directly measure compressive strength (the ability to withstand squeezing forces). Instead, it gives an indirect estimate. To create a reliable correlation, researchers often compare the rebound numbers to actual compressive strength tests conducted on concrete samples.

It's important to remember that factors like surface conditions, moisture levels, and the age of the concrete can affect rebound measurements. For this reason, a single measurement may not provide a complete picture of the concrete's strength.

Figure 2: Correlation of Hammer Rebound Number to Compressive Strength



History & Development

Swiss engineer Ernst Schmidt developed the rebound hammer, commonly known as the Schmidt hammer, in the late 1940s to address the need for a simple, non-destructive method of testing the hardness and strength of concrete. At the time, many construction projects were becoming larger and more complex, and reliable methods for evaluating the quality of concrete in structures were essential to ensure safety and durability. The traditional methods for testing concrete strength involved taking samples and performing destructive testing, which was time-consuming, expensive, and required specialized equipment.

Schmidt's goal was to create a portable, user-friendly device that could give engineers and construction workers a quick estimate of concrete strength without damaging the material. His design used the principle of rebound mechanics, where the energy reflected back from a surface could be measured and correlated with the material's hardness. The hammer would strike the concrete, and the distance it rebounded would give an indication of how hard and dense the concrete was, which directly related to its strength.

Schmidt's invention came at a time when post-war rebuilding efforts in Europe were driving significant infrastructure development. Large-scale construction projects, such as bridges, dams, and high-rise buildings, needed quick and efficient quality checks to ensure that the materials used were up to standard. The Schmidt hammer provided a much-needed solution, allowing for on-site testing without the need for lab-based analysis. Over time, this tool became an industry standard in construction and civil engineering because of its ease of use, low cost, and ability to provide immediate feedback.

Schmidt's rebound hammer continues to be widely used today in assessing the condition of concrete structures, providing a non-destructive means of testing that remains both practical and reliable.

Summary

The rebound hammer test serves as a valuable method for assessing concrete strength in a quick and efficient manner. This test not only highlights the physical properties of the concrete but also provides insight into its overall quality and durability. By measuring how much energy rebounds from the surface, engineers and construction professionals can gain a valuable understanding of the concrete's condition without needing to conduct more invasive and time-consuming tests. While it offers a useful estimate, it's essential to consider the context of the measurements, such as surface conditions and environmental factors. Ultimately, the rebound hammer test exemplifies a practical balance between speed and reliability, helping ensure that structures meet safety and performance standards.

About Admixtures for Ready Mixed Concrete

What are chemical admixtures for ready mixed concrete?

Chemical admixtures are ingredients added to ready-mixed concrete during its mixing to enhance or modify the concrete's properties. These admixtures are typically used to improve various aspects of concrete performance, such as workability, durability, strength, and setting time. Admixtures have the capacity to improve the durability, workability, or strength aspects of a particular concrete blend.

Admixtures are instrumental in addressing challenging construction scenarios, such as extreme temperature conditions during placement, the need for efficient pumping, rapid strength development, or adherence to stringent low water-to-cement ratio criteria.

What are some of the most common admixtures?

1. Air-Entraining Admixtures

Air-Entraining Admixtures are liquid chemicals added to concrete during mixing to create tiny air bubbles called entrained air. These micro-bubbles help concrete resist damage from freezing, thawing, and de-icing salts. They can also make freshly mixed concrete easier to work with and reduce problems like bleeding and separation.

For exterior flatwork projects like parking lots, driveways, sidewalks, pool decks, and patios that face freezing weather or de-icing salts, it's recommended to include about 4% to 7% air in the concrete, depending on the size of the rocks in the mix. However, air isn't needed for indoor structural concrete since it doesn't experience freezing and thawing. And if you want a smooth, troweled finish for your concrete flatwork, it's best to avoid air-entraining admixtures.

Keep in mind that in concrete mixes with high cement content, adding entrained air can make the concrete about 5% weaker for every 1% of air added. But in mixes with low cement content, adding air has a smaller impact and might even slightly increase strength because it reduces the need for extra water. When choosing air-entraining admixtures, be sure they meet ASTM C 260 standards.

2. Water Reducing Admixtures serve two main purposes:

1. They decrease the water content in fresh concrete, making it stronger.
2. They increase the workability (slump) of concrete without adding extra water.

These additives typically reduce the amount of water needed for a specific concrete consistency, which means you can achieve the same strength with less water. They work by spreading the cement particles more efficiently in the concrete mix, resulting in increased strength or allowing for a reduction in the cement content while maintaining the same strength. Water reducers are useful for improving how concrete flows without adding water. This is handy for tasks like pumping concrete and working in hot weather when you might need more water. However, some water reducers may speed up the loss of slump over time. Make sure the water reducers you use meet the Type A requirements in ASTM C 494.

Mid-range water reducers are popular because they have an even greater ability to reduce the water content in concrete. These admixtures are favored for their ability to improve the finish of concrete flatwork. They must meet at least the Type A requirements specified in ASTM C 494 since they do not have a separate classification in admixture specifications.

3. Retarders

Retarders are chemicals that slow down the beginning of the concrete setting process, often postponing it by an hour or longer. They are useful in hot weather when the heat can make concrete set too quickly. When you have extensive projects or are working in hot conditions, it's a good idea to choose concrete with a retarder. This gives you extra time for placing and finishing the concrete. Additionally, most retarders also serve as water reducers. Retarders should meet the specifications for Type B or D in ASTM C 494.

4. Accelerators

Accelerators speed up the concrete's initial setting time and promote early strength development. They don't act as antifreeze, but rather, they quicken the setting process and the rate at which the concrete becomes strong. This helps the concrete withstand freezing temperatures better. Accelerators are valuable in situations where construction needs to progress rapidly, allowing for early removal of forms, opening structures to traffic, or applying loads.

Liquid accelerators that meet ASTM C 494 Types C and E requirements are introduced at the concrete batch plant. There are two main types: chloride-based and non-chloride-based accelerators. Calcium chloride, available in liquid or flake form, is one of the cost-effective and efficient accelerators and must meet the requirements of ASTM D 98. For unreinforced concrete, it can be used up to 2% of the cement's weight. However, chloride can potentially corrode reinforcing steel. So, lower chloride limits apply to reinforced concrete.

It's important to avoid chloride-based materials in pre-stressed concrete and concrete with embedded aluminum or galvanized metal, as they can increase the risk of corrosion. Non-chloride accelerators are a better choice when there's concern about corrosion of embedded metals or reinforcement in the concrete.

5. High-Range Water Reducers

High-Range Water-Reducers (HRWR) belong to a special category of water-reducers often referred to as **superplasticizers**. These HRWRs can substantially cut down the amount of water in a given concrete mix, usually by an impressive 12 to 25%. The primary purposes of HRWRs are to enhance concrete strength and reduce its permeability by minimizing the water content in the mix. Alternatively, they can significantly increase the slump, transforming the concrete into a more flowable state without the need for additional water.

HRWRs play a crucial role in creating high-strength and high-performance concrete blends, especially those with elevated levels of cementitious materials or containing silica fume. For instance, adding a standard amount of HRWR to concrete with a 3 to 4-inch slump can elevate the slump to approximately 8 inches.

It's worth noting that some HRWRs may lead to a faster slump loss over time, causing the concrete to return to its original slump within 30 to 45 minutes. In certain situations, HRWRs can be added to the concrete mix at the job site under controlled conditions. The specifications for HRWRs are detailed in ASTM C 494 under Types F and G, as well as in ASTM C 1017 under Types 1 and 2.

Other Products

In addition to the common admixtures mentioned above, there is a range of specialized products available to enhance various aspects of concrete for a wide array of applications. These products encompass corrosion inhibitors, substances that reduce shrinkage, anti-washout agents, admixtures that stabilize hydration or delay setting, additives that mitigate the risk of alkali aggregate reactions, aids for pumping, moisture-resistant additives, and a diverse selection of colors and products designed to enhance the visual appeal of concrete.

About Synthetic Fiber Concrete Additives

Synthetic fibers designed specifically for use in concrete are made from man-made materials that can withstand the long-term alkaline environment of concrete. These fibers are added to the concrete before or during mixing. Using synthetic fibers at typical addition rates does not require any changes to the mix design.

Synthetic fibers enhance both the plastic and hardened states of concrete. These benefits include a reduction in plastic settlement cracks, as well as shrinkage cracks, and a decrease in permeability. Additionally, synthetic fibers contribute to increased impact and abrasion resistance, while also providing shatter resistance.

Synthetic Fibers in Concrete During Plastic Phase

Changes in concrete's volume during its early development create weakened areas and cracks due to stresses exceeding the concrete's strength at times. Synthetic fibers help to stop micro shrinkage cracks from expanding due to the mechanical barrier provided by the fibers. These fibers also prevent settlement cracks during concrete setting. Even distribution of fibers discourages large capillary formation from water migration. Synthetic fibers decrease permeability by reducing plastic cracks and bleeding tendencies.

Synthetic Fibers in Hardened Concrete

Using synthetic fibers in early age concrete continues to enhance its properties even in the hardened state. Synthetic fibers contribute to lower permeability and increase resistance to shattering, abrasion, and impact forces in hardened concrete. The introduction of synthetic fibers significantly improves the concrete's ability to withstand shattering forces. Unlike plain concrete, which may shatter upon compression, synthetic fibers designed for concrete tightly hold it together, preventing shattering.

Additionally, synthetic fibers enhance abrasion resistance by maintaining a more consistent water-to-cement ratio at the surface, as they minimize variable bleed water. This improvement is further supported by the internal settlement support provided by synthetic fibers, ensuring uniform bleeding. By reducing plastic cracking, synthetic fibers enhance concrete's impact resistance due to their relatively low modulus, which enables shock absorption.

Overall, synthetic fibers contribute to the long-term integrity of concrete by minimizing plastic settlement and shrinkage crack formation, lowering permeability, and increasing resistance to abrasion, shattering, and impact forces. Furthermore, synthetic fibers are compatible with all admixtures, silica fumes, and cement chemistries.

Synthetic Fibers as Secondary Reinforcement

Synthetic fibers that meet specific criteria for hardened concrete can serve as nonstructural temperature or secondary reinforcement. It is important for these fibers to be backed by documentation that proves they can maintain concrete integrity even after cracking. Distributing synthetic fibers evenly throughout the concrete ensures that secondary reinforcement is strategically placed.

Synthetic Fibers Can Be Used for These Applications:

1. To decrease cracking in concrete that results from plastic shrinkage.

2. As an alternative method for nonstructural secondary and/or temperature reinforcement.

3. For enhanced resistance to impact, abrasion, and shattering in concrete.

4. To improve internal support and cohesion for concrete used in steep inclines, shotcrete, and slipformed placements.

5. To reduce concrete cracking caused by plastic settlement.

6. For assistance in lowering concrete permeability.

7. For placements where nonmetallic materials are necessary.

8. For areas needing materials resistant to both alkali and chemicals.

	DO NOT USE Synthetic Fibers for These Applications:
1.	Managing cracks caused by outside pressures
2.	Improved development of structural strength.
3.	Substitution of any moment-resisting or structural steel reinforcement.
4.	Decreased thickness of ground-level slabs.
5.	Minimizing or eliminating curling and/or creep.
6.	Expanding ACI or PCA control joint recommendations.
7.	Supporting a decrease in the dimensions of support columns.
8.	Reducing the thickness of bonded or unbonded overlay sections.

Using Superplasticizer Additives in Concrete

A superplasticizer is a chemical additive used in concrete mixtures to enhance its flowability and workability without sacrificing strength. It achieves this by dispersing cement particles more effectively and reducing the water-to-cement ratio needed for a given level of workability. Superplasticizers are often added to concrete mixes where high strength, high durability, and improved placement characteristics are required.

Superplasticizers are typically sulfonated melamine formaldehyde (SMF), sulfonated naphthalene formaldehyde (SNF), or polycarboxylate-based. These chemicals work by dispersing cement particles and reducing the surface tension between particles, thereby allowing them to flow more freely. This improved flowability leads to better compaction and reduced need for water, which can result in higher strength and durability of the concrete.

Superplasticizers are commonly used in a variety of concrete applications, including high-strength concrete, self-compacting concrete, and in situations where concrete needs to be pumped long distances or placed in congested reinforcement areas.

Advantages of Using Superplasticizer:

Using superplasticizers in concrete offers several advantages:

1. **Improved workability:** Superplasticizers enhance the flowability and workability of concrete, making it easier to place and compact. This allows for easier handling during construction, reducing labor and equipment requirements.
2. **Increased strength:** By reducing the water-to-cement ratio while maintaining workability, superplasticizers can lead to higher compressive strength in the hardened concrete. This results in stronger and more durable structures.
3. **Enhanced durability:** Superplasticizers improve the homogeneity and density of concrete, resulting in reduced permeability and improved resistance to chemical attack, abrasion, and freeze-thaw cycles. This leads to longer-lasting concrete structures.
4. **Better finish:** The improved flowability provided by superplasticizers allows for smoother concrete surfaces with fewer voids and imperfections. This results in better surface finishes, reducing the need for additional surface treatments.
5. **Increased flexibility in design:** Superplasticizers enable the production of concrete mixes with varying water content while maintaining desired workability. This flexibility allows engineers and architects to design concrete mixes tailored to specific project requirements, such as strength, durability, and aesthetic considerations.

Disadvantages of Using Superplasticizer:

While superplasticizers offer several advantages, there are also some potential disadvantages associated with their use in concrete:

1. **Cost:** Superplasticizers can be relatively expensive compared to traditional concrete additives. The cost of superplasticizers may outweigh their benefits for certain projects, especially those with tight budget constraints.
2. **Set time control:** Superplasticizers can extend the setting time of concrete, especially when used in higher dosages or in combination with certain cement types. This may require careful monitoring and adjustment of the concrete mix to ensure proper setting and finishing times.

3. **Retention of workability:** Depending on the specific type and dosage of superplasticizer used, there may be limitations on the duration of workability retention. Concrete mixtures with high doses of superplasticizers may lose workability more rapidly, requiring faster placement and finishing.
4. **Compatibility with other admixtures:** Superplasticizers may interact with other chemical admixtures in concrete, affecting their performance or causing unintended consequences. **Careful testing and compatibility evaluations are necessary when using superplasticizers in combination with other additives.**
5. **Potential for air entrainment:** In some cases, excessive use of superplasticizers can lead to entrainment of air in the concrete mixture, which may compromise its strength and durability. Proper dosage control and mix design optimization are essential to prevent air entrainment issues.

How Do Plasticizers Differ from Superplasticizers?

Plasticizers and superplasticizers both improve the workability of concrete, but they achieve this through different mechanisms and have different effects on water reduction, dosage rates, and chemical composition. Plasticizers and superplasticizers are both types of chemical additives used in concrete, but they serve different purposes and have distinct effects on concrete properties:

1. Purpose:

Plasticizers: Plasticizers, also known as mid-range water reducers, are additives that improve the workability of concrete by reducing the amount of water required for a given slump or consistency. They help increase the flow of concrete while maintaining a constant water content.

Superplasticizers: Superplasticizers, on the other hand, are high-range water reducers primarily used to enhance the flowability and workability of concrete without significantly increasing its water content. They achieve this by dispersing cement particles more effectively, reducing the water-to-cement ratio needed for a given level of workability.

2. Water reduction:

Plasticizers: Plasticizers reduce the water content in concrete by dispersing cement particles more efficiently, allowing for increased workability without compromising strength.

Superplasticizers: Superplasticizers also reduce the water content in concrete, but they achieve this by dispersing cement particles more effectively and dramatically decreasing the water-to-cement ratio. This results in much higher flowability and workability without sacrificing strength.

3. Dosage rates:

Plasticizers: Plasticizers are typically used at lower dosage rates compared to superplasticizers. They are effective in improving workability while minimizing the risk of segregation and bleeding.

Superplasticizers: Superplasticizers are used at higher dosage rates compared to plasticizers. They are particularly useful in applications requiring high-strength concrete, long-distance pumping, or where very high flowability is necessary.

4. Chemical composition:

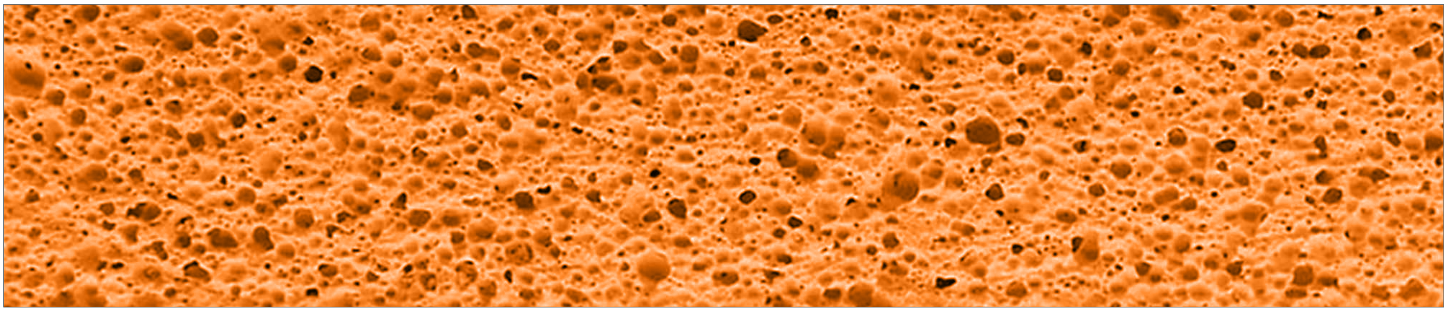
Plasticizers: Plasticizers are often based on lignosulfonates, hydroxylated carboxylic acids, or other organic compounds.

Superplasticizers: Superplasticizers can be sulfonated melamine formaldehyde (SMF), sulfonated naphthalene formaldehyde (SNF), or polycarboxylate-based. They are chemically designed to disperse cement particles more effectively and reduce water demand in concrete mixes.

Your Ready-Mixed Concrete Supplier Can Help

Talk to your ready mixed concrete supplier about selecting the most suitable superplasticizer for your project's specific requirements. Consider factors such as the desired level of workability, strength requirements, and environmental considerations. Discuss the available options, including sulfonated melamine formaldehyde (SMF), sulfonated naphthalene formaldehyde (SNF), or polycarboxylate-based superplasticizers, and their respective dosage rates and effects on concrete properties. Your supplier can provide valuable guidance on choosing the right superplasticizer to optimize concrete performance while ensuring cost-effectiveness and sustainability. Collaborating with your supplier ensures that you make informed decisions tailored to your project's needs, ultimately resulting in successful concrete applications.

Air Entraining Admixtures For Concrete



History

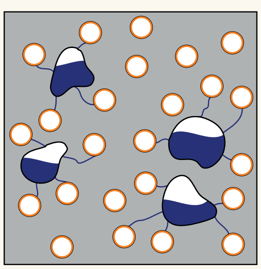
Air-entraining admixtures were discovered in the 1930s. These admixtures for concrete were developed by researchers working for the U.S. Bureau of Public Roads (now the Federal Highway Administration) in the 1930s. The discovery was made by R. E. Davis, R. W. Carlson, and L. H. Martin, who were investigating ways to improve the durability of concrete, especially in cold climates that are subject to freeze-thaw cycles. Their work led to the development of these admixtures, which create small air bubbles within the concrete, significantly enhancing its resistance to freeze-thaw damage and improving its overall durability.

Benefits

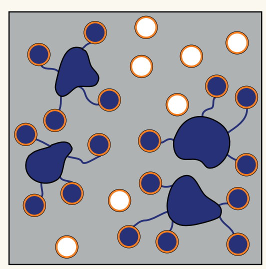
Air-entraining admixtures enhance concrete's durability, workability, and resistance to various forms of environmental and chemical damage, making them an essential component in many concrete applications — particularly in regions with harsh weather conditions.

1. **Improved Freeze-Thaw Resistance:** As water freezes, it expands by approximately 9% by volume, causing pressures that can rupture concrete and cause scaling. Air-entraining admixtures create microscopic air bubbles within the concrete, providing space for water to expand when it freezes. This reduces internal pressure and prevents cracking & spalling in freeze-thaw conditions.

Figure 1: How Air Entrainment Helps Concrete Resist Freeze-Thaw Cycles



1. Entrained air leaves evenly dispersed microscopic voids in the concrete. This creates space for water to expand into when it freezes.



2. When water freezes, it expands by approximately 9% by volume. The freezing water expands through capillary pores, into the air entrainment voids instead of cracking the concrete.

2. **Increased Durability:** The presence of air bubbles enhances the concrete's resistance to weathering and chemical attacks, leading to a longer lifespan for structures exposed to harsh environments.
3. **Enhanced Workability:** Air-entrained concrete is easier to work with, as the microscopic bubbles improve the mix's plasticity and cohesiveness. This makes the concrete easier to place, finish, and compact.
4. **Reduced Bleeding and Segregation:** The uniform distribution of air bubbles helps to stabilize the mix, reducing the tendency for water and fine particles to separate from the aggregate. This leads to a more uniform and stable concrete mix.
5. **Decreased Permeability:** The air voids created by the admixture reduce the concrete's permeability, making it less susceptible to water penetration and the subsequent damage from cycles of freezing and thawing, as well as from chemical attacks.
6. **Enhanced Resistance to Sulfate Attack:** Air-entrained concrete exhibits better resistance to sulfate attack, which can cause expansion and cracking. The air bubbles help to mitigate the stress induced by sulfate reactions.
7. **Improved Surface Finish:** The improved workability and reduced bleeding contribute to a better-quality surface finish, with fewer defects such as scaling and crazing.

8. **Increased Scaling Resistance:** Air-entrained concrete is more resistant to surface scaling caused by deicing salts and other chemical exposure, which is particularly beneficial for pavements, driveways, and other exposed surfaces.
9. **Reduced Risk of Alkali-Aggregate Reaction (AAR):** The air voids can help mitigate the effects of alkali-aggregate reactions, which cause expansion and cracking. The entrained air provides space for the reaction products to expand, reducing internal stress.

Drawbacks

While air-entraining admixtures offer significant benefits to concrete, such as improved durability and freeze-thaw resistance, they also come with some potential drawbacks:

- **Reduced Strength:** Introducing air into the concrete mix decreases its overall density and can reduce the compressive strength of the concrete. While the trade-off is often acceptable for the benefits gained in durability, it is still a crucial consideration in structural applications where high strength is essential. For every 1% of air that is added, approximately 3–5% of strength is lost.
- **Increased Porosity:** The air voids created by air-entraining admixtures increase the porosity of the concrete. This can potentially reduce the concrete's resistance to abrasion, making it less suitable for surfaces subjected to heavy wear, such as industrial floors.
- **Potential for Over-Entraining:** If ***too much*** air is introduced into the mix, it can lead to excessive air content, which significantly reduces concrete's strength and durability. Careful control & monitoring of air content are required to ensure optimal performance.
- **Variability in Air Content:** Achieving consistent air content can be challenging due to variations in mixing, placing, and finishing techniques. Inconsistent air entrainment can lead to uneven performance and durability across different sections of the concrete.
- **Cost:** Air-entraining admixtures add to the cost of the concrete mix. While this is often justified by the benefits provided, it can be a concern for projects with tight budgets or where the benefits of air entrainment are not critical.
- **Potential Compatibility Issues:** Air-entraining admixtures need to be compatible with other admixtures used in the concrete mix. Incompatibilities can lead to issues such as segregation, setting problems, or reduced effectiveness of the admixtures.
- **Impact on Workability:** While air entrainment generally improves workability, in some cases, it can lead to overly cohesive mixes that may be more challenging to place and finish, especially in mixes with low water content.
- **Surface Finish Concerns:** Excessive air entrainment can lead to surface defects such as scaling, spalling, or pop-outs, particularly in exposed concrete surfaces. Proper finishing techniques are essential to mitigate these issues.
- **Longer Curing Times:** In some instances, air-entrained concrete may require longer curing times to achieve desired strength and durability characteristics, potentially impacting project timelines.

While air-entraining admixtures provide significant advantages in durability and freeze-thaw resistance, they must be used carefully & with proper quality control to avoid potential drawbacks such as reduced strength, increased porosity, and variability in performance.

What is the difference between entrapped air and entrained air?

Entrained air is intentionally introduced to enhance concrete's performance, particularly its durability in freeze-thaw conditions. Entrapped air is an unwanted byproduct of the mixing process that can adversely affect the concrete's strength and integrity.

Entrapped Air occurs naturally during the mixing and handling process of concrete. These are irregular and larger air voids that get trapped in the mix due to insufficient consolidation. Entrapped air usually consists of larger, irregularly shaped voids that can be several millimeters in diameter. The distribution is uneven, leading to pockets of air. This is generally considered undesirable as it weakens the concrete. Large, irregular voids reduce the strength and durability of the concrete and can lead to higher permeability, making the concrete more susceptible to damage and degradation. Entrapped air is difficult to control, because it is unintentional. It can be minimized by proper compaction, vibration, and placement techniques during the mixing and pouring of concrete.

Entrained Air is introduced intentionally through the use of air-entraining admixtures or agents. These admixtures are added to the concrete mix to create microscopic air bubbles. Entrained air consists of uniformly distributed microscopic bubbles, typically less than 1 millimeter in diameter. These bubbles are evenly dispersed throughout the concrete. This enhances the durability of concrete, especially in environments that are subject to freeze-thaw cycles. The small, uniformly distributed bubbles provide space for water to expand when it freezes, reducing internal pressure and cracking. Entrained air also improves workability and reduces bleeding and segregation. Entrained air can be controlled and measured accurately through the use of admixtures and proper mixing techniques. The desired amount of air entrainment is typically specified and achieved as per standards.

Adding Water to Concrete at the Jobsite

Why add water at the jobsite?

If ready-mixed concrete arrives at the jobsite with a lower slump than specified, or if it is viscous to the point that it adversely affects the placeability of the concrete, the buyer may wish to have the slump adjusted there on-site. This can be done while the concrete is still in the truck's mixer.

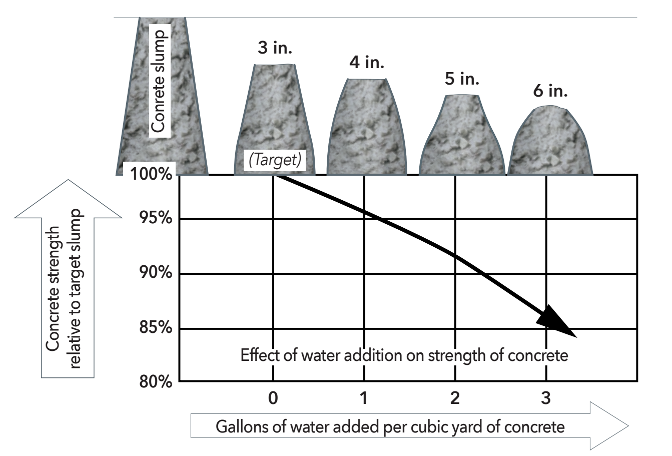
Water can be added to the concrete to bring the slump up to an acceptable or specified level. This can be done as long as the specified slump and/or the water-to-cement ratio is **not** exceeded. Adding water at the jobsite in this manner is in accordance with ASTM C 94, Standard Specification for Ready Mixed Concrete.

Effect on slump and strength

Ready mixed concrete suppliers design concrete mixes according to industry standards. This is to provide the intended performance characteristics of the concrete. Addition of water in excess of that in the mix design will affect the concrete's properties. This can include reducing strength, as shown in **Figure 1**. It can also include increasing the concrete's susceptibility to cracking.

If the buyer requests additional water in excess of the design mix, the buyer assumes responsibility for the resulting quality of the concrete.

Figure 1: Effect of water addition on slump and strength of concrete



An alternative

There is an alternative to adding water to the concrete. A water reducing admixture or superplasticizer can be used to increase the slump of the concrete, rather than adding water to it. As long as segregation is avoided, increasing concrete slump by using admixtures normally will not alter the concrete's properties significantly.

What is involved in the process?

a. The maximum allowable slump of the concrete must be specified, or determined from the specified nominal slump plus tolerances.

b. Before discharging concrete at the jobsite, the actual slump of the concrete must be estimated or determined. If the slump is measured, it should be from a sample taken from the first 1/4 cubic yard of discharged concrete, and the result used as an indicator of concrete consistency — and **not** an acceptance test. Tests for acceptance of concrete should be made in accordance with ASTM C 172.

c. At the jobsite, water should be added to the entire batch of concrete so that the volume of concrete being adjusted is known. A common rule of thumb is: 1 gallon, or roughly 10 pounds, of water per cubic yard for a 1 inch increase in slump.

d. All water added to the concrete on the jobsite must be measured and recorded.

e. ASTM C 94 requires an additional 30 revolutions of the mixer drum at mixing speed after adding the water. In fact, 10 revolutions will be sufficient if the truck is able to mix at 20 revolutions per minute or faster.

f. The amount of water added should be controlled, so that the maximum slump and/or water-to-cement ratio (as indicated in the specification) is not exceeded. After more than 1/4 cubic yard of the concrete is discharged, no water addition is permitted.

g. After obtaining the desired slump and/or maximum water-to-cement ratio, no further addition of water on the jobsite is permitted.

h. It would be wise to hold a pre-concreting conference, in order to establish the proper procedures to be followed, and to determine who is authorized to request water addition. Also, the method to be used for documentation of water added at the jobsite should be clearly defined.

ASTM C 94 Jobsite Water Addition

1. Establish the maximum allowable slump and water content permitted by the job specification.
2. Estimate or determine the concrete slump from the first portion of concrete discharged from the truck.
3. Add an amount of water such that the maximum slump or water-cement ratio according to the specification is not exceeded.
4. Measure and record the amount of water added. Water in excess of that permitted above should be authorized by a designated representative of the purchaser.
5. Mix the concrete for 30 revolutions of the mixer drum at mixing speed.
6. Do not add water if:
   - **a.** the maximum water-cement ratio is reached,
   - **b.** the maximum slump is obtained, or
   - **c.** more than 1/4 cubic yard has been discharged from the mixer.

Concrete Surface Dusting: Causes & Prevention

"Dusting" is when the surface of hardened concrete breaks down into a loose powder. This is also sometimes referred to as "chalking." These surfaces are easily turned into powder under any kind of traffic and can be scratched easily.

What causes concrete surface dusting?

A concrete surface dusts under traffic due to weakness of the wear surface. This weakness can be caused by numerous factors, including:

1. Performing any finishing operation while there is bleed water on the surface or before the concrete has finished bleeding. Working this bleed water back into the top 1/4 inch of the slab creates a surface layer with a very high water-cement ratio, resulting in low strength.
2. Placing concrete over a non-absorptive subgrade or polyethylene vapor retarder reduces normal absorption by the subgrade, increases bleeding, and thus raises the risk of surface dusting.

3. Conducting floating and/or troweling operations after moisture condenses from warm humid air onto cold concrete. In cold weather, particularly with concrete in basement floors, the concrete sets slowly. If the humidity is relatively high, water will condense on the freshly placed concrete. If this water is troweled into the surface, it will lead to dusting.

4. Insufficient ventilation in enclosed spaces. Carbon dioxide emitted from open salamanders, gasoline engines or generators, power buggies, or mixer engines may cause a chemical reaction called carbonation, significantly reducing the strength and hardness of the concrete surface.

5. Lack of proper curing frequently leads to a soft surface layer that readily dusts under foot traffic.

6. Failure to adequately shield freshly poured concrete from rain, snow, or drying winds can cause the surface to freeze, weakening it and leading to dusting.

Methods to prevent concrete surface dusting:

Use a concrete mix with minimal water content & suitable slump.

Concrete with minimal water content, yet with a suitable slump for placement and finishing, yields a robust, long-lasting, and wear-resistant surface. It's advisable to utilize concrete with a moderate slump, generally not exceeding 5 inches. If a higher slump is necessary, the concrete mixture should be formulated to achieve the required strength without excessive bleeding or separation. Water-reducing admixtures are commonly employed to enhance slump while keeping water content low. This becomes crucial, especially in cold weather conditions where delayed setting prolongs bleeding.

DO NOT, under any circumstances, add dry cement into the surface of plastic concrete to absorb bleed water.

Avoid sprinkling or troweling dry cement onto the surface of plastic concrete to absorb bleed water. Instead, eliminate bleed water by dragging a garden hose across the surface. To minimize excessive bleeding of concrete, consider using air-entrained concrete, adjusting mix proportions, or accelerating the setting time.

Never perform finishing operations while water remains on the surface or while the concrete continues to bleed.

Avoid performing any finishing operations while water is present on the surface or while the concrete is still bleeding. Immediately follow initial screeding with bull floating to prevent bleed water from being incorporated into the surface layer. Refrain from using a jitterbug, as it tends to bring excess mortar to the surface. Never add water to the surface to aid in finishing operations.

DO NOT place concrete directly on polyethylene vapor retarders or non-absorptive subgrades.

Avoid placing concrete directly on polyethylene vapor retarders or non-absorptive subgrades as it can lead to issues like dusting, scaling, and cracking. Instead, lay down 3 to 4 inches of a trimmable, compactible fill, such as crusher-run material, over vapor retarders or non-absorptive subgrade before pouring concrete. In instances of high evaporation rates, lightly moisten absorptive subgrades just before concrete placement, ensuring water does not pool or accumulate on the subgrade surface.

Ensure proper curing by applying an appropriate cover.

Ensure proper curing by applying a liquid membrane curing compound or covering the surface with water, damp burlap, or other curing materials immediately after finishing to maintain moisture in the slab. Protecting the concrete from environmental factors in its early stages is crucial.

Ensure adequate concrete temperature in cold weather.

To pour concrete successfully in cold weather, ensure the concrete temperature stays above 50°F. This often involves using an accelerating admixture to achieve the necessary temperature and promote proper setting and curing despite the cold. Cold temperatures slow down concrete hydration, causing delays in setting and strength development. Maintaining suitable temperatures throughout the process is crucial to mitigate these effects and ensure concrete quality.

Table 1: Five Basic Rules to Prevent Dusting	
1.	Utilize concrete with a moderate slump, ensuring it does not exceed 5 inches.
2.	Avoid commencing finishing operations while the concrete is still bleeding.
3.	Refrain from broadcasting cement or sprinkling water on concrete before or during finishing operations.
4.	Ensure proper ventilation to exhaust gases from gas-fired heaters in enclosed spaces.
5.	Implement sufficient curing techniques to preserve moisture in the concrete during the initial 3 to 7 days.

Methods for repairing dusting or chalking of concrete:

1. Sandblast, shot blast, or use a high-pressure washer to eliminate the weak surface layer.
2. To minimize or eliminate dusting, apply a commercially available chemical floor hardener, such as sodium silicate (water glass) or metallic zinc or magnesium fluosilicate, following the manufacturer's directions on thoroughly dried concrete. If dusting persists, consider using a coating such as latex formulations, epoxy sealers, or cement paint.
3. In severe cases, achieve a serviceable floor by wet-grinding the surface to durable substrate concrete. This may be followed by properly bonded placement of a topping course. If this is not feasible, consider installing a floor covering like carpeting or vinyl tile, which is the most cost-effective solution to severe dusting. However, be aware that preparation is required since adhesives for floor covering materials won't adhere to floors with a dusting problem, and dusting can penetrate through carpeting.

Concrete Cracking And Saw Joints

Concrete, like other construction materials, contracts and expands with changes in moisture and temperature. It can also bend, somewhat, depending on how much weight is on it and how it's supported. If precautions aren't taken during design and construction to handle these movements, cracks may form.

Common Types of Cracks:

There are several types of common cracks that can occur:

1. **Plastic Shrinkage Cracks:** These are narrow cracks that form on the surface of freshly poured concrete during the early stages of curing. They occur when the surface of the concrete dries out too quickly before it has had a chance to fully set and harden. These cracks typically appear as random lines or networks on the surface and are often shallow.

   Plastic shrinkage cracks are primarily caused by rapid evaporation of moisture from the concrete surface due to factors such as high temperatures, low humidity, and wind. As the surface moisture evaporates faster than it can be replaced by hydration from within the concrete, the surface layer contracts, leading to the formation of cracks.

   Plastic shrinkage cracks are generally superficial and do not significantly affect the structural integrity of the concrete. However, they can detract from the appearance of the finished surface and may need to be repaired or filled to prevent water infiltration and further deterioration.
2. **Cracks Resulting From Improper Jointing:** Improper jointing can lead to excessive stress concentrations in concrete, especially at corners or edges where there are no joints. This stress can cause the concrete to crack as it contracts during the curing process. Also, changes in temperature can cause concrete to expand and contract. Without properly spaced joints to accommodate this movement, the concrete may crack due to thermal stresses.

   In pavements and other structural applications, traffic loads can induce stresses in the concrete. Without adequate jointing to control these stresses, the concrete may crack under the pressure of heavy loads.
3. **Cracks That Result From External Restraint:** These cracks occur when the concrete is prevented from expanding, contracting, or deforming freely, leading to the development of stress within the material. These types of cracks can include Curvature Cracking, Corner Cracking, Tensile Cracking, and Warping or Curling Cracks.
4. **Cracks Caused By Lack Of An Isolation Joint:** Isolation joints are intentional gaps or spaces left between adjacent concrete elements to allow for movement and prevent cracking. When isolation joints are not provided, several types of cracks can develop

that compromise the structural integrity and durability of the concrete. Properly incorporating isolation joints into concrete design and construction is essential for controlling cracking and ensuring the long-term performance of concrete structures.

5. **Cracks Caused By Freezing & Thawing Cycles:** These cracks are primarily caused by the expansion and contraction of water within the concrete due to cyclic freezing and thawing cycles. They occur primarily in regions with cold climates where temperatures fluctuate above and below the freezing point of water.
6. **Craze Cracks:** Craze cracks in concrete are fine, shallow surface cracks that resemble a spider web or a network of intersecting lines. These cracks are primarily caused by the tensile stresses generated within the concrete surface during the drying and curing process. As the concrete dries and shrinks, especially during the initial stages of curing, tensile stresses develop at the surface due to differential drying rates between the surface layer and the underlying concrete. These stresses can exceed the tensile strength of the concrete, leading to the formation of fine cracks on the surface.
7. **Settlement Cracks:** These cracks occur when the soil beneath a concrete slab compresses or settles unevenly, causing the concrete to crack as it adjusts to the changing support conditions. They typically occur in structures such as buildings, foundations, and pavements. Settlement cracks in concrete can pose structural and safety concerns, as they may compromise the integrity of the concrete slab and lead to further damage if left unaddressed.

Most concrete cracks typically result from incorrect design and construction methods, including: neglecting isolation and contraction joints and using improper jointing techniques; inadequate preparation of the subgrade; excessive water added to high slump concrete during construction; improper finishing; and insufficient or absent curing.

Methods To Minimize Cracking:

Concrete cracking is common but can be minimized by following basic concreting practices:

- **Subgrade and Formwork:** Remove topsoil and soft spots, compact the soil or fill, slope for drainage, and avoid placing concrete on frozen subgrades. Ensure formwork is sturdy to withstand concrete pressure.
- **Concrete:** Use moderate slump concrete, avoid retempering, and specify air-entrained concrete for freezing conditions.
- **Finishing:** Bull float promptly after screeding, avoid water during finishing, and use broom finish for exterior surfaces. Prevent rapid drying with wind breaks or wet coverings.
- **Curing:** Start curing immediately, use liquid membrane or damp burlap for at least 3 days, and consider a second application of curing compound.
- **Joints:** Create contraction joints spaced properly and run tooled or saw-cut joints at the right time. Use isolation joints to prevent bond with adjacent elements.
- **Cover Over Reinforcement:** Ensure at least 2 inches of concrete cover over reinforcement to prevent contact with salt and moisture, thus preventing cracks caused by rust expansion.

Saw Joints

Saw joints in concrete refer to intentional cuts or grooves made in concrete surfaces after it has hardened but before it fully sets. These joints are created using specialized sawing equipment and are essential for controlling cracking and ensuring the structural integrity of the concrete. Some key aspects of saw joints in concrete include:

- **Purpose:** Saw joints are primarily installed to control the cracking that naturally occurs in concrete due to shrinkage during the curing process and temperature changes. By creating predetermined lines of weakness, saw joints encourage cracks to occur along these lines, preventing random cracking that can compromise the concrete's strength and appearance.
- **Timing:** Saw joints are typically made within the first 24 hours after the concrete is poured and finished. The concrete needs to be firm enough to support the weight of the sawing equipment but still relatively fresh to allow for clean cuts without excessive chipping or spalling.
- **Equipment:** Specialized concrete saws are used to create saw joints. These saws can be either hand-held or walk-behind machines equipped with diamond blades designed specifically for cutting through concrete. The blades may be wet or dry depending on the specific requirements of the project.
- **Spacing and Depth:** The spacing and depth of saw joints are critical factors in their effectiveness. The spacing between saw cuts depends on various factors, including the thickness of the concrete slab, its intended use, and environmental conditions. Generally, saw cuts are made at regular intervals to create rectangular or square-shaped sections. The depth of the saw cuts is typically one-fourth to one-third of the slab thickness.

- **Pattern:** Saw joints can be installed in various patterns depending on the specific requirements of the project. Common patterns include straight lines, diagonal lines, or grids. The choice of pattern may depend on aesthetic preferences, structural considerations, or functional requirements.
- **Sealing:** After saw joints are installed, they are often filled with a joint sealing compound to prevent water infiltration, reduce the risk of spalling, and prolong the lifespan of the concrete. Joint sealants also help maintain the structural integrity of the concrete by minimizing the intrusion of debris and chemicals.

Saw joints play a crucial role in ensuring the durability and performance of concrete structures by controlling cracking and promoting long-term stability. Properly designed and installed saw joints are essential for maintaining the integrity and appearance of concrete surfaces in various applications, including roads, sidewalks, driveways, and industrial floors.

The Role of Temperature in Concrete Cracking

What is Heat of Hydration?

When water is added to cement, it initiates a series of chemical reactions collectively known as hydration. The hydration process generates heat as a result of the chemical reactions that occur between cement and water. This phenomenon, known as the exothermic reaction, is a critical aspect of concrete curing. The primary compounds in cement react with water to form calcium silicate hydrate (C-S-H) and calcium hydroxide (CH). These reactions generate heat as a byproduct — known as "heat of hydration."

Stages of Heat Generation

The heat generation during hydration occurs in stages. First is the **Initial Stage**: Upon mixing, there's a rapid but brief generation of heat, known as the initial heat burst, which lasts for a few minutes.

This is followed by a **Dormant Period** where heat generation slows down. During this phase, the concrete remains workable.

After the dormant period is the **Acceleration Phase**. The main hydration reactions begin, leading to a significant increase in heat generation. This is when the concrete starts to harden and gain strength.

Deceleration and Steady State: As hydration continues, the rate of heat generation gradually decreases until it reaches a steady state as the reactions near completion.

Heat generated during hydration is beneficial in many cases because it accelerates the curing process and increases the early strength of concrete. However, in mass concrete pours or large structures, excessive heat generation can create temperature differentials between the interior and exterior of the concrete, leading to cracking. Managing the heat of hydration through mix design, cooling methods, and proper curing practices is essential to ensure the structural integrity and durability of the concrete.

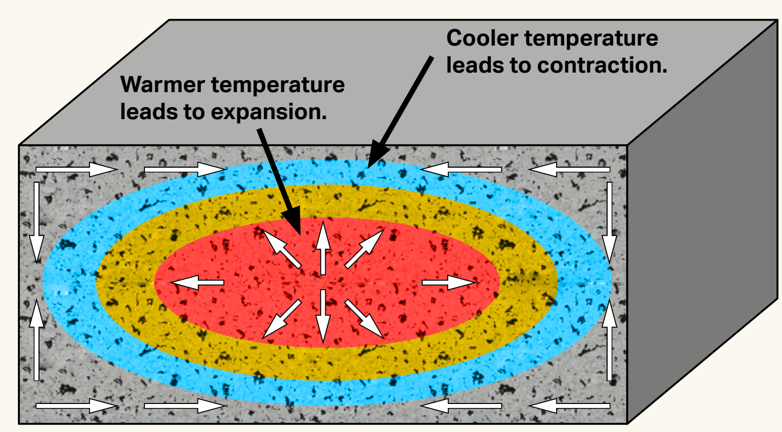
A Temperature Differential Occurs as Heat Dissipates

The temperature throughout freshly poured concrete is not uniform. Heat dissipates more easily, (and therefore more rapidly), along the outer surfaces of the concrete. As the outer surfaces cool and harden, the concrete in these areas begins to contract.

However, the temperature in the core of the concrete remains heated for longer. This heat causes an outward expansion of the concrete.

These opposing forces cause internal stresses in the concrete. If the temperature differential becomes too great, cracking may result.

Figure 1: Expansion & Contraction from Temperature Differential



What Role Does Temperature Play in Concrete Cracking?

There are various ways that temperature plays a role in the tendency for new concrete to crack.

1. **Thermal Expansion and Contraction:** High temperatures cause concrete to expand, while low temperatures cause it to contract. If concrete is subjected to significant temperature fluctuations, these expansions and contractions can induce stress within the material, leading to cracks.
2. **Temperature Differential:** If different parts of the concrete structure experience different temperatures, this can create internal stresses due to uneven expansion or contraction, leading to thermal cracking.
3. **Curing Conditions:** The temperature during the curing process is vital. Excessively high temperatures during curing can cause the concrete to set too quickly, reducing its final strength and increasing the likelihood of cracks. Conversely, very low temperatures can slow down the curing process, leading to delayed setting times and potential freezing of the mix, which can also cause cracks.
4. **Plastic Shrinkage Cracking:** If the surface of freshly poured concrete dries out too quickly due to high temperatures (especially in combination with wind or low humidity), it can shrink rapidly, causing shrinkage cracks. This is more common in hot weather.
5. **Thermal Gradient:** During the early stages of curing, if there's a significant temperature gradient between the interior and exterior of the concrete (like in mass concrete pours), the differential cooling rates can cause internal stresses that lead to cracks.

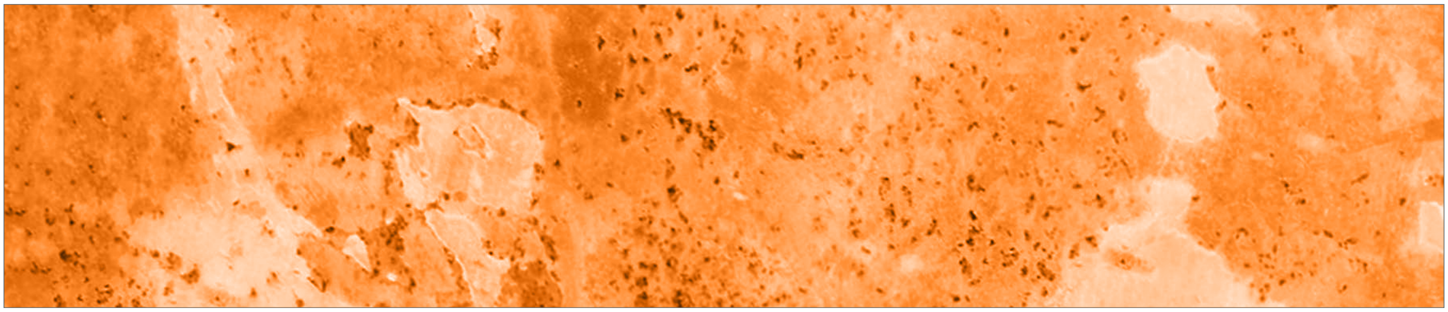
Managing Concrete Temperature

Effective management of concrete temperature during a pour is crucial to ensuring the quality, strength, and durability of the finished product. Temperature control is particularly important in large or mass concrete pours, where excessive heat generation can lead to cracking, delayed setting, and reduced strength. Here are some effective strategies:

1. **Pre-Cooling the Ingredients:**
   - **Chilled Water:** Use chilled water for mixing to lower the initial temperature of the concrete.
   - **Ice:** Replace part of the mix water with crushed ice, which melts and absorbs heat as it mixes, lowering the concrete temperature.
   - **Cool Aggregates:** Pre-cool the aggregates by shading them or spraying them with cold water before mixing. This reduces the temperature of the overall mix.
2. **Controlling the Mix Design:**
   - **Low Heat Cement:** Use a cement type that produces less heat during hydration, such as Type IV cement, which is specifically designed for large pours.
   - **Supplementary Cementitious Materials:** Incorporate materials like fly ash or slag, which generate less heat during the hydration process.
   - **Lower Cement Content:** Reduce the cement content in the mix, as less cement means less heat generation. This option is particularly effective if the concrete producer is using a precision inline aggregate blending batch plant. This method of mixing concrete is proven to produce concrete of exceptional strength and quality over traditional methods when mixing with reduced cement content.
3. **Temperature Monitoring:**
   - **Thermocouples:** Embed thermocouples in the concrete to monitor internal temperatures at different depths. This allows for real-time adjustments if temperatures approach critical limits.
   - **Thermal Control Plan:** Develop and implement a thermal control plan that sets temperature thresholds, identifies cooling methods, and outlines actions to be taken if temperatures exceed safe limits.
4. **Environmental Controls:**
   - **Insulating Blankets:** Cover the concrete with insulating blankets or thermal mats to reduce heat loss during cold weather or to slow down the temperature rise in hot weather.
   - **Windbreaks and Shading:** Set up windbreaks and provide shading to reduce the effects of wind and direct sunlight, which can accelerate surface drying and create temperature gradients.
5. **Staggered Pours:** Pour the concrete in layers or segments. Allow each layer to cool and cure before pouring the next.
6. **Curing Methods:**
   - **Moist Curing:** Keep the concrete surface moist by applying water, using wet burlap, or applying curing compounds. This slows down the evaporation process, helps maintain a more consistent temperature, and reduces the risk of cracking.
   - **Extended Curing:** In some cases, extending the curing period with moist curing or by maintaining a more controlled environment can help manage temperature and improve the overall quality of the concrete.

By combining these methods, concrete temperature can be effectively managed during a pour, minimizing the risk of thermal cracking and ensuring the long-term durability of the structure.

Surface Discoloration of Concrete



About concrete surface discoloration

Discoloration of concrete refers to changes or variations in the color of the concrete surface that differ from the intended or expected color. This phenomenon can occur for several reasons and can manifest as patches, streaks, or general unevenness in color. Addressing concrete discoloration typically involves identifying the root cause and taking corrective actions, such as adjusting the mix design, improving curing practices, or applying surface treatments.

What are the most common types of surface discoloration?

Efflorescence:
White, powdery deposits on the surface of the concrete. Occurs when soluble salts within the concrete migrate to the surface and react with carbon dioxide in the air.

Mottling or Blotching:
Irregular, patchy areas of varying shades of color. Can be caused by uneven curing, inconsistent water-cement ratios, or variations in the concrete mix.

Streaks or Stripes:
Linear discolorations that can result from the use of different batches of concrete, improper finishing techniques, or variations in the application of curing compounds.

Dark Spots or Stains:
Can be caused by contaminants like oil or rust; or result from uneven application of curing compounds or surface treatments.

Shadowing:
Variations in the depth of concrete over reinforcing steel, can lead to dark or light areas following the pattern of the reinforcement.

Color Fading:
Lightening or bleaching often caused by exposure to sunlight (UV rays) or the use of poor-quality pigments in colored concrete.

Yellowing:
Can result from using some curing compounds, admixtures, or sealers that react to environmental conditions or UV exposure.

Surface Dusting:
A white, dusty residue on the surface, often resulting from improper curing or finishing techniques.

Differential Curing:
This leads to areas of varying shades or colors, typically due to uneven moisture retention during the curing process.

What causes surface discoloration?

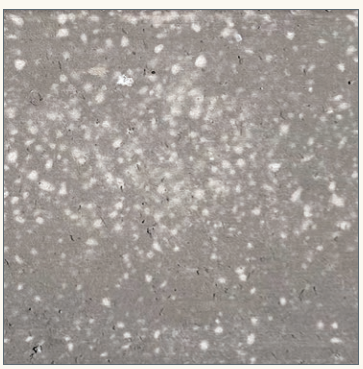
Discoloration from changes in cement or fine aggregate sources in different batches during a placement sequence can happen. However, this is usually rare and minor. Cement that has hydrated more will typically be lighter in color. Inconsistent use of admixtures, not enough mixing time, and incorrect timing of finishing operations can cause this effect. Concrete with ground slag as a cementitious material may show a yellowish to greenish hue, which will fade over time. However, concrete with ground slag generally has a lighter color. Discoloration in concrete that is cast in forms or slabs on grade is usually due to a change in either the concrete mix or construction practices. Most studies find that no single factor causes discoloration.

Preventing concrete surface discoloration

Concrete surface discoloration can be minimized or prevented by following best practices from the mixing stage, through the curing process. Preventing concrete surface discoloration involves careful attention to various aspects of concrete mixing, placing, finishing, and curing. Here are some strategies to help prevent discoloration:

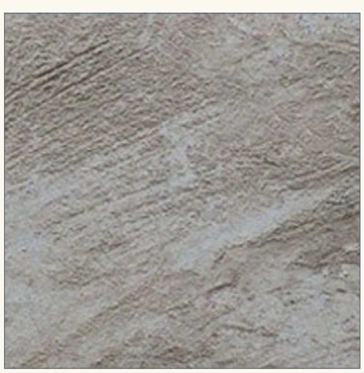
1. **Use Low-Alkali Cement:** Using cement with a low alkali content reduces the factors that lead to some types of discoloration.
2. **Consistent Water-Cement Ratio:** Maintain a uniform water-cement ratio in all batches to ensure even hydration and color.
3. **Avoid Admixtures with Calcium Chloride or Chloride-Bearing Chemicals:** Calcium chloride is a major cause of concrete discoloration. Avoid calcium chloride accelerators, which can cause discoloration. Use high-quality admixtures and ensure they are uniformly mixed into the concrete.
4. **Use Uniform Materials:** Source cement, aggregates, and admixtures from consistent suppliers to avoid variations in color.
5. **Consistent Formwork:** The type and condition of the formwork can affect the surface color of the concrete. Forms with different absorption rates will create surfaces with different shades. Additionally, changing the type or brand of form release agent can also alter the color of the concrete.
6. **Thorough Mixing:** Ensure concrete is mixed thoroughly to evenly distribute materials and admixtures.
7. **Prevent Trowel Burning on Concrete Surfaces:** The most common issue is that metal fragments from the trowel get embedded in the concrete. Hard-troweled concrete can appear darker due to the densified surface, which lowers the water-cement ratio. This lower ratio affects how the cement hydrates, leading to a darker color. Also, troweling the surface too early increases the water-cement ratio, making the color lighter.
8. **Proper Curing:** Apply consistent curing methods to maintain uniform moisture and temperature. Use curing blankets, plastic sheeting, or curing compounds to protect the concrete surface. Inconsistent curing affects how well the cement hydrates, potentially leading to discoloration. If plastic sheeting is in direct contact with the concrete, it creates streaks. Using a uniform application of a high-quality spray or curing compound might be a better choice.
9. **Prevent Contamination:** Keep the concrete surface clean and free from contaminants like oil, grease, dirt, or chemicals during mixing, placing, and curing. Also, protect the concrete from adverse environmental conditions such as rain, snow, and direct sunlight, especially during the early curing stages.
10. **Proper Use of Ground Slag:** Be aware that concrete containing ground slag may initially exhibit a yellowish to greenish hue, which will fade over time. Ensure this is accounted for in planning and communication.

Figure 1: Five Common Types of Concrete Surface Discoloration


Efflorescence

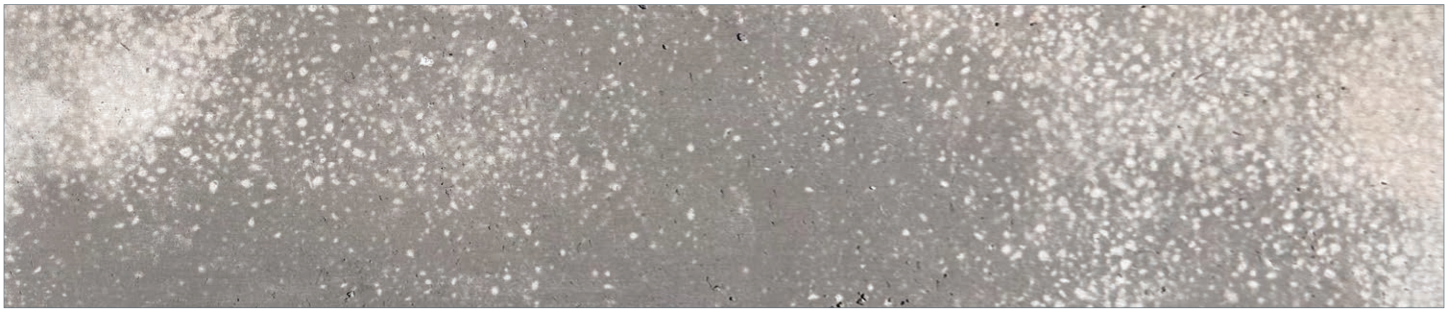

Mottling / Blotching


Streaks from sheeting contact


Surface Dusting


Shadowing

White Spotting / Efflorescence of Concrete



What is White Spotting / Efflorescence?

"White spotting" of concrete, also known as efflorescence, is a common issue where white, powdery spots or streaks appear on the surface of concrete. This phenomenon is primarily caused by the movement of water through the concrete, which dissolves soluble salts that are present within the material. When the water reaches the surface and evaporates, it leaves behind these salts, creating the characteristic white deposits. Factors contributing to efflorescence include:

Water Movement: Water moving through the concrete can dissolve salts from within the concrete or from the ground beneath it. When this water reaches the surface and evaporates, the salts are left behind.

Salt Content: The presence of soluble salts in the concrete mix or in the surrounding environment can lead to efflorescence. Common salts include calcium hydroxide, which can react with carbon dioxide in the air to form calcium carbonate, creating white spots.

Porosity of the Concrete: More porous concrete allows easier passage of water, increasing the likelihood of efflorescence. Factors such as improper mixing, curing, or compaction can affect porosity.

Environmental Conditions: High humidity, rain, and other environmental factors that lead to water saturation of concrete can increase the risk of white spotting.

Methods to Minimize or Prevent Efflorescence

While efflorescence does not typically harm the structural integrity of the concrete, it can be aesthetically undesirable. To manage or prevent white spotting, several steps can be taken:

1. Use Low-Permeability Concrete:

Low-permeability concrete minimizes or prevents efflorescence by reducing the amount of water that can enter and move through the concrete. Efflorescence occurs when water carries soluble salts to the surface, where it evaporates and leaves behind white deposits. By making concrete less permeable, the movement of water and dissolved salts is restricted, thus preventing the conditions that cause efflorescence. Here's how low-permeability concrete achieves this:

- **Dense Microstructure:** Low-permeability concrete has a denser microstructure due to a well-graded mix, proper water-cement ratio, and thorough compaction. This density means there are fewer and smaller capillary pores for water to travel through.
- **Reduced Water-Cement Ratio:** By using a lower water-cement ratio, the concrete mixture becomes more compact and less porous. Excess water in the mix can create capillary channels as it evaporates, so limiting this water is crucial for reducing permeability.
- **Use of Supplementary Cementitious Materials (SCMs):** Materials like fly ash, slag, and silica fume are added to the concrete mix to improve its density and reduce permeability. These materials react with calcium hydroxide in the concrete to form additional cementitious compounds, filling in the pore spaces.

By implementing these strategies, low-permeability concrete effectively minimizes the pathways through which water and dissolved salts can travel. This reduction in water movement through the concrete significantly lowers the risk of efflorescence, maintaining both the aesthetic and functional qualities of the concrete structure.

2. Use Admixtures in the Concrete Mix:

- **Water-Reducing Admixtures** such as plasticizers and superplasticizers reduce the water content in the concrete mix without compromising workability, resulting in a denser, less porous concrete. Lower water content decreases the capillary channels through which water and dissolved salts can move, reducing the risk of efflorescence.
- **Hydrophobic Admixtures** create a hydrophobic effect within the concrete, repelling water and preventing it from penetrating the concrete. Reduced water ingress significantly lowers the potential for soluble salts to migrate to the surface.
- **Integral Waterproofing Admixtures** reduce the permeability of concrete by filling pores and capillary channels, or by forming a water-resistant gel within the concrete matrix. Enhanced resistance to water penetration helps prevent the formation and migration of efflorescence-causing salts.
- **Crystalline Admixtures** react with water and unhydrated cement particles to form insoluble crystals that fill capillary pores and micro-cracks in the concrete. The formation of crystals continues over time, improving the long-term durability and water resistance of the concrete.
- **Calcium Nitrate Admixtures:** Although primarily used to protect steel reinforcement, calcium nitrite can also reduce efflorescence by altering the chemistry of the concrete to reduce soluble salt formation. This provides a dual benefit of corrosion protection and reduced risk of efflorescence.

3. Sealants and Coatings:

Sealants and coatings that prevent or minimize efflorescence in concrete work by creating a barrier that reduces water penetration into the concrete. Common types of sealants and coatings that are used for this purpose include:

- **Silane and Siloxane Sealers:** Penetrating sealers that chemically bond with the concrete repel water by creating a hydrophobic surface, reducing water absorption and the risk of efflorescence. Best used on exterior surfaces where water exposure is significant.
- **Acrylic Sealers:** These form a thin, protective film on the surface of the concrete to provide a physical barrier to water penetration and enhance the appearance of the concrete. Suitable for both interior and exterior applications; available in water-based and solvent-based formulations.
- **Epoxy Coatings:** Create a strong, durable surface coating that is highly resistant to water and chemicals. Epoxy coatings completely seal the surface, preventing water from entering the concrete. Often used for industrial floors, garages, and other high-traffic areas.
- **Polyurethane Coatings:** These flexible and durable coatings, offer excellent resistance to water, sealing the surface to protect against water ingress. Ideal for areas that require a tough, long-lasting finish, such as warehouses and exterior concrete surfaces.
- **Silicate Sealers:** These are penetrating sealers that react with the concrete to form a dense, crystalline structure. They reduce the size of the pores in the concrete, minimizing water penetration and efflorescence. Best for basement walls, foundations, and other structures where deep penetration is needed.
- **Polyaspartic Coatings:** These are fast-curing, flexible, and extremely durable, providing a seamless barrier against water and other contaminants. Often used in commercial and industrial settings for floors and other surfaces that need quick return to service.

4. Proper Drainage:

Proper drainage is crucial in preventing or minimizing efflorescence in concrete by controlling the amount of water that comes into contact with and penetrates the concrete. Efflorescence occurs when water carrying soluble salts moves through the concrete and evaporates at the surface, leaving behind white salt deposits. Effective drainage helps mitigate this process in several ways:

- **Reduces Water Saturation:** Proper drainage systems ensure that water is efficiently diverted away from concrete surfaces. By minimizing the water that can come into contact with the concrete, the likelihood of water penetrating the concrete and dissolving salts is reduced.
- **Controls Hydrostatic Pressure:** Drainage systems alleviate hydrostatic pressure that builds up behind or beneath concrete structures, such as retaining walls, foundations, or slabs. Reduced hydrostatic pressure decreases the amount of water forced into the concrete, thereby lowering the potential for efflorescence.
- **Prevents Water Pooling:** Proper grading and drainage features, such as gutters, downspouts, and drainage pipes, prevent water from pooling around concrete surfaces. Standing water around concrete can seep into it over time, increasing the risk of efflorescence. By preventing pooling, drainage systems reduce this risk.
- **Promotes Rapid Drying:** Good drainage allows water to quickly move away from concrete surfaces, promoting faster drying times. Less water remaining on or near the concrete surface means there is less opportunity for water to penetrate and transport salts to the surface.

Sulfate Attack of Concrete

Chemical attacks on concrete refer to the deterioration and damage caused by various chemical substances that react with components of the concrete. These reactions can compromise the integrity, strength, and durability of concrete structures. One of the most common types of chemical attacks on concrete is sulfate attack.

Sulfate attack causes expansion and cracking in concrete due to the infiltration of SO_4 ions. As concrete cracks, its permeability increases, allowing water to penetrate more easily and accelerating the deterioration process.

Types of Sulfate Attack

Sulfate attack in concrete refers to the deterioration and damage of concrete structures caused by the reaction of sulfate ions (SO_4^{2-}) with components of the concrete, primarily the cement paste. This reaction leads to the formation of expansive products that cause internal pressure, resulting in cracking, spalling, and overall loss of structural integrity. Sulfate attack can significantly reduce the lifespan and durability of concrete structures. There are two main types of sulfate attack:

1. **External Sulfate Attack:**
   - Occurs when sulfate ions from external sources, such as soil, groundwater, seawater, or industrial effluents, penetrate into the concrete.
   - Common sources include gypsum, sodium sulfate, magnesium sulfate, and ammonium sulfate.
   - The sulfate ions react with the hydrated cement compounds, particularly calcium hydroxide and tricalcium aluminate (C_3A), forming gypsum ($CaSO_4 \cdot 2H_2O$) and ettringite ($3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$). These products have a larger volume than the original compounds, causing expansion and cracking.
2. **Internal Sulfate Attack (Delayed Ettringite Formation):**
   - Results from sulfate compounds present within the concrete mixture itself, typically due to the use of sulfate-bearing materials like certain types of aggregates or cement.
   - This type of attack often occurs at elevated temperatures, where ettringite formation is initially suppressed during the early hydration period and later forms as the concrete cools and becomes saturated with moisture.
   - Delayed formation of ettringite leads to internal expansion and cracking similar to external sulfate attack.

Effects of Sulfate Attack on Concrete:

- **Expansion and Cracking:** The reaction of sulfate ions with hydrated cement compounds, particularly calcium hydroxide and tricalcium aluminate (C_3A), leads to the formation of expansive products like gypsum and ettringite. These products increase in volume, causing internal stress and leading to cracking and spalling of the concrete surface.
- **Increased Permeability:** Cracking due to sulfate attack increases the permeability of the concrete, allowing more aggressive agents, such as water, chlorides, and additional sulfates, to penetrate deeper into the concrete. This worsens the deterioration process.
- **Loss of Strength:** The expansive forces generated by the formation of ettringite and gypsum can disrupt the concrete matrix, reducing the bond strength between the aggregate and the cement paste. This results in a loss of compressive and tensile strength of the concrete.
- **Spalling and Surface Damage:** The expansion and cracking often cause surface layers of the concrete to break off or spall, leading to rough and uneven surfaces. This not only affects the aesthetics but also exposes deeper layers of the concrete to further attack.
- **Disintegration of Concrete:** Severe sulfate attack can lead to complete disintegration of the concrete. The cohesive properties of the cement paste are compromised, causing the concrete to crumble and lose its structural integrity.

- **Reduction in Durability:** Overall, sulfate attack reduces the durability of concrete structures. The continuous expansion, cracking, and loss of material make the concrete more susceptible to other forms of deterioration, such as freeze-thaw cycles, chloride-induced corrosion, and mechanical wear.
- **Corrosion of Reinforcement:** Increased permeability and cracking due to sulfate attack can allow chlorides and moisture to reach the steel reinforcement within the concrete, leading to corrosion. Corroded steel expands, causing further internal pressure and exacerbating the cracking and spalling.
- **Aesthetic Degradation:** Sulfate attack often results in visible damage such as cracking, spalling, and surface discoloration, which negatively impacts the appearance of the concrete structure.

Prevention and Mitigation

Sulfate attack of concrete can be prevented or mitigated (lessened) through several measures designed to limit the exposure of concrete to sulfate ions and to enhance the concrete's resistance to such exposure. Here are three key strategies:

1. Use Sulfate-Resistant Cement:

- **Low-C_3A Cement:** Use cements with low tricalcium aluminate (C_3A) content, such as Type V Portland cement, which is specifically designed to resist sulfate attack.
- **Blended Cements:** Incorporate supplementary cementitious materials like fly ash, slag, or silica fume to reduce the permeability of the concrete and improve its sulfate resistance.

2. Optimize Concrete Mix Design:

- **Low Water-Cement Ratio:** Use a low water-cement ratio to reduce the porosity and permeability of the concrete, making it more difficult for sulfate ions to penetrate.
- **Proper Curing:** Ensure proper curing of concrete to achieve maximum hydration and strength, which enhances durability and resistance to chemical attack.
- **Quality Aggregates:** Use high-quality, non-reactive aggregates to minimize the potential for internal sulfate sources.

3. Environmental Control:

- **Soil Treatment:** Modify the surrounding soil to reduce sulfate concentrations or improve drainage to minimize contact with sulfate-laden water.
- **Proper Drainage:** Ensure proper drainage around concrete structures to prevent standing water and reduce exposure to sulfates.

Can Admixtures Help?

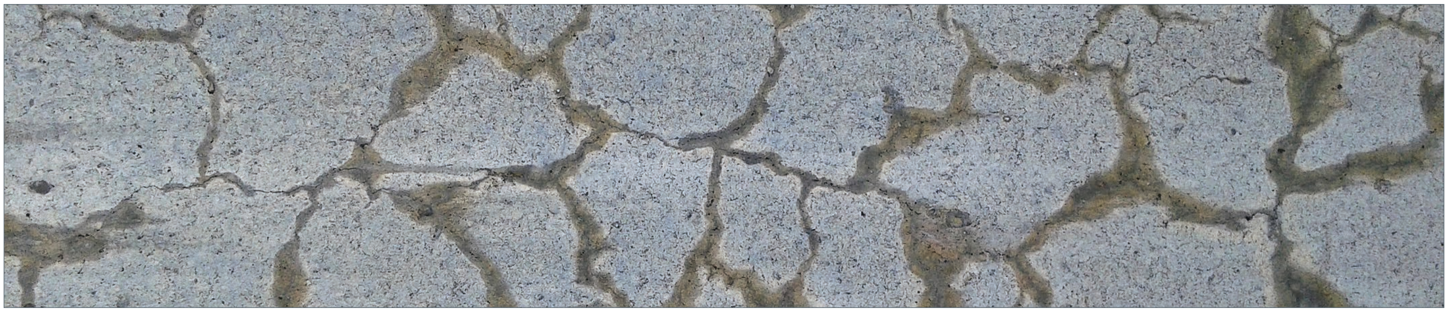
Admixtures can help prevent or mitigate sulfate attack on concrete. Many admixtures work by making the concrete denser and less permeable, which limits the ingress of sulfate ions and other aggressive agents. Some admixtures chemically alter the concrete to make it less reactive with sulfates. For example, pozzolanic materials consume calcium hydroxide, which would otherwise react with sulfates.

Strengthening the Matrix: By refining the microstructure and increasing the amount of C-S-H, admixtures strengthen the concrete matrix, making it more resistant to internal expansion and cracking caused by sulfate attack.

Table 1: Types of Admixtures and How They Contribute to Enhancing Sulfate Resistance:

FLY ASH	Reacts with calcium hydroxide in the cement paste to form additional calcium silicate hydrate (C-S-H), which densifies the concrete matrix and reduces permeability, making it more resistant to sulfate ingress.
SILICA FUME	Highly reactive pozzolan that significantly reduces the permeability of concrete and enhances its durability against sulfate attack.
SLAG CEMENT	Ground granulated blast-furnace slag (GGBFS) undergoes a pozzolanic reaction with calcium hydroxide (a product of Portland cement hydration) to form additional calcium silicate hydrate (C-S-H). This reaction reduces the amount of free calcium hydroxide, which is highly susceptible to sulfate attack, thus enhancing the sulfate resistance of the concrete.
WATER-REDUCING ADMIXTURES	These admixtures reduce the water content in the concrete mix without compromising workability, resulting in a lower water-cement ratio and a denser, less permeable concrete matrix.
SUPERPLASTICIZERS	High-range water reducers (superplasticizers) allow for even lower water-cement ratios, further improving concrete density and sulfate resistance.
AIR-ENTRAINING ADMIXTURES	While primarily used for improving freeze-thaw resistance, air-entraining admixtures can also enhance the durability of concrete by reducing permeability and providing space for expansive reactions to occur without causing damage.

Alkali-Silica Reactivity (ASR) in Concrete



Alkali-Silica Reactivity, (also referred to as ASR), in concrete is a chemical reaction that occurs between the alkali hydroxides in Portland cement and reactive forms of silica found in some aggregates. This reaction produces an expansive gel, which absorbs water and swells, leading to various detrimental effects on the concrete.

Key Aspects of Alkali-Silica Reactivity

Reaction Process:

The alkali hydroxides (primarily sodium and potassium hydroxides) in the cement react with amorphous or poorly crystalline silica present in certain aggregates. This reaction forms an alkali-silica gel, which has a high affinity for moisture.

Expansion and Cracking:

The gel absorbs water and expands, creating internal pressures within the concrete. This expansion leads to cracking, which can propagate throughout the concrete, reducing its structural integrity.

Symptoms and Effects:

- **Cracking:** Visible cracking patterns, often in a network or map-like pattern, on the surface of the concrete.
- **Expansion:** The overall expansion of the concrete element, which can cause misalignment and structural issues.
- **Decreased Durability:** Increased permeability due to cracking, which allows other aggressive agents like water and chlorides to penetrate more easily, leading to further deterioration.
- **Spalling:** Pieces of concrete may break off from the surface.

Figure 1: Effects of ASR on a Concrete Structure

Can Alkali-Silica Reactivity Be Predicted?

Alkali-Silica Reactivity (ASR) in concrete can be predicted through various testing methods and evaluations. Here are some approaches used to predict ASR:

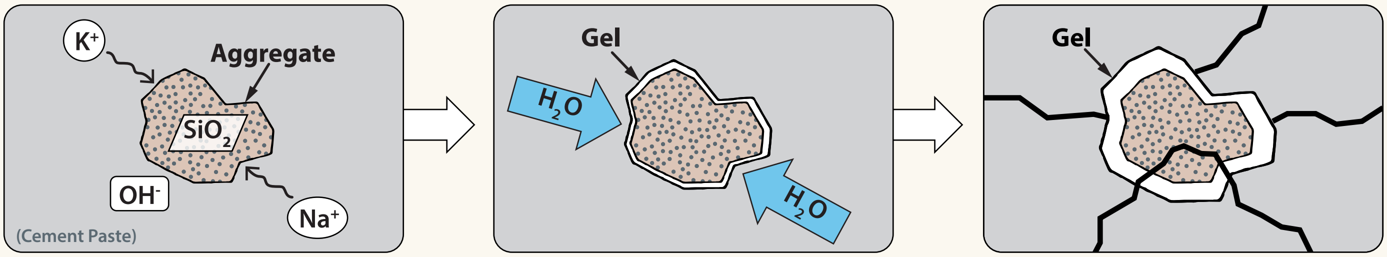
Petrographic Analysis:

- **Microscopic Examination:** Evaluates the mineral composition and texture of aggregates to identify the presence of reactive silica.
- **Petrographic Reports:** These detailed reports provide insights into the potential reactivity of aggregate based on its mineralogy.

Chemical Testing:

- **Alkali-Silica Reactivity (ASTM C289):** A chemical test that determines the potential reactivity of aggregates by measuring the amount of silica dissolved in an alkaline solution.
- **Mortar-Bar Test (ASTM C1260):** A rapid test that involves casting mortar bars with the aggregate in question and storing them in a high-alkali environment. The expansion of the bars is measured over time to assess reactivity.

Figure 2: The Process of Alkali-Silica Reaction in Concrete



1. Alkali hydroxides (primarily sodium and potassium hydroxides) in the cement react with unstable silica present in certain aggregates.

K^+ represents positively charged potassium ions

OH^- represents negatively charged hydroxide ions.

Na^+ represents positively charged sodium ions.

SiO_2 represents silicon dioxide.

2. This reaction forms an alkali-silica gel around the aggregate. This gel has a high affinity for moisture. The gel absorbs water and expands, creating internal pressures within the concrete.

3. This expansion leads to cracking, which can propagate throughout the concrete, reducing its structural integrity.

Accelerated Mortar Bar Test (ASTM C1567):

- **Modified Test:** Similar to ASTM C1260, but uses additional supplementary cementitious materials like fly ash or slag to determine their effectiveness in mitigating ASR.

Concrete Prism Test (ASTM C1293):

- **Long-Term Test:** Involves casting concrete prisms with the aggregate in question and storing them under controlled conditions. The expansion of the prisms is measured over a period of one to two years to assess reactivity.

Field Performance History:

- **Historical Data:** Reviewing the performance history of concrete structures using the same or similar aggregates in similar environmental conditions can provide valuable insights into potential ASR issues.

Alkali Content Analysis:

- **Cement Alkali Content:** Analyzing alkali content in the cement to ensure it is within acceptable limits to reduce the risk of ASR.
- **Alkali Loading:** Calculating the total alkali loading in the concrete mix, considering both the cement and any supplementary cementitious materials.

By employing these methods, engineers and researchers can predict the potential for ASR in concrete and take appropriate measures to mitigate its effects. This proactive approach is crucial in preventing ASR-related damage and ensuring the longevity and durability of concrete structures.

Prevention and Mitigation

Alkali-Silica Reactivity in concrete can be prevented or mitigated (lessened) through several strategies. These methods aim to minimize the conditions that lead to ASR or to counteract its effects if reactive aggregates are used.

1. **Use Low-Alkali Cement:** Using cement with a low alkali content (typically less than 0.60% Na_2O equivalent) reduces the availability of alkalis that contribute to ASR.
2. **Blended Cements:** Using blended cements containing pozzolans or slag can also help reduce the effective alkali content.
3. **Supplementary Cementitious Materials (SCMs):** Adding SCMs such as fly ash, silica fume, or slag to the concrete mix can mitigate ASR. These materials react with the alkalis, reducing their availability to react with the silica in the aggregates. SCMs participate in pozzolanic reactions that consume alkalis, thereby lowering the potential for ASR.
4. **Chemical Admixtures, Lithium-Based:** Adding lithium compounds (e.g., lithium nitrate) to the concrete mix can help mitigate ASR by preventing the formation of expansive ASR gel.

Essential Tips for Using Concrete in Cold Weather

Placing concrete in cold weather presents unique challenges. But, with the right preparations, you can ensure a durable and strong result. When temperatures drop, concrete's curing process slows, which can compromise its strength and longevity if not properly managed. This reaction slows significantly when temperatures fall below 50°F and nearly stops around freezing. If concrete freezes before it gains enough strength, the expanding water inside can cause cracking and structural damage. The goal in cold weather is to maintain the concrete's internal temperature and optimize conditions for curing.

1. The Role of Heated Mix Water

Heated mix water is one of the most effective ways to maintain the proper temperature of concrete during cold weather. By heating the water used in the mix, you can:

- **Start with a Warmer Mix:** Heated water raises the overall temperature of the concrete, helping to counteract heat loss during transportation and placement.
- **Accelerate Hydration:** Warm concrete cures faster, reducing the risk of freezing before it reaches critical strength (approximately 500 psi, usually within 24 hours).
- **Improve Workability:** A warm mix remains more pliable during placement, making it easier to work with.

How Hot Should the Water Be?

The temperature of the heated water depends on the ambient conditions and the desired concrete temperature. Producers must be cautious, as excessively hot water (above 140°F) can cause flash setting, which is rapid hardening of the mix. Experienced concrete producers like Triangle Ready Mix will ensure that heated mix water is used at the proper temperature.

2. Admixtures for Cold Weather Concrete

Admixtures are essential for optimizing concrete performance in cold conditions. Two common types used during cold weather are accelerators and air-entraining admixtures.

Accelerators

Accelerators speed up the hydration process, allowing concrete to gain strength more quickly. This is particularly important in cold weather, where the curing process naturally slows down.

- **Calcium Chloride Accelerators:** These are cost-effective and commonly used. However, they may not be suitable for projects involving steel reinforcement, as calcium chloride can promote corrosion.
- **Non-Chloride Accelerators:** A safer choice for reinforced concrete, providing similar benefits without the risk of corrosion.

Benefits of accelerators include:

1. Reduced time needed for initial set.
2. Faster strength gain, allowing earlier removal of forms or blankets.
3. Lower risk of damage from freezing temperatures.

Air-Entraining Admixtures

Air-entraining admixtures introduce tiny, evenly distributed air bubbles into the concrete. These bubbles improve the concrete's resistance to freeze-thaw cycles by providing space for water to expand as it freezes.

- Air-entrained concrete is especially important for outdoor surfaces like sidewalks, driveways, and bridges.
- It also enhances workability, which is helpful in cold weather when the mix can become stiffer.

3. The Importance of Low Water-Cement Ratio Mixes

A low water-cement ratio is critical for durable concrete, especially in cold weather. The water-cement ratio refers to the amount of water compared to the cement in the mix. Lower ratios result in stronger and less permeable concrete.

Benefits in Cold Weather:

- **Reduced Freezing Risk:** Less water in the mix means less water that could potentially freeze and cause cracking.
- **Improved Durability:** Low water-cement ratios produce denser concrete, which is better able to resist the damaging effects of freeze-thaw cycles.
- **Faster Strength Gain:** Less water means the concrete reaches its intended strength more quickly.

How to Achieve a Low Water-Cement Ratio:

- Use plasticizers or superplasticizers to improve workability without adding extra water.
- Be precise during mixing to avoid over-watering.

Key Takeaways

When it comes to ordering and placing concrete in cold weather, success depends on maintaining the right temperature and optimizing curing conditions. Here's how Triangle Ready Mix can help you get the job done right:

1. **Order heated mix water** to ensure your concrete maintains the necessary temperature for proper curing, even in the coldest conditions. At Triangle Ready Mix, we can provide heated water to give your mix the best start.
2. **Specify admixtures** like accelerators for faster curing or air-entraining admixtures for superior freeze-thaw resistance. Our expert team can guide you in selecting the right combination to meet the unique demands of your project.
3. **Request a low water-cement ratio** to reduce freezing risks and improve strength. Triangle Ready Mix ensures precision in every batch, delivering a consistent and high-quality mix that performs under pressure.

Triangle Ready Mix is experienced at producing concrete during cold weather and provides several important resources to help with your cold weather concrete project. From heated mix water to expertly tailored admixtures, we ensure your concrete is prepared to perform, even in challenging conditions. Our precision batching process guarantees a consistent, high-quality mix with the right water-cement ratio to reduce freezing risks and enhance durability — and does so with far more precision and consistency than most other concrete batch plants. With Triangle Ready Mix, you get more than concrete. You get the expertise and reliability needed to pour with confidence, no matter the temperature.

Placing Concrete During Cold Weather

How does cold weather affect concrete production and placement?

During cold weather, when the average daily temperature stays under 40°F for over three consecutive days, it's important to take extra care when working with concrete. Special care should be taken when placing it, finishing it and letting it set, to mitigate the impact of cold weather. Given the swift changes in weather that often occur in winter, adherence to sound concrete practices and meticulous planning becomes crucial. To work with concrete in cold weather, it's important to know what factors affect concrete properties.

When concrete is still wet and moldable (we call this the "plastic state"), it can freeze if the temperature drops below about 25°F. If this happens, the concrete's strength could drop by more than 50%, and it won't last as long. To prevent freezing, it's crucial to keep the concrete protected until it's strong enough, with a minimum compressive strength of 500 psi. This usually takes about two days after it's placed and maintained at a temperature of 50°F.

Low concrete temperature has a significant impact on the speed of cement hydration, leading to a slower setting and a slower rate of strength gain. It's helpful to follow this general guideline: a decrease in concrete temperature of **20°F** will roughly **double** the time it takes to set. When planning construction operations, such as removal of forms, it's essential to consider the slower setting and strength gain to ensure everything is properly scheduled.

Concrete that is in contact with water and exposed to cycles of freezing and thawing should be air-entrained. Even if the freezing cycles only occur during construction, the concrete should be air-entrained. Freshly poured concrete is saturated with water and should be protected from cycles of freezing and thawing until it has gained a compressive strength of at least 3500 psi.

Cement hydration is a chemical reaction that generates heat. To keep the concrete curing well, it's important to keep this heat. Insulate freshly poured concrete to maintain good curing temperatures. Avoid large temperature differences between the surface and the inside of the concrete – if it goes beyond 35°F, it might lead to cracking. When removing insulation or protective measures, do it gradually to prevent thermal shock.

Placing concrete during cold weather

Recommended concrete temperatures at the time of placement are shown below, in **Table 1.** The ready-mixed concrete producer has the ability to regulate the temperature of the concrete by heating the mix water and/or the aggregates. They can then supply concrete in compliance with the guidelines outlined in ASTM C 94.

Concrete temperature in cold weather should not surpass these recommended temperatures by more than 20°F. When concrete is at a higher temperature, it requires more mixing water, experiences a higher rate of slump loss, and becomes more prone to cracking. The act of placing concrete in cold weather offers the chance for superior quality, as a cooler initial concrete temperature generally leads to higher ultimate strength.

Table 1: Recommended Concrete Temperature at Time of Placement

Section Size, minimum dimension	Concrete Temperature as Placed
Less than 12 inches	**55°F**
12 – 36 inches	**50°F**
36 – 72 inches	**45°F**

The colder temperatures in winter typically result in a slower setting time and delayed strength gain for concrete. This, in turn, leads to postponed finishing operations and removal of forms. To counteract this, chemical admixtures and adjustments to the concrete mixture can be employed to hasten the setting time and strength gain. In winter, accelerating chemical admixtures, which adhere to ASTM C 494—Types C (accelerating) and E (water-reducing and accelerating), are commonly utilized.

While calcium chloride serves as a common and effective accelerating admixture, it should not exceed a maximum dosage of 2% by weight of cement. For prestressed concrete or situations where corrosion of steel reinforcement or metal in contact with concrete is a concern, non-chloride, non-corrosive accelerators are recommended. It's important to note that while accelerating admixtures speed up the setting and strength gain, they do not prevent concrete from freezing, and their use does not exempt the requirements for concrete temperature, appropriate curing, and protection from freezing.

To accelerate the setting time and strength gain of the concrete, it is possible to increase the quantity of Portland cement or opt for a Type III cement known for its high early strength. In cold weather, it might be feasible to decrease the relative percentage of fly ash or ground slag in the cementitious material component, although this adjustment might pose challenges if the mixture was originally designed for durability. The optimal decision should seek a cost-effective solution while mitigating the effects on the final properties of the concrete.

Concrete should be placed with the lowest practical slump to minimize bleeding and setting time. The addition of 1 to 2 gallons of water per cubic yard will extend the setting time by ½ to 2 hours. Prolonged setting times will extend the bleeding duration. Do not initiate finishing operations while the concrete is still bleeding, as it will result in a compromised and weakened surface.

Before pouring concrete, it's crucial to make adequate preparations. Ensure that snow, ice, and frost are cleared, and that the temperature of surfaces and metallic embedments in contact with concrete is above freezing. This may involve insulating or heating subgrades and contact surfaces before placement.

Have all the necessary materials and equipment ready to safeguard the concrete during and after placement, preventing early-age freezing and retaining the heat generated by cement hydration. Common measures include using insulated blankets, tarps, and straw covered with plastic sheets. Depending on ambient conditions, additional protection may require enclosures and insulated forms. Pay special attention to corners and edges, as they are particularly susceptible to heat loss.

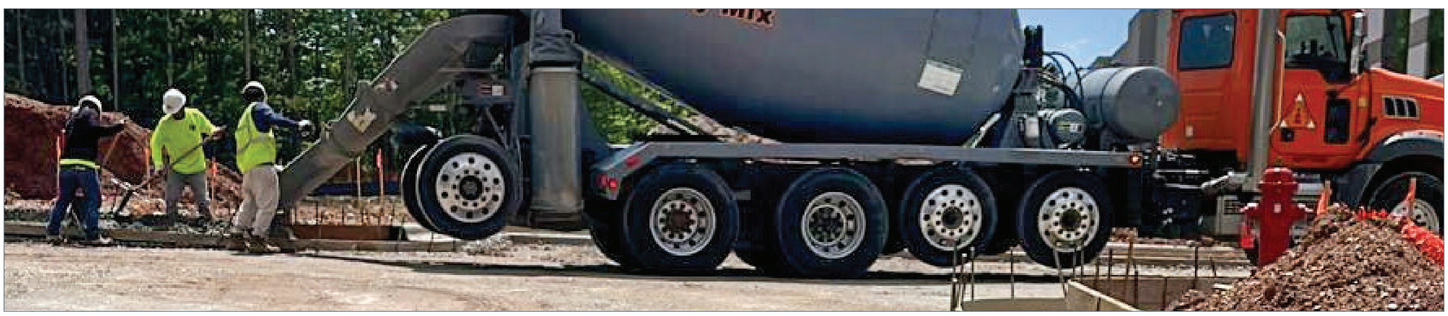
For safety reasons, fossil-fueled heaters in enclosed spaces should be vented. This venting also helps prevent the carbonation of newly placed concrete surfaces, which can lead to dusting.

To prevent plastic shrinkage cracks, it's essential to avoid allowing the concrete surface to dry out while it's still in a plastic state. Subsequently, proper curing of the concrete is crucial. Avoid water curing when freezing temperatures are anticipated, and instead opt for membrane-forming curing compounds or impervious paper and plastic sheets for concrete slabs.

Forming materials, excluding metals, play a crucial role in retaining and evenly distributing heat, offering sufficient protection in moderately cold weather. In extremely cold temperatures, it is advisable to utilize insulating blankets or insulated forms, particularly for thin sections. The removal of forms should be delayed for a period ranging from 1 to 7 days, taking into account the setting characteristics, ambient conditions, and anticipated structural loading. To assess the in-place concrete strength before removing forms or applying loads, either field-cured cylinders or nondestructive methods should be employed. It's important to note that field-cured cylinders are not suitable for quality assurance purposes.

Extra attention is essential when dealing with concrete test specimens used for accepting concrete. Cylinders should be stored in insulated boxes, possibly equipped with temperature controls, to ensure they are cured within the range of 60°F to 80°F for the initial 24 to 48 hours. It is recommended to place a minimum/maximum thermometer in the curing box to keep a temperature record.

Concrete Curing in Hot Weather



How does hot weather affect concrete curing?

Curing is the maintaining of adequate moisture content and temperature in concrete at early stages, so that it may develop properties like its desired strength and durability. Curing begins immediately after placement and finishing. The availability of sufficient moisture is crucial for the chemical reaction called hydration in concrete's cementitious materials. This is essential for producing a high-quality product. Insufficient moisture due to drying can hinder this reaction, preventing the concrete from achieving its desired properties.

Temperature plays a vital role in the curing process. Higher temperatures accelerate hydration, and consequently, strength development. Concrete temperature should be maintained above 50°F to ensure an adequate rate of strength gain. Additionally, a uniform temperature throughout the concrete section during the strength development phase helps prevent thermal cracking.

In the case of exposed concrete, factors like relative humidity and wind conditions become significant as they influence the rate of moisture evaporation from the concrete surface. Failure to address these factors properly could lead to issues such as cracking, compromised surface quality, and reduced durability. Implementing protective measures to control moisture evaporation from the concrete surface before it sets is essential in preventing plastic shrinkage cracking.

Why take hot weather into consideration?

1. Predictable Strength Gain

Ensuring predictable strength gain is essential in concrete construction. Studies reveal that concrete exposed to dry conditions may experience up to a 50 percent reduction in its potential strength compared to adequately moist-cured concrete. High-temperature placements might result in rapid early strength, but it could lead to diminished later strengths. Conversely, concrete placed in cold weather will require more time to gain strength, potentially delaying form removal and subsequent construction.

2. Improved Durability

Proper curing significantly enhances concrete's durability. Well-cured concrete exhibits improved surface hardness, making it more resistant to wear and abrasion. Additionally, curing renders concrete more impervious to water, safeguarding it against the infiltration of moisture and water-borne chemicals. This increased durability and protection contribute to a longer service life.

3. Better Serviceablility and Appearance

Optimal curing practices not only impact strength and durability, but also affect the serviceability and appearance of concrete. Inadequately cured concrete can result in a soft surface with diminished resistance to wear and abrasion. However, with proper curing, undesirable concrete surface effects like crazing, dusting, and scaling are significantly reduced.

How to manage curing of concrete in hot weather

Moisture Requirements

To prevent plastic shrinkage cracking, it is crucial to shield concrete from moisture loss until the final finishing stage. This can be achieved by employing appropriate methods such as wind breaks, fogger sprays, or misters. Once the final finishing is complete, the concrete surface should be consistently kept wet or sealed to avoid evaporation for at least several days post-finishing.

Methods for Keeping the Concrete Wet:

1. **Burlap or Cotton Mats.** To ensure proper curing, burlap or cotton mats and rugs can be employed along with a soaker hose or sprinkler. It is crucial to prevent the coverings from drying out and absorbing water from the concrete. Care should be taken to overlap the edges of the materials and weigh them down securely to prevent displacement.
2. **Straw, Sprinkled with Water.** For effective curing, straw can be utilized by regularly sprinkling it with water. However, caution is necessary as straw is prone to being blown away by the wind and can pose a fire hazard if it dries out. A layer of straw approximately 6 inches thick should be applied and covered with a tarp for added protection.
3. **Damp Earth, Sand or Sawdust.** For curing flatwork, such as floors, damp earth, sand, or sawdust can be effectively employed. However, it is essential to ensure that these materials are free from any organic or iron-staining contaminants.
4. **Sprinkling.** Continuous sprinkling can be a suitable curing method, especially if the air temperature remains well above freezing. It is crucial to prevent the concrete from drying out between soakings, as this practice of alternate wetting and drying is not considered adequate for proper curing.
5. **Ponding.** An excellent method for curing concrete slabs is through ponding, which involves applying a layer of water over the surface. To ensure effectiveness, the water temperature should not be more than 20°F cooler than the concrete, and the dike surrounding the pond must be secure to prevent leaks.

Types of Moisture Retaining Materials:

1. **Liquid Membrane Curing Compounds.** Liquid membrane-forming curing compounds must adhere to ASTM C 309 standards. These compounds should be applied to the concrete surface approximately one hour after finishing. Avoid applying them to concrete that is still bleeding or shows a visible water sheen on the surface. While a clear liquid compound may be used, opting for a white pigment offers reflective properties and enables visual inspection of coverage. A single coat may suffice, but if possible, applying a second coat at right angles to the first is recommended for uniform coverage. For concrete surfaces intended to be painted or covered with vinyl or ceramic tiles, it's essential to use a non-reactive liquid compound that won't interfere with the paint or adhesives. Alternatively, a compound that can be easily brushed or washed off should be utilized.
2. **Plastic Sheets.** Plastic sheets are a viable option for curing concrete and are available in clear, white (reflective), or pigmented variations. The plastic used should comply with ASTM C 171 standards and be at least 4 mils thick, preferably reinforced with glass fibers. In colder ambient temperatures below 60°F, dark-colored sheets are recommended, while reflective sheets should be used when temperatures exceed 85°F. Promptly lay the plastic in direct contact with the concrete surface without causing any damage to it. Ensure that the edges of the sheets overlap, and securely fasten them with waterproof tape. Weigh them down to prevent wind from getting underneath. Be cautious with the application of plastic, as it may create dark streaks on the concrete wherever there are wrinkles. Thus, it should not be used on concrete surfaces where appearance is a significant consideration.
3. **Waterproof Paper.** Waterproof paper serves a similar purpose to plastic sheeting but without causing any damage to the concrete surface. Typically, it consists of two layers of kraft paper cemented together and reinforced with fiber. It is important to ensure that the waterproof paper conforms to ASTM C 171 standards.

Be aware that products marketed as evaporation retardants are specifically intended to decrease the rate of evaporation before the concrete sets, helping to prevent plastic shrinkage cracking. These materials should **not** be employed for the final curing process.

Temperature Control

In cold weather conditions, it is crucial to control the cooling rate of concrete, ensuring it does not exceed 5°F per hour during the initial 24 hours. To prevent freezing, concrete should be shielded until it attains a compressive strength of at least 500 psi, utilizing insulating materials. When freezing temperatures are expected, curing methods that retain moisture are preferred over wet curing. Exercise caution to avoid rapid temperature fluctuations once the protective measures are removed. See **Table 1**.

In hot weather, you must be mindful of higher initial curing temperatures. This can lead to rapid early strength gain, but may result in lower final strength. To achieve lower curing temperatures in hot weather, water curing and sprinkling techniques are viable options. Protect concrete from day and night temperature extremes that could lead to cooling faster than 5°F per hour during the first 24 hours.

Table 1: Sample Minimum Curing Period to Achieve 50% of Specified Strength*

Type I Cement	Type II Cement	Type III Cement
Temperature: 50 degrees F		
6 Days	**9 Days**	**3 Days**
Temperature: 70 degrees F		
4 Days	**6 Days**	**3 Days**
**Values are approximate and based on cylinder strength tests.*		

Glossary of Ready Mixed Concrete Terms

For general educational purposes, Triangle Ready Mix presents this glossary of terms that are used in the ready-mixed concrete industry. We hope that readers may find it informative and useful in learning more about ready-mixed concrete.

– A –

Accelerator A chemical which, when added to concrete, shortens the time of set and increases the early stages of hardening and strength development.

Admixture A material other than water, aggregates or hydraulic cement used as an ingredient of concrete. Most commonly used admixtures are chemical solutions that are carefully metered into concrete batches to lend or enhance a specific property of the concrete.

Agent A general term for a material that may be used either as an addition to cement or an admixture in concrete, for example, air-entraining agent. Sometimes called an additive.

Aggregate Granular material such as sand, gravel, or crushed stone which, when blended with cement & water, makes concrete.

Air Content The volume of the air voids in concrete, expressed as a percentage of total volume of the concrete.

Air-Entraining Agent An admixture which causes microscopic air bubbles to be incorporated in the concrete during mixing. Usually to increase its workability and freeze/thaw resistance.

American Concrete Institute (ACI) An organization responsible for writing and publishing codes and standards and guidance documents for concrete construction.

American Society for Testing and Materials (ASTM) An organization that writes and publishes test methods and standard specifications for a wide variety of materials.

Axle Load The portion of the gross weight of a vehicle transmitted to a roadway through the wheels supporting a given axle.

– B –

Bag of Cement A quantity of Portland cement equivalent to a loose cubic foot of the bulk material; Equals 94 lb. (42.6 kg) in the United States. Also called Sack of Cement.

Barrel of Cement A quantity of Portland cement equal to 4 bags or 376 lb. (170 kg).

Batch The materials in or the concrete produced from a single mixing cycle or load of concrete.

Batch Plant The equipment required to batch & mix concrete, including bins, silos, hoppers, conveyors, weigh-batchers, etc.

Bleeding Movement of mixing water to the surface of freshly placed concrete caused by the settling of solid materials.

Bonding Agent A coating applied to an existing surface to create a bond between it and a succeeding layer, for example, between a concrete subsurface and a terrazzo topping.

Broom Finish The surface texture obtained by stroking a broom over freshly placed concrete.

Buggy A wheeled hand or motor-driven cart, usually rubber tired, for transporting small quantities of concrete from hoppers or mixers to forms. Also referred to as a Georgia Buggy.

Bull Float A tool with a large, flat rectangular piece of aluminum, magnesium, or wood with a long handle. It is often used to smooth large areas of a slab immediately after the concrete is struck off with a screed.

Bush-Hammer Finish A decorative finish on concrete obtained by chipping off the surface mortar.

– C –

Cement See Hydraulic Cement and Portland Cement.

Cement Balls Tennis ball to volleyball-sized lumps of cement, sand and coarse aggregate that form in the truck drum during loading and mixing. Cement balls generally break free from the head of the drum and roll down the chute when concrete is discharged.

Cement Content Quantity of cement contained in a cubic yard or cubic meter of concrete, expressed as a weight. For example, 500 lb. per yd3 or 297 kg per m3.

Cement, Expansive A special cement, which causes concrete to expand slightly, rather than shrink, at an early age.

Cement, High-Early Strength Cement characterized by producing higher early strength in concrete than regular cement. Called Type Ill in the United States.

Central Mixed Concrete Concrete completely mixed in a stationary mixer and then transported to the jobsite.

Chute A rounded, sloping trough or tube for moving concrete from a higher to a lower point.

Compressive Strength The measured maximum resistance of a concrete specimen to compressive loading expressed in pound per square inch (psi). In the metric system Mega Pascal (MPa) are used to express compressive strength. A typical 6 inch (150 mm) diameter concrete cylinder, equivalent to roughly 3000 to 6000 psi (21 to 41 MPa), will support a load of 40 to 80 tons (36 to 72 metric tons).

Concrete A heavy, versatile building material made from combining coarse and fine aggregate, hydraulic cement and water.

Concrete, Lightweight Concrete made with lightweight aggregates, typically weighing 75 – 80% as much as normal weight concrete.

Concrete, Plain Concrete without any steel reinforcing bars.

Concrete Plant Manufacturers Bureau (CPMB) An organization of concrete plant manufacturers that publishes standards for concrete plants. Most concrete plants have a CPMB rating plate showing its maximum rated load size.

Concrete Pump A machine which conveys concrete to the point of placement via a pipeline and/or hose.

Concrete, Reinforced Concrete with embedded steel reinforcing bars

Confined Space A space that is: (1) difficult to enter or exit, (2) not designed for people to stay in, and (3) has certain hazards. A truck mixer drum is a confined space.

Construction Joint A joint where two adjacent placements of concrete meet. The joint may be keyed, bonded or reinforced.

Contraction Joint A formed, tooled or sawed groove in a concrete structure, floor slab, or pavement to regulate the location of cracks in the concrete.

Conveyor A continuous belt for moving materials.

Core Test A compression test on a concrete sample drilled from hardened concrete.

Corrosion Destruction, or deterioration of concrete reinforcement by chemical, electrochemical or electrolytic reaction. Often results in the rusting/deterioration of reinforcing steel and frequently cause by from de-icing salt applied to the concrete or salts from seawater in a marine environment.

Crack A complete or incomplete separation of the concrete into two or more parts caused by breaking or fracturing.

Craze Cracks Fine, shallow, random cracks or fissures in a concrete surface.

Crazing The development of craze cracks, or the pattern of craze cracks in a concrete surface.

Cubic Meter Unit of measure in the metric system. Equal to 1.3 cubic yards. Written as m3.

Cubic Yard Unit of measure of concrete volume in the USA. Written as cu. yd. or yd3. Equal to 27 cubic feet or approx. 0.76 m3

Curing The maintenance of favorable moisture and temperature conditions for freshly placed concrete during its early stages so that the concrete can develop strength and other properties.

Cylinder, Concrete A strength test specimen. Molded by placing concrete in a plastic, metal, or cardboard mold, which is usually two times its diameter in height. In the United States, 6 x 12 inch (150 x 300 mm) or 4 x 8 inch (100 x 200 mm) are the standard test cylinder size.

– D –

Darby A hand-held straightedge, 3 to 8 ft. (1 to 2.5 m) long, used to smooth and level concrete in the early stage of finishing.

Drum Speed (rpm) The rate of rotation of the mixer drum when used for charging, mixing, agitating or discharging concrete. Recommended drum speeds must be shown on the manufacturer's plate.

Drying Shrinkage Contraction caused by moisture loss from hardened concrete sometimes resulting in cracks in the concrete occurring days, weeks, or months after placement.

Dusting The appearance of powdered material at the surface of hardened concrete.

– E –

Early Strength The strength of concrete as measured in the first three days or earlier after placement.

Efflorescence A deposit of salts (usually white compounds) formed on a hardened concrete surface.

Entrained Air Microscopic air bubbles intentionally incorporated in concrete (using an admixture) during mixing to improve freeze/thaw durability and workability.

Entrapped Air Air voids in concrete which are not purposely entrained. Entrapped air voids are larger than entrained air bubbles and offer little protection from freeze/thaw cycles. They often result from incomplete vibration or compaction.

Expansion Joint A separation between pavement slabs on grade, or between adjoining parts of a structure that to allow room for the concrete to move or expand. Usually filled with a compressible material.

– F –

False Set Premature rapid stiffening of fresh concrete. False-setting concrete can usually be remixed without additional water to become workable again. See flash set.

Field-Cured Cylinder Test cylinders cured in the same way as the concrete in the forms to indicate when the forms may be removed, when construction may continue or when the structure may be put in service.

Final Set A degree of stiffening of concrete after initial set, such that it will support a weight to an established level. See initial set.

Finishing The process of leveling, smoothing, compacting, and otherwise treating the surface of fresh concrete.

Flash Set Premature rapid stiffening of fresh concrete. The concrete usually requires remixing with additional water to become workable again. See false set.

Flexural Strength The ability of concrete to withstand bending. Measured by breaking a test beam molded from the concrete.

Float A small, handheld tool, made of wood, aluminum or magnesium, used in finishing after placement and strike off of a fresh concrete surface.

Fly Ash The fine ash resulting from burning coal in electric utility plants. Used as a mineral admixture or pozzolan in concrete. See pozzolan.

– G –

Georgia Buggy A wheeled hand or motor-driven cart, usually rubber tired, for transporting small quantities of concrete from hoppers or mixers to forms.

Groover Hand tool used to form grooves or joints in concrete slabs to control the location of cracks. Also called a jointing tool.

Gross Vehicle Weight The total weight of a vehicle, e.g., the empty weight of a vehicle plus the weight of the payload.

Grout Pourable mix of cement & water, with or without aggregates. Used to fill cracks & voids or to prime concrete pumps.

– H –

Hairline Cracks Small, barely visible cracks in a concrete surface. See craze cracks.

Hardener A chemical applied to concrete floors to reduce wear and/or dusting.

Heavyweight Aggregate Aggregate of high density, such as iron or steel shot, used for making heavyweight concrete.

High-Strength Concrete Concrete with a 28-day design strength of 6000 psi (41 MPa} or greater.

High-Range-Water-Reducing Admixture A water reducing admixture that markedly increases the slump of fresh concrete and greatly enhances its flowability. Also called a superplasticizer.

High-Early-Strength Concrete Concrete made with a special cement(s) or admixture(s) that reaches a specified strength at an earlier age than normal concrete.

Hydration The chemical reaction between hydraulic cement and water.

Hopper A funnel-shape box or tank from which or through which material can be discharged evenly.

Hydraulic Cement A cement that sets and hardens via a chemical reaction with water, such as portland cement.

– I –

Initial Set A degree of stiffening of concrete, less than final set, such that it will support a weight to an established level, e.g., the weight of a finisher standing on a concrete slab. See final set.

– J –

Joint A physical separation or break in cast-in-place concrete.

– L –

Lightweight Aggregates Aggregate of low density such as expanded clay or shale, slag, pumice, etc. Used for making lightweight concrete

Lock Out Mechanically and/or electronically disabling a piece of equipment so that it cannot start or become energized. See, also, tag out.

– M –

Material Safety Data Sheet (MSDS) A document providing information on a product's potential safety or environmental hazards and precautionary measures for those who use the product. See SDS

Mineral Admixture A fine powdered material such as fly ash or slag cement which may be used to improve the workability, strength or durability characteristics of concrete, also called supplementary cementing material. See pozzolan.

Mixer Capacity The volume of concrete permitted to be mixed or carried in a truck mixer.

Mortar A mixture consisting of cement, water and fine aggregate.

– N –

National Ready Mixed Concrete Association (NRMCA) The national trade association in the US for ready mixed concrete producers, dedicated to advocacy, promotion, research, education and training.

– P –

Paste The portion of concrete consisting of cement and water.

Peeling Thin flakes of mortar breaking away from a concrete surface. See scaling.

Plastic Shrinkage Cracks Cracks which appear in fresh concrete soon after placing and finishing while the concrete is still plastic.

Preventive Maintenance (PM) Scheduled, periodic vehicle maintenance that follows a prescribed routine. Preventive maintenance includes inspecting, adjusting, testing, clamping, tightening, cleaning, draining, flushing, adding fluids and lubricants and replacing filters.

Portland Cement General, all-purpose, hydraulic cement. Manufactured by heating several minerals together in a large kiln and grinding the resultant cement clinker into a fine powder. The active ingredient in concrete that causes it to set and gain strength.

Pozzolan Naturally occurring or man-made materials which chemically react in concrete to form compounds with some cementing properties. A pozzolan, such as fly ash, is sometimes called a mineral admixture.

– R –

Rebound Hammer A non-destructive testing device used to quickly estimate the in-place compressive strength of hardened concrete.

Reinforcement Steel bars or wire mesh used in concrete to increase the load carrying capacity of a structure and/or to prevent cracks from widening.

Retarder An admixture which delays the setting time of concrete. Also called a set-retarder.

– S –

Sand Streaks A streak of exposed sand in a formed concrete surface, often due to inadequate mixing of the concrete

Scaling Flaking or peeling of the top surface of hardened concrete. See peeling.

Screed A tool, sometimes a long board, used for striking off the concrete surface.

Sedimentation Pit (or pond) A washout pit or series of pits, often with separate chambers or basins, designed to allow solids to settle out of concrete wash water. Sedimentation pits may be concrete lined structures or earthen ponds.

Segregation Separation of the coarse aggregate from the mortar portion of the concrete.

Safety Data Sheet (MSDS) A document providing information on a product's potential safety or environmental hazards and precautionary measures for those who use the product.

Shrink-Mixed Concrete Ready mixed concrete partially mixed in a plant mixer and then discharged into a truck mixer where its mixing is completed.

Silica Fume A very fine powdered material with particles about 100 times smaller than portland cement particles. Used for making high strength, low permeability concrete.

Slag, ground A by-product of iron mills, ground to a fine powder and used as a cementitious material in concrete. Also known as Ground Granulated Blast-furnace slag.

Slump A measure of the consistency of fresh concrete.

Slump Cone A cone shaped mold with an 8-inch (200 mm) base diameter, a 4-inch (100 mm) top diameter, and 12-inch (300 mm) height, used to test the slump of fresh concrete.

Slump Meter A gauge on the hydraulic system of the truck mixer which measures the approximate slump of the concrete in the revolving drum.

Slurry A mixture of water and cement.

Spalling Chipping or chunks of concrete fragments separating from a hardened concrete surface.

Stamped Concrete Finish The surface texture obtained by using a stamp to imprint a design in the surface of a concrete slab during finishing.

Strength Generic term for concrete's ability to resist loads without breaking.

Superplasticizer A high-range-water-reducing admixture (see definition above).

– T –

Tagout Placing a tag or notice on a piece of equipment indicating that it is out of service. See locked out.

Topping A layer of concrete placed to form a floor surface over a concrete base.

Trowel A steel, flat, hand tool used in finishing to achieve a smooth, hard, dense surface on a concrete slab.

Trowel Finish A smooth finish obtained by using a steel hand trowel or power trowel on a concrete slab.

Truck Mixed Concrete Ready mixed concrete mixed in a truck mixer; also called transit-mixed concrete.

Truck Mixer Manufacturer's Bureau (TMMB) Organization of truck mixer manufacturers that maintains standards for concrete truck mixers. Most truck mixers have a TMMB rating plate indicating compliance with these standards.

– U –

Unit Weight (density) The weight of concrete per unit volume. Usually expressed in pounds per cubic foot (abbreviated as lb./cu. ft., e.g., 150.0 lb./cu. ft. (kilograms per cubic meter e.g., 2400 kg/m3)

– W –

Water-Cement Ratio A ratio of the weight of water to the weight of cement, in concrete, expressed as a decimal, e.g., 0.45.

Water-Reducing Admixture A liquid admixture that increases the slump of fresh concrete without increasing the water content or maintains the slump with a reduced amount of water.

TriAngle™ READY MIX

The Contractor's Choice!

an L&L Construction Group company

Dispatch: 919.948.6351
TriangleReadyMix.com

Publication # 24-05-059 R4/12-24