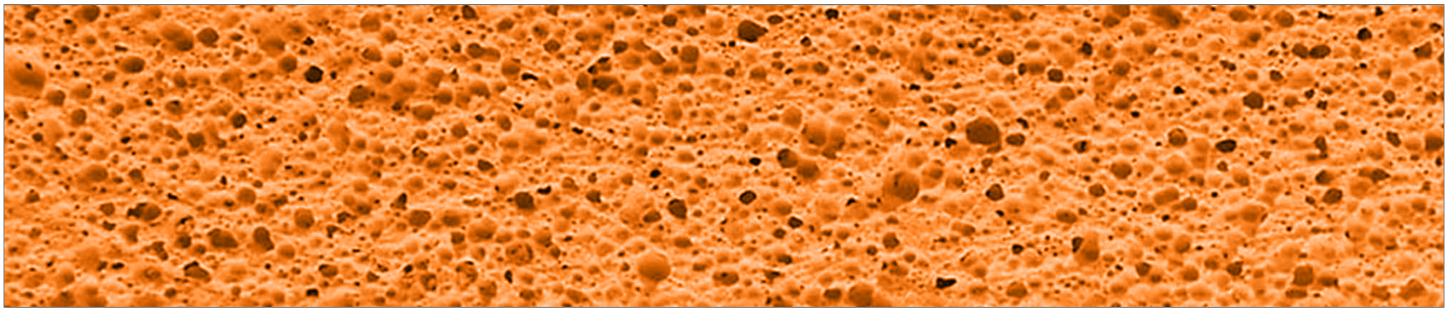
Triangle Tech Tips

References and resources from Triangle Ready Mix

Publication # 24-06-064 R1/01-25

Air Entraining Admixtures For Concrete



History

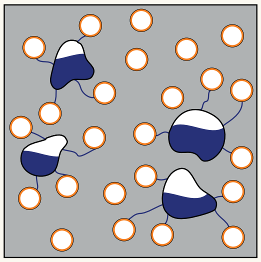
Air-entraining admixtures were discovered in the 1930s. These admixtures for concrete were developed by researchers working for the U.S. Bureau of Public Roads (now the Federal Highway Administration) in the 1930s. The discovery was made by R. E. Davis, R. W. Carlson, and L. H. Martin, who were investigating 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

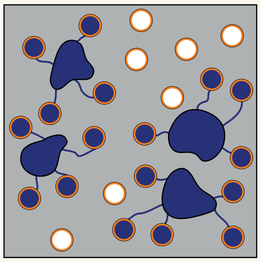
Air-entraining admixtures enhance concrete's durability, workability, and resistance to various forms of environmental and chemical damage, making them an essential component in many concrete applications — particularly in regions with harsh weather conditions.

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.