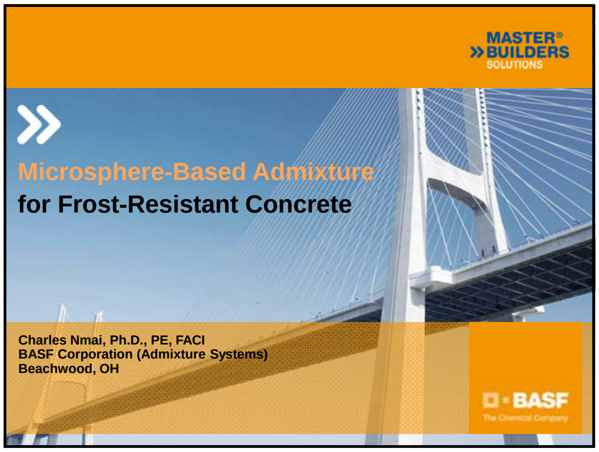


Microsphere-Based Admixture for Frost-Resistant Concrete

Charles Nmai, Ph.D., PE, FACI
BASF Corporation (Admixture Systems)
Beachwood, OH

Overview

- Brief recap of current state-of-the-practice for improving the freeze-thaw durability of concrete
- Microsphere-based admixture for freeze-thaw durability
  - The technology
  - Mechanism of protection
  - BASF Point-of-Use Manufacturing System
  - Performance data
  - Proposed fresh concrete test method
  - Detection in hardened concrete
  - Field trials
- Summary

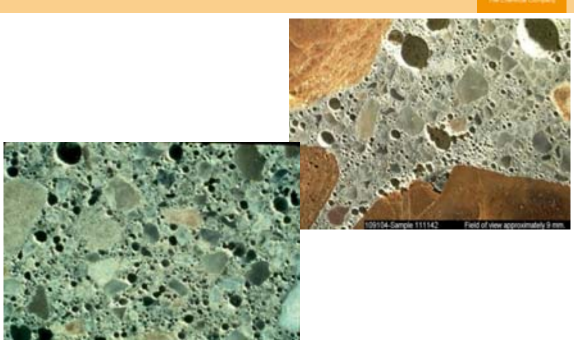
We've known since the 1930s…

Entraining Air in Concrete Improves its Freeze-Thaw Durability!

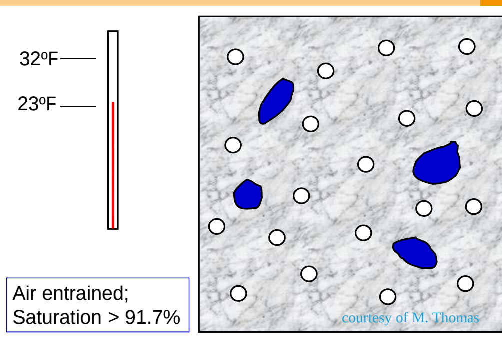
Mechanism of Air Entrainment using Air-Entraining Admixtures

- Air is Generated into Concrete During the Mixing Process
- Entrapped / Entrained Air

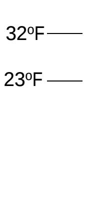
Air-Voids in Hardened Concrete

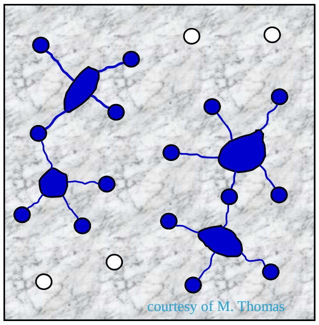


Mechanism of Protection by Air-Voids in Concrete



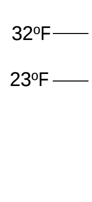
Mechanism of Protection by Air-Voids in Concrete

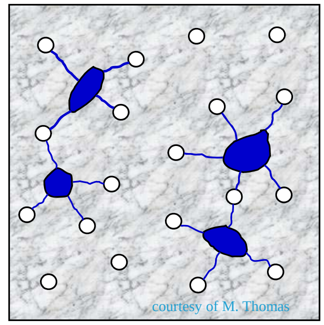




Air entrained;
Saturation > 91.7%

Mechanism of Protection by Air-Voids in Concrete





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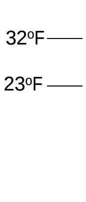
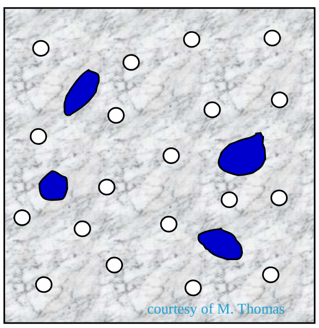
Mechanism of Protection by Air-Voids in Concrete





Air entrained;
Saturation > 91.7%

Fluctuations in Air Content

BATCH PLANT

- Aggregate gradation
- Cement changes
- Supplementary materials
- Concrete temperatures
- Slump consistency
- AE dosage/ dispensing
- Mixing dynamics
- Contamination

JOBSITE

- Addition of water
- Addition of HRWR
- Addition of pigments
- Addition of fibers
- Mixing dynamics
- Calibration of meter
- Improper testing
- Pumping

Slump and Air Content are Intertwined!

Slump too low!
Air too low!

Consistency Needed

Slump too high!
Air too low!

Slump ok!
Air ok!

Slump too high!
Air too high!

Air Entrainment Variability

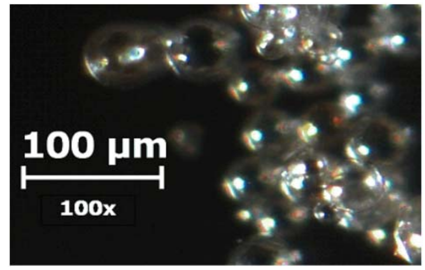
Producer Costs:

- ❑ Cement
- ❑ Rejected loads
- ❑ Claims
- ❑ Fines/penalties due to job delays
- ❑ Redosing
- ❑ Public relations and corporate image
- ❑ Equipment
- ❑ Quality control personnel

Air content variability is the number one production problem facing the North American concrete industry today!

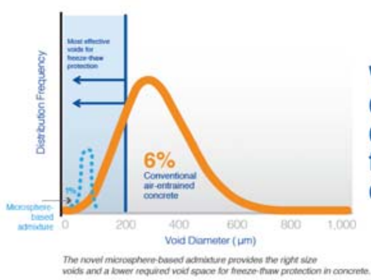
A New Way of Making Concrete Freeze-Thaw Durable

Technology Breakthrough



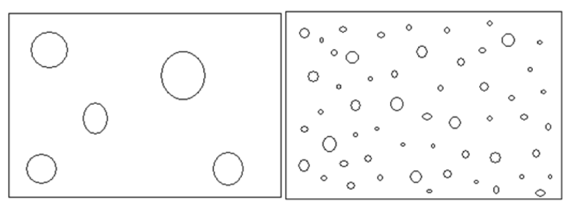
Liquid Microsphere-based Admixture

Microsphere Particle Size vs. Air Voids from Conventional Air Entrainment



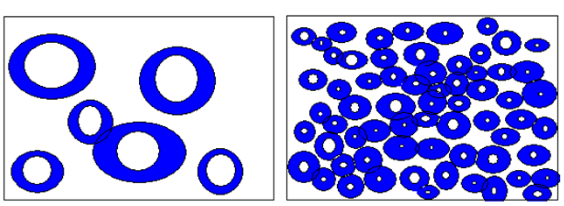
Void quantity, diameter and distribution frequency comparison

Both 5% Air Content

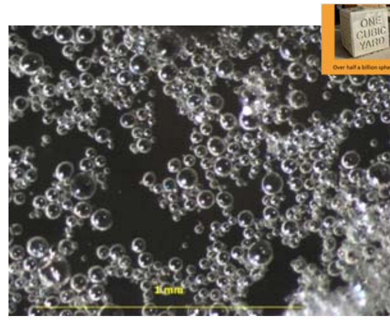


“Sphere of Influence”

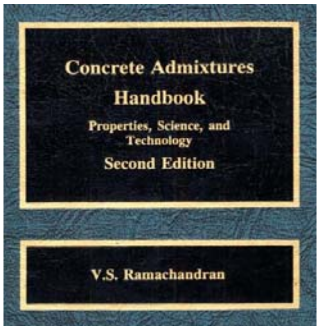
Spacing Factor: 0.008-in. regardless of void size



How many Microspheres?



Frost Resistance Using Microspheres



Frost Resistance Using Microspheres

An innovative approach in the area of air-entraining admixtures is the use of preformed bubble reservoirs in the form of porous particles. In one method, hollow plastic microspheres with diameters between 10 and 60 µm are added to concrete.[36] The voids in the particle are smaller than those in the air-entrained concrete (10–3000 µm). Addition of 1% by weight of cement of these microspheres to concrete corresponds to 0.7% by volume of concrete. The spacing factor equivalent using these spheres is 0.07 mm, well below the permissible maximum. Sommer[36] compared the losses in weight of concrete (due to freezing and de-icing salt attack) containing 5% entrained air with that containing 0.3, 0.6, 0.9, 1.2 and 1.5% hollow microspheres. Adequate frost resistance was attained using 0.9% of the microspheres. No further advantage was observed using higher proportions. Thus 1% hollow sphere was found to be as effective as 5% entrained air. The workability as a measure of consistency was increased by the

Frost Resistance Using Microspheres

Chemical Admixtures–Recent Developments *155*

microsphere addition to the same extent as that provided by 5% air. The 28-day strength was higher with microspheres, being 40 MPa/mm^2 and 38 MPa/mm^2 with 1% hollow spheres and 5% air, respectively.

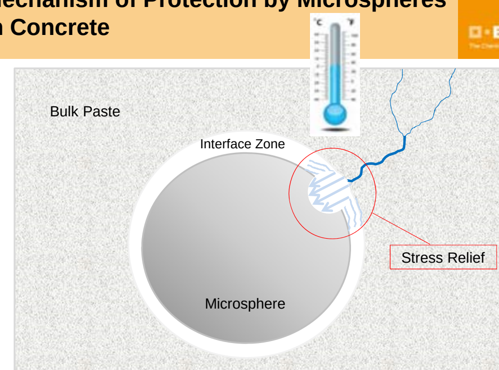
Vanhanen[37] confirmed some of the findings of Sommer.[36] Using 0.3, 0.6, 0.9 and 1.2% microspheres by weight of cement, concretes were made. The resulting compressive strength and frost resistance of these mixtures were compared with those of reference concretes (with and without air entrainment). The frost resistance was improved considerably in concrete containing microspheres. A minimum amount of 0.6% microsphere was needed for good frost resistance. It was also concluded that the compressive strength of air-entrained concrete (with respect to the plain non-air entrained concrete) was less than that containing the microspheres.

Microsphere-Based Admixture

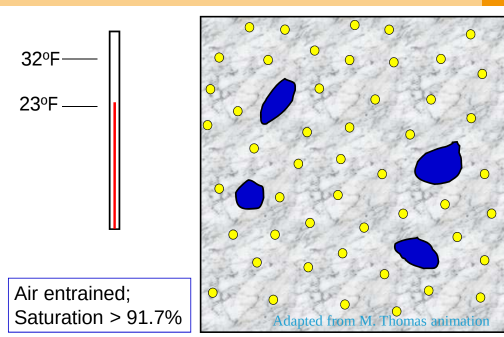
Patent-Pending

- Liquid admixture - proprietary chemistry
  - Single dosage by volume of concrete (1%)
    - 6.1 gal/yd^3 [30 L/m^3] of finished product
  - Microspheres - hollow
  - Highly-resilient, tough, flexible shell
  - Guarantees right size spheres
  - Provide stress relief zones
  - Equivalent performance to air-entrained concrete

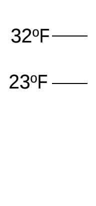
Mechanism of Protection by Microspheres in Concrete



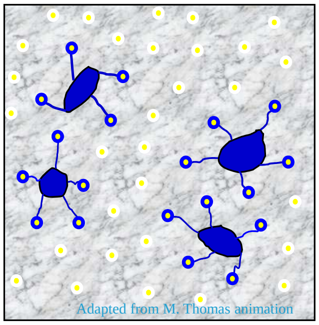
Mechanism of Protection by Microspheres in Concrete



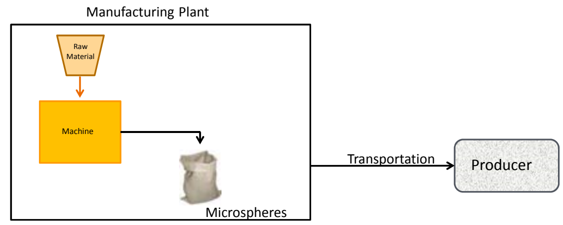
Mechanism of Protection by Microspheres in Concrete



Air entrained;
Saturation > 91.7%



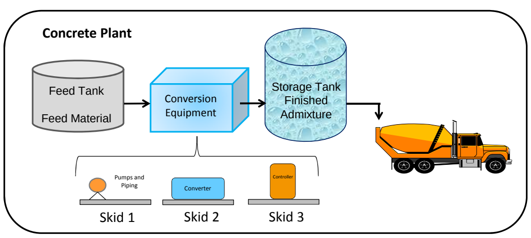
Use of Microspheres is NOT New!



- Microsphere technology used in Central Europe
- Shipping and transportation costs prohibitive
- Use limited to niche applications

BASF Point-Of-Use Manufacturing System

Patents-Pending



Economic Feasibility

BASF Point-Of-Use Manufacturing System

Patents-Pending

Performance Data

Lab Data

Mix #	Nominal Proportions, lb/yd^3 (kg/m^3)				AEA* Dosage	Microsphere-Based Admixture	Air Content	Slump	Durability Factor
	Portland Cement	Fine Aggregate	Coarse Aggregate	Water	fl oz/cwt (mL/100 kg)	(% by volume)	(%)	in. (mm)	(% @ 300 cycles)
1	517 (307)	1380 (819)	1882 (1116)	284 (168)	0.9 (60)		5.6	4.0 (100)	97
2						2.00	2.3	1.75 (45)	98
3						1.50	2.2	2.0 (50)	99
4						1.00	2.2	2.5 (65)	94
5						0.75	2.1	3.0 (75)	95

* Air-entraining admixture

Performance Data

Field Data

Mix #**	Nominal Proportions, lb/yd^3 (kg/m^3)			AEA* Dosage	Microsphere-Based Admixture	Air Content	Slump	Durability Factor	Compressive Strength psi (MPa)	
	Portland Cement	Fly Ash	Water	fl oz/cwt (mL/100 kg)	(% by volume)	(%)	in. (mm)	(% @ 300 cycles)	7-Day	28-Day
1-C	560 (332)	60 (36)	273 (162)	0.6 (39)		8.0	5.25 (135)	97	4590 (31.7)	6060 (41.8)
2-C					1.00	2.9	5.50 (140)	97	5070 (40.0)	6530 (45.0)
1-D				0.5 (33)		8.2	9.25 (235)	102	3770 (26.0)	5010 (34.6)
2-D					1.00	2.7	7.25 (185)	98	4610 (31.8)	6380 (44.0)
3-D					1.00	3.2	7.50 (190)	100	4860 (33.5)	6540 (45.1)

* Air-entraining admixture

** C - Central mixer; D - Dry batch

Performance Data (High LOI Fly Ash)

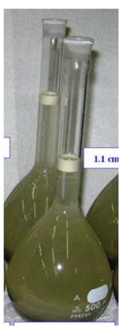
Mix ID	Fly Ash (% of cementitious)	Air-Entraining Admixture mL/100 kg (fl oz/cwt)	Microsphere-Based Admixture (% by volume)	Air Content %	Slump mm (in.)	Durability Factor %
7	0	60 (0.93)		7.0	170 (7.25)	97
8	20	990 (15.2)		4.8	210 (8.25)	97
9	20		0.75	2.0	220 (8.75)	97
10	20		1.00	2.1	210 (8.25)	99
11	20		1.25	2.0	210 (8.25)	99

Performance Data (High SRAs & OCIA)

Mix ID	OCIA L/m^3 (gal/yd^3)	SRA L/m^3 (gal/yd^3)	Microsphere-Based Admixture (% by volume)	Air Content %	Slump mm (in.)	Durability Factor %
1	5.0 (1.0)		0.75	3.3	185 (7.25)	98
2	5.0 (1.0)		1.00	2.9	170 (6.75)	98
3	5.0 (1.0)		1.25	3.1	165 (6.5)	98
4		3.75 (0.75)	0.75	2.2	100 (4.0)	98
5		3.75 (0.75)	1.00	2.3	85 (3.25)	99
6		3.75 (0.75)	1.25	2.4	100 (4.0)	98

OCIA - organic corrosion-inhibiting admixture; SRA - shrinkage-reducing admixture

Proposed ASTM Test Method
(Recovery Test)



Proposed ASTM Test Method
(Recovery Test)

Proposed ASTM Test Method
(Recovery Test)

Proposed ASTM Test Method
(Recovery Test)

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Designation: C XXX/C YYY–14

Standard Test Method for
Determining the Microsphere Content in Fresh Concrete by the Volumetric Method[1]

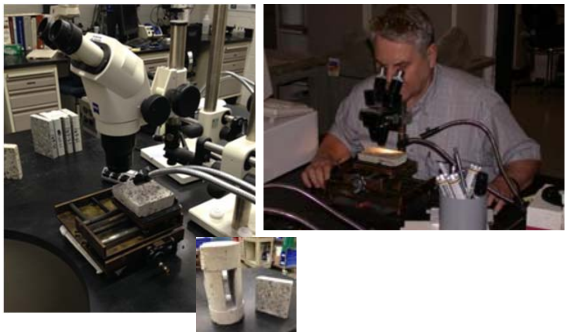
This standard is issued under the fixed designation C XXX/C YYY-12; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

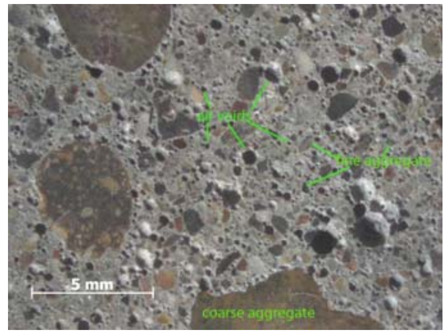
1.1 This test method covers the recovery and determination of microsphere content in fresh concrete.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

"Counting Air"- ASTM C 457

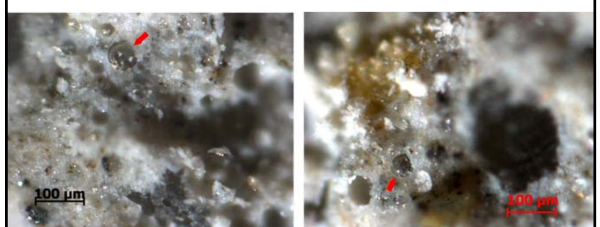


Air-Entrained Concrete

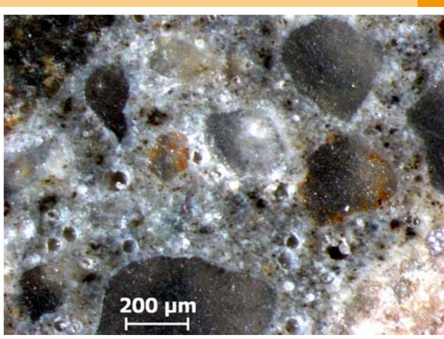


Microsphere Technology

Fractured Surfaces



Cut and Lapped Surface, microspheres



Field Trial

Field Trial in Minneapolis, MN

Concept Validation / Market Awareness

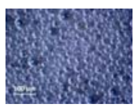
BASF The Chemical Company

BASF The Chemical Company

In Summary,…

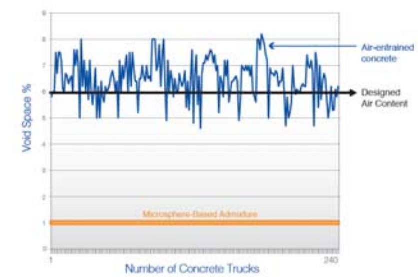
Microspheres vs. Air-Entrainment

BASF The Chemical Company

	Air Entrainment	Microspheres	Advantage
Concrete Production			Right size and spacing
Mixing and Transport			Robustness
Pumping, vibration, and finishing			Resilient

Air Content Variability

BASF The Chemical Company



Use of the novel microsphere-based admixture in concrete significantly reduces the variability and required volume of void space for providing freeze-thaw protection.

Mixture Proportioning Considerations

BASF The Chemical Company

- Current mixes will need to be adjusted for:
  - Yield
  - Workability
- Mixes can be optimized if desired

Summary

BASF The Chemical Company

- Use of microsphere for frost resistance is a proven technology
- A patent-pending liquid microsphere-based admixture
- A patent-pending point-of-use manufacturing system

NEW!

- Market awareness and market acceptance activities underway
- Commercial availability in 2015

New, Innovative System for Freeze-Thaw Durability
Eliminates the Need for Air-Entrained Concrete!

Coming Soon…

MasterSphere FT 300 Admixture