Grace at a Glance

- Leading specialty chemical and materials company
- Founded in 1854
- 2009 worldwide sales: $2.8 billion
- Approximately 6,000 employees
- Offices in over 40 countries
- Listed on the New York Stock Exchange (GRA)
- Member of Fortune 1000
Business Portfolio

2009 Grace Sales by Product Group

- $1.0 billion Grace Davison Refining Technologies (36%)
- $0.9 billion Grace Construction Products (21%)
- $0.6 billion Grace Davison Materials Technologies (11%)
- $0.3 billion Grace Davison Specialty Technologies (32%)

2009 Grace Sales by Region

- $1.1 billion Europe, Middle East and Africa (39%)
- $1.0 billion North America (36%)
- $0.5 billion Asia Pacific (18%)
- $0.2 billion Latin America (7%)

Numbers may not total due to rounding.
54 plants provide a global footprint and ensure a global service
# Grace Construction Products

## Product Range

<table>
<thead>
<tr>
<th>Specialty Construction Chemicals (SCC)</th>
<th>Specialty Building Materials (SBM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Concrete Admixtures</td>
<td>▪ Waterproofing Systems</td>
</tr>
<tr>
<td>→ # 2 world wide</td>
<td></td>
</tr>
<tr>
<td>▪ Cement Additives</td>
<td>▪ Fire Protection Products</td>
</tr>
<tr>
<td>→ # 1 world wide</td>
<td></td>
</tr>
<tr>
<td>▪ Masonry Products</td>
<td></td>
</tr>
<tr>
<td>▪ Architectural Concrete</td>
<td></td>
</tr>
</tbody>
</table>
Why use an additive?

- Cement can be made without using chemical additives
- They are not (usually) needed
- So why do some plants use them?

How to discover a profitable way to exploit the application of a chemical additive?

- Create economic value from the benefits that an additive can create that exceeds their cost
- Requires knowledge of cement plant, cement, market requirements, costs, flexibilities/constraints, etc
- Requires knowledge of cement additive capabilities, applications, formulations, costs, etc
- Requires a rigorous evaluation procedure
Why Grace?

- World Leading supplier to the cement industry since 1930’s
- Dedicated organization, focused on cement
- Network of laboratories for technical service, R&D and longer term Innovation
- Technical specialists with strong expertise in cement production, grinding, cement chemistry, and chemical formulations
- Proven product development and introduction to the industry
- Rigorous evaluation and application analysis with established methods and tools
- Global presence & global organization
- Successful sales to more than 500mmt cement
Value of Cement Additives

- **Increase in cement mill output**, with associated reduction in cement mill system kWh/tonne, reduction in mill run hours and reduction in cement grinding costs.
- Increase production capacity to **meet sales** volume.
- **Improving cement flowability** (reduce pack-set) to shorten loading/unloading operations and **reduce distribution costs**.
- **Improve cement performance**, to meet customer needs, satisfy Standards, meet/exceed competition and improve market position.
- Improve cement performance to allow **clinker chemistry changes** or to **lower raw material/fuel costs** from use of alternative materials.
- Improve cement performance to **increase use of cementitious materials** (i.e. non Portland cement clinker).
- Improve cement performance to use cementitious materials to **reduce the clinker factor** to lower compositional costs, to increase cement volume per unit of clinker, to reduce environmental impact (e.g. CO₂).
- Improve cement performance to permit higher class of cement or **new cement type** or to meet new market needs.
Cement Additives – Development

Chemical compounds for use in the production of cement to increase the output and efficiency of the grinding process and improve the performance and quality of the finished cement, with the objective to reduce overall manufacturing costs.

<table>
<thead>
<tr>
<th>Year</th>
<th>Additive/Improver</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>HEA2® amine acetate grinding aids patented</td>
</tr>
<tr>
<td>1970</td>
<td>TDA® Quality Improver series introduced for blended cement</td>
</tr>
<tr>
<td>1990</td>
<td>CBA® Quality Improvers developed and patented</td>
</tr>
<tr>
<td>2003</td>
<td>ESE® non-chloride early strength enhancers introduced</td>
</tr>
<tr>
<td>2004</td>
<td>SYNCHRO® chromium-reducing additives introduced</td>
</tr>
</tbody>
</table>
Cement Additives – Traditional Groups

- **Cement Processing Additives:** Grinding Aids
  - Improve grinding process efficiency: increase tonnes/hour & reduce specific energy consumption

- **Cement Performance Additives:** Quality Improvers
  - Significantly improve cement performance and quality
  - E.g.: increased strength development, accelerated/delayed setting, reduced water demand, etc.
  - Allow higher clinker replacement levels

- **Cement Functional Additives:**
  - Masonry Cement Additives
  - Chromium (VI) Reducing Additives
Cement Additives – Capabilities

- Reduce coating and Reduce Packset
- Increase Mill Output, by 5 - 30%
- Narrower cement PSD (Increase RRN)

- Increase 28-day strength, 5-15% or say 2 - 10 MPa
- Increase 2-day strength, 10-30% or say 2 - 10 MPa
- Reduce setting time, 10-40 minutes (initial set)
- Extend setting time, 10-40 minutes (initial set)
- Reduce water demand (concrete), by 2 - 5%
Customised Cement Additives Evaluation

Defining Targets

- Opportunity Assessment
- Additive Target
- Value Created
- Product Selection
- Plant Trial
- Agreement

- Process Cement Performance
- Grinding System Cement & Market Performance
- Energy Costs Material costs Production Market Value
- Screen Customise Dosage Cost
- Industrial Test Customer Plant Shared Results
- Supply Conditions Service & Support

Value

- What are the Targets of a Chemical Additive?
- Understand the Total Value
- Customised Solution, Meeting Targets, Creating Net Economic Benefit
- Continual Assessment And Improvement

Product

- Where can a Chemical Additive Create Benefits?
- Mutual Assessment Mutual Agreement

Proving

Closing

## Product selection

<table>
<thead>
<tr>
<th></th>
<th>Typical Range g/t</th>
<th>Typical Dosage g/t</th>
<th>Contribution to Cement Cl g/t</th>
<th>Cement Flowability, Packset</th>
<th>Grinding Aid</th>
<th>Water Demand</th>
<th>Setting Time 1-3d</th>
<th>Compressive Strength 28d</th>
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<tr>
<td>MTDA</td>
<td>150-500</td>
<td>300</td>
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<td>**</td>
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<tr>
<td>HEA2 M/K</td>
<td>150-500</td>
<td>300</td>
<td>0</td>
<td>***</td>
<td>***</td>
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<tr>
<td>HEA2 SP</td>
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<tr>
<td>TDA Z</td>
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<td>(-)</td>
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<td>1000-2000</td>
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## Simplified Value Model

### Grinding Aid, Low Cost Grinding Aid, Quality Improver, Customized Product

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<thead>
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<th>Reference</th>
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<th>GA 1</th>
<th>GA 2</th>
<th>QI</th>
<th>QI 2</th>
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<tr>
<td>Additive Cost/t</td>
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<td>0.23</td>
<td>0.15</td>
<td>0.46</td>
<td>0.60</td>
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<tr>
<td>Dosage g/t</td>
<td>0</td>
<td>900</td>
<td>600</td>
<td>1300</td>
<td>2000</td>
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<tr>
<td>SCM %</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>19</td>
<td>24</td>
</tr>
<tr>
<td>t/hr</td>
<td>110</td>
<td>120</td>
<td>120</td>
<td>122</td>
<td>122</td>
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<tr>
<td>kWh/t</td>
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<td>kWh/t cost</td>
<td>3.34</td>
<td>3.06</td>
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<td>3.01</td>
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<tr>
<td>R&amp;M Cost/t</td>
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<td>0.37</td>
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<td>Composition cost/t</td>
<td>17.50</td>
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<tr>
<td>CO2 cost/t</td>
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<td>0.00</td>
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<tr>
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<td>0.77</td>
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<td>Additive Cost/t</td>
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<td>0.09</td>
<td>0.16</td>
<td>0.31</td>
<td>0.67</td>
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<tr>
<td>Net Saving/t</td>
<td>75,900</td>
<td>141,525</td>
<td>273,838</td>
<td>584,463</td>
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<tr>
<td>Annual Saving</td>
<td>39%</td>
<td>108%</td>
<td>69%</td>
<td>111%</td>
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<tr>
<td>% Return</td>
<td>875,000</td>
<td>875,000</td>
<td>921,053</td>
<td>985,915</td>
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<tr>
<td>Increase</td>
<td>0</td>
<td>0</td>
<td>46,053</td>
<td>110,915</td>
<td></td>
</tr>
</tbody>
</table>

1 Assumes 5% gypsum

- **GA 1** Traditional grinding aid
- **GA 2** Formulated low cost grinding aid
- **QI** Traditional Quality Improver
- **QI 2** Customized Quality Improver

### Key Metrics

- **Mill Power**: 4,000 kW
- **Electricity**: 0.075 Eu/kWh
- **R&M**: 0.4 Eu/t
- **Additive Cost/t**: 0.00
- **Clinker CO2 Factor**: 862 kg/t
- **Clinker**: 700,000 tonnes
- **SCM**: 10 Eu/t
- **Cement Volume**: 875,000 tonnes
- **Increase**: 46,053 tonnes
Technical Support

- Cement additive value assessment and optimization
  - Cement Additive selection
  - Cement Additive trials
- Mill Audits
- Problem solving
  - Mill system
  - Cement performance
  - Concrete performance
  - Concrete admixture issues
- Cement Technology Training
Cement Additives

- Usually added directly to the mill or mill feed
- Use permitted by Cement Standards
- Formulated cement additives used since 1930’s
- Usually water based solutions
- Introduced at low levels, typically at:
  - between 0.01% and 0.20% or
- Processing Additives
- Performance Additives
- Functional Additives
Principal application is for an increase in tonnes/hour at constant cement fineness ($m^2/kg$)

Usually low dosage, typically at:

- between 100 and 500g/t (100 - 500ppm)

Influence on cement quality is usually small (or not the main intention for their use)

The majority are based on alkanolamine and polyglycol chemistry
Performance Additives

- Principal application is for an intended influence on cement performance characteristics

- Usually also provide benefits as a grinding aid

- Usually higher dosage, typically at:
  - between 400 and 2000g/t (400 - 2000ppm)
  - Usually higher cost/tonne of cement (but greater benefits)

- Utilise a combination of chemicals, often both organic and inorganic

- Formulated to provide specific benefits

- Can increase SCM and lower CO2
Functional Additives

- Intended to provide a new function to the cement
- Can also provide benefits as a grinding aid
- Utilise a combination of chemicals, often both organic and inorganic
- Formulated to provide specific benefits
- Application Examples:
  - Masonry Cement
    - Air, Board life, Water retention
  - Chromium Reduction
Their main influence is to reduce the effects of inter-particle attractive forces.

This provides benefits to grinding efficiency via:

- Reduced agglomeration and coating of the mill internals
- Improved dispersion of feed to the separator - increased separator efficiency, lower by-pass
- A reduction in the mill filling level
Grinding Mechanisms

Mechanisms of Grinding Aids
Agglomeration and Coating

• Rittinger - Linear Relationship between SSA and Energy
• Deviation due to Agglomeration and Coating
  • Mechanical Causes - particle packing
  • Physical Causes - surface charges
  • Thermodynamic Causes - surface energy
  • Chemical Causes - hydration bridges
• Agglomeration and Dis-Agglomeration
• Coating - compressible layer
Grinding Mechanisms

**Grindability Curves - Rittinger**

- **Rittinger**
- **Deviation from Rittinger**
- **Agglomeration/Grinding**

- **“Straight Line” - Rittinger**
- **Mill Only kWh/tonne**
- **“Agglomeration”**
- **Grind “End-Point”**

January 20, 2012
Grinding Mechanisms
Grinding Mechanisms

Mill Audit - Chamber 2 Coating

- Liners and grinding media
  - 1. “None”
    - Appearance of “metal” as surface
  - 2. “Light”
    - Appearance of “cement” as surface
    - Readily cleaned by hand to reveal “metal” surface
  - 3. “Moderate”
    - Appearance of “heavier” cement as surface
    - Partially cleaned by hand to reveal “cement/metal” surface
  - 4. “Heavy”
    - Appearance of “thick” cement as surface
    - Difficult to see metal surface, even after cleaning by hand
Influence of Mill Exit Fineness on Ball Mill Efficiency

- Mill Exit Fineness (m²/kg)
- Mill Efficiency (cm²/joule)

No Additive
Influence of Mill Exit Fineness on Ball Mill Efficiency

Mill Exit Fineness (m²/kg)

Mill Efficiency (cm²/joule)

No Additive
Influence of Mill Exit Fineness on Ball Mill Efficiency

Increased Grinding Efficiency

With additive

No Additive
Separator Performance
Coarse Grade Efficiency - Tromp curve

No Additive
Grinding Mechanisms

Separator Performance
Coarse Grade Efficiency - Tromp curve

Reduced Fines
Agglomeration and
Entrainment

No Additive

With additive
(same C. Load)

Reduced By-Pass

Particle Size

Coarse Grade Efficiency (%)
Mill Hold-Up, Residence Time, Void Filling

- Hold-Up = Tonnes of Material Retained in the Mill
- Residence Time = Hold-Up/Total Feed Rate, \((RT = W/F)\)
- Void Filling = Percentage of Media Voids taken by Material

- Residence Time by Fluorescein Tracing
  - Then Hold-Up, \((W = RT \times F)\)
  - Then Void Filling (From volumes of media and material).

- Void Filling by Mill Internal Inspection
Grinding Mechanisms

Powder Loading, Void Filling

Height Above Powder

Height Above Charge

High Void Filling

Volume Loading

Low Void Filling

Mill Diameter
Influence of Powder Filling on Mill efficiency

- Low Efficiency - High Rate of Breakage
  - Low Residence Time

- Optimum Powder Filling at 85% of Voids

- Low Efficiency - High Residence Time
  - Low Rate of Breakage

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Grinding Mechanisms

Factors Influencing Void Filling

• Diaphragm Design and Condition
• Mill Throughput
• Media Sizes
• Volume Loading
• Material Characteristics (fineness, moisture,…)
• Separator Type, Efficiency and Circulating Load
• Mill speed
• Mill Ventilation
• Cement Additives (type and dosage)
Influence of Mill Throughput on Void Filling

Grinding Mechanisms
Influence of Ball Size on Void Filling

Grinding Mechanisms
Mechanisms of Grinding Aids

- Increased dry flowability
- Reduced Mill Residence Time
- Reduced Mill Hold-Up
- Reduced Void Filling
  - Reduction Typically 10-40%

- Can represent 10% gain in efficiency
Grinding Mechanisms

Influence of Powder Filling on Mill efficiency

Typical Mill Operation at >100% (2nd Chamber)
For optimised Circulating Load

Optimum Powder Filling at 85% Void Filling

Low Void Filling = Low Efficiency - High Rate of Breakage - Low Residence Time
High Void Filling = Low Efficiency - High Residence Time - Low Rate of Breakage
Grinding Mechanisms - Summary

- Grinding Efficiency can be 0-30% higher
  - Reduced agglomeration and coating of the mill internals
    - Can be up to 10% benefit
    - More important at high fineness (and can be more than 10%)
  - Improved dispersion of feed to the separator, leading to increased separator efficiency, lower by-pass
    - Can be up to 5% of benefit
    - More important in older separators
  - A reduction in the mill filling level
    - Can be up to and more than 10% benefit
    - BUT can be a negative effect
    - More important in mills with high void filling
Effectiveness of Grinding Additives for Increased Grinding Efficiency

<table>
<thead>
<tr>
<th>Void Filling</th>
<th>Heavy</th>
<th>Moderate</th>
<th>Light/None</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;1.10</td>
<td>*****</td>
<td>****</td>
<td>***</td>
</tr>
<tr>
<td>0.90 - 1.10</td>
<td>****</td>
<td>***</td>
<td>**</td>
</tr>
<tr>
<td>&lt;0.90</td>
<td>***</td>
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</tbody>
</table>

**Key:**

- ***** Excellent Effectiveness
- **** Very Good Effectiveness
- *** Good Effectiveness
- ** Moderate Effectiveness
- * Minimal Effectiveness

**Note:** Effectiveness of grinding additives refers to grinding efficiency only, i.e. mill output and kWh/t, not to effectiveness of enhancing cement performance.
Vertical Mills - Influence of Cement Additives

- Improves dispersion in the separator
- Results in less fines returned to the bed.
- Faster compaction speed
- Less vibration
- Assists the de-aeration process in front of the roll.

- Fines to separator
- Coarser material back to table
- Improves dispersion at the nozzle ring
- Oversize to scraper channel
- Dam Ring
- 40 - 60 m/s