



Saving Energy in Ready Mixed Concrete Production

**An ENERGY STAR® Quick Guide for
Managing Energy**

August 2013

Saving Energy in Ready Mixed Concrete Production

An ENERGY STAR® Quick Guide for Managing Energy

Katerina Kermeli, University of Utrecht

Ernst Worrell, University of Utrecht

Eric Masanet, Northwestern University

August 2013

Disclaimer

This document was prepared for the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor any persons or organizations involved in its development, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe on privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or any persons or organizations involved in its development. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Acknowledgment

This work was funded by the U.S. Environmental Protection Agency. Initial work was begun under the U.S. Department of Energy Contract No. DE-AC02-05CH11231, and was completed under the U.S. Environmental Protection Agency Contract No. EP-BPA-12-H-0012.

Table of Contents

Introduction: Energy Management is Good for Your Business.....	1
1 Where is Energy Used?.....	2
1.1 Ready Mixed Concrete Production	2
2 Managing Energy Use.....	3
2.1 Effective Principles for Energy Savings.....	3
2.2 Elements of the Energy Management Process	5
2.3 Plant Energy Assessments	5
2.4 Energy Monitoring Systems	6
3 Where to Improve Energy Efficiency in Concrete Production: Common Plant Systems ...	7
3.1 Building Lighting	7
3.2 Motors	8
3.3 Compressed Air.....	9
3.4 Hot Water and Steam Systems.....	11
3.5 Chillers	11
3.6 Dust Collectors	12
4 Energy Efficiency Opportunities for Ready Mixed Concrete Production Processes	13
4.1 Cold Weather Concreting.....	13
4.2 Humidity Control	14
4.3 Mixing	14
4.4 Truck Operation and Fleet Management.....	15
4.5 Returned Concrete	16
4.6 Miscellaneous.....	18
5 Summary.....	18
6 Glossary.....	20
7 References.....	23

Figures

Figure 1. Ready mixed concrete production.	2
Figure 2. Energy breakdown in ready mixed concrete manufacturing.....	3
Figure 3. Elements of strategic energy management, ENERGY STAR <i>Guidelines for Energy Management</i>	5

Introduction: Energy Management is Good for Your Business

Effective energy management helps a company keep costs down and stay competitive. The U.S. Environmental Protection Agency (EPA), through the ENERGY STAR program, has observed that a well-run energy program can reduce energy costs by 3% to 10% annually, as well as reduce waste and emissions, which also are costly.

Companies can differ in the amount of energy they use even when they belong to the same industry, operate under the same market conditions, and use the same equipment.

High performing organizations:

- actively manage energy,
- adopt a structured approach,
- establish policies and procedures for long-term results,
- have senior management's support,
- allocate staff and resources,
- establish goals,
- develop management structures that empower staff to address energy efficiency issues directly, and,
- build a culture of continuous improvement.

Sound, plant-wide energy management combined with energy-efficient technologies offer additional benefits, such as improved product quality, increased production, and process efficiency. As part of a company's overall environmental strategy, energy efficiency improvements often lead to reductions in emissions of greenhouse gases (GHGs) and other air pollutants.

This *Quick Guide* provides basic information to identify cost-effective practices and technologies for reducing energy use throughout a company's operations. It focuses on the most important systems, equipment, processes, and practices that account for the bulk of energy consumption in ready mixed concrete production. For more detailed information on efficiency opportunities in the U.S. concrete industry, consult [*Energy Efficiency Improvement and Cost Saving Opportunities for the Concrete Industry. An ENERGY STAR Guide for Energy and Plant Managers.*](#)¹

1 Where is Energy Used?

Knowing where energy is used in a plant is an important first step in managing energy.

1.1 Ready Mixed Concrete Production

An overview of ready mixed concrete production is shown in Figure 1. According to a survey of 47 facilities across the United States,² most of the fuel was used in boilers (49%) for hot-water production and building heat. An overview of the energy breakdown is shown in Figure 2.

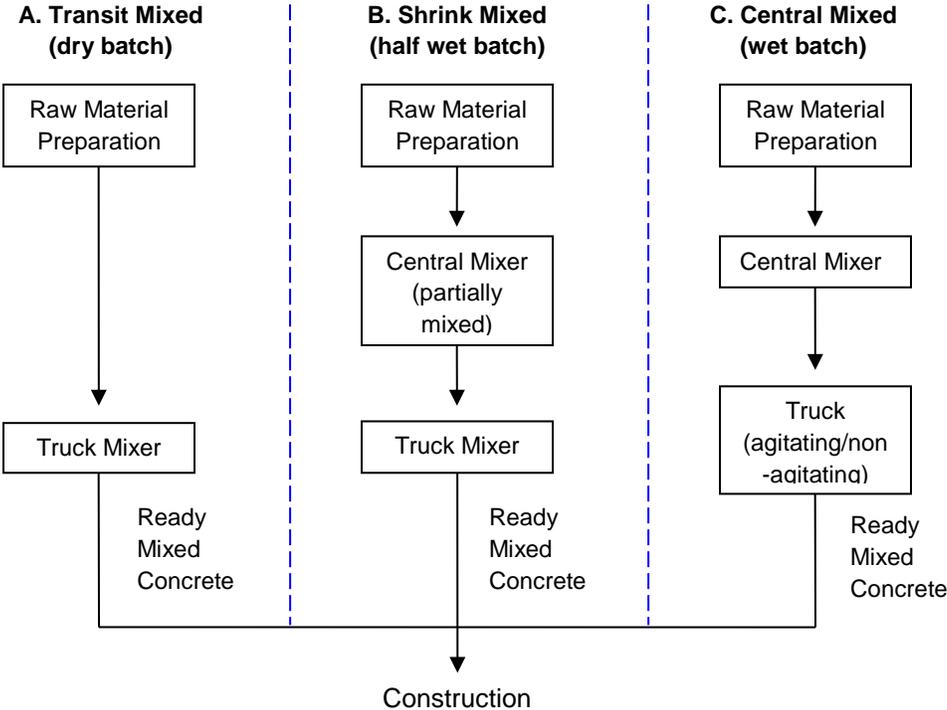


Figure 1. Ready mixed concrete production.

Ready Mixed Concrete Industry

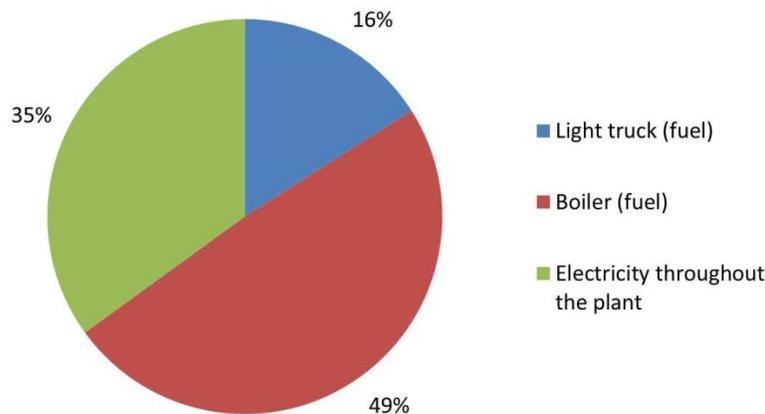


Figure 2. Energy breakdown in ready mixed concrete manufacturing.

Energy intensities and fuel types for an individual ready mixed concrete production plant will vary. According to a Portland Cement Association (PCA) survey,² the average specific energy consumption in the U.S ready mixed concrete industry is 31 kBtu/yd³ of concrete, but can be as high as several hundred kBtu/yd³.^{3,4,5} The specific energy consumption of a ready mixed concrete facility depends on climate conditions and the state of the equipment. Energy consumption for ready mixed concrete delivery is estimated to be on the same order of magnitude as the energy consumption at the ready mixed concrete plant.⁵

2 Managing Energy Use

An organization-wide energy management program is the best way to save energy and money. EPA offers tools and resources to help you build a strategic energy management program. All resources can be found at www.energystar.gov/industry.

2.1 Effective Principles for Energy Savings

For success, apply these basic principles. Any company of any size can do it!

- **Make energy a priority.** *Everyone* in the company, including senior management, must recognize that reducing energy use is an important business objective that must be part of decision making.

ENERGY STAR® energy management resources

EPA's ENERGY STAR® [Guidelines for Energy Management](#) provides a basic energy management structure that is easy to follow.

Another ENERGY STAR guide, [Teaming Up to Save Energy](#), outlines how to form an energy team within your organization and assign roles and responsibilities for managing energy.

- **Commit to save energy.** Every level of the organization must support a commitment to improve energy efficiency.
- **Assign responsibility.** Someone must be assigned responsibility for managing energy. An energy team, with roles assigned to each member, is a practical way to share the load.
- **Look beyond first cost.** You get what you pay for. Energy-efficient equipment and products may cost more initially but the long-term savings will surpass the initial cost.
- **Make energy management a continuous process.** Successful energy management goes beyond installing a few energy-efficient light bulbs. Build a company-wide energy program and make energy one of the top items managed by the business.
 - Understand your energy use
 - Set goals
 - Put in place good operations and maintenance practices
 - Encourage behavioral changes
 - Track and benchmark energy use
 - Engage every employee

Educated, empowered employees identify and achieve energy savings

Engage employees and operators in the energy program, especially the assessments, projects, and day-to-day decisions. An effective energy-awareness campaign:

- Educates employees and operators on how their work practices affect the company, energy use, costs, and the environment
- Informs employees on how they can manage energy in their day-to-day responsibilities
- Reminds employees about the company's energy goals

EPA works with companies to identify the basics of an effective energy management program by using the [ENERGY STAR Guidelines for Energy Management](#). To assess how your company manages energy, use [ENERGY STAR's Energy Program Assessment Matrix](#), located within the Guidelines. Figure 3 shows the main steps to form an energy program.

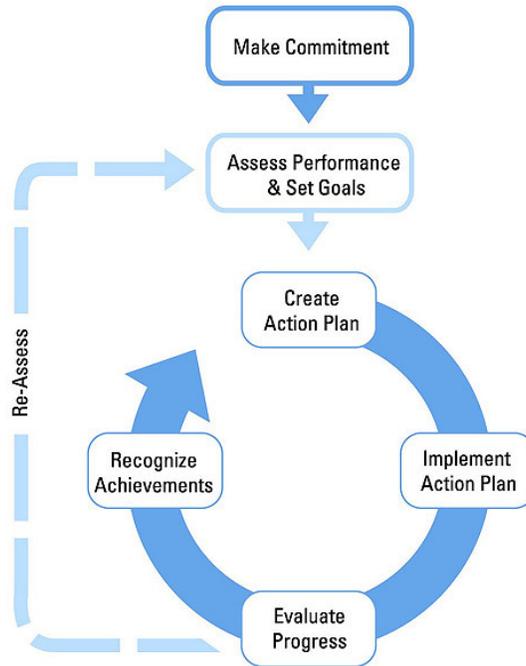


Figure 3. Elements of strategic energy management, ENERGY STAR *Guidelines for Energy Management*.

2.2 Elements of the Energy Management Process

Four key elements contribute to the energy management process: (1) energy audits/assessments, (2) energy teams, (3) employee awareness, and (4) energy monitoring.

2.3 Plant Energy Assessments

Plant energy assessments determine where and how much energy is consumed, and identify steps to improve the facility's energy efficiency and save money. The assessment can focus on the whole site or specific systems and processes. Easy tools to get energy management started at a site are EPA's [ENERGY STAR Facility Assessment Matrix](#) and [ENERGY STAR Small/Medium Manufacturer Energy Management Assessment Matrix](#).

Assessments can be conducted by company staff, the local electric utility, contractors, or government programs.

- **Staff teams.** If company employees perform the plant assessment, team up staff from various departments across the facility. This brings together a spectrum of experience and knowledge on the plant and its processes. Facilities of any size can successfully use this method. EPA, through ENERGY STAR, provides guidance for one such type of assessment, the Energy Treasure Hunt (see www.energystar.gov/industry for more information).
- **Electric utility program.** Local utility companies work with their industrial clients to achieve energy savings in existing facilities and in the design of new facilities. Check with your local electric utility to see what assistance it provides. Utilities sometimes offer specific programs for improving plant systems such as lighting or motors.

- **Federal government programs.** The U.S. DOE supports plant assessments through the [Industrial Assessment Center \(IAC\)](#) program. IACs are designed to help small- and medium-size enterprises. Universities that participate in the program offer free assessments, performed by students and university staff, to local companies.

2.4 Energy Monitoring Systems

Every company should compile, track, and benchmark energy data. Reliable energy data helps a company manage energy and interpret energy efficiency trends over time and take corrective action when necessary.

Data on energy use can be found in utility bills, fuel purchase receipts, or from self-installed meters. Submetering different production departments provides improved metrics and enables quick pinpointing of areas where energy problems may occur.

Using an energy monitoring system is ideal. It requires little or no up-front capital and can result in immediate savings. Energy monitoring systems include submeters at key areas in a plant to strategically track and manage energy. The meters' data should be managed with a data-management tool; a simple spreadsheet may be sufficient, or tailored software is also available that can help identify problems and savings.

In its simplest form, an energy monitoring system should be based on:

- Monthly utility billing and energy-use data for the past 12 to 24 months
- Monthly production figures

Using a simple spreadsheet, both can be plotted in graphs to understand the relationship between energy use and production and to identify any trends.

- Graph of energy use and production over time
- Graph of energy costs and production over time
- Graph of energy use on vertical axis against production on horizontal axis
- Graph of energy use divided by production (showing specific energy consumption)

Tools offered within commonly used spreadsheet packages can help to identify relationships and quantify trends. Graphs can be made for fuel and electricity separately, as well as for total energy use (showing both in the same units, such as megajoules or British thermal units) and costs. EPA has developed a basic [Energy Tracking Tool](#) for companies and sites to use to track energy.

Often the analysis will show periods of good performance and poor performance — this information helps a company set targets for energy consumption based on expected production volumes. Tracking energy use by entering new data and evaluating it regularly will help identify problems and improve energy savings.

Energy monitoring provides data useful for corporate greenhouse gas accounting initiatives. Successful monitoring programs regularly (sometimes daily) report energy use to identify increased use and costs that could be caused by operational inefficiencies. Energy monitoring

and -metering systems also help companies to participate in emergency demand response programs, in which utility companies provide financial incentives to customers who reduce their energy loads during peak demand times.

3 Where to Improve Energy Efficiency in Concrete Production: Common Plant Systems

According to Titan America, which conducted energy assessments in ready mixed concrete plants, low- to no-cost improvements can reduce energy costs by more than 20%.⁶ Such energy savings contribute directly to a company's bottom line by improving operating costs.

This section identifies key ways to control energy use in common plant systems. For further information on these measures, consult the [Energy Efficiency Improvement and Cost Saving Opportunities for the Concrete Industry](#).¹

3.1 Building Lighting

Lighting is a big portion of electrical consumption. Energy-efficient lighting can give substantial savings.

Cost-effective measures to save on lighting energy are discussed below.

Replace incandescent lamps with compact fluorescent lamps (CFLs). A fluorescent lamp lasts roughly 10 times longer than an incandescent light and is significantly more energy-efficient.

Replace T-12 tubes with T-8 tubes. T-12 tubes consume significant amounts of electricity, and have poor efficacy, lamp life, lumen depreciation, and color rendering index. Typical energy savings from replacing a T-12 lamp by a T-8 lamp are about 30%.

Replace mercury lamps. Where color rendition is critical, metal halide lamps can replace mercury or fluorescent lamps, leading to energy savings of up to 50%. Where color rendition is not critical, high-pressure sodium lamps offer energy savings of 50% to 60% compared with mercury lamps.

Reduce high-intensity discharge (HID) voltage. Commercially available voltage controllers are easily fitted to a central panel switch and constrict the flow of electricity to lighting fixtures, reducing voltage and saving

Did you know?

Only a small part of the energy used in a lighting fixture results in lighting? Much is lost as heat. Install energy-efficient lighting.

Case study: LED lighting

Titan America installed 10 LED fixtures instead of HID fixtures on a beltline. HID fixtures, which needed more time to switch on, had remained on during the night for employees to check equipment. With the installation of LED fixtures characterized by "instant on" and the use of light-switch timers, the lights now burn only 250 hours instead of 4,000 hours per year. This resulted in higher than anticipated savings in electricity, of about \$50 per fixture per year.⁶

energy, with an imperceptible loss of light. A Toyota production facility installed reduced-voltage HID lights and reduced lighting energy consumption by 30%.

Case study: Efficient motors

CEMEX (formerly RMC Pacific Materials) had 13 worn and inefficient motors in cement blowers and silo pumps. Using DOE's MotorMaster+ software tool, plant personnel identified causes of inefficiency.⁷ New, more efficient motors yielded 2 million kWh energy savings and \$168,000. Annual savings in maintenance costs came to \$30,000.

Consider replacing HID lighting with high-intensity fluorescent lights. Traditional HID lighting can be replaced with T-5 high-intensity fluorescent lighting systems, which use high-efficiency fluorescent lamps, electronic ballasts, and high-efficacy fixtures to maximize output to work areas. The payback period is typically below three years, but it can be as low as a few months, as several electrical utility companies offer rebates to replace inefficient lighting.⁸

3.2 Motors

Motors are the biggest consumer of industrial electricity. They are used in many areas, such as HVAC, compressed air, and pumps. When considering energy efficiency improvements to a facility's motor systems, take a "systems approach," focusing not simply on the motor but on the entire motor system (the motor; driven equipment such as pumps, fans, and compressors; and controls).

A systems approach for motors includes the following steps.

1. Locate and identify all motors in the facility.
2. Document conditions and specifications of each motor to provide a current systems inventory.
3. Assess the needs and actual use of motor systems to determine whether motors are properly sized and how well each one meets the needs of its driven equipment.
4. Collect information on potential repairs and upgrades to the motor systems, including economic costs and benefits of implementing repairs and upgrades, to help with decision-making.
5. If upgrades are pursued, monitor the upgraded system's performance to determine actual cost savings.

Did you know?

Up to 95% of a motor's costs come from the energy consumed over its lifetime, while only about 5% of a motor's costs come from its purchase, installation, and maintenance.⁹

Tips: Motor System Energy Efficiency Measures

Select motors strategically	Analyze the life-cycle costs rather than just the initial purchase and installation costs. Up to 95% of a motor's lifetime costs come from the energy it consumes over its lifetime, while only about 5% of its costs come from its purchase, installation, and maintenance. ⁹
Motor efficiency	Selecting energy-efficient motors is an important strategy for reducing motor system life-cycle costs. With proper installation, energy-efficient motors can run cooler (which may help reduce facility cooling loads) and have higher service factors, longer bearing life, longer insulation life, and less vibration.
Maintain your motors	Motor maintenance prolongs motor life and anticipates possible failures. Savings from an ongoing motor maintenance program can range from 2% to 30% of total motor system energy use.
Ensure motors are properly sized	A wrong-sized motor leads to unnecessary energy losses. Replacing oversize motors with properly sized motors saves U.S. industry, on average, 1.2% of total motor system electricity consumption.
Motor automation	Automatic shutdown of motors that otherwise would be left idling can reduce energy costs without requiring high investment. According to plant assessments from Titan America, a 25 hp non-automated motor, running unloaded for 5 hours per day, costs about \$1,000 annually. ⁶
Consider adjustable-speed drives (ASDs)	The ready mixed concrete industry commonly keeps mixers idling at full load all the time, even when there are no trucks to be loaded, to ensure concrete does not set in the drum. In this case, adjustable-speed drives (ASDs) could result in significant energy savings. Energy savings may vary from 7% to as high as 60%, depending on the use pattern of the motor.

3.3 Compressed Air

Compressed air is the most expensive form of energy used in an industrial plant because of its poor efficiency, typically about 10% from start to end use. The use of compressed air should be limited to the minimum quantity for the shortest possible time, constantly monitored, and weighed against alternatives. Many energy reduction options for

Case study: Air leak repair

Roanoke Cement, after conducting an ultrasonic leak audit in a concrete facility, discovered seven leaks. The annual cost of the leaks was \$740.

compressed air systems are not prohibitively expensive. Payback periods for some are extremely short, often less than one year.

Tips: Compressed Air Energy Efficiency Measures

<p>Maintain compressed-air systems</p>	<p>Inadequate maintenance can lower compression efficiency, increase air leakage or pressure variability, and can lead to increased operating temperatures, poor moisture control, and excessive contamination of compressed air system components. The following maintenance activities will reduce these problems and save energy.</p> <ul style="list-style-type: none"> • Inspect and periodically clean filters to keep the compressor and intercooling surfaces clean and foul-free. • Keep motors and compressors properly lubricated. • Inspect fans and water pumps regularly to ensure proper performance. • Inspect drain traps periodically to ensure they are not stuck in the open or closed position and are clean. • If using compressors with belts, check the belts for wear and adjust them. Check water cooling systems for water quality (pH and total dissolved solids), flow, and temperature. • Specify pressure regulators that close when failing. • Applications requiring compressed air should be checked for excessive pressure, duration, or volume.
<p>Reduce leaks in pipes and equipment</p>	<p>The best way to detect leaks is with an ultrasonic acoustic detector, which can recognize the high-frequency hissing sounds associated with air leaks. After being identified, leaks should be tracked, repaired, and verified. Leak detection and correction programs should be ongoing efforts.</p>
<p>Turn off unnecessary compressed air</p>	<p>Air should be turned off completely to equipment no longer using compressed air. This can be done using a simple solenoid valve.</p>
<p>Controls</p>	<p>A control strategy ensures that only the right amount of compressed air, at the right time, is generated and used in the production system. To determine proper control systems, assess compressed air requirements over time to establish a load profile. When demand is less than peak, the most efficient strategy is to use multiple smaller compressors with sequencing controls. Facilities with a flat load profile can use simpler control strategies.</p>

3.4 Hot Water and Steam Systems

Whatever the use or source of hot water or steam, efficiency improvements in generation, distribution, and end use are possible. According to the U.S. DOE, a typical industrial steam-system assessment can identify potential energy use and cost savings of 10% to 15% per year.¹⁰ Major efficiency strategies are:

Control boiler processes. Flue-gas monitors maintain optimum flame temperature and monitor carbon monoxide (CO), oxygen, and smoke. Using a combination of CO and oxygen readings, it is possible to optimize the fuel/air mixture for high flame temperature (and thus the best energy efficiency) and lower air-pollutant emissions. Case studies indicate that the average payback period for this measure is about 1.7 years.

Implement a boiler maintenance program. A simple maintenance program can result in substantial savings by ensuring all boiler components operate at peak performance. Without a good maintenance system, burners and condensate-return systems can wear or get out of adjustment, costing a steam system up to 30% of its initial efficiency over two to three years.

Did you know?

On average, the energy savings associated with improved boiler maintenance are estimated at 10%. Improved maintenance may also reduce the emission of criteria air pollutants.

Improve distribution system insulation. Using more insulating material or the best type of insulation for the application can save energy in steam systems. The payback period for improved insulation is typically about one year, according to industrial case studies.

Maintain distribution system insulation. When heat distribution systems have undergone repair, the insulation often is not replaced. Some types of insulation can become brittle or rot over time. A regular inspection and maintenance system for insulation can save energy.

Repair leaks. As with steam traps, steam distribution piping networks often have leaks that can go undetected without a regular inspection and maintenance program. Repairing leaks in an industrial steam distribution system will lead to energy savings of about 5% to 10%, according to U.S. DOE estimates.

3.5 Chillers

When ready mixed concrete is manufactured at elevated temperatures, its properties can be affected. When the ambient temperature is high, many concrete facilities produce chilled water to cool raw material and use it as batch water. Other methods of concrete pre-cooling include cooling mixing water with liquid nitrogen, and cooling concrete with ice or liquid nitrogen.¹¹

The U.S. DOE's [Chilled Water System Analysis Tool](#) (CWSAT) helps energy and plant managers identify efficiency improvements in chiller water systems. The user can make changes on equipment such as chillers, pumps, and towers and determine the energy and cost savings of these changes. A more detailed description of energy efficiency opportunities in chiller systems is provided by U.S. DOE.¹²

There are several ways to improve chiller efficiency and reduce operational costs¹² which are described below.

Raise chilled water temperature. The energy use in both types of liquid chillers (mechanical compression or absorption) increases as the temperature difference between the evaporator and the condenser increases. By raising the chilled water temperature, the evaporator temperature will increase, decreasing the required temperature lift.

Reduce condenser water temperature. Similarly, decreasing water temperature in the condenser will limit the temperature difference between the condenser and the evaporator, decreasing the required temperature lift.

Keep heat transfer surfaces clean. Heat transfer efficiency in the chiller system can decrease with mineral or sludge buildup on the heat transfer surfaces. Regular cleaning improves the system's efficiency.

Remove trapped air from the condenser. Trapped air in the condenser limits the cold surface exposed to the refrigerant. This can be overcome only with higher pressure (and temperature).

Use naturally occurring cooling water. When the outside temperature is not very high, naturally occurring cool water could be used instead of chilled water when available. See also Section 4.6.

Replace absorption chillers with electric drive centrifugal chillers. In a typical absorption chiller, 1.6 Btu of thermal energy are required to remove 1 Btu of energy from the thermal water. However, only 0.2 Btu of electric energy is required in modern electric drive centrifugal chillers to remove 1 Btu of energy from the thermal water.

Did you know?

On a centrifugal chiller, increasing the temperature of the chilled water by 2°F to 3°F can improve the system's efficiency by 3% to 5%.

3.6 Dust Collectors

To ensure proper operation of dust collectors, pulse air jets, mechanical shakers, bags, and cartridges should be inspected regularly. Fabric bags must be sized correctly and fitted properly, and all worn fabrics should be replaced.¹³

During plant assessments, Titan America has regularly found dust collectors in operation all day, although they are only needed during truck loading.⁶ Significant energy savings are expected when the motors that drive the dust collectors are shut down when not needed. Titan America⁶ found a number of best practices that can ensure efficient operation of baghouse filters at minimum energy requirements:

- **Seal areas**, as the existence of leaks will increase draft requirements.
- Employ the **minimum effective draft**. Extra draft will accumulate more dust on the filters, increasing wear of ducts and bags. Use dampers and/or variable-speed fans to control the draft.

- **Automate dust collectors** so they do not operate unless needed.
- **Resize and slow down fans that are too big.** This will result in energy savings. Installing an adjustable-speed drive (ASD) will require higher capital investment but will result in increased energy savings.
- **Maintain a differential pressure** across the dust collector (pressure difference between the dirty and clean side of the bags) between 4 to 5 inches of water. For efficient operation of dust collectors, filters should be relatively dirty or have a dust cake.
- Use a **differential pressure control system** on the cleaning system. Differential pressure should range between 4 and 5 inches of water when a fan-driven dust collector is used.
- A compressed air jet-pulse cleaning system should use the **minimum effective pressure**, which usually ranges between 60 and 70 psi, and not more than the manufacturer's recommended pressure when a pneumatic shaker is used.
- Employ a **rather short pulse** to shake extra dust off in the case of compressed air blowdown systems.

4 Energy Efficiency Opportunities for Ready Mixed Concrete Production Processes

The measures below address the energy efficiency of practices, processes, and technologies used specifically in U.S. ready mixed concrete manufacturing. A variety of energy and material efficiency measures are listed that can yield substantial cost savings while increasing or maintaining plant throughput and in some cases improving product quality.

4.1 Cold Weather Concreting

Ready mixed concrete production in cold climates is energy intensive due to the need to heat water and aggregates. The most significant energy savings are realized when boiler efficiency is improved and the water content of coarse and fine aggregates is kept low. Additional measures are as follows.

Provide shelter. The energy requirement to dry aggregates with a typical water content of 5% is around 23 lb of steam/hour per short ton of aggregate. When water content doubles, the steam requirement increases to 39 lb of steam/hour per short ton of aggregate; an increase of almost 70%.¹⁴ Thus, storing aggregates under shelter can lead to significant energy savings.^{14,15}

Create paved and sloped areas to place stockpiles. Aggregates are usually stockpiled on the ground without any precautions for water drainage, resulting in high water content, especially at the base of the pile. For example, when the area beneath the stockpiles in an asphalt-mix plant

was paved and inclined, aggregate moisture content decreased by nearly 2%, resulting in nearly 30% less steam needed for drying.¹⁴ Additional benefits accrue as fewer raw materials are mixed with the soil (3% material savings). Fuel is saved as well, as less is required for mobile equipment when storage areas are paved. The average corresponding payback period is estimated as less than seven months.

4.2 Humidity Control

The strength and flowability of ready mixed concrete depends greatly on the water content of the mix. Accurate control of the water-to-cement ratio is translated into less cement and admixture consumption per ton of ready mixed concrete produced.

Case study: Sensors

According to Hydronix, the cement savings from adopting sensors and an automatic water control system are around 6 kg/short ton of concrete. The payback time is reported to range from 2 to 6 months.

Tips: Humidity Control Measures

<p>Turn a dry-batch plant into a wet-batch</p>	<p>Cazacliu and Ventura¹⁶ have shown that the addition of a central mixer in a ready mixed concrete facility can improve water control, and when accurately used achieve significant savings in cement consumption, estimated at about 34 lb/yd³ (20 kg/m³). The cost savings of reducing cement use amount to \$90,000/year for a dry-batch plant with an annual production of 60,000 yd³, assuming a cement price of \$90/short ton cement. A typical payback period is estimated to range between 1 and 3 years.</p>
<p>Install microwave sensors and automatic water control</p>	<p>To help control water content, microwave humidity sensors can be installed in the aggregate bins or in the conveyor belt, but they can also be installed inside the mixer.^{17,18}</p>

4.3 Mixing

Energy requirements for the mixing process depend on the concrete mix, mixer type, batch size, and loading method. Energy consumption is influenced by many parameters and cannot be considered a good indicator of the mixer's efficiency.¹⁹ In this report, an efficient mixer is defined as the mixer that mixes all ready mixed concrete constituent materials uniformly without favoring one over another, using the least amount of energy.

Optimize mixing time. By tracking mix homogeneity, a shorter mixing duration can be determined, which reduces power consumption. Different mixes will need different mixing times to reach optimum uniformity.²⁰

Two ways to determine concrete homogeneity are to (1) track power consumption change during mixing, and (2) use humidity sensors.^{21,22}

- **Track power change during mixing.** Tracking power consumption can help determine the product's homogeneity during batching.²¹ Power consumption is related to the resistive torque produced by mixing materials.
- **Use humidity sensors.** Humidity sensors can be helpful in determining product homogeneity.¹⁸ Data can be used to improve product quality and save energy by matching mixing-cycle duration to the optimal time. For more information on humidity sensors, see Section 4.2, Humidity Control.

Mixer type. For conventional mixes, no specific type of mixer produced a clear advantage in product quality.²⁴ Several factors should be considered when choosing the best mixer for a specific application:

- (1) distance from the job site,
- (2) volume of concrete needed per hour,
- (3) operational cost, and
- (4) product quality (most important).

When mixing a special concrete (e.g., low water/cement ratio), the use of a specific mixer type for special concretes could be beneficial.

Twin-shaft mixers were found to perform better than drum mixers in the case of high-performance concrete (HPC) with low binder content, requiring less mixing time and power.²⁵ The power consumption in a planetary mixer is reported to be 25% less than in a pan mixer.²⁶

Planetary mixers reportedly require 15% to 25% less cement than spiral blade mixers.²⁷ They are characterized by increased maintenance costs (over the maintenance costs required for twin-shaft mixers) due to their many moving parts.²⁷

4.4 Truck Operation and Fleet Management

Transporting ready mixed concrete to the construction site imposes one of the most significant costs to the concrete industry. Improving truck operation and fleet management reduces delivery time and fuel consumption.

Track fuel consumption. Most ready mixed concrete companies calculate fuel consumption (mainly diesel oil) in miles per gallon (mpg). In 2010, the average fuel consumption was 3.4 mpg.²⁸ The highest and the lowest fuel consumption appearing in a 2010 NRMCA survey were 7.0 mpg and 2.1 mpg.²⁸ The spread in fuel consumption suggests significant room for improvement. However, tracking only miles per gallon does not show the larger picture, as

Case study: Humidity sensors

Daily water additions to the concrete mix and lengthy mixing cycles were the norm for a concrete block, manhole, and prefabricated garage production facility in Southern Bavaria (Germany). The plant installed a microwave sensor, which showed the mixing cycle could be reduced without affecting product quality.²³ Before the sensor installation, dry mixing lasted around 80 seconds. The sensor showed that 40 seconds would be optimal. The cycle was optimized, and power consumption and mixer wear were reduced. The sensor also indicated that the wet mixing cycle should be extended to achieve product homogeneity. In the end, product quality was improved and the overall mixing cycle was reduced.

trucks spend significant time idling, batching, and traveling off-road. Tracking truck fuel consumption during the day enables optimization of fuel efficiency.

Fuel consumption can be simply determined by gathering information on the miles and hours a truck was driven and the time spent idling. Installing diesel flow meters in trucks provides more precise information on real-time fuel consumption (or later in downloadable format). Flow meters help track truck efficiency and identify further improvement options, such as retrofitting or replacement.

Reduce idle time. The American Trucking Association (ATA) reports that idling consumes 1.2 billion gallons of truck diesel fuel annually.²⁹ Reducing idling time could save fuel and maintenance costs.

In collaboration with the truck drivers, Titan America identified a number of best practices,³⁰ including:

- Shutting off the engine when washing the truck between loads.
- Training fleet coordinators to improve truck dispatching.
- Discovering driver misconceptions about vehicles.
- Identifying technologies that reduce idling time, such as a spray nozzle or a wash rack.
- Wiring radios to the battery to avoid needing the engine on to power the radio.

Case study: Reduce idle time

Titan America identified and promoted several best driver practices concerning truck idling. The result was a 38% reduction in idle time within 2 months.

Route optimization. A route-planning system such as GPS (global positioning system) can save fuel by finding a shorter distance to the construction site. Road gradation, idling time, and other factors influencing fuel consumption should be considered.

4.5 Returned Concrete

In the United States an annual average of 5% of ready mixed concrete is returned to the batching plant.³¹

Returned concrete should not be sent to landfills, but reused in various ways. The advantages are obvious: reduction in disposal, transportation, and water costs (when water is also recycled), reduced exploitation of natural resources, and reduction of landfill waste. Examples are:

Excess concrete reduction. Reduce the ordering safety factor and improve estimations of the amount of concrete needed at the job site. Cutting back on excess concrete production results in less concrete returned to the plant.

Reuse on the plant site. Returned concrete can be reused on the plant site, for example, for paving the plant itself. This reduces landfill costs and cuts back on dust from trucks driving on unpaved plant surfaces.

Batch on top. Small quantities of fresh returned concrete (less than 5%) can be used with the next batch without affecting its properties.³² Hydration stabilizing admixtures (HSAs) can also be used to stabilize the hydration of cement. Hydration stabilizers with water are sprayed on the

mixer's walls at the end of the day. The following day, the new ready mixed concrete batch is placed into the truck, without reclaiming the previous days' returned ready mixed concrete. This measure is usually adopted in small-scale batching plants, and although it can be cost-effective, it is not always practicable as product specifications can limit its use.³³

Stoning out. Stoning out is an efficient way to retrieve and reuse returned concrete as aggregate since it requires no investment, maintenance, or admixture costs. The mixer is loaded with 2 tons of aggregate and 200 liters of water and brought to the point of discharge about 4 to 5 times. The mixture can either remain in the truck overnight and be used the next day — after making some adjustments — as part of the first batch, or placed on the top of the aggregate stockpile for future use.³⁵

Mechanical concrete reclaimer. Returned ready mixed concrete can be processed through a mechanical reclaimer, which separates aggregates and grey water (slurry composed of cement and water). The reclaimed aggregates and grey water can be used in the concrete mixer. The main advantages of this method are reuse of returned concrete and elimination of washout water. Payback time for an average-capacity facility is estimated to range between 2.5 and 3 years.

Crushing and recycling concrete. When returned to the plant, fresh ready mixed concrete can be left to harden and afterward crushed for further processing. Crushed concrete aggregate (CCA) can be used in concrete production or at the plant site, as road base, or fill. This option has a significant potential in the United States, and could be used to recycle 60% of returned concrete.³³ The investment cost for an average crusher is estimated at \$70,000.³⁶

The net cost savings vary according to the CCA separation scheme adopted and range between \$0.3/yd³ and \$4.0/yd³ of concrete produced.³³ The payback time ranges from a few months to a maximum of 4 years.

Case study: Waste reduction

To solve the problem of handling returned concrete, a ready mixed concrete facility in North Carolina's Watauga County decided to install a concrete reclaimer along with a water settling basin.³⁴ The initial investment was \$140,000. The annual aggregate generation was estimated at 5.1 million pounds, and the annual water recovery was 650,000 gallons (a part was also collected from runoff water). The net annual savings were approximately \$45,000; the payback period was 3 years.

4.6 Miscellaneous

Optimize Ready Mixed Concrete Mixture. According to experimental case studies on the production of concrete floors and high-performance concrete (HPC) blocks,³⁸ concrete mix optimization can yield significant savings in material costs. Material cost reduction was mainly achieved by substituting cement with cementitious materials, fly ash, and granulated blast-furnace slag.

Concrete Pre-cooling. High ambient temperatures affect mixing, curing, and placement of ready mixed concrete, with a negative impact on concrete properties.

Several approaches can be taken to control concreting at elevated temperatures:

- Aggregates can be stored in large-capacity stockpiles — as temperature can remain low in the center — and in covered and shaded areas.
- Painting the mixing and hauling equipment in light colors can be very helpful.³⁹
- Raw materials can be pre-cooled. Methods for concrete pre-cooling are:
 - Cooling with chilled batch water (either from a natural cold water source or a chiller).
 - Cooling mixing water with liquid nitrogen.
 - Cooling batch water with a geothermal heat pump.
 - Cooling concrete with ice.
 - Evaporative cooling coarse aggregates by wetting stockpiles.
 - Cooling concrete with liquid nitrogen.

According to the ACI 305 report, a major way to reduce concrete temperature is to add ice as a part of the batching water,¹¹ though the cost of installing an ice plant is high.

Case study: Mixture optimization

Soil Retention Products (SRP) in Romoland, California, which makes a variety of concrete products, produces concrete mix with up to 40% Class F fly ash content.³⁷ By avoiding concrete mix overdesigning by imposing specific cement content and w/c ratios, SRP can produce high-quality and cost-effective products.

5 Summary

By increasing energy efficiency, companies can cut costs and increase predictable earnings even when faced with ongoing energy price volatility. Considering the negative impacts that such volatility has on the bottom line, such as potential sharp increases in natural gas prices, energy efficiency improvements are needed today more than ever, and many firms are reaping the rewards of these investments. Companies also turn to energy-efficient methods to reduce their criteria pollutant and carbon emissions, to meet corporate environmental goals.

This *Quick Guide* summarizes many energy-efficient technologies and practices that are proven, cost-effective, and available to implement today. To achieve ongoing success,

establish a focused, strategic energy management program that helps you identify and implement energy efficiency measures and practices across the organization and ensure continuous improvement. For all of the energy efficiency measures presented in this guide, research their economics and applicability to your facility's unique production practices to assess each one's feasibility and potential benefits.

6 Glossary

ACI	American Concrete Institute
ANSI	American National Standards Institute
ASD	adjustable speed drive
ATA	American Trucking Association
Btu	British thermal unit
CCA	crushed concrete aggregate
CEE	Consortium for Energy Efficiency
CFL	compact fluorescent lamp
CIPEC	Canadian Industry Program for Energy Conservation
CMU	concrete masonry unit
CO	carbon monoxide
CWSAT	Chilled Water System Analysis Tool
DOE	Department of Energy
EASA	Electrical Apparatus Service Association
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
<i>fib</i>	Fédération Internationale du Béton
GHG	greenhouse gas
GJ	gigajoule
GPS	global positioning system
HID	high-intensity discharge
HPC	high-performance concrete
hp	horsepower
HSA	hydration stabilizing admixture
HVAC	heating, ventilation, and air conditioning

IAC	Industrial Assessment Center
ISO	International Organization of Standardization
kBtu	Thousand British Thermal Unit
kg	kilogram
kW	kilowatt
kWh	kilowatt hour
lb	pound
LBNL	Lawrence Berkeley National Laboratory
LCC	life-cycle costing
LED	light emitting diode
LN	liquid nitrogen
MBtu	Million British thermal units
m	Meter
m ³	cubic meters
MJ	Megajoule
mm	millimeter
mpg	miles per gallon
NEMA	National Electrical Manufacturers Association
NO _x	nitrogen oxide
NRMCA	National Ready Mixed Concrete Association
PCA	Portland Cement Association
PCI	Precast/Prestressed Concrete Institute
pH	Potential of Hydrogen
psi	pounds per square inch
psig	pounds per square inch gauge
PTO	power take-off

RMC	ready mixed concrete
w/c	water to cement
yd ²	square yard
yd ³	cubic yard

7 References

- 1 Kermeli, K., E. Worrell, E. Masanet. 2011. Energy Efficiency Improvement and Cost Saving Opportunities for the Concrete Industry – An ENERGY STAR® Guide for Energy and Plant Managers. Berkeley, California: Lawrence Berkeley National Laboratory.
- 2 Marceau, M. L., M. A. Nisbet, M. G. VanGeem. 2007. *Life Cycle Inventory of Portland Cement Concrete*, SN3011, Portland Cement Association (PCA), Skokie, Illinois.
- 3 Fédération Internationale du Béton (*fib*). 2003. Environmental Issues in Prefabrication. Lausanne. ISBN 978-2-88394-061-1.
- 4 Fédération Internationale du Béton (*fib*). 2004. Environmental design: State-of-art report. Lausanne. ISBN 978-2-88394-068-0.
- 5 Nielsen, C. V., M. Glavind. 2007. Danish Experiences with a Decade of Green Concrete. *Journal of Advanced Concrete Technology*. 5 (1), pp. 3-12.
- 6 Bayne, C. 2011. Titan America. Personal Communication.
- 7 United States Department of Energy (DOE). 2005. CEMEX: Cement Manufacturer Saves 2.1 kWh Annually with a Motor Retrofit Project. Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program, Washington, D.C.
- 8 Dominion (no date). Lighting Rewards. <http://www.dom.com/dominion-virginia-power/customer-service/energy-conservation/pdf/va-lighting-rewards-rebate-chart.pdf>
- 9 Motor Decisions Matter (MDM). 2007. *Motor Planning Kit*. Boston, Massachusetts. www.motorsmatter.org/tools/mpkv21.pdf.
- 10 United States Department of Energy (DOE). 2006. *Save Energy Now in Your Steam Systems*. Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program, Washington, D.C. Report DOE/GO-102006-2275.
- 11 American Concrete Institute (ACI) Committee 305. 1991. Hot Weather Concreting. Farmington Hills, Michigan. ACI 305R-91.
- 12 United States Department of Energy, Energy Efficiency and Renewable Energy (DOE). 2010. *Operations and Maintenance Best Practices, A Guide to Achieving Operational Efficiency, Release 3.0*. Office of Energy Efficiency and Renewable Energy, Washington, D.C.
- 13 Millennium EMS Solutions Ltd. (MEMS). 2010. *Guide to the Code of Practice for the BC Concrete and Concrete Products Industry*. Version 6. BC Ready Mixed Concrete Association.

- 14 Stamper, G., R. L. Koral, C. Strock. 1979. *Handbook of Air Conditioning Heating and Ventilating. Space Heating*. 3rd ed. United States of America: Sixth Printing.
- 15 Ang, B. W., T. F. Fwa, T. T. Ng. 1993. "Analysis of Process Energy Use of Asphalt-Mixing Plants." *Energy*, 18 (7), pp.769-777.
- 16 Cazacliu, B. and Ventura, A. 2010. "Technical and Environmental Effects of Concrete Production: dry batch versus central mixed plant". *Journal of Cleaner Production*, 18, pp.1320-1327.
- 17 Boscolo, A., C. Mangiavacchi, O. Tuzzi. 1993. "Fuzzy Sensor Data Fusion for Quality Monitoring in Concrete Mixing Plant" *Conference Record-IEEE Instrumentation and Measurement Technology Conference*, pp.671-675.
- 18 Wang, K. and Hu, J. 2005. "Use of a Moisture Sensor for Monitoring the Effect of Mixing Procedure on Uniformity of Concrete Mixtures." *Journal of Advanced Concrete Technology*, 3(3), pp.371-383.
- 19 Ferraris, C. F. 2001. "Concrete Mixing Methods and Concrete Mixers: State of the Art." *Journal of Research of the National Institute of Standards and Technology*, 106, pp.391-399.
- 20 Rupnow, T. D., V. R. Schaefer, K. Wang, B. L. Hermanson. 2007. *Improving Portland Cement Concrete Mix Consistency and Production Rate Through Two-Stage Mixing*. National Concrete Pavement Technology Center.
- 21 Chopin, D., B. Cazacliu, F. De Larrard, R. Schell. 2007. "Monitoring of Concrete Homogenisation with the Power Consumption Curve." *Materials and Structures*, 40, pp.897-907.
- 22 Cazacliu, B. G., P. O. Vandanjon, F. De Lallard, D. Chopin. 2002. "Current Issues in Concrete Mixing Research". In: Dhir, R. K., Hewlett, P. C., Csetenyi, L. J.(eds.), *Proceedings of the International Conference: Innovations and Developments in Concrete Materials and Construction*, Dundee, September, pp.837-847.
- 23 Hydronix, Ltd. 2005. "Moisture Measurement for Rotating Pan Mixers." *Concrete Technology, Concrete Plant International (CPI) Journal*, August, 2005. pp. 88-95. <http://www.cpi-worldwide.com/>
- 24 International Organization of Standardisation (ISO) 18650-1. 2004. *Building Construction Machinery and Equipment. Concrete Mixers. Part 1: Terminology and Commercial Specifications*, Geneva 2004.
- 25 Chang, P. K., Y.N. Peng. 2001. "Influence of Mixing Techniques on Properties of High Performance Concrete." *Cement and Concrete Research*, 31 (1), pp. 87-95.

- 26 Budny, E., M. Chlosta, H. J. Meyer, M. J. Skibniewski. 2009. "Construction Machinery". In: K. H. Grote, E. Antonsson, (eds.) *Handbook of Mechanical Engineering*. New York: Springer. Ch. 14.
- 27 Shepherdson, R. 2010. "Selecting the Best Mixer for your Application. Concrete Technology. Production Optimization." *CPI Concrete Plant International (CPI) Journal Industry*. March, 2010 pp. 22-25. <http://www.cpi-worldwide.com/>
- 28 Jones, T., M. Zagula, J. Hinkle, B. Mobley, G. Mullings. 2010. "2010 National Ready Mixed Concrete Association (NRMCA) Fleet Benchmarking and Cost Surveys." *Concrete InFocus*, pp. 7-13. September/October 2010. <http://www.nxtbook.com/nxtbooks/naylor/NRCS0410/index.php#/0>
- 29 American Trucking Associations (ATA). 2008a. Idling Reduction. <http://www.truckline.com/advisories/environment/pages/idlingreduction.aspx>
- 30 Downs, D. 2009. Fleet Truck Idle Time Reduction Initiative. Titan America. ENERGY STAR Focus on Energy Efficiency in Cement Manufacturing. November 2009.
- 31 Paolini M., R. Khurana. 1998. "Admixtures for Recycling of Waste Concrete." *Cement and Concrete Composites*. 20, pp. 221-229.
- 32 Obla, K., Kim, H., Lobo, K. 2007. Crushed Returned Concrete as Aggregates for New Concrete. Final Report of the RMC Research and Education Foundation. Project 05-13
- 33 Kawai, K., T. Sugiyama, K. Kobayashi, S. Sano. 2005. "Inventory Data and Case Studies for Environmental Performance Evaluation of Concrete Structure Construction." *Journal of Advanced Technology*, 3 (3), pp. 435-456.
- 34 Division of Pollution Prevention and Environmental Assistance (DPPEA). 1995a. Case Study: Watauga Ready Mix Corporation. SIC 3300 Case Studies.
- 35 Sealey, B. J., P. S. Philips, G. J. Hill. 2001. "Waste Management Issues for the UK Ready-Mixed Concrete Industry." *Resources Conservation and Recycling*, 32, pp.321-331.
- 36 Joint Service Pollution Prevention 2003. Concrete/Asphalt Crushers. http://www.p2sustainabilitylibrary.mil/p2_opportunity_handbook/7_III_6.html
- 37 Mc Craven, S. No date. Precast Concrete Offers Achievable Solutions for Specifiers and Producers. Precast Solutions. <http://www.solutions.precast.org/precast-concrete-sustainability-case-study>
- 38 Obla, K., F. Rodriguez, S. B. Barka. 2005. "Experimental Case Study Demonstrates Advantages of Performance Specifications." *Concrete inFocus*, pp. 32- 42. Summer 2005. http://www.nrmca.org/news/connections/Summer_2005.pdf

39 American Concrete Institute (ACI) Committee 207. 1993. Cooling and Insulating Systems for Mass Concrete. Farmington Hills, Michigan. ACI 207.4R-93.