Climate Change and Concrete

NRMCA

Concrete and CO_2

- Most widely used building material
- Beauty, strength and durability
- Used all types of construction
  - Homes, buildings, roads, bridges, airports and subways
- Environmental performance compares well to other building materials
- As with any building product concrete and its ingredients do require energy to produce
- Results in the generation of CO_2
- CO_2 produced during manufacturing is small

Concrete is the most widely used building material in the world because of its beauty, strength and durability, among other benefits. Concrete is used in nearly every type of construction, including homes, buildings, roads, bridges, airports and subways, just to name a few. And in an era of increased attention on the environmental impact of construction, concrete performs well when compared to other building materials. As with any building product, concrete and its ingredients do require energy to produce that in turn results in the generation of carbon dioxide, or CO2. But the amount of CO2 produced during manufacturing and the net impact of using concrete as a building material is relatively small.

Minimizing Carbon Footprint

Concrete Feature	Effect on Carbon Footprint
Most ingredients require little processing	Minimizes energy of production
Most materials harvested and manufactured locally	Minimizes transportation energy
Building systems combine insulation and thermal mass	Homes and buildings more energy efficient
Long service life	Minimizes reconstruction, repair and maintenance
Pavement and exterior cladding are light in color	Minimizes urban heat island effect
Incorporates recycled industrial byproducts	Reduces the energy required for manufacturing
Absorbs CO_2 throughout its lifetime through carbonation	Reduces carbon footprint

The following features of concrete construction help minimize its carbon footprint:

Concrete is resource efficient and the ingredients require little processing.

Most materials for concrete are harvested and manufactured locally which minimizes transportation energy.

Concrete building systems combine insulation and thermal mass to make homes and buildings more energy efficient.

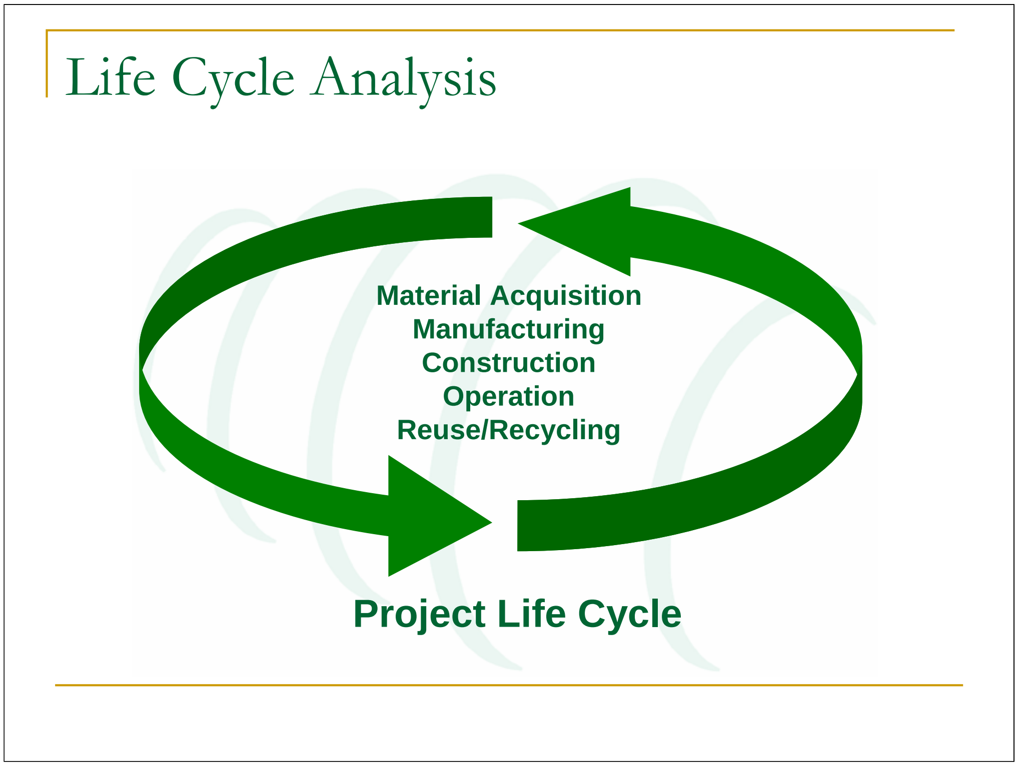
Concrete has a long service life for buildings and transportation infrastructure, thereby increasing the period between reconstruction, repair and maintenance and the associated environmental impact.

Concrete, when used as pavement or exterior cladding, helps minimize the urban heat island effect thus reducing the energy required to heat and cool our homes and buildings.

Concrete incorporates recycled industrial byproducts such as fly ash, slag and silica fume which helps reduce the energy required for manufacturing.

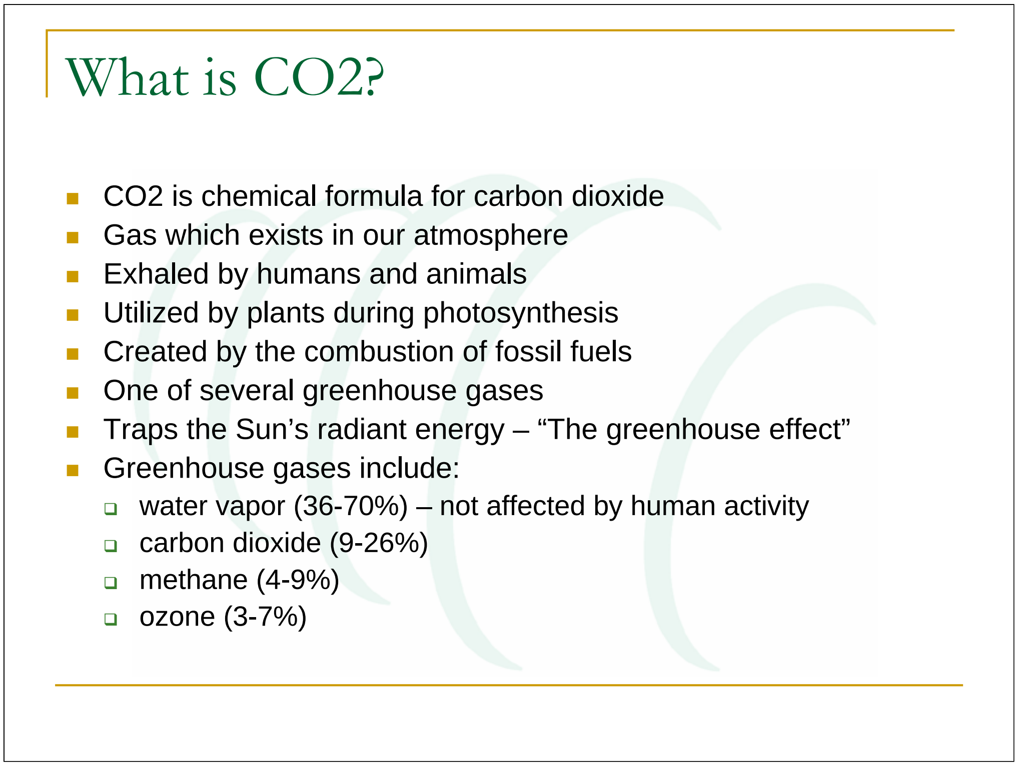
Concrete absorbs CO2 throughout its lifetime through a process called carbonation, helping reduce its carbon footprint.

All that being said, the following facts help tell the story of concrete and CO2.



•When looking at carbon footprint, it is important to look at the complete life cycle of the building including material acquisition, manufacturing, construction, operation, and reuse/recycling.

•All phases of a building or product should be considered. Simply looking at the acquisition and manufacturing phases ignores impacts during the operational phase. Reuse/recycling considers new options once the product or building has reached the end of its service life.



What is CO2?

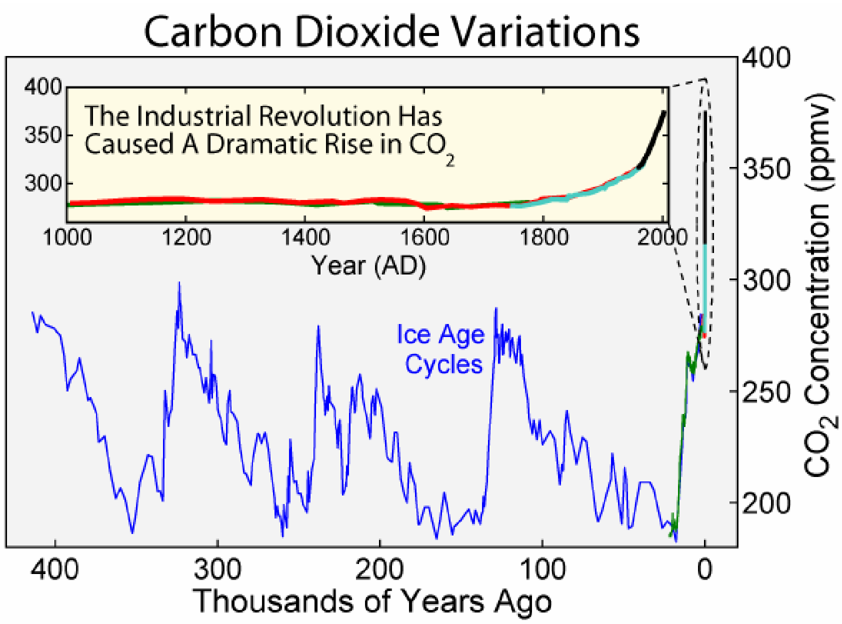
CO2 is the chemical formula for carbon dioxide, a gas which exists in relatively small amounts (380 parts per million or ppm) in our atmosphere.

In general, it is exhaled by humans and animals and utilized by plants during photosynthesis. Additionally, carbon dioxide is created by the combustion of fossil fuels or plant matter, among other chemical processes.

Carbon dioxide is one of several greenhouse gases that can cause global warming by trapping the Sun's radiant energy in our atmosphere. This process is called the greenhouse effect.

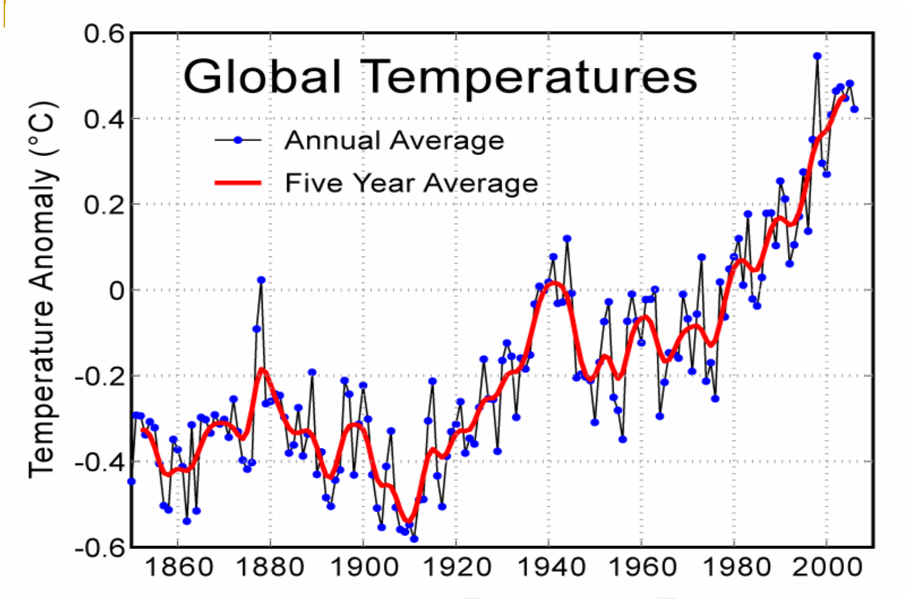
Greenhouse gases include water vapor (36-70%), carbon dioxide (9-26%), methane (4-9%) and ozone (3-7%), among others. The percentages indicate the approximate range of the greenhouse effect resulting from these greenhouse gas sources. Water vapor, the major source, is not affected by human activity.[i]

[i] Water vapour: feedback or forcing? RealClimate, http://www.realclimate.org/index.php?p=142.



Atmospheric concentrations of CO2 are expressed in units of parts per million by volume (ppm). Since the beginning of the Industrial Revolution in the late 1700s, the concentration of CO2 in our atmosphere has increased by about 100 ppm (from 280 ppm to 380 ppm). The first 50 ppm increase took place in about 200 years, from the start of the Industrial Revolution to around 1973; the next 50 ppm increase took place in about 33 years, from 1973 to 2006. It is estimated that 64% of the CO2 in the atmosphere is due to burning fossil fuels.[i]

[i] Carbon Dioxide Information Analysis Center, http://cdiac.ornl.gov/pns/faq.html

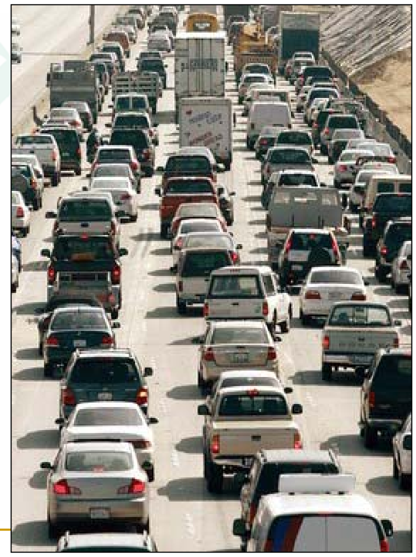


What is global warming?

Global warming is the increase in the average temperature of the Earth's atmosphere and oceans as a result of the buildup of greenhouse gases in our atmosphere. Global warming is sometimes called climate change.

Causes of Greenhouse Gases

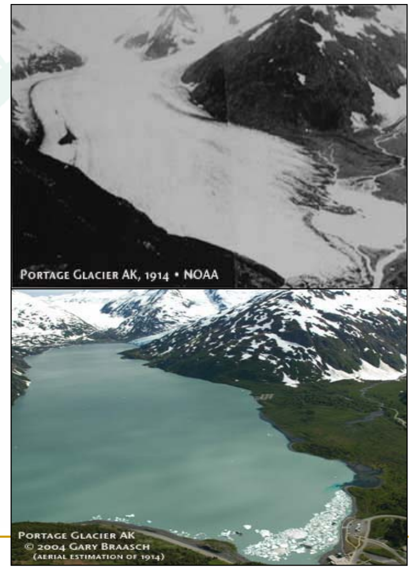
- Natural events
  - Volcanic eruptions
  - Forest fires
- Human activity:
  - Deforestation
  - Burning fossil fuels
  - Products manufacturing
  - Drivin cars and trucks
  - Heat and cool homes
  - Heat and cool buildings
  - Livestock
  - Agriculture
  - Landfill emissions
  - Chlorofluorocarbons in refrigeration systems



Greenhouse gases can either be caused by natural events such as volcanic eruptions or human activity such as deforestation or burning fossil fuels to manufacture products, power our cars and trucks, or to create the energy to heat and cool the homes we live in and the buildings we work in. Livestock, agriculture, landfill emissions and use of chlorofluorocarbons in refrigeration systems are other sources of greenhouse gases resulting from human activity.

Global Warming

- Many scientists believe global warming will cause
  - Rise in sea level
  - Increase extreme weather
  - Change precipitation
  - Changes agricultural yields
  - Glacier retreat
  - Species extinctions
  - Increases in disease



Many scientists believe global warming will cause a rise in sea level, increase the intensity of extreme weather, and change the amount and pattern of precipitation. Other effects could include changes in agricultural yields, glacier retreat, species extinctions and increases in disease. These effects could severely impact the Earth's ability to support life.

Causes of Global Warming

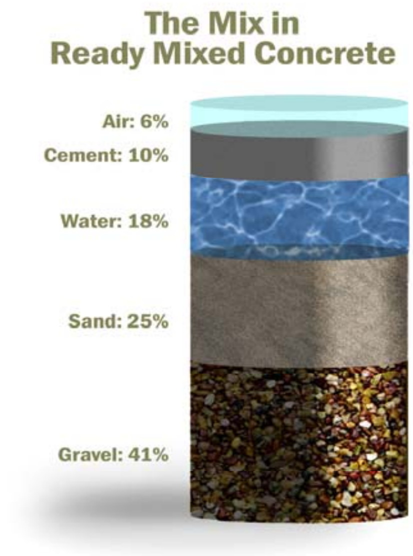
- Many scientists believe global warming caused by greenhouse gas emissions from:
  - Energy production
  - Transportation
  - Industry
  - Agriculture

Coal fired electric power plant

Many scientists believe recently observed global warming is partially caused by greenhouse gas emissions from energy production, transportation, industry and agriculture.

Cement and concrete?

- Cement ingredient of concrete
- Fine, gray powder
- Mixed with water, sand gravel to form concrete
- Cement acts as the binding agent
- Cement is produced by cement manufacturers
- Concrete produced by concrete producers



What’s the difference between cement and concrete?

The terms cement and concrete are often used interchangeably. Cement is an ingredient of concrete. It's the fine, gray powder that, when mixed with water, sand and gravel, forms the rock-like mass known as concrete. Cement acts as the binding agent or glue. Cement is produced by cement manufacturers around the world in cement plants.

Clinker and Cement

Clinker: product from the burning process during manufacturing process

Cement: clinker is interground with other ingredients to produce cement

The product from the burning process during manufacture of cement, called clinker, is then interground with other ingredients to produce the final cement product.

Concrete

- Rock-like mass used to build most structures

Concrete is the rock-like product that is used to build our homes, buildings, roads, bridges, airports and subways, among other critical structures. Concrete is used in almost every form of construction. It’s made by concrete producers who combine materials, including cement, water, sand and gravel, along with other chemicals and minerals to create concrete.

Does cement generate CO_2?

- As with all industrial processes
- Cement generates CO_2
- Made from natural minerals
  - calcium (60%) from limestone
  - silicon (20%)
  - aluminum (10%)
  - iron (10%)
- Heated in large kiln to 1500° C
- Converts raw materials to clinker
- CO_2 generated from two sources
  - Fossil fuels in burning process
  - Calcination - calcium carbonate broken down to calcium oxide with release of $C0_2$

Does cement manufacturing generate CO2?

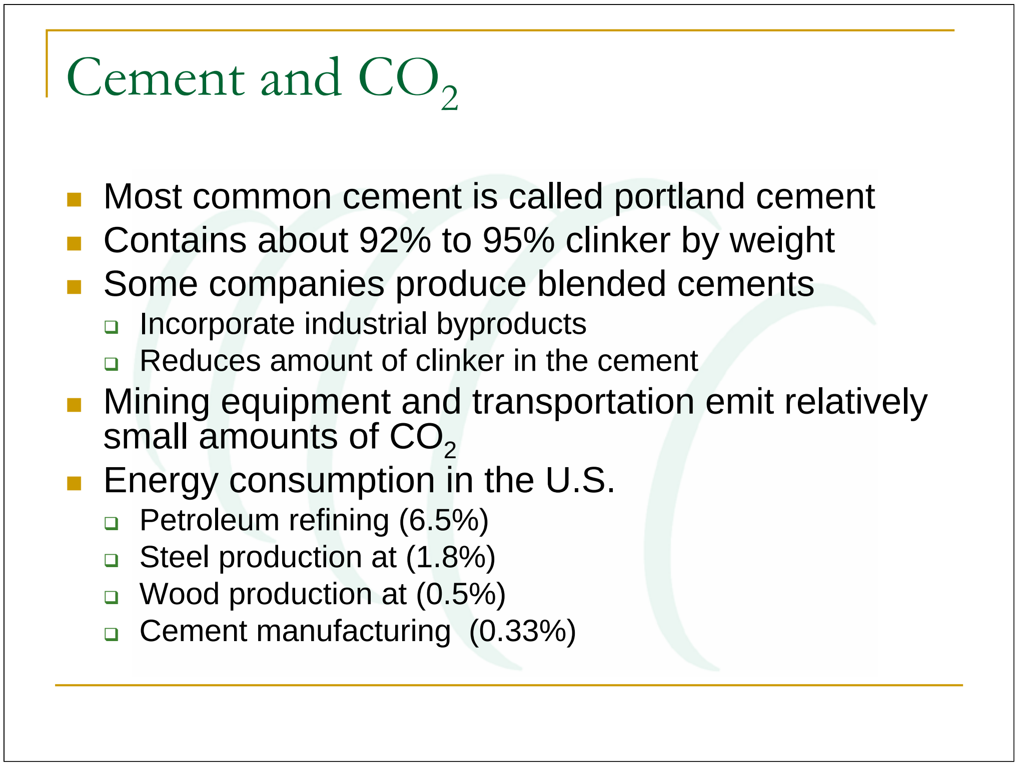
As with all industrial processes requiring energy, manufacturing cement does result in the generation of CO2.

Cement is manufactured from a combination of naturally occurring minerals - calcium (60% by weight) mainly from limestone or calcium carbonate, silicon (20%), aluminum (10%), iron (10%) and small amounts of other ingredients and heated in a large kiln to over 1500° C (2700° F) to convert the raw materials into clinker.

For the most part, CO2 is generated from two different sources during the cement manufacturing process:

Use of fossil fuels in the burning process;

Calcination, when calcium carbonate is heated and broken down to calcium oxide with the release of C02.



The most commonly used cement is called portland cement. It contains about 92% to 95% clinker by weight. Some companies produce blended cements that incorporate other industrial byproducts that have cementitious properties, thus reducing the amount of clinker in the cement.

Other parts of the manufacturing process such as operating mining equipment for extracting the raw materials and transportation of the raw materials to the cement plant emit relatively small amounts of CO2.

According to the Department of Energy, cement production accounts for 0.33% of energy consumption in the U.S. The current level is low compared with other industries, such as petroleum refining at 6.5%, steel production at 1.8% and wood production at 0.5%.[i]

[i] Portland Cement Association, Briefing Kit, Sustainable Development, http://www.cement.org/concretethinking/FAQ.asp.

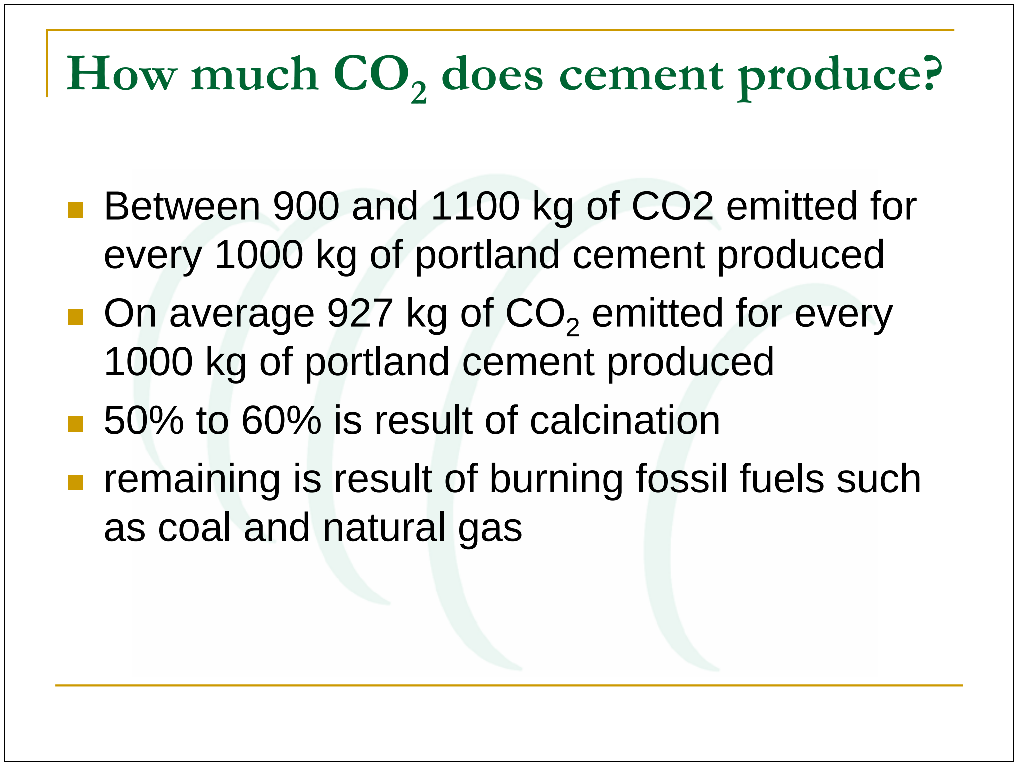
Does concrete produce CO_2?

- Water, sand, stone or gravel and other ingredients make up about 90% of concrete
- Mining sand and gravel, crushing stone, combining the materials and transportation concrete requires very little energy
- Emits a relatively small amount of CO_2
- Nearly all the CO_2 embodied in concrete is a direct result of the use of portland cement

Does concrete manufacturing produce CO2?

Water, sand, stone or gravel and other ingredients make up about 90% of the concrete mixture by weight. The process of mining sand and gravel, crushing stone, combining the materials in a concrete plant and transporting concrete to the construction site requires very little energy and therefore only emits a relatively small amount of CO2 into the atmosphere.

Consequently, nearly all the CO2 embodied in concrete is a direct result of the use of portland cement in the concrete mixture.



How much CO2 does cement manufacturing produce?

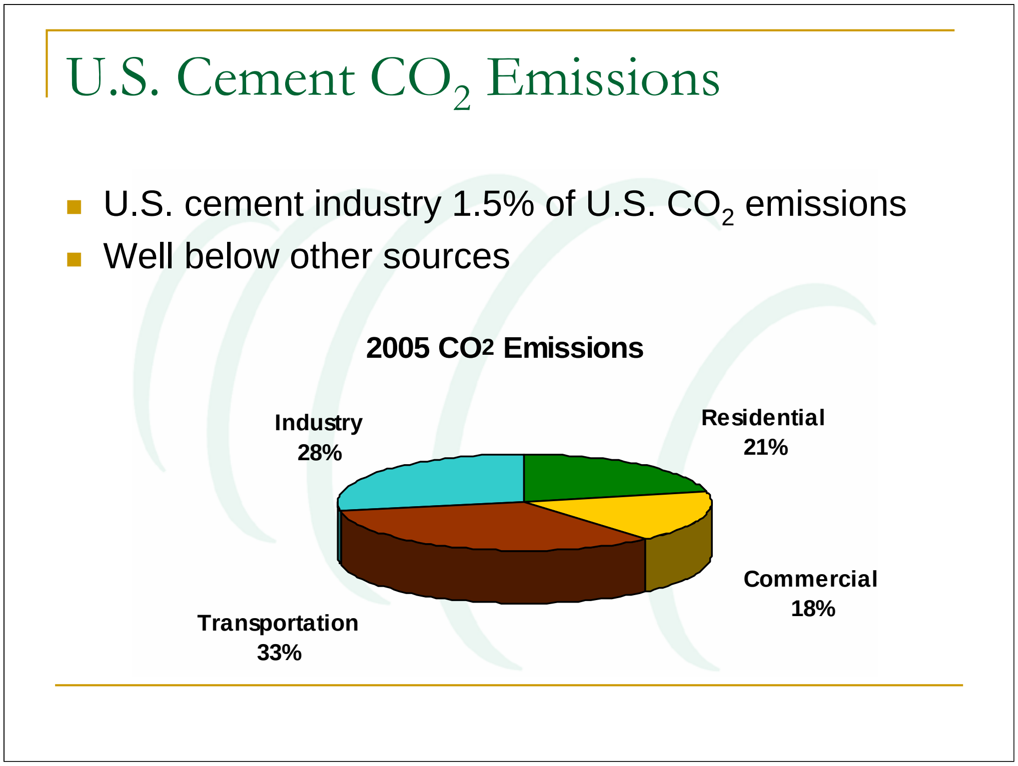
According to EPA, between 900 and 1100 kg (1984 and 2425 lbs) of CO2 is emitted for every 1000 kg (2205 lbs) of portland cement produced in the U.S. This depends on the fuel type, raw ingredients used and the energy efficiency of the cement plant.[i]

According to the Portland Cement Association, on average 927 kg (2044 lb) of CO2 are emitted for every 1000 kg (2205 lb) of portland cement produced in the U.S.[ii]

Between 50% and 60% of the CO2 emitted is a result of calcination of calcium carbonate raw materials, a necessary part of the manufacturing process. The remaining CO2 emitted is a result of burning fossil fuels such as coal and natural gas to heat the raw materials in the kiln.

[i] *AP 42 - Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*, Environmental Protection Agency, Washington, DC, 2005.

[ii] Marceau, Medgar L.; Nisbet, Michael A., and VanGeem, Martha G., *Life Cycle Inventory of Portland Cement Manufacture*, SN2095b, Portland Cement Association, Skokie, IL, 2006, 69 pages.



The U.S. cement industry accounts for approximately 1.5% of U.S. CO2 emissions, well below other sources such as heating and cooling our homes (21%), heating and cooling our buildings (18%), driving our cars and trucks (33%) and industrial operations (28%).[i]

[i] Emissions of Greenhouse Gases in the United States 2005, U.S. Department of Energy, February 2007, http://www.eia.doe.gov/oiaf/1605/ggrpt/summary/index.html.

Global CO_2 Production

- Cement accounts for 5% of the global CO_2
- Global cement production in 2005
  - Total: 2300 million metric tons (Mt)
  - China: 1038 Mt
  - India: 145 Mt
  - United States: 100 Mt
- Global emissions will decrease as countries like China replace old kilns

The global cement industry accounts for approximately 5% of the global CO2 emissions.[i] Numbers as low as 3% are also quoted.[ii] Global emission contributions from cement production are likely to decrease as countries like China replace old kilns. The U.S. cement industry has made considerable strides to improve its energy efficiency and reduce emissions.

In 2005, the U.S. cement industry manufactured about 100 million metric tons (Mt) (110 million tons) of cement and imported about 28 Mt (31 million tons). In 2005, the U.S. was the third largest cement manufacturing country behind China, 1038 Mt (1144 million tons) and India, 145 Mt (160 million tons.) Total global cement production in 2005 was 2300 Mt (2535 million tons). U.S. cement manufacturing capacity is 4.3% of global capacity.[iii]

[i] *The Cement Sustainability Initiative*, World Business Council for Sustainable Development, Geneva, Switzerland, 2007.

[ii] Raupach, M.R. *et al.* (2007) "Global and regional drivers of accelerating CO2 emissions," *Proc. Nat. Acad. Sci.* 104(24): 10288-93.

[iii] *2005 Mineral Yearbook – Cement*, Van Oss, Hendrik, US Geological Survey, U.S. Department of the Interior, http://minerals.er.usgs.gov/minerals/pubs/commodity/cement/

How much CO_2 embodied in concrete?

- Small percentage embodied in concrete
- Concrete uses 7% and 15% cement by weight
- The average quantity of cement is around 250 kg/m3
- 100 to 300 kg of CO_2 embodied per cubic meter
- That's 5% to 13% of the weight of concrete
- CO_2 reabsorbed into concrete through carbonation
- 33% to 57% of CO_2 emitted from calcination is reabsorbed through carbonation over 100-year life

How much CO2 is embodied in concrete?

A relatively small percentage of CO2 is embodied in concrete since cement is an ingredient of concrete which comprises a relatively small portion of the overall concrete mixture. It is important to note that structures are built with concrete and not cement. Nearly all the CO2 embodied in concrete is a direct result of the use of cement in the concrete mixture.

Concrete uses about 7% and 15% cement by weight depending on the performance requirements for the concrete. The average quantity of cement is around 250 kg/m3 (420 lb/yd3). One cubic meter (m3) of concrete weighs approximately 2400 kg (1 cubic yard weighs approximately 3800 lb).

As a result of using cement in concrete, approximately 100 to 300 kg of CO2 is embodied for every cubic meter of concrete (170 to 500 lb per yd3) produced or approximately 5% to 13% of the weight of concrete produced. The quantity is directly related to the quantity of portland cement used.[i]

A significant portion of the CO2 produced during manufacturing of cement is reabsorbed into concrete during the product life cycle through a process called carbonation. One research study estimates that between 33% and 57% of the CO2 emitted from calcination will be reabsorbed through carbonation of concrete surfaces over a 100-year life cycle.[ii]

[i] Marceau, Medgar L., Nisbet, Michael A., and VanGeem, Martha G., *Life Cycle Inventory of Portland Cement Concrete*, SN3011, Portland Cement Association, Skokie, IL, 2007, 121 pages.

[ii] Pade, Claus *et al.* "The CO2 Uptake of Concrete in the Perspective of Life Cycle Inventory," International Symposium on Sustainability in the Cement and Concrete Industry, Lillehammer, Norway, September 2007.

How does concrete compare to other building materials?

- Concrete has low energy consumption and CO_2 emissions compared to:
  - Steel
  - Wood
  - Asphalt

How does concrete compare to other building materials?

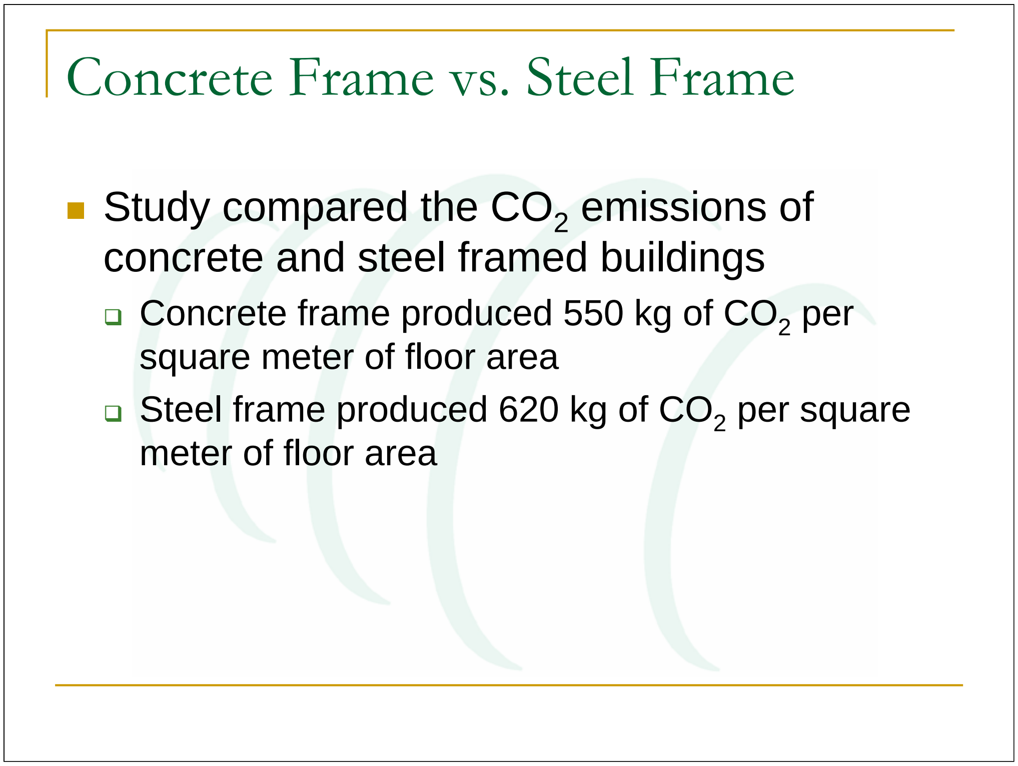
•Concrete compares favorably to other building materials such as steel, wood and asphalt when analyzing energy consumption and CO2 emissions.

Concrete vs. Wood Frame

- Thermal mass systems save energy
- Lower CO_2 emissions from building occupancy
- Research study compared energy performance of various concrete wall systems to wood and steel:
  - Concrete systems reduced energy by 17%
  - Stick-frame house must be 2x12 with R-38 insulation to achieve same energy performance as insulated concrete wall comprised of 150 mm of concrete and two layers of 60 mm thick rigid insulation

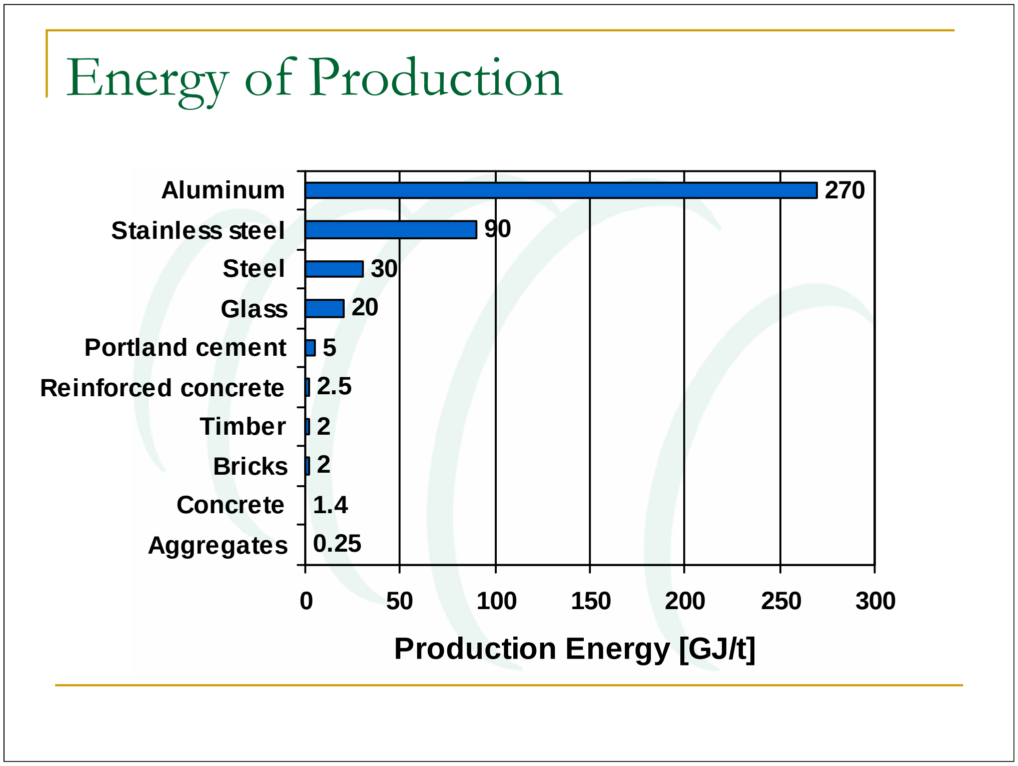
Concrete building systems such as insulating concrete forms and tilt-up concrete incorporate insulation and thermal mass energy efficient wall systems that save energy over the life of a building, resulting in significantly lower CO_2 emissions related to building occupancy when compared to wood and steel frame construction. In one research study comparing energy performance of various concrete wall systems to wood frame and steel frame structures, concrete wall systems reduced energy requirements for a typical home by more than 17%. By comparison, a stick-frame house would have to be built with 2x12 lumber and R-38 insulation to achieve the same energy performance as the insulated concrete wall comprised of 150 mm (6 in) of concrete and two layers of 60 mm (2 in) thick rigid insulation.[i]

[i] Gajda, John, Energy Use of Single-Family Houses With Various Exterior Walls, CD026, Portland Cement Association, Skokie, IL, 2001, 49 pages.



In another study that compared the CO2 emissions of concrete and steel framed buildings on a per-square-meter basis, concrete produced 550 kg of CO2 per square meter of floor area (112 lb/ft2) and steel produced 620 kg of CO2 per square meter of floor area (127 lb/ft2.)[i]

[i] Guggemos, A. A. and Horvath, A., Comparison of Environmental Effects of Steel- and Concrete-Framed Buildings, ASCE Journal of Infrastructure Systems, June 2005, American Society of Civil Engineers, Reston, VA, 2005.



One research study compared the energy of production for concrete and other common building materials for raw material extraction, transportation and manufacturing. The study concludes that the energy required to produce one metric ton of reinforced concrete was 2.5 GJ/t (2.2 million BTU/ton) compared to 30 GJ/t (25.8 million BTU/ton) for steel and 2.0 GJ/t (1.7 million BTU/ton) for wood. The same study compared the CO_2 emissions of several different building materials per 1000 kg (2205 lb) for residential construction and concluded that concrete produced 147 kg (324 lb) of CO_2, metals produced 3000 kg (6614 lb) of CO_2, and wood produced 127 kg (280 lb) of CO_2.[i]

[i] Pentalla, Vesa, *Concrete and Sustainable Development*, ACI Materials Journal, September-October 1997, American Concrete Institute, Farmington Hills, MI, 1997.

Concrete vs. Asphalt Pavements

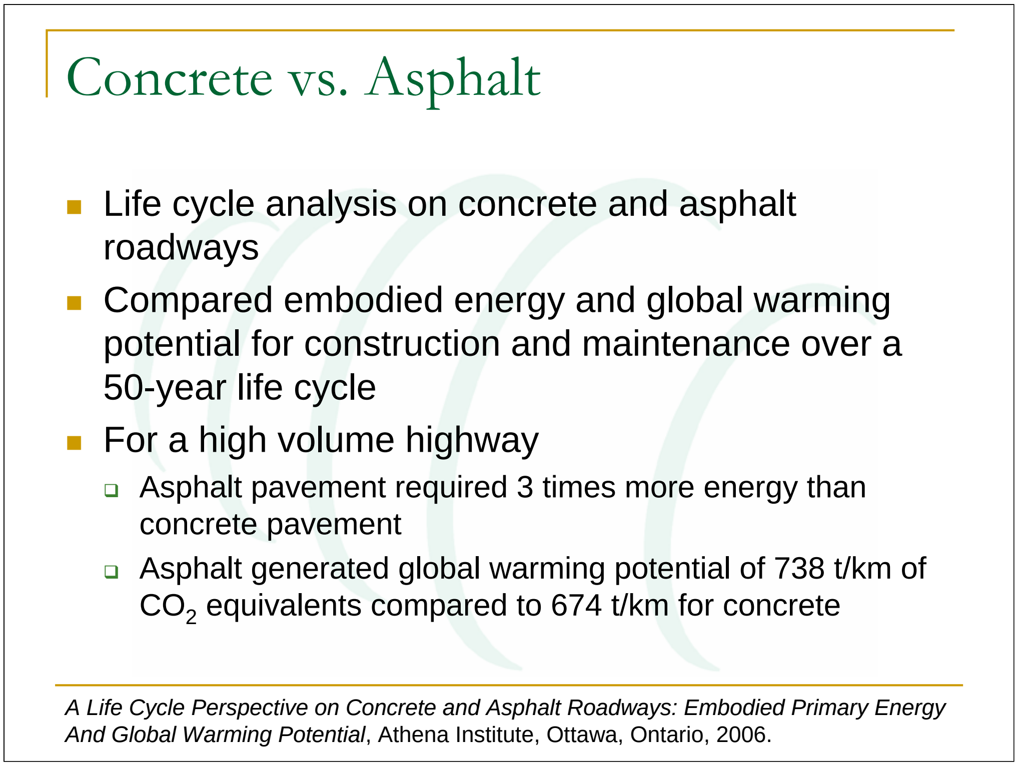
Annual Savings and Reductions for Major Urban Arterial Highway			
	Results based on driving on concrete vs. asphalt pavement		
	Minimum 0.8%	Average 3.85%	Maximum 6.9%
Fuel Savings (liters)	**377,000**	**1,813,000**	**3,249,000**
Dollar Savings ($)	**338,000**	**1,625,000**	**2,912,000**
CO_2 Reductions (t)	**1,039**	**5,000**	**8,950**

Taylor, G.W., *Additional Analysis of the Effect of Pavement Structures on Truck Fuel Consumption,* National Research Council of Canada (NRC), Ottawa, Ontario, 2002.
Taylor, G.W. and Patten, J.D., *Effects of Pavement Structure on Vehicle Fuel Consumption - Phase III,* National Research Council of Canada, Ottawa, Ontario, 2006.

Studies conducted by National Resources Council of Canada compared fuel consumption and emissions for a 100 km (??? mi) section of a major urban arterial highway, one paved with asphalt and the other paved with concrete. These studies concluded that heavy trucks traveling on concrete pavement accumulate statistically significant fuel savings, ranging from 0.8% to 6.9%. These fuel savings also lead to reductions in greenhouse gas emissions and air pollutants.[i],[ii]

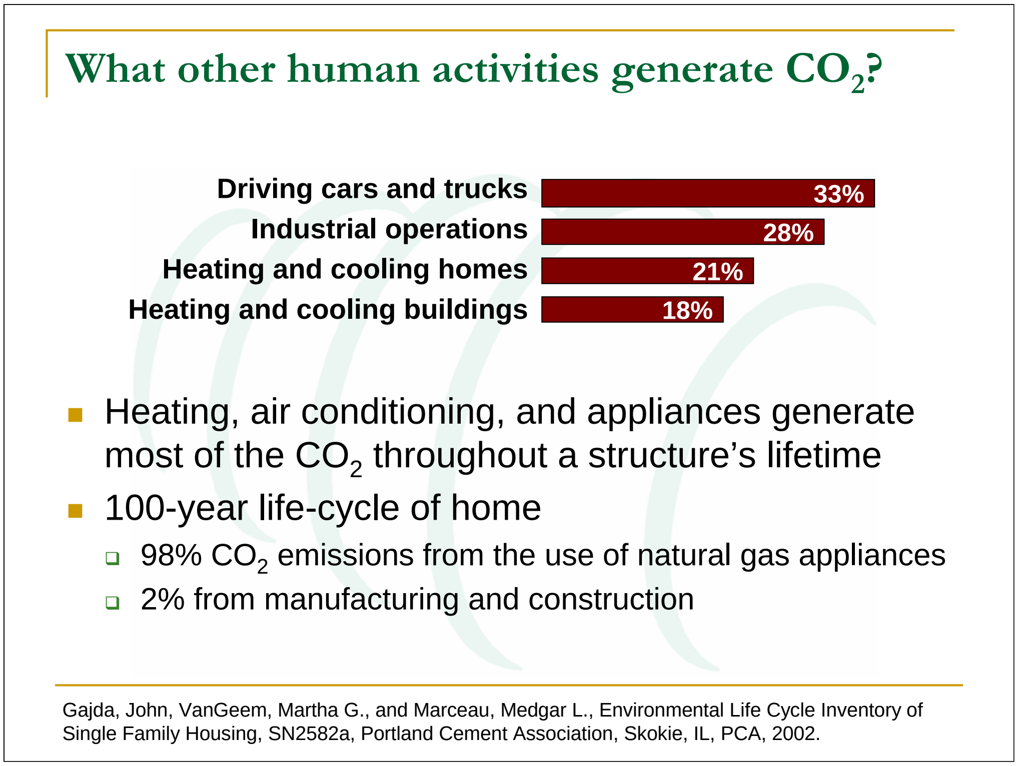
[i] Taylor, G.W., *Additional Analysis of the Effect of Pavement Structures on Truck Fuel Consumption,* National Research Council of Canada (NRC), Ottawa, Ontario, 2002.

[ii] Taylor, G.W. and Patten, J.D., *Effects of Pavement Structure on Vehicle Fuel Consumption - Phase III,* National Research Council of Canada, Ottawa, Ontario, 2006.



Athena Institute conducted a life cycle analysis on concrete and asphalt roadways to compare embodied energy and global warming potential for construction and maintenance over a 50-year life cycle. The study concluded that for a high volume highway, the asphalt pavement alternative required three times more energy than their concrete pavement counterparts from a life cycle perspective. For a high volume roadway, asphalt generated global warming potential of 738 t/km (??? tons/mi) of CO2 equivalents compared to 674 t/km (??? tons/mi) of CO2 for concrete.[i]

[i] *A Life Cycle Perspective on Concrete and Asphalt Roadways: Embodied Primary Energy And Global Warming Potential*, Athena Institute, Ottawa, Ontario, 2006.



What other human activities generate CO2?

Although cement and concrete manufacturing contribute to CO2 emissions, it is a small fraction of that generated by other human activity. The four largest generators of CO2 in the U.S. are:

Heating and cooling homes (21%)

Heating and cooling buildings (18%)

Driving cars and trucks (33%)

Industrial operations (28%).

In fact when it comes to homes and buildings, it's not the manufacturing and construction phase that generates most of the CO2. It's the operational phase where heating, air conditioning, and appliances generate most of the CO2 throughout a structure's lifetime.

In one study, approximately 98% of the CO2 emissions from a home were from the use of natural gas appliances throughout its 100-year lifetime. Only about 2% was attributed to the manufacturing and construction phase.[i]

[i] Gajda, John, VanGeem, Martha G., and Marceau, Medgar L., Environmental Life Cycle Inventory of Single Family Housing, SN2582a, Portland Cement Association, Skokie, IL, PCA, 2002.

What is the cement industry doing?

- 33% reduction in CO_2 since 1972
- Additional 10% reduction by 2020 from 1990 levels
- Limestone additions
  - Saves 11.8 Trillion Btus
  - Eliminates 2.5 million tons of CO_2
- Reduce waste by 60%

What is the cement industry doing to reduce and minimize greenhouse gases?

The cement industry was among the first to tackle the issue of climate change. Since 1975, the cement industry has reduced emissions by 33%. By the year 2020, the industry plans to voluntarily reduce CO2 emissions by 10% below 1990 levels. The industry has also committed to reduce cement kiln dust, waste related to the manufacturing process, by 60% by 2020.

The primary options for reducing the quantity of CO2 generated during cement manufacturing process is to use alternatives to fossil fuels, change the raw ingredients used in manufacture and intergrind additional materials with the clinker.

The most recent progress involves newly introduced guidelines that will allow for greater use of limestone as interground material in finished cement. This will have no impact on product performance but will ultimately reduce CO2 by more than 2.5 Mt (2.8 million tons) per year in the U.S. Using interground limestone in cement is common practice in Europe and Canada.

What is concrete industry doing?

- Committed to continuous environmental improvement
- P2P Initiative (Prescriptive to Performance Specifications for Concrete)
- The P2P Initiative removes limits on materials
- Allows producers to meet performance requirements
- Minimize environmental impact

www.nrmca.org/P2P

What is the concrete industry doing to reduce greenhouse gases?

The U.S. concrete industry is committed to continuous environmental improvement through process innovation and product standards that lead to reduced environmental impact.

The U.S. concrete industry has implemented the P2P Initiative (Prescriptive to Performance Specifications for Concrete) which provides concrete producers more flexibility to optimize concrete mixtures for intended performance that will also reduce environmental impact, including CO2 emissions.[i]

Traditionally, construction specifications for concrete have required unnecessarily high quantities of portland cement along with other limits on the use of supplementary cementitious materials. These limits are incorporated in the industry's standards and specifications. The P2P Initiative proposes to eliminate many of these limits and evolve to performance-based standards. This will reduce the environmental impact of concrete as a building material.

[i] National Ready Mixed Concrete Association, P2P Initiative, http://www.nrmca.org/P2P .

Recycled Industrial Byproducts

- Uses of industrial byproducts
  - Fly ash
  - Blast furnace slag
  - Silica fume
- Supplement a portion cement
- Otherwise end up in landfills
- Called supplementary cementitious materials (SCMs)
- Improves strength and durability
- Reduces CO_2 embodied in concrete
  - Typical values 15% to 40%
  - As much as 70%

The U.S. concrete industry uses a significant amount of industrial byproducts such as fly ash, blast furnace slag and silica fume to supplement a portion of the cement used in concrete. These industrial products that would otherwise end up in landfills are called supplementary cementitious materials or SCMs for short. The use of SCMs in concrete work in combination with portland cement to improve strength and durability in addition to reducing the CO2 embodied in concrete by as much as 70%, with typical values ranging between 15 and 40%.

Environmental Best Practices

- Reuse and recycling of waste from concrete manufacture
  - Wash water
  - Returned concrete
  - Industrial waste water
  - Foundry sands
  - Glass and other
- Materials would otherwise landfilled

The concrete industry also incorporates a variety of environmental best management practices in the production of its product. These include the reuse and recycling of waste from concrete manufacture such as water and unused returned concrete. It also incorporates waste byproducts from other industries such as recycled industrial waste water, foundry sands, glass and other materials that would typically end up in landfills.

Conclusion

- Concrete industry dedicated to continuous environmental improvement
- Through process and product innovation
- Performs well when compared to other building materials
- However, there is always room for improvement
- CO_2 produced is relatively small
- One of the lowest carbon footprints

The concrete industry is dedicated to continuous environmental improvement through process and product innovation. Concrete performs well when compared to other building materials but when it comes to sustainable development there is always room for improvement. As with any building product, concrete and its ingredients do require energy to produce which in turn produces carbon dioxide or CO2. But the amount of CO2 produced during manufacturing is relatively small when compared with other building materials and when compared with other human activities such as heating and cooling our homes and buildings or operating our cars and trucks. Concrete's many benefits help make it an environmentally friendly choice for construction with one of the lowest carbon footprints of any building material.

Questions?

NRMCA