

Crosstalk



CONCRETE FACTS

THE ANCIENT Romans were the first to mix sand and gravel with water and a bonding agent to make concrete. Although they called it *opus cementitium*, the bonding agent differed from that used in modern cement: It was a mixture of gypsum, quicklime, and pozzolana, a volcanic sand from Puteoli, near Mount Vesuvius, that made an outstanding material fit for massive vaults. Rome's Pantheon, completed in 126 C.E., still spans a greater distance than any other structure made of non-reinforced concrete.

The modern cement industry began in 1824, when Joseph Aspdin, of England,

patented his firing of limestone and clay at high temperatures. Lime, silica, and alumina are the dominant constituents of modern cement; adding water, sand and gravel produces a slurry that hardens into concrete as it cures. The typical ratios are 7 to 15 percent cement, 14 to 21 percent water, and 60 to 75 percent sand and gravel.

Concrete is remarkably strong under compression. Today's formulations can resist a crushing pressure of more than 100 megapascals (14,500 pounds per square inch)—about the weight of an African bull elephant balanced on a coin. However, a pulling force of just 2 to 5 MPa

can tear concrete apart; human skin is far stronger in this respect.

This tensile weakness can be offset by reinforcement. This technique was first used in iron-reinforced troughs for plants built by Joseph Monier, a French gardener, during the 1860s. Before the end of the 19th century, steel reinforcement was common in construction. In 1903 the Ingalls Building, in Cincinnati, became the world's first reinforced-concrete skyscraper. Eventually engineers began pouring concrete into forms containing steel wires or bars that were tensioned just before or after the concrete was cast. Such pre- or poststressing further enhances the material's tensile strength.

Today concrete is everywhere. It can be seen in the Burj Khalifa Tower in Dubai, the world's tallest building, and in the sail-like Sydney Opera House, perhaps

NUMBERS DON'T LIE BY VACLAV SMIL

THE NUMBERS GIVEN ARE THE WEIGHTS OF THE CONCRETE (NOT CEMENT) USED IN THE STRUCTURES' CONSTRUCTION.

the most visually striking application. Reinforced concrete has made it possible to build massive hydroelectric dams, long bridges, and gigantic offshore drilling platforms, as well as to pave roads, freeways, parking lots, and airport runways.

From 1900 to 1928, the U.S. consumption of cement (recall that cement makes up no more than 15 percent of concrete) rose tenfold, to 30 million metric tons. The postwar economic expansion, including the construction of the Interstate Highway System, raised consumption to a peak of about 128 million tons by 2005; recent rates are around 100 million tons a year. China became the world's largest producer in 1985, and its output of cement—above 2.3 billion metric tons in 2018—now accounts for nearly 60 percent of the global total. In 2017 and 2018 China made slightly more cement (about 4.7 billion tons) than the United States had made throughout the entire 20th century.

But concrete does not last forever, the Pantheon's extraordinary longevity constituting a rare exception. Concrete deteriorates in all climates in a process that is accelerated by acid deposition, vibration, structural overloading, and salt-induced corrosion of the reinforcing steel. As a result, the concretization of the world has produced tens of billions of tons of material that will soon have to be replaced, destroyed, or simply abandoned.

The environmental impact of concrete is another worry. The industry burns low-quality coal and petroleum coke, producing roughly a ton of carbon dioxide per ton of cement, which works out to about 5 percent of global carbon emissions from fossil fuels. This carbon footprint can be reduced by recycling concrete, by using blast-furnace slag and fly ash captured in power plants, or by adopting one of the several new low-carbon or no-carbon processes. But these improvements would make only a small dent in a business whose global output now surpasses 4 billion metric tons. ■

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1. THREE GORGES DAM, CHINA
65.5 MILLION METRIC TONS



2. GRAND COULEE DAM, WASHINGTON
21.7 MILLION METRIC TONS



3. PANAMA CANAL
6.8 MILLION METRIC TONS



4. HOOVER DAM, ARIZONA AND NEVADA
6.0 MILLION METRIC TONS



5. KING FAHD CAUSEWAY, SAUDI ARABIA AND
BAHRAIN, 0.84 MILLION METRIC TONS



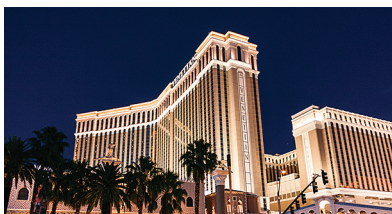
6. THE PENTAGON, WASHINGTON, D.C.
0.80 MILLION METRIC TONS



7. PETRONAS TWIN TOWERS, MALAYSIA
0.39 MILLION METRIC TONS



8. BURJ KHALIFA TOWER, UNITED ARAB
EMIRATES, 0.11 MILLION METRIC TONS



9. THE VENETIAN HOTEL, LAS VEGAS
0.039 MILLION METRIC TONS



10. WILSHIRE GRAND HOTEL, LOS ANGELES
0.037 MILLION METRIC TONS

DATA SOURCES: ARCHITIZER.COM, U.S. BUREAU OF RECLAMATION, PANAMA CANAL MUSEUM/UNIVERSITY OF FLORIDA; PHOTOS: ISTOCKPHOTO (10)