Chapter 1

Concrete

To make concrete, you mix cement with water and an aggregate (sand or rock). The cement is usually only about 10 to 15 percent of the mixture. The cement reacts with the water, and the resulting solid binds the aggregate together. In 2019, the world consumed 4.5 billion tons of cement.

Concrete is hard and durable. The mortar between the pyramids at Giza is concrete — it is now 5000 years old. Today, we use concrete to build many structures including buildings, bridges, airport runways, and dams. Grout and mortar are related materials but different in that they are used as bonding or filler materials within construction.

There are many kinds of cement, but the most common is Portland cement. It is made by heating limestone (calcium carbonate) with clay (for silicon) in a kiln. Two things come out of the kiln: Carbon dioxide and a hard substance called "clinker". The clinker is ground up with some gypsum before it is sent to market.

The carbon dioxide is released into the atmosphere, making it an exothermic reaction. Cement manufacturing is responsible for about 8% of the world's CO_2 emissions; it is a major contributor to climate change.

Especially hard concrete, like that used in a nuclear power plant, can support 3,000 kg per centimeter without being crushed. However, if you pull on two ends of a piece of concrete, it comes apart relatively easily. We say that concrete can handle a lot of *compressive stress*, but not much *tensile* stress.

1.1 Steel reinforced concrete

Many places where we use concrete (like in a bridge), we need both compressive and tensile stress. Often, the top of a beam is undergoing compression and the bottom of the beam is undergoing tension.

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Steel has tremendous tensile strength, but not as much compressive strength as concrete. To get both tensile *and* compressive strength, we often bury steel bars or cables inside the concrete. This is known as *steel-reinforced concrete*. The concrete generally does a very good job protecting the steel, which keeps it from rusting.

You may have heard of *rebar* before. That is just short for "reinforcing bar". Typically, rebar

has bumps and ridges that keep the bar and the concrete from moving independently.

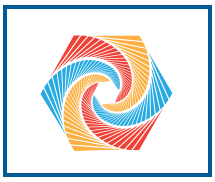
1.2 Recycling concrete

Many concrete structures only last about 100 years. When they are demolished, the concrete can be reused as aggregate in other projects. Often, the concrete bits are mixed with cement and made into concrete once more.

If the concrete to be reused is reinforced with steel, the steel has to be removed and recycled separately. The concrete is then crushed into small pieces.

Appendix A

Answers to Exercises



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