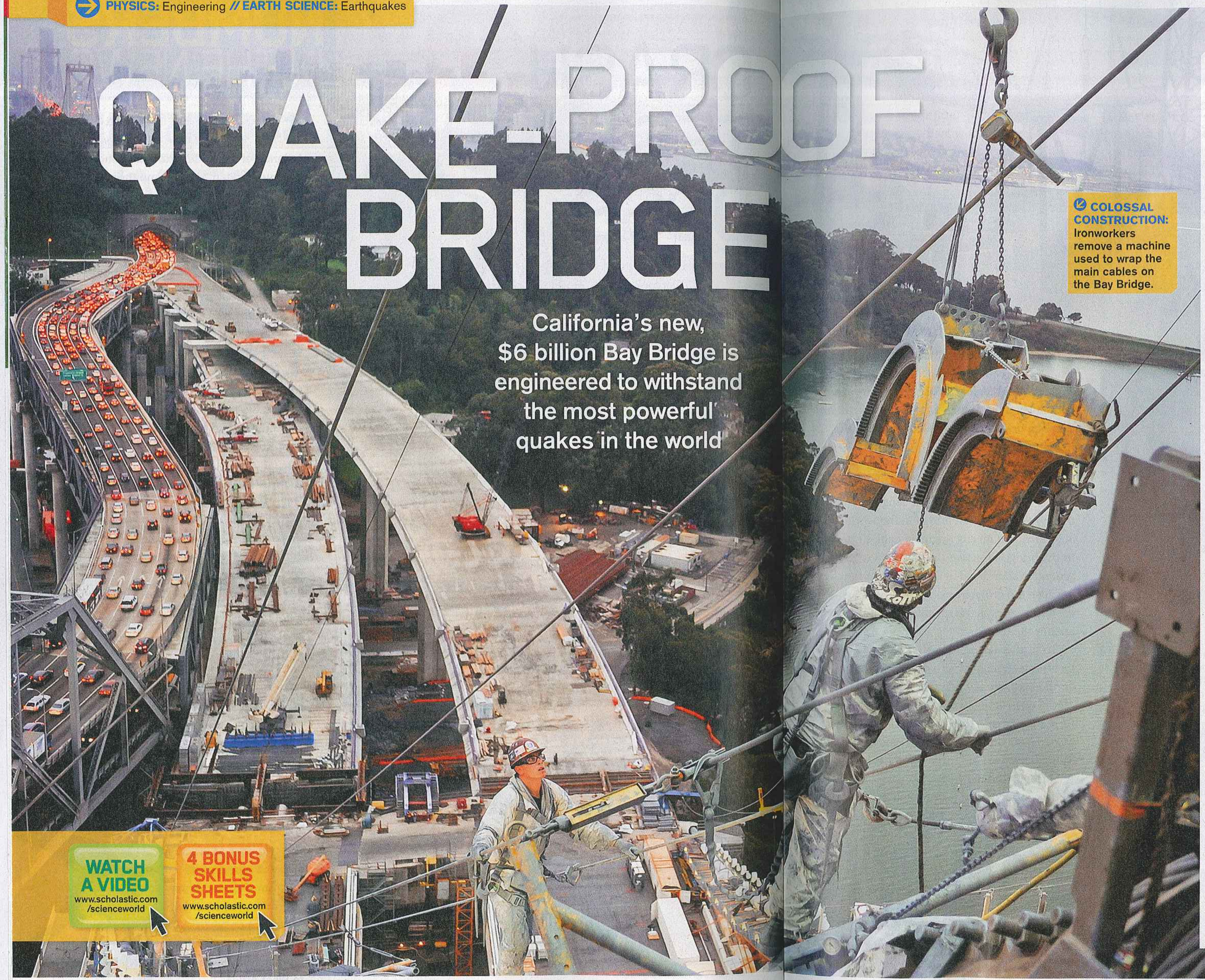
QUAKE-PROOF BRIDGE

California's new, $6 billion Bay Bridge is engineered to withstand the most powerful quakes in the world



COLOSSAL CONSTRUCTION: Ironworkers remove a machine used to wrap the main cables on the Bay Bridge.

On October 17, 1989, a devastating earthquake shook San Francisco, California. For 15 seconds, the massive 7.1 magnitude quake rattled the city, injuring thousands of people and causing billions of dollars in damage to buildings and roads.

One of the most visible signs of destruction was on the Bay Bridge, a roughly 7.2 kilometer (4.5 mile)-long roadway that spans San Francisco Bay. The quake caused part of the bridge to shift and a 15.2-meter (50-foot), 250-ton section of the bridge's eastern span to collapse. One driver was killed when her car tumbled off the edge and collided with debris.

The bridge was fixed and reopened a month after the quake, but knowing that such a major structure was so weak made people nervous. So engineers began building a new eastern span of the Bay Bridge alongside the old structure. They knew it had to be tough enough to withstand the most powerful earthquakes in the world.

In September, the upgraded Bay Bridge opened to the public. It took $6 billion and more than 14 years to complete the new span. The old section of the bridge will be demolished in a few years. The Bay Bridge is now one of the strongest in the world.

SUPERSTRONG STRUCTURE

The Bay Bridge is a *suspension bridge*. Cables connect the bridge's eastern span to a tower that's 160 m (525 ft) from the top to the seafloor (*see Suspension-Bridge Structure, p. 11*). The suspension design helps the bridge absorb vibrations from the ground and from traffic. It's strong enough to support 10 lanes of traffic and the more than 270,000 cars that travel across it daily.

During an earthquake, the suspension bridge's cables will act like the ropes on a swing. "Imagine swinging back and forth on a swing set," says Marwan Nader, the bridge's lead designer. "If the ground shakes underneath you, you'd barely feel it. But if you're sitting on a rigid chair and the ground

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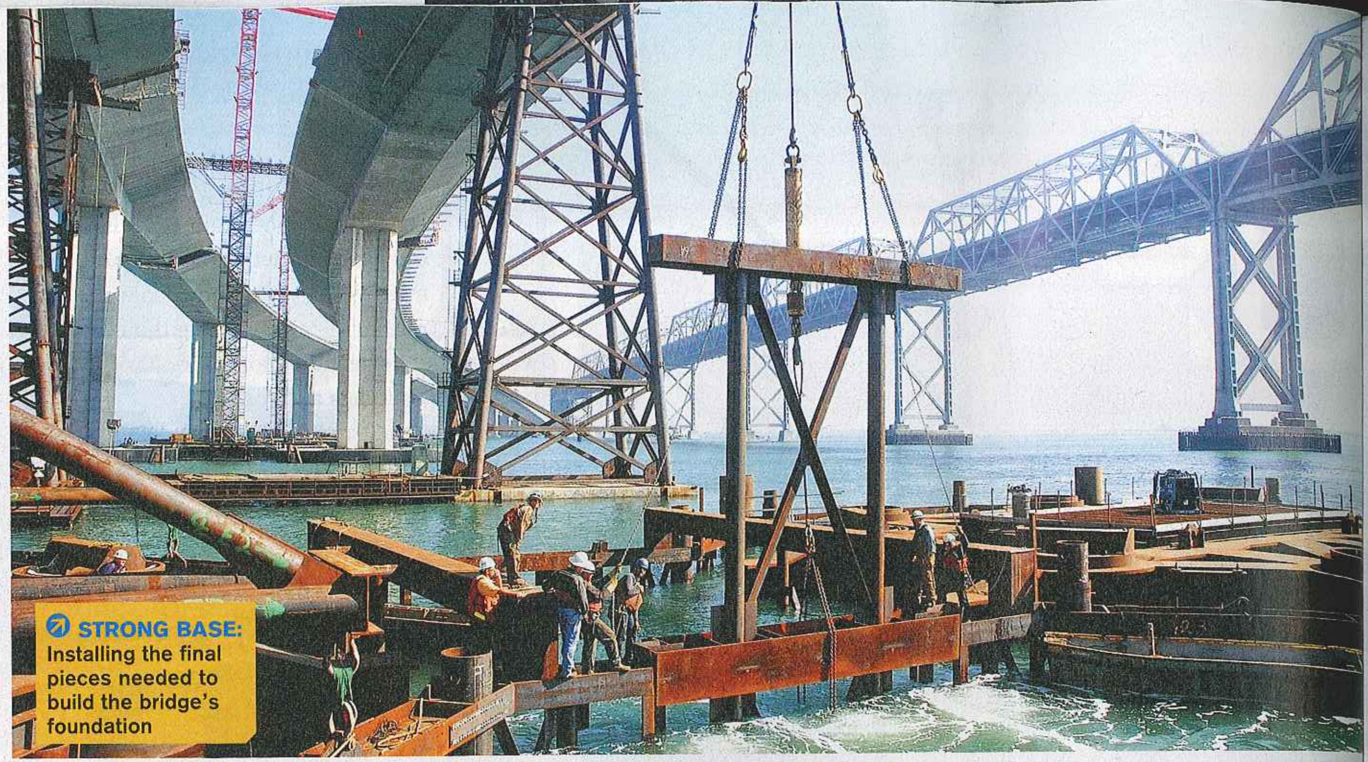
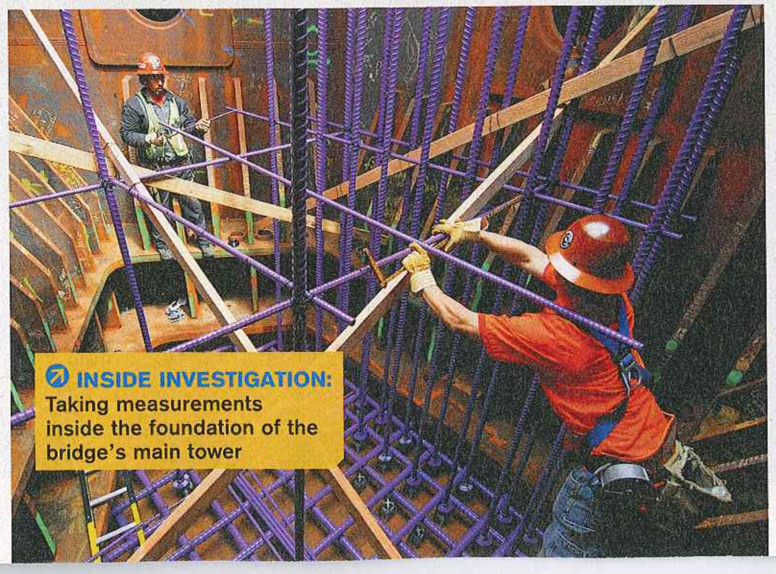


STRONG BASE: Installing the final pieces needed to build the bridge's foundation

HEAVY LIFTING: Connecting a 600-ton shackle to a device that lifts the bridge's deck into place



INSIDE INVESTIGATION: Taking measurements inside the foundation of the bridge's main tower

shakes, you'd feel it." Like a swing's ropes, the cables on the suspension bridge—rather than the bridge itself—absorb the brunt of the vibrations.

ADJUSTING THE ANCHORS

The new Bay Bridge is the longest *self-anchored* suspension bridge in the world. *Self-anchored* means the main cables attach to the bridge's roadway, rather than to the ground. Nader decided to use this design because the ground next to the bridge's eastern span was too unstable to safely anchor the cables.

To further ensure that the bridge would be strong enough to withstand a major earthquake like the one that hit the area in 1989, construction workers drilled more than 91 m (300 ft) into the bay's floor. There they placed steel-anchoring devices called *pilings*. The pilings were set three times deeper than the bridge's old footings.

The rod-like pilings are stuck in the ground at an angle. This helps distribute vibrations from an earthquake and keep the bridge stable. To understand how it works, try this: Stand very straight with your feet next to each other and have a friend give you a gentle push. Most likely, you'll stumble. Then stand with your legs spread apart. In this pose, you have much better balance. You're more likely to resist the force of the push and stay upright. The bridge works in the same way.

A BRIDGE THAT MOVES

The Bay Bridge is located dangerously close to two major *faults*—boundaries where rocks slide past each other, generating earthquakes. To the bridge's west is the San Andreas Fault, and to its east is the Hayward Fault.

Because the area is so geologically active, scientists predict that in addition to many smaller quakes, there's a 62 percent chance that a quake of magnitude 6.7 or greater will hit the area by 2032. Nader realized that to withstand a major quake, the bridge would need to be flexible enough to move with the shaking earth.

That's when Nader and his team of engineers came up with one of the bridge's most important features: the tower that holds up all the cables. Many bridges have towers that look similar to the new Bay Bridge tower at first glance, but this one is special because it has four distinct shafts. The shafts are connected by parts called shear links that act like shock absorbers. This means the tower won't be hit with as much force during a quake. These shear links allow the tower to bend without breaking when an earthquake strikes.

In addition, the bridge's roadway is made of multiple panels, so it can shift a full yard from side to side during an earthquake without breaking.

"The bridge is a major lifeline between San Francisco and the East Bay," says Nader. "If that line is cut during an earthquake, emergency responders won't be able to get where they need to go." The new bridge should be safe to use within hours of a big quake—unlike the old bridge, which took a month to reopen following the 1989 quake.

Nader says watching cars zoom over the new Bay Bridge for the first time was a proud moment. "I experienced the 1989 quake and saw the damage that occurred. It's a relief to know we now have a structure that will help keep people safe for years to come."

—Amy Barth

CORE QUESTION

What are two features of the new Bay Bridge that will help it withstand earthquakes? Cite examples from the text.