Lesson: "Can you design a building that survives an earthquake?"

VIDEO TRANSCRIPT

EXPLORATION VIDEO 1

Hi. It's Jay from the Mystery Science team. Check this out. This is a video taken in a cafe during an earthquake. It's not just the camera that's shaking. Everything is. The counter is shaking. The tables are shaking. Coffee is sloshing around. Cups are even tumbling over. An earthquake is when the ground shakes in a particular area because vibrations are rippling through the Earth's surface. Notice how during an earthquake here, the water in this swimming pool is sloshing out over the sides. And during this earthquake here, a similar thing is happening to this fish tank. Earthquakes are a common natural hazard. They happen in many places around the world. They can be very big and destructive, but often they're so small you might barely notice. Some can only be detected by scientists with special equipment, like these vibration sensors buried in the ground. Still, a big earthquake can make a big impact. If the shaking is strong, things can fall and break. Buildings can get damaged. The ground can shake loose and reveal layers of dirt buried below. Big vibrations from earthquakes can move areas of dirt, rocks, or water around, leading to other natural hazards like landslides. The bad news is we can't really stop earthquakes from happening, and we can't predict exactly when or exactly where an earthquake will strike. But there are still some things we can do to help protect against earthquake damage. And there are ways we can learn about earthquakes without waiting around for a real one to hit. Check this out. These might look like real buildings, but they are actually large-sized models, a pretend version of something that scientists use to learn about the real thing. Why aren't they using a real building? Well, just watch. Underneath the model buildings is something called a shake table. It's not like your dinner table. A shake table is a machine that creates a shaking motion similar to an earthquake. Engineers use shake tables to understand how real earthquakes impact big buildings. An engineer is someone who uses science to come up with solutions to problems. Today, you are going to be an earthquake engineer. You're going to use science ideas to find solutions to the problems caused by earthquakes. When an engineer starts a new project, their step one is always the same: identify a problem. Let's watch this shake table test again. What is the problem earthquakes cause for this building?

EXPLORATION VIDEO 2

This shake table test shows us a big problem. When the earth shakes, buildings can get damaged and even collapse. But check this out. This is a different model building about to do a shake table test. Watch what happens. See that? The table shook, and the model building wobbled, but it didn't fall. So maybe that means some buildings can survive earthquakes better than others, but how? Now there's lots of reasons why some areas experience less earthquake damage than others. Earthquakes are complicated, but engineers have noticed some buildings get less damaged because of the way they are built. Engineers often call how something is made or built its design. The design of some buildings helps them withstand earthquakes. The design of other buildings does not. After an engineer identifies the problem, they also need to do research to look for information that can help them solve the problem. So let's take a look at how different building designs have fared during earthquakes and see if we can learn anything useful for solving our problem. Check out this building. Look closely. The upper floors of the building are big and heavy with lots of concrete, but the bottom floor is nearly empty. It has these big open spaces with not a lot helping hold up those beams. Compared to the top floors, the bottom floor is weaker and less supported. Some engineers wanted to learn more, so they built a big model building with this problem on purpose. See how there's lots of heavy stuff at the top, but the bottom floor has these big empty spaces. They put their model on a shake table and watch. It collapses. This design is great for some situations. There's space to park your car in there, but in a big earthquake, look what can happen. That heavy top topples, crunching the floor below. Now compare that to this building. This is the Transamerica Pyramid in San Francisco, USA. San Francisco gets earthquakes often. Over the years, this building has survived some big ones, and it's still standing strong. Or check out this building. This is the Yokohama Tower in Yokohama, Japan. This building has also survived a lot of earthquakes without falling down. These buildings are not exactly the same, but they've both managed to survive earthquakes. They can give us ideas for how to build, just like collapsed buildings can give us ideas about how not to build. Take a close look at these two earthquake-resistant buildings. See if you can notice anything they have in common. Okay, engineers. Now that you've identified and researched the problem, it's time to imagine possible solutions. Today, you're going to design a building that can survive an earthquake. What could you include in your design? Think about the design of buildings you've seen.

ACTIVITY INTRODUCTION VIDEO

In today's activity, you're going to continue your journey as an earthquake engineer. Your mission is to design a building that can survive an earthquake. This is Quake City. It's a lovely place to live, except for all the earthquakes. The mayor of the city, Mayor Rumble, needs your help to design a new building that can stay standing during these earthquakes. That's where you come in. You'll work with a partner to design and build a model of a building for Quake City that you think can stay standing during an earthquake. You'll test to see how your model building fares against an earthquake by using this, your very own shake table test. If your building doesn't work that well the first time, that's okay. You'll use what you learn from your test to improve your design and try to make it stronger, just like real engineers do. Can you design a solution for Quake City's problem? We'll get you started, step by step.

ACTIVITY STEP 1

In today's activity, you'll work with a partner. If you are working on your own, that's okay too. When you're ready to move to the next step, click the arrow on the right.

ACTIVITY STEP 2

We've received a note from Mayor Rumble. It contains details about what your building needs to be considered successful. These are called criteria. Your building must be at least four inches tall. It must be able to stand up without you holding it. And it must be able to stay standing during a shake table test for at least five seconds. Think you can do it? Find your worksheet and write down Mayor Rumble's criteria here in question number 2.

ACTIVITY STEP 3

You also need to know any limits you have. These are called constraints. Your main constraint today is that you and your partner can only use toothpicks and marshmallows to build your model building. Get your supplies.

ACTIVITY STEP 4

All right, engineers. You're about to start building your building. This is a time to experiment with different ideas. When you're making your own designs, there's always more than one right way to do things. Try using your supplies in different ways to find out what works and what doesn't. Talk with your partner and try each other's ideas. Work together to make one building that you and your partner agree on. This is what you'll test next to see if it meets Mayor Rumble's criteria. We suggest you take ten minutes to experiment and build. Good luck, engineers. When you're ready to move on, click the arrow.

ACTIVITY STEP 5

It's time to test how your building handles an earthquake. Engineers test what they build because it helps them learn more about what they can improve in their designs. Watch how we test our building first before you do anything. You'll carefully move your building onto your shake table. Hold onto the corner with three fingers, like this. Then shake it back and forth for five seconds. Keep your arm flat against your desk when you do this. Observe closely. If your building falls over and breaks during your test, that's okay. It means you learned more about what doesn't work, and you can try again with new ideas next time. Now get your shake table.

ACTIVITY STEP 6

Earthquake incoming! When your teacher tells you to, test your building. Can it meet the criteria? Can it stay standing for a five-second shake? As you test your building, observe closely.

ACTIVITY STEP 7

After testing, engineers pause to reflect on how well their designs worked. Discuss what parts of your building's design worked well? What didn't work well? What do you want to try next to improve your design?

ACTIVITY STEP 8

Now use what you learned from your test to improve your buildings. If your building fell over during your shake table test, keep improving it until it can stay standing. If your building did stay standing, Mayor Rumble has an extra challenge for you. Engineers, I need your help again to make a new, taller earthquake-safe building. Your new challenge criteria is to make the tallest building you can. Remember, though, it has to still be able to withstand a five-second shake test. Are you up for the challenge? Continue building and testing for the original criteria or try Mayor Rumble's extra-tall challenge. We suggest taking about ten minutes. When you're ready to move on, click the arrow.

ACTIVITY STEP 9

Earthquake incoming! If you haven't done so already, test your new building on your shake table. Can it withstand a five-second shake?

ACTIVITY STEP 10

You designed, built, and tested just like a real engineer. Way to go! Now, answer question 3 on your worksheet. Draw your most successful building design in the space provided. Your drawing doesn't have to be perfect. Here's an example of how we drew our building. We drew the lines and dots to show the toothpicks and marshmallows. Then answer questions 4 and 5.

ACTIVITY STEP 11

Engineers learn a lot by sharing their ideas with others. Share your building with your class. Then discuss. What parts of your design helped your building meet the criteria? After seeing your classmates' designs, do you have any new ideas that could make your building even better?

WRAP-UP VIDEO

Congratulations, earthquake engineers. You've gone through the engineering design process. Let's recap. First, you identified a problem. Earthquakes cause buildings to fall down and get damaged. And you researched more about why buildings break during earthquakes. Then you imagined solutions that might help a building stay standing. With those ideas in mind, you started building. There was a lot you had to think about. Both the criteria you were trying to meet, like making your building withstand shaking, and the constraints you had to work with, like only having toothpicks and marshmallows as building materials. After you finished your model building, you tested it on the shake table to see what it might actually do in an earthquake. After your test, you went back and rebuilt and retested to improve your designs, and then shared the solutions you designed with others. If you had more time, you could keep doing this process, testing, improving, and retesting until your design was as strong as it could be. Quake City is a made-up place, but this is the same process that engineers follow in the real world. While all of these steps are important, testing is an especially big deal. When a design fails a test, that gives an engineer information. Something isn't working. Then they have a chance to rebuild and fix the problem, which leads to an improved, stronger solution in the end. For example, when we built our model building, we first tried building a square base, like this. But that design didn't hold up on the shake table. So next time, we tried a different approach. We made our designs with wider bases like this, and that worked better. By testing models and seeing which ideas fail, engineers can discover and fix problems before they cause harm. For example, remember those buildings with the empty bottom floors that collapsed so easily in an earthquake? After seeing how those designs failed, engineers improved their designs. Today, buildings like these often get built with extra supports that make the bottom stronger so they don't collapse. Or consider this: when you use the shake table, you might have noticed that your building slid around. In a real earthquake, that would be a big problem. Like this house that actually slid off its foundation during an earthquake. Buildings need ways to secure them in place. Check this out. This building is literally tied down to the ground. These cables here were added to this building's design to help it stay stable during a quake. And here's another clever earthquake-resistant design. This is a hospital in Ishinomaki, Japan. From this view, it doesn't look that unusual. But if you look underground, see these? The entire hospital is basically built on springs under the ground. Those springs absorb some of the vibrations from an earthquake, so the building doesn't shake as badly. In two thousand eleven, this hospital survived a huge quake without breaking a single window. Solutions like these can prevent problems caused by earthquakes. No matter where you live, and whether there are big earthquakes there or not, the earth around us changes constantly in big ways and small. Natural hazards like earthquakes are part of our world. So, having a process that helps us design solutions to the problems natural hazards cause is important. By identifying problems, imagining solutions, building, testing, improving, and sharing ideas, engineers like you can make our lives safer and better, even when the ground is unsteady beneath our feet. Keep solving problems, and stay curious.