

Shake Table Bridge Challenge: Define, Build, Shake, Improve

Investigation question: How can a craft-stick bridge be designed to carry its load through three measured levels of shaking, meeting the performance targets its importance demands, within a materials budget?

Engineering design challenge

Groups of 4

2 sessions

Setup 10 · Activity 90 · Cleanup 10 min

MS-ETS1-1 · practice

MS-ETS1-2 · practice

MS-ESS3-2 · practice

Name _____

Group _____

Date _____

Your role today

- ☐ **Lead builder:** Leads construction from the group's sketch and keeps the bridge within the design rules.
- ☐ **Shaker:** Practices the three shaking levels until the stroke count matches the target, then shakes the group's bridge (and checks one other group's calibration).
- ☐ **Measurer:** Measures mid-span sag with the ruler before and after each level, counts loosened or broken joints, and decides the rating with the recorder.
- ☐ **Budget keeper and recorder:** Tracks every material used and its cost, fills the test tables, and reports the group's results to the class table.

Safety

- Wear goggles while shaking and whenever rubber bands are stretched: a band can snap and a stick can flip up during shaking.
- Pinch point: keep fingers off the tray rim and away from the gap between the moving platform and the rim. The shaker holds the platform by its sides only and reverses at the tape mark instead of slamming into the rim.
- Rollers must stay inside the tray. Pick up any pencil, penny or paper clip that falls to the floor at once; round objects underfoot are a slip hazard.
- Broken craft sticks splinter. Break or cut sticks pointing down at the table, never toward a face, and put broken pieces in the trash.
- Cut away from your body with scissors. Use latex-free rubber bands in case anyone has a latex allergy. Wash hands after handling the pennies.
- No hot glue or other heated tools: glue guns run well above 50 degrees C. Tape, clips, string and bands are the only fasteners.

Procedure

1. Session 1. Draw an importance card. Read the performance targets for your bridge type and the design rules. Complete the design brief: write each criterion as a precise, measurable statement and say how you will check it, then list the constraints. Answer q1 and q2.

2. Calibrate the shaker: with an empty platform, the shaker practices each level with the metronome while the recorder counts strokes for 10 seconds. Repeat until the count is within 2 of the target (20, 27, 33). Record both counts.
3. Sketch version 1 and label the materials, joints and how the load's weight is carried to the banks. Estimate the cost; it must not exceed your budget.
4. Build version 1 (25 minutes). The bridge must span the 25 cm gap, have a deck at least 6 cm wide, rest on the banks with nothing touching the platform between them, and be attached only with budgeted tape, clips, string or bands. Record the actual materials and cost.
5. Session 2. Test version 1. Measure the deck height at mid-span with no load, then place the penny bag at mid-span and measure again (sag = unloaded height minus loaded height). Shake at Level 1, inspect, measure and rate; then Level 2; then Level 3. Do not repair between levels. Use the rating scale exactly as written.
6. Report your bridge type, cost, main design features and three ratings to the class table. Study the table and answer q3: which features do the best-performing bridges share?
7. Redesign: change one main feature (answer q4 first, including your prediction), staying within budget. Build version 2 and test it with the same shaker, the same load position and the same levels.
8. Answer the analysis questions individually. Return pennies, rollers and boxes; recycle unbroken sticks.

Record your observations

Lab 2 recording sheet: Shake Table Bridge Challenge

Your county needs a new bridge in earthquake country. How well the bridge must survive shaking depends on how important it is. Your group has drawn one bridge type. Your job is to write precise criteria, build a bridge that meets them within your budget, test it with **measured** shaking, and improve it using the class's evidence.

Measured shaking levels — A **stroke** is one move of the platform from one side mark to the other.

Level 1 (frequent, moderate): marks 1 cm each side of center, one stroke per beat at 120 beats per minute, for 10 seconds (20 strokes). **Level 2 (rare, strong):** marks 2 cm each side, 160 beats per minute, 15 seconds (40 strokes). **Level 3 (very rare, strongest):** marks 3 cm each side, 200 beats per minute, 15 seconds (50 strokes). Before testing, count strokes for 10 seconds; you must be within 2 of 20, 27 or 33.

Rating scale (decide after each level) — **No damage:** load on the deck, no joint loosened, sag increased by 2 mm or less. **Minor damage, stays open:** load on the deck, at most 2 joints loosened and none broken, sag increased by 5 mm or less. **Damaged, emergency use only:** load on the deck and the deck still spans the gap, but more damage than that. **Closed, still standing:** the load fell off or the deck tilted badly, but the bridge still spans the gap without touching the platform. **Collapsed:** any part of the deck touches the platform between the banks, or the bridge falls off a bank.

Performance targets by bridge type (meet the target or do better)

Bridge type and budget	After Level 1	After Level 2	After Level 3
Ordinary (farm road), 40 units	Minor damage, stays open	Closed, still standing	Closed, still standing
Important (main road), 55 units	No damage	Damaged, emergency use only	Closed, still standing
Lifeline (only hospital route), 70 units	No damage	Minor damage, stays open	Damaged, emergency use only

Material prices

Material	Cost in units
1 craft stick	1
10 cm of masking tape	1
1 paper clip	1
1 rubber band	2
10 cm of string	1
1 index card	2

Design rules: span the 25 cm gap and rest on top of both banks; deck at least 6 cm wide; nothing may touch the platform between the banks (it is the river); only the listed materials, no glue; 25 minutes to build each version; every piece of material counts toward the budget, including tape used to attach the bridge to the banks.

Our design brief (write precise, measurable statements)

Item	Our precise statement	How we will measure or check it
Bridge type and budget		
Criterion after Level 1		
Criterion after Level 2		
Criterion after Level 3		
Load and span criteria		
Constraint: budget		
Constraint: materials and rules		
Constraint: time		

1. A classmate's brief says, 'Our bridge should be strong and not break.' Rewrite this as two precise criteria for your bridge type that someone else could check with a ruler and the rating scale.

2. Which of your criteria or constraints comes from the science of earthquakes (how strong or how frequent shaking is), and which comes from people's needs or limits? Give one of each.

-  Sketch version 1 from the side and from above. Label the materials, every joint, the banks, and arrows showing how the weight of the load travels to the banks.

Version 1 materials and cost

Material	Quantity used	Unit cost	Cost
Craft sticks		1	
Tape (10 cm pieces)		1	
Paper clips		1	
Rubber bands		2	
String (10 cm pieces)		1	
Index cards		2	
Total			

Shaker calibration (strokes counted in 10 seconds)

Level	Target strokes in 10 s	Practice count 1	Practice count 2
1	20		
2	27		
3	33		

Version 1 test results

Stage	Load on deck? (Y/N)	Deck height at mid-span (mm)	Sag change since loaded (mm)	Joints loosened / broken	Rating	Target met? (Y/N)
No load						
Loaded, before shaking			0			
After Level 1						
After Level 2						
After Level 3						

Class comparison table

Group	Bridge type	Main design features	Cost (units)	Level 1 rating	Level 2 rating	Level 3 rating
1						
2						
3						
4						
5						
6						
7						
8						

3. Look across the class table. Which design features do the best-performing bridges share, and which features show up in bridges that failed early? Name at least two features and the groups that show them.

4. Redesign plan: which one main feature will you change for version 2, which test result is it meant to fix, and what do you predict will happen at each level?

Version 2 test results

Stage	Load on deck? (Y/N)	Deck height at mid-span (mm)	Sag change since loaded (mm)	Joints loosened / broken	Rating	Target met? (Y/N)
No load						
Loaded, before shaking			0			
After Level 1						
After Level 2						
After Level 3						

Analysis questions

5. Did version 1 and version 2 meet each of your criteria and stay within every constraint? Use the ratings, sag changes and costs from your tables.

6. Pick the feature that made the biggest difference across the class (for example triangles, cross-bracing, a wide or low structure, a curb on the deck, or flexible connections). Explain, in terms of forces and motion, why it helped the bridge survive shaking.

7. Level 3 moves the platform 3 times as far as Level 1 and about 1.7 times as often. Describe one way the shake table is a good model of earthquake shaking and two ways it is not like a real earthquake hitting a real bridge.

8. The three bridge types had different targets and budgets. Explain why a county would set a higher target and spend more on a lifeline bridge than on a farm-road bridge, using the idea that stronger shaking is rarer.

9. List three things the class kept the same so that the designs could be compared fairly. Then name one thing that may still have made the comparison unfair and how you would fix it.

- 10.** After the 1995 Kobe earthquake, Japan placed many new buildings on rubber-and-steel bearings, and parts of the new Bay Bridge span are designed to bend and absorb energy so the main structure is protected. Did any bridge in your class use a similar idea? Explain how letting part of a structure move or bend can reduce damage.
