

MAINTENANCE AND INSPECTION OF BRIDGE STAY CABLE SYSTEMS

Workshop on Wind-Induced Vibrations
St. Louis, Missouri
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Introduction

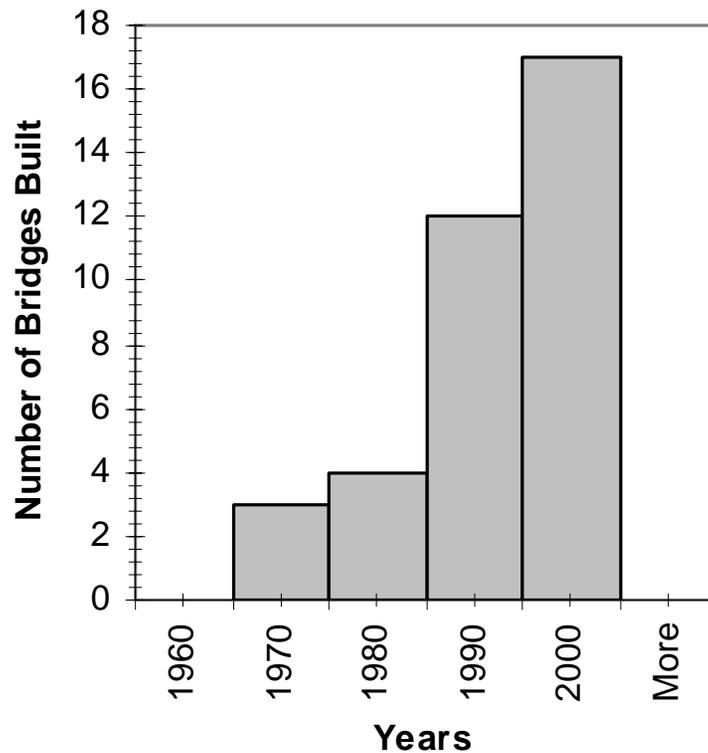
- This work is based on NCHRP Synthesis 353, Inspection and Maintenance of Bridge Stay Cable Systems, 2005.
- A comprehensive review of literature
- A questionnaire for US and Canadian agencies
- Review of test reports, maintenance manuals
- Patent searches,...

US Inventory

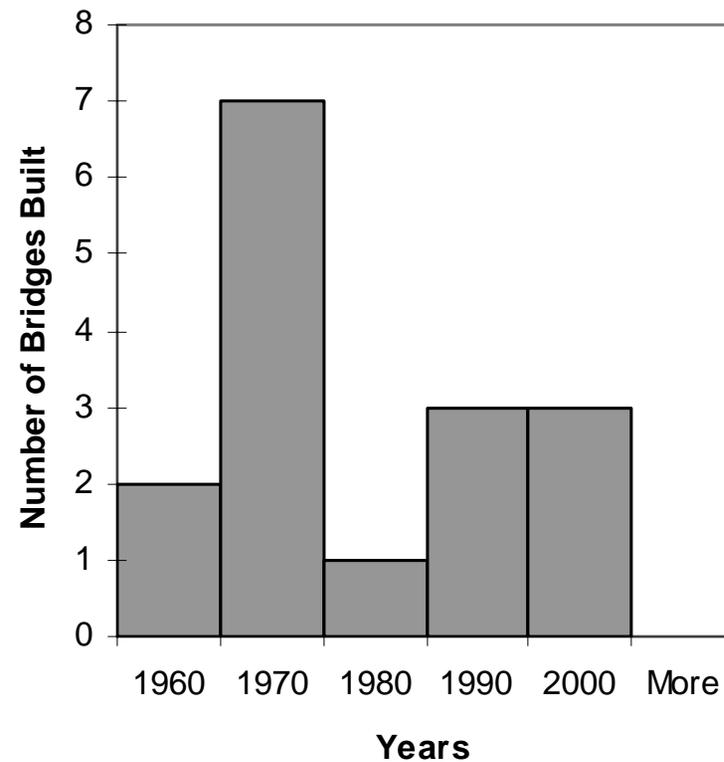
No	Bridge Name	State	Span, m (ft)	Year	Survey in?
1	Cooper River Bridge	South Carolina	472 (1546)	2005	yes
2	Greenville Br, US 82 Over Mississippi	Mississippi	420 (1378)	2005	yes
3	Dame Point Bridge	Florida	397 (1300)	1989	yes
4	Fred Hartman /Houston Ship Channel	Texas	381 (1250)	1995	yes
5	Sidney Lanier Bridge, Brunswick	Georgia	381 (1250)	2003	yes
6	Hale Boggs / Luling Bridge	Louisiana	373 (1222)	1984	yes
7	Sunshine Skyway Bridge	Florida	366 (1200)	1987	no
8	William Natcher / Owensboro Bridge	Kentucky	366 (1200)	2002	yes
9	Bill Emerson / Cape Girardeau Bridge	Missouri	351 (1150)	2003	yes
10	Talmadge Memorial Bridge, Savannah	Georgia	336 (1100)	1991	yes

Cable-Stayed Bridges in the U.S. and Canada

Cable-Stayed Bridge Construction in the U.S.



Cable-Stayed Bridge Construction in Canada

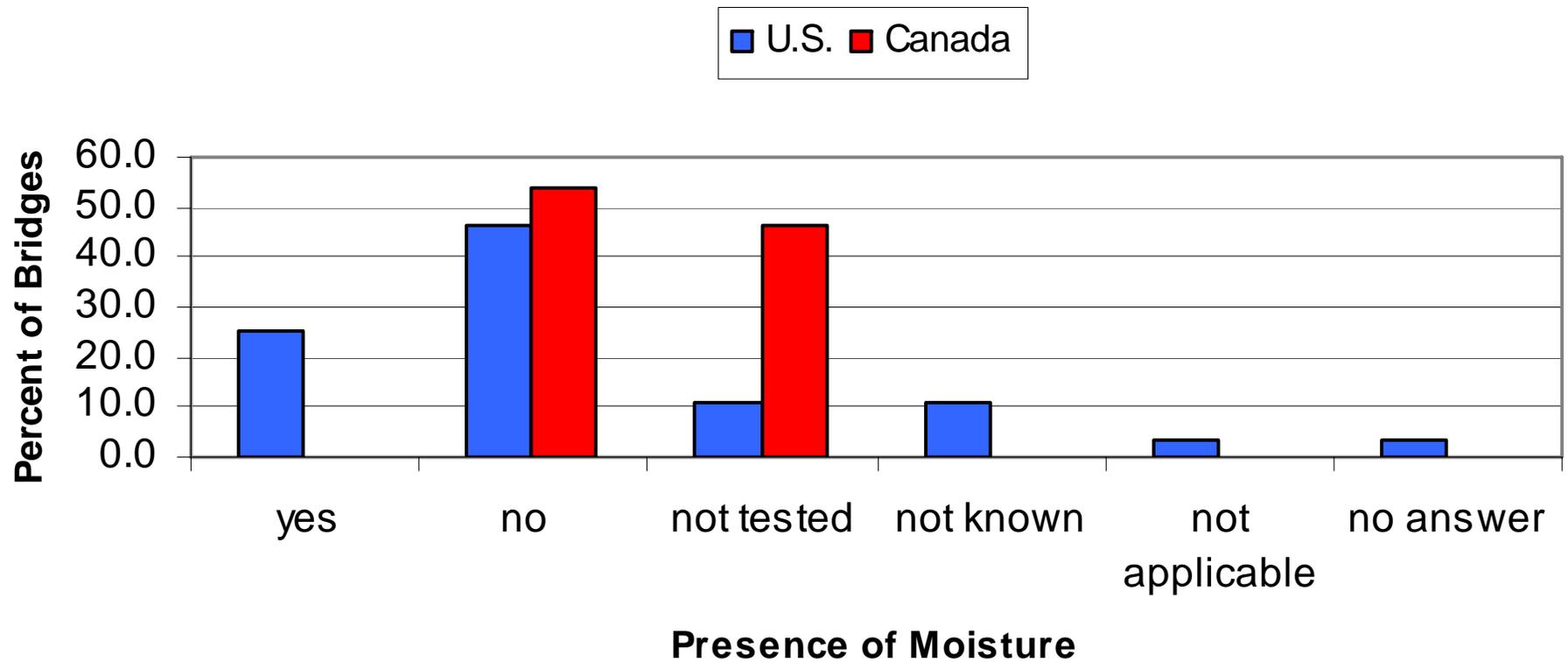


No. of Bridges

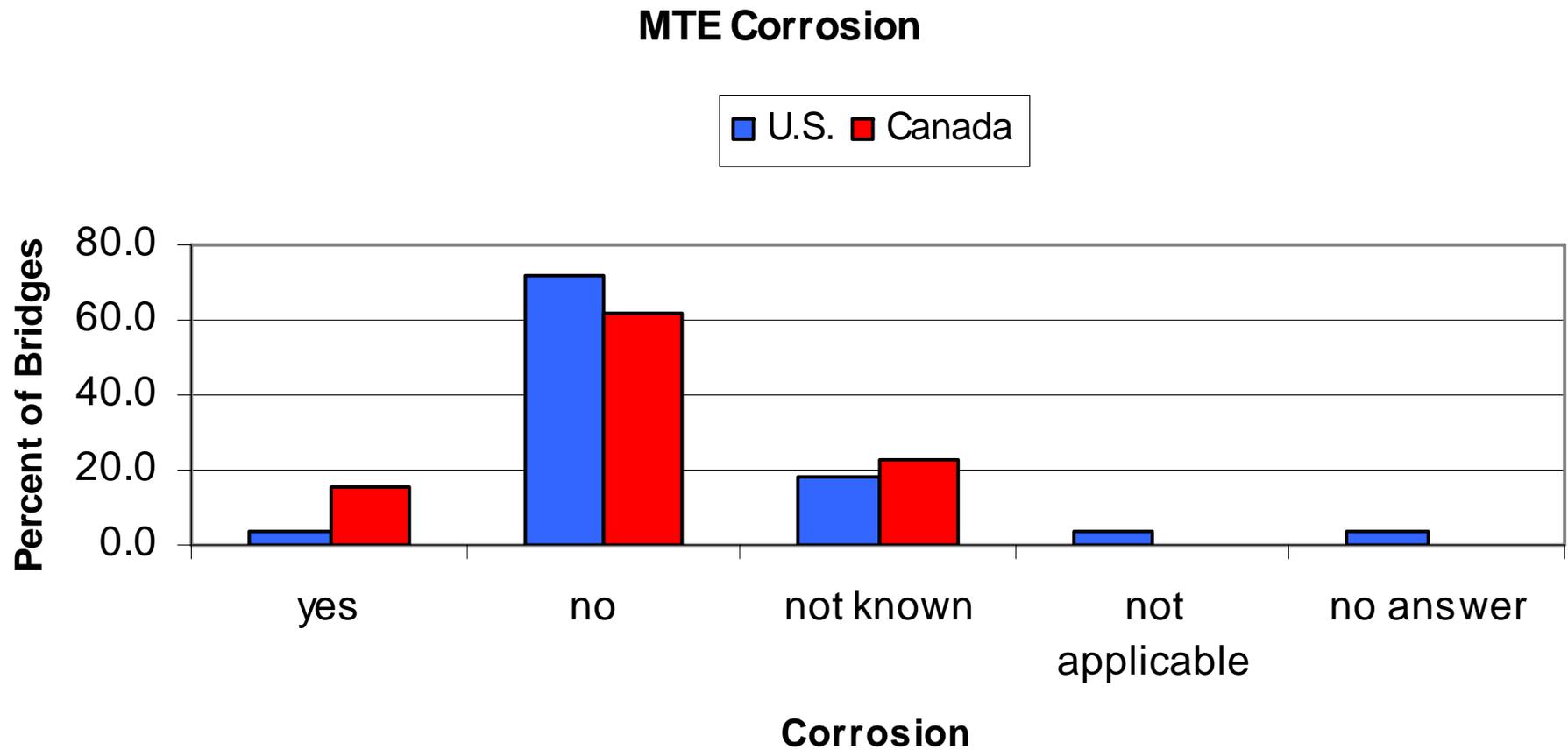
- In the U.S., over 40 cable-stayed bridges - the oldest is the **Sitka Harbor Bridge** in Alaska built in 1970
- In Canada, over 16 cable-stayed bridges - the oldest is the **North Romaine Bridge** in Quebec built in 1960.

Moisture inside Cable?

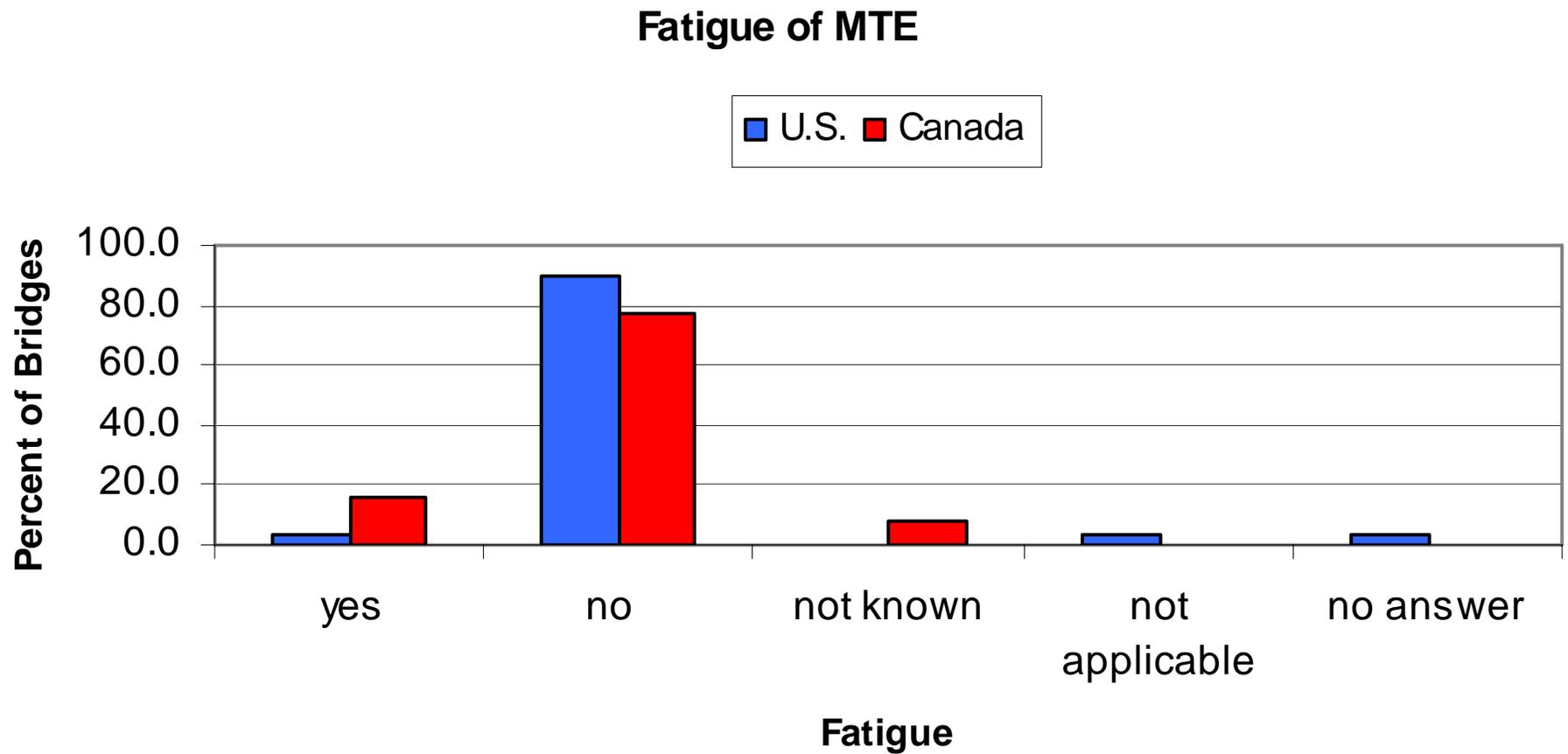
Moisture Inside Stay Cables



MTE Corrosion?

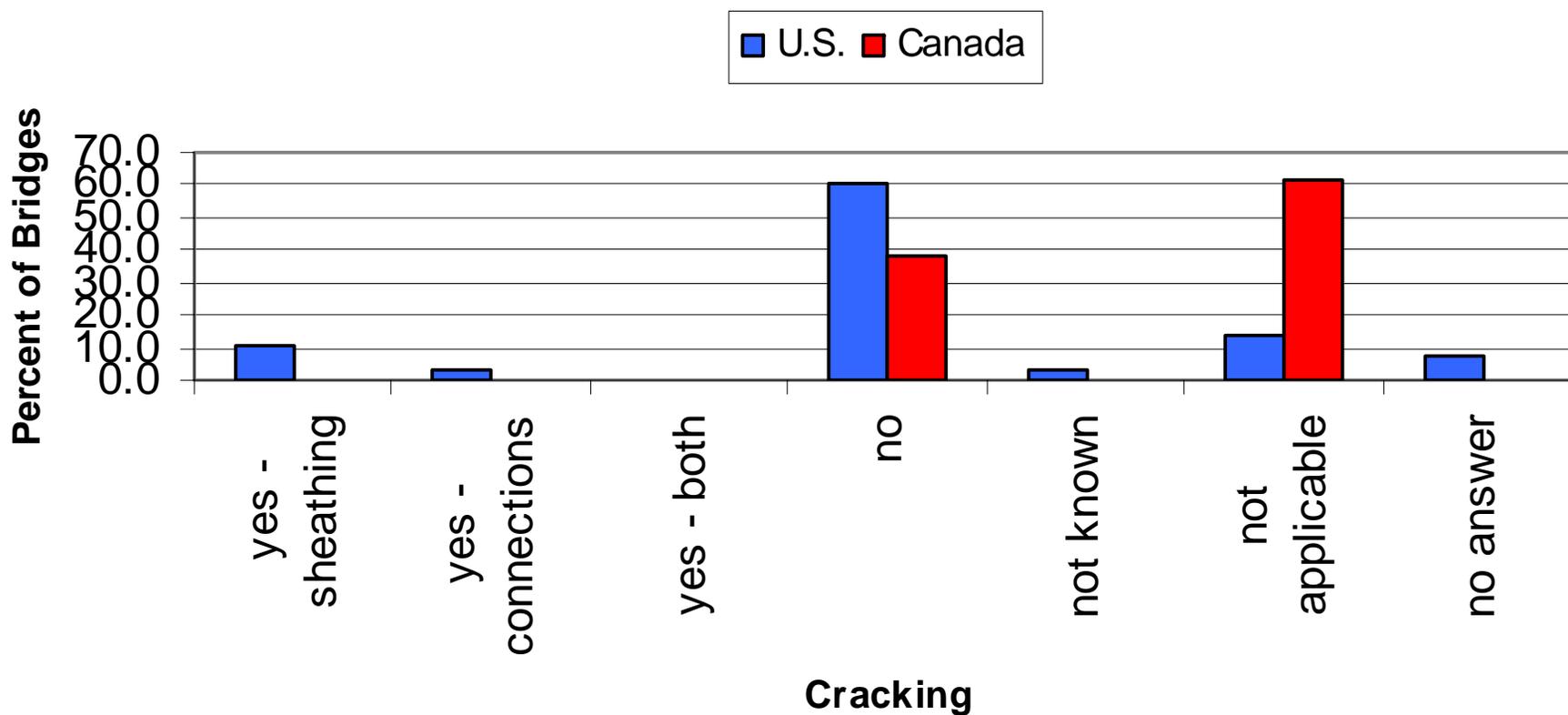


Fatigue?



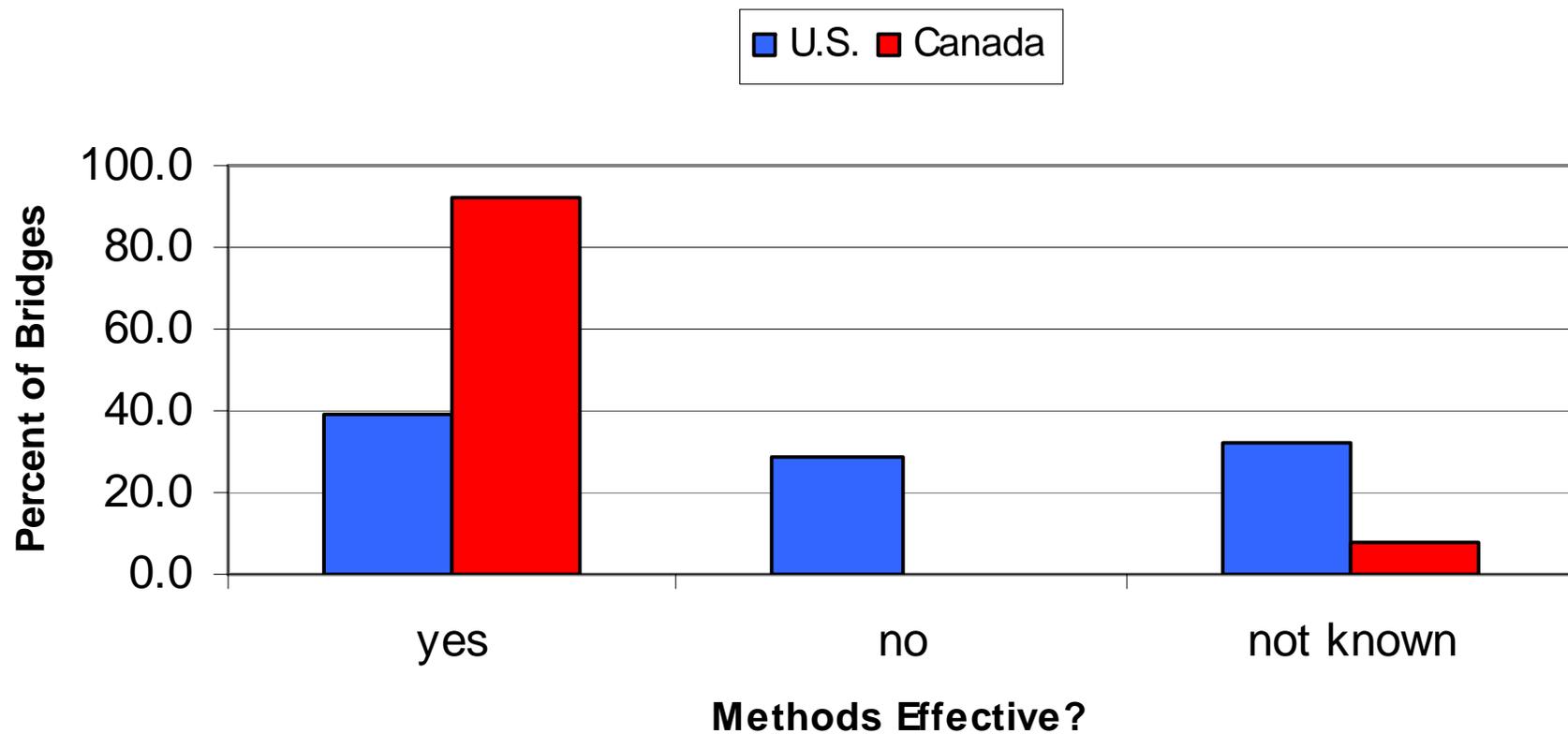
Cracking of Sheathing or Connections?

Cracking of Sheathing and Connections



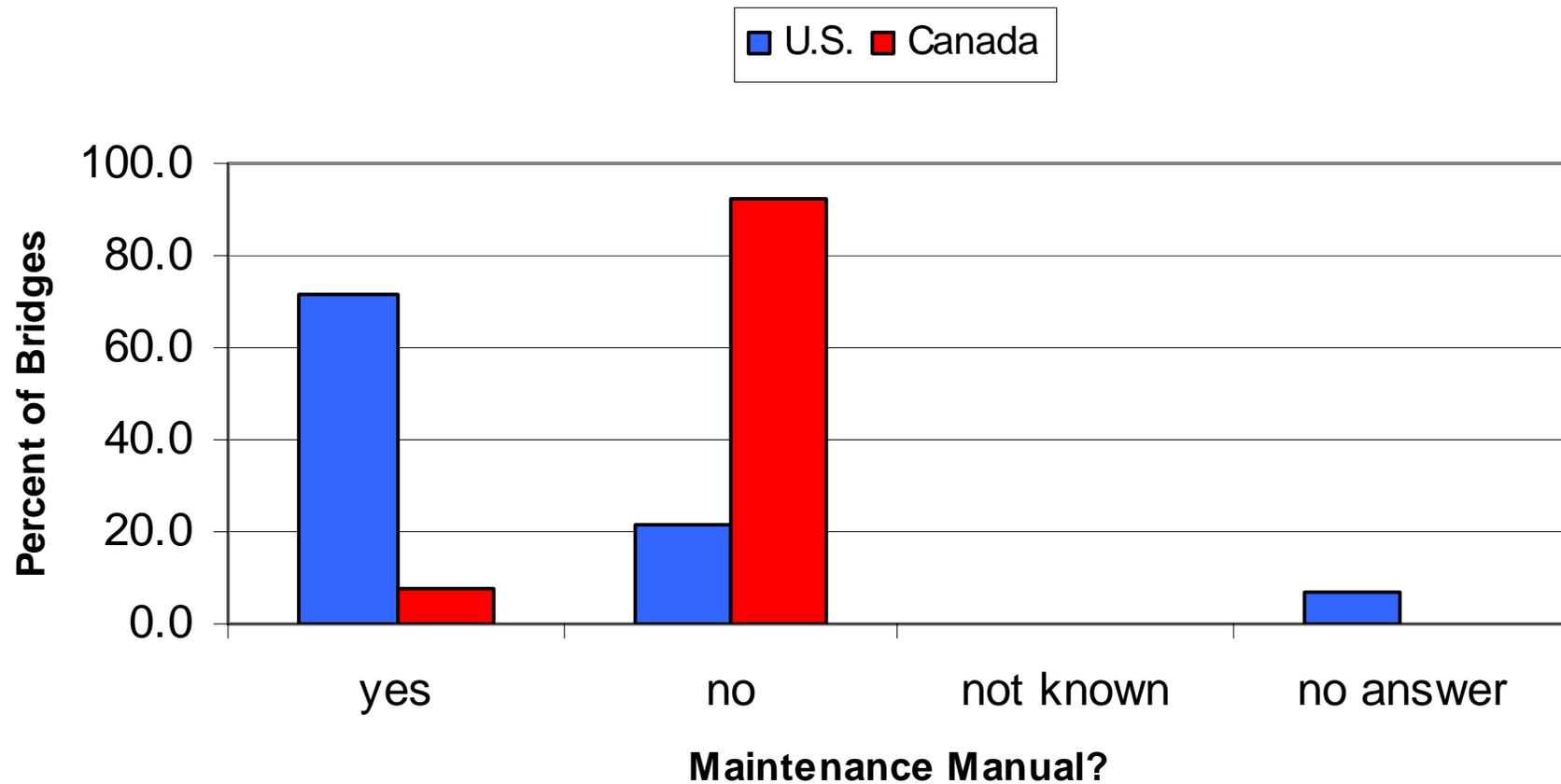
Methods Effective?

Inspection, testing, monitoring and Repair Effective and Adequate?

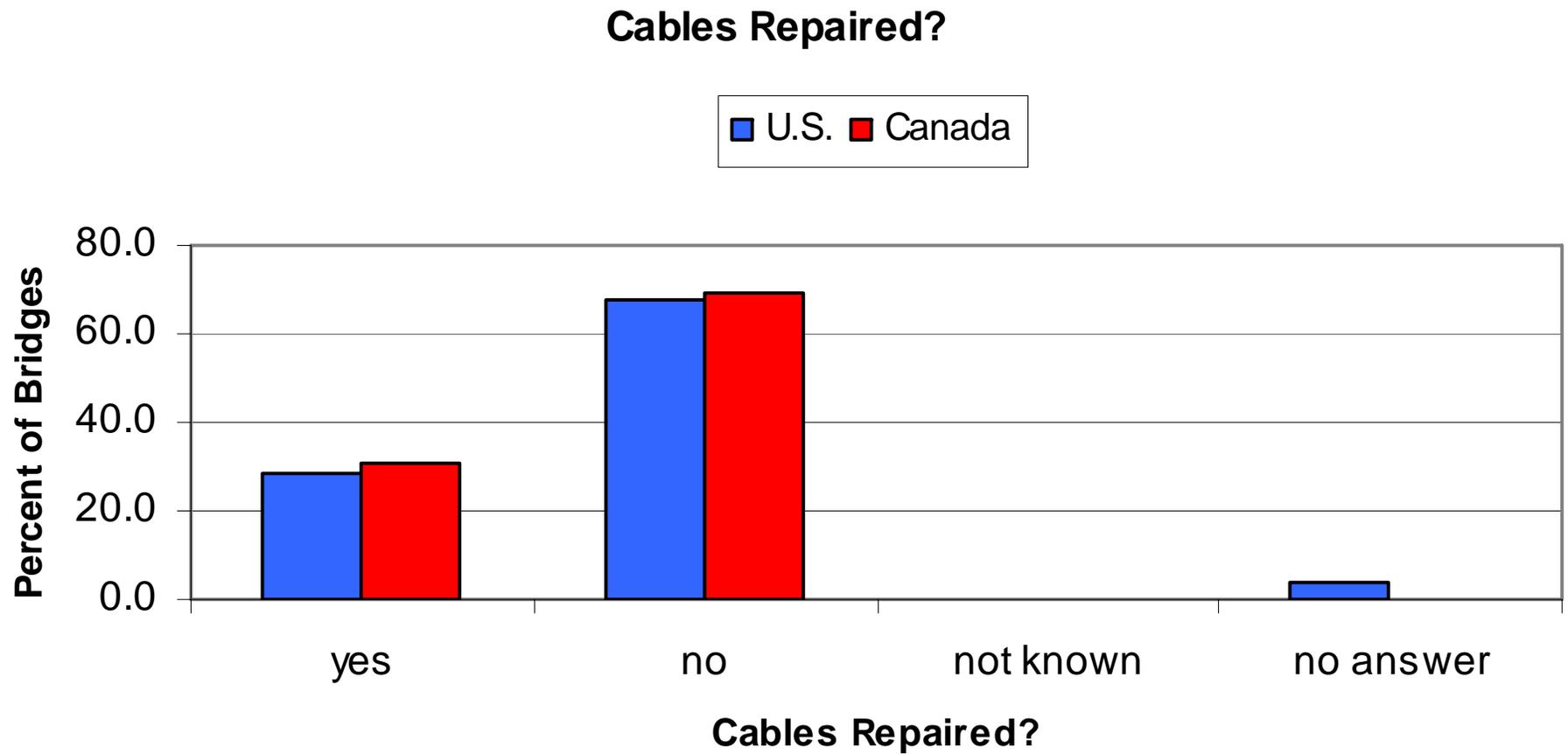


Manual Available?

Inspection & Maintenance Manual Available?

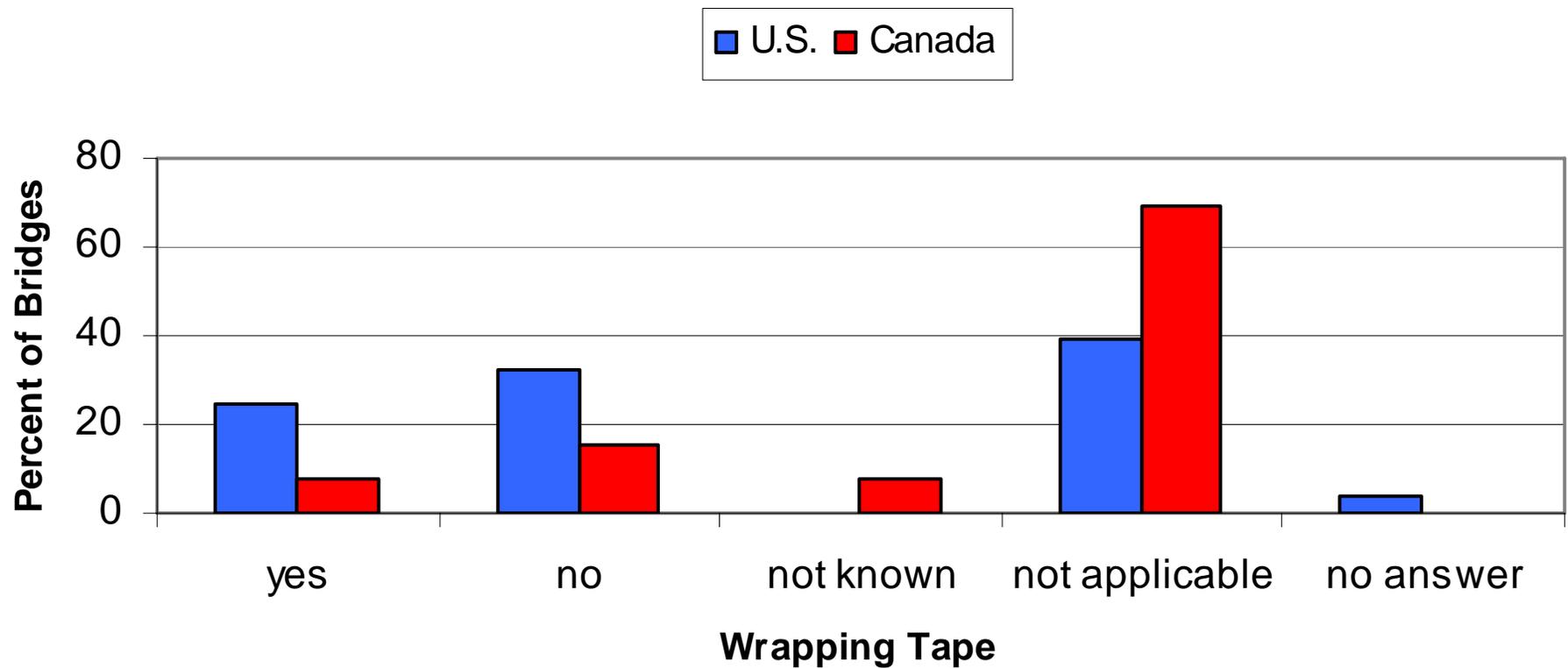


Cables Repaired?



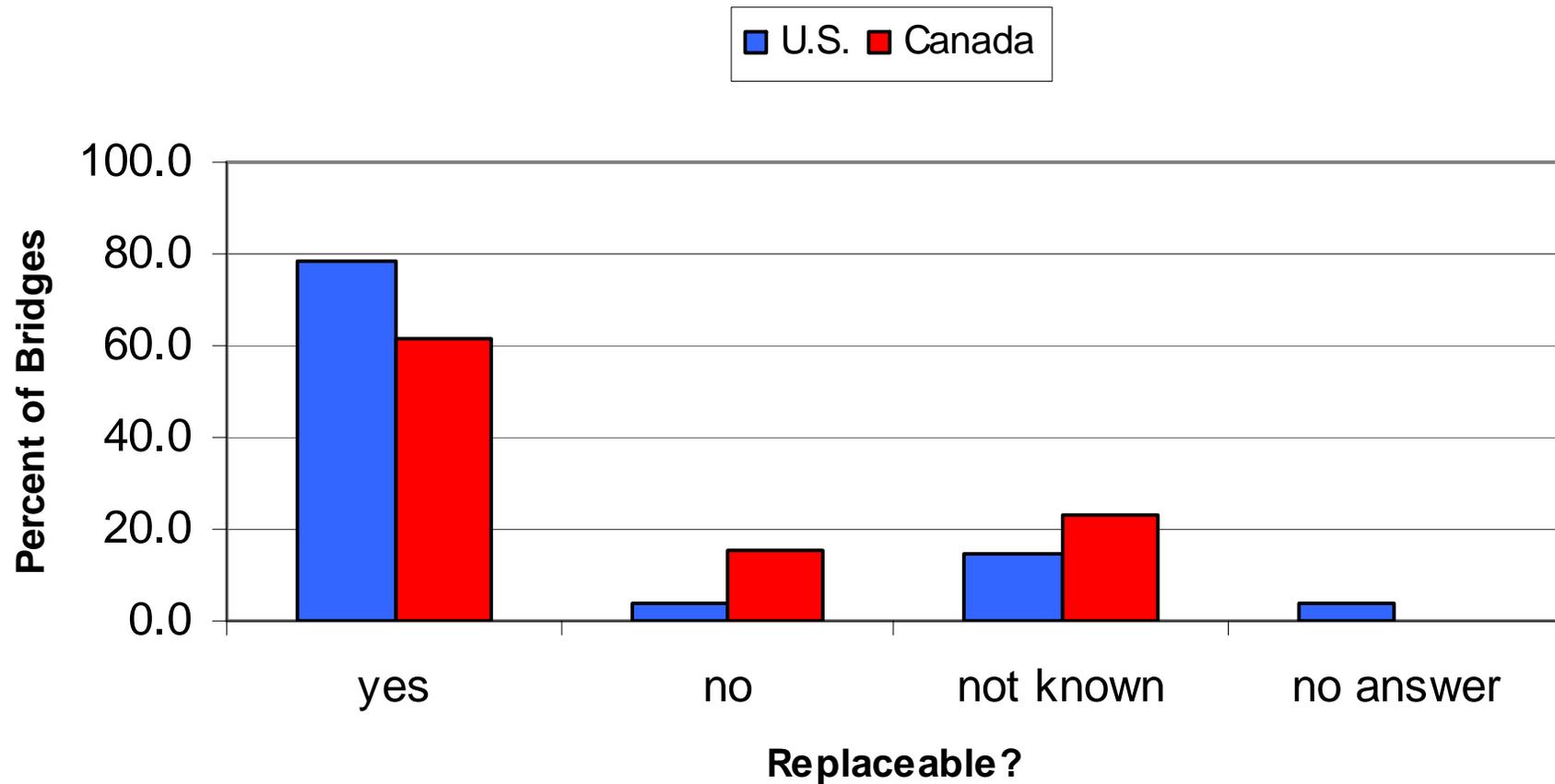
Damage to Tape?

Damage to Wrapping Tape



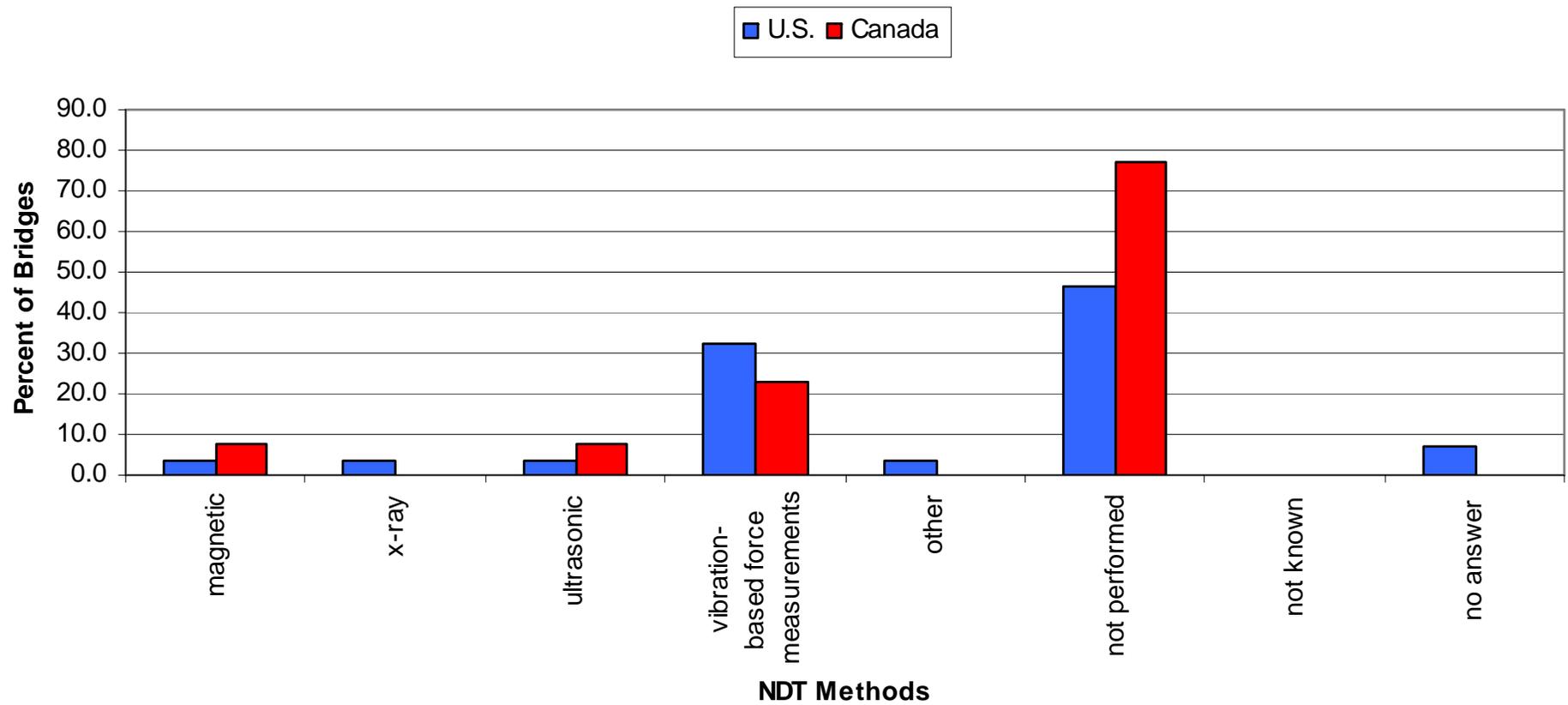
Cables Replaceable?

Can the Cables (or Strands) be Replaced?



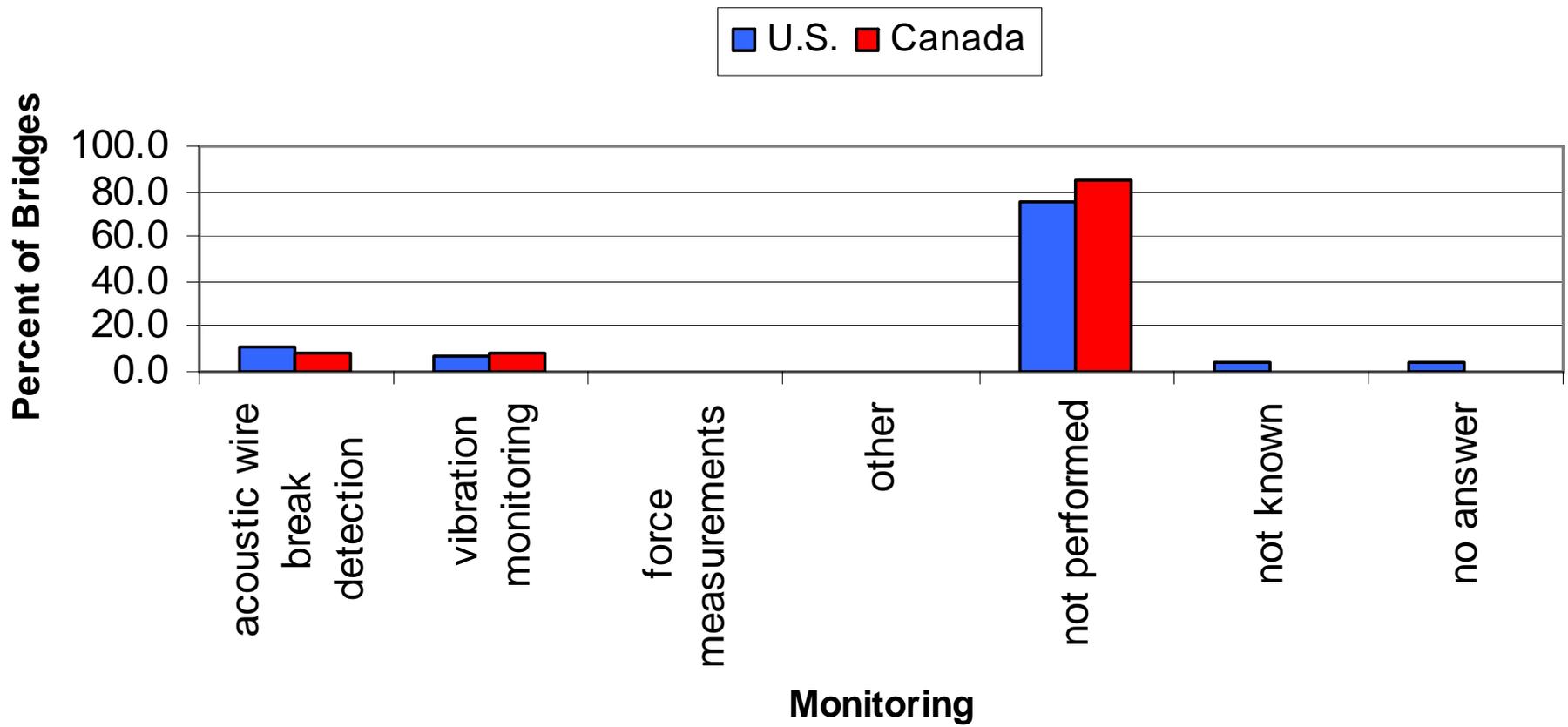
NDT on Stay Cables?

Non-Destructive Testing on Stay Cables?

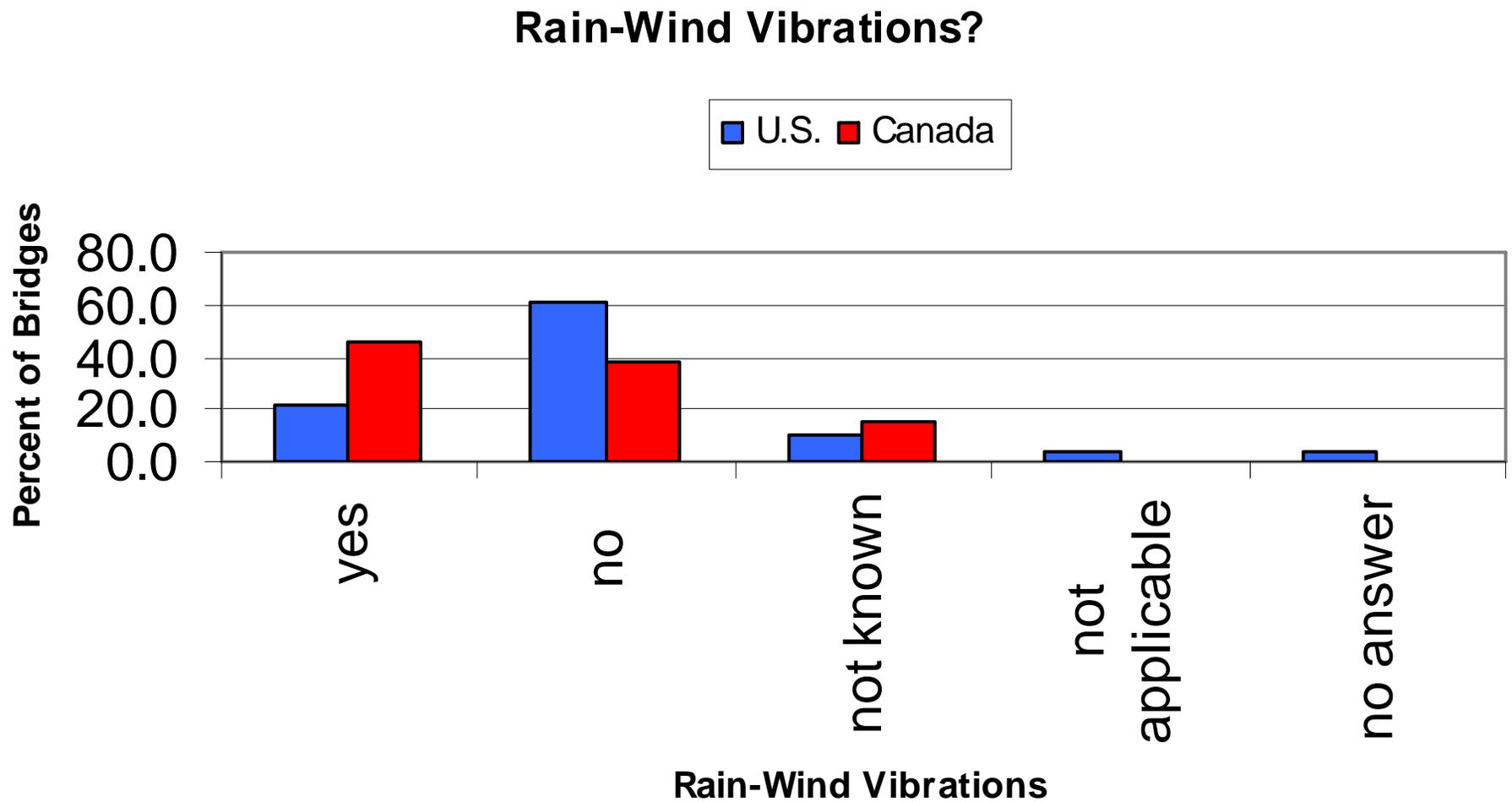


Long-Term Monitoring?

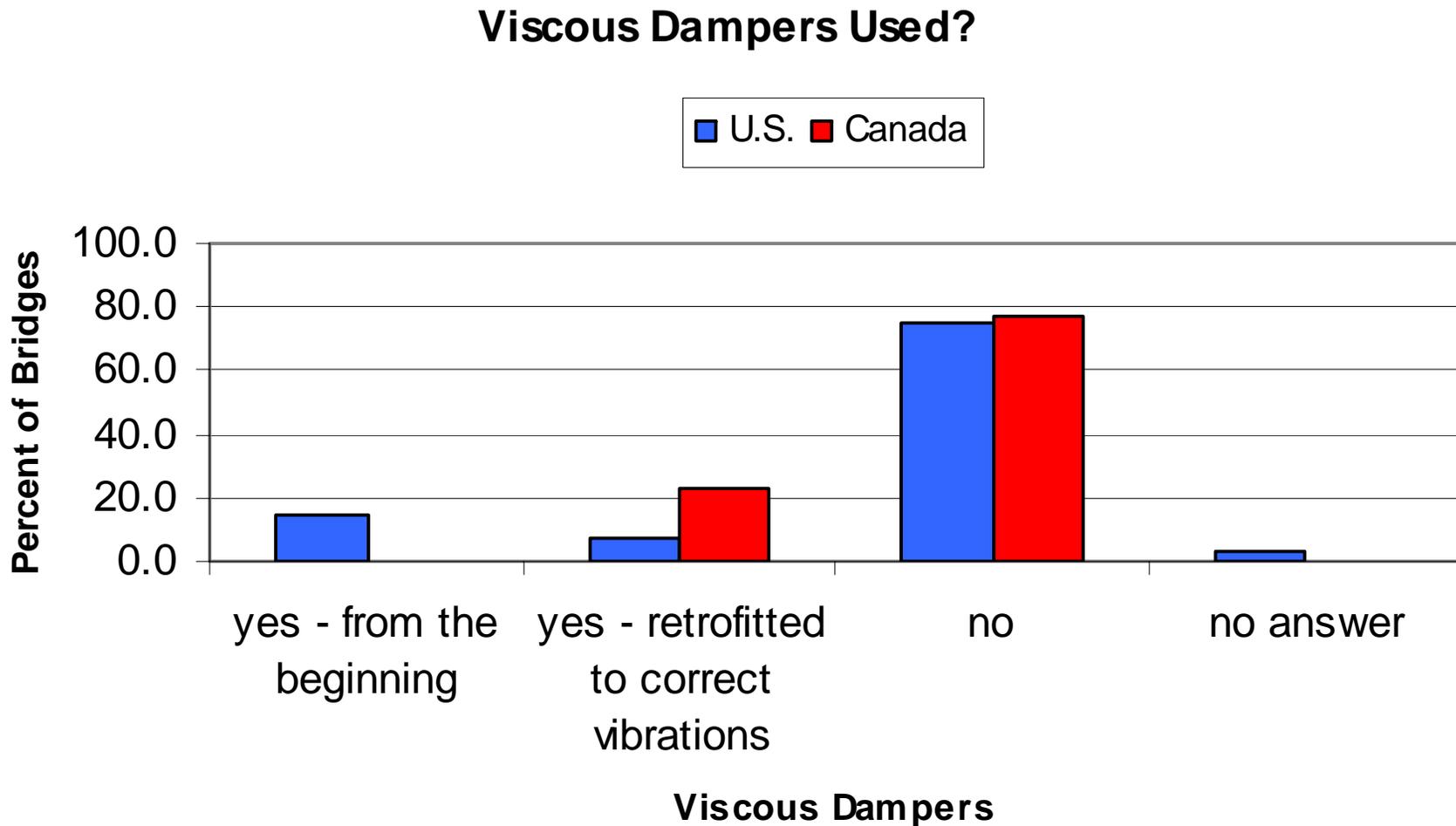
Sensor Based Long-Term Monitoring?



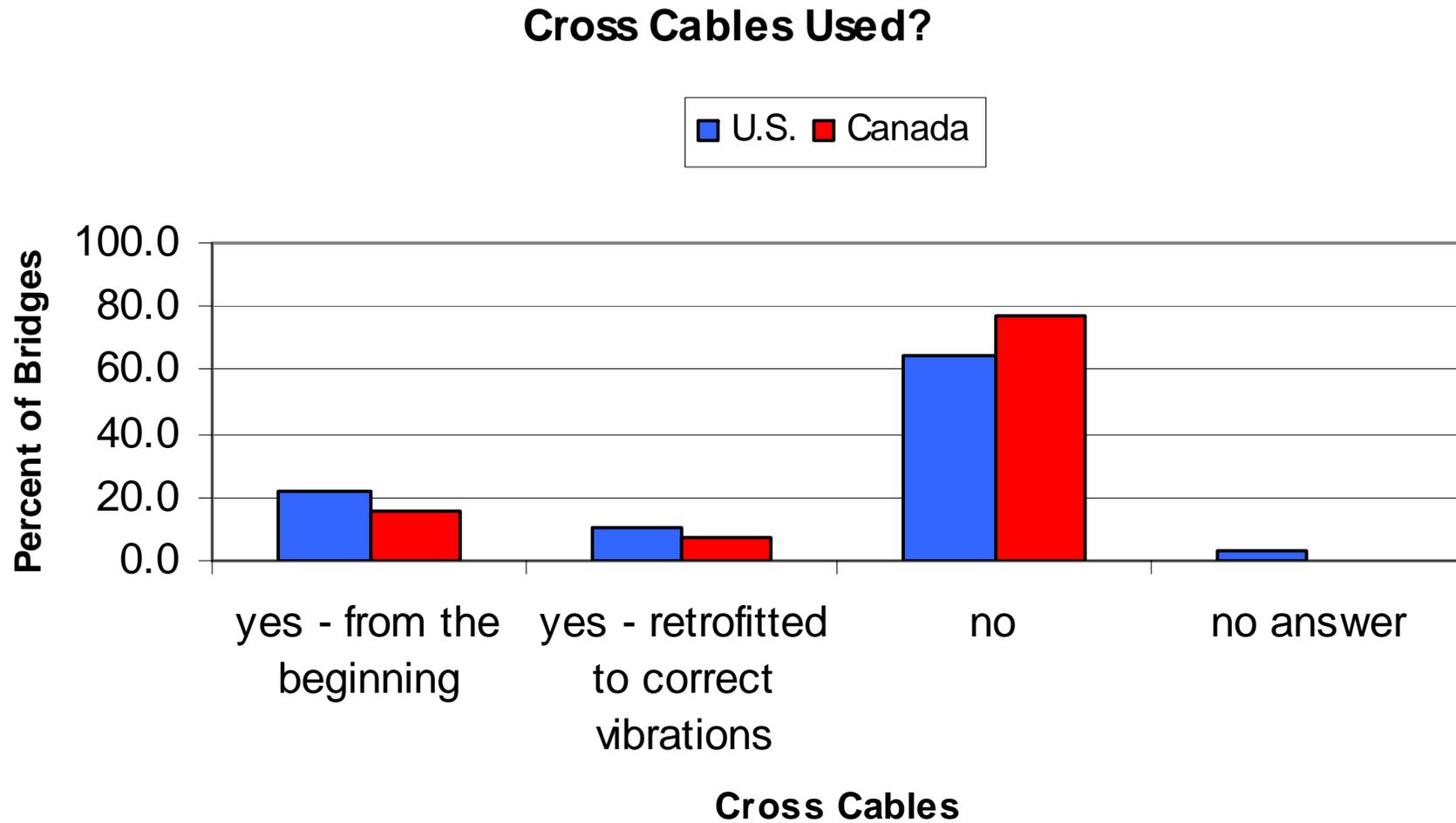
Rain-Wind Vibrations?



Viscous Dampers Used?



Cross Cables Used?



Visual Inspections

- In great majority of cases, this is the only method utilized in cable-stayed bridges.
- Typically include surveys of the exterior surfaces of cables, exposed surfaces of the anchorages, cross cables and their connections, dampers, and conditions of neoprene boots and guide pipes.
- Inspections of neoprene rings inside guide pipes are also performed in some inspections.

Visual Inspections (Cont.)

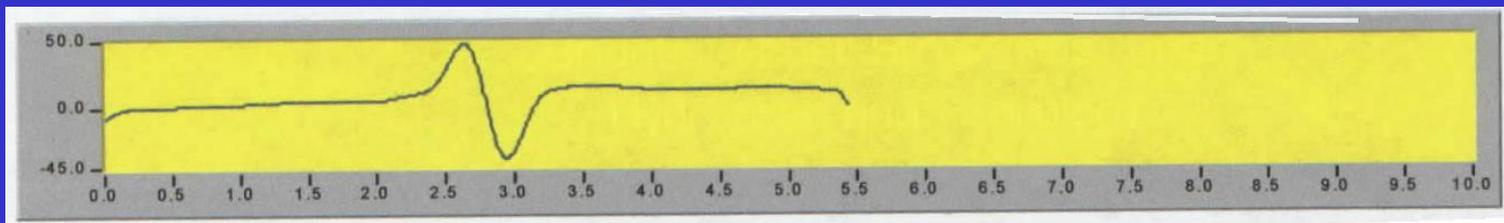
- Borescopes or videoscopes can be used to check the condition of the cable and presence of moisture inside the guide pipe.
- Anchorage caps can be removed to check the condition of wedges or button heads, and to check for moisture.
- Visual inspections could potentially involve measurements of cable sag and inclination angle by the inspector from the deck level using simple devices.

Magnetic Flux Leakage

- Long history in inspection of industrial cables and ropes.
- Systems that can travel along the stay cable are commercially available.
- This method does not work well with cables that have steel sheathing.
- The cable size cannot be too large in diameter

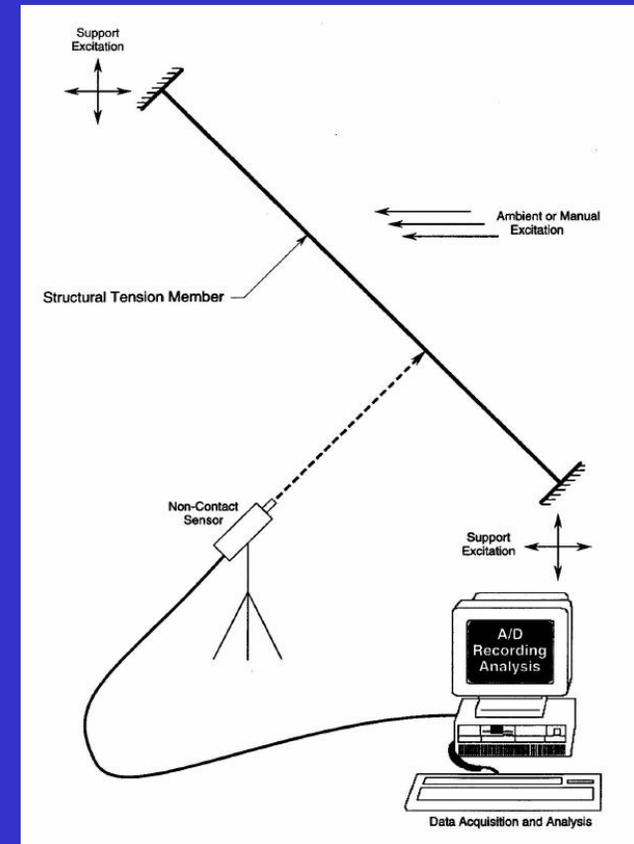
Magnetic Flux Leakage (Cont.)

- The system can identify the extent of damage and its location along the length of cable, but cannot identify location of damage within the cross section.
- In its current state of development, this method cannot be used for inspections in the anchorage zones and the vicinity of anchorage zones. Unfortunately, those are the areas where most serious problems have occurred.



Cable Force Measurements

- Using accelerometers
- Using non-contact sensors such as laser vibrometers



Cable Force Measurements (Cont.)

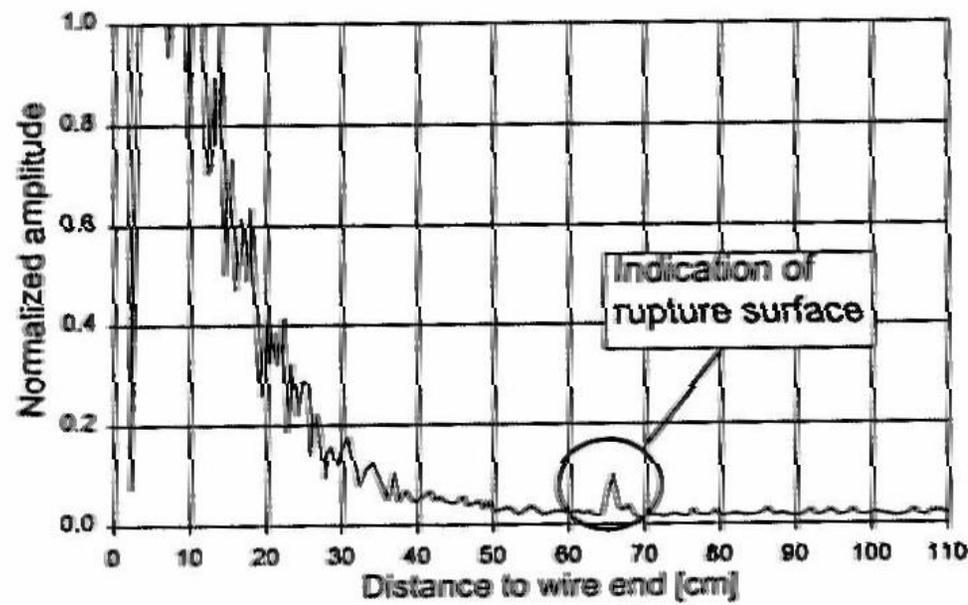
- This approach is the most widely used, and sometimes misunderstood, NDE method.
- Measurement of cable forces can help determine if global stiffness changes have occurred in cables. However, moderate damage, in the form of MTE section loss, does not necessarily translate into global stiffness change.

Cable Force Measurements (Cont.)

- In grouted cables, a broken wire can redevelop its stress a short distance away. *Therefore, when cable forces in a grouted cable array do not change over time, it cannot necessarily be concluded that there is no loss of MTE.*

Ultrasonic Testing

- A stress wave is sent into the wire or strand at the anchorage and the reflections are monitored and displayed.



Ultrasonic Testing (Cont.)

- There has not been a systematic and controlled evaluation of this method to determine its degree of effectiveness for stay cable anchorages.
- Calibration with mock-up required.

Ultrasonic Testing (Cont.)

- Seven-wire strand a larger challenge than individual wires because transmission of stress waves in them is more complex.
- The operator must be highly qualified since the judgment of the operator is crucial.
- The problems arise due to the anchorage materials surrounding the MTE. The stress wave attenuates significantly in a wire embedded in grout or epoxy compared to a wire in air.

Ultrasonic Testing (Cont.)

- This method is not applied to the MTE in the free length of cable.
- UT is the only known and practical test that is currently available for the assessment of MTE in the anchorage zones of typical U.S. stay cables.

Radiography

- This method has the potential to successfully assess conditions of cable anchorages where access to the perimeter can be achieved.
- This method was used on the anchorages of the Meridian Bridge in California.
- Safety issue, cost, and typically large and heavy equipment have significantly limited their use.

Acoustic Monitoring

- It is a passive monitoring system.
- AM has long used to detect wire breaks in the stay cable test specimens.
- As a wire breaks, a stress wave travels along the length of the cable in both directions.
- Accelerometers attached at the anchorage can detect the event and determine its location along the cable.

Acoustic Monitoring (Cont.)

- The recorded response or “signature” can be analyzed to determine if the event is in fact a wire break.
- A commercial system is currently available and has been installed on a number of bridges.
- In grouted cables, the attenuation of the wave is significantly higher than in the ungrouted cables.

NDT For Stay Cables

- There is not a single method that would provide answers for all the questions regarding the condition of stay cables.
- In most cases, it is the combination of NDT techniques together with the experience, knowledge, and judgment of engineers, inspectors and technicians that can lead to the appropriate answer.
- The effectiveness and accuracy of many of the methods described above would be significantly enhanced if baseline comparative measurements are available.

Recommendations

- Suggest minimum information to be included in maintenance manuals.
- Perform research on ultrasonic testing of MTE in various types of anchorages.
- Perform research on improving the effectiveness of visual inspection techniques, and the development of visually inspectable stay cable systems.

Recommendations (Cont.)

- Perform research on the feasibility of built-in or remote inspection and imaging systems for monitoring of MTE conditions in the cables (especially anchorages) for incorporation into new cable designs.
- Perform research on identifying appropriate choice and use of combinations of NDE methods based on the conditions at hand.

Recommendations (Cont.)

- Perform research on feasibility of global, 3-dimensional, physical mapping of stay cables.
- Study the creation of a national resource for information on stay cables and cable-stayed bridges
- Study creation of periodic training programs for state engineers and inspectors.

Thank You