



Bridge Adaptation

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Bridge Adaptation on a Global Perspective

- Growing climate risks—storm surge, sea-level rise, flooding, tsunamis, extreme winds—are increasing global bridge vulnerability.
- Many existing bridges were designed using historic climate assumptions, not modern hazard intensities.
- Common failures worldwide include deck uplift, unseating, scour, and lateral displacement
- Successful adaptation strategies:
 - Elevated decks and increased freeboard
 - Improved girder geometry & venting to reduce air-entrapment uplift
 - Stronger bearings, shear keys & anchorage
 - Battered piles & deeper foundations for lateral and scour resistance
 - Structural Health Monitoring (SHM) for real-time performance
- Modern approaches use robust climate-informed optimization to plan upgrades



Why Bridge Adaptation Matters



Coastal bridges face increasing risks from storm surge, sea-level rise, and extreme weather events.



The I-10 Twin Span Bridge failure is one of the most documented surge-induced collapses in U.S. history.



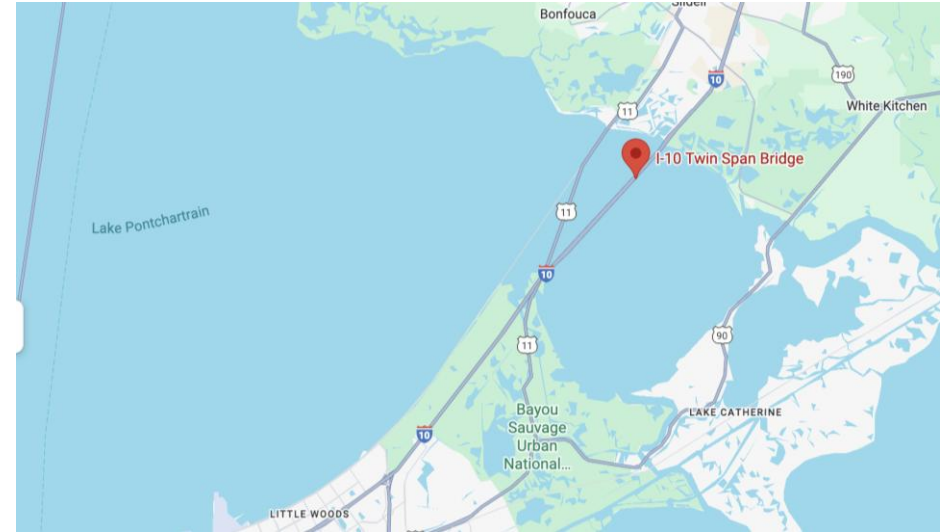
Failure of critical infrastructure can disrupt evacuation routes, emergency responses, and regional mobility.



Lessons inform national bridge design, geotechnical practice, and SHM deployment.

Old I-10 Twin Span Bridge

- New Orleans, one of the 3 main connections
- Construction timeline (1963 → 2005 collapse → 2011 completion)
- Built in 1963
- Length: 5.4 miles (8.6 km)
- Structure: Two parallel bridges (eastbound and westbound)
- Elevation: 8.5 ft above mean high water (approach spans)
- Span configuration: 436 simply supported precast concrete spans per approach
- weight \approx 285 tons each
- Structural detail: Box-like underside created by girders and diaphragms, open downward.



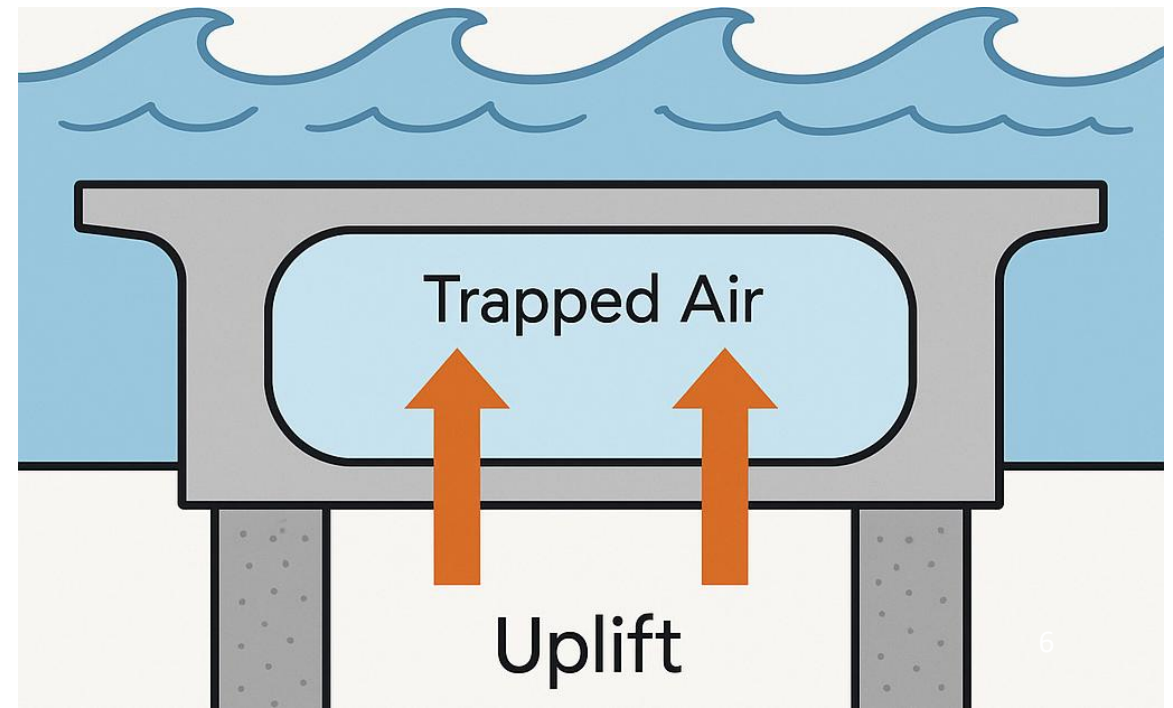
Damage Observed

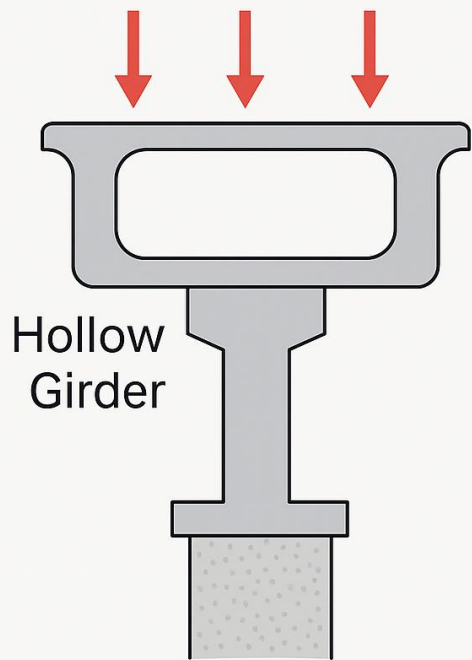
- 58 spans failed:
 - 38 eastbound spans
 - 20 westbound spans
- Lateral displacement of 1–2 girder spacings before falling off supports.
- Approach spans experienced nearly all failures — low elevation + hollow girders made them highly vulnerable.
- Substructure mostly intact:
- Columns and pedestals showed minimal damage
- Indicates failure mechanism was superstructure uplift, not foundation instability
- Main navigation span remained intact due to higher elevation and deeper structure.



What happened

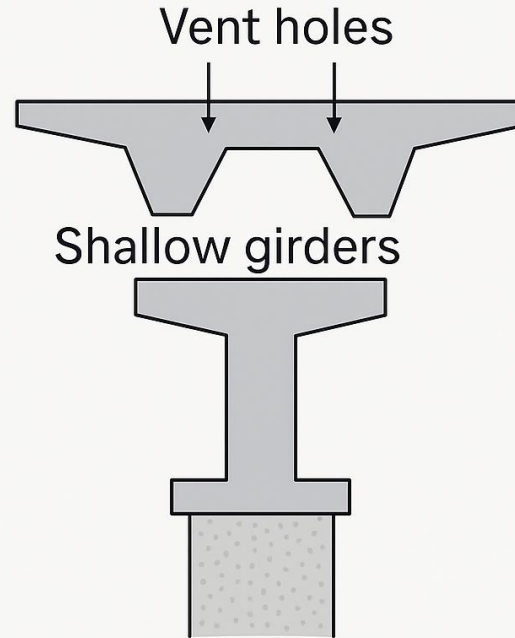
- Storm surge raised water levels beneath the bridge.
- Air became trapped inside the hollow underside of the decks.
- This trapped air reduced effective gravity load, making spans buoyant.
- Floating decks required minimal horizontal force from waves, wind, or current to shift.
- Spans moved eastward, opposite major wind direction → confirms surge-driven buoyancy caused displacement.
- Nearby bridges (U.S. 11 and railroad) experienced little to no damage





Hollow Girder

I-10 Bridge



Vent holes

Shallow girders

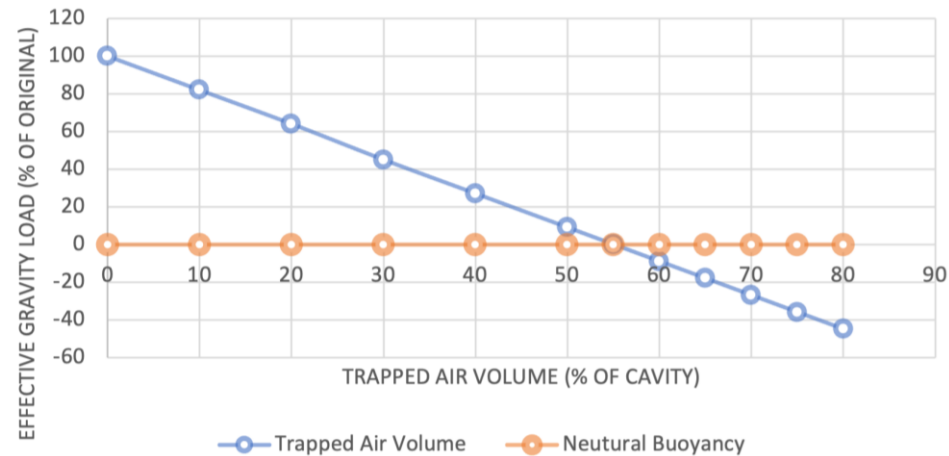
U.S. 11 Bridge

Structural Comparison

- U.S. Highway 11 Bridge:
 - Shallow girders + vent holes prevented air entrapment
 - Lower buoyancy → spans stayed seated
- Railroad Bridge:
 - Solid slab deck → *no hollow space* for air to trap
 - Equipped with shear keys → prevented lateral movement
- Both bridges saw the same storm surge, yet remained intact → confirms that:
 - Structural geometry,
 - Air-release capability,
 - Span-to-support connectivity played a larger role in survivability than wind forces.
- Supports the conclusion that the I-10 failure was uplift-dominant, not wind-dominant.

Hydrostatic Analysis

Trapped Air Volume vs Effective Gravity Load



- Hydrostatic Principle:
 - Buoyant force = weight of displaced water. Larger air cavity → smaller effective weight.
- Hydrostatic lab experiment using a rectangular box confirmed the failure mechanism.
 - Critical Threshold: 55% air volume, net gravity load = 0 → structure becomes neutrally buoyant.
 - I-10 spans had ≈70% trapped air volume, leading to flotation.
- Frictional resistance dropped, allowing spans to slide sideways.
- Structural geometry strongly influenced damage severity.

Stakeholders

- **Owner:** Louisiana Department of Transportation & Development (LADOTD).
- **Funding:** Federal Highway Administration (FHWA) Emergency Relief Program.
- **Research & Instrumentation:**
 - Louisiana Transportation Research Center (LTRC)
 - Louisiana State University
 - Geocomp Corporation
- **Design & Reconstruction:** Volkert, Inc.
- No one was held responsible for the collapse



New Bridge and Its Adaptation

- Elevation increased from 8.5 ft → 30 ft
- New high-rise span: 80-ft vertical clearance
- Built 300 ft east of original alignment
- Foundation: redesigned with deep piles + robust bents
- Two parallel spans each 60 ft wide → 3 lanes + 12-ft shoulders
- Designed specifically to withstand large storm surge
- Equipped with impact sensors, storm surge sensors, SHM system (FHWA)
- Construction cost: \$803 million, completed by Sept 2011
- Objectives:
 - Validate battered pile foundation design.
 - Establish real-time monitoring for short- and long-term performance.
 - Enhance safety and durability of critical bridge infrastructure.

Improvement

Feature	Old Bridge (1963 Design)	New Bridge (Post-Katrina Reconstruction)
Elevation above water	8.5 ft above mean high water → directly exposed to storm surge	30 ft above mean high water → safely above surge and wave impact zone
Navigation clearance	Low clearance; only one high navigation span in the middle	80-ft high-rise span provides vessel clearance + reduces wave impact
Structural system	Hollow girder boxes forming downward-facing air cavities	Deeper, solid, and better-detailed superstructure reduces air entrapment; stronger span-to-support connections
Foundation	Straight piles with less lateral resistance	24-pile battered groups (1:6 slope) → high lateral capacity; validated by full-scale lateral load test
Storm-surge vulnerability	Low, flat causeway spans → deck flotation, lateral sliding, collapse	Elevated profile + stronger anchorage → no flotation risk, improved surge resistance
Span behavior under surge	Friction-only bearings + no shear keys → spans easily displaced	Anchored bearings + lateral restraint → deck remains seated
Monitoring & resilience	No monitoring system	Full SHM on key piers: inclinometers, strain gauges, accelerometers, corrosion sensors
Overall performance expectation	Vulnerable to future storm surge events	Designed to withstand extreme storm surge, barge impact, and long-term deterioration

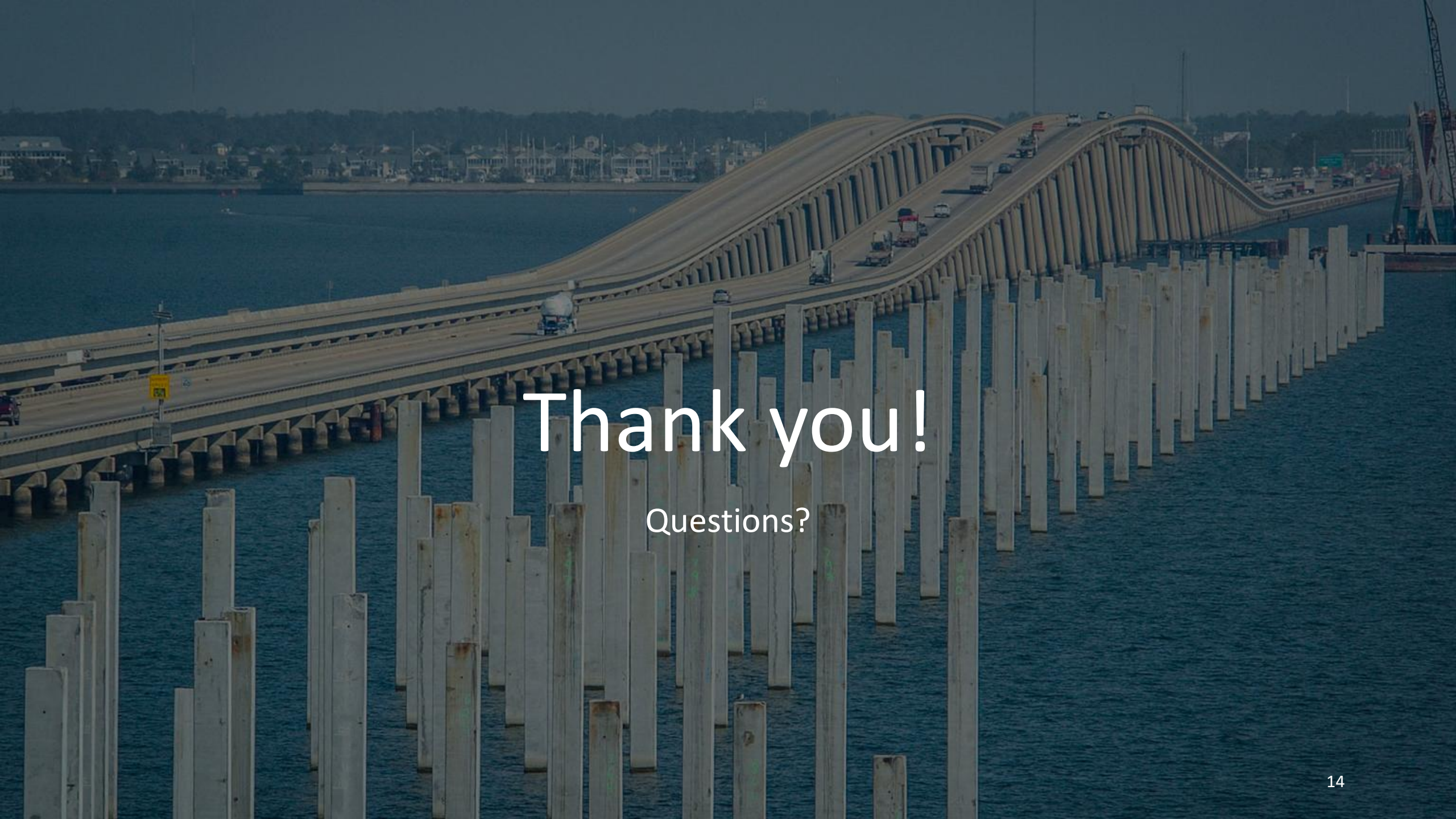


Conclusion

- **Failure Summary:**
 - Collapse caused by buoyancy + weak restraining details, not foundation failure.
- **Design Lessons:**
 - Elevation is critical in surge-prone regions.
 - Air release detailing (vent holes, solid decks) is essential.
 - Foundation design must consider lateral demands from surge.
- **Adaptation for Future Bridges:**
 - Retrofit older spans with anti-uplift anchorage.
 - Install SHM to monitor movement, corrosion, wave pressure.
 - Prioritize raising low-elevation coastal bridges.
- **Broader Implications:**
 - Applicable to low-slab bridges, waterfront piers, causeway structures.

Reference

- 1. Collapse Case Study (2005)
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Thank you!

Questions?