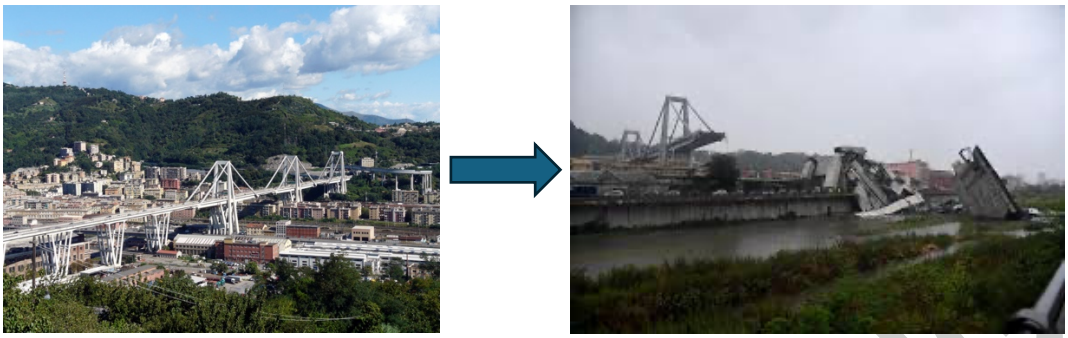
SOIL ENGINEERING
ADVISORY SERVICES
RELIABILITY IS THE CORNERSTONE OF A PRODUCTIVE OPERATION

THE MORANDI BRIDGE DISASTER COULD HAVE BEEN PREVENTED

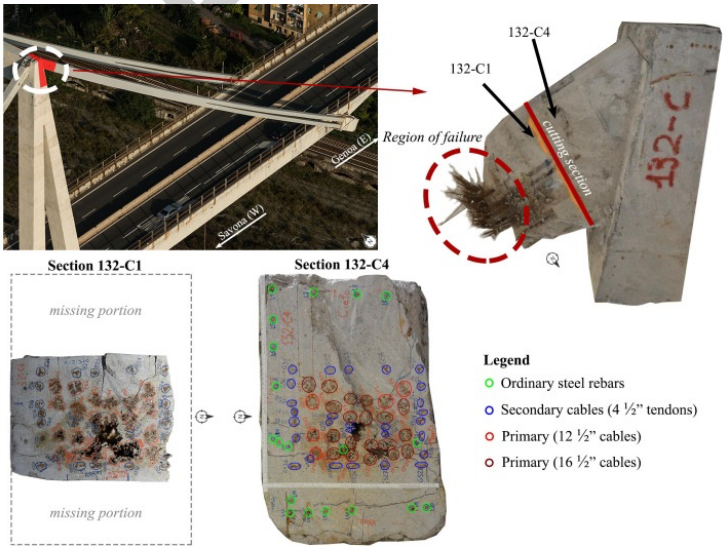


The collapse of the Morandi Bridge in Genoa, Italy, on August 14, 2018, was a result of a combination of **flawed original design**, **long-term corrosion and material degradation**, and **insufficient maintenance and monitoring**. The failure of a single stay cable on pylon 9 triggered a chain reaction that brought down a section of the bridge, killing 43 people.

Key Factors in the Failure Analysis

- **Design Deficiencies:** The bridge, designed by Riccardo Morandi and opened in 1967, had a unique cable-stayed design that used relatively few stays made of prestressed concrete.
    - **Inaccurate Calculations:** Some experts believe the original calculations for how the concrete and prestressing tendons would age and perform over time were inaccurate.
    - **Lack of Redundancy:** The design's reliance on only a few stay cables per pylon meant there was little structural redundancy; the failure of one stay could lead to a catastrophic collapse.
    - **Concealed Tendons:** The critical prestressing tendons were encased in concrete, making them vulnerable to corrosion that was difficult to detect through standard inspections.

- **Corrosion and Material Degradation:** The bridge experienced persistent problems and required constant, costly maintenance throughout its 50-year lifespan.
    - **Vulnerability to Water Damage:** The concrete was prone to cracking, which allowed water ingress, leading to the corrosion of the internal steel tendons.
    - **Advanced Deterioration:** Years before the collapse, reports noted severe degradation of the stays, with one report in early 2018 indicating a 10 to 20% reduction in the cross-section of the tendons in the area that eventually failed.



- **Insufficient Maintenance and Oversight:** The company responsible for the bridge's management and safety, Autostrade per l'Italia (ASPI), was found responsible for a "reactive" rather than "predict and prevent" approach to asset management.
    - **Ignored Warning Signs:** Cracks and other signs of damage were monitored for years, but no suggestion was made to reduce the load on the bridge or close it to traffic.
    - **Flawed Inspection Practices:** The inspection and repair processes failed to address the underlying degradation effectively.

The failure of a single stay cable due to this combination of factors triggered the collapse. Post-collapse analysis using methods like the Applied Element Method (AEM) confirmed that the stay cable was the most critical element whose failure would cause the observed collapse mechanism.

GENERAL COMMENTS (SOIL ENGINEERING)

1. RELIABILTY IS THE CORNERSTONE OF A PRODUCTIVE (AND SAFE) OPERATION.
2. DESIGN SHOULD ALWAYS CONSIDER A RELIABILITY, AVAILABILITY AND MAINTAINABILITY ANALYSIS.
3. DESIGN MUST INCLUDE A SYSTEMATIC AND RECOGNIZED RISK ANALYSIS LEADED BY A NON-INVOLVED THIRD PARTY. PREVENTATIVE OR CORRECTIVE ACTIONS MUST BE IMPLEMENTED DURING THIS STAGE AND DURING CONSTRUCTION.
4. MAINTENANCE MUST INCLUDE A CONTINOUS IMPROVEMENT APPROACH RECORDING LESSON LEARNED AND INCIDENTS TO “IMPLEMENT” CORRECTIVE ACTIONS.
5. MAINTENANCE MUST INCLUDE INSPECTION AND MAINTENANCE PLANS APPLIED PERIODICALLY AND RESULTS STUDIED AND ANALYZED FOR ASSURANCE OF SAFETY AND CORRECT OPERATION. NDE TECHNIQUES MUST

ENSURE THE ON TIME CAPTURE OF ALL FAILURE MODES AND MOST OF THE FAILURE MECHANISMS.

6. CONTINGENCY PLANS MUST BE ALWAYS IN PLACE TO ENSURE PREPAREDNESS TO FACE UNEXPECTED OR HIGH RISK ISSUES IN A “ON TIME” AND EFFICIENT MANNER.
7. A FMEA ANALYSIS WOULD HAVE BEEN OF USE IN THIS CASE, ANALYZING EACH PART OF THE BRIDGE FAILURE MODES AND RISKS ASSOCIATED TO DEFINE AND IMPLEMENT PREVENTATIVE ACTIONS.
8. IT DOESN'T MATTER IF A PROJECT HAS BEEN IN SERVICE FOR A LONG TIME, IT'S ALWAYS TIME TO RENEW ALL STAGES OF ITS DEVELOPMENT, UPDATING THEM AND APPLYING CORRECTIONS.

SOIL ENGINEERING MASTERS LONG EXPERIENCE IN ALL THE PROJECT CYCLE ACTIONS AND ANALYSES THAT ALLOW FOR A SAFE, PRODUCTIVE AND PROFITABLE OPERATION (INCLUDING MAINTENANCE).

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