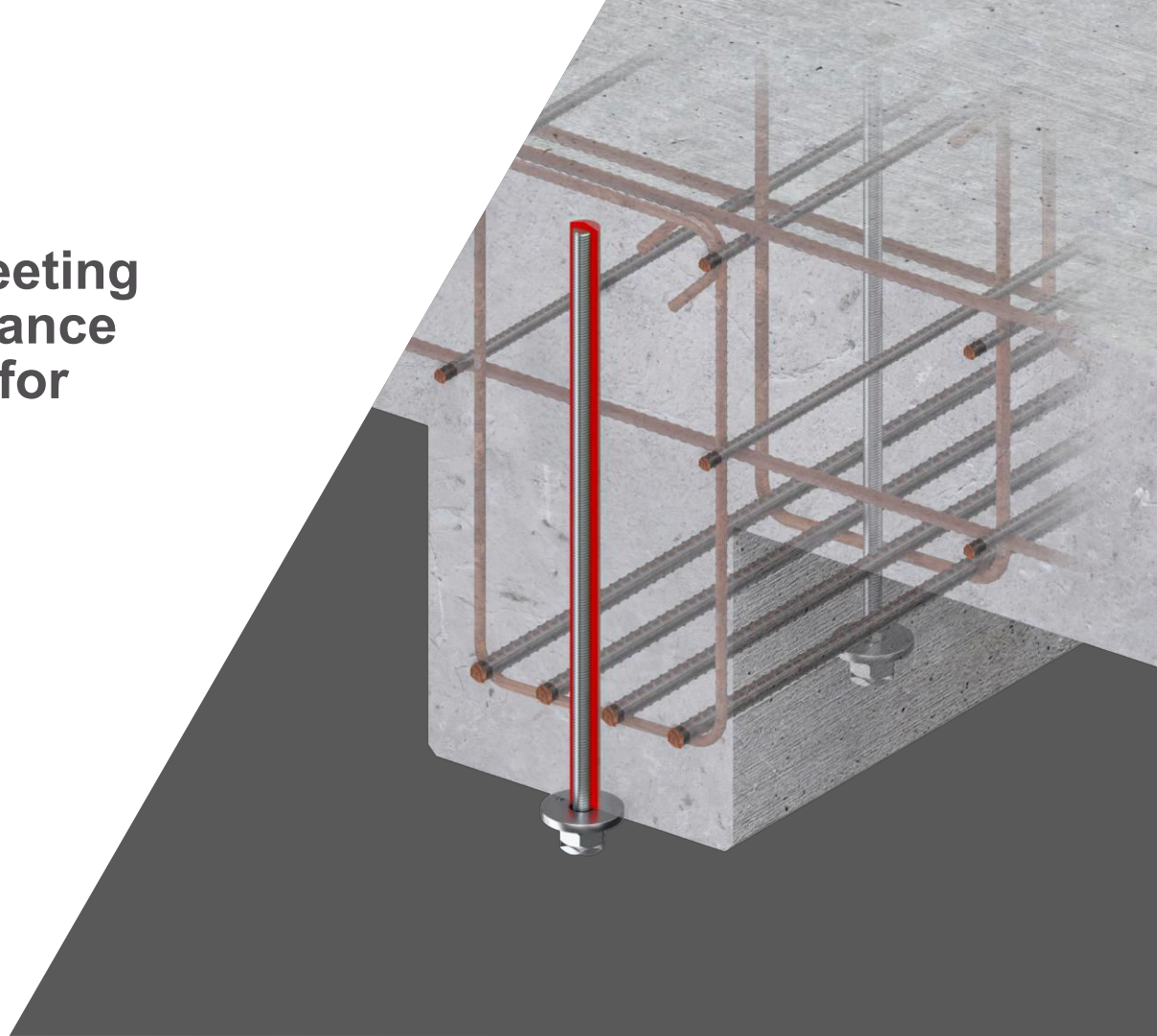
Bridge rehabilitation: meeting evolving safety, performance and durability demands for aging infrastructure

Amol Singh
Technical Project Manager



Session Outline

- Triggers for Structural Strengthening
- Common methods to strengthen concrete members
- An innovative solution for strengthening concrete deficient in shear
- Impact on Sustainability
- Key Summary

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Triggers for Structural Strengthening
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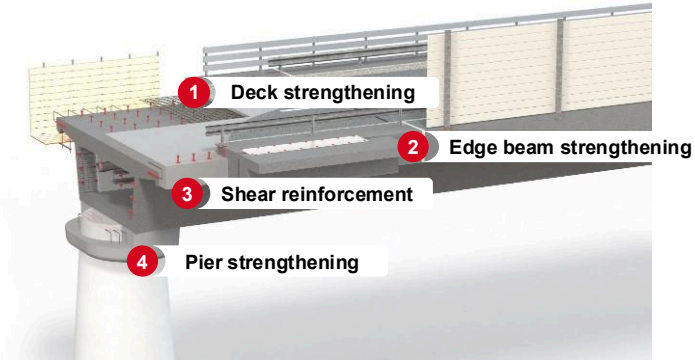
Structural strengthening is present across the construction industry

Several reasons trigger the need to strengthen buildings & bridges:

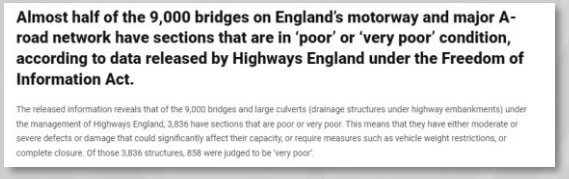
Change of use	Modifications (e.g. adding openings, floors, extensions) without changing use	Maintaining serviceability limits
End of service life	Enhancement of seismic resistance	Preventing corrosion to reinforcement

Strengthening often can be a superior choice vs. demolition & rebuild:

- Can provide 15-70% quicker turnaround time
- Prevents interruption of building / bridge use
- 10-75% reduction in material savings

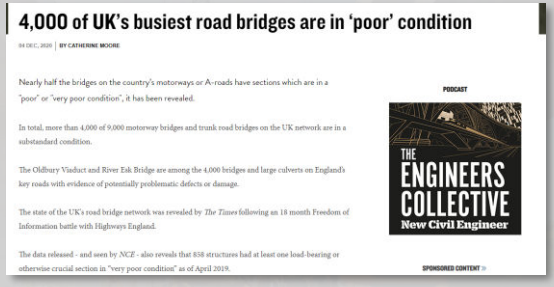


Adapting infrastructure for modern demands: thousands of bridges await upgrades



Almost half of the 9,000 bridges on England's motorway and major A-road network have sections that are in 'poor' or 'very poor' condition, according to data released by Highways England under the Freedom of Information Act.

The released information reveals that of the 9,000 bridges and large culverts (drainage structures under highway embankments) under the management of Highways England, 3,836 have sections that are poor or very poor. This means that they have either moderate or severe defects or damage that could significantly affect their capacity, or require measures such as vehicle weight restrictions, or complete closure. Of those 3,836 structures, 858 were judged to be 'very poor'.



4,000 of UK's busiest road bridges are in 'poor' condition

04 DEC, 2020 | BY CATHERINE MOORE

Nearly half the bridges on the country's motorways or A-roads have sections which are in a "poor" or "very poor condition", it has been revealed.

In total, more than 4,000 of 9,000 motorway bridges and trunk road bridges on the UK network are in a substandard condition.

The Oldbury Viaduct and River Esk Bridge are among the 4,000 bridges and large culverts on England's key roads with evidence of potentially problematic defects or damage.

The state of the UK's road bridge network was revealed by *The Times* following an 18 month Freedom of Information battle with Highways England.

The data released - and seen by *NCE* - also reveals that 858 structures had at least one load-bearing or otherwise crucial section in "very poor condition" as of April 2019.

PODCAST

THE ENGINEERS COLLECTIVE
New Civil Engineer

SPONSORED CONTENT

In 2020, NCE released an article stating that over 50% of the bridges are in 'poor' or 'very poor' condition

~9000 road bridges in the UK

01 There are over 8864 road bridges in the UK with an average length of over 20 meters

>3000 motorway bridges >50 years old

02 Establishing a service live of 50 years, over 3086 of the total bridges are approaching the end of their service life (built between 1960-1980)

3000 bridges unable to support the heaviest vehicles

03 Approximately 3000 bridges are currently unable to support the heaviest vehicles, slowing down journeys.

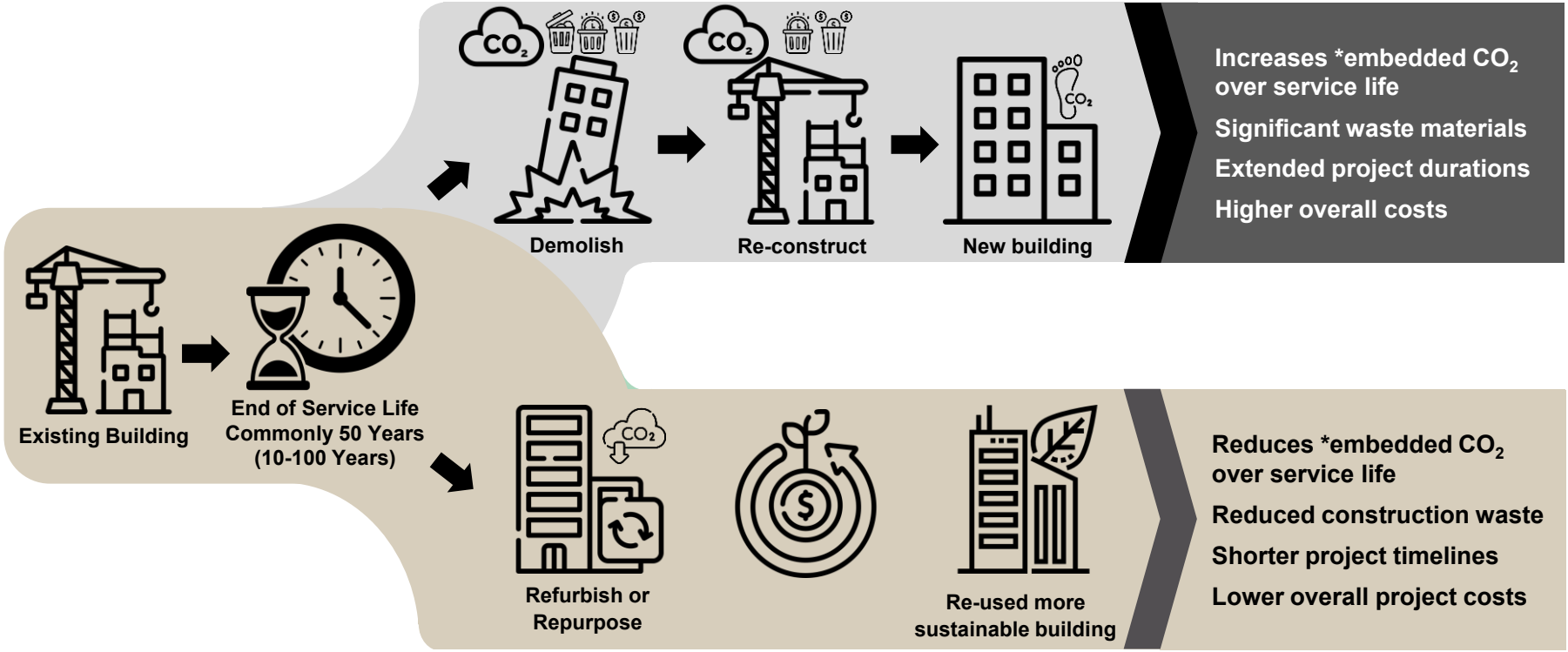
Source: https://www.gov.uk/government/news/1-billion-backed-renewal-of-broken-bridges-ruined-roads-and-tired-tunnels-and-new-thames-crossing-cash
Source: 4,000 of UK's busiest road bridges are in 'poor' condition | New Civil Engineer

The recent Carola Bridge collapse in Dresden reiterates the urgency required to take preventative actions

- Built originally in 1895, rebuilt in 1967-71
- First renovated in 1996
- Widened in 2019 to accommodate additional bicycle lanes
- Was marked for strengthening in 2025
- Collapsed Sep 2024
- **Main cause identified**: hydrogen-induced corrosion cracking of the reinforcement, undetected despite regular inspections.

Source: https://tu-dresden.de/bu/bauingenieurwesen/imb/das-institut/news/einsturz-der-carolabruecke-in-dresden?set_language=en
https://www.newcivilengineer.com/latest/dresden-bridge-failure-caused-by-hydrogen-induced-stress-corrosion-report-confirms-19-12-2024/

Strengthening solutions enable service life extension of structures, preventing demolition and reconstruction



Embedded CO_2 typically represents around 25% of a building's total Life Cycle Carbon Footprint (LCCF) - https://doi.org/10.1016/j.rser.2017.07.061.

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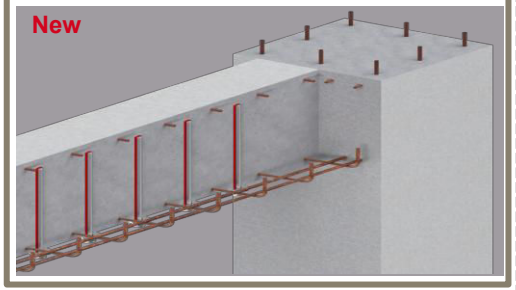
Different strengthening methods are available to the industry

Structural Strengthening Applications where Hilti can support

Post-installed punching shear reinforcement

Post-installed shear reinforcement



Shear infill walls

Concrete overlay

Concrete jacketing

Alternative Methods*

FRP jacketing

External Post-tensioning

Steel plate reinforcement

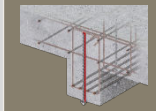
Textile reinforced mortar

not exhaustive

Civil & infrastructure structural strengthening

Bridge deck slab

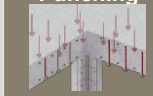
HIT-Shear



Overlay

Tunnel ceiling

HIT-Punching



HIT-Shear

Retaining walls

Overlay

HIT-Shear

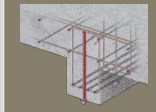
Piers/columns

Concrete jacketing

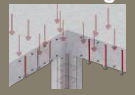
Steel jacketing

Pier/column cap

HIT-Shear



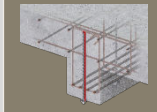
HIT-Punching



Overlay

Girders/Beams

HIT-Shear



Overlay

Post-tensioning

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Over 20 years of developing the use of post-installed rods as shear reinforcement

EN1992-1:2005
EN1992-2:2005

fib Model Code 2010

EN1992-1:2023
EN1992-2:2023

2005

2006-12

2013

2016

2023

2024

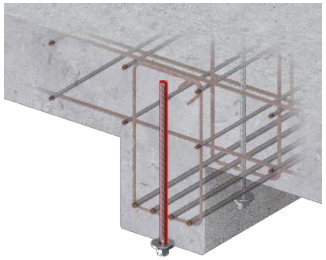
Research & **scientific publications** on use of Hilti HZA-P rods & HIT-RE 500 as **post-installed shear** & punching shear **reinforcement**

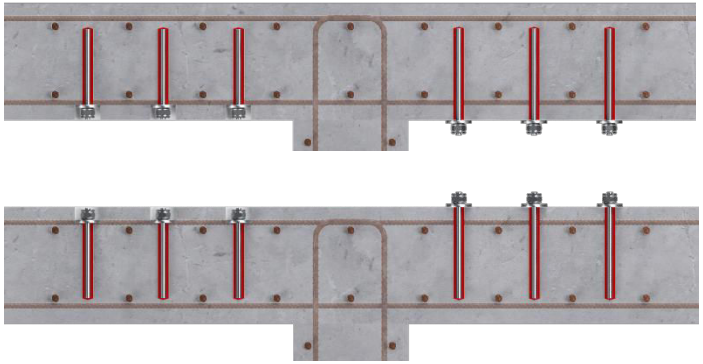
Expert Report on use of HIT-RE 500 V3 & HZA-P as **shear** reinforcement

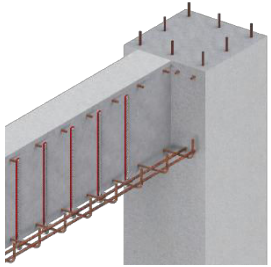
Expert Report on use of HIT-RE 500 V3 & HZA-P as **punching shear** reinforcement

DIBt *aBG* Z-15.5-383 for HIT-RE 500 V4 & HAS(-U) rods as **post-installed shear reinforcement**

Strengthening concrete members with post-installed shear reinforcement made easy





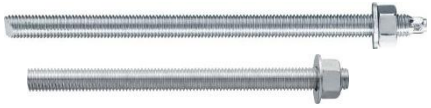


Design Software:

PROFIS Engineering Suite

Mortar:

HIT-RE 500 V4



Steel elements:

HAS (cut or meter) & HAS-U both in A4 & 8.8 with filling set

Installation tools:

- Drill machine
- Hammer drill bit
- Hollow drill bit
- Setting tool

Installation tools:

- Injection dispenser

- Automated torque

A standardised assessment framework is key to establish system performance

Establishment level	Test standard	Technical data	Design	Example
Well-established method	EOTA EAD	ETA	EuroCode	Fastening in concrete, EN 1992-4:2018
Relatively established method	EOTA TR	ETA	EOTA TR	Concrete Overlay, TR 066
New innovative method	GCTP (EN 1990)	aBG / aBZ*	EN 1992-based	HIT-Shear → DIBt aBG *Z-15.5-383*

EAD


ETA

EOTA = European Organisation for Technical Assessment

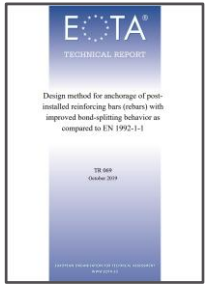
EAD = European Assessment Document

ETA = European Technical Assessment

TR = Technical Report

GCTP = General Construction Technique Permit

DIBt = *Deutsches Institut für Bautechnik*



TR

GCTP (aBG)

Eurocodes evolve over time, and innovative solutions follow a step-by-step path – from testing to eventual inclusion in design practice

**Issued by DIBt*

Annex D of EN 1990, Design assisted by testing → GCTP

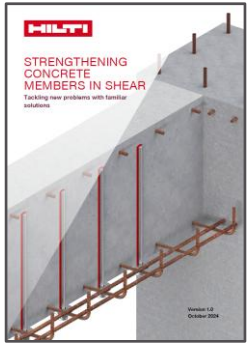
Post-installed shear reinforcement system is proven to work similar to traditional cast-in shear links

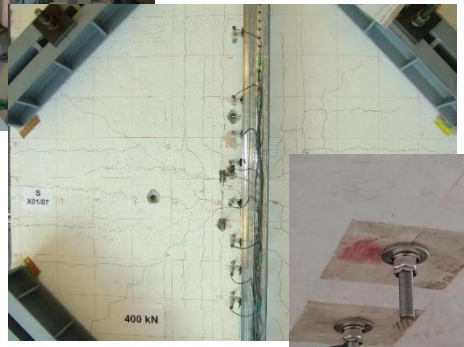

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM
EN 1990:2002+A1
December 2005
English version
Eurocode - Basis of structural design

RUHR UNIVERSITÄT BOCHUM
RUB

Deutsches Institut für Bautechnik
DIBt


An efficient post-installed shear-strengthening solution for RC structural elements


HILTI
STRENGTHENING CONCRETE MEMBERS IN SHEAR
Tackling new problems with familiar solutions

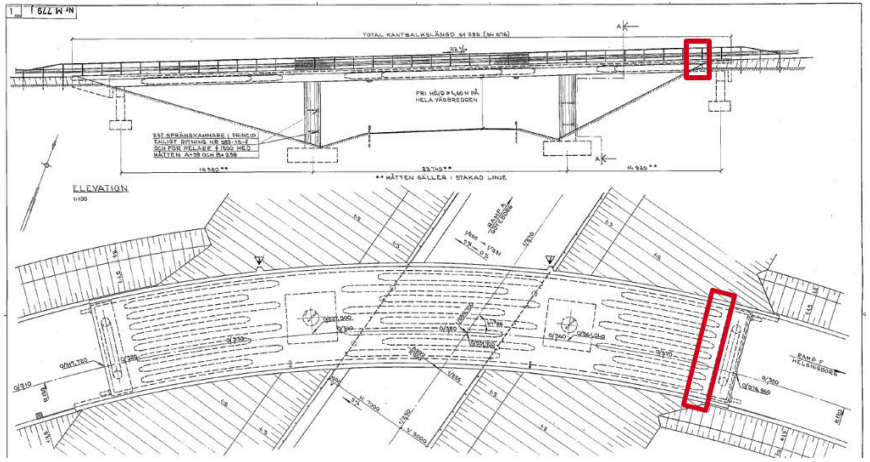

400 kN

RUHR UNIVERSITÄT BOCHUM
RUB
HILTI


General construction technique permit
DIBt

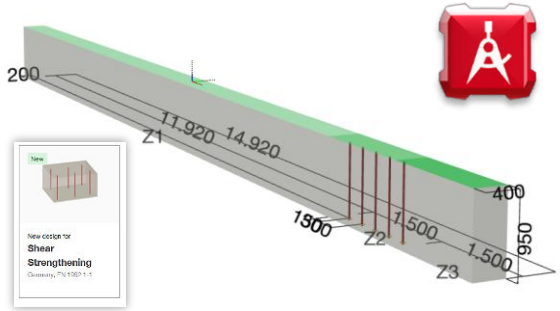
Bridge strengthening: pilot project with Swedish Transport Agency with HIT-Shear system

- 3-span continuous plate highway bridge with hollow sections of a total length of 58 m.
- The need for shear strengthening is limited to an area in the shortest span close to the very right support.



End-to-End Solution will be provided starting from Design in PROFIS, followed by an efficient installation method

Design module in PROFIS



- Design flexibility in strut angle,
- Arrangement of the strengthening elements,
- Diameters, and
- Corrosion resistance classes

Differentiated Hardware

5 pcs **HAS-U A4 M20 + HIT-RE 500 V4 + Filling set** with effective depth 890 mm in 9 rows = 45 pcs of post-installed reinforcement elements ensure that the bridge has a shear capacity.

Differentiated Hardware

Efficient installation practices ensure that the solution is installed as specified

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Comparison of demolition vs strengthening of a bridge – A theoretical example

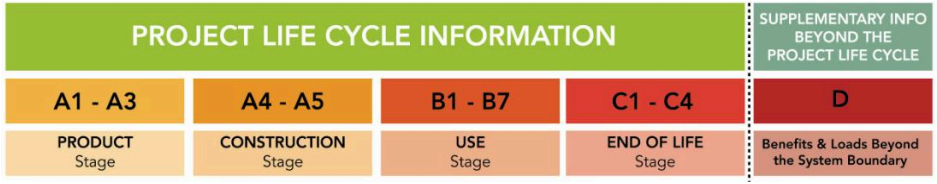
Fachhochschule Kiel
University of Applied Sciences

EKSH
Gesellschaft für
Energie und Klimaschutz
Schleswig-Holstein

- **Study Title**: *CO_2-Bilanzierung von Brückenbauwerken*
- **Objective**: To analyse and quantify CO_2 emissions associated with the construction and maintenance of bridge structures
- **Scope of investigation:** 6945 bridges in Schleswig-Holstein, Germany
- **Key Findings**: Detailed assessment of CO_2 emissions at various stages of bridge construction.

Link to the study: FH Kiel

The study established a typical bridge profile, providing its lifecycle emissions assuming demolition



Parameters of the typical bridge

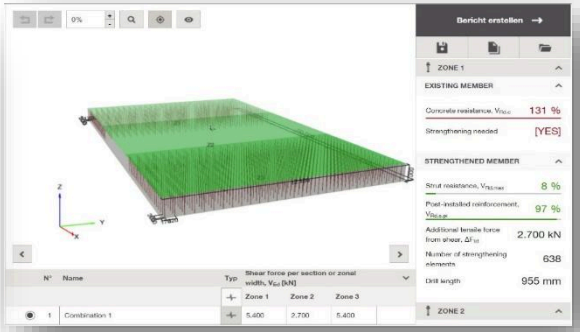
Clearance height	4,80 m
Construction width	12,10 m
Utilization width	11,60 m
Span width	21,00 m
Cross section	Prestressed concrete slab 1,0 m

6,945 examined bridges within the defined scope revealed a typical bridge profile.

CO_2 assessment

CO_2 assessment was conducted for each component of the bridge over all phases of its lifespan.

Bridge modelling in PROFIS



Shear Strengthening module in PROFIS Engineering was used to assess & strengthen this theoretical bridge.

Strengthening reduces the carbon footprint and construction cost by over 97%

	HILTI	vs	REBUILD
CO_2 Emissions	4.3 tonnes		996 tonnes
in materials	4.3 t		366 t
in detours	0 t		630 t
Cost	€35.9k		€799.2k
	+20 years of lifespan		-210 days out of operation

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We aim to provide the industry with a toolbox of solutions to strengthen buildings and bridges

- Develop solutions for **concrete jacketing** & **overlay**, and **post-installed reinforcement** of different structural members, backed by:
  - **Differentiated hardware and design methods**
  - **Structural design software and services**
  - **Learning material** (articles, webinars, etc.)
- **Full coverage** with robust Qualification and Approvals to the state-of-the-art
- Cover key performance attributes in different load conditions: **fatigue** (from traffic on bridges), **fire, seismic**, and **service life**.
- Become a strong **partner** for the industry for strengthening applications

Thank you for listening.