Top12 – lowest life-cycle costs in high chloride-exposed reinforced infrastructures*

In the past, increased damage has occurred to traffic structures of very low age. The reason for this is the high level of de-icing salt impact caused by deicing salt/brine from winter road clearance services, which causes chloride-induced reinforcement corrosion. The repair of resulting damage is very cost-intensive, not least because of required traffic safety measures. More and more often the question arises: Which measures have to be taken in order to reduce costs and, at the same time, to ensure a high durability and robustness of the measure.

In this context, life-cycle cost considerations were carried out for high chloride-exposed components, such as bridge caps/parapets, central bridge piers, tunnel emergency walkways and tunnel inner walls. For an objective comparison, in addition to various steel grades (carbon steel vs. stainless reinforcing steel), surface protection systems (incl. depth hydrophobing) and various repair strategies (renewal of surface protection system vs. repair or demolition/new construction) were considered. For a final evaluation of relevant variants, in addition to the life cycle costs, the topics "durability" and "practical construction aspects" were also taken into account.

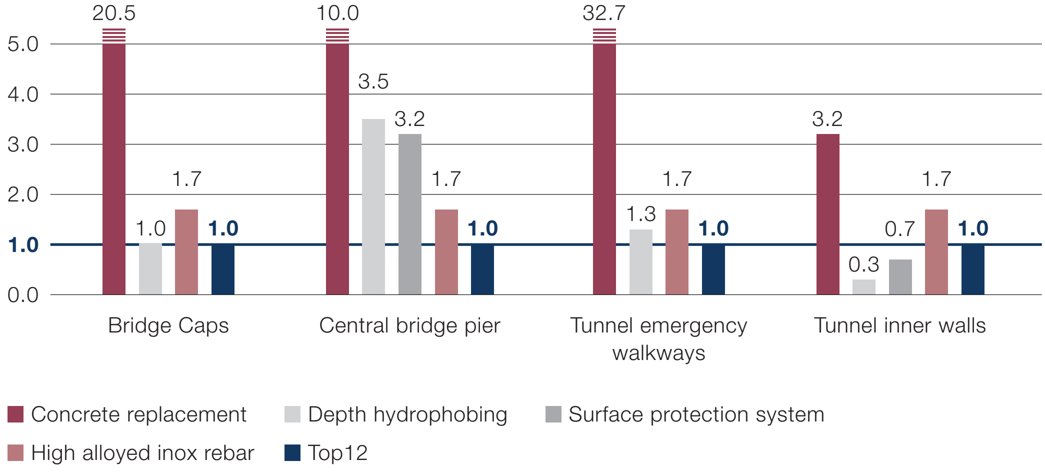
Results out of service life calculations (w/b = 0.45; β = 0,5)*

Component	Type of reinforcement	Chloride exposure [M.-%/b] (Cs, Δx)	Concrete cover [mm] (μ / σ)	Type of binder	Calculated service life [a]	Target service life [a]
Bridge Caps	Carbon steel	3.5	50 / 6	CEM II/B-S	14	50
	Top12				>100	
Central bridge pier	Carbon steel	3.0	55 / 8	CEM II/B-S + 30kg/m³ FA	73	100
	Top12				>>100	
Tunnel emergency walkways	Carbon steel	5.0	50 / 6	CEM II/B-S	10	50
	Top12				55	
Tunnel inner walls	Carbon steel	4.0	60 / 6	CEM II/B-S + 30kg/m³ FA	68	100
	Top12				>>100	

*Showed data and figures adapted from advisory opinion 16-192/1.1.3 from "Ingenieurbüro Schießl Gehlen Sodeikat GmbH" (Munich 26th of July 2018, Germany)

Results of life cycle costs*

Comparison of different variants (standardised to Top12) – vertical axis cut off at factor 5.0



Conclusions*

a) Conventional concrete replacement as a reactive repair strategy (carbon steel, no surface protection) results in the highest life cycle costs for all components!
   - Top12 steel has significantly lower life cycle costs, especially with low reinforcement content.

*"For a final evaluation, the topics 'durability' and 'practical construction' were also considered. If considering all three aspects for the evaluation (costs, durability and practical construction advantages) Top12 steel showed the best performance."**

b) Comparison of Top12 with "carbon steel with surface protection measures":
   - For components with small concrete surfaces (pier), the variant with Top12 steel is more favourable.
   - For components with low reinforcement content (e.g. bridge caps, tunnel emergency walkways), the life cycle costs are roughly the same or the variant with Top12 is somewhat cheaper
   - For highly reinforced components with large concrete surfaces, e.g. tunnel inner walls, the variant with carbon steel and surface protection system is more cost-effective. Savings potential exists with Top12 in the use of mixed reinforcement (mix of carbon steel and Top12 with direct electrical contact).

c) Comparison of Top12 with high alloyed inox rebar:
   - Life cycle costs for Top12 approx. 40% lower

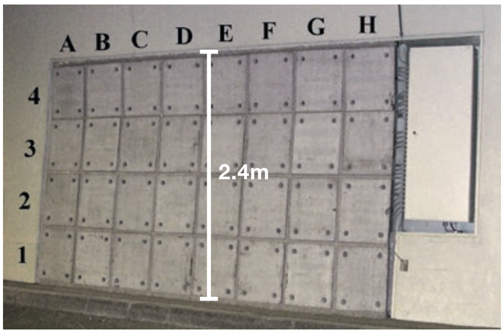
*Showed data and figures adapted from advisory opinion 16-192/1.1.3 from "Ingenieurbüro Schießl Gehlen Sodeikat GmbH" (Munich 26th of July 2018, Germany)

SWISS STEEL AG | Emmenweidstrasse 90, 6020 Emmenbrücke, Switzerland
Phone: +41 41 209 51 51, bauprodukte@swiss-steel.com, www.swiss-steel.com/top12

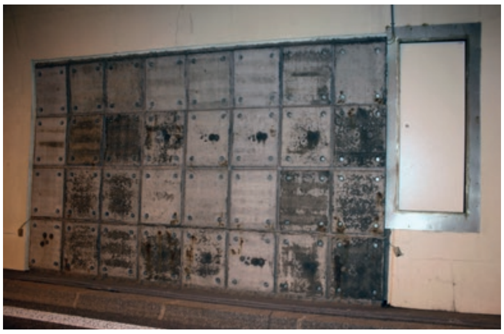
Measures to increase durability – Field experiments in the Naxberg tunnel in Switzerland*

The construction of durable transport infrastructures requires knowledge of the damage mechanisms taking place and as well the impact and effectiveness of various measures. One of the main causes of damage to infrastructure structures is chloride induced corrosion of the reinforcement. There is still no consensus on the most effective and economical long-term measures for this type of damage, especially for traffic infrastructure exposed to splash water, neither for new buildings nor for repairs.

Objectives of the research project*
Aims of the project are the investigation of the corrosion behaviour of different steel qualities in different concretes under real exposure conditions, the influence of the concrete cover on the initiation and the corrosion progress, the dependence of water and chloride ingress over time and the determination of parameters for probabilistic durability considerations.



2000

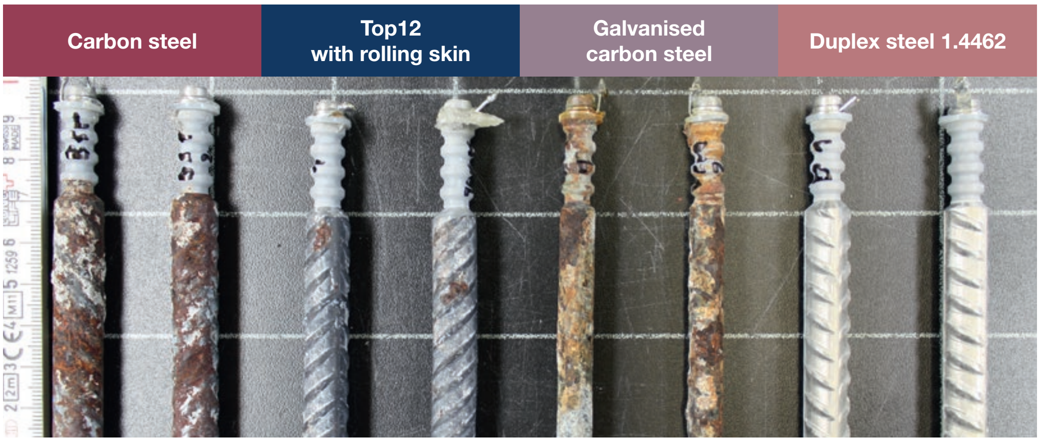


2012

Test field in the Naxberg tunnel*
Since 2000, a field test with instrumented concrete slabs has been running for 12 years in the Naxberg tunnel on the A2 near Göschenen (CH). As part of the repair of the tunnel, a unique test rig was set up, offering space for 32 test plates and enabling long-term investigation of damage processes and measures to improve durability (initiation and corrosion phase) under real conditions.

*Showed data and figures adapted from Y. Schiegg; F. Hunkeler; D. Keller; H. Ungricht (2017): Measures to increase durability – Continuation of the field experiment in the Naxberg tunnel. Volume 683 of the Federal Department of the Environment, Transport, Energy and Communications, Federal Roads Office (ASTRA).

Results after 12 years in alpine tunnel exposition (concrete cover = 10mm)*



- Carbon steel and galvanised steel showed pitting corrosion and a corroded steel surface of more than 70%

- The zinc coating is practically completely dissolved and the steel underneath corrodes under pitting appearance. The zinc coating corrodes in moist and chloride-containing concrete at high speed, so that the protective effect of the zinc is quickly exhausted and represent no added value.

- The stainless steel "Top12" has only a few small rust spots without measurable material loss

- Stainless duplex steel 1.4462 is absolutely bright and still passive, as expected

Conclusion for a sustainable infrastructure

The overall material system must be considered and optimised regarding present chloride exposure conditions and desired service life. This means a combination of…

1. Optimised concrete technology, respectively best choice of local available binder system regarding chloride-resistance (e.g. CEM I plus fly ash / blast-furnace slag)

2. If concrete technology cannot guarantee the desired service life, stainless reinforcing steel has to be considered (e.g. Top12)

3. If both measures (1+2) can not ensure the planned service life, an additional initial surface protection system (e.g. depth hydrophobing) can be an economic fall-back level to preserve the condition state

*Showed data and figures adapted from Y. Schiegg; F. Hunkeler; D. Keller; H. Ungricht (2017): Measures to increase durability – Continuation of the field experiment in the Naxberg tunnel. Volume 683 of the Federal Department of the Environment, Transport, Energy and Communications, Federal Roads Office (ASTRA).

SWISS STEEL AG | Emmenweidstrasse 90, 6020 Emmenbrücke, Switzerland
Phone: +41 41 209 51 51, bauprodukte@swiss-steel.com, www.swiss-steel.com/top12