SIMPLE CONCRETE LIFE EXTENSION

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Abstract. *Concrete life is submitted to the influence of climate and time. Much is done to design mix to ensure the durability of concrete, as well as preventing its collapse through the use of many different coating solutions. Every process insitu is manual and therefore subject to failure. Those errors will demand maintenance in time to prevent concrete disintegration. Using stainless steel reinforcement on exposed zones secure extended lifetime and no maintenance, as corrosion is no longer an issue. The simplicity of this solution is obvious thus very much unfamiliar to most engineers as knowledge and references they do not access. By eliminating all risks of corrosion on the bearing structure, the success of the construction does no longer depend on the skills of the people involved. The inner qualities of stainless steels; equal tensile and fatigue strengths , sustainability, low magnetism, non corrosive , must be told to improve confidence in a 98% recyclable product..*

1 INTRODUCTION

This paper aim at providing simple solutions to extend concrete life for constructions, regardless of the surrounding environnement. It is based on extensive field experience as well as own studies at Valbruna steel mill, and related literature.

2 STAINLESS STEELS

2.1 Much info but little knowledge

Stainless steels are mostly known as the expensive material they are made of,

Not what they are capable of. Stainless steels as concrete reinforcement are globally a relatively new application, as the oldest infrastructure made entirely of stainless steel is only 72 years old. Since then, thousands of articles, tests and studies on concrete durability have included comments on stainless steels reinforcements, as one alternative to prevent structural failure. However, this extensive literature available for all engineers and designers is mainly information rather than knowledge: very few consultants have knowledge of what to use and how to use it.

2.2 Basics of stainless steels

Stainless steels were developed for industrial applications, very far from construction. Most of the products are exposed directly to many different environments, and the steel mills responded by designing a large number of steel grades. Most of these are nevertheless not relevant for concrete applications, as for instance surface treatment is obviously the least interesting in a structural engineers approach. The qualities needed are the mechanical and corrosion properties of stainless steel reinforcements IN the concrete.

2.3 Stainless steel grades

The best suitable grades for concrete applications have different corrosion threshold and equal mechanical properties to carbon steel, allowing engineers to design their structures "as usual", using the same tensile strength.

But for most stainless steels, tensile strength ends up much higher than necessary, as material content fulfils other specifications.
This is truly the case for 1.4401 or 316 for instance; whose corrosion threshold exceeds what is necessary in most projects and environments.
Steel mills have since developed special qualities, called duplex, to minimize production costs as nickel content is lower. It resulted in effective reinforcement material with higher corrosion threshold as the basic 1.4301 or 304 quality.

Today, there are still countries using other grades, but globally, the dominant types are :

1.4301 or 304
1.4401 or 316
1.4362 or lean duplex
1.4462 or duplex

3 STAINLESS STEEL REINFORCEMENTS

3.1 Manufacturing

Stainless steel rebars do have a higher toughness than carbon steel, and are therefore more difficult to bend & cut. However fabrication and binding is similar to carbon steel, thus stainless steel wire and couplers must be used as components for the reinforcements.
Welding is in any case not recommended, as it weakens the corrosion ability of any steel grade at the welding point.

3.2 Contamination

In a free environment, stainless steels in contact with carbon steels will corrode shortly over time. What will start as a local corrosion will spread through the bars after a while.
Though contamination might be an issue for exposed stainless steels, it is not for concrete applications. Concrete acts as a shell, in which corrosion does not occur, and even stops.

It is not yet possible to predict corrosion of stainless steel rebars in time, but reinforcements of the progresso pier have not yet shown traces of corrosion after 72 years in one of the most aggressive environment.

4 PROTECTION STRATEGY

Designers are mislead on where and how to use stainless steels , in order to reduce risks of spalling and cracking in concrete structures. Obviously, stainless steel is too expensive a material to convince any builder so switch over 100%. Besides, it appears that this is not necessary if you consider the constructions geometry.

4.1 Exposed zones

Considering any structure, there are zones more exposed than others to wind, water, rain, or because of concrete grade, coverage or crack potential.
Those are the very zones first in need of maintenance over time.
In this process of defining expositions risks, do also consider zones with difficult accessibility,
As though maintenance might not be needed as often, costs will be much heavier.

4.2 Example of exposed zones on a bridge

Every project is of course different, but as an example of what the designer might consider exposed zones, the bridge on figure below shows how little use of stainless steels might enhance Concrete durability over time. From estimated 50 years lifetime to 150, with cautious use of SSR.

Figure 1: Bridge example

a) Edges: Any edge will automatically be exposed to erosion, and they represent the most obvious locations to be reinforced with stainless steels, regardless of the concrete cover. In this case, they are also exposed to salt/chlorides for winter de-icing.

b) Tidal zone: the constant variation of water level leaves concrete alternatively in contact with air and chlorides, in zones where maintenance is also notoriously difficult. The use of stainless steels here is very much relevant for the structures life time.

c) Splash zone: Though not as exposed as the tidal zones, splash zones are quite difficult to predict. Chloride concentration might be lower than in the tidal zone, but enough to provoke damage. 4.3 Condensation zones

4.3 Condensation zones

This is one application where SSR should be mandatory, might it be submerged structures (like parking) or parts of structures dividing cold and hot environment. Unless these are of course isolated to avoid thermal breaks. Condensation is in any case impossible to predict, as inside and outside temperatures might fluctuate rapidly and with high delta. The following figure 2 shows the example of the underwater parking structure from Tjuvholmen project.

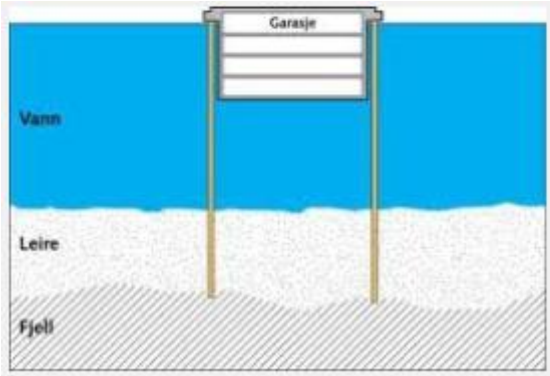

Figure 2: Tjuvholmen, Oslo

4.3 Difficult or inabordable access zones

One obvious application is of course any zone with difficult or impossible access, as it would be very costly, if possible, to rehabilitate over time. There are many ways of protection the structure, either by coating, wrapping or cladding. Whatever the technology, these are very unlikely to last 50 years in certain conditions. The choice of SSR in the structure should therefore be considered also.

For instance, concrete GBS in very aggressive environment with chemical and mechanical attacks on concrete surface. In this case on figure 3, GBS surrounded continuously by high waves and ice, providing heavy erosion in an inaccessible location.

Figure 3: GBS on Sakhalin island

5 EXECUTION

The best argument for using stainless steels reinforcements is the risk of error on the job site, unless all elements are prefabricated of course. The more complicated the structure is, the higher the risks. The longer the service life of the construction, the higher the probability of corrosion, as even small deviations will end up big over time. When considering an extended lifetime, away from any given standard, one must considers all factors inherent to a project. The non exhaustive list is to be found on table 1. However detailed the approach is, it is still theory to be put in practice on the job site. Even though control is ensured by skilled engineers or technicians, no one stands behind every worker.

Durability parameters
Chloride content
Temperature
Exposition time
Cracks
Exposed zones

Table 1: Durability parameters of RC

As for the concrete parameters, they are well known; cement type, w/c ratio, fines content, chloride content, aggregates…. Though it seems complicated to consider all these figures, the concrete industry is very much able to design a mix with an extended service life, in almost any given environment.

5.3 Concrete cover

Experience on sites has shown that concrete cover, far beyond cracking, is the major factor for early concrete damage. Cracking will provoke local corrosion unlikely to weaken bond strength, and propagation would not happen. Insufficient concrete cover will on the other hand weaken bond strength along the rebar, and reduce the bending capacity of the structure. The correlation between concrete cover and expected life time is furthermore no linear, but exponential: actual concrete cover variation will result in serious lifetime reductions, as shown on figure 4.

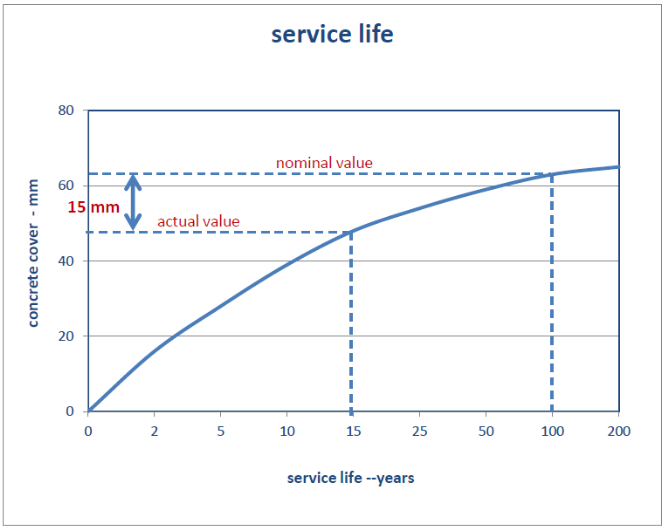

Figure 4: Service life to concrete cover

5.4 Wrong choice of steel grade

They are over 700 stainless steel grades, but most hardly relevant as concrete reinforcement material. For this very reason, designers and engineers get confused about the right choice to make. As life time is yet a very complicated question to address, the choice of stainless steel grade is easier. When mechanical properties are equal to or higher than carbon steel, only corrosion resistance differs. Table 2 shows the simple relation between steel grade and environment. If in doubt, choose a higher grade.

ENVIRONNEMENT	CAUSE OF CORROSION	SUGGESTED STEEL
Mildly Aggressive	Low chloride content	304L
Aggressive	High chloride content	316L
very Aggressive	carbonation and chloride penetration, high temperature and/or high temperature and fluctuations	316L / duplex / super duplex

By courtesy of Valbruna

Table 2: choice of stainless steel grade

6 MAINTENANCE

Maintenance of concrete infrastructures depends very much of the location and the execution of the project. On a European level, we do spend 1% of the constructions price on maintenance per year. Meaning that for 100 years lifetime, the structure will cost 2 the initial price : build one, pay for two.

The only SSR concrete structure old enough to give back data, the progreso pier in Mexico, has shown non-corroded rebars with only 18 mm of concrete cover in the splash areas of the piles, despite its location in a subtropical and saline environment.

Other projects will in time show their performance, such as the tjuvholmen project in Oslo Norway, and the upcoming Forth Bridge in Scotland.