Common Stainless Alloys used in the UK

The recently revised British Standard BS6744:2001 for the use of stainless steel in concrete structures is like all Standards a fudge. However, it introduces a much broader range of stainless alloys. Whereas the old BS was limited to two alloys, the new BS introduces six. These alloys allow for design in all conditions including full immersion to part exposure from temperate to equatorial environments and all related levels of aggressivity.

There are three commonly specified alloys within this set of alloys:

- Steel Designation No.: EN1.4301 - what was Grade 304
- Steel Designation No.: EN1.4436 - what was commonly referred to as 'Marine Grade' 316
- Steel Designation No.: EN1.4462 - what is commonly reffered to as Duplex

The ranking of their relative ability to withstand 'pitting' as measured by the BRE's Pitting Resistant Equivalent Number are listed in the table below against each alloy. The only issue and variance with the BS is the Standard's limitation in the use of EN1.4462. It was perceived that this Duplex alloy could only be produced in a high tensile condition of 650 MPa Rp0.2. Research indicates that this alloy, when produced in bigger bars 25 mm dia and above, could be susceptible to Hydrogen Embrittlement. However, it is now generally recognised that Duplex can be produced to the much lower tensile of 500 MPa Rp0.2. In this condition, the risk of Hydrogen Embrittlement is not considered a risk from a specification standpoint. This meant, for example, that it was specified in the Shenzhen Western Corridor, Hong Kong project. The Duplex alloys are the best stainless alloys from both corrosion resistant and mechanical properties with the very limited exception of magnetic permeability and a more limited working temperature range - see table below.

Steel Designation No.	PREN	Working Temperature Range	Stainless Steel Type
EN1.4301	19	-200°C to + 700°C	Austenitic
EN1.4436	27	-200°C to + 700°C	Austenitic
EN1.4462	35	-40°C to + 300°C	Duplex

We describe below a most exciting development in the Duplex alloys which may, in time, help to revolutionise the use of stainless steel in the construction industry.

Dominance of EN1.4301:

It is common for designers and specifiers to over compensate: 'if stainless steel is to be used, it is expensive, so let us use the best'. Given the relative cost and volatility in the price of stainless steel, this approach is often a recipe for very expensive projects and an effective method of turning the end user away from use of stainless. The difference in price between EN1.4301 and EN1.4436 is very appreciable. EN1.4462 tends to float up and down against the price of EN1.4436. It can be lower and equally much higher. The excuse for this variation is the influence of Molybednum in the chemical composition of Duplex and the method of production. There is an additional 0.5% Mo in EN1.4462 versus EN1.4436. It is much more difficult to produce than the austenitic stainless steels both in terms of production time, control and subsequent pickling requirements but it is debateable as to whether this justifies the price differential it is given by the producing mills.

Given the difference is cost between these alloys, with EN1.4301, being substantially cheaper than the other two alloys mentioned, it is important to stress the relative robustness of EN1.4301.

Within the industry, the best example of the use of stainless reinforcement to date, providing solid empirical evidence for its use, is the Progeso Pier. Progreso extends for 1.8km into the Gulf of Mexico off the Yucatan Peninsula. Completed in 1941 by the Danish contractor, Christiani & Nielsen, it was 'rediscovered' by Arminox of Denmark in 1989.

The Mexican Authorities have not spent money on the maintenance of this pier which is extensively used by heavy vehicles.

At the time that Christiani & Nielsen built Progreso, there was no option of obtaining fresh water and the aggregate mix contained heavily saline coral. It was a mix which dictated a more robust form of reinforcement than carbon steel could offer. They opted for stainless steel. When Ramboll was commissioned to analyse the reinforcement, it was discovered still to be in good condition. More importantly, the chemisty of the stainless steel was analysed and it was revealed as an 18/8 stainless steel AISI 304 or, simply, Grade 304. The importance of this revelation cannot be underestimated.

The fact that Grade 304 (similar to EN1.4301) could withstand: an aggressive chloride ion environment in the concrete: Gulf of Mexico climatic conditions in an inter-tidal zone (wetting and drying) for over 60 years and still continue to do its job firmly supports the theoretical evidence presented by the PREN data. The environmental conditions are rated by ISO as Gategory 5 - the worst.

The conclusion from this practical example of the use of the simplest of stainless steel alloys within the British Standard is that, in a temperate climate, the least expensive of the stainless steels should be used in nearly every case where there is cover of at least 25mm with a good concrete strength. It should be noted here that the UK Highways Agency requires minimum cover of 30mm when using stainless and a 40MPa concrete strength.

It is to be accepted that cautious 'belt and braces' designers and specifiers will err on the side of caution in aggressive environments where, perhaps, quality of workmanship may not ideal. However, we would suggest that the compensating factor should be depth of cover rather than increase in corrosion resistance offered by EN1.4436 and EN1.4462. Clearly, there is a play-off between the cost of increased cover versus cost of a more expensive stainless alloy.

Regardless, the beauty of stainless steel is that it offers a proven solution to durability leading to fulfilment of Service Life Design expectations.