ASSESSMENT OF THE RESISTANCE OF STAINLESS STEEL CLAD BARS TO CHLORIDE-INDUCED CORROSION IN CONCRETE

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MAIN CAUSE OF PREMATURE BRIDGE DETERIORATION

- Corrosion of Bars
  - CL^-
  - CO_2

NEW GOAL FOR SERVICE LIFE OF FUTURE BRIDGES

- For Major Bridges — 100 years*
- Minor Bridges — 75 years*

* without a major repair.

DESIGN OPTIONS FOR PREVENTING CORROSION IN FUTURE BRIDGES

- Use of Low-Permeability Concrete.
- Provision of Sufficient Concrete Cover for the Reinforcement.
- Use of Corrosion Inhibitors.
- Use of Corrosion-Resistant Bars.

BAR REQUIREMENTS:

- High Tolerance for Chloride.
- Easy to Fabricate at Construction Sites.
- Durable Enough to Withstand Mis-handlings During Transport and Construction.
- Affordable.

Stainless Steel-Clad Carbon Steel Bars

Assessment of the Resistance of the Clad Bars to Chloride-Induced Corrosion in Concrete:

1. Embedded the clad bars in concrete blocks (almost similar to ASTM G109).
2. Weekly exposed the blocks to 3 days of ponding with a NaCl solution and 4 days of drying.

Assessment …..: (Continued)

3. Weekly monitored the corrosion status of each bar to pinpoint its time-to-corrosion (T_C)
4. Estimated the chloride concentration in the concrete at each T_C.
5. For comparison,

The Following Bars Were Also Tested:

- Carbon Steel
- 304 Austenitic Stainless Steel
- 316LN Austenitic Stainless Steel

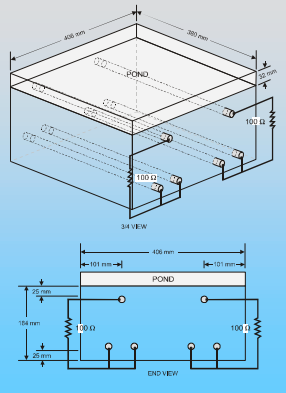
MATRIX FOR THE TEST CONCRETE BLOCKS

Bar	Bar Combination		No. of Blocks
	Top	Bottom	
Carbon Steel	Carbon Steel	Carbon Steel	8
304	304	304	4
	304	Carbon Steel	4
316LN	316LN	316LN	4
	316LN	Carbon Steel	4

MATRIX FOR THE TEST CONCRETE BLOCKS (Contd.)

Bar	Bar Combination		No. of Blocks
	Top	Bottom	
Clad	Clad	Clad	4
	Clad	Carbon Steel	4
Clad (w/ 3-mm holes)	Clad (w/3-mm holes)	Clad	4
Clad (w/ 25-mm cut)	Clad (w/ 25-mm cut)	Clad	4

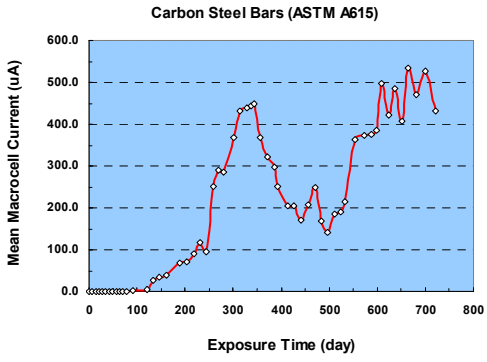
Test Concrete Blocks



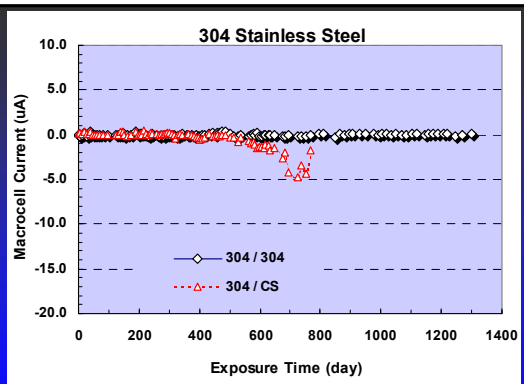
Exposure of the Concrete Blocks

RESULTS

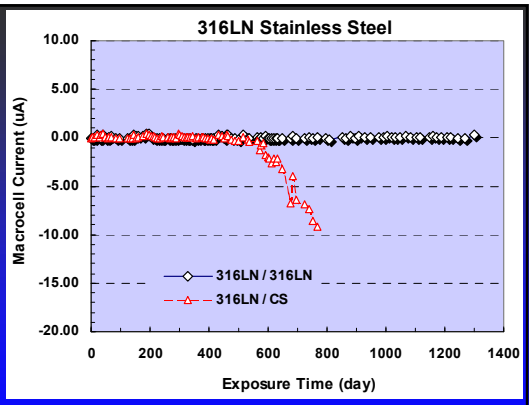
Mean Macrocell Currents (between the top and the bottom bars, per ASTM G-109)



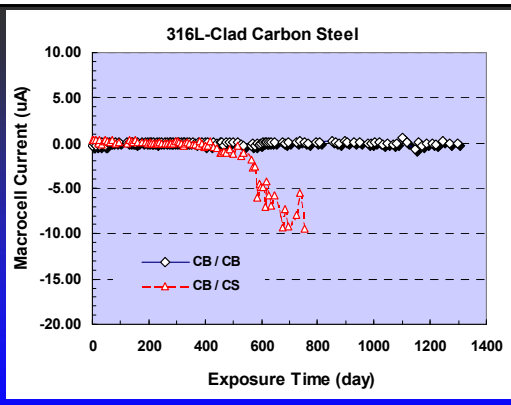
Time-to-Corrosion = 92 ± 3 days



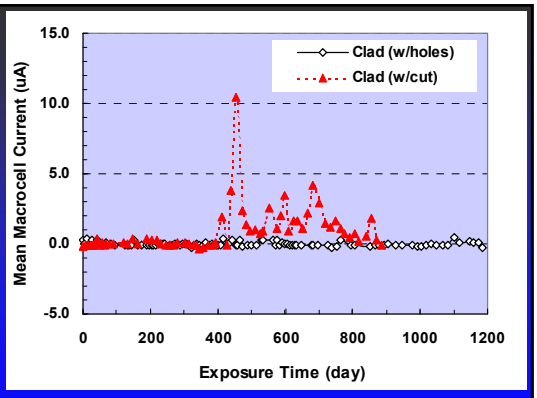
Time-to-Corrosion > 1,300 days



Time-to-Corrosion > 1,300 days



Time-to-Corrosion > 1,300 days



$T_{clad\ w/\ holes}$ > 1,300 days
$T_{clad\ w/\ cut}$ = 392 ± 3 days

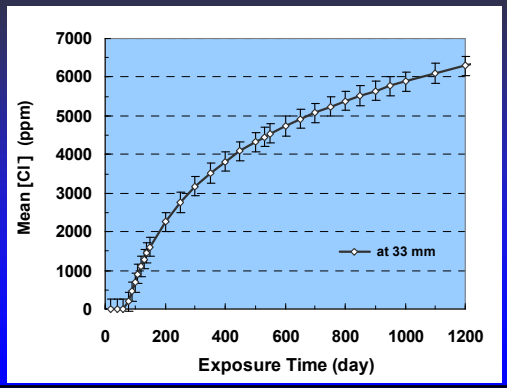
SUMMARY

Bar	Time-to-Corrosion (day)
Carbon Steel	92 ± 3
340 Stainless	> 1,300
316LN Stainless	> 1,300
316L-Clad (no defect)	> 1,300
316L-Clad (w/ holes)	> 1,300
316L-Clad (w/ cut)	392

RESULTS

[Cl^-] vs. Depth (in Concrete) vs. Exposure Time

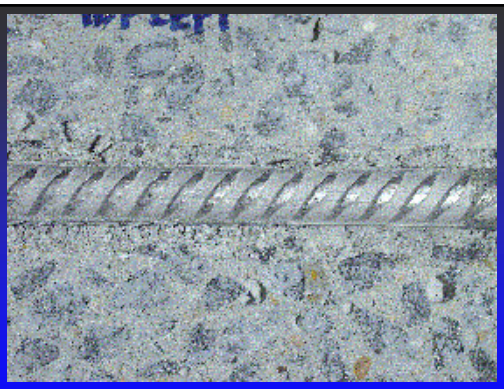
The best-fit curve relating [Cl^-], at depth of top bars, to exposure time.



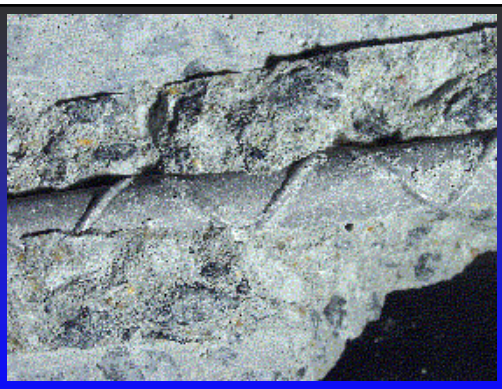
Estimated Chloride Corrosion Thresholds For The Different Bars

Bar	$[CL^-]_{corr}$ (ppm)	Ratio
Carbon Steel	430 - 580	1.0
340	> 6,470*	> 11.2 - 14.2*
316LN	> 6,470*	> 11.2 - 14.2*
316L-Clad	> 6,470*	> 11.2 - 14.2*
316L-Clad (w/holes)	> 6,470*	> 11.2 - 14.2*
316L-Clad (w/cut)	3,750 - 3,790	6.5 - 8.8

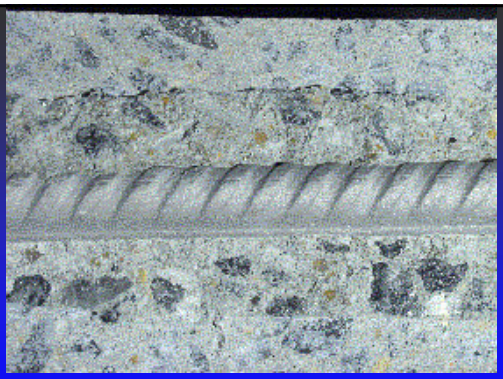
AUTOPSY OF SOME CONCRETE BLOCKS



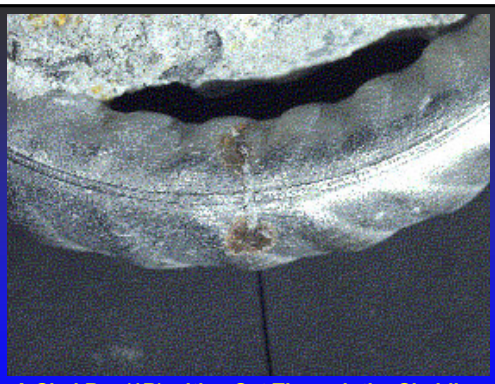
A 316 LN Stainless Steel Bar



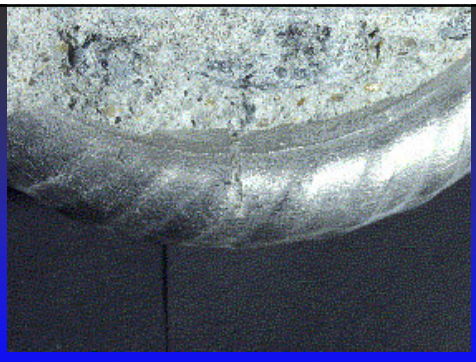
A 340 Stainless Steel Bar



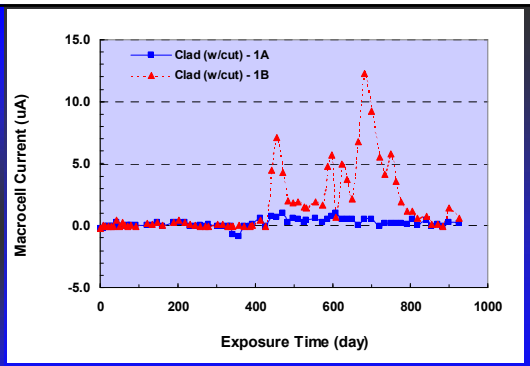
A 316L Stainless Steel-Clad Bar



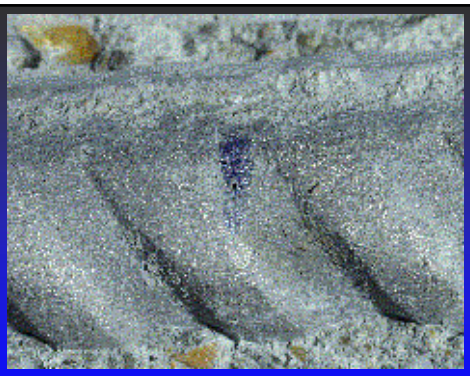
A Clad Bar (1B) with a Cut Through the Cladding. Notice the Small Corroded Area at Each Cut End and the cut is filled with cement paste.



A Second Clad Bar (1A) with a Cut Through the Cladding From the Same Concrete Block. Notice There is No Sign of Corrosion Near the Cut.



The differences in the macrocell currents of Clad Bars 1A and 1B explained the difference in the conditions of these two bars, as revealed in the autopsy.



A Clad Bar with One of the Holes (shaded area) Through the Cladding. (Notice There is No Sign of Corrosion.)

CONCLUSIONS

- During the 1,300 days of weekly salt exposure, the clad bars exhibited the same degree of tolerance to Cl^- as the solid 304 and 316LN austenitic stainless steel bars.
- These bars were shown to have Cl^- tolerances that are at least 11.2 to 14.2 times that of carbon steel bars.

- ❖ It appeared that defects in the cladding may, to some extent, affect the corrosion resistance of the clad bars.
- ❖ The extent is dependent on the type of defect and size.

Thank you very much.