

Tecnochem is a component of the Italian Committee for the European Project COST 521, Scientific and Technical research organized by the European Commission, for the Research action on **CORROSION OF STEEL IN REINFORCED CONCRETE STRUCTURES :**

- Preventive measures
- Monitoring of corrosion
- Maintenance methods

*European Commission
COST (European Project "Co-Operation in the field of Scientific and Technical research")*

COST 521 Action
"Corrosion of Steel in Reinforced Concrete Structures"

WORKSHOP
21 - 24 September 1999
Annecy (France)
Hotel du Département, salle Pierre Martin

Organisation:

- * Laboratoire Central des Ponts et Chaussées, Paris
- * Conseil Général de la Haute-Savoie, Annecy
- * Direction Départementale de l'Équipement Haute-Savoie, Annecy

Dario Rosignoli
TECNOCHEM ITALIANA Spa

**ELECTROCHEMICAL
MEASURES FOR THE EVALUATION OF
MULTIPLE CORROSION INHIBITING
SYNERGIES (MuCIS^â) IN THE
DEVELOPMENT OF REPAIR SYSTEMS
OF REINFORCED CONCRETE
STRUCTURES**

There are well known the problems of structures deterioration induced from steel bars corrosion in the reinforced concretes, particularly when humid ambiental conditions and with chlorides presence.

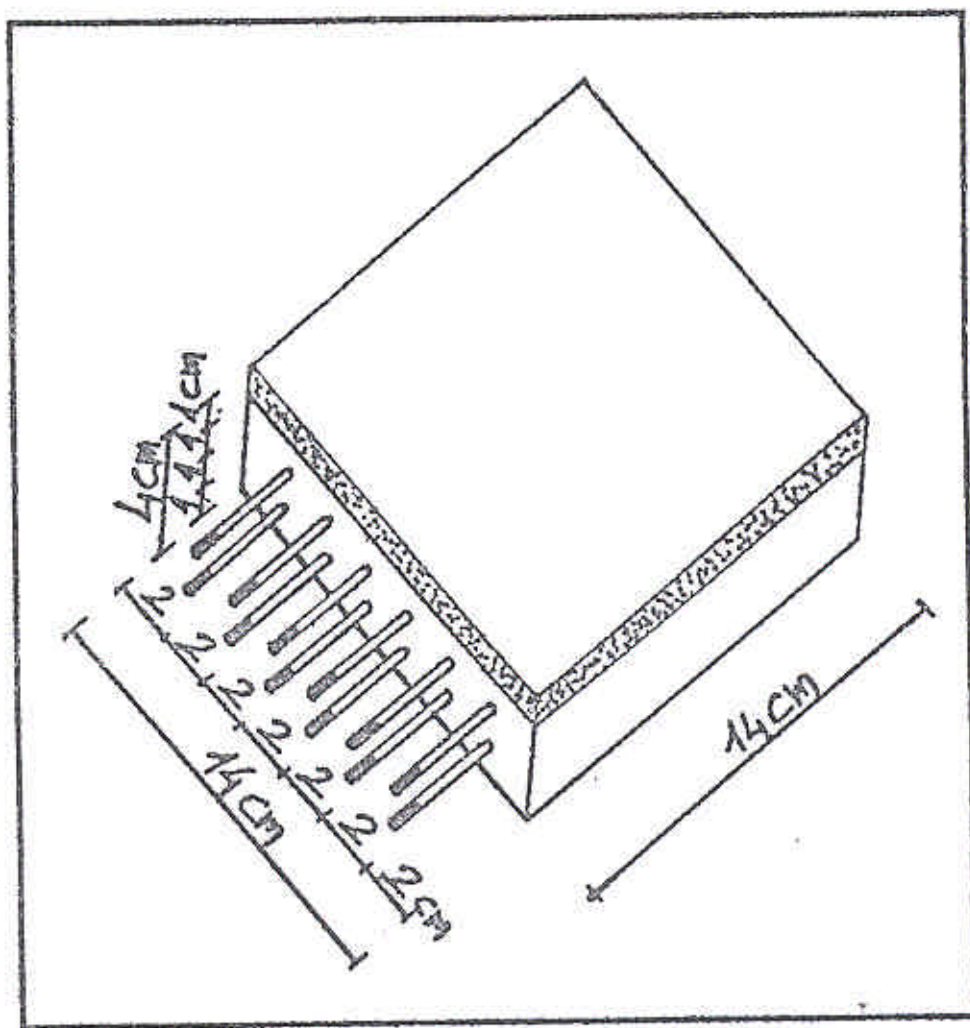
The use of Very High Durability Repair Systems (VHDRS^â) are researched and developed.

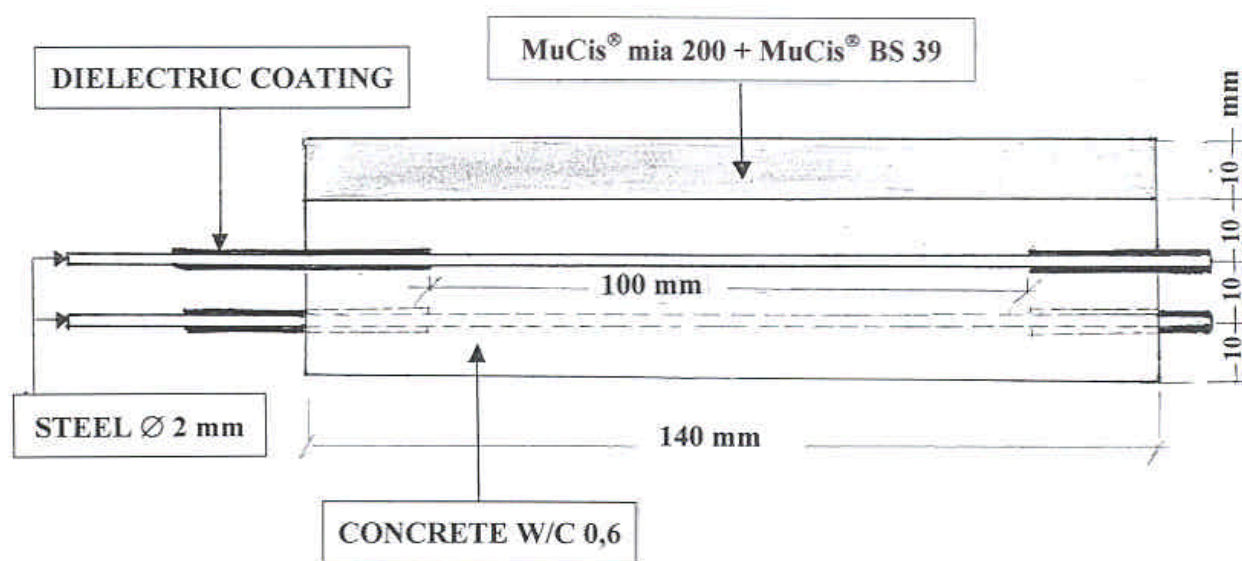
O B J E C T I V E S

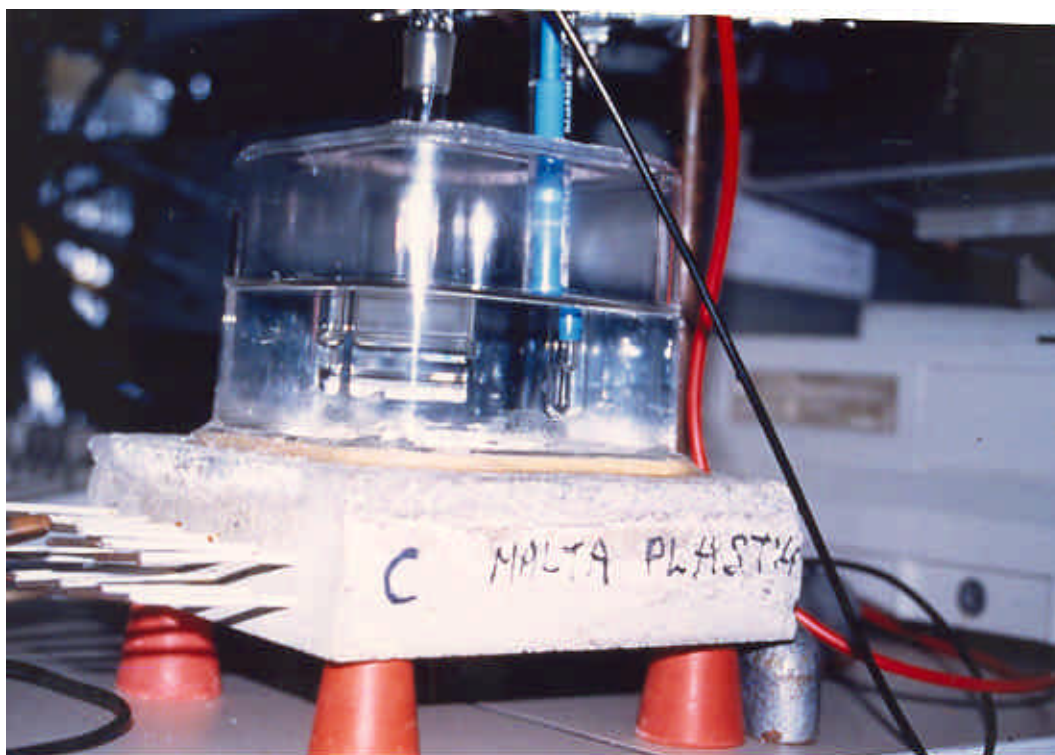
➔ The use of MODEL SPECIMENS on which make measures of the electrochemical parameters of corrosion in as simple and fast as possible way.

➔ The R & D of advanced repair systems (VHDRS^â) containing Multiple Corrosion Inhibiting Synergies (MuCIS^â) together with high level of rheological and physico-mechanical performances.

The specimen used







(modello campione per misure elettrochimiche)

**THE SAMPLE MODEL USED FOR THE
ELECTROCHEMICAL DETERMINATIONS**

The concrete mix design

Cement type	42,5 Porland
Dosage	400 Kg./cu.m.
Aggregates	0 , 8 mm (Bolomey)
W / C	0,6
<i>Containing or not containing NaCl 2%</i>	

Tests briefing

Test	MuCIS^â	NaCl in the concrete mix
C1 (blank)	no	no
C2 (MuCIS^â)	yes	no
E3 (MuCIS^â)	yes	yes (2%)

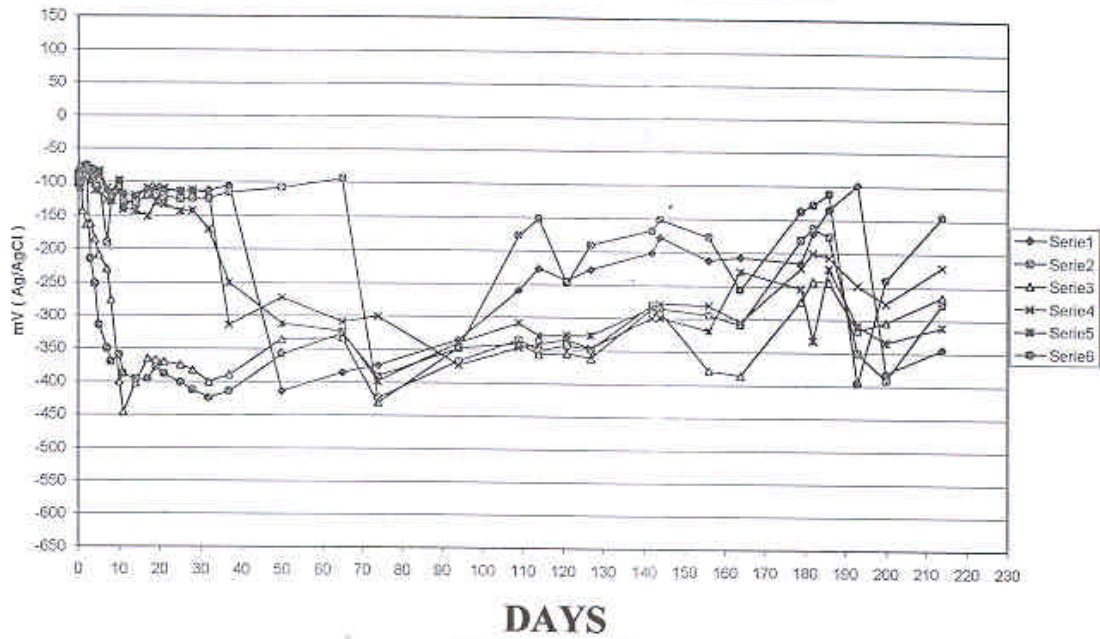
Measures of **CORROSION POTENTIAL**

It is the measure of the state of corrosion activity or corrosion passivity of the steel bars.

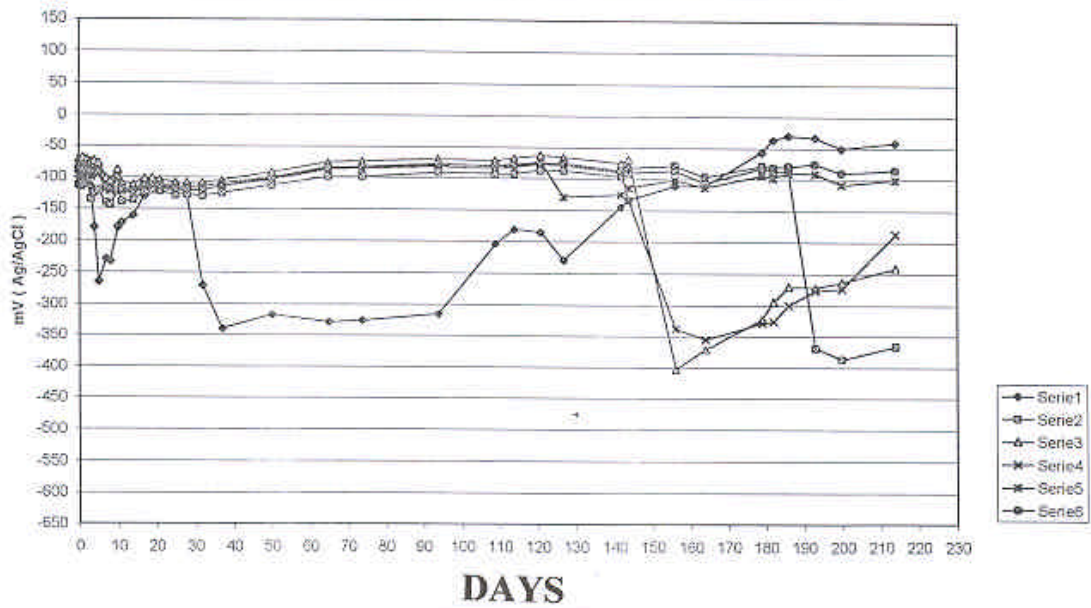
As orientative indications we can consider 4 ranges of potential ref. to the reference electrode Ag/AgCl.

$V > -150 \text{ mV (Ag/AgCl)}$	passivity
$-150 > V > -250$	activity
$-250 > V > -500$	strong activity
$-500 > V$	diffusion control

CORROSION POTENTIAL TEST C1 (blank) Ist steel bars level

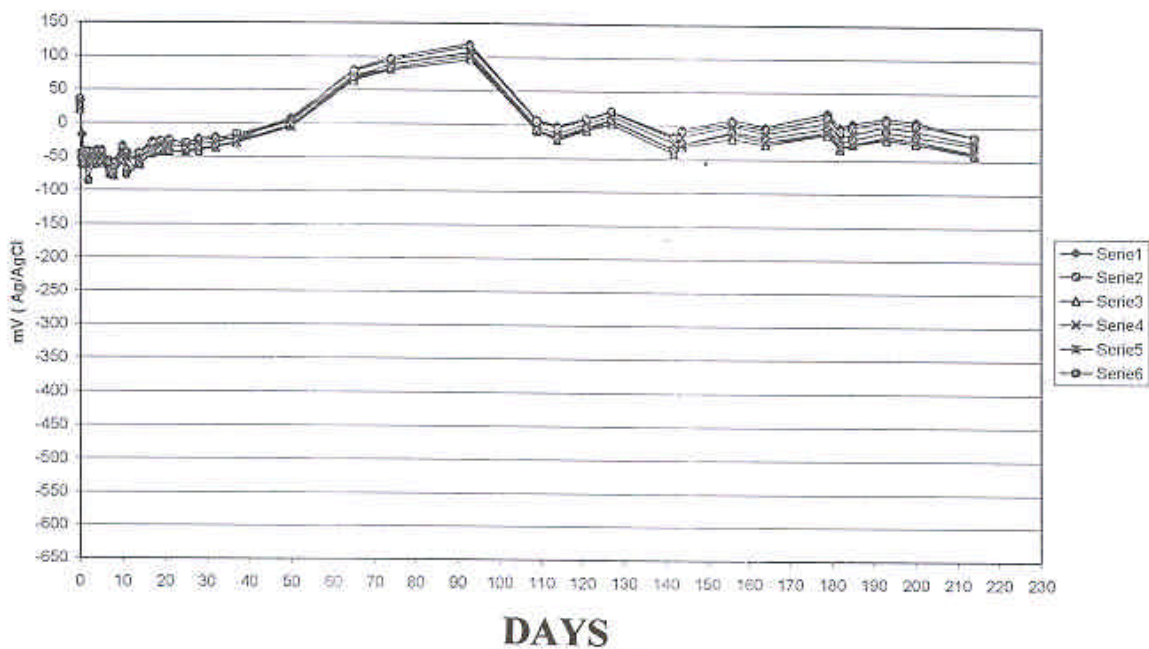


CORROSION POTENTIAL TEST C1 (blank) IInd steel bars level



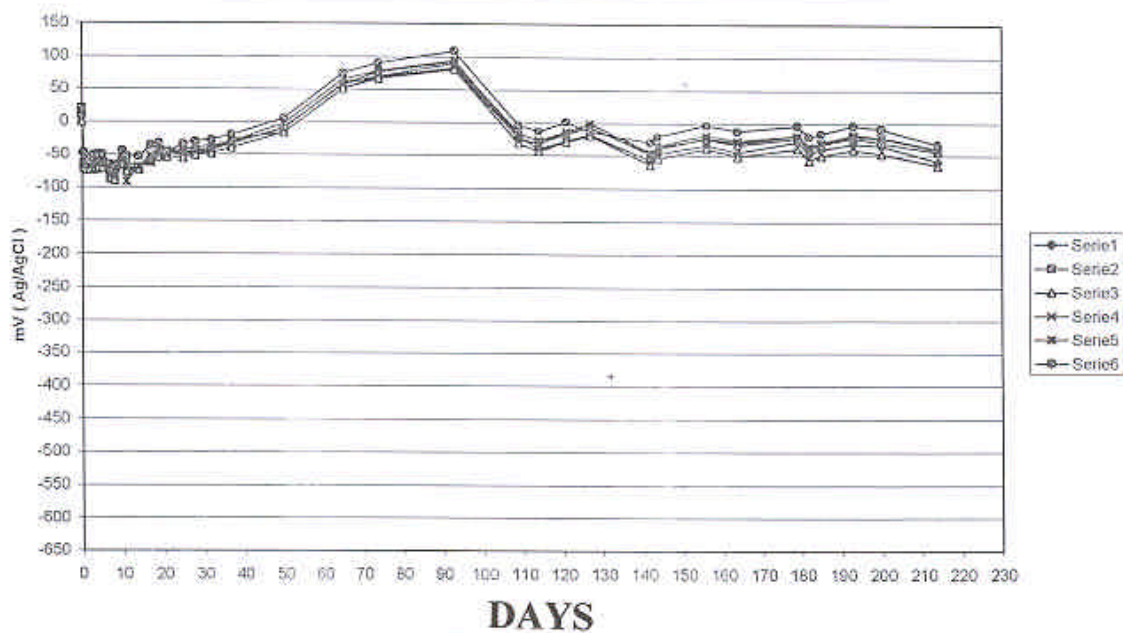
CORROSION POTENTIAL

TEST C2 (MuCIS®) Ist steel bars level

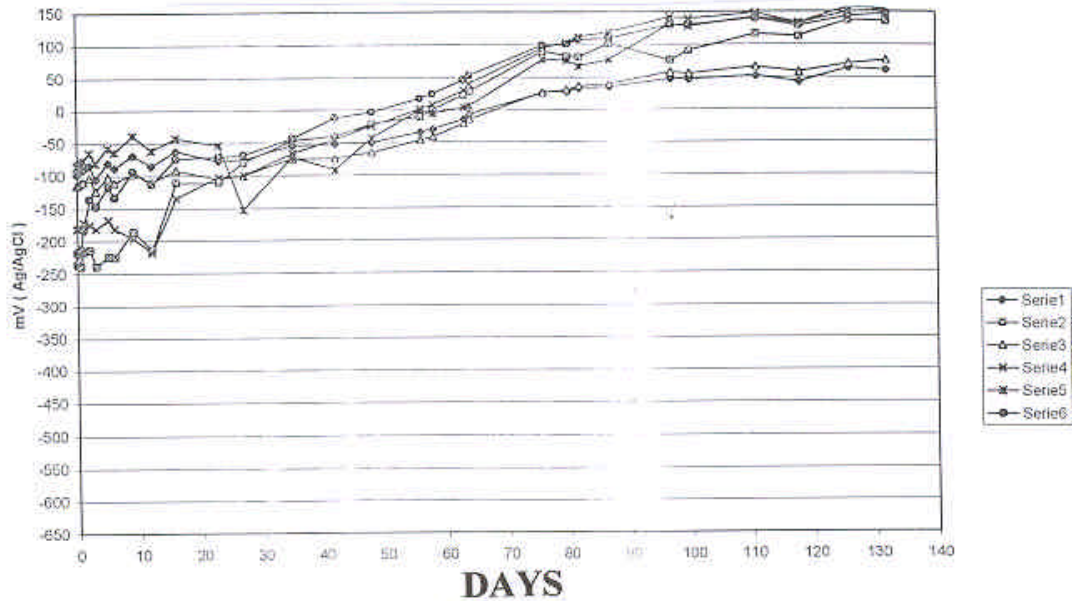


CORROSION POTENTIAL

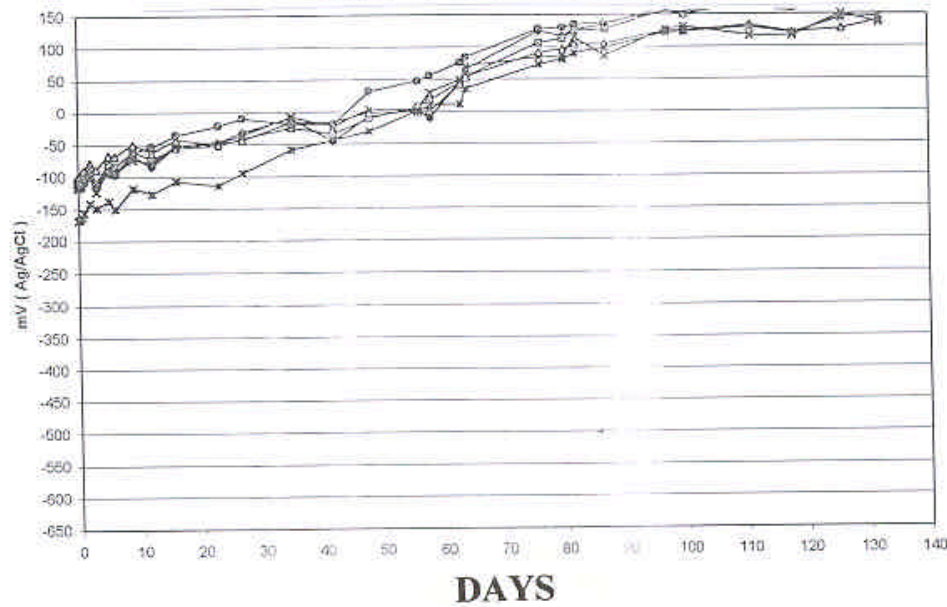
TEST C2 (MuCIS®) IInd steel bars level



CORROSION POTENTIAL
TEST E3 (MuCIS®) Ist steel bars level
2% NaCl in the concrete mix



CORROSION POTENTIAL
TEST E3 (MuCIS®) IInd steel bars level
2% NaCl in the concrete mix



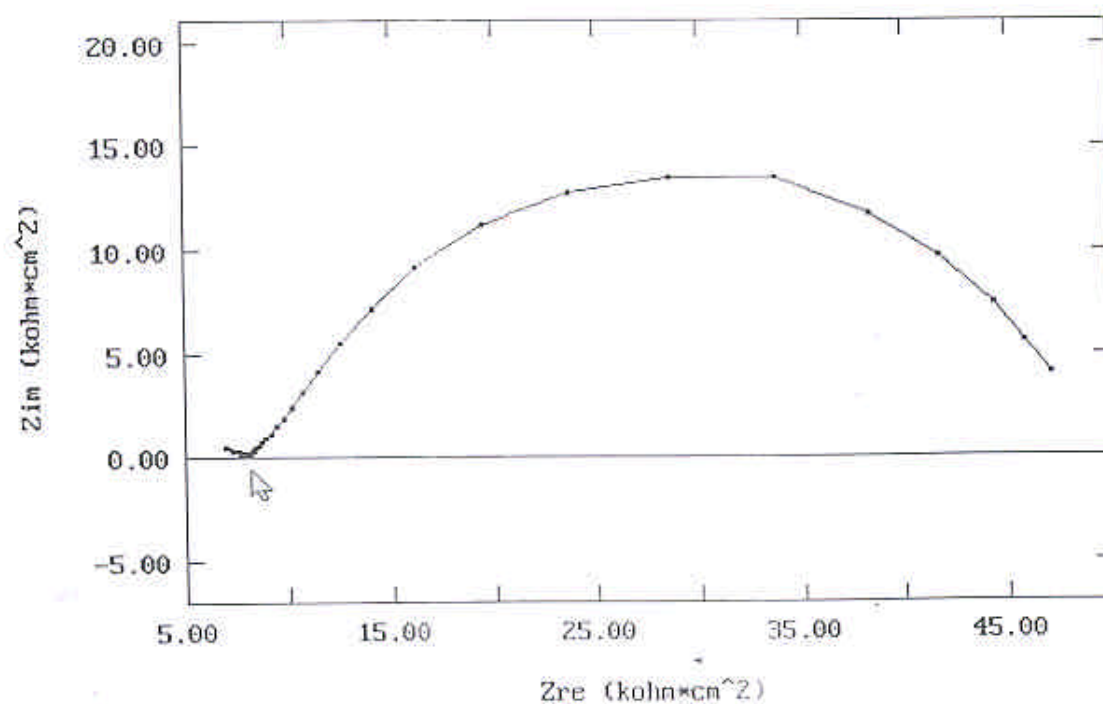
Measures of IMPEDANCE SPECTROSCOPY

The more advanced electrochemical technique giving the possibility of wider consideration on the samples performances is the impedance spectroscopy.

$$R_0$$

R_0 is the first interesting parameter and it represents the resistance to the passage of electrical charges through the electrolita and, mainly in this case, through the mortar or concrete layers covering the steel bars. This parameter is evidenced in the NYQUIST diagram (like here following represented) on the lower value of REAL IMPEDANCE in the point in which the semicircunference (representing the faradic reaction happening on the steel bars) intersects the REAL AXIS indicated for the arrow.

INDIVIDUATION OF R_0

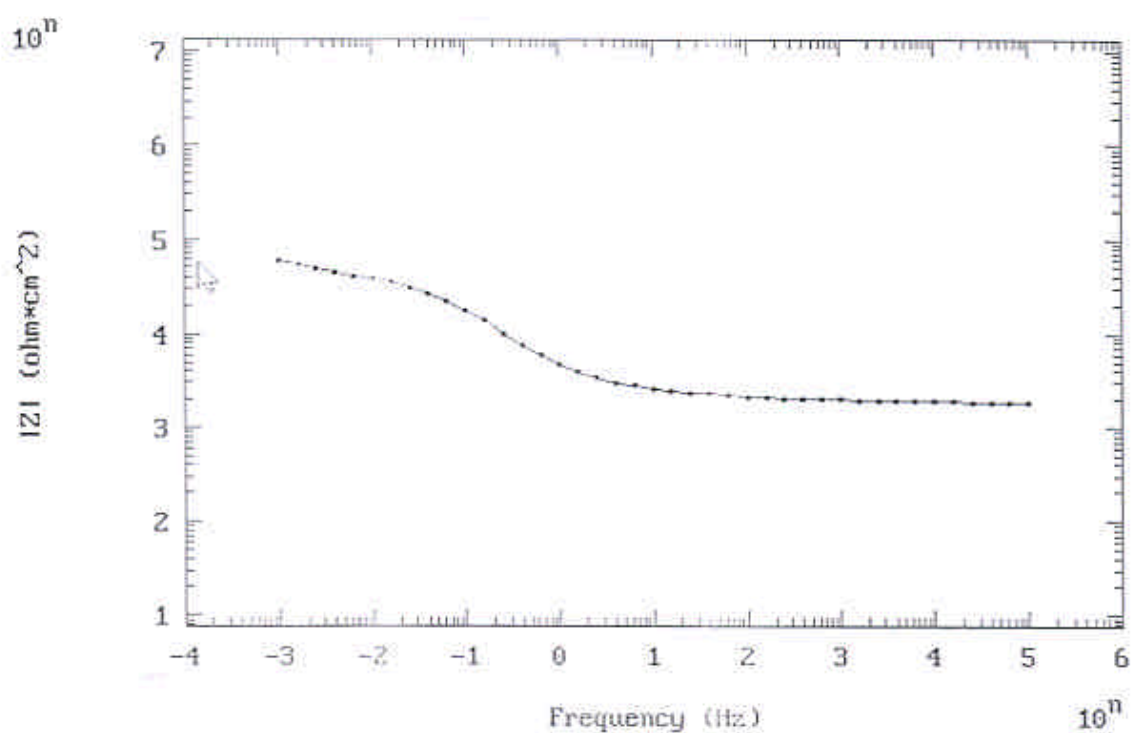


$$R_p$$

R_p the Polarization Resistance is the second parameter evidenced from the impedance diagrams and it is inversely proportional to the speed of corrosion.

Referring to the following diagram (Bode type, frequency-modulus) it is possible to extrapolate the value of the IMPEDANCE MODULUS at the lower value of frequency (as indicated from the arrow).

INDIVIDUATION OF R_p



TEST	nr. days of NaCl 3% sol. ponding	potential	R _o	R _p
*C1 (blank)	1	-143	1100	900000
*C1 (blank)	3	-208	1580	1000000
*C1 (blank)	10	-401	1270	90000
*C1 (blank)	21	-370	1920	60000
*C1 (blank)	50	-265	2650	180000
*C2 (MuCIS ^â)	0	-28	17000	1000000
*C2 (MuCIS ^â)	25	-33	16200	1000000
*C2 (MuCIS ^â)	50	-8	16500	1200000
*C2 (MuCIS ^â)	142	-40	28000	1200000
*C2 (MuCIS ^â)	144	-39	50000	1000000
**E3 (MuCIS ^â)	12	-217	18000	350000
**E3 (MuCIS ^â)	48	-26	24000	1150000
**E3 (MuCIS ^â)	63	+53	50000	1200000
**E3 (MuCIS ^â)	130	+109	50000	1150000

POTENTIAL R_o, R_p values ref. to C1, C2 and E3 tests.

R_o = resistance to the passage of electrical charges through the electrolita and,

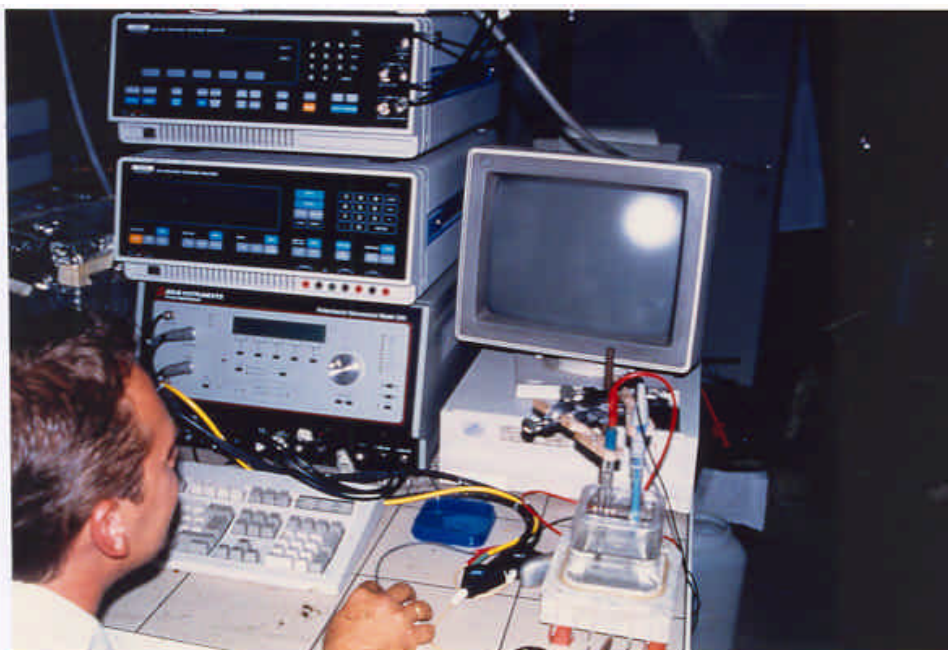
mainly through the mortar layer (see diagram : Individuation of R_o)

R_p = polarization resistance (see diagram : Individuation of R_p)

note : R_p is inversely proportional to the speed of corrosion

*** Concrete not containing NaCl**

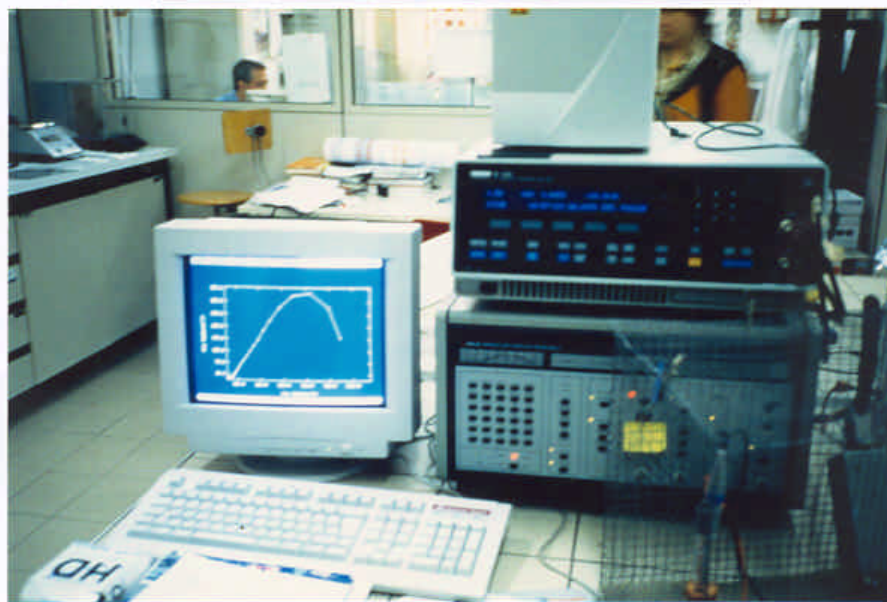
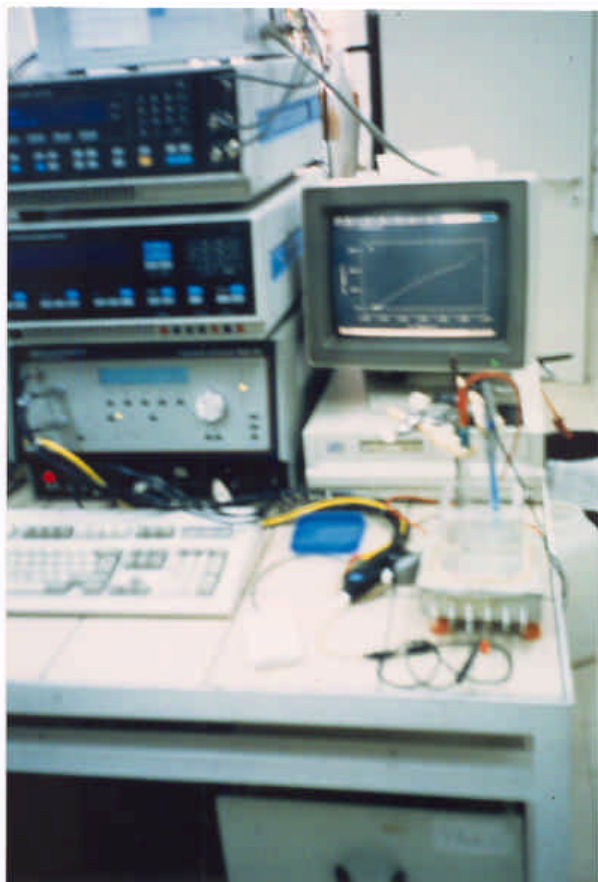
**** Concrete containing 2% NaCl**



THE INSTRUMENTS USED FOR THE
SPECTROSCOPY IMPEDANCE MEASUREMENTS



**THE INSTRUMENTS USED FOR THE
SPECTROSCOPY IMPEDANCE MEASUREMENTS**

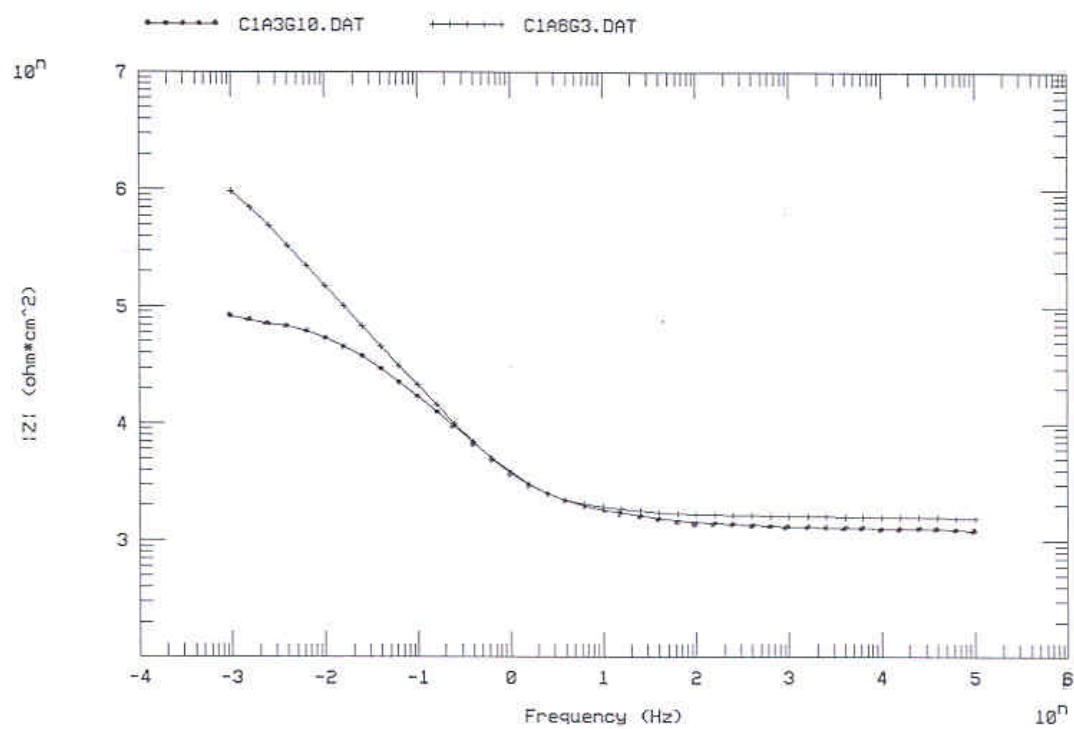


THE INSTRUMENTS USED FOR THE
SPECTROSCOPY IMPEDANCE MEASUREMENTS

TEST C1 (BLANK) : IMPEDANCE DIAGRAM

----- C1 after 3 days

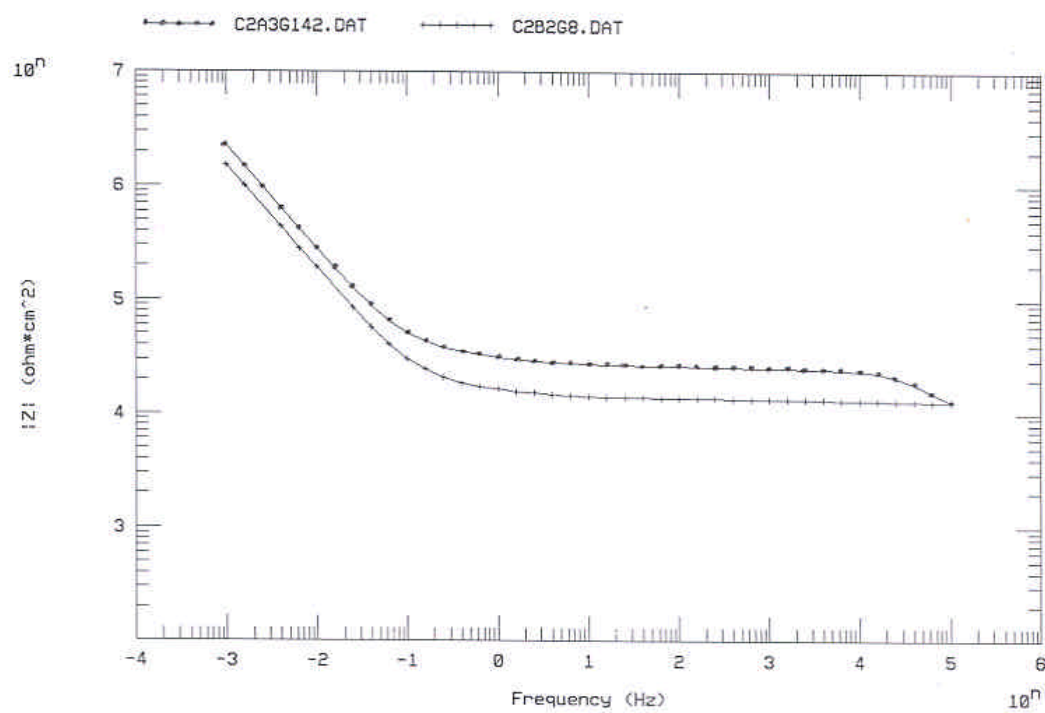
----- C1 after 10 days



TEST C2 (MuCIS[®]) : IMPEDANCE DIAGRAM

—+—+— C2 after 8 days

—+—+— C2 after 142 days






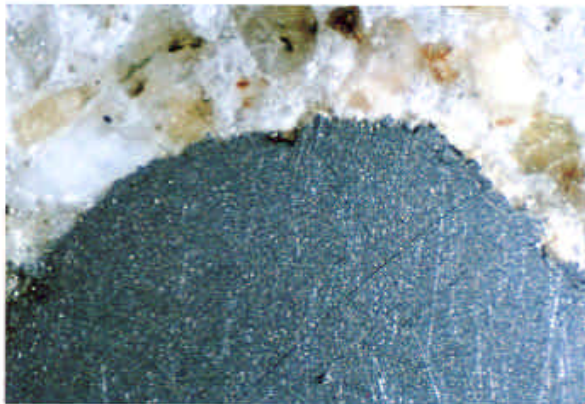
WITHOUT MuCIS®



MuCis® mia 200 + MuCis® BS 39

CONCRETES CONTAINING $\text{Cl}^- = 6\%$ REF. TO CEMENT WEIGHT
(15 TIMES MORE THAN THE LIMIT VALUE OF EUROPEAN SPEC.)

STEEL BAR Ø 6 mm PROTECTED WITH

AFTER 450 DAYS CURING



37 MAGN. PERFECTLY CONSERVED BAR

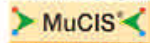
STEEL BAR Ø 6 mm
WITHOUT 
AFTER 450 DAYS CURING



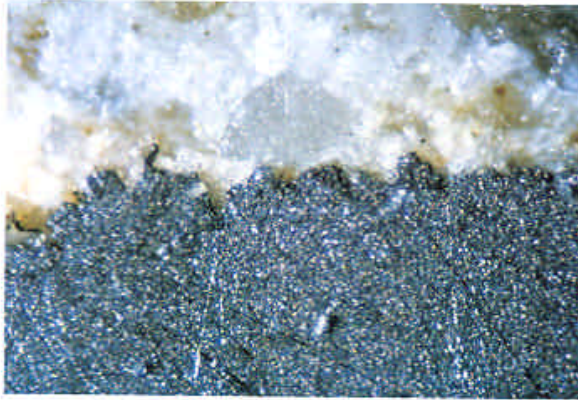
37 MAGN. ADVANCED CORROSION
DIFFUSION THROUGH CONCRETE.
POROSITY OF FERROUS HYDROXIDE

CONCRETES CONTAINING $Cl^- = 6\%$ REF. TO CEMENT WEIGHT
(15 TIMES MORE THAN THE LIMIT VALUE OF EUROPEAN SPEC.)

STEEL BAR Ø 6 mm PROTECTED WITH



AFTER 450 DAYS CURING

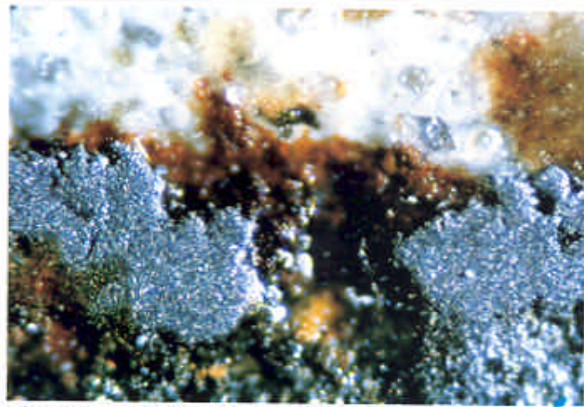


140 MAGN. REBAR WITH EVIDENCES OF PERFECTLY
CONSERVED SURFACE ROUGHNESS

STEEL BAR Ø 6 mm

WITHOUT 

AFTER 450 DAYS CURING



140 MAGN. HIGH MAGN. OF CORROSION PATH

TESTS MADE ACCORDING TO
ASTM C876 (Corrosion Potential)

and

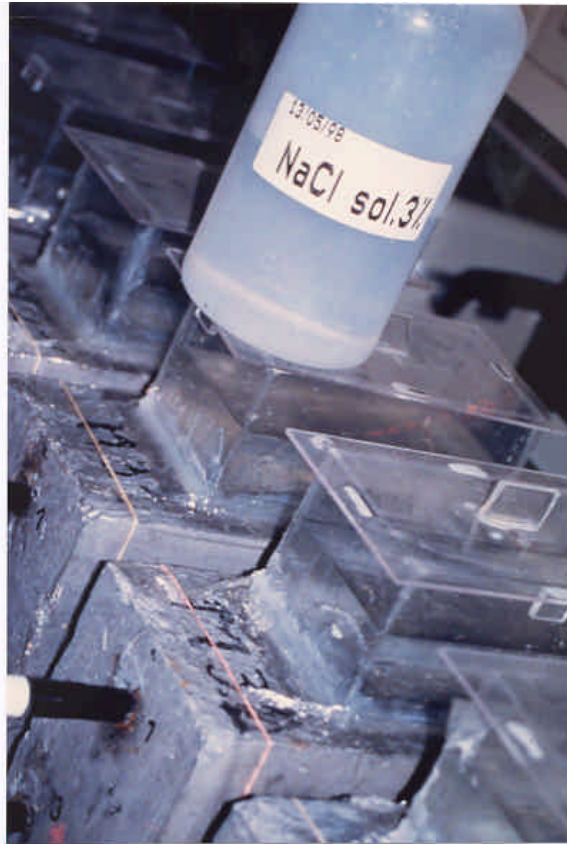
ASTM G109 (Corrosion Current)

using

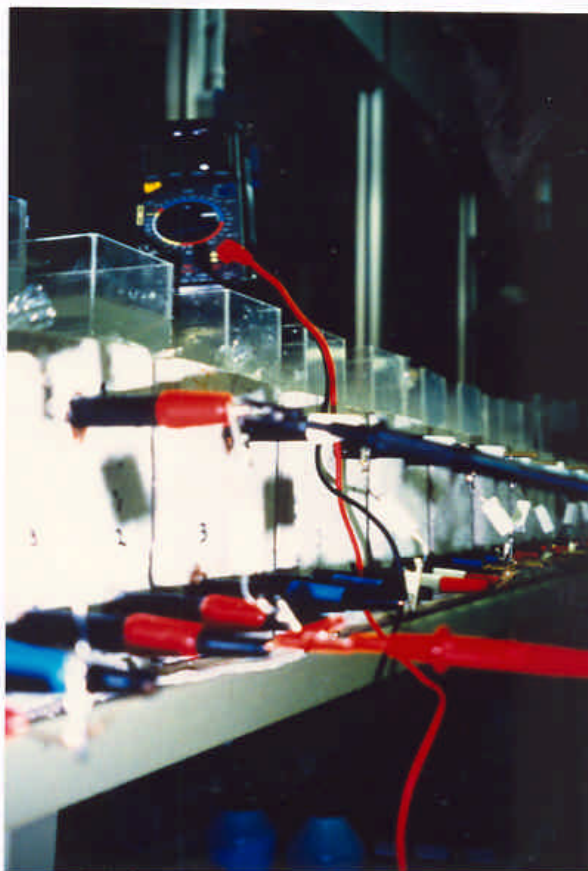
GECORR 6 technique



**SPECIMENS PREPARATION ACCORDING
TO ASTM G109 SPECIFICATION**



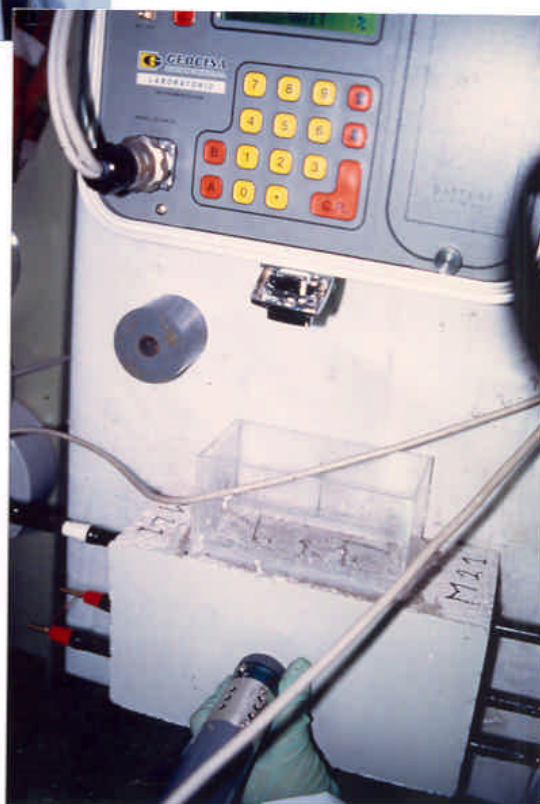
SPECIMENS PREPARATION ACCORDING
TO ASTM G109 SPECIFICATION



MEASURING WITH GECORR 6 APPARATUS



MEASURING
WITH
GECORR 6
APPARATUS

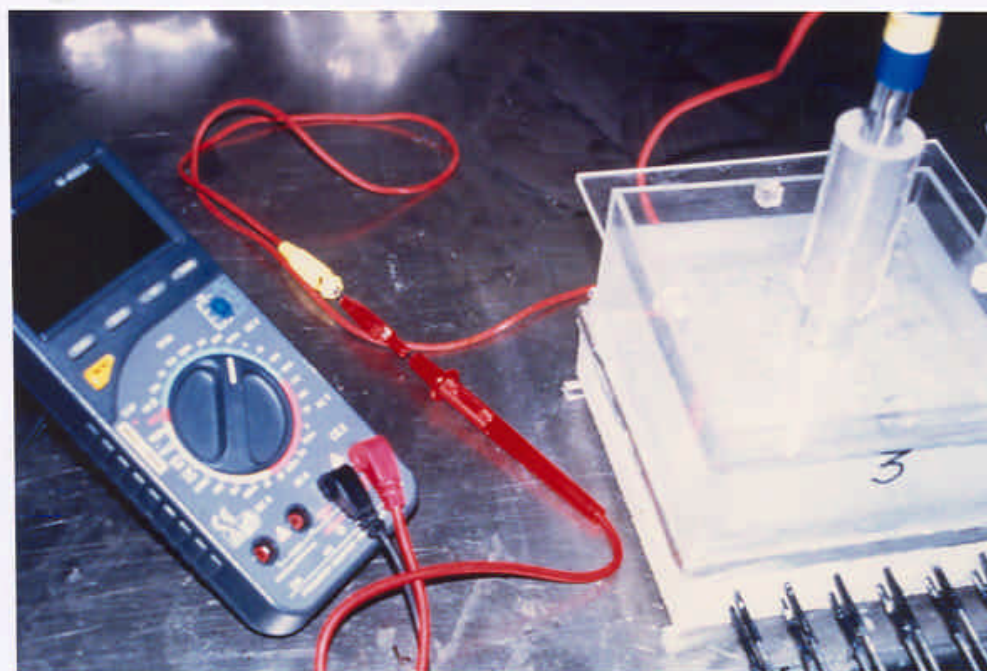
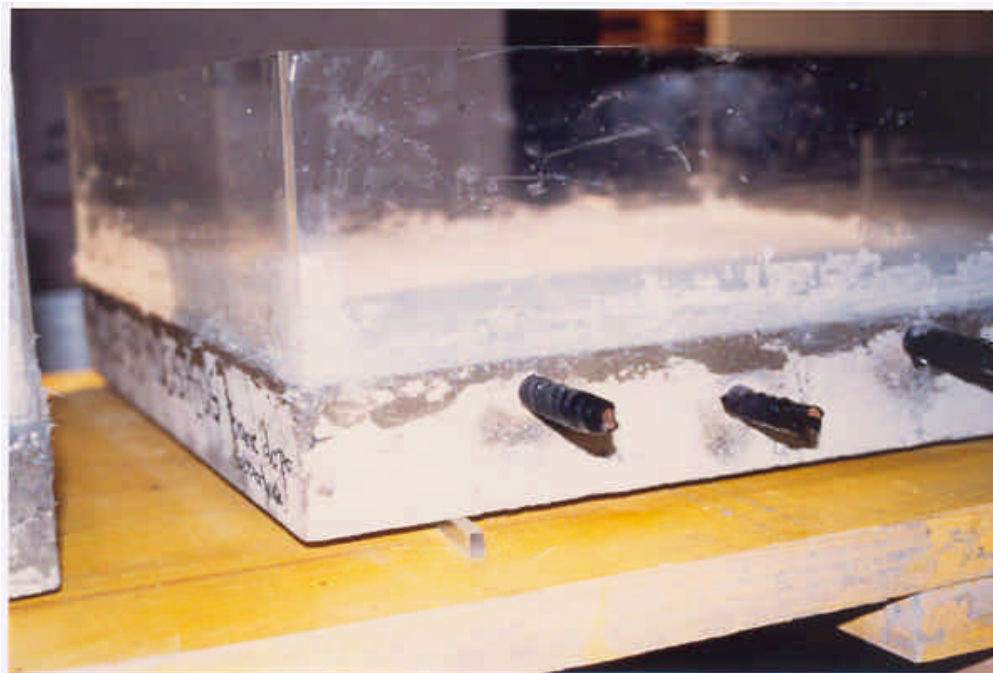




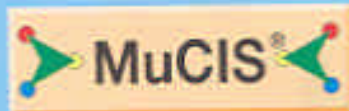
MEASURING WITH GECORR 6 APPARATUS



**DIFFERENTIATED SPECIMENS FOR
STEEL BARS CORROSION DETERMINATIONS**



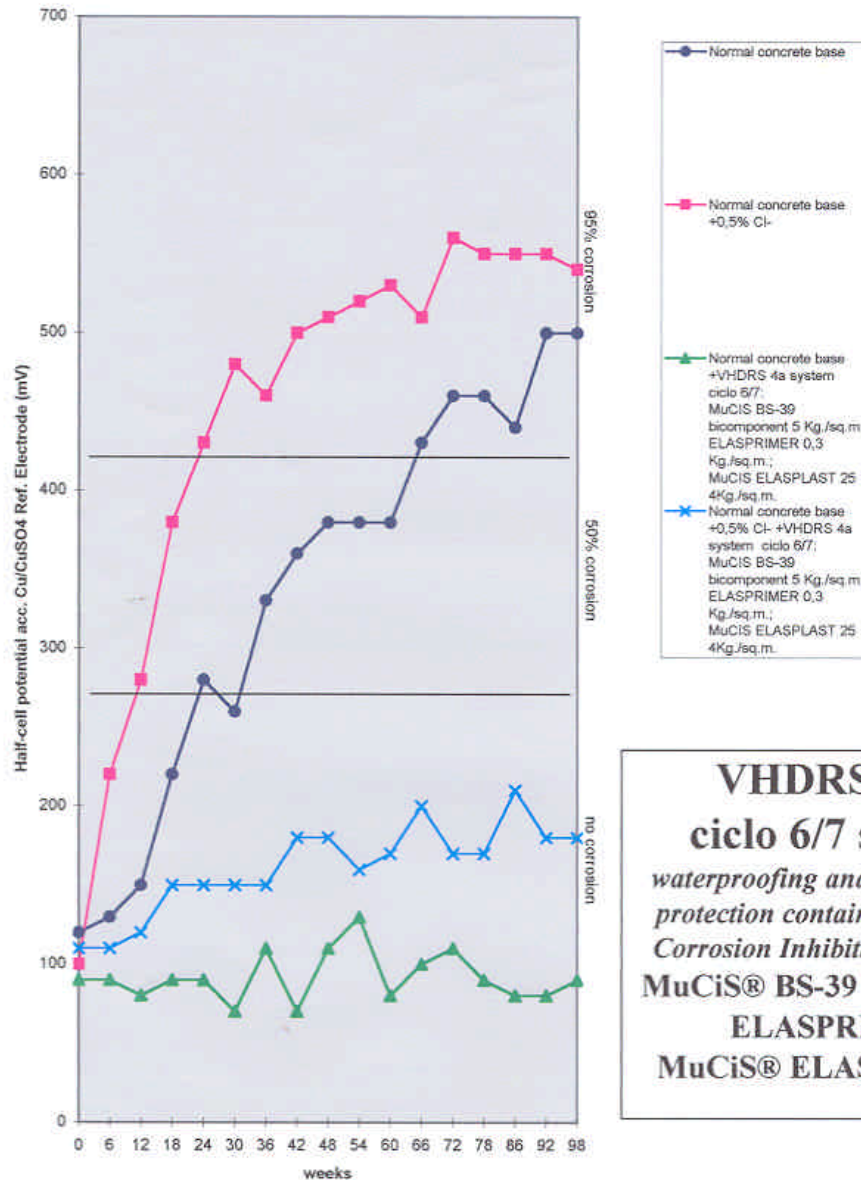
**DIFFERENTIATED SPECIMENS FOR
STEEL BARS CORROSION DETERMINATIONS**



Multiple Corrosion Inhibiting Synergies

- CATHODIC AND ANODIC PROTECTION
- CONTAINING MIGRATING CORROSION INHIBITORS
- INTERFACE CORROSION INHIBITORS
- INTERFACE PASSIVATING FUNCTIONS
- BARRIER AGAINST CHLORIDES PENETRATION AND AGAINST CARBONATION

ASTM C 876



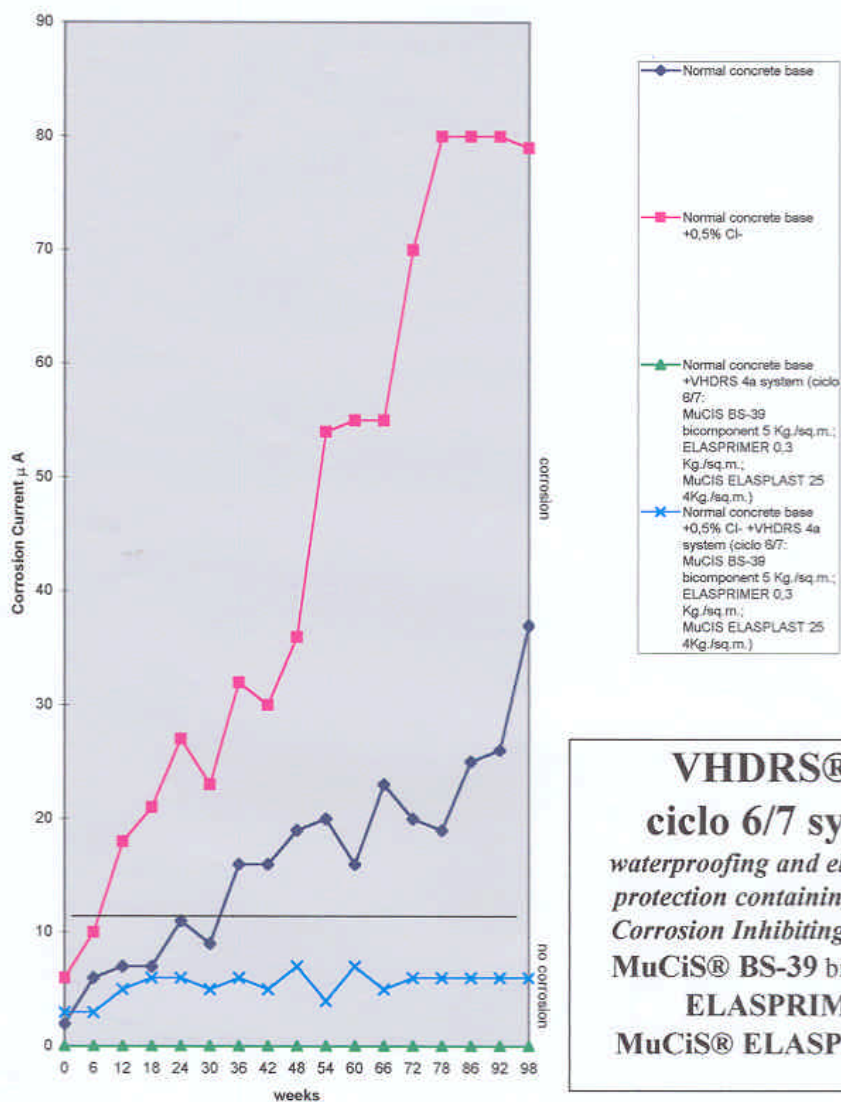
**VHDS® 4a
ciclo 6/7 system**
*waterproofing and elastoplastic
protection containing Multiple
Corrosion Inhibiting Synergies*
**MuCiS® BS-39 biocomponent
ELASPRIMER
MuCiS® ELASPLAST 25**

Anticorrosion performances tests according to ASTM C 876



Quality System: ISO 9002 since FEBRUARY 1993

ASTM G 109



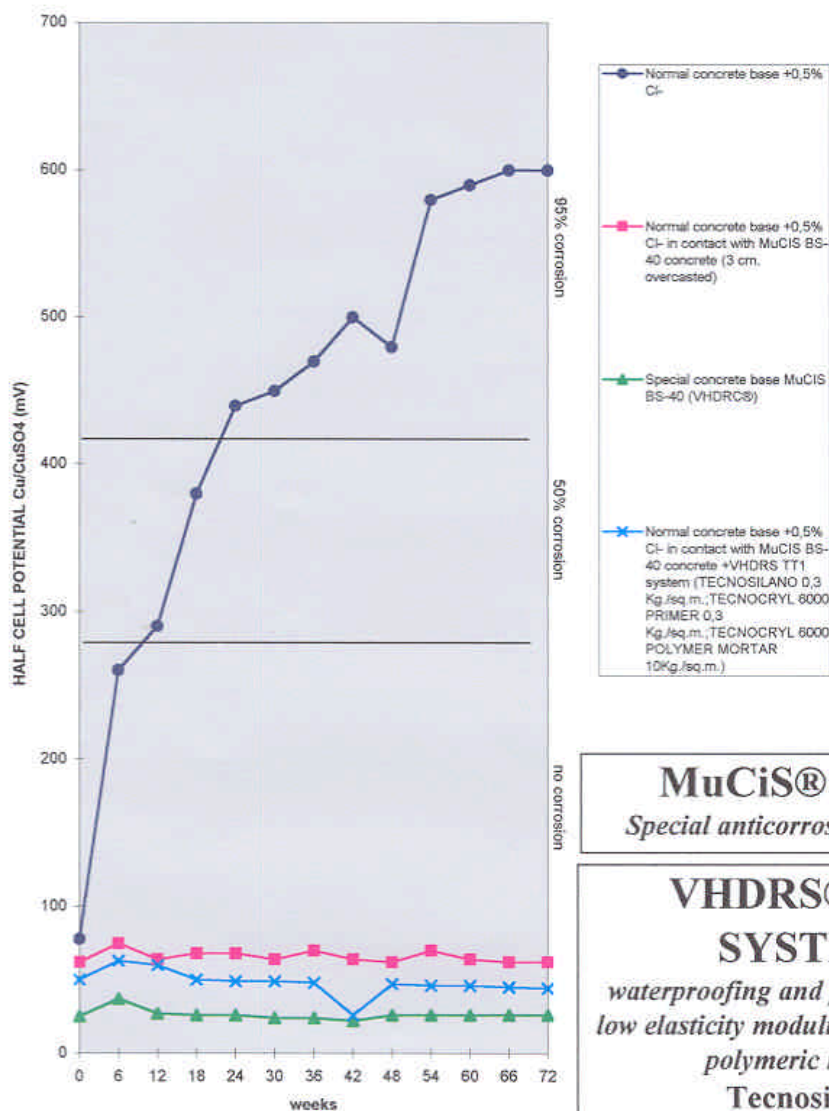
VHDRS® 4a
ciclo 6/7 system
*waterproofing and elastoplastic
protection containing Multiple
Corrosion Inhibiting Synergies*
MuCiS® BS-39 bicomponent
ELASPRIMER
MuCiS® ELASPLAST 25

Anticorrosion performances tests according to ASTM G 109



Quality System **ISO 9002** since **FEBRUARY 1993**

ASTM C 876



MuCiS® BS-40
Special anticorrosion concrete

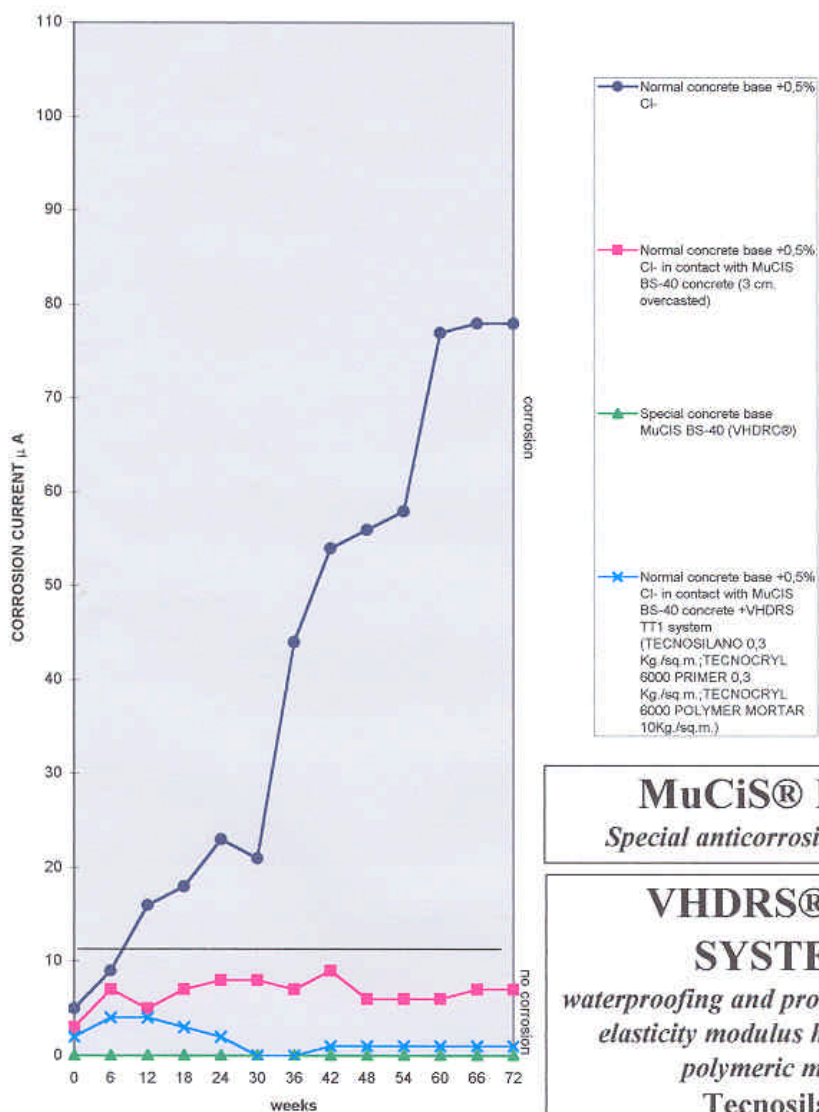
**VHDC® TT1
SYSTEM**
*waterproofing and protection with
low elasticity modulus high strength
polymeric mortar*
Tecnosilano
Tecnocryl 6000 Primer
Tecnocryl 6000 Polymer Mortar

Anticorrosion performances tests according to ASTM C 876



Quality System **ISO 9002** since **FEBRUARY 1993**

ASTM G 109



MuCiS® BS-40
Special anticorrosion concrete

**VHDRS® TT1
SYSTEM**
*waterproofing and protection with low
elasticity modulus high strenght
polymeric mortar*
Tecnosilano
Tecnocryl 6000 Primer
Tecnocryl 6000 Polymer Mortar

Anticorrosion performances tests according to ASTM G 109



Quality System **ISO 9002** since **FEBRUARY 1993**