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REPORT ON TESTING RESULTS

Client:	**„CorteCros“ d.o.o.** **Nova Ves 57; 10 000 Zagreb, Croatia**
Contract/order:	From 08th July 2009
Building product:	Corrosion migrating inhibitors MCI-2005, MCI 2005- NS
Tested properties:	Testing of compressive strength according HRN EN 12190:2001 and flexural strength according HRN EN 196-1:2005 at the age of 28 days; Determination of the effect on corrosion susceptibility of reinforcing steel by potentiostatic electro-chemical test according HRN EN 480-14:2007

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The Laboratory expects information from the Client about the provided service on the form avaliable at www.igh.hr

Test results refer only to the tested specimens. Partial copying of this report is not permitted without written authorization from the Head of the Laboratory. Total number of pages: 9; number of annexes: 0

CONTENT:

1 INTRODUCTION

On the basis of the order provided from the firm „CorteCros“ d.o.o.Nova Ves 57; 10 000 Zagreb, on testing of the efficiency of products MCI-2005, MCI-2005 NS following testing program was done:

1) Production and curing of concrete / mortar specimens
   - Reference concrete / mortar specimens,
   - Concrete / mortar specimens with the addition of MCI-2005 according to producer's specifications
   - Concrete / mortar specimens with the addition of MCI-2005 NS according to producer's specifications
2) Testing of mechanical properties of reference mortar and mortar with the addition of MCI 2005 and MCI 2005 NS – compressive strength according HRN EN 12190 and flexural strength according to HRN EN 196-1
3) Determination of influence of addition of corrosion inhibitors MCI 2005 and MCI 2005 NS on corrosion of steel reinforcement embedded in concrete by potentiostatic electrochemical testing according to HRN EN 480-14:2007
4) Report on testing results

2 TESTING RESULTS ON COMPRESSIVE STRENGTH AND FLEXURAL STRENGTH

Product:	A) Reference mortar B) Mortar with migrating corrosion inhibitors MCI-2005 C) Mortar with migrating corrosion inhibitors MCI-2005 NS
Mixture proportions for 1m^3:	Mixing with hand mixer, 3 minutes A) Cement 519,8 kg, water 259,90 kg and aggregate 1559,40 kg B) Cement 519,8 kg, water 259,90 kg, inhibitor MCI 2005 0,6 l for 1m^3 and aggregate 1557,14 kg C) Cement 519,8 kg, water 259,90 kg, inhibitor MCI 2005 NS 0,6 l for 1m^3 and aggregate 1557,14 kg
Comment	Specimens are produced at the Laboratory for Concrete and Bricks in Zagreb
Date of specimens production:	2009-09-09 until 2009-09-10
Date of specimens acceptance:	--
Tested according standards:	HRN EN 12190:2001 + HRN EN 196-1:2005
Tested properties:	Compressive strength and flexural strength at the age of 28 days
Equipment:	Balance Mettler Toledo (o.m. 1976), Vernier calliper (o.m.2281), Pressure machine Zwick (o.m. 2444), Pressure machine Toni Technik (o.m. 2443)
Place of testing:	Laboratory for Concrete and Bricks 2 2121 - Zagreb
Deviations from the standard:	NO
Comment:	Determination of flexural strength was additionally performed according to HRN EN 196-1:2005, which is out of the scope of accreditation.

Table 1 Results of testing compressive and flexural strength

SPECIMENS TYPE		SIZE OF SPECIMENS (mm)			DENSITY (kg/dm^3)	STRENGTH (MPa)						
						ON FLEXURE (BENDING)			ON COMPRESSION			
									Individual			
TESTING TYOE	NAME OF PRODUCT	l	b	h		Individual	Min. value	Average value	I	II	Min. value	Average value
A) REF.		2009-10-07 (28 days)										
PS 009/1	REF.	160,50	40,00	40,60	2,17	5,76	5,45	**5,81**	33,77	33,65	32,80	**34,22**
PS 009/2	REF.	160,80	40,00	40,70	2,17	6,22			34,55	32,80		
PS 009/3	REF.	160,70	40,00	40,50	2,16	5,45			34,00	36,57		
B) MCI-2005		2009-10-08 (28 days)										
PS 010/1	MCI 2005	160,60	40,00	40,40	2,18	6,76	6,17	**6,48**	37,81	36,20	35,89	**37,36**
PS 010/2	MCI 2005	160,50	40,00	40,50	2,17	6,17			35,89	37,01		
PS 010/3	MCI 2005	160,50	40,10	40,60	2,18	6,49			38,94	38,28		
C) MCI-2005 NS		2009-10-08 (28 days)										
PS 011/1	MCI 2005 NS	160,50	40,00	40,60	2,15	6,03	5,62	**6,18**	33,21	33,48	32,74	**36,28**
PS 011/2	MCI 2005 NS	160,40	40,00	40,20	2,15	6,88			33,57	32,96		
PS 011/3	MCI 2005 NS	150,50	40,00	40,40	2,31	5,62			33,01	32,74		

3 TESTING RESULTS OF CORROSION INHIBITORS' INFLUENCE ON STEEL REINFORCEMENT CORROSION

The influence of corrosion inhibitors on corrosion of steel reinforcement embedded in concrete / mortar was performed according to HRN EN 480-14:2007. In total 9 specimens were produced, 3 groups with 3 specimens in each group with embedded steel reinforcement ϕ 6 mm. Specimens were designated as follows:

A) Reference mortar (LB 056/09/1-3)
B) Mortar with MCI-2005 (LB 057/09/1-3)
C) Mortar with MCI-2005 NS (LB 058/09/1-3)

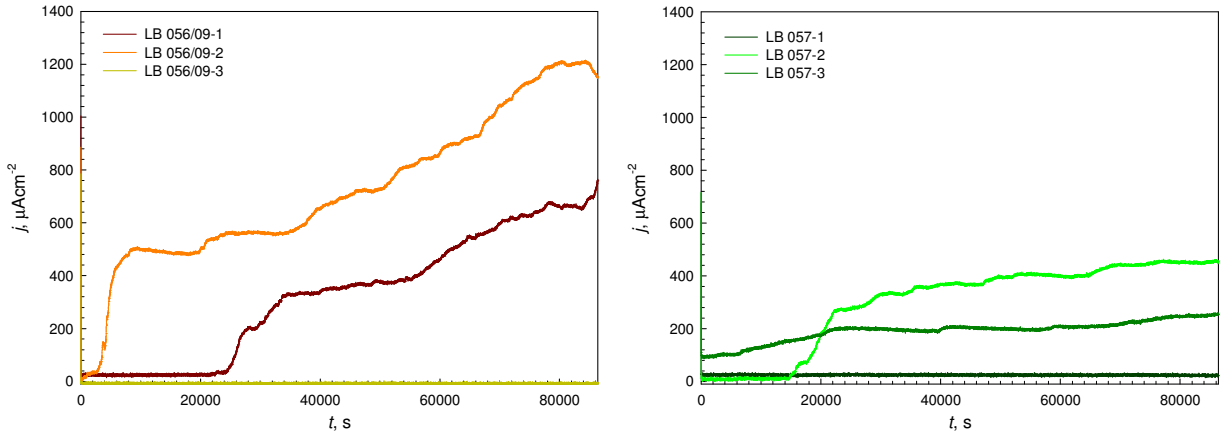
3.1 Testing method

In order to determine the influence of inhibitors on corrosion susceptibility of reinforcing steel, the accelerated corrosion testing was performed by potentiostatic electro-chemical test (anodic polarization) according to the standard HRN EN 480-14:2007. During testing the instrument PAR VMP2 was applied, with three electrode system – working electrode as reinforcing steel, measurement or reference electrode as saturated calomel electrode (SCE), and counter electrode as graphite bar.
According to the standard HRN EN 480-1:2007 the influence of concrete admixtures on corrosion of reinforcing steel is tested by potentiostatic polarization on steel specimens embedded in

concrete. Specimens are exposed to electrolyte solution (3,5 % NaCl solution in distillated water) during 24 hours, while the change of potential is recorded with the time. During next 24 hours the potential is maintained between working and reference electrode (+500±5) mV_{NHE} (according to the hydrogen reference electrode). During polarization the change of current between working and counter electrodes is continuously recorded with the time. After 24 hours concrete specimens are broken to visually inspect polarized surface of reinforcing steel. The testing result is counted as maximum current between 1st and 24th hour of testing and expressed as current over polarized surface of reinforcing steel.

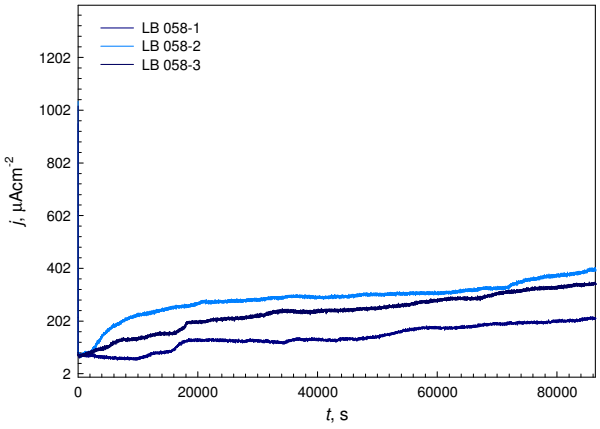
3.2 Results of testing

In Figure 1 a), b) and c) results of testing by potentiostatic polarization method are shown, where the change of corrosion current is recorded during time. Sudden increase of current indicates the loss of passive film stability at the steel surface, which is built in the alkaline environment such as concrete or mortar.
In Figure 2 a), b) and c) the average change of corrosion current in time during potentiostatic polarization is shown, for each group of tested specimens: LB 056 in Fig. 2a), LB 057 in Fig. 2b) and LB 058 in Fig. 2c). In Table 1 numerical values of each testing result as well as the average value for each group of tested specimens are given.



a) reference mortar

b) mortar with MCI 2005 addition



c) mortar with MCI 2005-NS addition

Figure 1 Change of current with the time for: ***a) specimens LB 056 – reference one; b) specimens LB 057 – with MCI 2005; c) specimens LB 058 – with MCI 2005 NS.***

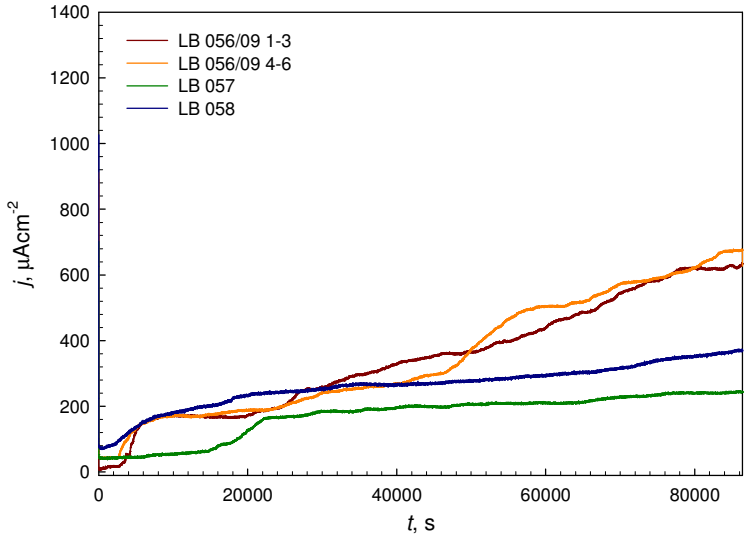


Figure 2 ***Change of corrosion current with the time as averaged values for each group of specimens***

Table 2 Results of potentiostatic polarization

Specimens group	Specimen name	Current after 1 h j_1, µAcm^{-2}	Current after 24 h j_{24}, µAcm^{-2}	Change of current j_{24} - j_1, µAcm^{-2}	Average change of current µAcm^{-2}
	056 - 1	27,4176	762,9904	735,5728	
056	056 - 2	128,2412	1151,0845	1022,8433	**583,09**
	056 - 3	-5,9595	-15,1073	-9,1478	
	057 - 1	26,6548	21,0611	-5,5937	
057	057 - 2	7,6529	453,1952	445,5423	**196,15**
	057 - 3	108,0178	256,5054	148,4876	
	058 - 1	71,6282	397,3651	325,7369	
058	058 - 2	126,3245	345,4962	219,1717	**220,88**
	058 - 3	95,3049	213,0339	117,729	

4 ANALYSIS OF RESULTS

In order to determine the influence of inhibitors on corrosion of reinforcing steel following analysis were performed:

- the analysis of corrosion current with the time
- the analysis of steel surface after corrosion testing
- analysis of inhibitors efficiency calculated according [Martinez, S., Štern, I. Corrosion and protection – experimental methods, HINUS, Zagreb, 1999].

According to the standard HRN EN 480-14:2007 for testing of admixtures on corrosion susceptibility of reinforcing steel the result of testing is expressed as the change of current between 1st and 24th hour during anodic potentiostatic polarization, over exposed steel surface. From the results given in Table 2 and Figure 2 it can be concluded that specimens' results expressed as corrosion current in µAcm^{-2} are following (from best to worst):

1- specimens 057 – MCI 2005 (the slowest corrosion)
2- specimens 058 – MCI 2005 NS
3- specimens 056 – reference specimens (the fastest corrosion)

After corrosion testing was finished, mortar specimens were broken in order to perform detailed visual inspection of polarized steel surface. In Figures 3 to 5 the appearance of polarized (unprotected) reinforcing steel surface after corrosion testing is shown.

Figure 3 ***Reinforcing steel after corrosion testing from specimens 056 – reference ones***

Visual inspection of steel bars after corrosion testing from mortar specimens signed 056 has given the result that 21 % of unprotected steel surface had corroded.

Figure 4 ***Reinforcing steel after corrosion testing from specimens 057 – with MCI 2005***

Visual inspection of steel bars after corrosion testing from mortar specimens signed 057 has given the result that 4,5 % of unprotected steel surface had corroded.

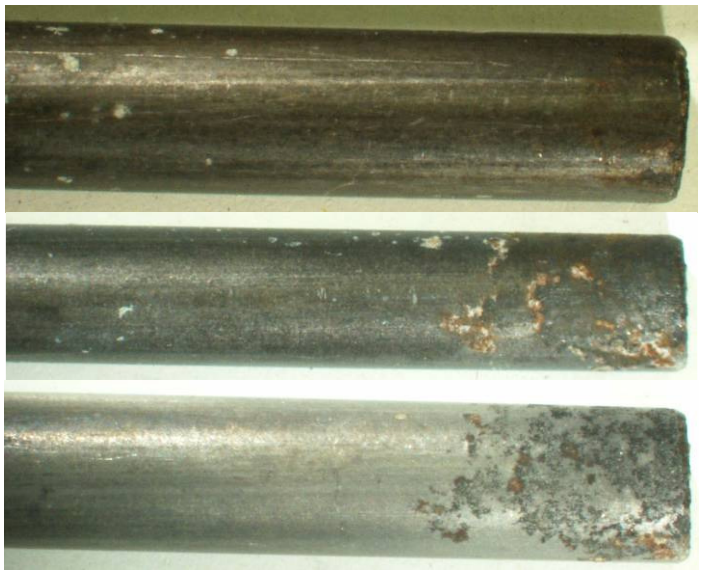


Figure 5 ***Reinforcing steel after corrosion testing from specimens 058 - with MCI 2005 NS***

Visual inspection of steel bars after corrosion testing from mortar specimens signed 058 has given the result that 9 % of unprotected steel surface had corroded.

The efficiency of corrosion inhibitors, η, may be calculated according following equation:

$$\eta = \frac{j^{\text{without inhibitor}} - j^{\text{with inhibitor}}}{j^{\text{without inhibitor}}} \times 100\ (\%) \qquad (1)$$

where:

$j^{\text{without inhibitor}}$ the change of current between 1st and 24th hour during anodic potentiostatic polarization for specimens without corrosion inhibitors

$j^{\text{with inhibitor}}$ the change of current between 1st and 24th hour during anodic potentiostatic polarization for specimens with corrosion inhibitors

In Figure 6 the results of calculation corrosion inhibitors efficiency according eq. (1) are shown.

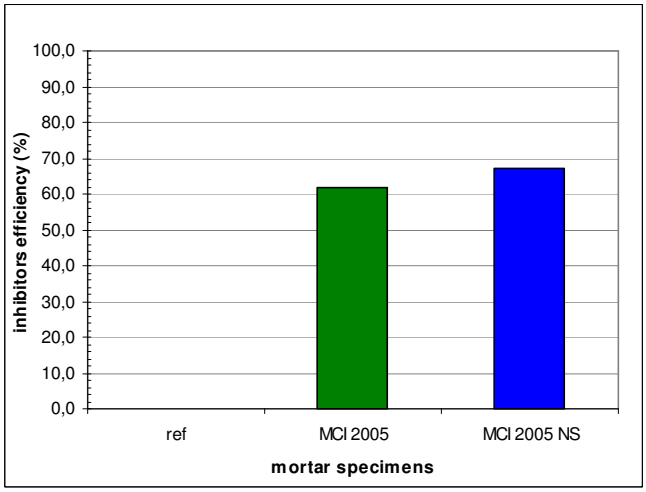


Figure 6 ***The efficiency of corrosion inhibitors***

From Figure 6 it can be concluded that corrosion inhibitors have shown following efficiency comparing to the reference specimens LB 056 without inhibitors additions as follows:

- corrosion inhibitor MCI 2005 in specimens 057 - **67% efficiency**,
- corrosion inhibitors MCI 2005 NS in specimens 058 - **62% efficiency.**

5 CONCLUSION

From the results of testing of mechanical properties of mortars, which include reference mortar and mortars with the addition of inhibitors MCI 2005 and MCI 2005 NS it is obvious that the addition of inhibitors MCI 2005 and MCI 2005 NS in the amount of producer's recommendations has improved mechanical properties (compressive strength and flexural strength) for approximately 10 % comparing to the referent ones.

From the electrochemical testing of the influence of migrating corrosion inhibitors on steel reinforcement corrosion by potentiostatic polarization it can be concluded that the addition of inhibitors MCI 2005 and MCI 2005 NS in fresh mortar have shown the ability of inhibition of steel corrosion comparing to the reference mortar without inhibitors.

Statement: Testing was carried out in accordance with standards except if noted under clause "Deviations from the standard"