APPLICATIONS ON REBARS

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Protection of reinforcement bars in concrete

The problem of concrete cracking

In the second half of the 21st century, the construction and building sector was characterised by a concrete-craze that assumed vast proportions in all continents. At the same time the technique of reinforcing the concrete with steel bars or rebars was developed. In the beginning people did not realise that these steel bars would cause such major problems after only a short period of time. Due to the formation of rust, the steel bars began to expand and the concrete began to crack, which led to gigantic safety problems.

During the last decennia the rebars have been protected by means of traditional anti-corrosion systems, such as hot-dip galvanisation. Indeed, if a rebar is protected against corrosion, then the concrete will remain safe and sound for 30 years before inspection is necessary. But a new and better solution is now on the market : the ZINGA film galvanising system will prolong the initial lifetime of the concrete to at least 100 years.

The mechanism of concrete cracking due to corrosion

The highly alkaline conditions inside concrete provide a passivating environment for the reinforcement bars. A thin layer of oxides forms on the steel surface. This oxide layer is stable in the alkali rich solution and protects the steel against further corrosion. The steel is unlikely to rust as long as the passivating conditions remain at a pH of 10.

Well compacted concrete and an adequate protection of the rebars also provide a physical barrier against corrosion by reducing the penetration of atmospheric carbon dioxide (CO_2), oxygen and moisture. (These 3 elements initiate and sustain corrosion reactions.)

Passivation can be destroyed due to a reduction in alkalinity. This can have various causes :
- infiltration of atmospheric carbon dioxide (CO_2) (carbonation)
- infiltration of sulphur dioxide (SO_2) in industrial climates
- infiltration of aggressive chloride ions in marine environments
- infiltration of de-icing salts sprayed on the concrete surface of roads in winter

The rust can form up to 2 times the volume of the initial steel and can cause cracking of the concrete or even the complete destruction of it.

Developments in anti-corrosion protection of rebars

Over the years, people have tried to protect concrete from cracking in several ways :
- by making a better compacted concrete
- by adding corrosion inhibitors to the concrete
- by active and passive protection of the rebars

The first type of protection that was used on rebars was paint. But coating rebars with an ordinary paint is of course no solution for the corrosion of the rebars. Very few paints sustain the high pH of fresh concrete (approx. pH 13). Moreover, a paint coating is porous. Penetration of moisture and oxygen can not be prohibited.

The second solution was hot-dip galvanisation, but this is still far from perfect. Cracks caused by the bending of the rebars, can easily destroy the galvanising layer. Another problem is that hot-dip galvanised rebars do not provide enough adhesion for the concrete. Moreover, the rebars need to be galvanised in a specialised workshop, equipped with a galvanising bath, which means that the rebars have to be restricted in size. This will cost time and money due to the distance and the transport to this galvanising workshop, which can be very expensive in some parts of the world.

The latest developments in the attempts to protect rebars against corrosion, prove to be ineffective as well. In North America, reinforcing concrete can be done with rebars made out of polypropylene, which is very expensive. This is still not a good solution because polypropylene does not provide an adequate adhesion for the concrete. In Germany a steel laminating plant will offer you stainless reinforcing steel (at a very high price of course). Here also there is a problem of adhesion with the concrete. Moreover, bending a stainless steel rebar is practically impossible without cracking.

The protection of rebars with ZINGA

In comparison with all other methods of protection that have been tried out on reinforcing steel, a thin layer of ZINGA (approx. 40 µm) provides the best protection at a very low and cost effective price.

ZINGA is a single-pack zinc coating that is easy to apply by brush, roller, spraying or dipping under any atmospheric condition. It offers a better cathodic protection than hot-dip galvanisation. This was proven in Europe, in the USA and in Asia, both in laboratory and in field testing. A dry ZINGA layer consists of 96% zinc, pure to 99.995% and homogeneously dispersed throughout the layer.

The surface preparation of new rebars should be done by blasting to cleanliness degree SA 2.5 and roughness degree Ra 12.5 µm. For repair of already rusted rebars, the rust should be removed by means of a steel brush, a needle hammer or high pressure water jetting (100 bars to 200 bars).

A ZINGA layer is flexible and compressible and will not crack or be damaged by bending the rebars. This is surely an important aspect in view of the fact that rebars are generally very roughly manipulated. Moreover, ZINGA offers a good adhesion to the concrete.

The drying time of ZINGA before the contact with the concrete is very short (approx. 15 min.). As soon as ZINGA is touch dry, the concrete can be cast. From the moment that the fresh concrete encapsulates the reinforcing steel protected by a ZINGA layer, some oxidation of the ZINGA layer will occur (due to the pH of the fresh concrete), which will have the following consequences :

- Zinc salts are formed on the surface of the coating. They will seal off the ZINGA layer completely, thus providing an additional barrier protection.
- The zinc salts will roughen the ZINGA surface. This will provide an even better adhesion for the concrete.

Extensive testing at the University of Gent (Belgium) has confirmed these unique qualities of ZINGA to protect rebars in concrete.

Resumed advantages of ZINGA

- ZINGA will offer an active cathodic protection to the rebars, equally effective as hot-dip galvanisation.
- ZINGA will provide an additional barrier protection to the rebars, due to the zinc salts on the surface.
- ZINGA is flexible and will not be damaged when the rebars are bended or handled roughly.
- ZINGA is easy to apply by brush, roll, dipping or spraying.
- ZINGA has a quick drying time.
- ZINGA can be applied in humid circumstances.
- Welding is possible on top of ZINGA.
- ZINGA can be used for the protection of new rebars as well as for the repair of old rebars.
- ZINGA can be touched up easily. A new layer will reliquify the old layer and the 2 layers will blend together to one homogeneous ZINGA layer.
- ZINGA offers a good adhesion to concrete. ZINGA passed the pull-out test according to the standard RILEM/CEB/FIP Rec. RC6-1978.

Conclusion

ZINGA will protect the rebars, and consequently the concrete, for a period of 100 years.

Protection of rebars in concrete

References

Building with Rebars - Russia

National Iranian Gas Company - Rebars - Iran

Chongqing Water Turbine Works - Rebars - China

Building with Rebars - Russia

System :

ZINGA 1 x 40 µm

In March 2002 ZINGA was applied on rebars to reinforce the walls of a large building in Russia.

These pictures were taken during the ZINGA application in the work shop and during the construction of the building.

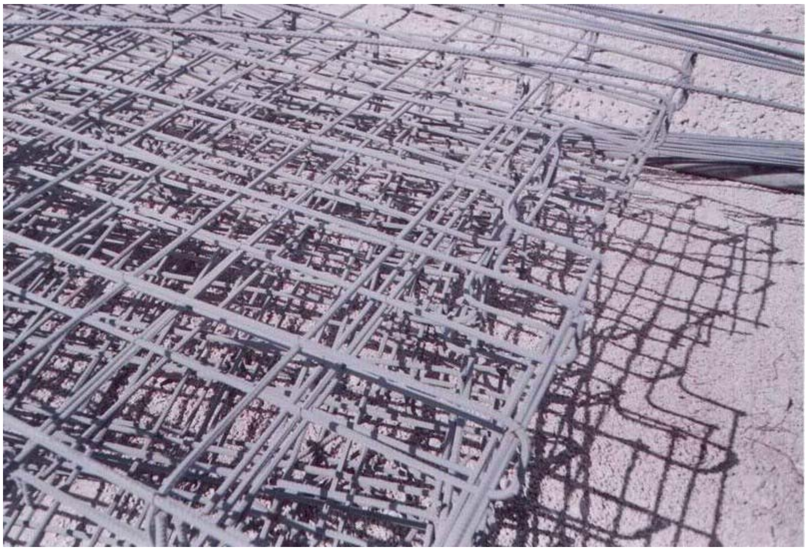
National Iranian Gas Company - Rebars - Iran

In December 2001 the National Iranian Gas Company has used ZINGA for the protection on rebars to reinforce the concrete walls of large round containers, during the construction of a sulphur export port in the special industry zone in Assaluyeh.

For the application of ZINGA they used a specially designed spraying machine for rebars.

System :

ZINGA	1 x 40 µm



Chongqing Water Turbine Works Company
Contractor - Rebars - China

System :

Rebars :
ZINGA 1 x 40 µm

Other structures :
ZINGA 2 x 50 µm

The company Chongqing Water Turbine Works (CWTW) is one of the main contractors for the construction of the Chongqing Monorail. The CWTW has applied ZINGA with satisfactory results on the rebars of the beam supports, directing splitter tracks and connecting plates. These pictures were taken on 16/04/02.

Protection of rebars in concrete

Reports of laboratory tests

Pull-out test on rebars - Belgium
University of Gent, 09/09/99
Report concerning the pull-out tests on rebars in concrete : comparison between uncoated rebars and rebars protected with ZINGA.

Test on rebars - Russia
National Research and Scientific Laboratory for Modified Concrete, 28/06/02
Report concerning the different tests on rebars in concrete protected with ZINGA. (Report in Russian with English translation).

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UNIVERSITEIT GENT

FACULTEIT TOEGEPASTE WETENSCHAPPEN

MECHANISCHE CONSTRUCTIE EN PRODUCTIE
CEL CORROSIE
Prof. dr. ir. J. Defrancq

Datum
25 augustus 1999

Report concerning the pull-out test performed on uncoated and Zinga coated rebars for

b.v.b.a. ZINGAMETALL

Our File nr: LS/154/180899/Z.M.W

1. Problem:

At the request of Mr. G. WILLEMOT, Zingametall, Eke, Belgium, the Laboratory Soete for Strength of Materials, **Corrosion Department**, applied for a pull-out test on non coated and Zinga coated rebars.

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2. Materials:

Three rebars with enhanced adherence $l = 1000$ mm $\phi = 18$ mm
One rebar is embedded in concrete in the uncoated condition.
Two rebars were first coated with a Zinga coating of 25 µm over a length of 500 mm and subsequently, after 72 hours of drying time, embedded in concrete.

3. Procedure:

The pull out test was performed in accordance with the specifications of the RILEM/CEB/FIP Recommendation RC6-1978 " Bond test reinforcing steel - 2. Pull-out test "

The rebars were embedded in the centre of concrete cubes with side equal to 10 times the diameter of the rebar. A plastic tube is slipped over the rebar in such a way that only 90 mm of the rebar is in contact with the concrete. The rebar protrudes for about 100 mm on the side where it is in contact with the concrete. The displacement transmitter is also mounted on this side. On the other side of the cube, the rebar protrudes for about 700 mm and the traction force is applied to this side of the rebar.

Together with the three rebar test specimens, five concrete cylinders were manufactured (ϕ = 150 mm h = 300 mm). These cylinders are needed for the evaluation of the concrete strength, which should approximate 30 N / mm^2 as close as possible.
The specimens were kept for three days in an air conditioned room at 20 ± 2°C and minimum 90% relative humidity. After removal of the shuttering, they were kept in an air conditioned room at 20 ± 2°C and 60 ± 5 % relative humidity.

After 28 days cure, the pull-out test was performed.

4. Results

4.1. Compression of the cylinders:

The results of the compression test are given in the following table:

Specimen	**Compressive strength N / mm^2**
1	30,81
2	30,5
3	31,03
4	30,13
5	30,02
Mean	30,5
Standard deviation	0,43

4.2. Pull-out test

The results of the pull-out test are given in figure 1. The measurement was stopped at the moment the maximum force was applied and the displacement increases with decreasing force, this in order to protect the transmitter.

The adhesion force is calculated by the means of the following formula:

$$\tau = \frac{F}{5 \pi d^2} \cdot \frac{30}{f_{cm}} \qquad \frac{N}{mm^2}$$

Whereby:

F:	maximum force (N)
d:	diameter of the rebar (18 mm)
f_{cm}:	mean compressive strength of the cylinders (N/mm^2)

The mean values are summarised in the table below:

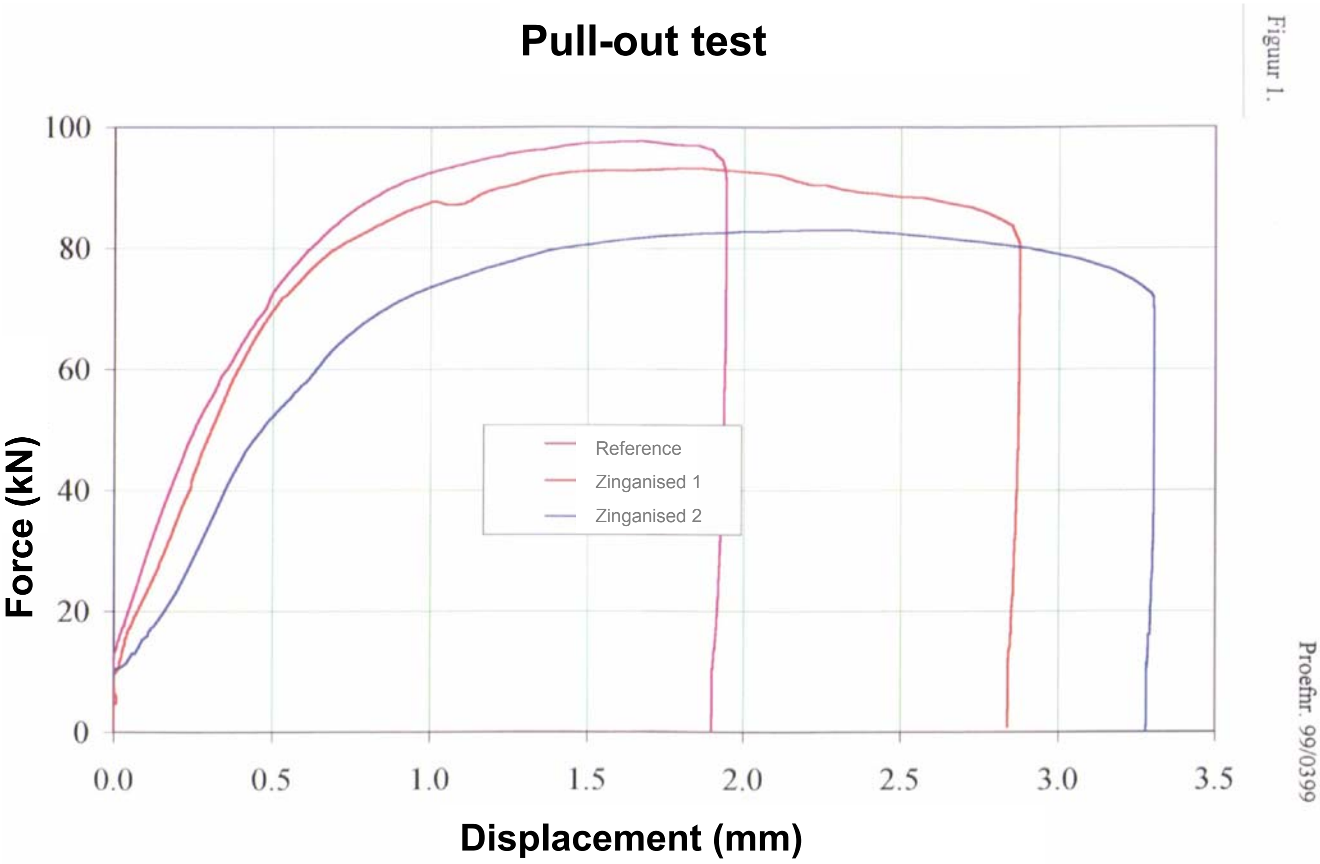
Specimen	F (N)	τ (N/mm^2)
Reference	97.800	18,90
Zinga Average	88.115	17,03

5. Conclusion:

The results indicate that, within a reasonable variation on the results of the measurements, the adhesion to concrete of rebars coated with Zinga is not adversely affected compared to the adhesion of non coated rebars.

Ghent, August 25 th 1999

Prof. Dr. ir. J. Defrancq



Pull-out test
Force (kN)
Displacement (mm)
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Reference
Zinganised 1
Zinganised 2
Figuur 1.
Proefnr. 99/0399

БЕЛОРУССКИЙ НАЦИОНАЛЬНЫЙ ТЕХНОЛОГИЧЕСКИЙ УНИВЕРСИТЕТ
НАУЧНО-ИССЛЕДОВАТЕЛЬСКАЯ ЧАСТЬ
ОТРАСЛЕВАЯ НАУЧНО-ИССЛНДОВАТЕЛЬСКАЯ ЛАБОРАТОРИЯ
МОДИФИЦИРОВАННОГО БЕТОНА
(ОНИЛ МБ)

Испытательная лаборатория
Аккредитована на право
Проведения испытаний в
Национальной системе
сертификации РБ
Аттестат N BY / 112.02.1.0.0024
От «14» августа 1994 года
Адрес ИЛ: 220027 г. Минск
Пр. Ф.Скорыны, 65, корп. 16.

УТВЕРЖДАЮ
Заведующий ОНИЛ МБ
Н.Л.Полейко
«28» июня 2002 г.
Протокол на 6 листах
в 3-х экземплярах

ПРОТОКОЛ ИСПЫТАНИЙ

№ 378 /02 от «28» июня 2002 г.

Наименование продукции: **Антикоррозионное покрытие «Zinga»**
Изготовитель: **Фирма «ZINGA METALL», Бельгия**
Адрес: **210023, г. Витебск, ул. 2-я Фрунзе,4**
Заявитель на проведение испытаний: **ПКП ООО « ОСТ»**
Дата испытаний: **апрель - июнь 2002 г.**
Вид испытаний: **согласно программе испытаний**
Наименование НД, на методы испытаний **согласно программе испытаний**
Количество испытываемых образцов **согласно НД на методы испытаний**
Наименование органа производившего отбор образцов на испытания: **РУП «Стройтехнорм»**

Акт отбора проб № 76-09 от 16 апреля 2002 г.

Место штампа лаборатории

Белорусская государственная
политехническая академия
Отраслевая научно-исследо
вательская лаборатория
модифицированного бетона
(ОНИЛ МБ)

РЕЗУЛЬТАТЫ ИСПЫТАНИЙ

Таблица 3

№ п/п	Наименование объекта испытаний, показатели, технические требования и т.д.	Номер пункта НД, устанавливающего требования к продукции	Номер пункта НД, устанавливающего метод испытаний	Нормированное значение показателей, установл. в НД	Фактическое значение показателей для каждого образца			
					1	2	3	Ср. зн.
1	Толщина пленки при покрытии в 1 слой, мкм		СТБ ГОСТ 51694		21	19	24	***21***
2	Прочность покрытия при ударе, см		ГОСТ 4765		50	50	50	***50***
3	Твердость пленки по маятниковому прибору М-3		ГОСТ 5233		0,41	0,39	0,43	***0,41***
4	Адгезия покрытия, балл		ГОСТ 15140		1	1	1	***1***
5	Сцепление бетона с арматурой, кН		Методика ОНИЛ МБ					
	после пропаривания:							
	обработанные «Zinga»							
	- гладкая				40,2	39,8	41,5	***40,5***
	- рифленая				96,4	92,8	94,6	***94,6***
	контрольные							
	- гладкая				41,8	42,2	42,2	***42,1***
	- рифленая				96,6	97,0	95,0	***96,2***
	снижение прочности							
	- гладкая							***3,9***
	- рифленая							***1,7***
	после 28 суток НВТ							
	обработанные «Zinga»							
	- гладкая				50,0	51,3	49,3	***50,2***
	- рифленая				120	116	117	***117,6***
	контрольные							
	- гладкая				51,9	51,8	53,0	***52,2***
	- рифленая				124	120	123	***122,3***
	снижение прочности							
	- гладкая							***4,0***
	- рифленая							***4,0***
6	Контроль защитных свойств покрытия (номер раствора - 37, время выдержки 0,5 мин.)		ГОСТ 9.302 п.6 табл. 12	цвет капли не изменяется до черного	***Цвет капли темно-синий***			
7	Устойчивость покрытия к воздействию климатических факторов (+70 °С - 30 °С), после 75 циклов		ГОСТ 9.401		АД1 АЗ1	АД1 АЗ1	АД1 АЗ1	***АД1 АЗ1***

Белорусская государственная политехническая академия
Отраслевая научно-исследовательская лаборатория модифицированного бетона (ОНИЛ МБ)

Продолжение таблицы 3

№ п/п	Наименование объекта испытаний, показатели, технические требования и т.д.	Номер пункта НД, устанавливающего требования к продукции	Номер пункта НД, устанавливающего метод испытаний	Нормированное значение показателей, установл. в НД	Фактическое значение показателей для каждого образца
8	Устойчивость покрытия к воздействию температуры (+95 ^{0}С) и повышенной влажности 90-96%. Адгезия покрытия после испытаний, балл		Методика ОНИЛ МБ		Коррозии металла, нарушения однородности, сплошности покрытия не обнаружено 1 1 1 *1*
9	Устойчивость к агрессивным средам: 3% р-р NaCl (pH-6,95) 1% р-р NaOH (pH-9,88) 5% р-р Na_2SO_4 (pH-7,44) - минеральное масло - нефть - р-р серной кислоты с pH 6,0; 5,5; 4,5; 3,5		ГОСТ 9.403 п.2.4.6		 АД1 АЗ1 АД1 АЗ1 АД1 АЗ1 АД1 АЗ1 АД1 АЗ1 АД1 АЗ1

Примечание: Антикоррозионное покрытие «Zinga» наносилась кистью на зачищенную и обезжиренную растворителем «Zingasolv» поверхность. Толщина слоя покрытия составляла 40-50 мкм. Определение устойчивости покрытия к воздействию температуры и повышенной влажности и прочности сцепления с арматурой производились на бетонных образцах-призмах согласно рисунка пр.1. Диаметр арматурного стержня 16 мм. Состав бетона для определения прочности сцепления и устойчивости к воздействию температуры и влажности: цемент М 500 Д 0 – 350 кг, щебень – 1130 кг, песок 820 кг, вода – 170 л. Режим тепловой обработки – 2+3+16+3. Температура экзотермического прогрева 95 °С, влажность 95 %. Прочность сцепления бетона с арматурой определялась после пропаривания и в возрасте 28 суток нормально-влажностного твердения. После определения прочности сцепления арматурные стержни извлекались из бетона и осматривались. Оценивалось состояние антикоррозионного покрытия и поверхности металла.

ЗАКЛЮЧЕНИЕ: Толщина пленки антикоррозионного покрытия «Zinga» нанесенного в один слой составляет 21 мкм. Прочность покрытия при ударе более 50 см. Твердость по маятниковому прибору М-3 – 0,41 ед. Адгезия соответствует баллу 1. Устойчивость покрытия к воздействию климатических факторов составляет более 75 циклов попеременного замораживания и оттаивания без снижения адгезии и изменения декоративных и защитных свойств. Контроль защитных свойств покрытия удовлетворяет требованиям ГОСТ 9.302 п.6. Антикоррозионное покрытие устойчиво к воздействию температуры и влажности при испытании в бетоне. Потеря прочности сцепления обработанной антикоррозионным покрытием «Zinga» арматуры составляет 1,7 % и 4,0 % для арматуры периодического профиля, 3,9 % и 4,0 % для гладкой арматуры после пропаривания и после нормально-влажностного твердения в течении 28 суток. Снижение прочности сцепления на 4,0 % является незначительным, и находится в пределах допустимой погрешности измерений.

М. н. с. ОНИЛ МБ Р.Ф. Осос

Белорусская государственная политехническая академия
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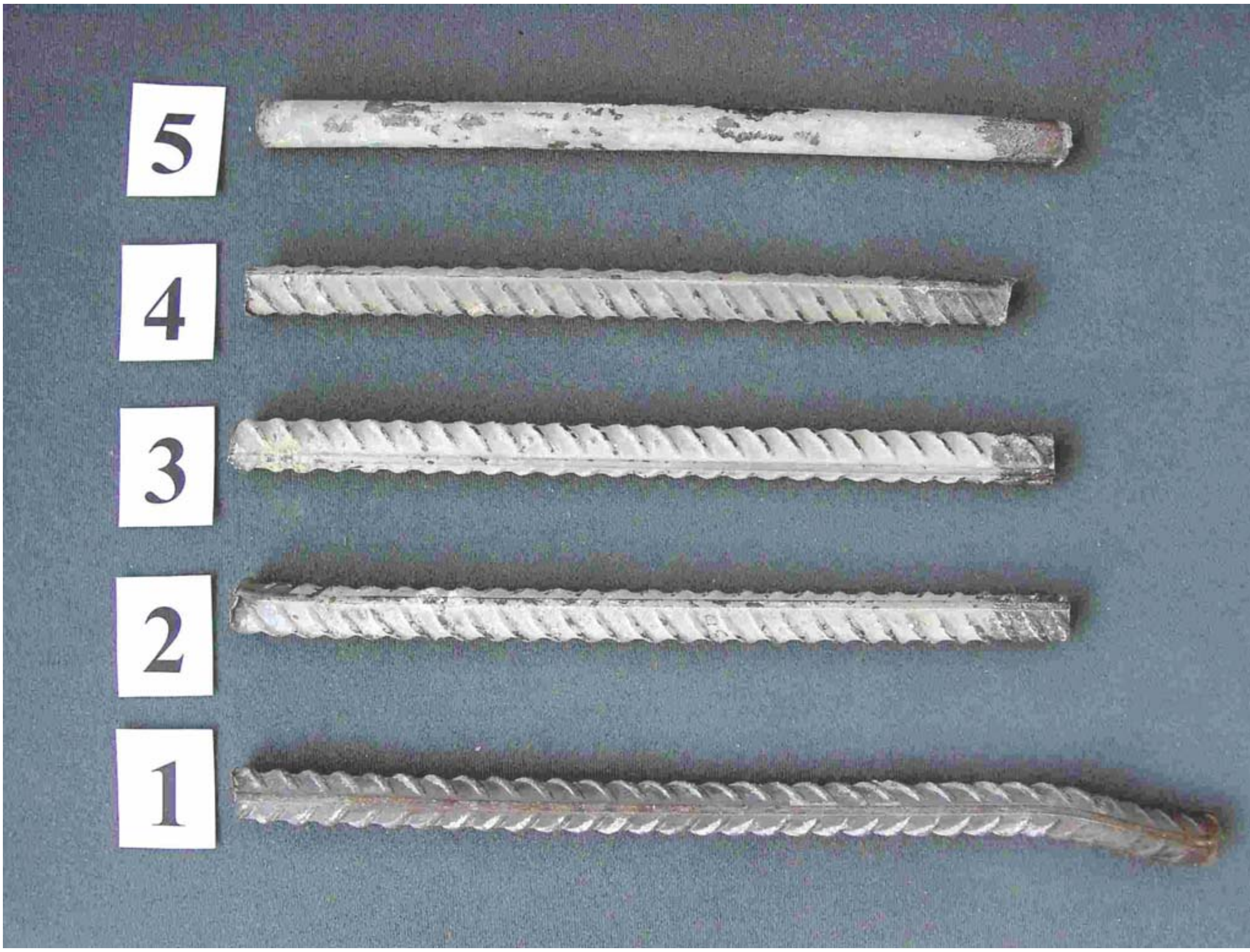
5
4
3
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1

National Research and Scientific Laboratory for Modified Concrete

Zinga on reinforcing structures in concrete

Report nr. 378/02 dated 28/06/02

Concerning the application of Zinga on reinforcing structures in concrete, we are glad to inform you that all testing results are positive and correspond to the required national standards.

№	Quality specification	Testing procedure regulations	Actual test results
1	One layer thickness of the coating applied by brush, µm	GOST 51694	21 µm
2	Impact resistance, cm	GOST 4765	50 cm
3	Film hardness measured with pendulum device M-3, conv. units	GOST 5233	0.41 units
4	Adhesion test per cross-cut between coating and steel surface, pts	GOST 15140	1 pts
5	Bond strength between concrete and steel, kN: 1. After steaming 1.1 samples with Zinga coated bars: - plain bars - knurled bars 1.2 testing samples with uncoated bars: - plain bars - knurled bars 2. After 28 days of concrete maturing under normal humidity conditions 2.1 samples with Zinga coated bars: - plain bars - knurled bars 2.2 testing samples with uncoated bars: - plain bars - knurled bars	Testing procedure of the National Research and Scientific Laboratory for Modified Concrete	 40.5 kN 94.6 kN 42.1 kN 96.2 kN 50.2 kN 117.6 kN 52.2 kN 122.3 kN
	3. Reduction of bond strength between concrete and steel due to the coating and after steaming, % - plain bars - knurled bars 4. Reduction of bond strength between concrete and steel after concrete maturing under normal humidity, % - plain bars - knurled bars		 3.9 % 1.7 % 4.0 % 4.0 %

6	Protective features of the coating (solution index – 37, endurance time – 0.5 min, for zinc solution the colour of the drop should not be changed to black)	GOST 9.302 p.6 table 12	the drop colour is blue
7	Coating stability under weathering factors (from +70°C to -30°C), cycles	GOST 9/401	75 cycles
8	1. The resistance of coated and concrete embedded reinforcement to temperature (+95°C) and high humidity (90-96%) (hydrothermal treatment of reinforced concrete)		No steel corrosion, homogeneity or continuity disturbances are observed
	2. Adhesion between the coating and reinforcement after hydrothermal treatment, pts	Testing procedure of the National research and Scientific laboratory for Modified Concrete	1 pts
9	Coating resistance to highly corrosive environment, hrs - 3% solution of NaCl (pH = 6.95) - 1% solution of NaOH (pH = 9.88) - 5% solution of Na_2SO_4 (pH = 7.44) - petroleum oil - petroleum - sulphuric acid solution with pH=6.0; pH=5.5; pH=4.5; pH=3.5	GOST 9.403 p.2.4.6	 48 hrs 48 hrs 48 hrs 48 hrs 48 hrs 48 hrs

Notice:

Anti-corrosive product Zinga was applied by brush on a degreased and treated surface. The coating thickness was 40-50 µm. The testing procedure for temperature and humidity resistance of the coating and for the adhesion with the reinforcing bars was conducted on concrete sampling cubes. The diameter of a reinforcing bar was 16 mm. The composition of the concrete used for testing the bond strength as well as temperature and humidity resistance was the following: cement M500 DO : 350 kg, crushed stone : 1130 kg, sand : 820 kg, water : 170 l, heat treatment condition : 2+3+16+3. Exothermal heating temperature was 95°C, humidity : 95%. The bond strength between concrete and bars was tested after steaming and 28 days of concrete maturing under normal humidity.

Conclusions:

Impact resistance is over 50 cm. Hardness measured with pendulum device M-3 is 0.41 units. Adhesion corresponds to 1. Coating stability under weathering conditions was checked through 75 freezing/thawing cycles without reduction in adhesion or changing in appearance and protection properties. The testing results of protection properties of the coating meet the requirements of GOST 9.302p.6 (national standard). Anticorrosive coating is stable under the temperature and humidity conditions while being tested in concrete. The reduction of bond strength between concrete and Zinga-coated bars by 4% is not big and within the measuring allowances.