OVERVIEW MAIN TEST REPORTS ON ZINGA

To view the actual reports, please contact a Zingametall representative.

GALVANIC PROTECTION

ISO 12944 - COT*

ISO 12944-6: Paints and varnishes -- Corrosion protection of steel structures by protective paint systems

The ISO 12944 standard is intended to assist engineers and corrosion experts in adopting best practice in corrosion protection of structural steel with coatings at new construction and repairs. ISO12944 is progressively superseding regional standards to become a truly global benchmark in corrosion control

Different ZINGA systems (see below) have been subjected to extensive testing such as water condensation test, neutral salt spray test, chemical resistance test and water immersion test. After a prescribed exposure test (depending on respresentative environment), the coating is assessed for adhesion, blistering, rusting, cracking and flaking.

Environments are classified according corrosivity from C1 to C5. Meaning:
- C1: Indoor, nutral atmosphere (classrooms, offices, ...)
- C2: Rural areas, low pollution (Rural buildings, traffic lights, ...)
- C3: Urban and industrial atmospheres, moderate sulphur dioxide levels, production areas with high humidity (City buildings, factories, sign posts, ...)
- C4: Industrial or coastal (with moderate salinity) zones (chemical factories, swimming pools, shipyards, ...)
- C5I: Industrial zones with high humidity and aggressive environment, continuous condensation and high pollution (heavy chemical factories, oil and gas facilities, ...)
- C5M: Coastal zones and marine zones with high salinity, continuous condensation and high pollution (Marine, offshore, estuaries, ...)

And three environments for structures in immersion:
- Im1: Clear, fresh or potable water
- Im2: Sea or brackish water (harbors with locks, jetties, offshore structures; make sure there is no stray current)
- Im3: Soil (underground storage, iron poles)

After exposure, the coating is evaluated as H(igh), M(edium) or L(ow); reflecting in a life expectancy of:
Low: Life expectancy less than 5 years
Medium: Life expectancy between 5 and 15 years
High: Life expectancy more than 15 years

Tested Zingametall sytems:

Systems with High Classification in C4 environment:
- ZINGA 2 x 60 µm DFT

Systems with High Classification in C5 environment:
- ZINGA 2 x 90 µm DFT
- ZINGA 1 x 60-80 µm DFT + Zingalufer 1 x 80 µm DFT
- ZINGA 1 x 60-80 µm DFT + Zingaceram HS 1 x 120 µm DFT
- ZINGA 1 x 60-80 µm DFT + Zingaceram HS 1 x 120 µm DFT + Zingaceram PU 1 x 60 µm DFT
- ZINGA 1 x 60-80 µm DFT + Zingaceram HS 1 x 120 µm DFT + Zingaceram EP 1 x 60 µm DFT

* COT bv. (Netherlands)

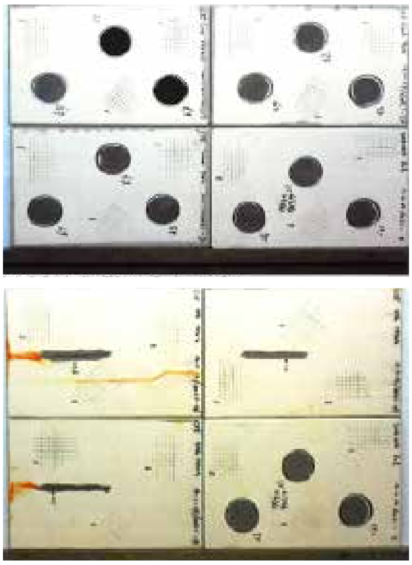
Systems with Medium Classification in Im2 and Im3:

- ZINGA 2 x 60 µm DFT
- ZINGA 2 x 90 µm DFT

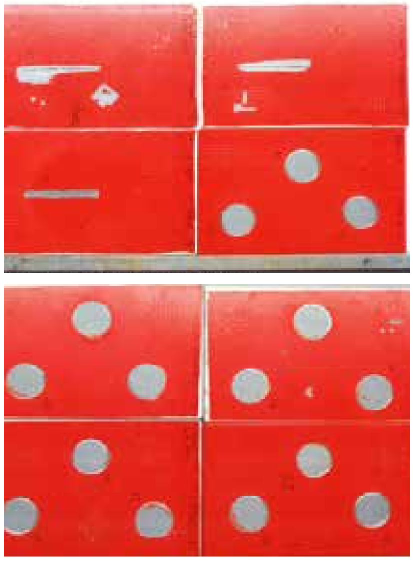
Systems with High Classification (Life expectancy > 15 years) in Im2 and Im3:

- ZINGA 1 x 60-80 µm DFT + Zingatarfree 2 x 100 µm DFT

ZINGA 2 x 90 µm DFT after 720 h condensation (above) and 1440 h salt spray (under)



ZINGA + Zingaceram HS + Zingaceram EP after 720 h condensation (above) and 1440 h salt spray (under)



ZINGA + Zingaceram HS + Zingaceram PU after 720 h condensation (above) and 1440 h salt spray (under)

ASTM B117 / ISO 9227 (SALT SPRAY TESTING) - COT / NCKU

ASTM B117: Standard practice for operating salt spray (fog) apparatus

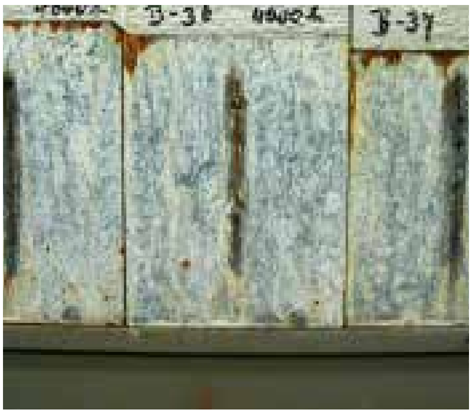
ISO 9227: Corrosion tests in artificial atmospheres -- Salt spray tests

ZINGA 120 µm DFT passed a 10.000 hours salt spray test (without scratch!) according ASTM B117 with 1% red rust on the surface.

ZINGA 180 µm DFT passed a 4200 hours salt spray test (with scratch, demanding higher galvanic protection) according ISO 9227 with 1-5% red rust on the surface.

ZINGA 2 x 90 µm DFT after 2000 h salt spray

ZINGA 2 x 90 µm DFT after 3000 h salt spray



ZINGA 2 x 90 µm DFT after 4000 h salt spray

NORSOK M-501 / ISO 20340 - COT

NORSOK M-501: Surface preparation and protective coating
ISO 20340: Paints and varnishes -- Performance requirements for protective paint systems for offshore and related structures

NORSOK M-501 is an industry standard for adequate surface preparation and use of coating materials, developed with the emergence of the Norwegian oil industry.
ISO 20340 deals with performance requirements for protective paint systems for offshore and related structures (i.e. those exposed to the offshore environment, as well as those immersed in sea or brackish water).

ZINGA has passed the 4200 hours seawater immersion test and the 4200 hours cyclic test without any formation of rust, blisters, cracks, flakes or cathodic disbondment. The pull-off adhesion test on ZINGA resulted in values of more than 7 MPa.

IMO MSC.215 (82) (BALLAST TANK TEST) - DNV*

IMO MSC.215 (82): performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers

ZINGA was applied on blast-cleaned test panels that were placed in a ballast tank filled with sea water with wave movement and cyclic heating. Other test panels were placed in a condensation chamber.
No corrosion of the steel substrate could be demonstrated. Based on the results of the testing, ZINGA meets the requirements of a B3 classification - due to insufficient adhesion (but this poses no threat to ZINGA, whereas paints rely on this to perform). In the report is stated that ZINGA has a beneficial corrosion protective performance. For B1 classification, we refer to ZINGA BT.

ZINGA 2 x 60 µm DFT after 180 days in a condensation chamber (left) or a wave tank (right)

BS3900-F10 (CATHODIC DISBONDMENT TEST) - BODYCOTE*

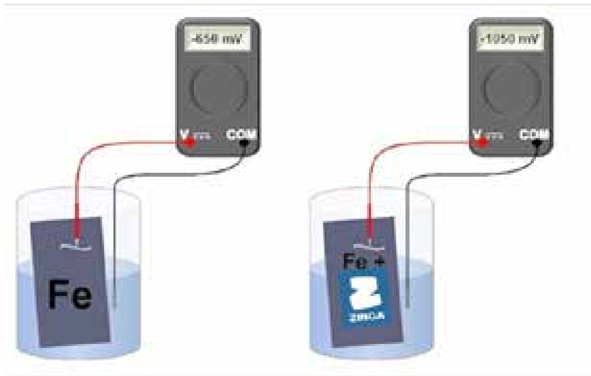
BS3900-F10: Methods of test for paints. Determination of resistance to cathodic disbonding of coatings for use in marine environments

ZINGA applied at 60 and 100 µm DFT was exposed during 26 weeks at -1,0 volt. The results was no cathodic disbondment at all.

* DNV - Det Norske Veritas (Norway) / Bodycote (UK)

ELECTRO-POTENTIAL MEASUREMENTS - COT

The sample ZINGA has been applied on sandblasted steel test panels of the specified quality. The test panels were partially immersed in 1.5% NaCl electrolyte at 23°C.
After 24 h immersion, the electrical potential of the panels has been determined, using a Standard Silverchloride Electrode (Ag/AgCl) as reference Electrode. Reported averaged measurements have been corrected for electrode drift and translated to SCE values.
The panels coated with ZINGA, have an averaged potential of -1110 mV (SCE); compared to -682 mV of blanc steel. The current density remains positive during the entire test, which indicates cathodic protetion by the coating.



ZINGA IN COMPARISON WITH HDG

ELECTRO-POTENTIAL MEASUREMENTS - UGENT / BNF*

In 2009, The University of Ghent (prof. dr. Defrancq) conducted several electrochemical tests to compare the galvanic protection of ZINGA to the established protection of Hot-Dip Galvanising. it was demonstrated that the short circuit flow of equal layer thicknesses of ZINGA and HDG have equal maximal current for an equal amount of time.
Therefore it is concluded that the electrochemical background of galvanic protection in ZINGA is equal to HDG.

In 1992, the renown research association BNF, performed extensive electrochemical testing on ZINGA and HDG.
In the experiment, the open circuit voltage and galvanic current between ZINGA and bare steel were measured over a range of area ratios. These results were compared with those from identical tests in which the ZINGA was replaced by hot-dipped galvanised steel.
The corrosion rate of the ZINGA coated specimens after 7 days exposure was 0.035mm/year, roughly 113 of the corrosion rate of galvanised steel panels under similar conditions (0.1 l mm/year). In the tests where the ZINGA coated and galvanised panels were coupled to mild steel samples, the potential of the coupled electrodes always remained below -800mV SCE, which showed that both ZINGA and galvanised steel offer good galvanic protection to the steel.

ASTM B117/ISO 9227 (SALT SPRAY TESTING) - SABS*

In this test is demonstrated that the loss in weight of ZINGA is 1/10 of the loss in weight of hot-dip galvanising after a 400 hours salt spray test. The layer thickness of ZINGA diminishes because ZINGA is being consumed, contrary to a paint that will start to peel off after a certain period of time. This illustrates the fundamental difference between a paint and a galvanising system.

* BNF - British Non-Ferrous Metals Research Association (UK) / SABS - South African Bureau of Standards (South-Afrioa)

FIELD TEST - SERVICE MARITIME DE LA VENDÉE

Two buoys (one treated with ZINGA, the other one hot-dip galvanised) have floated in the Atlantic
Ocean for four years. After those four years, the buoy treated with ZINGA showed no trace of rust
while the hot-dip galvanised buoy was severely corroded in several places.

Left: Buoy treated with ZINGA + topcoat

Right: Buoy treated with HDG + topcoat

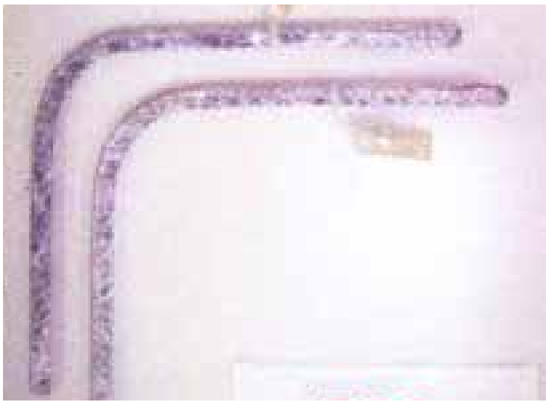
ZINGA ON REBARS

ASTM B117 / ISO 9227 (SALT SPRAY TESTING) - SAI / JU / AUPTT*

Steel Authority of India (2006):
A comparison was made between uncoated steel rebars, fusion bonded epoxy coated rebars (FBEC), hot-dip galvanised rebars (HDG) and zinganised rebars (ZINGA). The corrosion rate per year was measured after immersion and salt spray. This test demonstrated several advantages of ZINGA: the greater degree of galvanic protection, the lower sacrificial zinc consumption due to the dispersion of zinc dust in the binder and the additional barrier protection created by the binder.
ZINGA > FBEC > HDG > Uncoated

Jadavpur University (2006):
A comparison was made between uncoated steel (Mild steel and Stainless steel) rebars, fusion bonded epoxy coated rebars (FBEC), hot-dip galvanised rebars (HDG) and zinganised rebars (ZINGA). The salt spray test pointed out that the zinganised rebars have a corrosion resistance that is about 2 times higher than that of hot-dip galvanised rebars. ZINGA is also least susceptible for stress corrosion cracking.
in NACE solution: ZINGA > HDG > FBEC > Stainless steel > Mild steel

Amirkabir University Poly Technic Tehran (2008):
The zinganised rebars passed the 500 hours salt spray test without formation of rust, peeling or blistering, not even in places where the coating was mechanically damaged. The rebars that were not zinganised were heavily corroded.



* SAI - Steel Authority of India (India) / JU - Jadavpur University (India) / Amirkabir University Poly Technic Tehran (Iran)

ISO 1519 (BEND TEST) - COT

ISO 1519: Paints and varnishes -- Bend test (cylindrical mandrel)

ZINGA has been applied at a layer thickness of 60 µm DFT on test panels and bent by a mandrel tester at 23°C and 50% RV. The diameter of the mandrels are 32 mm, 25 mm, 20 mm, 16 mm, 13 mm, 12 mm, 10 mm, 8 mm, 6 mm, 5 mm, 4 mm, 3 mm and 2 mm.
Immediately after bending, the coating has been examined under good illumination with normal corrected vision.

ZINGA showed no cracks when bending on a cylindrical mandrel with a diameter of 12 mm.

RILEM / CEB / FIP RC6 (PULL OUT TEST) - UGENT

RILEM/CEM/FIP Recommendation RC6-1978: Technical Recommendations for the Testing and Use of Construction Materials: Bond test reinforcing steel - 2. Pull-out test

Three rebars with enhanced adhercnce L = 1000 mm; ø =18 mm were tested.
- 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 subsequenty. after 72 hours of drying time, embedded in concrete.

The rebars were embedded in the center of concrete cubes and 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.
After 28 days cure, the pull-out test was performed.

An average adhesion force for ZINGA on rebars of 17.03 N/mm was found. This was comparable to the uncoated rebars (18.90 N/mm).
It was concluded by Prof. Dr. Eng. Defrancq that the adhesion to concrete of rebars coated with ZINGA is not advesely affected compared to the adhesion of non coated rebars.

CLEAVE ADHESION TEST - B-HOLDING*

A custom test was designed to test the adhesion of (zinganised) rebars to the concrete. A rebar coated with ZINGA, an untreated and a sandblasted rebar were imbedded in concrete.
The rebars were aged using SO_2 (Kesternich).

The concrete was cleaved, in order to set free the steel reinforcement.

Conclusion:
It is clearly more difficult to cleave the rebar bloc containing the steel rod protected with ZINGA. The adherence of the concrete to the Zinganised rod is better. The actual cleavage happens in the concrete (in contrast to the other two rebars, which cleaved neatly between steel and concrete), which indicates a strong adherence.

* B-Holding (Belgium)

(NON) TOXICITY OF ZINGA

AS/NZS 4020 (CONTACT WITH DRINKING WATER TEST) - AWQC*

AS/NZS 4020 (2005): Testing of products for use in contact with drinking water

ZINGA was put through extensive testing by the Australian Water Quality Centre.
The water in contact with ZINGA was tested on taste (1000 mm^2/L) and appearance (15000 mm^2/L), on growth of aquatic micro-organisms (6300 mm^2/L), cytotoxic and mutagenic activity (15000 mm^2/L) and an analysis of a metal extraction (15000 mm^2/L) was performed.

The results demonstrate compliance to AS/NZS 4020 for ZINGA.

BS 6920 (CONTACT WITH DRINKING WATER TEST) - WRAS*

BS 6920: Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water.

Even though ZINGA is a metallic coating, it was tested according to the standard BS 6920 to determine whether or not the quality of potable water is affected when it is in contact with a ZINGA layer.

The water was analysed on taste, appearance, growth of micro organisms, extraction of harmful substances and extraction of metals. The obtained results complied with the requirements and ZINGA was found suitable for contact with potable water.

Since its review in 2008, ZINGA could no longer be tested according this standard excluding al metallic coatings.

ZINGA RELIQUIFICATION

MICROSCOPIC ANALYSIS - UGENT

A custom test was designed to demonstrate that a newly applied ZINGA layer makes the former layer liquid again so that both layers blend together to one single homogeneous layer. The new layer recharges the old one.

A thin copper film layer was applied on top of ZINGA and photographed. Afterwards, a second layer of ZINGA was applied an the layer was photographed again. The same procedure was repeated with a zinc rich coating.

The first picture shows dispersion of the copper layer through the blended ZINGA layer, while the second depicts two separated layers with the copper layer in between.

The ZINGA film galvanising system is very easy to maintain and to recharge: there is no need for gritblasting, contrary to the surface preparation that is required when a traditional paint has been used.

Copper particles on top of ZINGA

Copper particles blend in two layers of ZINGA

Copper particles in between the two layers of epoxy paint

* AWQC - Australian Water Quality Centre (Australia) / WRAS - Water Regulations Advisory Scheme (UK)

MACROSCOPIC ANALYSIS - STANGERS

Dried "caked" ZINGA was reliquidised using new ZINGA on different plates, brushes and different times of drying.
It was found that "ZINGA is easy to apply by brush and resoftens caked ZINGA or dry ZINGA films as claimed by the manufacturer. This property enables ZINGA to be built up into thick composite layers avoiding the discrete films achieved with conventional coatings."

End conclusion: "It is evident that the product has special properties which place it, as far as we know, into a unique category."

SURFACE SPREAD OF FLAMES OF ZINGA

EN 13501-1 (FIRE TEST) - EFECTIS

EN 13501-1 (2007) + A1 (2009): Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests

Determination of the ignitability properties of the product, by direct small flame impingement according to EN ISO 11925-2:2010, with the objective to obtain the reaction to fire classification according to EN 13501-1:2007+A1:2009.

Determination of the reaction to fire properties of the product, when exposed to the termal attack by a single burning item according to EN 13823:201, with the objective to obtain the reaction to fire classification according to EN 13501-1:2007+A1:2009.

A total of twelve single ignitability tests were carried out according to EN ISO 11925-2.

A total of three single burning item tests were carried out according to EN 13823.

ZINGA 2 x 90 µm DFT Reaction to fire classification: **B - s1, d0**

BS 476-6 (FIRE TEST) - SGS YARSLEY TECHNICAL SERVICES

BS 476-6: Fire Tests on Building materials and structures – Method of test for fire propagation for products

This Part of BS 476 specifies a method of test, the result being expressed as a fire propagation index, that provides a comparative measure of the contribution to the growth of fire made by an essentially flat material, composite or assembly. It is primarily intended for the assessment of the performance of internal wall and ceiling linings.

The results of the test according to the BS 476: part 6 show that ZINGA has a class 0 surface. ZINGA did not ignite during exposure to heating.

FRICTION COEFFICIENT OF ZINGA

GB 50017-2003 & GB 50205-2001 (ANTI-SLIP COEFFICIENT) - CNCSQSTC*

GB 50017-2003 Code for design of steel structures
GB 50205-2001 Code for Acceptance of Construction Quality of Steel Structures

In Octobre 2005, ZINGA coated plates have been tested according GB 50017 and GB 50205 to assess the slip friction coefficient (μ) of high strength bolts adjoining steel sections.

The results demonstrate that ZINGA coated surfaces of high strenght bolts have increased friction (compared to bare steel or galvanised steel) with results of μ between 0.5 and 0.7. This is beneficial for construction.

ASTM A325 & A490 (ANTI-SLIP COEFFICIENT) - KTA TATOR*

ASTM A490: Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
ASTM A325: Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

Plates coated with 100 μm DFT of ZINGA, were loaded onto a horizontal rod, based on contact surfaces having similar coating thickness. A clamping force of 49 kips (= 218 kN) was applied to the test assembly, then a compressive load was applied to the machined edge of the middle plate at a rate no-to-exceed 25 kips/minute, to induce a slip. The slip load for each test assembly is divided by two times the clamping force to obtain the slip coefficient.

ZINGA exhibited a slip coefficient of 0.52 and passed the 1,000 hour Creep Deformation test. ZINGA is therefore certified class B.

WELDING OF ZINGA

WELDING TEST - UGENT

A set of 3 x 2 plates, covered with a layer of ZINGA, the thickness of which was respectively 15 μm DFT, 40 μm DFT and 60 μm DFT. After a polymerisation period of seven days the two plates covered with the same coating thickness were welded together by hand.

None of the 3 specimens shows any deficiency, neither in the welding seams nor in the steel itself.

WELDING TRIALS - TATA STEEL*

Before their use of ZINGA on rail tracks, TATA Steel investigated not only the performance of the coating, but also its weldability.
On trials, they performed weld trials with ZINGA coated tracks and found that the process was not negatively affected by the coating. No localised melting of the zinc based coating had occurred and there was no evidence of die burns or pick up in either the rails or the copper dies.

The four foot length was subsequently bend tested and despite the apparent slippage broke at 1430 kN. This comfortably passed the Network Rail specification minimum of 1220 kN. The grab marks induced by the compressional strength of 1.5 tons, required to hold the rail-track ends together during the welding operation illustrate how ZINGA was crushed into the metal during this phase.

* China National Construction Steel Quality Supervision and Test Center (China) / KTA Tator (USA) / TATA Steel (World wide)