I. 2.1 RHEINZINK® AS A MATERIAL/GENERAL

I. 2.1.1 History

Although the Babylonians and Assyrians knew of zinc as an alloying component of brass, zinc as a metal was only introduced in the 17th and 18th centuries. According to a publication dated 1637, the Chinese were first to succeed in obtaining metallic zinc by means of smelting. By 1720, zinc was produced on a fairly large scale in Swansea, Wales, probably based on the oriental technique. In 1743, William Champion built the first zinc smelter in Bristol, England, producing about 200 tonnes of zinc a year. Other smelters appeared in Upper Silesia and in the Aachen-Lüttich area.

The earliest use of zinc was as a constituent alloy of brass and, after its rollability was discovered (see below), as rolled sheet metal for construction applications, such as roofing, eavestroughs, downspouts and other components. Evidence of this exists in numerous technical manuals dealing primarily with application techniques for smooth sheet metal and the detailing of joints. Another use was in ornamental metalwork (see Part III. 6.4). Fig. 1 shows an example of this application by the highly respected architect Karl Friedrich Schinkel (1781-1841). Zinc casting was already common by then.

Fig. 1: 19th century ornamental metalwork at Glienicke Palace in Berlin, Germany.

In 1805 it was discovered that zinc could be rolled at temperatures of 100° to 150° C. The first zinc rolling mill was established in Belgium. In 1821, several rolling mills followed in Silesia. The rolling technique customary then, and used until the 1960s in Western Europe, was the pack-rolling method (see Fig. 2), which is still used in some parts of Eastern Europe. The only products of this rolling method were sheets, usually in a standard format of 1 x 2 m. The thicknesses were stated in numbers (such as zinc No. 14 0.7 mm), which indicated the approximate thickness of a sheet, making the considerable thickness tolerances less obvious.

In the course of technological development, the purity of the base material reached 98.5%, yet its qualities were not nearly as high as those of today's material. Thus, pack-rolled zinc could not be

Fig. 2: The pack-rolling process for sheet metal was used until the 1960s in Central Europe and is still used in some parts of Eastern Europe.

folded parallel to the direction in which it had been rolled. It had no fatigue strength and its coefficient of expansion was 0.036 mm/1.0 m · 1 K, to name only a few of its shortcomings.

Since these material properties no longer met market requirements in Western Europe, this rolling technique and the associated material technology were replaced in Germany in the mid 1960s by the RHEINZINK process and the material called RHEINZINK® (see Part I. 2.2).

I. 2.1.2 General environmental relevance/AUB Certificate

Our greater awareness of health issues, and the increasing number of illnesses whose causes and treatment are unknown, have justifiably increased our sensitivity to environmental concerns. The careless sins of past and present are being relentlessly revealed. Thanks to improvements in analytical methods, the tolerance limits of individual substances have dropped greatly, which in turn has contributed to increasing our environmental sensitivities. Understandably it is becoming more and more difficult to evaluate substances in absolute and quantitative terms. Environmentally, this leads to uncertainties and sometimes to over reactions.

For reasons of clarity, substances are divided into groups, generally according to common properties, such as the group of heavy metals (see Fig. 3), which includes all metals whose specific weight is more than 5.0 g/cm³. As far as iron and zinc are concerned, it would be wrong to conclude that all heavy metals are toxic, since specific weight has nothing to do with environmental impact.

Light	Moderate	Severe
reduction in number of sperm cells	retarded growth	skin infection
weight loss	under developed testicles	hair loss
	changes in the skin	diarrhea
	loss of appetite	mental disorder
	mental apathy	infections
	impaired healing of wounds	
	deviations in sense of taste	
	problems in adapting to the dark	

Table 1: Symptoms of zinc deficiency according to Prof. Hans-Jürgen Hapke.

Environmental relevance
It is not possible to apply evaluation criteria to all substances alike in terms of their effect on animal and plant life. Firstly it is necessary to draw a distinction between humans, animals and plants, and eventually also between species. It can be said that in all of the above cases, zinc is essential, a vital trace element. In terms of organic life, zinc is second only in importance to iron.

As stated, most life processes in the cells of the human body are controlled by enzymes. For many enzymes, zinc, as a controlling ingredient, participates in the activity of the nucleus, since it activates the enzymes controlling nuclear division and cell multiplication.

The importance of zinc can best be illustrated by a list of symptoms caused by zinc deficiency (see Table 1). Deficiency symptoms, which have been observed all over the world, are almost exclusively diet-related. The daily zinc intake recommended by the German Society for Nutrition is between 10 and 20 mg. Table 3 (page 24) provides an overview of the zinc content in foods. For example, it takes 150 g of rolled oats, one of the foods with the highest zinc content, to meet our daily zinc requirement. This is the equivalent of about 30 tablespoons.

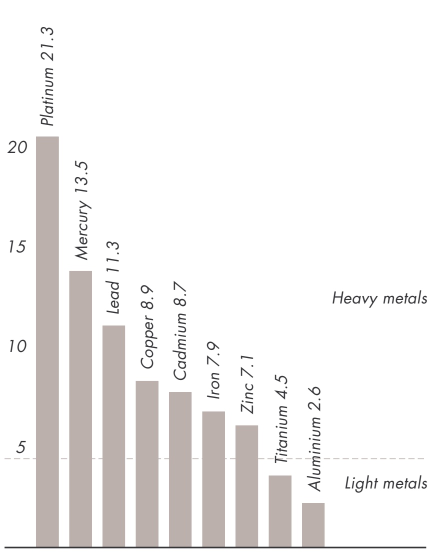


Fig. 3: Division of metals into heavy and light metals by their specific weights.

Meat		Fruit	
Beef	25 – 50	Berries	1 – 2
Poultry	up to 29	Citrus fruit	1 – 12
Oysters	100 – 400	Cherries	1 – 22
Milk products, eggs		**Vegetables**	
Butter	1 – 3	Spinach	2 – 11
Whole milk	3 – 6	Lettuce	2 – 11
Eggs	8 – 20	Cabbage	2 – 15
Cheese	10 – 90	Pulses	10 – 90
Feeds (dry matter)		**Grain products**	
Grain	30 – 60	White products	1 – 8
Grass silage	30 – 70	Whole-grain bread	5 – 17
Hay	20 – 50	Rye bread	up to 22
Commercial feed	60 – 250	Rolled oats	70 – 140

Table 2: Zinc content in foodstuffs (mg/kg fresh weight)

Fig. 4: In plants, zinc deficiency can lead to symptoms such as yellowing (chlorosis) of the leaves.

Humans have to absorb zinc on a regular basis, since the human organism does not accumulate it in sufficient amounts. This characteristic is utilized in therapeutics, where zinc is used to remove accumulated heavy metals such as lead or cadmium from the human body. Medical history relates no cases of a chronic over-supply of zinc.

In general, what applies to humans also applies to animals. The difference is that the daily requirement in cattle, for example, is 50 mg/kg of dry feed in the total ration; in piglets the requirement is as high as 80-100 mg/kg. Therefore, in certain cases, the German Feed Products Regulations prescribe a mandatory minimum zinc content. In animals, an adequate zinc supply can also provide partial protection against the detrimental effects of environmental contamination by cadmium, a toxic heavy metal. The most obvious manifestations of zinc deficiency are a general decline in metabolic activities and reduced feed intake.

An acute overdose is registered only in the rare cases when zinc exceeds more than 10 times the normal requirement; even then it does not lead to symptoms of poisoning, but rather to an impairment of other absorption processes.

Plants, too, cannot thrive if their zinc level is too low, although their requirement and tolerance levels have a wider range. Table 6 illustrates this. Plants prefer to absorb zinc in the form of ions (see table 3).

Zinc deficiency in plants manifests itself in the yellowing (chlorosis) of the leaves between the veins (see Fig. 4), in smaller leaf size, insufficient foliation, or the rosetting of leaves at the shoot terminal. It must be taken into account, however, that such symptoms can also have other causes.

Harm due to an excess of zinc is very rare and has so far been registered only on sites with extremely high zinc contents, such as mine dumps. Such damage may manifest itself primarily in the form of iron deficiency, since excessive zinc concentrations in soil can block the metabolism of iron.

Fig. 5: Example of a "grey water" utilization system: "House in the Vineyard" community centre in Markdorf, Germany.

Susceptible	Less susceptible	Not susceptible
Citrus trees	Cotton	Peas
Deciduous trees	Potatoes	Small-grained
		cereals
Pecan trees	Tomatoes	Peppermint
Pines (Australia)	Alfalfa	Asparagus
Grapes	Clover (Trifolium spp.)	Mustard and other
		crucifera
Beans	Millet	Forage grasses
(Phaseolus vulgaris)	Sudan grass	Safflower
Soybeans	Sugar beets	Carrots
Hops		
Corn (maize)		
Lima beans		
Flax		
Castor-oil seeds		
Onions		

Table 3: Susceptibility of plants to zinc deficiency (according to VIETS, F.G.Jr., 1966).

Certified as an environmentally friendly product
In addition to the quality assurance of the product, RHEINZINK®-Titanium Zinc Made in Germany was certified by the Working Group for Environmentally Friendly Building Products [Arbeitsgemeinschaft umweltverträgliches Bauprodukt e.V. (AUB)] in August 1999. This organization promotes the production and utilization of environmentally-friendly building materials, which do not pose any health risks. This official certificate confirms that RHEINZINK® is an extremely environmentally-friendly product, which does not pose any health risks.

This assessment is based on a detailed description of the material, its behaviour in various building phases and, in particular, content disclosure. In so doing, the AUB guidelines are compliant with the fundamental document entitled "Hygiene, Health and Environmental Protection". Insofar as the Working Group deems it reasonable, higher than normal national and international standards apply.

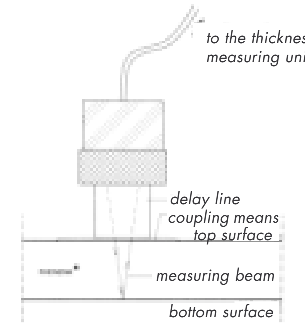
RHEINZINK® is classified as an example of ecological balance. Following extensive tests, the Assessment Committee was able to determine that all of the requirements to be taken into account had been met: from extraction of the raw material to processing, use of the latest production equipment, to up to 90% recyclability. The greatest possible environmental protection is guaranteed in the entire life cycle.

Utilization of rainwater – biodegradability of roll emulsion water
The roll emulsion used during RHEINZINK®-production was tested for biodegradability according to the OECD guidelines, by the Fresenius Institute in Taunusstein, Germany. It was certified as "lightly biodegradable".
In view of increasing expenditures for the purification of drinking water, efforts are being made to increase the utilization of collected rain water run-off (see Fig. 5). As far as roofs are concerned, there is no doubt that the zinc ion content in rain water run-off does not in any way corrode in-house installations or lead to deposits. This has been confirmed in an expert's report of the Material Inspection Office (Materialprüfungsamt) in Dortmund.

Note regarding the overall evaluation
An evaluation of the environmental impact of materials must also include further aspects such as corrosion rates and life expectancy (see Part I. 2.1.3), primary energy content (see Part I. 2.1.4), recyclability and exhaustion of natural resources (see Part I. 2.1.5) and the release of chemically bonded substances or acids (such as hydrocarbonic acids) through the effect of weather, such as UV radiation, wind and rain. With respect to the latter it should be noted that the pH value of rain water running off roofs has been found to increase from 5.6 to a maximum of 6.7.

CERTIFIED BY THE **ASSOCIATION FOR ENVIRONMENTALLY PROOFED BUILDING PRODUCTS** NUMBER OF CERTIFICATE Z.RHE199

Fig. 1: Principle of non-destructive ultrasound thickness measuring tests.



I. 2.1.3 Corrosion rates and life expectancy

Corrosion rates of RHEINZINK® surfaces are of interest from both an ecological and an environmental point of view.

According to a survey conducted in 1987 by the Ecotec Institute in Munich, the atmospheric corrosion of exposed metal surfaces (both galvanized and solid zinc) contributed only 5.9% of the zinc contamination of sewage treatment plants in the state of Hesse. Nevertheless, considering the environmental sensitivities discussed in Part I. 2.1.2, there is considerable interest in a more scientific analysis.

Customers choosing RHEINZINK® and investing in a long-lasting, low maintenance asset, share this interest (albeit from a different point of view) when seeking to make an accurate evaluation of their investment.

RHEINZINK® has good atmospheric resistance. As with all materials, it is subject to a natural thinning through erosion and corrosion which determines its life expectancy. In this regard, RHEINZINK® should not be compared with galvanized steel plate that has an average zinc coating of 25 µm; nor should RHEINZINK® roof surfaces be compared with RHEINZINK® eavestroughs, since they are subject to completely different stresses (see below).

A: Roofs and curtain walls
A wide range of values can be found in literature devoted to the topic, most are the results of laboratory tests simulating the composition of air in different climates as well as in industrial and rural settings. These studies from the 50s and 60s were unable to take into account either the precipitation rates or the relationship to roof pitch. On the other hand, there are two methods for studying actual zinc removal rates in the field, which depend largely on the composition of air and rain (especially SO^2), rain intensity, pitch and orientation of surfaces. One is the non-destructive ultrasound thickness measuring test, the other is the quantitative determination of the zinc ions in the rain water run-off.

Ultrasound thickness measuring test
A set number of measuring points are separately defined, measured and statistically evaluated, by roof pitch and orientation (see Fig. 1 and 3). This process is repeated at regular intervals. The difference in thickness, relative to the time interval, is used to calculate the annual thickness removal rate.

RHEINZINK has employed this method since 1979 to conduct thickness measuring tests on various buildings with RHEINZINK® roofing and cladding. These took into account not only roof pitches ranging from flat to steep, but also substances present in alpine air and industrial air. For example, in the Ruhr region, a mean thickness removal rate of 4 µm/year was determined over a period of 14 years in roofs with a 3° pitch. At the same time, these marginal conditions were the most unfavourable because high SO_2 values prevailed; these have been reduced significantly due to environmental protection measures. In terms of the half-value thickness (= a thickness removal rate up to one half of the initial thickness of the material), these RHEINZINK® roofs have a minimum life expectancy of approximately 80 to 100 years.

Under favourable conditions, such as curtain walls in the alpine region, our findings indicate surface removal rates below 1 µm/year, these findings could only be determined over very long periods of time. The corresponding maximum life expectancy would be about 350 years. The studies were made available in 1991 for public and scientific use.

Fig.2: Thickness measurement with the ultrasound thickness measuring unit.

Zinc ion determination
A second method of determining atmospheric corrosion rates is accomplished by measuring the zinc ion content in rainwater run-off. In contrast to the above method, these tests can only be carried out In test labs. The University of Hannover, which cooperated with RHEINZINK to conduct the tests, erected model roof surfaces, each measuring 4.00 m², with varying pitches and orientations, but with otherwise identical conditions to field installations. All precipitation was collected in special containers. The quantities were measured and analyzed for their zinc ion content and pH value at intervals of two to four weeks (every 12 weeks in the second year of testing - see Table 1).

Since the formation of the patina (see Part I. 2.2.6) has a significant impact on the zinc ion release, and since the zinc ions released drop considerably as the patina develops, the zinc removal rates found in the first test interval (1991 - 1998; see Table 1) constitute a relative maximum. For an evaluation of zinc removal rates, see Part I. 2.1.2.

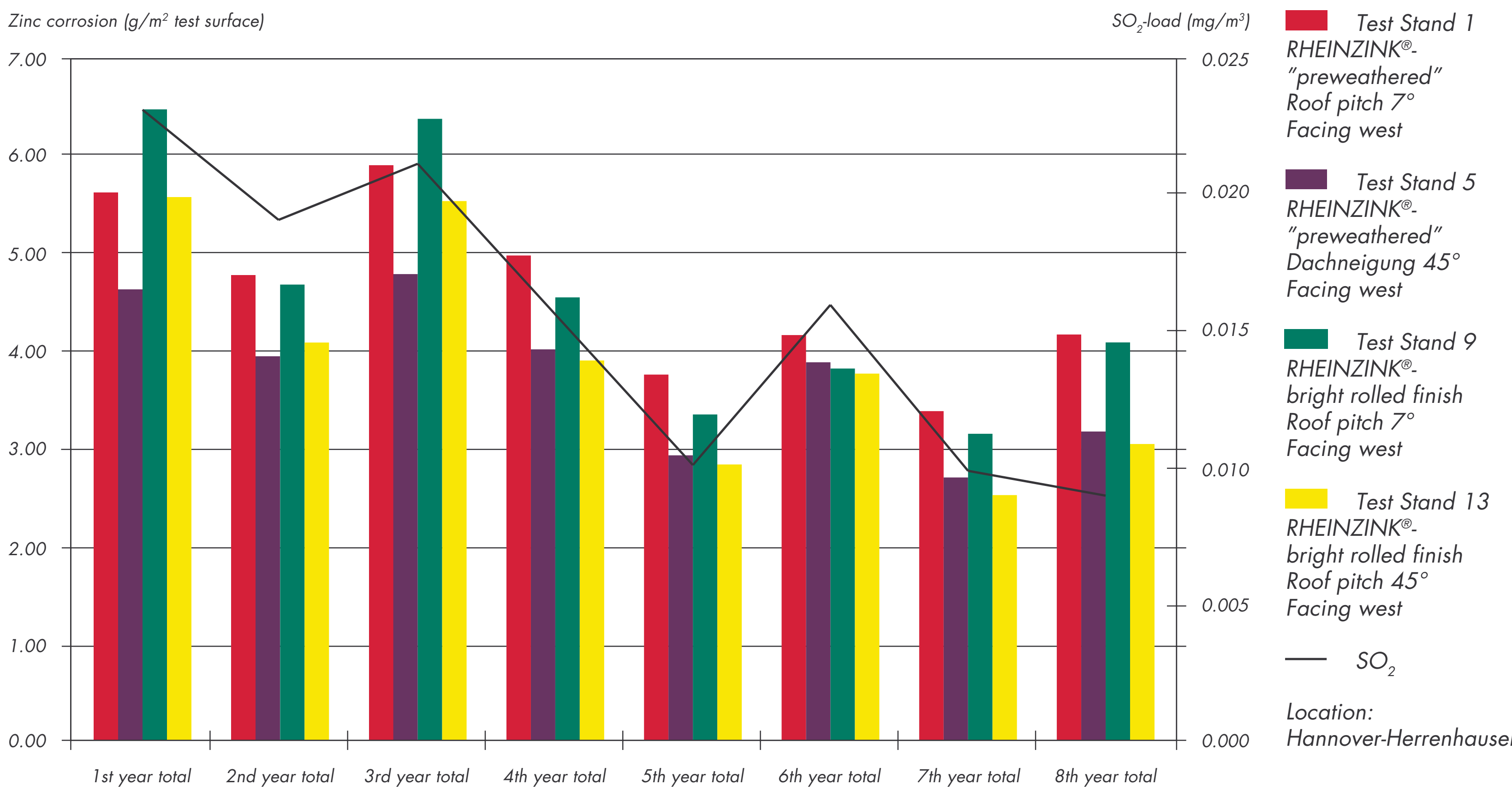


Table 1: Test results from the outdoor exposure unit at the University of Hannover using shiny and "preweathered" RHEINZINK® at a pitch of 7° and 45°. The varying amount of corrosion is primarily due to the SO_2- concentration of the environment, the various surface orientations and the intensity of precipitation (Reference: "METALL", 05/99).

B: Eavestroughs

Corrosion stress on eavestroughs and the resulting zinc removal cannot be compared with that of roof surfaces. The erosion/corrosion which occurs is the result not only of a direct stress from precipitation, but also from the pollutants which may or may not accumulate on the roofs above the eavestroughs.

Pollutants from rain water accumulate in porous roof materials as the result of evaporation processes. When the precipitation stress is slight, for example in the form of drizzle, dew or fog, these pollutants form a very concentrated solution which can affect the eavestrough in vulnerable areas ("deep beads", etc.); a "steady drip" will also contribute to a relatively shorter life expectancy.

Furthermore, in the case of relatively inert roofing materials, any sulphur concentration in rain water is drained via the eavestrough. This increases the removal rate accordingly.

In 1988, a field test by the Technical University of Düsseldorf indicated that the full surface of the eavestrough should not be included in calculating the removal, since only about 9% of the eavestrough surface comes in contact with rain water. In addition, this surface is usually covered with a protective layer of airborne sand and dirt. Therefore, an increased removal rate is usually found on the sides of eavesthroughs prone to isolated drip points. If a dripping area lies within the running portion of the eavestrough, there is very little increase in the removal rate.

I. 2.1.4 Primary energy content

The primary energy content of a substance is defined as the energy required for its production.
The need to conserve natural resources (see Part I. 2.1.5) is making consumers more and more aware of a product's primary energy content. In the final analysis, energy is also a resource.

Strips and sheets made of RHEINZINK®, have a primary energy content of 3610 kW hours per tonne. In comparison with other metals this value is extremely low, yet it includes all production steps necessary in manufacturing RHEINZINK® sheet metal:

- Ore production underground
- Preparation (reduction, floatation)
- Electrolysis (including roasting and leaching)
- Smelting (RHEINZINK)
- Rolling (RHEINZINK)
- Finishing (RHEINZINK)

Note
When comparing primary energy contents, especially in the case of metals, it must be ensured that these values relate to the same refining level (in this case to finished strips and sheets). Furthermore, the efficiency factor of the power station must be taken into account.

I. 2.1.5 Deposits and recycling

Geologically and geographically, zinc ores occur in large quantities all over the world. At present, the largest mining operations are in Australia, Canada and Peru. But other countries, such as the USA, Mexico, Ireland, Poland, Russia, Spain, Sweden, the former Yugoslavia, North Korea, China, Japan and Zaire are also world class zinc producers, followed by roughly another 20 countries. The vast majority of mining operations are underground.

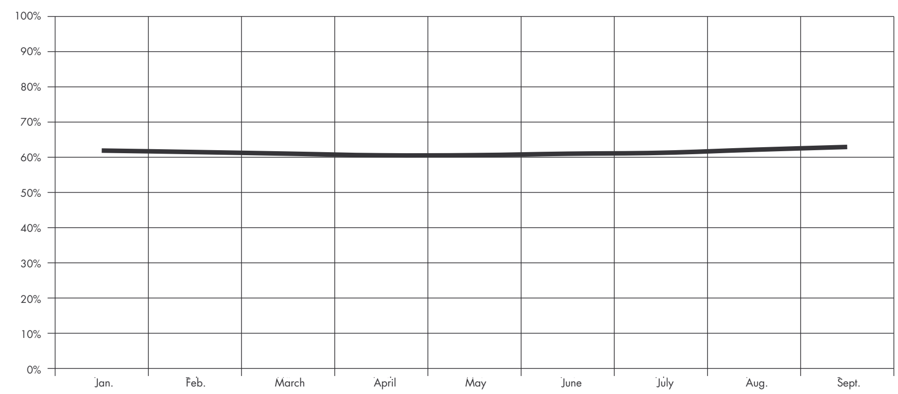


Fig. 1: The price of scrap zinc as a percentage of fine zinc price (Zn 99.995 % in 2000).

Many zinc deposits, including those in Central Europe, are already known, but are mined only when demand increases. In most cases, the entire potential yield is difficult to estimate and is only of interest to mining concerns as far as the immediate future where a foreseeable economic time frame is concerned. In addition, in many countries the potential yield is taken as a basis for taxation, which is another reason why zinc deposits available worldwide are considerably underestimated. This, in turn, results in misleading reports.

In practice, the implementation of recycling opportunities increases in relation to its economic feasibility. In the case of zinc sheets, recycling only requires an energy expenditure in the order of 5% of the primary energy content.

All scrap metal generated in the production of RHEINZINK® (see Part I. 2.28) is ultimately returned to the production process.

In Germany, the demand for scrap zinc sheet, available as a result of the low energy expenditure, is reflected in an average scrap price of about 55-60% of the fine zinc price. This economic incentive is high enough to motivate the zinc-sheet processing trades to recycle their scrap. We can therefore assume a recycling level of more than 90% in these circumstances.

Another important motive for recycling zinc is political and has to do with the desire to reduce dependence on foreign suppliers, since zinc production is concentrated in countries such as Australia, Canada and Peru, while the most important consumer countries, apart from the USA, are primarily the European Union and Japan.

I. 2.1.6 Response to weather conditions

Temperature, fires and UV

In general, RHEINZINK® is temperature-resistant, non-combustible, and UV-resistant. Its melting point is 418 °C, with a recrystallization limit (important for soldering; see Part I. 3.1.6) of about 300 °C.

Linear deformation due to heat must be taken into account as a factor in construction design (see Part I. 3.3). The temperature of RHEINZINK® affects the workability of the material (see Part I. 3.1.4). The material temperature can deviate greatly from the air temperature due to radiation (see below).

Tests conducted for RHEINZINK on the cupola roof of the information centre at the Hannover Trade Fair (which is clad in RHEINZINK®) showed material temperature fluctuations in daily and annual cycles, as well as in relation to the roof's pitch and its exposure to the sun (see graphs 1-3). The maximum material temperature measured over a period of two years (1989-1991) was 65 °C, and the minimum temperature was -14 °C, while the maximum value by which it fell below the air temperature was 6 K. There were more than five days per year that the material did not warm up to the air temperature level throughout the day.

Wind, rain, snow, rotting

No detrimental effects due to wind erosion have been reported in relation to RHEINZINK®. Rain and snow affect RHEINZINK® only to the extent of the minimum thickness removal described in Part I. 2.1.3. RHEINZINK® is also UV-resistant and rot-resistant.

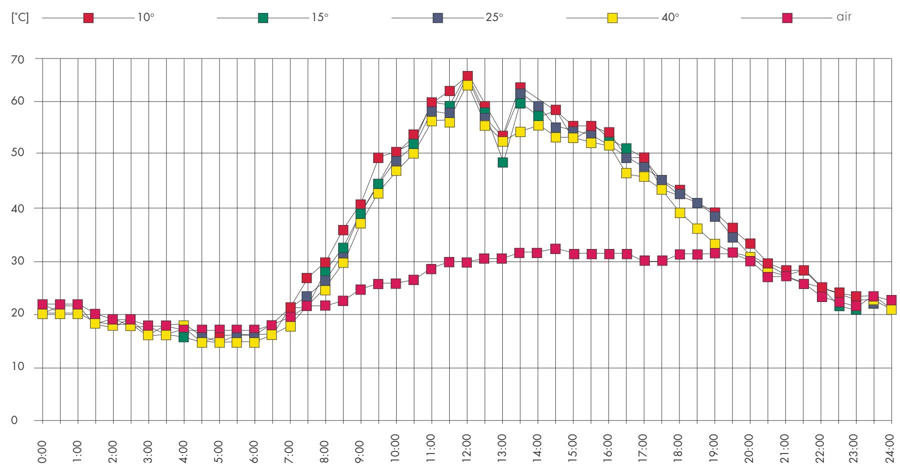


Fig. 1: Daily cycle: RHEINZINK® surface temperatures on a 25° roof pitch on a warm summer day.

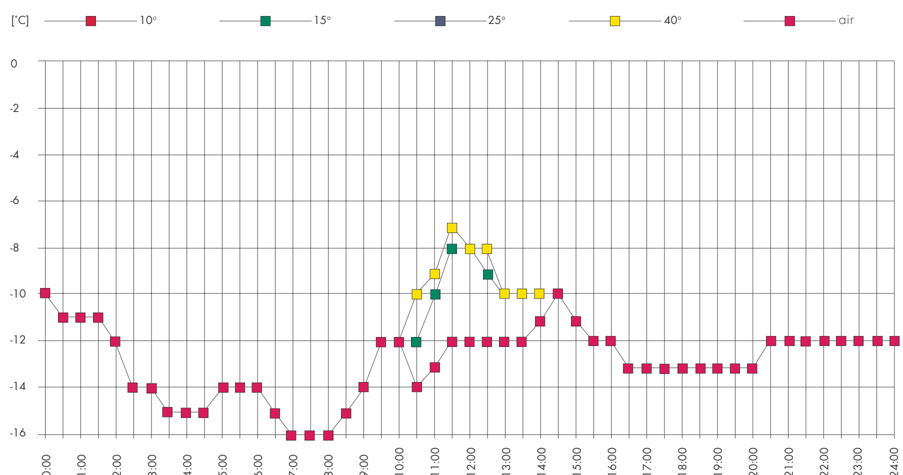


Fig. 2: Daily cycle: RHEINZINK® surface temperatures on a 25° roof pitch on a cold and cloudy winter day.

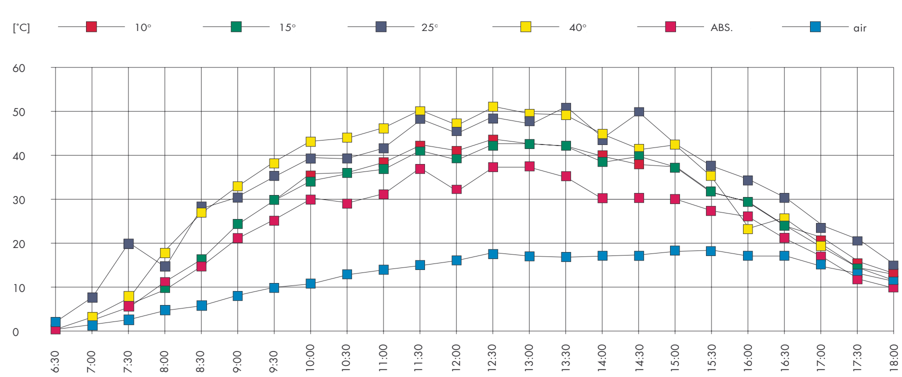


Fig. 3: Effect of the roof pitch on the material surface temperature on a fall day.

I. 2.1.7 Response to other influences

This chapter outlines RHEINZINK®´s response to a variety of known influences and offers recommendations for protective measures.

The following influences are discussed:

- Bitumen
- Sealants
- Iron oxide
- Oil Heating
- Paint coats
- Glass
- Wood
- Wood preservatives
- Perspiration
- Metals
- Mortar and concrete
- Cleaning agents
- Moisture without air
- Other influences

Bitumen

Under certain conditions (e. g. UV radiation), bitumen can cause zinc to corrode. This has been known for almost 60 years (Bibliography in VEDAG Yearbook 1936/R. Deis, pp. 123/135). Studies by Professor Witt in the 1980s ("Oxidationssäurenkorrosion durch Dachdeckungsbitumen" ["Reaction of bituminous roofing material to oxidation"] or "Verhalten bituminöser Werkstoffe unter UV-Bestrahlung" ["Behaviour of bituminous materials to UV radiation"]) and other publications have not only confirmed these findings, but extended them in a number of critical areas. RHEINZINK's intensive laboratory tests and practical experience have produced the same results.

These results have long been common knowledge and have already been incorporated into the technical rules for the sheet metal trade. The phenomenon of this type of corrosion can be explained as follows: UV radiation and weathering leads to bituminous waste products, which cause an acid reaction when dissolved in water. Even with small amounts of water, such as in fog, dew or drizzle, highly acid concentrations are formed which attack most metals.

If bitumen is installed without an effective radiation shield, e. g. a 5 cm layer of gravel, all metal parts, such as wall abutments, eaves flashings, eavestroughs, etc., must be protected and seperated from the bitumen with an impermeable material.

Sealants

Most sealants used in sheet metal work are single-component silicone systems which are subdivided into various subsystems. As far as their effect on RHEINZINK® metal is concerned, all systems with a neutral or alkaline reaction (pH 12) can be used without a problem. Systems with an acid reaction, such as acetate systems (ie. acetoxy or acetic acid systems) must not come in contact with RHEINZINK®, as they may cause corrosion.

Iron oxide

Rust streaking (a rust-brown discoloration) occurs when the surface coating of steel components no longer provides adequate protection due to the surface removal of the relatively thin zinc layer (the galvanization). This happens mostly at the unprotected cut edges of these components. In addition, rust discoloration may occur as the result of brake grit, especially in the vicinity of busy railway stations.

When the above-cited cases consist of pure iron oxide deposits, there is no risk of corrosion, and the defect is only visual.

Oil Heating

In some instances, where oil heating is used, discolouration was noticed around the chimney area on the roofs, RHEINZINK®-roofs, among others. This was not the case for gas heating.

Visual impairment does not affect durability. It is caused by emission deposits from oil combustion. Heating oil still contains minor, non-combustible ash content such as sulfur and sometimes ferriferous additives.

Apart from taking local conditions into account, (chimney location, wind and weather conditions), the heating unit, including the flue system, should be designed and operated so that the exhaust gases are not deposited around the opening of the chimney. It is recommended that ferriferous additives not be used or, that the proportions are carefully complied with and, if possible, to use low-sulfur heating oil.

Additional information can be obtained from the Federal Association of the German Heating Industry, BDH, (Bundesverband der Deutschen Heizungsindustrie, BDH) Information Sheet No. 16, or, from the furnace manufacturer (e.g. Viessmann or Buderus).

Paint coats

Problems arising from the use of paint coats fall into two categories: those which affect RHEINZINK® in the form of visible run-offs from other surfaces, and those which occur in the form of secretions when paint is improperly applied to RHEINZINK®.

The composition and production technology of coatings should be such that they do not chalk, i.e. that they do not secrete any substances due to UV radiation, rain and wind. When chalking does occur, the type of released or secreted substances dictate whether their effect on RHEINZINK® is corrosive or of a purely aesthetic nature.

Acrylic resin based coatings, for example, are regarded as inert and do not affect components made of RHEINZINK® situated below them. On the other hand, PVC based coatings can, under certain conditions, release substances which, in conjunction with moisture, may lead to visible and corrosion-like surface changes.

If it is necessary to coat RHEINZINK®, it is essential to choose the right paint, and that proper care be taken in applying it. The manufacturer´s instructions should indicate the suitability of a paint and its method of application, especially the preparation required and the minimum thickness of coats.
Improper application, especially poor preparation of the surface, incorporation of foreign bodies into the paint, or an inadequate thickness of coats, leads to weak spots where corrosion can occur.

Glass
Glass is regarded as inert. In construction technology this means that under normal weather conditions, glass neither releases any substances in itself, nor does it form any substances by reacting with other materials in the environment.

Changes in the RHEINZINK® patina which are sometimes visible under glass surfaces are often due to deposits of dirt being washed up and incorporated into the patina. In addition, chemicals found in rain water, such as sulfuric compounds, which are not neutralized, can also lead to a discoloration of the patina. Discoloration can also be caused by paint-coated frames or covering elements, or by certain materials used for gasketing.

Wood
Some types of wood contain acids. This can cause a problem when surfaces which are covered or clad with wooden shingles, for example, are draining over surfaces covered with RHEINZINK®.

To date, very little information has been collected about this. There have been cases where serious surface discoloration and even corrosion was caused by red cedar and oak.

Wood preservatives
In Austria, Switzerland and Germany (DIN VOB 18339) it is mandatory to use a bond-breaker. The stated reason is that wood preservatives have a corroding effect on the underside of metals. On the other hand, RHEINZINK's experience has put this theory into question, at least as far as RHEINZINK® material is concerned. To learn more, the University of Hannover was contracted to carry out tests on RHEINZINK®.

The tests proved that wooden forms made of spruce, which were pressure-impregnated with various wood preservatives in the full cell process, have only a marginally corrosion-promoting effect, even under conditions of the most extreme moisture, which are still encountered in construction practice. The promotion or acceleration of corrosion only occurs with the constant presence of moisture. As shown below, moisture on its own will cause corrosion when CO_2 is lacking. The tests were conducted with the most common wood preservatives, both conventional and chromate-free types, and the influence of temperature was also taken into account.

These tests did not take into account the fact that uncovered impregnated wooden surfaces draining over already installed RHEINZINK® surfaces will lead to streaks of run-off. This is of particular importance during construction.

Perspiration
Upon delivery, the surface of RHEINZINK® is natural and unprotected. If bare hands are used when handling the material, fingerprints could be left on the surface, which will discolour the metal due to the acidity contained in perspiration. Fingerprints can be removed immediately following installation with ROTOL® NEW FORMULA A2, a protective surface oil. If the discolouration is not removed immediately, the fingerprints will be incorporated into the patina. Depending on the duration and intensity of patina development, these marks can become permanent.

Metals
Corrosion caused by electrochemical reactions can occur in metals when two metals differing in voltage potential are combined in such a way that the metal with the higher voltage potential lies higher up on the structure such that rain water flowing over it serves as an electrolyte.

In practice, however, the danger of corrosion is often over-estimated. The actual extent of corrosion depends not only on the area ratio of the neighbouring metals, but also on their actual service potential.

Experience has shown, for example, that no problems arise when RHEINZINK® is combined with

- Aluminum
- Lead
- galvanized steel
- stainless steel.

When RHEINZINK® and aluminum are used together in construction, there is often direct contact between the two. Although some deem this to be problematic, there is, in principle, no risk of contact corrosion.

The reasons are as follows: both metals become coated with protective layers of zinc carbonate or aluminum oxide (an anodized coating), which have very similar service potentials, namely about -200 mV in the case of RHEINZINK® and -170 mV in the case of aluminum. However corrosion that would be of practical significance in construction occurs only at potential differences of 400 mV or more, as in the case of RHEINZINK® and silver. This is confirmed in technical literature as well as in the article "Das Korrosionsverhalten von Aluminium bei Kontakt mit Zink im Bauwesen" ["The corrosive behaviour of aluminum in contact with zinc in building construction"] by Professor C.A. Witt. In contrast, a combination with copper, as the metal higher up on the structure, should be avoided.

Mortar and concrete
Solid and dry building materials do not in themselves attack zinc, because they are moisture free. Corrosion is possible only if the cavities which exist in almost every building material contain water, and if enough oxygen can diffuse into the zinc surface.

Alkaline chlorine-free mortar or concrete does not lead to critical corrosion of zinc, even in the presence of a slight amount of moisture due to the formation of calcium hydroxide zincates. Zincates act as a protective coating and therefore make the zinc in contact with hardened concrete highly resistant to corrosion.

Plaster causes corrosion problems only if it is in a constant state of dampness, in which case the pores are filled with a saturated calcium solution, which stimulates corrosion. Considering that plaster usually dries quickly, corrosion is unlikely in the long run.

The following applies equally to all types of mortar and concrete:

1. They can become a corrosion problem through chlorides, which may have been added to the mixing water in the form of calcium chlorides or magnesium chlorides as bonding agents or antifreeze. Such problems may actively persist beyond the bonding or drying phase.

2. When RHEINZINK® accidentally comes in contact with mortar residue which is not removed promptly, the moisture content of the mortar may cause superficial changes which, while they have no destructive effect, may present an aesthetic defect.

Cleaning agents
It is customary in construction to use cleaning agents either for a "final cleaning" prior to acceptance of a building site, or as part of regular building maintenance. Most of these agents interfere with RHEINZINK®'s natural patination process, which results in usually irreversible visual blemishes. For this reason, direct contact should be avoided by applying suitable covers or taking other precautionary measures.

Note
Covers should be applied in such a way that ventilation of the covered components is ensured. If this is impossible for structural reasons, the following should be noted:

- do not place covers directly over wet RHEINZINK®;
- ensure that the covering material itself is not damp.

If these precautions are not taken, the formation of zinc oxide can be expected, which in turn is a visual blemish (see Part I. 2.2.6).

Moisture without ventilation
In contrast to the behaviour of RHEINZINK® surfaces in direct contact with the atmosphere (see Part I. 2.2.6), other criteria apply to the metal underside.

On the underside, the zinc carbonate cannot form because of the lack of carbon dioxide from the air. Therefore, the metal remains bright. If the zinc has been installed while damp (see Part I. 3.2), there may be a slight formation of zinc hydroxide, but this is of no consequence.

If the metal underside is subjected to moisture for some time, due to errors in construction or installation, a phenomenon called hot-water corrosion can be expected, especially under the influence of higher material temperatures. This causes pitting corrosion, which may destroy the metal roof from below.

This type of corrosion can be avoided by observing the rules of construction physics (see Part II. 1), by avoiding installation errors and by making it possible for the moisture to evaporate. The latter applies, for example, in the case of ventilated roofs, with wood sheathing for subroofs without seperating layers (see Part II. 4.2), and also for structured underlays (see Part II. 4.3.1).

Other influences
Extreme stress can be expected if RHEINZINK® roof drainage systems must be installed under a layer of old roof tiles (which may even be covered with moss). In such cases, corrosion may occur especially in areas where water drains into the eavestrough via curved or hollow tiles. This is due to the fact that in the course of aging, the tiles have stored atmospheric contaminants, which they release in the form of weak solutions (e. g.

in conjunction with SO^2) when subjected to low-level moisture (fog, dew, drizzle). Under such circumstances, new eaves-troughs often (depending on weather conditions during installation) do not have a chance to form a protective layer in the areas where they are particularly subjected to these stresses. A protective coat of paint is recommended in such cases (see Part I. 2.1.9).

Temporary surface protection using strippable film
It is possible to protect the zinc surface from negative influences during the construction phase by placing a self-adhesive protective film on the upward facing surface. This is done by the manufacturer. This protective film should be removed immediately following installation. The strippable film serves to protect the surface from dirt and pollution during transportation and storage. During installation, it protects the material from neighbouring trades and influences from adajcent building materials, e.g. curtain walls, window sills or the steep-pitched sections of mansard roofs. Strippable film should be requested when the material is ordered.

2. 1.8 Surface run-off

Carbonization products (see Part I. 2.2.6) cause no discoloration. Therefore, rainwater draining off RHEINZINK® roofs and coming in contact with adjacent building components will not leave ugly traces of run-off caused by the roofing material itself.

However, traces of run-off can occur if large amounts of zinc hydroxide have formed on the metal surface due to improper storage, etc.

Furthermore, depending on the amount of pollution in the neighbourhood, certain quantities of dirt may accumulate on low pitch roofs. Such external influences can lead to traces of run-off, unless remedial measures are taken to prevent them

I. 2.1.9 Coatings

Scope
Due to the naturally forming protective layer of zinc carbonate (see Part I. 2.2.6), an additional protective coat of paint is not required for RHEINZINK® under normal environmental conditions. Only under exceptional circumstances does RHEINZINK® require a coat of paint, such as to protect the roof against extreme corrosion caused by oxidation products, or aesthetic considerations such as the creation of small visually contrasting areas. If it is desirable to have large painted areas, industrial pre-coating is recommended.

Preparation
RHEINZINK® surfaces can only be painted without initial preparation by chemically neutral degreasing if the surfaces are already naturally weathered, clean and dry.

Paints
A large number of paints are commercially available. The effectiveness of protective coatings must be demonstrated by the paint manufacturer. Acrylic resin and latex paints are recommended.

Bituminous paints, which were preferred at one time because of their low cost, are no longer recommended. These paints can cause corrosion (see Part I. 2.1.7) when inappropriately applied to areas where the weathering has been removed or the metal is bright, or when simply applied poorly, which happens all too frequently (e.g. grooving formed by using hard brushes, etc.). When bituminous paint is applied to large surfaces subject to UV radiation, corrosion can occur to unprotected drainage elements (such as downspouts) when subsequently installed. For both reasons, we recommend service contracts with particularly short maintenance intervals if bituminous paint is to be used.

Caution
Bituminous emulsions, which are used for insulation coatings, are not suitable as paint for RHEINZINK®, as they can cause corrosion due to their high alkalinity.

Application
All paints must be applied as specified by the manufacturer, evenly over the entire surface, without leaving pores, and in coats of appropriate thickness. If the paint contains pores, moisture penetration can be expected, which in turn can lead to corrosion.

All paints are subject to wear and aging, and require maintenance in the form of a new coat of paint on a regular basis. In such cases, it is always advisable to sign a service contract.