

PROTECT OUR EUROPEAN OUTDOOR BRONZE MONUMENTS

GOOD PRACTICE GUIDE

Edited by Christian DEGRIGNY

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Contents

Acknowledgements

Contributors

Foreword

(Greetings by the Mayor of Athens, Greetings by the Minister of Culture)???

Introduction Urban planning for the protection of outdoor monuments

CHAPTER 1 The meaning of outdoor bronze monuments to European citizens

- 1.1. Social and historical aspects
- 1.2. The Bronze monuments in Athens
- 1.3. Bronze sculptures in Göteborg – kings and fighters, water and shipping - donations and the art for everybody
- 1.4. The importance of outdoor bronze monuments in Munich

CHAPTER 2 The construction of an outdoor bronze sculpture

- 2.1. The lost wax process
- 2.2. The sand-casting process
- 2.3. What is bronze?
- 2.4. What is patina?

CHAPTER 3 Deterioration of outdoor bronze monuments

- 3.1. General principles on the corrosion of copper based alloys
- 3.2. What factors affect the deterioration of outdoor bronze monuments?
- 3.3. Problems that face outdoor bronze monuments

CHAPTER 4 Conservation strategy

- 4.1. General approach
- 4.2. Case studies

CHAPTER 5 A maintenance plan

- 5.1. Athens experience
- 5.2. Göteborg experience
- 5.3. Munich experience

Conclusion

Bibliography

Acknowledgements

This Good Practice Guide presents three different approaches of the management, conservation and maintenance of outdoor bronze monuments in Europe. Athens, Göteborg and Munich are European cities facing different problems and through this project they have tried to gather their experiences which are presented in the following pages. This project would not have been possible without the financial support of the European Commission and both the editor and the authors are grateful to the European Commission for its essential contribution.

One might be careful while writing such a document, especially when just a few countries are represented. The future readers of this document will find some advices, interesting comments or experiences and some kind of methodology on how to manage, conserve and maintain our outdoor bronze sculptures. But these texts do not intend to give a common European approach.

To write and publish such a document in less than one year has been a challenge. I would like to thank then all the authors for their major contribution. Most of them did not only write their chapters but gave constructive comments on the whole document. Nevertheless to respect their particular approach, their name has been left under their different texts.

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Foreword

1/ Presentation of the European project and the consortium (co-ordinator and partners).

2/ For the GPG:

Our objective with this GPG is not to concentrate only on the problem of the conservation of outdoor bronze monuments, their construction and their conservation. These subjects have indeed been studied thoroughly and a huge literature already exists (see the bibliography given at the end of the GPG). We want in addition to give other approach of these monuments that might be useful to a larger public. Social and historical aspects are then developed and are illustrated with case studies. We emphasise too the importance of management and maintenance of these monuments which have essential consequences on their protection and conservation in the long term.

The three cities considered here are facing different degradation and conservation problems of their outdoor bronze monuments. One of the major achievement of this project has been to compare the conservation approaches of each city and to discuss about the maintenance programmes. These experiences will be added data to the study of outdoor bronze monuments all around Europe and might be used to define a proper management and maintenance policy.

We hope with that GPG to produce a document that will be of some use to the professionals who have to deal with the conservation of outdoor bronze monuments. Of course it can be improved and we would be interested in your different comments...

The contributors

Introduction

Urban planning for the protection of outdoor monuments

Managing our cultural heritage is a great responsibility. This responsibility goes along with the obligation to preserve all monuments witnessing our civilization for the future generations. This task requires knowledge, sensitivity, specialization, ability to co-operate and co-ordinate actions, open mind and the existence of a powerful legislation providing for any intervention.

The role of the state

To begin with, as far as the role of the state is concerned, there is a major need to declare all outdoor sculptures monuments. This assures their protection by a specific body and helps the public to realize that they must respect them as if they were museum exhibits.

It is believed that all outdoor sculptures cannot be considered as monuments. At this point, an important issue arises. It concerns the definition of a monument and the question whether it has to be dissociated from the definition of a work of art. The philosophical aspect of this issue is yet unresolved because opinions diverge about terminology. According to the definition that dominates a monument is a witness of a civilization. So, outdoor sculptures can be undoubtedly considered as monuments and not as objects just needing special care and protection.

The situation concerning the protection of outdoor monuments in Munich, Göteborg and Athens is quite different. In the case of Athens, the majority of outdoor sculptures have not been declared as monuments and consequently they are not protected by the law. The Traditional Buildings and Monuments Division of the Municipality of Athens, responsible for this area for the last six years, has always considered them as monuments representing art, Greek history and culture. They must therefore be respected and all works have been carried out according to the rules of art and science. However, their declaration as monuments is an issue which needs to be settled.

The role of the body responsible for the protection of monuments

Documentation

The documentation of monuments is of great help for those managing our cultural heritage. This enlightens all aspects concerning art, the history which justifies the existence of the monument, the artist and the entire construction. Documentation does not only involve the collection of information about the past but it also registers and files all present interventions which will be evaluated at a later date.

All data gathered from the documentation are stored in a database. To be more exact, this database contains historic data, data concerning the location and the description of the monument, the biography of both the sculptor and the person depicted, relevant bibliography, reports on former maintenance works and expertise on the condition of the monument. It is enriched by photographs belonging to archives as well as photographs taken during the maintenance or restoration works.

It is obvious that this information is useful for an art and history researcher as well as for an expert. It also facilitates the work of the body managing the sculptures because it enables them to monitor their present condition, to study and programme all required interventions and mostly evaluate the results of previous works. All this represents the objective of the maintenance plan that must be included in the annual technical programme of the body.

Evaluation

It is also necessary to evaluate all monuments, a task easily carried out thanks to processing the above data. The evaluation consists in defining the values that envelop a monument. In other words, it is about a theoretical approach that could play a significant role in planning the maintenance or restoration of the monument in order to promote these values. The values and the systems of values (historic, aesthetic and artistic values, the landmark value, the value of symbolism etc) cannot be here analysed because they constitute the objective of a philosophical approach in the history of maintenance.

Monuments and citizens, a relationship to be restored

Promoting these values contributes to restore the message conveyed by the outdoor monuments, to realize their meaning for the city and its citizens as well as their role in civilization. It also contributes to identify the person depicted and the reason for his or her commemoration in order not to insult their memory by vandalism or other shameful actions. Revealing the message of the monument sensitizes citizens and society as a whole and determines their attitude towards the works of art.

This objective can be achieved through an effective educational system and through information campaigns. They are the result of both state and individual concern. However, it is disappointing that few citizens recognize the existing outdoor monuments, that they pass them by without noticing them and that they look at them without really paying attention to them. This can be explained by the:

- Lack of information
- Lack of signs
- Abandonment of the sculpture
- Inadequate cultural education

Great effort and real concern on the part of the state are needed in order to deal with all these problems. Our suggestion concerns mostly the awakening of sensitivity and respect towards all monuments witnessing our culture. Emphasis must be put on the most ductile and most sensible social group: the children. The more they have an adequate approach to outdoor monuments, the more we can hope for an appropriate future attitude. Educational institutions, teachers, parents, bodies responsible for the protection of monuments, they must all motivate children, kindle their imagination and talk to their soul. Educational programmes can take place at public places where children can communicate with monuments and where many activities can be performed.

This perspective does not exclude adults from a sensitizing effort. This is possible by publishing a maintenance study as well as all the issues arisen. It is also necessary to inform them about our cultural wealth or launch a “protection campaign” which might cast publicity on this subject.

Maintenance plan

Following the historic documentation, the study of values and the definition of the elements causing damage/corrosion, the objectives of maintenance works must be planned according to the principles of science on matters of cultural heritage. This planning is an attempt to eliminate the damaging elements and assure future protection. This might involve a direct or an indirect maintenance project. The former demands the intervention on the monument and the latter the elimination of damaging elements without necessarily intervening on the monument.

Direct maintenance has mainly to do with the monument's surrounding place. It is quite easy to determine the damaging elements linked with the surrounding place of a monument and then to eliminate them. For instance, if the monument is easily accessible and has therefore been vandalised, measures must be taken to make access more difficult. This goal can be achieved by means of more natural and ecological solutions such as surrounding the monument with wide but short bushes. In case a monument has suffered irreparable damage due to pollution or poor quality of the material used, the only way to protect it is to remove and replace it by a copy. Pigeons can also cause damage by polluting and subsequently corroding the surface of bronzes.

It is necessary to emphasise the importance of the surrounding place of a monument for the monument itself because they are strictly associated. There is a major need to protect the surrounding place in order to promote the value of the work of art and not to condemn it. It is also worthwhile mentioning the wrong choice of places to host outdoor monuments. The only criterion for selecting the location of a monument is the decoration of a place. For Athens, this attitude also explains the fact that monuments are mostly found in the city centre while the districts are lacking of these monuments.

The direct maintenance, the planning, the carrying out as well as the supervision and the evaluation of the entire project require the co-operation of many experts such as conservators, chemical engineers, art historians, architects, civil engineers, etc. This co-operation is hard to be achieved if the parties involved lack of maturity. A mature and responsible attitude can be often fostered by the body entrusted with the protection of monuments.

According to all declarations for the protection of our cultural heritage, maintenance works consist in an irreversible intervention. It is therefore advisable to carry out works that do not have quick, impressive or radical results because they might cause immediate or long-term damage to the monument's surface. There is a whole procedure to respect and follow: cleaning, fixing, maintaining, restoring and protecting the monument. This procedure is planned by experts and it is obvious that it does not apply to all cases. Planning and documenting the works carried out, the tests done and their results are necessary for both the maintenance project and its evaluation.

Most theoretical issues involve complementing the figure or the symbol represented in order to render it recognisable and deciding on the restoration of damage representing the history of the sculpture such as holes by bullets that mark many sculptures in Athens. Decisions on such issues must be jointly taken and require adequate knowledge of the subject and all the qualities mentioned at the beginning.

Following the completion of maintenance works, one question remains: What is to be done in the future? An option is to wait until the monument suffers a new damage to take further action.

It is however better to plan a programme monitoring the current condition of monuments (which is not difficult thanks to the existing data base) in order to make a report on it on a regular basis and then plan further action. The implementation of this project is of major importance for managing properly the monuments. Last but not least, all parties involved in the protection of our cultural heritage must act with a sense of responsibility and moral obligation to both past and future.

By Zetta Antonopoulou

CHAPTER 1

The meaning of our outdoor bronze monuments to European citizens

1.1. Social and historical aspects

A sculpture represents a major expressive and creative way through which the feelings, the thoughts and the concerns of an artist or a sponsor (like kings) are expressed¹. At the same time people understand the history by means of it. It consists one of the visual arts and it is therefore expressed through the image, through what observers can see, through what the soul feels and perceives. The result of an artist's work, the sculpture, awakens various feelings to each one of us. Most observers are satisfied by an aesthetic result belonging to the category of the "beautiful" and the "optimum", an admiration for giving shape to movements and sentiments, a result characterized as "three-dimensional" and "spiritual". The more the depiction is closer to reality, the more the public understands it and feels awe. That's presumably the reason for which the classical art principles affected artistic expression regardless of the time period or the place.

1.1.a. Sculpture in public spaces

A sculpture becomes an art related to public when cities and generally organized societies are formed. The sculptured work of art is no longer exclusively found in mansion gardens or royal palaces; it is also placed at public places, it consists an element of the city, it belongs to the public. It holds a monumental value, since it functions as an artistic creation commemorating events or people. The work of art by itself or as a complement of a structure becomes a monument in commemoration of a person, a historic or else event; it often expresses vanity or excessive egoism, an idea or a political ideology. It undoubtedly shows the wish to familiarise future generations with the history of their ancestors. It aims at preserving this witness to eternity. Many times it is simply a reference, it plays a purely decorative role and the public simply admires it.

Creating and erecting a monument at a public place can be the result of an individual initiative, a donation, or of a state concern, when the state wants to adorn the city and its buildings with monumental or decorative sculptures. The monumental form or picture is and has been a part of the methods for the official power to mark its influence and its connection to traditions. The public spaces in cities accordingly have monuments placed as an indication that the power exists in the public and daily life. Later in the 19th century the democratic ideas of the public art as an art available to all people become significant. The art should belong to everybody and be the poetic force in the society.

Outdoor monuments that are the subject of our study belong to the category of modern monuments. They are associated with the urban development in Europe mostly in the 18th and the 19th centuries based on the humanist values according to which the past must be commemorated and respected.

¹ One of the German Kings (Ludwig I) e.g. had much influence on the patination of several sculptures.

1.1.b. Historical monuments

The monuments with historic value are usually found at places associated with the historic events they represent (e.g. at the residence of the person depicted, in battlefields etc). They can also be placed at a central point (a big square) sending out their message to all citizens. In Europe these monuments mostly depict princes, kings, pontiffs, eminent figures. In the late 18th century and mainly in the 19th century they at last depict men of letters and artists. Great historic deeds are usually commemorated by architectural monuments such as columns and arches, which is not the case for the 19th century Greece. In the 20th century, following the two World Wars, the need to commemorate rises again. However, the types and the subjects of historic monuments have reached saturation point.

The increase in the number of monuments and the exhaustion of subjects along with the historic developments resulted in a range of new subjects inspired by the lower and humbler classes of society. It is doubtful though that there is an intention to glorify humble people. The depiction of everyday life is associated with more democratic societies. In this case, however, everyday life is not awarded a historic or honorary value but an artistic and a rather decorative one.

1.1.c. Decorative monuments

The monuments of decorative character are placed in parks, big gardens, squares, avenues. They are considered as autonomous, that is to be they are not the result of a commission limiting partly the inspiration of the artist and they do not have a historic meaning. These monuments serve an embellishment purpose and they are often combined with water (fountains and lakes). Adorning gardens is an idea developed in the second half of the 16th century in Europe (Italy, France - Versailles). This idea is materialized in the streets and the parks of the cities when open spaces justifying or requiring a monument are designed. This tendency reaches its peak during the Rococo and the Baroque periods.

If one wants to classify the outdoor monuments, the following categories exist: statues, equestrian statues, busts, heroic monuments, free compositions, groups. As far as the material used is concerned, the relevant categories include marble, stone, bronze, metal, glass etc.

Outdoor monuments have both a historic and an artistic character. The latter automatically places them among the works of art. All works of art convey a message to us: it is the simple identification of the figure or the event represented and commemorated. There is a need to keep the history engraved in our memory, which is the initial objective of the creation of the sculpture.

1.1.d. The meaning of outdoor monuments

In addition, a considerable number of important information on civilization is gathered by observing and studying sculptured monuments. This information involves the style, the medium and the process of creation. This is an important material for studying the History of Art, the influences interchanged among nations. It is really impressive the fact that art has no limits, that it assimilates and expresses the qualities and characteristics of each culture. Significant information is also collected about the techniques used for the creation of a sculpture, the marble-works, the foundries as well as about the technology of media by studying the corrosion and the damage suffered due to the exposure to the environment.

In conclusion, monuments play a major role in the history of the city. In a matter of speaking, they represent the history of a city since the citizens identify in them personalities, heroes, benefactors, mythological and historical scenes, deeds of heroism. One can collect useful information by studying their location in the town planning network, or touching information by studying details such as the marks of bullets on many sculptures in Athens.

The outdoor monument represents for the majority of us an expression of art and civilization. By observing the monuments of our city, a part of our everyday life, their grandeur will move us.

By Zetta Antonopoulou

1.2.The Bronze monuments in Athens

1.2.a. Historical basis

In 1830, Greece is recognized as an independent state.² This period signals the end of a long effort aiming at liberating the country from the Turkish rule, finding its national identity as well as a place among the other independent states of the West. A few years later in September of 1834 Athens becomes the seat of the Greek monarchy and the capital of the independent Greek state.³ Prince Frederic Otto, second-born son of the King of Bavaria, Ludwig I, has been appointed as King of Greece³. Otto's arrival, and his staff, consisted of Bavarian scientists, is followed by a period dedicated to the concern for the antiquities and the new artistic creation, thus achieving the ideological support of the new state.

At that moment, the population of Athens is about 8000 people and a project regarding the building of the capital is implemented. This project is based on the town planning network designed by Stamatis Kleantis (architect, Berlin's Academy graduate) and his colleague Edouard Schaubert focusing on the royal palace of king Otto.

In Athens flourishes the movement of neo-classicism.⁴ The newly built city mirrored the urban architecture: public buildings of rare beauty and aesthetics illustrate this tendency. Moreover, these buildings aim at endowing the city with a monumental character worthy of a glorious past, of Greek antiquity. At the same time, there is a need for the city to resemble to other European cities.

1.2.b. The appearance of sculpture

As a consequence of the above, all kinds of arts bloomed including sculpture, an art promoting the image of our country in exhibitions abroad and creating important and outstanding works of art.

² Greece's independency was recognized with the signing of the London's protocol, in February 1830.

² Nafplion had already been nominated as a temporary capital of Greece. Among the cities that have claimed for capital (Athens, Corinth, Nafplio, Argos, Tripoli, Syros, Megara) Athens had a fair chance of winning due to its ancient glory. An important factor that had also contributed to the selection of the city was that Athens had the favour of the Bavarian King, Ludwig, Otto's father.

³ By protocol in May 1832 in London.

⁴ The classicism, as a result of the movement of philhellenism and the tours in the Greek province, has already been created, disseminated and prevailed throughout Europe and especially in Bavaria. After Otto and his staff, consisted of Bavarian, was installed in Athens, German classicism was introduced and assimilated as revealed by the Athenian public buildings designed by north European architects. As a result of this assimilation, we had the processing, the adaptation to the Greek reality and, finally the differentiation from the west European prototypes. The neoclassicism in Athens was characterized by the simplicity, the vividness and the fitting to the simple urban architecture.

Art is no longer exclusively present at private places (e.g. the residence of a wealthy bourgeois who could afford the commission of a statue) but also at public places : squares, parks and avenues are adorned with statues of various forms, sizes and subjects. Their creation results from state or individual initiative and is part of a project to decorate the city. It is of great interest to observe statues commemorating a person or an event that are not playing a simple decorative role. The first sculptures meet this wish. The glorious past of the heroes of the Independence War, philhellenes or benefactors constitute some of the favourite subjects. They also meet the need of the nation to show their gratitude, to be inspired while continuing to struggle and hope. The statues of ancient gods are lasting reminders of the grandeur of classical Athens and awaken in the soul of modern Greeks a feeling of pride and superiority. As it is obvious, the power of sculpture is beyond a simple artistic expression; it is a national need for memory and honour, need of national evolution.

At this point, we could not fail to mention a place where some of the most important outdoor sculptures are on display: the First Cemetery of Athens (Fig. 1.1). This place helps us to observe the evolution of art, its variety and the creations of some of the greatest artists. It also gives us the opportunity to admire remarkable works of art.

Fig. 1.1.: The First Cemetery in Athens (general aspect). Credit Municipality of Athens, Department of Traditional Buildings and Monuments.

The sculptures in Athens are mainly made of marble. The clarity and the transparency of marble has often been associated with the Greek light. Marble was particularly popular in antiquity and found in abundance in the hills surrounding the city. It was easily quarried and processed by craftsmen. Most of these craftsmen who settled and worked in the capital for many years, were from the island of Tinos which had the longest tradition in plastic arts and marble-sculpture.

Bronze as a medium used by sculptors appeared many years later. The first sculpture was erected in Athens in 1834 (the monument of the Holy Company of 1821)⁴ while the first bronze monument was the statue of general Theodoros Kolokotronis that was cast in 1900 and erected in the capital in 1904. The absence of bronze sculptures is due rather to practical reasons: the lack of foundries for large constructions. A great quantity of bronze was needed for the construction of the Kolokotronis statue in Nafplion (about 5 tons) which was found by melting gun fragments dating from the Turkish invasion. The selection of these bronze pieces was made by Trikoupis, the then Minister of War.

All the early bronze sculptures of Athens were made abroad by Greek sculptors or foreigners. Lazaros Sohos for instance who worked the Kolokotronis statue lived in Paris from 1881 to 1901 and was particularly influenced by Marie-Jean-Antonin Mercié, one of the most eminent academic sculptors of the time. The foundry where the statue was cast, was one of the best in Paris. According to sources the majority of the most important statues of Paris were made there. It was the Thiebaut Frères foundry housed at 33, Quessant street. Its name inscribed on the statue (actually their name is associated with the name of their successor L. Gasne) and embossed on its base confirms this information.

The name of foundries on many bronze sculptures gives important information on the history of art and the history of a civilization which have both a local and an international character. In more recent times, foundries operated in Greece but it appears that their operation will eventually stop. The most important foundry where most bronze sculptures of the 20th century were made is the the Army Foundry.

⁴ Γιαννουδάκη Τ. , Τα υπαίθρια γλυπτά του Δήμου Αθηναίων 1832-1922, Μεταπτυχιακή εργασία, ΑΠΘ, 1994

Out of 220 sculptured monuments in Athens, the bronze ones (63 registered until now) represent a percentage of about 30%. Most of them have been made during the last years. Nowadays, artists prefer metal possibly because it is in abundance and more resistant than marble to pollution and environmental conditions.

Art passed through many phases following the major historic moments of the nation before ending up in a polymorphism, in the freedom and the variety of the media used. The sculptures cast in bronze are mostly equestrian statues [T. Kolokotronis, King Constantine, (Fig. 1.2) Georgios Karaiskakis], statues [K. Palaiologos, (Fig. 1.3) Archbishop Damaskinos, O. Elytis etc], free compositions– inspired by the Greek mythology- [Theseus saving Hippodameian (Fig. 1.4)], modern creations [such as the monuments commemorating respectively the Air Force soldiers fell on the field of honour and the National Reconciliation(fig. 1.5)], lamp-posts (adorned with cupids)(Fig. 1.6), busts [Christophoros Nezer, Dominikos Theotokopoulos (Fig. 1.7), Athanasios Lefkaditis etc].

Fig. 1.2.: Equestrian statue of King Constantine at Pedion tou Areos. It was made in Italy, by the architect Taettriani and the sculptor Parisi, and was erected in 1938. Credit Municipality of Athens, Department of Traditional Buildings and Monuments.

Fig. 1.3.: Statue of Constantine Paleologos IA', at Mitropoleos square. It was made by Sp. Goggakis at 1989. Credit Municipality of Athens, Department of Traditional Buildings and Monuments.

Fig. 1.4.: Theseus saving Hippodameian at Victoria's square, by the German sculptor Joh. Pfuhl, in Berlin at 1906, donated at the Municipality of Athens at 1927. It was erected at Syntagma square at first. At 1938 it was transferred at its present location. Credit Municipality of Athens, Department of Traditional Buildings and Monuments.

Fig. 1.5.: Lamp-post in Kypseli, made by A. Durenne in Paris, end of 19th century-beginning of the 20th. Credit Municipality of Athens, Department of Traditional Buildings and Monuments.

Fig. 1.6.: Monument of the National Reconciliation at Klafthmonos square, made by Doropoulos Vassilis at 1988. Credit Municipality of Athens, Department of Traditional Buildings and Monuments.

Fig. 1.7.: Bust of Dominikos Theotokopoulos at Akadimias street, center of Athens, made by Kostas Valsamis in Paris. It was erected at 1990. Credit Municipality of Athens, Department of Traditional Buildings and Monuments.

It is easy to understand that outdoor bronze sculptures in Athens, even if fewer than the marble ones, give us a wide range of information on the artistic tradition, their construction, the history of the city while representing monumental creations of incomparable art and beauty.

By Zetta Antonopoulou

1.3. Bronze sculptures in Göteborg – kings and fighters, water and shipping - donations and the art for everybody

Göteborg - a city with the population of 500.000 habitants – is situated at the West coast of Sweden. The proximity to the sea and the harbour are some of the characteristic features of the city. Today, it has as many as 600 artworks. Monuments, sculptures, busts and fountains embellish streets, squares and parks both in the city and in the suburbs. Among the outdoor artworks, bronze is the dominant material category presenting 200 of the sculptures in the city. Other material of sculptures during the 19th century is e.g. granite, iron, zinc and in few cases marble. Since the second part of the 20th century, concrete, enamel, wood, glass, and plastic have also become common materials for outdoor sculptures.

From a historical perspective, Göteborg, founded in 1623, has statues dating back to the middle of the 19th century, the oldest statue in bronze being the monument of the king Gustav II Adolf from 1854 (Fig. 1.8). Only a dozen of the bronze sculptures were inaugurated before the 1920's.

Accordingly, most artworks in Göteborg are modern and have been erected after the 1950's when the art was brought out to the people on the streets in Sweden.

Figure 1.8.: Gustav II Adolf standing highly erected pointing at the ground of Göteborg that he founded in 1623. This is the first bronze monument in the city and was cast in 1854. The monument was made by the sculptor Bengt Erland Fogelberg (1786-1854).

1.3.a. Water, shipping and trade

Something that people often remembers after visiting big cities is the sculptures. They are on post cards and as pictures in the visitors' mind. Those who have visited Göteborg probably will remember the large bronze sculpture Poseidon surrounded by sparkling water cascades in a fountain located in the middle of the place Götaplatsen (Fig. 1.9). Both the place and the artwork are monumental. In the background the immense façade of the Museum of Art is built in the austere style of the 1920's. Poseidon is created by Carl Milles (1875-1955), a Swedish sculptor with worldwide fame. Characteristic for Milles is the classical motifs often taken from the mythology. The powerful Poseidon, 7 m high, has become a profile for the city of Göteborg situated at the waterfront.

Figure 1.9.: The Poseidon fountain by Carl Milles (1875-1955) was erected 1921-31. Credit?

The first sculpture of a woman in public space surmounting a fountain in central Göteborg had the French name "La Semeuse" (Fig. 1.10). The artwork is from 1883 and was inaugurated on the day of Johanna after which the sculpture in popular speech was named "Johanna".

Figure 1.10.: "La Semeuse" from 1883 by Per Hasselberg is the first sculpture of a woman in the city. Credit?

Particularly the water, shipping and trade are the theme in many of the public decorations in Göteborg. Here are the Tritons, nymphs, ships, waves, fishes etc. Also the seaman's wife waiting at the shore – a sculpture placed on a campanile highly erected above the sea in Göteborg harbour.

One group of sculptures placed in the square Järntorget also turn the minds to water and the trade ways linking countries together (Fig. 1.11). The fountain Järntorgsbrunnen was created as a memory of iron-cargo shipped to countries far away. The five women placed on the rim of the fountain symbolize the five parts of the world. Another monument recalling the wide world, in this case America is the Delaware monument on the pier in the harbour.

Figure 1.11.: In the fountain "Järntorgsbrunnen" (inaugurated 1927) by Tore Strindberg the five women are symbolizing the five parts of the world where the iron-cargo were shipped to from Göteborg harbour. Credit?

Sculptures of younger date, from 1990's, are the two lions lying on granite bases on both sides of the Lion stairs in central town, guarding the western sea entrance to the city. Another modern figure in the city centre is "The Neck is playing". The evil spirit of the water is both beautiful and dangerous and with the music of his violin he is seducing and drowning people in the water.

1.3.b. The men and female characters

In Göteborg, as in most places in the world, art in public space has been created to embellish cities and celebrate the memory of persons or events. It also gives patrons of the arts a possibility to leave behind something of long-lasting value. So did also Charles Felix Lindberg, a tradesman who at the turn of the century donated large amounts to the decoration and embellishment of the city of Göteborg. His money still today is used for the decoration of the public space. Many of the

sculptures that have been created by these donations are in the city centre. Several of the older ones, from the end of the 19th century and the first decades of the 20th century have the characters of national romanticism. They are figurative and often represent famous men of the country. Others are monumental, figuring kings and mythical shapes. Some sculptures are also women, in most cases featuring nature as “The spring”, “The haze”, “Summer”, “Flora” and others (See Fig. 4 ? of the Haze).

1.3.c. Kings and fighters

One expression of the political power is the statue from 1854 figuring the Swedish king Gustav II Adolf standing highly erected pointing at the ground of the city he founded 200 years earlier (Fig. 1. 8). The square where he is placed is named after the king and is Göteborg’s official centre. An additional statue mediating the power is “Karl IX”, a Swedish king riding on his horse. Nobody could imagine at the grand inauguration in 1904 that the artwork should later be named “The copper mare” and become one of the popular meeting places in the city. “The knife-wrestlers” is another historical sculpture that have given name on the park where it is placed (See fig 4.??). The motif is Old Norse depicting two young fighters strapped together with a belt, fighting a violent life-and-death struggle.

1.3.d. Unobtrusive and in a class by itself

If you ask to the citizens of Göteborg what sculpture they like most, many would answer ”Karin Boye”, a figure of one of our well-known poets in simple summer-dress viewing the largest commercial street in Göteborg (Fig. 1.12). The figure is unobtrusive, loved and also cared for. Often fresh flowers are slipped into her small hands of bronze. “Karin Boye”, inaugurated in the middle of the 1980’s was the first named statue of a well-known woman placed in Göteborg.

Figure 1.12.: The bronze sculpture of “Karin Boye”, a well-known Swedish poet, is loved and cared for (by Peter Linde 1984). Credit?

1.3.e. Forming the place for everybody

Many sculptures created in the 1960’s, 70’s and 80’s are in the local centres of the suburbs. Decisive for these art projects were the expansive house-building and the one-percentage-rule demanding that one percentage of the costs for new buildings should be invested in the public embellishment. One characteristic feature for the late public art is that it is an integrated part of the environment. Another is the democratic idea of public art as an art available to all people. The art should belong to everybody and be the poetic force in society.

One good example where the sculpture forms the place is the “Reclining figure” by Henry Moore, an abstract piece of art from the 1960’s that enriches the large central park Slottskogen (Fig. 1.13). Sculptures in Göteborg today mainly associate to modern ones. Several artworks have been shown in Park exhibitions with the aim to give guidance in looking at art and to reach a wider audience – which also have been successful.

Figure 1.13.: “Reclining figure” by Henry Moore (cast 1961) in the large central park “Slottskogen”.

By Kate Ryffé and Helena Strandberg

1.4. The importance of outdoor bronze monuments in Munich

There is a considerable number of Outdoor bronze monuments in Munich. At least ten of them can be dated back to the time before 1800. Among this oldest group are also complex monuments, such as the Wittelsbacherbrunnen consisting of many individual figures and ornamental parts and the famous Mariensäule (Marian column) with a gilded bronze Madonna on top of the column as well as four groups of Putti fighting evil forces.

At least thirty life-sized or more than life-sized outdoor monuments date back to the 19th century, among them we find such prominent objects as the Bavaria monument and a bronze lions' quadriga 5 m in height (Fig. 1.14). The most famous bronze monument in Munich is the so-called Bavaria, a personification of the Bavarian state (Fig. 1.15).



Figure 1.14.: Close-up of 5m high lions'quadriga on top of the Siegestor, by Johann Halbig, unveiled in 1852. Picture before restoration by the Municipality of Munich in 1996-97. Credit Bavarian State Department of Historical Monuments.



Figure 1.15.: The Bavaria Monument, by Ludwig Schwanthaler (1850) in front of the Hall of Fame, height of the bronze figure 18 meters. Visitors can walk up inside to the head and have a look around through three small windows on top of the head. Credit Bavarian State Department of Historical Monuments.

This gigantic bronze sculpture was designed by Leo von Klenze as the architect and Ludwig Schwanthaler as the artist. It was unveiled in 1850 by Ferdinand von Miller who had established the Royal Bavarian Bronze Foundry in 1824. For the largest piece, the upper part of the body, about 25 metric tons of bronze had to be melted. The overall weight of the bronze parts of the Bavaria is about 70 tons. In comparison the typical weight of a 3 m bronze statue is usually in the range of about only 2 tons. Visitors can enter the Bavaria through a bronze door at the back of the stone base and climb up to the head via a flight of winding stairs. There are two “bronze cushion“ seats inside the head where visitors can sit down and have a look at the Theresienwiese area (the place of the annual Oktoberfest). Even today the Bavaria is among the biggest bronze monuments worldwide and one of the very few that can be studied from the inside.

Around the middle of the 19th century a new generation of monuments was devoted to famous citizens like the founder of the Munich optical industry Fraunhofer (Fig. 1.16), to Schelling the philosopher and to Count Rumford (Fig. 1.17), an ingenious multi-talented man who worked on thermodynamics as well as on city park design and the improvement of the nutrition of the poor.

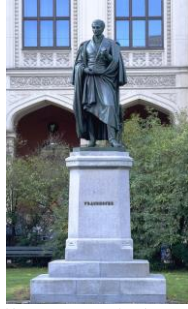


Figure 1.16.: Fraunhofer Monument, by Johan Halbig, unveiled in 1868, after restoration in 1998. The restoration was funded by the Rotary Club München. Credit Sachers.



Figure. 1.17.: Count Rumford Monument, by Kaspar Zumbusch, unveiled in 1867, after restoration in 1998. The restoration was funded by the Rotary Club München. Credit Sachers.

Though the monuments are an important part of the townscape many citizens are not really aware of their presence and significance. Of course tourists take typical photographic snapshots in front of the monuments e.g. with the family standing on the base of the monument for King Max Joseph I (Fig. 1.18) in front of the opera, with the hands on the bronze lions' legs. There is also an old saying that rubbing the nose of the small lions' heads in front of the Residence will provide a certain wealth for the person who does it.



Figure 1.18.: Monument for King Max I. Joseph, by Christian Daniel Rauch, unveiled in 1835, before restoration by the Municipality of Munich (1988). Credit Bavarian State Department of Historical Monuments.

Only great changes like restorations or the absence of a monument will be noticed by newspapers and people passing by, thus giving back some of the lost attention to the monument. Recent and present restorations, e.g. those of the Mariensäule and of the Bavaria have brought back a great part of the public interest. It was a big and positive surprise that a 45 minutes television documentary on the history of the Bavaria monument was able to compete with soap operas on other TV channels.

By Anke Doktor and Martin Mach

CHAPTER 2

The construction of an outdoor bronze sculpture

Before dealing with degradation and conservation aspects of bronze monuments, it is essential to know how these monuments were constructed. It is the aim of this chapter to give some general ideas on the subject and more particularly on the bronze sculpture which is the most complex part.

Since ancient times people have been forming metals and creating bronze sculptures. The processes for bronze casting have improved throughout the centuries in Europe but even today the skills of ancient Chinese foundry men have been unsurpassed. In most countries the so-called lost-wax process was the first attempt to solve complex casting tasks. In the 19th century the different variants of the sand-casting process became familiar, in particular for very large monuments. But they did not completely replace the lost-wax process. A further process, by which metal sculptures were created, was established in the middle of the 19th century: it was called electrotyping (a procedure which forms a metal layer by means of galvanic deposition). Typical electrotype sculptures consist of a layer of pure copper that has a similar outer appearance as bronze. As they are sometimes misinterpreted as bronze sculptures, they should be mentioned here as an aside.

Though many modern variants of bronze casting were established in the technical field, bronze sculptures have been cast through centuries either by means of the classical lost-wax process or by means of the sand forming process.

2.1. The lost-wax process

Figure 2.1. shows this most familiar process for artistic casting. The lost-wax process is based on a negative form of the original sculpture. The form is made out of plaster which is covered on the inside by a wax layer of approximately 0.5-1 cm thickness. In a second step the space inside the plaster form behind the wax layer is totally filled with clay mixture on an iron armature to support the structure. The resulting wax layer is a very thin layer between the plaster negative and the clay/brick core. Afterwards the plaster negative will be removed and fine details can be added to the wax surface. The entrance tubes for the molten bronze are formed out of wax and joined to the wax surface. After that the whole casting form is covered by several layers of complex clay-based mixtures. Core pins help to fix the distance between the casting core and the outer form. Heat is applied to melt the wax and create a hollow space for the metal. When all the wax has flown out of the form, the inner and outer casting form will be heated before the molten metal is cast in. This burning process will stabilise the casting form chemically and mechanically so that it will not be cracked during the casting process. At last the molten metal is poured through the tubes into the hollow space between the inner and outer form.

The lost-wax process is expensive, laborious and risky. A minor defect in the construction of the mould might endanger the whole procedure.

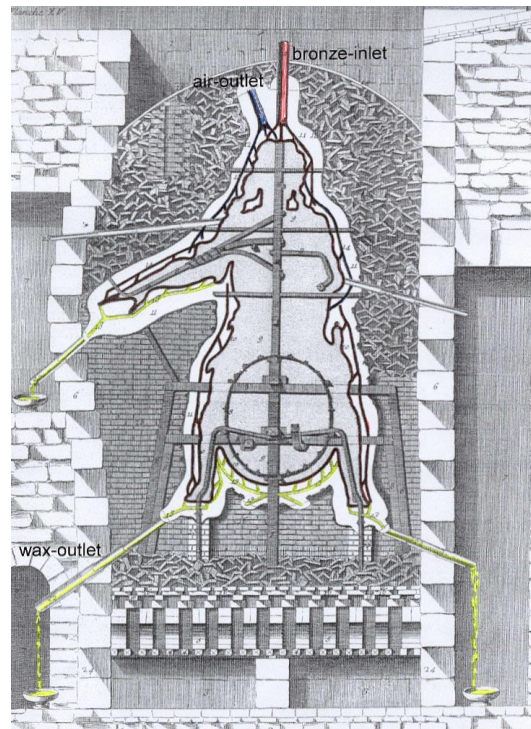


Figure 2.1.: The lost-wax process. Yellow: Heated wax flowing out of the form. Red: Hollow space left by the lost wax for the bronze. Blue: Trapped air within the form must escape by means of special vents. From Boffrand, Paris 1743.

2.2. The sand-casting process

In the 19th century most bronze monuments were cast by means of the sand forming process. The forming material for the outer form and the core consists of sand. Before the casting the clay form has to be heated until there is no more water in it. If there is only a minute amount of water the molten metal flowing into the form would create steam that might burst the form within seconds. Normal sand without any binder would disintegrate during the drying into single grains, but a comparatively small amount of clay mineral in the sand will help to create a fire-proof mould.

As stated in the discussion of the lost-wax process, also in this case the aim is to create a hollow space between the outer form and the casting core where the molten bronze will be filled in. The process begins with an artist's model, usually in clay. From the original, piece moulds are taken to make a plaster replica (a positive). After the plaster replica has dried and been shellacked, it is half-buried in a bed of sand held in a rigid metal frame, usually cast iron or wrought iron (Fig. 2.2.a). The surface of the plaster is dusted with talc as a separator or release agent, and the sand is packed firmly in place, a process called ramming. At the end the exposed top half of the sculpture will be covered by a series of small, carefully moulded sand pieces (Fig. 2.2.b). The form pieces are fixed by core pins in the outer layer of sand and the whole negative form is then dusted with talc or carbon dust for an easier removing from the cast bronze later on. The pieces of sand are held in place by a coarser outer bed of sand, supported in a second metal frame and again rammed to stabilise the material (Fig. 2.2.c). This same process has to be carried out for the other side of the plaster replica (Fig. 2.2.d and 2.2.e). After that it is very important to extract the plaster replica without disturbing the very fine sand mould pieces (Fig. 2.2.f).

The void within the two halves of the mould is filled with a core. The core is constructed around an armature made of iron pipe, rod or wire (Fig. 2.2.g and 2.2.h). Some rods project out and serve to steady the core in the mould during casting. The core material usually contains plaster, sand furthermore wax rods or organic material. The basic idea behind this is to make the core material as porous as possible because it will expand and contract during the heating and cooling of the bronze casting process. Now the inner form is almost completed but it still fills up the entire cavity formerly occupied by the replica. So it has to be scraped back to generate a hollow space for the bronze (Fig. 2.2.i). Now the surfaces of the halves of the mould are pierced in a number of places to provide channels that serve various purposes (Fig. 2.2.j). Some channels, called gates, allow hot metal to enter the empty space; others, called vents, permit gas to escape during the casting process. The metal is melted in a crucible and poured into the mould through funnels.

During the casting, it is possible that the sand pieces shift a bit or get small cracks. This causes characteristic seams in the sculpture that have later to be worked over.

A very good indication that a bronze monument is made by the lost-wax process is the great number of core pins keeping the distance between the core and the outer form. Core-pins are always absent in the sand forming process because they do not provide stability in the sand.

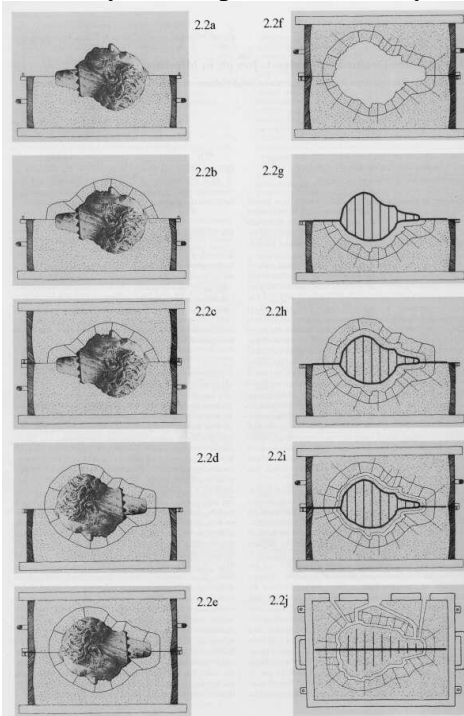


Figure 2.2.: The sand-casting process and working steps. From Lüer, Leipzig ~1902.

2.3. What is bronze?

Pure copper is not as fusible as bronze because it spatters during the casting and sets under blistering. Therefore there are only very few monuments of cast copper worldwide. Copper alloys with tin (Sn) and zinc (Zn) are better to cast than pure copper. The composition of art foundry bronzes changed over time. Whereas the oldest Egyptian bronze sculptures were made out of a mixture of copper and lead the Greek and Roman bronze sculptures contained less lead but more tin and zinc. The German bronze sculptures of the Middle Ages were predominantly copper alloyed with tin and only a very small amount of lead or zinc. But there are a lot of brass monuments in the Nuremberg area.

19th century chemists considered a pure tin bronze as the very best choice in order to achieve a nice natural patina. Foundry men liked to have more freedom and had individual habits. Casting procedure were always optimised for certain alloys. This practise has roots in the history of each foundry where an alloy which gives good results will never be used in another. A good illustration of this empirical approach is the consideration by many foundry men in Germany that the alloy used by the famous J.B. Keller in France for his famous equestrian monuments was the best suited for big bronze monuments. It had even a proper name in Germany (“Keller-Bronze”), but chemists did not agree with this.

In the beginning 20th century it was considered that the best bronze contains 90-93% Cu and 7-10% Sn. The 93% Cu/7% Sn-bronze was used especially for the bronze sculptures in Germany of the modern age For smaller monuments and ornaments mixtures of 88-92% Cu, 8-6% Zn and 4-2% Sn were used.

The use of various copper alloys lead to different characteristics for the bronze sculptures. The addition of Sn increases the hardness of the metal and the quality of polishing of the material, while Zn improves the pourability. Lead increases the image sharpness. Depending on the history or origin, the bronze contains other traces like nickel (Ni), silver (Ag), antimony (Sb), arsenic (As) or iron (Fe), but as metal traces they do not influence the metallurgical properties of the bronze metal.

The famous Chinese mirror alloys contain between 20 and 27% tin and up to 6% lead so that they have a silvery-white colour and resistance against colour changing. However this type of alloy is brittle and difficult to engrave.

Copper and tin can easily be mixed by heating to high temperatures in the mass ratio that is typical for bronze. During the cooling of the copper alloys after the casting the copper-tin mixture hardens first in mixed crystals. Lead is completely insoluble in these mixed crystals and stays liquid for a longer time because of its lower melting point. So lead hardens at last between the copper-tin crystals and fills even the smallest unevenness between metal and form. So it is obvious that a higher content of lead within the copper alloy leads to an increasing image sharpness.

Table 2.1 shows some types of copper alloys and their different compositions. There are two fundamentally different types of bronzes called red brass (Rg) and tin bronze. Tin bronzes only contain copper and tin whereas the red brass alloys contain also small amounts of zinc and lead.

Type of copper alloy	Cu [weight %]	Sn [weight %]	Zn [weight %]	Pb [weight %]
Rg A	84	5	7	4
G-CuSn4ZnPb (Rg 4)	93	4	2	1
G-CuSn5ZnPb (Rg 5)	85	5	7	3
G-CuSn7ZnPb (Rg 7)	83	7	4	6
G-CuSn8Zn (Rg 8)	82	8	10	-
G-CuSn9Zn (Rg 9)	85	9	6	-
G-CuSn10Zn (Rg 10)	86	10	4	-
G-CuSn10	90	10	-	-
G-CuSn12	88	12	-	-
G-CuSn14	86	14	-	-

Table 2.1.: Types of copper alloys used in casting and their different compositions. From Deutsche Norm, DIN 1705, Kupfer-Zinn-und Kupfer-Zinn-Zink-Gußlegierungen (Guß-Zinnbronze und Rotguß), Berlin November 1981.

2.4 What is a patina?

As the discussion of this question fills books it is not possible to describe the term "patina" appropriately within two pages. So discussion about patina is controversial and wide ranging, but most conservators are in agreement that a patina on a bronze sculpture should be such as that the bronze still bears its peculiar metallic character. Nevertheless there is no clear distinction between the terms "patina" and "corrosion layer". From a corrosion scientist's point of view both terms describe similar chemical situations. E.g. a patina and a corrosion layer both might have incorporated deposited material from outside like fat from touching or traces of dirt. But as a rule the concept "patina" includes an aesthetic appreciation whereas the term "corrosion layer" does not.

A major benefit of a patina in the positive sense of the word is that it protects the metal against destruction by environmental pollution and furthermore might be of a positive aesthetic value. Figure 2.3 shows a cross-section of a sample from an outdoor bronze sculpture. This is an example of a naturally grown patina that is no more protective.

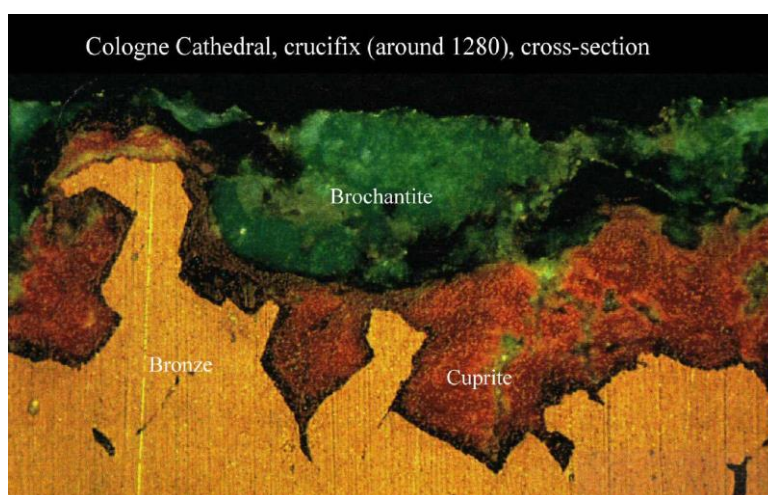


Figure 2.3.: Typical cross-section of an outdoor bronze sculpture (width: 0.6 mm). The assumed original surface has been destroyed to a great extent in the green areas.

There are two types of patina, natural and artificial. "Natural" or "artificial" refers to the causes of the patina formation, so a natural patina means that it has been formed by environmental influence only. The terms do not tell us whether the respective layer is stable or not. Some people prefer to distinguish "outdoor patina" and "indoor patina", with outdoor patina being dominated by green basic copper sulphates and indoor patina as a brown cuprite (copper-I-oxide) patina. An artificial patina is maintained by applying chemicals or paint onto the surface of the bronze sculpture to provide an "antique" finish or for various styles of coloration. Many modern sculptures are artificially patinated.

To focus on the characteristics of patina on bronzes, it is necessary to have a look on the vocabulary. There are four basic attributes of a patina on bronze sculpture; these are typically paired as "natural" and "artificial" and as "stable" and "active". The terms "stable" and "active" refer to the condition and reactivity of the patina and distinguish between two kinds of bronze corrosion. The so-called "noble patina" consists of corrosion products that are at the same time attractive and chemically stable. This type of patina is for example often found on excavated Etruscan and Chinese mirrors. A stable patina is hard to find outdoors in these days because it is formed over a long time period with little pollution. As a consequence there is only a slow corrosion and time enough to form a stable corrosion layer. A noble patina on outdoor bronze sculptures can be defined

as a green or brown, shiny, peculiarly attractive, translucent surface which leaves no doubt that the metal lies beneath. The translucent surface does not result from treatment but is simply caused by gentle patina formation. It owes its beauty not only to a green colour. As a rule warm, red-brown tones are displayed as well. The original contours of the bronze with all its finishing details must be visible and the patina should have an enamel-like surface.

A chemically and mechanically stable patina normally has a glossy, translucent surface and a dense smooth layer of brownish cuprite (copper-(I)-oxide) close to the metal surface. The smoothness and gloss of the surface can be enhanced by the occasional touching of passers-by. The active or virulent patina consists of those corrosion products that actively corrode the metal surface. It is mostly of modern origin, namely caused by industrial pollution (presence of sulphates see below) and can be found on the surface of urban outdoor bronze sculptures but also on very old archaeological bronzes (presence of chlorides).

In modern times sulphur dioxide air pollution has formed light-green patinas consisting of basic copper sulphates. This kind of look has become familiar and is sometimes described as a typical natural patina. This modern type of patina might be protective in some cases for the metal but is not very stable mechanically and chemically. However it might have a cultural value and carry marks from tools and other information. Sometimes it is considered to have an aesthetic value but of course the judgement may vary from object to object and among people and cultures.

A scientific clue to the understanding of the character of a natural outdoor patina lies in the properties of the base material. The patina will develop in a positive manner when the alloy is homogeneous, fine-grained, dense and not too porous. The surface has to be so smooth that oxidation occurs very slowly.

Finally it has to be pointed out that there are always exceptions and special cases. This short overview is intended as a quick information only and cannot replace the study of actual monuments and further literature as mentioned above.

By Anke Doktor and Martin Mach

CHAPTER 3

Deterioration of outdoor bronze monuments

3.1. General principles on the corrosion of copper based alloys

Metals have the tendency to corrode. Obtained from stable minerals which had to be melted or transformed, they tend with time to come back to their original state.

This statement is well understood by everyone and conservators looking after metal objects know very well that if such an object is left unprotected in the harsh atmospheric or other environment, its appearance will gradually change and its surface will become covered with streaks, run offs, and disfiguring corrosion layers.

Corrosion processes are taking place at the atomic level and involve not only the metal itself but the environment (mostly humidity, oxygen O_2 and other gas present in the atmosphere). Exchange of electrons are involved in electrochemical processes and conduct on the metal surface (M) to the dissolution of positive charged metal particles (cations M^+) and from the environment to the formation of negative charged particles (anions OH^-). Both particles react to form a more or less protective film ($M(OH)_n$) on the metal surface (Fig. 3.1).

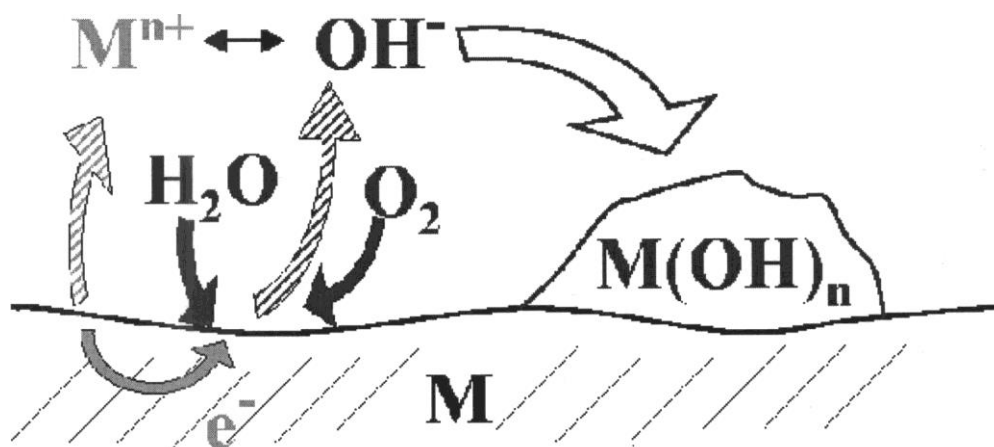


Figure 3.1.: Representation of electrochemical reactions taking place at the metal surface.

Heterogeneities and defaults present at the metal surface, particularly in the case of alloys (pores, boundaries between grains of different composition, inclusions combining the different elements...) are preferential site for corrosion processes. According to the metal microstructure they will develop from pitting corrosion to general corrosion (on the whole surface or inside the metal).

Water tends to favour corrosion processes but oxidation also occurs in dry atmospheres and may even conduct to the formation of a very protective oxide film.

Usually atmospheres are classified as rural, urban (SO_2 deposition rate 10-80mg SO_2 per m^2/day), industrial (SO_2 deposition rate > 200mg per m^2/day) and marine (between 5 to 500mg NaCl per m^2/day and can be as high as 1500mg).

Copper and bronze have always been regarded as corrosion resistant materials in outdoor environments in comparison to iron alloys but the metal surface may be heavily damaged (etched).

Corrosion rates have been recorded in field exposures of copper and bronze coupons in different environments, The general rate is higher on copper than bronze and is slightly higher on unsheltered samples than on sheltered ones (Tab. 3.1).

Samples	Mass loss after 1 year (mg/cm ² year)	Mass loss after 4 years (mg/cm ² year)	Penetration after 4 years (µm/year)
Sheltered copper	0.1-1.7	0.1-1.4	0.1-1.6
Unsheltered copper	0.3-2.8	0.5-2.0	0.6-2.2
Sheltered bronze	0.1-0.7	0.1-1.0	0.1-1.1
Unsheltered bronze	0.3-1.5	0.2-1.6	0.2-1.8

Table 3.1.: Mass loss and calculated penetration for copper and bronze samples (Rg7) exposed at 39 sites in 14 countries after 1 or 4 years respectively. From Stöckle et al,1993.

When considering the characteristic features of the corrosion layers obtained, 4 different cases are usually observed (Fig. 3.2):

- dark smooth area found on rain-sheltered areas. They correspond usually to the original surface. Oxide layer (cuprite Cu₂O) combined with soot particles and chloride species (atacamite Cu₂(OH)₃Cl) may be identified.
- Black crust found on rain-sheltered areas and for monuments older than several decades. In addition to the previous compounds copper sulphates (brochantite Cu₄(OH)₆SO₄ and antlerite Cu₃(OH)₄SO₄) are found.
- Light green areas on horizontal or inclined rain-exposed areas. Exposure to rain causes the dissolution of the corrosion layers, sometimes exposing the underlying cuprite layer.
- Light vertical streaks on rain exposed areas.

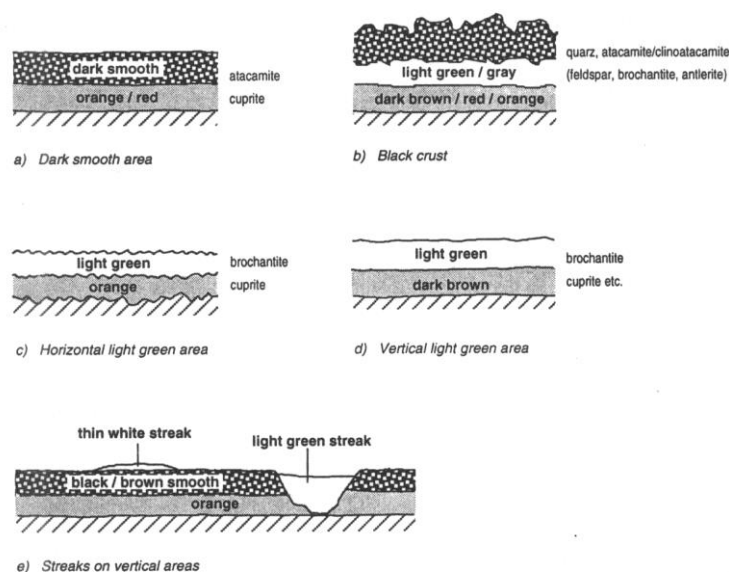


Figure 3.2.: Sketches illustrating cross-sections of characteristic patina layers on outdoor sculptures. From Strandberg, 1997c.

Different factors affect the presence of corrosion layers and their particular development. They are presented below.

Corrosion also occurs on artificial patinated metal surfaces covered or not with a coating (wax). Complex reactions may then be involved in addition to the basic principles described previously.

By Christian Degriigny and Dimitrios Charalambous

3.2. What factors affect the deterioration of outdoor bronze monuments?

Among the factors mentioned below, the acid rain and the application of graffiti are of particular importance nowadays and bring new maintenance problems. In the following we concentrate on the bronze part of the monument.

3.2.a. Techniques of construction

The alloy composition of the monument may influence the deterioration process. However, of more importance is the structure of the bronze surface. A smooth surface that is chased and polished and is free from pores and cracks best resists corrosion.

Iron parts in bronze sculptures may cause big problem due to galvanic corrosion. Large sculptures are often constructed with an iron skeleton serving as an inner armature for the core, and smaller sculptures occasionally have reinforcement in some weak parts. Iron bolts are sometimes used for joining. Iron parts will rust and cause rusty stains. The large volume of the iron corrosion products may also cause cracks in the bronze. Stainless steel is a better choice of material when new constructions are made.

3.2.b. Artificial patination

The appearance of bronze may vary due to the artificial patination method used when the monument was made. When a sculpture has been dark-patinated it may still appear darker for some decades than if green patinated (this is attributed to both the composition of the patina and its smoother surface). Other characteristic features due to patination method may be localized corrosion. Patchy and cracked patterns on sculptures may also indicate an original patination or surface treatment.

3.2.c. Humidity and climate

The humidity in the air is of great importance for the deterioration. Many corrosion mechanisms are only occurring above a certain critical relative humidity (RH). About 70% RH is critical for many corrosion processes on bronze. As indicated in table 3.2 the mean humidity in Göteborg and Munich is close or above this critical humidity, while in Athens it is below. Consequently, the corrosion rate is much higher in the humid Göteborg and Munich than in the arid Athens.

	Rain (mm/y ear)	pH of rain	RH (%)			SO ₂ (10 ⁻⁶ g/m ³)			NO ₂ (10 ⁻⁶ g/m ³)			Soot (10 ⁻⁶ g/m ³)		
			Ann	Wint	Sum	Ann	Wint	Sum	Ann	Wint	Sum	Ann	Wint	Sum
Göteborg 1997	900	4.5	75	85	65	4	6		30	30		4	6	
Munich 1999	800	5.5 to 6	67	75	60	5	8	2	39	47	32	34	38	30
Athens 1999	400		63	73	48	39	60	28	91	87	100	106	118	94

Table 3.2.: Climate and air-pollution values in the cities of Göteborg, Munich and Athens. Annual, winter and summer values are presented. (Munich source: *Lufthygienischer Jahresbericht 1990 to 1999*. Bayerisches Landesamt für Umweltschutz 1999; Athens source: *Greek National Observatory*; and Göteborg source: *Lufföreningar i Göteborg. Årsrapport 1997, Miljöförvaltningen, Miljö Göteborg (1998)*)

A marine climate is a strongly corroding factor for all metals. The salt that is transported with wind and rain causes pitting corrosion of the metal. If the air is additionally polluted with sulphur dioxide a synergistic effect occurs. Soluble compounds thus are formed resulting in weathering of the patina.

In Nordic countries when marble is used as a material for the base, transformation of water in ice may provoke damage of the material (cracking and deformation). As a result this process will destabilise the bronze sculpture placed on it. Due to safety reasons, special attention of these monuments is needed.

3.2.d. Outdoor pollution

There is a range of pollutants in the outdoor city air, which are crucial for the deterioration processes on the bronze monuments. Mean values of some air-pollutants in the city air are shown in table 3.2.

Sulphur dioxide (SO₂) from the combustion of fossil fuel creates an acid electrolyte on the bronze surface when water is present and forms the corrosion product brochantite (Cu₄(OH)₆SO₄) by time. This corrosion product gives the characteristic light green appearance of outdoor bronze sculptures in cities. The SO₂ levels showed very high levels in the 1970's in many cities in Europe (one to two magnitudes higher) but have decreased during the last decades, especially in the north of Europe (Fig. 3.3). This has resulted in less amount of brochantite forming on bronzes nowadays.

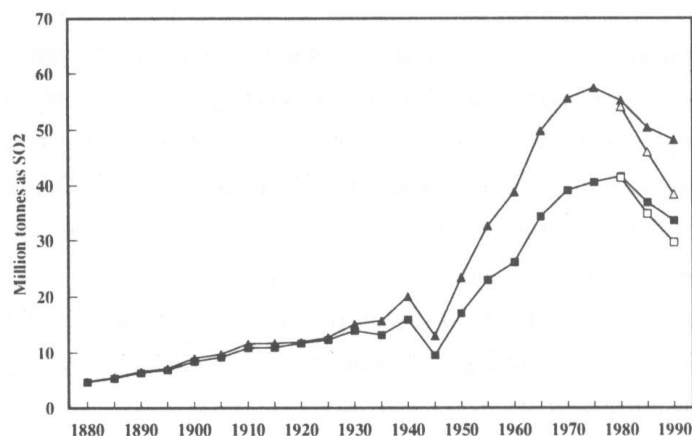


Figure 3.3.: Historical emissions of sulphur dioxide in Europe between 1880 and 1990. Source: Mylona, S. *Trends of sulphur dioxide emissions, air concentrations and depositions of sulphur in Europe since 1880*. Meteorological Synthesizing Centre-West, The Norwegian Meteorological Inst., EMEP/MSW report 2/93 (1993), p 22.

The corrosion rate of outdoor bronze monuments is closely related to the concentrations of acid forming gases. In particular the amount of sulphur dioxide is correlated to the mass loss of outdoor bronze sculptures as shown in figure 3.4.

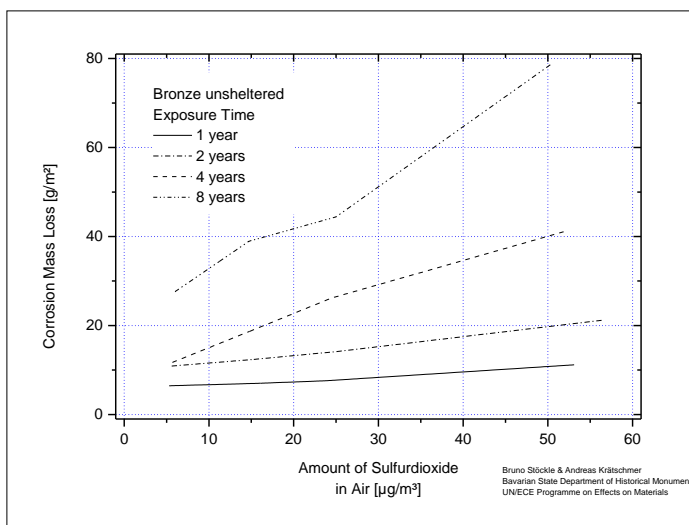


Figure 3.4.: Dose-response function of unsheltered bronze exposed for 1, 2, 4, and 8 years. The material was exposed in 12 European countries and in the United States and Canada. Obviously, the damages follow an exponential curve. Bronze alloy: G-CuSn7ZnPb (RG 7). From: Stöckle et al, 1993.

NO_2 is a corrosive acid forming substance that shows synergistic effects with SO_2 on copper and bronze corrosion. The main source for NO_2 emissions in city air is automotive exhausts. The pollutant level is clearly related to the intensity of the traffic. In urban air, NO_2 has not showed any decreased trend during the last decades.

Ozone is a strong oxidant that also shows synergistic effects with SO_2 and increases the corrosion rate of bronzes.

Soot comes from incomplete fuel combustion and consists mainly of carbon. Soot is correlated to SO_2 emissions in a historical perspective and has simultaneously decreased in many European cities the last decades. Soot mixed with corrosion colours the black rain shaded parts on bronze sculptures.

Dust particles may be of many various kinds, sometimes protective for the material properties, and sometimes damaging. An important aesthetic damaging factor is that dust deposited on a monument covers and makes the surface of monuments dull so the artistic expression may be obscure. Dust often contains sand and soil particles. Salt particles from the sea and from the dusty winter roads in the Northern countries may deposit and be very corrosive. A thin layer of iron particles from tram's dust may deposit in bronze patina and may sometimes form a dense, smooth "yellow patina" that has some aesthetic qualities and protecting properties.

3.2.e. Acid rain

Natural precipitation, rain and snow, is slightly acidic and pH in natural rainwater is about 5.6. Over the last few decades, the acidity in rainwater generally has exhibited much greater acidity due to the widespread occurrence of SO_2 and NO_2 . This phenomenon has been particularly important in Nordic countries as shown on figure 3.5. Today the acidity of rain in Europe is generally about 10 times higher than in the middle of the century and no decreasing trend is evident. The pH of rain is consequently lower.

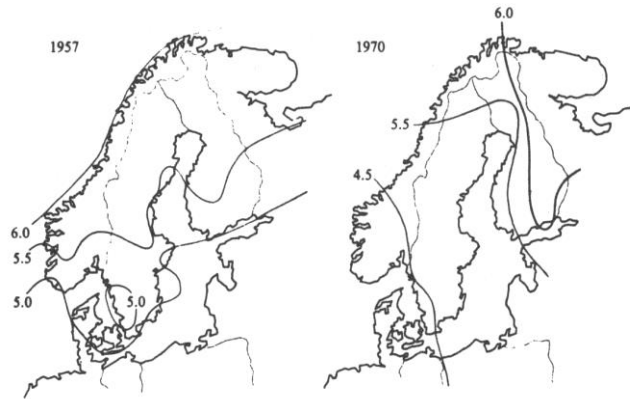


Figure 3.5.: Increase of precipitation acidity in Scandinavia between 1957 and 1970. The solid lines mark contours of equal pH. From Wayne, 1985, p201. Source: Linkens, G., *Chem. Engng News* 54 (1976) 29.

The acidity in the rain may dissolve locally the patina that protects the bronze metal of the monuments and initiate electrochemical corrosion processes between the bare metal and the surrounding patina. This dissolution of the patina may also result in the loss of original surface texture, e.g. tool marks on the surface.

3.2.f. The location in the city

The location of a monument is of certain importance for its condition. Sculptures in parks sheltered from wind and traffic are better preserved than objects exposed to heavy traffic. Trees and bushes absorb the air-pollutants and create a better atmosphere. Deep pits in the bronze surface created by pitting corrosion are often observed on parts of sculptures close to the traffic.

Objects exposed to strong winds from the sea are characterised by being more light-green and deteriorated on this side.

3.2.g. Use of the monuments

Many monuments have a practical function that may become a threat to the material properties and intrinsic symbolic values of works of art. Water fountains, sculptural parts frequently touched by man, and sculptures inviting and intended for children's climbing, are example of monuments being used. On the other hand traces of such practical use can be of importance for the true interpretation of the image of the sculpture. Some modern artists appreciate children climbing and other use of the monuments. However, artists sometimes have changed their opinion when the marked wear become evident.

To a certain degree the touching, which implies polishing of the surface, preserves the monument. The surface becomes smooth and maybe greasy which inhibits the corrosion. However, if the wear goes beyond the cuprite patina and shows the bare shiny metal surface a prohibition to touching should be considered.

Fountains sometimes suffer from thick deposits of lime from the pipe water that discolour and cover the surface of the bronze. The aesthetic values certainly decrease with such crusts, however this alkaline deposit may also protect the patina. Water rinsing the surface of a bronze may protect the surface to some degree but at the same time mechanically wears the patina off. Some parts of fountains, which are not rinsed, are constantly at very high relative humidity. This is a very corrosive environment and pitting corrosion may be severe. Algae sometimes grow on the lime and dust deposits on bronze sculptures.

Many monuments also have a practical function for animals. Birds love certain sculptures. Bird-droppings may cause corrosion damage since their debris contain corrosive agents dissolving the patina compounds. Greenish disfiguring deposits and streaks are formed on the bronze sculptures.

Spiders and other insects may also like to live in the monuments but do not cause any harm.

3.2.h. Vandalism

Graffiti and scrawl is a great problem in cities and has increased considerably in the last decade. Vandalism may alter more drastically the appearance of an outdoor sculpture. The use of spray paint or felt tip marker is a way of expressing public discontent towards government or society at large. More radical forms of expression may be to use explosives or to physically remove the sculpture or parts of it from its location. Here, such reactions may merit removing such a monument, especially when it endangers people's lives.

The bronze parts of the monuments are not used to be the most inviting to paint on, but the flat bases, often in stone, seems to be inviting surfaces to write tags on. Paint products on bronze surfaces may sometimes be impossible to remove without damaging the complete patina of the object, especially when time has passed and the paint has been included in the corrosion products. Graffiti paint should therefore be removed immediately. Professional guidance should be consulted since acidic cleaning agents and hot medium pressure water may damage the patina.

Bronze is a rather hard and tough material that is not so easy to break without tools. However, there are incidents where protruding parts have been broken off sculptures only by mans power. Since many monuments are symbols with various meaning provoking vandalism sometimes occur. At several occasions the head of the famous Copenhagen Mermaid have been sawed away. In Athens, ... Monument has been several times the target of soldiers during the second world war who shoted it (Fig. 3.6). There are also political actions aimed towards monuments symbolizing the power. Some examples can be mentioned. The Peter I monument in Moscow was exposed to a bomb attack 1997. The bronze Lions in front of the Norwegian Parliament House in Oslo were also set in fire in 2001.

Figure 3.6: ... Monument, by..., shoted with bullets during the 2nd war. Credit?

By Helena Strandberg

3.3. Problems that face outdoor bronze sculptures

The problems that face outdoor bronze monuments are essentially all man-made. While these problems can be classified, they vary depending on the techniques of construction, location and environmental setting of each monument, and subsequent documentation, treatment and maintenance program in each city. For example, outdoor bronze monuments in Munich or Göteborg tend to be more heavily corroded than in Athens. These cities in Northern Europe have heavier rainfalls and are more humid than a country like Greece, which is warmer and more arid in its climate. In today's polluted environment, rain in most rural areas in Europe is acidic, which results in further stimulating corrosion of outdoor bronze metal. However, outdoor bronze monuments in Athens suffer more from vandalism than in Munich or Göteborg, most likely due to public insensitivity towards the history of their city's monuments. The public may be uninformed of both the historical and artistic significance of these works of art.

Acid rain and vandalism are man-made factors that alter visually the appearance of bronze sculptures and disfigure them. Pollution such as acid rain changes slowly the colour and texture of the original surface. Unfortunately, the colour changes are not uniform, so that on an artificial black patina surface, streaks or patches of light green may appear, which are unpleasing to the eye, and affect the artist's original intention. This phenomenon characterises particularly monuments of the last decades. This corrosion may also cause serious damage to changes in the surface texture. The corrosion layers that form with time may hide or distort surface details, such as tool marks that are signatures of the artist and craftsman.

Many factors influence the extent of deterioration caused by acid rain and vandalism to such monuments. For example, the shape of the monument or holes located in metal due to casting methods may result in more accumulation of water in certain areas of the sculpture. Improper materials used or unrefined finishing in the techniques of construction of a sculpture can lead to unpredictable problems when they come in contact with water.

Also, monuments located in hidden and isolated areas that can be reached by the public tend to be easy targets for graffiti. Lack of urban planning in proper placement or an uninformed public as to the historic significance of a monument increases the chances of monuments becoming attacked by passers-by.

Finally, the biggest problem that faces outdoor bronze monuments is a lack of funding and proper planning to protect them. Some city officials believe that caring for outdoor bronze monuments is similar to cleaning a sidewalk. Untrained personnel who do not have knowledge, experience, or judgment in the conservation of such objects have caused much damage to such works of art. While it would be unthinkable to use untrained workers to restore or even touch a museum object, in some cities it is common practice for such workers to handle our monuments. Furthermore, some cities may sporadically invest in restoring some of its outdoor monuments, without even considering investing long-term in maintaining them.

By Vasilike Argyropoulos

3.3.a. Athens: vandalism but slight corrosion problems

There are around 63 outdoor bronze monuments in Athens. A conservation survey, which means documenting the location, historical information, and condition of the monument, has recently been carried out for all the monuments. The results show that around 20% have graffiti on the metal surface of the sculpture either in the form of paint or felt tip marker. Around 15% have graffiti problems on the marble base of the monument. A few monuments have missing parts, due to vandalism.

The annual SO₂, NO₂, and soot values in Athens are more than double the values of Göteborg or Munich (Tab. 3.2). One would expect with such high pollution levels for outdoor bronze monuments to be in worse condition than those in Munich or Göteborg. On the contrary, due to the low annual rainfall and relative humidity, outdoor bronze monuments corrode at a much slower rate than in northern European countries. Nonetheless, monuments that have been placed outside for more than 10 to 15 years show visible signs of alterations on the surface of the metal. These alterations are in the form of streaking or light green patches, which are disfiguring to the original appearance of the sculpture. Older monuments around 100 years old, such as the Kolokotronis

monument, show signs of black crusts on the surface of the metal, as well as streaking and light green patches.

By Vasilike Argyropoulos

3.3.b. Göteborg: sculptures in a rough marine environment

The outdoor monuments in Göteborg face a rough humid and corrosive environment. The city is situated on the west coast of Sweden and has a strongly corrosive climate due to the proximity to the sea that brings sea salt by the western winds, high humidity in the air, pollution from heavy traffic and industry, and an acid rain falling. These factors affect the outdoor monuments in such way that they will corrode faster than e.g. in Athens that has a dryer climate or in Munich that has an inland climate. Therefore the monuments may turn green in a few decades in Göteborg and this is the way the people in the city are used to see the monuments. However, the green patina and also the black soot crust on old monuments is nowadays dissolving by the acid rain. This causes the streaked appearance on sculptures. The patina on rain-exposed parts of the sculpture become weathered and destroyed.

In Göteborg, the sculptures from the 1940s and 1950s appear to be in a rapid change. They show evident colour contrasts between dark and light green areas and distinct vertical streaks caused by the rain. Orange or brown areas also occur indicating the leaching of patina compounds.

Older sculptures, from the 19th century or from the beginning of this century, exhibit considerably thicker corrosion product layers. In some cases the sculptures appear predominantly green. Thick black hard crusts are evident in rain-sheltered areas. The green discoloration on adjacent stone bases of older sculptures, especially when they are made of marble, also indicate the dissolution and washing-out of copper compounds, especially on marble bases (see figure 1.8 of Gustav II Adolf in Göteborg).

By Helena Strandberg

3.3.c. Munich: a typical case of western Europe large city

Damages on historical monuments have to be interpreted with respect to the environmental situation in the surrounding area. Germany has a continuous weather and pollution monitoring since about 1950. As there were no suitable methods before that time, those measurements were only done sporadically. Like in other countries in western Europe the SO₂ pollution has decreased. In East Germany the situation has improved most.

Munich is a large city in the south of Germany that nowadays has a moderately corrosive climate. Outdoor bronze monuments have to resist to influences by heavy traffic and acid rain. Fountain sculptures are exposed to water that contains a considerable amount of calcium carbonate as well. This often causes the formation of thick crusts on the sculptures. The colour changes to light grey. The visual appearance and changes of the visual appearance of Munich's outdoor bronze monuments is similar to the situation in Göteborg. First the monuments turn to dark-brown or black, then acidic attack begins to undermine the black surface, a process which is being signalled by the formation of green corrosion products. This lasts at least a few decades. It is the typical fate of bronzes of the 19th century.

More than 75% of the Munich bronze monuments are situated in or near the city centre where the amount of SO₂ has been 20-40 µg/m³ in 1967. The majority of bronze monuments from the 16th-18th century are situated in inner courtyards but still in vicinity to main streets. About 25 big bronze monuments are standing directly at streets. Most big bronze monuments of the 19th century are situated on squares with high traffic in the city centre where they face the main sources of air pollution.

By Anke Doktor and Martin Mach

CHAPTER 4

Conservation Strategy

4.1. General approach

4.1.a. Planning conservation

Professional conservation practice presumes an understanding of many factors. Among these are the intent of the artist, considerations of the values that people attach to the objects, and the use of the monument. Moreover, the practice assumes a sound knowledge of the effects of time on the material properties, its implications for the object and various treatments according to the principles established. However, in many cases decisions concerning selection of conservation treatment often take place without a professional conservator involved in planning and/or execution of conservation interventions.

4.1.b. Ethical considerations

Standards of conservation have been developed to guide intervention for all kinds of cultural property and are found in some of the recent documents including: the AIC document (revised 1979), the Venice Charter (1964; revised 1978), the Burra Charter (Australia ICOMOS 1988), and the Nara document (1995). All these documents identify the conservation process as one governed by absolute respect for the aesthetic, historic, and physical integrity of the object with a high sense of moral responsibility. This implies obligations that fall into the following categories:

- to perform research and documentation, i.e. to record physical, archival, and other evidence before and after any intervention;
- to respect cumulative age-value, i.e. to acknowledge the work as a cumulative physical record of human activity embodying cultural values, materials, and techniques;
- to safeguard authenticity, i.e. to respect and understand the values attributed to the heritage. However, it is not possible to base judgments of value and authenticity on absolute criteria, since judgments may differ from culture to culture, and even within the same culture;
- to perform minimum reintegration, i.e. to re-establish structural, aesthetic, and semiotic legibility with the least possible interference with the original;
- to perform interventions that will allow other options and further treatment in the future.

4.1.c. Documentation

Documentation should always be performed before, during and after any intervention. This includes e.g.:

- photo documentation;
- historical research of the object;
- recording of the condition of the object, e.g. colour, patina cross sections;
- definition of the “original surface”;
- recording of damages;
- analysis of the object, e.g. corrosion samples, alloy composition;

- analysis of the environment;
- analysis of causes of damages;
- documentation of all measures performed including method, material, products, and chemicals.

To find the causes for the actual condition historic research is necessary. Analyses of corrosion samples and e.g. alloy composition may reveal causes for deterioration and information relevant for the history of technology.

This documentation is essential to establish the condition report and define the conservation plan.

4.1.d. Choice of interventions

Interventions may be exercised in different ways to preserve qualities of significance. They should be minimised as they may always involve some loss of value. Different degrees of intervention are identified which can take place separately or simultaneously in conservation treatment. They are presented below:

- *Prevention* of deterioration may include planned measures after diagnosis, e.g. to reduce atmospheric pollution. Preventive measures for new sculptures may be the consideration of appropriate patination methods for sculptures and locations for inauguration. Regular professional inspection and maintenance plans to prevent the development of undesirable changes are other preventive measures.
- *Preservation* signifies the effort to keep cultural property in the existing state, e.g. by maintenance, including superficial cleaning of surface dirt and repair. By removing corrosive agents such actions may preserve sculptures from deterioration.
- *Consolidation* is the addition of supportive materials to ensure structural integrity. This includes application of coatings to preserve patina of sculpture from corrosive atmosphere and acid rain, e.g. by waxes. Preservation by consolidation may be executed with the aim to "freeze" objects in the existing state with use of conservation materials regarded as "reversible", and sometimes with material that is supposed to be long-time durable. Retreatable methods, e.g. the use of waxes, allow future treatment and are of considerable significance for architecture and outdoor monuments in corrosive environments.
- *Restoration* is the renewal of material components, which implies the revival of an original concept or legibility of an object, e.g. in cases where random coloration of corrosion and crusts visually destroys sculptural form and reading of surface texture. This may include total or partial removal of corrosion products, mechanically (e.g. by metallic wool; abrasive pads; abrasive tools; peening with sand, glass beads or granulates of walnut shells; or by ultra-high-pressure water) or chemically (e.g. by chelating agents or acids). After removal of corrosion products, repatination of the sculpture may be performed with chemicals. Restoration is often a controversial issue. The main motives for such actions often are based on aesthetic and/or functional considerations, and not primarily on efforts to reduce the rate of decay.
- *Reproduction* implies copying an extant artefact, e.g. when the original version has to be moved. Such protection of an authentic work may be the case for sculptures of exceptional value, or when an object is threatened by the surrounding environment.
- *Reconstruction* must be based on accurate documentation. A missing part of a sculpture may be reconstructed since it sometimes is necessary in order to re-establish visual appearance and meaning. However, it should neither replace nor compete with the original work or with the conservation process, but be an integral part of the object.

4.1.e. Preventive strategies

- *Professionals* should be consulted *before* any intervention on outdoor art.
- *Education and supervision* in conservation for all professionals involved in the handling of outdoor public art is necessary.
- *Professional inspection* of outdoor art should be performed regularly.
- *Maintenance plans* should be designed and implemented to prevent the development of undesirable changes.
- Conservation should be considered already at the *commissioning* of new art-works. The construction, choice of material and patination method could be discussed with craftsmen and artists before the construction begins to avoid safety, structural and aesthetic problems in the future. The location of inauguration could also be considered in this context.

4.1.f. Treatment

Minimal and retreatable intervention performances should preferably be chosen and strong measures such as restoration avoided if possible. However within this range there are many ways to treat the objects.

When minimal intervention is performed the patina on the sculpture is respected as an integrated part of the object and will never be taken off to the bare metal. However, deposits of soot and dust that cover the surface and may be corrosive is removed, as well as some corrosion that disfigures the original surface texture. The aim is to clean from dirt, uncover the original surface and strengthen the patina by making it denser e.g. by polishing.

The conservators methods for cleaning include low-pressure water, nylon brushes, and scalpels. Chemicals are used selectively with great care with the risk to stimulate further corrosion. The use of harder methods like blasting with walnut shells and medium-pressure water are sometimes used by conservators but may remove some of the light green patina. Sandblasting has to be avoided because even the finest and softest material removes the green patina completely while the brown cuprite patina is more stable.

The cleaning is restricted to the controlled removing of crusts of dirt and sometimes lime (in the case of fountain sculptures) that lies above the original patina. As already said the aim of a bronze conservation is to maintain the ageing value and not to uncover the shiny metal surface. The disturbing layers are removed with stainless steel scalpels. If there are brittle layers and thick lime crusts, vibrating tools can come to use, but only if the crusts can be removed in flakes. It may also be necessary to dense the rough crusts with rotating synthetic brushes. Laser cleaning is being discussed right now but its use is still far away from the practise routine work.

A wax coating may have a positive influence on the visual appearance because colour contrasts caused by corrosion will be reduced and the surface gets a silky metallic shine. One question may be why not covering the whole sculpture with a modern kind of synthetic coating? There are many disadvantages for those methods. First of all the metallic character of the sculpture will be reduced and the sculpture will achieve a shiny, more plastic look. The lacquer does not disappear by weathering but stay on the surface in that partly disappeared state, which makes the bronze look grey and neglected after a while. A partial renewing of the coating is neither possible. Lacquers have been developed for outdoor copper and bronzes (Incralac, Ormocer) but they have not found a large application in conservation.

Instead, the microcrystalline waxes are mainly used for conservation today and have been optimised for metal conservation. Chemically, they are to the largest part paraffin waxes consisting of long chain and sometimes branching hydrocarbons. They have a good water resistance but allow oxygen to diffuse through. The melting point of the wax should be high enough so the wax does not get sticky under sunlight. Beeswax is another wax that has long been used in conservation. It is simpler to apply but may become soft and sticky under sunlight and is more rapidly worn off.

The conservation with wax has the disadvantage that it cannot stand raining as long as a lacquer. On the other hand it remains at least for two years (in Göteborg and Munich) on the exposed parts and clearly longer on sheltered parts. Wax coatings can be renewed partly without problems and if nobody cares about the coating they simply disappear through raining without leaving traces or damages. Last but not least they adjust the colour contrasts and to some degree restore the lost metallic look.

In most cases the restoration measures concerns only the outer surface of the sculpture, but sometimes it can also be necessary to have a look on the interior parts, in particular if there are rust streams or cracks visible on the surface. These damages are often caused by an iron construction lying inside the sculpture. When the iron is corroding it expands its volume and may break the bronze structure. When severe interventions have to be done, like restoration of structurally damaged sculptures, reconstructions, and new joints for sculptures, conservation professionals should always be consulted.

By Helena Strandberg

4.2. Cases studies

In the following we present some case studies that illustrate the general strategy chosen by the three partners of the European project. Some of the partners, from Munich and Göteborg, have a large experience in the conservation of outdoor bronze monuments and used then well defined procedures. Athenians partners that began in the field benefited from the experience of their colleagues. The conservation of the Kolotronis monument in Athens is taken as an example and is described thoroughly. Strategies for other monuments are described more briefly.

4.2.a. Monument in Athens

Two monuments were considered in Athens, Kolotronis monument and the bust of Lekaditis.

Theodoros Kolokotronis



Figure 4.1.: Theodoros Kolokotronis monument in front of the Old Parliament building in Athens. Credit?

The sculpture of Theodoros Kolokotronis located in front of the old Parliament building in Athens was made in 1900 and erected in 1904 (Fig. 4.1). Kolokotronis or the ‘Old Man’ as he is nicknamed by Greeks was the beloved war hero of the Greek War of Independence in 1821, and he inspires and unites Greek people. The sculpture was created by Lazaros Sochos, who was one of the most distinguished Greek Sculptors, and has won international awards. The statue was manufactured by L_Gasne, successor of Thiebaut Frères Parisian foundry.

There are no records that the monument has ever been treated before by conservators, although there are testimonials by museum employees located next to the monument that measures to clean the monument have taken place in the past. It was chosen for our campaign of “Protect our Outdoor Bronze Monuments”, because of its importance to the Greek people and no thorough examination exists describing its details of construction or its current condition.

Construction

The monument stands around 9m from the ground on a marble base that has bronze relief representations of war scenes on either side of the base also created by Sochos in 1895 and 1897 (Fig. 4.2).



Figure 4.2.: Bronze plaque made in 1895 and located on marble base, which depicts Kolokotronis with his raised sword leading the Greek troops, and successfully fighting off the Turks. Sochos is also depicted among the Greek troops. Credit?

The base was designed by the architect Alexander Nikoloudis and made by the sculptor Ioannis Karakatsanis using two types of marble, Kokkinara and Pentelic for the three levels of the base.

Further inspection of the monument indicates that it was cast in 5 separate pieces, the helmet, the upper body, the lower body with horse and base, the head of the horse, and the tail of the horse (Fig. 4.3)

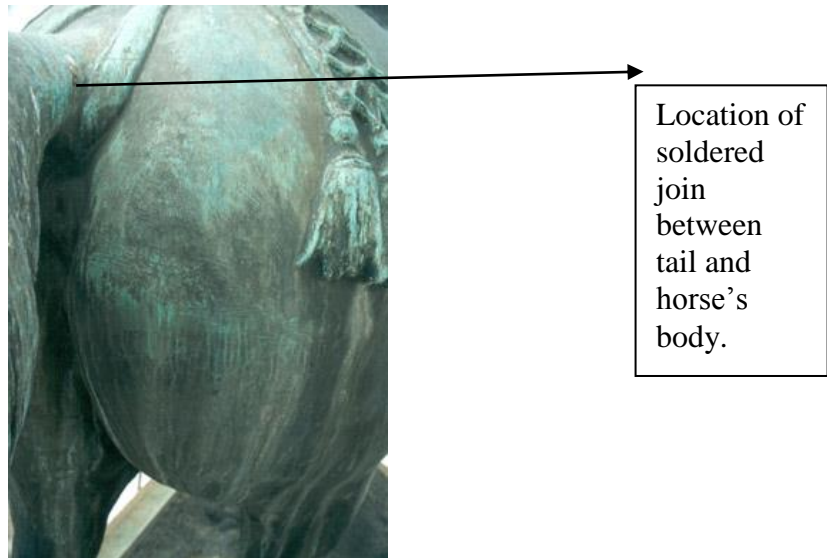


Figure 4.3.: indicates the soldered join of the Horse's tail to the body of the horse. Credit?

The horse's reins, gunpowder holder, and straps on Kolokotronis were added to the monument as separate pieces. All pieces were soldered in place and/or held together with screws. For example, the helmet has 3 screws (at both sides and back of the head), and has stucco covering the entire periphery of the join of the helmet to the head of Kolokotronis (Fig. 4.4).

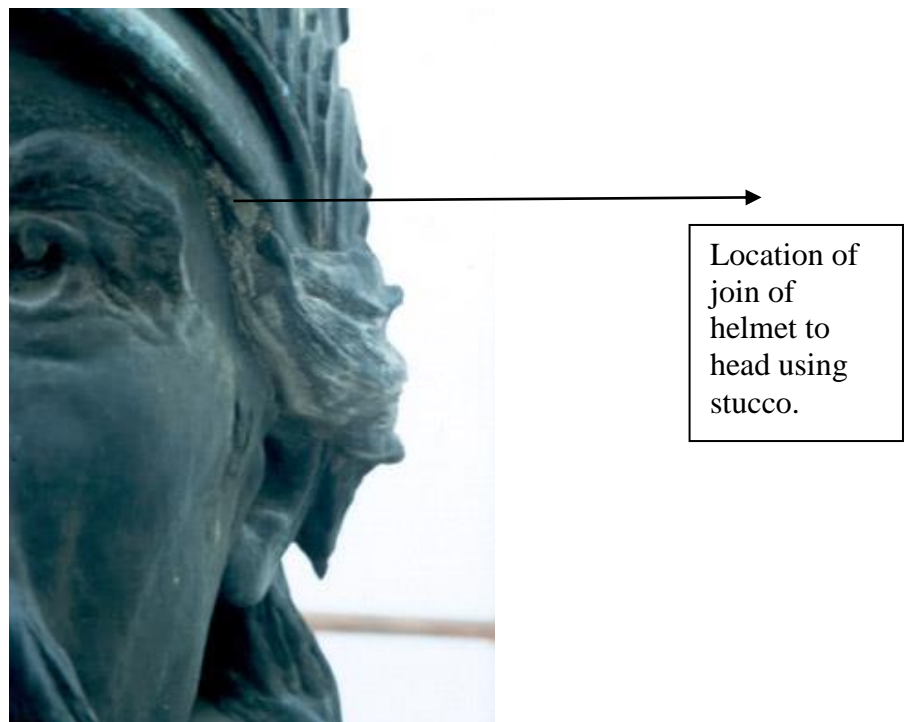


Figure 4.4.: Shows the stucco that was used to help secure the helmet to the head of Kolokotronis. Credit?

This unrefined join of the helmet stands out to the rest of the sculpture, where the soldered parts can barely be identified due to its fine craftsmanship. Closer inspection of the helmet provides further evidence as to why Lazaros Sochos produced such a rough join on the helmet. An epigraphy was found behind the tail of the helmet, which reads “Despite Soho’s will, my Kolokotronis wears again the helmet, Paris 190(9 or 2?) (Fig. 4.5). A mould of the epigraphy was taken and using a scanning electron microscope it was possible to determine that the last digit in the date is actually 2. (Fig. 4.6).



Figure 4.5.: Indicates the location where Sochos placed his objection to the placement of the helmet on Kolokotronis. Credit?

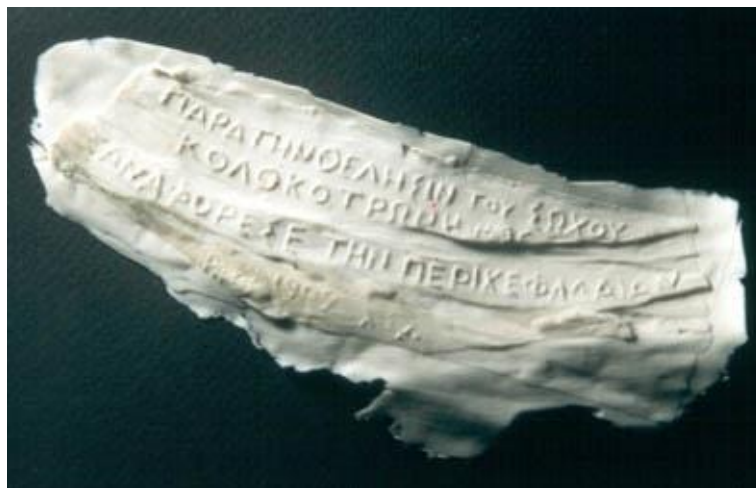


Figure 4.6.: Mould of the inscription at the back of the helmet. Credit?

The epigraphy on the helmet makes it clear that the artist’s intention for his sculpture was overridden by the desire of a committee, who commissioned the work.

The bottom part of the sculpture was cast including a bronze base with decorative relief. The bronze base has four bolts that secure it to the marble base. The sculpture shakes when a hand applies even slight pressure; such elasticity is needed for the bronze sculpture to prevent it from cracking at the base.

Scientific examination of the monument revealed that the chemical composition of metal to be Cu 89.5%, Zn 4.9%, Sn 5.1% on the heel of the right leg of Kolokotronis and with the same composition on the front right leg of the horse. This alloy is not the one which resists the best in corrosive atmospheres but due to the dry climate of Athens, the corrosion of the monument appears to be limited compared to what could be found in Göteborg and Munich.

Techniques to determine the internal structure of the monument, such as use of an iron skeleton or lead metal were not applied, because of the location of the monument (in a central location with passers-by throughout the night and day so that it was not be safe to use low levels of irradiation to identify the internal structure). However, our discussions with today's Greek sculptors lead us to believe that the horse's legs were cast hollow and were later filled with lead metal, so as to support the sculpture.

It was common for sculptor's of this period to artificially patinate with sulphur liver the bronze monument to give a shiny black appearance. Examination of the bronze monument, in locations that are sheltered from rain reveals a dark black colour on the surface, most probably the original surface. The horse's body has been chased, which provides a rippling reflection of light as opposed to the smooth metal surface as in the face of Kolokotronis, which provides a steady reflection of light.

Condition report

The bronze statue

The original appearance of the monument has altered after 100 years of exposure to the pollution of downtown Athens, with its location in one of the busiest commercial streets in the city. The sculpture is covered with dirt and debris from the surrounding environment. The top of the sculpture is light green where it frequently comes in contact with rainwater (Fig. 4.7). Other locations have signs of disfiguring streaking, caused by the run-off of rainwater or acid attack through the condensation of water vapour (Fig. 4.8). In locations that water does not frequent, dirt and debris has accumulated, and slowly formed thick hard black crusts (Fig. 4.9). Scientific analysis of the corrosion layers revealed that the black crusts are made up of different mixtures of gypsum, quartz, calcite, atacamite and crystalline carbon due to soot. The presence of soot particles gives the crust its black colour. This is typically found on bronze monuments of such age.

Examination underneath the crusts revealed the presence of a red-brown layer, most probably cuprite, a stable corrosion product. Other corrosion products detected were atacamite, copper sulphate hydroxide, copper sulphate hydrate, all typically found on outdoor bronze monuments in Europe. Malachite was also detected, which is more uncommon to find on outdoor monuments.



Figure 4.7.: Green patches on Bronze Sculpture. Credit?



Figure 4.8.: Streaking on Horse's body. Credit?



Figure 4.9.: Signs of thick black crusts on Bronze sculpture. Credit?

A few very minor cracks were located in the monument at join (top of horse) and at the side of the horse. Also, two screws were missing from the reins of the horse. Finally, many scratches possibly made with a scalpel were found at the sides of the horse and underneath horse's stirrup. This leads us to believe that someone had tried to clean the sculpture before (Fig. 4.10). Otherwise, such damaging marks may have occurred when the monument was moved from the top of Kolokotronis Street to its current location in 1954.



Figure 4.10.: Evidence of scratches on bottom of stirrup. Credit?

The marble base

The marble base has many conservation problems caused by the polluted environment and vandalism. The top part of the base with decorated relief has the most problems with areas of thick black crusts (Fig. 4.11), cracks, and even missing sections of the decoration (Fig. 4.12). Scientific analysis of the black crusts indicates that it contains gypsum and soot. The cracks and green stains have formed from run-off of water from the bronze monument (Fig. 4.11). Many locations in decorated sections of the marble base have a sugary appearance, which reduces the decorated relief representation. Also, in many sections on the base exist purplish black stains caused by microbiological attack to the marble. A more frustrating problem is the disfiguring graffiti in front of the base at the epigraphy (Fig. 4.13). Felt tip marker has been used to write two large words. Previous measures were taken to remove this graffiti, which unfortunately etch the surface of the marble, which was later disguised using white paint and gesso. Finally, careful examination has revealed that most probably the marble was coated with either a wax or oil from a previous treatment for its protection.

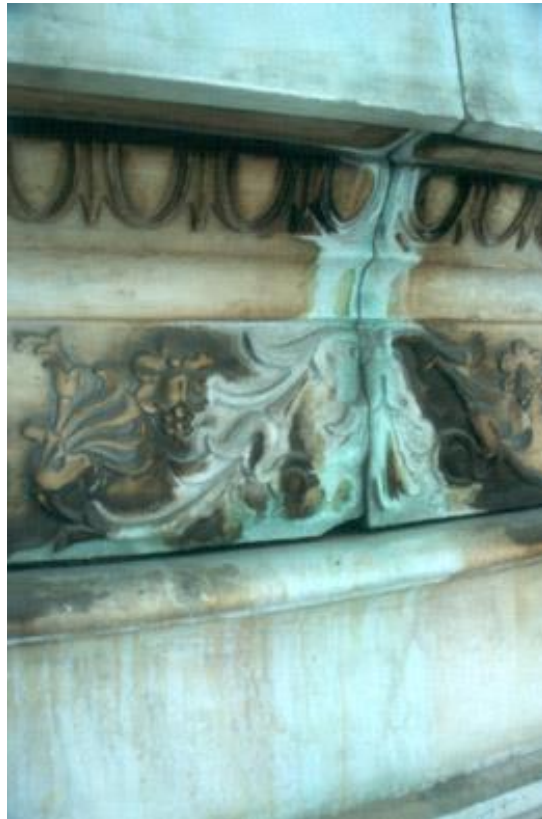


Figure 4.11. Black crusts and green stains on upper part of marble base. Credit?



Figure 4.12.: Cracks caused by water run off. Credit?

The bronze plaques were in excellent condition when compared to the sculpture or the marble base.

Conservation plan

The conservation treatment was conducted in two phases, first the bronze sculpture and then its marble base with side bronze plaques. The first approach was the following: removal for the sculpture and the base of external material that may continue to actively corrode or deteriorate the metal or marble ; further cleaning may be conducted to bring out decorative details that are lost in the corrosion layers ; touch ups to the colour or restorations for missing parts conducted to improve the aesthetic appearance of the monument and finally, application of a protective coating to help to slow down any further alterations to the surface appearance and to allow for easy removal of future applications of graffiti.

Conservation treatment

For the bronze sculpture, all dirt, debris, soot, and other soluble corrosion products was removed with soft filtered water under pressure and a mild soap, used commonly in metals conservation. As much dirt was removed as possible without harming the metal surface or the patina underneath. Then mechanical cleaning using a scalpel and other tools was conducted to remove black crusts to reveal decorative detail. Care was taken not to remove the stable cuprite layer underneath the black crusts. In some locations, it was decided not to remove the black crust at all, because revealing the cuprite layer on large surfaces, such as the side of the horse's head would alter considerably the colour of the darkly patinated surface. This followed our decision not to use any chemicals to clean or tone down variations in colour on the metal surface. Such a decision was necessary, because once the scaffolding is gone, the sculpture cannot be easily approached by the conservator to be assured that with time the surface is not affected by possible residual chemicals that may have remained on the surface after treatment. Also, the public from below cannot see with great detail slight variations in surface colour. After mechanical cleaning, the surface was rewashed with soft filtered water and degreased using acetone. A protective microcrystalline wax coating (TeCero 3534F, Tromm Company) was applied by heating the metal surface to around 100°C. The wax coating also toned down the variations in colour, and gave the surface a darker appearance than before, as was the artist's original intention. The bronze plaques on the base, due to their excellent condition, were simply washed and waxed as described above. No further mechanical cleaning was required.

For the marble base, any disfiguring variations in colour caused by black crusts or green stains is easily detected by passers-by. Thus, dirt, debris, black crusts, green stains, and graffiti had to be removed as much as possible without harming the marble. First dirt, debris, and other soluble products were removed with soft water saturated with calcium sulphate (explain why). For efficient treatment, it was deemed necessary to remove black crusts and green stains using pastes with absorbent clays (which chemicals in the paste?), which were thoroughly rinsed off with filtered water. This treatment was time consuming, since it was conducted in stages with careful examination to ensure the marble was not affected. Some mechanical cleaning with scalpel for careful in-depth probing and removal of the black crusts was necessary in the decorated relief. Then the decorative relief was consolidated. It proved impossible to remove the purplish-black stains caused by biological attack, which could only be toned down in colour.

More problematic was the removal of the graffiti made with felt tip marker, which was located in a visible location and disfigured the monument. The felt tip marker had penetrated the porous surface of the marble after many years. The only recourse was to destroy the marker with a paste containing a chlorinated solvent. This paste did not completely remove all traces of the marker. After consultation it was decided not to disguise the remaining graffiti, so that the public may become sensitised to the destructive and the permanent affect of graffiti. Then the entire marble was covered with a protective coating of anti-graffiti product, which contains wax, so that any subsequent vandalism with paint or felt-tip marker can be more easily removed. The epigraphy both on the front and back of the base was retouched only with black paint.

Finally, it was decided not to replace the missing parts in the decorative relief. Fitting in new pieces of worked marble in the decorated sections, would require that some of the original marble would have to be removed. The missing parts were deemed not to affect the overall aesthetic appearance of the base, and thus it was decided to not restore these sections.

The final appearance of the monument after treatment can be seen in the Figures below (which one).

Fig...

Lekaditis bust

Conclusions

A total of 12 conservators at different times worked on the monument for an operation that lasted just over 2 months. This does not include the scientists, historical researcher, photographer, and videoscoper who aided in the documentation and analysis phase of the conservation work. Also, technicians from the Municipality of Athens were responsible for raising the scaffolding and ensuring safety in operating the electricity and water on-site. The total cost of the operation was around 35.000 Euros without profit. Do such operations mean that the monument will not have to be maintained? It will be necessary to reapply the protective coatings both on the bronze sculpture and marble base every 3-5 years based on the experience in Germany and Sweden, at a much lower cost to that of the original treatment. Such preventive measures will ensure minimal changes to the

surface appearance of the bronze and marble, and will prevent subsequent retreatment at a later stage.

The conservation treatment of the Kolokotronis monument made front-page news, and appeared several times on television new channels in Greece. The public frequently stopped the conservators at work to shout up words of support and to find out more information about the project. The public's message was clear; Athenians adore their 'Old Man', and very much want to keep him bright and shiny. Our public campaign to Protect our Outdoor Bronze Monuments has succeeded.

By Vasilike Argyropoulos

4.2.b. Monuments in Göteborg

In Göteborg, three bronze sculptures were selected for this project. The largest sculpture was "The knife-wrestlers" and the treatment will be described below while the two smaller sculptures "The haze" and "Wadman" are only shortly presented.

The knife-wrestlers

History of the monument

The Swedish sculptor Johan Peter Molin (1814-73) first exhibited "The knife-wrestlers" in Paris 1859 (Fig. 4.). The sculpture is from the National Romantic period, a part of the Nordic history when the Nordic myths and tales inspired the art. In "The knife-wrestlers" Molin made a dramatic interpretation with realism in figures and movements.



Figure 4.: "The knife-wrestlers" before conservation. The whole sculpture is 3.43 m height and the postament is 1.97 m in length. The second relief is viewed from this side. Credit: Claes Jansson.

The original sculpture exhibited in Paris was made of zinc and was painted to achieve the appearance of green bronze. After exhibition in Paris and London it arrived in Göteborg and was placed outdoors in the city. The bronze surface had to be regularly repainted and by time the thick layers deformed the sculptural details. This aesthetic problem raised a discussion in the community.

Finally in 1912 funds were raised for casting a new copy of the sculpture, this time in real bronze. In 1913 the new bronze sculpture, weighting 1400 kg, cast at Otto Mayer's foundry in Stockholm, arrived in Göteborg by train.

The tale on the monument

The monument (Fig 4. and 4.) shows two muscular men with knives in their hands fighting against each other when linked together with a belt around their waists. This was an old Nordic way of fighting described in the tales.



Figure 4.2: Before conservation. Close-up of "The knife-wrestlers". Credit: Claes Jansson.

The four reliefs around the postament and the runes tell more of the tale. Ragnar and Björn are foster brothers, now Vikings in the West. When they return home they both fall in love with Gerda, a beautiful woman living in their house. The love slowly tears the bond of brotherhood apart. The first relief shows when Gerda gives mead to the brothers that are tense and wordless. The fight is a fact when Björn break the silence and stretches his arm towards Gerda (relief two, fig. 4.1). In the third relief (Fig. 4.) Gerda is pleading for the brother's lives. The end of the tale is a tragedy where the girl grieves the dead men and their friendship.



Figure 4.: Before conservation. The third relief on the postament of "The knife-wrestlers". Credit: Claes Jansson.

Construction and original appearance

The whole monument is 3.43 m high and the size of the men is somewhat less than natural man size. The bronze is cast in many pieces that are joined together. The composition of the bronze is given in table 4.1. It can be classified among the corrosion resistant alloy. When the whole monument was lifted for transport to the conservation workshop the inside revealed some joints showing folds with screws (Fig 4.).

Element	Cu	Sn	Pb	Zn	Fe	Ni	Ag	Sb	As	Bi	Co	Au	Cd
Conc. %	91,11	8,00	0,2	0,04	0,04	0,04	0,02	0,04	0,5	<0,025	<0,005	<0,01	<0,001

Table 4.1.: ICP analysis of “the knife-wrestlers” by Josef Riederer, Rathgen-Forschungslabor, Berlin, Oct.2001.



Figure 4.: Interior parts of “The knife-wrestlers”. The ceiling of the postament and the runes above the relief are viewed. The bronze peg in the middle is one of only two joins between the upper part of the sculpture and the postament. Photo: Helena Strandberg.

Originally, the surface on the sculpture was black, shiny and smooth, carefully chased and artificially patinated with sulphur liver before the inauguration in 1914. The appearance has changed during the 20th century due to the polluted environment and activities around the sculpture. Today, many patches from repairs of casting defects appear on the surface. These were not visible originally due to the artificial patination but have appeared by time in the corrosion layer.

The monument and the surrounding

The sculpture is placed in the busy central public commercial street in Göteborg where many people, as well as cars and trams, are passing day and night. It is viewed from a close perspective and is frequently touched. Events often occur around this sculpture and the postament is used as a shelter and background for various activities that leave traces on the monument.

Condition and causes

Before conservation, the sculpture appeared much dirtier and more corroded than others from the same age in Göteborg (Fig 4.1, 4.2, 4.3). The legibility had decreased due to thick deposits of soot, dust, scrawl, sticky stuff and corrosion, especially on the postament. Traces of white paint were visible originating from an occasion of vandalism in the 1960's where all the sculpture was covered in paint.

The original dark smooth surface, viewed on old photos, that was probably dominant until the 1970's, was not evident any more. Instead, the sculpture appeared mainly light green and streaked before conservation. Thick black rough corrosion crusts also covered many parts sheltered from rain. Under these crusts, corrosion was active in pits with green corrosion. Analysis confirmed (nantokite beneath the black crust) that the sculpture suffered from bronze disease that is caused by high amounts of chlorides.

The fourth relief heading towards the street had a damaged porous surface with no original patina. The sculpture probably have been blasted or treated with acid previously when cleaned from scrawl and paint.

The largest problem though was a beige opaque and rough concrete-like deposit all over the skyward surfaces on the monument, which was very difficult to remove. X-ray diffraction analysis showed that the deposit contained a range of concrete mineral fillers (albite, quartz, high-temp quartz, gypsum from calcite, and microcline), which confirmed that the deposit was concrete probably originating from construction work in the proximity.

To sum up, the bad condition of this sculpture is mainly caused by its very exposed position to traffic and diverse human activities. Moreover, it has not been sheltered when constructions have been built in the proximity and not been cleaned in a proper way previously.

Conservation plan

The purpose of the conservation treatment was:

- to respect the aesthetic, historic, and physical integrity of the object according to the conservation ethics.
- to perform minimum intervention, i.e. not remove the "original patina" and preserve the light-green corrosion layer on the etched rain-exposed parts.
- to remove disfiguring deposits of concrete, soil, sand and soot and some corrosion products.
- to protect and consolidate the patina layer with a suitable wax.
- to integrate colour contrast by the wax treatment.

Conservation treatment

The cleaning included removal of deposits, scrawl, paint and some corrosion; with water, soft brushes and scalpels. On some smaller parts chemicals were used. The green patina on the etched rain-stroked parts, protecting the metal was preserved. In some parts the green layer was removed to uncover the black original patina that was found closest to the metal.

The thin hard concrete layer deposited on the surface, could only be removed with effort by scalpels. This was a very time consuming treatment and therefore only some important parts were cleaned this way.

Afterwards, a thin wax (TeCero 3534F, Tromm Company) layer was applied for aesthetic reasons and to protect the surface from the rough outdoor environment. The wax paste was applied with brushes on a heated bronze surface. Figures 4... show the sculpture and some details after treatment.



Figure 4.: "The knife-wrestlers" after conservation. Credit: Claes Jansson.

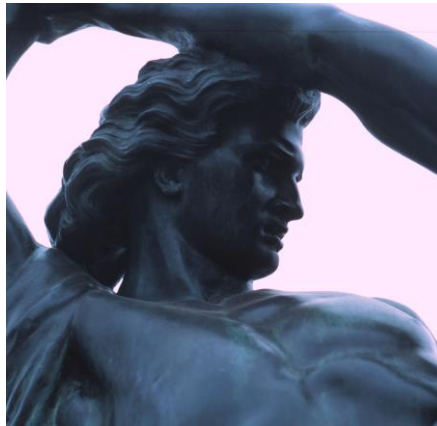


Figure 4.: After conservation. Close-up Close-up of "The knife-wrestlers". Credit: Claes Jansson.



Figure 4.: After conservation. The third relief on the postament of "The knife-wrestler". Photo: Claes Jansson.

“The Haze”

This sculpture was first made in gypsum in 1885 by G. Lindberg. It was later cast in bronze 1914 and placed in a park in Göteborg. The sculpture was probably patinated green originally.



Figure 4.: “The haze” before conservation. Credit: Claes Jansson.

The patina on “The Haze” was mainly smooth and light green but etched in a cracked pattern on rain-striking parts (Fig 4.). In some parts there was a yellowish smooth beautiful patina. The surface was very gently washed not to destroy the green patina, and the black crust was cleaned with a scalpel, before the patina was consolidated with wax (Fig. 4.).

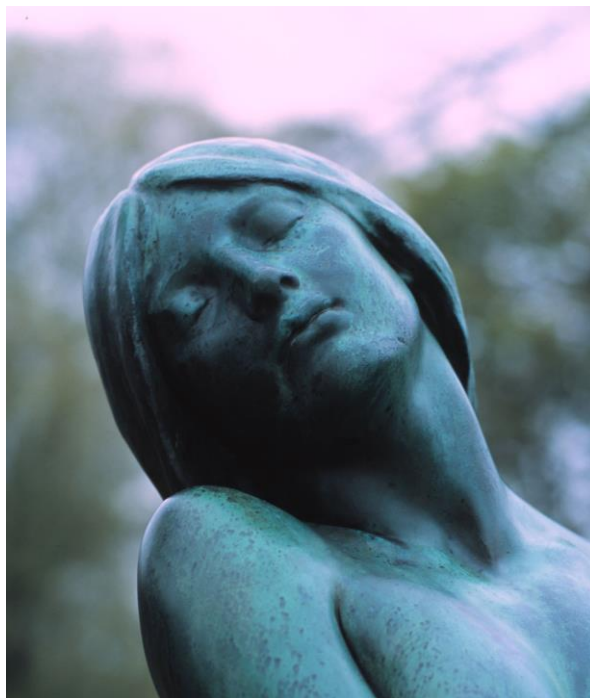


Figure 4.9.: “The haze” after conservation. Credit: Claes Jansson

Wadman bust

The bust of J. A. Wadman is one of the oldest outdoor bronzes in Göteborg and was sculptured by J. P. Molin 1969. It was treated about the same way as “The knife-wrestlers” though it was much easier to clean since it had always been placed in a park shielded from traffic.



Figure 4.1.: “Wadman” before conservation. Credit: Claes Jansson.



Figure 4.11.: “Wadman” after conservation. Credit: Claes Jansson.

By Helena Strandberg

4.2.c. Monuments in Munich

Due to the complexity of the monument considered, the Amazone, no other monument was treated during the project.

The Amazone

The Amazone was cast in 1935, unveiled in 1936. These dates were unknown before the beginning of that project. Photographs of the foundry with the Amazone appearing out of the casting mould have been found since. The monument simply represents an Amazone sitting on horseback. It is a full-size reproduction of a smaller bronze Amazone by the famous Munich painter Franz von Stuck which had been produced short before 1900.

With the Amazone, Franz von Stuck followed a popular style of fairy-tale human-animal creatures which was very much appreciated by the Munich citizens. More than 20 of those small Amazones

are known. The big Amazone we are considering here was cast after Stuck's death and put in front of the Villa Stuck posthum.



Figure 4.?: The Amazone sitting on horseback, before restoration. Credit Bavarian State Department of Historical Monuments.

The Amazone has been selected for this project because of its special colouring consisting of pigmented and gilded layers. Red pigments are found on the Amazone's hair and gilding is used on the helmet (Fig. 4. and 4.) and the horse's mane and tail. In Germany colouring on outdoor bronze monuments is rare to find.



Figure 4.?: The Amazone in front of the Villa Stuck Museum, Munich, in 1990. Gilded and painted areas are visible. Credit Christian Gruber.

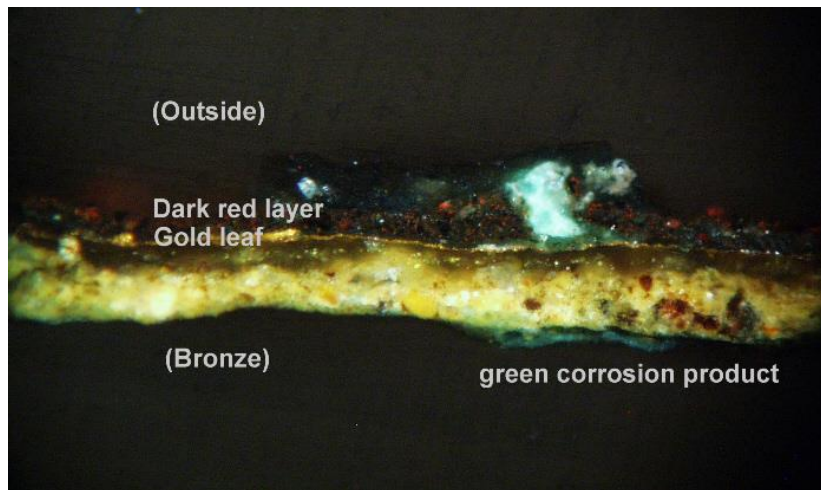


Fig. 4.?: Cross-section through an embedded paint layer sample from the red hair of the Amazone. Maximum layer thickness 150µm. Credit Martin Mach.

The corrosion of the sculpture looks similar to other bronze monuments in Munich which normally appear with a green and black patina. The heavy corrosion of the Amazone is to some part due to the alloy (Tab.4.2) which is not very corrosion resistant (due to its rather low tin content) and due to the situation close to a big street with about 50.000 vehicles passing by per day.

Element	Cu	Sn	Pb	Zn	Fe	Ni	Ag	Sb	As	Bi	Co	Au	Cd
Conc. %	86,34	4,56	1,21	7,28	0,16	0,29	0,02	0,13	<0,1	<0,025	<0,005	<0,01	<0,001

Table 4.2.: ICP analysis of the Amazone by Josef Riederer, Rathgen-Forschungslabor, Berlin, Oct.2001.

As expected the green areas (streaking) of the surface are found on exposed parts of the sculpture whereas in sheltered parts more or less thick black crusts appear. Although it is only 66 years old, it shows the same corrosion effects as sculptures which are about 150 years or older.

Conservation plan

The basic conservation strategy for the Amazone has been similar to most of other bronze monuments. It was decided to clean the surface from dirt and to put a microcrystalline wax (TeCero 3534F, Tromm Company) on it that might possibly be slightly pigmented in black to give an impression of the original outlook.

The gilded and pigmented parts of the sculpture have been cleaned. This cleaning has been performed mechanically due to the small amount of the gold layer.

After the cleaning also the coloured parts of the figure will be been coated with a microcrystalline wax (not chosen yet). A wax having a slightly lower melting point than the TeCero 3534F will be preferred. This and the sticking properties of the wax seem to be most suitable to consolidate the fragile rests of the colouring and gilding.

There was a serious damage on the right arm of the Amazone, close to the shoulder: one of the big iron screws which join the arm and the body of the Amazone was heavily corroded and had blown out a covering bronze patch (Fig. 4..?). So the rest of the bronze patch and the iron screw has been removed and cleaned and finally the patch has been replaced.



Fig. 4.?: Detail: damage at the right upper arm of the Amazone caused by an interior rusting iron screw. Credit: Martin Mach.

There was a further damage on the right foreleg of the horse. Also in this case a small bronze patch had been pressed out by the rusting armature.

Another problem is the joining of the sculpture with the base because until now it was only standing loosely upon the base. In fact the sculpture had been moved some centimetres out of the centre of the base. It might be knocked over its base by vandals. As a consequence an appropriate join will have to be constructed. The basic idea is to have a reversible joint. Under the plinth of the Amazone are two unused bronze nuts with interior threads. Stainless steel rods will be fitted into these threads and will be stuck into concentric cylindric tubes which will be fixed to the base. So it will be possible to lift the Amazone from its base in a vertical direction but it will not be possible to knock it from its base by a horizontal impact.

By Anke Doktor and Martin Mach

CHAPTER 5

A Maintenance Plan

The damages on the monuments today are mainly caused by the bad environmental situation and a lack of care. So obviously, apart from the improvement of the air quality, it is of great importance to check the bronze monuments regularly.

But how can this be initiated? First of all there has to be financial support for any step of maintaining an object. In most cases it is difficult to receive funds from the municipal authority. Strangely it is easier to raise money for a big restoration that gets much public attention than to support the maintenance with small amounts for a regular care.

After all the public has to become interested in the monument. It would be much easier if a kind of association or organization could identify itself with the sculpture. A possibility could be for example to sell the monument for a symbolic price of 1 Euro or simply give it as a present so that the association is only responsible for the maintenance. It will surely find funds for an annual cleaning and waxing. The aim should always be to make the public aware of the importance of the maintenance of a monument. If this has been achieved, there may be a sponsor to be found who will finance the restoration and of course be responsible for the care later on. These ideas are not very new. In the late 19th century for example the foundry-men already appealed to the public to do a cleaning of the sculptures every Saturday evening.

This is also the way that Sweden has developed in the last decades, selling out the property in common to the market. But the disadvantages of this method are obvious, too. Sponsorship is soon the only way for culture to exist. It may be a point to let associations be responsible - if they are rich. Small associations will probably never pay for conservation.

Often an extensive restoration is most impressive for the public and the results are in most cases very good. However conservation should not be restricted to these occasional and very expensive measures. Regular care is just as important for a sculpture, otherwise after three years without care, it will be in a bad condition again. Metal monuments are objects that need constant attention. Therefore it is important for outdoor bronze sculptures to receive a regular annual service. After the cleaning of the bronze surface with water and brushes usually a wax coating will be applied. This kind of conservation has to be controlled and renewed every two years, at fountain sculptures even every year. Therefore normally contracts with self-employed restorers are made.

A maintenance plan can also include yearly inspections, yearly cleaning with water, a control of all measures performed concerning cultural objects and a documentation of all measures in a database. The yearly inspection are occasions to check the overall state of the monument, the breakdown of the coating on the bronze sculpture and how the patina or the corrosion layers are behaving. As a result measures are taken to clean the non adherent deposits which may favour the corrosion processes and to apply locally a new wax layer. Decisions about more important interventions might be taken too and budgets planned.

Usually visits are conducted by professionals who are aware of corrosion processes on bronze monuments. Their approach is then based on their experience. No monitoring technique tested until now is performing well enough to assist them in their maintenance decision. It is then difficult to

tell exactly when and why some interventions are needed. It might happen that the corrosion that has taken place is not so damaging for the monument (tarnishing) and the intervention is then based only on aesthetic reasons.

If administrations have to be convinced to fund maintenance programs, they need to know why this maintenance is needed and how much it will cost. In the following some original proposals are made to give arguments to professionals to promote such maintenance programmes.

By Anke Doktor and Martin Mach

5.1 Athens experience

The city of Athens has not really any experience on maintenance programmes. When some damage occurs on monuments (graffiti), an intervention is not always decided (except for Truman statue, as I remember...).

Due to the interest of the City in the conservation of the Kolotronis monument, it has been decided that a maintenance programme would be set up for this monument which could then be applied to other monuments. As mentioned before, the study of the condition of the Kolotronis monument revealed that the sculpture was not heavily corroded. The conservation treatment was then quite basic and did not conduct to any dismantling and consolidation of the whole structure.

The maintenance of this monument does not seem to be an impossible task in that condition. But the question is to know when the interventions will be needed. Monitoring techniques have then to be developed. The team of professionals tried different tools for documenting and analysing the condition state of the sculpture as it is now. Video films, X-fluorescence measurements at specific areas and replicas of the surface were realised once the treatment was achieved and will be compared to new results obtained in the future (when and how often?) to see how the sculpture behaves with time.

Pictures are needed here.

Based on these data, it will be possible to propose a good maintenance programme and to budget it. This approach will be then applied to other monuments in Athens exposed to a similar environment.

A survey of all the bronze monuments in Athens has first been conducted in parallel to the programme and was based on the database established for this project. This survey has shown that most of the monuments were suffering from graffiti applications. Otherwise they were in quite good condition as it has been described previously.

A policy of cleaning of these graffiti as soon as possible will be needed before conducting a conservation treatment.

By Vasilike Argyropoulos

5.2 Göteborg experience

Bronze monuments mean very much for the people who live in Göteborg and for the people who visit the city. In the Municipality of Göteborg, where the Parks- and nature administration is caring for the main part of the public art in the city, the consciousness have just awoken that outdoor art will not last forever and that they will presumably last longer if they are cared for.

Until recently care for outdoor monuments have been neglected in Göteborg as well as in other cities in Scandinavia. Maintenance has mainly been considered for functional damages, e.g. in fountains, and sometimes for removal of graffiti and scrawl. Today, the only maintenance of sculptures in Göteborg is cleaning after exposure to scrawl. The cleaning is done by building and cleaning enterprises using methods that are not always the best for the monuments. Accordingly, there is a lot to work for in this field.

The formulation of a conservation policy for outdoor art in Göteborg would be a great step in the right direction. It could include how to regulate the antiquarian control for all measures concerning cultural objects. It should also tell about how to take care of the monuments, and which qualifications those who make the practical work ought to have, maybe some kind of certificate for enterprises. Proper documentation of all the artworks and measures performed is necessary as well. A database for the sculptures in Göteborg is now existing but need to be extended and updated. These are all important issues to start with taking a step further in protecting our outdoor bronze monuments.

By Helen Svenstam and Helena Strandberg

5.3 Munich experience

The restoration and maintenance work performed by the Municipality of Munich and the Bavarian State Department of Historical Monuments is based on a few assumptions that will be discussed below. It has led to the following conclusions and practical hints with respect to maintenance.

5.3.a. The maintenance procedure and the basic philosophy behind

Every few years there are friendly suggestions by non-professionals interested in conservation to analyse the preservation state of all monuments made out of metal scientifically and then to classify them according to their degree of corrosion, soiling, graffiti and other criteria, all classifications being based upon quantitative data only. Further on it is suggested to design a restoration and maintenance plan which would foresee a clearly defined measure for each category. At the first sight this might sound thoroughly reasonable and as a really logical and scientific way to proceed.

But when thought to the end it becomes obvious that such a procedure would in fact tend to transform our monuments to homogeneous classes of uniform objects. Nobody would really want that e.g. all wrought iron crosses of a cemetery would have exactly the same finish and the same visual age appearance or that all bronze monuments would look just the same in spite of their individual significance, their varying history and age.

It must furthermore be accepted as a part of our cultural diversity that some monuments tend to get more attention and care by the public, whereas others might be rejected and that the interest in the monuments as a whole will depend very much on the given economic and political situation.

Nevertheless probably all of us will agree that some basic care should be applied to all monuments, so there will and should be a kind of typical restoration and maintenance procedure approach. This approach as a rule will be not as rigid as the strict classification approach mentioned above but has turned out as a good working solution in practice.

The philosophy behind maintenance is to avoid harsh cleaning and expensive restorations measures by means a regular but mild cleaning and conservation procedure. This will at the same time preserve the individual character of the monuments and broaden the intervals of restorations. All bronze monuments therefore should be carefully cleaned on a yearly basis. Conservation coatings should be checked and partially reapplied.

In case further steps like removal of crusts or new conservation measures should be considered as necessary, care must be taken that this is in fact done by a professional restorer and that the procedure will not be harmful to the monument or its patina layers. The term 'cleaning' tends to be misinterpreted by untrained or not properly trained personnel. It has happened that the outer surface of monuments was in fact completely destroyed by what was considered a 'cleaning procedure', e.g. by sandblasting or acid treatment. Any kind of change in the maintenance procedure, above all the use of new methods, should be discussed and decided by a group of conservation professionals.

5.3.b. Regular routine inspections - intervals and aims of the inspection

Though any type of appropriate surface conservation will persist for more than only one year, a yearly inspection of each bronze monument is advisable. This inspection should also include a look for possibly missing or deformed parts, for traces of rusty runoff indicating interior problems, for graffiti and -which in fact happens rarely- newly formed cracks.

5.3.c. The financial and administrative basis

There must be a solid financial and administrative basis in order to implement and to carry on with the maintenance procedure.

Of course there are many different styles in how to achieve and promote maintenance. As maintenance is always a long-term issue it must be associated to long lasting administrative structures, not to temporary projects. Nevertheless a project might help to attract private people's and institutions' interests and can help to provide some funding.

There must be some kind of permanent active interest raising (public relations) and fund raising for the monuments in order to guarantee mid-range and long-range maintenance. It might be also a good practice to have restoration costs linked to subsequent maintenance costs, that means that an institution that is willing to pay for a restoration should be asked to pay for subsequent maintenance as well.

When looking back in history we will find nice examples of how long-term monuments' care was planned already before 1900. There are examples of special foundations taking care for individual monuments. It was also decided to have festivities around the monuments every year in order to attract the public's attention to them and to have individual bank accounts for the regular inspection and care of the monuments. As has been learnt in Germany even those wise precautions were soon superseded by wars, economical crises, political changes and a lack of public interest.

As soon as the positive input ceases, controlling and cost cutting units within the administrations and regional authorities will tend to cancel the respective funds in favour of other, seemingly more urgent tasks. So the maintenance activities will always reflect the overall political and economical situation and the number and power of individuals interested in the monuments. This also implies that all of us can help in some way to contribute to perform a good job on the monuments or might just remain lazy.

By Martin Mach

Conclusion

It is difficult to give a common approach for the management, conservation and maintenance of outdoor bronze monuments from so different experiences. If the management and the conservation are following strict rules in Munich, it is because the town has a long experience in the field and a competent staff working everyday with professionals. In Göteborg, the professionals exist but the administration has just realised how important it is to define specific methodology of management and conservation for these monuments. In Athens, the subject is more or less completely new.

We have seen that the first step is the protection of the monuments. Once this work is done, the next step is to have a team of professionals to deal with the specific problem of these monuments. This team could include an art historian, a conservator, a scientist who would be in charge of the documentation, the conservation and the maintenance of the monuments. If the states have to initiate the project, the citizens interest in their monuments has to be restored. Publicity campaigns are here needed.

Any conservation work cannot be done without considering the future maintenance of the monument. Conservation strategies are globally the same all around Europe. What is different from one country to another is the facilities and the staff dedicated to the conservation of these monuments. Here rich western countries are favoured.

Maintenance guidelines exist in each country. Some are basic and are applied in all countries. Others are most specific and depend on the particular interest of citizens or on tools developed with the experience.

Bibliography

- Alessandrini, G., Dassu, G., Pedferri, P. and Re, G. On the conservation of the baptistry doors in Florence. *Studies in Conservation* **24** (1979) 108-124.
- Alunno-Rossetti, V. and Marabelli, M. Analyses of the patinas of a gilded horse of St Mark's basilica in Venice: Corrosion mechanisms and conservation problems. *Studies in Conservation* **21** (1976) 161-170.
- Appelbaum, B. Criteria for treatment: Reversibility. *JAIC* **26** (1987) 65 (?).
- Baboian, R., Cliver, B. and Bellante, L. (Eds.). The Statue of Liberty restoration. Proc. *The Statue of Liberty – today for tomorrow conference*, New York, October 1986, NACE, Houston, Texas (1990). 149 pages (?).
- Block, I., Jensen, N., Sommer, S. M. and Buckingham, W. F. Chloride leaching from outdoor bronzes. *ICOM Committee for Conservation Triennial Meeting*, Dresden, Vol. 3 (1990) 1057(?).
- Boffrand. Description de ce qui a été pratique pour fondre en bronze d'un seul jet la figure equestre de Louis XIV, Paris 1743 (Editor and pages)
- Brendel, K., Gruber, C. and Mach, M. Preliminary analysis, conservation and restoration of bronze monuments in Bavaria. In Proc. from *Eurocare-Copal (EU 316) Workshop, Budapest*, 9 May 1994, Institut für Silicatchemie und Archäometrie, Vienna (1994) (pages)
- Dolcini, L. (Ed) *Verrocchio's Christ and St. Thomas – a masterpiece of sculpture from Renaissance Florence*. The Metropolitan Museum of Art, New York (1992) (?).
- Drayman-Weisser, T. (Ed.). Proc. *Dialogue/89-, The conservation of bronze sculpture in the outdoor environment: A dialogue among conservators, curators, environmental scientists, and corrosion engineers*, Houston, Texas, 1989. NACE (1992). 390 pages (?).
- Eriksson, P., Johansson, L-G. and Gullman, J. Initial stages of copper corrosion in humid air containing SO₂ and NO₂. *J. Electrochem. Soc.* **140** (1993) 53-59.
- EURO CARE-COPAL-workshops in Prague (1995) and Vienna (1996) (?).
- Feilden, B. M. *An introduction to conservation of cultural property*. Ed. by United Nations Educational Scientific and Cultural Organization, Rome (1979). (pages)
- Fiorentino, P., Marabelli, M., Matteini, M. and Moles, A. The condition of the 'door of paradise' by L. Ghiberti. Tests and proposals for cleaning. *Studies in Conservation* **27** (1982) 145-153.
- Forster, K. W. Monument/memory and the morality of architecture. *Oppositions* (1982) 2.
- Gaspar, P., Gulbransen, L. and Weil, P. D. Recent developments in the conservation of outdoor bronze monuments. *ICOM Committee for Conservation Triennial Meeting*, Vol. 23/12 (1978) 1-7.
- Gettens, R. J. Composition of the patina on a modern bronze statue. *Technical Studies in the Field of Fine Arts* **2** (1933) 31-33.
- Gullman, J. and Törnblom, M. *Bronze sculpture – Its making and unmaking*. Ed. by Central Board of National Antiquities, Stockholm (1994). 185 pages (?).
- Harris, R. The treatment of outdoor metal sculpture in the United States. *Conservation News, UKIC* **54** (1994) 15 (?).
- Hawkins, D. T. The restoration of metal monuments: A bibliography, 1933-1986. *Corrosion Science* **27** (1987) 771-782.
- Herrmann, P. Problematik des Korrosionsschutzes von Denkmälern. *Metalloberfläche* **44** (1990) 563-566.

- Hughes, J. Prevention of conservation problems of outdoor sculpture – The importance of the commissioning documentation. *ICOM Committee for Conservation 11th Triennial Meeting*, Edinburgh, Vol. 2 (1996) 876-883.
- Hughes, R. and Rowe, M. *The colouring, bronzing and patination of metals*. van Nostrand Reinhold Company, New York (1983) 1-46.
- ICCROM, Proc. *Conservation of Metal Statuary and Architectural Decoration in Open-air Exposure*, Paris, 1986. ICCROM, Rome (1987) 1-297.
- ICOMOS, *Australia ICOMOS charter for the conservation of places of cultural significance (Burra Charter) 1981* (1988) (pages).
- Jack, J. F. S. The cleaning and preservation of bronze statues. *The Museum Journal* **50** (1951) 231 (?).
- Jokilehto, J. Authenticity: a general framework for the concept. In Proc. *Nara Conference on Authenticity*, Nara, Japan, November, 1994. Ed. by K. Larsen, UNESCO, Paris, Agency for Cultural Affairs, Tokyo (1995) 17 (?).
- Larsen, K. (Ed.). Proc. *Nara Conference on Authenticity*, Nara, Japan, November, 1994. UNESCO, Paris, Agency for Cultural Affairs, Tokyo (1995). 427 pages (?).
- Lehmann, J. Corrosion of monuments and antiquities made of copper and copper alloy in out-door exhibits. *ICOM Committee for Conservation Triennial Meeting*, Madrid, Vol. 2/5 (1972) (pages).
- Lemaire, R. and Stovel, H. (Eds.). Nara document on authenticity. In Proc. *Nara Conference on Authenticity*, Nara, Japan, November, 1994. Ed. by K. Larsen, UNESCO, Paris, Agency for Cultural Affairs, Tokyo (1995) (pages).
- Lewin, S. Z. A new approach to establishing the authenticity of patinas on copper-base artefacts. In Proc. *Application of Science in Examination of Works of Art*, Boston (1970) 62-66.
- Lüer, H., *Technik der Bronzeplastik*, Leipzig ≈1902, (ed.? Pages?)
- Mach, M. and Reinhardt, U. Reifenabrieb in der Patina auf Bronzen im Freien. *Wiener Berichte über Naturwissenschaft in der Kunst*, Doppelband 1987/88, **4/5** (1988a) 220-221.
- Mach, M., Reinhardt, U. and Snethlage, R. Elementverteilungsbilder von Querschnitten durch Bronze- und Kupferpatina von Objekten im Freien. *Wiener Berichte über Naturwissenschaft in der Kunst*, Doppelband 1987/88, **4/5** (1988b) 214-219.
- Mach, M. and Snethlage, R. Die Analyse der Patina von Bronzen im Freien. *Zeitschrift für Kunsttechnologie und Konservierung* **3** (1989) 231-235.
- Mach, M. Der Guß des Denkmals für Max I. Joseph in München, Notizen zur Königlichen Erzgießerei, zum Gußverfahren und zur Legierung des Monuments. Arbeitsheft 86 des Bayerischen Landesamtes für Denkmalpflege, München 1996, 101-117.
- Mach, M. (Ed.), *Metallrestaurierung – Metal Restoration*, Arbeitsheft des Bayerischen Landesamtes für Denkmalpflege, München (1998) 194p.
- Maertens, H. *Die Deutschen Bildsäulen-Denkmale des XIX. Jahrhunderts*, Stuttgart 1892 (pages)
- Matero, F. G. The conservation of immovable cultural property: Ethical and practical dilemmas. *J. of American Inst. of Conservation* **32** (1993) 15-21.
- Mattsson, E. and Holm, R. Atmospheric corrosion of copper and its alloys. *Atmospheric Corrosion* (1982) 365-381.
- Mattsson, E., *Basic corrosion technology for scientist and engineers*, the Institute of Materials, 2nd Ed., 1996 (page).
- Meißner, B., Doktor, A., Mach, M. *Bronze- und Galvanoplastik, Geschichte-Materialanalyse-Restaurierung*, Arbeitsheft 5, Landesamt für Denkmalpflege Sachsen, Landesamt für Denkmalpflege Sachsen-Anhalt, Dresden (2001) 172p.

- Merk-Gould, L., Herskovitz, R. and Wilson, C. Field tests on removing corrosion from outdoor bronze sculptures using medium pressure water. *ICOM Committee for Conservation 10th Triennial Meeting*, Washington, Vol. 2 (1993) 772-778.
- Naudé, V. N. (Ed.). Proc. *Sculptural Monuments in an Outdoor Environment*, Philadelphia, November 1983. Pennsylvania Academy of Fine Arts (1983c). 110 pages (?).
- New conservation methods for outdoor bronze monuments, Research report n°3, EU 16637EN (1996) 226 pages.
- Nosek, E. M. A new composition of patina from the roof of the Wawel Cathedral. *ICOM Committee for Conservation Triennial Meeting*, Zagreb, Vol. 23/6 (1978) (page).
- Perocco, G. *The horses of San Marco – Venice*. Thames and Hudson, London (1979) 1-245.
- Pichler, B., Vendl, A., Pongratz, S. and Sauer, R. Untersuchungen von Patinaproben des Denkmals Kaiser Joseph II. in Wien. In Proc. from a *Workshop in Budapest*, 9 May 1994. Institut für Silicatchemie und Archäometrie, Vienna (1994) (page).
- Riederer, J. Corrosion damage on bronze sculptures. *ICOM Committee for Conservation Triennial meeting*, Madrid 1972. Vol. 2/5 (1972) (page).
- Riederer, J. Korrosionsschaden an Bronzeplastiken. *Werkstoffe und Korrosion* **23** (1972b) 1097 (?).
- Riederer, J. Die Pflege von Bronzeskulpturen im Freien. *Berliner Beiträge zur Archäometrie* **2** (1977) 96-104.
- Riederer, J. Der Schutz von Metallskulpturen im Freien vor Umwelteinflüssen. *Neue Museums Kunde* **25** (1982) 63-65.
- Riegl, A. The modern cult of monuments: its character and its origin. *Oppositions* (1982) 21
- Robbiola, L., Fiaud, C. and Penec, S. New model of outdoor bronze corrosion and its implications for conservation. *ICOM Committee for Conservation 10th Triennial Meeting*, Washington, Vol. 2 (1993) 796-802.
- Robbiola, L. and Hurtel, L.-P. Nouvelle contribution à l'étude des mécanismes de corrosion des bronzes de plein air: caractérisation de l'altération de bronzes de Rodin. *Mémoires et Études Sci. Revue de Metallurgie*, Decembre (1991) 809 (?).
- Rodhe, H., Langner, J., Gallardo, L. and Kjellström, E. Global scale transport of acidifying pollutants. In Proc. *Acid Reign '95*, June 1995, Göteborg. Ed. by P. Grennfelt *et al.*, Kluwer Academic Publishers, Dordrecht, Netherlands, Vol. 1 (1996) 37 (?).
- Roidl, E. Restaurierung- und Konservierungsmethoden bei Bronzen im Freien. *Maltechnik-Restaurio* **4** (1987) 9 (?).
- Rosvall, J. (Ed.). Proc. *Air pollution and conservation – safeguarding our architectural heritage*, Rome, 1986. Elsevier, Amsterdam (1988) (page).
- Scott, D. Bronze disease: A review of some chemical problems and the role of relative humidity. *JAIC* **29** (1990) 193 (?).
- Scully, J.-C., *The fundamentals of corrosion*, Pergamon Press, 3rd Ed. 1990 (page).
- Selwyn, L., Binnie, N. E., Poitras, J., Laver, M. E. and Downham, D. A. Outdoor bronze statues: analysis of metal and surface samples. *Studies in Conservation* **41** (1996) 205 (?).
- Sharkey, J. B. and Lewin, S. Z. Conditions governing the formation of atacamite and paratacamite. *The Am. Mineralogist* **56** (1971) 179 (?).
- Shreir, L. L. (Ed.). *Corrosion*. Vol. 2: Corrosion control. George Newnes Limited, London (1963) (page).
- Sommers, J. Gilding the Lily: The patination of Henry Moore's bronze sculpture. In Proc. *From Marble to Chocolate. The conservation of modern sculpture*, Tate Gallery, London. Ed. by J. Heuman, Archetype Publications (1995b) 144 (?).
- Strandberg, H. *Patina på bronsstatyer*. Diploma thesis, The School of Conservation, The Royal Academy of Fine Arts, Copenhagen (1986) (page).

- Strandberg, H. Reactions of copper patina compounds – I. Influence of some air pollutants.. *Atmospheric Environment* (1997a) ([page](#)).
- Strandberg, H. Reactions of copper patina compounds – II. Influence of sodium chloride in the presence of some air pollutants. *Atmospheric Environment* (1997b) ([page](#)).
- Strandberg, H., Johansson, L.-G. and Lindqvist, O. The atmospheric corrosion of statue bronzes exposed to SO₂ and NO₂. *Materials and Corrosion* (1997) November or December issue ([page](#)).
- Strandberg, H., Johansson, G. and Rosvall, J. Outdoor bronze sculptures – a conservation view on the examination of the state of preservation. *ICOM Committee for Conservation Triennial Meeting*, Edinburgh, Vol. 2 (1996) 894 (Paper II) (?).
- Strandberg, H. and Rosvall, J. *Bronsskulpturer utomhus i Göteborg – en undersökning av bevarandetilståndet*. Institute of Conservation, Göteborg University, 1994:16 (1994) ([page](#)).
- Strandberg, H. *Perspectives on bronze sculpture conservation. Modelling copper and bronze corrosion*. Doctoral dissertation in Environmental Science, Göteborg University, Sweden (1997) ([page](#)).
- Stöckle, B., Fitz, S., Mach, M., Pöhlmann, G. and Snetlage, R. Die atmosphärische Korrosion von Kupfer und Bronze im Rahmen des UN/ECE-Expositionsprogramms. Zwischenbericht nach 4-jähriger Bewitterung. *Werkstoffe und Korrosion* **44** (1993) 48-56.
- Stöckle, B., Krätschmer, A., Mach, M. and Snetlage, R. *Corrosion attack on copper and cast bronze. Evaluation after 8 years*. UN ECE ICP on effects on materials, Bavarian State Conservation Office, Munich (1996) Draft report ([page](#)).
- Timofeeva, N., Kassatonova, I., Arakelian, F., Bakaliarova, E. and Sizov, B. Etudes complexes du monument à Minime et Pojarski. *ICOM Committee for Conservation Triennial Meeting*, Dresden, Vol. 2 (1990) 754 (?).
- UNESCO. International charter for the conservation and restoration of monuments and sites (Venice Charter) 1964. *Erder* (1978) ([page](#)).
- van Gigch, J. P., Rosvall, J. and Lagerqvist, B. Setting a strategic framework for conservation standards. *Standards for preservation and rehabilitation*, ASTM STP 1258. Ed. by S. J. Kelley, American Society for Testing and Materials, West Conshohocken, USA (1996) 64.
- Vendl, A., Sauer, R. and Pichler, B. Untersuchungen an Patina- und Metallproben von Figuren des Millenniums-Denkmales in Budapest. In Proc. from a *Workshop in Budapest*, 9 May 1994, Institut für Silicatchemie und Archäometrie, Vienna (1994) ([page](#)).
- Wayne, R. *Chemistry of atmospheres. An introduction to the chemistry of the atmospheres of earth, the planets, and their satellites*. Oxford University Press, New York (1985) 1-361.
- Weil, P. D. A review of the history and practice of patination. *NBS Special publication 479*; US Department of Commerce, corrosion and metal artefacts (1977) 77 (?).
- Weil, P. D. The conservation of outdoor bronze sculpture: A review of modern theory and practice. *AIC Preprints, San Francisco* (1980) 129-140.
- Weil, P. D. ‘Visually illiterate’ and ‘historically ignorant’: The need to re-examine art conservation’s humanistic foundations. *AIC preprint* (1984) 1-14.
- Weil, P. D., Gaspar, P., Gulbransen, L., Lindberg, R. and Zimmerman, D. The corrosive deterioration of outdoor bronze sculpture. In *Science and Technology in the Service of Conservation*, IIC preprints, Washington (1982) 130 (?).
- Wikström, L. A view of sculpture conservation in Finland. In Proc. *Sculpture Conservation: Preservation or Interference?*, Liverpool 1994. Ed. by P. Lindley, Scholar Press (1995) Chapter 17. In press.
- Zelst, L. v. and Lachevre, J.-L. Outdoor bronze sculpture: Problems & procedures of protective treatment. *Technology and Conservation* **8** (1983) 18-24.