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KONZERVATORSKO-RESTAURATORSKI ZAHVATI NA ANTIČKOJ MRAMORNOJ SKULPTURI CARICE IZ ZBIRKE ARHEOLOŠKOG MUZEJA ZADAR

Autor iznosi kratki pregled konzervatorsko-restauratorskih radova na antičkoj mramornoj skulpturi carice iz zbirke Arheološkog muzeja Zadar. Radovi su obuhvaćali demontažu skulpture iz postava, čišćenje površine mramora, istraživanje potencijalnih ostataka polikromije, vakuumsku konsolidaciju mramora te montažu u antički postav Arheološkog muzeja Zadar. Zahvati su obrađeni u sklopu praktične nastave na Odsjeku za konzervaciju i restauraciju kamena Umjetničke akademije u Splitu.

Ključne riječi: Zadar, antička skulptura, konzervacija, restauracija, vakuumska konsolidacija, Umjetnička akademija u Splitu

ANCIENT ROMAN MARBLE SCULPTURE OF AN EMPRESS FROM THE ARCHAEOLOGICAL MUSEUM ZADAR, CONSERVATION WORKS

The author give a brief overview of the conservation-restoration work on the ancient marble sculpture of an empress from the collection of the Archaeological Museum Zadar. The process included dismantling the sculpture from the exhibition, cleaning the surface of the marble, exploring potential remains of polychromy, the vacuum consolidation of the marble, and installation in the ancient exhibition of the Archaeological Museum Zadar. The interventions were done as part of the practical course at the Department of conservation-restoration of stone at the Arts Academy in Split.

Key words: Zadar, ancient sculpture, conservation, restoration, vacuum consolidation, the Arts Academy in Split

UVOD

Ulomak monumentalnog kipa carice datiran je u sredinu 1. st. poslije Kr., a izrađen je od mramora grčkog podrijetla (visina 160 cm / širina 59 cm / dubina 35 cm, težine cca 600 kg). Kip je izvorno bio nadnaravne veličine. Odsječen je ispod linije prsa, kipu nedostaje glava, obje ruke, noge i baza. Primijećeno je da se površina skulpture osipa te su se na nekim mjestima pojavile veće i manje pukotine koje bi sigurno tijekom vremena dovele do lomova i odvajanja fragmenata od cjeline. Glava i ruke s mogućim atributima nedostaju, a to su elementi koji bi doprinijeli dodatnom tumačenju skulpture. Možemo pretpostaviti da kip predstavlja neku rimsku caricu ili caricu u liku neke rimske boginje (sl. 1).[1] U posjedu je Zbirke antičke skulpture Arheološkog muzeja Zadar, inv. br. A10581. Na skulpturi su provedena ispitivanja štetnih soli i pregled pod UV svjetlom s ciljem detektiranja mogućih ostataka polikromije. Nakon analiza, obavljeni su restauratorsko-konzervatorski zahvati čišćenja, podljepljivanja te vakuumske konsolidiranje mramora. Cijeli proces popraćen je pisanom i digitalnom dokumentacijom.

Slika 1. Ulomak antičke mramorne skulpture
Figure 1. Fragment of an ancient marble sculpture
foto / photo by: **I. Duvnjak**

1 N. Cambi 2005, 32–33.

INTRODUCTION

The fragment of the monumental statue of the empress was dated to the middle of the 1st century AD, and it is made out of marble of Greek provenance (160cm in height / 59cm in breadth / 35cm in depth, weighing approximately 600kg). The statue was originally of heroic size. It is cut below the chest line and the statue lacks the head, both arms, legs and base. It has been observed that the surface of the sculpture is eroding, and in some places larger and smaller fissures have emerged which, during the course of time, will certainly lead to fractures and separation of the fragments from the whole. The head and hands with possible attributes are missing, and these elements would contribute to the additional interpretation of the sculpture. We can assume that the statue represents a Roman empress or empress in the form of a Roman goddess (Fig. 1).[1] It is in the possession of the Archaeological museum Zadar as a part of the Ancient Sculpture Collection, Inv. No. A10581. The sculpture was tested for harmful salts and examined under the UV light in order to detect possible residues of polychromy. After the studies, the restoration-conservation interventions of cleaning, pre-consolidation and vacuum consolidation of the marble were carried out. The entire process is accompanied by written and digital documentation.

Slika 2. Demontaža
Figure 2. Dismantling
foto / photo by: **I. Duvnjak**

1 N. Cambi 2005, 32–33.

Slika 3. Transport
Figure 3. Transport

foto / photo by: **I. Duvnjak**

DEMONTAŽA

Jedan od najzahtjevnijih poslova bila je demontaža i transport skulpture. Prije bilo kakvog zahvata vizualno se pregledalo fizičko stanje kamena te su se odredile smjernice demontaže. Zaključeno je da će se skulpturu morati dobro zaštititi prilikom manipulativnih zahvata. Cijela skulptura umotana je u debelu spužvu te je remenom i ručnom dizalicom podignuta i odvojena od željeznog trna i postolja na kojem je stajala (sl. 2). Potom je spuštena na drvenu paletu i osigurana s pomoću zatega. Skulptura se nalazila na prvom katu Arheološkog muzeja Zadar te ju je trebalo spustiti stepenicama u prizemlje (sl. 3), da bi ju se potom ukrcalo u kombi te transportiralo do radionice restauratorsko-konzervatorskog odjela Umjetničke akademije u Splitu gdje je ponovo postavljena okomito za daljnje konzervatorske zahvate.

ANALIZA SOLI

Kao prvi korak trebalo je uzorkovati površinu kamena koji se osipa zbog sumnje na prisutnost soli. Uz onečišćenje zraka, topljive soli jedan su od glavnih uzroka propadanja kamena. Postoji mnogo načina na koje sol može dospjeti u kamen iz atmosfere ili iz tla kapilarnim putem. Štetne topljive soli ne nastaju samo na kamenu koji se nalazi u

DISMANTLING

One of the most demanding jobs was the dismantling and the transportation of the sculpture. Prior to any intervention, the physical condition of the stone was visually inspected and the dismantling guidelines were laid down. It was concluded that the sculpture would have to be well protected during manipulation. The whole sculpture was wrapped in thick sponge and it was lifted by a belt and hand hoist and separated from the iron tenon and its base (Fig. 2). It was then lowered to a wooden pallet and secured with clamps. The sculpture was located on the first floor of the Archaeological Museum Zadar and it had to be lowered to the ground floor via stairs (Fig. 3). Afterwards, it was loaded into a van and transported to the workshop of the restoration-conservation department at the Arts Academy in Split, where it was vertically re-erected for further conservation interventions.

SALT ANALYSIS

As a first step, it was necessary to sample the surface of the stone which is eroding due to the suspected presence of salt. In addition to air pollution, soluble salts are one of the main causes of stone deterioration. There are many ways in which salt can reach the stone from the atmosphere or from the soil in a capillary way. Harmful soluble salts not only occur on stone found in the exterior, but can also occur on stone placed in inadequate museum conditions.[2] Through crystallization, soluble salts such as chlorides, sulphates, nitrates, carbonates, and hydrocarbons create pressure in the capillaries of the stone, leading to erosion, flaking and fracturing of the stone mass. Its presence can be proved by chemical analyses performed by a chemist so that the correct procedure for their extraction, if necessary, can be determined.[3] Samples from the sculpture fragment were taken using cellulose pulp. The surface was well soaked with water before applying the pulp. A cellulose pulp coating which was soaked in distilled water, was applied to the wet surface and placed on the stone, ensuring that it adhered well to the stone surface (Fig. 4). Through the process of drying, the salts from the stone are transferred onto the surface of the pulp, which is sent to the laboratory for testing.[4] The results have shown that the presence of soluble salts on the sculpture was below the detection limit, so a desalination method was not required.

2 C. A. Price 1996, 7–9. Soluble salts may be present in the monument material, and the crystallization process may be triggered by inadequate treatment in museum conditions, that is, if no desalination process is performed and the sculpture is exposed to large fluctuations in temperature and humidity.
3 I. Donelli, H. Malinar 2015, 143.
4 I. Donelli, H. Malinar 2015, 144–146.

LOKALITET: Zadar, Arheološki muzej Zadar, kip carice LOCATION: Zadar, Archaeological museum Zadar, statue of an empress		
SVRHA UZORKOVANJA: određivanje količine vodotopljivih soli SAMPLING PURPOSE: determining the amount of water-soluble salts VRSTA ANALIZE: kvalitativna i kvantitativna kemijska analiza TYPE OF ANALYSIS: qualitative and quantitative chemical analysis		
DATUM UZORKOVANJA / DATE OF SAMPLING: listopad, 2018. / October, 2018	UZORKOVAO / SAMPLED BY: Siniša Bizjak, doc.	ANALIZU ZATRAŽIO / ANALYSIS REQUESTED BY: Siniša Bizjak, doc.

KOLIČINA UZORAKA / THEAMOUNT OF SAMPLES	MJESTO UZORKOVANJA / SAMPLING PLACE
2	površina mramornog kipa / surface of a marble statue surface

vrsta uzorka / type of sample	kamen, pulpa / stone, pulp						
kloridi, Cl^- / chlorides, Cl^-	-						
sulfati, SO_4^{2-} / sulfates, SO_4^{2-}	-						
nitrati, NO_3^- / nitrates, NO_3^-	-						

LEGENDA: ¾ nema, tragovi, + malo, ++ puno, +++ jako puno / LEGEND: ¾ negative, trace amount, + low, ++ high, +++ very high presence
škodljiva koncentracija, moguća škodljivost, neškodljiva koncentracija / harmful concentration, possible harmfulness, harmless concentration

Tablica 1. Određivanje količine vodotopljivih soli; kvalitativna i kvantitativna kemijska analiza. Analizirao analitički laboratorij Umjetničke akademije u Splitu: dr. sc. Ivica Ljubenkov (16. 11. 2018.).
Table 1. Determining the amount of water-soluble salts; qualitative and quantitative chemical analysis. Analyzed by the Arts Academy in Split Analytical Laboratory: Ivica Ljubenkov, PhD (16 November 2018)

Izradio / prepared by: **I. Ljubenkov**

eksterijeru, nego se mogu pojaviti na kamenu koji je smješten u neadekvatnim muzejskim uvjetima.[2] Topljive soli kao što su kloridi, sulfati, nitrati, karbonati i hidrokarbonati kristalizacijom stvaraju tlak u kapilarama kamena te dovode do osipanja, ljuskanja i lomova kamene mase. Njihovu prisutnost možemo dokazati kemijskim analizama koje će obaviti kemičar da bismo mogli odrediti ispravan postupak za njihovu ekstrakciju ako je potrebna.[3] Kod ulomka skulpture, uzorci su uzeti s pomoću celulozne pulpe. Prije nego što je nanesena pulpa, površina je dobro namočena vodom. Na mokru površinu nanesen je oblog od celulozne

METHODS:

Quantitatively determined anions:
Cl^- – Mohr's titration method
CO_3^{2-}, HCO_3^-, OH^- – titration method (volumetric)
SO_4^{2-} – gravimetric precipitation with $BaCl_2$
NO_3^- – colorimetric, colorimeter MA 9502

The anion concentrations are expressed in mass percent (%) relative to the dry sample mass.

From the salt analysis it can be concluded that it is not necessary to carry out the desalination process since the presence of elements that may originate from harmful salts is in this case below the detection limits, and therefore does not pose a risk to the stone in terms of harmful effects (Table 1).

Restorers sometimes encounter stone monuments that were polychrome in the past. The polychromy residues on

2 C. A. Price 1996, 7–9. Topljive soli mogu postojati u materijalu spomenika, a proces kristalizacije može biti potaknut neadekvatnim tretmanom u muzejskim uvjetima, dakle ako nije obavljen postupak desalinizacije, a skulptura je izložena velikim oscilacijama temperature i vlažnosti.

3 I. Donelli, H. Malinar 2015, 143.

pulpe koja je namočena u destiliranu vodu i stavljena na kamen, pazeći da dobro prianja na kamenu površinu (sl. 4). Sušenjem, soli iz kamena prelaze na površinu pulpe koja se šalje u laboratorij na ispitivanje.[4] Rezultati su pokazali da je prisutnost topljivih soli u skulpturi ispod granice detekcije, pa metoda desalinizacije nije potrebna.

METODE RADA:

Kvantitativno su određeni anioni:
Cl^- – metodom titracije po Mohru
CO_3^{2-},HCO_3^-, OH^- – metodom titracije (volumetrijski)
SO_4^{2-} – gravimetrijskim taloženjem s $BaCl_2$
NO_3^- – kolorimetrijski, kolorimetar MA 9502

Koncentracije aniona izražene su u masenim postotcima (%) u odnosu na masu suhog uzorka.

Analizom soli može se zaključiti da nije potrebno izvršiti postupak desalinizacije jer je prisutnost elemenata koji mogu potjecati od štetnih soli u ovom slučaju ispod granica detekcije, pa ne predstavlja opasnost za kamen u smislu štetnog djelovanja (Tablica 1).

Restauratori se ponekad susreću s kamenim spomenicima koji su u prošlosti bili polikromirani. Ostatci polikromije na antičkim spomenicima predstavljaju veliki problem jer se inače nalaze samo u tragovima koji se na prvi pogled čine kao prljavština, pa postoji velika opasnost od njihova uklanjanja. Zato je potrebno skulpturu pogledati pod UV svjetlom prije bilo kakvog restauratorskog zahvata. Ultraljubičasto svjetlo elektromagnetsko je zračenje valnih duljina od 10 do 400 nanometara. Većina kemijskih tvari snažno upija UV zračenje. Promatranje fluorescencije može se koristiti kao neinvazivna analitička metoda pri ispitivanju materijala.[5]

Prije početka konzervatorsko-restauratorskih radova skulptura je detaljno pregledana pod UV svjetlom jer su na određenim dijelovima draperije skulpture, u predjelu nogu, zamijećene okeraste mrlje koje su pobudile sumnju u postojanje ostataka polikromije na mramoru. Nažalost, na površini skulpture nisu pronađeni ostatci boje, već su spomenute mrlje uzrokovane oksidacijom metala koji je vjerojatno bio uz skulpturu dok je ležala u zemlji (sl. 5).

Čišćenje

Tehnike čišćenja možemo podijeliti u tri osnovne skupine: mehaničke metode čišćenja, tehnike čišćenja isključivo uz uporabu vode i kemijske metode.[6] Uklanjanjem površinskih nečistoća možemo dobiti bolji uvid u stanje kamena te odrediti koji će daljnji zahvati biti potrebni. Glavni razlog

Slika 4. Celulozna pulpa
Figure 4. Cellulose pulp

foto / photo by: **A. M. Lučić**

ancient monuments pose a big problem because they are usually found only in traces which at first glance seem like dirt, so there is a great danger of their removal. Therefore, it is necessary to observe the sculpture under the UV light before any restoration intervention. Ultraviolet light is an electromagnetic radiation of wavelengths of 10 to 400 nanometers. Most chemical substances strongly absorb the UV radiation. Fluorescence observation can be used as a non-invasive analytical method when examining materials.[5]

Before the start of the conservation-restoration works, the sculpture was thoroughly inspected under the UV light because on the certain parts of the drapery of the sculpture, in the area of the legs, ocher stains were spotted, which raised the suspicion of the existence of polychromy residues on the marble. Unfortunately, no paint remnants were found on the surface of the sculpture, and the aforementioned stains were caused by the oxidation of the metal, which was probably adjacent to the sculpture while it was lying in the ground (Fig. 5).

Cleaning

Cleaning techniques can be divided into three basic groups: mechanical cleaning methods, cleaning techniques using solely water and chemical methods.[6] By removing the surface impurities, a better understanding of the state of the stone can be gained and it can be determined which further interventions will be needed. The main reason for cleaning is that it can make a big difference in the aesthetic appearance of the object or article being cleaned, and often the substances which are

4 I. Donelli, H. Malinar 2015, 144–146.
5 D. Measday 2017.
6 I. Donelli, H. Malinar 2015, 120–126.

5 D. Measday 2017.
6 I. Donelli, H. Malinar 2015, 120–126.

Slika 5. Prikaz fragmenta skulpture pod UV svjetlom
Figure 5. View of the sculpture fragment under UV light
foto / photo by: **I. Duvnjak**

čišćenja jest što se njime može postići velika razlika u estetskom izgledu objekta ili predmeta koji se čisti, a često su supstance prisutne u sloju površinskih nečistoća i štetne za sam kameni materijal, pa ih je potrebno uklanjati kako bi se usporio proces propadanja same skulpture.[7]

Mehaničko čišćenje
Mehaničko čišćenje obavlja se ručno ili strojno. Za ručno se čišćenje najčešće koriste skalpeli, četke različitih tvrdoća, stakleni štapići i razni klesarski alati. Na skulpturi iz Arheološkog muzeja Zadar, u području baze, nalazile su se manje količine portland cementa upotrijebljenog prilikom prijašnjih zahvata (sl. 6). Cementno onečišćenje uklonjeno je mehanički, čekićem, dlijetom i skalpelom.

Ultrazvučna igla
Ultrazvučna igla ili „kavitron" u konzervaciji se koristi za fine i osjetljive radove. Vrh igle kroz koju prolazi voda vibrira te, prislanjajući iglu na onečišćenu površinu, vibracijom nastaju šupljine u vodi koje nisu ispunjene zrakom, nego u njima nastaje vakuum koji uzrokuje ljuštenje kamenca.

7 C. A. Price 1996, 13–14.

Slika 6. Cementne naslage na bazi skulpture
Figure 6. Cement deposits on the base of the sculpture
foto / photo by: **A. M. Lučić**

present in the surface impurities layer are harmful to the stone material itself, so they must be removed to delay the process of sculpture decay.[7]

Mechanical cleaning
Mechanical cleaning is done manually or by machine. Scalpels, brushes of different hardness, glass sticks and various stonemason tools are most commonly used for manual cleaning. The sculpture from the Archaeological Museum Zadar contained smaller quantities of Portland cement in the area of the base, which was used in previous interventions (Fig. 6). The cement contamination was removed mechanically with a hammer, chisel and scalpel.

Ultrasonic needle
The ultrasonic needle or "cavitron" is used in conservation for fine and sensitive work. The water passes through the tip of the vibrating needle and by pushing the needle on the contaminated surface, the vibration creates cavities in the water which are not filled with air; instead the cavities create a vacuum which causes the limescale to peel off. This phenomenon is called cavitation. This instrument is suitable for cleaning marble and granite.[8] In our case, the harder impurities on the stone surface and the cement residues on the base, which were not removed with a chisel, were carefully removed with the ultrasonic needle (Fig. 7).

Steam cleaning
The surface of the marble sculpture of the empress was covered with a layer of impurity (dust and grease) and

7 C. A. Price 1996, 13–14.
8 I. Donelli, H. Malinar 2015, 134.

Slika 7. Čišćenje ultrazvučnom iglom
Figure 7. Ultrasonic needle cleaning
foto / photo by: **I. Duvnjak**

Slika 8. Čišćenje vodenom parom
Figure 8. Steam cleaning
foto / photo by: **I. Duvnjak**

Ta se pojava naziva kavitacija. Taj je aparat pogodan za čišćenje mramora i granita.[8] U našem slučaju ultrazvučnom iglom pažljivo su uklonjene tvrdokornije nečistoće na površini kamena i ostatci cementa na bazi koji nisu uklonjeni dlijetom (sl. 7).

Čišćenje vodenom parom

Površina mramorne skulpture carice bila je prekrivena slojem nečistoće (prašina i masnoća) te tankim koricama kalcifikata. Za uklanjanje štetnih naslaga te vrste, najboljom metodom pokazalo se čišćenje vodenom parom pod pritiskom (sl. 8). Čišćenje vodenom parom nedestruktivan je način uklanjanja površinske nečistoće, ne ostavlja tragove i ne šteti materijalu (sl. 9).

Uklanjanje ispuna

Na području lijevog boka skulpture, veća je vertikalna pukotina prilikom starijih intervencija bila popunjena poliesterskim ljepilom te je bila izrazito uočljiva što je nagrđivalo opći estetski dojam skulpture (sl. 10). Ljepilo

Slika 9. Rezultat čišćenja vodenom parom
Figure 9. Result of steam cleaning
foto / photo by: **A. M. Lučić**

a thin coat of calcifications. Cleaning with pressurized water vapor has proved to be the best method for the removal of this type of harmful deposits (Fig. 8). Steam cleaning is a non-destructive way of removing surface

8 I. Donelli, H. Malinar 2015, 134.

Slika 10. Pukotina ispunjena poliesterskim ljepilom
Figure 10. Fissure filled with polyester adhesive
foto / photo by: **A. M. Lučić**

Slika 11. Uklanjanje ispuna
Figure 11. Fillings removal
foto / photo by: **A. M. Lučić**

je pažljivo uklonjeno mehanički, skalpelom i zubarskim alatom, prethodnim zagrijavanjem vrućim zrakom (sl. 11).

Podljepljivanje

Na površini mramora vidljivo je mnoštvo vertikalnih mikro i makropukotina koje dugoročno mogu utjecati na stabilnost skulpture. Kako bi se spriječio daljnji gubitak mramorne mase, bilo je potrebno podlijepiti ranije spomenute pukotine. U postupku podljepljivanja korištena je 3-postotna otopina Paraloida B-72 u acetonu koja je nanesena u pukotinu kistom (sl. 12a; sl. 12b). Paraloid B-72 termoplastična je smola po sastavu kopolimer metil-akrilata i etil-metakrilata. Izuzetno je stabilna smola koja predstavlja standard stabilnosti za konzervatorsko-restauratorske materijale. Ne mijenja svoju prozirnost, a i ostaje trajno topljiv u otapalima nepolarnijim od toluena ili ksilena. Nedostatak mu je što je topljiv jedino u otapalima s velikim udjelom aromata.[9] Ta smola u konzervaciji i restauraciji ima mnoštvo primjena. Može se

impurities, leaving no traces and causing no damage to the material (Fig. 9).

Fillings removal

During older interventions, a larger vertical fissure on the left hip area of the sculpture was filled with polyester adhesive and it was highly noticeable, which marred the general aesthetic impression of the sculpture (Fig. 10). The adhesive was pre-heated with hot air and carefully removed mechanically, with a scalpel and dental tool (Fig. 11).

Pre-consolidation

There are many vertical micro- and macro-fissures on the surface of the marble which can affect the stability of the sculpture in the long term. In order to prevent further loss of marble mass, it was necessary to consolidate the aforementioned fissures. The 3% solution of Paraloid B-72 in acetone was used in the process of pre-consolidation and it was applied to the fissure with a brush (Fig. 12a; Fig. 12b). Paraloid B-72 is a thermoplastic resin in the compound of copolymer methyl acrylate and ethyl methacrylate. It is an extremely stable resin which represents the standard of stability for conservation-restoration materials. It does not change its opacity, and it remains permanently soluble in

9 G. Wheeler 2005, 70.

Slika 12a, 12b. Podljepljivanje pukotina
Figure 12a, 12b. Fissure pre-consolidation
foto / photo by: **A. M. Lučić**

koristiti kao npr. reverzibilno ljepilo, smjesa za zapune i zaštitni lak.

Konsolidacija

Konsolidacijom kamena nazivamo sve postupke čija je namjena vraćanja izgubljene kohezije kamenom materijalu, odnosno njegovo učvršćenje. Ti postupci najčešće uključuju unos određene otopine u kamen. Konsolidanti mogu biti organskog ili anorganskog podrijetla. Nakon impregnacije određenom otopinom, dolazi do kemijske reakcije. Otapalo ispari, a konsolidant se polimerizira, čime učvršćuje samo kamenu strukturu. Tim postupkom konsolidirani kamen ne bi smio u konzervacijskom smislu premašiti originalna mehanička svojstva zdravog kamena.[10] Konsolidant se na površinu najčešće nanosi premazivanjem, prskanjem, pipetiranjem, potapanjem ili je uvučen u kamen kapilarnim djelovanjem. Vakuumska konsolidacija koristi se da bi olakšala prodor konsolidanta u kamene predmete. Vakuumski sustav razvio je Balfour Beatty Limited (Balvac) za uporabu na spomenicima.[11]

solvents which are more non-polar than toluene or xylene. The disadvantage is that it is soluble only in solvents with a high content of aromatics.[9] This resin has many uses in conservation and restoration. For example, it can be used as a reversible adhesive, filler mixture and protective varnish.

Consolidation

The consolidation of stone entails all processes whose purpose is to restore the lost cohesion of the stone material, that is, its reinforcement. These procedures usually involve the introduction of a particular solution into the stone. The consolidants may be of organic or inorganic origin. After the impregnation with a certain solution, a chemical reaction occurs. The solvent is evaporated and the consolidant is polymerized, thus reinforcing only the stone structure. In this way, the consolidated stone should not, in the conservation sense, exceed the original mechanical properties of healthy stone.[10] The consolidant is usually applied to the surface by coating, spraying, pipetting, immersion, or it is drawn into the stone through capillary action. Vacuum consolidation is used to facilitate the penetration of the consolidant into stone objects. The vacuum system was developed by Balfour Beatty Limited (Balvac) for the use on monuments.[11]

10 I. Donelli, H. Malinar 2015, 146.
11 E. Doehne, C. A. Price 2010, 36.

9 G. Wheeler 2005, 70.
10 I. Donelli, H. Malinar 2015, 146.
11 E. Doehne, C. A. Price 2010, 36.

Slika 13. Vakuumska konsolidacija skulpture
Figure 13. Vacuum consolidation of the sculpture
foto / photo by: **A. M. Lučić**

Vakuumska konsolidacija

Osim uobičajenih tehnika impregnacije kamena kao što su prskanje, premazivanje i potapanje, možemo upotrijebiti i vakuumsku konsolidaciju. Odjel konzervacije i restauracije kamena u Splitu već nekoliko godina radi na ispitivanju konsolidacije kamena s pomoću vakuuma. Tom metodom vakuumske konsolidacije obrađeno je više kamenih umjetnina. Uporabom FTIR spektrometrije prati se dubina prodiranja konsolidanta u strukturu kamena. Vakuumska aparatura sastoji se od vakuumske pumpe, vakuumske komore, cilindra za sakupljanje viška konsolidanta, ventila i plastičnih cijevi. Za objekte većih dimenzija vakuumiranje se može vršiti i u plastičnim folijama koje treba pripremiti varenjem rubova. Princip rada poprilično je jednostavan. Fleksibilnu plastičnu cijev provedemo do cilindra za vakuumiranje ili kroz plastičnu foliju te ju spojimo s vakuumskom pumpom. Drugu plastičnu cijev uronimo u spremnik u kojem je konsolidant te ju provedemo do cilindra ili kroz plastičnu foliju u kojoj se nalazi predmet. Nakon što se postigne podtlak od -1 bara, što kontroliramo tlakomjerom, zatvaramo ventil na vakuumskoj pumpi te otvaramo ventil na spremniku u kojem je konsolidant.

Vacuum consolidation

In addition to usual stone impregnation techniques such as spraying, coating and immersion, vacuum consolidation can also be used. The Department of Conservation - Restoration of stone in Split has been working for several years on the investigation of the vacuum consolidation of stone. Several stone artworks were processed with the method of vacuum consolidation. FTIR spectroscopy monitors the depth of penetration of the consolidant into the stone structure. The vacuum apparatus consists of a vacuum pump, a vacuum chamber, a cylinder for collecting excess consolidant, valves and plastic tubes. For larger objects, the vacuuming can also be carried out in plastic sheets which must be prepared by sealing the edges. The operating principle is quite simple. The flexible plastic tube is conducted toward the vacuum cylinder or connected to the vacuum pump through the plastic sheet. The second plastic tube is submerged in the container filled with consolidant and it is conducted toward the cylinder or through the plastic sheet in which the object is placed. After the negative pressure of -1 bar, controlled by a pressure gauge, is reached, the valve on the vacuum pump is closed and the valve on the container holding the consolidant is opened.

The consolidation of the sculpture was completed by a vacuum process (Fig. 13). This method was chosen because the entire surface of the marble sculpture was eroded in some places and it was covered in microfissures and macro-fissures, so it was necessary to ensure adequate penetration of the consolidant into the material. The process begins with the wrapping of the sculpture in geotextiles to prevent the breaching of the sheet under vacuum. The next step is the manufacture of a plastic bag for vacuuming and the installation of a valve that suctions air and releases the consolidant. Prior to the release of the consolidant, it is necessary to bring the sculpture to the state of vacuum and potentially fill in the fissures through which air breach occurs. The consolidant is released through a valve at the bottom of the sculpture and it gradually ascends to the outlet valve located at the top. The unabsorbed consolidant flows through the upper valve into the container with the indicated units of measurement which serve to accurately determine the amount of the consolidant which the sculpture has absorbed.

The described procedure can be repeated several times if needed. During the vacuum process, about

Slika 14a, 14b. Retuširanje
Figure 14a, 14b. Retouching
foto / photo by: **I. Duvnjak**

Konsolidacija skulpture izvedena je postupkom vakuuma (sl. 13). Ta je metoda izabrana zato što se cijela površina mramorne skulpture na nekim mjestima osipala te je bila prekrivena mikropukotinama i makropukotinama, pa je bilo potrebno osigurati adekvatan prodor konsolidanta u materijal. Postupak započinje omotavanjem skulpture u geotekstil kako ne bi došlo do proboja folije pod utjecajem vakuuma. Sljedeći je korak izrada plastične vreće za vakuumiranje i ugradnja ventila za isisavanje zraka i puštanje konsolidanta. Prije puštanja konsolidanta potrebno je dovesti skulpturu do stanja vakuuma te potencijalno popuniti pukotine kroz koje dolazi do prodora zraka. Konsolidant se pušta kroz ventil u dnu skulpture te se postupno penje do izlaznog ventila koji se nalazi na vrhu. Neupijeni konsolidant kroz gornji ventil istječe u posudu s označenim mjernim jedinicama kako bi se s točnošću ustvrdilo koliko je konsolidanta skulptura primila.

Opisani postupak može se ponoviti više puta po potrebi. Tijekom postupka vakuumiranja u skulpturu je utrošeno oko 3 litre etil-silikatnog konsolidanta.[12]

3 liters of ethyl silicate consolidant were used on the sculpture.[12]

Retouching

Due to the overall aesthetic and visual impression of the compactness of the sculpture, a process of retouching the surface fissures was performed. Larger fissures and ruptures were retouched using Paraloid B-72 dissolved in acetone, with the addition of marble flour and sand. The mixture was applied with a dental tool and a brush. After drying, the mixture used in the filling has a remarkable effect and the reconstructions are therefore very noticeable. By scraping the retouched spots with the glass fiber pen, a matt surface similar to the original marble was achieved (Figs. 13, 14a, 14b).

12 G. Wheeler 2005, 75–85; I. Donelli, H. Malinar 2015, 143. $(C_2H_5)_4SiO_4$. Rabi se za učvršćivanje vrlo poroznih vapnenaca, pješčenjaka i mramora. Etilni silikat se utjecajem vlage iz zraka nakon nanošenja na kamen razgrađuje (hidroliza). Produkt razgradnje silicijeva je kiselina, a nusprodukt je etilni alkohol, C_2H_5OH, koji isparava. Silicijeva kiselina dalje se dekompozira u kremen, SiO_2, koji učvršćuje strukturu kamena.

12 G. Wheeler 2005, 75–85; I. Donelli, H. Malinar 2015, 143. $(C_2H_5)_4SiO_4$. It is used for fixing very porous limestone, sandstone and marble. Under the influence of moisture from the air, ethyl silicate breaks down upon application to the stone (hydrolysis). The decomposition product is silicic acid, and the byproduct is ethyl alcohol, C_2H_5OH, which evaporates. Silicic acid is further decomposed into quartz, SiO_2, which solidifies the structure of the rock.

Retuširanje

Radi cjelokupnog estetskog i vizualnog dojma kompaktnosti skulpture, izveden je postupak retuširanja površinskih pukotina. Veće pukotine i napuknuća retuširana su upotrebom Paraloida B-72 otopljenog u acetonu, uz dodavanje mramornog brašna i pijeska. Smjesa se nanosila zubarskim alatom i kistom. Nakon sušenja smjesa korištena prilikom popunjavanja ima sjajni efekt, pa su rekonstrukcije stoga veoma uočljive. Stružući olovkom sa staklenim vlaknima retuširana mjesta, dobila se matirana površina slična mramornom izvorniku (sl. 13, 14a, 14b).

DOKUMENTACIJA

Prvi korak svakog konzervatorsko-restauratorskog zahvata preliminarni je pregled objekta. Očevidom se dobiva opća predodžba o stanju kamena i izrađuje se najnužnija dokumentacija. To je prije svega fotodokumentiranje, zatim i izrada skica i crteža te kraći zapisi o zatečenom stanju. Tijekom radova potrebno je dokumentirati sve nalaze i momente koji su važni kod dokazivanja ispravnosti postupka. Isto tako, po završetku radova treba dokumentirati novo stanje koje je rezultat konzervatorsko-restauratorskog zahvata.[13]

Opseg dokumentiranja spomenika ili objekta ovisi o njegovoj kompleksnosti i obujmu konzervatorsko-restauratorskih radova. U ovom slučaju priloženi su crteži skulpture sa sve četiri strane. Crvenom bojom označene su veće pukotine i napuknuća koja su tijekom konzervatorsko-restauratorskih radova podlijepljene i retuširane. Plavom bojom označene su zone koje sadrže niz mikropuknuća (sl. 15).

Nakon svih konzervatorsko-restauratorskih zahvata skulptura je vraćena i postavljena na prvotno mjesto u antički postav Arheološkog muzeja Zadar.

DOCUMENTATION

The first step of any conservation-restoration intervention is a preliminary inspection of the object. An investigation offers a general impression of the state of the stone and the essential documentation is created. First and foremost, this includes photo documentation, then drafting of sketches and drawings and brief notes of the existing state. During the work it is necessary to document all findings and moments that are important in proving the adequacy of the procedure. Also, upon completion of the work, a new condition resulting from the conservation-restoration intervention should be documented.[13]

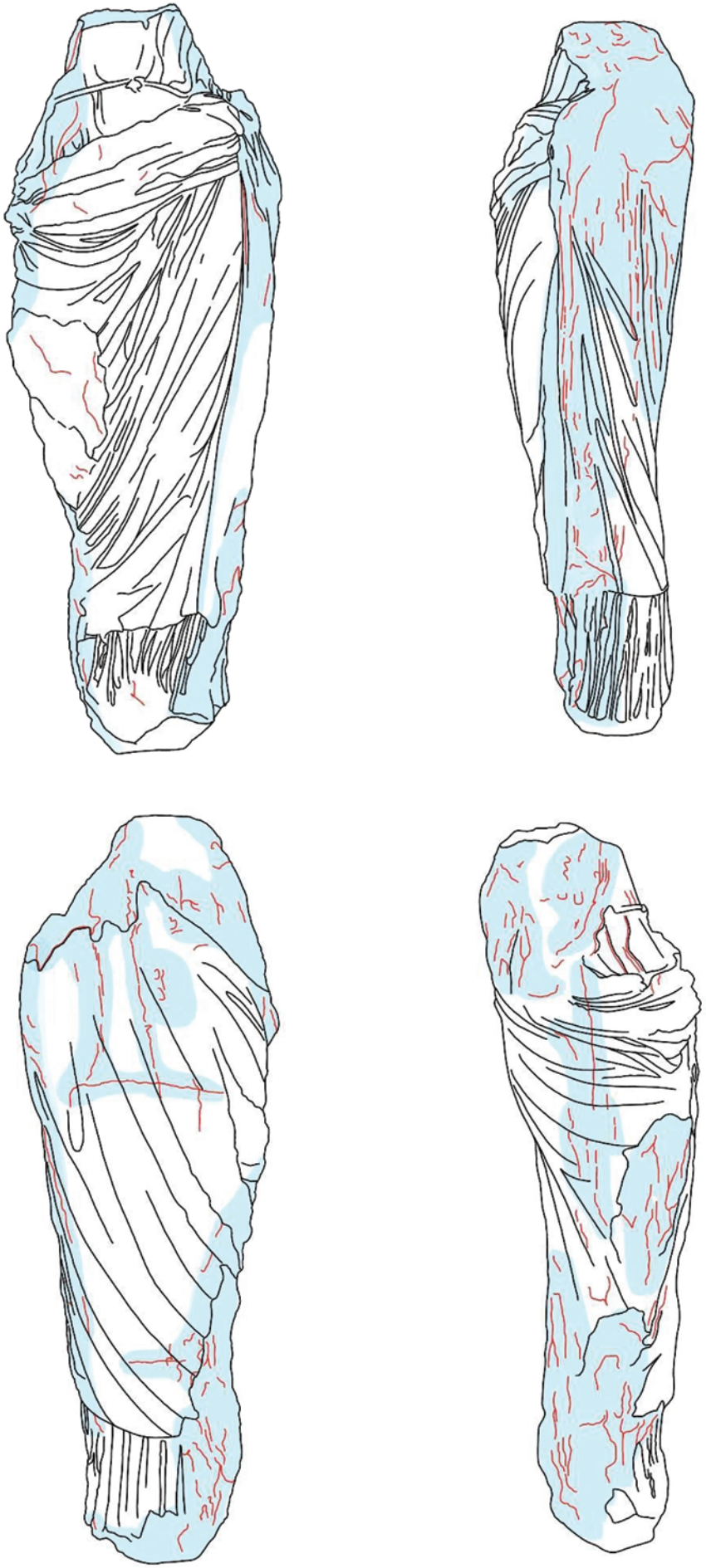
The extent of documenting a monument or object depends on its complexity and the extent of the conservation-restoration works. In this case, the drawings of the sculpture on all four sides are enclosed. The color red indicates larger fissures and ruptures that have been pre-consolidated and retouched during the conservation-restoration works. The zones containing a series of micro-fissures are indicated in blue (Fig. 15).

After all the conservation-restoration interventions, the sculpture was restored and placed in its original place in the ancient exhibition of the Archaeological Museum Zadar.

13 I. Donelli, H. Malinar 2015, 115–125.

13 I. Donelli, H. Malinar 2015, 115–125.

Slika 15. Digitalna dokumentacija
Figure 15. Digital documentation
crtež / drawing by: **I. Duvnjak**



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