Stone

Since the Palaeolithic period, man has been able to shape and work stone. The oldest cultures still show their presence in the form of stone monuments and sculptures. Stone is resilient in most environments. However, weathering erodes the original worked surfaces.

Sandstone, marble, limestone and granite are only a few of the stones used to express the artisans' view of his surroundings. Each material has different properties and poses a challenge to the craftsman.

There are two types of sandstone used for buildings and sculptures: calcareous and siliceous sandstone. Calcareous sandstone tends to deteriorate faster since the calcium carbonate that binds the sand together is more readily dissolved by acid rain.

Marble and limestone are also calcareous stones and are easily attacked by acids. They are porous and soft and so scratch easily and are frequently stained due to environmental causes.

Granite is one of the most resilient stones used to produce sculptures and other ornamental features. It is fairly resilient to wear and tear and environmental impact in comparison to the other stones used. However, due to its brittle nature it chips easily. An interesting feature of some granite types is that when in contact with fire they can explode violently.

Handling

It is imperative to understand the artwork that has to be moved or handled. The following points should be kept in mind.

Before moving a work of art made of stone, it has to be ensured that it is sturdy enough to be moved.

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Cotton or nitrile gloves should be worn when handling artworks in stone or it has to be ensured that hands are very clean. A note of caution, cotton gloves can entangle with rough stone surfaces.

If a stone object is moved on a mount, it needs to be secured adequately and no part should be abraded by the support itself. Therefore, it is always advisable to remove all stones from their mounts prior to moving them. Large stones are best demounted using lifting equipment, to minimise the stresses exerted onto the mounting areas. Be sure that the attachment points for the lifting straps are strong enough and the straps secured properly.

All protruding parts, be they original or restored, need to be checked if they are detachable or loose, especially since old restorations are susceptible to new damage and need to be carefully checked along the original—restoration interface. Large and small pieces are only to be moved by hand a short distance. Small pieces should be moved from shelf to padded cart with the cart placed as close as feasible to the shelf. Large pieces should be lifted onto inert, padded pallets and whenever necessary by movable lifting equipment. They should be securely strapped to the pallet for the safety of both the object and personnel during movement (Fig. 1).

The mode of transport has to be in good working order and suitable for the artefact moved. Usually carts trolleys and forklift trucks are labeled with weight limits and under no circumstances should they be overloaded or used as ladders.

Before moving an artwork, ensure that the path to the destination is clear and that no protruding wall fixtures or doors are blocking the free movement of your object, and that there is sufficient illumination of the path.

Loose footwear or clothing that can entangle with the artwork are not suitable. No rings or buckles should come in contact with the stone surface since it may easily causes chipping or scratches. Artefacts should never be lifted at protruding parts; they might be frail, brittle or loose. Transport stone objects in crates or boxes, whenever feasible.

Display

Marble, limestone and sandstone sculptures should not be displayed outdoors, since air pollution in urban environments can cause the rapid deterioration of the surfaces. This often results in black streaks or crusts.

Granite can be displayed outdoors. However, it should be carefully monitored and maintained. Always raise stone slightly from the ground and use a water/moisture barrier between the object and the surface it is resting on. This prevents potentially contaminated water from the ground entering the stone and being transported through capillary action throughout the sculpture. Cyclic wetting and drying can cause damage to the body and especially the surface of a sculpture. Old sculptures can contain repairs with iron dowels, and humidity can result in corrosion of these iron rods with the resulting rust causing stains in the stonework or even cracking due to expansion of the rust (corrosion jacking).

Fig. 1 Egyptian limestone sculptor's model 305-30 BC; the edges on the proper *right side* are missing and disfigure the overall appearance of the model since the missing edges distract strongly from the original carving. By replacing the missing edges, the visual integrity of the piece is restored without altering the original figure

Frequently, antique stone artefacts have been drilled for mounting. In recent years, this has become unacceptable for most museums and collectors. Drilling can cause stresses within the stone, this can lead to micro-cracking and even result in fracturing of the stone. Modern mounting specialists will try to display objects by non-invasive techniques such as clamps and contoured armatures of the underside of the artwork. When displaying a sculpture, it is important that the object is

Fig. 2 This Gandara Buddha was mounted with brackets to a stainless steel base without the need to drill

mounted appropriately and that the centre of gravity (also called centre of mass) of an object is taken into account. Much of the damage caused to sculptures is due to accidental toppling (Fig. 2).

When exposing stones to strong light sources, it is important that previous restorations are identified and potential accelerated ageing is prevented. Frequently, excessive lighting can cause rapid deterioration of inappropriate glues, resulting in joint failure and further breakage.

Antique stone can also have remains of old colour decorations, these can fade when exposed to high light levels.

Maintenance

The surface of stone can be dusted with a longhaired brush. It has to be ensured that the metal ferrule around the stem of the brush is adequately protected with masking tape, so as to not scratch the surface of the stone.

Air from aerosol-cans can also be utilised in dust removal. However, as with brushing, this has to be done with caution, since it can dislodge loose fragments on antique and damaged stone or drive small dust particles into the capillaries.

Some antique stone sculptures have been found to have the remains of old painted decoration. These have to be dusted carefully so as not to damage the original pigmented areas. In come cases, the pigments might need consolidation treatment by a specialist conservator.

Fig. 3 Roman marble hand holding a Parazonium, 1st Century A.D., before, during and after conservation

Outdoor stone sculptures or architectural parts can be carefully rinsed with water.

However, the possibility of previous restorations has to be borne in mind. A professional conservator will know the best approach to maintaining the sculptures to ensure minimal deterioration due to their outdoor exposure (Figs. 3 and 4).

Packing and Storage

Before moving stone it is essential they be condition checked to prevent damage. The surface of the sculpture should be protected by a layer of acid free paper. No tape is to be used in the first layer of wrapping. Then a double layer of bubble wrap is to be wrapped around the body. The bubbles have to face each other to minimise the pressure points. In case of very heavy pieces, the bubble wrap can be substituted by several layers of clean thick blankets. However, this is only a

Fig. 4 Roman marble head of Doryphoros 2nd Century AD; the damaged nose was restored. However, the restoration is not stylistically correct and this will be immediately obvious to a connoisseur examining the head in future. Faltermeier (2012), www.faltermeier.biz

Table 1 Suitable and unsuitable packing materials

Appropriate	Inappropriate
Acid free paper	Newspaper
Acid free cardboard tubes	Toilet paper
Bubble wrap	Vinyl chloride, urethane foams, Styrofoam
Polyethylene foam, bags, tubes, boxes	Fabric fibres
Polyester film (Mylar Type D®)	Cotton wool
Aluminium foil (The above need to be specific archival quality or tested in advance)	Composite woods such as fibreboards and chip boards (only as outer casing)

temporary measure during transit, never for long-term storage. For long-term storage, polyethylene foam should be used. The common yellow foam or Styrofoam is not to be used, since this can deteriorate and stick to the artwork. The stone is then placed into a crate made of inert plastic. The crate is padded with shock absorbent polyethylene foam (Table 1).

Stone can be stored at various temperatures and humidity ranges. However, it is important to check for old repairs and restorations, since these can be susceptible to temperature and humidity changes. Generally it is thought that restored objects made of stone should be stored at a relative humidity of between 45 and 55 % and a temperature between 20 and 23 °C. Wet or humid stone artefacts cannot be stored in an environment likely to freeze; ice crystals can damage porous and frail surfaces due to an increase in pressure during crystallisation of water present.

Some excavated stones contain soluble salts. These objects should be desalinated by a professional before storage. A fluctuating humidity will most probably result in salt damage due to the re-crystallisation of soluble salts at low humidity levels. If desalination is not feasible, the stones need to be stored at a very stable relative humidity.

When storing heavy stones, it is often advised to take them off their mounts. It is best to place the object on clean, inert polyethylene foam. The weight should be

carried by the largest part closest to the centre of gravity of the artwork. Any protruding parts need to be protected and supported.

Since hardly any storage area is dust free, it is best to cover the stone with clean white cotton sheets.

Conservation and Restoration

In many cases, broken and damaged stones have been repaired using commonly available, rapid-curing epoxies or polyesters. These resins result in yellow staining and damage of the surface due to their poor ageing properties. It is very difficult if not impossible to remove these stains when the glues have been drawn into capillaries, in-between the grains or crystals of a stone matrix during the curing process. Accumulative effects due to temperature and light also cause these old repairs to fail, since the resins break down with age and lose their cohesive strength.

In the past, fractured protruding parts are often reinforced using iron or copper rods. These corrode rapidly in moist tropical climates or in outdoor stones and iron rods and their expanding corrosion will result in pressure, cracking and splitting of the adjacent stone. Iron, copper or copper alloy rods and their corrosion products, can in many cases, cause staining of the surrounding surface. A professional conservator will replace these with non-corroding stainless steel rods. When planning for outdoor exposure, it is warranted to use techniques such as ultrasound to detect old iron rods to prevent future damage due to their corrosion. This can be easily liaised by a local conservator and an engineering company (Fig. 5).

Fig. 5 The antique marble bust above was restored using an iron pin and plaster. The pin corroded and stained the original patina of the marble surface. It is fortunate that the drilled hole is much larger than the pin and that plaster was used, since the corroded and expanding pin only damaged the plaster and did not cause cracking of the original marble

Marble and limestone with black streaks should not be cleaned with commercially available cleaning solutions. These can have an adverse effect and can potentially dissolve the surface. Scrubbing the stone with heavy-duty sponges and brushes can abrade the surface and erode fine decorations. A conservator will use pH neutral soap and soft brushes to remove dust and grim while chemicals such as complexing agents, are used to remove stubborn stains.

Antique stone sculptures or architectural elements are frequently heavily restored. Many countries that are hosts to a thriving antique trade also have their own restorers; these restorers; re-carve missing pieces from similar stones. Since freshly excavated archaeological stone sculptures are frequently carved from regional stone, it can be difficult to distinguish old and new parts by colour or structure of a stone since the same or similar materials are still readily available.

The new additions can usually be distinguished by their deliberate wear of the surface, and the lack of natural staining and weathering. Frequently the joint of the original part and the re-carved part is filed down to allow a perfect surface appearance. This abrasion will have resulted in the damage of the original ancient surface. To mask the variation in colour and texture, the whole sculpture is then frequently soaked in chemicals and/or coated with waxes and pigments to resemble an ancient surface. In most instances, a mixture of solvents and chemicals easily removes the waxes and pigments. However, there are cases where damaged missing original features for example or worn decorations are re-carved out of the damaged surface material. This kind of treatment is much harder to detect and variations in surface weathering usually are a good indicator for a newly exposed surface in the recently carved areas (Figs. 6 and 7).

Testing and Analytical Methods

The simplest way determining which parts of a stone sculpture are antique or recent restoration is through test cleaning an inconspicuous area with water. (Caution: this should only be done with the permission of the owner. Additionally, any dirt, grime and other contaminating material can be driven into the surface of the stone.) Most restorations or synthetic additions will react differently to water. However, if the surface has been coated with a synthetic material or wax, this method will not work well (Fig. 8).

If a stone has fractured or chipped surfaces then a microscope or good magnifying glass (30× or larger) can be used to examine the stone fabric. Most stones, being porous) have a graduation in colour from the surface into the core of the piece. This colour change varies from stone to stone and depends upon the type of burial environment. I have seen cases in which shellac and other materials have been applied to imitate this gradual penetration of deterioration and discolouration. If this is suspected it should be followed up with careful surface testing to confirm if the material is soluble in organic solvents, indicating a synthetic resin has been used.

Fig. 6 Antique marble leopard from a palace in Bikaner Rajasthan. The detailed *insert* shows the previous restoration attempt. The aged and *yellowed* synthetic resin used to join the fragment has deteriorated. The resulting failure caused a new break visible as the clean broken edge. *Below* the Leopards paw restored and airbrushed. The new treatment is reversible. Faltermeier (2012), www.faltermeier.biz

Fig. 7 Gandara relief. The previously restored piece had various false heads. The heads were removed, the surface cleaned and gap-filled, and colour matched

Old restorations made of synthetic resins or synthetic fillers can be identified in most cases using infrared or ultraviolet lamps and/or by a simple heat test. A fine needle is heated to red-hot and then the suspicious surface is probed. If smoke and a hole with elevated rim develops the filler is most probably synthetic. This technique does not work with plaster and cement fillers. Plaster fillers tend to be softer than stone and much more homogenous than most stones. Cement fillers tend to have a clear boundary between stone and cement interface.

Microscopy:

Microscopy can show inconsistencies in wear and tear, distinguish between old and new damage and reveal modern additions. Binocular microscopy and oblique light is most useful (Fig. 9).

Ultraviolet Light (UV) and Infrared Light (IR):

This can show up variations in materials, revealing modern additions, and in some cases traces of old painted decorations.

Fig. 8 The Khmer gray stone sculpture of Narashima was analysed using solvent based Spot-Testing. The *yellow dashed lines* indicate the areas where the new carvings were added. The hips of the figure are the original area. The torso and the legs were newly carved and added. It is interesting to note the great difference in colour and structure. The hips are well aged and the deteriorated discolouration cannot be removed with solvents or a mixture of various chemicals. Faltermeier (2012), www.faltermeier.biz

Chemical Spot Tests:

Various chemicals are applied in small areas to detect inconsistencies in the surface materials and the application of modern coatings to improve the appearance.

X-ray Diffraction (XRD):

This technology is used to identify the minerals present in a stone.

Fig. 9 Vishnu sandstone sculpture, Cambodia; the legs of this figure are replacements. The *infrared image* clearly shows the difference in surface and the great variations in tool marks and the original weathering of the antique areas above the legs

Cross-sections:

Mounted thin sections of the stone viewed in an analytical microscope can highlight erosion and deterioration patterns and type of minerals present. This is necessarily a destructive technique unless there are loose fragments that may be sacrificed.