Air-abrasive Procedures in the Conservation and Restoration of Stone Cultural Objects and Monuments

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Abstract: Air-abrasion represents a well-known practice that consists of projecting a stream of fine solid particles onto a surface by means of compressed air. Commonly referred to as sandblasting and microblasting, it has been both praised and criticized over the course of time. This article sets out to present a general overview of the air-abrasive cleaning procedures utilized in the conservation and restoration of stone-made cultural objects and monuments. It analyzes the origin and development of this technology, pointing out different technical and ethical aspects of its use.

Keywords: Air-abrasion, Microblasting, Procedures, Stone, Conservation, Restoration

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1. Introduction

The abrasive property of sand and its effect on stone surfaces have long been noticed and have become a subject of study for engineers, conservators, geologists, and archaeologists. Wind erosion, one of the main factors of stone weathering, is facilitated by sand particles carried by the air currents. This effect can be noticed on the pyramids of Dahshur [1], the Karnak Temple Complex in Egypt [2], as well as the more than 110 rock-cut tombs in Hegra in Saudi Arabia [3], among others. This natural destructive effect was harnessed with a different scope in the second half of the 19th century when sandblasting was first utilized. It involved projecting a stream of fine granular particles onto surfaces by means of a jet of compressed air. Today, this firmly established technology is adjusted to different fields of work and all sizes of projects, from the most massive, such as building facades, to the most delicate, such as archaeological artifacts. Adjusting it for use on cultural heritage objects and historic monuments has been a long process, and it can be considered still under debate.

2. History and early development

The first known invention patent regarding air-abrasive technology dates back to 1870, and its declared purpose was “cutting and engraving stone, metal, glass” [4]. As air compressors developed from rudimentary steam power to oil, electric, and diesel (mainly spurred by the construction and mining industries for pneumatic tools), air abrasion gradually gained popularity, being well established by the early 1900s. Its most widespread application remains to this day in the industrial sector and shipyards for cleaning and preparing metal surfaces. Its wide industrial potential helped further develop its design and construction.

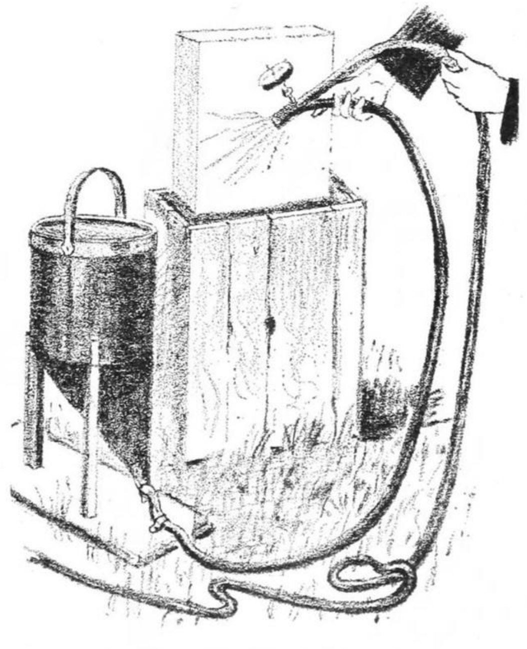

Fig. 1: Illustration of an early sandblasting device from 1919 [5].

As early as 1919, we find in the "Monument Dealer's Manual" a reference that gives valuable insight: "The original sand blast has been used for cleaning various kinds of building stone and for removing dirt and rust from metals for years. The apparatus consisted of two tubes ending in a single nozzle. Through one of these, air was forced under pressure from a compressed air reservoir, and through the other, sand was forced by means of air pressure from a closed reservoir" [5]. This short text is accompanied by an illustration, as seen in Fig. 1. The author further describes a modification of this device for cleaning marble, involving a sand recipient installed at the end of the air pressure hose. Varieties of this system are still used today for airbrushes and small-scale sandblasting.

As the technique became more established and widespread, some stonemasonry school textbooks also gave schematics of sandblasting devices (Fig. 2), advising caution in their use for cleaning. Such cleaning procedures would occasionally be part of stone carvers' activity.

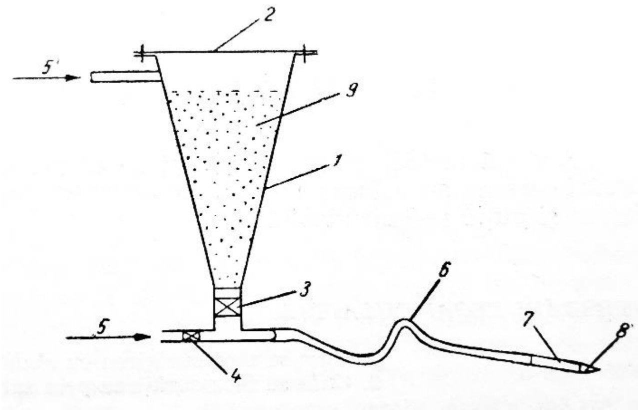

Fig. 2: Sandblasting device illustrated in a 1969 stonemasonry textbook. [6]

An adapted version of air abrasion was introduced in the dental medical field in 1945 [7], outlining what would be referred to as micro air abrasion or microblasting. This involved much finer abrasives and smaller installations. The main types of powders used would be aluminum oxide and sodium bicarbonate. The early 1960s also saw a further introduction of micro air abrasion in the field of paleontology, specifically of fossil preparation, an idea experimented with previously as early as 1894 [8]. This application is very relevant, as it can be linked to its eventual use in museum laboratory settings and on potentially fragile objects. In 1968 the company Comco would produce a compact device called the Microblaster.

3. Adjustment to stone conservation and restoration

Although technological advancement might mistakenly be viewed as similar to a living organism that evolves over time, information was not always as available as it is now. Therefore, while events and inventions are worth acknowledging, technologies in different parts of the world may have developed separately and at a different pace. Since a clear distinction between air abrasive procedures was not made until more recent decades, an exact timeline cannot be precisely made. Presently, microblasting is accepted as a valid method of cleaning stone artifacts and surfaces of monuments. Other accepted devices are pneumatic pens, laser machines, vacuums, steamers, and water misting installations. None of these are universally adequate, since restoration procedures must be utilized in accordance with the desired result and the composition, solidity, and texture of the artifact (while still respecting basic conservation principles). Air-abrasion is no exception. In this regard, it's worth noting some published observations.

In 1952, Soviet engineer A.M. Orlov describes "sand cleaning" as a procedure that "removes the superficial, dirty layer of stone," restoring its "fresh look" due to revealing a clean layer. He further indicates that it is to be used on hard rocks only, while on architectural profiles the pressure should be reduced to 0.5–1 atm. He specifies that architectural monuments should only be cleaned with water and steam [9].

In 1973, G.A. Sleater of the Center of Building Technology remarks that a drawback of sandblasting is that "it will remove decayed or soft stone as well as dirt" [10]. In 1979, architectural historian Anne Grimmer points out that "abrasive cleaning is destructive to historic building materials" [11], while in 1982, the Committee on Conservation of Historic Stone Buildings and Monuments concludes that "air-abrasive methods probably have caused more damage to masonry surfaces in the past two decades than any others" [12].

As can be seen, the concern about air-abrasion is not regarding its efficiency but regarding its safety, especially when dealing with cultural heritage that is of great historical value. As shown in the beginning of this article, this technology was developed specifically for engraving and cutting, along with cleaning. In the industrial field, it's commonly used for treating metal surfaces for better adhesion of paint. This in itself indicates possible issues with microblasting since it may later promote adhesion of pollutants or other types of films and crusts. Abrasion marks or pitting can also occur during cleaning, even if this may only be visible on a microscope. This cannot be disregarded as insignificant, since many artifacts and historical monuments contain very subtle marks indicating the techniques and tools of their making. Ultimately, the safety of the cleaning procedure will depend on the restorer/conservator and their experience and skill.

4. Challenges and technical aspects

Micro air-abrasion is a modified version of sandblasting utilizing much finer abrasives and reduced pressure. It can be considered specialized precision technology. However, its use poses a number of challenges:

- Lack of professional qualifications in the field. While "sandblaster" is a well-established profession with a corresponding vocational certification, microblasting is usually only formally taught to dentists and dental technicians.
- High risk of damage to cultural heritage if used improperly.
- Health hazards if used without proper work safety measures.
- Environmental hazards. Large-scale work will produce airborne dust, which may be hard to contain, settling over surrounding areas, including vegetation. Debris resulting from the process will not be reused, generating waste material, while the inevitable noise pollution can disrupt local wildlife or communities. This also applies to other activities related to worksites.
- Lack of standardization. The tubing, type of nozzle, and fittings vary according to country of origin and producer. Replacement parts may be unavailable or costly.
- Equipment fragility. While conservators may choose to use medical equipment, which is perfectly suitable for a laboratory setting, these can prove to be extremely fragile when working in situ on restoration worksites.
- Unsuitable tubing. Most medical microblasters have a short pressure tube, which is only suitable in laboratories. While this issue can be dealt with by some minor modifications, different tubes of the same quality and specifications may prove hard to obtain in some places.
- Misleading product descriptions. Regarding their grain size, abrasive powders for sandblasting are usually measured in mesh, while abrasive powders for microblasting are measured in microns or micrometers (µ or µm). Generally, the former is sold in sacks, while the other is in plastic recipients. However, the packaging of the product may just display a number, for example, 200 or 80, although normally the producer will specify the unit of measurement.

Table 1: Unit conversion.

Mathematical conversion		Mesh size conversion	
Micron (µm)	Mesh	Micron (µm)	Mesh
37	400	30	400
44	325	40	325
53	270	50	270
63	230	63	230
74	200	75	200
88	170	90	170
105	140	100	140
125	120	125	120
149	100	150	100
177	80	170	80
210	70	200	70
250	60	250	60
297	50	300	50
354	45	350	45
400	40	400	40
500	35	500	35
595	30	600	30

As illustrated in Table 1, while 30 mesh is mathematically 595 µm, the equivalent in abrasive powder will be 600 µm. Common abrasives for microblasting will be 50, 75, 100, 125, and 250 µm, depending on need, and may go up to 600 µm. However, for use on historic building surfaces, materials will not be less than 80 mesh for the coarsest work and will go to 325-400 for the finest. As shown before, the finest will be expressed in µm and utilized by means of micro-abrasive installations.

Further important factors will be nozzle size (the carbide tip of the handpiece at the end of the pressure hose), air pressure, working distance, and type of abrasive used. For carbide nozzles used in microblasting, the available diameters range from approximately 0.4 mm to 1.8 mm. In practice, a diameter of 0.8-1 mm to 1.4 mm is more common. Air pressure may be expressed in bar, psi, MPa, or atm (Table 2). Although most European specifications will be expressed in bar, conversion may be needed for other foreign devices.

Table 2: Pressure unit conversion.

bar	psi	MPa	atm
1	14.50	0.1	0.98
2	29.02	0.2	1.97
3	43.54	0.3	2.96
4	58.06	0.4	3.94
5	72.58	0.5	4.93
6	87.10	0.6	5.92
7	101.62	0.7	6.90

Following the kinetic energy formula [13], air abrasion uses the velocity of the propelled particles to remove surface deposits and layers with a higher Mohs hardness than the abrasive itself. This makes it possible to utilize much less abrasive powders such as sodium bicarbonate in microblasting. Cellulose powder has also been used experimentally for cleaning artwork printed on paper [14]. On the other end of the spectrum, aluminum oxide requires a low working pressure due to its high mineral hardness. When cleaning stone, however, some particular issues exist. Using extremely gentle abrasive powders with low pressure may be ineffective, and if the reverse is attempted, there is a risk of damage. Air abrasion is intended for cleaning layers of substance less hard than the substrate, which in the case of stone may not always apply. Difficult surface deposits may be harder than the substrate, while in other cases the perceived dirt represents a decayed layer of the stone. Furthermore, stone itself is not always homogenous and may have vulnerable areas not apparent by visual inspection, a matter that should be addressed beforehand through non-destructive testing.

Currently, companies such as CTS and IBIX have developed air-abrasive units that Italians and French call mini sandblasters, a distinction not usually made in English. The IBIX Nano is a portable-sized air-abrasive device very similar in nature to microblasters but having the advantages of greater versatility and a stronger build, which is well adapted to construction and restoration site conditions. Such devices, however, require much larger diesel air compressors and additional air-drying systems.

Abrasives have also diversified over time, from the early use of plain sand, iron grit, and quartz to a wide selection including aluminum oxide, glass powder, dolomite, walnut shell grains, garnet, and dry ice.

5. Conclusions

Air-abrasive cleaning is an effective method of removing surface deposits and graffiti from stone, especially in the case of non-historical structures and objects. Regarding monuments and artifacts, its potential for harm must be weighed along with its potential for good. Similar to how a surgical scalpel is used in very delicate procedures on valuable works of art, only the attention, dexterity, and skill of the restorer-conservator will make the difference. However, since air-abrasion represents only a small percent of restoration procedures, the odds of the average conservator utilizing it every day on historical material are very slim. Furthermore, the skill required to safely operate air-abrasive devices is formed by practice and investment in tools and materials. Hence, in the absence of standardization, practitioners rely on empirical methods and personal experience. Establishing a specialization course for microblasting would be beneficial for the professional development of any staff involved in heritage restoration, whether they will apply it or not. Such a program could be implemented through a partnership of public institutions with private companies and vocational training providers. This would mark a positive step in the direction of standardizing a domain that is largely unregulated. Further development potential will remain, as always, dependent on fields of work with a significant demand for such technology.

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