MINISTERIO
DE CULTURA

International Conference on Stonework Heritage in Micronesia

November 14-15, 2007
Micronesian Ballroom
Guam Hilton Hotel

SPANISH PROGRAM
FOR CULTURAL COOPERATION
with the collaboration of the
GUAM PRESERVATION TRUST
and the
HISTORIC RESOURCES DIVISION,
DEPARTMENT OF PARKS
AND RECREATION

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Stonework Heritage in Micronesia

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Stonework Heritage in Micronesia

Conference Opening Remarks, Nov. 14-15, 2007

By José R. Rodríguez

Ladies and gentlemen, thank you for being here today at the opening of the **International Conference on Stonework Heritage in Micronesia.** For those of you who are from Guam, and for those of you who are from abroad, whether from the Northern Marianas, Ponhpei, the Philippines or Spain, welcome to the Micronesian Room of the Guam Hilton Hotel.

As a result of the Protocol of Valladolid, signed in 1999 by Guam, the Northern Mariana Islands, Palau and the Federated States of Micronesia and Spain, the ties between our countries were renewed, and there was an agreement to promote and increase our cultural relations. I want to mention here the significant role played by Dr. Katherine Aguon (of Guam) and Dr. Rufino Mauricio (of the Federated States of Micronesia) in the signature of the Protocol. In 2001, these islands were included under the scope of the Spanish Program for Cultural Cooperation.

The Spanish Program for Cultural Cooperation is a grant program between the Ministry of Culture of Spain and the Philippines, Guam, the Northern Mariana Islands, Republic of Palau and the Federated States of Micronesia. It was designed to foster closer ties between our countries through the collaborative works of scholars in the Humanities and the Social Sciences.

While preparing for this conference, we had the enormous advantage of partnering with the Guam Preservation Trust, headed by its Chief Program Officer Joseph Quinata, Program Officers Rosanna Barcinas and Ruby Santos. They have played major roles in this project. I want to express our gratitude to the Historic Resources Division, of the Department of Parks and Recreation office – I still have to learn how to say "Parks and Rec"- that joined the team as soon as Patrick Lujan knew about it. The conference would not be the same without such partnership.

I had the privilege of meeting Rosanna when she visited Manila to participate in another conference about the application of plaster or *paletada* in Spanish colonial buildings. I must say that the collaboration of the Guam Preservation Trust has been instrumental. The Trust has continuously assisted in the preparation of the conference in ways that would take too long to enumerate, from the identification of the speakers, to the technical assistance during the preparation.

I am sure that for those of you who are familiar with the activities of the Guam Preservation Trust, there is nothing new in what I am saying. For us, this is the first time that we had a project together and I am glad to say that we look forward to repeating the experience. Thank you so much, Mr. Quinata, for having your office participate in the conference, and for the wonderful dinner in which we were welcomed last night at the Capuchin's friary.

It is a sweet and sour feeling to know that a two-day conference does not give enough time to discuss all the issues and to give room for all the speakers. This means that there is a growing demand for dialogue and exchange on cultural and historic preservation issues.

To all of you, thank you for coming. *Bienvenidos*, welcome to the conference and let's start with the discussions, in the hope that gatherings like this will be continued in the future. Thank you very much.

Conference Rationale

By Carlos Madrid
Spanish Program for Cultural Cooperation, Academic Coordinator

The Merriam-Webster dictionary defines Stonework as “a structure or part built of stone.” And “the shaping, preparation, or setting of stone.” The same source defines “heritage” as the “property that descends to an heir” or “something transmitted by or acquired from a predecessor.” We refer as Stonework Heritage as the heritage of structures made of stone.

Our conference aligns with the principles of UNESCO for cultural heritage. UNESCO considers that “it can best protect cultural diversity through actions involving sites that bear witness to multiple cultural identities, are representative of minority cultural heritages, are of founding significance, or are in imminent danger of destruction”.

Development that endangers natural and cultural environment is not sustainable. The Universal Declaration of Cultural Diversity has two major goals: first, to ensure respect for cultural identities with the participation of all peoples in a democratic framework and, second, to contribute to the emergence of a favourable climate for the creativity of all. In other words, it’s a matter of making culture a factor of development.

Current development creates new challenges and different kinds of risks throughout the world. Both tangible and intangible heritage is endangered, subjected to renovated pressures exercised from economic, political or military priorities. To prevent and protect those heritages, UNESCO hosted the Convention on Biological Diversity (2000), the Convention on the Protection of Underwater Cultural Heritage (2001) and the Convention for the Safeguarding of Intangible Cultural Heritage (2003).

Cultural heritage represents one of the most significant aspects of the identity of a nation and its material manifestation across times and periods. The physical presence of a historic structure is a visible testimony of the past that contributes to the maintenance of the collective conscience of the community.

The Micronesian region is significantly rich and diverse in cultural heritage. By incorporating it into a collective appreciation, we are better prepared to move forward for the new challenges of the future. In a world where cultural tourism is growing in importance the historic heritage of Micronesia represents an economic venue for sustained development. Hence, community involvement and awareness of historic heritage has played a growing role in recent years.

In order to contribute to those dynamics, and in the light of the cultural and historic relations between Spain, Guam, Northern Mariana Islands, Federated States of Micronesia and Palau, the **Spanish Program for Cultural Cooperation**, with the collaboration and partnership of the **Guam Preservation Trust**, along with the **Historic Resources Division of the Department of Parks and Recreation Office**; hosts this *International Conference on Stonework Heritage in Micronesia*.

The conference invited experts and individuals from the Micronesian Region, the Philippines, and Spain to present papers on historic stonework heritage and tackle issues such as the challenges in its conservation, restoration techniques, contemporary tourist potential, and appreciation among the community. The publication of the papers will increase the corpus of bibliographic materials that may serve as a reference in the coming future.

In this *International Conference on Stonework Heritage*, organizers, presenters and participants belong to different disciplines: Archaeology, History, and Architecture. Each of us has different approaches towards cultural heritage: recovery, restoration, protection, and revitalization. These disciplines are simply different sides of one and the same coin. We are here because we belong to the same group, whose professional activity is oriented to foster a better understanding of cultural heritage in its different manifestations. We envision a situation in which gatherings like this that we are about to celebrate, shall not be an exception.

This conference aligns with Article 7 of UNESCO's Universal Declaration of Cultural Diversity, adopted on November 2, 2001,

Article 7 – Cultural heritage as the wellspring of creativity

Creation draws on the roots of cultural tradition, but flourishes in contact with other cultures. For this reason, heritage in all its forms must be preserved, enhanced and handed on to future generations as a record of human experience and aspirations, so as to foster creativity in all its diversity and to inspire genuine dialogue among cultures.

Stone Conservation of Spanish Colonial Structures in a Tropical Setting

By Maria Bernardita Maronilla-Reyes

Chemist Conservator, UST Center for the Conservation of Cultural Property and Environment in the Tropics University of Santo Tomas, Espana, Manila, Philippines

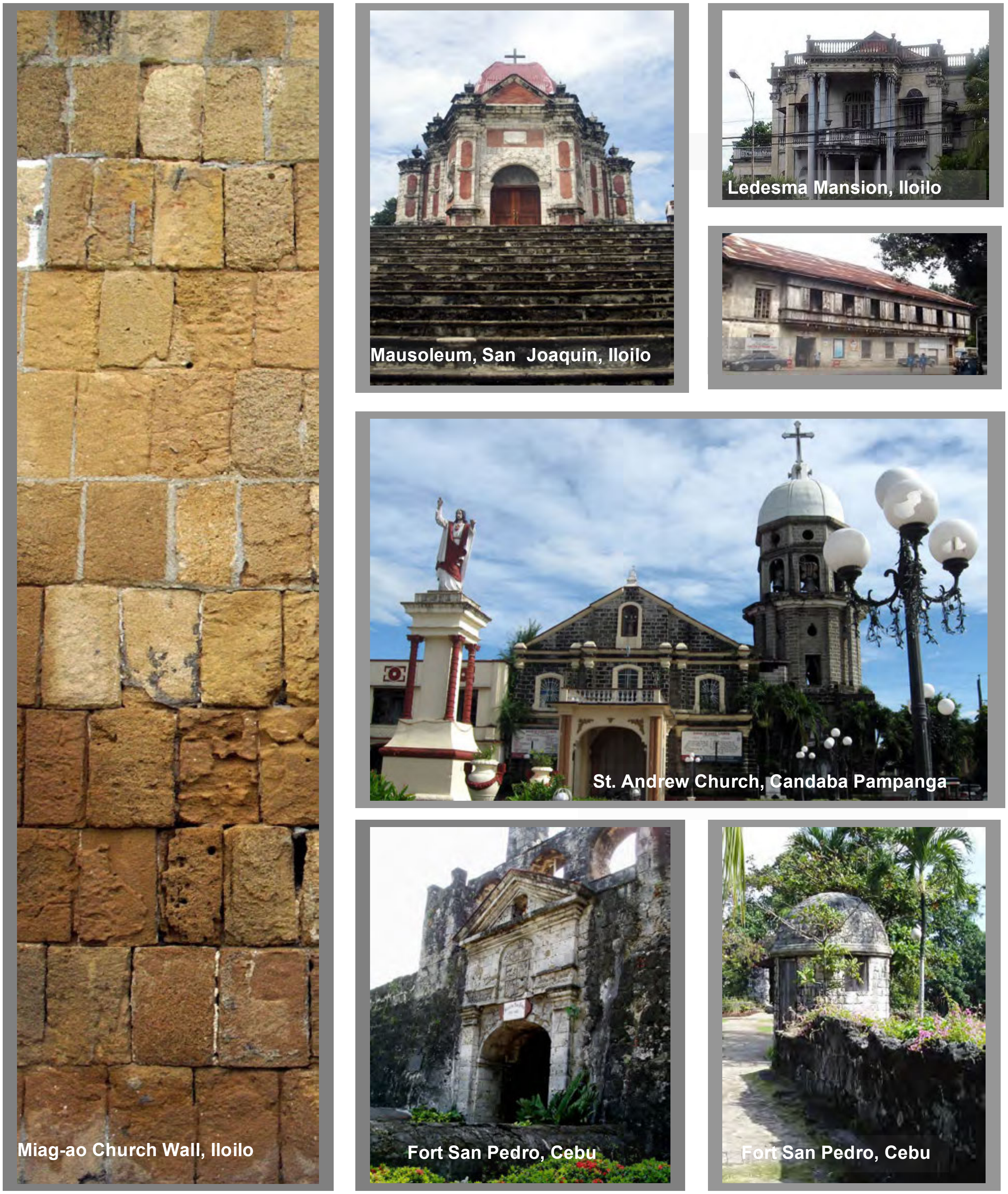
Stone conservation of Spanish colonial structures in a tropical setting is a very challenging task. Deterioration of many types of stone is accelerated in a hot and humid climate. Seismic activity caused by earthquakes and volcanic eruptions aggravates this problem. The earth movements result in cracks and fractures in the structures, which become deterioration sites for growth of vegetation or for birds and rodents to settle in. Frequent flooding makes this situation even more complex.

The tradition of building with stone was introduced by Spain to the Philippines. Prior to Spain's colonization in 1565, indigenous Filipino architecture used wood and thatch. This local technique was adopted until a fire razed Manila in 1583. A decree was issued four years later to build mainly with stone.[1]

Spanish colonial structures are basically made of limestone and adobe (volcanic tuff) incorporated with red bricks. The architectural forms and styles vary from municipal, religious and domestic buildings to military forts, watch towers and lighthouses. (Figs. 1 & 2)[2] A typical "earthquake baroque" church would have a rectangular single-nave architecture with bell towers, buttresses, pinnacles and crenellations. These features make them appear massive like fortresses and "baroque" for their decorative value of florid embellishments.[3] Wooden poles, sheathed with stone curtain walls, were frequently used as the main structural members.[4] Walls are one to two meters thick made of rough stones, pebbles, and gravel mixed with mortar then surfaced with hewn stone blocks, or layer upon layer of bricks and mortar. Molasses and crushed seashells were mixed into the lime mixture to ensure the binding strength of the mortar, although some claim that egg-whites and egg-shells were also part of the formula.[5] Sometimes, mashed *puso-puso* leaves, previously soaked and cut, were added for water repellency.[6] Lime/sand plaster was used on the surface as protection against weathering. Stucco or plaster was also used for aesthetic reasons - unifying an otherwise heterogeneous surface.

During the American occupation in the early 1900's, the competition of bricks and other manufactured products like cement encroached upon the general use of traditional stones.[7] These stones still find a market today but mainly as cladding material for modern construction.
To date, the Spanish colonial structures which have survived the vicissitudes of time and the effects of weathering over the past centuries are still visible and functional. The more predominant structures in the Philippines are Catholic stone churches. At least 29 churches have been declared national cultural treasures. Four are included in UNESCO's list of world heritage sites.

Figure 1: Spanish Colonial Structures Made of Coralline Limestone



Stone Conservation Defined

Stone conservation is an intervention to stabilize the condition of stone and to prevent, retard or arrest its deterioration. Before any intervention can be undertaken the following requisites are necessary: 1) understanding the nature of stone and related materials, plus the environment in which they are located, 2) assessment of the condition of stone - the causes of the deterioration problems and their extent, and 3) knowledge of and experience in the different treatment options.

Conservation of Stone Built Heritage

The conservation of stone built structures is a bigger concern than that of dealing with stone materials alone. It involves the conservation of the entire historic fabric of the structure including architectural and decorative features. It takes into consideration the interests of different stakeholders, viz: the custodians or the caretakers of the built heritage (government and non-government organizations), the owners of the property or the local people, the visitors or tourists, the benefactors of the project and the conservators.

This highly specialized operation is usually assigned to a restoration architect, in collaboration with a stone specialist. While conservation is to stabilize the condition of stone, restoration is an attempt to bring back deteriorated stone and structure to its original, form, shape and condition. The architect consults other allied professionals as early as the planning stage - thus making it necessarily a multidisciplinary task, involving also engineers, geologists, scientists, etc. (Fig.3 Stone Conservation: A Multidisciplinary Task).[1]

Among his objectives are: to understand the building, its materials and its values, to preserve and reveal aesthetic and historic values of the structure, to respect the original materials, and to see to it that additions are distinct from the original architectural composition and bear a contemporary stamp.[2] Contributions of all periods to the building of a monument are to be respected and replacement of missing parts must integrate harmoniously with the whole.[3] Structural modifications must be carefully studied before any intervention is done as this may lead to irreparable loss or damage to the building. Necessary measures for the security, protection and survival of the cultural property -in case of a disaster- are also to be given attention.

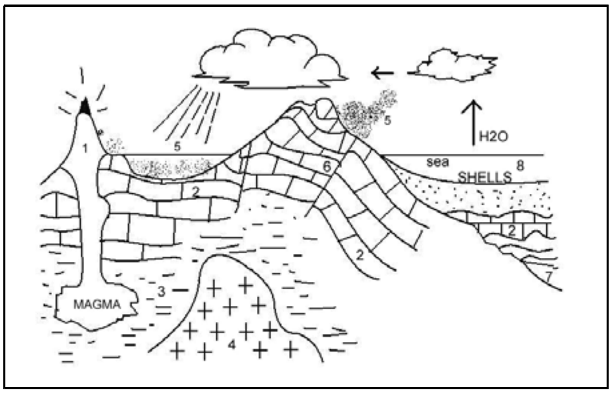
Principles of Conservation

The three (3) generally accepted principles of conservation are: minimalism, reversibility (or, nowadays, retreatability) and compatible stability. *Minimalism* means the least intervention necessary. It suggests that the better intervention is the one with the least changes in the characteristics of the original. *Reversibility* is the ability to undo what has been done. A good example is the use of materials that can be removed in case it is decided later to distinguish the original from additions. However, this may seem unrealistic when dealing with consolidation. A consolidant applied onto a pulverizing stone would be quite impossible to remove from the stone once it has penetrated and has been integrated with it. This is where retreatability comes in. *Compatible stability* refers to the use of materials compatible with and never stronger than the original. Stronger materials like cement or modern concrete will always cause stress and strain on the weaker, deteriorating stone. Cement plaster will detach eventually, bringing with it some of the original stone.

Conservation in the New Century [4]

In the new century, conservation is slowly evolving from a neutral act to a critical act - a matter of interpretation. Apparently, this act is dictated by contemporary values and beliefs, and, in the process “transforms heritage”. But this is not something to be construed as negative. Heritage, to be relevant, must pursue its connections to the present, but, through controlled change. The question to ask is “how much change is desirable or even ethical?”

Fig. 4: Genetic Scheme of Rocks (Lazzarini)



1. Igneous Rocks: lavas 2. Recent Sedimentary Rocks 3. Contact Metamorphosed Rocks 4. Igneous Rocks: Plutonites 5. Sediments 6. Ancient Sedimentary Rocks 7. Regional Metamorphosed Rocks 8. Sea (Sedimentary Basin)

Table 1: Different Porosities of Stones (Rossi-Doria)

TYPE OF ROCK	POROSITY
Soft Limestone (Coralline)	4.0 - 42%
Hard Limestone	0.8 – 27%
Sandstones	0.5 – 42%
Marble	0.1 – 10%
Granite	0.05 – 2.8%
Basalt	0.1 - 10%

Dilemma in Conservation

Options will always vary regarding which technique to apply or which products to use in conservation. Removal of moss alone on a stone surface seems to be a neutral act but applying a herbicide is another story. There have always been opposing views on whether to remove the plaster for aesthetics or retain it for protection; whether to plaster and repaint or just apply plaster without repainting; whether to consolidate with resins and other chemical products or plainly use lime or replace materials.

Evaluation of the importance of elements in the structure and the decision as to what may be destroyed will have to be agreed upon by the different stakeholders. To remove the positive alteration (patina) from a stone surface, for example, is a result of taste and prejudices. Decisions can vary among persons, cultures and with time.[5] It cannot be left to the decision of one individual in charge of the work. The availability of resources will also have to be considered. Resources do not only pertain to financial or manpower requirements but also to the materials needed, possible alternatives, etc.

Understanding the Nature of Stone

Understanding of the nature of stone as a building material is the key to assessment and successful treatment. It is important to be familiar not only with the properties of the original stone, but also with those of the altered stone, and similar stones that could be used as replacements. Knowledge of the properties of related materials like cement, mortars and plasters is also crucial.

Stones for building structures are cut, shaped or polished rocks. Rocks form an integral part of the earth's crust. A rock may be defined as being made up of a mineral or an aggregation of minerals. A rock may either be sedimentary, metamorphic or igneous – depending on the genesis of its formation. (Fig. 4)[6] Beneath the earth's crust is the mantle, and beneath the mantle, the nucleus. The earth's crust is partly penetrated by light silicates of the upper mantle or "SiAl" (Silica/ Alumina). SiAl extends approximately 30 kilometers under the continents. It is compositionally heterogeneous granite rock. SiAl changes to SiMa, made of heavier, darker silicates in the lower mantle. It occupies the depth range of 30 –60 kilometers. Its average composition is that of basalt. The nucleus or core of the earth is a concentration of heavy masses of compounds of iron and of nickel.

Types of Rock

Sedimentary rocks account for 75% of the sub-aerial and underwater surfaces of the earth's crust. They are the type most often used in building construction. They may originate from mud (clays), sand (sandstones), chalk (limestone) or pyroclastic (tuff) materials formed by compaction or cementation of sediments. They have different porosities, upon which their stability is dependent. (Table 1: Different Porosities of Stones)[7] Of the remaining surface of the earth's crust, igneous rocks account for 5%, metamorphic rocks such as marble, account for 4% and ice ~ 16%.

Igneous or plutonic rocks are formed when the hot fluid magma inside the earth's crust cools. Magma may be considered mixed solutions of various melted and gaseous compounds, mostly silicates. The principal components, apart from silica, are oxides of aluminum and iron, calcium and magnesium, potassium and sodium. The secondary components are oxides of titanium and zinc, magnesium and barium, chromium and phosphorous. Granite, a type of igneous rock, is found in many historic local structures. It is commonly known in the Philippines as "piedra china" because the granite used in the country came from China.[8] Apparently, it was used as ballast for ships coming in to Manila Bay and later exchanged with goods from local traders. However, those used for the San Agustin Church in Intramuros were purchased from Canton in 1780's.[9]

Metamorphic rocks are found in different parts of the earth's crust. Quantitatively, they belong to the most important type of rock. They are formed when rocks change from their original structure by the action of extreme pressure, heat or the various combinations of these factors. Limestone, which is a sedimentary rock, can metamorphose into marble. Both are compositionally calcium carbonate.

The common rock sources for stone building materials are argillites (clays), limestone, sandstone, slate, marble, granite and basalt

Limestone: Coralline and Non-coralline[10]

Limestone is a sedimentary rock which is either oolithic, or calcite cemented calcareous stone formed of shell fragments, particularly non-crystalline in nature. It has no cleavage lines, is uniform in structure and composition, and may however show a bedded stratification.

In the Philippines, limestone is widely distributed throughout all the islands. It was used as construction material in the 16th century and, later, as raw material for cement manufacture. Coralline limestone is usually quarried from sedimentary basins. It is soft and porous. Tertiary sedimentary basins of coral stones are found in Luzon Central Valley, Cagayan Valley, Southeast Luzon, Iloilo, Visayan Sea, Cotabato, Davao, Agusan, Palawan and Sulu Sea. The limestone cliffs of El Nido in Palawan are massive rocks formed some 250 million years ago from thick layers of coral deposits.

Dolomitic limestone, which are rich in magnesium, are abundant in Cebu (largest deposits found in Fuente, Carmen), in Calatagan and Sta. Maria, Batangas, in Negros Occidental and Oriental, in Northern Leyte and in Davao Oriental.

Non-coralline limestone are quarried from marble-like formations. They are harder and can be polished. They are found in Mindoro, Sierra Madre, Buruanga Peninsula, Romblon, Palawan, and Zamboanga. Coralline limestones, as reef formations 150 to 400 meters thick, are found in Southeastern Luzon, Central Visayas and North, East and Southern Mindanao.

The most available and important limestone in the vicinity of Manila is found near Montalban, about 30 kilometers from Manila, and in a semi-mountainous country about 7 kilometers north of Binangonan, Rizal, and about 20 kilometers from Manila.[11] The limestone in both places are hard and crystalline, and the deposits are uniform in chemical composition –almost pure calcite. They were used as raw materials for the manufacture of cement and sand-lime brick.

Adobe (Volcanic Tuff)[12]

Adobe (volcanic tuff or unbaked mudbrick) is a rock that was once loose pyroclastic material. It could have been fine volcanic ash or coarse cinders but when cemented together it is called tuff. As a building material, it is naturally quarried as clay stone. There is another type of clay, known as "mud-brick", which is molded and sun-baked. Red bricks are clay materials fired or baked at high temperatures. The red color is due to the iron content.

In the Philippines, the main supply of adobe comes from Luzon. They are especially abundant in west central Luzon, extending almost unbrokenly from near Lingayen Gulf to the seacoast of Batangas, practically blanketing or covering all of the massive rocks of the region. In Bulacan province it is quarried almost continuously throughout the year. Adobe quarried in Quezon City belongs to the Diliman Tuff, member of the Guadalupe Formation, and to the Taal Tuff. Large quantities of this stone have been quarried near the Guadalupe area, along the Pasig River.[13] It was used in the construction of many churches, buildings, walls and fortresses of Intramuros, Manila.[14] It is described as very workable since it is so soft that it can be quarried with an axe, but that it hardens rapidly on exposure. The Mount Mayamot quarry is currently active and the tuff quarried from it is known as Guadalupe tuff. It is similar in nature to some of the volcanic tuffs used in historic construction and to that of an important petroglyph site nearby Angono.[15] Other sources of adobe are Aklan, Antique, Ilocos Sur, Laguna, Samar and Surigao. Volcanic tuff can also be found in the Agusan-Pulangui region, interior from Cagayan, Misamis.

Tuffs vary considerably in texture, color, density and chemical composition. The harder varieties are preferred for construction, though much of the softer material is used locally because it is cheaper. The coarse grained and hard varieties are quarried throughout all the year in the vicinity of Meycauayan, Bulacan. The fine-grained and soft varieties are quarried at Santa Mesa, Rizal, and at Tayawanak, Cavite.

A microscopic examination done by Alvin J. Cox in 1915, showed the tuff in the vicinity of Manila as andesitic (darker in color) with a cementing material -which is probably in greater part volcanic ash- and is largely composed of oxide of iron.[16] It might also be mentioned that a certain amount of pumice is nearly almost always to be found in this tuff. Pumice is volcanic glass, which has an abrasive quality. Incidentally, a study by Paterno and Charola (2000) mentions that Guadalupe tuff, used extensively in modern construction in Manila (as cladding material), has similar properties to those used in historic construction in Manila. The tuff is composed of a glassy matrix (60%) with clasts (30%) of pumice and some basalt. The dominant minerals are feldspars with negligible clay content.[17]

Adobe (siliceous) vs. Coralline Limestone (carbonaceous)

In the Philippines, colonial stone structures are usually made either of adobe or of coralline stone. Both are sedimentary rocks. (Table 2: Chemical Compositions of Stones)[18] Corals shaped into stones which have not yet petrified are simply corals or coral stones. (Fig. 5: Sample Textures of Building Stones) Local adobe (volcanic tuff or tufa) is argillaceous –meaning of clay materials. It is also siliceous –since sheet silicate is a component of clay. Clays are formed by atmospheric weathering of several rock types. They have a suctioning effect for moisture because of their fine particles.[19] They are very plastic when wet and can be dispersed completely when more water is added.

Coralline stone is a type of limestone. It is petrified corals. It is calcareous because it has calcium. It is also carbonaceous because it is a carbonate of calcium. It is chemically calcium carbonate. It is very sensitive to acidic environment.

During in-situ analysis, a simple way to determine whether a stone is adobe or coralline is by using 10% hydrochloric acid (muriatic acid). Effervescence on the stone surface, after placing a drop or two of the acid, is indicative of limestone. The carbonates of limestone react with the acid and carbon dioxide gas is released in the form of bubbles. What is left is the calcium skeleton, the rest are pores.

Cement

While adobe is clay (siliceous) and coralline limestone is calcareous (has calcium), cement is burnt clay and limestone.

This is to say that raw materials used in the manufacture of Portland cement come from these two types of deposits. Clay easily pulverizes upon exposure to water while coralline limestones develop increased porosity due to release of carbon dioxide when exposed to acidic environment. When calcium carbonate (limestone) and silicates (clay) are mixed and fired (or calcined) at a very high temperature of 1200 to 1400 degrees centigrade, all the oxides and carbonates are released in the air. It results in the fusion of calcium with the silicates and aluminates of clays. The clinker formed is composed of calcium silicates and calcium aluminates. Gypsum is added as retardant. The clinker is ground into a greenish grey powder called Portland cement. It was named so because its color is similar to that of Portland stone, a common building stone in the UK. There are different types of Portland cements. Portland -with low alkali/ sulfate content- is the one recommended to be added to lime plaster to increase the binding capacity.[20] (Table 3:Types of Portland Cement)[21]

Portland Cement vs. Pozzolan Cement

There are different types of cement. Those which harden or set in water are called hydraulic cements. Portland and Pozzolan cements are of this type. Pozzolan cement is modified Portland through addition of vitrified materials such as powdered tiles or pottery. This diluted powder makes it less expensive than pure Portland cement. It has a longer curing time, but once it sets, usually after 40 days, it develops superior strength.

Natural pozzolan is a type of earth material of glassy volcanic origin. It can produce hydraulic reaction with slaked lime. It was discovered during the Hellenistic Period (around the 4th century B.C.) in the city of Pozzuoli, near Naples from which its name was derived.[22] (Table 4: Hydraulic Cements)[23]

Hydraulic Mortars

Hydraulic mortars set or harden upon reaction with water. Portland cement is one example. It reacts with water and hardens upon drying. The components responsible for reacting with water are calcium silicate and calcium aluminates. Lime (the source of calcium) mixed with pozzolanic

Fig. 5: Textures of Building Stones

CORAL STONE

CORALLINE LIMESTONE

NON-CORALLINE LIMESTONE

ADOBE (Volcanic Tuff)

GRANITE

Table 2: Chemical Compositions of Stones (Montoto)

	Siliceous		Carbonated		
	Granite	Siliceous sandstone	Marble	Limestone	*Dolomite*
SiO_2	77.8	83.0	0.1	0.4	*1.1*
Al_2O_3	11.8	4.3	0.1	0.0	*0.5*
Fe_2O_3	1.6	2.5	0.2	0.0	*0.3*
CaO	0.4	1.7	54.5	54.4	*34.9*
MgO	0.1	3.4	0.7	0.0	*16.9*
Na_2O	2.9	0.9	0.0	0.0	*0.1*
K_2O	4.6	2.0	0.0	0.0	*0.0*
					Esbert et al 1997

Table 3: Types of Portland Cement (ASTM)

TYPE		USE
Type 1	Ordinary Portland	General construction
Type 2	Moderate Heat Portland	Acidic environment
Type 3	Rapid Hardening	Rush works
Type 4	Low Heat Portland	Dams
Type 5	Sulfate Resisting Portland	Sewage disposal plants

Table 4: Types of Hydraulic Cements

- **PORTLAND** - 1824 by J. Aspdin
- **POZZOLAN**
  -Volcanic tuff + sand = superior strength mortar
  -in Pozzuoli near Rome
  -Artificial Pozzolan is powdered tiles or pottery
- **HIGH ALUMINA**
- **SPECIAL CEMENTS**

materials (the source of silicates and aluminates) form a hydraulic mortar. Other similar materials (like clay limestone) show the same properties. (Table 5: Cement Mortars)[24]

Modern Concrete

Modern concrete is a mixture of cement, sand and gravel. It is hard, brittle, can withstand compressive stress but is weak against tensile strength. This weakness is overcome by reinforcing concrete with steel, a high tensile strength material. Reinforced concrete was introduced in the second half of the 19th century in France. Pre-stressed concrete, which uses steel cables, appeared 100 years later.[25] Steel has almost the same expansion coefficient as concrete and cement adheres very well to its surface. The basic environment of cement makes corrosion rate of steel very slow.

Relevance of Cement Quarries to Conservation

Since quarries and cement plants indicate possible sources of clay (silica and alumina) and limestone, their location becomes relevant specifically when replacement of highly deteriorated stones is being considered as a 'loss compensation method'. The raw materials in cement manufacture -and not cement itself- are considered for use in restoration. Cement is too compact and strong for powdery adobe or porous limestone.

Lime

Apart from cement, hydraulic mortar and modern concrete, other binding materials used in construction are lime and gypsum. Sand or aggregates of sandstone, pozzolanic materials and ash brick are used as fillers for these binders. In conservation, the usual proportion of binder to filler is 1:3. Lime is usually mixed with a little cement to improve its hydraulic property.[26]

Lime is the result of burnt limestone. It is locally known as "apog". Quicklime is calcium oxide. It is produced by heating limestone in kilns at a high temperature of 700 – 900 degrees centigrade. It results to de-carbonation or release of carbon dioxide. Apart from heat, dissolution of carbonates could also result from reaction of limestone with acids. This is the reason why deterioration of limestone is accelerated in a hot humid country such as the Philippines. Humidity accelerates acid attack on stones, leaving them porous where the carbonates are dissolved.

The use of lime plasters dates back to the Neolithic period.[27] In the historic period, it appeared in the Mycenean and Minoic Civilization (Knossos palace 1700 B.C.).[28] In Egypt, it was used quite late, in 300 B.C. (Ptolemaic period). This could be due to the fact that lime is prepared at much higher temperature compared to Plaster of Paris.

Quicklime vs. Slaked lime

Slaked lime is quicklime in water. It is calcium hydroxide or hydrated calcium oxide. It develops heat upon contact with water so it must be prepared with great attention. For a good product, the right amount of water must be used. If water is excessive, a soft greasy mass is obtained (lime paste). Upon contact with air, it dries progressively until the hydroxide is converted back to hard carbonate.

In conservation it is advisable to slake lime before use. Slaking lime can take months or even years. A long slaking improves plasticity of the lime putty.[29] (Table 8)[30]

Lime Mortar

Sand is the typical filler for lime. Sand must be washed clean to remove salts, clay or organic materials which slow down the already slow hardening process. Typical formulations are 1:2 lime/sand or 1:3 lime/ sand with the right amount or water to make a paste. It is important to note that lime mortars show good workability if the addition of water is rather generous. Conversely, the mechanical properties of the hardened mortars are improved if the amount of water is reduced. Proper balance between workability and strength must always be achieved. This requires a lot of experience. Even with less water, workability could be achieved through the use of fluidizers.[31] (Tables 6 & 7)[32]

Lime mortars have similar properties to those used in ancient calcareous masonry. However, they harden very slowly and may not harden at all in damp conditions as drying and the presence of air are required for hardening.[33] Due to this limitation, lime-pozzolan or lime-cement mixtures are preferred to effect faster hardening. The usual formulation is 1: 4: 3 where 1 is cement, 4 is lime, and 3 is sand.[34]

Table 5: CEMENT MORTAR (Torraca)

Defects Of Portland Cement Mortars when Used In Stone Conservation
• High compressive strength and elasticity modulus • Large thermal expansion coefficient • High amount of soluble salts • High density and thermal conductivity • Low porosity with very small pores

Table 6: LIME MORTAR (Torraca)

Defects of Lime Mortars When Used in Stone Conservation
• Slow and difficult setting; May not harden in damp climates • High Deformability • High porosity consisting of very large pores

Table 7: LIME-CEMENT MORTAR (Torraca)

Lime-cement Mortar as Alternative to Pure Lime Mortar In Stone Conservation
• Small amount of low alkali, low sulphate cement + Slaked lime (1:4) • Cement diluted with calcium carbonate or pulverized limestone

Table 8: LIME MORTAR (Ashurst)

Procedures for Obtaining Optimum Performance from Lime Mortars (non-hydrated)
1. Slake quicklime on site to form a soft putty. Stir continuously during slaking. Keep under water at least 1 week. Sieve to remove lumps. OR: Soak Hydrated Lime Powder in enough water to form a soft putty. Leave at least 16 hrs. 2. Mix putty with desired aggregates in desired proportion (e.g. 1:3) Mechanically or by hand to form "coarse stuff". 3. Store enough "course Stuff" in plastic bins under wet sacks. Make an airtight LID. Every extra week of storage is beneficial. 4. Remove enough "course stuff" for the days work. Beat, ram and mix until a good workable mix is obtained. Try not to add water, but if you must, keep to a minimum. 5. Add "pozzolanic" setting aids, if needed. At this stage, mix very thoroughly. 6. Protect finished work from rain, heat and local draughts.

Gypsum

If limestone is carbonated calcium, gypsum is sulfated calcium. It is chemically calcium sulfate with two molecules of water ($CaSO_4.2H_2O$). As a mortar or plaster, gypsum is slightly soluble in water. Being so, it is not normally used on exposed surfaces in damp climates.

It was used in Egypt both as mortar among blocks of stones (pyramids) and as plaster as early as the 3rd millennium B.C. When heated at 130 degrees centigrade, part of its water content evaporates and it becomes "Plaster of Paris" or "escayola". Plaster of Paris ($CaSO_4.1/2\ H2O$) sets rapidly when mixed with water. Upon drying, it is converted back to gypsum.

Most of the black encrustations on façades of coralline limestone could be attributed to gypsum. The sulfates originate from the surrounding polluted air or from nearby salts from the sea. The black color is due to entrapped carbon particulates from car exhausts and other industrial plant emissions.

Assessing of the Condition of Stone

The condition of stone refers to the superficial, material and structural state of the built heritage including a description of previous interventions such as stone replacement, metal insertions, plastic repair, synthetic applications, etc. Historic stone structures can be considered in good condition when they are stable and well maintained. They may appear unsightly - with surface dirt, accretions, soiling and graffiti - but they may not necessarily be in bad condition. On the contrary, they may appear intact but may actually be decaying underneath. Deteriorating structures are those which have become weak or unstable due to interrelated factors. Degradation is the advanced state of deterioration with more visible signs of loss of material and/or with disintegration.

Assessment and Examination

A detailed evaluation of the condition of stone requires a systematic and comprehensive study. It entails assessment of the built structure in general, and examination of the stone materials in particular. As already stated, it is not just the job of the restoration architect or the stone conservator. It is a multidisciplinary task. Conservation scientists like chemists undertake research studies on chemical reactions taking place in the stone that cause crystallization, decay or erosion, etc.; petrographers focus on the morphology of the stones and minerals; geologists and physicists are concerned with sonic and vibration measurements; biologists are concerned with the growth of vegetation like moss and microorganisms; conservation architects/ engineers deal with structure related damages, etc.

Requisites of a Systematic Assessment

As mentioned before, knowledge of the nature and composition of stone materials is prime and foremost before making an assessment. It is also important to understand how the environment and setting affect the individual stones and the structure. The other important requisites are: a) knowledge of the provenance of stones and how they were prepared, b) knowledge of typical stone conservation problems, their causes, and effects, c) knowledge of options for their conservation, restoration, repair and maintenance, d) knowledge of old construction methods, and e) training and/or experience in old construction methods or previous restoration.

Assessment Procedure

The actual assessment can be undertaken referring to the following steps as a guide: 1) Identify all internal and external factors causing stress, strain, alterations, etc, 2) determine whether deterioration process is active, whether structural fault is static or still moving, and to what extent, 3) determine original materials used: from the locality or from elsewhere, 4) consider generally accepted principles, taking note of the availability of materials. Provide material alternatives and conservation/ repair options, and 5) determine future use of the structure.

Documentation

Apart from a written record of the state of conservation of stone materials and the built structure, a graphic representation is a must. This is executed by mapping stone and masonry morphologies over the drawing of the façade, walls etc. or over photo images. It aims to a) provide a visual description of their actual condition, e.g., deposits on the surface, material loss, structural damage, etc., b) indicate constituent materials such as limestone, adobe, marble, etc., and c) specify areas with previous surface applications or intervention, e.g., remains of polychromy, artificial patina, graffiti/ paint applications, stone replacements/ insertions, cement fillings, synthetic fillings, former surface treatment, metal insertions, (includes consolidants or protective coatings). It serves as a good reference in monitoring the state of conservation of a heritage structure through periods of time, and as a means of studying the processes, cycles or patterns of change or transformation. Moreover, it aids in preparing conservation plans.

Tests and Analyses

There are standard test methods available for the different test procedures for different stone properties and conservation products. However, more often than not, they yield different results (Henriques,1992).[35] In view of this, standardization of test methods has been developed by different groups such as *RILEM 25 PEM and 59 TPM*, and the *Italian Commissione NORMAL* (Alessandrini and Pasetti 1991).[36] There is a good review of literature which deals with the testing of products and provides an outline of testing methods from the mid-19th century to the present (Tabasso and Simon 2006).[37] It discusses weaknesses in some current methodologies.

Why Undertake Tests

Tests and analyses are performed to a) identify the types of stone and determine their properties, b) identify the deterioration products present and analyze how they were formed, c) determine the conservation problems, their causes, effects and extent of damage, d) test and experiment on compatible materials and products to use (herbicides, consolidants and protectants) and suitable mortar- plaster formulations, e) come up with possible treatment options based on test results and their interpretation, and f) make recommendations for the appropriate conservation intervention –easy to apply, workable and cost effective. It will be helpful to have knowledge of old construction methods and traditional materials.

Table 9: Characterization of Stone (Montoto)

What to identify in Stones

A. ROCK-FORMING COMPONENTS		
PROPERTIES	**ROLE**	**TECHNIQUE**
Texture	**"Rock architecture"**	
Pores/fissures	Paths for: water, pollutants, salts	Fluorescent microscopy, SEM
Grain interlocking	mechanical strength, rock cohesion	Polarizing microscopy, SEM
Anisotropy	Physical properties, direction dependent	NDT (Non Destructive Test)
Mineralogy	**Chemical composition, reactivity**	Polarizing microscopy, SEM + EDAX
B. STONE COMPONENTS		
Stress concentration		AE/MS
Rock foundation		
Building	Mechanical instability	
Masonry (salt crystallization)	Thermal stresses (thermal fatigue)	
Internal fractures	Mechanical instability, water paths	Ultrasonics
Internal zones of weathering	Degree of deterioration	Tomography
Mechanic	To know state stability-instability, fissure development	
Stress-strain curve		
Compressive strength	Mechanical behavior	Destructive tests
Tensile strength	Deformability	
Elastic modulus		
Fissure propagation	To predict failure/ collapse	NDT

Stone Characterization

Studies on the chemical, physical and mechanical characterization of stone deterioration will depend on a) on the rock formations from which they originate (petrology, mineralogy, microscopy, chemistry, colorimetry), b) their actual position within the structure (architecture and engineering – bedding etc.), c) the location on which the structure stands (geology, soil analysis, seismology) and d) the environment which surrounds it (whether polluted, near coasts or quarry sites, etc, and the human activity in the area). Tests and analyses have to be performed on site and in the laboratory. The methods of study must be non-invasive as much as possible.

A table for stone characterization is provided herewith indicating what to identify in stones (Montoto, 2001).[38] It enumerates the different properties of stone, the role of the properties identified and the techniques of analyzing or testing samples. (Table 9: Characterization of Stone Properties)[39]

Interpretation of Results

Results of tests will have to be interpreted and their relevance explained. Otherwise, they will be of no use to a wider audience. For example, if the humidity level inside the room is higher than the humidity outside the building, what will it imply? It means that the source of humidity is from inside and that there might be a leaking pipe somewhere. Another example is the result of a mortar sample taken from a stone wall yielding high iron content. Oxidized Iron is associated with rust and can indicate that the metal reinforcements within the stone wall might be absorbing moisture from some source.

Conservation Problems (Table 10)

The most predominant conservation problem of Spanish colonial structures in a tropical setting is stone decay and the growth of vegetation on the surface. Cracks and fissures are apparent. Salt deposits and stains of varying colors and compositions are also very noticeable.

More particular to adobe is pulverization and dissolution of stone. Upon exposure to rain, the weak binding capacity of adobe makes it lose its integrity and simply crumble away. It is composed of glassy materials and the binding clay. Incidentally, the percentage of clay in Philippine adobe is negligible making it a very weak building material. [40] Structures made of coralline limestone also pulverize but, unlike adobe, develop voids when attacked by acidic rain. The carbonates are released as carbon dioxide and the skeleton remaining is calcium. This phenomenon is described as alveolar erosion.

Causes

Conservation problems of stones and stone built structures can be attributed to intrinsic and extrinsic causes. Intrinsic problems are those originally present in the stone at the time the structure was built, viz: substandard materials, wrong bedding of stone layering, architectural and/ or engineering defects, etc. Extrinsic problems are those caused by external factors, viz: a) weathering, b) biological attacks (microorganisms, insects, rodents and growth of vegetation), c) chemical transformations (pollution, water infiltration, rising damp), d) physical damage (losses, cracks and fissures), e) structural defects (walls- leaning, bulging, settling and fracturing; joints – open, fractured, decaying or powdery; opening of natural vents; expansion of rusting iron, etc), f) human-related activities (vandalism, terrorism, war) and g) natural disasters (fire, earthquakes, typhoons etc).

Effects: Stone Alterations (Fig. 6*)*

Typical stone alterations are: 1) powdering or pulverization, 2) increased porosity (alveolar erosion), 3) dissolution, 4) salt crystallization or efflorescence, 5) black/ brown/ white/ green encrustations, 6) external depositions and droppings, 7) internal depositions (stalactites and stalagmites), 8) scaling, spalling 9) splitting, 10) fissures, cracks and fracture, 11) discoloration, etc. The type of stone and its quality are relevant to the type of problems which develop. Poor quality adobe stones easily dissolve in the rain especially if not protected by a plaster. A good reference for the weathering forms on stone monuments in the form of a photo atlas has been prepared by Fitzer and can be accessed at the internet.[41]

TABLE 10: CONSERVATION PROBLEMS, CAUSES and SOLUTIONS

PROBLEMS		Possible CAUSES	Solutions
General	**Specific**		(treatment options/ repair)
A. Surface Accumulations (positive alterations)	• Dust, dirt, grime • Soiling, accretions • Bird droppings, graffiti, patina • Removable Stains	• Pollution • Lack of maintenance • Vandalism	• Cleaning • Maintenance
B. Biodeterioration	• Cracking, fissures • Bacterial growths • Moss, algae, lichens • Superior Plants • Insects, pests, tunneling	• Weakening of structure due to roots • Humidity, rising damp • Metabolism products of biological agents • Rodent, insects settling	• Cleaning: cut, brush • Water Spraying, etc • Biocides and herbicides • Maintenance
C. Chemical Transformations (negative alterations)	• Pulverization • Alveolar erosion • Increased porosity • Salt crystallization • Encrustations • Chromatic alteration: fading /discoloration • Staining (iron oxide, copper salts)	• Soluble salt re-crystallization/ • Dissolution • Hydration/ de-hydration • Rising damp • Condensation/ evaporation • Release of carbonates • Acid rain, flooding, pollution: particulates	• Desalination • Electro osmosis, siphons • Thermal Insulation • Roof drains, • Add width to roof • Trenches/ canals • Damp course • Consolidation • Protective treatments
D. Physical Alterations	• Cracks and fissures • Splitting, scaling, pitting • Stains, losses • Mechanical abrasion • Salt /frost bursting,	• Vibrations/ movements • Fluctuations in relative humidity & temperature • Thermal expansion • Plasticity due to stress • Wind • Natural disasters	• Plastic repair: • Pointing • Grouting • Plastering • Consolidation • Protection
E. Structure related Damages	WALLS • Leaning • Bulging • Settling • Fracturing JOINTS • Open • Deeply weathered • Very powdery • Decaying around the joints	• Settlement of ground • Removal of ties • Collapse of restraining arches, vaults or buttresses • Inappropriate alteration • Wash out of core filling • Stronger mortar than stones • Poor adhesion between mortar and stones • Unsuitable mortar used in earlier repair	• Take down and rebuild sections • Introduce grout • Introduce underpinning • Introduce ties and stitches • • • Rake out, hand grout, tamp and rake • Rake out and point only • Cut out and re-point • Rake or cut out, plug and point • Use water repellant (rarely)

Fig. 6: STONE CONSERVATION PROBLEMS in a TROPICAL SETTING

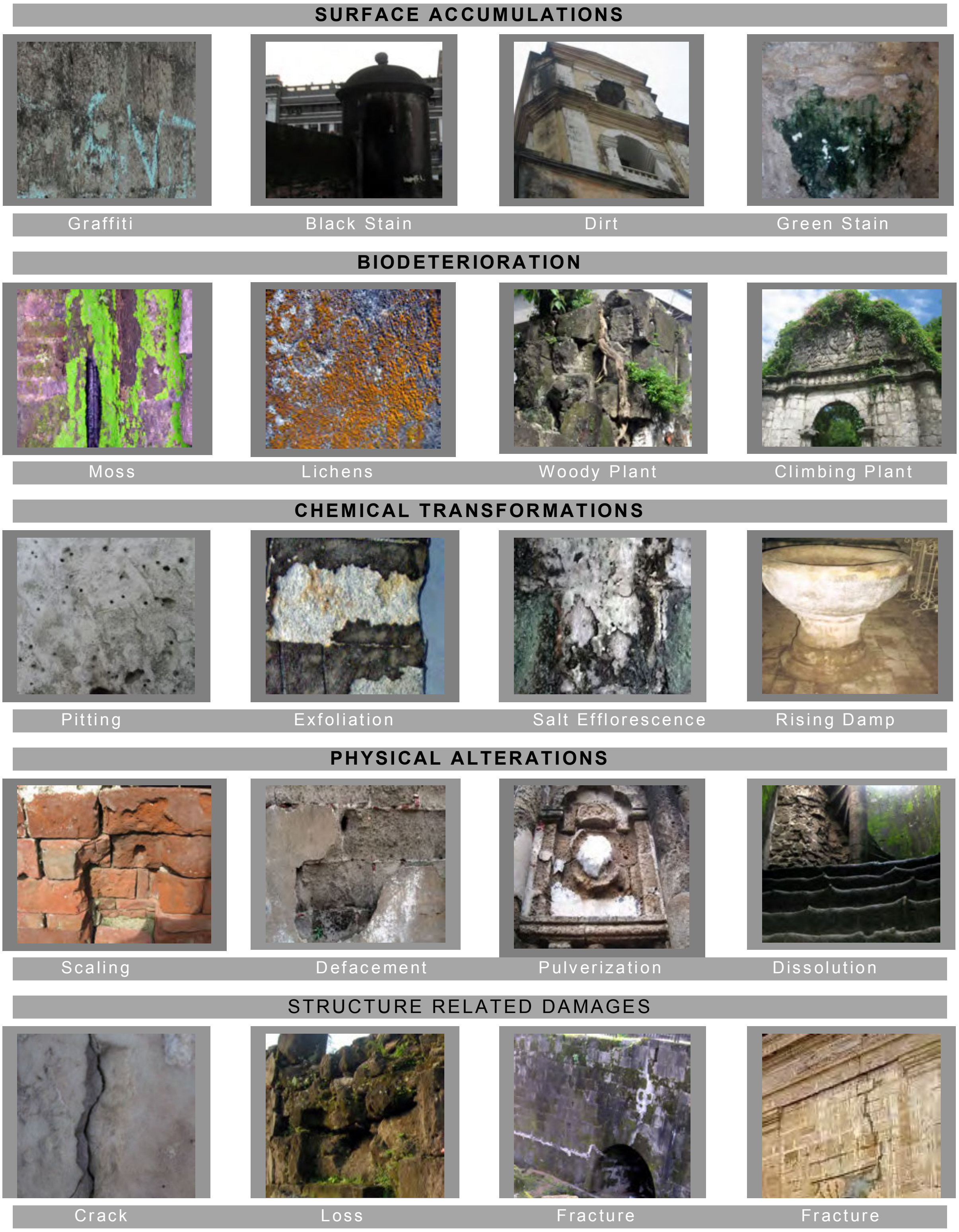
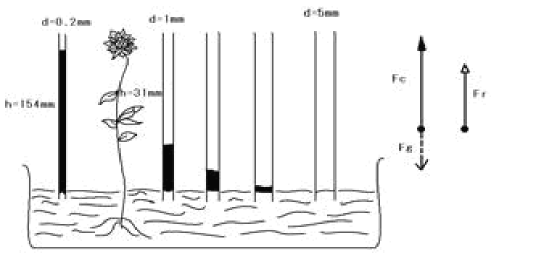


Table 11: THE MOST IMPORTANT SOLUBLE SALTS IN WALLS (Andreas Arnold)

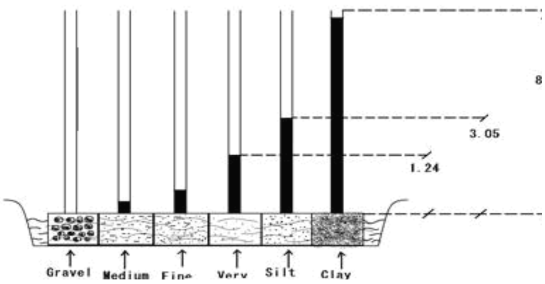
	Carbonates		
Calcite	$CaCO_3$	**Dolomite**	$CaMg(CO_3)_2$
Magnesite	$MgCO_3$	**Nesquehonite**	$MgCO_3 \cdot 3H_2O$
Hydromagnesite	$Mg[OH(CO_3)_2]_2 \cdot 4H_2O$	**Lansfordite**	$MgCO_3 \cdot 5H_2O$
Natrite	$Na_2CO_3 \cdot 10H_2O$	**Thermonatrite**	$Na_2CO_3 \cdot H_2O$
Nahcolite	$NaHCO_3$	**Trona**	$Na_3H(CO_3)_2 \cdot 2H_2O$
Kalicinite	$KHCO_3$		
	Sulphates		
Gypsum	$CaSO_2 \cdot 2H_2O$	**Bassanite**	$CaSO_4 \cdot 1/2\ H_2O$
Epsomite	$MgSO_4 \cdot 7H_2O$	**Hexahydrite**	$MgSO_4 \cdot 6H_2O$
Kieserite	$MgSO_4 \cdot H_2O$	**Darapskite**	$Na_3(SO_4)(NO_3) \cdot H_2O$
Mirabilite	$Na_2SO_4 \cdot 10H_2O$	**Thenardite**	Na_2SO_4
Arcanite	K_2SO_4	**Astrakanite**	$Na_2Mg(SO_4)_2 \cdot 4H_2O$
Picromerite	$K_2Mg(SO_4)_2 \cdot 6H_2O$	**Syngenite**	$K_2Ca(SO_4)_2 \cdot H_2O$
Gorgeyite	$K_2Ca_5(SO_4)_6 \cdot H_2O$	**Glaserite**	$K_3Na(SO_4)_2$
Boussingaultite	$(NH_4)_2Mg(SO_4)_2 \cdot 6H_2O$	**Thaumasite**	$Ca_3Si(OH)_6(CO_3)(SO_4) \cdot 12H2O$
Ettringite	$Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O$		
	Chlorides		
Bischofite	$MgCl_2 \cdot 6H_2O$	**Antarticite**	$CaCl_2 \cdot 6H_2O$
Tachyhydrite	$CaMg_2Cl_6 \cdot 12H_2O$	**Halite**	$NaCl$
Sylvine	KCl		
	Nitrates		
Nitrocalcite	$Ca(NO_3)_2 \cdot 4H_2O$	**Nitromagnesite**	$Mg(NO_3)_2 \cdot 6H_2O$
Nitronatrite	$NaNO_3$	**Nitrokalite**	KNO_3
	Oxalates		
Whewellite	$Ca(C_2O_4) \cdot H_2O$	**Weddellite**	$Ca(C_2O_4) \cdot 2H_2O$

Fig. 7: Capillary Rise vs. Diameter of Pores (Massari)



Smaller the diameter, the higher the rise

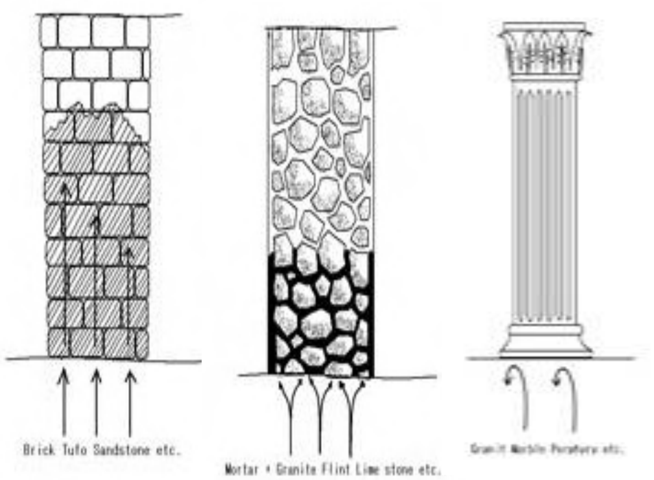
Fig. 8: Capillary Rise vs. Fineness of Particles (Massari)



gravel sand fine sand very fine sand silt clay

The finer the particles, the higher the rise

Fig.9: Capillary Rise vs. the Type of Stones (Massari)



Porous In Between Non Porous

Structure Related Damages: Walls and Joints

Structure related damages refer to stone walls - whether leaning, bulging, settling or fracturing' and to joints - if open and fractured, etc.[42] Unstable walls usually result from settlement of ground, removal of ties, collapse of restraining arches, vaults or buttresses, inappropriate previous repairs, and by washout of core fillings.[43] Open and damaged joints are often caused by the use of mortars stronger than the stone, poor adhesion between mortar and stones, and unsuitable mortar used in earlier repair.

Water and Soluble Salts: Major Causes of Stone Decay

The action of water is considered one of the greatest threats to stonework. It causes de-stabilization of the chemical and physical characteristics of the porous stone. Once water has penetrated the stone and is absorbed, reaction starts to take place. Water transports dissolved salts and produces damaging deterioration. It also disturbs the natural moisture content of the stone. Moreover, it provides a suitable condition for plants to grow and activates pollution. Incidentally, the behavior of water in porous building materials, as presented by Pender - through a chronological literature review --, would be a good reference (2004).[44] It discusses why materials attract moisture in relation to porosity, permeability and capillarity.

Types of Humidity

The types of humidity can be classified according to the system by which it penetrates the stone: a) capillary rise, b) hygroscopicity, c) condensation and d) infiltration of water.[45] *Capillary rise* is a phenomenon where humidity from underground e.g. water table, leaks, sewage, or water supply system, is suctioned upwards by the stone walls. The smaller the diameter of the capillaries (pores), the higher the rise of water within the stone walls – this is balanced by the rate of evaporation from the wall. (Fig. 7)[46] Similarly, the finer the stone components of the walls, the higher the capillary rise. (Figs.8, 9)[47] The usual height it reaches is considered the deterioration site. It is where the water starts to evaporate and where dissolved salts re-crystallize.

Hygroscopicity is the ability to attract water. Even if a wall is not directly connected to the water source from underground, pressure equalization will always attract humidity into a capillary.[48] By the physico-chemical process of adsorption, water molecules will first tend to adhere to the pore surface, then to the liquid film over that surface.[49] Once the surface of the stone pores is moistened by the liquid film, capillarity rise takes effect and moves faster. Also, some salts e.g. sodium chloride (NaCl) are hygroscopic.

Condensation is the transformation of water vapor to liquid state upon cooling. When the humidity in a warm room increases, it tends to condense on the interior wall, if it is cooler outside the wall. Too many visitors of tombs and crypts, for example, can bring about increased humidity through their perspiration, breathing, etc.[50] This is likely to be followed by condensation on the stone surface. It is important to monitor humidity and temperature levels especially when dealing with stone walls with mural paintings.

Soluble Salts (Table 11: Soluble Salts in Building Stones)[51]

The cycle of hydration/ de-hydration, dissolution and re-crystallization of salt involves: 1) moisture infiltration from the ground (rising damp), from rain hitting the roof and walls, from leaking pipes, etc. 2) transport and percolation of moisture within the structure and dissolving salts in the process, and 3) evaporation of the moisture with the dissolved salts towards the surface as the temperature rises and re-crystallizing the salts near and/ or on the stone surface. This cycle is aggravated in an acidic environment by the presence of gaseous pollutants. It is important to note that the removal of salt efflorescence on the surface will not stabilize the condition of stone, but will help the salts being introduced once again into the wall at the next wet cycle. The source of the problem must be identified, that is, the source of humidity, and must be eliminated or minimized.

Types of Soluble Salts

The types of salts present as deterioration products help gauge the extent of the conservation problem. The higher the content of soluble salts in porous stone, the faster the deterioration. Sodium sulfate salts can increase in volume as much as ten times upon re-crystallization. Their affinity to water is quite large compared to that of calcium. The more sodium salts present in the pores of the stone, the faster the tendency of stone to disintegrate. Sodium sulfate and sodium carbonate converts to natrite and mirabilite, -the typical salts which hint advanced state of deterioration. Other salts such as sulfates (e.g.calcium sulfate) and chlorides (e.g. sodium chloride), are also indicators.

Conservation Treatment Options

As mentioned earlier, the conservation of stone built heritage is a complex endeavor. It is a highly specialized field involving the expertise of multi-disciplines. It tackles direct conservation and preventive measures of preserving the structure through documentation, pollution control, maintenance, disaster planning –among others. It also takes into consideration the interests of the different stake holders and the intangible value which the structure represents.

Conservation treatment of actual stones is yet another difficult task. It requires specialized training on applications of theories of conservation and of relevant developments in science and technology. It implies a basic knowledge of the properties of stone, related materials and traditional methods of construction. A scientific examination of the condition of stone is most crucial (diagnosis). Familiarity and experience with the different treatment procedures is imperative.

Five Basic Steps

Stone conservation treatment procedures generally cover five basic steps: 1) cleaning, 2) chemical stabilization of deteriorating stone, 3) physical stabilization of the individual stone and the structure, including mechanical stabilization, 4) aesthetic unity (optional) and, 5) protection of stone from the harsh environment.

Cleaning

Cleaning is the removal of surface accumulations not originally present on the surface of the stone or the plaster. Its aim is to improve the appearance of the building, to reveal the real condition of the underlying stone and to remove harmful materials.[52] It can be carried out mechanically, chemically, by air or water pressure, by poultice or by laser. The latter has gained importance in the recent years. Some dirt and soiling are just superficial. Others are deep rooted. Others have developed through the years to become part of the stone such as natural patina, but this is not dirt. Removing them may be removing part of history. A listing of the different cleaning techniques is provided in table form. (Table 12)[53], [54]

Types of Elements to Clean

The three types of elements to clean are: a) those just sitting on the surface (positive alterations), b) those coming out to the surface (salts), and c) those which form or grow on the surface and penetrate into the stone (plants). Positive alterations are those which do not alter the stone properties, viz: dust, soiling, grime, certain accretions, graffiti and other markings stamped or written on the surface. Negative alterations are those which have negative effects so as to cause a decline in the characteristics of stone e.g., salts developing on the surface. Microorganisms, lower plants and higher vegetation are also negative alterations. They are examples of biodeteriorgens which can be killed with biocides or herbicides. Their presence loosens the stone subsurface. Pulling them out is dangerous because part of the stone will be carried away as well as mortar joints. Cutting them, without following the application of a herbicide, might encourage more growth.

Trial Cleaning

Before any cleaning is undertaken, it is important to undertake trial cleaning on test areas done on wet and dry surface. Assessment of trial areas should include a) potential damage to the stone texture, b) color changes, c) probable appearance of façade after cleaning, and e) an estimate of the periodic re-cleaning operations and the effects on the building.[55]

Biological Cleaning: Plant Removal

Plants grow on damp walls, along mortar joints and where organic matter accumulates. They cause chemical and physical damage to stone. This is due to their metabolism products and the effects of their growth. Their characteristics depend on their life cycle, penetration capacity through the root system, degree of extension and lignification.[56] Their root system can spread throughout the stone and their stems can grow several meters long -making them difficult to handle.[57]

Moss and algae can be removed mechanically by hand brushing and then spraying with a solution of hydrogen peroxide.[58] The roots can stay alive and regenerate as soon as the climatic conditions become favorable. Higher plants can be cut but the remaining parts and roots within the stone structure cannot be removed. Doing so will harm the stone. Herbicides will have to be applied. They can prevent growth and kill the vegetation. The negative effect is that they can endanger the stone and the environment.

Herbicide Administration

Herbicide administration will require survey, lab experiment and determination of the doses to recommend.[59] It must be noted that plants are more resistant to herbicides in the natural environment than in the lab. Further, most of the herbicides are acidic and are not to be used for limestone. Studies have shown that neutralizing acidic herbicides with alkalines will not affect their efficacy.[60]

Choosing a Herbicide

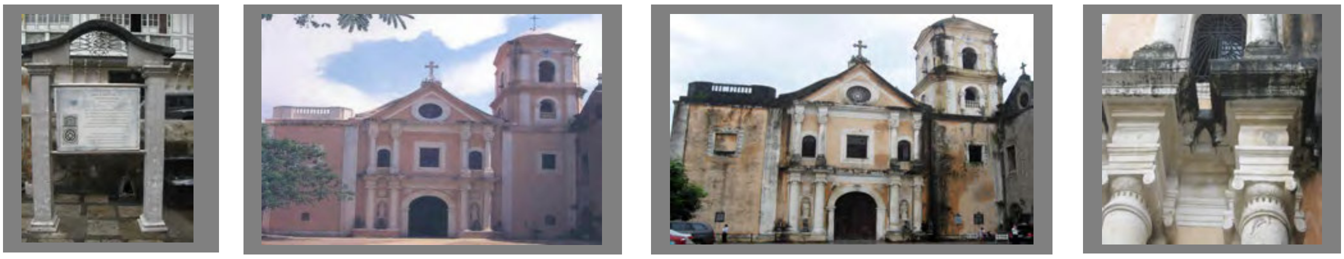
In choosing a herbicide, it is best to look for one with the following characteristics: low toxicity, environment friendly, wide range of action, no interference with the stone, minimum side effects, easy to use, low price and high efficiency.[61] The efficacy will depend on the type of stone, the type of plant, and the method of application.[62]

Application of a biocide or herbicide will depend on the type of plants to remove. Elimination of herbaceous plants can be done by aspiration of the whole plant (Caneva,1991). Woody plants will have to be cut but the rest growing partially within the stone will have to be left as is. Total removal will cause serious damage. Nonetheless, some plants may play a

Fig.10: Man and Stone Deterioration

INDUCED DETERIORATION**:** Some plants can interfere with the foundation of the structure. The root system may reach lengths up to 8 meters; will penetrate the concrete, develop fissures, where water will start to seep in. Effects are detrimental to the structure and commuters. This is dangerous!

CEMENT ON ADOBE: Cement is too strong and compact for weak adobe. It leads to defacement. Damp from the ground, rain, leaking pipes, etc. penetrates the walls, dissolves the salts, which re-crystallize on the surface when water is changed to vapor as temperature increases. Air or vapor pressure from within the walls pushes the cement plaster but cannot “breathe”. Stone is decayed underneath. Even incompatible paint prevents water in the wall, absorbed from the ground, from escaping towards the surface. *Use materials compatible with, never stronger than the original stone.*



FINDING THE SOURCE OF HUMIDITY: Even with routine maintenance, regeneration and re-infestation of microorganisms, moss and algae will be unavoidable in a tropical country -as long as there will be moisture trapped within the walls. It is important to identify the source of the problem such as leaking pipes or defective downspouts before even attempting to clean or repaint.

Table 12: Different Types of Cleaning Methods

CLEANING METHODS		[British Standard (BS 8221-18 2000)]
General	**Specific**	**Remarks**
Hand Cleaning	Brushes Hand held abrasive blocks Plastic mesh and non abrasive hand scourers	To remove softened or loosely attached dry matter For flat surfaces and sound surfaces Use for terra cotta, glass and faience
Water Cleaning	Ordinary water Nebulous water and fine water sprays Pulse Cleaning; Hot water	All potential water entry points should be sealed with sheet tapes
Pressure Operated Cleaning	Water and air pressure Pressure Washing(Low, M, H) Steam Cleaning Abrasive Cleaning (Dry air and Wet air); Micro abrasives	Abrasives: Calcium carbonate, aluminum oxide, sodium bicarbonate, silicon carbide, glass beads, crushed glass
Chemical Cleaning	General (biocides, water repellants) Pre-wetting and rinsing; Pack and Poultice Clay	Must be rinsed, neutralized and rinsed again Sepiolite, paper pulp, methyl cellulose
Mechanical Cleaning	Scalpel Cleaning Tooling	Paint removal; sensitive and labor intensive only for valuable surfaces For heavy dirt encrustations use sharp chisels and mallets
Laser Cleaning		Damages from incorrect use results in mineralogical, color and other surface changes
Biocides		Must be applied to weathered protected surfaces; kill 1st existing growth and re-apply after cleaning. Lichens should be pre wetted; Dead growth should be removed by scraping and brushing

A Comparison of Cleaning Methods				(BRE Digest 111.1972, p 21)
Method	Speed	Cost	Advantages	Disadvantages
Water spray	Slow	Low	No risk of damage to masonry except under frost conditions. No danger to public or operatives. Quiet.	Limestone may develop brown, patchy stains. Water penetration may damage interior finishes, hidden timber and ferrous metals. Some risk of drain blockage. Possible nuisance from spray and saturation of surrounding ground. Often requires supplementing with an abrasive method or high pressure water lance.
Dry grit-blasting	Fast	High	No water to cause staining or internal damage. Can be used in any season.	Risk of damage to surface being cleaned and to adjacent surfaces, including glass. Cannot be used on soft stone. Possible noise and dust nuisance; Risk of drain blocking. Injurious dust from siliceous materials. For best results need to be followed by vigorous water washing.
Steam cleaning	Slow	Medium	No damage to masonry except under frost cond.	As "water spray" but with less risk of staining. Not easy to obtain uniformly clean appearance.
Wet grit-blasting	Fast	High	Less water than with water spray method. Less visible dust than with dry grit-blasting.	Similar to dry grit-blasting but greater risk of drain blockage. Some risk of staining limestone. Can result in mottled finish if operatives are unskilled.
Mechanical cleaning	Fast	High	No water to cause staining/internal damage. Used in any season.	Considerable risk of damage to surface, especially mouldings. Injurious dust from siliceous materials. Hand rubbing may be necessary for acceptable finish.
Hydrofluoric acid preparations	Medium	Low	Will not damage unglazed masonry or painted surface. Quiet.	Needs extreme care in handling - can cause serious skin burns, and instant damage to unprotected glazing and polished surfaces. Scaffold pole ends need to be plugged and boards carefully rinsed.
Caustic alkalis	Fast	Low	Rapid cleaning of some types of limestone with minimum use of water.	Needs extreme care in use; can cause serious skin burns and damage to glazing, aluminum, galvanized surfaces and paint. Incorrect use can cause damage to masonry.

useful role as static reinforcement for the structure.[63] If the stems are sufficiently thick, they will have to be injected with a biocide into the stem instead of the whole plant being aspiratied (Caneva, 1991; Almeida et al).[64]

Plants Dangerous to Stones

The plant species that can cause severe damage to stone are the larger ones, particularly, the ivy, *Hedera helix subp.canariensis.* It grows rapidly while its aerial roots have special searching effects (Ashurst and Ashurst,1988).[65] The ivy also has a root system that can reach lengths up to 8 meters, and which may interfere with the foundations of the structure.[66] Another dangerous species of climbing plants is *Rubis ulmifotius*. It has strong woody roots which may reach up to 2 meters. The *honeysuckle, Lonicera estrusca*, is another plant with roots which can grow up to 8 meters (Cutler and Richardson, 1984).[67] Incidentally, it is sad to notice that similar climbing plants are planted at the concrete posts of the mass transportation system of a certain city. (Fig.10). The detrimental effects are not immediate but will eventually be felt, not only by the structure, but by the commuters.

Regeneration of Plants after Treatment

Different species have different sensitivities to the same herbicide. Some annual plants can take four days to die.[68] Woody plants can take 5 to 20 days and still others can take 30 to 40 days. Others learn to adapt to very dry condition because they have a special type of metabolism that allows them to conserve water, making them resistant to treatment.[69] Even after an effective treatment has been applied, newly germinated plants are likely to appear again as seedlings of the same species. This recurs as soon as the climate becomes favorable ~ usually 8 months after treatment. [70] The cycle of regeneration and re-infestation of plants even after treatment is unavoidable in a tropical setting. It is best to have long term planning for weed control to avoid wastage of money, time and effort.

Chemical Stabilization

Chemical stabilization is the attempt to prevent or stop chemical reactions resulting in the modification of the composition of stone. It is important to identify the cause/s of reactions and determine ways to control them. Incidentally, chemical transformations also weaken the physical stability of stone.

As discussed earlier, the action of water and the presence of soluble salts are apparently the major causes of the decline in the chemical properties of porous stones in the tropics. They are aggravated by the presence of gaseous pollutants, secretions of biodeteriogens, the effects of biocides and herbicides, vegetation, and the cycle of wetting and drying. Water can come from underground and seep through the stone capillaries as rising damp. It can come from the rain and infiltrate the roof and outer walls specifically through cracks and open joints. It can come from leaking pipes and downspouts and circulate within the walls through the stone pores. It can also come from human perspiration and other sources of humidity buildup inside a room.

Practical Techniques to Minimize the Action of Water on Stones

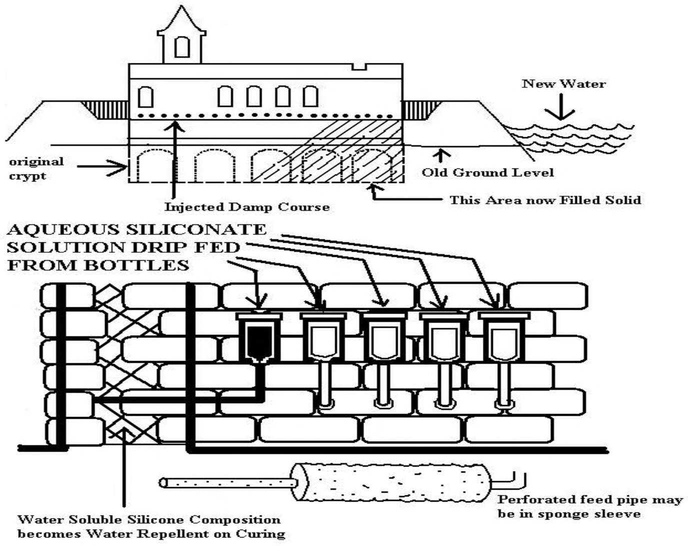
Rising damp can be prevented by installing a damp course or by building trenches or ventilated areas around the exterior walls. Water coming from the roof or leaking pipes and downspouts can be prevented by adding width to roof, apart from regularly checking the roof drains and downspouts for leaks, etc.

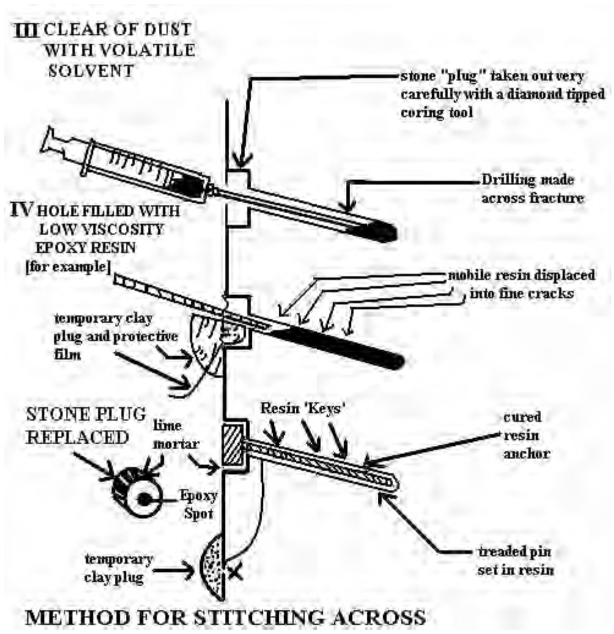
Stone structures contaminated by soluble salts can be made to undergo desalination. Simple cleaning of the surface is not sufficient to eliminate these harmful compounds. They must be removed especially if the stone is to be subsequently consolidated and/or rendered with a protective coating. Desalination can be done by applying poultice on the surface. It usually consists of clay, wood or paper pulp, a combination of these two, or lime-poor mortar.[71] For this to be successful, however, it is important that the source of soluble salts is eliminated or at least reduced.

Physical Stabilization

Physical and mechanical stabilization is the action taken to correct alterations affecting the physical properties of stone. It is to compensate for loss in physical strength due to the presence of fissures and cracks, weakening (pulverization) and loss of material, the effects of vegetation, vibrations and

Fig. 11: **Ashurst's TECHNIQUES of PLASTIC REPAIR** (John Ashurst)





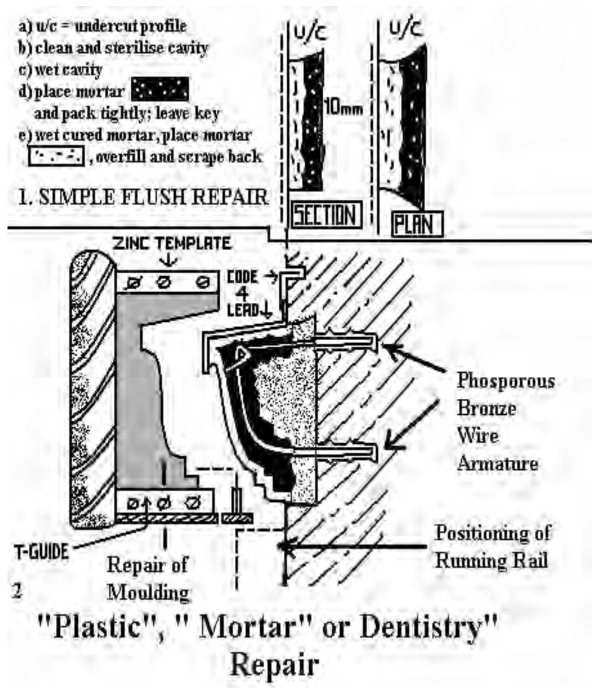
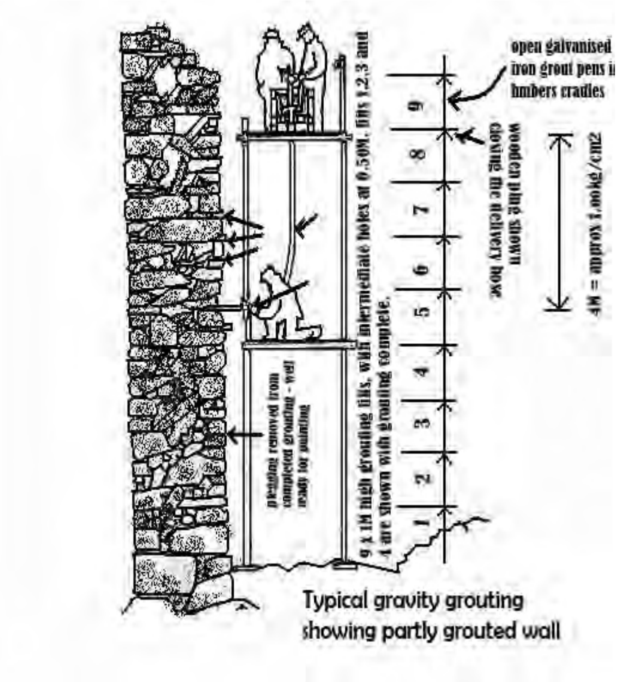
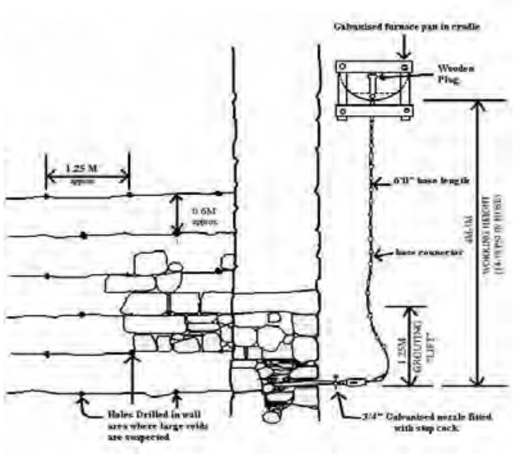
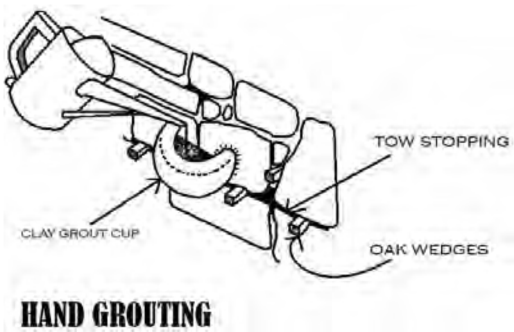
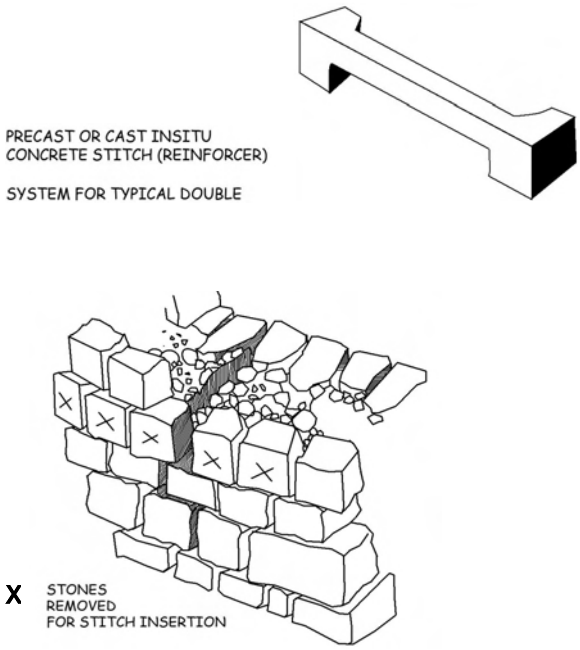


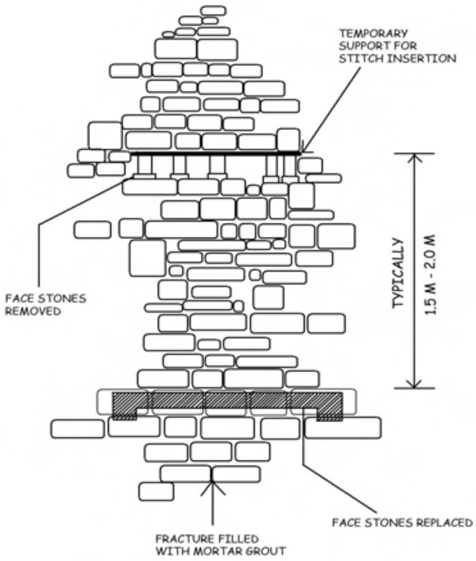
Fig. 12: Ashurst 's TECHNIQUES of GROUTING and STITCHING (John Ashurst)











movements, etc. More than the damage to individual stones, structure related damages such as the fracture on walls, opening of joints etc. are to be given priority.

If the chemist conservator specializes on the study of chemical reactions affecting the stones, the architect restorer specializes on ways to correct structural damages affecting the stones. They are to collaborate in the following: 1) consolidation of loose, pulverizing and incoherent components, 2) filling (plastic repair) of cracks and fissures, 3) replacement of severely damaged load bearing stones, and 4) adding similar materials to gaps, missing portions and losses. The choice of treatment is critical and no single treatment is applicable in all cases. Caution must be taken in considering the use of materials foreign to stone. Prior to these treatments, the architect and engineers must first address the problems pertaining to damaged walls and joints, and problems with foundations.

Loss Compensation Methods

Stone replacement, addition and filling (plastic repair) are loss compensation methods. They are similar to treatment procedures in dentistry. A severely damaged tooth can be extracted and replaced with similar tooth. Wide gaps between teeth can also be added with the same. If the cavities are reparable, filling can be the alternative. Replacements and fillers have to match the original stone in terms of properties. Artificial stones can also be considered. Aesthetic unity is optional because some prefer to distinguish additions from the original.[72]

Choice of Loss Compensation Methods

Loss compensation methods must meet the following criteria: a) reversible, b) must, as much as possible, not require removal of original materials for its application (sometimes this is unavoidable), c) use inert materials, d) must not introduce soluble salts, highly alkaline or acidic materials, or mechanical stress to the substrate, e) have lesser strength than the original stone, f) meet health and safety standards such as building safety codes, g) cost effective, h) meet aesthetic requirements and i) have desirable working properties.

Consolidation

Consolidation is carried out by applying a product that can penetrate the stone to unite the incoherent with the coherent material. The technique of application can be by brushing on the stone surface, by spray, pipette, or by immersion, and drawn into stone by capillary.[73] Consolidation is not just to fill in the hollows. Its aim is to restore the internal cohesion of eroded or weakened stone to enable it to resist weathering anew. Consolidants must have sufficient penetrating capacity (fluidity) to enter deeply within the stone in order to reach and "bind" together the disintegrating material. The depth of penetration will depend, not only on the fluidity of the consolidant, but also on the porosity of the stone and the mode of application. If the penetration is not sufficient, there will be a tendency to form a dividing plane along which alteration can proceed preferentially. Diluting a product may initially exhibit excellent penetration but evaporation of the solvent towards the surface tends to form only a thin superficial consolidated layer. It is important to check that the product does not react in any way with the stone or alter its appearance in color and in texture. It must, in theory, be reversible although in reality it is quite impossible to attain such quality. Once a product has penetrated the stone, even if it comes with a solvent, it cannot be removed without damaging the stone. This is where retreatability becomes important.

Types of Consolidants

Consolidants can be divided into two groups: inorganic and organic. Inorganic consolidants were used extensively during the 19th century.[74] The side effects are whitening within the voids and pores caused by precipitation of salt or by chemical reaction with stone.[75] This technique produces a new phase which binds the deteriorated particles of stone together, e.g. silica phase to consolidate sandstone; calcium and barium carbonates to consolidate calcareous stones.[76] Nowadays there has been a revival of inorganic treatments: the Lime Method, barium hydroxide and oxalates.

Organic consolidants on the other hand, were first developed in the 1960's. But these do not seem to be feasible for use in a tropical setting. There are reports that some stone structures in temperate countries consolidated with organic polymers failed after several years.[77] Water gradually eroded the consolidated surface, and proceeded into the untreated stone.[78] There are also "mixed" consolidants – the silanes which have had some success, especially on sandstones.

Before attempting to use anything synthetic on an important historical structure, it will be good to consider other options. Even a careful study or experimentation of the product in situ or in a laboratory cannot assure that the product will work.[79] Mistakes can be costly as chemicals are expensive and the stone may be irreversibly damaged. A list of consolidants is provided in a separate table. (Table 13)[80]

Filling (Plastic Repair): Pointing and Grouting

Plastic repair is a system for local damages in which a filler is introduced into stone to compensate for loss in strength and material. It prevents accumulation of harmful elements into the voids in stone. It uses a pliable material which hardens in place while adhering itself to stone and filling the voids. (Fig. 11)[81]

Plastic fillings are composed of a binder and filler (matrix or aggregates) plus color components and special additives. They are used where cracks, fissures or hollows are present. It is a requirement to do plastic repair before attempting any consolidation treatment. Besides the common mortar or grout (liquid mortar), epoxy resins can be used as they possess great adhesive properties. However, they are very susceptible to oxidation, and therefore should only be used to fill in deep cracks or hollows. A more stable resin such as acrylic resins can be subsequently applied to provide protection. These two resins can also be used in conjunction with an aggregate to produce a type of mortar with good adhesive and elastic properties.

Pure cement fillers must be avoided as these can contain alkaline compounds and sulfates capable of forming soluble salts within the stone. Besides, cement is generally less porous and "stronger" than porous building stones, creating new problems due to the incompatibility of the two materials.

Problems with Compact and Non porous Fills

Outdoor fills must possess properties similar to those of the original stone. This is to allow equivalent exchange of water across the stone compensation interface (area with fill) and to react with the environment in a compatible manner.[82] If the interface is harder than the original stone, the stone will be eroded. Water and soluble salts can accumulate around said fill leading to damage. Further damage can result from fluctuations in temperature and relative humidity. The reason is that two different materials react differently to climate changes leading to mechanical stress and strain on the stone.

The "Sacrificial" Fill

Since it is difficult to achieve an exact match to the original stone, the fill should be somewhat more porous, more permeable, and slightly weaker than the stone. It becomes the "sacrificial" fill attracting moisture and salts and thus causing erosion of the fill instead of the original stone.[83] As regards stones with large protruding loss, replacement or "piecing in" must be considered because they will be difficult to fill.

Replacements and Additions

Replacement is a system of compensation in which a piece of stone is fitted to the area of loss in the original stone.[84] It is made of a newly carved stone or some similar modeled material.[85] Its use is justified when damage to stone affects its load bearing function. Retrofitting is an operation using innovative and tested techniques specifically developed for adobe structures and designed to observe minimal intervention.[86]

Replacement can be "in kind"- made of exactly the same stone; "near kind" -similar stone; or an "imitation.[87] Sometimes, a perfect match can be salvaged from an inconspicuous part of the building. Supporting rods or polymeric composites are used to dowel pieces together. (Fig. 12)[88] They are attached to the original stone, previously planed for the break edges. Typical adhesives are epoxy, polyester or mortar, and clamped so the joint may set. The problem with epoxy and polyester resins is that they weather poorly and darken upon oxidation due to light.[89] Inserts or replacements must be finished using the same profile and texture as the original stone. Patching can be

Table 13: CONSOLIDANTS and PROTECTANTS (Cassar)

INORGANIC CONSOLIDANTS		
Alkali metal silicates	Na_2SiO_3 K_2SiO_3	• React with water and CO_2 • Form silica gel that functions as the consolidant • Also form salts to the surface producing efflorescence
Fluosilicates	$MgSiF_6$ $ZnSiF_6$ $Al_2(SiF_6)_3$ $PbSiF_6$	• Only on stones with $CaCO_3$ because of the by-product silicate oxide in water which acts as the consolidant • Reaction directly happens between the stone and the reagent which should be avoided
Barium Hydroxide	$Ba(OH)_2$	• Used in conjunction with urea to form $BaCO_3$ • Restores cohesion, strengthens, consolidates the stone • Developed for the treatment of small objects
ORGANIC CONSOLIDANTS		
Silanes	Alkyl, alkoxy silanes	• Diluted with alcoholic solvents which favors their extremely small dimensions and thus easily penetrates materials • React with atmospheric humidity polymerize w/in the material to form large molecules
Silicic Esters	Alkyl alkoxy silanes	• Silane which reacts with atmospheric humidity, forms silica gel as binder • Have advantage of forming an alcoholic residue which does not react with the material and can evaporate
Siloxanes	Polymers of organic Si compounds	• Partially polymerized before being applied • Larger molecules hence less volatile than silanes but also less penetrative • Used primarily as protectives
Epoxy Resins		• Used as structural adhesives, less commonly as consolidants • Poor penetration, irreversible and difficult to clean • Cause inc. in fragility and yellowing of the material in the presence of UV
Acrylic Resins		• thermoplastic forming weak electrostatic bonds between the single chains • Unable to absorb pressure so they are generally used as protectives • Possess a high molecular weight so penetration is difficult

ORGANIC PROTECTANTS		
Siliconates	Methyl siliconates of sodium, Potassium, propyl siliconates of potassium.	• Water-soluble • Present certain problems, such as their slow rate of polymerization (at least 24 hours) making it possible to be removed by rain water during this period • Limited durability of the treatment and the poor strength especially for the methyl siliconates.
Silicone resins	CH_3, C_2H_5, C_3H_7, C_4H_9	• Completely polymerized molecules; do not form any new links after being applied. • Dissolved in an organic solvent such as white spirit • Transported by means of the solvent into the superficial pores and capillaries of the material. • On evaporation of the solvent, the resin is deposited within the surface layer where it exerts a hydrophobic effect.
Perfluoropolyethers	Permeable to gas, colorless, transparent, stable to heat, light and chemicals	• Possess all the qualities necessary to act as stone protectants • Insoluble in common organic solvents, but soluble in fluorocarbons, making the treatment durable but also reversible
Waxes		• Used to provide surface protection to non-porous calcareous stones • Tend however to make the stone appear darker and give the surface a slightly shiny appearance
Acrylic resins		• Tend to provide good water repellancy, especially when used in conjunction with silicon resins.

done using a cementious grout. Incidentally, painted wood was once used to reconstruct or fill large losses when stone replacement was uneconomical.[90]

Guide for a Good Replacement

The replacement must integrate harmoniously with the whole but must be distinguishable from the original so that restoration does not falsify the artistic and historic evidence.[91] Additions are to be undertaken only if they do not detract from interesting parts of the building, its traditional setting, balance of its composition and its relationship with its surroundings.[92]

Aesthetic Unity

Aesthetic unity is the optional part of treatment. It is basically cosmetic improvement. It is an attempt to improve the appearance of the stone surface after conservation and restoration. In the absence of aesthetic balance manifested by chromatic alteration, formation of patina, fading color, change in texture, etc, efforts can be made so that alterations may not be unsightly. Replacements and additions, although distinguished from the original, must unite harmoniously with the built structure. Even in adaptive re-use of a historic building, aesthetic unity must be considered.

Protection of Stones

Surface protection can be achieved by way of surface coatings or plasters. It is an important phase - specifically for stone buildings which have been cleaned and/or consolidated. Protectants are considered “sacrificial layers” too because they, instead of the underlying stone, are the ones attacked by the harsh environment, at least for a reasonable period of time.

Paintwork can be considered as protective of the material they cover; but they must be compatible with the stone. They must be hydrophobic but permeable to gas (water vapor). When air bubbles form on a painted surface, it indicates that moisture is trapped beneath and the air (water vapor) produced inside is trying to escape. (Fig. 12) This is the reason why the paint starts to peel off.

Some stone buildings require protective coatings to carry out its function without being visible. In this respect, a number of clear organic products have been produced. These include waxes, siliconates, silicone resins, acrylic resins, perfluoropolyethers, siloxanes and polyurethanes (the latter usually as anti-graffiti coatings). A list of these products is provided herewith in table form (Table 13).[93]

Organic Protective Coatings

Even in a temperate environment, protective treatments with synthetic products (organic) do not always protect the stone and may actually accelerate the deterioration process.[94] In an article, Varas reported that the Royal Palace in Madrid (completed in 1734), made of granite and limestone, was applied with a protective coating sometime in the 1970’s. [95] It was cleaned in 2002 using water-jet pressure but only to reveal more stains and deterioration of the stones.[96]

Protective coatings have the tendency to modify their composition over time due to decaying process underneath and possible reactions with additives in cleaning interventions.[97] They prevent entry of rainwater and atmospheric pollutants into the wall but also prevent water from escaping. Some allow the passage of water in the vapor phase. Protectants may work well in the beginning but the entry of water through mortar joints or leakage from pipes and downspouts trap water inside the barrier. As already stated, this condition favors the formation of salts which grow in size by a repeated process of crystallization-dissolution, hydration-dehydration due to wetting and drying. [98] Water with dissolved salts tends to emerge through fissures and joints. This leads to flaking, breakdown of the protective coating, and the formation of salt efflorescence on the surface and sub-surface. When the coatings have disappeared, percolating water tends to accumulate and produce stains on the stones. Brown stains can be the result of oxidation of iron anchorages used in the original structure.

Caution should therefore be made before attempting to use anything synthetic on an important historical structure. Science cannot duplicate the “natural” tropical environment nor solve the stone problems totally. Even a careful study or experimentation of the product in situ or in a laboratory cannot assure that the product will work.[99]

Inorganic Protective Layers

There are three general classifications of inorganic system: lime-based plasters, natural cement and modern cement coatings. They are still chosen over organic polymers mainly because of their strength, stability, durability, and availability.[100] The disadvantages of cement mixes include excessive hardness; introduction of soluble salts, poor permeability by salts and moisture, shrinkage, introduction of large amounts of moisture to the stone during use; and a generally cool, opaque appearance.[101]

Traditional Techniques of Plastering

Nothing can be more natural than applying the original technique in protecting a historical stone structure – the use of pure lime plaster (*palitada*) with egg white as binder and crushed corals and other carbonaceous materials as fillers.[102] It was used in the olden times because cement was not yet invented and lime was abundant. But to use eggs now would be impractical. It is a very tedious job just to separate the white from the yolk alone. Moreover, it is expensive in terms of manpower and the material cost. The high shrinkage of egg white is another subject for study. The use of eggs also leads to microbiological attack.

To use a plaster (lime only) or mortar (lime/sand) compatible with and not stronger than the original stone is an option to take. It is workable in a tropical environment and in a setting where budget for conservation is nil. Torraca suggests that adding a little Portland cement to act as binder to lime/ sand mortar can be effective.[103] Otherwise, strong rainfall and wind would easily remove pure lime plaster. The reasons given are presented in table form. (see Table 7) The proportion suggested is 1:4:3 where 1 is cement, 4 is lime and 3 is sand or crushed stones. This is just a guiding formula which can be tested in situ and the components adjusted accordingly. River sand has to be washed well. Portland cement -low in alkalines and sulfates must be used. White cement is preferable. Hydraulic lime can also be used; or lime with pozzolanic additives, instead of cement. Regular maintenance is important.

To Plaster or Not to Plaster

In stone conservation, to plaster or not to plaster is not a matter of choice -in a tropical setting at least. To expose the bare stone – originally plastered- is contrary to the principles of conservation. The plaster, as stated earlier, serves as sacrificial layer to be exposed to weathering, in lieu, of the stone beneath. However, there are cultural workers who prefer to de-plaster the surface of interior and exterior walls, specifically of churches, for "aesthetic reasons". Apparently, the underlying bricks would reveal a better appearance of the red colored stones than the white lime plaster.

Because of this situation –where original stones are exposed, this writer experimented on inorganic paints at the San Agustin Conservation laboratory in Intramuros, Manila. The objective was to come up with a thin protective film simulating/ resembling the exposed stones -in texture and color. This is to comply with the aesthetic considerations which brought about the decision to remove the plaster. One experiment was intended for coralline limestone; the other for adobe, and another for bricks. Lime was added with a little cement, mixed with crushed coralline stones (or adobe or bricks) in different proportions. It was pigmented with colored marble dust or colored chalk to get the matching color in the dry form. Methyl cellulose paste was mixed to the desired consistency. Water was added in varying quantities to each mixture to achieve the desired consistency as a paint mixture. Each mixture was tested on several parts of the de-plastered stone wall using a paint brush for application. They were left for several weeks exposed to typhoons and the heat of the sun. As of this date, the results are still promising.

Conservation Intervention: A Practical Approach

To date, numerous requests for technical assistance on stone conservation are continuously being received by this writer. They are usually from custodians of stone built church heritage in the Philippines. Other queries are from local architects and contractors. The main problem is the lack of conservation specialist available. Second is limited funding.

Third is non allotment of budget for a stone specialist. The immediate concern is how to get started with the conservation and restoration project.

To respond to this situation, this writer has developed a summary of the different steps applicable in a tropical setting. It is a result of her replies, candid but practical, of queries perennially posed to her. Admittedly, it is not the ideal formula but it can serve as practical guide to those with little or no background in this field.

As mentioned earlier, colonial stone structures are all exhibiting decay and growth of vegetation. This is due to water ingression into stone. The hot humid climate and abundant rainfall accompanied by flooding -throughout the year- is the hazard. The proposed practical intervention could not be discussed any better than by first citing a typical request letter with the answer (Fig. 13), and second, by putting in table form the step by step procedure as a guide (Table 14).

Summary, Conclusion and Recommendation

The conservation of Spanish colonial structures in a tropical setting is an enormous and complex task. If it were a stone object in a museum or an outdoor stone sculpture, it would have been a simpler job.

Spanish colonial would connote ~150-year old stones to treat. Ageing of stone is a natural process, but in a hot humid climate, it is not the case. It is described as “accelerated ageing” which is actually *deterioration*. In a country like the Philippine archiepelago, situated in an earthquake belt, the phenomenon is even worse. It is called “accelerated deterioration”.

The common building stones used in Spanish colonial structures are coralline limestone and adobe (volcanic tuff). Both are porous sedimentary stones. They can be infiltrated by water (rain), can retain water, and can absorb water (from ground). Coralline limestones are calcareous stones formed from sediments of corals. They are highly reactive to acids - releasing carbon dioxide upon contact. The adobe or volcanic tuffs are siliceous stones made of clay. They are easily washed away by strong rain. Unlike red brick clays, they are naturally quarried.

Other materials related to stone are lime, gypsum and Portland cement. They are used as plasters or mortars. Lime plaster can be mixed with a little cement or pozzolanic additives to improve its binding capacity. Otherwise, it would easily be washed out by strong rain. On the other hand, cement is too strong and compact for the porous stones. It can be diluted with lime, sand and pozzolanic materials. Low sulfate and low sodium cements are recommended for use when mixed with lime.

The main cause of stone problems in a tropical setting is the action of water followed by the formation of salts. Water will always find its way into the stone –from the ground, from the walls, from the roofs and from leaks into its internal structure. Water will percolate within walls and dissolve soluble salts. The salts will increase in size upon re-crystallization near the surface. Re-crystallization occurs during evaporation as temperature increases. Evaporation (breathing of stone) can be impeded by cement plaster or an impermeable synthetic coating on the surface. In this situation, the stones cannot “breathe”. As a consequence, dissolved salts re-crystallize inside the walls instead of on the surface. Either way, stone is deteriorated. This cycle is repeated as long as there is the action of water occurring and the presence of soluble salts.

Some surface coatings claim to allow stones to “breathe”, being permeable to gas (water vapor) but impermeable to water (liquid). However, when there is too much water or humidity within the stone walls and/or when salts are present, their efficacy fails. Humidity or dampness in the stone walls can be traced in areas where microorganisms and plants grow profusely. When vegetation cannot be controlled, cracks start to develop. This is “natural” condition of stone structures in a tropical country. The stones always act as humid substrates conducive for microorganisms and plants to grow. To remove them with herbicides is costly and if not correctly chosen, these can damage the stones. Plants will always regenerate and re-infest as soon as the condition is favorable.

Fig. 13: Typical Request letter Regarding Conservation of Spanish Colonial Stone Churches

Dear **Ms. Reyes**,

Please find the **Proposed Adobe Stone Work Restoration** submitted by Architect *Somebody* as part of the restoration project for our cathedral.

Please help us in evaluating the said proposal.

We will appreciate it very much if you could submit to us your written evaluation as soon as possible.

God bless you!

Monsignor
Rector of the Cathedral

Dear **Monsignor**,

I believe first and foremost, we need to have a **copy of the original plans** of your cathedral. Please request this from the Diocesan Archives (architectural, electrical, mechanical, etc.) and previous restoration plans and report if any.

We need to **identify all sources of dampness** as they cause adobe to deteriorate;

- Said plans will help locate gutters, duct works, drain, downspouts, even common conduits and non-used conduits (air con ducts, refrigeration piping, HVAC drains might be passing walls causing seepage;
- Leaks, roof defects, cracks, etc must also be identified.

Adobe stones, plasters, mouldings, etc with visible signs of deterioration will need to be identified and the **surface area of damage quantified for costing** purposes.

We need to do sampling on identified area of damage for **laboratory analysis**;

- I need to interpret the lab results to assess extent of deterioration and make recommendations;
- We also need to have lab analysis of adobe replacements to check if compatible with the original;
- I suspect cement plaster was used only on certain wall areas. I need to do sampling beneath these areas.

To cut on cost of mouldings which would need restoration, we could request restorers to **take photos** and submit quotation based on their **inspection** and volume of work involved.

We must not forget the **effects of rising damp from the ground**. We need to re-direct humidity rising to adobe stones. There are options in this regard which I could discuss more in detail.

Finally, I heard that adobe stones of your cathedral could still be procured from the original quarry site in the nearby province of *somewhere*. Please check this out.

Hope this helps.

Maita Reyes
Chemist Conservator

Table 14: STONE CONSERVATION: A PRACTICAL APPROACH

Step-by-Step Procedure	Description	Remarks
A. Research	1) Building type; year of establishment; architect; engineer 2) Location; vicinity map -near the river, seas etc.; 3) Orientation 4) Geology and topography; quarries in the vicinity; fault zone, etc. 5) Climate type	• This is necessary before going to the site • Bureau of Mines for the Local mineral deposits • PAG-ASA for the climate parameter
B. Site Inspection	1) Photo documentation 2) Sampling 3) In-situ preliminary analyses (T, %RH, magnifier, compass, tool kit) 4) Listing of a. all structural defects b. all visible stone alterations 5) Listing of all other building materials used 6) Environmental survey 7) Interview with local residents	• Photo documentation: façade, the interior details, the different types of stones, different types of deterioration, vegetation, the surroundings, distribution of cracks, • Samples of stone, mortar, plaster, cladding, soil • In-situ test: T %RH, UV, Compass, muriatic acid • Structural defects: • Stone alterations: • Other building materials used: glass, iron, steel, copper, aluminum, narra, mahogany, molave, vigan tiles, *piedra china*, PVC, Resins • Environmental survey :traffic, trains, machinery, industrial plant (vibrations) Rivers, lakes, or seas Quarries and mine sites Interview re: Flooding, local available materials
C. Lab Test and Analyses	1) Chemical and mineralogical type/s of stone (sound and deteriorated stone) 2) Biological agents (photo identification) 3) Soil analysis 4) Air analysis 5) Seismic/ vibration graphs	• Bureau of Mines: microscopic, porosity, tensile, compressive strength • Nat'l Museum: Botany and Zoology • Bureau of Soils • DOH; DOLE; Occupational Health and Safety
D. Experimentation	1) Cement/ lime/ filler formulations: 2) Herbicides and micro biocides	• Portland and Pozzolan; Marble Dust Fillers; Washed sand; Unwashed sands Consider Shrinkage Color Matching • Check effect of herbicide on the stone; culture • Survey: suppliers available
E. In-situ Trials and Testing	1) Cement/ lime/ filler formulations: 2) Herbicides and micro biocides	• Portland and Pozzolan; Marble dust fillers; • Washed sand; unwashed sands Test Shrinkage Color Matching • Test with samples from Suppliers
F. Interpretation of	1) Consult a Restoration Architect	• Results are useless if their significance could not

Results/	2) Consult a Stone Conservation Scientist	be determined • Ex.1: High iron content in mortar, the conservation scientist would consider the presence of reinforced concrete underlying. • Ex.2: The presence of gypsum taken from a limestone facade; the lab analyst would just say it is present, to the conservation scientist, it could indicate that air pollutants could be the source of sulfates which crystallize on the facade, The black color could be due to trapped carbon particulates from exhaust of cars.
G. Conclusions	1) Identification of materials, deterioration products, thriving biological agents 2) Causes and extent of deterioration 3) Compatible materials and appropriate chemical	• This shall be based on lab test results, experiment, research, or interview and/ or site inspection, environmental survey corroborated by lab tests and experimentation
H. Recommendations	1) Repair options 2) Stone treatment 3) Alternative methods and materials 4) Schedule of work	Based on: • Research • Site observations • Interview with local residents • Results of lab tests • Experiments and in site trials
I. Costs Estimates/ Options	1) Preparations 2) Materials 3) Labor	
J. Preparations	1) Paper Works: documentation, contracts, permits 2) Site : clearing, coordination with local in charge 3) Materials: canvass, purchase, fabricate a. Construction paraphernalia b. Tools and supplies c. Chemicals, cleaning agents, consolidants d. Binders and fillers 4) Prepare the building: a) preliminary cleaning- grime, dust dirt b) removal of previous repairs	
K. Structural Repairs	1) Walls 2) Joints	
L. Treatment of Stone	1) Cleaning 2) Chemical Stability 3) Physical/ Mechanical Stability 4) Aesthetic Unity 5) Protection	

The best way to deal with the problem of humidity is by identifying its source/s and preventing them from entering the stone. Roof drains, downspouts can be checked for leaks. Damp courses can be installed. Trenches can be built around the walls so that rising damp may be retarded. Water repellants can be applied on the stone surface to minimize the effects of water infiltration. But the choice of products to use is crucial. They may inhibit water from entering but may prevent humidity within the walls from getting out. The usual products available are synthetic materials like acrylic resins. They are organic chemical products which are foreign to inorganic stone. Consolidants and protective coatings have similar properties. They are not only expensive but are risky to use. Their effects are damaging and irreversible. Practically synthetic resins eventually cause conservation problems.[104]

In view of the aforementioned, it is advisable to use inorganic materials like lime and natural cement in a tropical environment. They have proven to be safe, easy to apply, and cost effective. Understanding the rationale behind traditional techniques and imitating the precision and patience of the artisans is advantageous. Modern technology which promises "easy to use -better performance" techniques and products will have to be carefully weighed before being even considered for use. Theoretical principles and practical achievements will have some gap somewhere.

Many conservation methods applied in the past, no matter how well researched and studied, seem to fail even in a temperate zone.[105] It could not be any worse in a tropical setting. It is safer and cheaper to adhere to more classical methods and materials. Nonetheless, no conservation treatment can be started without understanding the nature of stone and related materials plus their environment, without assessing the condition of individual stones and the stone built structure, and without knowing and having experience in the different treatment options.

There are many other concerns in stone conservation which make it complex, viz: the interest of all stakeholders, limitations set by legislation, financial constraints, varying opinions as to which elements are important - the historical, cultural, religious values, contradicting views on functionality and preservation of the building, disagreements on techniques and products, the failure to come up with a continuous maintenance effort after treatment, etc.

In addressing all these, the ideal approach to stone conservation and restoration of the built structure is to bring together allied professionals to study, analyze and come up with the most applicable conservation schemes. But this is not the reality. Budget is always limited, especially for the planning and diagnostic aspects.

Because of this reality, this writer has learned to see in and through the eyes of the different allied professionals viz: historian, architect, engineer, geologist, chemist, biologist, mason, etc. The diversity of topics covered in this paper attests to this. The stone conservator is left with no choice but to develop a practical approach to address the situation, no matter how complicated it may seem. Based on research, lecture notes from her expert Professors and from experience, the writer is able to prepare a practical conservation guide. It is a summary of the step-by-step procedure on how to approach conservation intervention. It is intended for cultural workers with little background on the field, that is, for those involved in historic structures in a tropical setting.

Through the years, the stone conservator learns to feel with the stones and see what lies beneath them, the story behind each and every historic structure. They are a part of our culture. They are deteriorating. They will be conserved and restored. This is the objective of this paper.

oOo

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Uses of Lime in Historic Buildings: Construction and Conservation

Lime-sand mortars as used in the context of Philippine construction during the Spanish Period

By Michael Manalo

Lime-based building materials were inarguably the most indispensable for construction during the Spanish colonial period in the Philippines. It's varied uses ranged from the structural to the protective and decorative. In this study, we use "mortar" ("*mortero*") as it appears in archival construction documents from 19th century Philippines. It's equivalent in the Mexican architectural lexicon would be "*mezcla*" or "mixture".

"Mortar," we now define as "a plastic mix of lime or cement, or a combination of both, with sand and water, used as a binder in masonry."[1] Being such, it is a material which can be trowelled and hardens in place. Speaking from a strictly 19th century Philippine (or "Spanish colonial") point of view, we should not confuse "mortar" with its application, in the English language, in bedding and jointing. "Mortar" during this period was simply a lime-sand mix, much like another Spanish construction term, "*argamasa*" which is used in making "*lechadas*" or ("*hormigones*") which are used to fill in wall cavities, as well as mortar joints and plastering, this latter otherwise known in Philippine parlance as "*palitada*."

Mortars are composed mainly of two basic materials mixed with water:

Lime

> "The lime to be used for the mixtures in this project should be of the ordinary type from this province and it should be perfectly slaked and without any other substance mixed with it."[2]

The lime is obtained from either limestone or from seashells. In the case of limestone (which may either be from an inland source or from the coast –

[1] CHING, Francis D.K., op. cit., p. 19.

[2] PNA, *Proyecto de la Casa Administración de los Ylocos en Vigan: Pliego de condiciones facultativas*, Vigan, Filipinas, 1873. "La cal empleada en la confección de mezclas de esta obra será de la ordinaria de la provincia debiendo estar perfectamente calcinada y apagada sin tener cantos ni caliches ni sustancia estraña alguna."

coral stones) it should have a calcium carbonate ($CaCO_3$) content of 95% or more, and, in burning the lime, the temperature should be 900 degrees centigrade to be able to produce calcium oxide.

The stones are broken into small pieces, in the case of the Philippines, roughly 5 cm. from side to side at the most, before it can be burnt. This cooking would be done in two manners: the traditional Philippine manner and the western manner. The first one uses an open fire which is composed of layers of wood, hay, dry bamboo and cow dung. The fire was allowed to burn for roughly 18 hours. The second is the technique introduced by the Spanish in which ovens ("*hornos*") are already employed to make cooking more effective.

After the cooking, the stones are moistened to produce a powder called "quicklime", although the normal procedure for many building projects was to place the burnt lime in chambers or vats where it disintegrated into powder as it lay in water. In many Spanish documents and treatises on architecture and construction, a popular phrase appears "*entre mas podrida esta major,*" meaning the more time the lime spent under water, the better it's qualities for construction became. The reason for keeping the lime in water was to keep it from hardening when exposed to the air. This is then the lime that is mixed with sand to make the mortar.

The next figure illustrates the cycle of lime, where it begins in the form of stone and ends in the exact same chemical composition as the stone in the beginning.

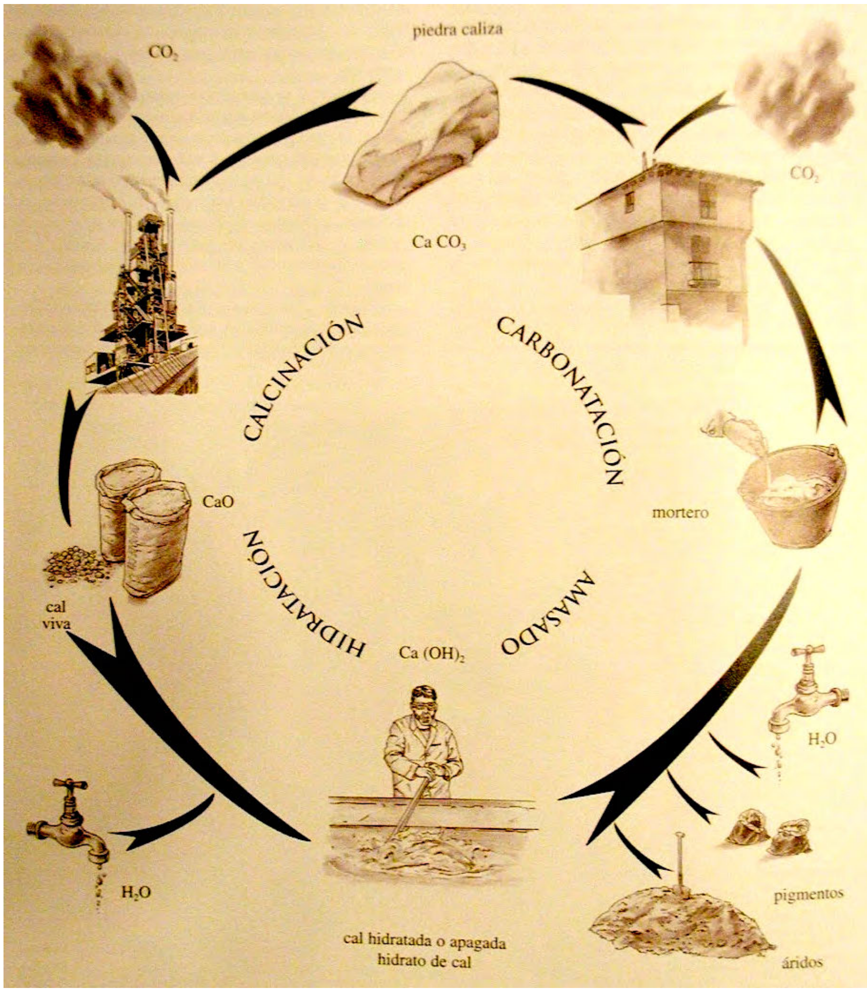

fig. 145 *ciclo de la cal; fuente: Editorial de los oficios: Guia práctica de la cal y el estuco*

Sand

> "The sand should come from the river, siliceous and homogeneous. It should be cleaned of mud and other alien substances and for this it should be cleaned as necessary."[3]

Sand is an important part of the mix and should be, as is logical, sourced from the locality, but never near the sea, as it is most probable that this would have a high salt content and will ultimately ruin the whole construction as salt will travel through the material and crystallize near the surface, breaking the physical composition of the material. Sand is crucial, given that, in many cases,

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[3] *Ibidem. "La arena será del río de grano siliceo regular y homogéneo, debiendo estar limpia de arcilla y sustancias estrañas por lo cual se lavará si fuese necesario*

it composes 50% of the mixture. The size of the granules used differed, depending on how the mixture was to be used, and much like modern construction, the coarse sand was used for rough civil works while fine sand was used to make the mix for plastering.

In Philippine colonial construction in the 19th century, it was the norm to use two types of mortars:

- Ordinary mortar: composed of one part lime and two parts sand which was mixed in wooden boards, as water was added until mix was deemed fit for use.
- Hydraulic mortar: composed of one part sand, four-tenths lime and three tenths fine brick powder. It was mixed in the same manner as ordinary mortar.

These basic mixtures were then used in building construction such as making the "*hormigon*" which is comprised of "50 parts mortar and 85 parts siliceous rock chipped to five centimeter-wide pieces." It follows that ordinary mortar was used for the ordinary "*hormigon*" while hydraulic mortar was used for the hydraulic type, such as those used in making the *azoteas* or flat roofs.

Lime-sand mortar is a material of great flexibility, as can be seen in the great variety of buildings constructed using this material as a binder or protective/decorative coating. One such example of this characteristic of lime-sand mortars is its use in brick buildings, as exemplified by the colonial houses of the heritage city of Vigan in northern Philippines. It can be observed that the rows of bricks are placed on a thick bedding of mortar, which, in many of the houses, has the same thickness as the bricks themselves. In an area with high seismic activity, the elasticity that this system of construction gives to the structure has insured is survival in a 200-year period. In fact, many of the earthquakes from the past thirty years have left little scars on these buildings, despite its weighty appearance and its age.

This shows the effectiveness of these mortar joints as they act as a cushion that absorbs the pressure exerted by the movement of the brick and tiles during an earthquake – something that a rigid binding material cannot achieve.

"Palitada"

What is locally referred to as "*palitada*" can be loosely translated into English as "plaster" or "render", and in Spanish as "*revoque*" (Spain) and "*aplanado*" (Mexico). The word itself originated from the Spanish "*paleta*", or "trowel" in English, one of the main tools used in plastering. This is used as a covering for walls, primarily to protect the building materials that are not very resistant to exposure to weather and the elements, using a lime-sand mixture. Secondly, it is used to even out the imperfections on the wall surface, which can then be finished with the necessary detailing.

Traditionally, plastered walls had a three-coat process: the "*retundido*", the "*revoque*" (thick layer) and the "*enlucido*" (fine layer for finishing). The *retundido* is also referred to as the *enfoscado* which is used to cover up uneven areas of the wall construction. More often than not, it is also the base for the *revoque*. In turn, many of the *Pliegos de Condiciones Facultativas* found in the Philippine National archives show that many times the *revoque* and *enlucido* are treated almost synonymously. The *enlucido* then becomes merely a coat of paint, although in construction manuals, this layer does have a thickness that should not go beyond 3 mm.

In total, all three layers of *palitada* will have a maximum thickness of between two and three centimeters and will be using ordinary mortar.

It has always been said that plastering or *palitada* is a necessity in the construction of colonial buildings, and among the many reasons for its application, three would best sum up its importance:

- Protection of building materials which offer low resistance to being exposed to the elements.
- Given that lime-sand *palitada* in itself a porous material, it does not make the surface completely impermeable, allowing for the easy evaporation of humidity contained within the wall.
- The decorative character of *palitada* gives it a clean and appealing appearance.

Moreover, the *palitada* is a "sacrificial layer" applied onto the surface of a building as it absorbs the impact of much of the problems which occur in this area of the structure, though if well made, lime-sand plastering can last hundreds of years, as evidenced by many constructions from antiquity which still conserve its plastering intact up to the colors. Though its more practical purpose maintains its importance as the first line of defense of the building materials that it conceals from problems caused by humidity and physical abrasion.

Design, historic coloration, and the *palitada*

In a more aesthetic sense, the *palitada* is also called by the Mexican architectural historian Juan Benito Artigas as the "Skin of Architecture" ("*piel de la arquitectura*") and emphasizes on its qualities as a canvas on which the decoration of a building is laid out – all that will characterize the prevailing tastes of the period. After all, the *palitada* is a form of finishing, and as this construction term suggests, without such treatments, a building is rendered incomplete – unfinished.

One very obvious application of the latter statement can be seen in the many brick buildings constructed in the Philippines wherein the plastering is used for final detailing. The simplest application of this detailing could be appreciated in the work on cornices, as bricks are laid out in a manner that brick courses jut out one over the other to give the necessary form and backing. The mortar is then trowelled onto the surface and subsequently a cutout form made of wood would then be used to scrape the excess mortar and give the cornice its final form.

Should the brick or stonework had carvings, which were then accentuated by the blank areas in a contrasting color formed by the *palitada*. There are also some exceptional cases wherein the *palitada* was used to create decoration in relief. This is much akin to the practice of *yesseria* in Spain and Latin America in which gesso is moulded and given its final form. In the Philippines, though, the sculpture in low relief is executed in the same lime-sand mix as the rest of the wall using a moulded stucco technique.

Also in the realm of interiors, it was also a common practice to have *palitad,* which is finished with a coat of decorative painting, which was common practice in structures built of brick or stone from the ground all the way to the trusses. It was unthinkable to have an unfinished wall, which is why interiors were, in many cases, lavishly decorated with paint and plaster. This was done in two ways: the first with the two to three-coat render, and the other by directly painting onto the surface of the building material of the wall, or, in some cases, the ceiling, this latter simply having the last coat – the *enlucido*.

Conclusion

Palitada is a word that is commonplace in today's construction parlance in the Philippines, and to this day it has exactly the same meaning as it had since the period of Spanish domination of the islands. What has changed, though, are the materials: as technology progressed, Filipino craftsmen embraced building solutions that would speed up the work – which is somewhat of a worldwide phenomenon. Even the renowned Filipino sculptor Isabelo Tampinco declared that when they shifted to making pre-cast concrete mouldings and ornaments, they effectively killed the painstaking art of carving on the round.

What is needed in the conservation of historic structures from the Spanish colonial period is a deep knowledge of construction methods and materials used during that era. Lime was an indispensable component of colonial structures before the advent and mass-usage of Portland cement. As the properties of lime have been hailed by many treatises for construction and architecture due to its versatility as a building material, in the modern age, these have sadly been overlooked, even in the conservation of historic structures, where the use of pure Portland cement is prevalent due to its easy handling.

It is hoped that through the dissemination of knowledge on the uses of lime in historic buildings, more professionals working in the conservation field will have a better understanding of how vital this material is not only in its construction, but also in safeguarding its preservation for generations to come.

Mampostería Architecture in the Northern Mariana Islands: A Preliminary Overview

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Introduction

Spanish stonework architecture of the *mampostería* type was introduced in the Mariana Islands following the establishment of a Jesuit mission on Guam in 1668. Although initially limited to important buildings and structures of the Spanish colonial administration, by the latter decades of the nineteenth century, *mampostería* had been adopted by indigenous Chamorros as a preferred construction method particularly for their residences.

Most *mampostería* architecture was constructed on Guam which served as the seat of the Spanish colonial administration from 1668 to 1898. Smaller numbers and types of *mampostería* buildings and structures were built in the Northern Mariana Islands of Rota, Tinian and Saipan which then were sparsely-populated outliers of the main Guam colony.[1] This article focuses on examples of *mampostería* architecture in Northern Mariana Islands since in comparison to similar architectural sites on Guam they have received little previous attention.[2]

An Overview of *Mampostería* Construction Techniques and Types

The *mampostería* (masonry) construction technique involved stacking stones (in the case of the Marianas, coralline limestone) to form thick walls which were held together by a mortar made from a mixture of slaked lime, sand and water.[3] Internal and external surfaces were plastered with a lime mortar and then whitewashed. In rare cases, normally restricted to important colonial architecture, exterior surfaces of walls were faced with flat cut stone.

Roofs of *mampostería* buildings were formed of timber superstructures which were covered by thatch or terracotta roofing tiles. By the late nineteenth century, roofs were also covered with galvanized iron or zinc sheets. Spanish authorities oversaw the construction of a variety of *mampostería* buildings and structures including forts, troop barracks, churches, schools, administrative buildings, residences, bell towers, bridges and ovens (Table 1). Many of these were built utilizing Chamorro labor.

Late in the Spanish administration, well-to-do Chamorro families also were constructing residences of *mampostería*. They first erected a timber frame, normally of the very durable *ifet* tree.[4] The support columns were then surrounded by an approximately 80 centimeter-thick *mampostería* wall built to a height ranging from one to two meters.

The ground floor of a typical *mampostería* residence was referred to as the *bodega* and was used as a storage area. This level possessed a floor of compacted soil or *ifet* planks. Outside access to the *bodega* was by a ground level opening sometimes equipped with a timber door. The *bodega* could also be accessed from the second floor by a wooden stairway.

The walls of the second floor, while sometimes constructed of *mampostería*, were more typically made of wooden laths plastered over with clay or mortar. This second floor served as the main living area. Its floor was constructed of joists and planking of *ifet*. The main living area was normally accessed by a stone stairway, in some cases quite massive. Windows typically had no glass but were closed by sliding wooden shutters (Safford 1905:26).

Chamorro *mampostería* residences in the Northern Mariana Islands were almost exclusively roofed with thatch[5] although by the early German period a few of the larger homes had roofs covered with imported ceramic tiles or sheet metal (Fritz 2001:24-25). Larger residences might also have a roofed porch. To the rear of the main residence was a separate cook house connected by the *batalan*[6], a raised walkway sometimes of compacted earth paved with stone but more commonly in Chamorro residences built of timber posts and planks (Safford 1902:26; Fritz 2001:24).

While Spanish officials on Guam employed professional stone masons from time to time, *mampostería* construction in the outlying Northern Mariana Islands typically was overseen by a few local craftsmen who possessed the basic skills necessary to complete the work.[7] Labor for house construction was normally provided by members of the extended family who were fed during the course of construction.

While a modest wood and thatch residence might only involve a few days of labor, *mampostería* construction required considerably time to complete. As a result, these residences were restricted to well-to-do families who could afford to feed workers for an extended period, to acquire the needed materials, and to pay for the services of a local mason. Public *mampostería* buildings, including churches, were built with community labor overseen by a priest or village mayor.

Mampostería buildings were desirable primarily because they stood up much better to the strong winds generated by frequent tropical storms than did those of wood and thatch. This advantage was offset by poor interior lighting and ventilation resulting from the small windows that were typical of *mampostería* construction (Marche 1982:23). These buildings also served as symbols of status and wealth in both the Spanish and Chamorro communities.[8]

Table 1.
Mampostería *Building and Structure Types, by Island*

Type	Guam	Saipan	Tinian	Rota
Religious				
Church	xxx	xxx	xxx	xxx
Convento	xxx	xxx		xxx
Bell Tower	xxx			
Devotional Chapel	xxx			xxx
Secular				
Palace		xxx		
Casa Real	xxx		xxx	xxx
School	xxx			
Hospital	xxx			
Jail	xxx			
Private Residence	xxx	xxx		xxx
Bridge	xxx			
Oven	xxx	xxx		xxx

Examples of *Mampostería* Architecture in the Northern Mariana Islands

Methodology

The following summary of *mampostería* architecture in the Northern Mariana Islands, specifically on Saipan, Tinian and Rota was gleaned from a review of readily available English-language sources. Particularly useful were the several volumes of Spanish government reports translated and annotated by Marjorie Driver and Omaira Brunal-Perry and the historical volumes published by the CNMI Division of Historic Preservation (HPO). The site files of the HPO were also consulted along with its photographic database.[9] A systematic examination of Spanish primary source documents, which was beyond the scope of this project, undoubtedly will reveal considerably more information on specific buildings and structures that once existed in the Northern Mariana Islands. This paper is limited to a preliminary overview of these architectural resources.

Saipan

Saipan's indigenous population violently resisted the efforts of the Jesuit mission and no permanent Spanish presence could be established until the island was subjugated by Spanish forces in 1695 (Russell 1998:311). At this time, Saipan's Chamorro residents were forced to abandon their traditional villages and hamlets and resettle into two mission villages situated along the western coast of the island – Fatiguan and Anaguam (Hezel:2000:25). These villages, each of which had a wood and thatch church, remained occupied until circa 1730 when their residents were moved to Guam (Hezel 2000:25).

Following the closure of the mission villages, Saipan remained unoccupied until the early decades of the nineteenth century at which time immigrants from the central Carolines were granted permission to establish a village at a place the Carolinians called Arabwal.[10] By the late 1850s, a few Chamorro families began settling on Saipan in a *barrio* adjacent to the Carolinian village. This settlement came to be called San Isidro de Garapan. In 1889, Carolinians from Tinian moved to Tanapag, roughly five kilometers north of Garapan, thus establishing the island's second settlement (Driver and Brunal-Perry 1998:96).

According to Governor Olive, in the late 1880s San Isidro de Garapan had three *barrios*, two occupied by Carolinians and one by Chamorro immigrants from Guam known as *radicados*.[11] The village had 145 houses, all of wood and thatch. Government buildings included a wood and thatch *casa real*[12] and a *tribunal*.[13] In between the Chamorro and Carolinian *barrios* was a Catholic church which was a *camarín* structure roofed with coconut leaves.[14] This was apparently built to replace an older *mampostería* church, built sometime in early 1860s, that had fallen into disrepair. Also present was the *convento* that served as the priest's residence.[15] The priest's residence was said to have been constructed from materials salvaged from a beached sailing ship (Olive 1984:42).

Little is known about Tanapag Village at the time of its initial establishment, but it likely comprised of one or two streets lined with wood and thatch residences of Carolinian design and a simple *camarín* style church. It was connected to the main settlement of Garapan by an unpaved footpath.

By the early 1890s, however, an influx of Chamorro settlers necessitated the construction of more substantial buildings, including *mampostería* churches in Garapan and Tanapag villages. Prosperous Chamorro families also built a few *mampostería* residences in Garapan. Tanapag, which was a Carolinian settlement, had no stone architecture with the exception of the church.

Documented examples of *mampostería* construction on Saipan include:

Virgen de Carmen Church (first building). Sometime after 1865, a church of *mampostería* was constructed in Garapan and dedicated to the Virgen de Carmen. This church was heavily damaged by a typhoon that struck Saipan in September 1868. A post typhoon report noted that "the stone walls of the church [had] collapsed, leaving the front and back walls of sacristy cracked, though still standing" (Driver and Brunal-Perry 1998:37). It was rebuilt by *don* Jose Paras Cruz the following year (Driver and Burnal-Perry 1998:39). Twenty years later, Olive observed that although this church was masonry, it was "poorly constructed and crumbling: the townspeople, however, have volunteered to repair it" (Olive 1984:42).

Virgen de Carmen Church (second building). A *mampostería* church "of average size and roofed with galvanized iron" was completed in Garapan on May 14, 1893 under the direction of Father Tomas Cueva, the parish priest (Driver 2000:19). The new church, also dedicated to the Virgen del Carmen, replaced a *camarín* style building constructed of wood and thatch. The new church was damaged by an earthquake in 1902 and subsequently renovated by the German administration. Renovation work included replacing the building's wooden roof supports with iron columns. It remained in use until 1944 when it was requisitioned by the Japanese military and used as a storage structure in the months before the battle for Saipan (Russell 1984:86). It was heavily damaged by artillery fire in June 1944 and its ruins bulldozed to make way for American military construction the following month.

Convento. A modest *mampostería* residence was constructed immediately north of the Virgen de Carmen Church. It appears in a photograph taken in 1902 (see Spennemann 2007:279). The building has a porch and a tile roof. It served as the priest's residence and was undoubtedly renovated over the years. Its date of construction is unknown.

Virgen de los Remedios Church. In 1894, a *mampostería* church was constructed in Tanapag Village under the direction of Father Cornelio García del Carmen. It was " a beautiful church, roofed in galvanized iron, dedicated to Nuestra Señora la Virgen de los Remedios, the patroness of the *pueblo*" (Driver 2000:21). The church was built by the residents of Tanapag with assistance from parishioners from Garapan, This church was utilized until its destruction in World War II.

Ada Residence. This impressive *mampostería* residence was constructed in Garapan Village in the 1890s by influential Chamorro businessman Pedro Ada. It had an ornate entrance featuring carved wood elements and was roofed in sheet metal. This residence was destroyed during the World War II battle for Saipan.

Diaz Residence. This was a two-story *mampostería* residence situated in Garapan Village owned by a well-to-do Chamorro named Vicente Diaz. It served as the residence of Governor Blanco during his short residence on Saipan in 1899. The flag raising ceremony marking the acquisition of the Northern Marianas by Germany on November 17, 1899 was held outside of this residence. Georg Fritz, the German District Officer who administered the German Marianas from 1899 to 1907, resided in this house for several months after his initial arrival on the island. It also served as the temporary seat of the administration until the completion of the permanent building next to the church (Spennemann 2007:155). This building was presumably destroyed during the World War II battle for Saipan.

Blanco Residence. This was a two-story *mampostería* residence situated in Garapan Village owned by the Blanco family. It was destroyed during the World War II battle for Saipan.

Miscellaneous Residences. There were a number of smaller *mampostería* residences constructed in Garapan Village during the late Spanish and early German period. These are known from photographs.

Ovens. Spoehr reports that Spanish style masonry ovens were introduced on Saipan during the Spanish period (Spoehr 2000:34). These were dome-shaped ovens, called *hotno*[16] by the Chamorros, were used to bake bread and breadfruit (see Safford 1902:35). They were undoubtedly associated with some of the *mampostería* residences in Garapan, although the author is aware of no photographic documentation from the Northern Mariana Islands. It is likely that all *hotno* were lost with the destruction of Garapan Village during World War II.

Tinian

Like their neighbors on Saipan, the people of Tinian were openly hostile to mission efforts. It wasn't until 1695 that Spanish forces finally succeeded in suppressing Chamorro resistance on Tinian. Soon after, its indigenous residents were resettled into mission villages in southern Guam (Hezel 2000:10-11). With the exception of periodic hunting expeditions from Guam, Tinian remained unoccupied until the 1860s when the island was leased to George Johnson, an American businessman who brought in several hundred Carolinian agricultural workers to produce copra. A village was established along the southwestern shore of the island. It was christened San Luis de Medina, after the Jesuit priest who was killed on Saipan in 1670. It possessed a single street with 30 cane and thatch residences for the 235 Carolinians who resided there (Olive 1984:37). In 1889, the village was abandoned when its residents moved *en mass* to Saipan where they settled at Tanapag. Tinian would remain unoccupied for the remainder of the Spanish period.

Documented *mampostería* buildings on Tinian include:

Masonry Chapel. A small masonry chapel was constructed by Johnston for use by the Carolinian agricultural workers (Calvo 1877: n.p.). In the 1880s, Olive described this church as being small and "constructed from the remains of one of the monuments, called *de los antigos* that used to stand on that spot." The wall of this chapel appears in several of the photographs taken by the Belgin naturalist Antoine-Alfred Marche during his visit to the island in 1888 (Marche 1982:33-35). This chapel was abandoned following the transfer of the residents of Medina Village to Saipan in 1889. It was likely destroyed by the Japanese to make way for modern development in Tinian Town in the 1930s.

Casa Real. Olive provided a description of the *casa real* that was present in Medina Village in the 1880s: “At its head [the village’s sole street] is the *casa real* constructed of masonry and also thatched with coconut fronds. This house is little better than the one on Rota” (Olive 1984:38). It was probably occupied by the sole Chamorro resident of the village who served as the *teniente* or deputy magistrate. No photographs of this building are known to exist.

Rota

Rota differs from Saipan and Tinian in the fact that it maintained a continuous Chamorro population for the entire span of Spanish occupation. Never openly hostile to the Jesuit missionaries, Rota’s relatively small population was brought under effective Spanish control by the early 1680s. Soon after, the island’s residents were forced to abandon traditional villages and hamlets and resettled into a mission village at Sosa (Russell 2002:33). This settlement subsequently came to be called “Songsong” after the Chamorro word for village. Olive provided a description of Songsong as it appeared in the late 1880s: All the inhabitants live in a village located on the isthmus and bearing the name of the island. It has eighty-nine houses, some of masonry, others of cane and thatch, situated on the four streets running parallel to both beaches and along two cross streets” (Olive 1984:36). Olive also noted that the village possessed a masonry church and *casa real*.

Documented examples of *mampostería* construction on Rota include:

San Francisco de Borja Catholic Church (first building). The first masonry church on Rota is believed to date to the mid-1700s. It was “of hewn stone, although of little architectural beauty ...” (Driver 2000:16). It was demolished in 1891 to make way for a new, larger church.

San Francisco de Borja Catholic Church (second building). This spacious church was constructed in 1891 by community labor under the direction of the parish priest Crisogono Ortin del Corazon de Jesus (Driver 2000:16). As was the case with its predecessor, the new church was dedicated to San Francisco de Borja. It was of *mampostería* construction with a thatch roof. It undoubtedly was repaired from time to time over the years. As some point, possibly during the early German administration, the church's thatch roof was replaced by galvanized iron. This church was utilized by the Rota community until approximately 1936 when the Japanese administration moved Chamorros out of Songsong and resettled them at a new village at Tatatchog. The church was then utilized by the Japanese as a social hall. It was destroyed by American bombing attacks in World War II.

Convento. A new parish house was constructed between 1889 and 1890 by Father Ortin (Driver 2000:16). It was said to have been built of "strong materials and roofed with thatch" (Driver 2000:16). It was situated just to the east of the church. Unspecified improvements to this building were made by Father Mariano Alegre de la Viren del Perpetuo Socorro who served as the priest on Rota from 1894 to 1899 (Driver 2000:16). This building was damaged during World War II but was repaired and used until the 1990s. It is extant but unoccupied.

Casa Real. This *mampostería* building was said to have been constructed in the early Spanish mission period (circa 1669-1690). It possessed a *bodega* and had solid *mampostería* walls. It was roofed in thatch. Access to the second floor was by a stone stairway. Governor Olive, writing in the 1880s, had the following to say about this building: "The *casa real*, pompously called *palacio*, where the *alcalde* lives, is small and shabby, built of masonry and thatched with coconut fronds (1984:36). At the time of the German occupation in 1899, this building was known as "*El Palacio Antiguo*" or "the ancient palace" (Spennemann 2008:105). Ruins of this building are extant.

Miscellaneous private residences. Olive noted the presence of masonry houses in Songsong in the 1880s. These residences were not described in detail but from photographs taken at the beginning of the 20th century, they were modest buildings roofed with thatch.

German Administrative Building. District Officer Georg Fritz ordered the construction of a masonry building in Songsong to serve as the seat of the seat of German colonial administration in Rota. It consisted of a *mampostería* foundation and wooden plank walls. It was roofed with galvanized iron sheets. Additional information about this building is undoubtedly contained in German colonial records. It is known from the photographic record (see Spennemann 2007:27).

Catholic Devotional Shrine. A small Catholic devotional shrine, located on the road to the Sabana, was built during the German administration (circa 1911) by a German Capuchin priest. It is the sole example of *mampostería* architecture constructed on Rota outside of Songsong Village. Modern renovations have included covering its external and internal walls with a Portland cement plaster. It is extant.

Summary

As this overview documents, *mampostería* architecture was constructed on Saipan, Tinian and Rota. Functional types included churches, convents, *casa real*, residences and ovens. Unlike Guam, however, no fortifications, bell towers, schools, hospitals or bridges were constructed in these outlying islands. Areas of occurrence are limited, with the exception of the devotional shrine on Rota, to the mission villages of Songsong, San Luis de Medina, San Isidro de Garapan and Tanapag.

No *mampostería* architecture on Saipan and Tinian predates the 1860s which is in keeping with the islands' settlement histories. Only Rota, the sole island north of Guam to be occupied continuously during the entire span of Spanish colonization, had *mampostería* architecture built prior to the nineteenth century. These included a church and a *casa real*, both likely dating to the eighteenth century.

Fierce fighting during World War II and the subsequent construction of extensive military facilities by U.S. forces in 1944-45 destroyed all *mampostería* buildings and structures on the islands of Saipan and Tinian. Rota, which was spared the total destruction of an invasion, possesses the only extant examples of *mampostería* architecture in the Northern Mariana Islands. These include a *casa real*, possibly built in the eighteenth century, a well-preserved convent built in 1891, and a small devotional shrine built circa 1911.

Although initially introduced by the Spanish, *mampostería* was eventually adopted by Chamorros as a preferred construction technique. Buildings and structures of *mampostería* continued to be constructed on Saipan, Tinian and Rota during the German administration (1899 to 1914) and many of these durable buildings were in use until they were destroyed during World War II.

Spanish building forms, although not constructed of traditional *mampostería* materials, would continue into the post-World War II era, at least on Saipan. Here, the island's main church, Mt. Carmel, built in Susupe in 1949, resembled earlier Spanish *mampostería* design with its long, rectangular shape and massive façade. Also continuing earlier Spanish architectural forms were a few *bodega* style concrete houses built by prominent families near the new church, and concrete and brick *hotno* to replace those ovens destroyed by the war. These forms, which continued into the 1950s, have since been replaced by more modern architectural designs.

The few extant examples of *mampostería* architecture are irreplaceable links to the islands' long association with Spain. In 1999, the CNMI signed the Valladolid Declaration with the Kingdom of Spain which called for the preservation of Spanish architecture in the Northern Mariana Islands. The author hopes that this preliminary overview will serve to encourage more detailed studies to better document this significant but very fragile class of historic resource.

Notes

1. No *mampostería* buildings or structures have been documented on Aguiguan (Goat Island) or the small, volcanic islands to the north of Saipan.

2. This paper summarizes a presentation I gave at the International Conference on Stonework Heritage in Micronesia held on Guam November 14-15, 2007 sponsored by the Spanish Program for Cultural Cooperation, the Guam Preservation Trust and the Historic Resources Division, Department of Parks and Recreation. I would like to thank conference organizers for inviting me to participate.

3. According to one observer "[t]he source of both the stone and the mortar used for building is chiefly coral rock. Coral fresh from the reef is not used, as it contains salt, with a tendency to remain soft and sticky. Coral hummocks for building are taken from the reef and allowed to weather for a long time, and the best of lime is burnt from coral rock and limestone of the ancient reefs composing the greater portion of the island" (Safford 1905:126).

4. *Ifit* (also *ifel*) (*Intsia bijuga*), is famous for its exceeding hardness and durability, qualities making it a valued building material.

5. Although swamp grass (*karisso*) was widely used on Guam, thatch for roofing on Saipan, Tinian and Rota was almost exclusively of coconut fronds.

6. *Batalan* is a Philippine term relating to residential architecture that, depending on the language, refers to a porch, veranda, kitchen or washroom. It likely was adopted into Chamorro following Spanish colonization. In Chamorro, the term refers to a raised walkway that connects the main residence with the cookhouse and, in some cases, the lavatory.

7. Safford, who had the opportunity to observe the construction of a *mampostería* residence during his stay on Guam, made the following observation: "[a]s a rule, the masonry work on the island, chiefly stone walls and the basements of houses, is substantial but crude. In squaring the stones and in laying them horizontal, the mason frequently depends upon his eye, though he may have both square and level at home. The result is, as may well be imagined, that frequently the corners of the buildings supposed to be square are by no means right angles, and the stone steps and terraces intended to be horizontal are far from it" (Safford 1902: 126).

8. Chamorros were no strangers to stone architecture. Their megalithic *latte* residences were constructed for hundreds of years before the arrival of Europeans. As one archaeologist noted "by building in stone, a very durable material, high ranking [Chamorro] families reinforced their own enduring social position. Also by elevating their houses above the ground and over the households of lower ranking individuals, families ... employed a symbolic gesture with nearly universal representation in Oceania, for relative height and elevation reflect subordinate-superordinate relations involving deference and authority" (Michael Graves quoted in Russell 1998:145). The adoption of *mampostería* residences may be seen as a continuation of this symbolic gesture employing imported construction techniques and architectural forms.

9. Particularly useful to this study was the Georg Fritz Photographic Collection which is accessible at the CNMI Division of Historic Preservation and the Micronesian Area Research Center, University of Guam.

10. Arabwal is the Carolinian term for a beach morning glory that grows in sandy areas (*Ipomoea pes-caprae*). The settlement at Arabwal was founded in 1839.

11. *Radicados* may be translated to mean "settlers."

12. *Casa Real* is a government residence or office building (Olive 1984:128).

13. *Tribunal* is a town hall, municipal building, courthouse and jail (Olive 1984:139).

14. The *camarín* was a barn-like structure with two lateral and two end walls, and a pitched roof. It was built of wood and thatch (Olive 1984:127).

15. *Convento* in the Philippines and the Mariana Islands is a term that commonly refers to the residence of the parish priest, usually built adjacent to the church (Olive 1984:129).

16. The Chamorro word *hotno* originates from *horno*, the Spanish term for oven.

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Photographs

Workers erect the wooden frame of a traditional Chamorro residence (Fritz Collection).

A massive stone stairway typical of *mampostería* architecture (Fritz Collection).


A wooden *batalan* linking a Chamorro residence with the kitchen.
Similar *batalan* were used in *mampostería* architecture (Fritz Collection).

Virgen del Carmen Church, Garapan, 1899 (Fritz Collection).

The Garapan *convento* pictured at left. At right is the renovated Virgen del Carmen following the 1902 earthquake (Fritz Collection).

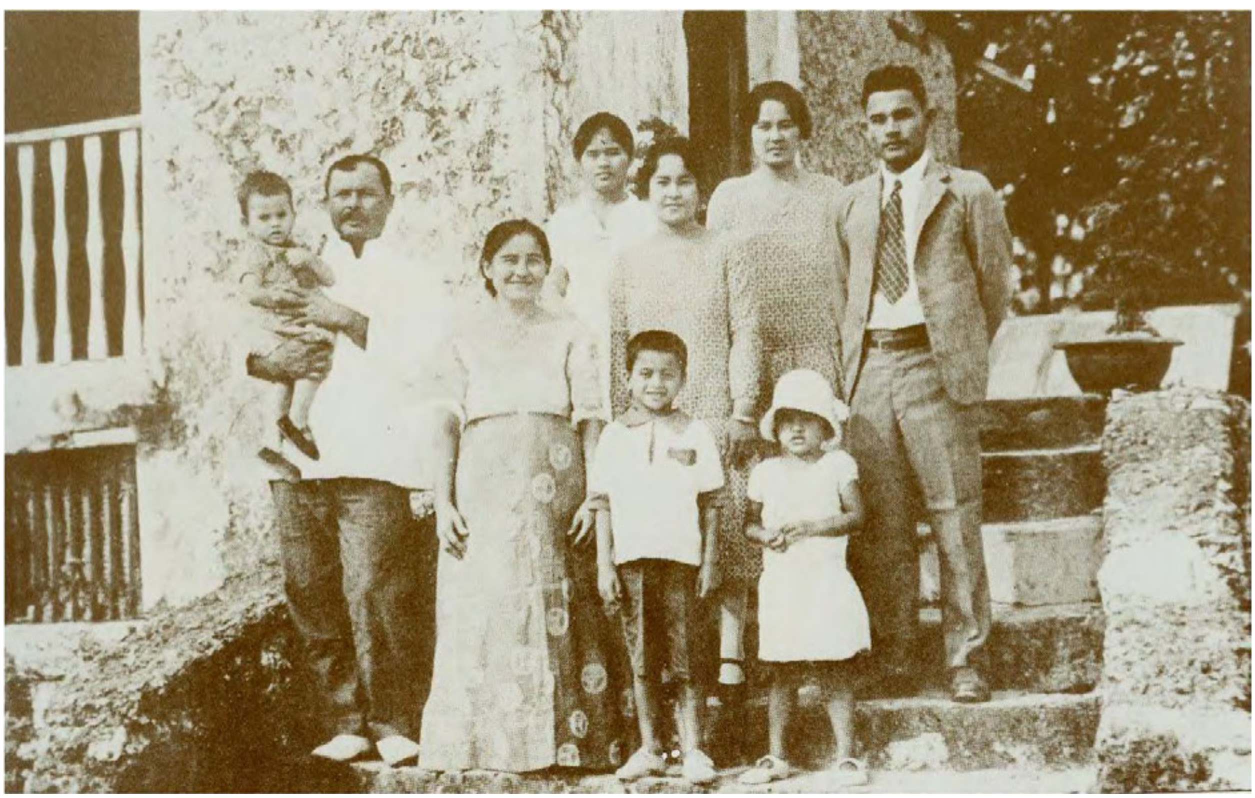
Virgen de los Remedios Church, Tapapag, circa 1900 (Spennemann).

The Ada residence, circa 1905 (Fritz Collection).


Details of the Ada residence, circa 1905 (Fritz Collection).

Flag raising ceremony on November 17, 1899 in front of the Diaz residence, Garapan.

The Diaz residence with troop barracks for Filipino troops. The Diaz residence was occupied by Spanish Governor Eugenio Blanco for several months in 1899. It was also used by German District Officer Georg Fritz following the German takeover.



The Blanco family in front of their Garapan residence, circa the early 1930s
(CNMI Division of Historic Preservation)

Unidentified *mampostería* residence in Garapan, circa 1905 (Fritz Collection).

Unidentified *mampostería* residence in Garpana, circa 1905 (Fritz Collection).


Carolinian women dance next to the masonry chapel in Medina Village, Tinian, 1888
(Marche Collection).


San Francisco de Borja Church, Songsong, circa 1900 (Fritz Collection).


The Rota *convento* has it appeared in 2004 (photo by author).

Casa Real, Songsong, circa 1900 (Fritz Collection).


The ruins of the *Casa Real*, Songsong, 2004 (photo by author).

The Merriam-Webster's Dictionary defines Stonework as "a structure or part built of stone" and "the shaping, preparation, or setting of stone." The same source defines "heritage" as the "property that descends to an heir" or "something transmitted by or acquired from a predecessor." Therefore, we refer to Stonework Heritage as the historic legacy of structures made of stone.

Cultural Heritage represents one of the most significant aspects of the identity of a nation and its material manifestation across eras and periods. The physical presence of a historic structure is a visible testimony of the past that contributes to the maintenance of the collective identity of a community.

In the light of the cultural and historic relations of Spain with Guam, Northern Mariana Islands, Federated States of Micronesia and Palau, the **Spanish Program for Cultural Cooperation**, with the collaboration of the **Guam Preservation Trust and the Historic Resources Division, Department of Parks and Recreation**, hosts this *International Conference on Stonework Heritage in Micronesia*.

The Micronesian Region is significantly rich and diverse in Cultural Heritage. By incorporating it into a collective appreciation, we are better prepared to move forward for the new challenges of the future. In a world wherein cultural tourism is growing in importance and numbers, the Historic Heritage of Micronesia represents an economic venue for sustained development.

UNESCO's Universal Declaration on Cultural Diversity and Tourism

Article 7

Creation draws on the roots of cultural tradition, but flourishes in contact with other cultures. For this reason, heritage in all its forms must be preserved, enhanced and handed on to future generations as a record of human experience and aspirations, so as to foster creativity in all its diversity and to inspire genuine dialogue among cultures.

MINISTERIO DE CULTURA

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