Restoration and Maintenance

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Produced and Published by the
Marble Institute of America
380 East Lorain St. Oberlin, Ohio 44074
Telephone: 440-250-9222
Fax: 440-774-9222
www.naturalstoneinstitute.org

RESTORATION AND MAINTENANCE – STONE GEOLOGY

1.0 INTRODUCTION

1.1 One cannot effectively participate in the field of stone restoration without at least a rudimentary understanding of the geological sciences. Stone composition is a far more complex issue than is commonly thought, and the in-service performance and behavior of the stone can be significantly influenced by even minor constituents of its composition. This issue is further complicated by the fact that while geologists and petrographers identify hundreds of different rock types, the stone industry uses much broader definitions of stone types than the scientific community. In doing so, the industry includes similar materials into various stone groups despite the fact that the stone does not technically and scientifically belong to that group. As practical examples, popular stones such as Crema Marfil and Rojo Alicante are commercially identified as "marble," even though they are not geologically marble, and would be scientifically classified as "hard, compact, dense limestone." Paradiso and Uba Tuba are commercially considered granite, yet they are actually "gneiss" and "charnockite," respectively. The differences in composition, behavior, and performance between these rocks and those rocks that scientifically belong in these classifications are generally slight, and negligible in most commercial issues. But to the restoration professional, such differences can be significant. Reference is made to the Marble Institute of America's *Dimension Stone Design Manual* Chapter 1 and Chapters 5 through 12. While a brief introduction of stone geology is offered here, a far more comprehensive discussion of the subject can be found in those chapters. The reader is strongly encouraged to study those sections thoroughly to gain a greater understanding of the subject matter.

2.0 STONE FORMATION

2.1 Thousands of stone deposits exist throughout the world. Yet all stones have been formed by one of three methods, and therefore all stones can be classified into one of three groups: Sedimentary, Metamorphic, and Igneous.

2.2 The term **Sedimentary** comes from the Latin word *sedimentum*, which means "sinking" or "settling." It is used to describe stone deposits that are formed when sediment is collected over geological periods of time, causing individual grains, or "clasts," to be cemented together by another agent. Common cementing agents, in descending order of preference, include silica, carbonate, iron oxides, and clay. Limestone and sandstone are examples of sedimentary rocks.

2.2.1 There also exist sedimentary stones which are not created from the settling of clasts, but are **chemical sedimentary stones**. Onyx is an example of a chemical sedimentary stone.

2.3 **Metamorphic** is a term used to describe stones that have undergone a change in structure. The term originates from two Greek words: *meta-*, meaning change, and *morphic*, meaning structure. Perhaps the best known example of a metamorphic rock is marble, which has changed its structure from a sedimentary limestone to a recrystallized rock fabric known as marble due to intense heat and pressure.

2.4 The term **Igneous** comes from the Latin word *ignis*, meaning fire. This term describes stones that were melted deep within

the earth by thermal energy released from the decay of radioactive minerals within the earth's core. These stones, eventually cooled and solidified, have been harvested for a variety of uses. Commercially, the most common of these rock types used is granite, yet many other igneous rock types exist in commercial trade.

3.0 STONE MINERALOGY

3.1 Siliceous and Calcareous Stones. Geologists have identified roughly 3,500 different minerals found in the earth's composition, yet only about a dozen of these minerals are commonly found in commercially-used stone varieties. As previously stated, however, even minerals found in trace levels of a rock fabric can influence the behavior and performance of the stone. Minerals that make up stone are commonly divided into two groups: siliceous, or silicate minerals, and calcareous, or calcium carbonate minerals. Stones that are comprised of siliceous minerals include granite, slate, and serpentine, while stones that are comprised of calcium carbonate components include marble, limestone, and travertine.

3.2 Mineral hardness is an extremely important consideration for the restoration professional. Mineral hardness determines how the stone will perform in service when subjected to abrasion, such as stones used for walking surfaces. Mineral hardness is also an important measurement in predicting how easily a stone can be resurfaced, as the grinding operation can be significantly slowed when hard minerals make up the stone fabric. In addition to the absolute hardness of a mineral, one must take into account the variability of mineral hardness within an installation. A patterned floor, using granite bands and travertine fields, can pose an extreme challenge to the restoration professional attempting to refinish it. The hardness of the granite requires aggressive abrasives to effectively work the material, yet these same abrasives can create uncontrollable dishing and gouging in the much softer travertine portions of the floor. Variability in mineral hardness can also exist within one stone. Such variability can create the same challenges in achieving a uniform level of grinding, and can also prevent a uniform level of gloss from being achieved due to the difference in the light reflectivity of the two portions of the stone.

3.2.1 Mineral hardness has long been measured by means of the **Mohs Scale of Relative Hardness**. In 1822, Friedrich Mohs, an Austrian mineralogist, published a paper on mineral hardness based on the scratch resistance of each of 10 minerals when tested against the other 9 minerals in his study. His published paper listed the 10 minerals in order of their relative scratch resistance. As simple as this study appears, almost two centuries later, we are still using Mohs' research and findings as the basic rank of mineral hardness. The ten stones included in Mohs' scale include:

Hardness	Mineral
1	Talc or Mica
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase
7	Quartz
8	Topaz
9	Corundum
10	Diamond

3.2.2 There are two common misconceptions regarding the Mohs scale. The first is that many do not clearly understand that **the scale is relative, not absolute**.

Relative simply means that "4" on the scale is harder than "3," and both of them are harder than "2." The scale offers no absolute information regarding how much harder, or whether the interval between 4 and 3 is greater or less than the interval between 3 and 2. A mineral with a hardness of 4 **IS NOT** twice as hard as a mineral with a hardness of 2. It is more than 10 times harder! Today, we have the instrumentation available to measure absolute hardness. If the Mohs scale reported absolute hardness, it would look like the table below:

Mineral	Relative	Absolute
Diamond	10	1600
Corundum	9	400
Topaz	8	200
Quartz	7	100
Orthoclase	6	72
Apatite	5	48
Fluorite	4	21
Calcite	3	9
Gypsum	2	2
Talc	1	1

3.2.3 The second area of confusion regarding the Mohs scale is that **it is a hardness scale of minerals, not stones**. Since nearly all stones are polymineralic, each mineral within the stone's composition has its own unique properties, including hardness. Oftentimes we see marketing literature for a certain stone that lists a "Mohs Hardness" for the stone. This is a technical inaccuracy, since the stone is comprised of a variety of minerals and each mineral has a unique hardness value. To ask, "What is the Mohs' hardness of this stone?" is the equivalent of asking, "What is the flavor of Neapolitan ice cream?" It depends on which part of the stone, or which part of the ice cream, we are talking about.

3.3 Chemical Resistance. There are a variety of chemicals that can attack the fabric of a stone, but acidic chemicals are the cause of most frequent concern. Acidic chemicals are commonly found in both commercial and residential settings, through food and beverages, as well as many common cleaners and detergents. One of the most frequent inadvertent acid exposures encountered in both residential and commercial settings is urine, which is quite acidic and has been responsible for the attack of many stone floors.

3.3.1 Acidic content is measured with the pH scale. The pH scale ranges from 0 to 14, although there are some exceptionally acidic substances that can actually be below zero on the pH scale. A value of 7 is neutral; anything lower than 7 is acidic, while anything above 7 is alkaline. The pH scale is not a linear scale, but a logarithmic scale. This means that a substance with a pH of 5 is 10 times more acidic than a substance with a pH of 6.

3.3.2 Generally speaking, **all calcareous stones are subject to acid attack**, even from the mild acids found in household settings. The most common result of acid exposure is etching, which is generally visible as a dull spot in an otherwise high gloss polished surface. Depending on the acidity of the attacking agent, the dwell time that the attacking agent was allowed on the stone surface, the vulnerability of the specific stone to acid reaction, and the number of repetitions allowed to occur, the result can be much more severe than a simple dull spot.

3.3.3 Siliceous stones are far more acid resistant than their calcareous counterparts. This does not mean that they are necessarily acid proof. Many siliceous stones include minerals of minor to trace levels of concentration which are acid vulnerable. Additionally, certain acid types will attack silicates. One of the better known examples is hydrofluoric acid (HF). This is a common component found in rust-removing stain

removers and rust-removing laundry stain removers. Accidental exposure of stone to compounds containing low concentrations of HF is fairly common.

3.3.4 Degradation due to salt attack is included in this section, but despite the fact that salt is a chemical, its mode of attack on natural stone is not actually chemical, but mechanical. Salt is readily soluble in water, and when in solution, can penetrate the pores of medium to highly porous stone fabrics. When the water evaporates, the salt will recrystallize within the confines of the pore cavity in the stone. The expansion caused by the recrystallization exerts significant pressure on the walls of the pore, and is great enough to cause fracturing, resulting in an exfoliation of the stone face. Salt exposure is most commonly experienced in northern climates where salt is used as a snow melting chemical. The exposure is not limited to exterior surfaces, however, as the salt is carried into the building envelope by the footwear of pedestrians. Salt attack can be evident in both commercial and residential properties, but it is far more prevalent in commercial settings due to the greater use of salts in those venues. Limestone and travertine are the two most commonly affected stones due to their pore volume and pore structure.

RESTORATION AND MAINTENANCE – STONE IDENTIFICATION

1.0 FIELD IDENTIFICATION TOOLS

1.1 Several simple field identification tools are available to measure hardness and acid sensitivity. Mohs Hardness picks can be purchased from any number of laboratory or geology supply vendors, generally for less than $100 per set. This set of picks consists of metal and/or plastic tipped instruments which are calibrated to correspond to the values on the Mohs scale. One simply attempts to scratch the stone surface with the pick. If the stone is scratched, it is softer than that value; if it is not scratched, it is harder than that value. The most common field test for acid resistance is to use a diluted concentration of hydrochloric acid (HCl), generally 5 or 10% concentration. The hardware store variety of HCl is muriatic acid, which contains about 30% HCl. Many field technicians purchase the economical muriatic acid and dilute it with water in a water to muriatic acid ratio of 5:1 to 2:1. Placing a drop of the diluted acid solution on an inconspicuous area of the stone surface will tell you if the stone is calcareous or siliceous. The acid will bubble and fizz when placed on calcareous stones, such as marble, limestone, or travertine, while it will rest on the surface of a siliceous stone, such as granite, quartzite, or slate, without any noticeable reactive activity. Remember that this is an aggressive acid, even after dilution. Safe handling practices with appropriate PPE are required at all times.

2.0 STONE FINISH IDENTIFICATION

2.1 The restoration professional must identify the finish originally applied to a stone surface. There are a variety of stone finishes in the marketplace, many of them proprietary, but the majority of stone installations will have one of the standard finishes listed below.

2.2 Polished surfaces are smooth, with a highly reflective, glossy face. The level of gloss will vary from stone to stone, and can vary between different regions of a stone. Gloss level is related to both mineral hardness and pore space, so significant variation exists. Gloss, or the level of reflectivity, can be measured with a gloss meter, but no industry consensus standard exists as to what level of gloss is required to define a surface as polished. If such a standard were to exist, it would actually be different for each stone on the market. Stone polishing is strictly a mechanical, abrasive process, with the exception of some marble varieties, in which oxalic acid might be used. It does not produce any level of pore closure, nor "mineral welding." As such, polishing does not reduce absorption of the surface. However, it does provide greater surface tension when fluids are applied to it.

2.3 Honed surfaces are typically produced with the same machinery used for polished surfaces, with only a few of the final abrasive heads removed. A honed surface has the same flatness and perceived smoothness as a polished surface, but has no or very limited reflectivity. Again, there is no industry consensus standard that establishes the limits in grit size or reflectivity that define the coarse and fine boundaries of honed finishes. It is commonly believed that honed surfaces have greater frictional properties than polished surfaces. This is true in some extremely coarse grit honed surfaces, but in the majority of

honed stones available in today's marketplace, the difference in measured friction between honed and polished surfaces is statistically irrelevant.

2.4 A variety of textured surfaces can be achieved in natural stones.

2.4.1 Acid Washed, or "Acid Etched," surfaces are created by intentionally inducing an acid attack on calcareous varieties of stone, leaving a rough textured surface. The depth of relief achieved is dependent upon the concentration of acid, vulnerability of the stone fabric to acid reaction, and dwell time of the acid application.

2.4.2 Flamed, or "Thermal," surfaces are created by briefly exposing the stone surface to a propane flame. The rapid heating of the outermost crystals of stone causes significant expansion and results in a thermal desegregation of the stone minerals. This finish is typically limited to granite and granite-like igneous rock varieties, but some other stones are also capable of taking a flamed finish. The depth of relief and related profilometry of the surface is dependent upon the stone's mineralogy, stone crystal size, and the setback, speed, and angle of incidence of the flame.

2.4.3 Sanded surfaces have been textured by abrasive particles striking the stone surface at high velocities. Again, the finish profilometry is dependent upon a multitude of factors, including the stone composition and hardness, particle size and velocity, and dwell time.

2.4.4 Cleft surfaces are produced by splitting the stone fabric along its rift, or direction of preferred separation. Virtually all stones can be cleft, but a much smaller variety of stones can be cleft to produce a surface that is suitable and safe for pedestrian ambulation. The most common stone to be supplied in a cleft surface is slate, some varieties of which cleft into extremely flat and uniform sheets.

3.0 DETECTION OF SURFACE TREATMENTS

3.1 Many stone surfaces today are treated with some type of surface-applied product, and in many cases, multiple products. Recognition and identification of these products is vital, as removal (or "stripping") of them is frequently required to prevent an incompatibility with subsequently applied products. The best scenario is if the owner has retained records of what has been used on the stone during its service life, from which the manufacturer can be contacted and exact chemistry and removal protocol can be determined. Four groups of surface applied products are discussed below.

3.2 Sealers. True sealers are rarely used in stone applications, as they prevent the stone from "breathing," and often create vapor pressures, blotchiness, or other negative aspects within the stone fabric. There are a few true sealers marketed for use on stone, but most commonly when a sealer is encountered, it is a product that was not specifically formulated for stone, but intended to be used on a different surface, such as wood. Sealer application can usually be detected by a "plastic-like" sacrificial surface compound on top of the stone.

3.3 Impregnators are the most common product applied post-fabrication to stone surfaces. An impregnator can be solvent carried or water carried. In either case, the carrier evaporates after application, and the active ingredients, which may be a small percentage of the original formula, remain to treat the stone surface. An impregnator "impregnates," or penetrates, the surface and

remains below the surface to a depth of a couple of millimeters, depending on the stone's porosity and density. Impregnators must be matched to the stone variety, as they are designed for optimum performance on a specific range of stone properties. Impregnators are usually detected by the stone's reaction to water droplets; the greater surface tension of an impregnated surface will cause "beading" of water droplets.

3.4 Dyes and some colored waxes are occasionally used by suppliers to alter the natural color of a stone to a color that is more desirable and in greater demand. The presence of a dye is rarely disclosed by the supplier. Some dyes can be detected with a simple cloth saturated in a solvent. Acetone, methyl ethyl ketone, and toluene are frequently used for this purpose. Not all dyes are soluble with these solvents, so while this simple test might confirm the presence of a dye, it cannot reliably confirm the absence of a dye.

3.5 Resin impregnation prior to polishing is common, especially in the countertop sector of the stone industry. The most common resin used worldwide is epoxy, but polyester and acrylic-based resins are also used.

3.5.1 Process. Though resin impregnation can be done entirely manually, most major stone slab sawyers and finishers use large, sophisticated process lines to perform this operation. The sawn, unfinished slab is screeded with the resin product. It is then placed over a vacuum table, which draws the resin deeper into the stone slab, then placed in an oven for accelerated heat curing. Once cured, the slab is sent to the polish line, where the majority of the resin is abraded from the slab. The residual resin exists only in the fissures, cracks, pits, and other surface interruptions of the slab, offering a cosmetically improved, uninterrupted reflective surface, unattainable in an untreated stone slab. The percentage of resin in the finished slab differs for each stone slab. Most overseas suppliers will not disclose the application of a resin treatment on their slab products. On rough slabs, the presence of resin treatment can usually be confirmed by observing the rough edges of the slab and noting the cured drippings of resin.

3.5.2 Problems with resin treatment. Although resin treatment does reduce the absorption of stone surfaces, it will not have the same effect as impregnator treatment. Resin treatment has long been associated with a darkening of the stone's natural color, which can present challenges in matching the color tone of an exposed polished edge to the treated surface. Some resins may also complicate the application of impregnators due to compatibility issues between the two products. No resin treatments have been proven to be 100% UV resistant. Discoloration (yellowing) of the resin is possible, though not likely. Due to the vast difference in rates of thermal expansion between cured plastics and natural stone, dislodging of resin fillers is commonly noted when such products are used in exterior settings. Degradation of exterior surfaces is likely even without freeze/thaw cycling. As such, the use of resin-treated stone materials in exterior applications is not recommended.

4.0 IDENTIFYING REPAIRS AND REINFORCEMENTS

4.1 Repairs and reinforcements are common and necessary in many stone varieties. The restoration professional must be able to detect and identify such repairs, because some modes of restorative procedures could compromise the integrity of the repair/reinforcement. A more comprehensive discussion of the allowable and anticipated

levels of repair and reinforcement can be found in the Marble Institute of America's *Soundness Classification* document.

4.2 Adhesive Repairs. Many repairs and reinforcements are adhesive, in which two portions of the stone have been re-cemented using a polymer adhesive. In some cases, this is actually an intentional fabrication technique (not a repair), such as using an adhered liner at a countertop edge to create a visually thicker edge.

4.2.1 Epoxy-based resins are best for adhesive repairs that carry any amount of load, because these products are stronger and have higher bond strengths and greater flexibility than polyester-based resin adhesives.

4.2.2 Polyester-based resin adhesives are preferred by many fabricators and installers because they typically offer lower cost, faster cure time, and more easily-attained color matches when dyed. Polyester adhesives are weaker and significantly more brittle than epoxies, making them a poor choice when high strength is required. However, this can be used as an advantage in some cases. If the seams of a kitchen countertop have been filled with epoxy, and the cabinetry moves, the stone is likely to crack, whereas as the same seam filled with polyester would have yielded prior to fracture of the stone.

4.3 Mechanical repairs. The use of adhesive alone is often inadequate to accomplish the structural augmentation desired in the stone. A mechanical device may also be incorporated into the repair or reinforcement to achieve the required stability.

4.3.1 Rodding is most commonly associated with kitchen countertop fabrication, specifically in narrow regions such as the rail in front of a kitchen sink or cooktop. Rodding is not limited to these conditions, and can also be used on facing panels. The technique involves cutting a groove, essentially a "dado," into the back surface of the stone slab that is just slightly (not more than perhaps 0.020") greater than the diameter or width of the rod. The rod, either metal or fiberglass, is fully encapsulated in epoxy (polyester is not effective in this application) within the groove. If metal is used, many choose stainless steel over mild steel, due to the quality control aspects of ensuring 100% unbreached encapsulation of the rod. This reinforcement technique is unidirectional, meaning that it is only effective in reinforcing the stone when the slab is being loaded in a manner that would cause the face to be concave and the back to be convex. Rodding is also ineffective if the groove is excessively oversized, as the adhesive cannot effectively transfer the strain to the rod and the resistance back to the stone. The third common error in rod installation is positioning the rod too deep, as the rod becomes less effective as its position advances toward the neutral axis of the stone.

4.3.2 Sticking, or dowelling, involves two pieces of stone being fastened together using a stainless steel pin epoxy-adhered into holes. This may be used to repair a cracked stone, or could be used as a higher strength method of adhesively bonding two stone units together. It may also be used as a secondary safety net in case the adhesive fails, such as a dowelled liner block on the back surface of a facing panel.

4.3.3 Fiberglass mesh backers are used to reinforce unstable slabs and tile to reduce the likelihood of fracture. This benefit is largely limited to the handling and transport of the slab. There is little permanent benefit after installation. Fabricators frequently use this technique in the interest of safety. If a slab is reinforced with a fiberglass mesh backer and is

fractured during transport, the fractured portion will be retained by the mesh, rather than falling to the shop floor and compromising safety. Like rodding, this reinforcement technique is unidirectional, meaning that it is only effective in reinforcing the stone when the slab is being loaded in a manner that would cause the face to be concave and the back to be convex. Two complications arise from the use of adhered fiberglass mesh backers. First, the back surface of the stone is truly sealed, eliminating vapor transfer at this point. Second, the ability of portland-based thinset to adhere to the epoxy coated back is severely compromised, and in most cases, effective bond can only be achieved by using epoxy-based thinset.

NOTES:

RESTORATION AND MAINTENANCE – STONE BEHAVIORAL GROUPS

1.0 INTRODUCTION

1.1 In this section, stone varieties are classified into behavioral groups to simplify the evaluation process and create predictable results across a broad spectrum of materials. Many stones can be applied to a particular behavioral group by sight. The technician begins by visually identifying the behavioral group based on common characteristics. It is important to have a general knowledge of stone and know the differences between marble, travertine, limestone, granite, and other stone. Physical characteristics and mineralogical makeup are the primary influences of how a stone behaves.

Stone Behavioral Groups		
Consistent	**Variegated**	**Quartzite/Granite**
Crema Marfil	Botticino	Serpentine
Limestone	Breccia	Quartzite
Travertine	Emperador	Granite
White Marble	Green Marble	

1.2 To refinish Crema Marfil and Noce Travertine to any level of gloss will require the same actions from the technician. Each of these stones can be classified into the same behavioral group. When considering how a stone will behave during the restoration process, the technician must look at the entire surface. Often there are two materials set into the same floor, either by design or mistake. Contrasting material such as Emperador Dark is frequently used in accent pieces between Crema Marfil or other class consistent tiles. If the accent pieces require refinishing, the technician must treat the entire floor as the more labor-intensive material. In this case, the entire surface must be considered to be Emperador Dark. Emperador Dark (a geological limestone) is a highly variegated brown commercial marble with multiple colored veins and textures ranging from white to tan to darker brown.

1.3 There are exceptions to any rule in creating qualitative results on natural stone surfaces. Most materials, however, will behave in predictable ways based on a sight classification.

2.0 TYPICAL GROUP CLASSIFICATIONS

2.1 Marble, Travertine and Limestone (referred to herein as MTL). There are two main behavioral groups for calcareous stones: Consistent and Variegated. MTL is a broad generalization of almost all calcareous stone, and covers probably 80% of what will be encountered when evaluating restoration and refinishing jobs. Most MTL floors can be treated with similar methods. Several specific trade names are used here as examples of stone products that fit into the described categories. These are examples only, and do not represent a complete list of materials. The specific stones were chosen because they are common and will be frequently encountered. The behavioral characteristics are the most important information to retain.

2.1.1 Consistent MTL group. This group has a consistent overall color, with light to moderate veining. While all stones are polymineralic, the stones in this classification will have one extremely dominant mineral in their fabric. Veining in consistent material is usually of one dominant color, as opposed to variegated stones, such as Emperador, and brecciated marble and limestone, which have multicolored veining trends. Crema Marfil is an example of the consistent MTL group. This stone is commonly commercialized as a

marble, yet geologically is a dense limestone. The surface is creamy white, with light to moderate veining. Most procedures and approaches for marble refinishing are based from working with this stone. It can be refinished with a typical set of resin diamond marble abrasives and polished with most marble polishing compounds. Stones that are comparable to Crema Marfil should be repaired, maintained and refinished using similar methods.

2.1.1.1 Effective Techniques. Crema Marfil is fairly soft when compared to other marbles. Resin diamond marble abrasives should be used, usually starting with 220 grit (depending on the severity of wear), and ending with 1800 grit. This grit selection is based on normal wear and tear for this material. Lippage removal will require a more rigid and aggressive grit selection. A standard rotary buffer with a weighted drive plate is ideal for normal refinishing procedures. This stone can be polished with a traditional wet-style polishing powder (usually containing oxalic acid and tin oxide). It can also be polished with the newer wet-to-dry method.

2.1.2 Porous Limestone refers to any limestone that appears to have a visibly porous surface. Generally, these stones will have densities of less than 150 lbs/ft³. When looking closely at the stone, tiny pinholes are visible in the surface, without magnification. Two common examples are Crema Europa from Spain and the French limestone, Beaumaniere. These are both very soft, very porous, and refinish using the same methods.

2.1.2.1 Effective Techniques. The micro-texture and inconsistent surface make this group difficult to repair. Most adhesives or patching material cure to a smooth, glossy texture and stand out easily against the grainy, matte surface of these stones. This group of limestone typically absorbs a lot of sealer in order to properly protect: approximately 100 to 200% more than typical marble or travertine surfaces. These stones will refinish nicely, but lack the depth and clarity of other materials due to the difference in surface texture. These stones also wear out resin diamonds very quickly due to the fluctuation of soft/hard mineral content. They should be taken as high as possible with diamonds before polishing and polished with a weighted machine and a traditional wet polishing powder.

2.1.3 Dense Limestone refers to any limestone that has a surface similar to marble. There are no visible holes or pits, and the surface will usually have a consistent finish. This class of limestone is very hard compared to other limestone, and densities can easily be in excess of 160 lbs/ft³. Examples of this class would be Jerusalem (also referred to as Ramon) and Jura Limestone.

2.1.3.1 Effective Techniques. Dense limestone is easier to repair, because the adhesives will blend better compared to softer limestone. Dense limestone acts more like marble than its porous counterparts, but will still lack depth and clarity. This group will also need to be sealed more thoroughly. This limestone is less abrasive than more porous limestone, but will still take its toll on abrasives. Dense limestone will sometimes not require the highest grit of diamonds when refinishing, but in most cases should be taken through the full range of resin abrasives before polishing. The full range of resin abrasives is important because dense limestone is so delicate, its surface tends to become uneven and bumpy (called "orange peel") when polishing due to its delicacy. Because of this, a chemically cold powder (one that has a relatively low acid content), or a two-step polishing procedure, should be used. By following these recommendations, the highest clarity can be achieved without the risk of "orange peel."

2.1.4 Travertine. Despite the common usage of the misnomer "travertine marble," travertine is a type of limestone. It is a sedimentary stone that is formed naturally by

existing limestone deposits that were dissolved, usually by hot and/or acidic springs, then transported to the surface where the material was allowed to settle and form a new stone deposit. Most travertine varieties behave very similarly. They all naturally contain holes or cavities. In many regions, travertine is the most commonly used natural stone for floors. It is generally easy to refinish and repair. Its hardness is typically between that of limestone and marble. Travertine has a reputation for being hard to maintain in high traffic areas. Holes or pits can open or develop, which will then collect dirt, making the floor harder to clean. Despite this, travertine is very serviceable and restoration efforts are nearly always successful.

2.1.4.1 Effective Techniques. Travertine can be refinished wet or dry, and can be polished with most marble polishing compounds on the market. Some travertine varieties are vulnerable to stunning, yet susceptibility to stun marks is not a common characteristic of all travertine.[1] Travertine is a good material to use when learning how to polish because it forgiving and difficult to over-polish.

2.1.5 White Marble. White Carrara (*Bianco Carrara*) is what most people think of when they hear "Italian Marble." It is a true geological marble. White Carrara is a white marble with gray veining. The tone of the background and intensity of veining can vary. Because of the geological makeup, mostly calcium carbonate, this material is consistent in hardness throughout. Calacatta and Statuary (*Bianco Statuario*) marble are from the same area of Italy, but are currently considered more rare and exotic. Some Greek and Turkish marbles are also similar to these types of Italian marble, but they exhibit a larger, more defined crystal structure.

2.1.5.1 Effective Techniques. White Carrara and its relatives vary, even though they can look identical. They are somewhat softer than other varieties of marble and should not be refinished dry. This group will overheat and burn easily.[2] Polishing should be done with a traditional style wet compound, although sometimes this group responds well to the wet-to-dry process. These stones tend to be very difficult to repair due to their crystal-like transparency. Using solid color patching material will stand out, even when matching the correct color. A transparent epoxy or urethane should be used, taking precautions not to create a stain in the material. These marbles stun very easily, resulting in noticeable solid white marks. Refinishing using a high grit diamond abrasive is the best practice for this group. Carrara can "orange peel" easily and will typically have a very slight texture to it.

2.1.6 General Notes Regarding Consistent MTLs. When polishing consistent materials, ending with a lower grit abrasive, such as 400 or 800 grit, a large amount of "hot" or acidic powder will be needed to create a clear reflective finish. However, care must be taken to avoid the "orange peel" effect. Consistent materials are easier to clean, hone, and polish.

2.1.7 Repairing Limestone and Marble. Limestone and white marble will absorb the solvent from some epoxy resins when performing a repair. This can result in a stain around the perimeter of the repair. Sometimes this stain can be removed, but most of the time it is permanent. One way to avoid possible staining is to thoroughly seal the area to be repaired before applying any adhesive.

[1] Stun marks are the result of explosions inside individual crystals in the stone. These marks are caused by sudden, pinpoint pressure impacting the surface of the stone.

[2] Oxalic acid, which is used to speed the polishing process, can burn marble. Burned marble has a dimpled appearance and a molten, plastic shine. Rehoning is necessary to remove the burnt surface.

Another way to avoid this issue is to use a patching material that will not create a stain. Be sure to test the patching material or consult the manufacturer prior to use.

2.1.8 Cleaning Limestone. Thorough cleaning is required for most limestone installations. While it may seem straight forward, there are some necessary precautions. Limestone is very porous, and oily cleaners may cause some discoloration, particularly with extended dwell times. If this occurs, it can usually be removed with additional cleaning, but prevention is a better practice than remedy in this case. Limestone can take 24 hours or more to dry out, so account for this when the job involves sealing after cleaning.

2.2 Variegated MTL Group. With MTL, if there is any question, it may be better to treat the stone as variegated. Variegated stones typically have a multicolored field and multicolored veining. This look is caused by the variety of minerals included in the stone fabric, which in turn can lead to those differing minerals having a non-uniform response to the abrasives and chemicals used in the restoration process. This class is considered more difficult to polish and requires special proprietary methods. To polish these surfaces, the restoration professional must use the highest diamond abrasives in the sequence and finish with chemically-cold polishing powders. Another method is to finish with an ultra-high grit abrasive pad or powder. One example is Emperador Dark marble. Although most people refer to it as marble, it is a dolomitic limestone, yet it is actually harder than most marbles. It is variegated, with veining that is affected differently than the other minerals in the stone.

2.2.1 Effective Techniques. Variegated stones do not take a deep, glossy shine like Crema Marfil or other similar materials, and will typically have imperfections that can be seen with natural light. Refinishing requires a little more finesse than most marbles because of the variation in hardness. It is recommended to use a finer resin diamond abrasive, up to 3,500 grit, before polishing. The polishing step should also be more aggressive than normal—more pressure, friction and time is necessary. Good quality diamonds are highly recommended. Because of the hardness of these stones, granite diamonds can sometimes be effective.

2.2.2 Other Types of Variegated marble include Rosso (with the exception of Rojo Alicante), Tennessee Pink, and the various types of breccia. A short checklist can be helpful in determining the steps necessary for refinishing variegated stone. Technicians should look for the following: color, veining, and color of veins in contrasts with color of field.

2.3 Consistent Variegated. There exists a sub-classification of stones that could be termed "consistent variegated." A prime example of this classification would be Botticino. Botticino is very similar to Crema Marfil (which is Class Consistent) and is also a compact limestone but is a little different to refinish. To the untrained eye Botticino can sometimes be mistaken for Crema Marfil, but it is harder.

2.3.1 Effective Techniques. Botticino has one characteristic that makes it drastically different. It has white, cloudy minerals in it that do not polish easily. These areas tend to burn or become very hazy as soon as they are polished. They occur in different concentrations across the different types of Botticino marble, but are almost always present. Botticino should be handled the same way as Crema Marfil, with the exception that the final polishing step must be done in a way to balance the polish and clarity so the white areas do not burn. Sometimes, Botticino can be refinished exclusively with fixed abrasives, up to approximately 8500 grit resin diamond abrasives without a polishing compound being used. The quality of the abrasives plays a critical role when using only fixed abrasives. Other times, polishing powders or liquid

crystallizer can be used to finish the polishing process.

2.4 Serpentine is a variegated stone with a marble-like appearance, but vastly different mineralogical makeup. True serpentine is a silicate, is acid resistant, and will be significantly harder (Mohs = 5) than marble. Due to the absence, or near absence, of calcium carbonate, serpentine does not typically react with the acids in most marble polishing powders that aid the polishing process. For this reason, technicians tend to treat serpentine surfaces more like granite. Many technicians prefer to use a crystallizer or low-acid, high-grit polishing powders and creams. Some stones, such as Rosso Levanto, are variegated marble, but include large swaths of serpentine mineral in them. Rosso Levanto is a distinctive reddish-maroon marble with white veins and hints of green and other colors, and should be treated as a serpentine for purposes of restoration and polishing. Most, but not all, green marble-like stones are serpentine.

2.4.1 Effective Techniques. Serpentine contains little to no calcium carbonate, and as such, will not react to traditional marble polishing powders. It can be etched and scratched, but not at easily as other MTL surfaces. When refinishing, it should be treated like granite. Using diamond abrasives and polishing compounds made for granite will be effective when working with serpentine. This group will not display a deep gloss or present a lot of clarity like marble.

2.5 Granite and Quartzite. Most dense crystalline materials behave similarly and can be classified into the same section. It is important to note that many of the "granite" materials evaluated may not actually be granite. Many of the "granites" with veining are actually gneiss. Solid black "granites" are usually gabbro. The main concern here is to simplify the selection process and avoid confusing the end-user. In other words, if it performs like granite in use, then it should be called granite. While this may not always be important to complete the project, a broader understanding of the mineral composition of the surface will help the technician diagnose and correct issues.

2.5.1 Identifying Granite and Quartzite. Quartzite and granite are very similar. In general, these are the hardest decorative stones. Granite or granite-like stone can be easier to identify because of the granular crystal structure. A true quartzite can look similar to marble, but is much harder. Since quartz is the hardest mineral found in abundance in granite, and since quartzite is nearly 100% quartz, it should be expected that a true quartzite is even harder than granite. This property can drastically increase the amount of time necessary flatten a floor to remove lippage. The best way to determine hardness is to perform a scratch test in an inconspicuous area.

2.5.2 Effective Techniques. Granite and quartzite are described as dense crystalline, but the crystal structures of some varieties are very porous. This is especially true on materials that are lighter in color, such as Giallo Ornamental, Santa Cecilia and Kashmir. It is very important to use a high quality impregnating repellent to minimize the darkening of the stone caused by absorption of water or other liquids. When polishing dense crystalline surfaces, the technician will often follow the same steps. These stones must be refinished using mechanical methods with abrasives to achieve the highest possible shine, because they do not react with conventional polishing powders and creams. This process takes a lot more time than polishing softer materials. The technician must take this into account when scheduling and bidding the project. Scratch removal on a granite countertop can take up to five times longer than the same scratch on MTL. Even though this group can be drastically different from one another, they are all refinished with the same processes and techniques. A granite-specific diamond abrasive is used for both. The major difference between the two is the final polishing step; quartzite requires several more applications of the final polish, and usually with

much more pressure. There are several ways to approach the final polish that will allow the stone to be polished back to a factory finish or better. Because these stones are so hard and typically found on countertops, which are closer to eye level, there is little to no room for error when refinishing. Even the slightest pf waves, ripples, or gloss inconsistencies are visually noticeable. Selection of the right type of abrasives and good quality tools is paramount to a successful restoration of these materials.

2.6 Sandstone is an extremely porous silica-based stone. The term "sandstone" describes the clast size (1/16 to 2 mm), rather than mineralogical composition. Sandstone can therefore be of a variety of mineral types, although the most common found in dimension stone use is quartz-based sandstone. The material that cements the clasts together has more influence on its performance and behavior than the actual sedimentary clasts.

2.6.1 Effective Techniques. The surface of sandstone looks and responds like fine sandpaper. It will wear out abrasives very quickly. Sandstone is not frequently refinished as often as it is simply cleaned. If there are scratches that need to be addressed, honing can be done similar to a hard limestone. The material will not take a glossy finish. Sealing can be time consuming and costly, because the high absorption and porosity of the stone requires multiple applications of generous amounts.

RESTORATION AND MAINTENANCE – DIAGNOSTICS

1.0 INTRODUCTION

1.1 The word **diagnosis** comes from the Greek word *diagignōskein*, which means "to distinguish." It aptly describes the process that the restoration professional must accomplish during the earliest phases of the project, even prior to submitting a proposal to the client for performing the necessary work. Without a proper diagnosis, it is not possible to prepare an accurate estimate of costs, time, or reasonable expectations for the quality and performance capability of the stone after completed restoration. A thorough and accurate diagnosis requires distinguishing between symptoms and the problems creating those symptoms. For example, cracks or dull spots in a stone floor are merely symptoms, and while those symptoms can be cosmetically treated, they will reappear if the root problems that caused them are not addressed. A thorough onsite inspection is necessary to provide the most accurate proposal and treatment recommendation. In some situations, identification and remedy of the problems may exceed the level of expertise of the restoration professional, requiring the consultation of additional professionals. The items addressed below provide a general guide for the diagnostician to accomplish this task.

2.0 STONE TYPE

2.1 Identifying Stone Types. Identification of the stone by customary trade name may not always be possible, nor is the country of origin always identifiable. The geological type of stone must always be confirmed. This information provides insight into the material's behavior in various environments, as well as its porosity, density, hardness, and other inherent characteristics. For example, more porous limestone may require more regular maintenance, such as additional sealer applications when installed in a wet environment. Similarly, a polished marble floor in a commercial application can be better protected against scratching and traffic pattern wear by the use of walk off mats.

2.2 Location. A stone's behavior can differ depending on the environment in which it is installed. For example, the performance of the same stone may be markedly different in high traffic versus low traffic areas, or in wet areas versus

3.0 EXISTING INSTALLATION METHOD

3.1 The methods with which the stone was originally installed must be verified before restorative work may commence. Stone will naturally age and wear throughout service. Knowing the age of the installation helps determine if the condition of the stone represents normal aging and patina, or an abnormal, premature degradation of the product as a result of conditions that need to be corrected.

3.2 The method of attachment used in an application must be determined to ensure that the planned restorative techniques will not compromise the attachment. It also must be verified that the method of attachment is still stable and reliable. If this is not verified, an installation could be cosmetically restored, but then fail structurally. The simplest methods of attachment involve adhesive bonding only. Floor and wall tiles are typically held in place by adhesive methods only. When the stone becomes thicker, starting at 20 mm and greater, mechanical anchors may have been

used in combination with or in lieu of the adhesive bonding.

3.3 Resources for Tile and Mechanical Anchors. Most adhesively-attached floor and wall applications have been installed using methods outlined in the Tile Council of North America's (TCNA) *Handbook for Ceramic, Glass, and Stone Tile Installation*. Readers are encouraged to obtain a copy of this publication (available for purchase through MIA's Online Bookstore) and familiarize themselves with it prior to evaluating existing tile installations. Readers are referred to MIA's Technical Bulletin, "Dimension Stone Anchorage; Theory, Practice, & Components," for a comprehensive discussion of mechanical anchorage techniques. A mechanical anchor is any device (usually a non-corroding metal such as stainless steel, aluminum, copper, brass, or bronze) used to secure the stone unit to an unyielding support, such as the building frame. Anchors are nearly always concealed in stonework, so the restoration professional must verify their location and ensure that the restorative procedures will neither expose them nor compromise their integrity.

4.0 MEASURING STONE THICKNESS

4.1 The thickness of the installed stone influences which restorative techniques may be attempted, and how aggressively those attempts may be implemented. Stone thickness should be evaluated in conjunction with stone strength. In flexure (bending), a stone's strength is proportional to the square of its thickness. Therefore, a 30 mm thick section of stone is over twice as strong as a 20 mm thick section of the same stone ($30^2 = 2.25 \times 20^2$)! But if the 30 mm stone is a relatively low strength stone with a flexural strength of 1,000 lbs/in², and the 20 mm stone is a high strength stone with a flexural strength of 2,500 lbs/in², the 20 mm section is actually stronger in service, despite its reduced thickness. When grinding operations are required, one must be careful to not only avoid grinding through the stone depth, but also grinding the stone to such a reduced thickness where it can no longer perform under load. It must also be ascertained that the stone is solid through its depth, as opposed to stone-faced units consisting of a very thin layer of stone laminated to ceramic, metal, or other backer units. While joint fillers can be abraded to facilitate viewing and measurement of the actual stone depth, a far easier and less invasive method is to take advantage of the existing mechanical and electrical penetrations. Simply removing a grate over a heating duct or removing the plate over an electrical switch or outlet will usually confirm the actual thickness of the stone units. Stone thickness can often be ascertained at the doorway to unfinished space; for instance, where the stone work truncates at the transition between a finished space and an unfinished utility room.

5.0 EVALUATION OF DESIGN AND EXECUTION

5.1 The existing design and installation must be evaluated for a series of potential deficiencies. If deficiencies are noted, the condition must be corrected as part of the restoration process, lest post-restoration failure is likely.

5.2 Five Categories of Movement Joints. A series of specialty joint designs is necessary in all finished stonework to facilitate dynamic building frame movements, differential thermal expansions and contractions, and permanent deformation

(creep) of structural units. These necessary functional joints are frequently omitted from stone installation designs, and their absence is one of the most common contributors to stone installation failure. These joints can be placed into five general categories: 1: **Expansion joints** typically go through the stone installation assembly and building structure, and accommodate relatively large movements anticipated in the building frame at that location. 2: **Isolation joints** are also typically carried through the building structure, and are most often used to bridge between different structural elements; for instance the separation between a footing pad at a column and the surrounding concrete slab. 3: **Control joints** are merely shallow cuts in concrete slabs which create a slightly weaker zone and direct, or "control," where shrinkage cracks will occur as the concrete cures. 4: **Perimeter joints** separate the finished stone surface at regions of discontinuity, for instance where horizontal finish planes intersect with vertical elements, such as walls or columns. 5: **Generic Movement joints** are simple soft joints occurring in the finish stone surface only, and are intended to provide an interruption in the accumulation of shear stresses resulting from differences in temperature or expansion rates between the stone and the rest of the assembly, or to accommodate differences in elongation or compression as a result of floor curvature. Refer to section EJ171 of the TCNA's *Handbook for Ceramic, Glass, and Stone Tile Installation* for additional information on these types of joints and requirements for their frequency in stone designs.

5.3 Substrate Rigidity. Stone is a quasi-brittle material and does not bend easily. A 12" x 12" x 3/8" stone tile could fracture with as little as 0.010" total deformation! As thin stone tiles (less than 20 mm thickness) are considered to be decorative, abrasion-resistance finishes only, they must rely on the rigidity of the substrate and bedding layers to develop their resistance to applied loads. There are two primary components to consider when evaluating whether or not the substrate has the required rigidity to adequately support the stone units.

5.3.1 Frame Deformation must be held to extremely low allowable deflections. Various documents (building code, ACI, and MIA) list a maximum allowable deflection anywhere from L/600 to L/1000. In addition to the basic deflection of the framing members, one must verify that the potential differential deflection between adjacent members is not excessive. Oftentimes, some type of load-sharing device is required to tie adjacent members together and reduce the inter-member differences in deflection under load. Since deflection and radius of curvature are not exactly the same thing, span length also becomes part of these analyses.

5.3.2 Substrate Panel Deformation. The substrate panel, be it a sheathing on a wall assembly or a subfloor/underlayment combination in a floor assembly must be sufficiently stiff to carry the loads experienced by the stone units back to the framing members without undue deformation.

5.4 The setting adhesive used, if possible, should be identified to verify its suitability and the quality control of its placement**.**

5.4.1 Appropriate Selection. Certain stone types require specific types of adhesives; for instance white colored thinsets are required for light colored marble and limestone, and epoxy-based thinsets are required for mesh-backed stones and many moisture sensitive stones.

5.4.2 Adequate Coverage. The adhesive must have adequate contact area with the stone unit. MIA's *Dimension Stone Design Manual* calls

for 95% contact with no voids exceeding 2 in² and no voids within 2" of tile corners on 10 mm tile. In 20 mm thick stone, 80% contact with no voids exceeding 4 in² and no voids within 2" of tile corners is required. All corners and edges of stone tiles must be fully supported and contact shall always be 95% in water-susceptible conditions.

5.4.3 Bond Strength. Adequate bond strength may not be achieved between some thinsets and stone materials with compromised bonding surfaces, such as those that have had mesh backing applied, or those that have been sealed or resin-treated on their bonding surface.

5.5 Stone Jointery Alignment influences both performance of the system and aesthetics of the finished installation.

5.5.1 Joint Width Tolerances. The installing contractor is allowed a tolerance of the greater of either 1/16" (1.5 mm) or 25% of the specified joint width when installing stone units. Many existing installations do not comply with this tolerance. The issue can often be remedied by field cutting joints during the restoration process. A wider joint of a uniform dimension will look better than a narrower joint of varied dimensions.

5.5.2 Lippage Tolerances. Stone flooring units are typically supplied with little or no chamfer at their perimeter, and are typically installed with narrower joints than other hard surface flooring products. These factors accentuate the perceived lippage, both from a visual aspect as well as an occupant safety aspect. Lippage tolerance between adjacent units of smooth finished stone flooring units is limited to 1/32" (<1 mm). The easiest way to measure this is with a digital caliper, using 0.031" as the maximum allowable measurement. A common method of field checking for lippage issues is to use a standard plastic credit card as a gauge, since most credit cards measure ±0.030" in thickness.

5.6 Wet Areas. Water infiltration of a stone system is always a concern, particularly if the stone system was not designed for water exposure. Evaluation of a proposed restoration project should include careful study of water control and flow, as well as evidence of water damage. In many cases, water damage repair requires complete removal and replacement of the installation, since the damage may be concealed by several layers of the installation system and is not accessible without excavation.

5.6.1 Water Control Slopes. Water flow is governed by gravity, therefore, sloping of surfaces toward a drain or other path of effective evacuation is a necessity that cannot be compromised. In general, any slope of less than 2% (¼" per foot, or 20 mm per m) is ineffective in achieving positive water flow. Inadequate slope is a condition that cannot be corrected in normal restorative procedures. One must carefully guard against reducing or eliminating existing water control slopes during restorative processes.

5.6.2 Drain Function. If the goal of the sloped surfaces is to direct water to a drain, then achieving that goal is useless unless the drain is fully functional to evacuate the water once it arrives. Drains must be inspected for proper operation, and in particular, subsurface weep holes in the drain assembly must be checked for proper water flow functionality.

5.6.3 Efflorescence is a collection of water-soluble compounds (typically salts) that have been carried to the stone surface by water. Efflorescence deposits typically carry two or more of the following: potassium, sodium, calcium, sulfates, carbonates, bicarbonates, and hydroxides. In some cases, the water

soluble compound can chemically combine with other compounds at the surface, creating a non-water-soluble compound. The key to preventing efflorescence is to control water migration. This may or may not be remediable in some restoration settings. Refer to ASTM C1400, *Standard Guide for Reduction of Efflorescence Potential in New Masonry Walls* for further guidance in this subject.

6.0 EVALUATION OF OCCUPANT AND IN-SERVICE INDUCED CONDITIONS

6.1 Current Maintenance Products and Procedures. A review of the products used and the procedures followed will provide insight into which professional maintenance treatments are to be prescribed for a situation. Some cleaners used by end-users can be harmful to the stone. These products may cause blemishes that require removing (i.e.: acidic cleaners that cause etching, abrasive cleaners that create dullness, oil-based surfactants that cause residue, or wax-based cleaners that cause build up). Knowing which cleaners have been or are being used will help determine the best cleaning techniques available. One challenge in determining these things is that the owner may not be the original owner of the property, and therefore unfamiliar with the entire history of maintenance procedures. A second challenge exists in that most owners do not perform their own maintenance, and are unlikely to be familiar with which products and/or procedures were used by employees or vendors.

6.2 Previous Restoration Processes. A restoration professional is often contacted due to dissatisfaction with work performed by another company. Correction of previous, inappropriate restoration processes will further complicate the task of restoring the stone. In extreme cases, the stone may have been altered beyond a state from which it can effectively be restored. Candid communication with the client is imperative to establish reasonable and attainable expectations for the project's outcome.

6.3 Staining does occur in natural stone. However, the stain potential of natural stone has perhaps been overhyped by marketing claims made by producers of competing materials.

6.3.1 The most important step in stain removal is to identify the staining agent. If this is not achievable by interviewing the building occupants and maintenance staff, one must speculate as to what the staining agent likely could have been based on available information. Information used in this speculation includes the stain color, shape, size, location, frequency, and a list of potential staining agents commonly found near the site of the stain.

6.3.1.1 Food and Beverage Stains include natural pigments (i.e.: fruit, juice, or wine stains), dissolved solids (i.e.: coffee stains), and oil-based stains (i.e.: cooking oils or meat fat stains). Food and beverage products may also be acidic and contribute to etching of calcareous stones.

6.3.1.2 Rust Stains are generated by contact or close proximity to corroding metals. Rust stains are some of the most difficult stains to eradicate. The source of the rust may be concealed by the stone assembly, such as a corroded fastener in substrate layers. In rare cases, the origin of the rust is a metallic-rich mineral within the stone fabric. Rust stains that originate from within or below the stone are generally not removable, since the source of the stain cannot be eliminated.

6.3.1.3 Soiling occurs when dirt mixed with oil or grease scratches, dulls, or discolors porous stone and grout. More porous stones, especially those pores visible to the naked eye (i.e.: limestone & travertine) are most vulnerable to soiling. Aggressive grinding or chemical treatments may be required to restore the stone's color. In extreme cases, soiling may be cost prohibitive to remove.

6.3.1.4 Efflorescence (as discussed in section 5.6.3 above) is always the result of water-soluble compounds carried to the surface by water migration. In most cases, the stain is easily removed, but reoccurrence is a certainty unless the water migration can be arrested.

6.3.1.5 Hazing is most frequently the result of improper or incomplete cleaning after the initial installation. The source of the haze is frequently grout, although it can also be a result of inappropriate or incorrectly applied sealers. Some grouts are so prone to hazing that masking the stone during grouting is the only way to reliably prevent hazing.

6.3.1.6 Grout Stains. All agents that can cause stains in stone will also cause stains in grout. Due to the high porosity of grouts, the same type of stain may penetrate deeper into grout than it will in stone.

6.3.2 Eradication. Nearly all stains can be removed from nearly all stone types. Stain identification is key; after identification, the removal can generally be accomplished quickly and effectively using proven methods. If the origin of the stain is unidentifiable, varying levels of trial and error are usually required.

6.4 Cracks. A crack is a separation of the stone fabric, typically along a grain boundary. Cracks are easily visible. In most situations, they extend through the entire thickness of the material. The crack may be the result of a single occurrence trauma, in which case the crack may be repaired without addressing the cause, as long as there is reasonable confidence that the trauma will not be repeated. When multiple cracking occurs within a stone installation, it is generally the result of a repeated occurrence (i.e.: excessive loading that occurs on a frequent basis), or a design/workmanship deficiency (i.e.: inadequate substrate rigidity or insufficient bedding coverage). In these cases, the cause of the cracking must be identified and corrected prior to the repair of the cracks to avoid repetition of the cracking.

6.4.1 Impact Cracks and/or Chips are caused when a heavy object falls onto the surface or when a heavy object is moved across the floor. In soft stones, the crack may be accompanied by a depression in the stone surface. A white or light crack "stun mark" is often visible in addition to the crack. These types of cracks are typically due to a one-time experience.

6.4.2 Cracks caused by excessive loading. Excessive loads may occur from vehicles, freight delivery dollies, furniture, or other sources. These may be individual or repeat occurrences. If the latter, customer education is paramount to ensure that the practice of excessive loading is discontinued after cracks are repaired.

6.4.3 Cracks caused by building movement. Dynamic building movements can be caused by foundation settling, thermal expansions/contractions, frame deflections, creep, and seismic or wind loads. With the exception of foundation settling, all of these movements should be anticipated, and the failure of the stone installation suggests an improper design.

6.4.4 Cracks due to improper stone installation. Voids in the setting beds, inadequate accommodation for thermal expansion, or failure to use appropriate membranes where required are frequent factors in cracked stone flooring and paving.

6.5 Chips and Spalls are most often caused by impact from dropped objects or rolling loads with hard wheeled equipment. The client needs to understand the cause of the problem to prevent further damage after restoration.

6.6 Etching is a dull whitish mark that results from a chemical reaction between a caustic or acidic liquid and calcium carbonate in stones like limestone, marble, travertine or engineered marble (man-made marble). The depth of etching may vary, from a minor surface attack representing itself as a dull spot on an otherwise glossy surface, to a deep attack with a penetration of a millimeter or more where a textural difference can be felt with one's fingers. Simply cleaning, polishing or resealing will not remove an etch mark. To completely remove the mark, it must be ground to the depth of the damage and refinished.

6.7 Pits and Voids (holes, fissures, chips, cavities, veins, etc.) are common for various stone types. Materials are filled with either resins or cementitious fillers during factory processing, or less frequently, in the field during installation. Over time, the filling can dislodge, requiring replacement during maintenance or restoration. Some stones, notably fleuri cut travertine, will have voids just below the surface of the stone concealed by a thin shell of stone fabric. These voids do not get filled due to their concealment, and are likely to be exposed as the shell of stone covering them is broken during service. Rolling loads with small diameter, hard wheels, and concentrated loads such as spike heeled shoes are common causes of exposing these voids.

6.8 Scratches are commonly caused by grit beneath shoes or furniture, sliding objects, or maintenance equipment with improper, worn, or dirty cleaning heads. The severity of a scratch can be assessed by running one's fingernail across it. If the fingernail pauses or catches in the scratch, it will normally take more aggressive measures to eliminate it, but scratches that do not catch a fingernail are usually minor and can be eliminated with refinishing.

6.8.1 Scratch removal can be accomplished through abrasive grinding, refinishing, and honing. The depth of the scratch determines the coarseness of the initial grit needed to remove it. Trial and error iterations may be required before one knows what starting grit is required. More experienced technicians may intuitively know which grit is needed to start the process.

6.8.2 Pressure Scratches actually damage the body of the stone tile through compression and gouging. These types of scratches are usually permanent, but can be minimized.

6.9 Topical Sealers (also referred to as film-forming sealers and coatings) differ from impregnating (also known as penetrating) and enhancing sealers in that they create a sacrificial coating on the stone's surface as they cure. These products must be stripped before maintenance or restoration attempts. Topical sealers contain waxes, acrylics, urethanes, and other chemicals that are high in solids – therefore, they do not penetrate the pores as effectively as impregnating repellents. Since they do not allow for vapor transmission, moisture can be trapped within the stone. Additional undesirable traits of topical sealers include color change (yellowing), flaking, dirt

attraction, vulnerability to scuffing, frequent reapplication intervals, and labor intensive removal processes.

6.10 Close grout examination is one of the more critical components of the site inspection. Grout is softer, more porous, and less resilient than stone. Grout will frequently show signs of distress before similar signs of distress are noted in the stone components of the installation. Sanded grout is most commonly used when stone tiles have been installed with relatively wide joints (≥3/16"). Since the sand in these grouts is harder than some stone varieties, scratching may have resulted during the grouting process if the stone was not adequately masked. Additional scratching may occur during the restoration processes if the sanded grout is not removed prior to restoration.

7.0 ADDITIONAL CONSIDERATIONS FOR EXTERIOR APPLICATIONS

7.1 Weathering. Weather exposure causes a degradation of the stone surface over time. The degree of weathering is dependent on both the type of stone and the severity of the environment in which it was installed. Weathering includes both physical and chemical attacks. It should be noted that some stones are simply not exterior-worthy materials, and no level of restoration can effectively compensate for an improper selection of a stone material.

7.2 Freeze/thaw issues. In regions where freeze/thaw cycling occurs, weathering can extend beyond cosmetic issues and become structural issues. It is not uncommon for improperly chosen stone species in freeze/thaw environments to degrade beyond a level where restoration is achievable. Horizontal applications are more severely affected than vertical, and grout distress usually prefaces or accompanies stone degradation.

7.3 Water Damage. With or without freeze/thaw cycling, water ponding and water transmission through the stone can break down either the stone fabric, the bedding layers, or both. Excessive water exposure and ponding can result from inadequate drainage, improperly prepared substrates, insufficient or negative slope, ineffective moisture membranes, or ground water transmission. These can result in various issues, such as excessive mineral build up, mildew and moss accumulation, damage from the expansion and contraction of more porous materials, surface exfoliation, and distress in the setting beds and/or grout.

7.4 Saltwater Environments (regions near oceans). Stone applications near saltwater environments may experience additional degradation due to exposure to salts. Salts attack the more porous varieties of stone via a mechanical, rather than chemical mode. When salt is carried in solution by water, it penetrates the pores of the stone. As the water evaporates, the salts recrystallize within the confines of the pores, and this recrystallization pressure is great enough to exfoliate the stone surface. Some sealers have proven to be effective in minimizing the effects of saltwater environments, or at least in retarding the rate of attack.

7.5 Pool/ hot-tub/ resort/ commercial center environments. Exterior applications of natural stone in high traffic and wet environments should be inspected for various post installation treatments that may have been applied to help improve slip resistance. Some stones may have been exposed to treatments such as acid

washing, brushing with abrasive-embedded brushes, or coated with topical finishes containing grit.

8.0 PREVENTING DAMAGE TO ADJACENT SURFACES AND BUILDING CONTENTS

8.1 SURFACES

8.1.1 Adjacent Floors. The maintenance or restoration processes used on natural stone may damage adjacent flooring materials. It is best to anticipate possible damage and take steps to protect these surfaces in the beginning.

8.1.2 Adjacent Rooms and Access Routes. Adjacent rooms are best protected by sealing the halls/doors that lead to them, particularly is any dry working will be performed. Access routes along which materials or equipment will be transported must be fully protected from damage to any of their surfaces.

8.1.3 Baseboards and Walls. If light honing and polishing is the only process needed, then it is only necessary to protect the base during the work. More aggressive restoration techniques, such as lippage removal, require the base to be removed. Depending on the material used for the base, removal and reinstallation may require a different trade be involved to assure quality workmanship results.

8.1.4 Thresholds and Transition Strips. If the threshold is stone, refinishing it should be part of the stone restoration process. If it is of a different material, it may be necessary to replace it after completing the project.

8.2 BUILDING CONTENTS

8.2.1 Furniture and other items. Moving furniture exposes the restoration contractor to additional liability in having his/her crews handle items for which they have not been trained. Moving a piano, for instance, is best handled by those who are professionals in that line of work, and in either case, is likely to result in the owner having to retune the instrument after it is returned to its original position.

8.2.2 Artwork and Antiques. Specialty items, such as artwork and antiques, can be valued at more than what the restoration professional's contract is. It is strongly encouraged that these items be handled by someone who is trained in this activity and specifically insured for the liability incurred.

9.0 UTILITIES AND ACCESS

9.1 Power Source. Prior to preparing an estimate for performing the work, it must be verified that adequate electrical power is available (both required voltage and amperage). If this is not the case, the cost of providing generators must be considered.

9.2 Water Supply. If adequate quality and quantity of water are not available onsite, considerable cost will be encountered in bringing water in from an outside source.

9.3 Water Discharge and Disposal. It must be verified if water discharge and disposal can be accomplished at the site, or if spent water supply and/or slurry needs to be removed from the site.

9.4 Building Occupants. Working in an occupied building may limit the hours available to the restoration contractor, and may also limit to number or size of areas that can be worked on at a time to avoid inconveniencing

building occupants. Early communication with the client is essential in determining a sequence of work areas and establishing an estimated duration for the project.

9.5 Business Schedules. Few business can absorb the cost of suspending their business during restoration. This may mean that the site is available only after hours or weekends. It also may add costs in daily cleanups and removal of equipment to allow the business to continue with only minor interruptions.

9.6 Noise and Dust Restrictions. Clients and neighboring homes or businesses may have legitimate objections to the creation of noise or dust. Any possible restrictions must be researched in advance.

10.0 SERIOUS ISSUES THAT REQUIRE RESEARCH AND MORE EXPERIENCE

10.1 The restoration contractor must be aware of the limits of his/her experience and expertise. Following is a partial list of possible scenarios which may require the consultation of another professional.

10.2 Structural Problems. Any symptom that suggests a structural problem with the building may exist: Extensive cracking, chipping, grout distress, or misalignment may indicate a structural issue with the building foundation or frame. If structural issues are suspected, a consultant who is licensed to practice in that jurisdiction should be involved in the analyses.

10.3 Extensive hollow sounds or adhesion problems. While epoxy injection or grout replacement may be a feasible remedy for limited occurrences, extensive hollow sounds or adhesion failures may represent a systemic problem with the stone installation. In these cases, a consultant experienced in stone tile forensics should be contacted.

10.4 Inadequate structural support and/or building movement issues. If either of these is suspected, a consultant who is licensed to practice in that jurisdiction should be involved in the analyses.

10.5 Substrates with high moisture. Some issues involving substrates with higher moisture levels can be mitigated through the use of a moisture retardant membrane. These barriers have varying levels of effectiveness. The following are some of the issues caused.

10.5.1 Stained Stone. Subsurface water, with or without impurities, will result in surface discoloration or staining of the stone. Removal of this discoloration is an ineffective solution unless the source of the moisture can be eliminated.

10.5.2 Stained Grout. Just as the stone can be stained, the grout will be stained as well, often to a greater degree.

10.5.3 Efflorescence requires the presence of water soluble salts in subsurface levels that are carried to the surface by moisture transmission, where they then recrystallize after the moisture evaporates. Elimination of the moisture source or addition of a barrier to the moisture path are the only permanent solutions.

10.5.4 Moisture Hazing. Generally, a non-stone substance, such as a sealer or resin, is the affected component when hazing at the surface has been triggered by chronic moisture transmission.

10.5.5 Spalling and other factors. This may indicate water migration or higher moisture levels.

RESTORATION AND MAINTENANCE – EQUIPMENT

1.0 INTRODUCTION

1.1 A complete list of equipment used in the process of restoring or maintaining stone would be very extensive. Individual preferences can dictate the need for a wide variety of items. The primary focus of this section is to identify and describe the most common equipment used in restoring, refinishing and maintaining stone.

2.0 FLOOR MACHINES

2.1 Mono-rotary machines are an absolute "must have" for stone restoration companies. Because mono-rotary machines utilize a single, often rigid, drive plate; with the correct abrasive they can be good for edge work on floors. Mono-rotary machines are single disc, single speed machines. The most common type is a 17-inch (430 mm), 180-RPM machine. They weight approximately 85 to 95 lbs (39 to 43 kg). Speed and weight vary with the manufacturer, but "180 RPM mono-rotary" is the general description used for what has become the most commonly used piece of equipment for stone refinishing. These machines can grind, hone, diamond polish, powder polish, clean, texture, or buff, depending on the accessory used.

2.1.1 The speed and weight of the machine can have a significant impact on the efficiency and quality of the finished product. When only diamond honing and refinishing, the optimal accessory is a weighted drive plate. This adds approximately 35 pounds (16 kg) to the machine and speeds up the diamond honing process. When grinding (also referred to as lippage removal), weight should be added to the machine to increase pressure and help speed up the process. Weights vary in size and shape depending on the manufacturer, but they typically mount on top of or around the motor housing. The weight of the machine while grinding should be approximately 200 pounds (90 kg).

2.1.2 Diamond Honing and Polishing. When diamond honing and polishing (220 resin grit through a powder polish), generally the faster the speed of the machine, the more weight you will need. Most floors requiring refinishing are 12 to 18-inch (300 to 450 mm) square tiles. The diamond abrasives need a minimum time on each tile to cut. If the machine is moving too quickly, the abrasives will not make a thorough cut. Adding weight to the top of a faster machine (200 RPM or faster) will add pressure to help the abrasives dig in a little more and speed up the process. On European-style machines, the motors are usually much slower (150 RPM). This eliminates the need for the extra weight, because the diamonds spend more time on each tile. Either configuration can yield the same results.

2.1.3 Mono-rotary machines have many attachments (most commonly, brushes). A light duty nylon brush can be used for scrubbing and rinsing polished stone floors without scratching them. Brush attachments increase in abrasiveness to do heavy scrubbing, texturing and even scarifying. Soft nylon and natural hair pads of all different grits and densities can be fitted on a standard pad driver as well. These can be used to clean, scrub, strip, refinish, polish and hone stone floors.

2.2 Planetary machines can be belt or gear driven. They are much heavier than mono-rotary machines, making them ideal for grinding. They are usually reserved for large residential and commercial jobs. They have a pivoting head, which self-levels as it goes over the floor. This allows the technician to push it like a lawnmower and not have to use his or her body to swing the entire weight of the machine

around. The most common configuration is 17 to 20-inch (430 to 510 mm) diameter with 3 satellite heads.

2.2.1 Active and passive planetary machines. Active planetary machines have "driven" heads. The main head, which is the large diameter, is driven by a belt or gear set. It is directly connected to the 3 planet heads and drives them continuously. Passive planetary machines have non-driven heads. The main head is driven by a belt or gear set, and the planet heads are essentially free to rotate in the direction they are pushed.

2.2.2 Floating and Rigid Heads. Floating heads are ideal for concrete. The heads are firmly attached to the machine, with rubber grommets or a cushion in between. This allows the heads to "float" over the highs and lows of the floor, or over bad lippage on stone tile floors. These types of heads are almost always present on belt-driven machines to help absorb the shock and keep the belt from slipping. Rigid heads are bolted to the machine. They are unforgiving and offer no flexibility. These are usually found on gear driven machines that are built heavy duty use. Rigid heads are used with the intention of planing down the stone floor to a perfectly flat surface. Some planetary machines have the flexibility to switch between the two head configurations by simply bolting the desired set of heads on the machine. These machines are preferred by many due to the flexibility that they offer.

2.3 Drive plates: 10", 17", 22", (250, 430, 560 mm) and larger

2.3.1 Steel drive plates usually feature a hook and loop attachment configuration on the bottom that are used to attach various diamond and other abrasive pads. This style is designed to withstand adding weight to the machine to give the abrasive more pressure and contact with the floor. Steel drive plates also feature a low center of gravity to speed up production. The plate usually weighs approximately 35 pounds (16 kg) and normally requires 2 hands to remove or install.

2.3.2 Lightweight drive plates. Nylon or plastic drive plates are classified as lightweight. This style is used for light-duty scrubbing and buffing and sometimes light refinishing or polishing. Lightweight drive plates only weigh a few pounds and are easy to remove or install with one hand. The ease of changing out the drive plate results in significant time savings.

3.0 HANDHELD MACHINES

3.1 Variable speed angle handheld polishers come in multiple varieties. For restoration and refinishing, it is best to own a variable speed polisher. The most commonly recommended variable handheld polisher is typically referred to as a 7-inch (180 mm) polisher. This polisher is designed to accept 7-inch (180 mm) grinding, honing, and polishing abrasives. The 7-inch (180 mm) polisher is larger than the machine referred to as a grinder. The motor is larger and more powerful. A 7-inch (180 mm) polisher usually features variable speed control. The ideal speeds start as low as 600 RPM. Most stone refinishing jobs can be completed under 1,000 RPM. The use of a slower speed creates less mess. Some restoration technicians prefer the 7-inch (180 mm) polisher because of the larger motor so that they can apply additional pressure to the grinder by leaning on the machine without the motor stalling out.

3.2 Pad drivers: 3, 4, 5 and 7-inch (75, 100, 125, and 180 mm). Pad drivers, also referred to as backer pads, are the connection between the tool and the abrasive. They attach to the angle grinder or polisher and provide a surface or mechanism for attaching the abrasive. They are available in several configurations.

3.2.1 Rigid aluminum pad drivers are the most rigid type available and are ideal for

refinishing slab counters. A rigid abrasive and pad driver will help the technician achieve a flatter finished surface, which is closer to the original factory polish.

3.2.2 Rigid composite pad drivers have the same features as aluminum pad drivers, but have a tendency to lose their perfectly flat profile or warp after extended time in service.

3.2.3 Flexible pad drivers are made of hard rubber and will flex a moderate amount when under pressure. These are generally used for fabrication when there is a contour or shape that needs to be polished. For restoration, these are great for working in showers or on tile countertops where rigid pad drivers might cause the abrasive to bounce from tile to tile.

3.2.4 Super flexible pad drivers are made from soft rubber and can be bent with minimal force. They are designed for extreme contours. Many restoration technicians use these with dry abrasives for quick touch ups on the edge of a low tile where it meets an adjoining high tile. As with other flexible pad drivers, these can make quick work of shower and tile countertop restoration because of the ability to allow abrasives to make contact with stone in low areas. Super flexible pad drivers can also be used in repairing and refinishing complex edges on stone tops.

3.2.5 Free spinning pad drivers are relatively new to the industry. The main drive plate is aluminum and fits onto the arbor of the machine. It is surrounded by a second plate, which acts as a shell, and is isolated by a bearing in between the two. When the outside plate hits glass, metal, or any other delicate surface, it stops spinning, but allows the inner drive plate with the abrasive attached to keep spinning. These are convenient in showers and when working around metal and glass edges, since they minimize potential damage to adjacent materials.

4.0 ABRASIVES

4.1 Abrasives are used to grind, hone, and polish stone for the purpose of restoring or refinishing. As stone wears, it become necessary to remove light or deep scratches, fill in voids or cracks with a patching material, and sometimes taper a surface to improve a transition. Each of these processes requires the use of abrasives. For scratch removal, the abrasive is used to grind down the surrounding material to the same plane as the low point of the scratch and continue using consecutively finer grit abrasives until the original finish is matched. Voids or cracks are repaired with a patching material. Abrasives are commonly used to smooth out the patched area and blend it to the same plane and finish as the surrounding stone. Transitions are needed when a stone floor is on a higher plane than an adjacent floor or when tiles have been installed with excessive lippage.

4.2 Silicon carbide and diamond are the most commonly used abrasive types for stone refinishing and restoration. Both are hard enough to abrade the hardest stone, but diamond, being the hardest natural substance in the world, will cut noticeably faster when working with very hard stone materials. The cost of most diamond abrasives is usually higher than silicon carbide. It is important, however, to include the costs of labor and machine hours in addition to abrasive costs when estimating total actual cost. In some cases, a diamond abrasive may cut too fast for the task. Keeping both types of abrasive in inventory is the solution that works best for most companies. Either abrasive can be used for the full range of refinishing or restoration tasks. These abrasives are available in many varieties as outlined in the following sections.

4.3 Bricks. 14 cm (5½") bricks are used in a sweeping rotary motion instead of a straight rotary motion. Because of the compound movement and features of most floor machines, 14 cm (5½") abrasives are not used for refinishing and restoration. The most

common abrasive bricks for stone refinishing and restoration are frankfurt segments. Frankfurt segments are a wedge-style brick designed to fit in to a wedge-shape shoe or opening connected to a drive plate. Frankfurt bricks, often referred to as frankfurt segments, are available in multiple abrasive types and bonds.

4.3.1 Frankfurt does not relate to a specific bond, but describes the shape and size of an abrasive type. The abrasive are attached to the drive plate by wedging them into a holder (sometimes referred to as a shoe). It is a widely recognized abrasive used on the more traditional style grinding machines and slab polishers from Europe. Frankfurt abrasives are typically used on flat floors or terrazzo only, and are generally not used on tile floors with lippage present. Some designs allow the abrasive to grind lippage flat. The brick-style frankfurt segments are inexpensive and wear out quickly, but provide phenomenal results. Onsite results with these segments is very close to that of the factory process. Because of their rigid design, there is absolutely no flexibility with these abrasives. This design ensures a high quality finished product. The floor machines designed for these frankfurt segments usually are more complicated to operate than more commonly found floor machines.

4.3.2 Magnesite bond frankfurt segments are typically used after sintered metal abrasives. They are structurally unstable and can break easily. The instability of this abrasive bond is two-fold. First, they are a poured brick abrasive, so dropping them will usually result in chipping or breaking. Second, sometimes the mixture is not properly prepared and the abrasives can shatter with the temperature change caused by getting them wet. Magnesite abrasive bricks, whether frankfurt or another type, wear down very quickly compared to other bonds. They are effective in removing heavy scratches from the lippage removal abrasives and leave a nice finish for the next step.

4.3.3 Synthetic bond frankfurt segments are similar to magnesite bond segments, but made from synthetic material. This makes them similar to resin bond abrasives. Synthetic bond abrasives can break fairly easily, but not as easily as magnesite bond. Using more forgiving raw materials creates the increased stability over magnesite. When finishing MTL floors and terrazzo, the synthetic tools will usually carry the finishing process to the end and complete the final preparation for the polishing step.

4.3.4 Hard synthetic bond frankfurt segments are very hard and can be used on concrete, granite, quartz, and quartzite surfaces. This abrasive bond is typically used after regular synthetic abrasives and continued to the end of surface preparation, or for hard materials only. Using a hard synthetic bond frankfurt segment will produce clarity that is ready for polishing.

4.3.5 Polishing and cleaning brick. The polishing (or cleaning) step is essentially an MTL (marble/limestone/travertine) polishing powder product compressed into a brick. There are usually two products and steps involved. The final frankfurt segment is usually made of pure oxalic acid. Many stone processing factories use oxalic acid during the final polishing step. When viewing MTL slabs in direct sunlight, faint swirl scratches can sometimes be detected. The swirl marks are a result of the final step being performed with a fixed abrasive and not a polishing powder.

4.4 Plugs are often referred to as terrazzo plugs because they are commonly used during the initial grinding process for terrazzo. The plugs are held in place using specially designed drive plates. Terrazzo plugs are usually made as a sintered metal bond diamond abrasive.

4.5 Abrasive pads are commonly referred to as discs or wheels because of their circular shape. Square or rectangular pads are also available for sanding blocks and orbital style sanders. The most common shape is

round and the most common sizes are 3, 4 and 5-inch (75, 100, and 125 mm). Pads are available in multiple bonds using diamond or silicon carbide as the abrasive type. Different manufacturers attempt to gain customer loyalty by using unique features like innovative bonds, grit size, segment design, tapered edges and others. A sintered metal bond abrasive used for more aggressive cutting is normally referred to as a lippage removal pad. These aggressive discs are typically mechanically attached directly to the tool or drive plate floor machines and handheld polishers. If using a handheld polisher to complete the outer edges of the floor near the walls, then a cup wheel would be used. A cup wheel is the handheld equivalent to lippage discs for floor machines. For lighter pads, the hook and loop system usually works well and helps to speed up the process of changing grits. Pads are the most common abrasive variety.

4.5.1 Fiber pads are not typically used for heavy grinding: only for honing and polishing. They are circular in shape, but the sizes used are typically much larger than the small 3, 4 or 5-inch (75, 100, and 125 mm) abrasive pads mentioned earlier. Fiber pads are woven, and some manufacturers use this weave to hold or suspend abrasive powders. Other manufacturers will lightly bond the woven pad with abrasives. A major advantage of fiber pads is that they will conform to low areas of the floor to abrade the entire floor. This is one of the most common varieties for refinishing.

4.5.2 Synthetic fiber pads are synthetic buffing pads that have abrasive grit incorporated into the pad. During the manufacturing process, these pads are sprayed with an abrasive impregnated liquid compound. This process allows the mixture to penetrate deep within the fibers of the pad. The result is abrasive content throughout the pad, which extends the service life of the pad. The abrasive life of these pads is similar to that of a thick resin diamond. When not in use, they should be stored properly to protect them from contamination from dirt or other foreign matter.

4.5.2.1 Pros of synthetic fiber pads.

- Cost effective
- Easy to use
- Very flexible; allows the abrasive to get in and out of low areas and lippage
- Work quickly
- Can achieve multiple levels of honed finishes, and in some cases, polishes, without leaving scratches or trailing marks

4.5.2.2 Cons of synthetic fiber pads.

- Cannot provide a flat for when used as a set (tend to texture the stone)
- Will not remove moderate to heavy scratches
- Can get damaged easily on stone tiles with heavy lippage

4.5.3 Dot pads. "Dot pad" is a generic name given to a certain type of fiber abrasive pad. These utilize a 17" (430 mm) synthetic fiber pad like described above but there are resin dots or diamond abrasive embedded resin sections permanently affixed to them. This variety has an advantage over the plain synthetic fiber pads because they contain hard resin dots, which allows them to work more quickly and provide a superior finish.

4.5.3.1 Pros of dot pads.

- Work quickly; provide a similar finish to traditional resin diamond pads
- Easy to work with
- Flexible and easy to navigate through lippage and other uneven areas
- Does not need to be protected as much as other synthetic fiber pads

4.5.3.2 Cons of dot pads.

- Expensive when compared to traditional diamond abrasive pads
- Fiber pad can get damaged before using the entire life of the pad

4.6 Abrasive bonds. The bond used for the abrasive can vary based on the abrasive type, grit, and task being performed. The bond holds the abrasive in place until it is used up. Depending on the task at hand and desired finish, different types of abrasives and bonds may be used. If the task is to remove heavy material stock, then a more durable bond and coarser abrasive is desired. If the task is to simply clean the surface, then a lighter bond and finer abrasive is desired. There are many different sizes, shapes, and prices for abrasives. With experience, each technician will develop a preference for different tasks.

4.6.1 Resin bond abrasives are by far the most commonly used and most widely recognized type. They are available in several shapes and sizes. Resin bond abrasives can start as low as 30-grit and go as high as 8,500-grit. This type is most commonly used for light refinishing to remove minor scratches, etch marks and to prepare for a honed or polished finish. Resin abrasives are produced in bonds specific for different stones and hardness. The general rule is that a soft resin is used for hard stones and a hard resin is used for soft stones. If a soft-bonded granite resin abrasive is used on marble, it will wear at an accelerated rate. The same scenario applies for using marble abrasives on granite. The resin needs to wear at the correct ratio in order to allow exposure to the diamond abrasive without causing the resin to form a coating over the abrasive. Soft stone attacks the soft bond in the abrasives, causing the bond to wear faster and lose diamond or abrasive particles. Resin bond abrasives come in rigid, semi-flexible, and flexible variations.

4.6.1.1 Rigid, puck style abrasives are usually used for flat floors. This type is also used after a floor has been ground flat, like in lippage removal. The rigid style will limit the amount of fluctuation in the flat appearance of the finished product by not allowing the tools to flex and dig into the stone.

4.6.1.2 Semi-flexible. For stone refinishing and restoration, semi-flexible abrasive pads are the most common flexible abrasives. Thick or thin, they all share a layer of foam or neoprene between the actual pad and the Velcro surface. This allows for some rigidity, but also some bend if the diamonds hit a sharp edge or uneven surface. If the flexibility is not there, the resin segments can break off. This type can be used on anything from a perfectly flat floor to a floor with moderate lippage. The flexibility of these pads will allow them to act as shock absorbers and ride up over the uneven tiles.

4.6.1.3 Flexible abrasive pads are the type most commonly used in stone fabrication shops, in 3" to 5" (75 to 125 mm) diameter. These are used on handheld machines to polish edges and tops of counters and other stone applications. Their flexibility allows the fabricator to avoid angling off a convex edge detail. A few companies make these in 3" (75 mm) diameter, which can be used on a floor machine. Foam risers almost always accompany this type of abrasive. The risers are very forgiving; almost spongy. They attach directly to the drive plate, and the abrasive pads attach to the riser, adding flexibility. This setup is used on floors with light to moderate lippage. The weight of the machine will compress the riser, allowing the edge of the pad to flex or curl slightly. This setup ensures that the abrasive reaches the low areas of the uneven tiles and help to eliminate picture framing.[1]

4.6.2 Marble bond resin diamond abrasive pads are designed specifically to be used on MTL surfaces. Marble abrasive pads can be used on these floor types, although some manufacturers produce pads specifically for each type. As mentioned previously in this chapter, a hard resin is more effective for soft stones like MTLs. Although not usually recommended, marble abrasives can also be used for concrete polishing. Many marble bond

[1] "Picture framing" is a term used in the stone restoration industry meaning that the low section of a tile are not abraded when working on a floor that is not completely flat.

abrasives will work quite well and provide reasonable service life when used on residential-type concrete. Other abrasives suited for concrete will be discussed throughout this chapter.

4.6.3 Granite bond resin diamond abrasive pads are designed to achieve the highest possible clarity before the final polishing step. Granite is very hard compared to MTL stones, so time becomes a factor. The higher quality the granite resin pad, the faster you will get to the polishing step. Also, the better quality finish the resin pads achieve, the less work is needed on the final polishing step. Due to the methods by which they are produced, higher quality abrasives will typically result in a premium price.

4.6.4 Phenolic bond resin diamond abrasive pads are used to withstand heat and friction. These abrasives are usually used for dry honing and polishing. Because of the heat generated from the friction during this process, the resin was designed to withstand the temperature without burning or glazing over. Most other abrasive bonds are damaged when exposed to the same conditions. Phenolic resins are made mostly for concrete and are classified as a resin or a resin-hybrid pad.

4.6.5 Hybrid bond diamond abrasive pads are relatively new. These utilize a traditional resin mixed with a soft metal like copper to create a pad that is extremely effective and forgiving. They are designed to remove material quickly and leave a smooth finish, so the next finer grit is easier transitioned. Hybrid pads can be used as transition pads when working your way out of the metal grinding stages into the resin honing stage. Hybrid bond abrasives will remove the heavy scratches of the metal lippage discs and leave a finish smooth enough to be picked up by the next resin step. They are a very helpful addition to the toolbox.

4.6.6 Metal bond diamond abrasives are heavy duty and used for coarse or initial grinding, also referred to as lippage or severe damage removal. They do the most work, take the most abuse, and produce the quickest results. Metal bond abrasives are mainly used for removing heavy scratches. They can also be used to remove chemical damage on terrazzo and concrete, remove lippage from uneven tiles, or remove a sizable amount of material. There are several different types of metal bonds that serve different purposes. Some of these are as thin as 1 mm (0.040") and are available up to 12 mm (½"). Metal bond abrasives can start as low as 6-grit and go all the way up to 1200-grit. The bond can greatly affect the finish. A metal bond 200-grit abrasive is much more aggressive than a resin bond 200-grit abrasive. To remove the scratch pattern of a metal bond abrasive quickly, it is necessary to use a much lower grit resin bond abrasive.

4.6.7 Sintered bond. Sintering is one of the most commonly used methods for assembling diamond abrasives in our industry. Bridge saw blades and most grinder blades use a sintered metal bond. When inspected closely, small diamond segments protruding from the metal surface can be seen, often with directional streaks trailing them. These appear almost like a comet and a tail. Sintering assembles abrasives in a manner that holds the diamonds within the body of the segment. As the abrasive or segment is used, the metal wears away, exposing new edges of the diamonds. This can be compared to a self-sharpening blade. However, if the metal used for the bond and the stone are not compatible, the metal will glaze over the diamond. It will essentially cover the diamond and slow down the process until it can be dressed to expose the diamond or cutting abrasive. This bond type is designed for rapid removal of stone. It will leave moderate to heavy scratches compared to other bonds. The most common application in the restoration industry for this bond is for lippage removal. Because of the materials used to make the sintered discs, they are the usually the most expensive, but also have the longest life span. Terrazzo plugs are made of sintered segments.

4.6.8 Copper bond. Copper diamond abrasive pads are also sintered, but significantly different. They are made with a softer lighter copper material as opposed to the heavier metal that is used for standard sintered tools. This bond is not recommended for the initial step in lippage removal because it will wear down very quickly and will not cut as fast. The copper bond was developed as a transitional bond to bridge the gap between metal and resin bonds. They offer the best of both worlds: heavy scratch removal while leaving a smooth finish to facilitate the transition into the resin steps. Copper bonds work well for cleaning up traffic worn or chemically damaged surfaces to prepare for refinishing. Copper bond discs are a "must-have" for the toolbox.

4.6.9 Vacuum brazed diamond abrasives are the most aggressive metals used for floor refinishing. This type of bond abrasive will cut very fast and leave heavy scratch marks. Unlike sintered diamond bonds, vacuum brazed abrasives are attached to the outermost surface, exposing all the diamonds on the face. This bond does not have the life span of sintered metals, but is less expensive. When the goal is to remove material as fast as possible, vacuum brazed is the normally the best choice. Because of their aggressive nature, they are not typically used on MTLs. Vacuum brazed diamonds are much thinner and lighter than sintered discs and will most likely have a convex shape to the face to allow for a smooth transition over uneven tiles.

4.6.10 Electroplated bonds are similar to vacuum brazed bond abrasives in appearance. These bonds are easily mistaken for each other. Electroplating is a coating, while vacuum brazing is a type of weld attachment. Electroplated diamonds are the thinnest in the metal group at 1 to 2mm thick (0.040 to 0.080"). The diamonds appear to be on the surface like brazed metals, but are attached through a different process. Electroplated bond abrasives are the least expensive of the metal group and also have the shortest lifespan. Similar to vacuum brazed abrasives, electroplated abrasives are extremely aggressive, but leave a much smoother finish when compared grit-to-grit. They can be used for quick repairs of heavily damaged material or as a transitional grit between sintered and resin abrasives. These abrasives can be used wet or dry, and excel on MTL stones. It is also possible to use them on concrete. However, electroplated bond abrasives do not hold up through use on harder stones, such as granite.

5.0 POLISHING COMPOUNDS

5.1 Marble polishing powders have revolutionized the refinishing and restoration industry by increasing production and improving quality. There are so many marble polishing powders on the market today it can be difficult to distinguish individual products. There are "hot" powders, "cold" powders, and many in between. For the purpose of this discussion, "hot" or "cold" refers not to temperature, but to acid content. Acids found in marble polishing powders vary, but a hot powder contains a higher percentage of acid. These tend to polish more quickly, but the technician risks over-use, which can result in a poor finish. Overuse of hot powders will result in an orange peel look on the stone. Cold powders have a lower acid content and take a little more time to work, but they provide better protection against overuse. Most polishing powders on the market work to some extent on most marbles. However, some marble will react differently and require the use of a different mix of acids. Each technician will develop the sense of what mixture is needed.

5.1.1 Types of marble polishing powders

5.1.1.1 Wet polishing powders are designed to be used with water. Water is added and worked into an area to generate a slurry. The polishing process is completed while the mixture is still wet, then the slurry is removed with a wet vacuum.

5.1.1.2 Wet-to-dry polishing powders are usually very "hot," meaning that they contain a lot of acid and work very quickly. Using this type of polishing powder means that the process is started either in a wet slurry, or with just a mist of water and worked until completely dry. The technician will get a feel for how much water is needed through experience. It is better to achieve the polish in stages than to risk over-polishing the stone and resulting in an orange peel appearance. Using wet-to-dry powders eliminates the need to vacuum after polishing each section. This process requires the use of more heavy-duty machinery, because of the significant friction produced during their use.

5.1.2 Ingredients for marble polishing powders. MTLs are calcium-carbonate based stones that react to most acids. Every marble polishing powder includes an acid and an abrasive, along with other proprietary ingredients.

5.1.2.1 Oxalic acid breaks down the surface of the stone to allow the abrasives to do the work. It activates when water is added.

5.1.2.2 Shellac is a type of resin that naturally occurs on trees. It is pulverized into a powder and added to the compound. The heat created by the friction from the polishing process melts the resin and deposits it into the micro-pores of the stone. It hardens immediately after cooling and helps give the floor a more uniform look and increases gloss.
Shellac is not often used in more recent powders to enter the market.

5.1.2.3 Aluminum oxide is a manufactured, inert powder. It is a pure abrasive and is used to achieve final polish. It is considered a super fine grit, although it is unclear just how fine it is, and works to smooth out the surface of the stone while it is in a vulnerable state from the oxalic acid. Aluminum oxide is harder than granite.

5.1.3 Characteristics of polishing powders. Polishing powders vary significantly among products. The amount of water and pads used, speed and weight of the machine (including weights added), and how long each section is polished all have an impact on the final polish.

5.1.3.1 The amount of water used can make the biggest difference when polishing. Using less water creates a more concentrated, or potent, powder. Using more water will dilute the powder, making it less effective. "Hotter" (more acidic) powders can be diluted down more for sensitive stones. Using too much powder and not enough water will damage the stone's finish.

5.1.3.2 Type of pad. The two major types of pads are white nylon polishing pads and hog's hair polishing pads.

5.1.3.2.1 White nylon polishing pads are dense and soft to the touch, with multiple fibers intertwined into the same area. Due to their density, they tend to hold more of the polishing compound on the immediate surface. This allows the compound to do all the work. There are pros and cons of this, depending on what type of stone is being worked on and what type of equipment is being used.

5.1.3.2.2 Hog's hair polishing pads are much coarser and less dense than white nylon polishing pads. The fibers are a mix of natural boar and synthetic. The fibers are thicker and the pad is less dense. Due to the lack of density, more of the polish is absorbed by the pad, leaving less on the contact surface. This adds a new dimension to the polishing process.

5.1.3.3 The amount of weight needed depends on the material more than the powder. Some materials "burn" easier than others. It is very similar to polishing automotive paint. The harder you push, the more friction is generated. Friction translates to heat and can orange peel—leaving a textured look to the finish. The experienced

technician will get a feeling for when adding weight is needed.

5.1.3.4 Speed has essentially the same effect as weight. More speed equals more friction, which in turn makes more heat. Increased speed also makes more mess, causing the slurry to travel further.

5.1.3.5 Time. How long each section is worked with a polishing powder can have a very big impact on the quality of the final polish. On marble, working a section too long with an acidic polishing powder can cause orange peel or etching. It is better to perform this task in stages until the technician is familiar with the reaction between the polishing powder and the marble. For granite, the overuse of polishing powders is not usually a problem, although it can leave the stone hazy or dull.

5.2 Polishing pastes are usually polishing powders in a paste form. They are already "active," containing their own liquid. Water can be added if the paste dries out or if a more diluted slurry is desired. Pastes are generally grittier than powders. The grit or chunks that can be seen and felt are oxalic acid chunks. These get absorbed into the polishing pad and act to further polish the material. Although it may feel like the paste will scratch the stone, it has no effect on the finished product. Oxalic acid is water-soluble and slowly dissolves while being used.

5.3 Liquid polishes, also known as crystallizers, are misted on the surface and buffed with a mono-rotary machine with heavy weight and a steel wool pad until dry. The liquid provides a chemical bond with the stone. The steel wool heats up the liquid and surface and allows it to harden as it fills in the scratches and pores of the stone. This process is used mostly in commercial maintenance settings, although it is not designed to be a maintenance product. Liquid polishes work differently than polishing powders and pastes. Polishing powders and pastes usually contain a fine abrasive and a mild acid which do not coat the material but act more like a super fine abrasive to enhance the reflective finish of the stone.

5.4 Honing powders can be used either for minor damage removal or finishing. Most honing powders are between 120 and 800 grit, depending on the manufacturer. Honing powders are made from aluminum oxide. These powders are used with water to create a slurry and are used to put a final honed finish on almost any material. Usually the stone will be refinished or the polish will be broken with diamond abrasives, then the honing powder will be used as a final step. Because the powder is loose, as opposed to a fixed abrasive, it leaves no detectable swirls or tool marks.

6.0 ADDITIONAL TOOLS AND SUPPLIES

6.1 Miscellaneous honing/polishing pads used with compounds and powders. Steel wool pads are used mostly when crystallizing. Champagne pads are used for honing and/or polishing. Black pads are used for stripping coatings. Tampico brushes are used for polishing.

6.2 Cleaners

6.2.1 Neutral cleaners have a pH of 7. They are neither acidic nor alkaline. Neutral cleaners are used for light washing, rinsing, cleaning and neutralizing after polishing or using an acid based cleaner. Homeowners are advised to use these.

6.2.2 Alkaline cleaners are at the top of the pH scale, with a pH typically between 12 and 14, depending on the manufacturer. Cleaners with a pH between 13 and 14 pH can damage polished MTL floors if not correctly diluted. This type of cleaner is usually used as a degreaser or to clean heavily soiled floors and grout. Alkaline cleaners are generally good at breaking down soap scum and weak waxes.

They can also be used to neutralize acidic cleaners.

6.2.3 Acidic cleaners are only used on natural stone when absolutely necessary and should be avoided inside the home if possible. Most acidic cleaners usually have a pH between 4 and 2, depending on the acid used. The most common acids used are phosphoric, hydrochloric and sulfuric. These cleaners are usually used for removing mineral and hard water deposits, cleaning excessively dirty grout, and removing rust stains. Only use acidic cleaners when other options have been exhausted.

6.3 Wet/dry vacuums perform a very necessary function. It would be difficult to refinish or restore stone without the ability to remove the dirt and debris or slurry created that could interfere with honing and polishing.

6.4 Antiquing Brushes. Antique finishes have become popular in recent years. The brushes used to achieve this finish come in several configurations. Antique finishes are usually presented in a matte or non-reflective range. When a more reflective finish is desired, each progressive grit will not reach as far into the lower areas of the stone. This results in only the highest points of the stone having a shine, giving it an antiqued or worn look.

6.4.1 Diamond wire brushes are by far the most aggressive. These brushes are made of relatively thick, hard bristles impregnated with diamond abrasives. Diamond wire brushes usually start at 36-grit and go up to 600-grit. They are usually used to remove the polish from granite and give it the initial antiqued or textured finish.

6.4.2 Rubber bristle brushes are produced featuring several different thicknesses and layers of bristles. There are different bristles and features designed for different grits. Lower grits will typically have very thin, concentrated bristles, typically used to reach the softer, lower textured areas of the stone. Most grits feature thicker, stiffer rubber bristles designed to reach most areas, but not the lowest sections of the stone. Higher grits feature larger, wider rubber bristles designed to skim across only the top sections of the texture. The larger, wider bristles are designed to put a shine on the peaks of the texture.

6.4.3 Carbide bristle brushes are made using silicon carbide abrasives. Thin, wiry bristles are impregnated with the abrasive. Carbide bristle brushes can be used for antiquing, light texturing, or just for scrubbing rough surfaces.

NOTES:

RESTORATION AND MAINTENANCE – REPAIRS

1.0 INTRODUCTION

1.1 Repairing stone is a normal part of restoration. Many stones, especially very decorative varieties, have natural voids and weaknesses. Filling these voids and reinforcing these weaknesses is normally started early in the processing phase at the factory level. The material is quarried in a block form; it is then transported to a factory for processing into useable products such as slabs or tile. After cutting these blocks into slabs, many materials are filled, repaired, or reinforced using a variety of methods. Once the initial repair or reinforcement is done, the product is ground down to start the finishing process. After the initial grinding step, it is sometimes necessary to touch up the repair before proceeding to finalize the desired finish for the stone.

1.2 Many installers will cull pieces from the lot during installation. In some cases, the quantity ordered is insufficient if extensive culling is required. The bid process can be very competitive, so extra pieces are a luxury that cannot always be afforded in order to win the bid. After installation, the existing repairs may need to be retouched. Often, the processing factory performs a generic repair that may work in some areas of the stone but is very noticeable in other areas. The factory doesn't always know the intended application of the product when they are producing it, so sometimes an inappropriate patching material is used (for example a polyester resin when the material will be used for an exterior application). In that case, the patch needs to be removed and replaced with a more suitable patching material. Other times repairs need to be made due to everyday use, faulty installation products or methods, structure settlement or movement, and occasionally abuse or failure to maintain. Post-installation repairs will be the primary focus of this section.

2.0 PRODUCTS AND SUPPLIES

2.1 Adhesives and Patching Materials. Before beginning the discussion of techniques, patching material selection will be discussed. No matter how good a repair looks cosmetically, if the wrong material was used it will not perform and must be redone. The most reliable product must be used to ensure the longevity of the repair.

2.1.1 Adhesives and patching materials are used to adhere broken pieces back together (also known as "sticking"), fill pits or voids (either natural or created by movement) and reinforce weaker areas of the stone. The materials that are most common in the stone industry are polyester, acrylic, epoxy, urethane and cyanoacrylate (also known as "CA").

2.1.2 Most of these materials are available in different viscosities for different applications. When trying to penetrate micro-fissures, the least viscous or thinnest product would be selected for this task. Many manufacturers refer to this as a "penetrant" or "super penetrant." For sticking loose pieces of stone together, a slightly thicker product would typically be used. This product is often referred to as "flowing." Filling holes and voids would require thickest product. Most manufacturers call this a "knife grade." Many of the products are two-part. Part one is typically referred to as the adhesive or resin and part two is typically referred to as the catalyst, hardener or curing agent. One product category requires no curing agent because the curing process is activated by exposure to air. Each product category will be discussed in further detail throughout the section.

2.2 Colors and tints can be added to adhesives and patching materials to provide a better cosmetic blend between the repair and

the surrounding stone. Follow the manufacturer's recommendation for use. Generally, if the missing sections of stone can be adhered back in to place, it will be a better repair than if patching material is substituted for the missing stone.

2.3 The basics of adhesives and patching materials are the same. One main difference is that most fast curing two-part products are mixed with colors or tints before the curing agent is added. Resin and curing agent for slower curing two-part products are often mixed together before the color is added. There can be differences even within adhesive categories because different manufacturers may use different ingredients to provide unique benefits. It is very important in any two-part product to mix the products according to the manufacturer's instructions.

2.3.1 CA glue. There is only one product listed below that is not categorized as a two-part adhesive or patching material. It is commonly known in the industry as CA glue or cyanoacrylate. This product can be used with an accelerating agent. The use of accelerators can expedite the already fast curing time. If using an accelerator, do not use an excessive amount on lightly colored stones. Overuse of accelerators is a common cause of staining in these stones. Accelerators are not necessary for the adhesive to cure. It is important to be familiar with the products before using something that may cause additional problems.

2.3.2 Volatile Organic Compounds (VOCs) can have a big impact on the selection of the material to be used for a repair. VOCs are typically measured in two main ways. VOCs as supplied is the measurement right out of the container. This value is typically higher because of the product concentration in the container. VOCs as applied is the measurement upon activation of the product. Once the product is activated the VOCs get consumed and there are fewer emitted in to the air. For projects requiring VOCs below a certain value it is important to know which VOC value is being referenced and how the measurement should be taken. Be sure to allow for proper ventilation and use the correct Personal Protective Equipment (PPE) while using adhesives or patching materials.

3.0 CHARACTERISTICS OF ADHESIVES AND PATCHING MATERIALS

3.1 Similar characteristics exist among the available adhesives and patching materials, although each variety has some distinct features which are described below.

3.2 Polyesters.

3.2.1 Polyesters resins are, at this time, the most popular patching material used in the stone industry. Some of the reasons for this popularity are assumed to be modest cost, rapid cure time, bond strength and familiarity in working with the material.

3.2.2 Polyester based adhesives are fast curing, two-part products, so colors or tints can be added to the resin before the hardener to achieve a visually better repair.

3.2.3 Using more catalyst can accelerate the cure rate, but there is a risk of a weaker and more brittle bond. The manufacturer's instructions for mixing should be followed closely for best performance.

3.2.4 Polyester adhesives are commonly used in countertop seams because movement usually results only in a failure in the adhesive without damage to the stone.

3.2.5 Polyester resin can be sanded and polished to a reasonably high shine, allowing it to better blend with polished stone.

3.3 Acrylics.

3.3.1 Acrylics became popular for use as penetrants and are considered among the least

viscous among the categories. Penetrants are commonly used to penetrate micro-fissures or very minute openings. Fissures are natural separations in stone and are very common among the most decorative varieties of natural stone. The next feature that helped this category gain popularity was the availability as a "water-clear" product. Many repairs are made better when the repair is "water-clear."

3.3.2 Curing agents are typically used on acrylics, and are usually liquid. This is done to keep the product clearer and less viscous.

3.3.3 Acrylics can be sanded and polished to a reasonably high shine, allowing it to better blend with polished stone.

3.4 Epoxy.

3.4.1 **Epoxies** became popular because of their superior bond strength when compared to other adhesives categories. Many people hesitate to use epoxies in some situations because of their lengthy cure time and increased cost. Epoxy is most associated for causing stains when used with white marble. Epoxies are most commonly mixed with other categories to make hybrid adhesives.

3.4.2 Staining can be a problem when using epoxy with white marble or other light colored porous stone. Be careful to test any adhesive for use with light colored marble, limestone and granite.

3.4.3 UV exposure can attack the look of epoxies, but the strength of bond is relatively unaffected. This makes it one of the few products that can be suitable for exterior applications.

3.4.4 The high strength and ductile properties of epoxy make it the preferred adhesive for use in structurally significant roles.

3.4.5 The curing of an epoxy is an exothermic chemical reaction, meaning it produces heat. Because of this, repairs requiring large amounts of adhesive may have to be done in steps to prevent excessive heat generation.

3.4.6 Epoxies are available in multiple viscosities: from penetrants to knife grade.

3.5 Urethane.

3.5.1 Urethane adhesives are the newest class of stone adhesives. The price of this category is relatively high. Urethane was developed to fill the gaps of the other product categories. Urethane has excellent clarity and its bond strength is close to the strength of epoxies.

3.5.2 Urethane is a slow cure, two-part adhesives. Using an accelerator can speed up the cure rate without the risk of a weaker or more brittle bond. Follow the manufacturer's instructions for mixing for best performance.

3.5.3 Urethane is used for many projects, including patching or filling voids in stone and bonding pieces of stone together. Urethane is also used as a caulk-like material for expansion joints and exterior joints.

3.5.4 The stone must be dry before using urethane adhesives, but this product can withstand exposure to moisture after curing.

3.5.5 The mixing ratio and thorough mixing are both critical to ensure complete polymerization when using urethanes.

3.6 Cyanoacrylate (CA) glues.

3.6.1 CA glues are gaining popularity in the stone industry because of the different viscosities available and the rapid cure time. CA glues are typically sold in small units because of their relatively short shelf life. They are often used to fill voids and micro-fissures. Because it is a fast curing product that rapidly cures when exposed to air, most professionals tint the stone prior to applying CA glue.

3.6.2 CA glue should not be used to bond pieces of stone together. CA glues do not bond as well as other categories.

3.6.3 The use of an accelerator can cause staining if overused on lighter, more absorbent stones.

3.6.4 CA glues are ideal for quick and easy repairs. They are suitable for UV exposure and outdoor environments. They can also be used for seams in countertops because movement usually results only in a failure in the adhesive and less damage to the stone.

3.7 Hybrids.

3.7.1 Hybrids have been developed by many adhesive manufacturers in an attempt to reduce the price of some adhesives and expand the benefits of others. A polyester/epoxy hybrid, referred to as a poly/epoxy, is the most popular hybrid.

3.7.2 Poly/epoxy hybrids have a stronger bond than polyester adhesives. The cure time is shortened when compared to epoxy adhesives. As with polyesters, the cure time of poly/epoxy hybrids can be adjusted.

3.7.3 Poly/epoxy hybrids are more flexible than polyester adhesives. The mixing ratio is not as critical with poly/epoxy hybrids as it is with epoxy.

3.7.4 Structural movement usually causes failure in the adhesive, so poly/epoxy hybrids are considered suitable for countertop seams. They are also used for countertop laminations, mitered drop edges, and rodding or doweling.

3.8 General notes about adhesives and patching materials.

3.8.1 Polyester, acrylic, and poly/epoxy require less hardener (usually in a ratio of 1% to 4% hardener by volume) or curing agent than epoxy. The typical mixing ratio for epoxy is either 2 to1 or 1 to1 resin to curing agent.

3.8.2 Polyester, acrylic, and some hybrids can typically share coloring systems. Epoxies and urethanes usually require their own specific coloring systems depending on the manufacturer.

3.8.3 Urethanes are unique from the rest of the adhesive categories. Many do not cure into a hard, polishable surface. Typically urethanes remain like a hard rubber, to allow for expansion and contraction.

3.8.4 For adhesives that require very accurate mixing ratios, most manufacturers will list the required component ratio both by volume and by weight (mass). Accurate digital scales can be readily obtained at a modest cost, and it is recommended to measure these components by weight (mass) as this method is more accurate than measurement by volume.

3.8.5 In the table at the end of this section, each product category is compared by its typical features. These features are listed at the top of the chart and the product categories are listed in the far left.

4.0 COLORS AND TINTS

4.1 Coloring powders, pastes, and liquids can be product specific, meaning there can be different color products made for polyester, acrylic, and hybrids than for epoxy and urethanes. Some tints are more UV sensitive than others. Check with the manufacturer to be sure the right tint for the adhesive and application is used.

4.2 When the right color is chosen, a repair will be visually undetectable. It takes practice and patience to find the right color. For some materials, like white marbles, it is better to have a semi-translucent mixture with just a hint of the correct shade of white. For other materials, a water-clear mixture works best. Attention should be paid to the specific shade in the area of needed repair. The color should be tested on a small area of the stone to

analyze the color match. If the patching material is a fast cure adhesive, the curing agent should not be added until the color is finalized. Sometimes the curing agent will change the color, so it is important to anticipate that and adjust for it. If the patching material is a slow cure adhesive, then there is usually time to make adjustments. For multi-colored materials, it may be necessary to use multiple shades and to repair in sections.

4.3 Translucent stones, such as onyx, will oftentimes be difficult or impossible to patch with perfect cosmetic results. This is due to the difference in light transmission within the stone fabric versus that of the patch.

5.0 TOOLS

5.1 Tools used for repairs may vary slightly, depending on the personal preferences of the technician. Despite this, the uses are universal.

5.2 Personal Protective Equipment (PPE). This includes gloves, vapor masks, dust masks, goggles, and other equipment as recommended by the adhesive, abrasive, or tool manufacturer.

5.3 Cleaning tools include vacuums, acetone, denatured alcohol, stone soap, intensive cleaners, razor blades, super fine steel wool, soft bristle brushes, rags, compressed air, and other items as recommended by the manufacturers.

5.4 Dispensing tools can be a pump, measuring cup, small capacity digital scale, putty knife, or anything similar.

5.5 Mixing tools can be a paint spatula, putty knife, mixing stick, or anything similar. Thorough mixing is necessary when adding color or curing agent to resin.

5.6 Spreading devices/tools. If the material is in liquid form, a spout is typically used for the initial application process. Afterwards, a putty knife or other spreading tool can be used. For thicker consistencies, a paint spatula, putty knife, or mixing stick will work. Afterwards, straight edge razor blades are mainly used to smooth out the mixture.

5.7 Finishing tools typically include razor blades, steel wool, and chemical solvents.

5.8 Grinding, honing, and polishing tools are die grinders, right angle grinders/polishers, diamond blades/grinding wheels, diamond bits, masonry bits, 3, 4, and 5-inch pad drivers (also known as backer pads), sandpaper (typically silicon carbide), and other abrasives (including antiquing brushes for textured finishes).

6.0 REPAIRS

6.1 Inspection. Performing a thorough inspection during the diagnostic phase of a project will allow the technician to discover which repairs are necessary to help prevent further deterioration of the stone. Many times the repairs will be natural voids or previous repairs that just need a touch up. Occasionally, repairs will be necessary because of structural movement or some other form of failure.

6.2 Types of Damage. It is helpful to determine what caused the damage so that changes can be made to help minimize the chances for reoccurrence.

6.2.1 Upward Crack. If one or two isolated tiles are involved, then the most probable cause is that the installer left a void under those tiles. Foot traffic, carts and other weight place on top of the damaged tiles exerted enough pressure on the unsupported section of the tile to cause it to crack. This is the classic example of an upward crack. In an upward crack, two sections of the tile are broken at an angle that has its high peak at the crack itself.

6.2.2 Inward or Downward Crack. Structural movement will typically cause damage to multiple tiles in a line that sometimes crack in an inward or downward angle. This line can be somewhat straight or it may move to one side slightly to seek out the weakest point of the stone. This is known in the industry as an inward or downward crack or indent fracture. These are mostly caused by the settlement of the floor and where the crack itself is at the lowest point of the tile.

6.2.3 Outward Crack. A crack in the sub floor, or the joint of two pieces of cementitious backerboard under the tiles, can be either upward, or simply a slight separation of the tiles called an outward crack. An outward crack is a slight gap caused by a separation of the stone. Both pieces of the stone are typically on the same plane.

6.2.4 Chips are typically missing sections of stone that is usually the result of an impact from a dropped object. Sometimes, as a result of a crack that splits, small sections of the stone will become dislodged and swept or vacuumed up and discarded. This creates a larger gap to be filled.

7.0 REPAIR SUGGESTIONS

7.1 Crack Repair.

7.1.2 For upward cracks, the first step is to determine is if any of the two (or more) parts of the cracked tile(s) are solid, or if they are slightly moving. In nearly all cases, the grout of a tile cracked upward has separated and become dislodged. It must be determined if there is enough room between the tiles (grout gap) to allow grout to be fully pushed in. If the section of grout is not deep enough to hold more grout, then more of the old grout may need to be removed. Before regrouting, check to see if either section of the broken tiles is loose. If there is no longer a bond between the tile and the subfloor, tapping the surface will produce hollow sounds. The unbonded area (or areas) can be fixed by injecting latex adhesive or a two-part epoxy to fill the void. After injecting the adhesive apply weight to the repaired areas and allow it to cure overnight or longer as recommended by the manufacturer. It is recommended to start these repairs a couple of days before you refinish the floor. After the tiles are secure, regrouting can be done to finish the repair.

7.1.3 Downward Cracks should not be repaired, because this can make them more noticeable. Most of the time such cracks are barely visible, because they only appear as an interruption of the light reflecting on the cracked tile. However, if the crack can be felt with the fingertips and is visible, it can sometimes be disguised by flattening it out. To flatten an indent fracture, use fine grit sandpaper (such as a 220 grit) and sand the hairline crack flat. Be careful not to create a dip by keeping the angle grinder flat. If the surface is being polished, it can be cleaned out and filled with penetrating adhesive to repair it and keep it clean during the process.

7.1.4 Outward Cracks involve several tiles in a row and can be repaired. It is important to inform the client that there is structural movement involved, so no guarantee can be given that it will not crack again. If the crack reoccurs, a better solution would be to install an expansion joint or a crack isolation membrane. Both of these remedies require that the stone tile be removed in order to make the corrections. It is very difficult to match existing stone unless the client kept extra pieces from the same lot.

7.2 Chips. For the best repair, some of the stone should be glued back in to place. If the chip was discarded and there are no extra pieces of stone available, then filling the void with an adhesive, as a patching material, is needed. It is necessary to clean the damaged area thoroughly before applying the adhesive. Once the patch has been made and cured the grinding and honing process can begin. To verify that the patch will blend, check the patch

by wetting the area after grinding the section flat and before finishing the honing and polishing process.

8.0 REPAIR TECHNIQUES

8.1 Preparation. The crack must first be prepared, and the appropriate filler must be determined. Vacuums and die grinders with an assortment of bits and blades are the most commonly used tools for crack preparation. The die grinder is used to dress up or enlarge the opening as necessary to ensure proper filling. If repairing a broken corner of a tile that is loose but still in place, it is best to proceed by removing the broken piece and cleaning the edges of the tile and the removed piece with a die grinder and abrasive bit. Afterwards, the corner should be dry-fitted in place to ensure that it is finished at the same plane as the rest of the stone. If it is high, continue to clean the void until it is almost flush. If it is low, fill the hole where the broken piece was with color-matching knife grade adhesive or a mixture of knife grade and flowing adhesive. Set the broken piece back into place by pushing it against the broken tile and as flush as possible with it. It is better to leave the corner very slightly raised rather than depressed. Once the repair is cured, grinding it until it is flush with the rest of the stone can flatten the corner out.

8.1.1 The consistency of the repair adhesive necessary will depend on the type of crack being repaired. For general crack repairs, use knife grade adhesive and push the adhesive into the void with a spreading tool such as a razor blade. It is best on fast cure two-part adhesives to mix the adhesive with the intended colors without adding curing agent until the client approves the mix. For adhesives known to shrink, it is necessary to apply excess adhesive to allow for shrinkage. Consider the finished appearance of the adhesive before using it on honed or textured materials.

8.2 Fixing micro-cracks and separations using a penetrating adhesive.

8.2.1 Before beginning repairs, consult the product's SDS to determine if PPE is necessary for the task. Begin by cleaning and drying the stone thoroughly.

8.2.2 Use a torch to warm the stone until it is warm, but not hot, to the touch. Do not use a flame near acetone or other solvents.

8.2.3 To minimize the risk of a large stain, it is best to mask off the stone with tape. Leave only a narrow opening (approximately 1/8" or 1/16" [3 or 1.5 mm] beyond the separation on each side) on the pieces needing repair.

8.2.4 Mix the penetrant according to the directions supplied by the manufacturer and add color if desired.

8.2.5 Pour and spread the adhesive into the crack. Allow the adhesive to penetrate the stone. The time span necessary will depend on the curing time of the adhesive. Allow the adhesive to cure for the time recommended by the manufacturer.

8.2.6 After the adhesive has cured, use a razor blade to remove the tape and any excess adhesive from the face of the stone. If this is done before the adhesive is fully cured, leave the excess adhesive to allow for shrinkage.

8.2.7 Grind, hone, and polish the stone as necessary to complete the repair.

8.3 Fixing macro-cracks and separations using flowing and knife grade adhesive.

8.3.1 Consult the material's SDS to determine if PPE is necessary before beginning repair. Begin by using a razor blade to remove loose pieces or existing fill from the crack. Clean all sections to be filled and allow the stone to dry thoroughly.

8.3.2 Mix adhesive according to directions supplied by the manufacturer. Add color if desired.

8.3.3 Apply adhesive. Use a razor blade or putty knife to smooth and remove any excess adhesive. Most adhesives shrink or settle as they cure; as such, it is recommended to leave any excess in the fill areas.

8.3.4 Allow the adhesive to cure for the time recommended by the manufacturer.

8.3.5 Grind, hone, and polish the stone as necessary to complete the repair.

8.4 Finishing the Repair.

8.4.1 In the case of a three-step restoration procedure (flattening, honing, and polishing), the de-lippage tools will take care of grinding the glue flush with the surface of the stone.

8.4.2 If performing a two-step restoration procedure (honing and polishing), excess filler should be grinded using a right-angle grinder/polisher with an 80, 120 or 220 grit sandpaper. The area should be sanded until the repair is flush with the rest of the stone.

8.5 Tips for a Better Color Match.

For a better matching repair, it is sometimes necessary to mix an inert material with the adhesive to give it the necessary "body." The most common inert materials used are marble, limestone or granite dust. Another possible choice is to mix color-matching unsanded grout with the adhesive. The grout is usually mixed approximately two parts grout to one part adhesive. Once the compound is thoroughly mixed, check the color match, add the curing agent, and proceed to fill the voids as usual. When grout is mixed with adhesive, it will become darker – as if it were wet. It will not go back to a lighter color as it would if it were mixed with water. The color of the uncured mix is a good indicator of the cured color. Before adding the curing agent, make sure to lighten the mixture to the desired color. The resulting compound will cure into an extremely hard material that can be worked in the same way that stone would. It is also capable of taking a polish.

8.6 Countertop Seam Leveling or Scratch Repair.

8.6.1 The goal of a multi-piece countertop installation should be scratch-free material and seams that are not easily visible. Sometimes there can be unavoidable problems that require addressing from an experienced stone technician. Occasionally, for various reasons, stone pieces are not perfectly flat. When these pieces are joined together at a seam, especially a 90-degree seam, the irregularities are noticeable. There are techniques used by many installers to adjust the material to achieve a better, more finished look.

8.6.2 Seam Setter. The most common technique is to use a seam-setter. A seam setter is a device used to draw stone pieces together and fit them at the same plane.

8.6.3 Seam Setter + Biscuit. Another, less common, technique is to use a biscuit joiner in combination with a seam setter. A biscuit joiner is a device used to cut grooves in the concealed edge of joined pieces to give them a mechanical anchor to help pieces remain at the same position relative to each other. In the groove cut by the device an oval-shaped biscuit is inserted. For the stone industry, this biscuit is usually plastic or stainless steel.

8.6.4 Shims. Often after the weight of the countertops is added and the cabinets are loaded, there is structural movement and settling that changes the original placement of these tops. In these case it is best to adjust the tops to their original position by adding hard shims. Shims are spacers used to adjust the surface position of stone countertops.

8.6.5 Seam Polishing. When surface irregularities are present and countertops

cannot be repositioned to an acceptable position, then seam polishing can be attempted. Before proceeding with any work, the area must be inspected to determine whether the seam is within grinding tolerance. 1/16" (1.5 mm) lippage is a significant amount of material to be taken down on a counter. Because of the height and frequent use of most countertops, it is viewed at and the close proximity to the eyes. Every dip and imperfection is magnified, especially in a well-lit area. The more material that must be taken down, the wider the work area must be to ensure a flat surface. A flat surface is free of any dips or wobbles in the reflection. While a seam of ⅛" (3 mm) lippage can be successfully removed, flattened, smoothed out and polished to show no distortion, it is extremely difficult and recommended to only be attempted by the most skilled technician. Lippage of 1/16" (1.5 mm) is the maximum recommended when grinding a seam in a granite countertop or vertical panel installation.

8.6.6 A seam that has been carefully prepared and installed with no obvious lippage should take approximately one to two hours to complete. Each additional 1/32" (0.8 mm) will add a significant amount of time to the process. Any additional treatment, such as adding glue to the seam, will add additional time. This process should not be considered a cure for unacceptable seam tolerances. It is more of an upgrade or premium service to provide the best possible finished product. As mentioned above, it can also performed to compensate for minor lippage instead of removal and replacing a top.

8.6.7 High sections of the seam must be identified. Because some granite slabs are prone to warpage, the high side may change positions several times from the front to rear of the counter. A warped slab or a high/low side that changes from front to back is not indicative of an inferior product, but it is a natural occurrence that sometimes cannot be avoided. Identifying the high side becomes more critical as the lippage increases. The idea is to grind the high side down to the low side: not to grind the high and low sides at the same time. Grinding only the high sections will minimize the physical work needed to flatten the seam, and it will significantly limit the chances of creating wobbles or dips in the reflection.

8.6.8 Conclusion. It is always best to practice the techniques described within this section in order to develop the skill necessary to achieve acceptable results. For practice, the ideal material would be a scrap piece of the same stone from the same lot, but that is not always possible. The next best piece to practice on would be a scrap piece of the same material from a different lot or a similar stone. Lighting on the job site, in all conditions, needs to be considered when analyzing the results. Only proceed after practicing and mastering the skills described.

9.0 RECOMMENDED TOOLS

9.1 Right-angle Polisher. The following features are recommended:

- 3-prong plug for safety
- Variable speed dial, up to 3,000 RPM
- Locking switch for continuous-on operation
- Lightweight (6 to 7 pounds, or ±3 kg)
- Variable trigger speed
- 5/8" – 11 TPI spindle thread
- 10 to 15 amps
- Constant speed under load

9.2 Turbo-style resin diamond abrasives (designed for use with granite) are the most preferred abrasive.

9.3 Rigid resin diamond abrasives are designed for use on granite floors.

10.0 RECOMMENDED PROCESS

10.1 All abrasives should be used with a generous amount of water, especially in the initial grinding and honing phases of the work. During the grinding and honing phase, abrasives below 1,000 grit are typically used. Granite, and stone sold as granite, is very hard and generates large quantities of heat when grinding, honing and polishing. The abrasives should stay lubricated and cool with the use of water.

10.2 Water supply can be reduced slightly during the polishing phase to improve contact between finer grit abrasives and the smoother stone surface. The polishing phase typically begins with 1,000 grit abrasives, then continues to the finest grit of the series. Water should not be reduced to the point that the area will dry completely.

10.3 Machine control is critical throughout the restoration process, but it is especially important during the grinding and honing stage. Any unnecessary or accidental pressure applied in the wrong area can create more work or even cause irreparable damage to the surface. The abrasives can be worked in a linear motion for part of the procedure, but the majority of the job should be done using tight, clockwise circles. Clockwise rotation is important because this will keep the slurry towards the center of the abrasive. This motion is opposite the motion of a floor machine.

10.4 When refinishing a seam or scratch in granite, the result is often slightly different than the factory finish of the surrounding areas. This is difficult to prevent, but it can be dealt with easily. During the final steps, the work area can be feathered out, or enlarged, while progressing to finer grits. When progressing to the final polishing step, fade the polish out into the surrounding area. This technique will make any difference in gloss or clarity almost impossible to detect. Client satisfaction is the ultimate goal, so leaving an obvious repair is unacceptable. Educating the client prior to repairing the stone will also help the client form reasonable expectations of what the finished job will look like.

10.5 Abrasives will often glaze over, meaning that the resin in the abrasive will cover the diamonds, rendering it ineffective. Abrasives should be dressed on a regular basis to ensure maximum efficiency.[1] Refer to the manufacturer's instructions before dressing abrasives.

[1] *Dressing* is the process of removing glazed resin, exposing the cutting abrasive.

PROPERTY	ADHESIVE TYPE						
	Polyester	Acrylic	Epoxy	Poly-Epoxy	Acrylic-Epoxy	Urethane (MPPH)	Cyanoacrylate
Usage	Most Common		Most Common				
Bond Strength	Strong	Stronger	Strongest	Stronger	Stronger	Stronger	
Cure Time	Fast (adjustable)	Fast (adjustable)	Slower	Fast (adjustable)	Fast (adjustable)	Fast (adjustable)	Fast (adjustable)
Clarity	Poor	Excellent	Good	Poor	Excellent	Excellent	Excellent
Staining Probability (dependent on stone)	Likely		Likely	Likely		Not Likely	Likely
Cost	Least Costly	Most Costly	Moderate	Middle	Most Costly	Most Costly	Most Costly
Fracture Mode	In Adhesive		Stone Fractures	In Adhesive			In Adhesive
Cosmetic Repair Difficulty	More Difficult	Easy	Most Difficult			Easy	Easy
Resistance to Dampness During Cure	Poor	Poor	Excellent	Poor	Poor	Poor	Poor
Resistance to Dampness After Cure	Poor	Poor	Excellent	Fair	Poor	Excellent	Poor
UV Resistance	Poor	Good	Fair	Poor	Good	Excellent	Good
Exterior/Interior Application	Interior Only	Ext/Int	Ext/Int	Interior Only	Ext/Int	Ext/Int	Ext/Int
Countertop Laminations/Mitered Edges	Not Recommended	OK	Best	Fair	OK	OK	Not Recommended
Doweling	OK	OK	OK	OK	OK	OK	Not Recommended
Rodding	Not Recommended	Not Recommended	OK	Not Recommended	Not Recommended	Not Recommended	Not Recommended
Flexibility	Poor	Poor	Somewhat	Somewhat	Somewhat	More Flexible	Poor
Shrinkage (after curing)	High	High	Slight	High	Moderate	Slight	Moderate
Penetration (low viscosity)	Slight	High	High	Slight	Slight	Slight	High
VOC Content	High	High	Low	High	High	Low	High
Flammability	High	High	Low	High	High	Low	High
Evaporative Rate (chemical components)	High	High	Low	High	High	Low	High
Resistance to "CHALKING"	Vulnerable	Good	Vulnerable	Vulnerable	Good	Good	Good
Resistance to "YELLOWING"	Vulnerable	Good	Vulnerable	Vulnerable	Good	Best	Good
Component Ratio Accuracy Requirement	Forgiving	Forgiving	Critical	Forgiving	Critical	Forgiving	N/A
Thorough Mixing Requirement	Forgiving	Forgiving	Critical	Forgiving	Forgiving	Critical	N/A
Shelf Life	1 to 2 yrs	6 mo to 1 yr	≥ 2 yrs	1 to 2 yrs	1 to 2 yrs	1 to 2 yrs	≤ 6 month

NOTES:

RESTORATION AND MAINTENANCE – RESTORATIVE PROCESSES

1.0 INTRODUCTION

1.1 The term *restoration* signifies "renovating, reconditioning, or returning" something to an "acceptable" or "near original" condition. Restoration starts with a comprehensive inspection of stone type, condition of the stone, and possible causes of the need for restoration.

1.2 Most often the need for restoration arises from the lack of proper maintenance. Other factors that make restoration necessary can include improper cleaning products, wear patterns, scratches, etch marks, stun marks, cracks, chips, breaks, contamination from pollutants such as smoke, leaks and floods, contact with wet environments, cold-weather treatments such as salt or ice melt, and degradation from years of normal exposure to the elements.

1.3 Processes unique to restoration include removing and replacing stained and degraded grout, removing deeper sub-surface blemishes, marks, soils, scratches, etch marks, cracks, chips, stun marks and wear patterns on stone, and filling larger holes and cracks with color-blended resins. Restoration involves the use of coarser diamond abrasives, such as 120, 100, 70, and lower grits. Refinishing involves the use of finer grit abrasives. Restoration also involves utilizing acidic or alkaline chemicals for more aggressive cleaning and stripping. During any process of restoration or refinishing, proper safety equipment must be used. For example, eye, skin and respiratory protection equipment must be used around chemicals, dust, and other hazards associated with the process.

2.0 SURFACE PREPARATION

2.1 Stripping and Removal of Coatings. When a stone surface has a coating, it must be removed before diagnosing what restoration work needs to be done to the stone. Coatings are applied to stone surfaces for several reasons. If a stone surface has been worn, scratched, or etched, a homeowner or contractor may apply a coating to inexpensively achieve a shine. Coatings are also used to seal stone surfaces. There are two distinct categories for coatings: water-based and solvent-based. Although solvent-based coatings have been the long-standing product of choice, there are many hazards associated with their use, including high VOCs and the need for respiratory and skin PPE. The technology for water-based coatings is improving rapidly, and the industry seems to be moving toward using more water-based products.

2.1.1 Coating removal is called "stripping." When stripping coatings, it is important to work in manageable areas. Failure to do so can cause the coating to cure in areas making it necessary to repeat the process. A chemical solution is used to emulsify and remove the coating from the stone surface. Most acrylic coatings that are installed on natural stone surfaces can be stripped using water-based stripping methods. Lacquers, urethanes, epoxies, and other clear paints are usually stripped using solvent-based methods.

2.1.2 Water-based Coatings. Acrylics and other waxes are stripped using a stripper properly diluted in water as directed by the manufacturer.

2.1.2.1 Dwell Time. The stripping solution is delivered with either a mop or airless pump sprayer. The solution must be allowed to sit in contact with the coating for a period of time in order to soften and loosen the coating and cause it to shrink away from the surface of the stone.

2.1.2.2 Agitation and Extraction. After the prescribed amount of dwell time, the surface is scrubbed with an abrasive pad or brush. This removes the remaining coating and converts it in to a liquid form. When the liquid becomes thick and colored, it should be removed from the immediate work area with a squeegee. The immediate work area should be examined to determine if the desired result has been achieved. If more work needs to be done, use the squeegee to move the liquid back in place to continue working the area. If the work is complete, use a wet vacuum to remove the liquid. This process is repeated until the entire area is complete.

2.1.3 Solvent-based Coatings. Lacquers and epoxies are stripped using a solvent-based stripper that is petroleum-based or from another solvent source, such as soy. Soy-based strippers tend to take longer to process, but the results are similar to petroleum strippers.

2.1.3.1 Dwell Time. Solvent-based strippers are gels and are usually applied using a brush or another type of spreading applicator. The gel is applied in such a way as to leave ¼" of the gel on the surface of the coating. Some technicians prefer to cover the treated surface with plastic to keep it wet and allow the stripper adequate time to react.

2.1.3.2 Agitation and Extraction. After the specified period of dwell time, the surface is scraped with a spatula and both the stripper and coating are discarded. Follow manufacturer's instructions for rinsing and removal of the gel.

2.1.4 Detailing is the process of completing stripping a coating. It can be done in several ways, based on the preference of the technician and the type of coating being removed. One method is to reapply the same stripper, allowing less contact time, then scrubbing and extracting it. This is done using the same methods as described above in the acrylic removal (water-based coatings). Some technicians use solvents such as mineral spirits, acetone, or alcohol to break and remove the remaining residues. Another method of detailing is done by immediate application and removal of water-based strippers.

2.1.5 Poulticing is a process of stain removal. A chemical is used to loosen the stain and an absorbent media is used to draw the stain out of the stone. While this can be used on any stone, it should first be determined if the chemical reaction might have an adverse effect of the stone. For example, when an acid is used to break down rust in any calcium carbonate based stone, the acid will etch the stone, making restoration or refinishing necessary. Poulticing requires the following steps.

2.1.5.1 Identify the stone type and the type and source of the stain. Often this can be determined by asking the building's owner, manager, or maintenance workers.

2.1.5.2 Once the source of the stain has been identified and removed, refer to Stains & Removal Procedures in the Maintenance section of this document to take the appropriate steps to remove the stain.

2.1.5.3 After the appropriate dwell time, remove the poultice from the stone. For large areas, a wet vacuum can be used to speed up the process.

2.1.5.4 Analyze the results and determine if another poultice application is needed. If not, follow up by cleaning the area with a pH neutral stone cleaner before restoring or refinishing the stone.

2.2 Masking and Protecting. Prior to stone restoration, adjacent areas should be masked. The term *mask* is commonly used to describe the process of applying protecting films or tapes to the surrounding area. The most common items that are masked include carpeting, hardwood floors, thresholds, trim or moldings, glass, and any and all dissimilar materials or stone types that could be negatively affected from contact with the cleaner, water, slurry, or polishing compound. Delicate painter's tape can be applied directly onto painted surfaces, stained finished wood, metal, or other sensitive surfaces. Ensure no tape is covering the stone that needs to be

refinished. Use caution when taping baseboard and finished hardwood because even the most delicate painter's tape may pull paint or stain off of these surfaces.

2.2.1 Adjacent areas should also be covered with other masking materials, such as static-cling painter's plastic film. Wax paper and pre-taped rolled plastic film is acceptable as well. Start at the baseboards and apply the masking material up and along the walls, cabinets, and adjacent flooring surfaces. Spot tape the masking material to these surfaces to ensure that plastic film does not fall into the working area during the restoration process.

2.2.2 Make sure to cut openings in the plastic film covering vents to allow proper airflow and to apply the film in a way that does not prevent the use of appliances and doors to a pantry, closet, or entry. Make certain that these accommodations do not allow the equipment, abrasives, or water and chemicals to cause damage. Use items like caution tape and wet floor signs if working in an area where pedestrian traffic is likely.

2.3 Cleaning. The stone should be swept, vacuumed, and wet mopped using a pH neutral stone cleaner prior to restoration. This will keep grit and dirt from doing further damage to the stone or causing damage to the abrasives.

3.0 MTL REFINISHING AND POLISHING

3.1 Preparation.

3.1.1 Equipment. There are many variations of machinery and abrasives. The list below is an example of what is typically used.

3.1.2 For lippage removal, use a heavy ridged planetary machine and/or a swing machine capable of being weighted. A variable speed machine can also be used. Access to extra weights is sometimes necessary.

3.1.3 An edging machine and/or variable speed angle grinder/polisher is the proper tool for edgework close to adjacent, dissimilar floor and wall materials. Use the same grit level of abrasives and steps that are being used on the main section of the floor.

3.1.4 A variable speed angle grinder/polisher is recommended for wall restoration.

3.1.5 Other Recommended Equipment.

- A squeegee with a rubber head and extension pole
- A wet/dry vacuum
- Metal bonded diamond abrasives (multiple grits) for floor and handheld machines
- Marble-specific, resin-bonded diamond abrasives for floor and handheld machines (approximately 30 grit through 3000 grit or higher, depending on abrasive manufacturer)
- Transitioning abrasives to be used between metal and resin-bonded abrasives
- Marble polishing compounds
- Hog's hair pads
- Diamond dressing compound or product to dress diamond abrasives[1]
- pH neutral cleaner

3.1.6 Surface Preparation.

3.1.6.1 Mask and protect the work area as described earlier in this section.

3.1.6.2 Remove baseboards and other trim to make the edge work more accessible.

[1] To *dress* a diamond means to remove metal or resin coating over the abrasive, exposing a better cutting surface.

3.1.6.3 Use a vacuum to clean the entire floor, making sure there is no debris that could get under the machinery.

3.1.6.4 Remove any coatings or waxes from surface using the proper methods described earlier in this section. If no coatings are present, wet mop the entire area with a pH neutral stone cleaner to remove lingering debris.

3.1.6.5 Repair all cracks and chips. Allow patching material to thoroughly cure before starting the refinishing process.

3.1.6.6 Check for any missing grout at joints and caulk. Fill prior to starting the refinishing process. This will ensure that the color will be a better match when the process is complete.

3.1.6.7 If the floor was grouted with sanded grout, it will need to be removed and replaced with unsanded grout. Otherwise the sand in the grout can become dislodged and can scratch the marble during the restoration process.

3.1.6.8 If the lippage averages more than 3/32", it is better to float the floor with the same color unsanded grout to protect the tile edges from chipping and/or cracking.[2]

3.2 MTL lippage removal is the process of grinding the floor flat to help make it easier to polish and maintain.

3.2.1 Edging. Most floors installed in the United States are not laid completely flat, nor are they ground in place, meaning that the floor has lippage. Before beginning the grinding process it is necessary to consider the edges of the floor. In some cases it may be possible to stop the grinding process 3 to 6 inches from the edges. This is a method better suited for experienced technicians. For best results, it is better to grind the floor flat to the edges. Below are two edging options for lippage removal based on job conditions.

3.2.1.1 Option A. If the baseboard and other trim can be removed, the machinery can be run tight to the edge of the wall on the first abrasive step. The second and subsequent steps will also be run tight to the wall. Any scratches along the outer edges will be concealed under the moldings when they are replaced. Put a section of the new molding (baseboard and other trim pieces) in place without attaching it to verify that the edges are properly finished. If not, the edges will need to be finished by using handheld equipment.

3.2.1.2 Option B. If the baseboard and other trim cannot be removed, then this or a similar grinding process should be followed. A popular method is to use a 2 X 4-inch piece of wood laid flat along the outer edge of the floor. Use this as an edge to complete the first abrasive step. On the next abrasive step, flip the wood onto the 2-inch side to use as an edge. This method will help to avoid having heavy scratches against the molding. For the next steps, the edge work will need to be done using a handheld machine, such as an angle grinder/polisher, with the appropriate diamond abrasives. Several steps will need to be done by hand to get a 4 to 5-inch perimeter of the floor complete. The edging process should match the process that will be performed for the entire floor.

3.3 Steps 1 and 2: First grinding. Using either option A or B, above, start the first grinding step. Place the lowest grit metal bond diamonds on the machine. The technician will need to decide with which metal bonded diamond abrasive grit to start the process based on how much material needs to be removed. A good baseline choice would be a 70/100-grit metal abrasive followed by a 120/200-grit metal, copper, or electro-plated abrasive. 50-grit metal abrasives are very aggressive and are

[2] To *float the floor* means to fill any low areas with a recommended floating material.

mainly used to grind the surface of concrete, but are not recommended for use by a beginner. Abrasives should be secured to the bottom of the machine by bolts, magnets, or cup holders. A large quantity of water is necessary for this step, so take precautions not to flood lower floors or have any water escape the work area. Build dams or pour stops if needed to control water flow to adjacent or lower areas.

3.3.1 Initial Grinding should be done in an out-of-the-way corner. The metal bonded diamond abrasive will dig in to the stone upon starting the machine. Work 50 to 100 square foot sections for the first step and run the machine north to south and then east to west. The goal is to level the floor in sections and then blend it all together. This step is noisy and time consuming, signaling that the floor is not yet flat. Using a squeegee, check the area being worked. Rinse the floor and let it dry. Inspect the area closely for inconsistencies in the abraded finish. It is critical to finish this step with a uniformly abraded surface. There will typically be some low corners that will need more attention. If inconsistencies are found, continue to go over those areas until it is uniform. This step will set the precedent for the remainder of the processes.

3.3.2 An equal or greater time should be spent on the seconding grinding. Make sure that all of the previous grit's scratches have been removed. If this process is not performed correctly, it will be noticeable in the final polish of the floor. After the 120/200-grit is complete, the floor is ready for the refinishing phase of the process.

3.4 MTL Refinishing. When refinishing a floor without lippage removal, the technician must determine the abrasive coarse enough to quickly remove the deepest scratch without being too aggressive and causing additional work. In most cases it is best to begin with 200-grit diamond abrasives, then progress to 400-grit and 800-grit prior to final polishing on most marble. In some cases, to obtain the optimal outcome, it may be necessary to progress up to 1800-grit diamond abrasives before moving on to the final polishing process. For heavily soiled, worn, or damaged floors, it may be necessary to start with a 120-grit or lower abrasive. If the floor is less worn, it may be acceptable to begin with a 400-grit abrasive. Some companies manufacture a 400-grit abrasive capable of removing etching and normal wear. The type of stone being restored also determines the abrasive starting point. For travertine and other stones known to have many voids, overworking them with 200-grit abrasives or lower can open up the voids and make it necessary to fill them.

3.4.1 Picture Framing. If lippage is not removed, diamond abrasives will not abrade the low sections of the tile edge, leaving a diamond hone on the high sections but the original finish on the low tile edge. This is known as picture framing. The prominence of picture framing is affected by the thickness of the abrasives being used. Diamond abrasives are commonly produced in thicknesses of 11, 9, 4, or 3 mm. The thicker the abrasive, the more rigid it tends to be and the more pronounced the picture framing would be. If the technician is not being contracted to remove the lippage by grinding the floor flat, it is better to use 4mm or thinner diamonds with a foam spacer for additional flexibility to reduce the picture framing affect.

3.5 Step 3: Light grinding or transitioning (step 1 if lippage removal is not performed). For refinishing, it is most common to begin with 220-grit diamond abrasives. To begin, the technician attaches the abrasives to a flexible riser pad. The two most common diamond configurations are 3 or 4 abrasive pads. If using 3 abrasives, the technician should place the diamonds evenly on the drive plate (for example at 12, 4 and 8 o'clock positions), forming a triangle pattern. If using 4 abrasives, the technician should space them evenly on the drive plate (for example at 12, 3, 6 and 9 o'clock positions), forming a square pattern. Spacing of the abrasive from

the outer edge of the drive plate is one method used by experienced technicians to ensure a more thorough overlap is achieved with finer grit abrasives.

3.5.1 If using a machine with a water tank, engage the water flow for 3 to 5 seconds at the beginning of the process to apply enough water to the working surface. Only enough water is needed to create a slurry with the consistency of skim milk. If water is running from the working area onto the low areas on the floor, too much water was used. Excess water will not affect the abrasive's ability to work in the initial stages, but it will cause potential work site problems such as water flowing into floor vents and through ceilings of the lower level floor. If necessary, add additional weights to the machine to increase the cut rate. Be careful when adding weight to the machine while working on filled stone like travertine. This will make it necessary to fill the voids created by overworking the stone.

3.5.2 Begin grinding in the far corner of the room, working backwards towards a natural stopping point, such as a front door or room transition. It is helpful to visualize the floor in 10 to 20 square foot sections and work each section moving from right to left or left to right in linear movements. When working in lower grits (200 and 400 grits), it is better to make two passes before moving down through the section. By making two passes, the technician will move the machine in a linear pattern from right to left or left to right, then reverse and move the machine over the same footprint returning to the starting point. Approximate coverage rate should be 10 square feet every 5 minutes when moving in a straight line. The technician should ensure 50% overlap of each pass throughout the floor. When using one pass (or 2 passes at lower grit levels),when the area is completed the technician should step back only about half of the width of the machine and reverse directions, moving at the same pace stated above. This will ensure there are no missed areas that will cause problems at the polishing stage of the project. Some technicians move the machine in circular motions. This is used across each section covering the same area, in the same amount of time, to ensure the stone is hit from different angles. Once a section is finished, all water and slurry should be moved from the working area using a squeegee, then extracted with a wet vacuum. Do not let the slurry dry on the surface of the stone. A clean, dry surface is necessary for the technician to inspect the work at each step to ensure that there are no inconsistencies in the abrasive pattern before moving to the next step. Using a squeegee to assess each area is the quickest technique. This step is accomplished more efficiently if a second technician is on hand to operate the squeegee and vacuum. This allows the first technician to move on to the next section of the floor while the second is vacuuming the previous section.

3.6 Step 4: Light grinding or initial honing step (step 2 if lippage removal is not performed). After the entire surface has been finished with 220-grit diamond abrasives, remove them from the drive plate and attach 400-grit abrasives, also using foam spacers. These abrasives should be attached in the same pattern as before, but placed slightly closer to the outer edge of the drive plate. This allows the technician to move the machine along walls and cabinets and easily overlap each grit level.

3.6.1 This step in the refinishing process can be thought of as the matte process of the honing phase. Each finer grit diamond abrasive will improve the color, shine, and clarity of the surface until a polish is produced.

3.7 Step 5: Honing step (step 3 if lippage removal is not performed). After finishing the entire floor with the 400-grit, the surface should be rinsed, vacuumed, and dried. The floor should be inspected to ensure that there is a consistent abrasive pattern and that it is ready for the next step. After 400-grit, each subsequent grit can be thought of as a polishing grit. The 800-grit abrasives should be attached to the drive plate as before, but moved even closer to the edge of the plate.

3.7.1 When refinishing MTL floors, it is common to stop after finishing with 800-grit. Some technicians choose to progress to 1800-grit or even 3000-grit. With 800, 1800 and above grit steps, it is acceptable to deviate from the process above. The technician can perform just one pass in each direction. This means that if the technician is moving from right to left, when they reach the opposite edge of the working area it is acceptable to take a step back half of the width of the machine and reverse direction. This makes work with the higher grits progress much quicker. The hardness and color of the stone being refinished usually has an impact on how fine the last grit needs to be. With experience, the technician will know how far to take this part of the process.

3.8 Step 6: Polishing step (step 4 if lippage removal is not performed). Prior to polishing, make sure masking is still intact. Polishing compounds contain acidic components that could damage metal or other adjacent surfaces. This step is typically the messiest, so proper masking will reduce clean up time upon project completion. Polishing compounds are covered in much more detail in chapter 5 of this document (Equipment).

3.8.1 After the floor has been refinished using traditional abrasives, it is ready for polishing. If at this point there are still picture frames, low points on the tile that are untouched by abrasive and appear polished, they should be minimal and will be completely removed by an experienced technician during the polishing step. There are a number of compounds that will achieve the desired result. The amount of compound used and time spent in each section varies slightly based on the hardness, mineral makeup, and color of the stone and compound being used. The processes as described below are general guidelines that may need adjustment in the field depending on job site and product variables.

3.8.2 Begin in a far corner of the room, working backwards towards a natural stopping point such as a front door or room transition. Slurry should not be tracked onto other sections of the floor, because it can create etch marks. Think of the floor in sections. On most MTL floors it is acceptable to polish 20 to 30 square foot sections at time. Place the polishing compound of choice on the floor by pouring it in a circle approximately 14 inches in diameter. When the machine head is put in contact with the floor, it should cover the applied compound. This will reduce the spray or spread of the compound across the floor. It is common to use ¼ to 1/3 of a cup of compound in each section of the floor. Place a white or natural hog's hair pad to the drive plate, ensuring that the plate is centered on the pad. Drop the machine head over the powder and apply water. If using a machine with a water tank, engage the water flow for 3 to 5 seconds at the beginning of this process.

3.8.3 Once the machine has started, work in circular motions covering approximately a 20-inch diameter section, while moving in a linear pattern. As with the diamond refinishing steps, it is important to overlap the work areas to ensure an even and uniform finish over the entire floor. Most technicians will check the polishing progress with a squeegee. When the desired polish has been achieved, rinse the working area and extract the slurry from the floor. Total working time per section should be between 90 seconds and 3 minutes, depending on floor type and compound used. This step should be repeated until the entire floor has been covered and the desired results have been achieved.

3.8.4 After the floor is polished, there will be residue in grout lines and on the surface of the tile. To remove the residue, add a pH neutral stone cleaner to the water tank of the machine or apply the cleaner to the floor using a pump sprayer. Then place a clean white pad or soft brush on the machine. Starting at the far end of the floor, working backwards toward a door or room threshold, scrub the floor to remove residue from the tile and grout lines. While the cleaner is still on the floor, use a sponge to clean edges and corners to remove

residue and debris. When the floor is dry, remove all tape and plastic film, then thoroughly dust mop the floor. The floor is now ready for sealing.

3.9 Sealing (using an impregnating repellant). For sealing, refer to chapter 8 of this document (Sealers). In general, a simple water test on the surface of the stone will determine its porosity. If the stone darkens when wet, sealing the stone can be beneficial. The general rule that applies to sealing stone is to start with a thoroughly clean and dry floor. Follow the manufacturer's recommendations for applying their product. A majority of sealer-related problems are caused by not following directions properly.

3.10 Other Finishes. Polished is still the most popular finish for stone. Other finishes typically seen on MTL are honed, bush-hammered, tumbled, and brushed (also known as antiqued, leathered or caressed). A floor will sometimes have a mixture of finishes in a pattern, making refinishing difficult. Understanding the factory process of creating these different finishes can be beneficial during refinishing.

3.10.1 Honing. A honed finish is achieved by stopping the process at least one step before achieving a polish. The typical honed finish is defined as being a matte or non-gloss finish without visual abrasive patterns. With MTL, this usually begins at the light grinding and honing steps.

3.10.2 Bush-hammering is a mechanical finish produced from impact by hand or a pneumatic hammer that creates a textured surface. It is typically used on cubic material; stone with a thickness greater than 2 inches.

3.10.3 A Tumbled Finish is usually achieved by placing smaller pieces of stone tiles in a tumbler, causing a chipped and worn look on unused pieces of stone. Bush-hammering, sandblasting and other methods can be used to give larger stones a tumbled look.

3.10.4 A Brushed Finish is achieved by using abrasive brushes in place of rigid abrasives to hone the surface of the stone. Materials that have a wide range in hardness usually produce the most diverse texture using this technique. Materials that do not contain a wide range of minerals with varying degrees of hardness are often textured mechanically before being honed with the abrasive brushes. These brushes usually start at 36 grit and continue to 1200 grit for an even finer finish. It is always best to research and experiment with different finishes to avoid damaging the installed floor.

4.0 GRANITE REFINISHING AND POLISHING

4.1 Process. The scope of this section includes all stones traded as granite by the stone industry. Refinishing and polishing a granite floor is considered a pinnacle achievement for any stone refinisher. A sound plan and the right tools and equipment are required. The technician must research available machinery and abrasives. Chapter 5 (Equipment) is a good place to begin this research. The machine and abrasive needs will vary.

4.1.1 Technicians must be patient when working on granite. To achieve a factory-like finish, some technicians may state that granite floors can be refinished without grinding by using only resin diamond abrasives and granite polishes. This is possible under the right conditions and on the right floor, but there are many variables that affect the results.

4.1.2 Granite refinishing becomes necessary for several reasons. Technicians may be called to restore a badly worn or abraded surface or a new floor installation with excessive lippage. Another reason would be to change the existing finish (changing from a polished to honed or honed to polished floor) for any number of reasons. It is also possible to be called in to brush or texture a granite floor. Textured finishes are becoming more popular

each year, so it is important to understand the process.

4.2 Equipment. There are many variations of machinery and abrasives. The list below is an example of what is typically used.

- A heavy ridged planetary machine and/or swing machine capable of being weighted. A variable speed machine is preferred. Access to extra weights can be necessary.
- An edging machine and/or variable speed angle grinder/polisher
- A squeegee with a rubber head and extension pole
- A wet/dry vacuum
- Metal bonded diamond abrasives (multiple grits) for flor and handheld machines
- Granite-specific, resin bonded diamond abrasives for floor and handheld machines - approximately 30 grit through 3000 grit or higher (depending on manufacturer)
- Copper-bonded diamond abrasives or hybrids used for transitioning between metal and resin-bonded abrasives
- Other transition abrasives for use after grinding to remove any excess scratches and prepare surface for honing
- Granite final polishing compounds
- Hog's hair pads for polishing
- Diamond dressing compounds or product to dress diamond abrasives
- pH neutral cleaner

4.3 Surface Preparation.

4.3.1 Mask and protect the work area as described in section 2.2.

4.3.2 If possible, remove baseboards and other trim to make edge work easier and more accessible.

4.3.3 Use a vacuum to clean the entire floor, making sure there is no debris that could get under the machinery.

4.3.4 Remove any coatings or waxes from the surface using the methods described in section 2.1.

4.3.5 If the floor was grouted with sanded grout, it must be replaced with unsanded grout.

4.3.6 If lippage averages more than 3/32", it is better to float the floor with the same color unsanded grout to protect the tiles from chipping and/or cracking.

4.4 Granite Lippage Removal. Before refinishing, all lippage must be eliminated so that the floor is flat. This is a once in a lifetime process for a granite floor that increases its value exponentially.

4.4.1 Edging. Edges must be considered before beginning the grinding process. In some cases it may be possible to stop the grinding process 3 to 6 inches from the edges. This is a method better suited for experienced technicians. For best results, grind the floor flat to the edges. Below are two edging options for lippage removal.

4.4.1.1 Option A. If baseboards and other trim can be removed, machinery can be run tight to the edge of the wall on the first abrasive step. The second and subsequent steps will also be run tight to the wall. Any scratches along the outer edges will be concealed under the replaced moldings (baseboards and other trim pieces). Put a section of the new molding in place without attaching it to verify that the edges are properly finished. If not, the edges will need to be finished by using handheld equipment.

4.4.1.2 Option B. If baseboards and other trim cannot be removed, then this or a similar grinding process should be followed. Use a 2 X 4-inch piece of wood laid flat along the outer

edge of the floor. Use this as an edge to complete the first abrasive step. On the next abrasive step, flip the wood onto the 2-inch side to use as an edge. This method will help avoid having heavy scratches against the molding. For the next steps, the edge work will need to be done using a handheld machine, such as an angle grinder, with the appropriate diamond abrasives. Several steps will need to be done by hand to get a 4 to 5-inch perimeter of the floor complete. The edging process should match the process that will be performed for the entire floor.

4.5 Step1: First grinding step. Using option A or B (above), start the first grinding step. Place the lowest grit metal bond diamonds on the machine. The metal bonded diamond abrasive grit used to start the process should be determined based on how much material needs to be removed. Although many variations can be used, a good baseline choice would be a 46/50 grit followed by a 100 grit abrasive (depending on the abrasive manufacturer).

4.5.1 Abrasives must be secured to the bottom of the machine by bolts, magnets or cup holders to ensure the first step goes smoothly. This step requires a great deal of water; build dams or pour stops if needed to control water flow to adjacent or lower areas. Start the machine at approximately 300 to 500 rpm, then find a speed that works best with the abrasives and the granite. Work 50 to 100 square foot sections for the first step and run the machine north to south, then east to west. Level the floor in sections and then blend together. It will take approximately 30 to 60 minutes for 50 to 100 square feet. This step is noisy, indicating that the floor is not yet flat. When the machine quiets down and becomes smooth, the floor is getting flat. This step sets the precedent for the remainder of the process.

4.5.2 Using a squeegee, check the area being worked. Rinse the floor and let it dry. Inspect the area closely for inconsistencies in the abraded finish. This step must finish with a uniformly abraded surface. If inconsistencies are found, continue to go over those areas until they are uniform. Areas with negative lippage should be worked using handheld machinery to avoid the risk of overgrinding, but be careful when using handheld machinery not to create a dip in those areas. It may be a better to add weight to the machine and make the corrections on the second step.

4.6 Step 2: Second grinding step. When the first step is complete and consistent, begin the second grinding step. Attach the next set of grinding abrasives to the machine. The machine can be run in any direction that ensures adequate surface coverage. Work the entire floor and remove all scratches from the previous grit. Run the machine as close to the edge as possible. After completing this step, rinse, dry, and examine the floor. This step must be finished with a uniformly abraded surface. Once the abraded surface is consistent, move to step 3. If using option B (described in section 4.4.1.2), complete the edging work using a handheld machine before moving to step 3.

4.7 Step 3: Transition step. This step transitions from metal-bond to resin-bond diamond abrasives. Use copper, ceramic, phenolic, or granite-specific resin-bond diamond abrasives to remove scratches from the last grinding process. It is usually best to drop to a lower grit than the last metal-bond grit used. For example, if the last metal bond grinding grit was a 100, step 3 should start with a 50 grit transition abrasive. Remove all scratches from previous grits and finish with a uniform abrasive pattern. If using option A, continue working each grit to the edge of the floor. If using option B, work the grit over the last metal cut to start blending each cut into the edge previously created. Clean, dry, and inspect the entire floor for uniformity before moving to the next step.

4.8 Steps 4 through 10: Honing and polishing steps. When floor is thoroughly clean and dry, inspect before proceeding.

4.8.1 Step 4. Attach 50 grit (or comparable grit) resin-bond diamond abrasives to the machine. The machine can be run in any direction that ensures adequate coverage of the surface. Work the entire floor and remove all scratches from the previous step's grit. After completing this step, rinse, allow the floor to dry, and inspect. If the abrasive pattern is uniform, move to step 5.

4.8.2 Step 5. Attach 100 grit (or comparable grit) resin-bond diamond abrasives to the machine. Continue with the same process as Step 4.

4.8.3 Step 6. Repeat step 4 using 200 grit resin-bond diamond abrasives.

4.8.4 Step 7. Repeat step 4 using 400 grit resin-bond diamond abrasives.

4.8.5 Step 8. Repeat step 4 using 800 grit resin-bond diamond abrasives.

4.8.9 Step 9. Repeat step 4 using 1500 grit resin-bond diamond abrasives.

4.8.10 Step 10. Repeat step 4 using 3000 grit resin-bond diamond abrasives.

4.8.11 Considerations. Inspection after Step 7 is typically more critical as you move into the honing and polishing phases. This can give you a glimpse of the consistency of the final polish. If the surface is uneven, it is imperative to go back over the floor until it is consistent. The speed of the machine can be increased when using the finer grit abrasives. For example, on Step 9 (1500 grit) the speed can be set to 1,100 RPMs. During the use of finer grit abrasives there is less material being removed and the water required to keep the stone and the abrasives cool is reduced. A heavy water flow during this phase increases the changes of hydroplaning or reduced stone to abrasive contact. However, too little water will cause the abrasive to heat up and glaze over.

4.9 Step 11: Final polishing step. The final polishing will only be as good as the honing of the surface. Simply put, if the floor is honed well, the polishing results will reflect that work.

4.9.1 There are many polishing compounds on the market, and each has its own strengths and weaknesses. For highly competitive jobs, an inexpensive but effective compound is often used. Stone that is polished with a chemical compound should receive a final cleaning with a pH neutral cleaner. The easiest compounds to use will be compounds that can be worked wet. Some companies prefer granite crystallizers that are applied using #1 grade steel wool.

4.10 Sealing (using an impregnating repellant). For sealing, refer to chapter 8 of this document (Sealers). In general, a simple water test on the surface of the stone will determine its porosity. If the stone darkens when wet, sealing the stone can be beneficial. The general rule that applies to sealing stone is to start with a thoroughly clean and dry floor. Follow the manufacturer's recommendations for applying their product. A majority of sealer-related problems are caused by not following directions properly.

4.11 Other Finishes. Different finishes are increasingly becoming more popular for natural stone. Finishes typically seen are honed, flamed, bush-hammered, and brushed (also known as antiqued, leathered or caressed). Most granite can be flamed and this is a popular choice for improving slip resistance. On occasion, a floor will have a mixture of finishes in some form of pattern, making refinishing difficult. Understanding the factory process of creating these different finishes can be beneficial when refinishing it.

4.11.1 A Honed Finish is achieved by stopping the process at least one step before achieving a polish. The typical honed finish is defined as being a matte or non-gloss finish without visual abrasive patterns. With granite,

this usually begins at Step 7 and continues to Step 9.

4.11.2 A Flamed Finish is achieved by using and oxygenated torch to heat the surface of the granite to approximately 1,600 degrees Fahrenheit. This process is not recommended for installed stone without thorough research and trials.

4.11.3 A bush-hammered finish is typically used on cubic material. It is a mechanical finish produced from impact by hand or a pneumatic hammer that creates a textured surface.

4.11.4 A Brushed Finish is achieved by using abrasive brushes in place of rigid abrasives to hone the surface of the stone. Materials that have a wide range in hardness usually produce the most diverse texture using this technique. Materials that do not contain a wide range of minerals with varying degrees of hardness are often textured mechanically before being honed with the abrasive brushes. These brushes usually start at 36 grit and continue to 1200 grit for an even finer finish. It is always best to research and experiment with different finishes to avoid damaging the installed floor.

5.0 GRANITE COUNTERTOP POLISHING

5.1 Granite is naturally resistant to scratches, chemicals (it is not acid sensitive), and moisture. Because of this, most granites maintain a high quality finish. It is not unusual for granite countertops to be serviced in 5-7 year windows or longer. In most cases only spot refinishing is required to remove a scratch or other imperfections from a portion of the countertop. These smaller areas can be polished to blend in with the entire countertop. Because they are naturally scratch resistant, granite countertops rarely, if ever, require refinishing using diamond abrasives. When they do, abrasives up to 3,500-grit followed by a buff abrasive pad should be used. Buff pads typically come in black or white varieties and contain extremely high grit abrasives (8,000 or 11,000-grit). The use of the buff abrasive pad will result in a high quality mechanical finish. When polishing granite, the better quality mechanical finish the technician can achieve, the easier it is to achieve an acceptable polish using chemical and abrasive granite polishing compounds.

5.2 Equipment. The following equipment is recommended for granite countertop polishing:

- Variable speed right-angle grinder/polisher
- 3, 4, 5, or 7-inch backer pad
- 3, 4, 5, or 7-inch diamond abrasives
- Water supply (spray bottle or water supply for a center water feed polisher)
- Squeegee
- Granite polishing compound
- Hog's hair burnishing pad
- pH neutral cleaner

5.3 Surface Preparation. Before beginning the refinishing process, adjacent areas (including floors, cabinets, walls, mirrors, ranges/cooktops, and refrigerators) should be masked. Delicate painters tape can be applied directly onto painted surfaces, finished wood, metal, and other sensitive surfaces. 2" painter's tape can also be applied to the edge of the counter, leaving approximately 1 to 1½-inches of tape above the surface of the countertop. This will reduce splatter and necessary cleanup. Use caution when taping painted cabinets and finished hardwood because even the most delicate painter's tape may pull paint or stain off of these surfaces.

5.3.1 Other masking materials should also be used. The most common masking material is static-cling painter's plastic film. Wax paper and pre-taped rolled plastic film are also acceptable. Starting at the top of the cabinets just below the countertop, unravel masking

material down and along cabinet faces. Then use a small piece of plastic to cover the range or cooktop. Plastic film or canvas tarps should be laid on the floor in the working area. Review the surroundings and cover furniture or other items that are close enough to be hit by splatter with plastic film or canvas tarps. Masking for countertop refinishing is designed to catch splatter. The splatter caused by countertop refinishing and polishing compounds will generally not stain or damage floors, cabinets, or nearby furniture, but protecting these surfaces with plastic film provides a professional look and greatly reduces clean up upon completion of the project.

5.4 Refinishing. Begin by identifying the area that requires refinishing. If it is a small scratch or small area, use a china marker or lumber crayon to circle the scratch.

5.4.1 Use a variable speed right-angle grinder with a 3, 4, 5, or 7-inch backer pad. It is common to refinish small areas using 3 or 4-inch diamond abrasives. Spray the working area with water. Allow for consistent and even water distribution; do not flood the surface. Choose a coarse grit abrasive (typically 50, 100, or 200-grit) and attach it to the backer pad. Use the highest or finest grit abrasive capable of effectively removing the imperfection. This will decrease the steps necessary to achieve the desired result.

5.4.2 After selecting the abrasive, place the machine flat on the surface and run the machine in an even, consistent pattern across the working area. The first step is not completed until the imperfection is removed. It may be necessary to pause and spray more water onto the surface if a constant water supply is not being used. Ensure that the edge of your working pattern (also known as the scratch profile) is even and does not show arrant scratches. Stop to clean slurry off the working area, using a rag or small squeegee to check progress. When finished with each step, clean the working area and dry it for inspection. Inspect the area closely to ensure that there is a consistent abrasive pattern. Once the imperfection has been successfully removed and the abrasive pattern is consistent, move to the next step.

5.4.3 Repeat the process above with the next finer-grit abrasive. Overlap the previous scratch profile by about 25% of the abrasive footprint to prevent a halo. Continue by moving the machine in a consistent pattern across the designated work area with each abrasive. The abrasive part of the work is completed when technician has progressed to the use of the buff pad and achieved a near factory shine mechanically. By overlapping and thoroughly inspecting the work, the reflective finish will be the same from the center to the outside of the scratch profile.

5.4.4 When using higher grits (1000-grit and finer) some technicians prefer to use the tool wet-to-dry. To do this, use a sprayer to apply a mist of water on to the work area. Start the machine on the lowest speed, applying more pressure than usual to the machine. Work the area back and forth until the area begins to dry out. As the area dries out, the abrasive will start to grip the surface and jerk the machine. Apply more pressure to the tooling head, creating more friction and heat. The work area will completely dry out. As this happens, continue applying pressure while increasing machine speed no higher than the middle speed setting of approximately 3,500 RPMs.

5.4.5 At this point, the work area should start to show a polish but the color will appear muted or greyed in comparison to the rest of the countertop. The depth and clarity of the reflection in the working area will be slightly diminished when compared to unworked areas. The surface is now ready for the use of polishing compound.

5.4.6 There are several different types of granite polishing compounds. Some are strictly abrasive products that contain aluminum or tin

oxide. Others are creams that combine chemical and abrasive technology. Regardless of the type of compound used, most technicians use a hog's hair burnishing pad that is cut to fit the backer pad (pad driver) to finish polishing the work area.

5.4.7 If a traditional powder is used, add enough powder to cover the area. Spray with enough water to wet the powder slightly, then place the machine on the wet powder. With the dial set to the lowest speed, start the machine. The process should produce a thick slurry of polishing compound. As the slurry dries onto the surface, spray a small amount of water to keep the surface and polishing compound wet. As the compound dries, add a little more, apply pressure, and increase the speed of the machine. The added pressure will cause friction and heat that creates a better polish.

5.4.8 If using a granite polishing cream or paste, place a quarter-sized amount on the surface of the work area for a section approximately 8-inches in diameter. Attach a 5 or 7-inch foam backer pad to the machine and use a hog's hair burnishing pad cut to fit the backer pad. Start the machine at the lowest speed to spread the product around on the surface in small sections. Use moderate pressure to work the product into the surface in a linear or figure-8 pattern. As the heat generated by the machine dries the cream, increase the speed of the machine and maintain a light pressure. After a few passes it may be necessary to increase the speed to the middle setting of approximately 3,500 RPMs and burnish the surface to achieve the high-gloss deep color of a factory finish. It may take multiple applications to achieve the desired finish and depth of color. The surface is ready for sealing when the desired level of polish and depth of color are achieved.

5.5 Cleaning and Polishing. Because granite holds up so well and rarely requires refinishing, technicians are often asked to clean and polish granite countertops. In these cases, it is common to polish the entire countertop surface with a granite polishing cream using a hog's hair burnishing pad or a spray polish/crystallizer with a steel wool pad. The hog's hair pad or steel wool pad is cut to fit the machine's backer pad. Both processes remove grimy buildup that dulls a countertop. This process enhances the color and shine of the stone and restores the surface to the level of finish the customer desires.

5.6 Sealing (using an impregnating repellant). For sealing, refer to chapter 8 of this document (Sealers). In general, a simple water test on the surface of the stone will determine its porosity. If the stone darkens when wet, sealing the stone can be beneficial. The general rule that applies to sealing stone is to start with a thoroughly clean and dry floor. Follow the manufacturer's recommendations for applying their product. A majority of sealer-related problems are caused by not following directions properly.

6.0 CRYSTALLIZATION

6.1 The term *crystallization* (also known as *vitrification* and *re-crystallization*) describes the act of polishing MTL and other surfaces containing calcium carbonate. Crystallizers usually contain magnesium hexafluorosilicate or a like compound. The compound is designed to react with the surface of MTL and chemically etch a shine into the surface. Although the majority of crystallizers are liquids, magnesium hexafluorosilicate is naturally a solid white salt and is present in many commercial marble polishing powders and pastes.

6.2 The polishing medium used during crystallization is a hog's hair pad, a white pad, or a steel wool pad. Steel wool is the most popular polishing medium used to crystallize a MTL surface. However, many newer products have been introduced that can be successfully used with hog's hair or white pads. When using steel wool, the fragments left behind can rust

causing staining to the stone and grout. Vacuuming or using a magnetic broom should always follow the use of steel wool to ensure that all fragments are removed.

6.3 Popularity. Crystallization is popular is because the average well-trained maintenance professional can crystallize 300 (or more) square feet per hour. A steel wool pad typically lasts 300 to 500 square feet when both sides are used. Crystallization is performed with a janitorial swing machine (also known as a janitorial buffer or floor buffer). A drive plate with sufficient "grab" to turn the steel wool is all that is needed. The operator usually pours the crystallizer, undiluted, into a chemical squirt bottle and sets the nozzle to a medium mist.

6.4 Process. Start from the upper left of a room or area (based on the revolutionary turn of the machine) and work toward the door or exit. Add a small amount of liquid to the surface and move the machine with the polishing media across it. Buff the surface until the streaks and liquid disappear. The movements should be overlapping to make sure all spatter marks are removed. Most technicians will work a five square foot area and work backwards, but some technicians work larger areas. After a short period of time, the steel wool pad will become loaded with residue from the buffing process and removal of excess crystallizer. When this happens, turn the pad over and buff the area just completed to remove final residue. The entire service area will be treated in the same way.

6.5 Dust will settle on the floor after polishing is complete. This is usually from the steel wool used in the process. Clean the area with a vacuum, magnetic broom, or microfiber dust mop to remove all steel wool residue. If the cleanup is not performed in a diligent manner, adding water from mopping and maintenance will react with the steel wool fragments and cause the floor to yellow and rust. This is usually seen on the edges of the tiles, in the grout, and sometimes on the surface of the stone.

NOTES:

RESTORATION AND MAINTENANCE – SEALERS

1.0 INTRODUCTION

1.1 Sealing is the process of applying chemical solutions—known as sealers—to stone that, when cured, alter the inherent absorption qualities, increase the resistance to staining, and/or alter the stone's appearance for aesthetic enhancement.

1.2 Sealing natural stone is a science involving knowledge from disciplines such as geology, construction, chemistry, and maintenance. The larger question is, "Does stone have to be sealed?" The short answer is, "No." Before dimension stone was cut and polished and set in a home or office, it was just a rock in the ground. There are millions of unsealed stone installations with which humans have interacted for hundreds, if not thousands, of years. Why is stone sealing now common? Modern consumers want to protect stone's appearance, reduce maintenance costs, and preserve the investment that stone surfaces represent.

1.3 Because of different performance goals, desires, and perceived acceptability for stone use, there are different product offerings in the market. The sealer product selection needs to be made based on sealer type and other criteria as described within this document. There are three basic categories of sealers commonly used in the stone industry.

2.0 TYPES AND CHARACTERISTICS OF SEALERS

2.1 Impregnating Repellents (also known as impregnators and penetrating sealers) are chemical compounds known as "Solids" or "Actives" (a contraction for "active ingredients") that are carried by water or a solvent ("Carriers") into the interior of the stone. When cured, these compounds provide resistance to stain sources or contaminants that are water or oil-borne. Impregnating repellents minimally affect the stone's color, texture, or finish, and require a minimum level of maintenance. They are composed mostly of silicone-based chemicals and fluoropolymers, and are ineffective against highly acidic or alkaline chemical etching. They require the use of pH-neutral cleaners. Most importantly, they allow moisture vapor transmission (MVT), which is the natural process of moisture transfer through the stone.

2.2 Color-enhancing Impregnators are a sub-category of impregnators that contain a higher concentration of actives or solids that darken and enrich certain natural stone colors. They are more viscous in consistency, moisture sensitive, require greater care during application, and should be applied when the stone is as dry as possible. Be sure to consult the manufacturer's directions for specifics. Color-enhancing impregnators also allow vapor transmission (MVT). They accentuate color and contrast, texture, and finish variations in the stone and grout and may create a light sheen.

2.3 Film-forming sealers (also known as "coatings" or "topical coatings") contain higher concentrations of actives compared to impregnating repellents or color-enhancing impregnators. The actives are deposited by a carrier onto the stone's surface, where they cure and ultimately create a hardened film. The film-forming sealer creates a sacrificial physical barrier between the stone's surface, potential contaminants, and the environment. They can consist of acrylic, urethane, and epoxy chemical compounds.

2.3.1 Important Characteristics of Film-forming Sealers. Film-forming sealers protect the stone's factory finish and diminish the effects of pedestrian and vehicle traffic. They can effect slip-resistance when wet, unless combined with grit additives, and can

create various types of finishes, from matte to high-gloss. Film-forming sealers can enhance color, texture, and finish variations in the stone and grout. They are subject to abrasion, which can breach the integrity of the protection the film-forming sealer affords and reflect the wear patterns of foot traffic. In the presence of Moisture Vapor Transmission (MVT) they could turn milky white. Film-forming sealers require additional cleaning steps and require the surface of the stone be maintained by high-speed burnishing and/or recoating at regular intervals.

2.4 Sealer Components. Sealers are comprised of two main components: carriers and actives (also known as "solids"). The primary carriers are water and solvent, and new carriers are being tested regularly.

2.4.1 Carriers. The carrier component of a sealer facilitates the delivery of the active ingredients to the interior of the stone.

2.4.1.1 Solvent-based Carriers usually contains higher amounts of Volatile Organic Compounds (VOCs). Most solvent-based sealers have strong, distinctive odors and require the use of Personal Protective Equipment (PPEs) and adequate ventilation during application and curing. Solvent-based sealers are sensitive to ambient air and surface temperatures. The stone should be dry. Excessive moisture inhibits a sealers' curing and may also prevent adequate protection. What constitutes "a dry stone" needs to be defined by reading the instructions or contacting the sealer's manufacturer. Generally, solvent-based sealers are better for higher density stones with lower porosity.[1]

2.4.1.2 Water-based Carriers usually have less VOC components, less odor, and less environmental regulations concerning their use. They rarely require PPE, though the method of application may require breathing protection. Consult the manufacturer's documentation for information. Water-based sealers are sensitive to lower temperatures, but less sensitive to higher moisture content in the stone. Consult sealer manufacturer for specific recommendations. Generally, water-based sealers are better for lower density stones with higher porosity.

2.4.2 Actives. Also known as "solids," actives are the chemicals that penetrate the stone and cure a few millimeters below the surface. They reside in the intercrystalline boundary areas and pores of the stone.

2.4.2.1 Silicone-based chemicals are used primarily for repelling water or water-borne contaminants. This quality is commonly referred to as hydrophobic. The actives for this category include silane, siloxane and silicone.

2.4.2.2 Fluoropolymers are used primarily for repelling oil or oil-borne contaminants. This is trait is commonly referred to as oleophobic.

2.5 General Characteristics of Sealers.

2.5.1 Sealing can alter the inherent absorption qualities of stone, increase resistance to staining, and/or alter the stone's appearance for aesthetic enhancement. In certain situations, sealers can be employed to improve slip resistance.

2.5.2 There are some conditions in which sealing stone could be ineffective or dangerous. Moisture, vapor, UV light, landscape, and chemical exposure are all variants that may render sealing inappropriate. For instance, freeze-thaw conditions and standing water can create slip hazards, and have the potential to damage material over time. Careful consideration of the activities and the manufacturer's recommendations will aid in the selection and application of a sealer for a particular installation.

[1] *Density* is the weight of material expressed as its mass divided by volume; *porosity* is the ratio of a stone's pores to its total volume; *porosity* is the ratio of a stone's pores to its total volume.

2.5.3 Sealers are maintenance products and require periodic reapplication. Even though some manufacturers warrant their sealers for certain time periods, because these sealers dissipate and lose their protective quality as time goes on, resealing is required.

2.5.4 Sealers do not alter a stone's molecular structure. In stone restoration work, a class of products known as consolidators and densifiers do reintroduce mineralogical components lost from the weathering process in order to slow the natural deterioration of the stone. These products are not considered sealers.

2.5.5 Depending on the type, sealers do make stone surfaces more resistant to water, oil, contaminant and weather. Some sealers repel both types of contaminants. However, they are not weatherproofing and waterproofing agents. They act as a barrier, but will break down through prolonged exposure to contaminants.

2.5.7 Sealer performance is not dependent on whether a product is solvent-based or water-based. There are varying degrees of quality amongst the water-based and solvent-based sealer categories. The sealer's quality is based on purity of the carrier, quality of the actives used, and concentration of actives in the product.

2.5.8 Sealer performance is dependent on the type of stone, the demands on it, and the location of the installation. Interior or exterior location, traffic levels, and climate extremes of the installation are contributing factors to product performance and will help determine the sealer selected. Tests should be conducted to ensure the right sealer is matched appropriately to a particular stone and application.

2.5.9 Sealer performance is only as good as the technician applying it. Following the manufacturer's directions is the best way to ensure a successful result. Thorough cleaning and preparation of a stone with approved chemicals and procedures, adequate drying time, and proper application techniques are critical to ensure a successful application.

3.0 DETERMINING THE APPROPRIATE SEALER

3.1 After the decision has been made to use a sealer, it is important to narrow the offerings. When determining which sealer is best suited for a material, stone care professionals must take several factors into account. It is best to begin with the identification of the stone's geological classification and identify the protection needed.

3.2 Geological Classification. Proper stone identification is important when applying sealers. Each stone classification has performance parameters. These parameters help establish the suitability of a particular stone for the considered or existing installation.

3.2.1 Hardness is a measure of the mineral's resistance to scratching.

3.2.2 Permeability is the capability of a porous rock or sediment to permit the flow of fluids through its pore spaces.

3.2.3 Chemical Sensitivity is a reaction to acid or alkaline. Natural stone is categorized into three basic geological classifications by their respective formation processes: sedimentary, metamorphic and igneous. Additionally, stones in each category can be either calcareous or siliceous, based on their mineral components. These mineral components determine the reactiveness of the stone to acid or alkaline solutions.

3.2.3.1 Calcareous Stone is composed mainly of calcium carbonate, a chemical compound commonly found in natural stone, shells, and pearls. Calcium carbonate is

sensitive to acidic solutions, so mild, non-acidic cleaners are recommended.

3.2.3.2 Siliceous Stone is composed primarily of silicates such as quartz, feldspar, and mica. As such, siliceous stone is generally resistant to most acids found in kitchen settings. Acidic cleaners are still not recommended, because these stones may contain trace levels of minerals that are vulnerable to acid attack, or the cleaners may contain levels of one of the few acid types that attack silicates such as hydrofluoric acid (e.g., toilet bowl cleaners, rust removers, chrome wheel cleaners, plant food and wood treatments containing ammonium bifluoride).

Geological Classification Chart

	Sedimentary	Metamorphic	Igneous
Calcareous	Limestone Travertine Onyx	Marble Serpentine	
Siliceous	Sandstone	Slate Quartzite Soapstone	Granite

3.3 Appropriate Material for the Intended Use. An analysis of whether the stone is suitable for the proposed use or existing installation is important. First, the environment needs to be identified. This is often done by consulting plan specifications and post-construction manuals and talking to sources such as the homeowner or tenant, building or maintenance manager. Once the nature of the use or environment is determined, stone professionals can help specify materials best suited for that use or environment. Possible sources to determine suitability can be the stone supplier, a stone maintenance and restoration contractor, an installation contractor, a stone geology resource, or MIA.

3.4 Determining the Potential Source of Staining or Problems. Residential homes require some different care and considerations than commercial or industrial buildings. Because of the different elements of exposure, interior stone behaves differently from exterior stone. Understanding the various types of contaminants and the environmental impact on stone applications will provide the information to decide the appropriate sealer. The product performance expectations must be realistic. It is important to note that neither impregnating repellents nor film-forming sealers can prevent normal weathering and deterioration from normal traffic and use.

3.4.1 Residential and Commercial Interiors. Always identify the possible sources for stains, evaluate the materials, stones, and sealers relative to the activities and stain sources present, and determine suitability of masking adjacent surfaces prior to sealing.

3.4.1.1 Considerations for Residential Interiors. The type of stone and susceptibility to reaction, abrasions, and other breakdown should always be considered, especially when working with polished marble and granite or honed travertine and limestone. The use area should also be considered, especially in high-traffic areas such as kitchens, family rooms, and bathrooms/showers. Other factors to consider in residential applications include: family size, pets, and associated use; foods and liquids (lemon, vinegar, wine, juices, and oils); cleaning chemicals (toilet bowl cleaners and citrus cleaners); and personal toiletries (lotion, shampoo, conditioner, hand soap).

3.4.1.2 Considerations for Commercial and Industrial Interiors. Factors to consider in commercial and industrial interiors include: issues caused by luggage, bell carts, dollies, and other equipment; water features and fountains; interior landscaping; proximity to food courts, restaurants, and common areas; maintenance practices and needs; slip resistance and safety; increased volume and traffic patterns; and sealer odors multiplying through HVAC systems.

3.4.2 Exteriors

3.4.2.1 Considerations for Exterior Applications. Vapor transmission must be

achieved in exterior applications. A lack of vapor transmission can lead to spalling and other issues. Several other things must be taken into consideration for exterior applications, including: biological growth (moss, algae, lichen, and mold), environmental conditions (freeze-thaw, salt water, high water tables, acid rain, pollution, UV exposure, and cold weather treatments such as grit or salt), vehicle stain sources (oils, antifreeze, and rubber marks), pitch of surface (should be 2%), landscape, fertilizer run-off, irrigation, and water run-off systems.

3.4.2.2 Further Considerations for Exterior Applications. Exterior installations are unique, because they will interact with climate and environmental forces as well as human activities. It is important to consult with manufacturers to determine their sealer's suitability with the stone and installation. A sealer's resistance to ultraviolet light degradation impacts its effective lifespan. In order to prevent freeze/thaw issues, a sealer used in an exterior installation should have an acceptable percentage of Moisture Vapor transmission (MVT).

3.5 Determining the Desired Finished Appearance. The choice of the final appearance of the stone is driven by aesthetic considerations, which will be determined by an architect, interior designer, and/or the owner of the property. Aesthetics is a major determinant in sealer selection. As mentioned above, different sealer types provide unique options for appearance. Impregnating repellents provide resistance to staining while retaining the natural appearance and beauty of stone. Color-enhancing impregnators can darken or bring back the color of polished stone to stone that has been textured or honed. Film-forming sealers provide a mechanical or physical barrier between the stone and potential stain sources. Film-forming sealers will also alter the natural appearance of a stone, changing sheen of the surface from a matte finish to a reflective finish or from a reflective finish to a matte finish.

3.5.1 Performance Expectations. There can be a trade-off between appearance and functionality. For instance, a film-forming sealer provides protection against chemical exposure to the stone, but usually gives the surface a plastic-like look. Each installation is unique and the sealer selection will require consideration of a number of variables, as listed in the next section.

3.5.2 Factors to Consider. Impregnating repellents are best for maintaining a stone's natural appearance. Color-enhancing impregnators best enrich a stone's color and character. Film-forming sealers are best for creating low-gloss, semi-glass, and high-gloss finishes.

3.6 Determining the Desired Level of Maintenance. Maintenance costs are often overlooked in the process of selecting a stone and sealers. Maintenance is the most important factor in preserving the appearance and protection of a sealed stone. The client's expectations need to be clarified in order to best assess the material and sealer for the desire outcome. Use and traffic, compounded with sealer choice and material used, can all affect maintenance needs.

3.6.1 Residential Clients typically expect a high level of presentation, but may fail to consider preservation requirements. It is important to set achievable expectations. Many residential clients want a material that usually requires a high level of maintenance to be maintenance free. Residential environments are typically maintained on a sporadic basis, depending on the commitment of the owner to the cleaning process.

3.6.2 Commercial Clients, Such as Hotel Facilities Managers, are often concerned about cost, durability, and safety. There are times when these clients have similar desires to the residential client, but there is usually very little emotion tied to their objectives. Commercial environments are typically maintained on a daily basis by either

in-house personnel or contracted cleaning firms.

3.6.3 Guidance in Sealer Selection. Type of sealer used and installation location will dictate the level of maintenance needed. Maintenance refers to regular periodic cleaning with the appropriate products and procedures. The installation type determines the cycle of cleaning.

3.6.4 Maintenance Needs. Maintenance charts, lists of acceptable products and equipment, training material, and training sessions with cleaning personnel are important in developing a realistic plan to sustain the service life of the sealed surface. Sometimes the cleaners recommended for use on stone with an impregnating repellent will contain small amounts of the sealer. This will help increase or eliminate the interval for reapplication. Check the specific product manufacturer's guidelines as to the maintenance of their products. A thorough understanding of an end user's expectations involves balancing form and function when applying sealers and because each installation is unique, sealer selection involves the consideration of multiple variables. Impregnating repellents provide longer-term protection and are less costly, due to their less-frequent maintenance needs. Also, there needs to be periodic reevaluation of methods based on product and technique advancements.

3.6.5 Determining the Tolerance for Volatile Organic Compounds (VOCs). Most solvent-based sealers have strong, distinctive odors and require the use of Personal Protective Equipment (PPE) and adequate ventilation during application and curing. If adequate ventilation is impossible during the application and curing process, then VOCs must be considered when deciding the appropriate sealer. Even when there is adequate ventilation, the use of personal protective equipment is still recommended.

4.0 BUDGETARY CONCERNS

4.1 Points to Consider. End users need to be informed about the projected maintenance costs. Facility managers need information regarding regular scheduled visits and the associated costs. Commercial and industrial applications need regular professional maintenance; and require daily or nightly cleaning as an ongoing service. Maintenance charts, lists of acceptable products and equipment, training material and training sessions with cleaning companies. Follow up visits by a stone care professional to ensure that the proper maintenance program has by followed.

5.0 FIELD TESTS FOR DETERMINING SEALING NEEDS

5.1 Performing field tests is a common industry practice for stone professionals. Most consider water absorption as being an important test, especially if the surface is exposed to water and water-borne contaminants. Water beading on the surface is not indicative of a sealed stone. The beading of water demonstrates the properties of surface tension. For example, water will react similarly when applied to factory resin-coated or enhanced stones and denser stones with tighter mineralogical matrices. It is important to note that some natural stones may not require sealing, and can even be negatively impacted if sealed. This negative impact is the result of the product not being absorbed in to the stone and drying on the surface. This is a correctable error, but it requires reactivating the product with a solvent and removing the residue while the product is in the reactivated state.

5.2 Selecting the Test Specimen. It is better to test a sample of the exact material (same stone and lot) than to risk damage to the installed material. The main negative issue with sample testing is the lack of the exact same history of the installed material after use. Sometimes inconspicuous areas, such as

closets, also lack chemical treatments that may have been applied to the conspicuous areas. If the issue can be duplicated on a sample or an inconspicuous area, then proceed by testing the sample or the inconspicuous area. To be sure that each sealer is given a fair chance it is recommended to determine that each sample or area has similar mineral and porosity characteristics. To keep chemical wicking from affecting your tests, be sure to physically separate or allow enough distance between test areas.

5.3 Recommended contaminates for basic field testing include: oils (corn, olive, coconut, or others that may come in contact with the stone), water (or water-based contaminants such as tea or coffee), acids (vinegar, citrus, fruit juice, etc.), red wine, or any other contaminant that may come in contact with the stone.

5.4 Preparation of the Stone. Clean the stone with a neutral pH stone cleaner and allow to dry for 24 hours or until thoroughly dry. Be sure to follow the preparation procedures recommended by the manufacturer of the sealer.

5.5 Application of Sealers. Sealers should be applied according to manufacturer's instructions. To get proper protection more than one application may be necessary.

5.6 Cure Time. Allow appropriate cure time per the manufacturer's recommendations.

5.7 Test Procedures. Stone care professionals must understand how to properly perform informal field tests. Testing is the best way to learn how the specific product or products will perform in a real life setting.

5.7.1 Record Keeping. Prepare a written and photographic log to document the test methods and results. Note date, time intervals, test area, and quadrant. Identify each contaminant tested, the quantity, and the amount of time left on the surface. Add any other important information such as moisture levels and temperature.

5.7.2 Label Test Area. Use a permanent marker on the label. Make sure that the marker or any label adhesive does not stain the stone. Include things that identify the whole area and quadrants (measurement marks can also be used with axis labels).

5.7.3 Exposure. Determine the length of exposure to each contaminant. If it is likely that the area may not be cleaned for a week, then the exposure time needs to be a week or more. On countertops, where they are likely cleaned multiple times throughout their use, an exposure of 8 to 24 hours should be sufficient.

5.7.4 Execute the Field Test in the Following Manner. Ensure surface is clean and dry. Apply an adequate, measured amount of the contaminant to the surface (for example: 1/2 teaspoon of water, oil, or vinegar). Allow the contaminant to dwell on the horizontal surface for five minutes or longer (as mentioned above). Ideally the contaminant (with the exception of acid) will be repelled for no less than ten minutes when placed on a properly cured sealer. Remove the contaminant by blotting the area. Do not wipe to dry. Carefully exam the test area directly afterwards and again later.

5.7.5 Results. After the predetermined exposure time has been reached, clean specimens with a neutral pH stone cleaner. Allow the area to dry once contaminant is removed (approximately 20 minutes for initial review and sometimes after a day or more depending on the results). Visually evaluate and log results. A successful stone/ sealer test would show no absorption, no staining, and no etching. If the stone turns darker, it will stain if not sealed. If the stone turns dull and whitish in color, then the stone is likely to etch. Another possibility is that an acidic solution can disturb the impregnating repellent that has been applied to a very dense stone so it appears

whitish. In this last scenario, the difference is that it still has polished reflection.

5.7.6 Etch Test. When working with an unidentifiable stone, the etch test will confirm if the stone is calcium carbonate based. To perform the etch test the stone care professional should use an acid that is commonly used around the stone on different areas of the stone. Serpentines will typically only react to mild acids in the calcium carbonate-based veins. It is recommended to test a sample of the same material and lot if possible. If the stone reacts to the acid, it will need to be restored to the original finish.

5.7.7 Other Things to Consider. Only perform these tests in an inconspicuous area or on an uninstalled sample tile. It is important to note that impregnating repellents will not repel acidic liquids like vinegar, lemon juice, red wines, tile cleaners, and so on. In fact, acids will damage the surface. Be prepared to repolish the surface after testing with acidic liquids. Topical sealers are much more effective at repelling acidic liquids.

6.0 FINAL THOUGHTS ABOUT SEALERS

6.1 The stone care professional plays a critical role in determining the selection of sealers. The desired appearance, functionality and maintenance required are all important considerations in the selection process. Whether involved with new construction or maintaining an existing structure, it is important to consult with others involved in the natural stone industry, understand the role of the specifying authority, and the various aspects of stone behavior in relation to environmental suitability to ensure the information provided is thorough, accurate and beneficial. The consummate professional is educated and experienced and has a thorough working knowledge of natural stone, sealers products, and the effects of various environments. The stone care professional provides counsel and evidence regarding which sealers would best preserve a stone's condition and presentation, and meets the end user's needs.

6.2 Important Points to Remember. Sealers are water, oil, dirt, contaminant, stain, and weather resistant agents only. Sealers minimize the effects of harmful contaminants, making end-user care and professional maintenance easier and less costly. Sealers are most effective when paired with the appropriate stone and substrate. Sealers applied to stone used in exterior and wet environments can alter the dynamic coefficient of friction. Appropriate tests should be performed to determine suitability prior to application. Sealers can minimize and slow the effects of biological, chemical, and physical interior and exterior weathering and their byproducts, such as exfoliation, fracturing, frost or salt-wedging, movement, oxidation, slaking, sugaring, etc., but cannot prevent them from occurring. No natural stone installation is maintenance-free.

RESTORATION AND MAINTENANCE – MAINTENANCE

1.0 INTRODUCTION

1.1 This section will provide end users with basic information pertaining to natural stone maintenance. Since general specifications and finishes of natural stone affect cleaning procedures, this section will include an overall description of the most common stone specifications and finishes. It is important to also acquire background data on the individual stone(s), such as type and source of stone, type of sealer used (if any), and recommendations of sealer manufacturers as to care of sealed stone, etc.

2.0 SLIP RESISTANCE OF STONE FLOOR SURFACES

2.1 In commercial environments it is important to maintain a log detailing daily and periodic maintenance. This log should document the procedures followed on days of inclement weather, such as rain or snow.

2.2 The Americans with Disabilities Act (ADA). This federal legislation, passed in 1990, is the most comprehensive civil rights legislation adopted to prohibit discrimination against people with disabilities. Public and private businesses, state and local government agencies, and private entities offering public accommodations and services, transportation, and utilities are required to comply with the law. At one time, ADA documents prescribed a recommended minimum coefficient of friction for walkway surfaces in accessible routes of commercial and public buildings, but the section of the ADA documents that contained this recommendation have since been withdrawn.

3.0 DEFINITIONS, PURPOSE, AND BENEFITS OF STONE MAINTENANCE

3.1 Polished-finish Stone has a glossy surface that provides clear reflections and accentuates the color, contrast, and character of the material. Due to abrasion from foot traffic, soft stones with a polished finish will generally wear to a dull surface. Due to varying hardness of the minerals that comprise the stone's fabric, uniform gloss and/or reflectivity may not always be achieved in all stones.

3.2 Honed-finish Stone has a smooth, matte surface with limited reflection. This finish is generally preferred for softer stone varieties used for floors, treads, thresholds, and other pedestrian locations where heavy traffic would dull a polished finish. Its lack of gloss makes it a more forgiving surface in that unevenness or waviness will not be as easily detected. Due to varying hardness of the minerals that comprise the stone's fabric, uniform gloss and/or reflectivity may not always be achieved in all stones.

3.3 Maintenance. Regular cleaning should be scheduled, using specific procedures, products, and equipment. Inspections should be performed at prescribed intervals.

3.4 Restoration involves the refinishing of existing stonework to return its appearance to that of a newly supplied, unworn product. This process may include minor repairs such as filling of chips or pits in the stone surface, replacement of cracked or missing grout, removal of stains and/or etching, and honing or polishing.

3.5 Purpose and Benefits of Maintenance.

3.5.1 Appearance. Efficient regular cleaning removes fine particulates, which can abrade and dull the surface of the stone over time.

3.5.2 Sustainability. Proper maintenance will lengthen the stone's service life, effectively delaying the need for more

aggressive restoration methods or replacement.

3.5.3 Safety. A properly maintained stone surface that is free of contaminants will provide a safer walking surface with better, and more uniform traction available for occupant ambulation.

4.0 CONDITIONS INFLUENCING MAINTENANCE

4.1 Stone type will determine necessary methods and frequency of maintenance. Knowledge of the stone's properties will aid in designing a maintenance program. For example, granite is a very hard stone with little absorption capacity, while limestone has a softer composition and a greater absorption capacity. The stone properties will also influence the selection of appropriate sealing products. For maintenance purposes, specific groups of stones should be considered in order to properly maintain them.

4.1.1 Group 1. Stones that typically do not contain calcium carbonate and typically do not react to most common acids:

- Igneous rocks: granite, basalt
- Metamorphic: slate, gneiss, schist
- Volcanic: Adoquin, Canterra

4.1.2 Group 2. Stones that contain calcium carbonate and typically react to common, mild acids:

- Calcite: marble, travertine, limestone, onyx, terrazzo

4.2 Installation Methods and Related Components.

4.2.1 Substrate. The rigidity and quality of the substrate may affect not only the performance of the stone, but also the necessary maintenance. Some substrates are very vulnerable to water infiltration, so maintenance methods must limit the amount of water used and the dwell time water is allowed on the stone surface.

4.2.2 Adhesives. Some adhesives may be adversely affected by some cleaning agents.

4.2.3 Grout. Various products are used for grouting joints (e.g.: cement, cement with additives, and epoxy), all of which have unique maintenance and sealing requirements.

4.2.4 Joint Sealant. Different elastomeric materials are used to caulk joints in finished stonework (e.g.: silicone, urethane, acrylic), each of which have unique performance traits and maintenance requirements.

4.3 Characteristics of Certain Stones. Many stones have unique features, such as fillers, voids, or repairs, which influence maintenance practices.

4.4 Condition of Stone Installation. Residual issues from the initial installation or previous restoration attempts, such as lippage, scratches, etch marks, acid burn marks, and cracks will influence maintenance needs or create a requirement for subsequent restoration activity.

4.5 Location of Installation.

4.5.1 Interior. Whether residential or commercial, interior surfaces require careful consideration of the surrounding materials. Maintenance can impact adjacent surfaces such as floor molding, furniture, other stone surfaces, wall coverings, and painted walls. Care must be taken to protect these surfaces or use materials that will not impact their appearance or function.

4.5.2 Exterior installations require the same attention to adjacent surfaces as interior settings. Additional attention must be paid to landscape, vegetation (plants, bushes and trees), and water runoff. Check federal, state, and local codes for building, safety, and environmental requirements.

4.5.3 High Rise Claddings. Cladding restoration is a specialty area due to the difficulty of access and potential influence to building seals and curtainwall performance. Adjacent materials, such as joint sealers and aluminum and glass curtainwall wall components must be protected from damage by chemical or abrasive cleaning methods used on the stone panels.

5.0 MAINTENACE METHODS FOR RESIDENTIAL CLEANING

5.1 Products and Equipment.

5.1.1 Products. Use only stone cleaners or pH neutral cleaners. Some stone cleaners also contain small amounts of sealer. These products help to maintain the level of protection.

5.1.2 Equipment. New equipment is being developed continually to clean stone surfaces. Common equipment used includes:

- A small canister vacuum with non-metallic wheels and a flat floor head with soft bristles made of nylon or horsehair, or a smooth felt liner along the bottom edges. Metal attachments should never be used.
- Clean cotton string or sponge mop. Dirty mop heads are a major source of residual soil on the floor.
- Plastic buckets. Never slide the bucket on the floor. If the bucket has wheels, they should be non-metallic and non-marring.
- In-home steamers. Steamer head rags should be changed frequently.
- Small scrub brush and/or a deck brush. Bristles should be soft nylon to reduce scratching.

5.2 Daily Maintenance. The removal of dirt, debris, and dust is essential to maintaining the appearance of the floor. All stone flooring should be dust mopped or vacuumed daily or as necessary to remove debris, dirt and fine particulate matter. Vacuuming is the preferred method because it lifts abrasive materials up and away from the floor. Dust mops should be dry and untreated.

5.3 Weekly maintenance involves washing with clean, potable water and pH neutral cleaners. Soapless cleaners are preferred because they minimize streaks and film. Mild, phosphate-free, biodegradable liquid dishwashing soaps or powders or stone soaps are acceptable if rinsing is thorough.

5.3.1 Process. Wet the stone surfaces with clean water. Using the cleaner (following manufacturer's directions), wash in small, overlapping sweeps. When using the brush apply light pressure so that only the ends of the bristles are doing the scrubbing. Work from the bottom up if it is a vertical surface. Rinse thoroughly with clean, potable water to remove all traces of soap or cleaner solution. Change the water in the rinse pail frequently. Dry with a soft cloth and allow to thoroughly air dry. Alternatively, employ the use of a wet vacuum to extract contaminants. In commercial applications with high traffic levels, the use of an automatic scrubber fitted with a disc-type brush system and continuous extraction is generally the most effective method. Brush aggressiveness must be matched to the stone type and hardness to prevent damage.

5.4 Safety Precautions. Any flooring surface, regardless of its finish, can be slippery when wet. Promptly remove liquids or foreign materials that might result in safety hazards before permitting pedestrian traffic. Use warning cones or other means of alerting occupants to a temporary reduction in traction.

5.5 Precautions. For counter or table tops, use coasters under all glasses, particularly those containing alcohol or citrus juices. Many common foods, drinks, and cosmetics contain acids that will etch or dull stone surfaces. Use trivets or mats under hot dishes and placemats under china, ceramics, silver, or other objects

that can scratch the surface. Blot spills with a paper towel or cloth as they occur or as soon as possible thereafter. Clean regularly with a neutral cleaner that does not contain solvents.

5.5.1 In food preparation areas, stone surfaces may require an impregnator or topical sealer. If an impregnator or topical sealer is applied, it must be nontoxic and safe for use on food preparation surfaces.

5.5.2 Never use acidic or ammoniated cleaner or chemicals on calcium carbonate-based stone surfaces. Use a cleaner specifically formulated for stone cleaning.

5.6 Heavy Duty Cleaning. High traffic areas such as kitchens may require a yearly deep cleaning and resealing. This requires the use of floor machines, brushes, and specialized pads.

6.0 MAINTENANCE METHODS FOR COMMERCIAL CLEANING AND SEALING

6.1 Group 1 includes stones that typically do not contain calcium carbonate and typically do not react to most common acids.

6.1.1 Igneous Rocks (granite and basalt).

- Clean daily, using methods outlined in section 5.0.
- Yearly (for floors and stairs): Scrub floors with a standard 175 RPM buffer, using a soft nylon brush and a neutral cleaner. An automatic scrubber machine can be used for larger floors. For stairs, use a slow speed hand polisher.
- Stone and/or grout may need to be resealed at intervals of 3 to 5 years. See section 9.0 for more information on sealing.
- Extremely worn or damaged surfaces will require restoration rather than standard cleaning.

6.1.2 Metamorphic Rocks (slate, gneiss, and schist).

- Clean daily, using methods outlined in section 5.0.
- Yearly (for floors and stairs): Scrub floors with a standard 175 RPM buffer, using a soft nylon brush and a neutral cleaner. An automatic scrubber machine can be used for larger floors. For stairs, use a slow speed hand polisher.
- The stone and/or grout may need resealed at intervals of 2 to 5 years. See section 9.0 for more information on sealing.

6.1.3 Volcanic Rocks (adoquin and canterra).

- Clean daily, using methods outlined in section 5.0.
- Yearly (for floors and stairs): Scrub floors with a standard 175 RPM buffer, using a soft nylon brush and a neutral cleaner. An automatic scrubber machine can be used for larger floors. For stairs, use a slow speed hand polisher.
- The stone and/or grout may need resealed at intervals of 2 to 5 years. See section 9.0 for more information on sealing.

6.2 Group 2 includes stones that typically contain calcium carbonate and react to acids. These calcite stones include marble, travertine, limestone, onyx, and terrazzo.

- Clean daily, using methods outlined in section 5.0.
- Twice yearly: Scrub floors with a standard 175 RPM buffer, using a soft nylon brush and a neutral cleaner. An automatic scrubber machine can be used for larger floors. For stairs, use a slow speed hand polisher.
- Stone and/or grout may need to be resealed at intervals of 2 to 3 years See

section 9.0 for more information on sealing.

- Extremely worn or damaged surfaces will require restoration rather than standard cleaning.

6.2.1 Maintaining Finishes on Calcite Stones.

6.2.1.1 Polished Surfaces. Buff the stone with a slurry of water and a non-acid polishing compound. Specialized diamond impregnated pads can also be used, using a standard 175 RPM buffer or a high-speed burnisher. Combining the compound with a diamond impregnated pad may produce a higher-gloss finish. A slow speed hand polisher can be used for stairs, walls, and tops. This should be done four times a year, or as needed.

6.2.1.2 Honed Surfaces. Buff the stone with a slurry of water and a non-acid honing compound. Specialized diamond impregnated pads can also be used, using a standard 175 RPM buffer or a high-speed burnisher. Combining the compound with the diamond impregnated pad may produce a better honed finish. A slow speed hand polisher can be used for stairs, walls, and tops. This should be done four times a year, or as needed.

7.0 MAINTENANCE METHODS FOR EXTERIOR STONE

7.1 Exterior stone is a general term denoting stone installed where temperature, moisture, and airborne contaminants are caused primarily or solely by forces of nature. It can be used in a honed, textured, or polished finish in any mode in an exterior environment. Uses include building cladding, walkways, steps or stairs, retaining walls, paving, fountains, benches, planters, and decorative items such as sculptures.

7.2 Normal Maintenance. In accessible areas, routinely follow maintenance procedures as specified in Sections 5.0 and 6.0 of this chapter, as applicable. Normal maintenance should include periodic inspection of stone surfaces for structural defects, movement, deterioration, or staining. Distress in joint fillers is a common sign of stone unit or substrate movements.

7.2.1 The large expanses of stone generally found on exterior applications may make it impractical to perform frequent normal maintenance. Large installations, however, should be given periodic overall cleaning to remove accumulated pollutants. If the exterior stone surface has calcium deposits, an acid cleaner can be used on igneous rocks only. Easily accessible stone surfaces such as steps, walkways, and fountains should be kept free of debris and soiling by periodically sweeping and washing with water.

7.3 Local Regulations. Many local municipalities have regulations related to water use and chemical disposal. Always check these regulations and authorizations before bidding on such cleaning projects; in some cases, there are additional costs associated with these regulations.

8.0 EXTERIOR BUILDING STONE CLEANING

8.1 Exterior building stone is considered in this section to be all stone used on the exterior of a structure, either as a structural component or as a facing material, with the exception of polished, finished marble. Although a polished finish is not recommended for exterior use with most marble varieties, it is occasionally used on storefronts, column facings, and similar treatments.

8.2 Regular Cleaning. The ideal in maintaining exterior building stone is to clean it at periodic intervals (at least annually, depending on atmospheric conditions) by simply hosing down with clean water. This will prevent accumulation of dirt and impurities. In accessible areas, routinely follow maintenance procedures as specified in Sections 5.0 and 6.0

of this chapter, as applicable. Brushes may be necessary for the removal of certain surface impurities. Soft fiber brushes are recommended.

8.3 Sporadic Cleaning. If the stone is not cleaned regularly, a water system (hydraulic, hydro-air, or plain water) will be the most effective method at the lowest cost.

8.4 Dirt on Older Buildings. When dirt has accumulated on older structures over a long period of time, a combination of methods may be necessary to properly clean the stone. A plain water jet will remove most accumulation. No chemicals should be used that could be harmful to the stone.

8.5 Test Panels. By cleaning and inspecting test panels, the Specifying Authority can determine if the method is satisfactory. This procedure eliminates the possibility of improper cleaning; since the Owner and Specifying Authority can see what results will be obtained prior to commencement of the total contract. It also gives the Cleaning Contractor a standard to work toward, making definition of the cleaning more specific for all parties.

8.6 Local Regulations. Many local municipalities have regulations related to water use and chemical disposal. Always check these regulations and authorizations before bidding on such cleaning projects; in some cases, there are additional costs associated with these regulations.

9.0 TOPICAL SEALERS AND IMPREGNATORS

9.1 Topical sealers are coatings designed to protect the surface of stone against water, oil, and other contaminants. They are formulated from natural wax, acrylic, and other plastic compounds.

9.2 Impregnators (penetrating sealers). Impregnators are generally hydrophobic (water-repelling), but some are also oleophobic (oil-repelling). They penetrate below the surface and become repellents. They keep contaminants out, but do not stop interior moisture from escaping. Impregnators are considered breathable, meaning they have vapor transmissibility.

9.3 Treatment Type. The type of stone and environment of the application determine the type of sealer treatment (impregnator or topical) to be used. All treatments must be applied in accordance with the manufacturer's specifications.

9.4 When to Seal. A treatment may be used when a defined benefit can be determined. For example:

- When the risk of staining is present
- As an aid in daily maintenance procedures
- Where a coating may help to preserve the stone finish in excessively high wear conditions
- Where weathering has affected or may affect the integrity of the stone surface
- To prolong the aesthetic beauty of the original installation
- Where the risk of graffiti or other vandalism is high.

10.0 STAINS AND REMOVAL PROCEDURES

10.1 Oil-based Stains (grease, tar, cooking oil, cosmetics). An oil-based stain will darken the stone and normally must be chemically dissolved so the source of the stain can be flushed or rinsed away. First, remove excess staining agent by wiping or chipping (if tar). Clean gently with a liquid cleanser, household detergent, ammonia, mineral spirits, or acetone. Do not pour cleaner directly on the staining agent, as this can thin the contaminant and further its penetration and spread. Partially saturate a paper or cloth towel with the cleaner and attempt to draw the stain into the towel. Commercially available

specialty cleaners, such as alkaline degreasers and/or poultices may also be used.

10.2 Organic Stains (coffee, tea, fruit, tobacco, paper, food, urine, leaves, bark, animal droppings). Organic stains may cause a pinkish-brown stain and may disappear after the source of the stain has been removed. Outdoors, with the sources removed, normal sun and rain action will generally bleach out the stains. Indoors, clean with 12% hydrogen peroxide and a few drops of ammonia. Commercially marketed cleaners and poultices are also available.

10.3 Inorganic Metal Stains (iron, rust, copper, bronze). Iron or rust stains are orange or brown and leave the shape of the staining object, such as nails, bolts, screws, cans, flowerpots, or metal furniture. Copper and bronze stains are green or muddy brown and result from the action of moisture on nearby or embedded bronze, copper, or brass items. Metal stains must be removed with a poultice (see Section 11.0 of this chapter). Deep-seated rust stains are extremely difficult to remove, and the stone may be permanently stained.

10.4 Biological Stains (algae, mildew, lichens, moss, and fungi): Clean with diluted (1/2 cup in a gallon of water) ammonia, bleach, or hydrogen peroxide. Do not mix bleach and ammonia; this combination creates a toxic gas. There are a number of commercial products available that are as effective as ammonia, bleach, or hydrogen peroxide without the potentially hazardous downside.

10.5 Ink Stains. Clean light-colored stones with bleach or hydrogen peroxide. Use lacquer thinner or acetone for dark-colored stones. Do not pour cleaner directly on the staining agent. This can thin the contaminant and further its penetration and spread. Partially saturate a paper or cloth towel with the cleaner and attempt to draw the stain into the towel.

10.6 Paint Stains. Small amounts of paint can be removed with lacquer thinner or scraped off carefully, using a razor blade. Heavy paint coverage should be removed with a commercial liquid paint stripper. Other methods to remove paint would include baking soda blasting or glass bead blasting. These methods should be undertaken by experienced professionals. Begin by testing a small area to determine the efficacy of the method. Do not use acids or flame tools to strip paint from stone. Use of solvents can potentially drive the stain further into the stone.

10.7 Water Spots and Rings (surface accumulation of hard water). Buff with dry steel wool.

10.8 Fire and Smoke Damage. Older stone surfaces and fireplaces stained by smoke or fire may require a thorough cleaning to restore their original appearance. Commercially available smoke removal products may save time and effort. Calcareous stones may also require refinishing due to etching from carbonic acid.

10.9 Etch Marks are caused by acids left on the surface of the stone. Some will etch the finish but not leave a stain; others will both etch and stain. Once the stain has been removed, wet the surface with clean water and sprinkle with polishing powder. Rub the powder into the stone with a damp cloth or by using a buffing pad with a low-speed power drill or polisher. Continue buffing until the etch mark disappears and the surface shines. Honing may be required for deep etching. This process may require the services of a professional refinisher.

10.10 Efflorescence is caused by water carrying soluble salts from below the surface of the stone. The salts are deposited and recrystallize upon evaporation of the water, leaving a powdery salt residue. If the installation is new, dust mop or vacuum the powder. Repeat as necessary as the stone dries out. Do not use water to remove the powder. If the problem persists, contact the contractor

to identify and remove the cause of the moisture.

11.0 POULTICE MIXTURES FOR VARIOUS STAINS

11.1 Overview. A poultice is a chemical or mixture of chemicals combined with an absorbent material to form a thick paste, which is applied to stone to remove stains.

11.2 Poultice materials include kaolin, fuller's earth, whiting, diatomaceous earth, powdered chalk, white molding plaster, and talc. Approximately one pound of prepared poultice material will cover one square foot. Do not use whiting or iron-type clays such as fuller's earth with acid chemicals as the chemical reaction will cancel the effect of the poultice. A poultice can also be prepared using white cotton balls, white paper towels or terry cloth rags, or gauze pads, which may be more effective when using highly volatile solvents such as acetone or mineral spirits. Premixed poultices are available in ready to use form or require adding only water. These are available from stone maintenance supply companies.

11.3 Prepare the Poultice. If using a powdered poultice material, mix with the cleaning agent or chemical to a paste with a thick, creamy consistency (approximately the consistency of peanut butter). If using paper, soak it in the chemical and let drain. Do not let the liquid drip. Prepare stain area. Wet the stained area with distilled water.

11.4 Apply the poultice to the stained area about 1/4" to 1/2" thick, and extend the poultice beyond the stained area by about 1". Use a wood or plastic scraper to spread the poultice evenly.

11.5 Cover the poultice with plastic and tape the edges to seal it. Punch several small holes in the plastic to allow vapor to escape.

11.6 Allow the poultice to dry thoroughly; this usually takes 24 to 48 hours. The drying process draws the stain out of the stone and into the poultice material. After approximately 24 hours, remove the plastic and allow the poultice to dry.

11.7 Remove the poultice from the stain. Rinse with distilled water and buff dry with a soft cloth. Repeat the poultice application if the stain is not removed. It may take five or more applications for difficult stains.

11.8 If the chemical etches the surface, apply polishing powder and buff with a polishing pad recommended by the polishing powder's manufacturer.

11.9 Poultice Mixtures for Various Stains.

11.9.1 Oil-based Stains. Poultice with baking soda and water or one of the powdered poultice materials and mineral spirits or a commercial degreaser.

11.9.2 Organic Stains. Poultice with one of the powdered poultice materials and acetone or 12% hydrogen peroxide solution.

11.9.3 Iron Stains. Poultice with diatomaceous earth and a commercially available rust remover. Rust stains are particularly difficult to remove; professional assistance may be required. Many rust removers contain acids that will etch marble, limestone, and certain granites.

11.9.4 Copper Stains. Poultice with a powdered poultice material and ammonia. These stains are difficult to remove; professional assistance may be required.

11.9.5 Paint Stains (water-based). Poultice with a powdered poultice material and a commercial paint remover.

11.9.6 Paint Stains (oil-based). Poultice with a powdered poultice material and mineral spirits. Deep stains may require methylene chloride. When using highly volatile solvents in

poulticing, use a paper towel, pouring the solvent on the paper towel and then placing the towel on the stained area.

11.9.7 Ink Stains. Poultice with a powdered poultice material and mineral spirits or methylene chloride. When using highly volatile solvents in poulticing, use a paper towel, pouring the solvent on the paper towel and then placing the towel on the stained area.

11.9.8 Biological Stains. Poultice with a poultice material and diluted ammonia, bleach, or hydrogen peroxide. Do not mix ammonia and bleach; this combination creates a toxic gas.

11.10 Flammable Materials. The preceding text does not address possible safety concerns associated with the use of flammable solvents. Refer to the manufacturer's labeling and MSDS for further direction in the safe handling and use of these products. Commercially available cleaners exist for remedy of many common stains. These cleaners may have fewer health and safety concerns. Always use appropriate Personal Protective Equipment (PPE) when handling solvents or other chemicals.

12.0 SPECIFICATIONS FOR BUILDING CLEANING

12.1 Introduction. This section pertains to the furnishing of all labor, materials, equipment, and services necessary for the complete cleaning of exterior building stone as indicated on the plans and described in the specifications.

12.2 Information to be shown on drawings:

- Location, size, and area or items to be cleaned
- Location, size, and number of test panels
- Areas not included in cleaning
- Location, size, and description of materials requiring protection
- Building and property boundaries

12.3 Repointing, Sealing, and Replacement. Specify if repointing or re-sealing of joints and replacement of stone are included in the cleaning scope of work.

12.4 Related sections are to be determined by design requirements.

12.5 Requirements.

12.5.1 General requirements include the plans, general conditions, supplementary general conditions, and the executed agreement.

12.5.2 Certified statements must be furnished as required, attesting that all materials to be used meet the requirements specified and approved.

12.5.3 Scheduling. Provide Specifying Authority with schedule of cleaning operations indicating time of day work will be performed. Wet cleaning methods should not be performed when temperatures reach 35°F or lower.

12.5.4 Test Areas. For approval by Specifying Authority, clean at least a 4'x4' test area for each type of soiling, stone variety, and finish requiring cleaning. Test panels should include intersection of horizontal and vertical joints. The approved panel(s) should be the standard for cleaning methods and finish of all areas to be cleaned.

12.5.5 Protection. For approval by Specifying Authority, provide material types and methods to protect adjacent materials and surfaces from damage, moisture, and staining. If other refurbishing operations are being conducted, protect cleaned stone areas with an approved non-staining covering.

12.5.6 Cleaning. After the surface has been cleaned, rinse with potable water applied to

the temperature and pressure of the municipal water supply.

12.6 Materials. Water should be potable, non-staining, and free of materials detrimental to the surface being cleaned.

12.7 Methods to be determined by approved test areas.

12.7.1 Hydraulic. Water at varying pressures between 300 and 600 psi and at municipal supply temperatures shall be jetted against the surface to be cleaned. Care must be exercised in selecting nozzle tip degree; zero nozzle tips should never be used.

12.7.2 Water Misting. Clean the surface with water. Misting heads are set up on scaffolding and water is misted onto the surface of the building. The misting heads may be set on a timer so that they go on and off intermittently. The intermittent cycle allows the building to dry and prevents oversaturation of the stone. This method is the safest for cleaning and is widely used on historical buildings.

12.7.3 Pressure washing employs the use of high-pressure water jets of up to 2,500 psi or more. Pressure washing works by blasting the dirt off the surface of the stone, and can cause irreversible damage to the stone surface. Pressure washing can be an effective and efficient means of removing dirt and other contaminants. Modern pressure washers can produce pressure in excess of 2,500 lbs/in², which can permanently damage many stone types. Maximum allowable pressure should be determined by slowly increasing pressure while testing in an inconspicuous area. In no case is pressure in excess of 1,000 lbs/in² recommended, and usually much less pressure is appropriate. Always use a fan-tip spray nozzle. Only highly trained technicians should employ this method.

12.7.4 Chemical cleaning is used in combination with one or several of the water washing methods to dislodge soiled particles. Chemicals can be dangerous to the stone, the technician, and the surrounding landscape. Therefore, all chemicals used must be tested and monitored.

12.7.5 Acids. Chemicals with a pH below 7 should not be used on calcareous or dolomitic stones.

12.7.6 Alkalis. Chemicals with a pH above 7 are safe for use on most stones. These are usually followed with a mild acid wash to neutralize the alkaline salts.

12.7.7 Neutral Cleaners. Chemicals containing surfactants with a pH equal to 7 are safe for most stones.

12.7.8 Solvents. Waterless chemicals, such as mineral spirits and acetone, are rarely used for building cleaning due to their high flammability.

12.7.9 Bacteria. Special bacteria can be applied to "eat" dirt and salts.

12.7.10 The J.O.S. system for removal of dirt and graffiti uses a low-pressure washer and milled glass or dolomite powder. Pre-rinsing is required.

12.7.11 Dry cleaning uses organic powder or mineral powder (aluminum silicate) crystals sized between 10 and 90 micros.

12.7.12 Sandblasting is an extremely aggressive method of cleaning and should only be considered when believed to be the only effective solution. Soda blasting (using baking soda in lieu of sand) is generally not as destructive and has some limited usage in the cleaning of natural stones.

12.8 Safety Requirements. All of the methods listed above require specialized equipment. Adherence to OSHA safety requirements by highly skilled technicians is mandatory.

12.9 Testing. All methods must be tested for potential damage to the stone.

COMMERCIAL AND HISTORIC RESTORATION

1.0 INTRODUCTION

1.1 When compared to residential restoration, commercial and historic stone restoration poses several unique requirements and challenges. While many underlying techniques in residential restoration are applicable to commercial projects, changes must be made to adapt to a more complex nature. Commercial and historic stone restoration both require a strong understanding of laws and regulations to protect the integrity of the structure as well as to avoid fines and/or citations. Further challenges arise due to the scale, intensity, location, traffic patterns and management of these projects. This section will cover most of the common requirements and challenges associated with commercial and historic restoration. For the purposes of this document, the term "restoration" will include cleaning, refinishing, repair, sealing, and maintaining.

2.0 DIFFERENCES

2.1 Rules and Regulations. On any commercial or historic project, it is absolutely necessary to familiarize oneself with and follow all federal, state, and local regulations and requirements. Regulations are in place for worker protection and public safety. Noncompliance with these mandates is not only dangerous and unprofessional, but can result in substantial fines. The most common sources for these regulations in the U.S. are the Occupational Safety and Health Administration (OSHA) and the U.S. Department of the Interior, through the National Park Service (NPS).

2.2 Size of Project. The size of lobbies or commercial spaces are typically larger than residential spaces, with significantly more "foot traffic," making "efficiencies of scale" more important for these projects.

2.3 Levels of Pedestrian Traffic. Pedestrian traffic rates in most commercial settings will generally be much greater than those encountered in residential settings. The amount of abrasive particles (dirt and grit) introduced to the stone surface via footwear is also substantially greater. These abrasive particles can do significant damage to most stone finishes, particularly in the softer stone varieties.

2.4 Challenges Encountered With Site Access and/or Restrictions

2.4.1 Work Platforms. Vertical surfaces in commercial applications can extend to great heights, often necessitating the use of work platforms beyond ladders. Scaffolding, scissors lifts, and even mast climbers or suspended scaffolding may be required to gain access to commercial facades. The use of these and other equipment requires knowledge of OSHA regulations, local ordinances (right-of-way permits), and common sense safety knowledge. All workers using elevated work platforms must be trained in the safe use of the equipment and the health and safety regulations that govern its use.

2.4.2 Existing lighting in commercial spaces may be insufficient for restoration work, or may be on automated switches that cannot be overridden by onsite restoration mechanics. The restoration contractor is usually best served by providing his/her own lighting equipment to adequately illuminate the work area.

2.4.3 Electrical Power. It must be verified that adequate electrical power is available (both required voltage and amperage). If this is not the case, the cost of providing generators must be taken into consideration.

2.4.4 Water Supply. If an adequate quality and quantity of water is not available onsite,

considerable cost will be encountered in bringing water from on outside source.

2.4.5 Water Discharge and Disposal. It must be verified if water discharge and disposal can be accomplished onsite, or if spent water supply and/or slurry must be removed from the site. This is just as important as verifying water supply.

2.4.6 Hours of Site Access. Many commercial restoration projects require that the work is performed when the building is unoccupied or at a reduced level of occupancy. This may require working at night or on the weekend. Ensure that onsite workers have access to the restoration company's management personnel, safety managers, and building managers while working during these non-traditional hours.

2.4.7 Maintaining Occupants' Access during Working Hours. Work areas may be limited in certain projects so that access can be maintained. For example, if the restoration includes the elevator cab floors in a hotel, it may be necessary to do one elevator at a time so that the other elevators remain functional, even in off-peak hours.

2.5 Unique Features Found in Commercial Buildings

2.5.1 Revolving Doors. In most cases a revolving door is not the only entrance to a building, so the revolving door area can be worked on while occupants are given an alternate, temporary entrance to the building. The doors can be collapsed or removed to increase access to the workspace during restoration. Pending weather and location of the project, varying levels of temporary building enclosure may be required over the area until the revolving doors can be replaced.

2.5.2 Staircases are common in commercial and historic restoration projects. Smaller equipment is normally utilized, and the production rate is greatly reduced. Due to mandated accessibility guidelines, staircases are rarely the only access point to a floor, so alternate means of access can usually be arranged while the staircase is being restored.

2.5.3 Vertical Surfaces (interior and exterior). It is far more common to encounter expansive vertical surfaces in commercial projects than in residential projects. In addition to general soiling, these surfaces can be abused by other construction trades, delivery equipment, improper cleaning methods, snow removal equipment, or signage and decoration mounting. It is important to eliminate the source of abuse to the surface prior to restoration, otherwise the damage will simply reoccur after the stone is restored.

2.5.4 Special Features (stone trim such as base, plinth blocks, jambs, casings, etc.) are not subject to normal foot traffic, but can still take abuse from getting hit with carts, vacuums, floor scrubbers and other items. Restoring specialty features can be very time consuming and the required hours can be difficult to estimate in the bidding phase. Additionally, these features are by design a "focal feature," so the customer's demands of the quality of the restoration efforts may be elevated.

2.5.5 Multi-component Surfaces. Surfaces that include different materials such as metal dividers, carpet, wood, or even stones of differing hardness present an additional challenge to the restoration professional. Protection of the various components becomes the responsibility of the restoration professional. Refer to the Restorative Processes section (p21-xx) for more information on how to handle multiple surfaces.

3.0 MAINTENANCE HISTORY AND PRODUCTS USED

3.1 Janitorial staffs of commercial buildings may be employees of the building owner, a building tenant, or a subcontractor.

Varying levels of stone care knowledge and experience exist amongst janitorial staffs and supervisors. Those with higher knowledge and experience levels, particularly when willing to research the unique maintenance needs of the stone product, are undoubtedly more successful in keeping building owners and occupants satisfied with the appearance and performance of the stone products. Refer to DSDM Chapter 9 (Maintenance) for more information on this topic.

3.1.1 The restoration professional is often responsible for instructing the janitorial staff on required techniques and products to use after the stone has been restored. In these cases, it is often easier to instruct a staff with little or no stone care experience, which eliminates the need to change the bad habits previously used by the staff.

3.1.2 The restoration professional is usually best serving the client by encouraging them to contract with experienced, competent stone maintenance providers for their daily or weekly maintenance needs. This usually proves to be a wise investment for facility managers and owners that want to protect their stone investment.

3.2 Maintenance Products

3.2.1 Topical sealers and/or coatings. Long-term waxes, sealers, epoxy coatings, and other topcoats are more common in older lobbies, when topcoats were the preferred option. These coatings must be removed prior to restoration of the stone surface. Identification of the product is usually necessary to ensure that the removal and disposal of it is done in a safe, environmentally friendly, and legal manner. Refer to DSDM Chapter 9 (Maintenance) for more information on this topic.

3.2.2 Short-term Coatings or Waxes. Stone maintenance and restoration professionals do not advocate the use of these products, except in extremely rare cases. Less competent restoration contractors may use these products to cover up processes that were not performed properly. Due to the topical coverage and prohibition of both fluid and vapor transmission, these products can actually damage the stone. However, since these products form a sacrificial layer above the stone's surface, there are unique exposure conditions where they may be recommended.

4.0 LABOR RESTRICTIONS

4.1 Unions. Commercial restoration projects frequently mandate that the work be performed by union personnel. Check all union regulations, including pay scales, benefits, and staffing requirements prior to bidding to ensure that adequate funding exists to comply with the unions' requirements. It is possible, depending on the nature of the work, that more than one union will have jurisdiction over parts of your scope of work.

4.2 Federal Projects. Most federal jobs require certified payroll reports. This report show which days were worked, labor classifications of the workforce, and rates of pay.

4.2.1 Labor Classifications and Education. All labor classifications and corresponding pay scales must be met. Maintain records to verify compliance in case the project is audited.

4.2.2 Confusion Regarding Classifications and Pay Scales. In some cases, it may be difficult to find an exact match of job descriptions in federal documents to accurately determine the correct pay rates. If doubt exists, contact the agency involved for their input. Maintain records and document all conversations in case a dispute develops at a later date.

4.2.3 Report Filing. Frequency of filing may vary from weekly to monthly. Determine the frequency required and comply with the reporting requirements.

4.2.4 Other Restrictions. Federal Department of Interior Standards must be followed. This requires a thorough knowledge of various restoration disciplines and an aptitude for report writing. Information on this can be found in section 12 of this chapter (Additional Learning Resources).

5.0 GETTING APPROVAL FOR WORK PERFORMED

5.1 Customer satisfaction is the ultimate goal. In order to achieve this goal, it is necessary to communicate the proposed improvements accurately. Test patches, mockups, and samples will help with this communication. Ideally, test areas or mockups should remain in place until the balance of the work is completed to serve as a benchmark of acceptance.

5.2 Single Person Responsibility. It is typically easier to communicate with and satisfy one person, such as a maintenance supervisor or facilities manager, who may have the sole authority to accept or reject the work of your crews. Additionally, if a problem or question arises, this person can usually be included in the problem solving and decision making processes.

5.3 Boards and Committees. When the contracting and acceptance of the work is decided by a board or committee, it may be difficult to achieve consensus within the group, since the individuals comprising the group may have differing standards, perceptions, and experiences. It is a good practice to meet with the group prior to submitting your proposal. This will allow you to learn of their exact expectations and provide an opportunity to discuss of how these how these expectations may impact the cost of the project.

5.3.1 Commercial Committees. One of the most common committees encountered in commercial work is the "condominium board," when doing work in a condominium complex. The emotional investment of its members may be high, since they are usually all property owners in the complex.

5.3.2 Historical Review Committees will be encountered any time work is done to a project that is deemed to have some level of historical significance.

6.0 MANAGING PERFORMANCE

6.1 Large commercial restoration projects may have extremely long durations. Progress and expenses must be tracked throughout the project to ensure that the anticipated profitability can be achieved. Discuss the labor and material requirements with the job foreman or superintendent at the beginning of the project and revisit these requirements frequently.

7.0 FUNDING, BILLING, AND COLLECTING

7.1 The process of payment on a commercial or historic project can be different than on a residential project. Sometimes payment will only be considered if the request is submitted on the responsibly party's form. Payment can also depend on the tax and restoration parameters allowed by the Historical Review Board, various funding procedures and taxes. Every state usually has a historical society, committee, or department in charge of maintaining and preserving historical landmarks. Depending on the historical structure or place, there may be available tax credits to help offset the costs of restoration or repair. The National Register of Historical Places, which is administered by the National Park Service, gives status and possible tax credits and funding for significantly historical structures.

8.0 ADDITIONAL RESOURCES

8.1 See the last section of this chapter for Additional Learning Resources.

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
All	Cracking, alignment, and grout distress	All Natural stones	Structural settling or instability	Consult with structural engineer for remedial suggestions. Replace tile or clean, prep and repair tile and refinish as necessary to smooth out repair.		Photo 53, Photo 75, Photo 127
All	Cracks in Slabs	All Natural stones	Fractures caused by material handling, substrate deformation, or vibration from field cutting.	Clean, prep and use a penetrating or flowing epoxy to bond though the stone. Next use a knife grade epoxy with the correct color tint if needed. For outdoor repairs, use a UV stable, two part epoxy with the correct color tint. For white marble and porous limestone, preseal to keep the resin from bleeding into the stones.		Photo 121
All	Exfoliation of Minerals at face of stone	All Natural stones	Exfoliation occurring either to poorly cemented minerals or minerals that have been loosened by expansions, mechanical stress, or freeze/thaw cycling.	Clean, prep, and fill with a clear or a custom colored epoxy. The stone may need to be resurfaced. If stone is resurfaced, apply appropriate impregnating sealer.		Photo 37, Photo 38, Photo 47, Photo 72
All	Spall (chips or splinters separated from the main mass of a stone)	All Natural stones	Lack of vapor transmission at stone's surface.	Remove coatings that block stone's ability to breathe.		Photo 68, Photo 80, Photo 84, Photo 128
All	Fissures	All Natural stones	Natural seams in the stone that have fully opened to be considered a crack or fracture.	Clean, prep and use a penetrating or flowing epoxy to bond though the stone, then a knife grade epoxy with the correct color tint if needed. For outdoor repairs, use a UV stable, two part epoxy with the correct color tint. For white marble and porous limestone, preseal to keep the resin from bleeding into the stones.		Photo 43
All	Gray colored stain bleeding through light stone	Light colored calcareous stones	Stone was installed using gray colored portland based thinset	Remove and replace - only white thinsets may be used with light colored calcareous stones.		

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
All	Pin Holes	Marble	Occasional small holes (*taroli* , in Italian) and voids are to be expected, and are characteristics of Soundness Classification B marbles.	Clean, prep and fill holes with color matched epoxy.		Photo 15
All	Ink Stains	All Natural stones	Ink pen or marker stains.	On light colored stones, clean with bleach or hydrogen peroxide. On dark colored stones, clean with lacquer thinner or acetone. Do a test in an inconspicuous area to make sure this is the correct method.		
All	Pits	Limestone	Numerous, possibly hundreds of small pits in the stone visible with certain lighting.	Clean and prep as best as possible and fill with CA glue, or color matched polyester acrylic.		Photo 59
All	Random Stains	All Natural stones	Random stains caused by known or unknown staining agents.	If possible, identify the stain origin, then poultice with appropriate poultice recipe. If stain origin cannot be identified, several trial and error attempts may be necessary. Multiple applications of poultice may be required to fully eradicate the stain.	MIA's book on Poultice	Photo 7, Photo 101
All	Dark spots remain after water wiped from stone.	All Natural stones	Sealer did not fully penetrate stone due to improper application.	Review manufacturer's application instructions to ensure proper application methods are being used. Allow full cure time between applications. Use multiple applications until desired performance is achieved.		Photo 64
All	Sticky or Clouded Surface	All Natural stones	This is usually the result of too much detergent or cleanser being used during normal cleaning maintenance.	Clean with a heavier cleaner for stone and hot water. For hair spray on marble, use a safe HD cleaner with a white pad.		Photo 44

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
All	Streaking or Haziness from Sealer	All Natural stones	Streaks or haze in cured sealer cannot be cleaned with regular cleaners.	Identify the sealer that was used, then try to re-emulsify with the same sealer with a white or hog's hair pad by breaking the surface tension and then wipe it up and buff it out. Or use Mineral Spirits and again break the surface tension. Or use a safe alkaline stripper and break the surface tension, wipe off and buff out. If unsuccessful, then stone must be refinished.		Photo 74, Photo 78
All	Swirl Marks	All Natural stones	Swirl marks in the stone surface are generally caused by equipment malfunctions or operator errors in the original fabrication of the stone or in a previous restoration attempt.	Start refinishing from the least abrasive diamond grit until you can successfully remove the swirl marks, then proceed to finer grit sizes until the desired gloss level is achieved.		Photo 40
All	Tape marks	All Natural stones	Dark banding visible in the stone surface is frequently residual adhesive from tape that had been applied and removed. Some tapes have mildly acidic adhesives, which are more prone to surface damage of calcareous stones. Extended dwell time on the stone surface, and exposure to sun or other heat source also increase the likelihood of tape marks.	Use acetone with a white nylon pad and rub vigorously. Multiple applications may be required. If unsuccessful, diamond grind the areas and then refinish to desired level of gloss. Some "feathering" and blending will be required.		Photo 42, Photo 51

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
All	Tape Residue	Countertop settling - edge not polished to factory polish - correct: break the seam, relevel the tops with proper support and polish the edges	Dark lines, usually dull, and often showing dirt collection.	Clean with acetone and a white pad vigorously. It the stain does not go away, diamond grind until the residue is gone, then bring back to the factory shine. (Note: tape adhesive may have penetrated significant depth of the stone, which can make the lines reappear if color enhancer is used).		Photo 71, Photo 51
All	Topical, colorful stains	All Natural stones	Usually this can be identified as paint.	Small amounts can be removed with lacquer thinner or scraped off carefully with a razor blade. Paint strippers can be effective but may etch some stones. Follow the manufacturers' directions for use of these products, and flush the area thoroughly with clean water. Use appropriate PPE when using these chemicals. Use only wood or plastic scrapers for removing the sludge and curdled paint. Normally, latex and acrylic paints will not cause staining. Oil-based paints, linseed oil, putty, caulks and sealants may cause oily stains. Refer to the section on oil-based stains. (In short, a good quality colloidal cleaner is probably the best and safest solution.)		
All	Yellowing	Light colored Natural Stones	Yellow-to-orange staining can either be from ferrous content indigenous to the stone fabric, or from an outside source, like a metal container or object in contact with the stone, or a fastener corroding beneath the stone.	Rust poultice will be required Most rust poultices are acid based and will etch calcium-carbonate based stones, so refinishing will be necessary after the rust treatment. Quick rust treatments can be less damaging to the stone but the purple stain left from improper use of some products can be fixed with 20-30% hydrogen peroxide. Testing in an inconspicuous area should be done before the final application.		Photo 95, Photo 96

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Countertop	Chipping due to impact	All Natural stones	Chips occurring from impact by pots, pans, and other hard objects.	Clean, prep, and fill chips with a polyester epoxy with a custom tint or CA Glue. For outside chips you will need a UV stable two part epoxy with a custom color tint. For white marble and porous limestone, preseal to prevent any bleeding from the resin in the two part epoxy. In some cases you may need to drill small holes into the chip to get better tooth or bite.		Photo 79
Countertop	Colored Stains	All Natural stones	Food, and specifically fruit and fruit juices, like grape juice, wine, coffee, vegetables, tea, and even grass and mud create different colored stains.	Use a poultice (a blend of clays) with hydrogen peroxide (20%). Use nitrile gloves and safety goggles when using this product. Sometimes a mild bleach solution will take stains out. Neutralize the beach after use with water mixed with a neutral cleaner. Calcareous stones may etch and the surface may need to be refinished.		
Countertop	Dark areas around fixtures and/or soap dispensers	All Natural stones	This is obviously a soap stain.	Wiping with a towel saturated in mineral spirits will usually be effective, although many applications are usually required. Denatured alcohol is also sometimes effective.		Photo 101
Countertop	Change or faded color	All Natural stones	Resin, color enhancer, or sealer not 100% UV resistant.	Refinish; use UV resistant resin/ color enhancer.		Photo 4
Countertop	Dark Stains (Oil)	All Natural stones	Dark colored stains are frequently oil based.	Use a poultice with the correct additive in the blend of powder or a good, ready-to-use poultice liquid. Follow manufactures' directions. This may have to be done over weeks or months until the stain is gone.		Photo 8, Photo 41, Photo 100, Photo 101, Photo 102
Countertop	Dull Edges	Granite, Marble, Limestone	Substandard edge polishing on original material.	Regrind with coarse grits and then bring the surface back to a factory shine using progressively finer grits.		Photo 12, Photo 13, Photo 14
Countertop	Dull or Clouded edges	All Stone Types	The edges are fuzzy and not even.	Diamond grind surface and repolish back to the desired gloss level.		Photo 63

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Countertop	Dull Spots or Rings	Marble	Areas are dull and have reduced gloss due to mild etching.	Diamond grind surface and repolish back to the desired gloss level.		Photo 45, Photo 110
Countertop	Etched areas	All Calcareous Stone Types	Dull areas around grout due to inappropriate (acidic) grout cleaner.	Diamond grind surface and repolish back to the desired gloss level.		Photo 104
Countertop	Green-to-blue Colored Stains	All Natural stones	Green-to-blue colored stains are usually cuprous in origin.	Clean the copper stain with a **very mild** acid. Neutralize and you have to resurface the stone back to its original state. If the stain remains, a poultice may be need with the correct additive for the stain.		Photo 18, Photo 28
Countertop	Hard water deposits near faucet fixtures	All Natural stones	Hard water deposits are usually caused by a combination of high mineral content water supply and occupants allowing the water to puddle, unwiped, on the countertop surface.	Carefully use single edge razor with mild soap to remove buildup from counter top, or remove the fixtures and refinish.		Photo 22
Countertop	Linear Crack at front of sink location	All Natural stones	This is typically indicative of a slab that has been "rodded," meaning that a reinforcement rod had been embedded into the underside of the slab at this location. If a mild steel rod has been used, and if the fabricator did not successfully fully encapsulate the rod in epoxy, corrosion can occur. The swelling of the rod due to corrosion can create enough pressure to crack the stone slab.	If you can open the stone carefully, pull out the metal rusted rod, using a two part UV stable epoxy with the correct color tint and glue it back together and top polish the next day. If the crack is too small to get any penetrating glue in, you might want to wait till it opens further. If unrepairable, the only remedy is replacement of the countertop.		Photo 29, Photo 30, Photo 76, Photo 99

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Countertop	Lippage on Countertops	All Natural stones	One stone slab is higher than adjacent slab.	Break the seam if possible. Use a seam setter to level the two slabs and apply a flowing epoxy followed by a knife grade epoxy with the correct color. Or diamond grind the high slab to match the other slab, and then refinish to original gloss.	DSDM, COUNTERTOPS: TOLERANCES -Lippage Section	Photo 17
Countertop	Mineral Pitting	Granite	All true granites contain a micaceous mineral called "biotite," which is a black colored mineral of "flakey" or layered construction. During the polishing process, biotite can be "plucked" from the stone fabric by the abrasive heads of the polishing machine, leaving a shallow pit in the surface.	Fill pits with CA adhesive and when cured, scrape with a razor in multiple directions until the filler matches the plane of the stone surface.		Photo 35
Countertop	Rings or Spots	Granite	Whitish rings or spots occurring on black granite (which technically are not granite) have often been blamed on dyes used in the stone. While this is possible, it is not as common as believed. These materials may have complex mineralogy including minerals that are not traditionally included in true granites. Calcium-carbonate based minerals and clays can be present in these materials, both of which can change color due to wet/dry cycling.	Either refinish starting with very fine grit, or buff with a pad.		Photo 3

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Countertop	Rings or Spots on Outdoor counters	All Natural stones	Commonly caused by the stone's reaction to ponded water on the surface.	Verify that it is a stain and not an etch. True granite can be cleaned with acidic cleaners. Calcareous stones must be resurfaced. These marks will usually reoccur if the exposure is unchanged.		Photo 106
Countertop	Surface staining from heat source	All Natural stones	Staining, discolored sealer, soot, or other stains from heat source such as fireplace or cooktop.	Deep clean all smoke stains (if needed) with an alkaline cleaner or mild acid, (5-6 on the pH scale). Diamond grind and polish back to desired gloss. Grinding may be required to significant depth if stone has been etched due to carbonic acid.		Photo 16
Countertop	White Rings	Granite	Stone had originally been dyed (normally black stones).	Attempt to re-dye to stabilize color.		Photo 85, Photo 86
Countertop	White Rings	Granite	Sealer did not fully penetrate stone.	Remove sealer with an acidic marble polishing compound.		Photo 3
Flooring	Blistered Surface	Granite	Moisture reacting with minerals in stone (this can be confused with spalling).	Stop source of moisture & resurface stone, refilling as necessary.	ANSI A118.10 TCNA F122 Stone or F121 Stone	Photo 36
Flooring	Blotchy, Uneven appearance in Color Enhanced Floor	All Natural stones	Usually caused by nonuniform application as a result of the floor being wet when the color enhancer was applied.	Strip the enhancer off and then start over. In some cases, refinishing will be required.		Photo 61
Flooring	Broken Corners	All Natural stones	Corners are broken, usually as a result of heavy rolling loads over corners that have no support due to voids in the setting bed.	Clean, prep and use preferably a slow curing epoxy with a custom color to rebuild the corners. Following cure of the epoxy diamond grind and refinish to desired gloss. A polyester resin (fast curing) can also be used, but does not have the performance of the epoxy.		Photo 19
Flooring	Cracking	Granite	Improper substrate	Replace tile.		Photo 31
Flooring	Cracking	Granite	Deflection issue	Check joist size, spacing & span.		Photo 31
Flooring	Cracking	Granite	Lack of crack isolation/suppression membrane.	Replace tile and utilize crack isolation membrane.		

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Flooring	Cracking	Marble	Seams in cement board not filled.	Tear out and replace.	ANSI 108.5	
Flooring	Cracking	Marble	Improper adhesive coverage.	Tear out and replace.	ANSI 108.5	Photo 27
Flooring	Cracking	Marble	Insufficient joint width at change of plane or other region of discontinuity.	Saw out and open joint with cosmetic repair.	TCNA EJ171	
Flooring	Cracking	Marble or Granite	Improper substrate.	Replace tile and implement correct installation method.	TCNA F250 Stone	Photo 1, Photo 10
Flooring	Cracking	Marble or Granite	Excessive deflection.	Check joist size, spacing and span.	TCNA F250 (Optional)	
Flooring	Cracking	Marble or Granite	Lack of crack isolation/suppression membrane.	Replace tile and utilize crack isolation membrane.	TCNA F125 Stone (Concrete)	Photo 27
Flooring	Cracking	Slate	Lack of bonding adhesive under the tile.	Use appropriate adhesive, reset with a minimum 95% of coverage with the mortar. Many times the stone can be reused.	ANSI 108.5	Photo 9, Photo 107, Photo 108
Flooring	Cracking	Slate	Lack of expansion joints.	Tear out and replace.	TCNA EJ171, F250 Stone	
Flooring	Cracking	Travertine	Lack of bonding adhesive under the tile.	Replace broken tile.	ANSI 108.5	Photo 23
Flooring	Cracking	Travertine	Lack of expansion joints.	Tear out and replace.	TCNA EJ171, F250 Stone	
Flooring	Cracking	Travertine	Lack of alkaline resistant mesh tape.	Tear out and replace.	ANSI 108.5, TCNA EJ171	
Flooring	Difference between covered areas and exposed	All Natural stones	Usually this is due to color change as a result of UV exposure of a wax.	Carefully strip off the wax, neutralize with water and refinish.		Photo 56 Photo 55
Flooring	Dimpled appearance	Travertine, Marble	Polishing compound used too hot resulting in 'orange peel'	Grind and refinish to original surface quality		Photo 125 Photo 124

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Flooring	Foot Prints in Sealed Stone	All Natural stones	Foot prints can be seen in certain lighting conditions in the sealed floor, but cannot be cleaned with regular cleaners due to floor having been walked on prior to full cure of the sealer.	Identify the sealer that was used, then try to re-emulsify with the same sealer with a white or hog's hair pad by breaking the surface tension and then wipe it up and buff it out. Or use Mineral Spirits and again break the surface tension. Or use a safe alkaline stripper and break the surface tension, wipe off and buff out. If unsuccessful, then stone must be refinished.		Photo 118 Photo 119
Flooring	Gaps in stone or corners	All Natural stones	Insufficient accommodation for thermal expansion and contraction	Cut grout joints and replace with appropriate movement and/or expansion joint detail per industry standards.	TCNA EJ171	Photo 26, Photo 70, Photo 105
Flooring	Indent Fractures	All Natural stones	Excessive and non-uniform depth of thinset over a membrane, creating uneven shrinkage and suction upon cure	Remove and replace, using proper floor leveling techniques and controlled thinset depth	TCNA F141	Photo 10, Photo 11
Flooring	Lippage on Floors	All Natural stones	One stone unit is higher that adjacent unit (Note: 1/32", or 0.8 mm is acceptable tolerance).	Either remove the tile and set a new one in place with correct alignment, or diamond grind the high tile to match the elevation of the surrounding tiles and refinish to achieve desired level of gloss.	MIA Design Manual, HORIZONTAL SURFACES – LIPPAGE TCNA Handbook, Lippage in Natural Stone Installations	Photo 73
Flooring	Loose Tiles	Slate	Lack of drainage mat and/ or waterproofing.	Tear out required to totally correct the problem. Many times the stone can be reused.	TCNA F122 Stone	
Flooring	Loose Tiles	Slate	Oil content present in slate.	Use appropriate adhesive to rebond and minimum 95% of coverage with the mortar. Apply a burn coat or scratch coat on the back of the tile.	ANSI A118.4	Photo 6
Flooring	Loose Tiles	Granite	Insufficient contact between adhesive and stone.	Achieve minimum of 95% of coverage on the bonding mortar (Dry & Wet Areas).	TCNA Handbook, ANSI 108.5 3.3, TCNA F102 Stone, ANSI 108.5.3.3	Photo 39

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Flooring	Loose Tiles	Slate	Lack of expansion joints.	Implement expansion joints.	TCNA EJ171 ANSI 108.1	
Flooring	Loose Tiles	Slate	Presence of bond breaker on concrete slab or substrate.	Remove bond breaker prior to repair.	TCNA F122 Stone	
Flooring	Missing grout or caulking	All Natural stones	Grout has eroded due to normal service exposure, but no other signs of distress exist.	Thoroughly remove all cracked grout and either re-grout or caulk with appropriate joint sealant.		Photo 24
Flooring	Picture Framing after installation	All Natural stones	Excessive moisture in bedding layers wicks into edges of stone, creating a darkened perimeter.	Open the grout and allow to dry or use a commercial dehumidifier to remove the moisture.	ANSI A108.5	Photo 34
Flooring	Plastic Look; Orange Peel	Marble	Over crystallization.	Grind and refinish to original surface quality.		Photo 125
Flooring	Smeared Grout	All Natural stones	Stones were not properly masked or cleaned during original grouting.	Carefully remove the excess grout with the proper cleaner for grout or a razor blade with soapy water to cut down any possible scratching the surfaces.	ANSI A108.10	Photo 126
Flooring	Stone Discoloration	Granite	Stone has lost its color (outdoor application) due to fading of dyes that were applied to original material.	Use enhancer or a colored tint with the enhancer per manufacture's directions.		
Flooring	Tenting	All Natural stones	Inadequate movement and/or expansion joints, causing compression in floor surface to raise, or "tent" two or more courses of tile.	Remove and replace affected stone, adding movement and/or expansion joints per industry recommendations.	TCNA EJ171	Photo 98

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Flooring	White, random direction lines in face of material	All stone, specifically soft marble and limestone.	This is referred to as "Indent fracturing," and is caused by non-uniform shrinkage of thinset that has either been used too thick, or too uneven, and typically over a membrane.	Replacement is the only remedy, with attention paid to proper slab leveling prior to installing replacement tiles.		Photo 87, Photo 88
Flooring	Yellow-to-brown blotchy surface on floors.	All calcareous stone types.	Residual wax on stone surface.	Carefully strip off the wax, neutralize with water and diamond grind, then refinish the floor to achieve desired level of gloss. Do a small test area in an inconspicuous area prior to starting balance of work. NOTE: Black or brown stripping pads can hone and open the softer stones.		Photo 54, Photo 55, Photo 56
Flooring	Yellow-to-brown blotchy surface on floors.	All siliceous stone types.	Residual wax on stone surface.	Carefully strip off the wax, neutralize with water and diamond grind, then refinish to achieve desired level of gloss. Do a test in an inconspicuous area before starting balance of work. NOTE: Black or brown stripping pads should not hurt the stones.		
Paving	Calcium deposits on stone surface.	All Natural stones	Lime from mortar has leached through to the surface as a result of the repeatedly saturated bed.	Clean all surfaces with acidic cleaner and refinish if necessary. Eventual failure is likely unless a method of bed drainage can be accomplished.	TCNA F103B	Photo 2
Paving	Erosion or excessive cracking of grout.	All Natural stones	Repeated saturation and/or freeze/thaw cycles of grout due to ponding as a result of insufficient surface slope.	Temporary correction can be achieved by surface cleaning the resultant staining and regrouting, but eventual failure of the system is nearly a certainty if not replaced.	TCNA F103B	Photo 2
Paving	Flaking	Slate, sandstone	Internal expansions within the stone fabric either due to freeze/thaw cycling or minerals with expansive behavior in a saturated state.	Clean up the loose pieces and then sand down the edge if it is a tripping hazard. Blend and feather with a brown and a black hypo pad (wet is better). Then dry and check for correct appearance. If too much breaks off, replace the tile or slab.		Photo 50, Photo 103

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Paving	Lifted tiles and extensive grout cracking.	All Natural stones	Moisture trapped below surface layer.	Remove the stone, clean the substrate and the back of the tile and then re-bond them using a hard scratch coat on the back of the tiles.		Photo 116
Paving	Ponding Water	All Natural stones	Insufficient surface slope.	Temporary correction can be achieved by surface cleaning the resultant staining, but eventual failure of the system is nearly a certainty if not replaced.	TCNA F103B	Photo 113, Photo 114 Photo 120
Paving	Water staining on exterior stairs.	All Natural stones	Usually caused by inadequate, or reverse pitch, of treads.	Surface cleaning of the stone will provide temporary cosmetic improvement, but permanent remedy can only be accomplished by removing and re-setting stones.		Photo 103
Showers	Corner area of shower floor is dark.	All Natural stones	This is usually caused by a flat, or reverse sloped area that does not drain properly.	Remove stone and re-set with proper slope. Check that membrane has proper slope and that dry-pack has adequate lateral transfer capability.		Photo 5, Photo 48
Showers	Etching in showers.	All calcareous stone types.	Dull areas due to use of inappropriate (acidic) cleaner.	Diamond grind surface and repolish back to the desired gloss level.		Photo 52
Showers	Extremely warped or exfoliated stone in wet area.	Some limestone, travertine, and onyx.	Selected stone was not appropriate for wet area exposure.	Remove and replace.		Photo 84
Showers	Faint rust colored stains in shower or curb.	Light colored calcareous stones.	Ferrous content indigenous to stone has oxidized.	Test section with rust removing poultice. Repolish surface as necessary. Seal stone with appropriate impregnating sealer. NOTE: Removal of stain is not always successful or permanent!	Current TCNA Handbook, Natural Stone Tile Selection and Installation Guide, "Iron Staining"	Photo 46, Photo 83
Showers	Gaps around tubs or other dissimilar materials.	All Natural stones	The grout is not adhering to the dissimilar material.	Carefully cut out the cracked grout and apply a flexible, non-shrinking sealant. (100% RTV Silicone) In wet areas make sure the substrate is fully dry before applying sealant.	TCNA EJ171	Photo 77
Showers	Growth occurring on shower curb.	All Natural stones	BOG (Bio-Organic-Growth) is present on shower curb.	Upgrade to frameless shower door.		Photo 67

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Showers	Hard Water Deposits	All Natural stones	Saturated subsurface allowing hard water to wick to stone surface, depositing hard water deposits on stone surface.	No permanent solution exists. Temporary correction may be achieved by diamond grinding the hard water deposits and removing the grout and allow to air dry. Regrout when dry. An alternate solution is to apply urethane caulk in place of grout.	TCNA F103	Photo 33, Photo 112
Showers	Heavy Water Deposits on Grout Lines in Shower Floor	All Natural stones	There are multiple possible causes for this: The weep holes could be clogged; the dry pack may be too tight and not allowing the water to drain down into the weep holes; or the water proofing membrane is not correctly sloped.	Try the weep holes first. If you cannot get it from the inside of the drain then remove the tiles and mud 4-6 inch around the drain and clean the weep holes from the outside and then set your dry pack again and tile and grout. If the pack is too tight, then the entire shower pan tile and mud must be removed and redone. If it is the water proofing membrane, well then you must remove the shower and start over.		Photo 20, Photo 21, Photo 58, Photo 65, Photo 66
Showers	Mildew Growth in shower walls and grout joints	High Porosity Stones	Inadequate sealing of high porosity stone, inappropriate stone selection, or high humidity is maintained in area when shower is not in use.	Clean with a safe mildew cleaner that will not etch stone, remove the affected grout lines, use a dehumidifier to dry out the substrate, when dry, re-grout, apply the sealer correctly and inform the client to keep the shower door open after use. Check the inside grout lines of the shower curb also.		Photo 122
Showers	Orange, Yellow, or Black Stains in a Wet Area	All Natural stones	This is frequently the growth of mildew as the result of inadequate ventilation	Clean with the proper mildew remover for natural stone. Bleach only puts the mold in dormancy; it does not kill it forever. Refinishing the stone may be necessary in some cases (see diamond grinding).		Photo 117, Photo 122, Photo 123
Showers	Rust bleeding through veins in stone	Light colored calcareous stones	Ferrous content indigenous to stone has oxidized, and is traveling through veins as the path of least resistance.	Test section with rust removing poultice. Repolish surface as necessary. Seal stone with appropriate impregnating sealer. NOTE: Removal of stain is not always successful or permanent!		Photo 81

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Showers	Rusting at Shower Drain	All Natural stones	Corrosion protection on shower drain has been breached, allowing rust to bleed into surrounding stone.	Test section with rust removing poultice. Seal stone with appropriate impregnating sealer. Replace drain.		Photo 83
Showers	Rusting on Walls, benches, or floors	Light colored calcareous stones	Ferrous content indigenous to stone has oxidized.	Test section with rust removing poultice. Repolish surface as necessary. Seal stone with appropriate impregnating sealer. NOTE: Removal of stain is not always successful or permanent!	Current TCNA Handbook, Natural Stone Tile Selection and Installation Guide, "Iron Staining"	Photo 89, Photo 91, Photo 92
Showers	Shower floor and walls are darkening	All Natural stones	This is frequently caused by clogged weep holes in the drain.	Clean out the inside of the drain and then clear the weep holes of white bar soap residue, hair, hair conditioner, hard water buildup, and body oils. This is for cast Iron drains. Check to verify that the weep holes are not plugged. Cut around the tar or membrane if necessary so the weep holes are clear.		Photo 62
Showers	Spalling of Stone	Limestone	Surface spalling, usually due to expansion of some mineral content during saturated state.	Grind and fill as necessary. Encapsulate limestone with penetrating epoxy.		Photo 82, Photo 97
Showers	Tiles becoming dislodged from wall surface	All Natural stones	Improper substrate typically "greenboard" gypsum board.	Moisture Resistant Gypsum Board, a.k.a. "Greenboard" is not an appropriate substrate for direct application of tiles in wet areas. Remove and replace.	Current TCNA and MIA documents	Photo 32
Showers	Water penetrating sheetrock backing	All Natural stones	Most commonly, this is leaking at the shower curb due to inadequate membrane overlap.	Take out the shower door and cut the grout line on the shower curb on both sides and now into the pan. Replace with epoxy grout or a polyurethane sealant. Another option is to tear it out and start over but slope the shower curb membrane back to the shower at a rate of ¼ inch per ft. Dry the substrate toughly before re-grouting.		Photo 5, Photo 25

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Showers	White area or surface degradation in green marble	Certain green marble and serpentine.	Many green marbles and serpentine do not perform well in wet environments.	Removal and replacement per MIA guidelines is best permanent solution. Use proper setting materials recommended for serpentine and green marble. Use of an impregnating sealer is also helpful.		Photo 49
Showers	White Spots on Mosaic Tiles	All Natural stones	This is caused by water evaporation when the shower is holding water.	Check weep holes, density of dry-pack, and slope of membrane.		Photo 109
Walls	Lippage on Walls	All Natural stones	One stone unit face is proud of adjacent units (Note: 1/32", or 0.8 mm is maximum acceptable tolerance).	Either remove the stone and re-set in place with correct alignment, or diamond grind the proud stone to match the elevation of the surrounding stones and refinish to achieve desired level of gloss.	DSDM, VERTICAL SURFACES – RELATED COMPONENTS Section 2.6 Lippage Current TCNA Handbook, Natural Stone Installations, "Lippage"	Photo 90, Photo 93, Photo 94
Walls	White Residue (Efflorescence)	All Stone Types	Moisture migrating from sub layers carrying salts, which are then deposited on stone surface.	Mechanically remove as much residue as possible with a dry brush. Then clean the area with a mild acid for slate, sandstone, and granite. For marble, a slightly alkaline chemical can be used. (8-9 on the pH scale). Note: Don't let it run down a vertical area as it may etch. Some neutral cleaners may also work.	TCNA F122 Stone (Concrete) or F101 Stone	Photo 57, Photo 69

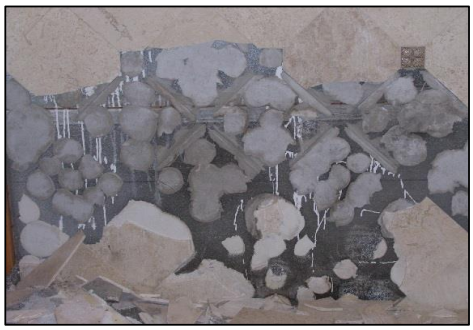

Photo # 1

Spot bonding - improper coverage

Photo # 2

Bonded to flashing - not suitable bonding substrate

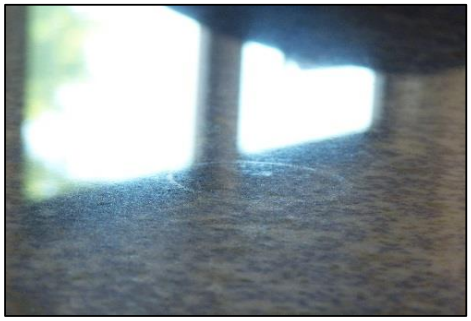

Photo # 3

Etch ring (resin enhancer disturbed) - correct: use final granite buff pad or powder

Photo # 4

Resin enhanced slab faded by UV exposure - correct: refinish; use a UV resistant enhancer/colorant

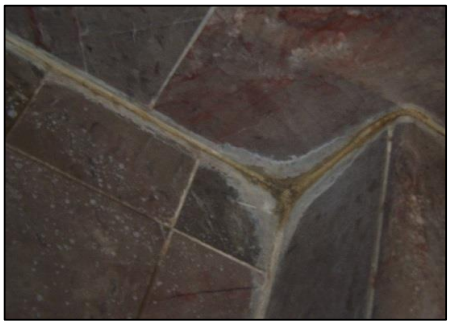

Photo # 5

Shower curb floor corner waterproof membrane improperly sloped to drain - cracked grout on shower curb (mineral deposits) - correct: remove grout, dry substrate with dehumidifier and regrout with epoxy

Photo # 6

Improper bonding coverage & improper bonding substrate (flashing)

Photo # 7

Sandstone improperly sealed (oil stain) - correct: remove stain and seal with multiple applications of appropriate sealer

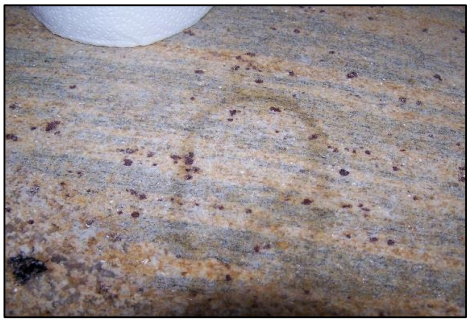

Photo # 8

Improperly sealed granite (oil stain) - correct: remove stain with poultice and use multiple applications of sealer

Photo # 9

Improper bonding, hollow slate tiles - correct: apply scratch to backs of slate & use a proper notched trowel method (per TCNA guidelines)

Photo # 10

Indent fractures - substrate (rubber soundproof material) - stone cannot take deflection

Photo # 11

Indent fractures, different cause - builder did not wait 28 days for thinset to cure

Photo # 12

Improper edging technique - correct: redo the edge correctly

Photo # 13

Another view of Photo 12

Photo # 14

Edge not polished to match factory finish

Photo # 15

Pits/holes in stone - correct: clean, prep and fill with the correct patching material

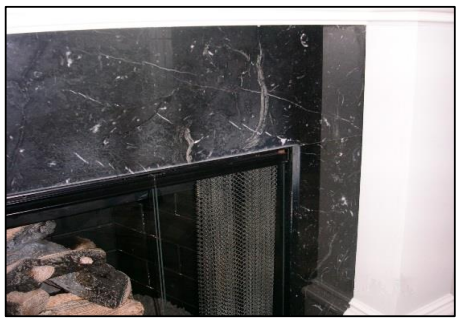

Photo # 16

Damage from heat - correct: clean soot and smoke with degreaser. Will need refinishing if etched.

Photo # 17

Countertop edge not polished to factory finish - correct: break the seam, relevel the tops with proper support and polish the edges

Photo # 18

Copper stain (caused by copper gutters) - Correct: use mild acid, then neutralize the acid or use a copper poultice & refinish area

Photo # 19

Chipped outcorner - correct: replace with matching material or clean, prep and fill with a slow-curing epoxy (not polyester)

Photo # 20

Shower pan holding water and corner improperly sloped to drain - correct: remove grout & drain and clean the weep holes. Dry thoroughly, regrout and seal

Photo # 21

Improper slope to drain, lacking two-stage drain function

Photo # 22

Calcium deposit on granite - correct: remove deposit with a straight-edge razor balde and soapy water (acid can damage plumbing fixture)

Photo # 23

Structural crack (foundation crack) - correct: replace broken tile

Photo # 24

Different expansion and contraction rates between floor and wall - correct: use the correct flexible material for this application

Photo # 25

Waterproofing membrane on the shower curb is not properly sloped to the drain - correct: redo per TCNA guidelines

Photo # 26

Cracked grout between tile and concrete - correct: install proper expansion joint material (no latex caulk)

Photo # 27

Crack (at tape) due to improperbond or excessive deflection. Also etched. Correct: check floor rigidity,

Photo # 28

Copper stain on natural stone - Correct: use mild acid, then neutralize the acid or use a copper poultice & refinish the area

Photo # 29

Blown rod from using metal in wet area and not encapsulated properly (fiberglass preferred)

Photo # 30

Blown rod from using metal in wet area and not encapsulated properly (fiberglass preferred)

Photo # 31

Structural crack (foundation crack) - floor joists too far apart and cannot properly support the weight (live-load and dead-load specification - see TCNA guidelines)

Photo # 32

Water intrusion - improper substrate

Photo # 33

Water intrusion into the substrate and permanently staining the tile on the way out

Photo # 34

Moisture in granite floor - partially hollow - caused by stripping wax & voids in substrate - correct: replace with proper TCNA methods or remove the grout, thoroughly dry and regrout (inject with adhesives to fill voids before grouting)

Photo # 35

Pitting in granite from high mica content in the stone - correct: clean, prep and fill with epoxy or CA glue

Photo # 36

Pitting similar to that shown in Photo 35

Photo # 37

Poor quality stone (close up) - correct: replace the countertop

Photo # 38

Poor quality stone (different view) - correct: replace the countertop

Photo # 39

Poor quality installation methods and lack of bonding material - correct: clean the back of tile and substrate and reinstall using proper TCNA installation methods

Photo # 40

Swirl marks - correct: Start refinishing from the least abrasive diamond grit until the swirl marks are removed. Proceed to finer grits until the desired gloss level is achieved.

Photo # 41

Oil staining in granite countertop - correct: use oil poultice and seal thoroughly with multiple applications

Photo # 42

Tape residue - correct: use acetone and a white pad - if the stone is stained below, then refinishing may be needed

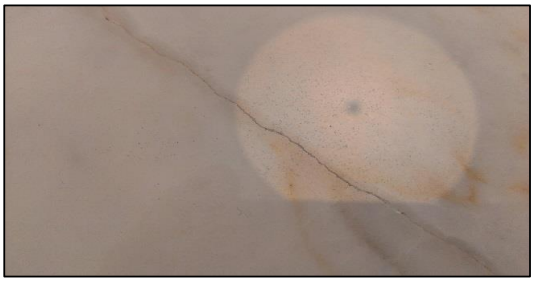

Photo # 43

Natural seams in the stone that have fully opened to be repaired like a crack or fracture

Photo # 44

Soap residue or surfactants from using the wrong cleaners - correct: remove with warm water and a good rinseless cleaner and a white pad

Photo # 45

Etch marks on polished travertine - correct: refinish the stone back to the factory polish

Photo # 46

Iron stain in white marble (white stones have iron content which oxidizes with moisture over time) - correct: use a rust poultice and refinish the stone

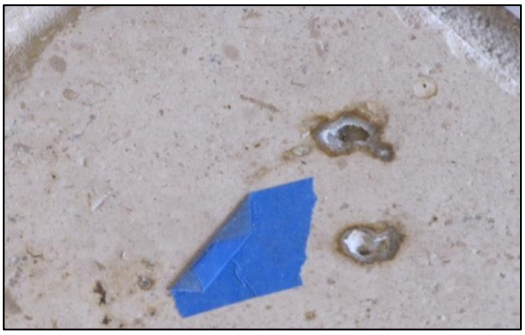

Photo # 47

Natural voids in some limestone - correct: clean, prep and fill with epoxy

Photo # 48

Shower pan holding water - correct: remove grout in critical areas, clean weep holes, thoroughly dry, grout and seal

Photo # 49

Lack of slope, moisture evaporation causing spalling - correct: remove and replace using TCNA guidelines

Photo # 50

Pressure on edges causing cleavage in stone to break off - partially hollow tile at the edge - correct: wet or dry sand the slate until smoother and fill void in with adhesive, then regrout

Photo # 51

Tape stain - oils from adhesive staining the stone - correct: vigorously clean with acetone and a white pad, grinding and refinishing may be necessary

Photo # 52

Badly etched stone shower - correct: grinding, refinishing and seal

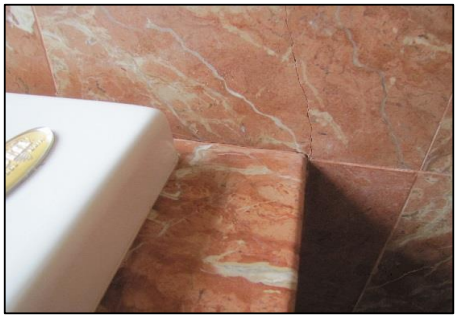

Photo # 53

Substructural crack on wall - correct: replace tile or clean, prep and repair tile and refinish as necessary to smooth out repair

Photo # 54

Multiple coats of topical sealer on a textured granite floor - correct: carefully strip the floor, allow to thoroughly dry and use an impregnator

Photo # 55

Another view of too many coats of topical sealer on a textured granite floor

Photo # 56

Another view of too many coats of topical sealer on a textured granite floor

Photo # 57

Hollow installation, efflorescence from joint resulting from moisture trying to escape

Photo # 58

Shower pan holding water and wicked off the walls past the membrane

Photo # 59

Holes in travertine - correct: clean, prep and fill with epoxy

Photo # 60

Blown rod from using metal in wet area and not encapsulated properly

Photo # 61

Using an enhancer on a moist floor - correct: strip the old enhancer, allow the floor to thoroughly dry and reapply enhancer correctly

Photo # 62

Inadequate waterproofing membrane installation leading to potentially clogged weepholes - correct: redo the the process according to TCNA guidelines and plumbing code

Photo # 63

Granite countertop edge not properly polished to match factory finish - correct: repolish the edge correctly

Photo # 64

Improper specification of material - very porous material in a wet area - correct: multiple sealing applications on multiple days

Photo # 65

Shower pan with clogged weepholes - correct: carefully remove grout, clear out the weepholes and allow substrate to thoroughly dry, then regrout and seal

Photo # 66

Inside of drain in MIA Photo 65

Photo # 67

Lack of slope on shower curb

Photo # 68

Spalling - correct: replace or clean, prep and repair

Photo # 69

Efflorescence - face of a waterfall in a pool - correct: use a mild acidic cleaner and neutralize

Photo # 70

Grout cracked - correct: cut out the grout and install an expansion joint material (driveway)

Photo # 71

Possible spacer used when resining stone slab leaving a stain within the resin - correct: completely refinish or replace

Photo # 72

Holes in a travertine - correct: clean, prep and refill

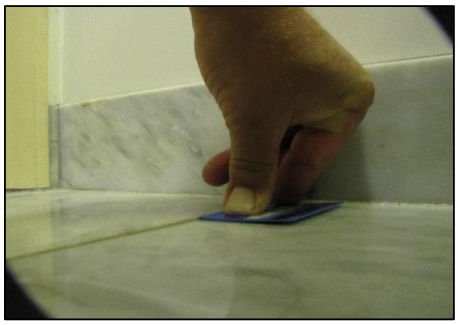

Photo # 73

Lippage - Maximum accepted lippage for the stone industry - correct: replace or grind and refinish back to specs

Photo # 74

Sealer streaking - correct: break down the sealer and follow manufacturer's recommendations

Photo # 75

Hollow edge - correct: replace tile or repair using the proper amount setting material to support the hollow areas, then clean, prep and fill

Photo # 76

Blown rod from using metal in wet area and not encapsulated properly (fiberglass preferred)

Photo # 77

Different expansion and contraction rates between rigid and flexible materials - correct: use the correct flexible material for this application

Photo # 78

Excess sealer

Photo # 79

Chip - correct: clean, prep and fill with epoxy or CA glue

Photo # 80

Spalling - correct: replace

Photo # 81

Iron oxidation - use a rust poultice, then seal thoroughly

Photo # 82

spalling on limestone shower floor - correct: replace floor

Photo # 83

Rust stain on limestone shower floor - rusted drain

Photo # 84

Spalling - correct: replace stone

Photo # 85

Dyed stone

Photo # 86

Dyed stone - another view

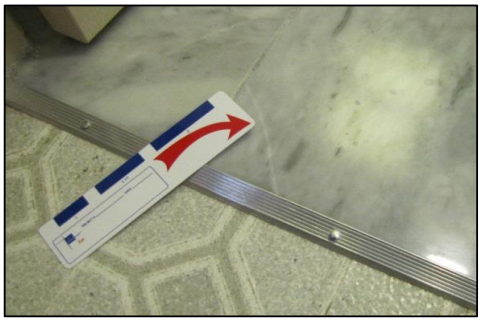

Photo # 87

Indent fracture - lack of bonding adhesive in the corner - correct: replace tile

Photo # 88

Shrinkage cracks - too much thinset adhesive used - correct: replace

Photo # 89

Same as MIA 91 & 92 - defective material for a wet application - correct: replace the material

Photo # 90

Excessive lippage - correct: replace the material

Photo # 91

Same as MIA Photo 89 & 92 - defective material for a wet application - correct: replace the material

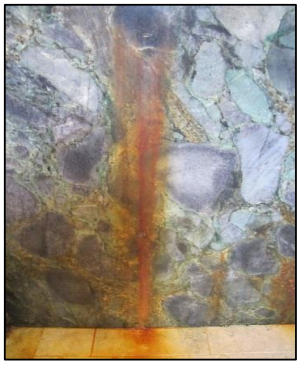

Photo # 92

Same as MIA Photo 89 & 91 - defective material for a wet application - correct: replace the material

Photo # 93

Misaligned, hollow and incorrectly spaced - correct: remove and replace

Photo # 94

Hollow tiles and spalling

Photo # 95

Stone not properly sealed

Photo # 96

Stone not properly sealed

Photo # 97

Spalling - moisture intrusion behind the wall - correct: replace it

Photo # 98

Tenting - remove and replace affected tiles. Add movement and/or expansion joints per industry

Photo # 99

Blown rod from using metal in wet area and not encapsulated properly (fiberglass preferred)

Photo # 100

Oil staining in granite countertop - correct: use oil poultice and seal thoroughly with multiple applications

Photo # 101

Soap staining granite countertop - correct: use towel saturated with mineral spirits. Repeat as necessary.

Photo # 102

Oil staining in granite countertop - correct: use oil poultice and seal thoroughly with multiple applications

Photo # 103

Efflorescence in slate

Photo # 104

Green (environmental) citrus cleaner on a marble floor used to clean the grout - correct: refinish the floor

Photo # 105

Tile separation due to lack of expansion joint - correct: cut grout and replace with appropriate expansion joint detail.

Photo # 106

Stain from planter - correct: mild acid wash, neutralize, refinish (blend and feather out)

Photo # 107

Project in Photo 108 after installation of expansion joints and proper bonding

Photo # 108

Lack of bonding adhesive under the tile - correct: use correct type and amount of bonding.

Photo # 109

Ceramic tile - pan is holding water - correct: remove tiles, clear the weepholes and replace per TCNA guidelines

Photo # 110

Etch mark on 'marble' - correct: refinish

Photo # 111

Spalling - wrong thinset on a large format tile - latex, modified thinset instead of a medium bed mortar - correct: replace

Photo # 112

Hard water deposits on black marble - correct: temporary fix: diamond grind, remove & replace grout when dry, or replace stone

Photo # 113

Another view of Photo 114

Photo # 114

Demonstrating surface slope. Ball bearings roll downhill.

Photo # 115

Moisture in substrate permanently staining slate pavers - tile sloped but the membrane is not

Photo # 116

Close-up of Photo 115

Photo # 117

Fungus - the start of mold in the grout line - correct: use a mildew cleaner that will not damage marble

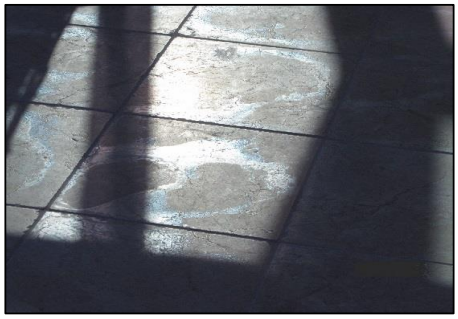

Photo # 118

Sealing in hot dry environment - dries too quickly

Photo # 119

Sealer walk on before dry - correct: re-emulsify sealer and buff. May have to refinish.

Photo # 120

Deck insufficiently sloped away from building - correct: remove and reinstall properly

Photo # 121

Cracks caused by material handling, substrate deformation, or vibration from field cutting

Photo # 122

Same as MIA Photo 123 - lack of proper maintenance, lack of proper sealing and keeping shower door closed after use (not allowing moisture to escape)

Photo # 123

Same as MIA Photo 122 - lack of proper maintenance, lack of proper sealing and keeping shower door closed after use (not allowing moisture to escape)

Photo # 124

Polishing compound too hot (orange peel) - correct: refinish with 'cold' powder.

Photo # 125

Close up of 124: Polishing compound too hot (orange peel) - correct: refinish with 'cold' powder.

Photo # 126

Excessive grout haze - correct: carefully clean excessive grout off of calcium based stone (if an acid is used, neutralize the acid and refinish the stone)

Photo # 127

Settling and chipped edges (caused by butt joint installation - minimum 1/16" gap)

Photo # 128

Spalling on outside of shower

RESTORATION AND MAINTENANCE

ADDITIONAL LEARNING RESOURCES

Stone Behavior Groups, pp. 21-10–16

- For more information about Crema Marfil and the company and quarries that produce it, see, http://www.levantina.com/us/.
- Online Resource: http://www.natural-stone-database.com, type "Crema Europa" in the search box.
- Online Resource: http://www.bempe.com/en/crema-europa-limestone
- Stone Care Guide, Ted McFadden. 2008.

Restorative Processes, pp. 21-51–66

- Stone Care Guide, Ted McFadden. 2008.
- Online Resource, http://www.stonerefinishing.com

Maintenance, pp. 21-75–84

- ASTM C1515–11, Standard Guide for Cleaning of Exterior Dimension Stone, Vertical and Horizontal Surfaces, New or Existing.
- Cleaning Masonry – Review of the Literature by Grimm, Clayford T., P.E. Construction Research Center, and University of Texas at Arlington, 1988.
- Cleaning Stone and Masonry, Clifton, James R., Editor. ASTM Special Technical Publication 935, American Society for Testing and Materials, 1983.
- Keeping It Clean by Grimmer, Anne E. U.S. Department of the Interior, National Park Service, Washington, DC: U.S. Government Printing Office, 1988
- "Cleaning of Masonry Interiors of Public Buildings," Cleaning Stone and Masonry by Roth, J.W., ASTM STP 935, 1986.
- "Chemical Cleaning of Historical Structures – A Practical Approach," Cleaning Stone And Masonry by Rudder, T.H., ASTM STP 935, 1986.
- "A Case Study of the Cleaning of Marble at the Schenectady, New York, City Hall," Cleaning Stone and Masonry, by Waite, J.C. and R.J. Chen, ASTM STP 935, 1986.
- "A Macrosteriogrammetric Technique for Measuring Surface Erosion Losses on Stone," Cleaning Stone and Masonry by Winkler, E.M., ASTM STP 935, 1986.

Commercial and Historic Restoration, pp. 21-85–88

- Occupational Safety and Health Administration (OSHA): https://www.osha.gov/law-regs.html

- Occupational Safety and Health Administration (O.S.H.A.) – Guide to *Controlling Silica Exposure:* https://www.osha.gov/Publications/3362silica-exposures.pdf
- Union Requirements – National Labor Relations Board: http://www.nlrb.gov/rights-we-protect/employerunion-rights-and-obligations
- Federal Labor Requirements – United States Department of Labor: http://www.dol.gov/whd/programs/dbra/wh347.htm
- National Park Service – Historic Rehabilitation Guidelines: http://www.nps.gov/tps/standards/rehabilitation/rehabilitation-guidelines.pdf
- National Park Service – The Secretary of the Interior's Standards for Rehabilitation: http://www.nps.gov/tps/standards/rehabilitation/rehab/stand.htm
- National Park Service – Tax Incentives: http://www.nps.gov/tps/tax-incentives.htm
- National Park Service – Register of Historic Places Database: http://www.nps.gov/history/nr/research/
- Milan Restoration Triumph – InfoTile.com http://www.infotile.com/pdfFile/Product/ProductFile/1604201343759.pdf
- Historic Preservation – Technical Procedures: http://www.gsa.gov/portal/content/111858
- National Trust for Historic Preservation: http://www.preservationnation.org

DSDM 7.2 (2011)

- ASTM International, ASTM C119, Standard Terminology Relating to Dimension Stone. West Conshohocken, PA: ASTM International.
- National Tile Contractors Association, NTCA Reference Manual. 2011. Jackson: NTCA.
- Tile Council of America, Tile Council of North America Installation Handbook. Princeton: TCA, 2011.
- International Code Council, 2012 International Plumbing Code. ICC, 2011.

