Materials and Fabrication Handbook

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Art in Public Places Program
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WASHINGTON STATE
ARTS COMMISSION

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INTRODUCTION

The Washington State Arts Commission (ArtsWA) cares for the State Art Collection with partner agencies (public schools, colleges, universities, and state agencies), who present the artwork in public spaces. Partner agencies and/or sites are responsible for all routine artwork maintenance.[1] The Arts Commission is responsible for conservation and restoration of the artwork, which is contingent upon receipt of adequate appropriations for this purpose.[2]

As part of our acquisition process, we recommend artists familiarize themselves with this handbook prior to the Artist Site Visit. The Arts Commission requires the artist to warranty newly commissioned artworks from defects for a minimum of two years[3] after installation. The information in this handbook is provided to aid artists in designing their projects from conception through installation, while considering long-term maintenance and future conservation issues. Our goal is to encourage creative liberty while ensuring the public investment reaches its full potential lifespan in a fiscally responsible way.

This resource is organized by material type with sub-sections discussing environmental concerns, fabrication techniques, and design considerations. A summary of ArtsWA requirements is provided at the end of each section for quick reference. This handbook will be regularly updated.

Follow all safety and manufacturer instructions when using any of the materials and products listed in the following pages. Consult manufacturer's technical departments, technical and specification sheets, or Material Safety Data Sheets (MSDS) for information on how to properly protect yourself from short and long-term effects of using these materials.

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[1] ArtCare: Maintenance and Stewardship. (PDF) ArtsWA pg. 5, 2006.
[2] ArtCare: Conservation and Restoration. ArtsWA page 7, 2006.
[3] Art in Public Places: Public Artist Handbook. ArtsWA pg. 25, 3/09.

RECOMMENDATIONS AND REQUIREMENTS FOR EVERY ARTWORK

Artists should take the following general construction and design recommendations and requirements into consideration in the creation of work for public spaces in order to minimize damage from vandalism, inherent vice[4], and the environment.

Please note that a structural engineer may require fabrication techniques and materials that conflict with those below in order to achieve structural integrity for a given design. In such cases, always follow the engineering requirements.

Interior

Interior environments tend to be less stressful to artwork than exterior environments. Vandalism is generally minimal and the environmental concerns of temperature and relative humidity are usually well controlled. The concerns for interior work are primarily construction, placement, and access. When designing for interior locations consider:

Windows

- Temperature and humidity can fluctuate rapidly and widely on the window facing side of an artwork.

- Using UV stable materials for works that will be exposed to direct sunlight will prevent colors from drastically fading or slow overall discoloration.

- Direct sunlight may significantly increase the surface temperature of the artwork and stress the medium, support structure, coatings, and finishes. Construction materials like adhesives, caulking, and grout should be selected for their ability to withstand rapid temperature changes.

HVAC Systems

- HVAC systems cause vibrations in the walls and support structure that may affect a nearby artwork over time. Including dampeners in the construction and installation of the artwork may be wise for long-term preservation.

- Air intakes for HVAC systems often pull dust and particulates towards them.

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[4] Inherent vice: A destructive element that is a part of the artwork that causes or contributes to its deterioration. Inherent vice is either not reparable or not easily remedied without completely dismantling and rebuilding the artwork. For example, wood pulp-based paper will turn yellow and become brittle because the PH level of the paper is not balanced; the paper will deteriorate due to its chemical properties.

- Vents circulate dust, which will collect in pockets and recesses on the artwork.

Public

- Safety is a primary concern and should be considered throughout every aspect of artwork design, fabrication, and installation. Avoid sharp points and edges and surfaces that can be a slip hazard. Fragile materials, components, surfaces, or easily leveraged parts can be bent or broken off accidentally or as an act of vandalism. Materials considered fragile are also easily abraded, dented, or scratched.

- Most partner agencies have specific safety guidelines for their campuses. Some materials may not be applied on site, i.e. silver leafing, certain paints or adhesives, etc. Materials applied on site must be approved by the partner agency and the ArtsWA project manager.[5]

- Works installed below six feet can unintentionally be scraped by backpacks or foreign objects.

General Environment

- Access for cleaning, maintenance, and repair is necessary. There should also be enough space to remove the work safely should the piece need to be deinstalled.

- Deinstallation of an artwork may happen for many reasons, such as conservation and/or maintenance of the artwork, new construction or remodeling at the site, or relocating the artwork to a new site. The work should be installed in a manner that will allow future art handlers to deinstall the work without causing unnecessary expense or damage to it. Public buildings are generally remodeled within 20 years, and often non-integrated artwork can outlive interior design trends if originally installed in a reversible manner.

Exterior

Vandalism and theft can be problems for exterior works of public art. Sound construction techniques, sealants, and proper installation methods will help reduce the effects of vandalism, or deter a would-be thief. Corrosion from environmental pressure is the most common long-term destructive element to an artwork's lifecycle. Routine maintenance can greatly reduce the effects of pollution and weather related stress on the surface, but cannot address problems of inherent vice. Some points to consider when designing exterior works are:

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[5] The ArtsWA Project Manager will need to know all of the materials to be applied on site, including adhesives and sealants, so he/she may direct the information to the appropriate person for determination.

Safety

- Artwork design should consider that the public may climb on the piece. Discouraging climbing is very important, especially for tall works.

- Most regions of Washington State experience heavy amounts of rain, ice, or snow throughout the year. Any exterior surface pedestrians will walk over is required to be fabricated of materials that do not create a slip hazard. Polished or lightly textured metal and stone surfaces are common slip hazards.

- Washington State has regions that can experience extreme heat in spring and summer months. When constructing artworks with materials that retain heat and potentially pose a burn hazard, consider incorporating design elements that would reduce the amount of direct sunlight exposure, or consider other materials.

- ArtsWA requires there to be no sharp points or edges in places where public interaction is possible.

- Polished metal in exterior environments must not create a glare that poses a safety risk to passing motorists and pedestrians. Reflection of sunlight from polished metal can also be a source of heat transfer to nearby objects and surfaces. All polished metal surfaces are required to be positioned in a manner that prevents heat transfer and glare that may pose a safety risk.

Local Environmental Concerns

The landscape and environment near the artwork should be considered as a factor in selecting appropriate materials.

- Insect infestations can severely damage an artwork. Pest control for specific materials should be considered for annual or anticipated special maintenance. If a particular material is especially prone to infestations, it is worthwhile to explore comparable materials.

- Bushes, trees, and foliage planted near an exterior work can create many sources of possible damage. Trees can weep difficult to remove sap onto the artwork, and the leaves from deciduous trees can plug drain holes and prevent water management systems[6] from working properly. Tree roots may also disturb the placement of the artwork. Grounds crews will likely spray fertilizer around any plantings near the artwork. By spacing the plantings far enough away from the artwork, there will be less of an opportunity for corrosive elements in the fertilizer to damage the artwork when it is sprayed or wind-blown onto the piece.

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[6] Water management systems include drains, gutters, and any system that deliberately directs water flow.

- Mold and mildew can damage many organic or porous materials. The most susceptible materials should not be considered when designing artwork in coastal zones.

- Artwork near saltwater often develops a layer of briny crust or coating. Some materials will experience accelerated deterioration due to the alkalinity of the local atmosphere.

- Roads, railroad tracks, and waterfront areas in close proximity create opportunities for vandals to throw large rocks at the artwork. Consider only the most durable materials in these environments.

- Industrial and automotive pollution can create a dark layer of oily residue on the surface of materials. The residue is difficult to clean and will retain airborne particulates (e.g. dirt, pollen).

Water and Condensation Management

Water and condensation management are very important for both external surfaces and internal voids of artwork components.

- Pooling water is damaging to most materials and creates an environment for mold and mildew growth, rot, oxidation, and the development of other agents of deterioration.

- Water will shorten the lifespan of most materials. Water features, sprinklers, and fountains in close proximity generally expose the artwork to increased humidity and overspray. Water may also create a slipping hazard for pedestrians.

Ground Level Placement

All artwork should be raised above grade by a 1 inch minimum, if set upon a hard, non-porous surface, and 4 inches if placed over lawn, foliage, or bare earth. If installing on lawn, creating a "mow strip" or buffer that prevents facilities personnel from having to use machinery for lawn maintenance within 6 inches of any portion of the artwork at ground level is essential. If the work needs to be closer to the ground than 4 inches, one solution would be to incorporate a drainage system of crushed gravel, at least 10 inches deep sub-grade, to allow moisture and water to evacuate quickly. This will also reduce the amount of ground moisture evaporation directly beneath the artwork.

Graffiti and Vandalism

Anti-graffiti coatings should be considered for use depending on the medium and potential rate of incidence. Some traditional sealants, i.e. wax, work as graffiti barriers and should be carefully researched as possible substitutes for commercial anti-graffiti coatings. Most sealants need some degree of maintenance, and eventual replenishment or total replacement. Sealants that require complete replacement are not desirable.

Placing artwork in locations with frequent pedestrian traffic, or visibility from roadways and public buildings are potential deterrents to vandalism and graffiti. Well-lit artwork at nighttime is a necessary element to inhibit vandalism.

Skateboarding

Benches, low concrete walls, stairs, and pathways are perfect skateboarding surfaces. Railings along stairs are also very popular with skateboarders, rollerbladers, and freestyle bicyclists. Skateboarders slide or grind along edges with the skateboard's painted wood underside or metal trucks. Paint or metal particles imbed in the surface of the artwork, causing damage. Recognizing that skateboarders generally need to generate speed to perform tricks will help determine the best, and least impacting design approach. Paver stones, exposed aggregate surfaces, height changes in close proximity to the artwork, blocks, and turf are all poor surfaces for skateboarding. If the surrounding landscape cannot be altered or designed with deterrents, incorporate deterrents onto the artwork itself. Long, smooth edges and slopes are targets for skaters, therefore notches, straps, or bumps should be considered to disrupt the ability of the skateboard to slide along the artwork's surface.

Theft Prevention

All publicly accessible artwork is required to use security hardware, which requires a special tool or driver bit to remove the hardware. ArtsWA prefers hex-pin hardware for screws and bolts, but will approve other types of security hardware on a case-by-case basis. Stainless steel security hardware is required for exterior artwork[7], and is often a specialty order item through hardware distributors *(see Hardware in the Metals section for more information)*. Three installation points of contact are recommended to properly secure artworks and components.

Accessibility for Maintenance

The artwork should be safely accessible for grounds and facilities personnel to perform annual routine maintenance**.** Light fixtures are required to be easily accessible for bulb replacement.

Fragile and Breakable Components

Fragile and breakable components should be protected against vandalism and thrown objects *(additional information is provided in Protective Covers on pg. 55 in the Plastics section)*.

- Polycarbonate sheet is a strong, clear protective cover and should be spaced from protected components no less than a ½ inch. The appropriate thickness of the polycarbonate will depend on the size of the span it will need to protect.

- Access to the artwork, and specifically the fragile components, for restoration of broken pieces is required. The ability to replace protective surfaces easily is also required.

[7] Aluminum artwork or components in direct contact with the hardware are exceptions and should utilize galvanized or zinc-plated steel security hardware instead.

Summary of ArtsWA Requirements

- Any exterior surface pedestrians will walk over is required to be fabricated of materials that do not create a slip hazard. (pg. 8)

- ArtsWA requires there to be no sharp points or edges in places where public interaction is possible. (pg. 8)

- All polished metal surfaces are required to be positioned in a manner that prevents heat transfer and glare that may pose a safety risk to motorists and pedestrians. (pg. 8)

- All publicly accessible artwork is required to use security hardware, which requires a special tool or driver bit to remove the hardware. (pg. 10)

    - Security hardware is required to be stainless steel with an exception for aluminum portions of artwork, in which cases galvanized or zinc-plated steel hardware is appropriate. (pg. 10)

- Light fixtures are required to be easily accessible for bulb replacement. (pg. 10)

- Access to the artwork and protective components is required. (pg. 10)

METAL

As a stand-alone material, a substrate for a finish, or internal supports and hardware, this medium is utilized in nearly every artwork in our collection in one way or another. Metal can be a superb material for interior and exterior use. When the appropriate material is matched to the site and when fabricated correctly and sealed (if appropriate), metal objects can enjoy a very long lifespan, often outliving the space in which they were originally placed.

Metals can be divided into two main sub-groups: non-ferrous and ferrous.

- Non-Ferrous – Metals and metal alloys that do not contain iron such as copper, bronze, brass, zinc, and aluminum. These metals do not rust, but instead develop an oxide, or coating, when left unsealed. These metals are generally acceptable in exterior environments when appropriately sealed and protected.

- Ferrous – Metals and alloys that contain iron such as mild steel, stainless steel, and weathering steel. In exterior or humid environments, many of these alloys will develop rust, or will develop rust colored oxides. Stainless steel alloys are ferrous even though they contain rust inhibiting properties. Weathering steel and stainless steel are considered appropriate for exterior environments. Mild steel is generally not suitable for outdoor public art regardless of the coating or sealant applied to the surface; with the possible exception of porcelain enamel artworks *(see Porcelain Enamel section on page 15 for more information).*

The compatibility of metals is a crucial factor when considering materials for creating exterior artwork. Compatibility can be measured by how near two dissimilar metals are in a galvanic series.[8] In general, the farther apart the metals are in the series, the less compatible they are. Common compatible metals to copper alloys are stainless steel and nickel. Common incompatible or "dissimilar" metals to copper alloys are iron, steel (mild/carbon), zinc, galvanized steel, and aluminum.

Fabrication Techniques and Design Considerations

Welding and Soldering

Welding and soldering are common methods of fabricating metal objects and components when the alloy of the metal parts being joined is the same. It is crucial that the welder be experienced in working with the specific material. Artworks utilizing structural welds; i.e. welds with specific requirements that are necessary to ensure the integrity of the structure, are required to be done in

[8] A potential difference exists between two dissimilar metals when they are introduced to a conductive or corrosive solution, or electrolyte. When metals are placed in direct contact with each other, this potential difference produces electron flow between them and accelerates corrosive activity on at least one of the metals.

accordance with welding requirements as determined by local and state building codes.[9] Artwork that includes metal components that are structurally necessary; i.e. stairs, handrails, benches, armatures, may require structural portions of the artwork to be welded by a fabricator or certified welder[10] that meets specific criteria determined by local and state building codes.

Joining Non-identical Alloys

Joining non-identical alloys by welding or soldering requires expert knowledge and is generally inappropriate. Bolts and mechanisms that can be tightened and/or removed as needed are preferred instead of rivets, and are required in the case of kinetic works.

Dielectric Gaskets

The use of dielectric gaskets, insulating materials that resist the flow of electric current, is required to insulate two incompatible metals from the damaging effects of galvanic corrosion. Dielectric gaskets can be in the form of silicon, Teflon, nylon, rubber, neoprene, or other non-conductive material *(for additional information, see the Dielectric Gaskets to Separate Dissimilar Materials on page 55, in the Plastics section).*

Hardware

Hardware should be stainless steel, or a material compatible to the component materials[11], unless otherwise required by an engineer for structural purposes. The use of anti-seize products are recommended when coating the threads of all hardware and are required when joining dissimilar metals.

Cast Metal Objects

Cast metal objects with a diameter or internal space larger than 2 inches wide should be hollow to reduce weight, amount of material[12], and reduce voids within the structure of the cast metal that enable agents of deterioration to develop. The one exception is cast aluminum in which solid castings could be acceptable; the casting parameters will be considered on a case-by-case basis.

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[9] The structural engineer reviewing the artwork may determine the structural welding requirements, however, if the engineer does not determine the welding requirements or if you need additional information, a list of jurisdictional Building Code Officials is available online at www.wabo.org in the Jurisdiction Map section. ArtsWA recommends contacting these officials if you have questions regarding structural requirements for your artwork.

[10] The Washington Association of Building Officials (WABO) oversees and conducts testing and certification of structural welders in Washington State. A WABO Welding Certification is a quality standard that meets the structural welding requirements of local and state building codes for Washington. The American Welding Society (AWS) also has a welding certification process that may meet state and local building code requirements for structural welding. Contact a Building Official working within the jurisdiction of your project for specific information.

[11] For instance, aluminum artwork mounted to a wall is more compatible with hot-dipped galvanized steel hardware than stainless steel hardware. Copper alloy metals should use stainless steel instead of galvanized steel hardware.

[12] Unnecessarily thick castings increase the foundry cost, which ultimately reduces the amount of money you will have to create the artwork. Also, using more material than is necessary may be inappropriate when considering the resources and environmental impact required to mine, smelt, and produce metal objects.

Fabricated Metal Objects

Fabricated metal objects with a diameter or internal space larger than 2 inches wide should be hollow to reduce weight and amount of material, unless otherwise required by an engineer for structural purposes. Found objects are not required to be hollow in their original state.[13]

Water and Condensation Management

Water and condensation management techniques for exterior works include:

- Drain holes are placed in low points of pockets that will hold more than a ½-cup of water. The holes allow the water to drain and the surface to dry out at the same rate as the surrounding surfaces.

- Weep holes allow moisture to drain out of hollow components and create airflow internally. Weep holes also help alleviate pressure buildup in hollow cast metal pieces and reduce the likelihood that moisture will be pushed through the porous sections of metal during natural heating and cooling phases.

- Slight angles on flat surfaces will help reduce pooling and allow the surface to drain.

- Sprinkler systems need to be designed and customized to avoid spraying the artwork with water.

- Surfaces of metal objects at ground level tend to wick moisture from the ground, sometimes as high as 8 inches above the grade. Constant or extended exposure to moisture increases the likelihood of corrosion and therefore shortens the lifespan of the metal portion of the work. Installing metal sculpture above grade is very important in preserving the artwork's structural integrity.

Inlaid metal pieces

Inlaid metal pieces at ground level in exterior environments are required to be sufficiently textured to eliminate potential slip hazards. All pieces must be grouted or caulked with appropriate material to prevent water from pooling underneath and freezing. Polished metal tiles are unacceptable in exterior environs.

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[13] Molds and reproductions of found objects are considered new objects and if cast in metal, should be hollow if larger than 2 inches in diameter or internal space.

Metal Sealants and Protective Coatings

Painted Metal

Painted metal is acceptable to ArtsWA on a case-by-case basis. Environment, location with respect to public interaction, and ease of repair or repainting help determine the appropriateness of painted metal pieces. Artists wishing to paint steel for exterior artworks are required to use stainless steel, typically type 304, or a non-ferrous metal, e.g. bronze, aluminum, as a substrate. Appropriate primers specifically formulated for the substrate alloy are required with any painted metal artwork. Your ArtsWA project manager may have paint and primer specifications depending on the type of metal and environmental conditions of the artwork.

Patination

Patination is a common and generally acceptable means of coloration for metal artwork.

- Non-ferrous metals that are patinated should have a protective sealant to allow them to age slowly and in a controlled manner. Sealing the patina will also slow or prevent environmental pressures (e.g. bird guano, pollution, graffiti) from significantly altering or damaging the patina. Chemicals used in a patina application that are outside of normal and proven industry standards may be subject to an extended warranty period to be determined by ArtsWA.

- Ferrous metals that are patinated may or may not require a sealant, depending upon the alloy of the metal and the environment. For instance, weathering steel is best left unsealed to allow it to develop the protective oxides it needs. Patinated mild steel is unacceptable in exterior environments.

Powder Coating

Powder coating is a popular coating for public artworks, typically over a mild steel substrate. It is widely used both for the range of colors achievable and its strength to withstand exterior environments. The primary problem with powder coating publicly accessible artwork is that acts of vandalism are difficult to repair, and once the surface of the powder coat is damaged, the metal substrate is susceptible to corrosion. All edges should be rounded to allow the powder coat to wrap around corners and maintain a consistent thickness. Powder coated pieces are best suited for dry climates[14] and artwork out of reach of the public. ArtsWA will not accept powder coated mild steel in exterior environments and requests artists to use stainless steel, type 304 or 316, or a non-ferrous metal, e.g. brass or aluminum, as an alternative substrate.

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[14] Dry climates in Washington State are considered climates with average annual relative humidity of less than 70 %. The process of powder coating metal objects does not ensure that all pinholes and voids in the metal will be coated. High relative humidity environments are more likely to cause condensation and water to enter the interior of the artwork, possibly resulting in corrosive activity to the metal.

Porcelain Enamel

Porcelain enamel, or vitreous enamel, is a popular coating for public art. The most common substrate is enameling steel[15], though copper is also often used as a substrate. Similar to powder coating, once the coating is damaged, the substrate becomes susceptible to corrosion. Steel substrates are the most susceptible, causing rust staining and the corrosion could result in a loss of material. The porcelain enamel is difficult to repair on site and most often requires the use of enamel paint to approximate the surrounding colors. ArtsWA will accept porcelain enamel artworks for interior environments and on a case-by-case basis with consideration of location, design, and public access for exterior environments. All sharp angles or edges should be rounded to allow the porcelain enamel to wrap around corners and maintain a consistent thickness. Enameling the entire substrate, including the backside, is encouraged for interior artwork, and is required for exterior porcelain enamel over a steel substrate.

Waxes

Paste waxes are a traditional sealant option and are appropriate for most metals. Waxes are easy to remove and easy to replenish. Weathering of waxes in an exterior environment tends to decrease the lifespan of the sealant, however the ease of replenishment is significantly better than any other type of sealant. Common waxes used for sealing metals and patinas are micro-crystalline wax, polyethylene wax, carnauba wax, and various mixtures of these waxes.[16] Beeswax is generally not acceptable by itself, especially in an exterior environment, but is sometimes used as a component in a wax recipe. Beeswax tends to darken and attract dirt and pollutants and is not recommended as a top-coat, or final, wax. Wax that is made with strong solvents, like xylene or toluene, may not be used if the metal surface is in contact with sealed wooden components of the artwork as these solvents may damage the wood sealant.

- Commercially available paste waxes that are commonly used to seal metal objects include SC Johnson®, Butchers Paste Wax®, TreWax®, Staples®, Bri-Wax®, Kiwi Neutral Shoe Polish®, and Renaissance Wax®. Some waxes are very good when applied to a warm or hot metal surface and others are better applied to a cold, room temperature metal surface.

- Pigmented waxes are sometimes used to alter or enhance the color of an object. Some commonly used and commercially available pigmented waxes are Kiwi Shoe Polishes® and Lincoln Shoe Polishes®. Sculpt Nouveau® makes colored waxes specially formulated for bronze and copper alloys, and a separate product specially formulated for iron and steel. Pigmented waxes are not suitable for exterior environments, where the metal will heat and the wax could rewet. If the metal surface reaches a high enough temperature, the wax could bead and run, which would cause streaking in the pigmented wax. Pigmented wax is only a surface application and is not permanent.

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[15] Enameling steel is a low carbon steel that is designed for the porcelain enameling industry. For technical and cost reasons, it is the most common substrate for this coating.

[16] Guide to Maintenance of Outdoor Sculpture; Bronze. pgs. 33-34.

Lacquers and Clear Coats

Lacquers and clear coats produce a high level of protection and a longer lifespan than wax. It is important to research the type of sealant that is most appropriate for the artwork, both aesthetically and functionally. Vandalism or failure of the sealant over time is difficult to repair without negatively affecting the appearance of the artwork and removal of these sealants is labor intensive. Most lacquers need to be removed and reapplied after 7 – 10 years of exposure to UV light and the exterior environment. The lifespan of the lacquer can be extended if a top-coat of wax is applied and routinely maintained.

Dyes

Dyes are an option for artists wishing to color certain types of metals that typically are not conducive to patination such as aluminum and stainless steel. Many companies that supply lacquer also have dyes available as an additive to their products. Product testing has shown that some dyes lift from the metal surface when wiped with a damp towel. These products must be sealed with a lacquer or wax and are only acceptable in interior environments.

Anti-graffiti coatings

Anti-graffiti coatings are used in many applications to allow for easy and quick removal of spray paint and other markings. These coatings often work best over a lacquer or polyurethane coating. The artist will need to research the many different types of anti-graffiti coatings to find a product that best suits the artwork, environment, and local or regional air quality regulations for Volatile Organic Compound (VOC) emissions if the sealant must be sprayed on. Anti-graffiti coatings are not required, but are suggested for use in locations where "tagging"[17] and graffiti is likely to occur. Some wax coatings may act as anti-graffiti coatings.

Summary of ArtsWA Requirements

- Non-ferrous metals are generally acceptable in exterior environments when appropriately sealed and protected. (pg. 12)
- Weathering steel and stainless steel are considered appropriate for exterior environments. (pg. 12)
- Mild steel is generally not suitable for outdoor public art regardless of the coating or sealant applied to the surface. (pg. 12)
- Artworks utilizing structural welds are required to be done in accordance with welding requirements as determined by local and state building codes. (pg. 12)

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[17] "Tagging" is a term used to describe a type of written graffiti like names or words, usually with spray paint or permanent marker, done quickly and generally with very little color.

- The use of dielectric gaskets is required for insulating two incompatible metals from the damaging effects of galvanic corrosion. (pg. 13)

- Inlaid metal pieces at ground level in exterior environments are required to be sufficiently textured to eliminate potential slip hazards. (pg. 14)

- Artists wishing to paint steel for exterior artworks are required to use stainless steel, typically type 304, or a non-ferrous metal, e.g. bronze, aluminum, as a substrate. (pg. 14)

    - Appropriate primers specifically formulated for the substrate alloy are required with any painted metal artwork. (pg. 15)

ArtsWA will not accept powder coated mild steel in exterior environments and requests artists to use stainless steel, type 304 or 316, or a non-ferrous metal, e.g. brass or aluminum, as an alternative substrate. (pg. 15)

- ArtsWA will accept porcelain enamel artworks for interior environments and on a case-by-case basis with consideration of location, design, and public access for exterior environments. (pg. 15)

    - Enameling the entire substrate is required for exterior porcelain enamel over a steel substrate. (pg. 15)

- Pigmented waxes are not suitable for exterior environments. (pg. 16)

- Dye products must be sealed with a lacquer or wax and are only acceptable in interior environments. (pg. 17)

WOOD

Wood is often used as a primary medium or major component of a given artwork. It is also commonly used in stretchers, strainers, and frames for paintings; substrate backing for fragile materials; and cleats in wall hanging apparatuses for relief and two-dimensional artwork. The climate of the Pacific Northwest presents a wide array of challenges to the artist who is trying to create an artwork incorporating wood with the goal of long-term durability.

The quality of the wood is important. Wood that is derived from the sapwood portion of the tree has less protection from insect and fungal attack and will likely be more responsive to humidity and moisture changes. The heartwood portion of the tree, which is the older, generally darker, center portion of the tree, is stronger and more resistant to the affects of the surrounding environment.

Wood is generally classified into two main groups:

- Hardwood – refers to wood from deciduous trees or shrubs[18]. This group of species is commonly used for flooring, fine woodworking, and finish carpentry. Though typically harder, not all hardwoods have a specific hardness that is greater than their softwood counterparts, for instance Balsa can be scored easily with your fingernail. Common types of North American hardwoods are Maple, Oak, American Birch, Cherry, Alder, and Walnut. Generally, the harder the wood, the more resistant it may be to effects from the environment and public interaction.

- Softwood – refers to wood from conifer trees, also known as evergreens[19]. There are some species of softwoods that are actually harder than some hardwoods, e.g. Pacific Yew. Softwoods are also commonly used in woodworking and carpentry; however, you will also see many of these varieties used in construction due to their lower cost. Common types of North American softwoods are Hemlock, Fir, Spruce, Pine, and Cedar.

Environmental Considerations

As a material for public art, wood offers an earthiness and a fundamental link to the Washington landscape. Wood often allows the public to experience the efforts of the artist's hand without the intervention of mechanical processes. However, as an organic material, wood in nearly every environment deteriorates naturally. In consideration of creating a sustainable artwork, these localized factors must be considered:

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[18] *Hardwoods of North America*. Forest Products Laboratory: USDA, 1995.
[19] *Softwoods of North America*. Forest Products Laboratory: USDA, 1997.

Relative Humidity and Temperature

Wood that is acclimated to one specific regional environment may swell, split, or crack if relocated to an environment where the relative humidity and temperature are not consistently the same. It is important to note that even for regional species, for instance along the coast, a consistent relative humidity of 50 - 60% is acceptable, but above 70% mold and insects could become a problem.[20] Average relative humidity along the coast of Washington State is generally above 70%, therefore, it is important to conduct research and choose regional species suited for the proposed site whenever possible.

- Temperature and relative humidity controlled environments are best. An interior environment allows the artist greater latitude in varieties of wood, treatments, compatibility with other materials, and joining methods and materials. However, be advised that unless the site location of the artwork is humidity controlled, even interior spaces experience fluctuations in humidity and temperature great enough to cause the wood to swell, split, or crack.

- Dimensional change in wood due to humidity and temperature fluctuation is not constant in all directions. This is very important to consider when fabricating artwork. As wood absorbs moisture, the cell walls expand and contract, but the length of the cell remains virtually constant. Therefore, there will be very little to no change in the longitudinal plane of the wood (the long axis of the tree), but the tangential plane (flatsawn board, flat or plain grain) and the radial plane (quartersawn board, vertical or edge grain) will expand and contract significantly. Along the tangential plane, the expansion could be upwards of 8%, and along the radial plane, expansion could reach 4%.[21]

- Polychrome and clear-coat sealants/surfaces are often more rigid than their wood substrates because the wood itself will expand and contract with changes in humidity and temperature. The movement beneath these coatings will eventually weaken their adherence to the wood, and cause them to crack and peel.[22]

Direct Exposure to Sunlight and UV Light

Direct exposure to sunlight and UV light breaks down the binding agent, or lignin, for the cellulosic fibers of the wood[23]. Excessive and prolonged exposure to UV light accelerates the deterioration of the material.

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[20] Murdock, Cynthia, and Al Levitan. *Appendix N: Curatorial Care of Wooden Objects (2002).* NPS Museum Handbook, Part 1. pg. N:15.
[21] Ibid. pgs. N:3, N:4.
[22] Guide to Maintenance of Outdoor Sculpture; Wood. pgs. 44-45.
[23] Ibid.

Direct Exposure to Moisture

Direct exposure to moisture is often the foundation for other agents of deterioration. Designing the work with good water management (e.g. not allowing water to pool, spacing slats far enough apart to allow surfaces to dry completely, elevating the work sufficiently above moist earth or lawn) will improve the lifespan of the material and help prevent agents of deterioration that are reliant on continuously high surface moisture.

Bacterial and Fungal Attack

Bacteria generally only affect water-saturated wood, but when it does thrive, it has damaging effects on the cell structure. Molds and mildews are a type of fungi that particularly affect the surface and aesthetic of the material. However, more damaging is stain fungi and decay fungi (e.g. brown rot and white rot) which have the capacity to destroy the cellular structure of the wood. Fungi flourish in high relative humidity environments typically above 65%. Decay fungi rely on the moisture content to reach very high levels before becoming real problems. Objects in constant or prolonged exposure to water are likely to develop the most damaging fungi.[24]

Insects, Birds, and Rodents

Insects in our region mostly prefer moist wood. Some feed on the wood, while others may excavate to create large chambers and shelter[25]. Beetles, Termites, Carpenter ants, Moisture ants, and Carpenter bees are commonly known to cause damage. By keeping the wood elevated from the ground, out of constant contact with water, and designed for easy and effective maintenance, insect infestations are less likely to occur. Rodents and birds do the most damage in trying to reach the insects for food or by eating the wood itself. Birds also like to perch on large wooden outdoor structures, where their guano can affect the wood surface negatively.

Public Interaction

Wood used in public art is an attractive material for vandals. Wood artwork should be placed in a highly visible location that is well lit at night. Anti-graffiti coatings specially designed for wood may need to be employed to prevent ink and staining, but unfortunately will not prevent people from scratching into the wood. Designs that prevent people from climbing and possibly stressing the artwork are encouraged.

Fabrication Techniques and Design Considerations

Sustainable artwork requires strong and durable fabrication techniques and thoughtful design considerations with respect to the previously mentioned environmental pressures placed on the artwork.

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[24] Murdock, Cynthia, and Al Levitan. *Appendix N: Curatorial Care of Wooden Objects (2002).* NPS Museum Handbook, Part 1. pgs. N:7, N:8.
[25] Ibid. pgs. N:7-N:9.

Durable Joinery

There are many types of joining techniques for laminating, splicing, and fabricating wood objects. Dovetail, mortise and tenon, dowel, dado tongue and rabbet, slip and lock corner, and tongue and groove are end-to-edge-grain joints proven to be durable[26]. Plain and mitre joints are also end-to-edge-grain joints but are typically only acceptable in construction, support structure, and internal framing situations where the joints can be sufficiently fortified with glue and metal hardware fasteners. When splicing wood, using end-grain joints, plain scarf, vertical structural fingerjoint, horizontal structural fingerjoint, or non-structural fingerjoint methods will increase the durability and longevity of the joint.

Veneers

Veneers are thin layers of wood over-layed onto another wood. Veneers are not appropriate for exterior artwork or high relative humidity environments. The expansion and contraction of the underlying wood is often different than the veneer, which causes premature failure of the binding material.

Metal Hardware

Metal hardware is commonly used to support certain types of joints, and is often employed as a functional or aesthetic design component of the artwork. The most common type of metal fasteners are steel screws. Certain types of wood are corrosive to metal fasteners,[27] likely damaging and staining the wood fibers. ArtsWA requires the use of stainless steel hardware for exterior applications. Painted, plated, and galvanized steel are generally not acceptable for exterior works, but are approved for interior locations with low relative humidity and controlled temperature.

Glues and Adhesives

Glues and adhesives are a common and often necessary component in creating wood sculpture. Three basic types are protein based (e.g. hide or fish glues, casein glue), vegetable based (e.g. starch paste, gums, and natural resins), and synthetic resins (e.g. glues that harden through evaporation of a solvent or a chemical reaction like a two-part system) [28]. Protein and vegetable glues are reversible and will be useful if future conservation treatment is necessary and are acceptable for interior works. Unfortunately, for exterior wooden objects, these glues are typically water-soluble and do not perform well in high and low relative humidity environments. They are also susceptible to biodeterioration and may attract insects. Synthetic resins are very strong, durable, and generally not affected by exterior environments. It is nearly impossible to reverse the adhesion of synthetic resins for purposes of conservation and the resins often have a higher strength than the surrounding wood.

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[26] Vick, Charles B. "Chapter 9: Adhesive Bonding of Wood Materials". *Wood Handbook - Wood as an Engineering Material*. USDA, pgs. 9-19.
[27] For instance, Oak contains high concentrations of tannic acid which are highly reactive to iron salts. Murdock, Cynthia, and Al Levitan. *Appendix N: Curatorial Care of Wooden Objects (2002)*. pg. N:10.
[28] Murdock, Cynthia, and Al Levitan. *Appendix N: Curatorial Care of Wooden Objects (2002)*. NPS Museum Handbook, Part 1. pg. N:11.

It is important to consider the species of wood being joined with adhesives. Generally, a higher density wood will yield an adhesion of lower quality. When selecting adhesives, be sure it is suitable for the type of wood being joined and is able to withstand expansion and contraction of the wood (i.e. elasticity of the adhesive). Joining wood with similar grain direction and cut (i.e. tangential, radial, or longitudinal grain direction) will help the pieces handle dimensional change due to loss or addition of moisture content. For example, wood components of tangential grain joined to components with radial grain will expand and contract at different rates. This will put stress on the joints and surrounding wood fibers and will result in accelerated breakdown of the joint.

Fastening to Dissimilar Materials

Joining wooden objects to other materials, such as metal, or ceramic, requires thoughtful consideration of each of the respective material properties and how they will react to an environment of changing relative humidity and temperature. For components with higher expansion and contraction rates, like wood, it is important to determine the range of possible expansion and contraction and prepare attachment systems to travel without causing stress to the attachment (e.g. when attaching bolts, drill the bolt holes larger, or create a slot for the bolt to travel through during expansion and contraction phases). Remember, the wood will expand mostly in width, and less in length (along the grain).

Preservatives

Preservatives are useful for minimizing damage from fungi, bacteria, and insects and can be used in conjunction with water repellants on exterior artworks to minimize the effects of biodeterioration[29]. ArtsWA will require the use of preservatives for exterior artworks on a case-by-case basis with consideration of environment, location, and artwork design.

There are two main groups of preservatives: waterborne and oilborne. There are many different types of chemicals within each group and each group offers specific protections for different situations. In considering preservatives for treating an artwork, it is important to check with local environmental agencies and current Environmental Protection Agency (EPA) regulations.

- Waterborne preservatives are excellent products for wood-based artwork when clean and paintable surfaces are preferred after the wood is treated.[30] Preferable preservatives are borates, or borate-based. The National Park Service lists two commercial products they find effective: Bora-Care® and Tim-Bor®. Borate preservatives do not discolor the wood or affect its structural properties. They protect against decay fungi and insects but do not protect against mold and mildew.[31] Borates are odorless, do not vaporize, and are minimally

[29] It is important for the preservative to be compatible with the water repellant. Check with the manufacturer's technical departments to ensure you are using the right combination of products.
[30] Ibach, Rebecca. "Chapter 14: Wood Preservation". *Wood Handbook - Wood as an Engineering Material*. USDA, pgs. 14-9, 14-10.
[31] Conserve O Gram 7/3; Protecting Wood with Preservatives and Water Repellants. NPS, pg. 2.

toxic to humans[32]. Hardware, with the exception of aluminum, is not affected by borate preservatives. At high enough concentrations, borates offer some fire resistance. The biggest drawback to borate preservatives is that due to their water solubility, they may leech out of the wood, killing some surrounding plants. The leeching can be controlled by applying and maintaining good quality water repellant over the preservative.

- Some water repellant manufacturers add preservatives to their products that may be used instead of borate preservatives. If you prefer to use water repellant over a borate treated surface, contact the manufacturer of the water repellant you are considering for compatibility requirements with borate treatments.

- Oilborne preservatives are generally suited for structural and underground, continuously moist environments, and are not generally appropriate for wood-based artwork.

Water Repellants

Water repellants are sealants, or finishes, that provide protection to the wood surface from liquid water[33]. ArtsWA requires the use of water repellants on all exterior artworks and for publicly accessible interior artworks. Stains, liquid waxes, paints, and synthetic sealants, e.g. polyurethanes, are acceptable for works in interior environments and some exterior environments with great consideration given to the specific location of the artwork. Most sealants for objects in outdoor environments have a lifespan between 3 – 5 years[34]. Top quality acrylic latex paints may reach a lifespan of 10 years, which is considered the high end of that sealant's lifespan. Wood species will impact the lifespan of the sealant.

Water repellant products are not necessarily the same as products designed to prevent water vapor transfer throughout the wood, a.k.a. products with high moisture-exclusion effectiveness.[35] It is important to seal the entire wood object (back, front, sides, and ends) to equalize the amount of moisture absorption throughout and help stabilize the material. The National Park Service recommends X-100 Natural Seal® by American Building Restoration Products, Inc. (ABR), which contains a highly effective mildewcide.[36] Another acceptable commercially available product that has been recommended to ArtsWA by a regional conservation specialist is the TWP® series by Gemini®.

- Most commercially available water repellants, like TWP® and X-100 Natural Seal®, are considered penetrating wood finishes, are mostly clear, and contain preservatives useful in

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[32] "Minimally toxic to humans" means that the product should not be ingested. It is important to follow the manufacturer's recommendations for personal safety when using any product.
[33] Williams, R. Sam. "Chapter 15: Finishing of Wood". *Wood Handbook, Wood as an Engineering Material.* USDA, pg. 15-10.
[34] Ibid. Table 15-5: pg. 15-15.
[35] Ibid. pgs. 15-9…15-11.
[36] Conserve O Gram 7/3: Protecting Wood with Preservatives and Water Repellants. NPS, pg 3.

protecting the wood from fungi, bacteria, and insects. Many products are available in subtle, and often transparent, color choices (e.g. cherry, maple, or black walnut stains).

- Paraffin Oil, aka Mineral Oil or White Mineral Oil, is considered a penetrating finish and is acceptable for use in interior environments, but due to extensive maintenance requirements, is not acceptable to ArtsWA in exterior environments.

- Oils, like tung and linseed, are also considered penetrating wood finishes but are not acceptable in exterior environments. Like Mineral Oil, these finishes are acceptable in interior environments.

- Semitransparent stains are generally water-repellant preservatives with inorganic pigments added for color and environmental protections. Due to the high solids content, these stains are generally more durable in an exterior environment than clear water-repellant preservatives and are considered an excellent choice for all properly prepared wood surfaces, including weathered wood.

- Film-forming finishes include varnish, paint, solid stains, and fire retardant coatings. These coatings range in effectiveness. Varnish is not acceptable in exterior environments. Most paints and solid stains can be formulated for exterior environments and generally offer the most protection for the wood. Paints and solid stains are not preservatives and will not prevent fungal growth. Acrylic formulated latex paint, though porous, has a longer lasting elasticity than oil-based paints and generally has a longer lifespan.

Water and Moisture Management

Water and moisture management techniques are important in extending the lifespan of exterior wood sculpture. The cut ends of wood pieces are the most susceptible to water damage and are required to be sealed, and positioned away from direct contact with standing water. Wooden objects cannot have pockets that hold or collect water and flat sections should be slightly angled to encourage rain and snow melt to run off. Organic material like moss, tree leaves, and needles are sources of biodeterioration as they hold moisture directly against the wood surface for extended periods of time. They can also become a source of dust and dirt collection, and if not cleaned on a regular basis will promote the growth of flora, e.g. ferns, moss, and plants. Be mindful of the seasonal changes in the surrounding landscape and how they can affect the materials of the artwork.

Conservation and Maintenance

Conservation and maintenance for wooden objects in exterior environments must be more comprehensive than for most other materials. Applying a protective coating every 3 years should be the minimum maintenance expectation and will vary depending on the type of coating formula used. Accessibility is required for allowing facilities personnel to adequately clean and maintain the work whether it is located in an interior or exterior setting.

Wood-based Product as Substrate or Support Material

There are many composite and laminate products on the market. Plywood is considerably stronger and able to withstand various stresses better than many solid wood products of similar size and thickness. When using plywood, ArtsWA requires thoroughly sealing the exposed laminate ends to adequately limit moisture absorption. The surfaces should be sealed similarly to solid wood components. Plywood is not acceptable for use in exterior artwork placement. Medium Density Fiberboard (MDF) is acceptable as a support material for interior artwork. All edges and surfaces must be properly sealed to prevent material off-gassing from damaging the artwork and the hardware. MDF is not acceptable for use in an exterior environment. Particle board, chip board, and some hard boards are not considered appropriate products as support material for fabrication. Other wood-based composite materials will be considered on a case-by-case basis with respect to its location, environment, and inclusion in the artwork design.

Summary of ArtsWA Requirements

- Veneers are not appropriate for exterior artwork or high relative humidity environments. (pg. 22)
- ArtsWA requires the use of stainless steel hardware for exterior applications. (pg. 22)
- ArtsWA will require the use of preservatives for exterior artworks on a case-by-case basis with consideration of environment, location, and artwork design. (pg. 23)
    - Oilborne preservatives are not generally appropriate for wood-based artwork. (pg. 24)
- ArtsWA requires the use of water repellants on all exterior artworks and for publicly accessible interior artworks. (pg. 24)
    - Paraffin Oil, aka Mineral Oil or White Mineral Oil, is not acceptable to ArtsWA in exterior environments. (pg. 24)
    - Oils, like tung and linseed, are not acceptable in exterior environments. (pg. 25)
    - Varnish is not acceptable in exterior environments. (pg. 25)
- The cut ends of wood pieces are the most susceptible to water damage and are required to be sealed, and positioned away from direct contact with standing water. (pg. 25)
- Accessibility is required in allowing facilities personnel to adequately clean and maintain the work whether it is located in an interior or exterior setting. (pg. 25)

- When using plywood, ArtsWA requires thoroughly sealing the exposed laminate ends to adequately limit moisture absorption. Plywood is not acceptable for use in exterior artwork placement. (pg. 25)

- Medium Density Fiberboard (MDF) is acceptable as a support material for interior artwork. (pg. 26)

    - All edges and surfaces must be properly sealed to prevent material off-gassing from damaging the artwork and the hardware. (pg. 26)

    - MDF is not acceptable for use in an exterior environment. (pg. 26)

CERAMIC

From dinnerware to one-of-a-kind artwork, ceramics have probably been the most utilized materials throughout our cultural development. Ceramic is defined as a non-metallic material or clay, which is corrosion resistant, and hardens when heated to a high temperature, or fired.

Earthenware, stoneware, porcelain, and mudbrick/adobe are common types of ceramic or clay bodies.

- Earthenware (low fire) is fairly porous and often requires glazing to minimize the porosity of the material. It is generally used for artwork such as reliefs and pottery, and includes unglazed terracotta. Earthenware glazes adhere to the surface, but do not penetrate deep into the ceramic body, and leave the artwork susceptible to damage from exterior elements. When compared to stoneware and porcelain, earthenware is porous, soft, and only acceptable in interior locations as public art with the exception of small mosaic tile.

- Stoneware (high fire) has very low to no porosity depending on the specific ceramic used. Though often glazed, it is not required for protection of the surface. Stoneware glazes tend to penetrate deep into the ceramic body. Stoneware may be acceptable in exterior environments provided the artwork cannot easily be broken or damaged by public interaction[37] or environmental hazards.

- Porcelain (high fire) is non-porous and may be acceptable in exterior environments provided the artwork is adequately protected from public interaction and environmental hazards.

- Mudbrick or Adobe is generally used in hand-built artworks and is unfired. This particular process and material is not appropriate for public art as it is susceptible to water damage and public interaction.

Environmental Considerations

Ceramic can be used in interior and exterior environments. ArtsWA accepts stoneware and porcelain bodies for use in exterior environments as they are typically more stable and less susceptible to freeze-thaw damage than earthenware. Small mosaic tiles that are glazed earthenware may also be acceptable on a case-by-case basis.

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[37] Public interaction is considered to be occasional wear and tear on the artwork from normal public exposure; e.g. people walking over pavers, or artwork that people will touch, sit on, or lean against.

Public Interaction

Public interaction with ceramic objects is generally acceptable. Exposed edges or corners are susceptible to damage from chipping or getting caught on clothing, backpacks, and purse straps. Placement in areas with ⅝ inch or larger sized rocks and found objects that can be thrown is discouraged as ceramic tiles and objects are brittle, easily damaged, and very difficult to repair. Damage from blunt trauma will most often require replacement of the ceramic piece.

Moisture and Water

Moisture and water in exterior environments are particularly damaging. Freeze-thaw effects can break the ceramic from the bonded substrate if not properly sealed. Snow melt and rainwater run-off are factors to be considered for exterior ceramic artwork.

Saltwater and Alkaline Environments

Saltwater and alkaline environments can be particularly damaging to ceramics, especially low fire ceramic bodies, as they develop and push salts through their porous ceramic body. The salts accumulate between the body and the glaze and weaken the bond between the two layers.[38]

Fabrication Techniques and Design Considerations

Glazes

Glazes are, in general terms, layers of glass fused to the ceramic body. Metal oxides are often added to the glaze to produce specific colors and effects. Glazes tend to be weakest and thinnest along a sharp edge or corner. Edges and corners of the artwork should be rounded for the glaze to wrap around the side.

Exterior Tile and Mosaic

Exterior tile and mosaic artwork requires a grout that will expand and contract with the medium. ArtsWA prefers the use of an acrylic mortar ad-mix.[39] Flat mosaics are required to be sufficiently angled to allow water to run off the surface.

Exterior Tile Pavers (glazed or unglazed)

Exterior tile pavers (glazed or unglazed) should not be used in heavy foot-traffic locations as they typically are not designed to withstand long term pedestrian activity.[40]

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[38] *Guide to the Maintenance of Outdoor Sculpture*. Materials Used in Outdoor Sculpture. pg. 43.
[39] Conservation and Maintenance of Contemporary Public Art. Appendix 1: Materials. Wanlass, Ralph, pg. 134.
[40] Ibid.pg. 133.

Substrates

Substrates for all tile and mosaic work are required to be cement board or cementitious in nature. Plywood and materials that have a high expansion and contraction rate are not appropriate for use as a substrate.

Internal Reinforcement

Internal reinforcement in the ceramic body can be a source of inherent vice. Steel or iron structural armatures are not appropriate, especially for exterior artwork in environments with high relative humidity. ArtsWA requires using stainless steel, preferably type 304 or 316, for armature material in exterior artworks.

Summary of ArtsWA Requirements

- Earthenware is only acceptable in interior locations as public art, with the possible exception of small, glazed mosaic tiles. (pg. 27)
- Stoneware may be acceptable in exterior environments. (pg. 27)
- Porcelain (high fire) may be acceptable in exterior environments. (pg. 27)
- Exterior tile and mosaic artwork requires a grout that will expand and contract with the medium. (pg. 28)
    - Flat mosaics (exterior) are required to be sufficiently angled to allow water to run off the surface. (pg. 28)
- Substrates for all tile and mosaic work are required to be cement board or cementitious in nature. (pg. 28)
- ArtsWA requires using stainless steel, preferably type 304 or 316, for armature material in exterior artworks. (pg. 29)

STONE

Conventional logic would suggest that all stone is well-suited for exterior environments, but this is not always the case. Different stone types are more resistant to certain types of decay phenomena and it is important to choose the right stone for the intended environment.

Stone can be broken down into three main classifications:

- Igneous - describes rock formed under conditions of intense heat or produced by the solidification of volcanic magma on or below the Earth's surface (e.g. granite).

- Sedimentary - describes rocks formed from material deposited as sediment by water, wind, or ice and then consolidated by pressure (e.g. sandstone, limestone).

- Metamorphic – describes a process of change in the physical structure of rock as a result of long-term heat and pressure, especially a change that increases the rock's hardness and crystalline structure (e.g. marble, alabaster).

Environmental Considerations

Stone can be susceptible to deterioration in an exterior environment as a result of:

- Its mineralogical and geochemical composition.

- Foliation and/or planar discontinuities with the material, which can be either inherent in the stone or caused by quarrying and tooling techniques.

- The object's orientation and surrounding environment, which affect the behavior of the stone as significant sources of moisture, salts and pollutants in the local environment can be agents of deterioration.

Dissimilar stone types tend to exhibit a variety of categorically different characteristics. There can also be significant variations between similar stone types from different quarries, and occasionally the same stone type from different sections of the same quarry.

When placing stone in exterior environments, consider these types of deterioration in order to choose and handle the material appropriately.

Mechanical/Physical Deterioration

Physical deterioration is often caused by both liquid water and water vapor entering the stone through pores, fissures, and larger cracks and is stored in porous voids. Water saturated stone is susceptible to damage during freeze-thaw cycling when water expands and fractures the surrounding

matrix or void walls. This weakens the material below the stone's surface while also generating more fissures and cracks along the surface that potentially draw in more water.

The following physical characteristics of stone will attract and retain large amounts of water and will therefore be more susceptible to mechanical deterioration:

- Highly porous stone with small to medium pores that are interconnected. Sandstone most commonly exhibits these characteristics, but granites and basalts can also have these characteristics.

- Stone with many fissures along the surface. For example, stone that has been damaged during the extraction or tooling process or recycled stone that has been exposed to weathering processes.

- Stone types with large amounts of veining, which often have chemical compositions that differ slightly from the bulk stone. Sedimentary stone such as limestone, sandstone, and travertine frequently have veining or layers with different chemical and physical compositions. Marble or any stone with visible veining can also exhibit these characteristics.

- Stone that is composed of many foliated planes may weather along those planes as water enters between the layers, causing freeze-thaw cycling and salt crystallization. This type of weathering can affect stone similarly to those with large amounts of veining such as sedimentary stone types and marble.

Frequently saturated stone is susceptible to salt crystallization as salts in the surrounding environment solubilize, enter the stone, and recrystalize inside voids in the stone as it dries. Accumulated salt crystallization has the same deteriorative effects as freeze-thaw cycling.

The object's orientation often affects how the stone will age. For instance, south faces tend to deteriorate more quickly in continental and dry climates as they experience more changes in temperature and freeze-thaw cycling than north faces.

Internal reinforcements, particularly steel or iron rods, expand when they corrode and could be a source of internal pressure.

Public interaction can also damage the stone, causing wear or broken pieces if struck with an object. Graffiti on stone is a concern with public art. The use of anti-graffiti coatings will be considered on a case-by-case basis and only anti-graffiti coatings designed for stone and approved by ArtsWA will be acceptable.

Biologic Deterioration

Biologic deterioration is characterized by the formation of lichen, algae, or bacterial growth on the surface or in the pores of the stone and can be a source of staining and surface discoloration. Plants with vines and large roots can be structurally damaging to the stone.[41]

Chemical Deterioration

Chemical deterioration is generally a result of a reaction between environmental pollutants, primarily sulfates, and the geochemical composition of the stone. Because some stones are less prone to such attack, it is important to carefully select a suitable stone if the object is placed in an environment with a high concentration of atmospheric pollutants, such as a city or near a busy road.

Some stones display certain performance characteristics over time. For example, some stones have minerals that migrate to the surface of the cut block, causing a permanent change in coloration. While this does not necessarily compromise the stone, it can be aesthetically disagreeable or incompatible with the original design. Such characteristics tend to be consistent with all blocks extracted from a certain quarry or a specific part of a quarry. These characteristics tend to be discovered after the stone is extracted and used, however, this information is often available through suppliers, conservators, or materials experts and should be considered prior to selecting the stone type.

Fabrication Techniques and Design Considerations

Stone is generally a heavy material and asymmetrical in shape. Therefore, the axis and center of gravity need considerable scrutiny in the design and placement of the object. Detailed drawings and measurements must be provided to engineers and contractors for proper placement and construction of artwork that incorporate large stones. Below is a list of considerations for creating stone sculpture or sculptural components to be placed in exterior environments.

Tooling and Form

Working the stone with high-powered or high-impact tools can cause minute stress-fractures that can facilitate mechanical and chemical deterioration.

Smaller sculptural features and objects provide greater opportunities for water to enter and cycle through the material. This is due to a greater surface area to mass ratio. Deteriorating mechanisms are generally accelerated in these components (see Mechanical and Chemical Deterioration mechanisms listed above).

Stone blocks with bedding planes, defined as the arrangement of rock strata, laid vertically will deteriorate significantly faster than stone with bedding planes laid horizontally.

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[41] Guide to the Maintenance of Outdoor Sculpture, pgs. 38 – 41.

Moisture and Water Management

Moisture isolation and water management techniques are characterized by good drainage and reduction of constant moisture to which the object is subjected. Placing a moisture-proof barrier, e.g. polyethylene sheeting, between the stone and ground is a preferred method of keeping moisture from condensing around the bottom or wicking up from the ground.

Placement

Placement near water drainage systems and below structures should be scrutinized for potentially damaging effects from overflow. Running water or constantly dripping water over stone will eventually damage the surface by creating channels, and can introduce pollutants that may chemically or biologically damage the surface of the object.

Water Repellent Coatings

Water repellant coatings may be appropriate depending on the type and porosity of the stone. Usually, these sealants are silicon based and because water can be trapped below the surface, this material should be used judiciously. Sealants and coatings other than specially designed water repellants are not acceptable for exterior placement.[42] ArtsWA will review all proposed stone sealants and approve on a case-by-case basis.

Mortars and Fill Materials

Mortars and fill materials must always be weaker than the surrounding stone. These materials should be low in alkalinity and soluble salts. Epoxy and other similar resins are generally not considered stable when used as fill materials and should only be used on interior artwork. [43]

Structural Reinforcement

Structural reinforcement is often necessary to stabilize sections of stone that may be fragile or more susceptible to physical deterioration. ArtsWA requires all metal reinforcement to be stainless steel, preferably type 304 or 316. It is acceptable to use epoxy or other resins to adhere the metal reinforcement bars internally.

Inlaid stone

Inlaid stone elements in exterior environments are required to be sufficiently textured, e.g. rough or deeply grooved, in order to avoid being a slip hazard. Stone tiles must be grouted or caulked with materials that are softer than the artwork materials. Stone varieties that soften by wear, textures that quickly fill-in with debris, and polished stone are unacceptable in exterior environments.

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[42] Guide to the Maintenance of Outdoor Sculpture, pgs. 38 – 41.
[43] Ibid.

Summary of ArtsWA Requirements

- The use of anti-graffiti coatings will be considered on a case-by-case basis and only anti-graffiti coatings designed for stone and approved by ArtsWA will be acceptable. (pg. 31)

- ArtsWA will review all proposed stone sealants and approve on a case-by-case basis. (pg. 33)

- Epoxy and other similar resins are generally not considered stable when used as fill materials and should only be used on interior artwork. (pg. 33)

- ArtsWA requires all metal reinforcement to be stainless steel, preferably type 304 or 316. (pg. 33)

- Inlaid stone elements in exterior environments are required to be sufficiently textured in order to avoid being a slip hazard. (pg. 33)

Special thanks for reviewing and co-authoring this section to Jessica Kottke, M.S. Historic Preservation, Seattle.

CONCRETE AND CAST STONE

Concrete and cast stone are durable materials for public art and are appropriate for exterior environments. Concrete is a mixture of cement, water, and aggregate, e.g. sand, pea gravel, crushed rock. Cast stone is defined as concrete mixed with specific types of aggregate; e.g. marble dust, often pigmented to mimic natural stone, and cast into a mold. Many of the same factors that affect stone in exterior environments also affect concrete and cast stone. However, technological advances in concrete formulation and sealants have improved the long-term performance of these mediums.

Environmental Considerations

There are few environmental concerns with properly cured and formulated concrete. Concrete and cast stone that is green, i.e. not sufficiently cured after being cast or poured, is susceptible to a decrease in strength and premature degradation. If the water, cement, and aggregate ratios are not properly formulated, often with too much water, the material can be brittle and less able to withstand stress, which can also lead to premature deterioration of the material.

Moisture

Moisture is a damaging element to concrete and cast stone in much the same way it is to solid stone. Water that penetrates through cracks and crevices to the interior of the object may freeze and expand, putting pressure on the structural integrity of the artwork. Cracks and crevices should be filled with mortar or other fill material, that is softer than the surrounding concrete or cast stone, and will prevent moisture from wicking in and out of these pathways.

Trees and Organic Landscape

Trees and organic landscape components can be damaging to nearby concrete slabs and footings. Roots from trees usually expand out from the trunk in nearly the same diameter as the overall circumference of the tree branches. Leaves and debris can fall onto the artwork surface and become a source of mold and mildew growth, staining the surface, and causing deterioration along edges or cracks. Fertilizer that splatters or lands on the concrete surface can oxidize and show rust stains. Placement of landscape elements that require frequent fertilization should be considered in the design.

Weathering

Weathering affects the cast stone or concrete differently across the surface of the object. For example, rain, snow, and wind will deteriorate portions or layers of a cast stone or concrete object where the material has trapped air below the surface or the physical nature of the material is less sound than the surrounding material. Normal weathering of other materials in the artwork may damage the concrete; for instance, water running off of a metal sculpture fabricated from Weathering Steel supported by a concrete plinth will cause iron oxides to run over the surface of the concrete and cause staining. Footings, plinths, and concrete pads should be sufficiently angled to allow water to drain away from the artwork so that it does not pool on the surface.

Fabrication Techniques and Design Considerations

One of the great benefits to concrete and cast stone is the ability to manipulate the medium by altering the formula of the component materials and incorporating additional materials. The ability to cast-in the internal reinforcement of the material is a fabrication technique that can greatly improve the lifespan of the material, without forfeiting aesthetic value.

Reinforced Concrete

Reinforcement material improves the strength of the concrete or cast stone beyond what the aggregate alone provides[44]. Some common types of reinforcement material follow:

- Glass Fiber Reinforced Concrete, or GFRC, is useful as a lightweight but strong medium. The glass fiber, most often alkaline resistant, will not corrode and generally has a long lifespan, dependent on usual stress-load.

- Plastic fibers, silica fume, and metakaolin are examples of other types of reinforcement material that can be added to the concrete or cast stone for increased strength. Some similar products being utilized by other public art agencies are Lithocrete®, Glasscrete®, and Syndecrete®.[45]

- Metal reinforcement, traditionally steel, e.g. rebar, wire mesh, screen, is common in exterior environments and is a cheap alternative to glass fiber, plastic fiber, silica fume, etc. However, metal does not have good elasticity and is not as accommodating to slight dimensional changes of concrete and cast stone exterior works. Corrosion can also be an issue with metal reinforcement. While steel completely imbedded within the concrete or cast stone tends to withstand corrosion, moisture that may leach in from cracks and pores in the surface may accelerate the corrosive activity of the steel. Exposed ends or chipped pieces of concrete along the edge or corners can also be a source for accelerated corrosion. If left untreated, corrosion can continue to the interior of the concrete (similar to how an insect bores a hole into wood), thus reducing the intended and possibly necessary strength of the material. As the metal corrodes, it expands and puts pressure on the surrounding concrete possibly cracking the material. When creating cast stone or concrete components for an exterior environment, ArtsWA prefers the use of stainless steel as a metal reinforcement.

Corners and Edges

Corners and edges are required to be rounded or beveled if located at a height or location accessible by the public. Ninety degree corners that experience foot traffic or public exposure are extremely

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[44] Reinforcement material like glass fiber, plastic fiber, silica fume, etc. can be used in conjunction with metal reinforcement for added strength. The amount and type of reinforcement materials will need to be discussed with and approved by a structural engineer licensed in the State of Washington.
[45] *Conservation and Maintenance of Contemporary Public Art*, Appendix 1:Materials; Los Angelas County Metropolitan Transportation Authority, California. Section by Ralph Wanlass. Pg. 132.

susceptible to breaks and chips. Beveling or rounding the corners will help protect the edges from breakage *(see the Skateboarding section on page 9 for information on skateboard mitigation techniques).*

Concrete Walkways and Plazas

Concrete walkways and plazas are difficult to make perfectly flat. Depressions in the surface allow water to pool and when frozen, can become a slip hazard. Providing a texture, slight slope to the surface, and frequent drain opportunities for large spans will improve the safety and integrity of the artist's original design. Smooth walking surfaces in exterior environments are unacceptable to ArtsWA.

Drain placement is an important and sometimes overlooked aspect of exterior plazas. A civil engineer or partner agency may require drains for large areas of concrete.

Crack/break lines and expansion joints are required for large spans of concrete and should be strategically placed. As concrete dries and the moisture evaporates it shrinks. Large spans will crack to compensate for the pressure on the material, occurring most often with horizontal or flat concrete. Crack/break lines are especially useful to direct cracking from pressure changes in the support of the concrete; e.g. upheaval from tree roots, settling of the earth below the concrete, expansion below the concrete due to pooling water that freezes. When incorporating long walls of concrete, monolithic walls with no sectional breaks, or large spans of flat concrete, ArtsWA requires crack lines to be placed at least every 8–10 linear feet. However, the artist is urged to design crack lines into the span which can occur more frequently.

As the temperature of concrete increases, it may expand. Expansion joints are made of material designed to withstand pressure and are required by ArtsWA for horizontal flatwork, i.e. concrete walkways, large spans, or plazas. Vertical and monolithic concrete walls may also require expansion joints. The structural or civil engineer may be able to determine the necessary placement of expansion joints to mitigate damage from expansion.

Cure Time

Cure time is the time necessary for the material to achieve the majority of its strength through chemical activity. Concrete and cast stone generally need a minimum of 4 days of cure time before being introduced to the public, particularly if the object or section is cast on-site. A structural engineer may specify a longer cure time, especially if the concrete will need to support heavy weight, e.g. driveways, emergency vehicle entrances, heavy foot traffic. ArtsWA requires the cure time to be 30 days if the object is cast at a remote location and transported to the site.[46]

[46] The stress of travel on concrete or cast stone that has not fully cured may result in unnecessary breaks or cracks in the material resulting in premature deterioration of the artwork.

Trapped Air

Trapped air within the material weakens the structural integrity. When casting into a mold or form, vibrating the air bubbles out of the material is crucial for long term strength and surface quality. Using a vacuum chamber for smaller objects while the concrete or cast stone is still fluid can be an effective method for removing trapped air.

Sealants

Sealant requirements for exposed concrete and cast stone are similar to those for natural stone and will be required on a case-by-case basis. Concrete materials are porous, therefore ArtsWA requires that any sealant used be penetrating[47] and breathable to allow moisture vapor to travel through the concrete. Painting concrete or cast stone is not acceptable in exterior environments and will be considered on a case-by-case basis for interior environments.

Stained Concrete

It is acceptable to stain concrete or cast stone for interior artwork using a variety of commercially available concrete stains. Usually acid in nature, concrete staining products are not considered sealants. They are susceptible to contamination, and therefore must be sealed with a product that meets ArtsWA requirements. Stained concrete in an exterior environment is not acceptable as the stain color is likely to fade and ArtsWA sealant requirements make it difficult to replenish the stain during future conservation efforts.

Pigmented Concrete

Pigmented concrete is a good alternative when color is desired. If placing artwork in an exterior environment, be sure the pigments are UV stable. Pigmented concrete yields the same color throughout, ensuring that damage or breaks will expose concrete of the same color. It should be sealed using the same method as uncolored concrete or cast stone.

Summary of ArtsWA Requirements

- Corners and edges are required to be rounded or beveled if located at a height or location accessible by the public. (pg. 37)
- Smooth walking surfaces in exterior environments are unacceptable to ArtsWA. (pg. 37)
- Crack/break lines and expansion joints are required for large spans of concrete and should be strategically placed. (pg. 37)

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[47] As opposed to waterproof sealants that adhere to the surface and prevent moisture vapor from traveling through the concrete, e.g. rubber based coatings.

    - When incorporating long walls of concrete, monolithic walls with no sectional breaks, or large spans of flat concrete, ArtsWA requires crack lines to be placed at least every 8–10 linear feet. (pg. 37)

- Expansion joints are made of material designed to withstand pressure and are required by ArtsWA for horizontal flatwork, i.e. concrete walkways, large spans, or plazas. (pg. 37)

    - Vertical and monolithic concrete walls may also require expansion joints. (pg. 37)

- ArtsWA requires the cure time to be 30 days if the object is cast at a remote location and transported to the site. (pg. 37)

- Sealant requirements for exposed concrete and cast stone are similar to those for natural stone and will be required on a case-by-case basis. (pg. 38)

    - Concrete materials are porous, therefore ArtsWA requires that any sealant used be penetrating and breathable to allow moisture vapor to travel through the concrete. (pg. 38)

    - Painting concrete or cast stone is not acceptable in exterior environments and will be considered on a case-by-case basis for interior environments. (pg. 38)

    - Stained concrete in an exterior environment is not acceptable as the stain color is likely to fade and ArtsWA sealant requirements make it difficult to replenish the stain during future conservation efforts. (pg. 38)

PLASTER

Plaster is a historic sculptural medium that is typically low in cost and easy to work. Due to the fragile nature of plaster, objects are required to be out of reach of the general public, and protected by a clear acrylic or polycarbonate cover. Plaster artworks are only acceptable in humidity, temperature, and sunlight controlled interior environments.

There are three primary categories of gypsum-based plaster used in the arts:

- Casting plaster is typically a soft, sculpture-friendly material used in producing objects that will be molded and cast in a more durable material. Casting plasters are not acceptable as a final sculptural material for public art. Some common names for casting plasters are Plaster of Paris, molding plaster, and art plaster.

- Industrial plaster is formulated specifically for industrial application, but is also useful in art production. Though improved in strength and performance, industrial plasters are not acceptable as a final sculptural material for public art, unless incorporated as a component of a multi-media artwork, which will be accepted on a case-by-case basis. Some common product names are Tuf-Cal™ plaster (US Gypsum Company), and Denscal™ (Georgia-Pacific).

- Gypsum cements are plaster products with added polymers and reinforcement material. The formulation is designed to create thin wall castings with high strength. These products could be acceptable for interior public art under the right conditions. Typically, these cements produce substantial heat when water is mixed and the material begins to set. When casting these products, it is important to use a mold material that will be able to withstand the exothermic reaction of the material. Some common product names are Hydro-Cal™ (US Gypsum Company), Hydro-Stone™ (US Gypsum Company), and Densite™ (Georgia-Pacific).

Summary of ArtsWA Requirements

- Plaster objects are required to be out of reach of the general public, protected by a clear acrylic or polycarbonate cover, and are only acceptable in humidity, temperature, and sunlight controlled interior environments.

- Casting plasters are not acceptable as a final sculptural material for public art.

- Industrial plasters are not acceptable as a final sculptural material for public art, unless incorporated as a component of a multi-media artwork, which will be accepted on a case-by-case basis.

- Gypsum cement products could be acceptable for interior public art under the right conditions.

TERRAZZO

Terrazzo is a type of floor or wall system[48] typically composed of ground or broken chips of stone and a binder, or matrix. Most terrazzo floors are sealed with an appropriate sealant for the environmental pressures placed on the flooring. Terrazzo is durable and is an acceptable medium for public art in all environments, however only certain types of terrazzo flooring are appropriate for exterior environments. For more information and to find terrazzo contractors, please consult the National Terrazzo and Mosaic Association (NTMA)[49], a non-profit trade association that has established national standards. Their membership is limited to terrazzo contactors that meet their standards. NTMA has published the *Terrazzo Specifications & Design Guide*, which is available on their website. ArtsWA requires that terrazzo be installed by a qualified contractor familiar with local and state building code requirements and has specific knowledge of the type of terrazzo system and matrix being used.

There are three types of matrices commonly used in terrazzo systems:

- Cementitious Matrices – White or gray Portland Cement is used as the binder. Most often white Portland Cement is used when adding pigments to color the matrix. White cement is uniform in color, whereas gray cement has subtly uneven color which may be noticeable in the finish. This material is breathable and allows water vapor to pass through the material. It is acceptable in exterior and interior environments.

- Resinous Matrices – A two part thermal setting binder system generally composed of polyester or epoxy. Resin matrices are lightweight, resistant to staining and corrosive compounds, and are useful for thin-set[50] terrazzo. Resinous systems tend to be non-breathable and do not allow water vapor to pass through the material easily. These systems are not acceptable in exterior environments.

- Modified Cementitious Matrices – Polyacrylate Modified Cement is used as the binder. This material is a good choice for thin-set terrazzo and is useful in interior environments, but requires stringent parameters when used in exterior environments.

There are a multitude of terrazzo systems that utilize one of the three terrazzo matrices. The most common are as follows:

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[48] A terrazzo system is any combination of underbed, binder, and topping. An underbed is cementitious material used to support the dividers and terrazzo topping, as defined by the National Terrazzo and Mosaic Association (NTMA). The binder, also known as the matrix, is used to hold the marble, glass, or other aggregate materials in place within terrazzo topping. The topping is the uppermost surface of the flooring or outermost surface of the wall and generally comprises the aggregate type, chip size, and surface treatment.

[49] The National Terrazzo and Mosaic Association, Inc., website: www.ntma.com, email: info@nmta.com, phone: (800) 323-9736

[50] Thin-set terrazzo utilizes small chips, size 0 or 1, which is about 3/16 to ¼ inch in size, and is generally only ¼ inch thick. This thickness requires a strong, stable sub-layer for support, e.g. a concrete slab.

- Thin-Set – A resinous or polyacrylate modified matrix generally ¼ to ⅜ inch in thickness placed over a flat concrete slab. The concrete slab must be flat, with less than ¼ inch tolerance over a 10 foot span, as thin-set will not appropriately compensate for unevenness in the underbed.

- Monolithic – A cementitious matrix generally ½ inch in thickness and placed over a concrete slab. The quality of this system relies heavily on the flatness and crack prevention systems of the concrete slab underneath.

- Bonded – A cementitious matrix and underbed system useful in exterior and interior environments. This system is most appropriate when the underbed needs to fill between 1 ¼ to 1 ¾ inch depth in addition to the ½ inch terrazzo topping. The bonded system is less dependent on the flatness of the concrete slab as the sand and cement underbed will compensate for variations in surface depth.

- Sand Cushion – A cementitious matrix topping similar to the Bonded system but that also incorporates the use of wire mesh, a more substantial sand layer, and isolation sheeting. This cement-based system is able to fill to a depth of 3 inches, including the ½ inch terrazzo topping. Exterior environments will require the use of an isolating membrane of polyethylene sheeting, or imperforated roofing felt, placed between the concrete slab and the sand layer of the underbed.[51]

- Structural – A cementitious matrix that is required to utilize an underbed concrete slab at least 4 inches thick and rated at 3,500 psi.

- Precast – A system of prefabricated custom units to be used in just about any location and for any purpose.

- Rustic – A terrazzo surface that is left rough and unpolished. This surface can be used with Sand Cushion, Bonded, Monolithic, and Structural systems. Rustic terrazzo can incorporate many different textures and can be weather and skid resistant, which makes it an acceptable surface for exterior locations.

Environmental Considerations

Exterior terrazzo floors are susceptible to damage from natural elements. While acceptable in most interior environments, terrazzo will be accepted by ArtsWA on a case-by-case basis in exterior environments.

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[51] *Terrazzo Specifications & Design Guide*, pg. 9-10. The National Terrazzo and Mosaic Association, Inc.

Safety

Terrazzo floors are typically polished to enhance the color and luster of the marble and dividers. Smooth and polished floors are slip hazards when wet. Interior works are required to use a terrazzo sealant rated by the Underwriters Laboratories (UL) with a non-slip rating of 0.5[52]. Interior areas with entrances from outdoors may be required to have walk-off mats for reducing slick surfaces during inclement weather. ArtsWA encourages artists to consider mat placement and size requirements as determined by a civil engineer or partner agency when designing a terrazzo floor. Exterior terrazzo floors are required by ArtsWA to have a Rustic surface with appropriate sealant.

Moisture

Moisture can damage terrazzo in much the same way it can damage concrete. Cracks and crevices that allow water to penetrate between the surface of the terrazzo and underbed may freeze and expand, putting pressure on the structural integrity of the topping. Proper drainage systems and careful placement of the terrazzo, especially in exterior settings, are crucial to the longevity of the material. When possible, exterior terrazzo should be sheltered.

Trees and Organic Landscape

Trees and organic landscape components can damage concrete slabs and footings that could be part of the underbed of exterior terrazzo. Roots from trees typically expand out from the trunk in nearly the same diameter as the overall circumference of the tree branches. Leaves and debris can fall onto the terrazzo and become a source of mold and mildew growth and cause staining to the surface and deterioration along edges. The use of fertilizer that splatters or lands on the terrazzo can oxidize and show rust stains. Placement of landscape elements that require frequent fertilization should be considered within the design.

Fabrication Techniques and Design Considerations

Types of Terrazzo

Types of terrazzo, or terrazzo toppings, are generally determined by the size and shape of marble chips, glass, or other aggregates being used. Common names of topping types are Standard, Venetian, and Palladiana.

Dividers

Dividers are used to distinguish the different colors of terrazzo from each other. Common divider materials are brass, plastic, and zinc. Check with the supplier, contractor, or NMTA before using brass or plastic dividers with resinous matrices as they may have a negative reaction to the material.

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[52] Recommended by The National Terrazzo and Mosaic Association, Inc.

Mineral Pigments

Mineral pigments, often in dry powder form, are used to color the terrazzo matrix. It is very important to use a mineral that is lime-proof, or a synthetic pigment compatible with Portland Cement, when using cementitious matrices.[53] The NTMA advises that for interior terrazzo, no more than 2 lbs of pigment should be used per bag of Portland Cement, and for exterior terrazzo no more than ½ lb of pigment per bag.

Vapor Barriers

Isolating membranes, or vapor barriers, prevent moisture from the ground from negatively impacting the terrazzo and should be employed in all exterior flooring applications. If a vapor barrier has been utilized beneath an existing concrete slab, then it is unnecessary to repeat the vapor barrier unless required with the chosen terrazzo system, e.g. Sand Cushion terrazzo systems.

Control and Expansion Joints

Control and expansion joints must be utilized correctly to control cracking of the underbed and terrazzo topping. Exterior terrazzo requires the use of expansion material along all edges and control joints[54]. The type of expansion material and frequency of control joints recommended will depend on the type of terrazzo system used and the environmental factors to which the material will be subjected.

Summary of ArtsWA Requirements

- ArtsWA requires that terrazzo be installed by a qualified contractor familiar with local and state building code requirements and has specific knowledge of the type of terrazzo system and matrix being used. (pg. 41)
- Cementitious matrices are acceptable in exterior and interior environments. (pg. 41)
- Resinous matrices are not acceptable in exterior environments. (pg. 41)
- Modified cementitious matrices are acceptable for thin-set terrazzo and are useful in interior environments, but require stringent parameters when used in exterior environments. (pg. 41)
- Interior works are required to use a terrazzo sealant rated by the Underwriters Laboratories (UL) with a non-slip rating of 0.5. (pg. 42)

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[53] *Terrazzo Specifications & Design Guide*; The National Terrazzo and Mosaic Association, Inc.
[54] A control joint is an intentional split in the flooring body or subfloor designed to allow shrinkage and expansion without damaging the terrazzo topping.

- Terrazzo will be accepted by ArtsWA on a case-by-case basis in exterior environments. (pg. 42)
    - Exterior terrazzo floors are required by ArtsWA to have a Rustic surface with appropriate sealant. (pg. 43)
    - Exterior terrazzo requires the use of expansion material along all edges and control joints. (pg. 44)

GLASS

Glass can be transparent, translucent, or opaque and found in just about any color, thickness, and shape imaginable, e.g. window panes, bottles, jars, plates, beads, jewelry, enamels for metal, and glazes for ceramic.

It is basically comprised of silica (commonly of sand or quartz) and flux which is an alkaline oxide such as lead, sodium, or potassium oxides.[55] Calcium oxide, also known as lime, is commonly added to the formula to stabilize the glass. Colored glass is produced by adding metal oxides such as iron, cobalt, copper, nickel, and chromium to the silica and flux.

Methods for producing glass used in artwork include:

- Cast Glass – Molten glass is poured, injected, or blown into a mold. The glass is then annealed[56] in a kiln and the temperature reduced slowly.

- Pressed and Blown Glass – Molten glass is gathered onto the end of a long hollow rod, shaped, and air blown into the center to create a void inside. Artists use shaping tools like shears and paddles to form the object before placing it in a kiln to be annealed.

- Fused Glass – Solid glass components are laminated and fused together inside a kiln that melts the glass into a near liquid state.

- Flat Glass – Panes are prefabricated industrially by rolling, drawing, or floating the glass. Generally, flat glass is used for windows, doors, and architectural design. Ultra Violet (UV) light inhibitors can be added to the glass for use in exterior environments. Glass panes can be etched or sandblasted to create imagery or design effects.

Artworks utilizing glass are generally made from hot-working and/or cold-working techniques. Hot-working techniques require the glass to be heated or molten to shape and manipulate the material, e.g. blowing, pressing, casting, or fusing in a kiln. Cold-working techniques refer to manipulation of the material after the artwork has cooled to room temperature, e.g. sandblasting, polishing, or acid-etching the surface.

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[55] National Park Service *Museum Handbook*, Part 1 (2000) Appendix P, pg. P:6

[56] "Anneal" v. To subject (glass or metal) to a process of heating and slow cooling in order to toughen and reduce brittleness. *The American Heritage Dictionary of the English Language*. 3rd ed. 1992.

Environmental Considerations

Glass is a durable material and is utilized for interior and exterior artwork. Proper placement of glass artwork is important. Though it is durable, glass is susceptible to damage from environmental causes.

Placement in Exterior Locations

Glass artwork should not be located under trees or locations where branches and falling debris can damage the artwork. Glass objects should also be free of water run-off, constant dripping, or abnormally humid environments, such as in close proximity to bodies of water like ponds, lakes, rivers, and streams.

Public Interaction

Public interaction with glass is generally acceptable. Exposed edges or corners are susceptible to damage from chipping or getting caught on clothing, backpacks, and purse straps. Sharp edges are a safety issue. Placement in areas with ¾ inch or larger sized rocks and found objects that can be thrown is discouraged, as glass usually requires complete replacement when broken.

Temperature Fluctuations

Extreme shifts in temperature can cause thermal shock, whereby one portion of the glass object heats and expands or cools and contracts faster than another portion of the same object causing cracks and breaks within the body of the object. Sources of thermal shock include:

- Exterior placement in regions that experience extreme fluctuations in temperature.
- While sunlight provides ample UV light, it is not typically damaging to colored glass objects, however, sunlight also emits infrared light which can radiantly heat the glass surface and cause thermal shock.[57]
- Artificial lighting can also be a source of infrared radiation. ArtsWA requires that flood lights with high radiant output and spot lights not be directly aimed at glass artwork. All artificial light sources should be sufficiently distanced from the artwork to limit heat transmission from fixtures in close proximity.

Water and Moisture

The chemical structure of a glass artwork will determine how susceptible it is to chemical deterioration from water and moisture.[58] In glass that is not formulated correctly, moisture can cause

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[57] National Park Service *Museum Handbook*, Part 1 (2000) Appendix P, pg. P:15
[58] Ibid. pg. P:11

chemical agents, i.e. sodium and potassium, to leech out of the glass. In some cases, chemical agents can absorb moisture on the surface of the glass and create hydroxides that damage the surface of the material.

Water should not be allowed to pool or become trapped within glass objects in exterior environments as freeze/thaw cycles can quickly damage the artwork.

Solarization

UV light can negatively affect some recycled or historic colorless glass of which manganese dioxide was used to decolorize the glass batch during the manufacturing process. Manganese dioxide was mostly discontinued just prior to World War I[59]. When exposed to UV light, this glass will turn varying shades of amethyst or purple.[60] Selenium dioxide was another decolorizing agent used to produce colorless glass from the early 1900s to around the 1950s, and when exposed to UV light, developed a straw-yellow tint[61].

Recycled or historic colorless glass should not be exposed to direct sunlight or light sources that emit high degrees of UV light if the age and formulation of the glass are unknown.

Fabrication and Design Considerations

Compatibility with Other Materials

Glass is generally compatible with most other materials. Oily materials, like leather, can be a source of chemically damaging agents to glass and should be distanced sufficiently to reduce the amount of contact the materials have. Certain plastics, resins, and rubbers that may leech chemicals over time may also be a source for chemically damaging elements and should be isolated from the glass as a precautionary measure. Spacers and gaskets should be easily accessible for replacement.

Materials that are reactive to or potentially damaged by the effects of moisture are required to be isolated from glass components in locations that experience more than a +/-10°F shift in temperature. Condensation and moisture will build up when the surface of the glass heats quickly and the relative humidity around the materials changes rapidly.

When fabricating artwork with flat glass panes or panels, consider the support material and how the materials will expand or contract with temperature change in exterior or direct sunlight environments. Provide space between the glass and the support material to allow for expansion and contraction. The space should be buffered by foam stripping to keep the artwork from slipping and allow the materials to move without causing significant stress to the glass.

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[59] Lindsey, Bill. "Colorless (aka "Clear")" *Bottle/ Glass Colors.* 2010 <http://www.sha.org/bottle/colors.htm>
[60] Canadian Conservation Institute. CCI Notes 5/1: Care of Ceramics and Glass, pg. 3
[61] Lindsey, Bill. "Colorless (aka "Clear")" *Bottle/ Glass Colors.* 2010 <http://www.sha.org/bottle/colors.htm>

Adhesives and Joining to Other Materials

There are few good adhesives that can be used to join glass to other materials. Silicone adhesives and sealants, i.e. caulk, are proven to work with glass that has been properly cleaned and prepared[62]. Silicone is compatible with some materials, but can be damaging to others due to the chemical properties of the adhesive or sealant, e.g. wood, most plastics, fibers, and textiles. Polyurethane sealants and adhesives are proven to work with prepared glass and can be useful with some materials with which silicone adhesives or sealants may not work, e.g. joining glass to rubber. It is important to discuss the effect an adhesive or sealant may have on the surrounding materials and performance in the intended environment with a conservation specialist.

Joining glass to other materials using adhesive, encapsulating the glass, e.g. framing and channeling, and mechanical attachments are acceptable methods of fabrication. The ability to easily remove glass artwork for cleaning, repair, or replacement is recommended to ensure the lifespan of the artwork.

Inlaid Glass in Pedestrian Walkways

Glass is a material that when wet is a slip hazard. Except in certain types of terrazzo flooring and concrete aggregates, glass is generally unacceptable as a component in pedestrian walkways due to safety concerns.

Edges

Publicly accessible glass artwork is required to have rounded, smooth edges, or a protective edge material like rubber, wood, or metal channel. Edges that are sharp or exposed may become chipped and are safety hazards.

Protective Coatings

Glass panes and panels are frequent targets for rock throwers in exterior settings. ArtsWA may require protective layers of polycarbonate to be placed in front of exposed glass artworks depending on location, public accessibility, the structural properties of the glass artwork, and access to the artwork for repairs or replacement.

Leaded/Stained Glass

Pieces of colored glass are assembled with leaded or zinc came and soldered together. Leaded came is soft and can be scratched easily. If an artist prefers to use leaded came and leaded solder in publicly accessible artwork, ArtsWA will require a layer of paste wax be applied over the surface of the came to limit lead exposure.

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[62] Properly prepared glass should be cleaned thoroughly. Some adhesives may require further preparation with alcohol or solvents to remove any waxes and oils that may be present on the surface of the glass.

Tempered Glass

Commonly known as safety glass, tempered glass is treated beyond the annealing process to toughen the material. There are a couple of processes for tempering glass, each with different results in toughness. The benefits of tempered glass are increased resilience to vandalism and thermal shock. The disadvantages to tempered glass are the inability to work the glass after the tempering process and any breaks or gouges will completely fracture or shatter the glass, making repairs virtually impossible.

Tempered glass is useful in panel or pane artwork that is accessible to the public. Should the surface be broken, this glass will shatter into small pieces rather than large sections that could severely injure someone. ArtsWA recommends consulting with glass manufacturers to determine what possibilities and processes are available for incorporating artistic elements with tempered glass.

Summary of ArtsWA Requirements

- ArtsWA requires that flood lights with high radiant output and spot lights not be directly aimed at glass artwork. (pg. 46)

- Materials that are reactive to or potentially damaged by the effects of moisture are required to be isolated from glass components in locations that experience more than a +/-10°F shift in temperature. (pg. 47)

- Except in certain types of terrazzo flooring and concrete aggregates, glass is generally unacceptable as a component in pedestrian walkways due to safety concerns. (pg. 48)

- Publicly accessible glass artwork is required to have rounded, smooth edges, or a protective edge material like rubber, wood, or metal channel. (pg. 48)

- ArtsWA may require protective layers of polycarbonate to be placed in front of exposed glass artworks depending on location, public accessibility, the structural properties of the glass artwork, and access to the artwork for repairs or replacement. (pg. 48)

- If an artist prefers to use leaded came and leaded solder in publicly accessible artwork, ArtsWA will require a layer of paste wax be applied over the surface of the came to limit lead exposure. (pg. 48)

PLASTIC

Forms of plastic have been in existence since the late 1800s and early 1900s. Bakelite was created in 1909, Rayon in 1910, and Alexander Parkes exhibited his man-made material called Parkesine, now called celluloid, in 1862. The inventor of Bakelite, Dr. Leo Hendrik Baekeland, coined the term "plastic" to generalize these man-made materials as they were easily moldable into many shapes[63]. The plastics industry has flourished since the end of WWI and now produces a seemingly infinite array of synthetic materials useful for nearly any application.

Plastic is one of the most utilized materials; it is used in food packaging, clothing, machinery, technology, and has inherent chemical properties that can be useful for some aspects of public art. The same chemical properties may also make it a poor choice for some public art use. To determine the best role for plastic within an artwork design, it is helpful to understand the basic structure and chemistry of the material.

Basic Chemistry of Plastic

A polymer[64] can be synthetic, such as plastic and synthetic rubber, or organic, such as animal horn, deoxyribonucleic acid (DNA), and hair. A synthetic polymer can be defined as "a useful chemical made of many repeating units."[65] Each unit, called a monomer, is comprised of a group of atoms that define the properties of the material, and when repeated multiple times and chemically bonded, create a polymer.

There are two general categories of plastic into which all varieties of synthetic polymers fall; thermoplastic and thermoset.

- Thermoplastic polymers are one dimensional, linear chains of monomers, similar in shape to a string of pearls, and are able to be melted and reshaped. Examples of thermoplastics are polyethylene bottles (e.g. water and carbonated soft drink bottles), acrylic (Plexiglas), and polyvinyl chloride (e.g. plumbing and home siding). These polymers constitute the majority of plastics in production.

- Thermoset polymers are two or three-dimensional monomer groups that are not able to be melted and reshaped. These polymers are usually comprised of two or more liquid components that when mixed together undergo a curing process. Examples of thermoset plastics are epoxy resins, polyurethanes, and unsaturated polyesters (e.g. bathtubs).

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[63] American Chemistry Council, Inc. *Plastics 101: life cycle of a plastic*. Learning Center: Plastics Division. <www.americanchemistry.com>
[64] "Polymer" n. Any of numerous natural and synthetic compounds of usually high molecular weight consisting of up to millions of repeated linked units, each a relatively light and simple molecule. *The American Heritage Dictionary of English Language*. 3rd ed. 1992.
[65] American Chemistry Council, Inc. *Plastics 101: the basics – polymer definition and properties*. Learning Center: Plastics Division. <www.americanchemistry.com>

Characteristics of Plastic

Plastic engineering occurs at the atomic level and therefore can be altered in a way that allows for nearly unlimited variability. A plastic that is composed of only one type of repeating monomer is called a homopolymer. By assembling dissimilar monomers into repeating units, the polymer becomes a copolymer. Manufacturers create copolymers with specific properties, often to be utilized with a special purpose, such as chemical resistance for hazardous chemical containers or high strength and heat resistance for automobile parts.

Though there are many variables and uses, most plastics have the following characteristics in common:

- Chemical resistance to hazardous and caustic materials. Though solvents may damage some plastics, some polymers can be engineered to withstand the most volatile solvents and chemicals.

- Insulation from electrical and thermal energy. Many plastics are non-conductive and can be used as covers over electrical hazards or as dielectric gaskets when isolating dissimilar metals. There are many polymers engineered to protect against heat, while other polymers are engineered to retain heat, such as fleece clothing and polypropylene undergarments.

- Light in weight and able to be engineered to maximize strength.

- Able to be manufactured in many different types of materials and products, e.g. surface coatings, fibers, large panels, foams of varying density.

- Deterioration is continuous and occurs at a molecular level throughout the material. Therefore, most plastics experience degradation or alteration of key physical properties *(see sub-heading Deterioration of Plastics in the following section titled Environmental Concerns).*

Production Methods

There are four primary methods used in producing and processing plastics[66].

- Extrusion – Plastic pellets or granules are placed into a hopper and heated. The hopper forces the fused and malleable material through a die that shapes the material and is allowed to air cool. Acrylic rods, plastic bags, and film are some examples of products made through this process.

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[66] American Chemistry Council, Inc. *Plastics 101: life cycle of a plastic - Production Processes*. Learning Center: Plastics Division. <www.americanchemistry.com>

- Injection Molding – Similar to extrusion, plastic pellets or granules are placed in a hopper, heated, and extruded. Instead of the material being pushed out to air cool, the near fluid plastic is pushed into a mold that shapes the part. Once the part is sufficiently cooled, the mold is opened and the part is removed. Solid parts and pieces like buttons, pen caps, and model car kits are examples of products created through this process.

- Blow Molding – This process combines extrusion and injection molding processes with air pressure to shape thin wall products. Plastic pellets are placed in a hopper, heated, and extruded as a thin tube into a mold. Compressed air is forced into the mold which compresses the near liquid material into the walls of the mold. Water and carbonated soft drink bottles, and milk jugs are examples of products made through this process.

- Rotational Molding – Plastic pellets can be placed into a mold and heated to a liquid state, or two or three-part resin systems are mixed and poured into a mold. The mold is turned on one or two separate axes to evenly spread the material until it hardens. This process commonly produces hollow objects, but is also useful for solid objects. It is commonly utilized for asymmetrical objects like toys, kayak bodies, and resin cast sculpture.

Environmental Considerations

Plastic engineering has made tremendous advances over the past 50 years. Many polymers are now created to withstand prolonged exposure to harsh chemicals and solvents; however, there are environmental limits to the appropriateness of plastic when used in public artwork.

Durability

Industrially produced plastic objects are classified within the plastics industry as durable or non-durable[67]. Products with a useful life of over three years are considered durable, e.g. appliances, plumbing materials, home siding. However, due to environmental considerations, many products are being engineered with a useful life of less than three years, which are considered non-durable, e.g. water and soda bottles, trash bags, food delivery systems. Essentially, any plastic that is created for short term use is likely engineered to be non-durable. Artists wishing to use found objects in their artwork should avoid using non-durable plastic objects as they are not designed to have an adequate lifespan for public artwork.

Artwork vs. Functional Protective Components

When considering the use of plastic in exterior environments, a distinction must made between what is the artwork, and what is a functional component designed to protect the artwork. For instance, a

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[67] American Chemistry Council, Inc. *Plastics 101: life cycle of a plastic - Production Processes*. Learning Center: Plastics Division. <www.americanchemistry.com>

cast acrylic relief would be considered the artwork, but a protective cover of polycarbonate over the relief would be considered a functional component designed to protect the artwork. ArtsWA requires functional components be designed to be easily replaceable, both in terms of how they are attached to the artwork and the ability to purchase a comparable replacement through a third party vendor.

This distinction is important as ArtsWA does not consider plastic artwork to be acceptable in exterior environments. However, ArtsWA does consider functional components made of plastic that are designed to protect the artwork to be appropriate for some exterior artwork, e.g. nylon or Teflon dielectric gaskets to isolate dissimilar materials, polycarbonate sheet to protect glass or neon artwork from vandalism, polyurethane and epoxy adhesives for joining materials, polyethylene vapor barriers for some terrazzo and concrete flooring systems, or acrylic latex paint to color and protect wood.

Deterioration of Plastics

Plastics continuously deteriorate[68]. The rate of deterioration depends on the chemical engineering of the polymer with respect to environmental forces to which the material is subjected. Some common deteriorating forces are:

- Radiation – Sunlight, fluorescent light, and other high intensity light expose the plastic to damaging UV radiation.

- Temperature – Heat tends to accelerate deterioration of many plastics and may increase the effects of Relative Humidity (RH) in the surrounding area. Cold temperatures will cause most plastics to become very brittle and more susceptible to breakage. Plastics are sensitive to temperature changes and may significantly expand and contract.

- Relative Humidity – Increased water vapor as a result of high RH may cause some plastics to decompose prematurely[69]. Some plastics, e.g. cellulose esters, nylon, polyester, may absorb the added moisture in the air and cause the material to expand[70]. Excessive moisture may activate some pollutants thereby accelerating the deterioration of the material.

- Pollutants – Atmospheric pollutants may accelerate the degradation of the material.

- Physical Stress – As a plastic object ages, its chemical properties change. Often the material becomes brittle or discolors. Expansion and contraction from temperature fluctuations become increasingly stressful to the material, eventually leading to significant damage or failure. Brittle materials are less likely to withstand public interaction.

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[68] Canadian Conservation Institute. CCI Notes 15/1: Care of Objects Made of Rubber and Plastic, pg. 1
[69] Ibid., pg. 4.
[70] Ibid., pg. 2.

- Structural Failure – Plastic sculpture often requires component parts to be mechanically attached with adhesives or bolts. The adhesives are often stronger than the surrounding material. As plastic ages, the material along the joints becomes brittle and the plastic may crack or rupture.

- Plastic may warp as gravitational forces continuously pull on the material. Adhesives and material around bolts are most susceptible to failure from this type of stress.

Interior Placement

Plastic artwork is acceptable in interior environments where direct sunlight and radiation from UV light (i.e. fluorescent lamps, natural light) is restricted, and where the type of plastic being used is appropriate for publicly accessible objects.

Exterior Placement

ArtsWA does not consider plastic artwork to be acceptable in exterior environments due to the environmental factors that accelerate the deterioration of the material.

Fabrication and Design Considerations

Cast Plastic Artwork

Some artists cast objects in plastic by mixing two or three part resin systems and pouring into molds. ArtsWA recommends using processes that utilize one of the four main production methods for producing cast resin objects *(see the section titled Production Methods under the main heading Plastic)*. Some fabrication suggestions for creating cast resin objects are:

- Use a vacuum chamber to remove air bubbles from the resin while it is still in a liquid state to reduce casting flaws, i.e. air pockets[71]. Voids remaining in the casting may be a place where deteriorating agents collect and may weaken the structural integrity of the material.

- Depending on the object being cast and the intricacy of the mold, the specific weight and viscosity of the resin system may not completely fill voids if relying on gravitational force alone. Therefore, additional forces such as compressed air from blow molding, hydraulics as used in injection molding, or centrifugal forces as used in rotational molding will aid in forcing the resin into the voids of the mold and yield a higher quality casting.

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[71] It is easier to pressure vacuum the bubbles out of the liquid components prior to mixing them. However, it is likely that more air bubbles will be introduced during the mixing phase. If the material allows you enough working time after mixing, then it may be possible to pressure vacuum the air bubbles out of the mixture. ArtsWA recommends consulting with the manufacturer or sales representative for process suggestions to achieve the best results.

- Some artists prefer to paint the resin into the mold as it solidifies creating thin walls of resin during the application of each coating. After the initial wall thickness is established, ArtsWA recommends using glass fiber, hemp, or other moisture excluding reinforcement material in the application of the secondary, or backup coats. Reinforcement materials increase the overall strength of the plastic.

Dielectric Gaskets to Separate Dissimilar Materials

Dielectric gaskets isolate materials from electrical conductivity. ArtsWA requires the use of dielectric gaskets when joining dissimilar metals to reduce the effects of galvanic corrosion on exterior artwork. Not all dielectric materials are plastic; however, many varieties of plastic are commonly used for dielectric purposes. Dielectric materials are required to be replaceable by easily removing the connected components for maintenance purposes.

Expansion and Contraction

Most plastic will expand and contract in all directions. Each type of plastic has specific expansion and contraction properties that depend on the formulation of the polymer. Expansion and contraction rates of a material are directly related to the amount of temperature fluctuation within and around the material. Radiation from direct sunlight can heat the material quickly and cause it to expand at nearly the same rate the surface temperature increases. For instance, a sheet of ¾ inch thick Sintra™, a PVC material, is calculated to expand .05mm per foot/per degree F increase. Over a 20 foot span, a 5°F rise in temperature would cause the material to linearly expand approximately 6mm (roughly ¼ inch). Compensating for a minimum of 10°F +/- change in temperature for most interior spaces is required. A 10°F rise in temperature would cause Sintra™ to linearly expand approximately ½" over a 20 foot span.

Plastic will buckle, crack, and occasionally rupture if the forces from expansion and contraction are greater than the strength of the material. As the material ages, it often becomes increasingly brittle and prone to cracking and rupturing. Some fabrication and design considerations for expansion and contraction are as follows:

- Bolt holes should be drilled wide enough to compensate for expansion and contraction by allowing the plastic to move in all directions around the mounting hardware.

- Glued joints experience stress in varying degrees and directions. When joining plastic to dissimilar materials, i.e. metal, wood, or a different type of plastic, ArtsWA recommends using bolting or framing installation rather than gluing methods.

- Framing plastic into a design element by encapsulating the material within channeling should allow space around the material for expansion and contraction.

Protective Covers

Clear acrylic covers, i.e. Plexiglas™, are appropriate for protecting interior artwork and should be a minimum wall thickness of $\frac{3}{16}$ inch for spans less than 36 inches in the longest direction. Acrylic

sheet covering spans greater than 36 inches in the longest direction should have ¼ inch minimum wall thickness.

If an exterior artwork needs a protective cover, ArtsWA requires the use of polycarbonate rather than acrylic sheet as the durability of polycarbonate is superior to most other clear plastic protective covers. The wall thickness will be considered on a case-by-case basis depending on the span the cover will need to protect. A space of ½ inch between the artwork and the protective cover is necessary to adequately protect fragile artwork from thrown objects by allowing the polycarbonate to flex during impact.

Coatings for Plastic

Coatings over plastic substrates, i.e. acrylic paint over non-woven plastic, are only acceptable in interior artworks on a case-by-case basis.

Coatings for Other Materials

There are many coatings made of plastic designed to protect the surface of other materials. For instance, polyurethane based products are popular spray or brush coatings for wood furniture, and are also available for protecting metals. Plastic coatings, e.g. acrylics, acrylic urethanes, polyesters, nitro cellulose, epoxies, are commonly referred to as clear coats or lacquers *(for additional information, see Metal Sealants and Protective Coatings on pg. 14, or Wood: Glues and Adhesives on pg.22, and Water Repellants on pg. 24).*

The use of clear coats will be acceptable to ArtsWA on a case-by-case basis. If a clear coat must be utilized to protect a component of public art, ArtsWA requires using thermoplastic varieties, e.g. Incralac™, Everbrite™, G.J. Nikolas and Sons™ exterior lacquers, as thermoplastics are easier to remove and repair.

Graffiti Removal

Graffiti on plastic artwork can be difficult to remove or repair. Solvents used for removing paint and ink can damage the plastic. Scratching and cuts into the plastic material are not easily removed by mechanical means and generally a fill material is not successful in disguising damage. Placing the artwork in a location that is either well monitored or inaccessible to the public is the most effective protection against graffiti and scratchiti[72].

Adhesives for Joining Plastic

There are many adhesives that are effective for joining plastic components and not surprisingly, most of these adhesives are synthetic polymers. Since plastic is a vast and varied array of materials, there is not one adhesive that works best for all plastic. Therefore, when joining plastic to any

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[72] Scratchiti – "A form of graffiti in which markings are etched into hard surfaces." Urban Dictionary. <http://www.urbandictionary.com/define.php?term=scratchiti>

material, be sure the adhesive works for both materials and will not deteriorate the plastic over time[73]. Cyano-acrylate adhesives, e.g. Superglue™, Krazyglue™, are typically strong and long-lasting. The downside to these adhesives is that they are not easily reversible and will often withstand a greater amount of stress than the surrounding material, resulting in the plastic cracking or rupturing before the glue joint fails. Epoxy-based adhesives are also commonly used for joining plastic, though epoxies are not reversible and tend to become brittle over time.

Summary of ArtsWA Requirements

- ArtsWA requires functional components be designed to be easily replaceable, both in terms of how they are attached to the artwork and the ability to purchase a comparable replacement through a vendor. (pg. 52)

- Plastic artwork is acceptable in interior environments where direct sunlight and radiation from UV light (i.e. fluorescent lamps) is restricted, and where the type of plastic being used is appropriate for publicly accessible objects. (pg. 54)

- ArtsWA does not consider plastic artwork to be acceptable in exterior environments due to the environmental factors that accelerate the deterioration of the material.(pg. 54)

    - ArtsWA does consider functional components made of plastic that are designed to protect the artwork to be appropriate for some exterior artwork. (see Artwork vs. Functional Protective Components on pg. 52 for information)

- ArtsWA requires the use of dielectric gaskets when joining dissimilar metals to reduce the effects of galvanic corrosion on exterior artwork. (pg. 55)

    - Dielectric materials are required to be easily replaceable by removing the connected components for maintenance purposes. (pg. 55)

- Compensating for a minimum of +/-10°F change in temperature for most interior spaces is required to account for expansion and contraction of the material. (pg. 55)

- If an exterior artwork needs a protective cover, ArtsWA requires the use of polycarbonate rather than acrylic. (pg. 55)

- Coatings over plastic substrates, i.e. acrylic paint over non-woven plastic, are only acceptable in interior artworks on a case-by-case basis. (pg. 56)

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[73] ArtsWA strongly recommends consulting with the manufacturer or sales representative to determine the appropriate adhesive to use.

- If a clear coat must be utilized to protect a component of public art, ArtsWA requires using thermoplastic varieties. The use of clear coats will be acceptable to ArtsWA on a case-by-case basis. (pg. 56)

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