MATERIALS COLLECTION PRIMER

INTRODUCTION

Generative relationships between the experiments and concerns of contemporary design practice and innovations in materials science and engineering are driving the development of radically new material forms, properties, and processes. New demands for thermal, mechanical, and aesthetic performance, closed-loop cycling, resource and energy efficiency, and equitable production relations influence material industries and become conceptual drivers of contemporary work. These factors radically alter design and construction processes, as well as exert impacts from nanoscopic to global scales.

This primer is an introduction for students investigating material topics in design and describes the organizational structure of the Materials Collection at the Harvard University Graduate School of Design (GSD). Basic material terms and definitions provide a point of departure for students seeking more advanced resources. The GSD Materials Collection taxonomy was developed by drawing terminology from sources of design, materials science, and the construction industry. This taxonomy provided the organizational structure to the primer contents – Composition, Form, Properties, and Processes.

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Processes classifies the manufacturing methods used to make the material. Processes can deform the original substance, be additive, or subtractive. They include: casting, molding, machining, deforming, surfacing, joining, and rapid prototyping.
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The Frances Loeb Design Library provides several resources to support research of materials – the Materials Collection’s online database, which provides access to the on-site collection, the Materials Collection Primer, written as an introduction for students investigating materials topics in design, a subscription to Materials ConneXion, a Materials Collection Research Guide with several non-library material resources, and books focused on materials for research and practice – GSD faculty material research, material catalogs, materials specific to architectural innovations, exploration of materials in architecture and landscape architecture, and fabrication and manufacturing of materials for architecture and landscape.

Search the Materials Collection by using the online catalog (http://materials.gsd.harvard.edu/materials)
Harvard University ID required

Learn more about materials at Harvard and beyond with our Research Guide (http://guides.library.harvard.edu/gsd/materials)

Visit Frances Loeb Library, Special Collections, lower level, L12

The Harvard Graduate School of Design’s Materials Collection emerged in 2004 as a manifestation of the School’s evolving engagement in materials. It is a collection of material samples ranging from innovative new materials to those found everyday in the built environment. The collection is one for designers, different than those for material scientists, yet it is not a typical material sample library found at a design firm that is organized by project use or application. The Materials Collection places emphasis on material composition and functional traits of the material samples, encouraging users to rethink conventional applications and promote material experimentation in design practice. These leading concepts are realized in the physical arrangement of the collection and data entry points of the online catalog.

The GSD Materials Collection is a collection of objects which visitors are encouraged to handle and study. The Materials Collection has been developed according to faculty and student research agendas, and has been focused in these areas:

- **Material Ecology**
  Materials that demonstrate the externalities and impacts of material production and use both within and outside of designed installation.

- **Fabrication Materials**
  Materials that can be used in the GSD Fabrication Lab, as well as alternatives to those currently in use.

- **Bio-based Materials**
  Materials derived from plant and animal based renewable resources and surplus stocks.

- **Recycled Materials**
  Materials made from recycled material stocks including polymers, metals, and ceramics.

- **Urban Scale Materials**
  Materials implemented and affecting climatic, aesthetic, and hydrological conditions at an urban scale – particularly ones contributing to or mediating urban heat, such as roofing, surfacing, infrastructural.

- **Materials in Use**
  Materials used in contemporary design projects.
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<td>Derived from or produced by organisms associated with the biological kingdom Plantae</td>
<td>Synthetic or semi-synthetic, organic polymers, whose polymer chains are linear and not cross-linked</td>
<td>Ferrous pure metals and alloys, metals based on iron</td>
<td>Inorganic, crystalline solids, and chemical compounds possessing a characteristic crystalline structure and chemical composition, sometimes with restricted variations</td>
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<td>Derived from or produced by organisms associated with the biological kingdom Fungi</td>
<td>Synthetic or semi-synthetic, organic polymers, whose polymer chains are networked and loosely cross-linked</td>
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<td>Inorganic, non-crystalline solids that are silica-based</td>
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The combination of cellulose, a crystalline polymer, and hemicelluloses, an amorphous polymer, make wood strong in tension. Lignin, another organic polymer, provides resistance to compression and makes wood an excellent fuel.

**TYPICAL MATERIALS**

**PLANT**

*Derived from or produced by organisms associated with the biological kingdom Plantae*

**PHYSICAL ATTRIBUTES**

*Derived from or produced by organisms associated with the biological kingdom Plantae*

**BIOCOMPOSITES**

*Biologically derived composites of polymers and fibers that contain mostly organic and sometimes inorganic compounds sourced from living organisms and/or formed by biochemical processes*

**APPLICATIONS**

Panel products, structural timber beam, coasters, instruments, packaging, utensils, tool handles, furniture, cladding, flooring, chop, dimensional lumber, structural timber, glue laminated timber (glulam), plywood, structural veneer lumber, blockboard, oriented strand board (OSB), Particleboard, fiberboard, insulating boards, plasterboard, cement fiberboard, structures, facades, furniture, insulating materials, sheathing paper, rope, geotextiles, flooring, filters, carpet, mattresses, wall coverings, fiber, textiles, cellophane, bioplastics, finishes, mulch, paper, rope, geotextiles, flooring, filters, carpet, mattresses, wall coverings, fiber, textiles, cellophane, bioplastics, finishes, mulch, paper, furniture, roofings, surfaces, natural dyes

**TERMINOLOGY**

Timber is wood in standing trees with the potential for lumber. Lumber is sawn or processed wood that has been sawn to specified dimensions and dried. Veneer refers to a thin layer of wood produced by slicing solid stock along the grain of the wood. Manufactured wood products: Glued structural members have an assembly of layers of wood glued under pressure. However, unlike plywood, the layers are thick and the product is usually only used for weight-bearing members. Examples are: glue laminated timbers (Glulam), structural composite lumber (SCL), laminated veneer lumber (LVL), parallel strand lumber (PSL), laminated strand lumber (LSL), and oriented strand lumber (OSL). Engineered wood includes glued structural members as well as finger-jointed lumber and I-Joists. Plywood is assembled of at least three veneer layers laid cross grain and glued together under pressure. Construction and industrial plywood is usually made from domestic softwood. Hardwood and decorative plywood is made from hardwoods. Composite panels extend or modify natural wood sizes or properties. Particleboard is assembled from particles of waste wood with an adhesive, cement, or gypsum binder. Waferboard and oriented strand board (OSB) are made from green roundwood. Fiber-based panels such as hardboard, medium density fiberboard (MDF) and insulation board are assembled from small wood fibers with binders in a dry process or without in a wet process. Heartwood is from the central core of a mature tree and is typically both stronger and darker in color than sapwood. Sapwood is from the outer growth rings on a tree and is usually lighter in color than heartwood. Greenwood is freshly cut, unseasoned (undried) wood. Grain is often used to describe a fine or coarse grain in reference to the annual rings but can also mean the direction of fibers on sawn lumber—spiral grain, straight grain or curly grain.

**Figure** is any distinctive appearance on a wood surface resulting from structure, irregular coloration, or abnormality. Knots in wood are the expression of where a tree limb grew from the trunk. These are often

**PROCESSING**

Debarked, chipped, plainsawn, quartersawn, rough sawn, flat sawn, rift sawn, sanded, burned, kiln dried, air dried, dip coated, impregnation
harder than the surrounding wood and affect the mechanical properties of the wood. Wood free of knots is called “clear.” The homogeneity of clear, straight-grained wood makes it the easiest wood to work.

**ANIMAL**

Derived from or produced by organisms associated with the biological kingdom Animalia

**TYPES**
- **Hair**: wool, cashmere (cashmere goats), pashmina (changthangi goat), mohair (angora goat), angora (rabbit hair), camel hair, alpaca (llama), horsehair, cow hair, human hair, yak fiber, guanaco fiber, chiengora (dog hair), possum fiber, qiviut (wool of the musk ox), vicuña wool. **Skin, tissue**: sinew (tendon), leather, hide, rawhide, catgut, parchment, vellum, sheepskin, pelt, fur, alligator, crocodile, snake, fish, cow intestine
- **Biomineralization**: opal, egg shells, bone, horn/ivory, seashells, pearl, hooves. **Other**: fertilizer/guano, sea sponges, byssus fiber/sea, spider silk, beeswax, milk casein, natural dyes

**PROCESSING**
- Salted, cured, brined, dried, tanned, soaked, dehairing-lime treatment, defleshed, delimed, plumped, split, shaved, setting out, nourishing, beat, staked, sleeked, ironed, plated, embossed, dyed, glued, sewn, shaped, calendered, spun, reeled, thrown, gimped, texturized, woven, knit, felted, hexagonal stitch, bonding, flared, bleached, treated

**APPLICATIONS**
- Plaster additives, upholstery, paper, soil amendments, insulation, textiles, surface coverings, rope/cord, wax, natural dyes

**FUNGI**

Derived from or produced by organisms associated with the biological kingdom Fungi

**TYPES**
- **Saprophytic** (a fungus that lives on dead organic matter), **mycorrhizal** (fungi that form a symbiotic relationship with a tree or other plant), **endophytic/parasitic** (a fungi that lives on another living species, deriving its sustenance to the detriment of its host).

**APPLICATIONS**
- Packaging, insulation, mycoremediation, pest control, natural dyes

**TERMINOLOGY**

*Mycelium* is a fungal network of threadlike cells. “Myceliated” describes the condition where the mycelium has colonized or infused through a substrate. **Mycology** is the study of fungi. **Hyphae** are individual fungal cells. A **substrate** such as straw, sawdust, compost, soil or other organic matter on which mushroom mycelium will grow.
POLYMERS

Petroleum-derived, human-made, non-renewable materials comprised of long, repeating, molecular chains whose central atom is almost always carbon.

PHYSICAL ATTRIBUTES
The chainlike molecules of synthesized polymers form both amorphous and crystalline arrays that allow easy formation into complex shapes, low in heat conductance, and low softening temperatures.

PROCESSING
Injection molding, sandwich injection molding, extrusion, calendaring, compression molding, casting, foaming, direct digital manufacturing, pultrusion, blow molding, rotational molding, thermoforming, gas-injection molding.

APPLICATIONS
Adhesives, carpets, gaskets and weatherstripping, laminates, coatings, pneumatic structures, roofing materials, vapor barriers and weatherstripping, liners (water features and landfill sites), flooring, sinks, glazing, decorative laminates, seals, sheet liners (water features and landfill sites), flooring.

TERMINOLOGY
Fillers are added to improve the workability, weight, and volume expansion characteristics of a material in order to reduce the material costs of the plastic. Can include kaolin, chalk, glass beads and talc. Reinforcement materials are used to improve the mechanical properties of plastics with fibers and textiles. Stabilizers are additives used to retard the degeneration of polymers caused by heat or photo-oxidation. Fire retardants inhibit or prevent combustion in plastics. They are added during polymerization. Foaming agents are additives that cause plastics to foam and produce a lighter weight and more insulative product. Coupling agents are used to facilitate the mixing of polymers or polymers and other materials that are incompatible. Colorants are insoluble pigments or soluble dyes used to color the plastic. Polymerization is the process of joining ethylene end to end to produce the long chain macromolecules. Plasticizers are incorporated into plastics to increase their flexibility. The addition of the plasticizer separates the molecular chains, decreasing their mutual attraction. Commodity plastics (versus engineering plastics) are commonly used in low physical properties and are commonly used in the production of everyday low-cost products. Includes vinyls, polylefins, and styrenes. Engineering plastics (versus commodity plastics) have superior physical, chemical, and thermal characteristics and are used in demanding environments. They include acetal, acryls, polyamides, and polycarbonates. Resins are prepared by polymerization and used with fillers, stabilizers and other components to form plastics.

THERMOPLASTIC

Polyolefins make up half of total global polymer production. It is low cost and nontoxic. Examples of materials in use include milkjugs, plasticcorks, thin walled plastic packaging, toys, cups. • Polyethylene (PE), High Density Polyethylene (HDPE/PE-HD), Trade name: Tyvek, Low Density Polyethylene (LDPE/PE-LD). Polypropylene (PP), Expanded Polypropylene (EPP), Ethylene Vinyl Acetate (EVA/EVAC), Lonomer resin Styrenes are easy to process and are low cost. They are categorized as general purpose (GPPS)–used for disposable food packaging, CD cases, and lighting diffusers—expanded (EPS)—used for electronics packaging foam, helmets, and thermal insulation—and high impact (HIPS)—used for product housing and toys. Trade name(s): EPS, Styrofoam. • Polystyrene (PS), Acrylonitrile Butadiene Styrene (ABS), Styrene acrylonitrile (SAN), Styrene butadiene styrene (SBS), Styrene ethylene butylene styrene (SEBS) Vinyls have a glossy appearance and are low cost. Half of the global production of vinyl is for the construction industry. They contain chlorine and dioxins that have been shown to be toxic. Examples of materials in use include records, extruded window frames, doorframes, guttering, credit cards, medical tubing, as a coating for upholstery and wallpaper, and electrically insulating products. • Polyvinyl chloride (PVC), Polyvinyl alcohol (PVOH), Polyvinyl butyral (PVB) Acrylics are used for applications where clarity, impact resistance and gloss are needed. They have a moderate cost and displays edge glow. Examples of materials in use include Corian counters, sheets for laser cutting, and control panels. • Polymethyl methacrylate (PMMA, Acrylic Glass), Polyacrylate (Acrylic) Polycarbonate is the toughest clear plastic but is prone to chemical and UV degradation. It is of moderate cost. Examples of materials in use include water bottles, spectacle lenses, police riot shields, beakers and CDs and DVDs. • Polycarbonate (PC), Trade name: Lexan Thermoplastic Polyesters have a high dimensional stability and are resistant to chemicals. Examples of materials in use include drink bottles, films for glass or plastic, light bulb housing, and mobile phone parts. • Polystyrene terphethalate (Trevira, PET, PETG, PETE), Polybutylene Terphethalate (PBT), Polycyclohexylene dimethylene terphethalate (PCT), Liquid crystal polymer (LCP), Thermoplastic polyester elastomer (TPC-ET) Polyamides are commonly known as nylon and are used in a wide range of applications. Examples of materials in use include bearings, electrical equipment housing, sports equipment, textiles, and rapid prototyping. • Polyamide (PA), Nylons, Aromatic polyamides. Trade name:
Kevlar. Fluropolymers are well suited to extreme environments. • Polytetrafluoroethylene (PTFE), Trade name: Teflon, Ethylene tetrafluoroethylene (ETFE), Fluorinated ethylene propylene (FEP)  

Thermoplastic Rubber Compounds combine the performance of rubber with the processing advantages of thermoplastics. Examples of materials in use include keypads, sportswear, and hot water tubing. • Melt-processed rubber (MPR), Thermoplastic vulcanizate (ETPV)  

Other Thermoplastics Acrylonitrile Styrene Acrylate (ASA), Trade name(s): Luran S, Bitumin, Polyamide (PI), Polycrylonitrile (PAN), Polyvinyl acetate (PVA/PVAC), Paraffin, Thermoplastic polyurethane (TPU, PU), Acetal/ Polyoxymethylene/polyacetal resin (POM)  

(4) (4)  

THERMOSET B2  

Synthetic or semi-synthetic, organic polymers, whose polymer chains have been irreversibly, densely cross-linked • irreversibly cures, cure induced by heat, chemical, or suitable irradiation  

TYPES  

Formaldehyde condensation resins have a hard and glossy finish and operate across a wide temperature range. Examples of materials in use include electrical housing, tableware, adhesives for laminating plywood, and billiard balls. • Phenol formaldehyde resin (PF), Trade name: Bakelite, Urea formaldehyde (UF), Melamine-formaldehyde/ melamine-formaldehyde resin (MF) (melamine), Phenolics: phenol-formaldehyde resins. Phenolic resin, Melamine phenol formaldehyde resin (MPF)  

Polymers and composites Polyester fiber (taffeta), Polyester resin  

Vinyl esters and composites are popular for laminating materials. • Vinyl ester  

Epoxyies and composites are applied as coatings and adhesives. Applications include laminating, casting and structural adhesives. • Polypeoxide resin (EP) (Epoxy resin)  

Polyurethanes are versatile and used as a solid cast material, foam, adhesive and liquid coating. Examples of materials in use include spray foam, upholstery and mattress foam, sports equipment, Lyrcra, Spanex, and as a bonding agent for wood. • Polyurethane/polyurethane resin (PUR)  

Other Thermosets Unsaturated polyester (UP), Aramid phenolic Glycol, Glass-reinforced plastics (GRP) (fiberglass), Polymides, Renewable polyethylene Copolymers  

ELASTOMER B3  

Synthetic or semi-synthetic, organic polymers, whose polymer chains are networked and loosely cross-linked • polymer with viscoelasticity, colloquially “elasticity”  

TYPES  

Silicones (SI) are low strength but versatile. They are used as adhesives, gels, rubbers, and rigid plastics. They have electrical resistance and high heat stability. Examples of materials in use include weatherstripping, medical equipment, lubricant, and kitchenware. • Silicone, Silicone resins  

Synthetic Rubbers are used in place of natural rubbers and have shape memory. Examples of materials in use include gaskets, seals, and wetsuits. • Isoprene rubber (IR), Synthetic version of natural rubber (Cured rubber, Vulcanized rubber), Chloroprene rubber (CR). Trade name: Neoprene, Ethylene propylene rubbers (EPM and EPDM), most widely used elastomer in construction, Trade names: Nordel, Buna, Dutral, Kelan, Vistalon, Butyl rubber (IIR), Butadiene rubber (BR), Acrylonitrile butadiene rubber (ABR), Styrene butadiene rubber (SBR/ GR-S)  

Other Elastomers Modified bitumen, Elastane (Spandex, Lyrcra), Polyurethane gel, Polyurethane flexible foam, Styrene-butadiene Styrene (SBS), Thermoplastic Elastomers (TPE)
METALS

Pure metallic elements, compounds, and alloys characterized by metallic bonds whose atoms readily lose electrons to form positive ions (cations)

PHYSICAL ATTRIBUTES
Metals are opaque, lustrous, strong, and comparatively heavy. They can be shaped and alloyed and are good conductors of heat and electricity. These properties follow from the close-packed crystal structure of the metallic bond.

PROCESSING
Annealing, anodizing, casting, drawing, electrochemical deposition, extrusion, forging, injection-molding, pressing, tempering, thermofusing/thermal welding, welding (oxy-acetylene welding, arc welding, gas metal welding, resistance welding), rolling (hot rolling, cold-rolling), stamping, thermal-arc spraying, electroplating, vapor deposition, sintering, welding, quench hardening, bending, cold forming, machining, riveting, soldering and brazing, laser sintering, panel heating, spinning, superforming, swaging, roll forming, electroforming, press braking, photochemical machining, laser cutting, electrical discharge machining, punching and blanking, water jet cutting, die cutting, powder coating, galvanizing, grinding, sanding, polishing, electropolishing, sandblasting, acid etching, CNC engraving or milling, foil blocking and embossing

APPLICATIONS
Structural system, cladding, roofing, coating, reinforcement in concrete, street furniture, drainage grates, railings, fasteners, pipes, guttering

TERMINOLOGY
Alloys are metals combined with other metal or non-metals. Bronze, steel, and brass are examples of alloys. Corrosion, or rust, is an irreversible reaction as a result of contact with oxygen. Cast iron and steel are especially vulnerable. Some metals create a passivation layer, a superficial corrosion that protects the core material. Galvanization (or galvanisation) is the process of applying a protective zinc coating to steel or iron in order to prevent rusting. Magnetism is a response to an applied magnetic field. Permanent magnets have magnetic fields caused by ferromagnetism, the strongest and most familiar type of magnetism. Non-magnetic substances include copper, aluminum, gases, and plastic. A material may exhibit more than one form of magnetism depending on its temperature. Magnetoresistive metals deform when exposed to a magnetic field. Magnetorheological fluid suspends micron-sized particles that harden in response to a magnetic field and soften when the field is removed. Metallurgy covers all the stages in the transformation of ore into metal. Muntz metal/alpha-beta brass: a form of brass with a high zinc content. Shape memory metal is a metal that returns to its original shape after deformation by heating or cooling. Nickel titanium and nickel iron are common. Superalloys are alloys developed for use in gas-turbine engines that can operate at elevated temperatures.

FERROUS C1

ferrous pure metals and alloy. Metals based on iron.

TYPES
Iron is plentiful and relatively cheap. It is extracted as an oxide, smelted by heating, and poured into ingots of "pig iron", 95% pure iron. Cast iron is re-heated pig iron, which can be toughened to make ductile iron and malleable cast iron. Wrought iron is iron hammered under heat to improve tensile strength. Steel, an alloy of iron and other metals, is less brittle, easier to work, and stronger than cast iron. Mild steel and medium carbon steel are commonly used for structural applications, low carbon steel for wire and thin plating, and high carbon steel for machines and tools. Stainless steel is an alloy that becomes corrosion resistant with the addition of a thin layer of oxidized chromium. Types are austenitic, ferritic, and martensitic; available polished or unpolished. Weathering Steel is a steel alloy containing copper. The iron oxide rust does not flake off when in contact with air. The patina varies with exposure, aspect and climate. COR-TEN is an example.

NON-FERROUS C2
Non-Ferrous pure metals and alloy. Metals with little or no iron content.

TYPES
Zinc forms a dull grey carbonate coating that makes it resistant to corrosion and weather. Zinc is also used as a coating for galvanized steel. Aluminum is the most widely used non-ferrous metal. It is light, strong, rust-resistant and easily worked. It is energy intensive to produce, but can be easily recycled. It is extracted from bauxite ore. Lead is corrosion resistant, malleable, resistant to acids, but toxic. Copper is an excellent conductor and relatively non-toxic. It weathers to a green patina, verdigris. Tin is a soft metal that forms a self-protecting oxide layer making it resistant to corrosion. Brass is an alloy of copper and zinc. It is easily machinable and corrosion resistant. Bronze is an alloy of copper and tin. Types include gun metal, bell metal, and phosphor bronze. Titanium is lightweight, very strong, corrosion resistant, and expensive. It is used in many alloys. Chromium (chrome) is very hard, does not corrode in air and can be polished to a mirror finish. It is often electroplated onto other metals. Nickel, silver, gold, mercury, and magnesium are other non-ferrous metals.
Steel structure and cables
MFO Park
Zurich, Switzerland, 2002
Burckhardt + Partner AG, Raderschall Landschaftsarchitekten AG

Repurposed steel shipping containers
Nomadic Museum
Santa Monica, CA, 2006
Shigeru Ban Architects

Stainless steel woven curtain
Princeton Parking Garage
Princeton, NJ, 2000
TEN Arquitectos

Articulating aluminum panels
Technorama Facade
The Swiss Science Center, Winterthur, Switzerland, 2002
Ned Kahn

Cast tombasil (white bronze) and copper panels
American Folk Art Museum
New York, NY, 2001
Tod Williams Billie Tsien Architects

MATERIALS IN USE
Inorganic, crystalline solids, and chemical compounds possessing a characteristic crystalline structure and chemical composition, sometimes with restricted variations

PHYSICAL ATTRIBUTES
Mineral materials have a high density, hardness, compressive strength, thermal conductivity and resistance to weathering due to their crystalline structure. The structure varies according to geologic origin.

GEOGENIC
Inorganic, crystalline solids and chemical compounds formed by geological processes

TYPES
A mineral is a naturally occurring substance solid at room temperature, representable by a chemical formula, and having an ordered atomic structure. Minerals are classed by their dominant chemistry into silicates (the most plentiful) and non-silicates: native elements, sulfides, halides, oxides and hydroxides, borates, sulfates, phosphates and carbonates and nitrates. Mineral examples include quartz, feldspar, mica, asbestos, tourmaline, aragonite, calcite, gypsum, phosphate minerals, borax, talc, kaolinite, salt, vermiculite, and malachite. Ores are minerals with a high concentration of a certain element, typically a metal. Gems are minerals with ornamental value distinguished from non-gems by their beauty, durability, and usually, rarity. Rock is a naturally occurring solid aggregate of one or more minerals or mineraloids. It is often termed natural rock or stone in the construction industry. Rocks like limestone are composed primarily of one mineral—calcite or aragonite. Other rocks can be defined by relative abundances of key minerals; a granite is defined by proportions of quartz, alkali feldspar, and plagioclase feldspar. Igneous rock is formed from liquid magma. Main constituents are feldspar, quartz, mica, augite, iron pyrites, and olivine. The three types are plutonic, hypabyssal, and extrusive/volcanic. Examples include obsidian, tuff, granite, trachyte, diorite, gabbro, basalt and pumice. Sedimentary rock is formed by the weathering, erosion, and deposition of particles of older rocks with pressure. It may contain plant or animal fossils. Main constituents are feldspar, quartz, and mica. Properties vary considerably depending on the pressure and temperature in their formation, and type of binder—usually silica or calcite. The two types of rock are clastic and chemical/precipitated. Examples include oolite/egg stone, brownstone, conglomerates, sandstones, siltstones, "flagstone," bluestone, limestone, dolomite, travertine, alabaster, Portland stone, and onyx. Metamorphic rock is formed from existing rocks though high pressure, high temperature, or chemical influences. Chemical composition and appearance vary considerably. The two types are orthorock and pararock. Examples include verd antique, asbestos, gneiss, serpentinite/serpentinite, slate/clayey shale, marble, soapstone/steatite, and quartzite. Disintegrated rocks and stones include the unconsolidated material above bedrock: boulders, cobble, sand, silt, clay, gravel, crushed gravel, pea gravel, bank-run gravel, crushed stone/rock, pebble, mineral aggregates, agricultural lime, and inorganic pigments consisting of colored earths and stone dust such as chalk, ochre, and umber. Earth in the topmost layer of the planet’s surface is composed of various ratios of disintegrated rock, clay, and decaying organic matter. These include: soil, loam, marl, clays (unfired), kaolin, topsoil, subsoil, sediment, bentonite, loess, chunam, and Fuller’s earth.

PROCESSING

APPLICATIONS
Minerals and Rock: cladding, floors, lintels, columns, roofs, paving, treads, curbs, worktops, sculpture, hearths, gabions, terrazzo, masonry grout, plaster, drainage, color additives, fertilizer, pavement base courses, concrete mixes, bituminous mixes, pervious pavements, landscape mulch, construction backfill Earth: cob, adobe/mud brick, piest rammed earth, cast earth, compressed earth block (CEB), Dutch brick, earthenbag construction, Superadobe, wattle and daub, earth ball finishing, peat walls, turf walls

TERMINOLOGY
Natural stone is from a specific geographical region used for decorative purposes in construction and sculpture. There are 5,000 types of worldwide. Examples are Laurentide Green Granite (Quebec) or Carrara Marble (Italy). This nomenclature is specific to the stone and differs from petrological classifications. Trade nomenclature can mislead as to a stone’s true properties. Dressed stone is stone worked to desired shape and smoothed on the face. A vein cut/cross cut is made to expose the stratified layers of a sedimentary deposit. A fleuri cut is a cross cut across sedimentary layers exposing a cloudlike or mottled appearance. Cut stone/dimension stone is wholly dressed and finished at a mill and ready to be set in the building in conformity to drawings and specifications. It is rarely used for structural members, but common as masonry veneer or...
Stone cladding. **Cast stone/reconstituted stone** is a hardened mix of concrete and fine stone aggregate surfaced to simulate natural stone. **Rubble masonry** is composed of collected fieldstones or stones as they have come from the quarry. **Ashlar masonry** is constructed of squared stones set in random or uniform courses. **Aggregates** are the product of natural processes (fluvial, glacial) or machine processes (crushed). They are typically a mix of different stone types. Graded aggregate contains a range of specific sizes, ungraded aggregate contains a broader range of sizes. **Lime** is calcium oxide or calcium hydroxide derived from limestone or chalk composed primarily of calcium carbonate. Burning (calcination) converts them into quicklime (calcium oxide, CaO) and, through the addition of water slaked lime or hydrated lime (calcium hydroxide, Ca(OH)2). When the term is encountered in an agricultural context, it refers to agricultural lime. Hydraulic lime will set underwater and non-hydraulic lime/ high calcium lime/ air lime cures by reaction with CO2 (carbonation). **Soil types** include grades and combinations of sand, clay, silt, loam, and hardpan. Classifications are different for geotechnical engineering and agriculture. In the U.S., engineers use the Unified Soil Classification System (USCS), and soil scientists use the U.S. Department of Agriculture's soil taxonomy. **Clay** consists of fine particles of feldspar and various impurities. **Loam** is a friable mixture of relatively even proportions of sand, silt and clay usually with some organic matter. **Silt** is composed of fine sand with fine decomposed organic material. The grains are microscopic and have little or no plasticity. **Sand** is composed of small particulates of rock ranging from ¼” in diameter or less. It is predominantly quartz with no binder. The grains are spherical or angular in shape. **Topsoil** is the fertile surface layer of soil as distinct from the subsoil. It contains much organic matter which makes for poor load sustaining properties. **Subsoil** is the layer beneath the topsoil. This is usually used for earthwork construction.

**ANTHROPOGENIC D2**

Inorganic, crystalline solids and chemical compounds manufactured by humans

**TYPES**

Nitrogen in manufactured fertilizers, potassium water glass/potassium silicate, synthetic inorganic pigments made from oxides of titanium, iron, chromium and zinc, silicone resins (part inorganic and part organic), manufactured potash, slag , expanded shale, clay and slate, and phosphogypsum (a by-product of potassium processing for fertilizer).

**MATERIALS IN USE**

- **Concave natural stone**
  - Weather Garden (Stone Yard)
  - Park Hyatt Hotel, Zurich, Switzerland, 2004
  - Vogt Landschaftsarchitekten

- **Earthen facades and floors**
  - Aomori Museum of Art
  - Aomori, Japan, 2006
  - Jun Aoki & Associates

- **Earth**
  - Storm King Wavefield
  - Mountainville, NY, 2009
  - Maya Lin

- **Rock filled gabions**
  - Dominus Winery
  - Yountville, CA, 1998
  - Herzog and de Meuron

- **Greek marble panels**
  - St. Pius Church
  - Meggen, Switzerland, 1966
  - Franz Fueg
Nonmetallic, inorganic solids formed by the ionic bonding of mineral material through human based processes of mixing and/or heating

PHYSICAL ATTRIBUTES
Ceramics usually consist of metallic and non-metallic atoms. The ionic and covalent bonds render ceramics hard, brittle and resistant to heat.

CLAY-BASED E1
Inorganic, crystalline composites made of fired clay, typically aluminosilicate and kaolinite, resembling glass in brittleness

TYPES
Primary Clay fires to white, has the highest percentage of clay minerals, is the least contaminated, and is fired 1250°C-1400°C. Suitable for heat-resistant applications. Kaolin/China Clay is a fine white clay used to manufacture porcelain, China, and white Portland cement. Secondary Clay fires to red, yellow, or white, contains less clay minerals and more feldspar, and is fired at 1150°C-1250°C. Used to make stoneware and earthenware. Tertiary Clay fires to red or yellow, contains the least amount of clay minerals and more iron, lime and feldspar, and is fired between 850°C and 1050°C.

APPLICATIONS
Facades, walls, paths, roads, roofing tiles, drainage pipes, structural clay tiles

TERMINOLOGY
Fat clay has a high loam content that increases the its elasticity but makes it susceptible to shrinkage and cracking. It is used to create machine pressed bricks and ceramic roofing tiles. Lean clay has a low loam content, low plasticity, and is used to produce hand-molded bricks and sanded facing bricks. Grog is a non-shrinking material that is added to clay to give dimensional stability. It can be sand, quartz dust, clay brick dust, slag, ash, or sawdust. Brick types include: hand molded, press-molded, extruded, and porous. Typical sizes are: Standard, Engineer, Elosure, Roman, Norman, Norwegian, Economy, Triple and Structural Clay Research (SCR) brick. Glazes are mixtures of fine clay, pigments and water that melt at lower temperatures than the base material. They give a clay product a vitreous surface after firing. Refractory means a material resists melting until high temperatures. Pure clay (hydrous aluminum silicate) is very refractory, most clays have impurities that allow the clay to melt at lower temperatures. Refractory ceramics include firebrick, used to line fireplaces. Terra cotta refers to earthenware or stoneware made of clay and pre-fired clay or grog. It does not shrink or distort during firing. Ceramic veneer is a type of terra-cotta.

CEMENTITIOUS E2
Inorganic, crystalline composites made of a combination of lime, alumina, and water

TYPES
Cement is a hydraulic binder. When mixed with water it begins an exothermic reaction that sets in both air and underwater to form a water-resistant hydrated cement. Portland cement is a standardized formulation of cement named after Portland stone, mined in Dorset, England. In the U.S. it has five compositional types set by ASTM C150: normal, moderate sulfate resistance, high early strength, low heat of hydration, and high sulfate resistance. European standard EN 197 divides Portland cements into five types based on the additional constituents: ordinary, Portland composite, blast furnace cement, pozzolanic cement, and composite cement. Other types of cement are: limestone cement, pulverized fuel ash (PFA), bent shale cement, white cement, flyash cement, and expansive cement among others. The powder used to make cement (erroneously called cement itself) is a combination of calcium carbonate plus the chemical reaction. Portland cement is a hydraulic binder. When mixed curing stops. The concrete continues to mature from liquid to solid cement. The three phases are initial set, solidifying, and final set. Curing is not a process of drying out. If water is removed, curing stops. The concrete continues to mature or afterharden even after a year, developing a higher strength. Mortar is a mixture of binder, sand, and water used to bond masonry units. Grout is a type of mortar used for filling recesses. Concrete masonry units

PROCESSING
Drying, Hatschek process, reinforcement, mixing, precasting, serilith procedure, shuttering, spraying, wellcrete method, wet-mix procedure, curing, surfacing (embossing, point tooling, bush hammering, comb chiseling, sawing, grinding, splitting, polishing, blasting, flame cleaning, brushing, washing, acid etching, photogravengraving), coating

APPLICATIONS
Civil engineering construction, foundations, building, pavers.

TERMINOLOGY
Formwork is a temporary mold to hold the cementitious liquid in place while it cures. It can be composed of boards, plywood, plastic panels, silicone rubber, steel, or polystyrene foam. Solidification is the process of change from liquid to solid cement. The three phases are initial set, solidifying, and final set. Curing is not a process of drying out. If water is removed, curing stops. The concrete continues to mature or afterharden even after a year, developing a higher strength. Mortar is a mixture of binder, sand, and water used to bond masonry units. Grout is a type of mortar used for filling recesses. Concrete masonry units
(CMU)/cinder blocks are mostly made with lightweight concrete with lightweight aggregates.

**GLASS**

Inorganic, non-crystalline solids that are silica-based

**TYPES**

**Soda-lime glass** allows a high level of light transmittance and is nominally colorless and therefore used for windows. This glass is inert and used for food containers. Soda-lime glass has a relatively high thermal expansion, making it poor at withstanding sudden thermal changes. It is the preferred glass in contemporary construction. **Lead glass** (Lead crystal or lead alkali glass) has up to 30% lead oxide which gives the glass a sparkling brilliance and clarity not achievable with soda-lime glass. It is used for luxury tableware and radiation shielding. Glass containing less than 24% lead oxide is referred to simply as crystal. **Borosilicate glass** is composed of silica (70-80%) and boric oxide (7-13%). It can withstand extreme temperature changes, is lighter than soda-lime glass by 15% and is easy to work. Trade name: Pyrex. **Vitreous silica or silica glass**, alumino-silicate glass, and glass ceramics are other types of less common glass.

**PROCESSING**

Lampworking, lost wax cast glass, sandblasting, kiln casting, acid etching, ribbon machine process, fusing, slumping, water-jet cutting, pressed glass, handblowing, hand blowing into molds, blow molding, press and blow process, silvering, brilliant-cutting, cold-working, enameling

**APPLICATIONS**

Windows, glass wool (insulation), glazing, lighting fixtures, road marking, mirrors, glass brick, glass block, tablewares, packaging, security glass, bakeware, optical fibers, tubing

**TERMINOLOGY**

**Float glass** is sheet glass produced by heating molten glass and floating it over molten tin. A ribbon is formed, rolled and cut into sheets. It is naturally tinted green. **Rolled glass**/ **patterned glass**/ **cast glass** is translucent and made by melting glass and passing it through rollers to give it texture. **Toughened glass** is pre-stressed by heating and quenching suddenly with cool air (tempered glass) or by ion exchange (chemical toughening). **Laminated glass** is stronger and will remain intact when broken. Security glass/bullet-resistant glass and blast-proof glass are types that use a PVB (polyvinyl butyral) plastic film as the core. **Holloware** accounts for most glass produced. It includes bottles, jars, tableware, tubular products, and hollow blocks used in the building industry. Most is made from soda-lime glass. **Glass fiber** is glass that has been processed into thin strands. Includes insulating glass, textile fibers, and optical fibers.

**MATERIALS IN USE**

- Tile and stone, wapan tiling, ceramic rubble
- Ningbo Historical Museum
  Ningbo, China, 2009
  Amateur Architecture Studio
  Dichroic, anti-reflective, reflective, and clear glass
  Harpa Facade
  Reykjavik, Iceland, 2011
  Studio Olafur Eliasson
  Glazed terracotta rods
  The New York Times Building Sunscreen
  New York, NY, 2007
  Renzo Piano Building Workshop & FXFOWLE Architects
  Rammed concrete
  Bruder Klaus Kapelle
  Mechernich, Germany, 2007
  Peter Zumthor
  Pre-cast concrete pavers
  Southeast Coastal Park
  Barcelona, Spain, 2004
  FOA (Foreign Office Architects)
**PLANAR**

**FILM**
Sheeting with a thickness less than 0.1”

**SHEET**
Sheets between 0.01” - 0.25” thick. **Rigid** or **Flexible**

**PANEL**
0.25” or more in thickness. Wider than 2’. **Rigid** or **Flexible**

**TILE**
Modular, small, thin pieces. Narrower than 2’ on all sides. Less than 1” thick.

**TEXTILE**
Flexible and thin, made of assembled fibers, with openings smaller than 0.25”. **Fabric** woven, knotted or similar, and 1/16” thick or less. **Mats** more than 1/16” thick, woven, knotted or similar. Felts matted fibers, neither woven, knotted, nor similar

**MESH**
Thin with uniform, small rectilinear openings visible to the eye. **Rigid** or **Flexible**

**HONEYCOMB**
Sheets formed into a hexagonal cell structure with openings visible to the eye. **Rigid** or **Flexible**

**LINEAR**

**CORD**
Twisted or formed flexible linear pieces composed of one or more single or plied filaments, strands, or yarns. **Ropes** more than 0.15” diameter. **Threads** less than 0.15” diameter. **Tapes** flat, thin and wide, more than 0.15”

**PROFILE**
Rigid linear pieces long in relation to their cross-section.

**VOLUMETRIC**

**BLOCK**
Volumetric, solid, dimensionally-stable units. Thicker than 1”.

**GRANULES**
Solid, small particles or grains. **Irregular** variable size and shape, larger than 1/32” diameter. **Regular** similar size and shape, larger than 1/32” diameter. **Powder** any solid, granular material smaller than 1/32” diameter

**FLUID**
Fluids with a constant density. **Liquid** aqueous. **Spray** liquid in suspension. **Foam** liquid with bubbles; it can flow, expand, and eventually solidify. **Gas** any substance in a gaseous state

**SEMISOLID**
Any material in gaseous state, including compressed gases. **Gel** jelly-like semi-solids. **Paste** spreadable semi-solids that harden after a defined procedure
MECHANICAL

DENSITY
Mass per unit of volume (kg/m³)

COMPRESSIVE STRENGTH
Stress at which it first suffers permanent (inelastic) deformation in compression (MPa)

TENSILE STRENGTH
Stress at which a round bar of the material, loaded in tension, separates (MPa)

YIELD STRENGTH
Stress at which it first suffers permanent (inelastic) deformation in tension (MPa)

BENDING STRENGTH
Stress at which it first suffers permanent (inelastic) deformation in bending (MPa)

SHEAR STRENGTH
Stress at which it first suffers permanent (inelastic) deformation in shear

ELONGATION
Extension in the length of a tensile specimen at fracture (%)

HARDNESS
Resistance to permanent fracture or plastic deformation due to a force applied with a sharp object (HV)

YOUNG'S MODULUS
Ratio of the uniaxial stress over the uniaxial strain. Used to measure the stiffness of an elastic material.

FATIGUE LIMIT
Range of cyclic stress that can be applied to the material without causing failure

HYGRO-THERMAL

THERMAL RESISTIVITY
The reciprocal of the rate at which heat is conducted through a solid (m²°C/W)

THERMAL EXPANSION COEFFICIENT
The degree of change in volume in response to a change in temperature (ustrain/°C)

MELTING POINT
Temperature at which a material turns abruptly from solid to liquid (°C)

SPECIFIC HEAT
Amount of heat required to raise the temperature of 1 kg of material by 1°C (J/kg °C)

EMISSIVITY
Measure of the heat radiation emitted by a material

WATER ABSORPTION
Increase in mass as a result of moisture absorption when a major surface of a specimen is placed in contact with liquid water (%)

POROSITY
Fraction of the volume of voids over the total volume

FLAMMABILITY
Degree of difficulty required to cause ignition or burning

VAPOR PERMEABILITY
Measure of the passage of water vapor through a substance
**ELECTRICAL**

**ELECTRICAL RESISTIVITY**
Capacity of a material to oppose to the flow of electric current. The reciprocal of Electrical Conductivity (conductor, semiconductor, insulator)

**OPTICAL**

**TRANSPARENCY**
Capacity of a material to transmit light through it (opaque, translucent, transparent)

**REFLECTANCE**
Capacity of a material to reflect light incident on its surface (specular (glossy), medium (satin), diffuse (matte))

**ACOUSTICAL**

**SOUND ABSORPTION**
Capacity of a material to change the acoustic energy of sound waves into another form, reducing the amount of reflected and transmitted sound (reflective, neutral, absorbent)

**SOUND ISOLATION**
Capacity of a material to prevent the transmission of sound through it (insulator, neutral, conductor)

**DURABILITY**

**FIRE RESISTANT**
Resists combustion for a specified time where the material will not fail structurally or allow transit of heat

**WATER RESISTANT**
Not easily harmed or affected by water or does not allow water to pass through easily

**FREEZE/THAW RESISTANT**
Solids that can resist cyclic freezing and melting without disintegration

**CHEMICAL RESISTANT**
Resists damage by chemical reactivity or solvent action

**CORROSION RESISTANT**
The capacity of a metal or alloy to resist the corrosive action of a medium. Determined by the rate of corrosion under given conditions

**UV RESISTANT**
Ability to withstand decay due to the damaging effect of the ultraviolet rays of the sun

**FUNGAL / BACTERIA / ANIMAL RESISTANT**
Ability to resist fungal or bacterial growth, or deter specific animal species on its surface

**RADIO FREQUENCY SHIELDING**
Prohibits electromagnetic radiation from penetrating the material

**ELECTROMAGNETIC INTERFERENCE (EMI) SHIELDING**
Reduces the electromagnetic field with barriers made of conductive or magnetic materials
CASTING
Processes based on the pouring of curable fluids into molds
- Centrifugal casting
- Die casting
- Investment casting
- Sand casting
- Slip casting
- Slumping

MOLDING
Processes based of the deformation of solid and semisolid materials applying high pressure against molds
- Autoclave molding
- Back-pressure forming
- Blow molding
- Bubble forming
- Cavity forming
- Cold isostatic pressing (cip)
- Compression molding
- Contact molding
- Diaphragm molding
- Dip molding
- Electroforming
- Explosive forming
- Foam molding
- Hot isostatic pressing (hip)
- Hydroforming or fluid forming
- Injection molding
- Powder molding
- Rotational molding
- Thermoforming
- Transfer molding
- Vacuum forming
- Vacuum infusion process (vip)

MACHINING
Processes based on the subtraction of material mainly by mechanical methods
- Blanking
- CNC cutting
- Drilling
- Electron-Beam Machining (EBM)
- Grinding
- Laser-beam cutting
- Lathing
- Milling
- Nibbling
- Oxyacetylene cutting
- Plasma-arc cutting
- Punching
- Water-jet cutting
- Water-jet abrasion
- Wire cutting
- Wire Electrical Discharge Machining (W-EDM)

DEFORMING
Processes based on the deformation of solid materials using mechanical devices
- Bending
- Blowing
- Die cutting
- Embossing
- Extrusion
- Forging
- Inflating
- Jiggering
- Jollying
- Pressing
- Pultrusion
- Rolling
- Rotary swaging
- Shearing
- Stamping
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<th>Processes based on the application of thin layers of fluids on the surface of a material</th>
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<td>Calendering</td>
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<td>Cubic printing</td>
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<th>Processes based on the connection of two or more parts to form a single unit of form</th>
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<td>Welding</td>
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<th>Processes based on the automated fabrication of products using additive techniques</th>
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<td>Contour crafting</td>
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<td>Fused Deposition Modeling (FDM)</td>
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<td>Laminated object manufacturing</td>
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<td>Laser Sintering</td>
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<td>Selective Laser Sintering (SLS)</td>
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<td>Selective Laser Melting (SLM)</td>
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<td>Stereolithography (STL)</td>
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**SURFACING**

**JOINING**

**RAPID PROTOTYPING**
Materials in Use, Biocomposites, page 4

Railroad tie wood, reclaimed
Biblioteca Municipal de Azkoitia, 2006
Estudio Beldarrain
© Jon Cazenave
http://places.designobserver.com/slideshow/rematerial-from-waste-to-architecture/13838/848/
accessed on 03/06/2014

Brazilian Ipe hardwood
Yokohama Ferry Terminal, 2002
FOA (Foreign Office Architects)
© Lise Larbjerg
http://www.arcspace.com/image-library/yokohama-
international-port-terminal/
accessed on 03/07/2014

Unbleached Kraft paper or tissue paper
Softwall
Molo Design
© Molo Design
http://moldesign.com/products/softwall-softblock-modular-
system-%20%2F%20fed-lighting
accessed on 03/07/2014

Gluelam scotch pine
Corole: high tension electricity pylon, 1994
Martin Szkely
© Alain Doviat
http://www.martinszekely.com/niveau4-industrie.php?
?y=2004&m=4&d=15&d2=52
accessed on 03/07/2014

Materials in Use, Polymers, page 6

Nylon fabric
Wendy, 2012
HWKN
© Michael Moran
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construction-complete-on-hkwns-wendy-at-moma-ps1.aspx
accessed on 03/07/2014

Polycarbonate panels
Model Workshop, 2002
Almann Satellar Wapnner Architekten
© Florian Hoeltzer, Stefan Müller-Naumann
detail/88/pics/?page=6
accessed on 03/07/2014

Acrylic rods
Seed Cathedral, 2002
Heatherwick Studio
© Daniele Mattioli
http://www.yatzer.com/2173_seed_cathedral_for_the_uk-
shanghai_pavilion_by_heatherwick_studio
accessed on 03/07/2014

PET
United Bottle, 2006
Instant Architects
© Van Alen Institute
http://www.vanalen.org/fellowship/fellows/03_02008_
hebelstollmanrelated_photos_content%3Dtrue
accessed on 03/07/2014

GRP, ETFE
Chanal Mobile Art Pavilion, 2008
Zaha Hadid Architects, ARUP
© Stefan Tuchlia
http://www.archdaily.com/144378/chanel-mobile-art-pavilion-
zhaha-hadid-architects_k5_5077/
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Materials in Use, Metals, page 8

Steel structure and cables
MFO Park, 2002
Burckhardt + Partner AG
© Burckhardt + Partner
http://www.burckhardtpartner.ch/en/references/items/new-
info-park.html
accessed on 03/07/2014

Steel shipping containers
Nomadic Museum, 2005
Shigeru Ban Architects
© Shigeru Ban Architects
http://www.dma-ny.com/site_sba/?page_id=307
accessed on 03/07/2014

Stainless steel woven curtain
Princeton Parking Garage, 2000
TEN Arquitectos
© TEN Arquitectos
http://www.ten-arquitectos.com/projecto.php?id=121
accessed on 03/07/2014

Articulating aluminum panels
Technorama Façade, 2002
Ned Kahn
© Ned Kahn Studios
http://nedkahn.com/portfolio/technorama-façade/
accessed on 03/07/2014

Cast tombasili (white bronze) and copper panels
American Folk Art Museum, 2001
Todd Williams Bilte Tisen Architects
© Michael Moran
http://blog.archpaper.com/wordpress/archives/16891
accessed on 03/07/2014

Concrete natural stone
Weather Garden (Stone Yard, Park Hyatt Hotel), 2004
Voort Landschapsarchitecten
© Vogli
accessed on 03/07/2014

Earthen facades and floors
Aomori Museum of Art, 2006
Jun Aoki & Associates
© Daici Ama
http://www.archdaily.com/126728/aomori-museum-of-art-jun-
aoki-associates/aomoni002/
accessed on 03/07/2014

Earth
Storm King Wavefield, 2009
Maya Lin Studio
© Librado Romero
html?q=0
accessed on 03/07/2014

Rock-filled gabions
Dominus Winery, 1998
Herzog and de Meuron
© Driessen
http://www.fotopedia.com/items/NV3fgkk-DZM-AU00n4jtlc
accessed on 03/07/2014

Greek marble
St. Plus Church, 1966
Franz Feug
© Frank Kaltenbach
http://www.detail-online.com/inspiration/discussion-taking-a-
second-look-%E2%80%99s-plus-catholic-church-in-
meeggen-108891.html
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Materials in Use, Ceramics, page 12

Tile and stone, wapan tiling, ceramic rubble
Ningbo Historical Museum, 2009
Amateure Architecture Studio
© Iwan Baan
accessed on 03/07/2014

Bichroic, anti-reflective, clear glass
Harpa Concert Hall, 2011
Henning Larsen Architects
© Henning Larsen Architects
http://www.archdaily.com/153520/harpa-concert-hall-and-
conference-centre-henning-larsen-architects/harpa-concert-
hall-and-conference-centre-in-reykjavik-11/
accessed on 03/07/2014

Glazed terracotta rods
Renzo Piano Building Workshop
© Renzo Piano Building Workshop, FXFOWLE
accessed on 03/07/2014

Rammed concrete
Bruder Klaus Kapelle, 2007
Peter Zumthor
© Samuel Ludwig
http://www.samuelludwig.com/peter-zumthor/
noi0mch2ak54c4o4bmi71xfkonwett
accessed on 03/07/2014

Pre-cast concrete pavers
Southeast Coastal Park, 2007
FOA (Foreign Office Architects)
© FOA
http://www.cyberarch.com/dossier.zoom_article_v2.php?brosser75&_articleID=1370&_photo=37578&modal=true&keepThis=true&
 rueheight=9006&width=800&TB_iframe=true
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