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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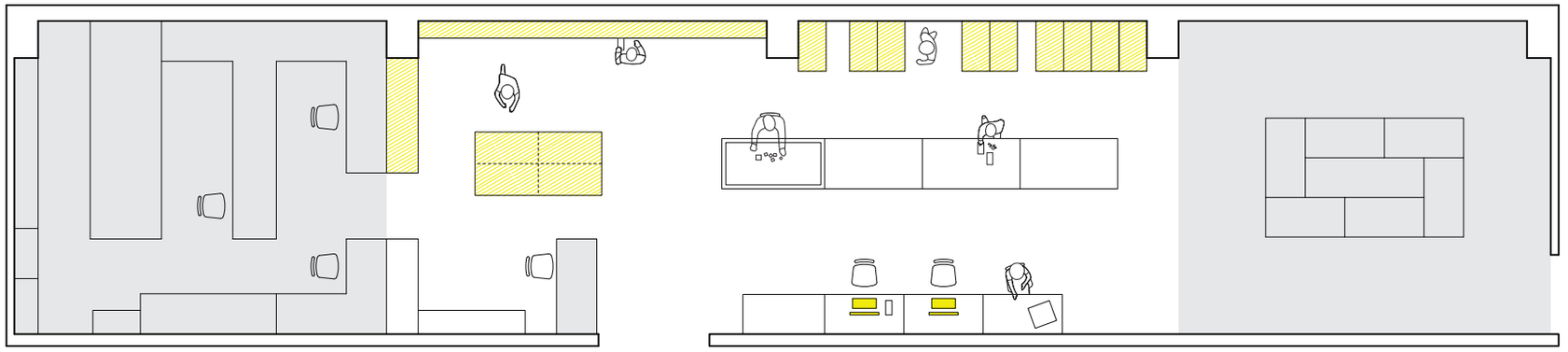
FRANCES LOEB LIBRARY
HARVARD GRADUATE SCHOOL OF DESIGN



MATERIALS RESEARCH

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, Visual + Materials Collections, lower level, L12

ABOUT

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 Visual + Materials Collections are two collections housed together in the Frances Loeb Library, a space that functions as a teaching and display venue for ongoing research and course work. 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.

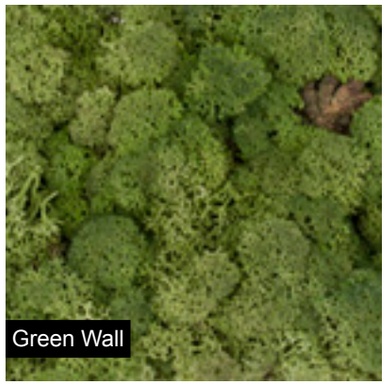
Fabrication Materials
Materials that can be used in the GSD Fabrication Lab, as well as alternatives to those currently in use.

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

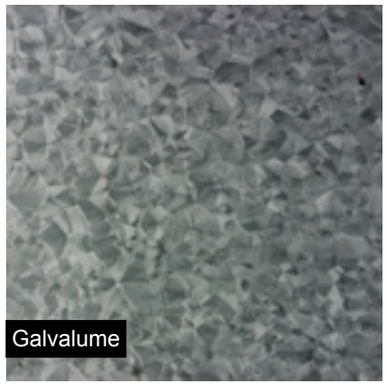
Recycled Materials
Materials made from recycled material stocks including polymers, metals, and ceramics.

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.


Green Wall


Aramid Fiber Honeycomb Cores


Galvalume


Dichroic Glass


Hydroton Clay Pebbles

BIOCOMPOSITES A

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

PLANT A1

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

ANIMAL A2

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

FUNGI A3

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

POLYMERS B

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

THERMOPLASTIC B1

Synthetic or semi-synthetic, organic polymers, whose polymer chains are linear and not cross-linked

THERMOSET B2

Synthetic or semi-synthetic, organic polymers, whose polymer chains have been irreversibly, densely cross-linked

ELASTOMER B3

Synthetic or semi-synthetic, organic polymers, whose polymer chains are networked and loosely cross-linked

METALS C

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

FERROUS C1

Ferrous pure metals and alloys, metals based on iron

NON-FERROUS C2

Non-Ferrous pure metals and alloys, metals with little or no iron content

MINERALS D

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

GEOGENIC D1

Inorganic, crystalline solids and chemical compounds formed by geological processes

ANTHROPOGENIC D2

Inorganic, crystalline solids and chemical compounds manufactured by humans

CERAMICS E

Nonmetallic, inorganic solids formed by the ionic bonding of mineral material through human based processes of mixing and/or heating

CLAY-BASED E1

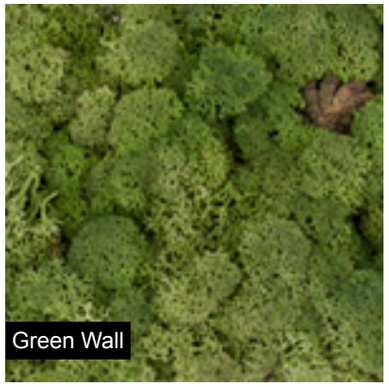
Inorganic, crystalline composites made of fired clay, typically aluminosilicate and kaolinite, resembling glass in brittleness

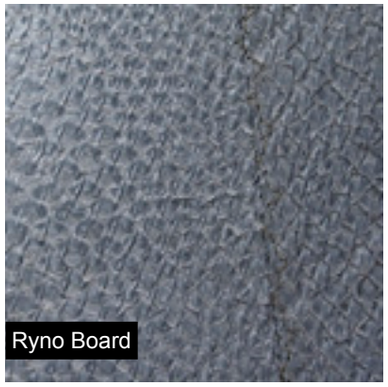
CEMENTITIOUS E2

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

GLASS E3

Inorganic, non-crystalline solids that are silica-based


Green Wall


Ryno Board


Mushroom Packaging (EcoCradle)

BIOCOMPOSITES A

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

PLANT A1

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

PHYSICAL ATTRIBUTES

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.

TYPES

Wood is the cellular tissue of the tree inside the cambium and is composed of 40-50% cellulose, 20-30% hemicellulose, and 20-30% lignin. Lignin makes timber strong in compression and tension. Wood and wood products are often graded based on the quality of the feedstock. The common tree name usually differs from the commercial name for the lumber, listed here. The commercial name for a lumber can include several botanical species. Softwoods refer to woods derived from coniferous/evergreen trees (gymnosperms). They are mostly softer and easier to work than hardwoods. They include: spruce, pine, fir, and cedar. Hardwoods refer to woods derived from deciduous/broad leaf trees (angiosperms). They are mostly harder in density than softwoods. Domestic hardwoods include: maple, beech, oak, poplar/aspen, and birch. Hardwoods, grown in tropical regions are typically valued for their rot-resistance, and lustrous colors. They may have irregular grain or hard mineral deposits that effect machining, and a few are endangered. They include: teak, mahogany, ipe, wenge, ebony, and rosewood. **Leaves and stalk**: flax, ramie (China grass), hemp, jute, piña (pineapple leaves), bamboo fiber/bamboo viscose, abaca (Manila hemp), henequen, istle, paper (wood pulp and cotton rag), cardboard, raffia, sisal (agave leaf), kenaf, bagasse (byproduct of sugarcane and sorghum production), rattan, thatch (reed), wicker (rattan, reed, rush), wheat, straw, coconut timber, carnuba wax (palm leaves), papyrus, vegetable/natural tannin. **Bark**: cork, bark. **Sap, pitch, or latex**: natural rubber, plant-derived resins, rosin, amber, pine tar, turpentine. **Seeds, nuts, fruit or drupe**: kapok (seed pod), seeds, cotton (seed fiber), coir (coconut husk), bayberry wax, linseed oil (flax seeds), linoleum, guar gum. **Cellulose**: cellulose acetate, cellulose triacetate, viscose, rayon, modal, lyocell, tall oil/tallol. **Other**: bioplastics (PLA, PHB, PA11) (starch-based and corn-based), vegetable dyes can come from the root, berries, bark, wood, or leaves of a plant

PROCESSING

Debarked, chipped, plainsawn, quartersawn, rough sawn, flat sawn, rift sawn, sanded, burned, kiln dried, air dried, dip coated, impregnation (fungicidal, insecticidal, dampproofing, fire-proofing), retification, lamination, rotary cut (veneers), slicing (veneers), pulped, digested, Kraft process, coated, whitened, pressed, foamed, printed

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, furniture, roofing, 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


Reclaimed railroad tie wood


Brazilian ipe


Unbleached Kraft paper


Gluelam


Bamboo

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 A2

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 A3

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/ mycelia 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.

MATERIALS IN USE

Railroad tie wood, reclaimed
Biblioteca Municipal de Azkoitia
Azkoitia, Basque Country, 2006
Estudio Beldarrain

Brazilian Ipe hardwood
Yokohama Ferry Terminal
Yokohama, Japan, 2002
Foreign Office Architects

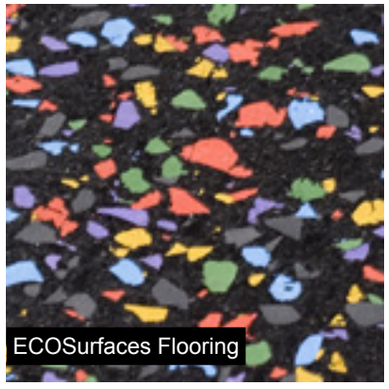
Unbleached kraft paper or tissue paper
Softwall
Molo Design

Gluelam Scotch Pine
Corolle: high tension electricity pylon
France, 1994
Martin Szekely

Bamboo
Haesley Nine Bridges Golf Clubhouse
Yeoju, South Korea, 2010
Shigeru Ban


Aramid Fiber Honeycomb Cores


Barricada


ECOSurfaces Flooring

POLYMERS B

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 waterproofing, waste piping and venting, water supply piping, fibers in fiber reinforced concrete, pipework and fittings, drainage systems, underground services, window and door frames, cladding, tensile membrane structures, bathtubs, sinks, glazing, decorative laminates, seals, sheet liners (water features and landfill sites), flooring

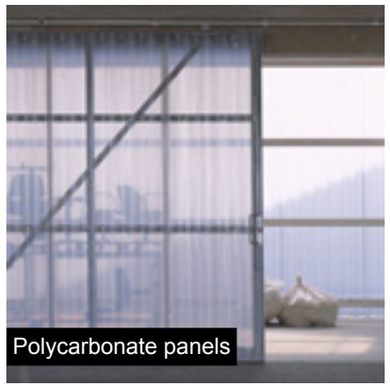
TERMINOLOGY
Fillers are added to improve the workability, weight, and volume expansion characteristics of a material in order to reduce the material costs of the plastic. Can include kaolin, chalk, glass beads and talc. **Reinforcement materials** are used to improve the mechanical properties of plastics 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, polyolefins, and styrenes. **Engineering plastics** (versus commodity plastics) have superior physical, chemical, and thermal characteristics and are used in demanding environments. They include acetals, acrylics, polyamides, and polycarbonates. **Resins** are prepared by polymerization and used with fillers, stabilizers and other components to form plastics.

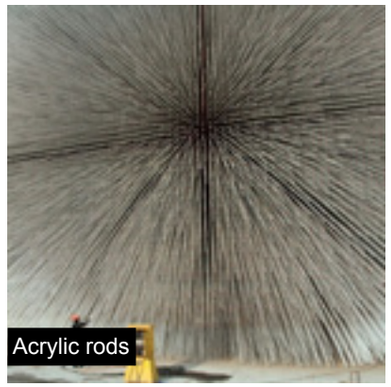
THERMOPLASTIC B1

Synthetic or semi-synthetic, organic polymers, whose polymer chains are linear and not cross-linked • pliable or moldable when heated, returns to solid state when cool, can be remolded

TYPES
Polyolefins make up half of total global polymer production. It is low cost and non-toxic. Examples of materials in use include milk jugs, plastic corks, 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), Polyacrilate (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. • Polyethylene terephthalate (Trevira, PET, PETG, PETE), Polybutylene Terephthalate (PBT), Polycyclohexylene dimethylene terephthalate (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:

Nylon fabric


Polycarbonate panels


Acrylic rods


PET


GRP, ETFE

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, Polyimide (PI), Polyacrylonitrile (PAN), Polyvinyl acetate (PVA/PVAC), Paraffin, Thermoplastic polyurethane (TPU, PU), Acetal/ Polyoxymethylene/polyacetal resin (POM) (acetal family)

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) **Polyesters and composites** Polyester fiber (taffeta), Polyester resin **Vinyl esters and composites** are popular for laminating materials. • Vinyl ester **Epoxies and composites** are applied as coatings and adhesives. Applications include laminating, casting and structural adhesives. • Polyepoxide 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, Lycra, Spandex, 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 Copolyesters

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 material 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, Keltan, Vistalon, Butyl rubber (IIR), Butadiene rubber (BR), Acrylonitrile butadiene rubber (ABR), Styrene butadiene rubber (SBR/ GR-S) **Other Elastomers** Modified bitumen, Elastane (Spandex, Lycra), Polyurethane gel, Polyurethane flexible foam, Styrene-butadiene Styrene (SBS), Thermoplastic Elastomers (TPE)

MATERIALS IN USE

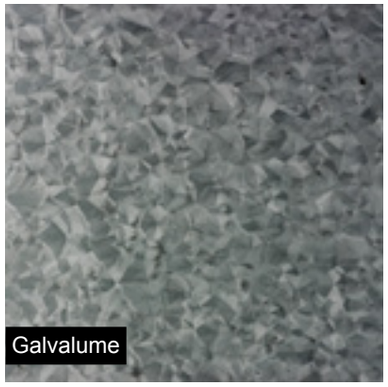
Nylon fabric
Meet Wendy
P.S. 1, New York, NY, 2012
HWKN

Polycarbonate panels
Model Workshop
Wolfratshausen, Germany, 2002
Allmann Sattler Wappner Architekten

Acrylic rods
Seed Cathedral
Shanghi, China, 2010
Heatherwick Studio

PET
United Bottle
2006
INSTANT Architects

GRP, ETFE
Chanel Mobile Art Pavillion
Hong Kong, New York, Tokyo, 2008
Zaha Hadid Architects, ARUP


Galvalume


EverGreen

METALS C

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 beating, 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. **Magnetorestrictive 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

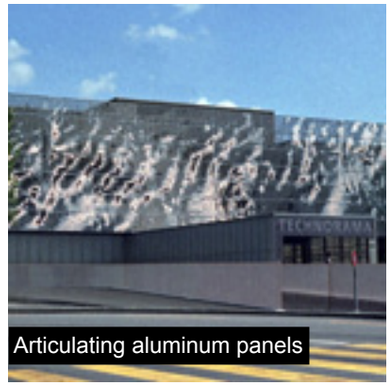
Non-Ferrous pure metals and alloy. Metals with little or no iron content.

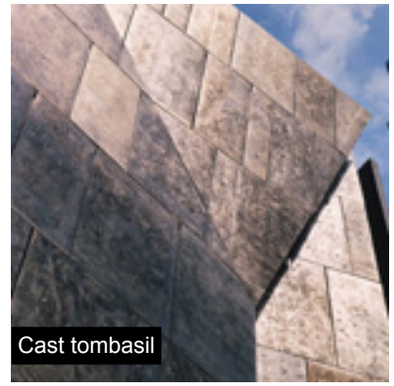
TYPES
Zinc forms a dull grey carbonate coating that makes it resistant to corrosion and weather. Zinc is also used as a coating for galvanized steel. **Aluminum** is the most widely used non-ferrous metal. It is light, strong, rust-resistant and easily worked. It is energy intensive to produce, but can 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-ferrrous metals.


Steel structure and cables


Steel shipping containers


Stainless steel woven curtain


Articulating aluminum panels


Cast tombasil

MATERIALS IN USE

Steel structure and cables
MFO Park
Zurich, Switzerland, 2002
Burckhardt + Partner AG, Raderschall Landschaftsarchitekten AG

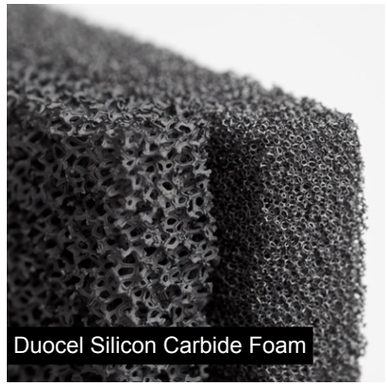
Repurposed steel shipping containers
Nomadic Museum
Santa Monica, CA, 2006
Shigeru Ban Architects

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


Dichroic Glass


Duocel Silicon Carbide Foam

MINERALS D

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 D1

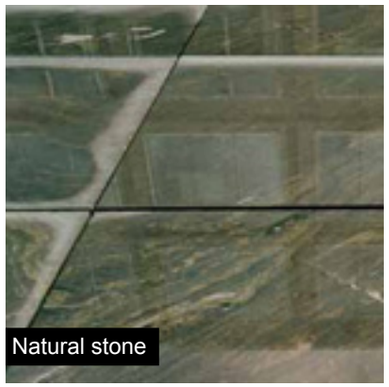
Inorganic, crystalline solids and chemical compounds formed by geological processes

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 that have 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, serpentine/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 top-most 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.

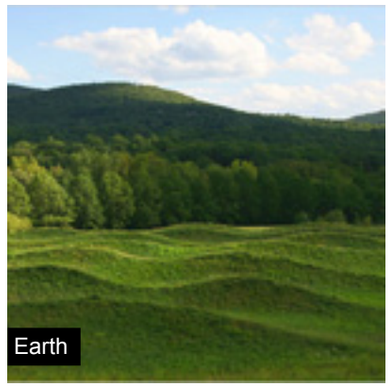
PROCESSING
Minerals and Rock: sawing, cleaving, printing, abrading, drilling, water jet cutting. Surface finishing (manual and industrial): pointed, ground, chiseled, bush hammered, diamond sawn, chat-sawn, shot-sawn, honed, fine-pitched, flamed, sandblasted, polished, raw stone, cloven/ split/cleft, embossed, planed, softened, quarry-faced/rock-faced, boasted, batted/tooled, quarry rough, rough cut, vermiculated, rough-punched, fair-picked, axed, sparrow pecked, fine-rubbed, gritted, eggshell/honed, acid washed, hydro, tumbled, plucked, broached, carborundum
Earth: molding, ramming, cobbing, sun-baking, mixing, casting, filling, throwing

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, pise/ rammed earth, cast earth, compressed earth block (CEB), Dutch brick, earthbag construction, Superadobe, wattle and daub, earth ball finishing, peat walls, turf walls

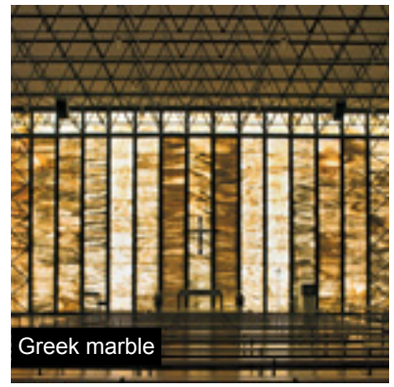
TERMINOLOGY
Natural stone is from a specific geographical region used for decorative purposes in construction and sculpture. There are 5,000 types of worldwide. Examples are Laurentide Green Granite (Quebec) or Carrara Marble (Italy) This nomenclature is specific to the trade and differs from petrological 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


Natural stone


Earthen facades and floors


Earth


Rock-filled gabions


Greek marble

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

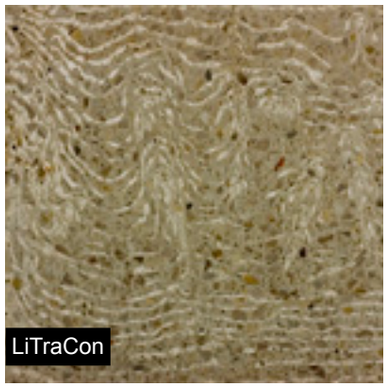
Earthen facades and floors
Aomori Museum of Art
Aomori, Japan, 2006
Jun Aoki & Associates

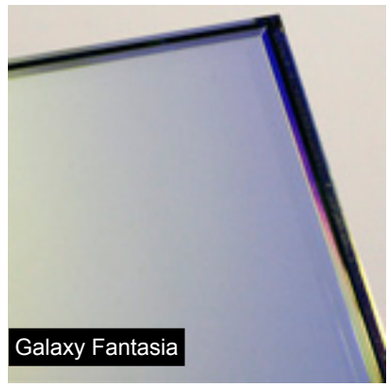
Earth
Storm King Wavefield
Mountainville, NY, 2009
Maya Lin

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

Greek marble panels
St. Pius Church
Meggen, Switzerland, 1966
Franz Fueg


Hydroton Clay Pebbles


LiTraCon


Galaxy Fantasia

CERAMICS E

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.

PROCESSING
Coloring, printing, sanding, reduction, dry-pressed, extruding, wire-cut, firing, drying, hand molding

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

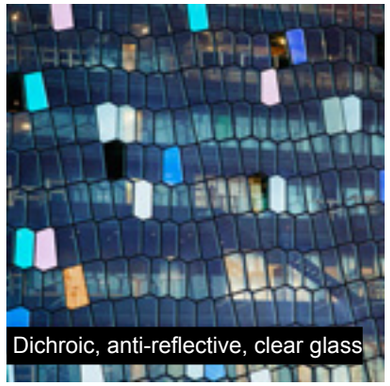
TYPES
Cement is a hydraulic binder. When mixed with water it begins an exothermic reaction that sets in both air and underwater to form a water-resistant hydrated cement. Portland cement is a standardized formulation of cement named after Portland stone, mined in Dorset, England. In the U.S. it has five 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), bunt 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 aluminum, silica, and iron necessary to make the chemical reaction. **Concrete** is a mixture of cement, water, and aggregates. Admixtures such as plasticizers, air entrainers, water proofers, retarders, accelerators, and stabilizers can also be added. It can either be pre-cast or cast in situ. Types include: normal weight, lightweight-structural, lightweight insulating, heavyweight, cellular, gap graded, shotcrete/gunite, pre-placed, pumped, ferrocement, fiber, nailing, no-slump, porous, tremie, polymer impregnated, polymer Portland cement, polymer, sulphur, reinforced, and prestressed.

PROCESSING
Dying, 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, photoengraving), coating

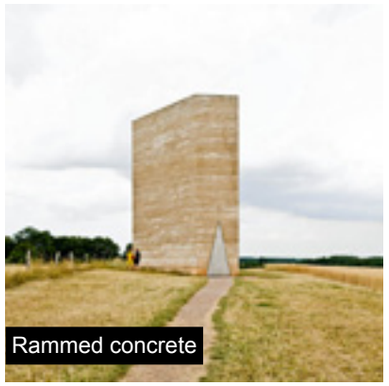
APPLICATIONS
Civil engineering construction, foundations, building, pavers.

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**


Tile, stone, ceramic rubble


Dichroic, anti-reflective, clear glass

Glazed terracotta rods


Rammed concrete


Pre-cast concrete pavers

(CMU)/cinder blocks are mostly made with lightweight concrete with lightweight aggregates.

GLASS E3

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. **Hollowware** 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
Reykjavík, 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)


Sensitile Terrazzo Tiles


Bekitex


TruStone (E-Crete)

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

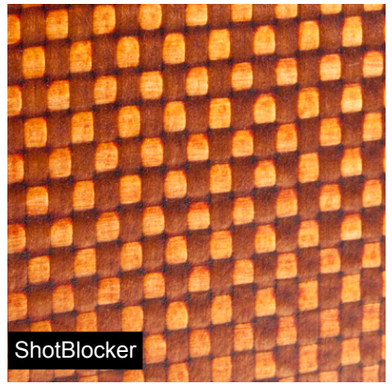
BLOCK
Volumetric, solid, dimensionally-stable units. Thicker than 1”.

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


Fortadur


ShotBlocker


HortiPerl

MECHANICAL

DENSITY
Mass per unit of volume (kg/m3)

COMPRESSION 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 (m°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

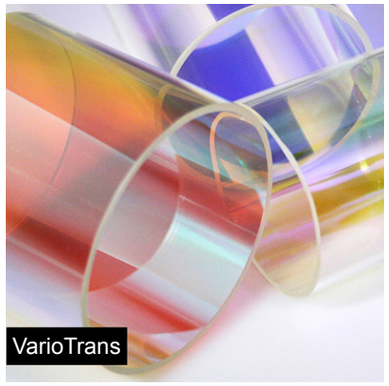
WATER ABSORPTION
Increase in mass as a result of moisture absorption when a major surface of a specimen is placed in contact with liquid water (%)

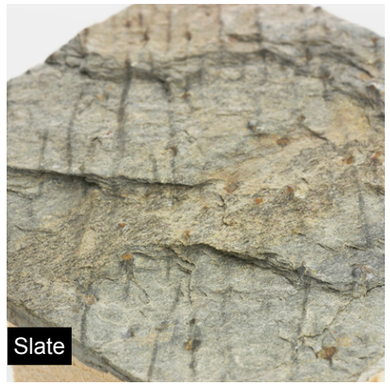
POROSITY
Fraction of the volume of voids over the total volume

FLAMMABILITY
Degree of difficulty required to cause ignition or burning

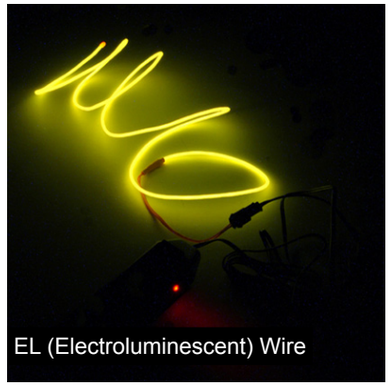
VAPOR PERMEABILITY
Measure of the passage of water vapor through a substance


TerraSkin


VarioTrans


Slate


Basaltex Non Woven Mats


EL (Electroluminescent) Wire

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

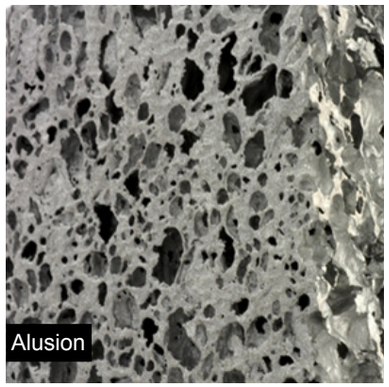
CORROSION RESISTANT
The capacity of a metal or alloy to resist the corrosive action of a medium. Determined by the rate of corrosion under given conditions

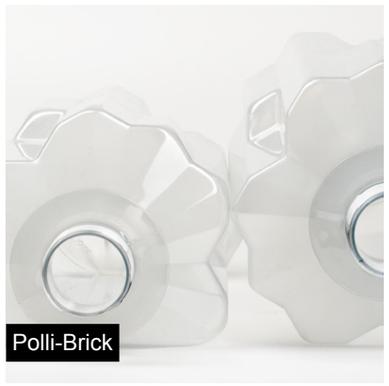
UV RESISTANT
Ability to withstand decay due to the damaging effect of the ultraviolet rays of the sun

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

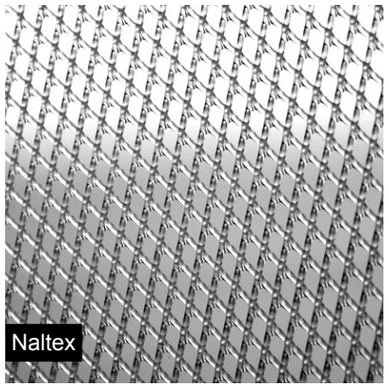
RADIO FREQUENCY SHIELDING
Prohibits electromagnetic radiation from penetrating the material

ELECTROMAGNETIC INTERFERENCE (EMI) SHIELDING
Reduces the electromagnetic field with barriers made of conductive or magnetic materials


Alusion


Polli-Brick


Art Diffusion


Naltex

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

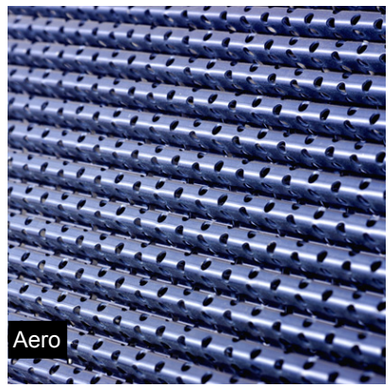
Processes based on the subtraction of material mainly by mechanical methods

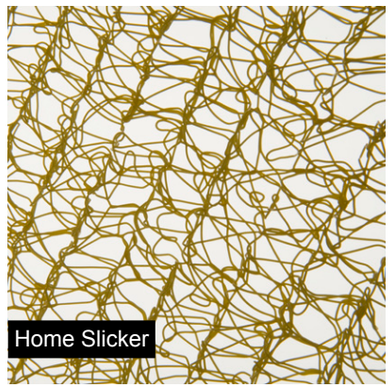
Blanking
CNC cutting
Drilling
Electron-Beam Machining (EBM)
Grinding
Laser-beam cutting
Lathing
Milling
Nibbling
Oxyacetylene cutting
Plasma-arc cutting
Punching
Water-jet cutting
Water-jet abrasion
Wire cutting
Wire Electrical Discharge Machining (W-EDM)

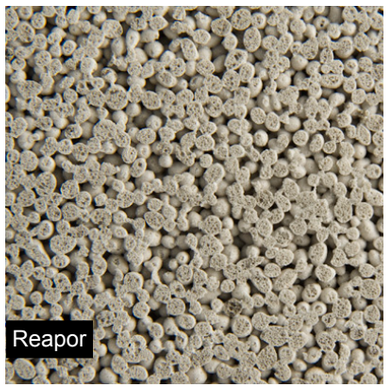
DEFORMING

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


Aero


Home Slicker


Reapor

SURFACING

Processes based on the application of thin layers of fluids on the surface of a material

Anodizing
Calendering
Coating
Cubic printing
Flame hardening
Galvanizing
Inkjet printing
Laser hardening
Over-mold surfacing
Pad printing
Photo-etching
Silk screen printing
Spray painting

JOINING

Processes based on the connection of two or more parts to form a single unit of form

Bonding
Doweling
Fastening
Filament Winding
Flexible adhesives
Knitting
Rigid adhesives
Soldering
Weaving
Welding

RAPID PROTOTYPING

Processes based on the automated fabrication of products using additive techniques

3D printing
Contour crafting
Fused Deposition Modeling (FDM)
Laminated object manufacturing
Laser Sintering
Selective Laser Sintering (SLS)
Selective Laser Melting (SLM)
Stereolithography (STL)

MATERIALS COLLECTION PRIMER

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IMAGE CREDITS

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Molo Design
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