making of architecture. As a catalog consisting primarily of 20th century buildings emerging from the modernist sensibilities, the diagrams illustrate contemporary formal and spatial repercussions emerging from the physicality of material manipulation and the intrinsic design decisions that emerge from material interaction.

The catalog tracks the conventions and concepts behind modern building science and material applications. The diagrammatic dissection of their application reveals the design influence of material, processes of fabrication, and the role of construction on architecture. The revelations of the diagrammatic comparative catalog allow for a material mastery through a catalog that illustrates material techniques and material use as expressions of architectural thought. Providing a horizontal and vertical graphic catalog with analytically cross referenced historical, material, tectonic and typological illustration this text articulates the traditions and trends of material as the defining premise in the making of architecture.

ARCHITECTURE AND MATERIALS

Architecture and material are intrinsically intertwined. The material matter from which built form is made serves as the media with which architects work. The understanding of the technical components is matched by the sensorial effects. The balance between these elements creates the vocabulary for understanding and wielding material.

Materials have long remained subservient to issues of form, structure, sustainability, and geometry. Typically discussed only in technical terms of construction, material has not been at the core of conceptual architectural discourse.

The making of architecture is guided by a material's manufacturing process and construction techniques. These systems establish specific boundaries with the freedom to operate within their systems. Design is not simply ingenuity of form but rather a collaboration of poetry and rational systems. It is the balance of these two that produce architecture. Perhaps the most famous declaration from Vitruvius in D'architectura is: "Well building hath three conditions: firmness, commodity, and delight."

Material has tactility and an intrinsic nature. Its visual and emotional characteristics carry an interpretation. Its use, whether honest or applied, establishes an aura and a narrative. The aura comes from an emotive and experiential association whereas the narrative tells the story of its history, fabrication, and application. Putting materials to best use involves an appreciation of their innate sensory qualities as well as their technical potential. This must be at the root of architectural design.

CONTEMPORARY MATERIAL HISTORY

The history of architecture is the history of material application and invention. The use of new materials and the re-interpretation of existing materials have been at the root of architectural evolution. The formal and spatial developments in architecture incurred through material exploration have yet to be fully documented. The role of material precedent, though essential to architectural education, design, and practice has been overlooked and talked around. The potential of this catalogue of material precedent, not simply from a technical vantage, but as an effectual design catalog of use, provides the opportunity to trend materiality and its relationship to architecture.

Prior to the industrial revolution, material was limited by the distance of transport [indigenous locally found building supplies] and the technology of local craft [the traditions of making passed down through cultural generations]. These limitations provided a continuity of materiality to form and effect generating a vernacular architecture. Wood was harvested locally, bricks were fired out of soil found within the area, and stone was taken from local quarries. The connection between the material for making and the act of making was distinctly attached to place and region. The industrial revolution brought about great change. Infrastructures for movement, combined with large populations and the emergence of new technologies such as steel and concrete shifted the palette available to the designer. The architect was suddenly presented with a selection of materials from which to choose. Considering cost, structure, form, and effect, materials were selected to ensure the ability to build relative to design intentions. Material limitation and abilities soon became expressive mechanisms bringing the influence of material to center stage in the design process. Suddenly the aesthetics and

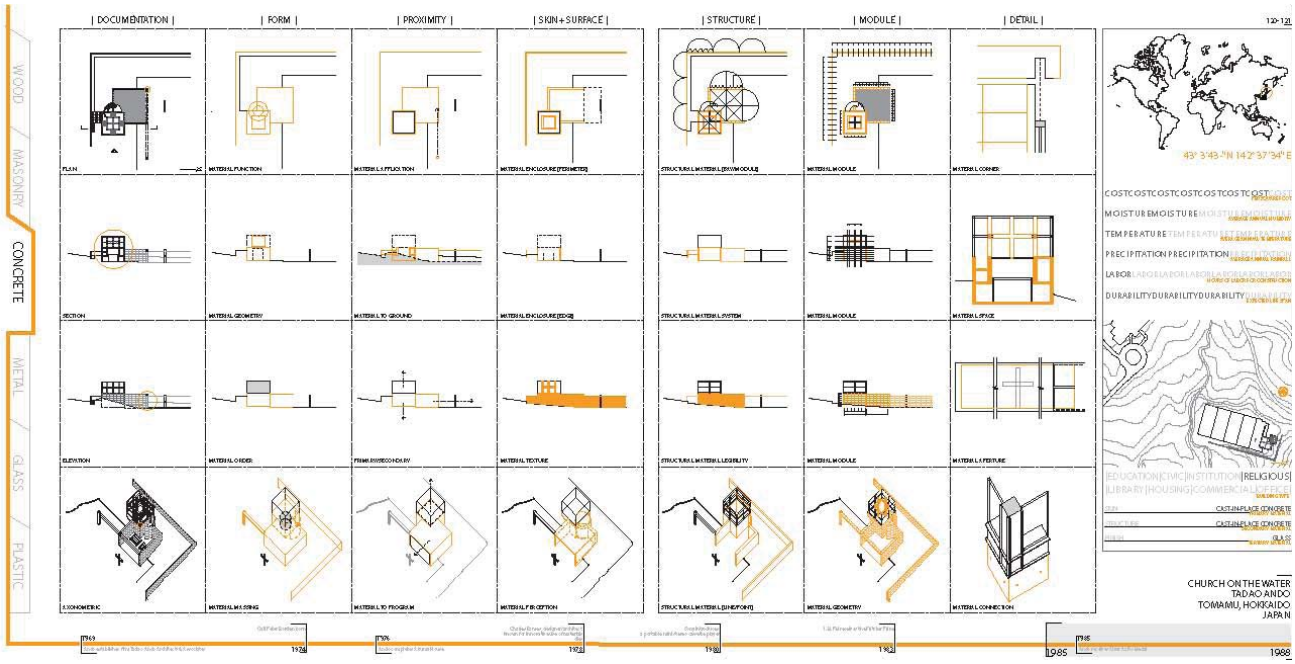

Figure 2. concrete precedent

form making was intertwined with material ability. The way skin to structure, and frame to enclosure were handled was suddenly a provocative resultant of design intention and execution all relative to the materials selected. Performance and technology as the only limitation, the expression of design came through the application, expression, and detailing of materiality. The role of architecture is no longer one of tradition or form, but one that was truly dependent upon material and its inter-relation with all these other issues of architecture.

The advent of technology has also brought enormous advancements in material processes. The invention of new materials and the updating of the traditional materials through new methods of fabrication, installation and application have all lead to an expansion of material capability and opportunity. Glass, steel, plastic and concrete can take on any form; wood technologies allowed for engineered lumber to accumulate smaller members into any shape and span; even woodchips and sawdust were conglomerated to recycled sheet materials such as OSB and MDF; even masonry has found new formal, and technical applications. The emergence of digital fabrication processes has similarly allowed a shift in methods of production and fabrication. Anything can be cut with ease and precision. Materials can be bent, rolled and cast with infinite flexibility. The diversity of options grows logarithmically each day.

MATERIAL PRESENCE OF MAKING

At the root of these issues of choice however are the intentions that aid in making the selection of any material or process and deciding how such a selection can effectually and formally be deployed to aid in the design implementation. How a material is used and perceived sits at the root of a material application and design. This text provides an indexical examination of the historical choices made by the worlds leading architects and provide comparative methodologies, historical trends and conceptual underpinnings of the interrelationship of architecture and materiality. Its pages unpack great works of architecture explicating the material conceptual organization as well as comparatively positioning their use to cultural, technical and personal design influences of each architects life, site and design opportunity. The comparative nature of the text then allows for the trends and sensibilities intrinsic to a material and provides a catalog of how to think and compose with a material.

Material is the media of architecture. It is a physical expression of context and culture. Its intrinsic

qualities and limitations determine the approach to design and form. It has the ability to define architecture. With specific dimension, weight, and technical qualities, a material directs a design process. As the foundational premise of making, material influences all else. These precedents illustrate how a vernacular material and building construction influence design. Examining the influence of: form, cost, methods of construction, fabrication of product, installation of materials, structural and aesthetic performance, ecological and sustainable impact, and spatial/light/visual/perceptual impact these projects provide an analytical process for the implementation of the potential of a material. These projects emerge from a sensibility founded in material celebration. They work within the guidelines of a material's performance, modularity, structural capabilities, formal presence and emotive power to produce an architecture that is of a material. As case studies they represent a material methodology founded in architecture of material influence.

Material precedent is an analytical precedent organized into three parts.

[1] The first section catalogs in a comparative grid 80 projects: 16 each in wood, masonry, concrete, and metal and 8 in both glass and plastic. These pages use a tab format on the left hand side of the page described by principal material. The grid has seven columns entitled left to right as: documentation [illustrating the building in four base drawings of: plan, section, elevation and axonometric], form [displaying the relation of material to from], proximity [addressing the interrelationships of materials], skin + surface [the articulation of material surface], structure [the material influence and articulation on the primary structural system], module [the role of material dimension], and detail [a closer scaling of the specific connections and detailed material design applications]. The matrix provides a comparative array of material application in a single simultaneous spread. The rows are laterally organized with plan, section, elevation, and axonometric. Scales are attempted to be consistent within each precedent, though at times for clarity a magnification of scale was necessary. In each of these instances a graphic scale is included.

[2] The second section of Material Precedent reiterates the primary diagrams in greater detail. Larger in scale and superimposed on ghosted backgrounds of the detailed building, these drawings translate each column into a four square page providing a more detailed reading of each building. Set across several spreads – this section allows for a display of the specificity per project as opposed to the comparative nature within a project of the first sections matrix.

[3] The third and final section is a comparative matrix of one topical diagramming component across the diverse projects. Mapping the same material issue across diverse architectural precedents, the comparative array allows for an understanding of relative usage of material. The comparative material type to application across building precedents allows for a depiction of the evolution of material application. These genealogies illustrate technical, cultural, and conceptual underpinnings of material use.

The use of architectural precedent provides a historical and typological cross section of case studies in material application. Through the comparative dissection of their conceptualization, organization, material selection, material use and material articulation, trends emerge. Their diagramming clearly reveals their position in architectural theory, the approach to material use, available technological capability, and the historical environment [both cultural and architectural]. The aggregation of these in classified material chapters allows for the revelation of sub-trends of the evolution of a material usage across the twentieth century. The broad array of comparative diagramming illustrates the interrelationships within a project and the sequential evolutionary approach to space and material from case study to case study. [Only a small selection of these diagrams are included due to lack of space]

A detailed examination of each project allows for a more in depth and specific examination of the material precedent. Each diagram is superimposed on a detailed drawing of the building. The juxtaposition allows for a specific catalog of representing the interrelationship of the organizational concepts of material usage to the architectural application. [These drawings are not included due to lack of space]

A cross-sectional comparison of precedents across type, time and material allows for a focused look at a specific aspect of materiality. The comparative simultaneity of the presentation of these diagrams permits a trending of use and a description of architectural methodologies. The comparative trends

suggest the diverse methods of applications and the consistencies, similarities and variables in material approach. Each diagram type is examined in a cross sectional comparative method. Arranged chronologically [left to right and top to bottom] the implications of history and technology relative to a singular conceptual consideration become graphically overt. [Only a small selection of these diagrams were included due to lack of space]

Diagrammatic Categories include: [the specific project by project textual analysis and select dia-

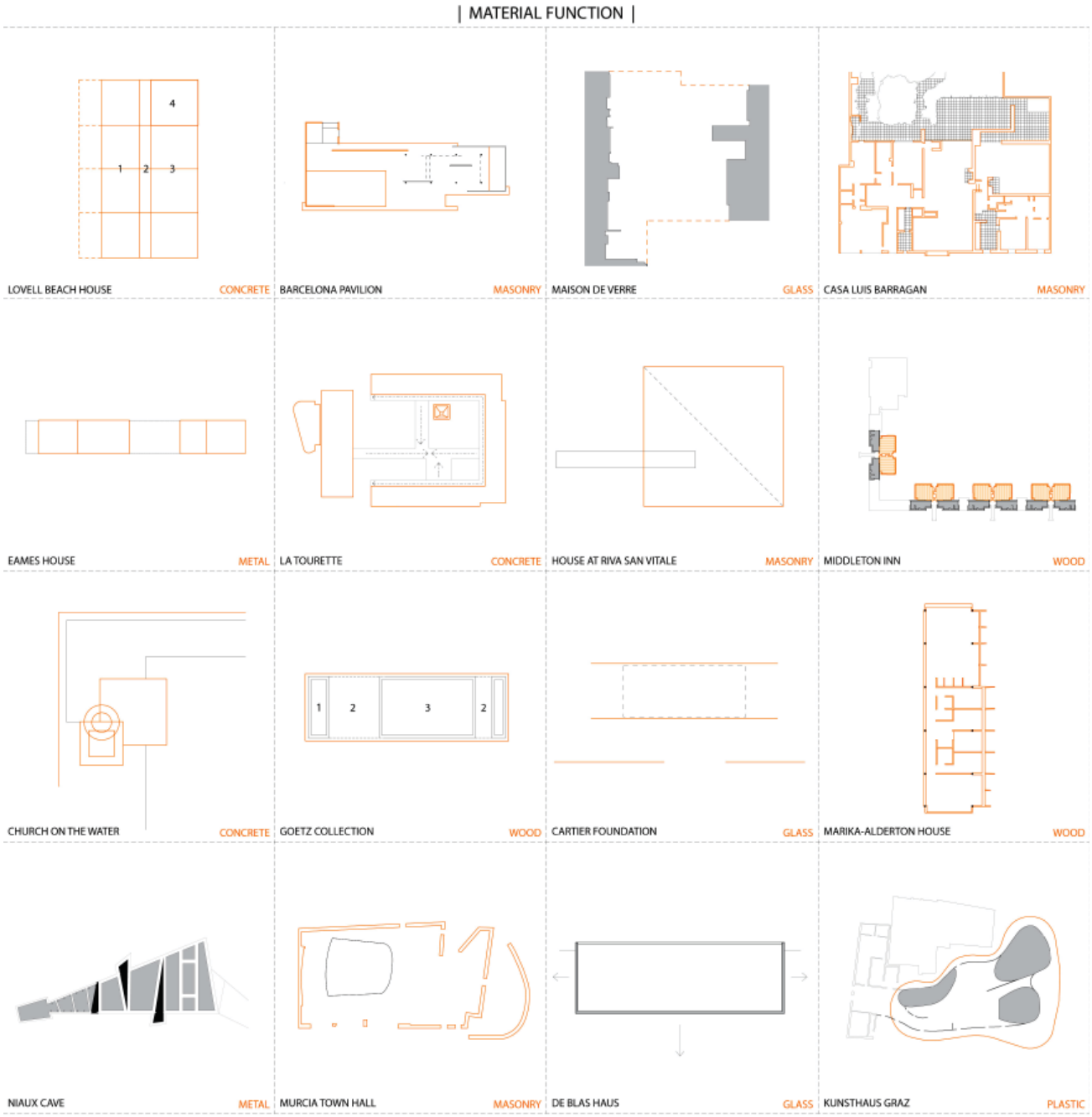

Figure 3. comparative analysis: material function

gram categories have been truncated due to space limitations]

MATERIAL FUNCTION diagrams in plan the relationship between material use and the formal and technical associations required by its functional application. These diagrams examine the role of a material's specific performance properties and its employment relative to the functional and practical necessities of the program and building performance. Each material is expressive of the conditions and requirements of its deployment. Defining the premise of skin in each application, material serves as the iconic designation of form in each project. The associated material tectonic employed extends its influence to express itself through the spatial concepts of the architecture. Steel defines vertical lines [Eames House and Niaux Caves], concrete defines planes and frames with variable openings [Lovell Beach House, La Tourette, Church on the Water] while masonry creates modulated solid edges [Casa Barragan and Murcia Town Hall]. Glass establishes transparent veils: flat ambiguous surfaces that exist but slip into a non presence allowing the dissolve of the enclosure and a perceived spatial connection between inside and outside. This is most prevalent in the De Blas Haus and Cartier foundation, though exists even when the glass is frosted and figured as in the glass block façade of the Maison de Verre. Each material relative to its function determines form.

Proximity – PRIMARY / SECONDARY diagrams the elevational relationship of the primary building material to the secondary building material focusing on the formal, functional and practical interrelationship of their material application. The hierarchy between these two levels is both formally and materially evident establishing the organizing geometries of the diverse layers. The proximity of a primary figure to a secondary figure builds on the formal reading of Material Application diagrams but engages the interrelationship with the secondary systemization. The interaction of the two can occur through superimposition, contrasting figures, interpenetration, banding, layering, or any other adverbial relationship. The result is a primary figuration and the secondary sub-systemization that through its geometry breaks down the material into fabricate-able and install-able pieces and reveals the tectonic intention of their aggregation.

Proximity – MATERIAL TO PROGRAM diagrams in axonometric the overall relationship of material usage to the primary programmatic and functional usages. By focusing on the three-dimensional volumetric associations of material to programmatic usage [and the associated functional requirements of a particular program], the articulation of "form following function" can be examined through material association. The relationship of the programmatic usage to the material selected depicts the narrative of the association creating the opportunity and potential for material to be an expressive sign system. The legibility of a material comes from a technical knowledge that engages an understanding of raw material, manufacturing processes, construction traditions and techniques, weathering and biological attack, and cultural associations. These innate properties of matter translate into forms that collaborate with materials to reveal their process.

Skin + Surface – MATERIAL ENCLOSURE [EDGE] diagrams in section the relationship of the outer plane of enclosure [skin] to the spatial, formal, and structural organization. Expressing the connection of how materials assemble into systems, the figuration of the perimeter as expressed through section extends the moves of plan in the Y axis [still dependent not simply upon the piece but the joint]. The collaboration of piece with joint determines the sectional spatial forms intrinsic to a material resulting in expressive and identifiable associations. The role of skin in section similarly works to define perimeter over the structure and programmatic innards. The figure establishes the legibility of an architectural idea's purity through the articulation of edge and boundary as extended into the vertical and thus now spatial dimension. The continuity and complexity of this line widely explicates the material articulation and the tectonic intricacy. The relationship of craft to figure is found in the method of material manipulation.

MATERIAL ORDER diagrams in elevation the hierarchy, sequence and organizational methods of material's influence on the architectural form. Like the examination in section the implication here is more spatial than formal. Looking at the organizational geometries and governing patterns of material relative to the form, the implications and legibility of volume and mass are articulated through the aggregation of the material pieces. The extension of the material module into the

overarching order of the formal expression is the ultimate collaboration of material with design. The definition of the overall form relative to the piece, the manner in which an aperture is made as a removal [both in terms of module and structural implications], and the relativism of these compositional pieces to the formal whole are the defining characteristics of a material's influence on form.

Skin + Surface – MATERIAL TEXTURE diagrams the elevational legibility of the material texture, color and surface. Reading the compositional aesthetics of the elevation, the collagist sensibility

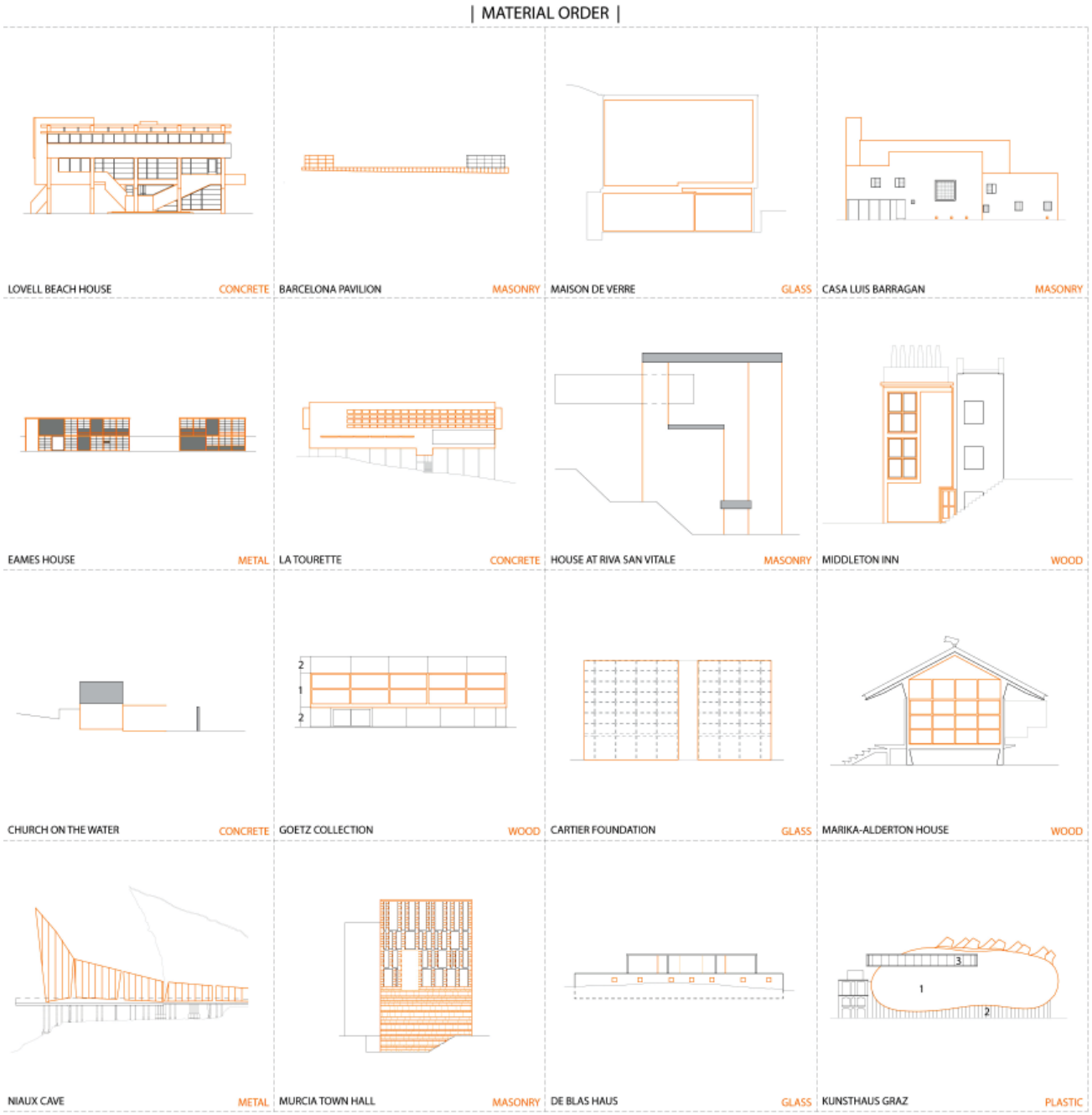

Figure 4. comparative analysis: material order

of pattern, texture, color, and depth of plane are all read against light. Like a composed painting, this image is dissected from the visual perceptual stance of the material on the architectural composition. The textural reading refers to the actual color and composition of the material. Wood for example can be classified as a generic type, but the variety of performance qualities, colors, hardness, resistance to rot, and workability are vastly different from species to species. This same textural legibility comes through the assembly and the expression of the unit and the joint. The scale and articulation of these connections define the legibility of the collective material reading and the overall compositional read to the architecture.

Module – MATERIAL MODULE diagrams in section the relationships of the manufacturing module intrinsic to a material relative to the space, form, and dimensions. Mapping the inherited dimensional constraints determined by the production and movement of a material to the sectional implications, the patterning of these scale elements and the articulation of their joinery to establish larger architectural spaces derived from addressing the relationship of piece to whole and unit to system. The module of material is an intrinsic fact that must be addressed. Certain materials default to a secondary system [such as concrete with formwork] to generate a dimensional constraint, but every material has a "natural" form and dimension. The negotiation of these constraints and the collaboration with these numeric proportions determine the dimensions of the whole and the integration of the modular unit into the consistency of the superstructural organization. In section the implication of the hand of construction relative to the material coursing relative to the body's perception develops the scale and legibility of this module to the spatial presence as a whole.

STRUCTURAL MATERIAL [BAY/MODULE] diagrams in plan the structural module of the building. Focusing on the influence of the structural material it illustrates the engineered structural response of material relative to performative need. Dependent upon the dimension of span relative to the spatial capabilities of the material an organizing geometry is established that sets the scale and legibility of a space. The role of structure in plan is of particular formal importance relative to material as the premise of line [load bearing walls] verses point [columns]. Each system establishes a certain way of making space. Load bearing materials verse cladding materials are revealed and their variation and interdependence highlighted.

STRUCTURAL MATERIAL [LINE/POINT] diagrams in axonometric the primary geometric and formal response of the structural material/system. Line refers the registration of a wall surface as a structural bearing wall in plan while point refers to the columnar system. Materials each subscribe intrinsically to one or the other [typically] as metal is point while masonry is line. Certain materials like concrete and wood have the potential to be either. The axonometric diagramming of the structural system and the material expression of this system suggest the three dimensional resolution of the underlying structure superimposed on the form. The relationship of the structural material to the primary material parallels the discussion of revelation and concealment and homogeneity verses cladding.

STRUCTURAL MATERIAL LEGIBILITY diagrams the elevational reading of the structural material. Focusing on the influence of the structural material it illustrates the interrelation of the engineered structural response of material and performative need to the form and composition. Questioning how the system reads from the exterior and whether the structural material is ever seen, the legibility diagrams examine the relationship of the forces of gravity to the formal expression. The integration of structure to skin and ultimately form is about the engagement of the physical requirements of a building to "stand-up" with the formal intentions and the legibility of these two systems. The idea of [1] reading a person's bones literally through their skin, [2] verses the broader legibility of a leg as column to transfer vertical loads, [3] verses a denial of all understanding of how the figure works structurally are the three basic stages of structural depiction: [1] literal, [2] figural, or [3] denied.

MATERIAL APPLICATION diagrams in plan the deployment of material and the associated perceptual, formal, and functional readings. Engaging the relationship between material and function the formal expression becomes the primary mediating element. The expression of the material's use and the tectonic deployment determines a functional programmatic legibility to the building. This begins with the formal expression intrinsic to the material followed by issues of practical performance includ-

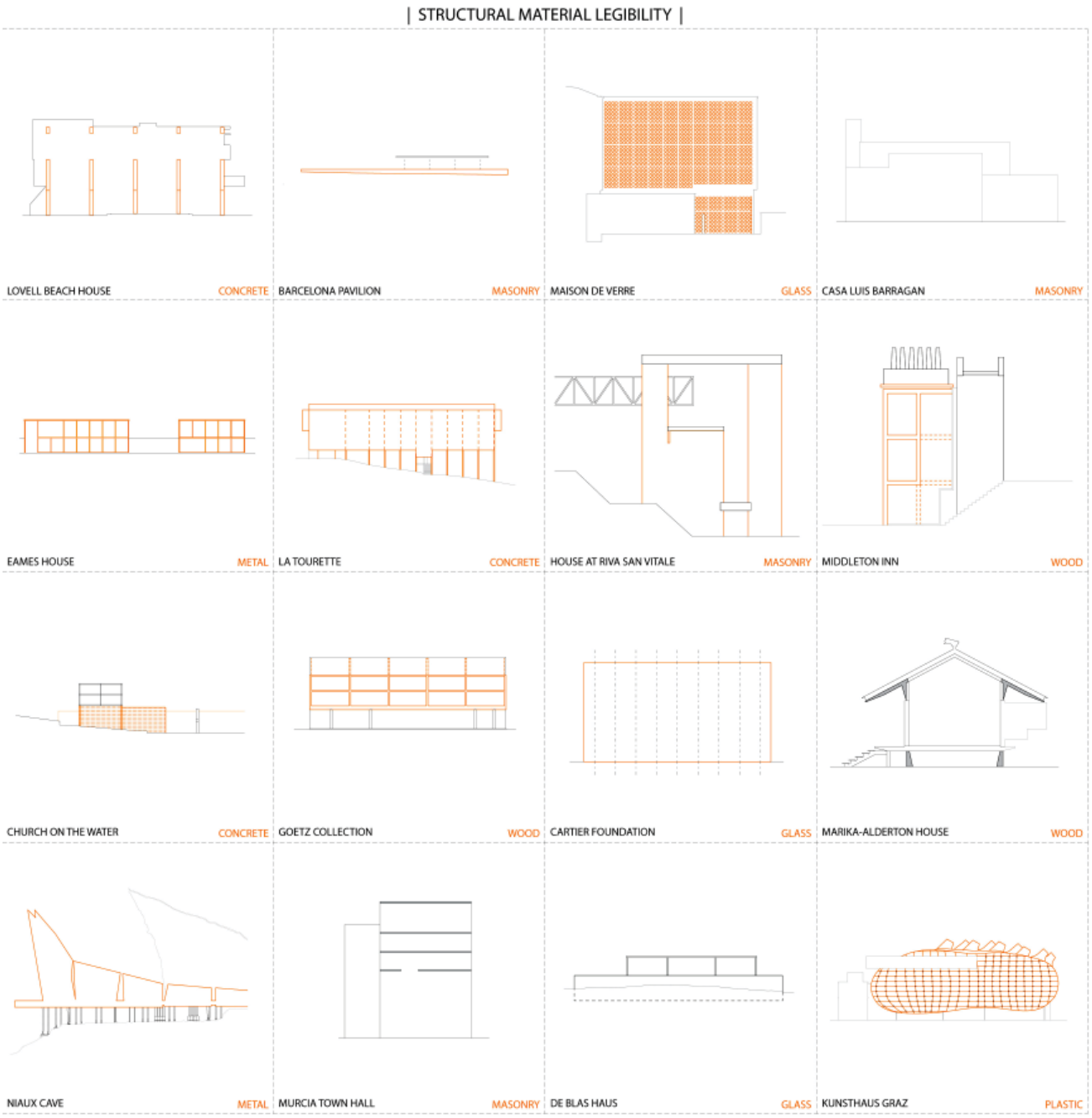

Figure 5. comparative analysis: structural material legibility

ing: durability, porosity and visual effect. A material's selection can be made for various reasons: availability, cost, durability, module, structural capability, or simply the functional applicability [metal to combat combustion, concrete for construction in corrosive environments or masonry as a low maintenance durable skin]. In each scenario the fundamental physical properties of the material are the base-line of design consideration. These properties mediated by the method of manufacturing and limited by the method of working [wood is easy to cut, metal can be welded, masonry is heavy and modular] develop the second tier of consideration. Finally and perhaps with the most variability is the

assembly and application. The systemization of the manufactured pieces and their formal and technical articulation are material design application.

CONCLUSION

Practice and pedagogy has shifted dramatically over the past century to engage emerging technologies, new availabilities of materials and a changing workforce and method of project delivery and construction. With an interest to engage a new literalism of architectural production, through the actual material construction and experimentation focused on performance and material expression, this text attempts to unpack iconic figures of architectural history and catalog their methodology relative to material.

Material is the matter-of-fact of architecture. It is the means of execution, a major force of resistance, and means of expression. Opposed to the paper or cardboard architecture, which was interested in removing the variable and agency of material (and where representation trumped construction), the architectural discipline today has begun to radically reorient itself towards a renewed relationship with materiality. This issue of materials as a topic is the "big" question of our generation. How do we engage architectural thought through making?

The proposition for a comparative diagramming allows for the exposure of trends: historical, tectonic and cultural variations. Illuminating these iconic buildings from a very specific vantage of materiality and a common method of diagrammatic representation to illustrate the trends and relativisms of each of the projects provides for an architectural lineage and historical mapping of materials and their deployment. The analytical and comparative nature of the text attempts to map associations of materiality with the diversity of considerations entering a project: budget, climate, availability of materials, dimensional characteristics, joinery, methods of fabrication and assembly, workability, sustainability, time of construction, durability, structural capability and legibility, and of course formal intention [to name a few]. The collective implications of these decisions and the resolution of each of these practical requirements in support of the architectural intention are essential to the execution of architecture. Serving as precedents these case studies illustrate how some of the best designers over the past century have addressed the issues of materiality and as a collective produce a handbook of modern tectonics.