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MANUFACTURING / MATERIAL / EFFECTS

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Materials and surfaces have a language of their own. Stone speaks of its distant geological origins, its durability and inherent symbol of permanence; brick makes one think of earth and fire, gravity and the ages past traditions of construction; bronze evokes the extreme heat of its manufacture, the intense processes of casting and the passage of time as measured in its patina. Wood speaks of its two existences and time scales, its first life as a growing tree, and its second as a human artefact made by the caring hand of a carpenter or cabinetmaker.

Over the past decade we have seen in architecture the re-emergence of complexity shaped forms and intricately patterned, striated surface configurations, and structures, whose design and production were fundamentally enabled by the capacity of digital technologies to accurately represent and precisely fabricate artifacts of almost any complexity. Some buildings produced by this digital technological shift feature smooth, “liquid” forms or what some describe as simple “boxes” with completely patterned envelopes; many blend both approaches. These new buildings are attractive to many who relish their innovative potential; to others they are merely provisional distractions from the historically distilled essence of the discipline. Beyond the valuation verdict ("good" or "bad"), the proliferation of these types of expressive projects is undeniable; often lacking (“good” or “bad”), the proliferation of these types of expressive projects is undeniable; often lacking the capacity to digitally design and manufacture highly complex, complexly patterned, or behaving dynamically – are the permanence of material conditions in buildings.

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Concrete, metal, and wood are losing their opacity. In the past few years, we have seen the emergence of ‘transparent concrete’, developed by LjTeaCee from Hungary (figure 1.2), and trans游艇 and wood panels, developed by 3M Inc. of Salt Lake City, Utah. Such unconventional articulation of conventional materials brings into focus long-established notions of material truth and signification in architecture. The new techniques teased out of ‘old’ materials are deployed to affect in new ways the ‘old’ perceptions of space, precisely because of the expectations of how the familiar materials should behave.

Aluminum is applied in new ways, as doubly-curved skins. The curvaceous building envelope of the Media Centre at the Lord’s Cricket Grounds in London (1999), designed by Future Systems, is a semi-monocoque aluminum shell, inspired by ‘stressed skins’ long used in automotive, aerospace, and shipbuilding production. In airplanes, for example, the cage-like airframe of reinforcement fibers, can be modulated by varying the quantity and pattern of their high formability, relatively low cost, minimum maintenance, and a relatively high strength-to-weight ratio. By combining materials or composites that change their properties dynamically in direct response to external and internal stimuli, such as light, heat and mechanical stresses. Solar Soltan and William MacDonald have explored materials such as ‘polyesters that undergo molecular reconstruction with stress’, ‘smart glass that responds to light and weather conditions’, ‘anti-bacterial woven-glass fiber wall covering’ and ‘polycromic fibreglass-reinforced polymer structural components’. Michael Silver’s Liquid Crystal Glass House (figures 1.3a–b) proposed for a site in Malibu, California, features a response constantly adapting electronic building skin made from panels which consist of a layer of liquid crystals sandwiched between two sheets of glass, allowing an electronic drift from transparency to opacity and vice versa. The interconnected liquid crystal glass panels are computationally controlled and can create different patterns of transparency and opacity, producing an envelope that is infinitely variable and visually unpredictable. Thom Faidherbe pursued a similar strategy in his Chromogenic Dwelling design proposal (figures 1.4a–c) for the Octavia Boulevard Housing Competition in San Francisco (2005). Electrochromic glass was used to create a changing pattern of visible solids and voids, where the building’s occupants could electronically switch the exterior glass into an opaque, transparent, or translucent surface in response to climate, light effects, and privacy requirements.

The Dutch design practice led by Ben van Berkel and Caroline Bos, has developed a polychromic laminated glass, with a reflective thin film between two sheets of glass that changes color depending on the light angle. It was used for the first time in the La Defense office complex in Almere, the Netherlands (2004); depending on the angle of incidence of sunlight, the façades facing the courtyard of this office complex change across the entire color spectrum during the day, from yellow to blue and red and from purple to green (figures 1.5a–b). The architects van Berkel and Bos were interested in ‘liquid skin’ space by testing ‘the malleability of colors almost as if [they] were de Chirico or Jeff Koons’, achieving “both phenomenological and literal transparency”.

Concrete panel. LiTraCon 1.2. Other commonly available materials, such as fiberglass, polymers and foams, rarely used in the building industry, are being closely scrutinized today for new geometries and new materialities: complex geometries open up a quest for new materials and vice versa. The physical characteristics of fiberglass make it particularly suitable for achieving complex forms. It is cast in liquid state, so it can conform to any mold shape and produce a surface of exceptional smoothness – a liquid, fluid materiality that produces liquid, fluid spatiality. The ‘liquid’ materials arousing particular interest among architects today are composites whose composition can be precisely designed and manufactured to meet specific performance criteria. Composites are actually solid materials created, as their name suggests, by combining two or more different constituent material components, often with very different characteristics, that interpenetrate with the strength of the sum of their individual parts. The result is a new material that offers a marked qualitative improvement in performance, with properties that are superior to those of the original components. Among composites, the polymer composite materials (or simply ‘plastics’) are being considered anew by some architects, primarily because of their high formability, relatively low cost, minimum maintenance, and a relatively high strength-to-weight ratio.
New skins can change not only their transparency and color, but also their shape in response to various environmental influences, as demonstrated by the Aegis Hyposurface project (figures 1.6a–f) by Mark Goultherope’s design firm, Philadelphia-based design firm. This “building envelope dynamic skin” has been already demonstrated in the SmartWrap project (figures 1.7) by KieranTimberlake, a Philadelphia-based design firm. This “building envelope of the future,” as it is referred to by its designers, is an ultra-thin composite material that integrates separate functional components of a conventional wall into one single element. The polymer-based material consists of a flexible metallic film (manufactured mechanically through slicing and cutting, thermally, acoustically, etc. Building materials can be manufactured mechanically through slicing and cutting, for example, shaped by force through bending, extruding, expanding, casting, etc. They are used in structural systems, in building envelopes, as surface finishes, etc. object and its function or meaning; it is an idea that has dominated Western architecture for the last 200 years."
"Affect is the conscious subjective aspect of an emotion considered apart from bodily changes. In contrast, “Affect is something produced by an agent on the experiential veracity of architecture. Peter Eisenman ideas about the performance of building skins and structures. In such “form follows performance,” strategies, the impulse is to harness the generative potential of nature, where evolutionary pressure forces organism to become highly optimized and efficient. Nature initiates search for new material effects, based on biological precedents – often referred to as biomimicry or biomimetics holds much promise as an overwhelming generative driving force for digitally driven contemporary architecture.

**EFFECTS**

There is a close relationship of materiality in architecture to the extended realm of effects and affects. Articulation of surface and formal effects can have a tremendous affect on the experiential volatility of architecture. Peter Eisenman makes the distinction between effect and affect rather clear. He states, “Effect is something produced by an agent or cause. In architecture it is the relationship between some
If we examine the deployment of material-driven ornamental strategies in the context of formal mechanistic operations, as we see in early modern architecture, we realize that, while not intended as decorative, there was an inherent expression of material in its natural form, or even affected by the machine process that manufactured it. “In fact, there is a subset of manufacturing that underlies the material-realized effects during the mechanistic age,” in its perfectly sliced and polished marble, repetitive standardized components, etc. According to Umberto Eco, in Renaissance and Baroque in his essay “Machine and Modern Times” (1977), modern times were used universally to effective, but it was the ornamental result of the effect that was celebrated, and not the procedural mechanics (machinic) operations, as we see in early Modernism. “Machines were definitively associated with the production of aesthetic effects and were used to produce ‘theaters’, or stunningly beautiful and amazing architectures.”

Phenomenological potential of material is increasingly given primary over fluid, supply potential of the digitally derived complex form and further is in opposition to the Baroque attitude. This recognition of the aesthetic appeal of the material affirms the significance assigned to “material imagination.” In Water and Dreams, his phenomenological investigation of poetic imagery, Bachelard makes a distinction between two forms of imagination: a formal imagination (“images of form”) and a material imagination (“images of matter”). According to Bachelard, both are present in nature and in mind; in nature, the “formal imagination” in the beauty of the flowers contains the “material imagination,” on the other hand, produces that which, in being, is both primitive and eternal. For Bachelard, “Images of matter” project deeper and more profound experiences than “images of free form.” In acknowledging Bachelard’s phenomenological distinction between the images of matter and the images of form, Juhari Pajamoina notes that “matter evokes unconscious images and emotions, but modernity at large has been primarily concerned with form.”

In his essay in 1992, Peter Eisenman went a step further, and lamented: “Architecture not only does not deal with affect, but it is often dealt with effect.” That is no longer true: in contemporary architecture, materials and their inherent properties are often fundamental points of departure for discovering and exploring new spatial possibilities (effects) and for designing different perceptions and experiences of architecture (affects). For example, as discussed later in this chapter in many projects by Herzog & de Meuron, the material is often foregrounded as an effect, the effect cannot be decoupled from the material. In returning architecture to both the realm of effects and affects, we should avoid instrumentalisng the links between design intentions and their material manifestations.

The typical tactic is to resort to material “determinism” by presuming that “correctly” selected materials will produce the desired effects both architecturally and performatively. That passive mode of material deployment must be challenged. As Toshiko Mori noted in Inmateriality/Tramaterial, “By understanding materials’ basic properties, putting their forces for greater performance, and at the same time being aware of their aesthetic, emotional and psychological effects, an essential design role can be regained and expanded.”

FROM SMOOTH TO PATTERNED

Digitally-based technologies and techniques have introduced new spatial and formal capacities to architecture. “This digital technological shift led to several lines of investigation in contemporary architecture: one aimed at seamless materiality, in which fluid smoothness was a primary design consideration, a second trajectory explored the outcome of changing angle of the viewer’s eyes to the surface, which resulted in striated, shredded surfaces attain a changing, but smooth rhythm, a pattern of alternating voids and solids that can dematerialize parts of the skin and render it almost entirely opaque depending on the viewing direction (figure 1.13); the ‘shredding’ also adds a much needed sense of scale. In addition, the ‘shredding’ can provide a subtle, dynamic optical effect resulting from the changing angle of the viewer’s eyes to the surface, which was aptly demonstrated by the ‘shredded’ skin of twisted towers in Basel, Switzerland (figure 1.14), designed by Herzog & de Meuron.”

Greg Lynn, for example, developed various strategies of creating apertures in the curvy skins of his buildings through “shredding,” the smooth morphology was adapted to the pragmatic requirements of bringing light and air into the buildings. The resulted striated, shredded surfaces attain a changing, but smooth rhythm, a pattern of alternating voids and solids that can dematerialize parts of the skin and render it almost entirely opaque depending on the viewing direction (figure 1.13); the “shredding” also adds a much needed sense of scale. In addition, the “shredding” can provide a subtle, dynamic optical effect resulting from the changing angle of the viewer’s eyes to the surface, which was aptly demonstrated by the “shredded” skin of twisted towers in Basel, Switzerland (figure 1.14), designed by Herzog & de Meuron. Among contemporary design practices, Herzog & de Meuron stand out in their unapologetic exploration of pattern, texture, and relief and the resulting material and surface effects they can produce. The “ornamented” sections, which can also change between the images of matter and the images of form, often wrapped with a highly decorative skin, has become their signature. In the Library of the Eberswalde Technical School in Eberswalde, Germany (1999), a
conventional, “box” building with horizontal, alternating strips of concrete and glass, images were silk-screened onto glass and concrete panels, literally blurring the material distinctions between the two (figure 1.15). The new addition to the Walker Art Museum in Minneapolis, Minnesota (2005, figure 1.16), for example, features a skin made from crumpled, aluminum mesh panels, “a blur between solid, translucent, and transparent” in the words of Jacques Herzog. The “ornamental” is not limited to the building skin only; the interior surfaces of the museum addition are decorated by swirling, lacy patterns cut in wood (figure 1.17) or embossed in metal panels (figure 1.18).

The scale of decoration in the buildings by Herzog & de Meuron can vary greatly, from several feet to several hundred feet. The large surfaces of the rain screen at the De Young Museum in San Francisco are made from over 7,000 copper panels, each of which features unique halftone cut-out and embossing patterns abstracted from images of the surrounding tree canopies (figure 1.19). The rain screen cladding is decorative, but it also has a purely functional purpose – to hide an integrated ventilation system and to diffuse exterior light falling into the galleries. Such a functional approach to ornamentation is typical of many of the projects by Herzog & de Meuron. A project with a similar functional intent can be found in the Thom Faulders-designed layered, porous skin of the Airspace façade in Tokyo, Japan (2007, figure 1.20a–b): “sunlight is refracted along its metallic surfaces; rainwater is channeled away from exterior walkways via capillary action, and interior views are shielded behind its variegated and foliage-like cover.”

Patterned surfaces of the Federation Square building in Melbourne (figure 1.21), designed by Lab Architecture Studio, are based on what is known in mathematics as pinwheel aperiodic tiling, enabling the designers to apply different scales of the same pattern across the building as needed. There are other notable examples in which patterning is based on mathematics. For example, Voronoi tessellation is a particularly popular algorithm today (figure 1.22). Daniel Libeskind, as well, proposed a patterned skin based on fractals for the extension he designed (with Cecil Balmond of Arup) for the Victoria & Albert Museum addition in London (figure 1.23).
Many of these patterning schemes can be extended from a two-dimensional to a three-dimensional realm (figure 1.24a–b), and emerge from basic mathematical operations in order to achieve complex results. A simple patterning scheme was used by Cecil Balmond and Toyo Ito in their design for the Serpentine Pavilion in London (2002, figure 1.25) to produce a complex-looking outcome. The apparently random patterning that wraps the entire pavilion is produced by incremental scaling and rotation of a series of inscribed squares, whose edges were extended and trimmed by the pavilion’s unfolded box shape (figure 1.26) to create a beautiful, seemingly irregular-looking pattern of alternating voids and solids. The “bird nest” random-looking structural pattern for the National Stadium in Beijing, China (2008, figure 1.27), designed by Herzog & de Meuron, is also based on a relatively simple set of rules to create the “extra-large” material effect. The nearby National Aquatics Center (2008, figure 1.28), designed by PTW Architects from Australia, provides another example of a large-scale material effect. The Water Cube, as the project is nicknamed, is a simple box that features a complex three-dimensional bubble patterning. Its geometric origin is the so-called Weaire-Phelan structure (figure 1.29), an efficient method of subdividing space using two kinds of cells of equal volume: an irregular pentagonal dodecahedron and a tetrakaidecahedron with 2 hexagons and 12 pentagons. This regular three-dimensional pattern was sliced with a non-aligned, i.e. slightly rotated rectilinear box to produce the seemingly irregular patterning effect on the exterior. Voids between structural members on the exterior and interior of the building are filled with inflated, pillow-like layers of plastic film called ethylene tetrafluoroethylene (ETFE). The material effects of this translucent, white, bubble-like skin is ethereal, literally inducing a sensation of being immersed into a giant foam-like structure. Finally, the Central China Television Center (CCTV) located further away in the newly emerging Beijing’s business district (to be also completed in 2008), also features an extra-large complex patterning scheme (figure 1.30), resulting in this case from the structural analysis of the stresses in the envelope of the building’s simply shaped spatial loop.

In many recently completed projects, patterning, however, is primarily decorative, i.e. there is little of the “functionalist ornamentation” as seen in the work of Herzog & de Meuron, described earlier. A good example of this purely decorative application of patterning is the recently completed Ministry of Culture and Communication in Paris, France (2005), designed by Francis Soler, wrapped in what C.C. Sullivan referred to as a “tech-nouveau” latticework screen of stainless steel with six recurring, symmetrical motifs (figure 1.31). The function of this decorative “wrapper” is to create a visual unity of two distinctly different buildings: the old, neo-classical building and its contemporary glass addition; technically, it is largely superficial.
Working on a much smaller scale, Bernard Cache explored the decorative realm of pattern, texture and relief, which also seems to be the current preoccupation of Greg Lynn, who, for example, in recent projects uses "surface geometry to emit texture information so that, like an animal skin, the pattern and relief is in sync with the form." For Cache, "objects are no longer designed but calculated," allowing the design of complex, variable shapes and laying "the foundation for a nonstandard mode of production." His objectiles (figure 1.32a–b), mainly furniture and paneling, are procedurally calculated in modeling software and are industrially produced with numerically-controlled machines. The modification of parameters of design, often random, allows the manufacture of unique objects in a series, thus making mass-customization, i.e. the industrial production of unique objects, possible.47–50

In many of his objectile designs, Cache exploits the decorative effect of the tooling path patterns that can be produced in the material by CNC milling machines. These material effects are directly related to how the surfaces are crafted in CNC milling. In CAD/CAM post-processing software, a NURBS surface is interpreted as an array of precise tool paths that produce a corrugated pattern in the material.47 By designing the tool paths carefully, richly patterned surfaces can be produced by carefully choreographing the milling sequence. Slight deviations in tool paths can produce surprisingly interesting effects in the material. The same two-dimensional (XY) tooling pattern, if varied in 2 directions for each manufactured instance, can produce a series of repetitive, yet differentiated objects.

This and similar carefully crafted tool path strategies have been used by Cache very effectively in a number of his objectiles; they appear as the information-driven, machinic tectonics inheriting (and redirecting) the modernist notions of ornament as resulting from manufacturing processes. Similar patterning techniques were used by Greg Lynn for interior wall panels (figure 1.33), as an "ornament that accentuates the formal relationship with gravity and structure." The resulting affect is in the material effect, whether small, medium, large, or extra-large.48 The points are used to constrain the digital fabric in the formwork, as it expands under the weight of poured plaster. As observed by Kudless, "The resultant plaster tile has a certain resonance with the body as it sags, expands, and stretches in its own relationship with gravity and structure." The resulting supple surface invites visitors to touch it, to sense its smooth undulations. The affect is in the material effect, whether small, medium, large, or extra-large.48

The projects presented so far raise the perennial questions of surface and form versus texture of appearance versus substance (or superficiality versus essence, as seen by some) in contemporary architecture. While the digital technologies of parametric design and fabrication offered new possibilities for nonuniform, non-monotonous, variable patterning and texturing of surfaces, the question of appropriateness, i.e. of cultural significance of such ornamentation or treatment of surfaces in a contemporary context also emerged.51–52

The famous manifesto Adolf Loos published in 1908, polemically entitled "Ornament and Crime," in which he described ornament as a need of the primitive man, arguing that the lack of decoration is a manifestation of a progressive, advanced culture, marked the emergence of the Modern Movement entrenched a perception that to be authentically "modern," one has to categorically remove all ornament, which consequently led to the barren surfaces of much twentieth-century architecture. It was the absence of historically traditional surface ornamentation that arguably made the minimalist aesthetics of Modernism less affective, contributing in part to its demise. The façades didn't shed the rhythm and the pattern — but their monotonous grids didn't give much to the eye. Moreover, in Loos' articulation of the minimal ornamental expression of modern architecture, he decreed the potential for lineages in this manner of thinking: "Modern ornament has neither forbears nor descendants, no past and no future."53 We take the "Semperian" position that "architecture comes to be defined in its essence as an ornamental activity."54 After all, throughout history the second half of the nineteenth-century ornamentation was used in buildings, both on the exterior and in the interior, to enhance and amplify presence and appearance, give scale and texture through intricate treatment of surfaces, and demonstrate the mastery of artisans and craftsmen. Ornament had largely a symbolic function — it embodied values and ideals that defined a particular culture, simultaneously acting as a symbolic construct and enabling the construction of symbolic meaning. Such an approach to ornamentation is in line with the view that the buildings are imbued by and are expressive of the social, economic, political and cultural context, i.e. buildings are representational, while simultaneously being active agents in defining that very same context.
Given the increasing presence of ornamentation in contemporary design (and not just in architecture but also in other design disciplines), an obvious question to ask is if there is any deeper significance, some kind of profound relevance of ornamentation today. A possible answer to that question could start with a definition of what constitutes an ornament in a contemporary context. As there are many possible definitions, perhaps it would be more appropriate to begin by making some basic distinctions about different kinds of ornament in architecture. In general, ornamentation can be decorative or applied, functional or integral, and mimetic or imitative. Ornament, when purely decorative, relies on its application to an already existing surface or an object; hence, such ornamentation could be classified as applied. Structural ornament is considered an integral part of the building’s structure, i.e. the structural components act simultaneously as ornaments, as was the case, for example, in gothic architecture. Such ornamentation can be described as functional or integral. Mimetic or imitative ornamentation is characterized by unambiguous meanings or symbolic significance – it is purely representational.

Today, however, when “decorative” is used to describe an artifact, the meaning is negative in most cases, suggesting that the work itself is superficial, devoid of any deeper meaning. The perception of superficial has often stems from the surface application of ornamentation – it is often seen as something more than an (unnecessary) embellishment to an “other,” as well as to something that is inferior.

When decoration is deployed in a contemporary context, it is often used to hide something unpleasant – or ornamentation – is a necessity, and perhaps as much as a biological need to generate underlying structure in the monotonous); it quickly “disconnects” in reading a particular pattern is recognized and represented in some physical manifestation, such as decoration, for example, that it becomes a cultural artifact – an ornament.

The human need to perceive, organize, and structure the world around us into patterns and rhythms is seen as intrinsic; decoration and ornament are recognized as indicators of neurological synergy of the eye and the brain. E. H. Gombrich offers evolutionary arguments that ornament is a result of a biological need to generate underlying structure in the surrounding environments: “I believe that in the struggle for existence organisms developed a sense of order not because their environment was generally orderly but rather because perception requires a framework against which to plot deviations from regularity.”

According to Gombrich, the human mind has an intrinsic need for “careful balance” between complexity and order. The mind has no trouble deconstructing a simple, regular grid (i.e. recognizing the monotonous); it quickly “disconnects” in reading complex, intelligent designs if it cannot recognize, such as decoration, for example, that it becomes a cultural artifact – an ornament.

Another way of understanding the significance of ornament is to compare it to pattern which could be described as an abstract construct characterized by repetition. As such, patterns exist in nature in all sorts of imaginable shapes, forms, and sizes. It is only when a particular pattern is recognized and represented in some physical manifestation, such as decoration, for example, that it becomes a cultural artifact – an ornament.

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Beyond the pragmatic instrumentalities of manufacturing material effects (as a presaging of new and old ways of thinking about architecture. The idea of a harmonious “whole” being greater than, and dependent upon the sum of its “parts,” has examined directly through interconnected relationships, layers of information, and a search for “integrity” in architecture. An example of the integrated application of the multiplicity of information about a project can be seen in the proliferation of ecological and bioclimatic design considerations if it cannot recognize, such as decoration, for example, that it becomes a cultural artifact – an ornament.

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glazing, mechanical, and electrical systems are synthesized into a single material entity. By producing materials in a digitally-controlled layer-by-layer fashion, as in additive fabrication, it is possible to embed various functional components, thus making them part of a single, complex composite material. This, in turn, implies designing with heterogeneous and non-isotropic materials, i.e., with materials in which variation is present not only in surface articulation, but also in material composition. We already have the technological capacity to design and manufacture materials that do not have uniform composition, properties, and appearance. With digital parametric design and production, variation becomes possible not only in spatial layouts and component dimensions, but also in material composition and surface articulation, offering unprecedented freedom from standardization that defined design and production for much of the twentieth century. Such variability raises a radical departure from the present normative practice. Whether the new “freedoms,” afforded by almost complete departure from the present normative practice. Whether the new “freedoms,” afforded by almost complete departure from the present normative practice. Whether the new “freedoms,” afforded by almost complete departure from the present normative practice. Whether the new “freedoms,” afforded by almost complete departure from the present normative practice. Whether the new “freedoms,” afforded by almost complete departure from the present normative practice.

32 Pallasmaa, op. cit.

33 Eisenman, op. cit. p. 43.

34 Toshiko Mori, op. cit., p. xiv.


37 As described online at http://www.beigedesign.com/proj_airspace.html.

38 Voronoi diagrams are named after Russian mathematician, Georgy Voronoi, who studied the general n-dimensional case of the conceptually simple decomposition scheme in 1908. In Voronoi tessellation, the decomposition of space is determined by distances to a specified discrete set of objects (points) in space.

39 The Weaire-Phelan structure is a complex three-dimensional structure devised in 1993 by Denis Weaire and Robert Phelan, two physicists based at Trinity College in Dublin, Ireland.

40 This extremely lightweight material was also used in the enclosures of the Allianz Arena in Munich, Germany (2005), designed by Herzog & de Meuron, and the Eden Project in Cornwall, England (2001), designed by Grimshaw and Partners.


44 Ibid.

45 The digitally-driven production processes introduce a different logic of *seriality* in architecture, one that is based on local variation and differentiation in series. In buildings, individual components could be customized using digital technologies of fabrication to allow optimal variance in response to differing local conditions in buildings, such as uniquely shaped and sized structural components that address different structural loads in the most optimal way, variable window shapes and sizes that correspond to differences in orientation and available views, etc.

46 In addition to careful crafting of the CNC tool paths (whether for milling or cutting) for each object produced in series, particular attention must be given to the overall *field effect* that is created by assembling the seemingly similar objects into a larger composition. This field effect can be described as a secondary pattern that emerges through the composition of primary, object-related tool path patterns. In many projects, however, it is the field effect that is the primary surface effect that is sought.

47 In a typical CNC production, however, the desired outcome is a smooth, featureless surface which is produced by using milling bits with a fairly small radius and tool paths that are closely spaced.

48 Another technique that Cache used was to work with flat-sheet laminated materials into which a certain topographic design is inscribed through milling, producing a contouring effect that reveals the laminate in subtle ways. In some projects, he used a parametrically controlled and varied spline curve to inscribe it into series of solid panels or to carve out complex shapes that can produce intricate screens with repetitive, yet differing patterns.


50 Cache’s *Objectile* website, now defunct, permitted customers to design their own patterns by varying the parameter values that control the geometry of patterning. The parameter values are then automatically transmitted to the fabricator and translated into CNC machine code for manufacturing.


52 Loos, op. cit.

53 Ibid.
