Lithophanic Dunes: The Dunejars

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ABSTRACT
The design of masonry, tile, and ceramics is an integral part of architectural history. High fired clays are unique in that they are amorphous, vitreous, and translucent. Similar types of light transmission through minerals and clays has been achieved in window panes using alabaster or marble, but unlike porcelain these cannot be cast, and they are susceptible to moisture. Additionally, glass and metal are commonly used to glaze ceramics, and this provides further possibility for the combination of translucency with surface ornamentation and decaling. It is within this architectural lineage, of compound stone and glass objects, that the Dunejars are situated. The Dunejars are translucent porcelain vessels that are designed as lenses to transmit different wavelengths of light into intricate and unexpected patterns. Similar recipes for porcelain were developed using wax positives during the 19th century to manufacture domestic Lithophanes; picturesque screens made of translucent porcelain, often displayed in windows or produced as candle shades (Maust 1986). The focus of the research involves pinpointing the lithophanic qualities of the clay so that they can be repeated by recipe, and refined through a digital workflow. The methods outlined here are the product of an interdisciplinary project residency at The European Ceramic Workcenter (Sundaymorning@EKWC) in 2018 to make tests, and obtain technical precision in the areas of, plaster mold design, slip-casting, finishing, firing, and glazing of the Dunejars. The modular implementation of these features at the scale of architecture can be applied across a range of scales, including fixtures, finishes and envelopes, all of which merit further investigation.
MATERIAL HISTORIES

Materiality and Compound Objects

The Dunejars are the fusion of several ceramic trajectories that have been culled from the unique mechanical properties of porcelain; its granular flow, its encoding as concave and convex surfaces, and its transparency. According to Gilbert Simondon, objects cannot be reduced to their form or matter. The process of becoming involves a transduction, a transfer of information through a material medium (Shaviro 2006). Secondly, the nature of this transfer, or individuation, relies on the technicalities and structure of the medium itself. More importantly, for Simondon, information is not an abstract entity that exists separately from its medium (Shaviro 2006).

The Dunejars and their predecessors, the Heap Tiles, belong to the material history of the porcelain. The porcelain’s granular morphology is reintroduced digitally to the Dunejars as a source of information to interact with light. This approach toward materiality defies the assignment of fixed attributes, and posits materials as an ‘ongoing historicity’ that have the capacity to carry on as ecologies (Ingold 2011, 434-435). Material ecologies can further be distinguished into qualities that belong to aesthetics, and properties which can be measured (Pye 1968, 47). The attunement of these two categories of knowledge is a key part of the ceramic process.

The balance of information also shapes the material ecology. According to Bateson, there is something unique about the “...art of one culture... that can have meaning or validity for critics raised in a different culture?” His theory is that it involves the graceful integration of conscious and unconscious information, and to this point he writes, “...In what form is information about psychic integration contained or coded in a work of art?” (Bateson 1999, 129). The archaeologist, Chantal Conneller points out ‘different understandings of materials are not simply ‘concepts’ set apart from ‘real’ properties; they are realized in terms of different practices that themselves have material effects” (Conneller 2011, 5). With porcelain, its technicalities are like switches in a circuit where the history of the material’s traits can be fused with bits of code, grains, and translucency. It’s within this grace of information that a new compound object fuses the traits of stone, grains, and glass.

Lithophanes

The history of ceramics includes a wide range of aesthetic categories that have been crafted in response to the specific qualities of individual clay bodies. Over the last two decades, digital design tools have been utilized to expand on
the possibilities for ceramics, and to cultivate new territo-
ries within the ceramic process. One of the unique qualities
of fine porcelain is that it is non-porous if fired to full
vitrification, resulting in a structure that can be translucent
depending upon the size of the particles, wall thickness,
and the temperature at which it is fired (Reijnders 2005,
42). When fine clay is fired at high temper-ature it appears
opaque in the presence of reflected light, but when it is
back-lit it becomes translucent. A process for engraving
porcelain “en grisaille” (in shades of grey) was patented in
1827, in France, by Baron de Bourgoing of Rubelles, and
eventually licensed to other factories in Europe where it
was produced commercially until 1902 (Maust 1986, 5).

According to art historian Margaret Carney, “[a]n investi-
gation of the latter, involves the 19th century phenomenon
known as lithophanes, derived from the Greek litho meaning
stone and phainen meaning to cause to appear. This Greek
derivation has proven to confuse some people who might
know some basic Greek, but do not know that lithophanes
have nothing to do with stone or a stone product, but
are made of porcelain” (Carney 2008, 9). Lithophanes
could be either pressed or slip cast, and they were fired
at about 1300° C (Carney 2012, 28). At this temperature
the porcelian is prone to deformation and cracking, and
it is estimated that up to 60 percent were discarded after
firing, making them difficult to produce (Carney 2012, 28).
The Dunejars were fired between 1223-1228° C, and if left
unsupported they also consistently cracked or deformed.

**Lithophanic Dunes**

The Dunejars (I & II) are slip cast in porcelain in the form
of cylindrical vessels (Figures 17 & 18). The slip casting
results in a consistent wall thickness of 3-4 mm, primarily
comprised of convex and concave lenses that converge
into sharply tapered edges (Figure 7). When these lenses
are backlit, the convex features, that face outward, turn
black, while the concave features, that face inward, glow.
All of the Dunejars share one thing in common; the back
and front of the jars, while not identical in their curvature,
are formal inversions of each other. While the lenses are
aligned in the x and y axes, the conics are inverted along
the z axis, and this orientation alters the light as it passes
through the porcelian (Figure 3). On the front of the jar, the
pattern of the light is visible as it passes through the holes
located within the convex lenses, while on the reverse side
it is only visible through the concave surface (Figures 19 &
20). When backlit, the dunes concavity produces a hollow-
face illusion (Figure 11). This phenomena, “in which a mask
appears as a convex face,” is an example of binocular depth
inversion, and it makes the surface direction appear ambig-
ous (Hill and Johnston 2007, 199).

The dunes are the virtual artefacts of a granular flow
as it passes through a two dimensional sieve. During
this process they produce residual heaps with concave
features. Conversely, the outflow of grains that pass
through the holes in a sieve produce heaps with convex
features (Russo 2014, 508). This makes them favorable to
slip casting, insofar as their constant pitch does not result
in undercuts. Formally, the Dunejars are morphological
siblings of this heaping phenomena, with one side displaying convex traits, and the other concave.

The Dunejars are backlit using a programmable mixture of red, green, and blue LED lights. Only after the jars are fired is it possible to observe the quality of the light as it passes through the porcelain. The blending of the different colors of light on the surface of the jar is a combination of direct light passing through the holes, and indirect light passing through the porcelain (Figure 1). Depending on the minerals in the clay, the light takes on a different tint. Surprisingly, the red and green wavelengths of light are transmitted as orange light, while blue light does pass through the porcelain. This confrontation, or fusion, with the porcelain is inaccessible, and cannot be represented in the design process. The source of the transduction lies in the technical movement of information between the real and sensual properties of the porcelain, as the jars are transformed from a virtual heap to a translucent lens.

THE CERAMIC PROCESS
Reusable Mold Cases
Each slip-cast object requires a plaster mold, and when producing multiple molds a custom mold case can save time. To accelerate production, mold cases are produced to aid in making copies of the mold often by using modular rails. There are several advantages to having a case: it can re-used, it can be easily reoriented during the casting process, aids can be mechanically fastened to it, and it makes it easier to correspond information between the digital model and the mold (Figures 4, 5 & 6). The pour cups, the case, and the positive were integrated into a single digital model. This made it possible to compute the part lines, and guarantee against undercuts that might trap the positive.

A waterproof plastic liner is constructed inside the case. Each of the mold parts is designed to meet along a part line. At the interface between each mold part is a ‘part face’. The mold for Dunejar II consists of four parts that are held together by friction; two internal plugs and two longitudinal halves. As the mold is cast none of the parts are removed until the entire mold is complete. As the plaster crystallizes, it expands less than 1 percent. This allows parts to expand tightly against each other. This is a design concern when determining the sequence for casting the mold parts, and it is the primary reason for casting the internal parts first (Figure 12). The expansion of the plaster can push adjacent mold parts off of the positive. When designing the case, and the sequencing of the pours, the expansion is utilized in such a way that the plaster expands inward, onto the plugs, insuring a tight fit between all of the parts. This property of the material is leveraged to produce extremely high tolerances that cannot be matched by milling when the mold is comprised of interlocked parts.

As subsequent mold parts are cast, they are lathered with three coats of soap foam to insure that the plaster parts do not bond. Where each part meets the positive, a raised seam is present on the surface of porcelain, and while these can be easily removed with a damp sponge, they can reappear, or ‘telescope’ after the part is fired (Figure 15).
Piercings through the sidewall allow for varied wavelengths of light to mix on the outside surface of the jar, 2019.

A cross section showing the narrow neck that provides a light baffle between the upper and lower portions of the jar, 2019.

A cross section showing the opposing orientation of the tapered edges of the concave (left side) and convex lenses (right side) and the shallower stepped lenses, 2019.

This is a product of the crystalline structure of the material as it flows into the seams, and it cannot be removed. To keep the number of seams to a minimum, the number of mold parts is minimized. Additional mold parts are only added if they are required to release the porcelain from the mold due to undercuts.

Pour cups are designed to cast the internal parts of the plaster according to precise draft angles (Figure 6). Typically, these partitions are made by hand from clay or wax, and discarded. The Dunejars are the first implementation at the EKWC to use a full set of digitally fabricated pour cups and case. Given the tolerances of the mold, recasting the initial parts is often necessary, and the cups save time.

To reduce the adhesion of the plaster to the plastic 3D filament, the interior faces of the cups are sanded, and coated with several coats of acrylic sealer. Each cup is designed with flanges that allow it to be fastened to the mold case. This insures that the mold parts do not come loose as the mold is rotated during the casting process. The 3 mm sidewall of each cup is designed to conform to the positive with a beveled edge. To ensure that the plaster does not leak out at the base of the cup, a continuous wax bead is inserted between the beveled edge and the positive. After the plaster is allowed to set for two hours, the cups are removed. The faces of the plaster are then shaved flat to insure that they will release during demolding. A third cup was used to define the pour hole for the porcelain slip. It is located at the base of the positive, and is designed to leave a large opening in the base of the mold. The mold case is designed with six removable plywood sides that allow the setup to be rotated and poured from four sides (Figure 4).

Plaster Molds for Porcelain

The production of porcelain molds is a complex design problem that extends beyond the casting of the object and the removal of the clay from the mold. A superior mold design must take into account the behavior of the material, and its tendency to deform due to its molecular structure (shape memory), its shrinkage when drying, or its plastic deformation during firing. Each of these behaviors are contextually specific, and they propagate in response to the morphology of the object at precise moments in the process. The single most important priority when designing a porcelain mold is to isolate these forces so that they cannot act in tandem on any particular area of the part.

After the mold was completed, it was determined that only one of the continuous edges along the bottom of the jar is prone to warping during firing.

To remedy the warpage, a plaster plug was designed to provide a continuous ‘J’ shaped flange along the bottom lip of the jar. This new mold plug was set within the initial pour hole. A digital model was made, and a plaster blank was cast for the part. After four days the plaster was completely dry, and the plug was milled. Air holes, and a pour hole were machined into the part, and their surfaces were coated with shellac. The plug was hand finished until it fit securely inside the pour hole at the base of the plaster mold. The unpredictability of the porcelain required for some parts of the mold design to be modified, and this was facilitated through the integration of the digital model. Recasting a mold part is difficult to achieve using manual methods, and it prohibits the use of the mold. The CNC milling of the plaster mold is another example of how
these methods were combined to introduce feedback loops during the mold making process.

Porcelain Slip Casting
In addition to precise molds which require minimal finishing, the casting of the slip is what distinguishes a superior piece. Once fired, the porcelain shrinks between 12-14 percent. Porcelain has an uncanny memory, and it will return to its deformed state. It is common for deformations that are introduced during demolding to re-emerge in the work when it is fired. This was further complicated by the jar’s asymmetry—more surface area on one side introduces different shrinkage rates, and this causes stress in the part. Careful management of the drying process, and procedural consistency are essential. Fresh plaster molds need to be used several times before the parts will release cleanly, and this is a natural sequence which makes the mold more porous over time. Plaster molds will yield roughly 20 parts before the salts in the clay begin to erode the details. With the Dunejars roughly 10 to 12 percent of the bisque fired parts are of exceptional quality, and this ratio meets the usual yield for fine porcelain. Additionally, parts can be lost during the second fire when they are glazed.

The process of slip-casting is carried out by pouring liquid clay into a plaster mold. The plaster is essential as it absorbs the water from the clay, and after a short period of time the slip is emptied out of the mold leaving a thin layer of clay on the inside surface of the mold. The longer the slip remains inside the mold the thicker the sidewall becomes. Tests were made ranging between 5 and 17 minutes until the desired thickness of 3-4 mm was achieved. The pieces with 3 mm sidewalls remained in the mold between 12 and 14 minutes (Figure 8).

There is a balance that has to be maintained between the strength, and the translucency of the porcelain, and this tradeoff cannot be fully determined until pieces are fired. Because a high kiln temperature is required (1230° C) to achieve the glass-like translucency the jar becomes plastic as it soaks at peak temperature. At 1225° C the mass of the upper bulb began to sink into the cylinder. To counter this a series of counter-molds, and support matrices were introduced.

Prior to pouring the slip, the mold parts are secured using mold straps. Great care must be taken to insure the mold is free of debris, and that all of the parts are properly aligned. Misalignment of one part can cause the parts to lock together with slip, or the mold parts can be forced out of position, resulting in leaks, pronounced standing seams or raised faces. Initially these casts were discarded, or fired as tests, but as the work developed some of these side-effects were incorporated into the jars. The mold is filled with a measured volume of slip through a very small opening, and it must be filled at the highest flow rate possible, without splashing, to insure against pour lines. If the speed of the pour fluctuates it will leave streaks in the piece. Air holes are located in the pour plug to insure that any air left inside the mold is chased out of the chamber as
Dunejar II. Plaster casting in the case. The two internal keys are cast first prior to being encased in the subsequent pour. Sundaymorning@EKWC, 2018.

Dunejar I. Plaster mold. The part lines are calculated on the digital model and are mapped to align with the demolding axis of the individual mold parts. Sundaymorning@EKWC, 2018.

Dunejar I. Slip casting. The porcelain clay prior to its removal from the plaster mold. Sundaymorning@EKWC, 2018.

Dunejar I. Finishing. Any raised seams (roughly 0.5 mm wide) are chased with a razor after the porcelain is leather-hard. Sundaymorning@EKWC, 2018.

Similar care has to be taken as the excess slip will also streak the sidewalls of the part if it is not completely emptied out. The slip has the viscosity of melted chocolate, and the surface coating has to be distributed evenly throughout the chamber to avoid splatters of streaks on the interior surface. These leftovers become visible when the jar is backlit. They can be prevented by rotating the mold upside down in a circular motion for several minutes until the chamber is completely emptied.

Finishing
The mold is then set upright on a flat surface, and a sharp knife is used to cut the exposed edge of the part away from the mold. This reduces the surface stress in the clay, making it less likely to crack along its edges as it begins to shrink. It was determined that the jars should stay in the mold for sixty to seventy-five minutes before it is demolded. This provides adequate time for the clay to shrink inside the mold. The smaller plugs are removed first, leaving the two...
larger halves of the mold. It was determined that as the clay shrank it was more likely to grab onto the convex surfaces in the mold. For this reason the concave side of the mold was removed first. At this point in the process the clay is leather-hard, and it is ready to be removed from the mold.

With the piece resting in the last part of the mold it is turned upright and the part is pushed out of the mold using compressed air (Figure 14). The jar was pitched upright onto a level drying plate set with cotton fleece. Over the next 24 hours the piece hand is finished. This requires the open edge at the base to be trimmed and leveled off. Any raised seams on the detailed areas are first chased with a knife, and then sponged smooth (Figure 15). The final step involves the piercing of the holes. Each jar has between eight and thirteen holes positioned on the convex side. It was common for the sharpened edges surrounding the holes to shear off if pressure was applied to the clay, and in some cases the chips were restored by hand. To avoid this, the clay was routed rather than pierced, and this allowed the excess clay to be removed from the hole (Figure 16). This was carried out in four stages, first using a 1/64" bit, followed by a 1/32" spherical engraving bit to carve a hole through the sidewall (Figure 16). Each hole was then shaved using the cutting edge of a 1/8" routing bit, and then a cylindrical jeweler’s file was used to shape the concave hole into an inverted cone. For the larger holes, wooden cocktail skewers were used to shape the neck of the hole, and polish the clay.

Opportunities for Development
The capability to pre-calculate the part lines with the 3d model provides a means to integrate any fairings and part plates into the positive prior to 3d printing (Figure 13). This would reduce setup time by limiting the number of parts inside the mold case, but would be at the expense of having the flexibility to make changes that come with having a complete positive.

The potential to directly mill the molds is an area for further research. CNC milling is used at the EKWC to produce molds. The mold plugs, and a series of counter-molds were successfully milled for the Dunejars. There is some loss in fidelity, versus 3d printing, but the mill can eliminate the need for 3d printing a positive. The first step involves casting a plaster blank. In some circumstances the time savings are offset by the casting of the plaster, and the time that it takes to dry depends upon the size of the part. Large blocks of plaster are difficult to cast without air entrapment. However, milled plaster is more porous than cast plaster, and it can be put into production more quickly. The challenges for keying milled molds increases dramatically.
as soon as more than two parts are required, and more
digital coordination is needed to mill separate parts that
‘jigsaw’ together.

There is also potential for bonding conductive decals, and
nano-inks to the porcelain. Currently the only way to apply
them is by hand, spray or brush. Because decals are water
borne they are slippery, and difficult to position on the
glazed surface. Their placement on complex surfaces is
currently unfeasible. The use of CNC for the deposition of
inks, or the robotic application of the glaze would be highly
beneficial.

CONCLUSION

There is skepticism surrounding the identity of the Dunejars
from ceramicists and computational designers alike. For
traditional ceramicists the jars are not ceramics; largely
due to the agency of the molds there is a sense that the
material appears to has been stripped of its individuality.
It is to this point that Simondon’s theory of individuation
is important. Form is never simply stamped onto matter.

Simondon identifies form and matter as two broken,
technological, half chains that are linked by (or through)
information (Taylor 2007, 9). The Dunejars are enmeshed in
the granular code of the porcelain. By investing the hollow
form of the dunes with a set of transparent qualities, the
dunes are transformed into lithophanic lenses. From this
perspective, the Dunejars are technically, and aesthetically
situated within the ceramic process.

When considering the role of computation there is the
burning question as to ‘why porcelain?’ The source of this
question often implies that computation is immaterial. To
understand this, it is important to return to Bateson’s intro-
duction of grace in cybernetics. Bateson identifies grace
in the work of art as ‘psychic integration’ or a balance
between the conscious and unconscious mind. With the
Dunejars there is a deliberate intent to fuse the conscious
presence of the computation (style) with the unconscious
(code) so that they cannot be easily peeled apart or
decrypted. Graham Harman refers to this type
of aesthetic experience as allure.

So, ‘why porcelain?’ It is a material ecology with its own
unique inputs, outputs, and qualities. This ecology is the
source of the code, and without the direct interaction
with the material the Dunejars would likely not exist. The
second concern is that computation is inherently immate-
rial, and its effects don’t involve matter. Information is not
autonomous, it belongs to an ecology of things. The role
of computation in the design of the Dunejars is to expand the material’s history by placing the virtual qualities of the code into a direct confrontation or acknowledgment with the material’s qualities. To this end, the virtual information serves as a mirror to identify knowledge and reshape the material’s future.

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NOTES
1. Lithophanes were not solely European inventions. Margaret Carney has identified a small mould-made Parian ware cup produced in China circa 1800.
2. Regarding aesthetic experience Graham Harman identifies the confrontation between real objects and their qualities as allure, “...an intimate bond between a thing’s unity and its plurality of [specific qualities] somehow partially disintegrates.”
3. Simondon identifies the concretization of forms as a technical process that evolves over time.

REFERENCES


Rhett Russo currently serves as the Undergraduate Chair in Architecture at RPI. He received his Masters of Architecture from Columbia University. Rhett has received numerous awards: The SOM fellowship, The Van Alen Institute Dinkeloo Fellowship at the American Academy in Rome, and the Young Architect’s Award from the Architectural League of New York. He is a former resident of the European Ceramic Workcenter, where he combined digital technology with ceramics. His work has been exhibited internationally at Object Rotterdam, The San Francisco Museum of Arts and Crafts, the Design Museum Den Bosch, and the Cluj Ceramics Biennale.