The architecture of the Nordic Marble 'left-over'

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"There is no waste in stone. There never was waste in stone." Pierre Bidaud, stone mason[1]

Marble, quarry waste, and the 'left-over'

The age of industrialized building processes–what has been broadly characterized as "take, make, waste"–is rapidly being reconceived as a circular system that redirects excess or discarded material flows back into the construction economy. Through the creative conception of new products and building systems, architectural design plays a critical role in increasing value around what was previously waste.[2] Dimensional stone quarries are some of the worst offenders, with some marble quarries yielding up to 80% waste. A limestone or granite quarry with a high recovery rate (over 50%) may still yield only 20-25% of material being used for dimensional blocks, with the remaining quarried material down-cycled into crushed aggregates.[3] There remains, even under the most favorable circumstances, a considerable problem with quarry waste.

The marble quarry in Fauske, Norway, from which the material in this project is taken, finds buyers for only around 20% of the marble it breaks from the earth. Most blocks are rejected based on color, size, or quality (e.g., cracks, chips, or heterogenous elements).[4] A recent focus on non-renewable materials in architecture has started to examine the discipline's role in promoting extractive practices.[5] Solutions point toward a greater emphasis on re-use and repair, in opposition to the taking of new materials out of the earth. Decorative materials such as marble draw particular ire, being hard-coded with associations of luxury and material excess.

As the stone mason Pierre Bidaud cleverly suggests above, however, the problem is not one of waste, but rather one of approach. Marble today has been reduced to a luxury finish whose extraction practices are almost entirely on Marx's notion of "externality".[6] A marble sink in a London bathroom leaves a tiny hole somewhere in Carrara, Italy, and the pockets of the Bin Laden family owners get a little fatter.[7] This represents an extremely narrow use-category for what is one of history's most widely admired materials, prized for its heterogeneous depth, aesthetic imagination and cultural associations. The (literally) superficial approach currently

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[1] Personal interview, August 24, 2022.
[2] Dirk E. Hebel, Marta H. Wisniewska & Felix Heisel, *Building from Waste: Recovered Materials in Architecture and Construction,* Birkhauser, 2014; Caroline O'Donnell, Dillon Pranger, eds. *The Architecture of Waste: Design for a Circular Economy*, Routledge, 2020.
[3] Ana Claudia Neri, Luis Enrique Sánchez, "A procedure to evaluate environmental rehabilitation in limestone quarries", *Journal of Environmental Management* 91 (2010): 2225-2237.
[4] These are anecdotal statistics based on field interviews in the Fauske quarry.
[5] Joseph Grima, "Design without Depletion: On the Need for a New Paradigm in Architecture", in: *Non-Extractive Architecture, Vol.1: On Designing without Depletion*, edited by Space Caviar, Steinberg Press, 2021.
[6] Karl Marx, *Capital*, vol. 1, Vintage Books, 1977, p. 638; Space Cavier, ibid.
[7] Veronique Mistiaen and Chiara Briganti, "Michelangelo's Marble is Being Sold Cheap by Industrialists", *Newsweek*, March 27, 2015. https://www.newsweek.com/2015/04/03/bin-ladens-and-tuscan-city-destroyed-marble-317224.html; Francesco Durante, Markus Kröger, and William LaFleur, "Extraction and Extractivisms: Definitions and Concepts", in *Our Extractive Age: Expressions of Violence and Resistance*, edited by Judith Shapiro and John-Andrew McNeish, Routledge, 2021.

driving the marble industry furthermore discounts completely the structural capacity of the material, which persists in every fragment of marble, no matter the size, shape or color.

So, the problem is not only about plugging waste back into the circular economy, it is also about re-framing completely how we imagine what is waste in the first place. Following this, we prefer the term 'left-over' rather than 'waste', in a subtle ploy to shift the terminology by which we speak of marble, or any other industrialized material, for that matter. We wish to move away from a productivist mentality focused on such dichotomies as useful/useless or sellable/non-sellable, mental processes that underwrite site intensive, global extractivist practice. The 'left-over' derives from cooking, where preparing with left-overs means to cook with anticipation to the next meal. In Italian, left-overs are called '*avanzi*' (fr. *avanzare*: to advance; move forward), which captures the notion that cooking today is also potentially valuable for future meals. This is a fundamentally different approach than the idea of food waste, which unimaginatively conceives of food as an inefficient stream of capital- and labor-intensive inputs and outputs.

Three 'turns' in *Wall One*

For marble, the notion of the left-over invokes the potential to utilize every fragment of marble that is quarried, no matter the size, color, patter or texture, and to transform it according to specific imaginaries and concrete conditions. *Wall One* was conceived as a demonstration of concealed potentials and an attempt to see marble as a heterogenous material of aesthetic imagination and structural possibility. The chosen marble originated in Fauske, Norway, in one of the earth's most northern, active marble quarries. The Fauske quarries produce several types of marble, all characterized by a complex, layered geology that is immediately read in the patterns and colors.[8] We specifically chose what is known commercially as 'Norwegian Rose', a white-pinkish clast with hints of green and orange. To prepare, we visited and performed a photogrammetry map of the quarry, and noted, among other landscape features, the propensity of large, magnificent marble blocks used for otherwise pedestrian uses, such as retaining walls and fencing. Several, forlorn caches of 10+ ton blocks sat near the quarry entrance, rejected by potential buyers because of their color, patterning or cracks. Piles of smaller fragments were scattered about the site, destined for the gravel crusher and the suburban gardens of northern Europe.

From such a visceral experience, we re-conceptualized these waste pieces as 'left-overs'. This involved inspecting individual fragments, valuing them for their specific qualities, and choosing a small sample to return to our workshops in Aarhus. In so doing, we activated three 'turns' away from prevalent assumptions behind marble in architecture.

The first 'turn' was toward the historical and cultural imagination of marble, which gave rise to practices such as book matching, and to the relation of color and pattern to localized geology and landscape. So much of marble's intrigue has to do with its visual impact and how architectural and sculptural programs responded to it, as well as to the associations made between marble and its site of origin.[9] The second 'turn' was related to the first, but focused

[8] V.A. Melezhik, T. Heldal, D. Roberts, I.M. Gorokhov, A.E. Fallick, "Depositional environment and apparent age of the Fauske carbonate conglomerate, North Norwegian Caledonides", *Norges geologiske undersøkelse Bulletin* 436 (2000): 147-168.
[9] Dario Gamboni, Gerhard Wolf, Jessica N. Richardson, *The Aesthetics of Marble: From Late Antiquity to the Present*, University of Chicago Press, 2021.

on the special capacity of marble to capture and transmit light–its translucency. While prized in the pre-modern imagination as window into spiritual light, called *lux*, today translucent marble is mostly experienced as kitsch and garish, belonging to corporate office lobbies and upscale hotel bars. We sought to expose the mysterious and captivating attribute of marble's crystalline interior, where the signature pinkish-red interior of Norwegian Rose, immersed within a matrix of snow-white-dolomite, offers a dialectic between hot and cold, fire and ice. And finally, for the third 'turn', we insisted that marble be released from its predominant, visual imaginary and be allowed to freely stack and bear its own weight, i.e., to have a tectonic dimension. The need to stack while minimizing cut-off material drove the formal resolution of the wall structure. A novel solution was found in the ancient roman building technique of *opus pseudoisodomum*, which was a method of structural, ashlar construction (cut and fitted, rectangular blocks, with overlapping joints), that, unlike the more common, *opus isodomum*, relied on variable, horizontal courses.[10] As in ancient Rome, the horizontal course variation allowed masons to optimize their labor and material use from a heterogenous group of stone sizes.

The making of *Wall One*

New technologies in digitization, robotic fabrication, and computational analysis offer the possibility to capably process small left-overs and re-engage with marble's historically-embedded fascinations and structural capacities. There is an integral link between *Wall One* as a demonstration of the three turns described above and the procedural developments that drove its making. What follows here is a short elaboration.

As previously argued, the appropriation of the marble left-overs began in the quarry. Our criteria were to work with between 100 and 150kg fragments (for ease of handling), gleaned from the quarry floor. We limited ourselves to Norwegian Rose, which was mixed among other varieties, and sought visual variation in grain pattering and color. These were crated and shipped to our workshops at Aarhus School of Architecture.

The first step was to rough cut the fragments and digitize them. This began by slicing each one into 70mm slabs, using our custom-built, robotic wire saw. Slab orientation was determined by the following, in order: a) the pose of the fragment, or how it naturally rests on the table; b) grain direction, ensuring that we slab-cut parallel to the grain, to achieve the most expressive patterning; and c) ensuring the maximum number of 70mm slabs. Following this, each slab was digitized using a FARO scanning arm. By probing 20 to 30 points along the top and bottom edges, a low-resolution representation of the slab perimeters provided the basis for a simple, 3-dimensional vector drawing of each slab.

The next step was to digitally sort and stack the slabs, and to outline a formal proposal for the wall based on our specific set of slabs, our slab catalogue. The digitized slab catalogue was fed into a Grasshopper definition that made stacking and sorting suggestions based on the constructive order of *opus pseudoisodmum*. Unlike the romans, however, *Wall One* employed the *opus* in a vertical, rather than horizontal fashion. Based on a user-variable set of parameters, the stacking and sorting definition determined the absolute minimum amount of aggregated cut-off needed for any possible wall constructed from our slab catalogue. The amount of aggregated cut-off was further conditioned by three parameters: overall wall height (we wished for around 2 meters), width (around 1 meter), and grain direction (all

[10] Vitruvius, *The Ten Books on Architecture*, translated by Morris Hicky Morgan, Dover, 1960, p. 52.

predominant grain directions were oriented vertically). An additional shuffling function allowed for us to choose from one of several possible solutions.

With the wall sorted and stacked, each individual slab could be re-defined as a rectangular block that, when taken in terms of the entire wall system, was guaranteed to produce the smallest, localized cut-off possible. The rectangular geometries provided the basis for a second operation that determined a ruled surface subtraction, performed again with our robotic wire cutter, that exposed a small patch of translucency. The geometry of the cut followed the same parabolic function but varied according to the individual block dimensions, achieving a consistent 4mm block thickness at the bottom of each block.

Once sorted and stacked and readied for wire cutting, each fragment was exported for fabrication. Fabrication instructions included the block dimensions and orientation within the rough slab, as well as locations for necessary trimming instructions. Here, the robotic fabrication environment proved invaluable, allowing us to perform multi-tool operations on each fragment without having to move it. First, the slab was mounted to the work table with suction cups and, using an Opti-trak camera system, coordinated with the digital workspace of the robotic environment. After calibrating our water pump and circulation systems, a spindle-mounted diamond bit trimmed the slab into a rectangular block. After a tool change, the robotic wire saw applied a single, ruled-surface cut. The block was removed, the edges filed, and a light soap-like finish was applied to protect it from handling and emphasize the vein patterning.

The fabrication of *Wall One* has itself produced its own left-overs, albeit much smaller and more specific than our starting set. In the spirit of the project, we decline to categorize these fragments as ‘waste’ (including the marble dust) and have carefully catalogued them in wood pallets, prepared for a future project.