PROCESSES OF CREATING SPACE

An Architectural Design Workbook

GEORG RAFAILIDIS AND
STEPHANIE DAVIDSON

Processes of Creating Space

Processes of Creating Space is a workbook for beginning designers that shows how to generate space with user experiences in mind. It explains how to keenly perceive your world and seamlessly integrate architectural representation into your design process. The book uses two main strategies, blending the design process with material processes and media techniques and "experiential typologies"—emphasizing first-hand experience of space. Five highly experimental assignments explore the interwoven relationship between design process and design tools, to help you learn when to incorporate writing, architectural photography, macro-photography, orthographic projection, perspective projection, hand-drawing, CAD, mass modeling, hot wire foam cutting, 3D modeling, multi-part plaster mold making, slip casting, plaster casting, paper casting, *monocoque* shell structures, working with latex, concrete, twine pulp, full-scale prototyping and more. Illustrated with more than 350 color images, the book also includes a section on material fabrication techniques and a glossary of technical terms.

An eResource containing downloadable essays, stop-motion videos, sample schedules, and supplementary information can be found here: www.routledge.com/9781138903685

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"Designing in the first place is thinking and a matter of organizing your creative powers. This book by all means will be helpful in this respect."

—Herman Hertzberger, Architect and Professor Emeritus, the Netherlands

"Processes of Creating Space provides an intelligent and thoughtful manual for students and practitioners alike, combining both the practical and intellectual studies in an exciting and challenging way."

—Rachel Whiteread, Artist, UK

"Not to dismiss the quantity and qualities of all the current means to explore and express architecture, Processes of Creating Space privileges re-enacting site specific discoveries and material media experiences to unfold one's own personal elements of language as a proper foundation to the complexities of today's architectures and cultures."

—Jacques Rousseau, Architect, Prix de Rome, Montréal, Canada

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Stephanie Davidson

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1 Introduction

1.1 Generating/Forming/Rethinking Space: Beginning Design Textbooks as Quiet Manifestos

The first year of studying architecture is packed with an introduction to an extraordinary range of skills to acquire and knowledge to digest. To integrate this range of skills and knowledge into design projects is a further challenge for students and instructors alike. This challenge is amplified by the fact that beginning design is often taught by teaching assistants and new faculty. In light of this, *Processes of Creating Space* radically rethinks the format of design-related courses and proposes the following strategies:

- First, seamlessly integrate the content of media classes with design studio to allow for productive synergies between the two to reduce redundancies.
- Second, propose a manual-like syllabus that makes use of the form-generating potential of media instead of its strictly representational use. In the exercises composed in chapter 3, "Manual of Spatial Processes," media is deployed to generate work in an "automatic" (similar to "automatic writing" in surrealism) manner, avoiding the common issue of starting on a blank page. This makes sure that there is consistent momentum and output in the design process, and always something to talk about for students and instructors as well.
- Third, intentionally focus on first-hand experience instead of abstract theories in this early stage of design education. Following this workbook, students engage in a design process that emphasizes the use of found situations (the outcome of media/material processes) and sharpens their perception and observation skills as designers. Students flip constantly back and forth between an unexpected outcome of a material process and its subsequent evaluation. This situation between chance and control is one that architects find themselves in constantly, and is well worth exercising from the start of an architectural education.

This book can be used like a tourist guidebook. The second chapter gives background information on the subject of architectural design. It describes the objectives and the methods supported by the book. The third chapter offers a series of five "guided tours" or exercises by which students exercise and train five distinct design processes. These exercises form a continuous multi-layered design process with a cumulative build-up in complexity. It is followed by a chapter with practical information containing detailed technical instruction on each newly introduced media and material process. At the end of the book students will find a glossary explaining the architectural and technical terminology introduced in the book.

The third chapter, with its five exercises, forms the heart of the book. The first exercise focuses on the direct experience and perception of space (3.1, "Experiential Assessment of Space"). **(1.1)** In this exercise, students leave their workspace and

roam the city equipped with a camera. The second exercise focuses on the graphic language of architectural drawing conventions (3.2, "Survey of Space"). **(1.2)** Here, students are trained in architectural drafting conventions. In the third exercise, students use a series of solid-void inversions to generate new readings and forms from their survey drawings (3.3, "Solid-Void Inversion of Space"). **(1.3)** Here, students are introduced to a range of new and material-intensive processes. The fourth exercise inhabits the newly generated spaces and trains architectural circulation, programming and spatial typologies (3.4, "Inhabitation and Space"). **(1.4)** The last exercise is done in groups and examines the relationship between form, space and structure at full scale (3.5, "Structure and Space"). **(1.5)**

Ultimately, the aim of this workbook is to encourage a multifaceted reading of space that is experiential, representational and performative. Students start by working with a single, full-scale space, and continue to develop a composition of several spaces that eventually turn back into the full-scale fabrication of a single space. During this process, students will learn to use numerous techniques and media for architectural design. In doing so, students will explore space not as clearly defined, but a rather complex conglomerate of numerous different properties, readings and perceptions.

Figure 1.1
Example of a space, a canopied entry to an office building, chosen by a student because of its strong and specific impact

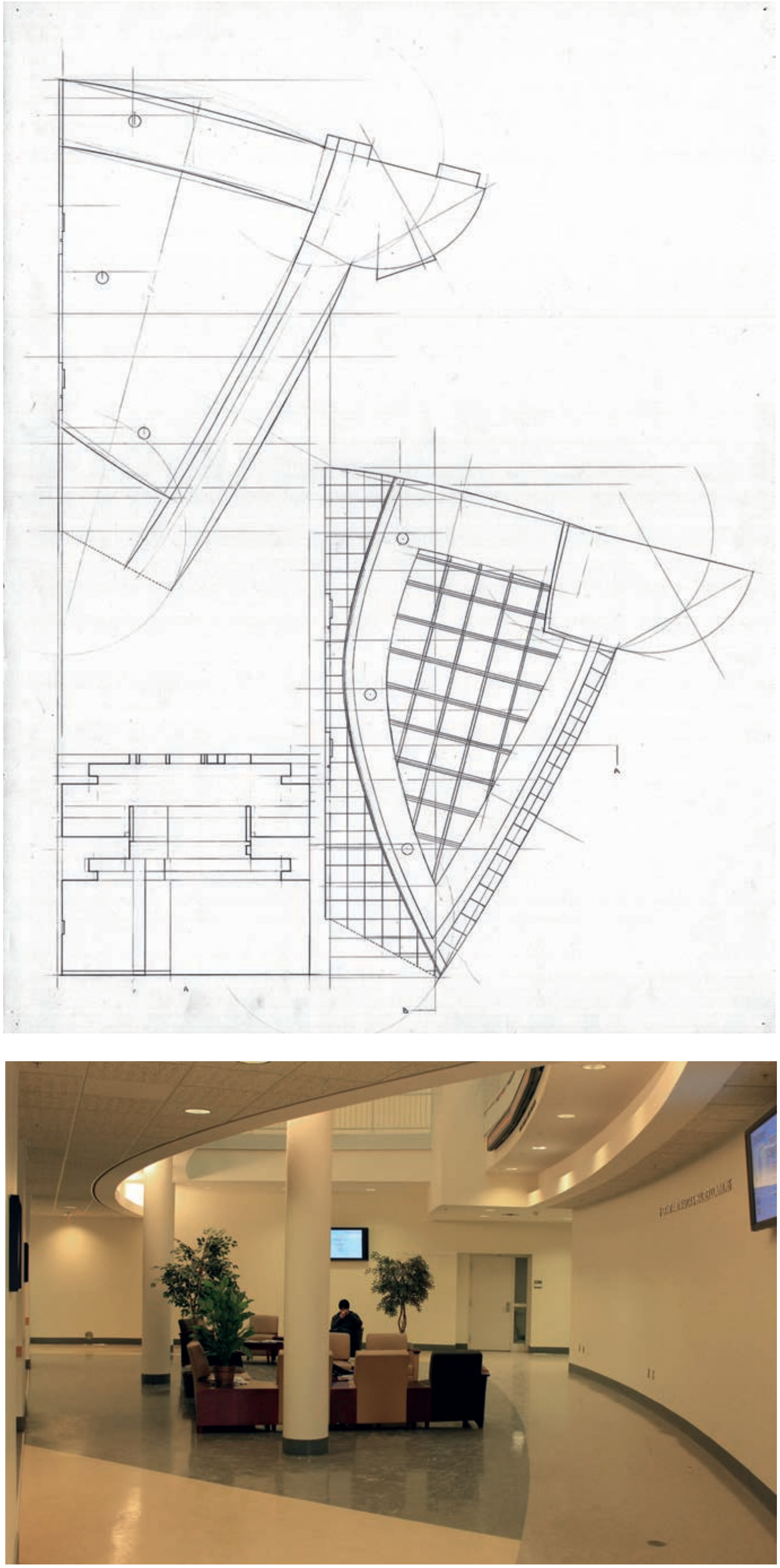


Figure 1.2
Hand drafted survey of a space (top), and the corresponding space, shown as a photo (below)

Figure 1.3
Multi-part plaster mold, partially disassembled, revealing foam mass model

Figure 1.4
Hand drafted sectional perspective of reconfigured mold pieces

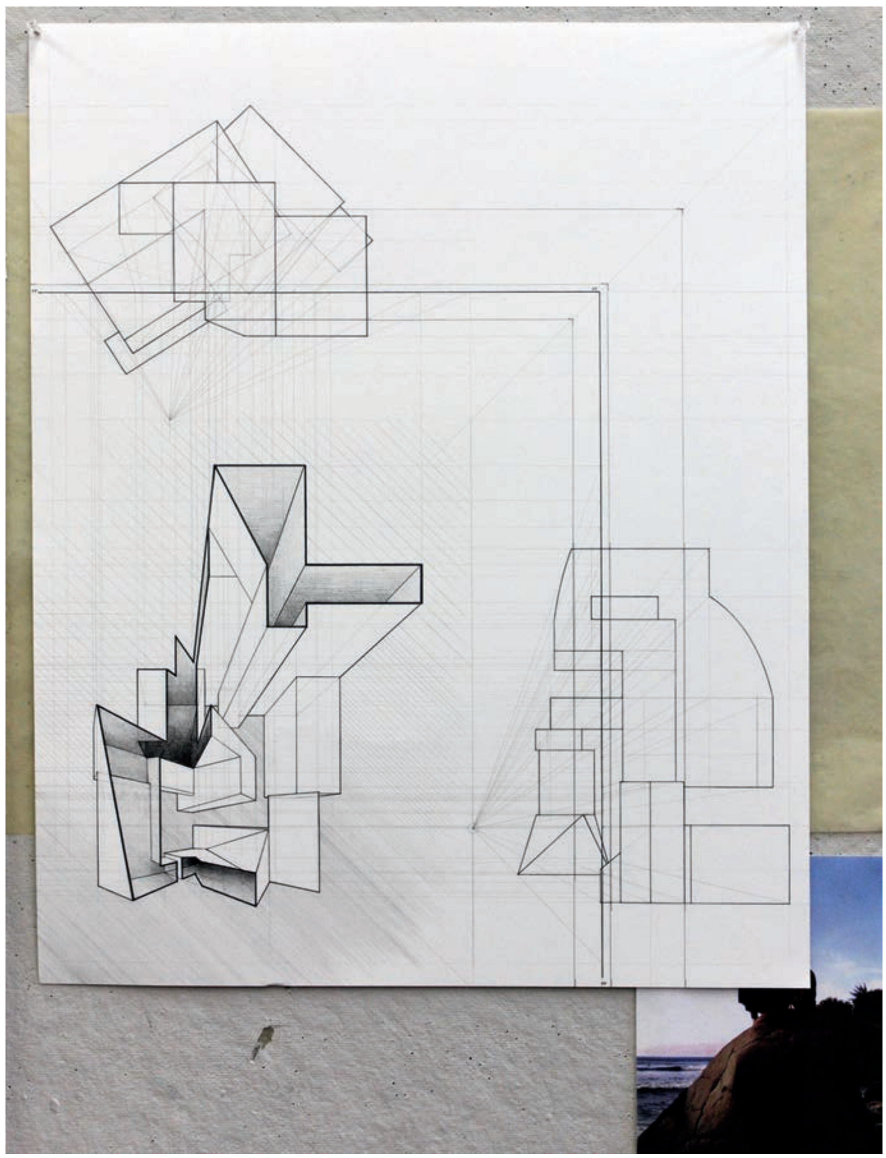


Figure 1.5
Fabrication of a full-scale planar structure using unwound sisal twine mixed with adhesive

1.1 GENERATING/FORMING/RETHINKING SPACE: BEGINNING DESIGN TEXTBOOKS AS QUIET MANIFESTOS

Why devote another book to the topic of beginning design pedagogy?

If architectural design were a stable discipline with a basic skill set, this question would be valid. However, akin to the built environment, the practice of architectural design is fluid and ever-transforming; any position taken with regard to architectural design is simultaneously a position in, and a contribution to, architectural discourse. Architectural discourse is, of course, also constantly evolving, never at rest, and dependent on the production of new positions, convictions, insights and preferences that have resonance with contemporary society. If design pedagogies play a crucial part in forming architectural debate, they need to also constantly evolve to feed that debate.

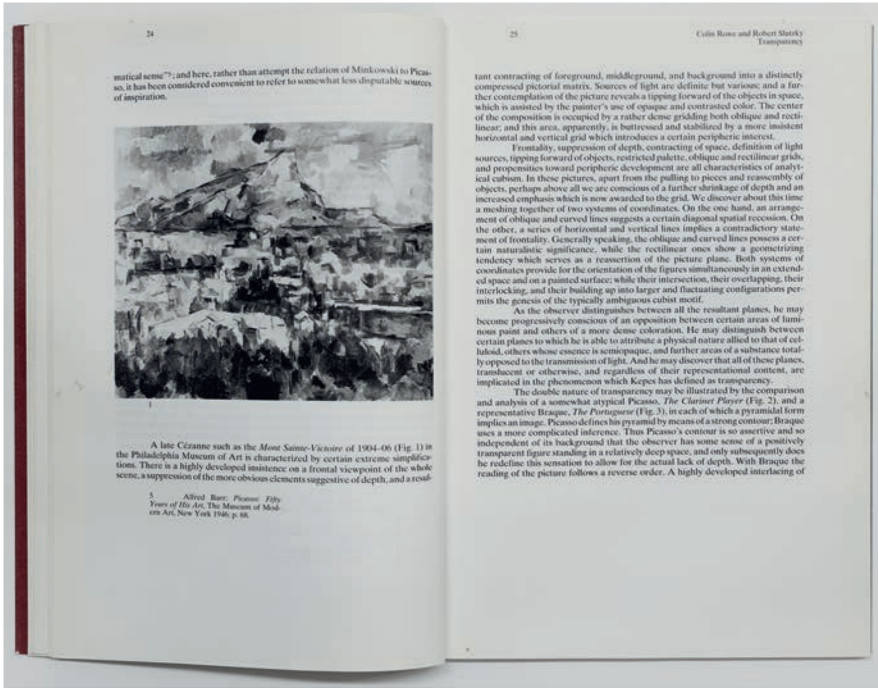
Publications on design pedagogy are especially effective in influencing architectural discourse because their polemic nature is downplayed; they come across as innocent design textbooks, filled with work by students who are just learning how to design. The particular kind of architecture, or the position within architectural discourse, that teachers and authors promote in these textbooks, often evades deeper critical reflection by the discipline. Nevertheless, these design studio pedagogies are potent in promoting architectural positions, enjoying, and maybe even exploiting, their privileged status as students' first institutionalized encounter with architecture. They establish design rituals that will inform the architectural production of prospective architects in a deep way. Some of the students become teachers themselves, amplifying the impact of design pedagogies rapidly.

In order to unravel the intellectual and formal underpinnings of *Processes of Creating Space*, we will look at a few case studies of publications on design pedagogy that informed this book. Each case study introduced aspects into the design process which were new at the time, and, by doing so, offered valuable new impulses to the architectural discipline as a whole.

Transparency

Transparency by Colin Rowe and Robert Slutzky with the relevant commentary and documentation of student work by Bernhard Hoesli and Werner Oechslin is a book that exemplifies how architectural design teaching manuals double as discursive documents. The foundation for the teaching agenda in *Transparency* was laid when Bernhard Hoesli and Colin Rowe started teaching at the University of Texas (UT) at Austin. Hoesli started in 1951 and quickly expanded his influence when he was given the responsibility to reorganize design studio pedagogy. By 1953, he had reorganized the sophomore studio sequence and was directing it according to his ideas.[1] A year later, Colin Rowe joined the faculty and collaborated with Hoesli to further restructure and develop the design studio pedagogy.[2]

John Hejduk and Bob Slutzky soon joined the young UT at Austin teaching movement. Together, they formed the core members of a group which came to be known as the "Texas Rangers."[3] In 1955, Rowe and Slutzky wrote the first version of an essay titled "Transparency"[4] which describes the core principles of the new teaching that emerged at the University of Texas at Austin.[5] Later formalized as a book, *Transparency* claims to be both an analysis of modern architecture's "spatial order," and a design pedagogy or recipe for architectural design, as best described by Bernard Hoesli himself, in a commentary chapter in the book written in 1968:



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matical sense"[5]; and here, rather than attempt the relation of Minkowski to Picasso, it has been considered convenient to refer to somewhat less disputable sources of inspiration.

1

A late Cézanne such as the *Mont Sainte-Victoire* of 1904-06 (Fig. 1) in the Philadelphia Museum of Art is characterized by certain extreme simplifications. There is a highly developed insistence on a frontal viewpoint of the whole scene, a suppression of the more obvious elements suggestive of depth, and a resul-

5 Alfred Barr: *Picasso: Fifty Years of His Art*, The Museum of Modern Art, New York 1946; p. 68.

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Colin Rowe and Robert Slutzky
Transparency

tant contracting of foreground, middleground, and background into a distinctly compressed pictorial matrix. Sources of light are definite but various; and a further contemplation of the picture reveals a tipping forward of the objects in space, which is assisted by the painter's use of opaque and contrasted color. The center of the composition is occupied by a rather dense gridding both oblique and rectilinear; and this area, apparently, is buttressed and stabilized by a more insistent horizontal and vertical grid which introduces a certain peripheric interest.

Frontality, suppression of depth, contracting of space, definition of light sources, tipping forward of objects, restricted palette, oblique and rectilinear grids, and propensities toward peripheric development are all characteristics of analytical cubism. In these pictures, apart from the pulling to pieces and reassembly of objects, perhaps above all we are conscious of a further shrinkage of depth and an increased emphasis which is now awarded to the grid. We discover about this time a meshing together of two systems of coordinates. On the one hand, an arrangement of oblique and curved lines suggests a certain diagonal spatial recession. On the other, a series of horizontal and vertical lines implies a contradictory statement of frontality. Generally speaking, the oblique and curved lines possess a certain naturalistic significance, while the rectilinear ones show a geometrizing tendency which serves as a reassertion of the picture plane. Both systems of coordinates provide for the orientation of the figures simultaneously in an extended space and on a painted surface; while their intersection, their overlapping, their interlocking, and their building up into larger and fluctuating configurations permits the genesis of the typically ambiguous cubist motif.

As the observer distinguishes between all the resultant planes, he may become progressively conscious of an opposition between certain areas of luminous paint and others of a more dense coloration. He may distinguish between certain planes to which he is able to attribute a physical nature allied to that of celluloid, others whose essence is semiopaque, and further areas of a substance totally opposed to the transmission of light. And he may discover that all of these planes, translucent or otherwise, and regardless of their representational content, are implicated in the phenomenon which Kepes has defined as transparency.

The double nature of transparency may be illustrated by the comparison and analysis of a somewhat atypical Picasso, *The Clarinet Player* (Fig. 2), and a representative Braque, *The Portuguese* (Fig. 3), in each of which a pyramidal form implies an image. Picasso defines his pyramid by means of a strong contour; Braque uses a more complicated inference. Thus Picasso's contour is so assertive and so independent of its background that the observer has some sense of a positively transparent figure standing in a relatively deep space, and only subsequently does he redefine this sensation to allow for the actual lack of depth. With Braque the reading of the picture follows a reverse order. A highly developed interlacing of

Figure 1.1.1
Open spread of *Transparency*, showing pages 24–25

So the concept of transparency has consequences in two directions. It gives us first of all the possibility to see familiar historical structures through new eyes, and it frees us, because we allow it, to see buildings and structures in connections independent of the differences between "historical" and "modern": secondly, it is a tool for the production of complex systems of order during the design process.[6]

Rowe and Slutzky applied terms like superimposition, ambivalence and simultaneity, which were used at the time to describe cubist painting, to modern architecture.[7] Their definitions of both "literal" and "phenomenal" transparency are rooted squarely in cubist painting:

> Our feeling for literal transparency seems to derive from two sources: from cubist painting and from what is usually designated as the machine aesthetic. Our feeling for phenomenal transparency probably derives from cubist painting alone; and a cubist canvas of around 1911 or 1912 would serve to illustrate the presence of both orders, or levels, of the transparent.[8]

The position taken in *Transparency* is that certain geometric logics developed in cubist paintings can be extracted from modern buildings and then used as a basis for a design process. **(1.1.1)**

The established faculty at UT at Austin rebelled against the changes in teaching design studio and the Texas Rangers were forced to leave the school by 1958.[9] Forcibly dispersed, the young teachers spread their pedagogical ideas to other schools, mainly Cornell, The Cooper Union and the Eidgenönissche Technische Hochschule (ETH) Zürich.[10] With wider-reaching influence, *Transparency* became one of the key texts used to understand and to design modern architecture. *Transparency* exemplifies the double role of design pedagogy: it served to educate architects and it contributed to the evolution of architectural discourse.

Figure 1.1.2
Open spread of *An Education of an Architect*, showing pages 260–261

Offshoots of *Transparency*

Subsequent publications on design pedagogy rooted in the ideas from *Transparency* consolidated the impact of this pioneering text. The ways of working promoted by the Texas Rangers decades ago are still felt in architectural design courses in many schools today. Under the leadership of John Hejduk, for example, student work from the Cooper Union is famously documented in the books *Education of an Architect: A Point of View* (1971) and *Education of an Architect: The Irwin S. Chanin School of Architecture of Cooper Union* (1988). **(1.1.2)** Since their publication, these books have had a wide-reaching influence themselves, due to what Peggy Deamer describes as, "the aura surrounding . . . John Hejduk, a figure of near messianic allure."[11] The former book served as the catalogue publication accompanying an exhibition of 54 student projects at the Museum of Modern Art in New York,[12] and this prominent location alone is testament to the discursive ambition of this design pedagogy. More recently, the ETH Zürich published two books which can be seen as part of the *Transparency* lineage. Both books document first-year design studio work emerging from courses developed by Marc Angélil at the ETH. Angélil was himself a student of Bernhard Hoesli's *Grundkurs* at the ETH in 1973.[13] *Inchoate* (2004) documents the first-year design studio at the ETH from 1997 to 2004. The selection of guest lecturers and critics (MVRDV, Daniel Libeskind, Frank Gehry and Greg Lynn) places this first-year pedagogy at the heart of the architectural discourse of the 1990s and beginning 2000s. After a critical evaluation of the course work of the first years, Angélil and his team produced the second book called *Deviations: Designing Architecture: A Manual* (2008).[14] *Deviations* documents a significant evolution out of the purely formalistic approach of the earlier decade which was inherited by *Transparency*, toward an inclusion of social norms and pressures. The self-designation as a "manual" also indicates a more pragmatic approach and suggests a textbook-like reading of the book as opposed to *Transparency* or the *Education of an Architect* series, which serve rather as a documentation of past student work. Marc Angélil and his team further developed the design pedagogy

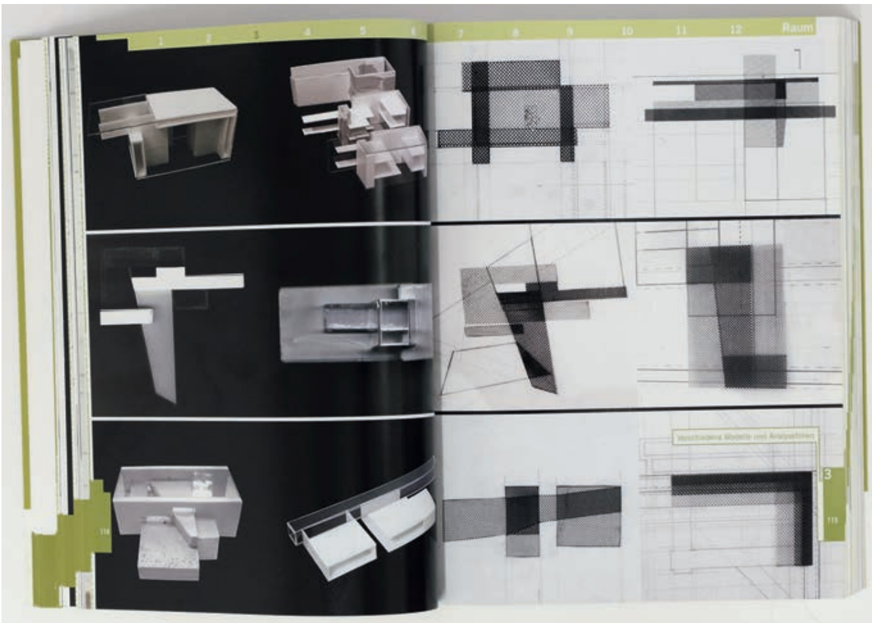

Figure 1.1.3
Open spread of *Deviations*, showing pages 114–115

of *Transparency* so that it addressed contemporary concerns, including themes like program and technology, in first-year course curriculum.

Process-Centric versus Building-Centric Architectural Design Approaches

The pedagogical approach to design in *Transparency* and its lineage focuses on the design processes themselves; it encourages students to critically reflect upon their own design process rather than the designed object, and privileges the overall, abstract, geometric logic of a proposed space over a detailed assembly of building elements. Cardboard models and drawings are the main mode of representation for this way of working. Student work shown in *Transparency* imposes the material and geometric logics of the representational media onto the building scale. How cardboard can be cut and folded, for example, has a strong influence on the formal outcomes of the architectural proposals; cardboard constructs are ends in themselves rather than a stand-in for a fictive building. Student work documented in *Deviations*, a generation following *Transparency*, continues this tendency; the projects break architecture down to abstract geometric forms: planes, lines, cuts and folds.[15] **(1.1.3)** For Angélil's first-year *Grundkurs*,[16] the design process and the educated student are the final product.

In stark contrast to the process-centric approach promoted in books like *Transparency* and *Deviations*, is Valerio Olgiati's book, *14 Student Projects with Valerio Olgiati 1998–2000* (2000).[17] This book, which emerged at the same time that Marc Angélil was teaching the first-year design studio at the ETH, treats architectural media and design processes as subservient to the architectural proposal, the building. Work documented in *14 Student Projects* is all formatted in the exact same manner. All drawings are drawn in a single, thin line weight. This reductive approach to representation diminishes the importance of the drawings to the extent that we are left with the bare building proposal. **(1.1.4)** All process is excluded and

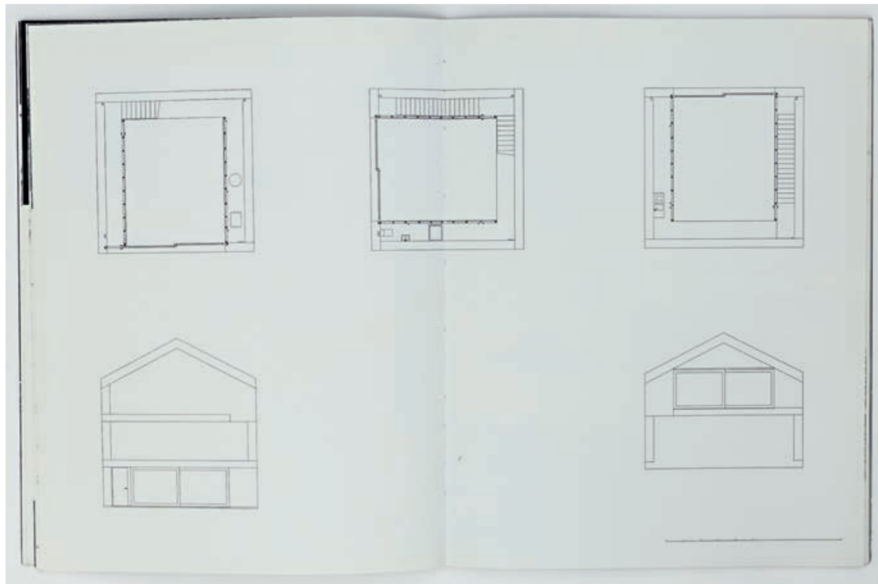

Figure 1.1.4
Open spread of *14 Student Projects with Valerio Olgiati*, pages not numbered

completely opaque to the reader. Looking more closely at each project, one discovers an unusually high degree of resolution to the architectural proposals. All drawings include construction information; the insulation layer, for example, is indicated in all cut views. Architecture here is composed of building elements instead of abstract, geometric forms: roofs, rain gutters, walls, window frames, insulation layers, foundations. The naming of the projects also follows that figurative logic: mountain station with hydraulic platform, high rise building with alternating office and apartment floors, office floors without columns, sports high rise building with granulated rubber façade, architect's office in large garden with two stairs. These project titles, in contrast to those used in *Deviations*, are composed of building elements instead of abstract geometries. Olgiati's design pedagogy agenda insists that architecture communicates ideas and contributes to the architectural field solely through buildings. The rejection of any process work is the exact opposite of the pedagogy of *Transparency*, which focuses solely on the design process.

Processes of Creating Space, its Influences and Aims

Processes of Creating Space, to a large extent, follows the lineage of ETH's *Grundkurs* in focusing on process, but our starting point is different. *Processes of Creating Space* always begins with a personal, first-hand observation of space at full scale and follows Olgiati's insistence on anchoring the design process in the actual built environment. In the first exercise, we send students out of the studio to search for a space that, in their opinion, offers a particular and strong affect. The first exercise fosters a personal encounter with architectural space. By emphasizing the subjective experience we align our agenda closely to the phenomenological understanding of architecture. We would like students to focus on their instinctive, physical first-hand experiences, which cannot be communicated through representational media. These experiences offer an understanding of powerful spatial qualities which are independent of official programs, functions or uses. We encourage students to adopt these spatial qualities as guiding principles in design

Figure 1.1.5
Covers of *Lessons for Students in Architecture* and *Space and the Architect: Lessons in Architecture 2*

instead of beginning with a program or function. In contemporary architectural practice, the lifespan of client briefs, programs and business plans are getting shorter and shorter in comparison to the lifespan of architecture. If architecture is to retain meaning over longer time spans, it has to relate to us through more fundamental spatial qualities. It is for this reason that we employ a phenomenological tactic and rely on the identification of powerful spatial experiences as a starting point for design. We do not promote phenomenology as an end in itself or out of personal preference. The architect Herman Hertzberger addressed the relationship between specific spatial qualities and building longevity and flexibility in a similar way in his teaching at the Delft University of Technology (TU Delft) from to 1973 to1999.[18] As an architect, he is firmly rooted in architectural structuralism, but the role of phenomenology in his thinking is indicated in his two design pedagogy publications: *Lessons for Students in Architecture* (1991)[19] and *Space and the Architect: Lessons in Architecture 2* (1999).[20] **(1.1.5)** These two books document lectures given by Herman Hertzberger at the TU Delft and are also examples of design pedagogy publications which double as architectural manifestos. In *Lessons for Students in Architecture*, Hertzberger introduces the notion of "polyvalence" to describe spatial typologies which could be used in different ways, similar to how a musical instrument can be used to play different types of music.[21] Hertzberger uses mainly photographic documentation of spatial case studies to make his point in his lectures. With these photographs, he captures the atmosphere of each of his case studies. He grounds his assessment of space in the lived experience of the inhabitant, which is a phenomenological standpoint. In *Processes of Creating Space* we call these spatial arrangements "experiential typologies," because geometric descriptions don't adequately describe them. Like Hertzberger, we use architectural photography in the first exercise to document the students' experiential findings.

The role of careful observation figures prominently in *Processes of Creating Space*. The first exercise is meant to be experienced like peeling a film off of your eyes and seeing everything around you in a clearer, sharper, and more detailed way. In the subsequent exercises, we ask students to constantly evaluate and look "hard" at the formal outcomes of each introduced media skill and material process.

We encourage students to draw from what they see and experience around them, and what they, themselves, make. In this way, we aim to avoid the extreme abstraction that happens in process-centric design methods; abstraction that is a valuable and core part of a rich, exploratory design process is made more complex by associating it with real, lived-in spaces. By inviting students to choose their own case study spaces, we invite an uncontrolled variable into the design process. Training students to constantly make sense out of unpredictable, found situations is part of our agenda, as this is, in our view, the main condition of contemporary architecture in an age of flickering, rapidly changing client briefs and business plans.

The format of *Processes of Creating Space* invites multiple uses and readings; it can be read as a critical commentary on contemporary processes of architectural design, and it can be read for its design exercises and technical instruction. The combination of this heterogeneous material, from discursive to pragmatic, aligns *Processes of Creating Space* with the many-formats-in-one-format of *Deviations*, and differentiates it from the more coherent formats of *Education of an Architect*, *14 Student Projects* or *Lessons for Students in Architecture*. In *Processes of Creating Space* we consciously do not distinguish between the technical and the cultural, the why and the how. We acknowledge the active role of media and materials in the design process by merging media and design into an integrated course. The media-specific processes become generative and allow students to understand the close and intertwined relationship between design tools, design process and the physical result.

In Herzberger's *Lessons for Students in Architecture*, he claims that "[r]ecipes for design are impossible to give" and that the aim of his lessons are "to stimulate students, to evoke in them an architectural frame of mind that will enable them to do their own work."[22] Our aim, in *Processes of Creating Space*, is the same. The "architectural frame of mind" that we try, throughout the book, to structure is one through which experiences and spaces are inextricably linked and equally important. What the book aims to show is that space is complex and with multiple meanings, changing constantly, in response to new inhabitants and perpetually changing contexts. Processes for designing space are equally complex—not singular, and not static—but varied, multi-layered and constantly evolving.

Notes

1 Alexander Caragonne, *The Texas Rangers: Notes from the Architectural Underground* (Cambridge, MA: MIT Press, 1995), 7.
2 Caragonne, *The Texas Rangers*, 9.
3 Caragonne, *The Texas Rangers*, vi–vii.
4 Colin Rowe and Robert Slutzky, "Transparency: Literal and Phenomenal," *Perspecta*, vol. 8 (1963): 45–54.
5 Caragonne, *The Texas Rangers*, 157–173.
6 Colin Rowe and Robert Slutzy, *Transparency* (Basel: Birkhäuser, 1997), 82.
7 Rowe and Slutzy, *Transparency*, 22.
8 Rowe and Slutzy, *Transparency*, 23.
9 Caragonne, *The Texas Rangers*, 53–65.
10 Caragonne, *The Texas Rangers*, 334–400.
11 Peggy Deamer, Book Review of Education of an Architect: A Point of View, edited by John Hejduk; Education of an Architect: The Irwin S. Chanin School of Architecture of Cooper Union, edited by Elizabeth Diller, Diane Lewis, Kim Shkapich. *Journal of Architectural Education*, vol. 65, issue 2 (2012): 135–137.

12 MoMA, Cooper Union Student Work in Architecture on View at the Museum of Modern Art. 1971.
13 "Marc Angélil talks about the tradition of the *Grundkurs* at the ETH Zürich and Bernhard Hoesli." YouTube video, 15:51. Posted by "Jonas Meylan," February 15, 2015. youtube.com/watch?v=K5QACx9o85U
14 Marc Angélil and Liat Uziyel, eds., *Inchoate: An Experiment in Architectural Education* (Barcelona: Actar, 2004); Marc Angélil and Dirk Hebel, *Deviations: Designing Architecture: A Manual* (Basel: Birkhäuser, 2008).
15 Angélil and Hebel, *Deviations*, 115.
16 Grundkurs is the German term referring to the foundation course in architectural design.
17 Valerio Olgiati, *14 Student Projects with Valerio Olgiati 1998–2000* (Luzern, Switzerland: Quart Verlag, 2000).
18 Herman Hertzberger, *Space and the Architect: Lessons for Students in Architecture 2* (Rotterdam: 010 Uitgeverij, 1999), back cover.
19 Herman Hertzberger, *Lessons for Students in Architecture* (Rotterdam: 010 Uitgeverij, 1991).
20 Hertzberger, *Space and the Architect.*
21 Hertzberger, *Lessons for Students in Architecture*, 146–151.
22 Hertzberger, *Lessons for Students in Architecture*, Foreword.

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2 Methodology

The design methodology for this workbook was developed out of the conviction that architecture should relate to us through program-independent, experiential and fundamental spatial qualities if it is to retain meaning over time. It is for that reason that the methodology of this workbook privileges first-hand experiences and encourages detailed, varied and idiosyncratic readings of spaces. Although the tasks and the deliverables in the "Manual of Spatial Processes" (chapter 3) and the instructions in the "Manual of Techniques" (chapter 4) are prescribed, the content—the discoveries that the student will make—is not. The very particular, experiential typologies that each student discovers and develops, are open, and rooted in their own personal experiences and insights. The design methodology introduces two main actors with which the student works—a space of their choosing, and an array of materials and media which act as investigative lenses onto their chosen space. Students are asked to cultivate a heightened awareness and sophisticated perception skills in order to extract rich insights and interpretations from their work with their chosen space, and with the outcomes of their Spatial Processes tasks. Students are therefore constantly using different tools for discovery: they will be able to flip between having chance (the outcome of the material processes) and control (their own perceptions and interpretations of the material processes and the resulting artifacts) lead the design process.

2.1 PERCEPTION

With this workbook, students should learn how to use direct, personal experiences of everyday spaces as prompts or as subject matter for architectural investigation and design. **(2.1.1)** The emphasis on working from a personal reading of space is deliberate, since, in the early stages of architectural education, students are not yet immersed deeply in the discipline. Personal connections to space can yield deeper understandings and can therefore be a more inspirational source of knowledge than working, for example, with case studies of notable buildings. Working with everyday surroundings is also meant as a perception-sharpener for students. They work from their subjective experience of a space, which means that they must become more reflexive in their understanding of spaces. Every student will have their own unforeseen subjective reading of space and the resulting richness and heterogeneity of the pool of readings allows students to learn from one another and "see" new things. This approach contrasts with the dogma that buildings are and should be *all about* one key, abstract spatial or formal principle. The main modes of knowledge production encouraged throughout this book include: analysis of personal experience, careful observation of everyday spaces and spatial interaction, appreciation for lived-in spaces, and first-hand discovery of unexpected spatial and atmospheric qualities. From this experiential starting point, students are asked to make very

Figure 2.1.1
Examples of spaces chosen by students because of their strong and specific impact

careful, deliberate observations and critical interpretations of their given situation. The discovery and description of formal and spatial qualities found in everyday situations, which might otherwise go unnoticed, are at the core of this workbook. Students should find that they are, little by little, more tuned-in to spatial situations. Their heightened level of perception and observation should become habitual. This heightened perception should carry over to the work that students produce; we ask students to constantly look closely and evaluate the formal outcomes of their design tasks, which often incorporate new media skills and material processes. This workbook aligns itself, in this regard, with the work of practitioners such as architect Sigurd Lewerentz and artist Rachel Whiteread. Lewerentz's investigations on rudimentary, everyday architectural elements, such as the window opening, gained their power from an unusual rigor in observing and rethinking of these elements. Colin St. John Wilson wrote about Lewerentz's observational skills in his essay "The Dilemma of Classicism":

> It is said that he could sit for a long time just looking at a common nail and asking himself how many ways it could be used—for out of the simple question a surprising answer could come. And we read also of his instruction to a despairing metal worker: All I know is that you are not going to do it the way you normally do . . . [W]hat is at issue for Lewerentz is the search beneath conventional appearance for the shock of a renewed truth.[1]

The idea that a "renewed truth" about everyday things can be revealed through concentrated looking is a potent one. The depth of perception that Lewerentz describes, and the will to see even common things like a nail afresh, is a skill that this workbook tries to build. In the case of Lewerentz, his ability to see things afresh, abstractly, free of associations, translated directly into his architectural work, where elements were often used in subtle and unexpected ways. **(2.1.2)**

Figure 2.1.2
Masonry detail from Church of St. Mark, Sigurd Lewerentz, Björkhagen, Stockholm, 1956, photograph by Adriaan Jurriëns

Whiteread's work also offers an example of how everyday situations can be interpreted in radically new ways and charged with new meaning. Her most noted work, "House," documented in a book by the same name by James Lingwood,[2] transforms an ordinary London terraced house, slated for demolition, into a powerful sculpture by simply utilizing it as the formwork for a cast of its entire interior. Whereas the methodology of casting, producing a solid-void inversion, was a controlled decision and act, the resulting forms were inherited by the existing house. Once the house was demolished and the cast interior revealed, it showed the everyday, unremarkable terraced house in an entirely new light. Without modifying or redesigning the house, Whiteread's project, through its particular method and materials, revealed an embedded character of the space in a fresh way.

Having well-honed, heightened perception skills will also assist students in continually making sense out of unpredictable, found situations. This is, in our view, the main condition of contemporary architecture: fast-changing, based on fleeting, temporal briefs and business plans. Perception is, arguably, the most important skill in being able to look at a given spatial situation and extract a rich, detailed reading of what is there, before beginning to work out what it could become.

2.2 CONTROL AND CHANCE

The balance between control and chance outlined in this workbook encourages students to make sense out of random constraints and qualities, stemming from the outcomes of the media investigations and the introduced material processes. Students are also asked to assemble the materials into a new whole with a clear intention. Using existing spaces and material processes places many things out of the control of the students; however, what they see and what they choose to work with is in their control. Students are in control of framing how they see their work, and filtering out all other possible readings. For example, casting a multi-part plaster mold (4.4) is a very involved and prescribed, traditional material process. The forms that the mold generates are partly the product of control, and partly the product of chance. The model of the space that is invested in the mold is chosen by the student, but not designed by the student; because of this, chance is invited into the formal process from the onset. Within the mold-making instructions themselves, there are a number of options that have formal consequences, and that require very specific and conscious input from the student (how to orient the model on the baseplate, how to define the parting lines for the mold). Evaluating the forms that are generated through mold making (3.3 and 3.4) also requires a heightened awareness and sharpened perception skills to discover their spatial potential. **(2.2.1)** Alternating back and forth between observation and action, inviting chance and taking control is continually trained in this design pedagogy. Being able to work within a set of predetermined constraints is crucial in the discipline of architecture, in which so many parameters are out of the architect's control (e.g. financial constraints, short-lived programs, site restrictions). This unpredictability relates also to the contemporary condition of architecture where its lifespan is much longer than the ever-shortening lifespan of client briefs and programs. Architects have to improvise with existing structures and imbue them with new meaning and use. The ambition here is to also apply this mode of working to the design of newly built structures.

Figure 2.2.1
Multi-piece plaster mold

2.3 MATERIAL PROCESSES

In architecture schools, the design studio is typically prioritized, and assigned more importance than the supporting technical and media classes. The design studio is where critical thinking is learned and exercised, whereas media classes are, more often than not, about acquiring technical and manual skill. The design studio asks the "why," whereas the media and technical courses address the more concrete and mundane "how." This workbook aims to eliminate this hierarchy, and makes media a source of critical, design questioning. For example, students are asked to reflect on questions such as: does the thickness and pliability of cardboard not have a direct influence on the form of design proposals? Bruno Latour and Albena Yaneva also question the preference of abstract thought processes over the more "lowly" technical infrastructure that puts them into form in the essay "Give me a gun and I make all buildings move."[3] They write:

> instead of analyzing the impact of Surrealism on the thinking and design philosophy of Rem Koolhaas, we should rather attempt to grasp the erratic behavior of the foam matter in the model-making venture in his office.[4]

This view, that the material level of working is equally important as the idea level of working, in informing architectural proposals, is supported in this workbook. What we encourage, through the set of design exercises, is that students become aware of how different media can shape architectural explorations and projects.

Latour also criticizes the humanities for privileging the intentional, conscious subject and ignoring the role of inanimate, will-less things. He argues that this split limits our understanding of human activities such as architecture. In *Reassembling the Social: An Introduction to Actor-Network-Theory*,[5] Latour unfolds this critique in further detail. In order to understand social phenomena, which include architecture, he suggests that all agents necessary to perform an event are of equal importance:

> If action is limited a priori to what 'intentional', 'meaningful' humans do, it is hard to see how a hammer, a basket, a door closer, a cat, a rug, a mug, a list, or a tag could act. They might exist in the domain of 'material' 'causal' relations, but not in the 'reflexive' 'symbolic' domain of social relations. By contrast, if we stick to our decision to start from the controversies about actors and agencies, then anything that does modify a state of affairs by making a difference is an actor—or, if it has no figuration yet, an actant. Thus, the questions to ask about any agent are simply the following: Does it make a difference in the course of some other agent's action or not? Is there some trial that allows someone to detect this difference? The rather common sense answer should be a resounding 'yes'.[6]

Following this line of thought, we integrated all required media courses into studio work; like a kettle in the process of boiling water, media are actors in the design process.[7] Materials can be seen as collaborators. Unlike most existing models of first-year design, in which media is taught as a separate course, this book ties specific media to design tasks. The aim is to encourage students to see the intertwined relationship between design process and design tools. Each introduced media skill is employed to investigate space from a new, media-specific angle. **(2.3.1)** And, like all design decisions, media are subject to questioning, invention and change—they are not absolute.

Figure 2.3.1
Full-scale installation, created with a reinforced concrete plane cast against a wall, scored, then tipped off the wall in a structurally strategic way to make an enclosure

Notes

1 Colin St. John Wilson, "The Dilemma of Classicism," in *Sigurd Lewerentz, 1885–1975: The Dilemma of Classicism,* by Hakon Ahlberg et al. (London: Architectural Association Publications, 1989), 7.
2 James Lingwood, ed., *Rachel Whiteread: House* (London: Phaidon Press, 1995).
3 Bruno Latour and Albena Yavena, "Give Me a Gun and I Will Make All Buildings Move: An ANT's View of Architecture," in *Explorations in Architecture: Teaching, Design, Research,* edited by Reto Geiser, 80–89 (Basel: Birkhäuser, 2008).
4 Latour and Yavena, "Give Me a Gun and I Will Make All Buildings Move," 88.
5 Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory* (New York: Oxford University Press, 2005).
6 Latour, *Reassembling the Social*, 71.
7 Latour, *Reassembling the Social*, 71.

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3 Manual of Spatial Processes

3.1 EXPERIENTIAL ASSESSMENT OF SPACE

Description

Experiential Typologies

The first of the five design exercises described in the "Manual of Spatial Processes" section hinges on first-hand experiences of space, a physical encounter with architecture. Being attuned to your personal and direct experience of space is one of the best ways of learning about architecture, as it is instinctive and does not need any previous knowledge. By starting with this phenomenological approach, the intention is to emphasize relationships between people and architecture that are formed independently from any specific use or, as it is known in the architecture realm, "program." These more fundamental, instinctive and immediate relationships to architecture help to define spatial meaning, independent from any short-lived program or client's brief. Because contemporary architecture is characterized by a tension between the long lifespans of buildings and the short lifespans of their functions, we question the idea of designing spaces based on functions. **(3.1.1)** Searching for architectural qualities that characterize buildings, independent of function, allows us to establish an array of experiential typologies—architectural "types" that are classified based on the strong spatial experiences that they offer, rather than the functions that they accommodate. **(3.1.2)** Having the ability to both see and charge architecture with these immediate, instinctive and elemental spatial qualities can be harnessed as a tool to give buildings enduring meaning.

Figure 3.1.1
Example of a function-based typology, now vacant, a strip mall in Buffalo, New York

Figure 3.1.2
Example of an experiential typology, the Richardson Complex in Buffalo, New York, was designed by architect H. H. Richardson in 1872 and opened in 1880 as an "Asylum for the Insane." The building is currently being renovated to house a hotel and cultural center

Sharp Perception

This exercise also establishes a mode of working which runs through all of the design exercises in the "Manual of Spatial Processes." This mode of working relies on sharpened perception and keen observation skills of a given spatial or formal situation. You are encouraged to find spatial qualities and analyze their attributes rather than generating something from scratch. As each exercise uses newly introduced media and material processes as both generative and investigative tools, you will have to constantly interpret the outcome of each media/material process, and look at the product closely to extract new insights about the space. In this first exercise, for example, you are introduced to three distinct media: field study, photography and text. As described in the "Methodology" section, these distinct media will enable you to investigate and reveal particular qualities in your chosen space if you employ the mode of looking closely.

Media Used as Generative and Investigative Tools

But, how exactly do you investigate space *through* media? Different spatial attributes come to the fore if you're physically immersed in a space, as opposed to simply looking at a photograph of the same space. Noting spatial qualities in words introduces again a different set of spatial insights. You could think of a specific media as a tour guide, in that it can show you a space in its own way; the tour given by each media will be unique. Each media has its own processes, potentials and constraints. The constraints *eliminate* certain aspects of your space, while the potentials *reveal* other aspects of your space. Each material-specific process also asks a different set of questions to the space. The particular constraints of photography, for example, including perspective lines, light qualities and angle of vision, and composition, filter the way that you perceive the space both while taking the photo and in the resulting photo itself. Each media tends to reveal qualities which might otherwise be invisible to you. This methodology depends, of course, on your keen observation skills, needed to reveal the potential, media-specific insights. At the same time that media is acting as a lens, by highlighting certain features of a space

and filtering others out, it also acts as a generative tool. In other words, media produces material meaning about the space by describing it in a particular way. The more media that you use to examine a space, the more that you will reveal and produce.

An example of this perceptual use of space is found in the first part of the exercise "Experiential Assessment of Space." This exercise involves a field study that relies exclusively on first-hand experience. By actively roaming your built environment with a heightened awareness of the impact that different spaces have on you, ignoring how a space is used, you can learn how space affects you, and begin to start evaluating space in a qualitative, experience-centered way. This constant scanning of the built environment, and identification of "experiential typologies" of space, should ultimately become habit. The field study should result in a specific space that you choose because of its strong impact on you, a site with which you'll work for the entire series of exercises. Once other media are introduced, your understanding of this space is made more complex. Photography, for example, involves the translation of a three-dimensional space that engages your whole body into a two-dimensional recording that has its own media-specific logic. Understanding the process of architectural photography will make you ask a different set of questions of your space (see 4. 1, "Taking Photos of Spaces"). Architect John Pawson, in his book, *A Visual Inventory* (2012), explains how not just photographers, but also the media of cameras and photos themselves, can often help us see a space in a new way:

> In the usual way of things, architects tend to work with particular photographers because trust in an individual's way of looking at things builds over a period of years. The subjectivity—the human-ness—of the perspective is the point. From time to time, however, technology rather than a particular eye offers new possibilities for seeing a subject.[1]

Writing a descriptive text about the space will, again, draw certain aspects out of the space and reformulate them in words. The work of French poet Georges Perec also stands as a strong precedent for the writing part of this exercise. Perec, particularly in his *Species of Spaces and Other Pieces* (1997), translates the everyday space around him—the streets of Paris, in his case—into an evocative descriptive text. He describes his relationship to his chosen media—words—at the beginning of the book:

> This is how space begins, with words only, signs traced on the blank page. To describe space: to name it, to trace it, like those portolano-makers who saturated the coastlines with the names of harbours, the names of capes, the names of inlets, until in the end the land was only separated from the sea by a continuous ribbon of text.[2]

Both Pawson and Perec describe their respective media as intimate partners in their exploration and inscription of spaces. The key to a successful spatial investigation is not just a mechanical deployment of various media, but rather, striking a collaboration with the media, understanding what it can do, and using keen observation to squeeze new insights out of the results of the exercises in order to experience your chosen space in a complex, multifaceted way.

Intended Learning Outcome

The learning outcome of the "Experiential Assessment of Space" should be that you begin to understand space as a complex, multifaceted entity that can offer lasting experiences independent of use or program. You should begin to establish a mode of working in which your ever-sharpening observation skills are constantly scanning the built environment. You should also begin to establish a mode of working in which you use different media and material processes to make things with the potential to reveal new insights about your chosen space. You should establish, through this exercise, basic skills in architectural photography as well as basic analytical and writing skills using architectural vocabulary.

Exercise

Media 1: Field Study

Roam the city with a heightened awareness of the physicality and materiality of the spaces as well as the effects that they have on you and the inhabitants. Find a space that relates to you in an immediate way. It can be a space in which you feel suddenly comfortable or that triggers your sudden interest for an unexplained reason. Find a space that strikes you as having a strong, specific characteristic. This characteristic should be experiential rather than formal or visual. The relationship between you and the space should depend on your personal experience while being immersed in it. Do not choose the space according to images and representations you have seen of that space. You are not restricted to spaces that you like, or that you deem well designed or beautiful. Rather, you should choose a space based on its impact on you. If it gives you a strong, immediate impression, then it is a good candidate to be your case study space.

The quality of the space could be characterized by any or many of the following characteristics:

- light/darkness
- contrast/shadow
- being abstract, or being figurative
- symbolism
- texture
- materials used
- fullness/emptiness
- richness/austerity
- chaos/order
- views offered
- publicness/privateness
- openings (windows, doors, operable openings)
- connections to the exterior
- proportion/scale
- narrowness/wideness
- highness/lowness
- sensory experience: smell, sound, temperature, humidity, air movement
- circulation
- the age/traces of use
- structural qualities
- clarity/obscurity.

Figure 3.1.3
Examples of volumes that generated a variety of unexpected, new volumes in the mold-making process

Your observations may address some of the above aspects but you are also encouraged to identify and address spatial aspects of your own finding.

The space should be one that you experience in your day-to-day life. Whether or not it is architect-designed is irrelevant. You are encouraged to find unexpected qualities in your everyday built environment through keen observation.

For easy handling in the next exercises, the space should fulfill the following criteria:

- It should not exceed an approximate volume of 20 x 20 x 20 ft (6 x 6 x 6 m) and should not be smaller than an approximate volume of 12 x 12 x 12 ft (3.5 x 3.5 x 3.5 m).
- It should be one to which you have easy access.
- You are also encouraged to find a space which is more complex in shape than a simple rectangular box. **(3.1.3)**

Media 2: Photo

Take one photo of the interior of the space. The photo should serve as a visual support for the spatial quality to which you are drawn. The idea here is not to try to match your experience with a photo, but rather to deepen your understanding of the space through new insights articulated visually in the photo. Neither experience nor a photo work alone, in this case; they are meant as steps toward a rich understanding of your space.

The photo should be printed in color on 11 x 17 in. (or A3) paper, landscape or portrait format. **(3.1.4)**

Refer to 4.1, "Taking Photos of Spaces," and follow these cues when taking your photos:

- The focal length will change the depth and perceived size of your space. Experiment with the focal length of your lens.
- The aperture setting will change how much of your image will be in sharp focus and how much will be blurred. Experiment with aperture settings.

Figure 3.1.4
Examples of students' photographs of spaces, printed and pinned up for presentation

- The exposure time will change how much motion blur you will get. Experiment with exposure times.
- You can control the perspective of your photograph by holding your camera absolutely level. You can avoid vertical lines tipping into a perspectival projection. Experiment with your position in the space and with holding your camera level and canted.
- The time of day that you choose to take your photo, as well as the weather conditions on that day, will impact the natural light of your space. Experiment with the time and general environmental conditions of your photo shoot.

Explore which settings, positions and time of day support your spatial insight and why.

By interrogating your space through these photographic parameters you are collecting new, photo-specific insights into your space. Compare your understanding of the space by photographing it with your previous first-hand experience. You were able to roam the space and experience the space with all senses *in situ*, meaning on site. When using photography to capture a space, you have to choose a fixed viewpoint. The space is recorded on a two-dimensional picture plane. What spatial attributes are you suppressing by photographing the space? What spatial attributes are you bringing to the fore by photographing the space? What additional spatial insights are you gaining through the method of photography compared to the first-hand experience? How do you compose the image, so that it is able to communicate the distinct quality of your space?

Questions of perspective, light and texture might come to the fore. Other spatial experiences could be substituted through visual effects. Blur for example could indicate movement. Blur could also indicate depth of space. Wind could be communicated through moving leaves. You can express soft and hard surface through your photograph. You could communicate sound through a busy scene.

You are now equipped with a new, photography-specific insight of your space, in addition to the first-hand experience. Both form a new, more complex and layered understanding of your space. **(3.1.5)**

Figure 3.1.5
Example of a particular, chosen space that corresponds with the example texts shown in this chapter

Media 3: Text

While you were roaming spaces, you connected to architecture in an instinctive, immediate way. You chose a space that had a strong, immediate impact on you. Now, through various media, you're analyzing how the space achieves its characteristic spatial condition. You were asked to photograph the space in a way that brought its strongest characteristic to the fore. Now you are asked to reflect upon your space through writing.

Formulate a concise description of the experience the space offers to you. Write your text while being *in* your space. Explain how you think the space achieves its particular spatial effect. Be as precise as possible. Make an argument. Describe which architectural elements are performing that experience. Be as direct as possible and use simple language. Write as if you were talking to someone; with a conversational tone you can be more easily understood. Your text is limited in length, so focus only on the essential and edit your text repeatedly. After writing a raw version of your text, let it rest and read it again, to see what works and what needs revision. Consider reading it aloud to catch any errors and awkward phrasing. Print your raw text and extract the clearest, single statement that expresses the defining quality that characterizes your space. Refine and reformulate that single statement as needed. **(3.1.6)**

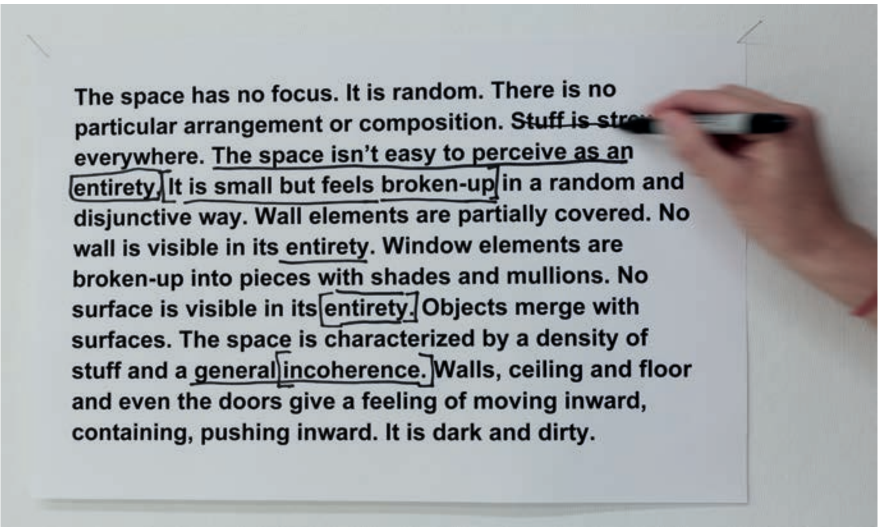


Figure 3.1.6
Example of a descriptive text before paring down into a focused, single statement

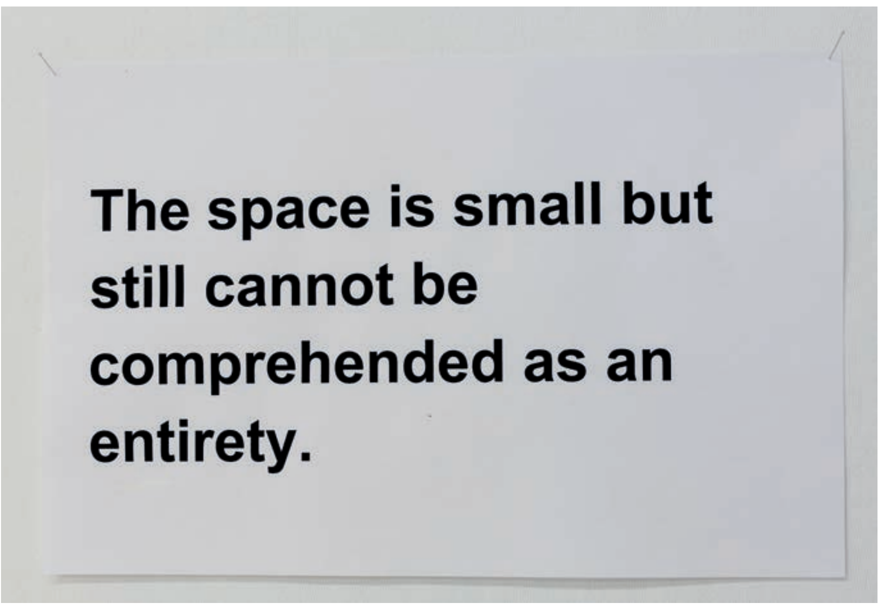


Figure 3.1.7
The same text as shown in the previous example, pared down into a focused, single statement

The single statement text should be printed in black and white on 11 x 17 in. (or A3) paper, landscape or portrait format, with 90-point, Arial text, left-justified, single spaced. **(3.1.7)**

Reflect upon and compare the distinct insights gained from the application of the three distinct media: first-hand experience, photographing and writing. Each of these three media contributed to a more complex, layered understanding of your space.

Notes

1 John Pawson, *A Visual Inventory* (London: Phaidon Press, 2012), 6.
2 Georges Perec, *Species of Spaces and Other Pieces* (London: Penguin Books, 1997), 13.

3.2 SURVEY OF SPACE

Description

Drawing: The Dominant Language of Architecture

Architecture is, on one level, a graphic language. More than verbal language or text, drawings can communicate architectural ideas, from overall images and design intentions to precise construction details. Drawings of buildings serve various purposes in architecture. Measuring existing buildings and drawing them as they are is one way that we can understand them and appropriate them into the language of architecture for further investigation and use. The objective of this task is for you to conduct a comprehensive survey of your chosen space, then translate and abstract it into the graphic language of architecture using orthographic projection. Instead of understanding orthographic drawings—plans, sections and elevations—as the primary medium through which architecture can be explained, it should be seen as just one of a variety of media through which space can be explored, represented and produced.

Drawing itself is a broad medium with many forms and roles in architecture. Orthographic projection, the process that generates the flat views of a building that are most commonly associated with architectural production, is also colloquially known as drafting. As George Barnett Johnston points out in his book, *Drafting Culture: A Social History of Architectural Graphic Standards*, while drafting and drawing share an etymology, their purpose and outcome can be wildly different:

> What is drafting? Perhaps the question is too obvious or any answer too trite. An English architect and author declared in 1912, "Generally, the object of architectural drawing is the representation of architecture. It will include a wide field of draughtsmanship [*sic*], ranging from the plainest and most practical working drawing made for the purpose of actual building, to the opposite pole of such wild visions of architecture as Piranesi gave the world in his Carceri d'Invenzione." The words "drafting" and "drawing" are etymologically linked through terms of work, acts of dragging or pulling tools across surfaces, whether inscribing marks upon the earth or plowing the parchment.[1]

Like any language, both drafting and drawing are constantly changing at the same time as remaining main sources of architectural communication. The well-known tome in North America, *Architectural Graphic Standards*, for example, has been updated and published eleven times since its first arrival in 1932.[2]

In his essay, "Translations from Drawing to Building," Robin Evans describes the dominant role that he sees drawings having in architectural production:

> My own suspicion of the enormous generative part played by architectural drawing stems from a brief period of teaching in an art college. Bringing with me the conviction that architecture and the visual arts were closely allied, I was soon struck by what seemed at the time a peculiar disadvantage under which architects labour, never working directly with the object of their thought, always working at it through some intervening medium, almost always the drawing, while painters and sculptors, who spend some time on the preliminary sketches and maquettes, all ended up with the thing itself which, naturally, absorbed most of their attention and effort.[3]

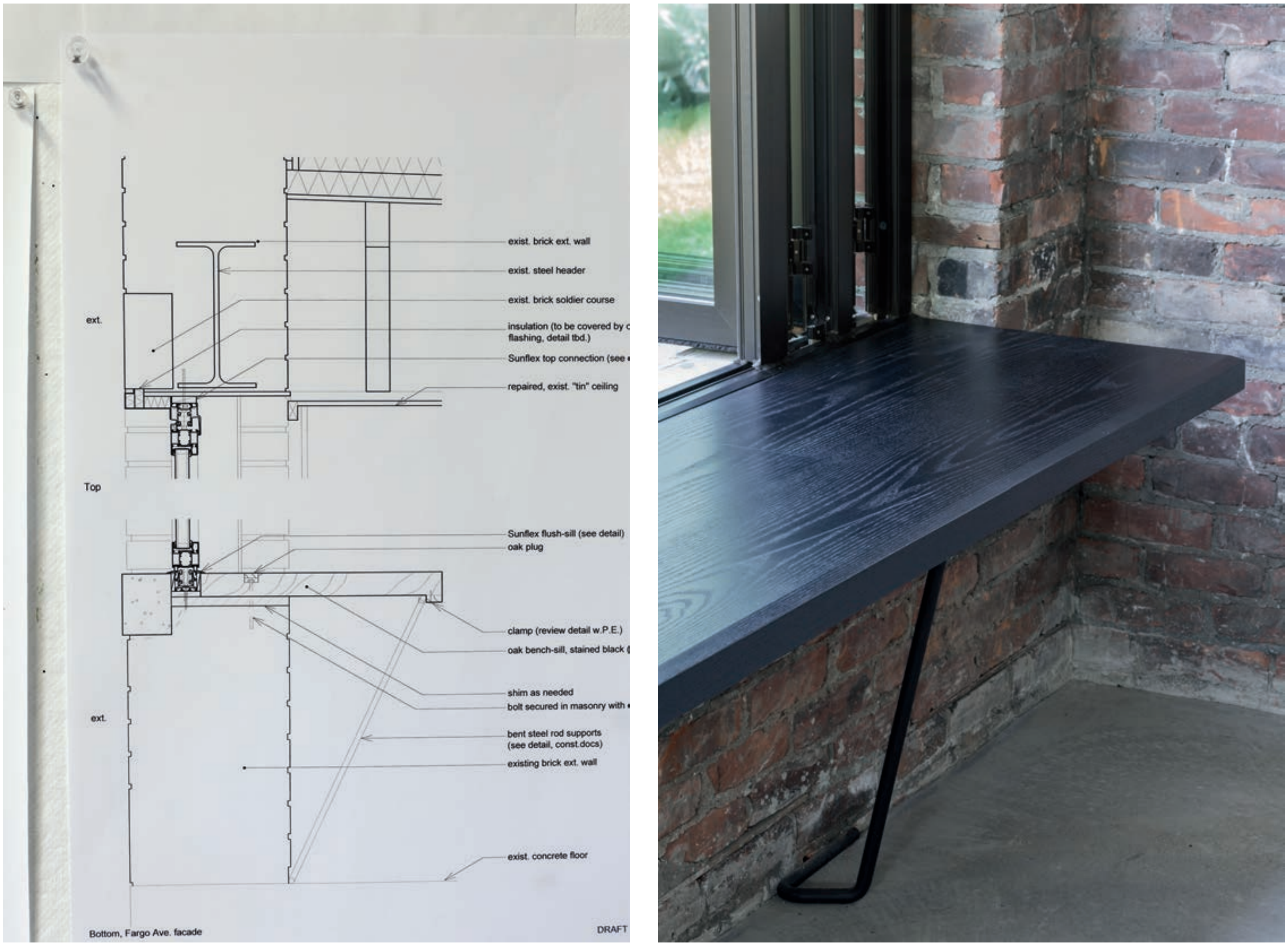


Figure 3.2.1
Example of detail drawing and corresponding, realized detail

An enormous array of skills and trades are needed to realize an architectural project. Unlike the sculptural project that Evans describes, an architectural project is rarely brought to realization by a single person. Drawings, in architecture, are facilitators. Written in a specialized graphic language, they convey essential information about how to realize a project. **(3.2.1)**

The Limitations of Architectural Drawing

As architects we rely so heavily on drawing, specifically drafting or orthographic drawing, that we tend to forget that drawings and buildings are two very different things. We often operate as if buildings can be defined comprehensively through drawings. But a drawing set differs from a building in a similar way that the photograph and the text that you made in "Experiential Assessment of Space" were distinct from your first-hand experience of your chosen space. Drawing, as a medium, promotes certain aspects of architecture while suppressing others. It is a medium with inherent constraints, capable of expressing certain aspects of architecture clearly and precisely, and incapable of describing others. Evans refers to the work

of the artist James Turrell to describe the constraints of architectural drawing: "The drawing has intrinsic limitations of reference. Not all things architectural (and Turrell's rooms are surely architectural) can be arrived at through drawing."[4] Turrell works with carefully calibrated light installations, which are fundamentally architectural in nature. But the light-specific quality of his work cannot be adequately represented through drawings. It can only be grasped through first-hand experience.

Evans, in his text and through his illustrations, shows us that architecture is much more complex than the three dimensions of Euclidian space: length, width and height.[5] But it is solely through these three dimensions that orthographic projections communicate space to us, excluding all other aspects. **(3.2.2)** Bruno Latour elaborates further on the limiting nature of a purely geometric description of architecture through drawing:

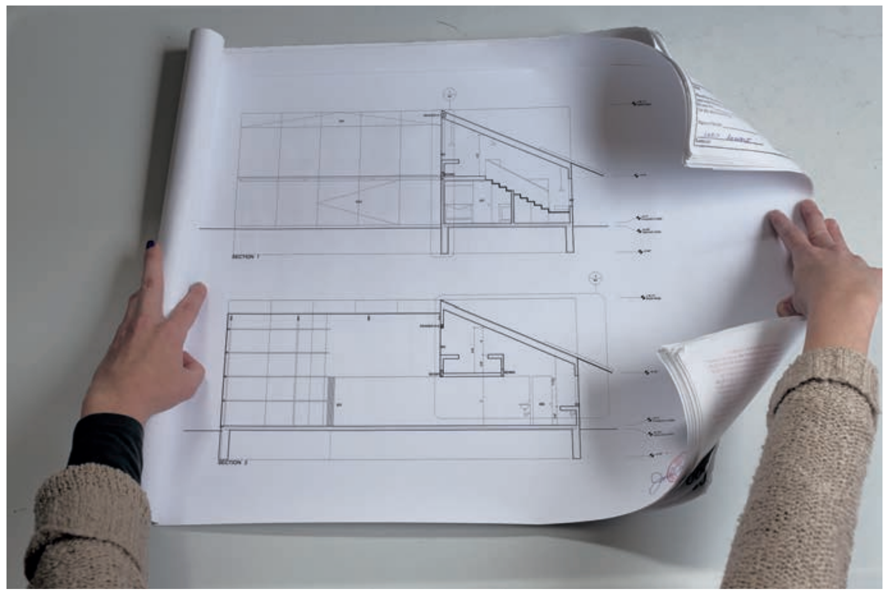


Figure 3.2.2
Permit drawing set, open at a page with a section through the loft space, and photo of the realized space, part of a studio in Buffalo, New York

> Where do you locate the budgeting and the different budget options? Where do you put the logistics of the many successive trades? Where do you situate the subtle evaluation of skilled versus unskilled practitioners? Where do you archive the many successive models that you had to modify so as to absorb the continuous demands of so many conflicting stakeholders—users, communities of neighbors, preservationists, clients, representatives of the government and city authorities? Where do you incorporate the changing program specifics? You need only to think for one minute, before confessing that Euclidian space is the space in which buildings are drawn on paper but not the environment in which buildings are built—and even less the world in which they are lived.[6]

Latour points out the limitations of orthographic drawings by describing them as part of an abstract, geometric world. At the same time as being at the core of architectural language, orthographic drawings need to be seen as one layer in a complex, multi-layered process of creating and understanding space.

The Media-Specific Lens of Orthographic Drawings

In typical architectural drawing you are drawing spaces which are still to be realized. For the purpose of our exercise on the other hand you have the advantage that you are drawing an existing space that you already experienced first-hand. With this sequence of exercises, you can compare for yourself the potentials and the limitations of orthographic drawing. Is the spatial quality that you argued for in the previous exercise communicated through your survey and your drafted drawings? If your drawings struggle to represent the spatial quality you were interested in, speculate why that is. You can see how the main working tool of architects—like all media and tools—is limited in its possibilities. Orthographic drawing might not necessarily be the best or most appropriate tool to design and develop a building that offers the spatial quality of your found space. On the other hand, your survey drawings offer new media-specific insights into your space. The multiview drawing set of your chosen space will show, for example, the precise, geometric structure behind your spatial experience. To further unravel these insights, we will look more closely into the orthographic projection method and the possibilities and advantages that it offers.

What Is Orthographic Projection?

As described in 4.3, "Orthographic Projection and Multiview Drawings," orthographic projections flatten three-dimensional objects into two-dimensional representations. This drawing technique, therefore, encourages flat surfaces and right angles. If you work mainly through plans and sections in your design process, you will tend to produce a sheet-like architecture, where the flat sheet of paper imposes its flatness onto flat walls and ceilings in buildings. Evans refers to this tendency for orthographic projection to influence the design of spaces; he credits the "affinity between paper and wall" for "transporting ideas into buildings without undue disfigurement."[7] It is this "affinity between paper and wall" which gives orthographic projection so much power, resulting in the architectural plan, section and elevation. Orthographic drawings allow us to work with, and control directly, the geometry, size and scale of architecture. Making both survey and orthographic drawings of your chosen space will give you a firm understanding of these characteristics; and you'll be able to relate these more concrete attributes of your space to your spatial experience.

Intended Learning Outcome

The learning outcome of "Survey of Space" should be that you understand how the dominant tool of architectural design—orthographic drawing—promotes certain aspects of spaces while eliminating others. As you become more fluent in your use of orthographic projection and begin to "speak" the language of architectural graphic standards with more ease, the possibilities of the medium will expand for you. But it is important to remember that it is one of many media available to you; exploit the medium for what it does well, and use it in concert with other media that might better support your particular spatial ambition throughout your design process.

Exercise

Media 1: Survey

Equipped with a measuring tape, pencil and paper or notebook, visit and measure the space that you chose in 3.1, "Experiential Assessment of Space." It is much easier to take measurements of a space with a partner, so pair up with a member of your studio section and work together for the duration of this exercise. Make hand drawings of all views that you need to measure: a plan, a reflected ceiling plan, sections and each interior elevation. Take all necessary measurements and mark them by hand into your drawings with any necessary notes and detail sketches. **(3.2.3)** Take an exhaustive series of snapshots that document the aspects of your space that you plan to include in your formally drafted drawing. These will help elucidate elements in your survey drawings that end up unclear. Bring your survey drawings back to studio and prepare to draft your drawings to scale (see "Glossary of Technical Terms and Materials").

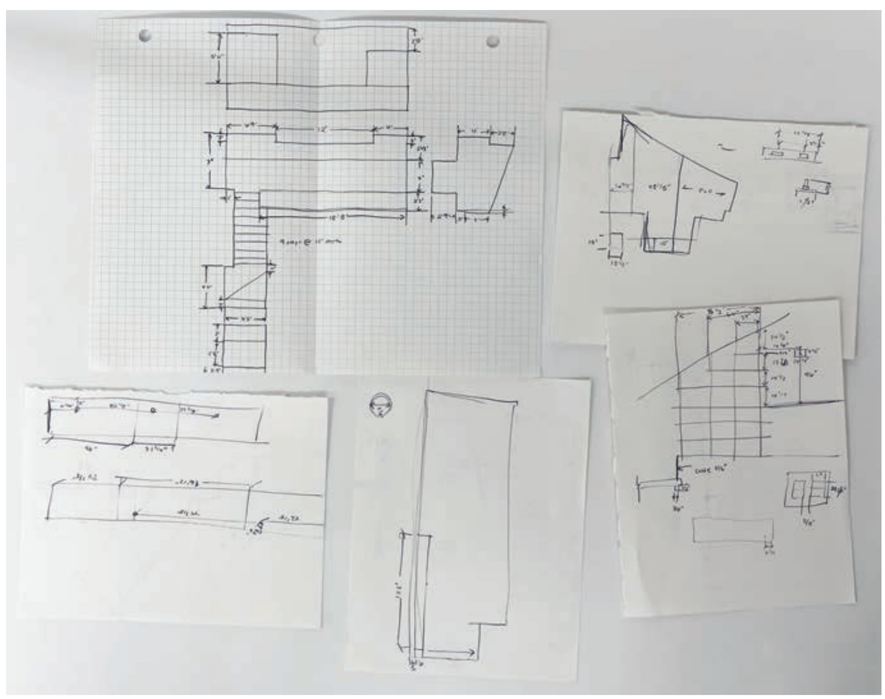


Figure 3.2.3
Example of survey notes taken on site

Media 2: Orthographic Drawings

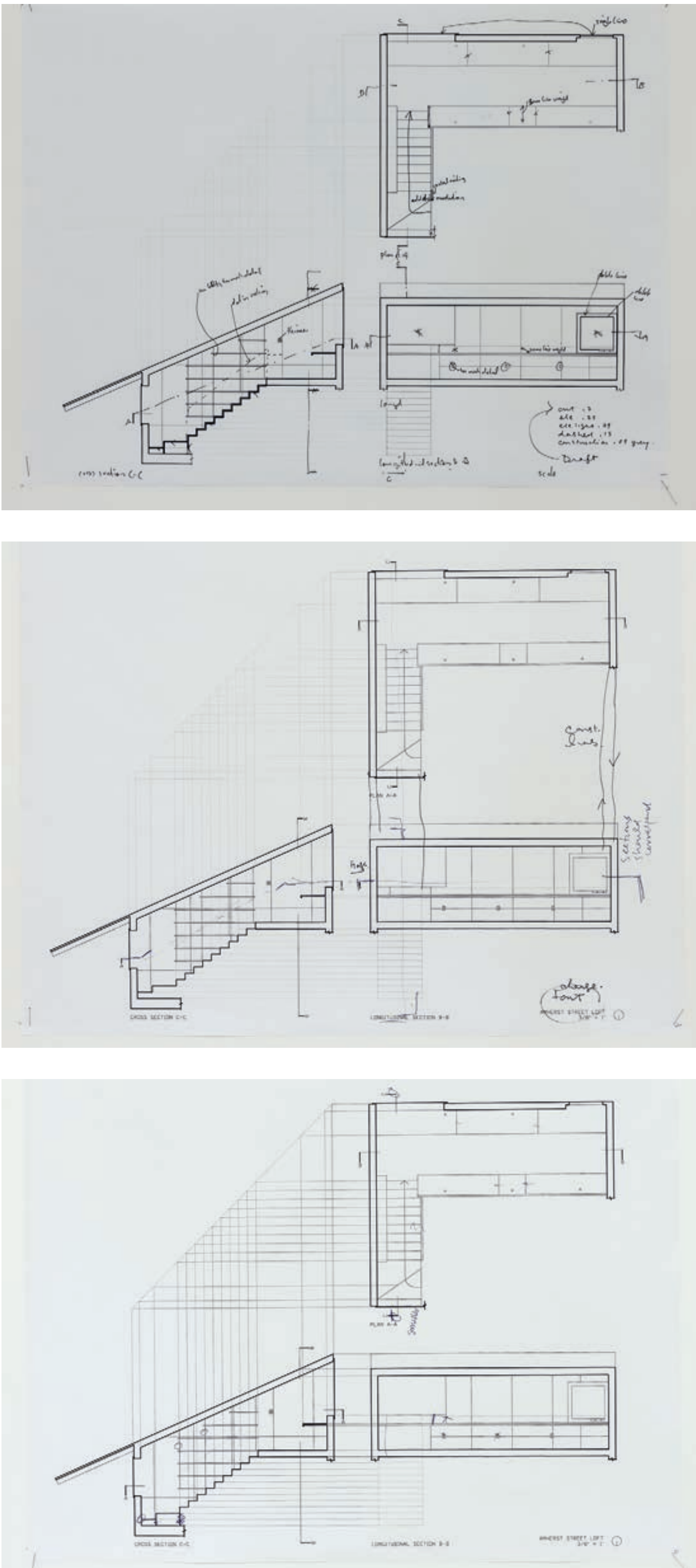


Figure 3.2.4
Series of test plots of multiview drawing set

Using your survey, formally document your space by making two sets of orthographic drawings. Refer to 4.3, "Orthographic Projection and Multiview Drawing," for a detailed discussion about these specific drawing types, and a series of step-by-step instructions for how to block out and construct the drawings.

Orthographic projection is a method used to generate two-dimensional views of three-dimensional objects. But the method itself doesn't determine the character or legibility of the orthographic drawing. How line types are handled, the composition of the drawing and the level of detail all impact the graphic character of the drawing significantly. Orthographic projection as a method is strict and precise; it can be done right or wrong. In contrast, there is no right or wrong way to establish the graphic character of a drawing. To define a drawing's graphic character, define its purpose, then define how best the drawing can serve that purpose.

In these two sheets, the purpose of the drawings is to graphically convey the precise geometric structure of your chosen space using the staple architectural language of orthographic projection. Although the given parameters may be strict, and may seem to predefine the graphic character of the drawings, there are still many decisions that you will make to impact how your drawings look and communicate. Focus on your multiview drawing first, and make several plotted versions before settling on a set of line types. **(3.2.4)** When you're satisfied with the set of line types for your multiview, use the same set for your internal elevation sheet 2.

Layout Sheet 1: Multiview Drawing

This drawing will contain the primary views of your chosen space—plan, cross section and longitudinal section—constructed on a single 18 x 24 in. or Arch C (42 x 59.4 cm or A2) paper. The exact composition will depend on your specific space, its geometry, size and the scale that you choose for your drawing. Decide upon a scale in consultation with your instructor. **(3.2.5)**

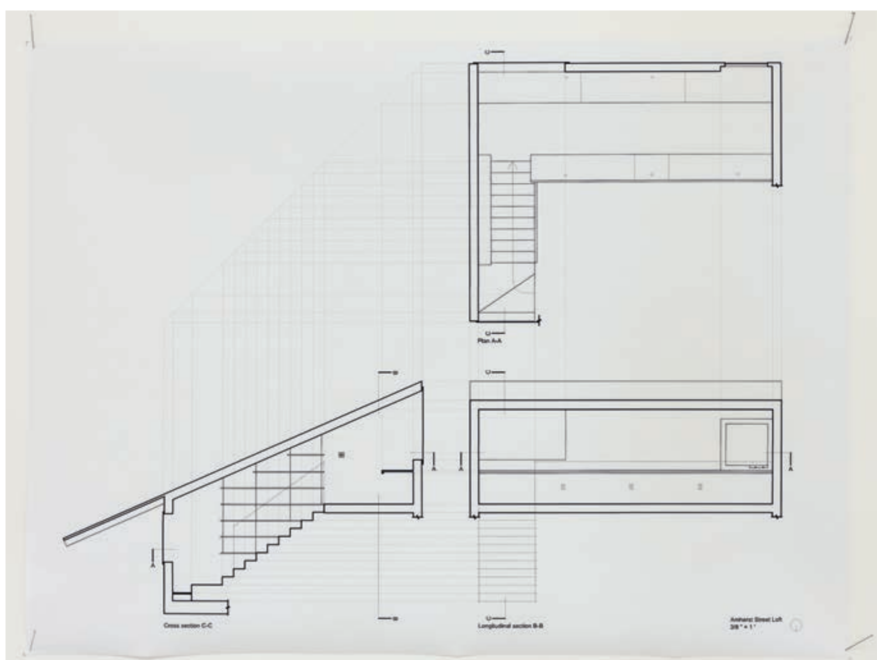


Figure 3.2.5
Final, plotted multiview drawing set

Layout Sheet 2: Internal Elevation Wrap-Around

This drawing will show all internal elevations of your space in a continuous band that can be folded to hark back to the original three-dimensional space. Organize the internal elevations as if you would fold all wall surfaces of your space flat, creating a long strip. Use the same scale that you chose for your sheet 1. **(3.2.6)**

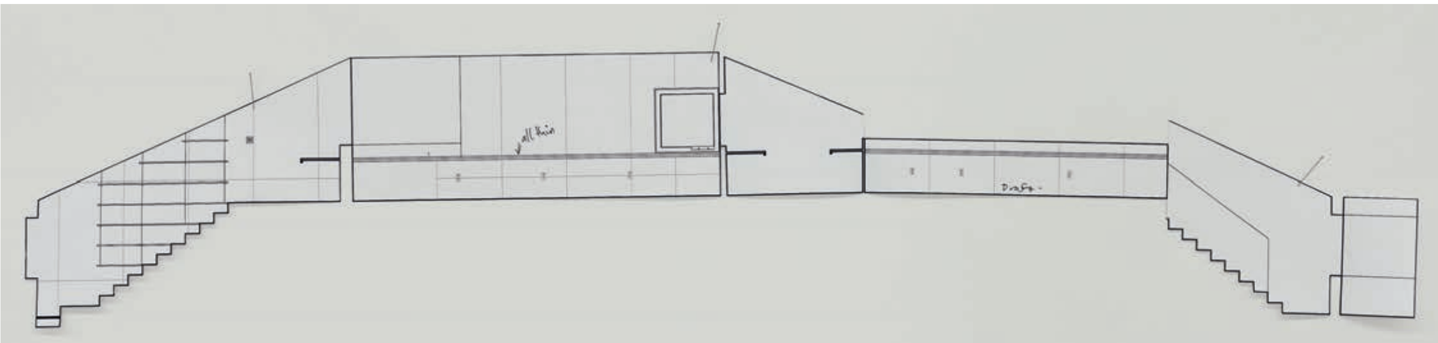


Figure 3.2.6
Final, plotted internal elevation wrap-around drawing

For both layouts, refer to 4.3, "Orthographic Projection and Multiview Drawing," for instruction about how to execute the drawings, how to organize your layers and line types and decide upon line weights. Experiment with your line weights to find the most legible version of your drawings.

Notes

1 George Barnett Johnston, *Drafting Culture: A Social History of Architectural Graphic Standards* (Cambridge, MA: MIT Press, 2008), 2.
2 Peter Booth Wiley, "Publisher's Notes," in *Architectural Graphic Standards*, eleventh edition, by the American Institute of Architects (Hoboken, NJ: John Wiley, 2007), xiii.
3 Robin Evans, *Translations from Drawing to Building and Other Essays* (London: Architectural Association Publications, 1997), 154.
4 Evans, *Translations from Drawing to Building*, 159.
5 Evans, *Translations from Drawing to Building*, 159.
6 Bruno Latour and Albena Yavena, "Give Me a Gun and I Will Make All Buildings Move: An ANT's View of Architecture," in *Explorations in Architecture: Teaching, Design, Research*, edited by Reto Geiser, 80–89 (Basel: Birkhäuser, 2008), 82.
7 Evans, *Translations from Drawing to Building*, 172.

3.3 SOLID-VOID INVERSION OF SPACE

Description

Solid and Void: Same and Different

Being able to think at various levels of abstraction is a continual challenge in architectural design. We are constantly trying to imagine the form and potential experience of spaces which are fundamentally void and immaterial. If we invert space from void to solid, also referred to as negative and positive space, we are able to look at, evaluate and further work with spaces in more tactile ways. Making inversions from solid to void allows us to create something radically new, while still having a clear reference to the existing form.

Rachel Whiteread, a sculptor who often works at an architectural scale, founded her entire body of work on this process of solid-void inversion. She takes familiar objects and spaces, like chairs and stairwells, and inverts the negative space held by these elements into solid objects by casting. The results work on a multiple levels: as objects, her sculptures are both familiar, and strange. As a process, her work prompts us to look at objects and spaces around us in new ways; negative space takes on a new dimension, as something potentially full and heavy. Whiteread herself describes the lure of the process:

> The very, very first sort of cast that I made when I realized that you could sort of really change something was when I pressed the spoon into sand and then poured some lead into it and it lost the spooness of the spoon so the hollow of the spoon had gone and that had become flat and you had this kind of little sort of lip around the side and it completely changed it, from one side it still looked like a spoon, from the other it looked like something entirely different and I just kind of fell in love with that process.[1]

The work of Rachel Whiteread shows how it is possible to de-familiarize everyday objects and spaces through solid-void inversions and gain new and unexpected insights. The objective of this task is to encourage an engagement with a space in both its positive and negative forms. We will test the generative potential of different techniques of solid-void inversions, seeing what new insights and possibilities the

Figure 3.3.1
Example of mass, urban-scale model, Davidson Rafailidis, Free Zoning, 2012

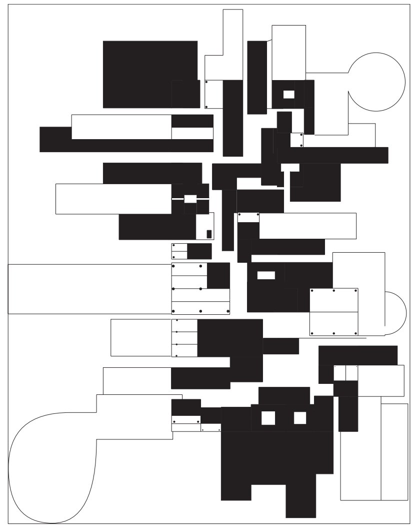
processes yield. We will use three techniques of solid-void inversion: mass modeling, multi-piece mold making and one-point perspectival projection.

Mass Modeling

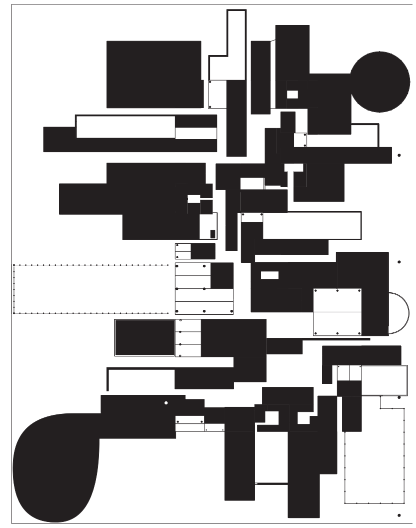
Architects use different types of models for different purposes. One of the types of models architects use is the mass model. We commonly use mass models to express and evaluate the general volume or mass of a building. Mass models are particularly common for urban-scale studies, where buildings are depicted at a small scale, and their general volumes and relationships to one another is more important than any particular detail or their interiors. **(3.3.1)** Mass models are solid, so they don't give any information about interior space; they show only the exterior form of a building. For our exercise, we will employ the mass modeling technique in an unusual way, inverting an interior space to a solid mass. By doing this, we will be exteriorizing the interior space, seeing the surface form of the space from the other side, inverting the space from void to solid. **(3.3.2)**

Figure 3.3.2
Photos of part of a space (top), and its corresponding "exteriorized" view as a mass model (bottom)

Figure 3.3.3
Figure-ground drawings corresponding to the example mass model, Davidson Rafailidis, Free Zoning, 2012



a. This figure-ground drawing shows building masses as solid, hatched areas, and general property boundaries with outlines.



b. This figure-ground drawing of the same urban context follows the techique of the Nolli plan, showing private space as hatched and publicly-accessible space as white.

Shifts in the typical application of standard techniques like mass modeling can reveal new insights. One example of a productive deviation in the application of a standard method of solid-void representation is the renowned Nolli plan, a city plan of Rome from 1748 by Giambattista Nolli.[2] The Nolli plan, upon first glance, appears as a straightforward figure-ground plan. Figure-ground plans are the two-dimensional equivalent to a mass model, they show the massing of buildings in plan view. In a conventional figure-ground drawing, all building mass is solid black and all void is white. **(3.3.3a-b)** Instead of following strictly the exterior outline of buildings to create the outline for the black hatch, however, Nolli, in his plan of Rome, "enters" buildings that have spaces open to the public and breaks the rule that interior spaces are never shown in a figure-ground drawing. Nolli "exteriorizes" particular interior spaces, and makes them read as part of the public, exterior space of streets and squares. With this deviation from the standard practice of figure-ground drawing, Nolli gives us a new and more insightful reading of how we can move throughout the city.

Mass models are easiest to make using massive (rather than planar) materials like wood and foam. Foam is light and easy to manipulate, and is the material that we'll work with for our task. Refer to 4.2, "Hot Wire Foam Cutting," for detailed instructions about working with foam to construct mass models.

Casting

Casting refers to the material process in which a material, in a liquid or viscous state, is used to fill a void, transforming the void to a solid. Casting is a form of recording, like photography. The liquid material used to pour has no shape in itself and is able to adopt any shape or form. Casting material into a mold, which defines a void or negative space, allows reproduction of a form. Similarly, in photography, a film negative allows reproduction of an image. Whereas in photography, the inversion is between light and dark, in casting, it is between solid and void. Because both of these reproduction techniques are strict, technical, material processes, they lend a technical, objective character to the result.

Figure 3.3.4
Foam model and corresponding multi-part plaster mold

In this exercise, we will employ casting to generate a multi-part plaster mold. In this process, an object is invested in plaster (see "Glossary of Technical Terms and Materials"). When it is released from the plaster mold, the object is visible as negative space, and the space around the object has been cast as the positive space. Seeing the matching set of the same object in its positive and negative forms will, particularly for an architecture student, offer a fundamental revelation, where an object is described in two distinct ways. **(3.3.4)** As described in 4.4, "Multi-Part Rigid Mold Making," a multi-part mold allows complex volumes to be invested and withdrawn without breaking either the mold or the model, and is capable of producing many copies of the object invested. Plaster molds can accommodate a variety of casting materials in the reproduction process. A common and traditional material used to create multiples from a plaster mold is clay slip. As described in 4.5, "Slip Casting," plaster and slip work interdependently in the slip-casting process to generate a clay shell. In the words of Andrew Martin, "[p]laster 'drinks' water. A plaster mold is similar to a large rigid sponge; it moves water from the surface into the mass."[3]

Making a multi-part mold is, itself, a design exercise. Like all design problems, there is no single solution in making a mold; there are many approaches that will work and others that simply won't. The technical requirement alone of defining parting lines to be able to release the object from the mold generates a whole set of new geometries and is an intriguing example of how project constraints can create unpredictable complexity and variation in the design process. **(3.3.5)** Another constraint to the making of a multi-piece mold is that you need to subdivide the negative space around the object and pour each mold piece individually with liquid plaster. Also required is a set of materials and tools that work well together in the process and that are able to withstand the structural forces of the liquid plaster pushing outward. These media-specific constraints will give you yet another new reading of the geometry of your space.

Designing a multi-piece mold involves handling the negative space around an object. Ultimately, mold making is a very direct way of inverting positive and negative

Figure 3.3.5
Parting lines drawn directly on a foam mass model showing where to place dams and define mold pieces in the mold-making process

Figure 3.3.6
Example of a designed in-between or void space, Davidson Rafailidis, Amherst Street Studio, Buffalo, New York, 2015, photo by Florian Holzherr

space. This relates to the architectural scale, where designing a building involves simultaneously handling the space *in* and *around* that building. A space outside a wall can be defined as a "room" just as a space on the interior side of a wall is thought of as a "room." **(3.3.6)**

One-Point Perspective

Like photography, perspective drawings allow you to construct a two-dimensional view of the space which is similar to standing in the actual space. Spatial depth is represented by converging lines of edges that are not parallel to the picture plane. If the width and the length of a space are parallel to the picture plane, then only the depth converges to a single vanishing point at the center of the image. This special case is called a one-point perspective, because it has a single vanishing point. This type of perspective emphasizes spatial depth and is therefore especially useful for interior spaces. We will exploit this specific property of the one-point perspective to create drawings of hollowed-out mold pieces. Compared to two- or three-point perspective drawing methods, one-point perspectival projection will offer us the most directed interior-view. In contrast to the first step of this exercise, where you solidified a hollow space through mass modeling, in this exercise you are hollowing out a solid volume with the one-point perspective drawing method. You will use perspective drawing not to just represent spaces, but rather, to extract spaces that your mold pieces, the forms that you newly generated, are suggesting. **(3.3.7)**

Intended Learning Outcome

The learning outcome of the exercises in "Solid-Void Inversion of Space" should be that you test the generative potential of different techniques of solid-void inversions, to gain new and unexpected insights about your chosen space. You should build upon your understanding of the physical geometry of your chosen space, and see it in a multifaceted way, as a solid mass, through the particular set of forms that it generates in the multi-piece mold-making process, and through the spatialization of these forms in one-point perspective drawing. What formal, geometric, scalar and proportional attributes do these forms have? What types of spaces do they suggest? This set of exercises should help you establish a comfort level working with abstraction, and beginning to extract spatial potentials from abstract, spatially suggestive objects. **(3.3.8)**

Exercise

Media 1: Mass Model

Using the survey drawings that you completed in the previous assignment, build a precise mass model of your space out of foam using a hot wire foam cutter (see 4.2, "Hot Wire Foam Cutting"). Mass models have no interior spaces and are made to represent the basic, overall volume of a space or a building. Your mass model, although geometrically true to the original space, offers a radically new reading simply because it is a void-to-solid inversion. This is another instance where media skills are fundamentally generative in nature. You can employ media to not just represent space but, further, to explore and understand space in unexpected ways. Find a scale for your model so that it is no more than approximately 8–10 in. (20–25 cm) in its largest dimension (see "Glossary of Technical Terms and Materials"). **(3.3.9)**

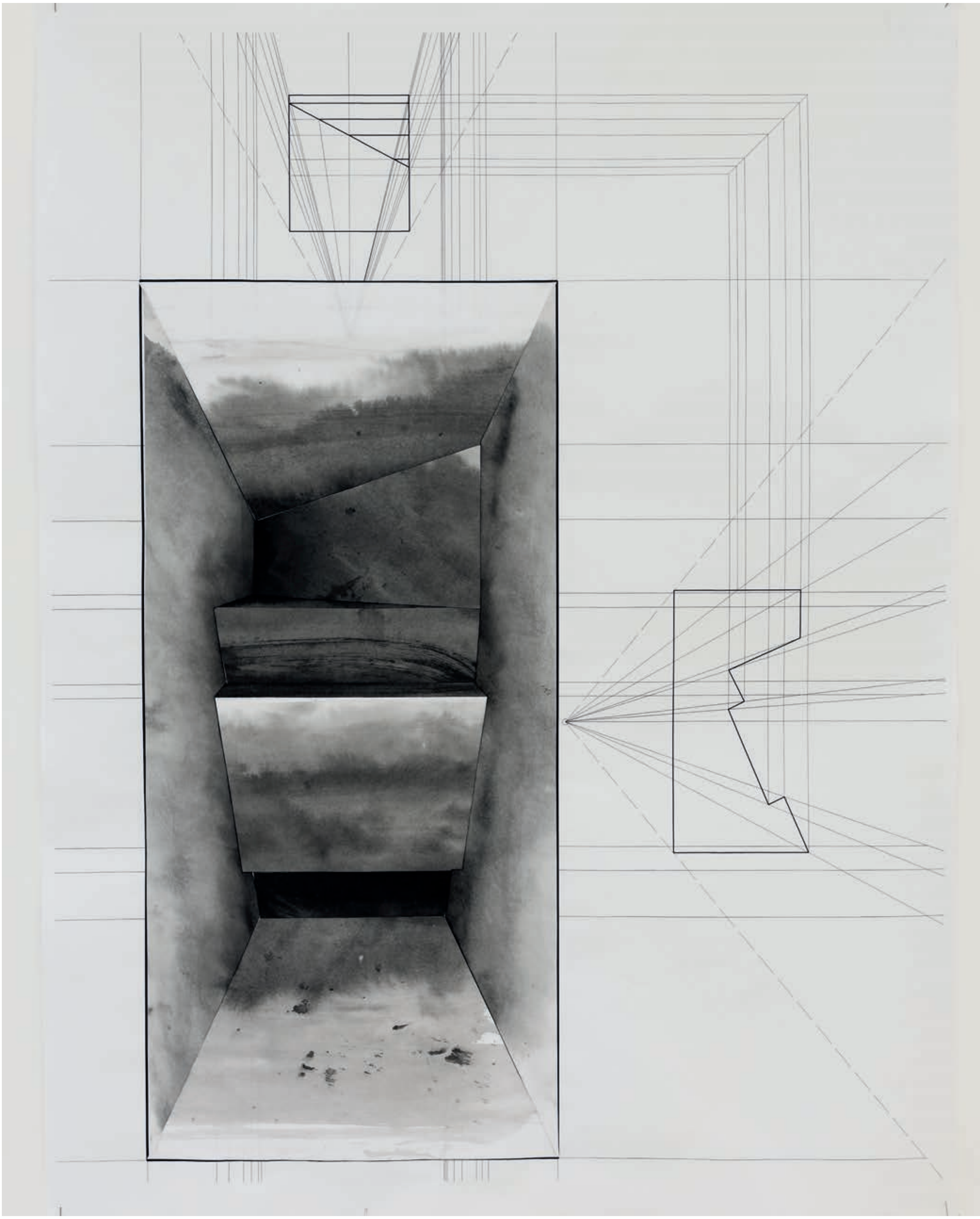


Figure 3.3.7
Plotted drawing of mold pieces translated into one-point perspectives

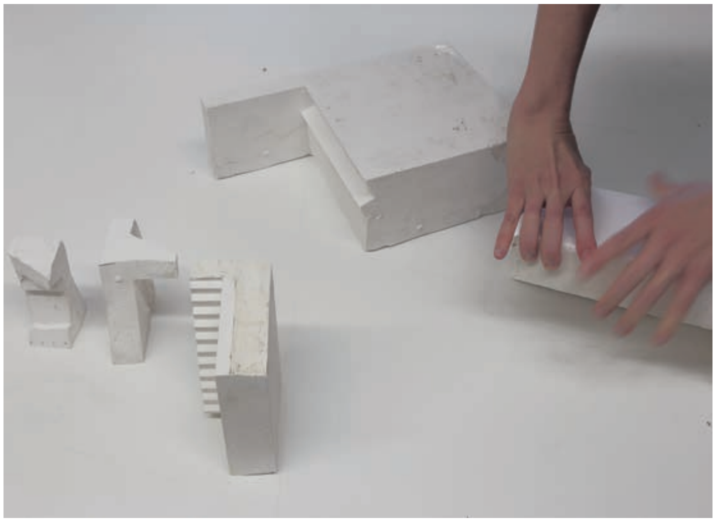


Figure 3.3.8
Mold pieces

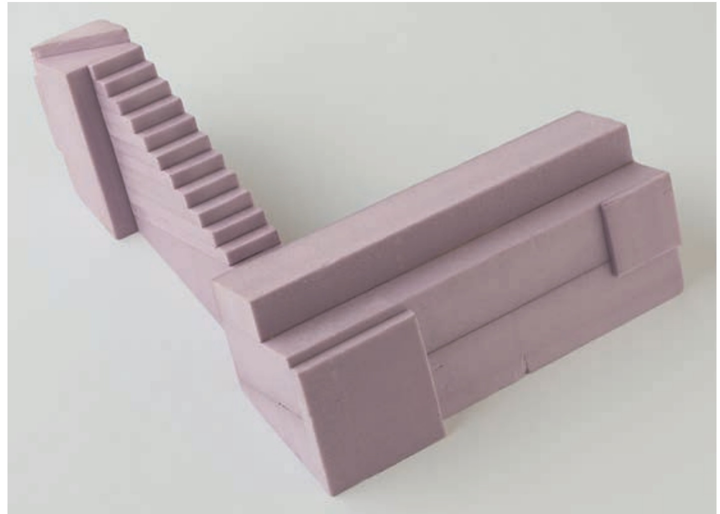


Figure 3.3.9
Foam mass model

One of the standard scales in this list should translate your room to the desired size (the metric equivalent to the imperial scales are the closest standard equivalents, not the actual equivalents):

3″ = 1′–0″ (1:5)
$1\frac{1}{2}$″ = 1′–0″ (1:10)
$\frac{3}{4}$″ = 1′–0″ (1:20)
$\frac{1}{2}$″ = 1′–0″ (1:25)
$\frac{1}{4}$″ = 1′–0″ (1:50)

Media 2: Multi-Part Plaster Mold

In this next step, we will learn from the traditional craft of multi-part plaster mold making, and create a solid-to-void inversion. Invest your foam mass model in plaster to make a mold with a minimum of five parts. Refer to the detailed instructions about the material behavior of plaster and the strict rules that need to be followed for a multi-part mold to function in 4.4, "Multi-Part Rigid Mold Making." Establishing the parting lines for the multi-piece mold requires you to analyze the geometry of your mass model from another point of view. In this process, you will gain an intimate understanding of your form in order to resolve undercuts and to define the sequence of pouring each mold piece. The design of the parting lines and the resulting mold pieces are critical. There are many solutions that will allow you to remove the mold pieces from the original foam piece.

Make an axonometric drawing of your foam model and your proposed mold pieces pulled away from it. This drawing will help you to project the mold pieces you will get by following the strict rules of rigid mold making. To construct an axonometric drawing refer to 4.3, "Orthographic Projection and Multiview Drawings." **(3.3.10)**

You are now ready to get involved in an intense, hands-on material exploration that results in five or more mold pieces, which all relate to and reflect an aspect of the original space. You can now clearly experience the form-generating potential of rigid mold making. **(3.3.11)**

By drawing your mass model and mold pieces in axonometric view, you can visualize the general forms of the mold pieces. This study shows just three of many possible ways of constructing a multi-piece mold.

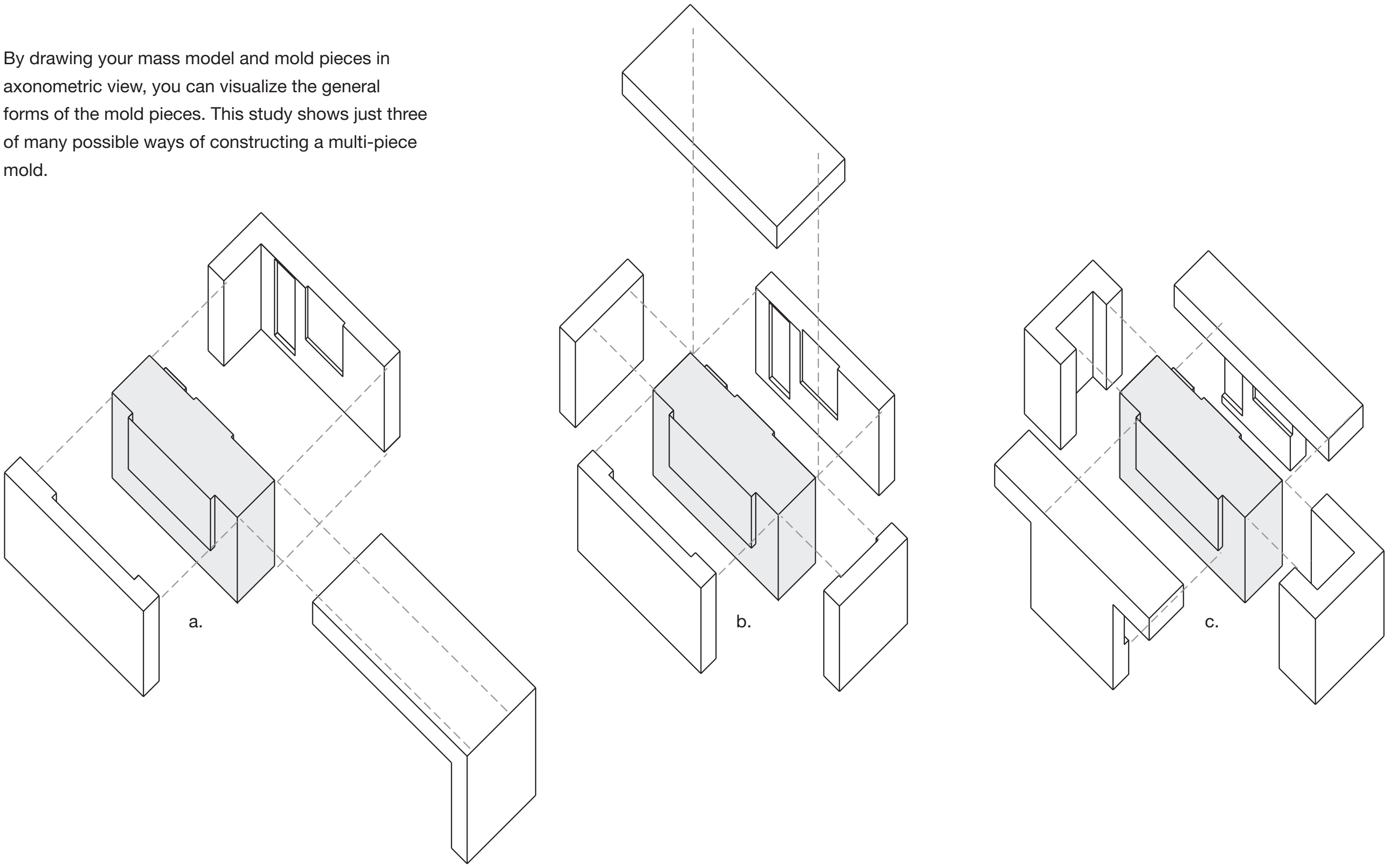


Figure 3.3.10
Axonometric drawing comparing different ways to subdivide mold pieces, shown pulled away from a mass model

Figure 3.3.11
Mold-making process

Media 3: One-Point Perspective

In a further analysis of what can emerge from a solid-to-void inversion, you will now draw each solid mold piece as a void using the technique of perspective drawing.

Choose your first mold piece and decide upon its orientation. For the purpose of a one-point perspective, make sure that at least one surface is completely vertical. Remember that your mold piece inherited the scale of your invested, scale foam model. Make a scaled figure and place it next to your mold piece. **(3.3.12)** Does the orientation of your mold piece offer an interesting space for the figure? Make notes of the spatial qualities of this orientation. Now rotate your mold piece onto its next surface and evaluate the spatial potential again. Continue this process with all surfaces of the mold piece. Which orientation do you think offers the most compelling interior space and why?

Once you decide upon an orientation, refer to 4.6, "Perspectival Projection—One-Point Perspective Drawing," for instruction about how to construct a perspective drawing. Through drawing, translate each of your five solid mold pieces into five spaces. Format the drawing on a single 18 x 24 in., or Arch C (42 x 59.4 cm or A2) paper. Jostle the views until you have a composition with a clear hierarchy in which one perspective is shown very large, with construction lines and corresponding plan and side elevation views, and the other perspectives are shown as thumbnails. **(3.3.13)** Refer to the techniques described and illustrated at the end of 4.6, "Perspectival Projection—One-Point Perspective Drawing," to add atmosphere, depth and texture to the perspectival framework of the large view on your layout.

Figure 3.3.12
Scale paper figure standing in relation to a plaster mold piece

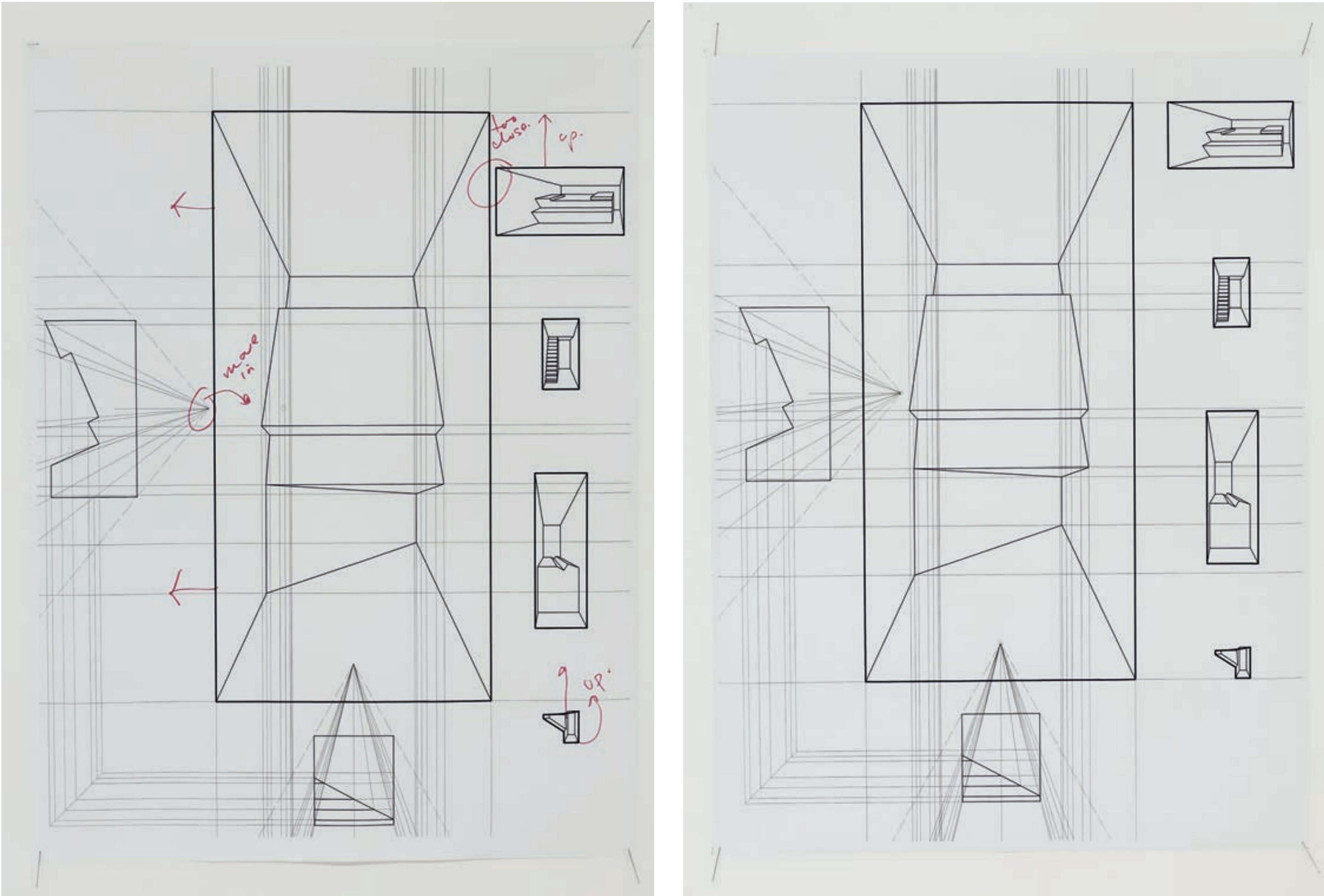


Figure 3.3.13
Draft and final plots of one-point perspective drawings

In the sequence of exercises so far, you have created a multi-layered project comprised of distinct media, materials and artifacts that offer representational, performative and experiential readings. You have also generated a new set of forms. Each is distinct but still closely related to one another and to the original space that you encountered in the first exercise. Observe the spatial characteristics that they have in common, and their distinct features.

Notes

1 “Rachel Whiteread Interview Pt 1,” YouTube video, 12:45, posted by “artheadful,” August 20, 2015, www.youtube.com/watch?v=Tz-EqD-j3lI.
2 “The Nolli Map Website,” University of Oregon, accessed November 1, 2015, http://nolli.uoregon.edu/default.asp.
3 Andrew Martin, *The Essential Guide to Mold Making & Slip Casting* (Asheville, NC: Lark Crafts, 2006), 27.

3.4 INHABITATION AND SPACE

Description

Form and Use

In the previous exercise, you fabricated a multi-part plaster mold. The relationship between the mold pieces and the mass model of your space illuminates further the geometry of your space by producing a set of forms related to the original, but still different. We will make use of this family of self-similar plaster pieces to make a spatial arrangement and investigate the complex relationship between form and use.

In practice, architecture is typically triggered by a use, a client's brief or a business plan. In our contemporary culture, however, the lifespan of these triggers is getting shorter and shorter in relation to the lifespan of buildings. This mismatch between the lifespan of contemporary uses and the buildings designed to accommodate these uses has led to an alarming amount of redundancy in our built environment. **(3.4.1)** The fundamental logic of design in mainstream architectural practice places fulfillment of a client's brief, which most often defines a "program" or use, as the primary concern. The increasing number of discarded, vacant, program-specific buildings in our built environment prompt us to ask two main questions:

Figure 3.4.1
Vacant, deteriorating building in a strip mall zone of Amherst, New York

Figure 3.4.2
Photograph of space chosen in the first exercise, printed and pinned on the wall

1. How can we design to create long-lasting meaning in the built environment within a global economy that operates through business plans that focus on the short term?
2. How can we make sense of old buildings and repeatedly reuse them for short-lived contemporary uses?

In this exercise, we will begin to tackle these two large and weighty design problems.

Experiential Typologies and Beginning a Generative Process

In the first exercise, we encouraged you to find a space that relates to you in an instinctive way, independent of any official program or use. The objective was to focus on spatial characteristics and the specific experiences that they offer. We believe it is exactly these spatial qualities, independent of use, that lend long-lasting meaning to buildings. In turn, this approach also gives us hints about how to answer our first question. **(3.4.2)**

After surveying and documenting your space using orthographic drawing techniques, you brought your space back into the three-dimensional world. This time the space is represented as a small-scale, mass model and a multi-piece plaster mold. The pieces of your plaster mold inherited some formal characteristics of your original space. In the previous exercise, you were asked to investigate the individual mold pieces as spaces, looking at them in axonometric and perspectival views, and in relation to a scaled figure. The objective was to use your chosen space to generate a set of forms, and then examine and familiarize yourself with the characteristics of these new forms as spaces. **(3.4.3)**

A New Unity

The mold pieces fit together in a specific and precise way. **(3.4.4)** In this exercise, you're asked to work with the distinct spaces of the mold pieces to create a new unity—a sequence of spaces designed according to a certain circulation typology

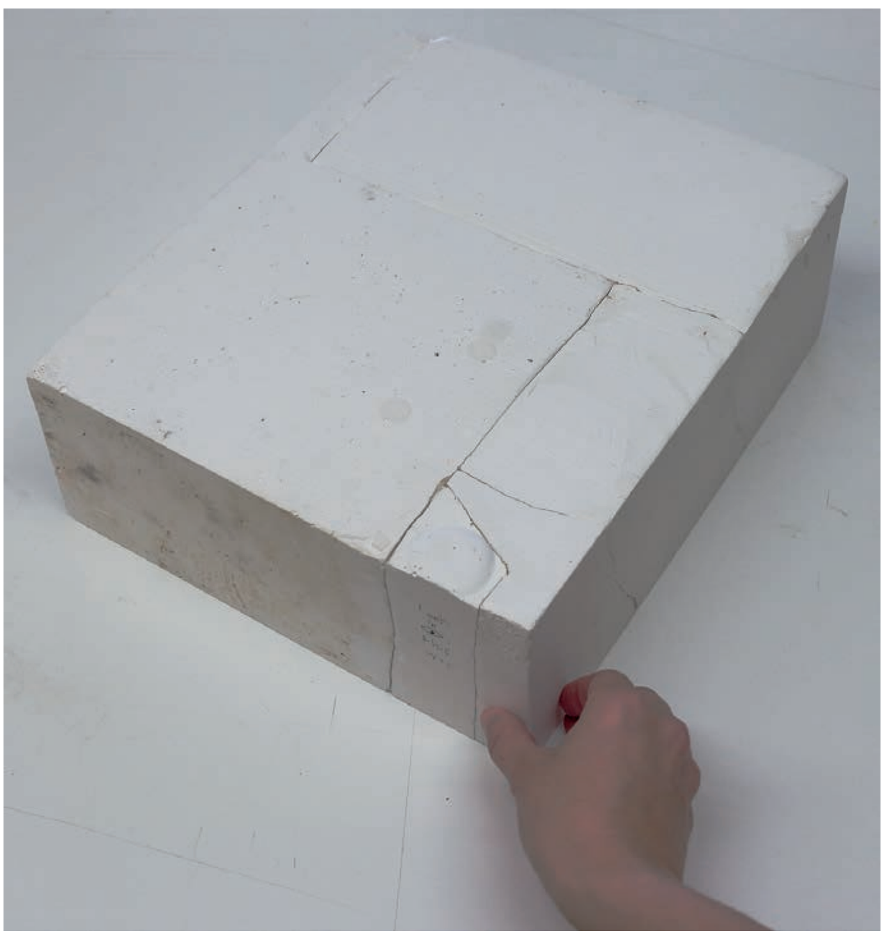


Figure 3.4.3
A scaled figure viewed in relation to a mold piece

Figure 3.4.4
The pieces of a multi-part mold fit together in a specific and precise way

and with certain spatial experiences in mind. The experiential quality of your spatial sequence should be so convincing that it gives meaning to your proposal, regardless of its intended use. Your new arrangement, like your originally chosen space, should stand as an "experiential typology," with a specific set of atmospheres. By designing spaces based on experiences, we're offering a way of engaging with our first question. Our objective is to create long-lasting meaning in the built environment rather than tailor buildings (with lifespans in the hundreds of years) to uses that might last just ten years or less.

One Building, Various Uses

By using the given spaces of your mold pieces, you will need to find correlations between existing form and use through careful observation of their incidental encounters. You will then test how your proposal works at accommodating various, random programs that you'll be assigned through a lottery. Think of the uses as tenants. For various reasons, no use will remain more than five years, but the building has a potential lifespan ten or twenty times that long. You know the spatial qualities of your arrangement or building well, since you have deliberately composed it. Now, by playing a kind of match-making game between certain characters of spaces and different uses, you'll be grappling with the second question, about how to continually repurpose existing buildings. Over time, the relationship between form and use are increasingly unpredictable. Developing the skill to make sense out of these chance encounters is increasingly relevant in practice where the reuse of buildings make up the bulk of commissions. As you interpret your programs through the lens of your given form, you are able to gain new insights about your program. Likewise, looking at your spatial sequence though the lens of a specific program gives you new readings of your spatial sequence, thereby adding to the step-by-step layering of spatial complexity that has happened in the exercises so far. **(3.4.5)**

Architectural Reconfiguration, A Precedent

There are intriguing architectural precedents for creating something completely new with readily available materials or building components. A prime example is the Cathedral Mosque in Cordoba. This building is mainly known in its current form as a hypostyle mosque.[1] However, the building elements with which this building is built were merely rearranged from a Visigoth church which stood at the same site.[2] The building elements and the painting on them clearly show the former configuration and use as a church. The cathedral mosque created something totally new (the hypostyle typology) with what was at hand and both conditions are visible simultaneously in its current form. The reused building elements were large enough to carry over the meaning from the previous building, whereas still small enough to create a totally new configuration. Your mold pieces are also specific enough to carry over the hidden parting lines of the mold configuration but will create something completely new and of its own when rearranged.

Monocoque

Once you've established a deliberate spatial sequence out of your mold pieces, creating a new unity, you will employ the strategy of *monocoque* to envelop the mold pieces in your chosen configuration (see "Glossary of Technical Terms and Materials"). In addition to making one piece out of the many pieces, this technique will also invert the composition from solid to void, creating a thin shell. A *monocoque*

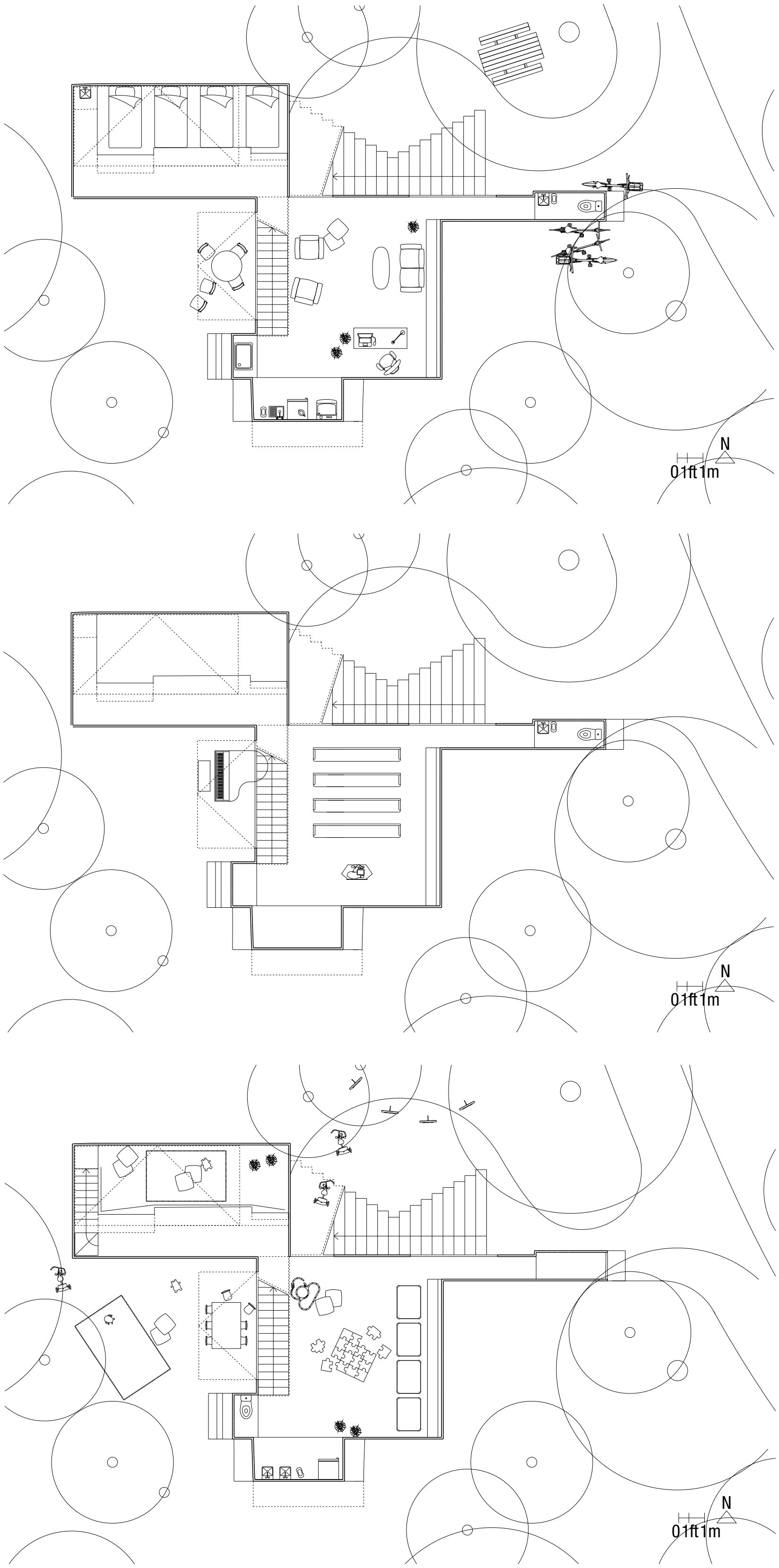


Figure 3.4.5
Example of a plan view of a cast paper *monocoque*, tested with three different programs: (top) hostel, (middle) chapel, (bottom) daycares

Figure 3.4.6
Making a sheet of cotton paper with linters to cast on a plaster armature

Figure 3.4.7
Cast paper *monocoque* with plaster mold pieces partially removed

is an external skin that acts as both a space-enclosing and structural element. It is a structural skin.

Using 4.7, "Paper Casting to Make a *Monocoque*," you will use the technique of paper casting with cotton linters to fabricate your *monocoque* shell (see "Glossary of Technical Terms and Materials"). Using your mold pieces as a substrate or armature to support the wet, interconnected fibers of the cotton linters, you will create a thin shell around your solid mass. **(3.4.6)** Although a form of casting, like your mold-making process, the result in this case is sheet-like instead of chunky. Here, like in the previous exercises, we are again using a specific material process as a form-generating tool. The structure, tectonic and form are the same, and the distinct fabric-like, translucent cotton shell defines the materiality. **(3.4.7)**

Intended Learning Outcome

The learning outcome of the exercises in "Inhabitation and Space" is that you perceive, understand and describe the spatial and experiential potentials of your mold pieces as spaces. In addition, we want you to unify those spaces into a new whole, with a clear and legible circulation principle. Like your chosen space at the beginning of this series of exercises, your new spatial composition should act as an "experiential typology," offering a specific and powerful experience or set of experiences that you define, and that function independently of program.

To test your spatial arrangement, you should compose a set of inhabitation patterns in and around your building, based on three different programs, which are assigned through a lottery. Through the lens of each new program, you should gain new and unexpected insights about your spatial composition. Illustrating your spatial arrangement as an inhabited plan, with a highly specific set of furniture, should allow you to graphically point to some spatial potentials that have, until now, remained very abstract. This set of exercises should give you a basic understanding of a variety of circulation typologies, and should help you describe spaces and atmospheres more explicitly, through more detailed drawings and interior model photographs.

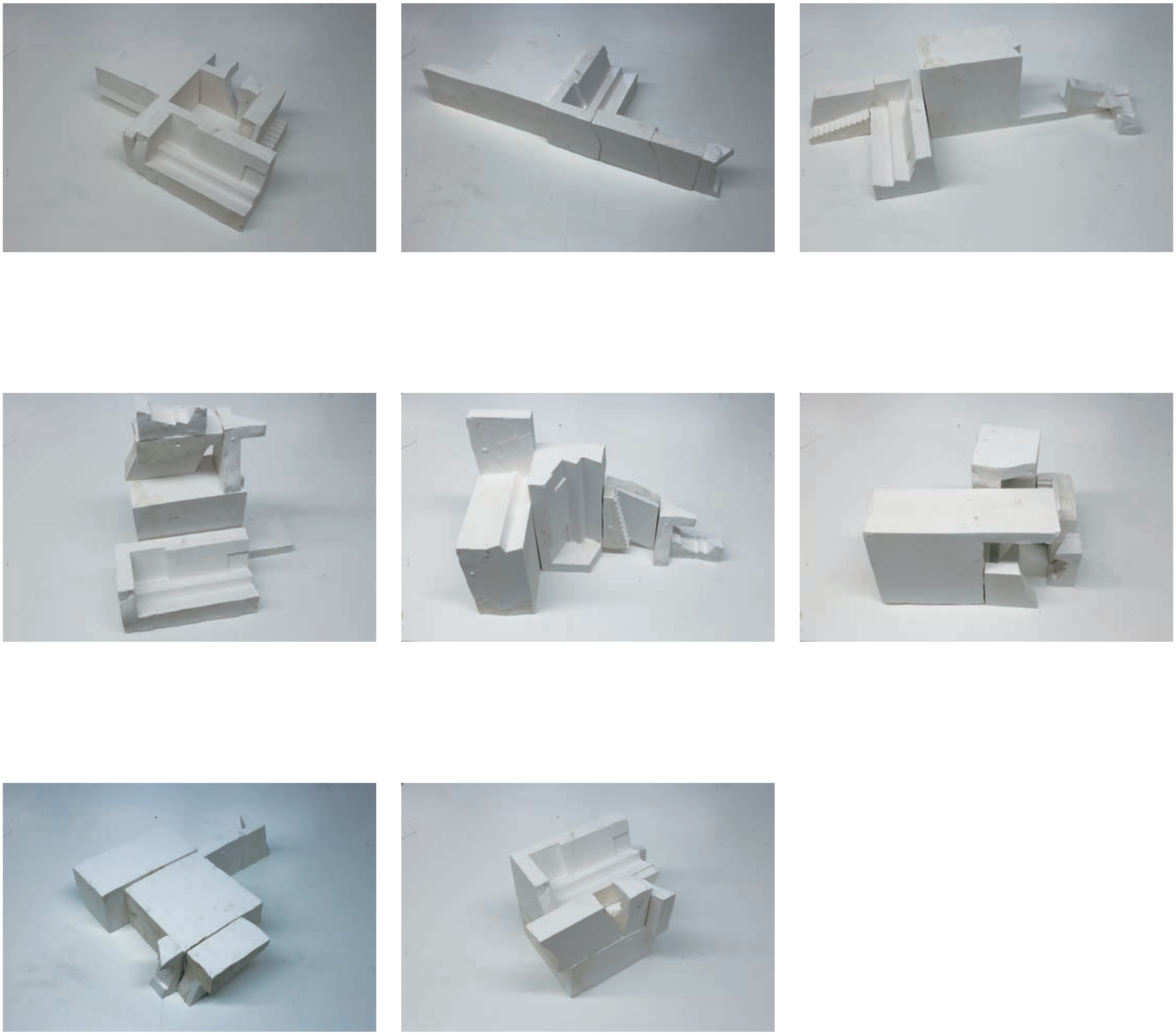


Figure 3.4.8
Using circulation typologies and other factors helping to define a part-to-whole relationship to explore various possible spatial sequences

Exercise

Media 1: Overlay

In your last exercise you conducted solid-to-void inversions of your individual mold pieces, and examined them as one-point perspective drawings and tonal collages. For this task, continue to look at your mold pieces as voids. Each mold piece suggests a specific space. At this stage, the specificity of these spaces is defined by their geometry, scale and proportion. Although they might have formal similarities, spatially they are isolated, as though they are separate, floating rooms.

Propose a sequence for your spaces that creates, as a whole, a new architectural quality. There are countless ways in which your set of mold parts can be arranged. So where do you begin?

One logic that ties a whole building together internally is its circulation (see "Glossary of Technical Terms and Materials"). Looking at circulation typologies in architecture will give you a starting point for making a different arrangement of your mold pieces. Refer to the "Circulation Typologies Reference" in the next section and see how your mold pieces respond as arrangements based on each circulation type. Document each arrangement photographically, from the same angle, to compare them. **(3.4.8)** Make notes and sketches about what you find compelling and what you find awkward about each arrangement.

As you assemble the pieces to a new whole, you will encounter the problem of part-to-whole relationship. How do the parts form a new interior whole, a spatial sequence that can be read as a new whole as well as individual instances? How do the parts form a new exterior form, while still being read as idiosyncratic, individual forms? How to the individual parts relate, in a consistent way, to each other, to create a whole?

As you look carefully at your mold pieces, you will discover that they are defined by three types of surfaces:

- surfaces defined by parting lines made with clay dams **(3.4.9)**
- surfaces defined by the cottle boards **(3.4.10)**
- surfaces defined by the form and surface detail of the mass model. **(3.4.11)**

Be intentional about how you're handling these very different and specific surfaces that characterize every single mold piece. Using consistency in how you handle each piece to create a unity will help you establish a strong part-to-whole relationship.

Assemble a minimum of six distinct arrangements that correspond to the circulation typologies and which have clear and deliberate part-to-whole strategies. Photograph each arrangement. Print each photo full-page on 8.5 x 11 in. (A4) paper, and create overlays by drawing directly on the prints, hollowing out the plaster volumes and investigating the internal spatial sequences with an informal drawing-as-thinking approach. **(3.4.12)**

Figure 3.4.9
Single mold piece showing the surface defined as a parting line

Figure 3.4.10
Single mold piece showing the flat surface defined by the cottle boards

Figure 3.4.11
Single mold piece showing the interior surface defined by the form and surface of the mass model

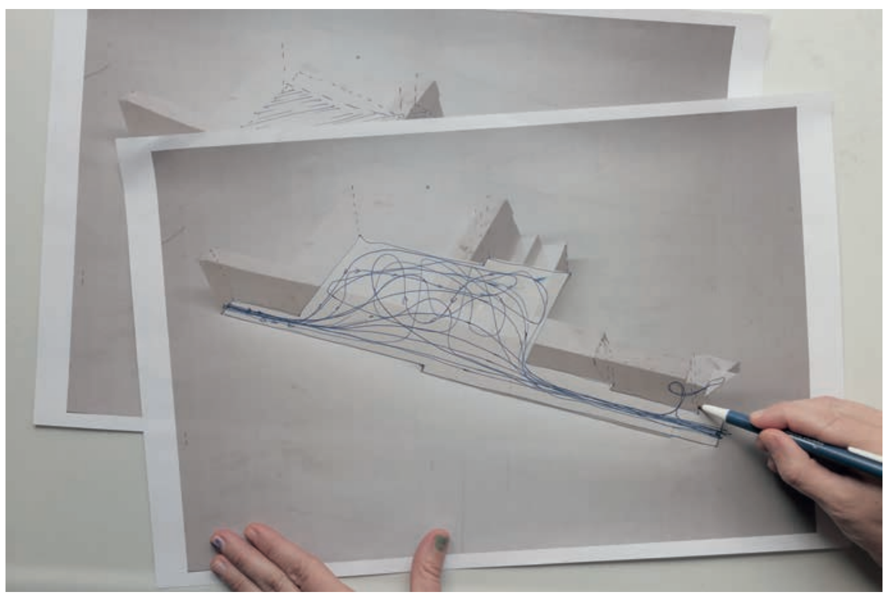


Figure 3.4.12
An example overlay, used to help envision the circulation that a particular spatial sequence would have

Circulation Typologies Reference

Basic circulation typologies and corresponding case studies:

Linear circulation; example: Museo La Conguinta, Peter Maerkli, Giornico Switzerland, 1989–1992 **(3.4.13)**

This building consists of three distinctly proportioned narrow rooms, connected lengthwise to create the narrowest possible building volume. One has to pass through one room to get to the next. The prescribed pathway encourages incidental encounters.

Around-the-corner; example: Resurrection Chapel, Sigurd Lewerentz, Stockholm, Sweden, 1925 **(3.4.14)**

In this example, views ahead are only visible by turning a corner. There isn't a single standpoint where the entire space can be viewed at once. Rather, the contrast of the two different spaces is underlined by the circulation.

Net; example: Bank of England, Sir John Soane, London England, 1788–1833 **(3.4.15)**

In this example, the large-scale building is a complex network of differentiated rooms.

Open; example: Los Manantiales Restaurant, Felix Candela, Xochilmico, Mexico, 1958 **(3.4.16)**

This example reads formally like a blanket hovering over the site, with no columns and making minimal contact with the ground. The interior space has a very immediate relationship with the exterior environment.

Open; example: Artist Studio, Davidson Rafailidis, Buffalo, New York, United States, 2015 **(3.4.17)**

In this example, three distinct, shed-like buildings are connected with an open floorplan, free of columns and partition walls.

Stair; example: Alte Pinakothek, Leo von Klenze, 1836 / Hans Doellgast, 1946–1957, Munich, Germany **(3.4.18)**

In this example, the entire length and height of the long Alte Pinakothek is experienced in walking the stairs, designed as part of the post-World War II renovation of the building by Doellgast.

Stair; example: Swiss Re competition entry, Christian Kerez, Zurich, Switzerland, 2010 **(3.4.19)**

In this example, the standard vertical core is rearticulated as a collection of diagonal stairway tubes.

Stair; example: Casa Malaparte, Adalberto Libera and Curzio Malaparte, Capri, Italy, 1937 **(3.4.20)**

This building is characterized by a large-scale exterior stairway that bridges the site and the building.

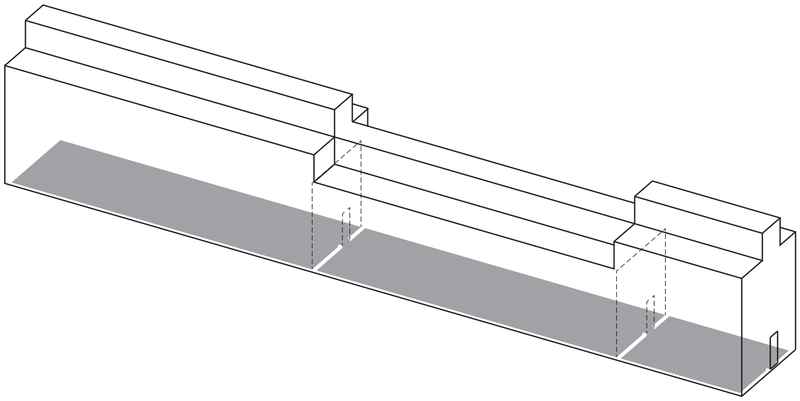


Figure 3.4.13
Linear circulation example, Museo La Conguinta

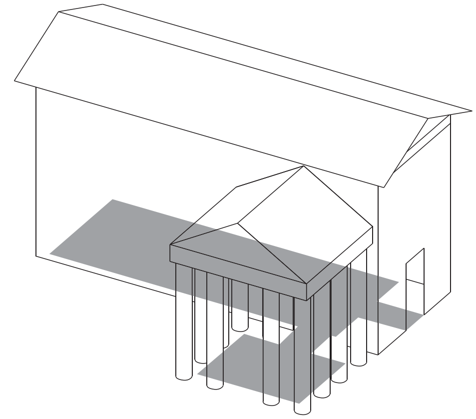
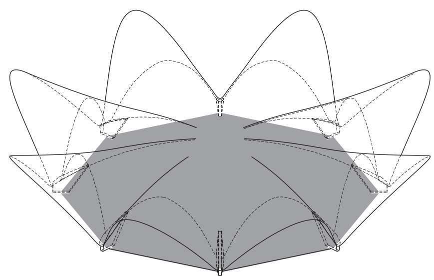


Figure 3.4.14
Around-the-corner circulation example, Resurrection Chapel



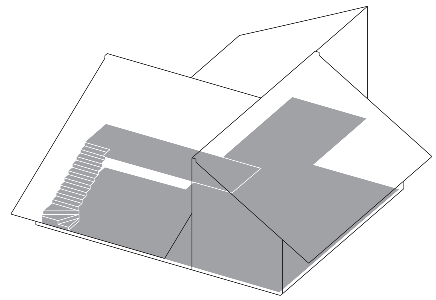
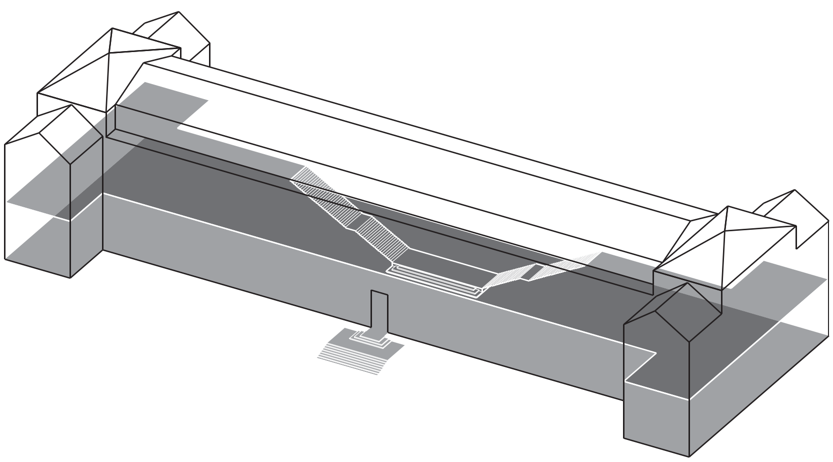


Figure 3.4.16
Open circulation example, Los Manantiales Restaurant

Figure 3.4.17
Open circulation example, Artist Studio

Figure 3.4.15
Net circulation example, Bank of England



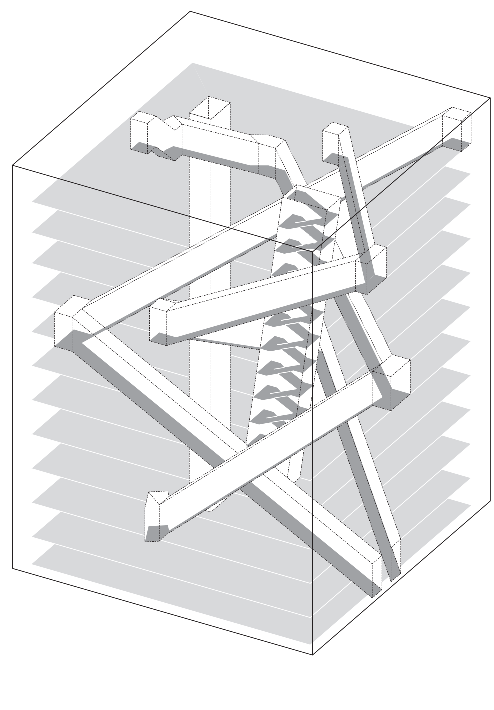


Figure 3.4.18
Stair circulation example, Alte Pinakothek

Figure 3.4.19
Stair circulation example, Swiss Re

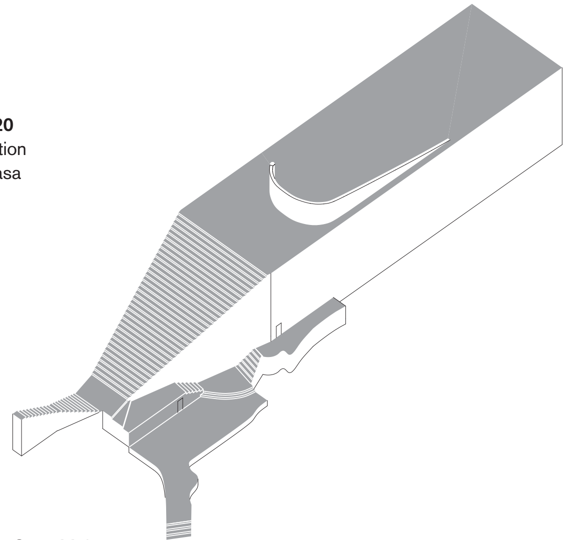


Figure 3.4.20
Stair circulation example, Casa Malaparte

Casa Malaparte
Adalberto Libera and Curzio Malaparte, Capri Italy, 1937

Scalinata di Trinità dei Monti (Spanish Steps)
Francesco de Sanctis, Rome Italy, 1723-1725

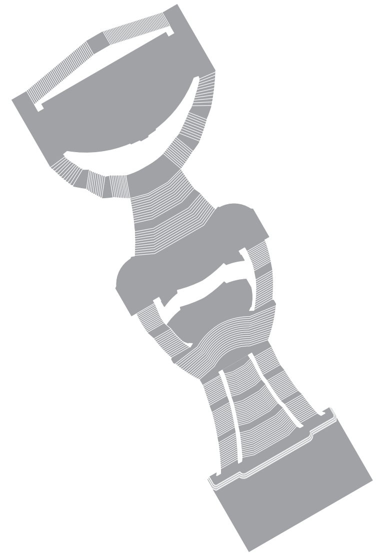


Figure 3.4.21
Stair circulation example, Spanish Steps

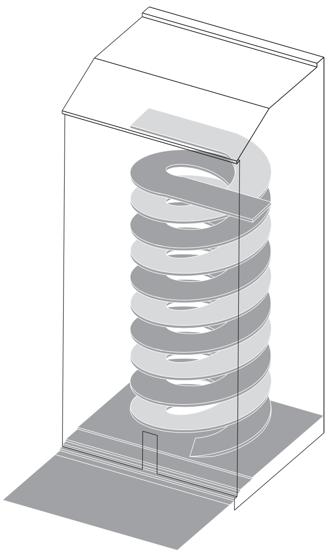
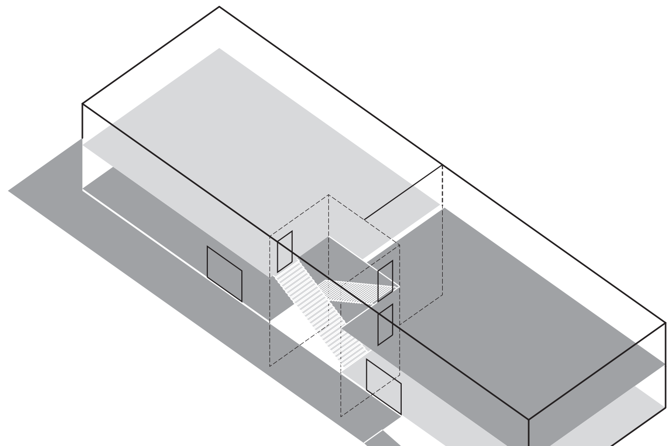


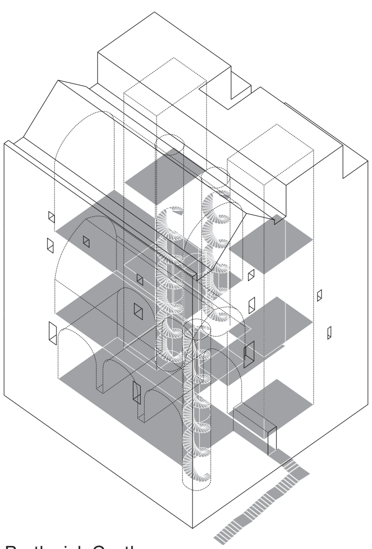
Figure 3.4.22
Ramp circulation example, Bramante Ramp in the Pio-Clementine Museum

Bramante Ramp in the Pio-Clementine Museum
Donato Bramate, Vatican City, Rome Italy, 1505

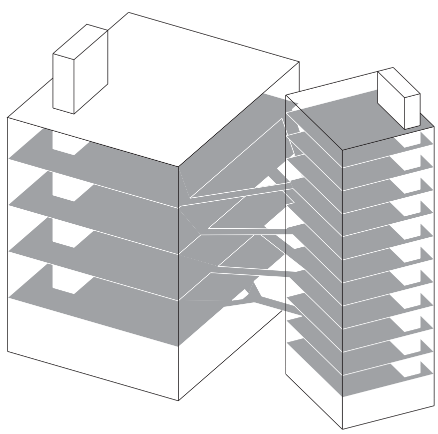


Private Residence
Harry Gugger, Basel Switzerland, 1995–96

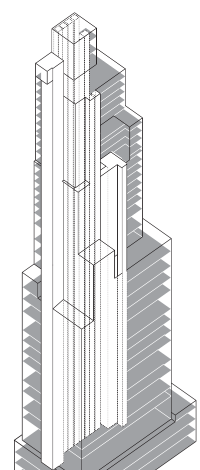
Figure 3.4.23
Stair circulation example, Private Residence



Borthwick Castle
Midlothian Scotland, 1430



SESC Pompeia
Lina Bo Bardi, São Paulo Brazil, 1977-86



Downtown Athletic Club
Starrett and Van Vleck, New York City, New York, United States, 1929-30

Figure 3.4.24
Stair circulation example, Borthwick Castle

Figure 3.4.25
Bridge circulation example, SESC Pompeia

Figure 3.4.26
Elevator circulation example, Downtown Athletic Club

Stair; example: *Scalinata di Trinità dei Monti* (Spanish Steps), Francesco de Sanctis, Rome, Italy, 1723–1725 **(3.4.21)**

This wide, plaza-like stair is not only for movement but also for pause, for inhabitation as a public space.

Ramp; example: Bramante Ramp in the Pio-Clementine Museum, Donato Bramate, Vatican City, Rome, Italy, 1505 **(3.4.22)**

This double-helix set of two intertwined, brick ramps allows uninterrupted traffic in each direction.

Stair; example: Private Residence, Harry Gugger, Basel, Switzerland, 1995–1996 **(3.4.23)**

This example is a hybrid between a semi-detached house and a double; a scissor stair gives both parties ground and upper floor areas, as well as access to both sides of the building volume.

Stair; example: Borthwick Castle, Midlothian, Scotland, 1430 **(3.4.24)**

In this castle from the late Middle Ages, circulation elements are freely "carved" into the thick walls, resulting in an unusually expressive vertical distribution of rooms.

Bridge; example: SESC Pompeia, Lina Bo Bardi, São Paulo, Brazil, 1977–1986 **(3.4.25)**

In this project, sport halls and changing rooms are pulled apart into two separate buildings. Bridges connect the two buildings.

Elevator; example: Downtown Athletic Club, Starrett and Van Vleck, New York City, New York, United States, 1929–1930 **(3.4.26)**

The elevator bred a completely new type of architecture at the turn of the last century, the skyscraper. This Art Deco skyscraper in New York City has 38 stories.

Media 2: Monocoque

Choose your strongest spatial sequence and use it to mold a paper pulp shell, following the instructions given in 4.7, "Paper Casting to Make a *Monocoque*." **(3.4.27)**

The resulting form is defined by the strategy of the *monocoque*. Do not add any additional walls or floors to your paper pulp shell. Where volumes touch, there is no surface, since you can't paper pulp in between these volumes. All articulation is achieved with the continuous exterior surface of the *monocoque* envelope. **(3.4.28)**

Media 3: Modification—Cutting, Scoring, Folding

Your paper shell is cast to make a fully enclosed space. Articulate the circulation elements and the openings for your spatial sequence by modifying your paper pulp *monocoque*. Develop a coherent language of modification for your specific spatial idea. **(3.4.29)**

The palette of circulation elements could include all forms of stairs, ramps, terraces, ladders, doors, windows, etc. To form these circulation elements, you have to create perforations in your paper pulp envelope. By transforming your paper pulp

Figure 3.4.27
Process, paper casting to make a *monocoque* over a plaster armature

Figure 3.4.28
Paper cast *monocoque* with plaster armature removed, top and interior views

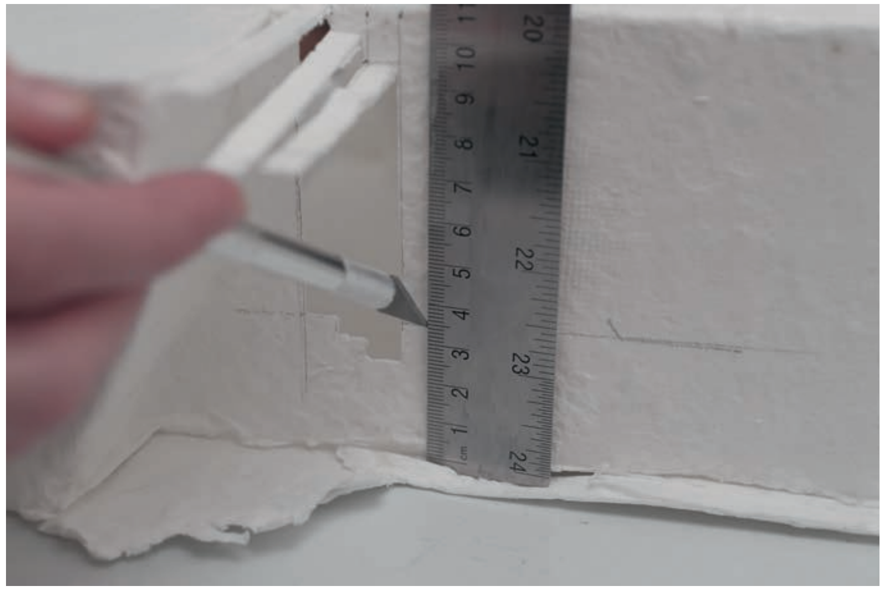


Figure 3.4.29
Modifying a paper cast *monocoque* by cutting and folding, in this case into an external staircase

Figure 3.4.30
Pine forest, Jamie Starling, "Pine Forest Two," photo taken at Jones Lake State Park, near Elizabethtown, North Carolina, USA, 2010

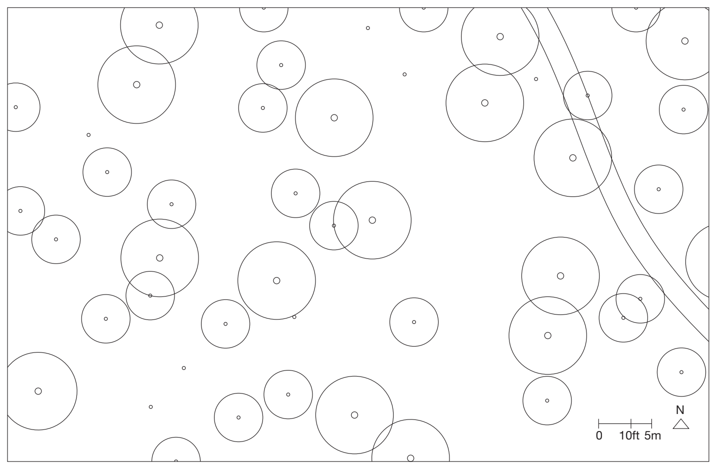


Figure 3.4.31
Site plan. Access to the forest site is from the South-East, via a gravel foot and bike path which continues Northward

model you should integrate openings for natural lighting, circulation and views in your proposal. The exterior of your envelope becomes accessible and will offer additional opportunities for inhabitation. Investigate these new interior/exterior relationships. The exterior context is a pine forest. **(3.4.30) (3.4.31)**

Media 4: Illustration

In the introduction to this exercise, we argued that buildings have a significantly longer lifespan than contemporary programs. Because of this, we asked you to design a spatial sequence defined by more fundamental, long-lived aspects, independent of program. Now you will test your project against the short-lived aspect of program/use. You will test the chance encounter between use and form through a program lottery.

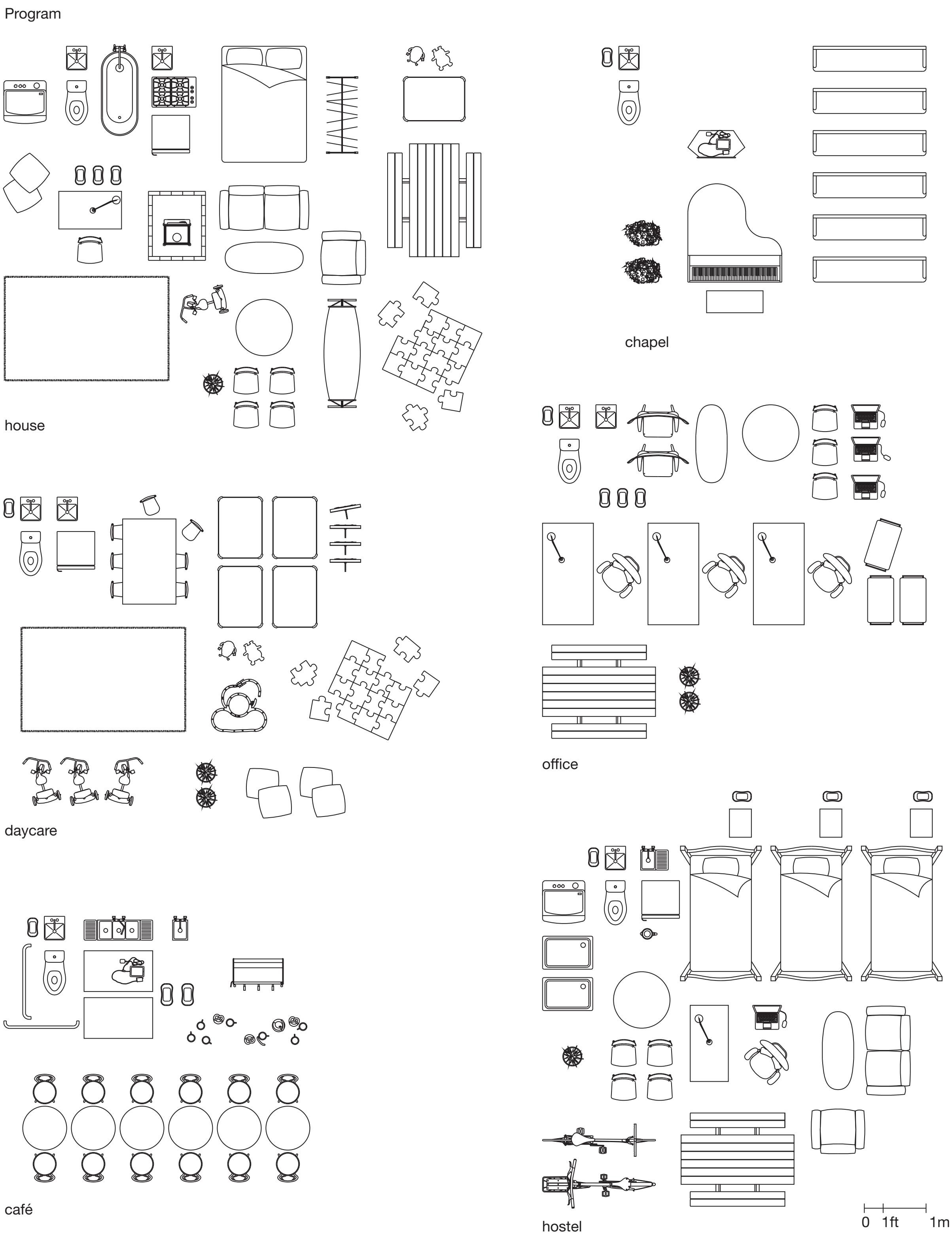


Figure 3.4.32
Illustrated furniture elements to use for six different programs: office, daycare, café, chapel, hostel, house

Three of these six programs will be given to you in a lottery organized by your instructor: **(3.4.32)**

- office
- daycare
- café
- chapel
- hostel
- house.

Make a set of orthographic drawings of your *monocoque*, assigning a uniform 2-in. (5-cm) wall thickness to the shell. **(3.4.33)** Use the plan view that shows the most of your spatial arrangement as the basis for your inhabitation illustrations. In a computer-aided design (CAD) program, open the set of illustrated inhabitation elements for each of your assigned programs and introduce your building to its new uses.

Your spatial proposal may resist the given program, the relationship between the spaces and the new use might have tensions. In other cases, your proposal may seem to *fit* or actively facilitate the given program very easily. How does your spatial sequence relate to each of your programs? Identify how and why this facilitation or resistance occurs through discussion with your instructor.

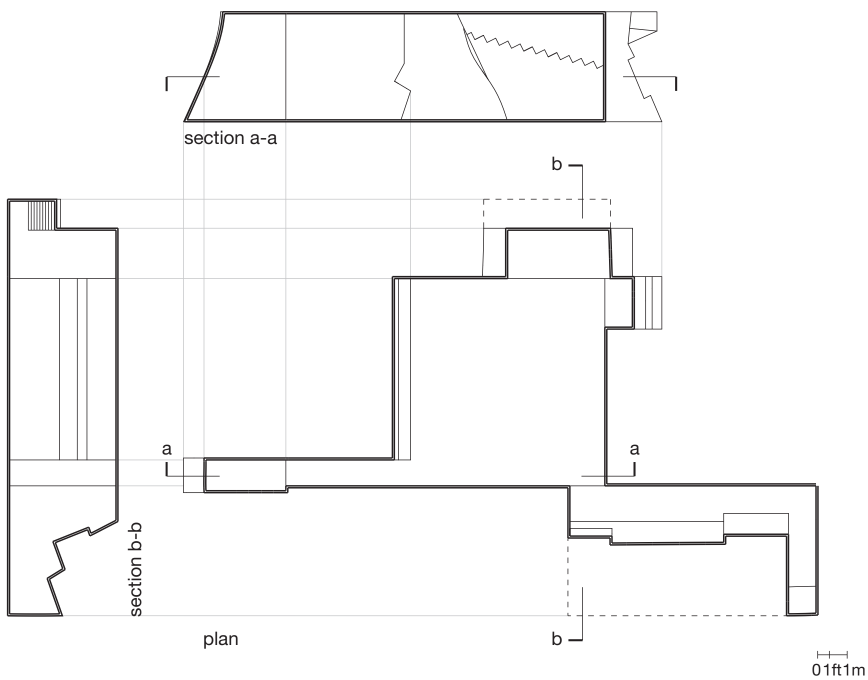


Figure 3.4.33
Orthographic drawing set of *monocoque* shell

Media 5: Macrophotography

Refer to 4.8, "Taking Photos of Scale Models," to document the interior spaces of your model through macrophotography. Construct a photographic sequence of at least three photos of different instances within your model interior. Some indication of scale should be used in each photo. This can be achieved in a very subtle way through a single furniture element or a hint of a figure. Populating the model interior

Figure 3.4.34
Sequence of interior model photos

with scale figures is the most straightforward way of indicating scale. Figures help viewers adopt a position in the photo of the space. Take a variety of photos, following the cues in 4.8, "Taking Photos of Scale Models," before choosing your sequence. Be deliberate about the lighting and the way in which the spaces are staged and framed. How can you best achieve the atmospheres that you imagine through photographs? Animate the physical environments of your model and work on your photography skills instead of relying on Photoshop. **(3.4.34)**

Notes

1 *Stan Allen,* "From Object to Field: Field Conditions in Architecture and Urbanism," in *Points + Lines: Diagrams and Projects for the City* (New York: Princeton Architectural Press, 1999), 92–102.

2 Brenda Deen Schildgen, *Heritage or Heresy: Preservation and Destruction of Religious Art and Architecture in Europe* (New York: Palgrave Macmillan, 2008), 84.

3.5 STRUCTURE AND SPACE

Description

Casting Thin Shells

In the last assignment, you worked with a cast paper *monocoque* at model scale. In this final assignment, you will investigate the structural performance of a thin *monocoque* at full scale. You will construct a large span with found forms and a weak material in a short time. Working at full scale will enable you to investigate the relationship between material behavior, structure and space. It should be a generative process, where the three main players—material, structure and space—are in constant conversation, helping to define the outcome. Structural performance can generate form and space. Chapter 4.11, "Planar Structures," describes the structural typology of the shell in detail.

When you invested your foam model in plaster you were looking at the form of your space through the lens of rigid, multi-part mold making, thinking about undercuts, parting lines and casting a material in its liquid state. At the same time, you learned a new media-specific dimension about the form of your space, enriching your understanding about and perception of the space. Similarly, by looking at the formal characteristics of the spaces surrounding you as potential supports for a planar structure, you learn a new dimension of surface form. All physical objects can transmit forces and are filled, more or less, with forces and resulting stresses, which are invisible to us. **(3.5.1)** It is only through symptoms like sagging, buckling, moving

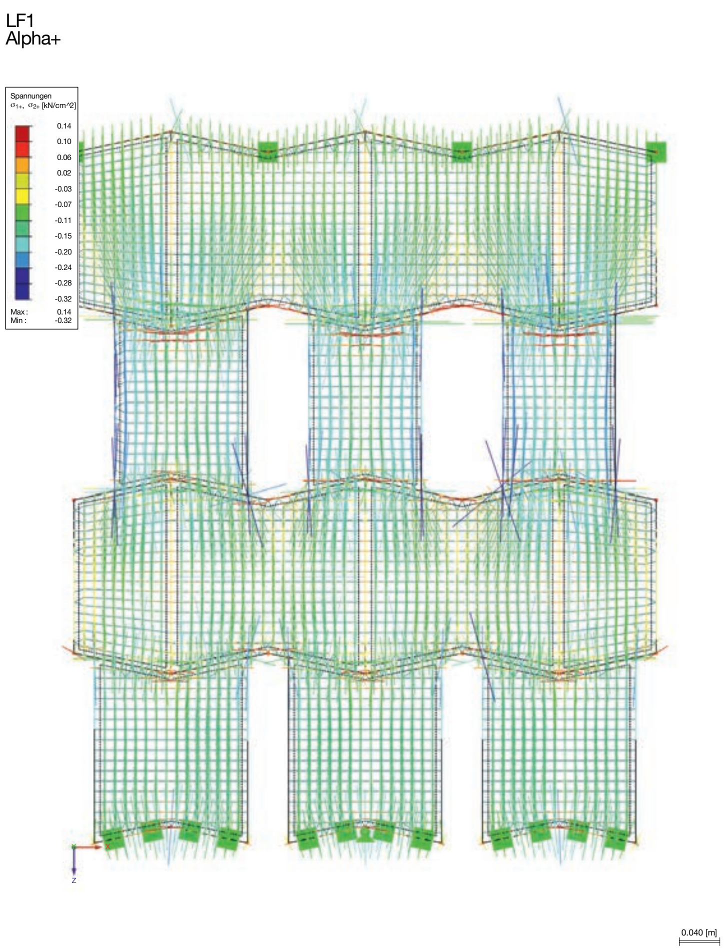


Figure 3.5.1
FEM (finite element method) structural analysis of a glass block wall assembly

Figure 3.5.2
Stress crack in drywall of a building that experienced sudden movement through jacking

and cracking that we can get a hunch about exactly how these invisible forces work. **(3.5.2)** But, according to the art historian Heinrich Wolfflin, we also have an intuitive understanding of these forces and how they relate to form because we feel them constantly within our bodies:

> Our own bodily organization is the form through which we apprehend everything physical. I shall now show that the basic elements of architecture—material and form, gravity and force—are defined by our experience of ourselves.[1]

Although each type of loading leads to certain types of structural forms (see chapter 4.11), it is fascinating that the optimal structural form which cannot be altered without decreasing its performance is not known to us.[2] Frei Otto is a structural engineer who devoted his life's work to the subject of lightweight structures: structures whose aim is to achieve structural performance with the least amount of material. Even Otto was unable to determine the single optimum form for a structural task:

> But after intensive research, we were forced to the conclusion that not even the form of a simple compression-loaded support with lowest possible material expenditure is known, let alone that of bending-stressed girders or beams. We can prove that considerable material savings must still be possible, but not by using the thinking normally applied these days by architects, engineers and even aircraft builders. A structure is designed more or less 'by inspriration' and then calculated. Where there is too much material, some is removed. This kind of method cannot break out of the limits set by the design, cannot produce unknown forms. We have experimented with completely different methods and were ourselves amazed how much progress could be made. We have not yet found direct access to the unimprovable form, to the optimum, except perhaps in some minimum-surface-type tents.[3]

Figure 3.5.3
Student workspace interior, potential site to support the casting of a shell

Structural form becomes even more complex when seen through the lens of architecture, where it is not only evaluated for its structural performance, but other criteria too. For example, the context and surrounding of structures, their use, formal preferences, materials available, material costs, skill set of workers, mathematical models available, construction time, etc., are all criteria used in the evaluation of structural form as space. Even within contexts of experimentation and research, there are always given constraints which need to be addressed in designing a structure. To prepare you to work within given constraints, for the exercise in this chapter you will be limited to the use of forms in your workspace.

From Surface to Space

Like the beginning of this design process, you need to roam for this exercise. You'll be asked to identify an area of your immediate, physical environment—your workspace—which could act as formwork to support the molding of a thin shell at 1:1 (e.g. corner, wall, niches, arch, I-beam, window, etc.). **(3.5.3)** The appropriation of characteristics or parts of spaces in which we live every day is a critical part of our design process. The process began with an everyday space and its immaterial attribute—its atmosphere—and with this assignment, the process closes the loop and revisits an everyday space, this time for a concrete task, a structural intervention. The last exercise draws upon many of the spatial and formal insights gained in previous exercises and ties them together: first-hand experience, looking hard, ad-hoc finding, solid-void inversion, casting and making *monocoque* shells.

Casting against an existing building surface has a series of consequences. Building formwork isn't necessary since you are finding formwork. Your cast is situated in an architectural context and scale. Your cast has a pictorial quality, it records and represents the building surface, similar to a photograph, but it does so at full scale. The picture plane is the building surface. **(3.5.4)** This immediacy questions the status of the original—the mold/formwork, and the reproduction. By using the building surface as formwork/mold, your cast can be read as the original, for which the existing building is a mere mold. Your cast would represent an original form that didn't previously exist. The status of your cast and the wall are in a

Figure 3.5.4
Pictorial quality of a full-scale, cast surface, recording characteristics of a building, in this case, an electric outlet

flickering relationship between original/mold/reproduction, offering multiple, simultaneous readings. And it is between these slippages of status between formwork and cast that your space is created. **(3.5.5)**

Seeing the Structural Potential of Surface Form

The spaces that you're asked to design are at once an ambiguous combination of reproduction and original, as well as a clear example of a *monocoque*. The shells invite both a structural reading and a spatial reading with respect to their site. As you roam your workspace and look for surfaces that might perform better structurally than others, you train your observation skills in a new category of structural performance. The structural performance of surface form is, in this exercise, directly tied with the formal and spatial qualities discussed above. Using scale models, you'll be able to better observe the structural potential of the *monocoque* that you plan to fabricate at full scale. **(3.5.6)**

Iterative Modeling

The task to construct a large span with found forms and a weak material in a short time is challenging; the scale, material and time frame are all significant constraints. The objective is to focus on the essence of the task and avoid being distracted by external ideas. The task of creating such large spans will lead to a "let's see what works" attitude, free of any formal preconceptions, focused on solutions that perform structurally. The size of the span also demands that you approach it in incremental steps. You will learn empirically, through trial and error, and you will work with what is known in the context of architectural design as "iterative modeling." Iterative modeling allows you to break down complex design tasks into separate variables that can be addressed one by one, instead of all at once. With this method, you can learn about each design variable and get control over it. How does iterative modeling work?

Choose a starting point of investigation. In your case, it could be the thinness of a cast. After you make a first patch of casting and release it, you look carefully at the

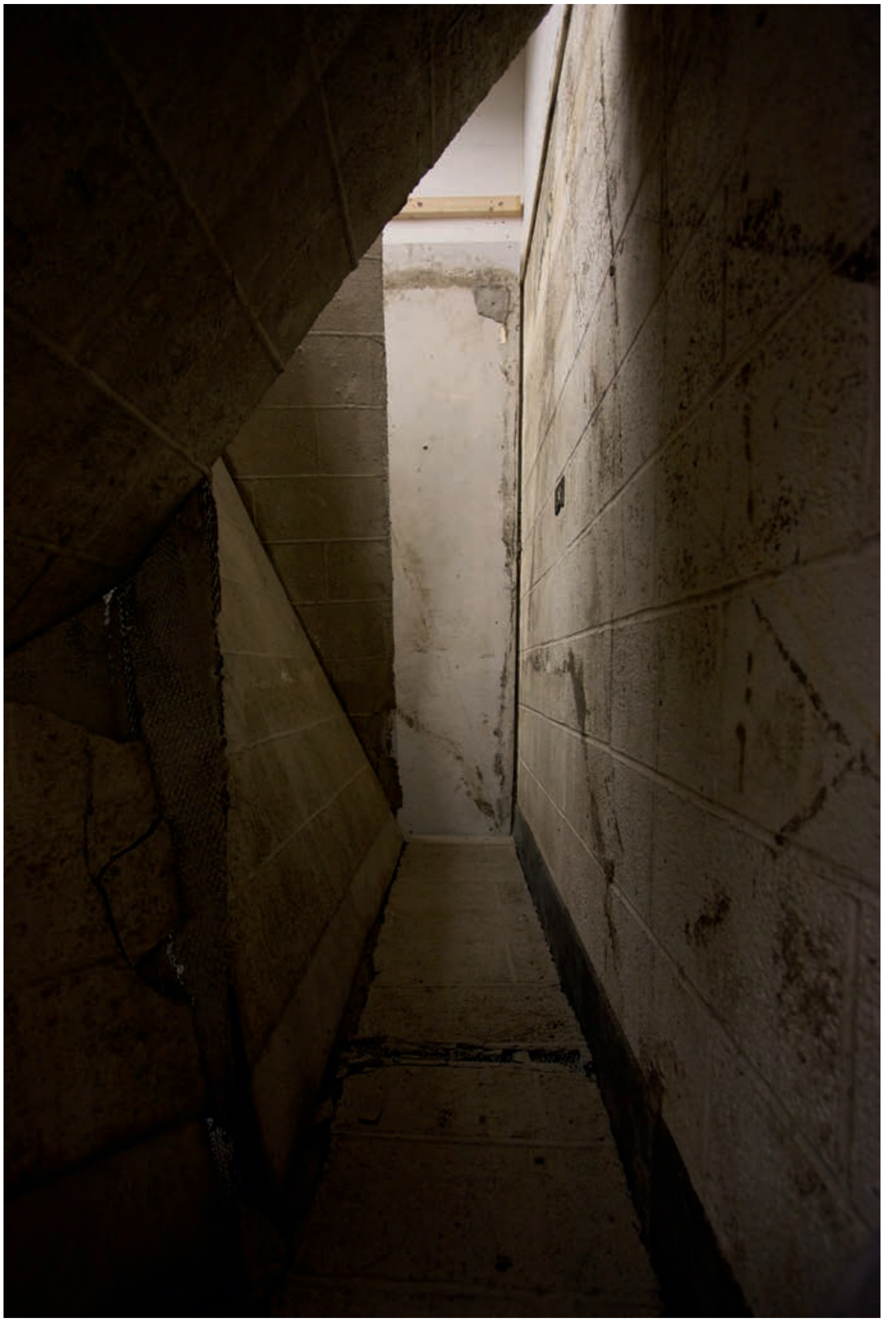


Figure 3.5.5
The wall surface and the cast surface, in this case, a reinforced concrete *monocoque*, have an ambiguous relationship with one another

result (empirical observation) and learn from it. Are there cracks? Why? What can you do about it? Do you think you could make it thinner? What in your process could you change to make it thinner? How cost and time intensive is this first artifact and what did you learn from it? What unexpected features emerged as you made your first artifact? Are these features desirable? Use and amplify desirable features in your next iteration. Are any features undesirable? How could you avoid them in a next iteration? Did you find any new, unexpected potentials? These could start a new line of investigation. **(3.5.7)**

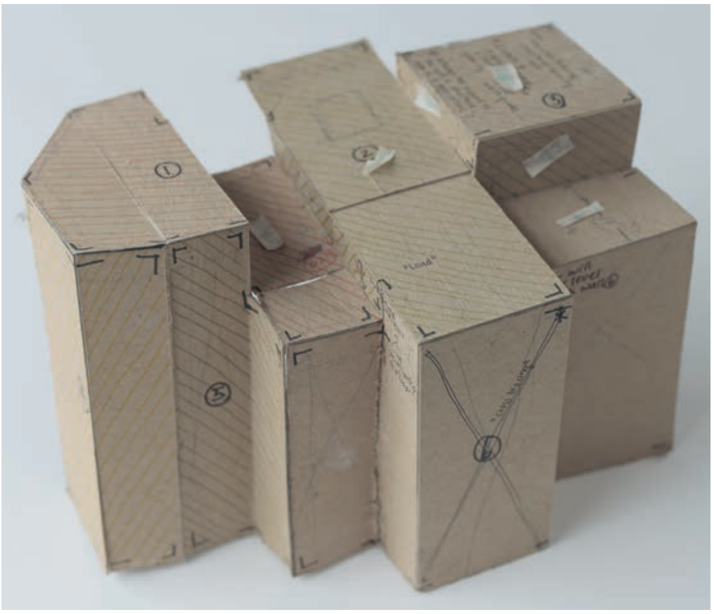


Figure 3.5.6
Scale model made to observe the structural potential of a *monocoque*

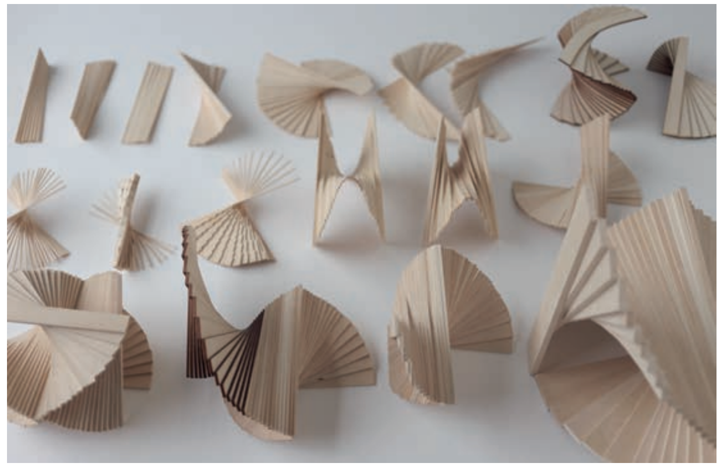


Figure 3.5.7
Example of models made in an iterative process, each exploring ruled surfaces with rotating boards. Each model builds upon the insights gained in the previous model

As you can see, failures in your artifact are more important than successes at this early stage of the project, as they offer important learning opportunities. Failures are productive at this point and unproductive in the end result.

The next model you produce will be an iteration of the first one and will incorporate what you learned from the previous artifact about thinness. Continue this process until you feel confident to handle the issue of thinness and continue to investigate for example the effect of form. Use the latest iteration of your thin artifact and test it against a new form. Is it stronger than before? How did it become stronger? Is it weaker? Why is it weaker?

Intended Learning Outcome

One objective of the exercise in "Structure and Space" is to avoid a common tendency in design studios where a simplistic dichotomy is created between the real and the represented. In the exercise in this chapter, the original, represented and performative aspects of materiality and space are dissected and reassembled into a new whole. Learning outcomes of the exercise should be that you see the structural potential in surface form, and, more broadly, the integrated nature of structure and space. Through engaging with materials and in the construction of a full-scale *monocoque*, you should develop a keener physical understanding of certain material behaviors and the consequences of structural forces. Through iterative modeling, you should experience the necessity for trial and error and empirical research in architecture.

Exercise

Media: Casting, Monocoque

Cast a thin shell of an existing part of your studio spaces at 1:1 (e.g. corner, wall, niches, arch, I-beam, window, etc.). The existing space will be your formwork. You will remove the shell and reposition (flip, rotate, move, etc.) to create a space.

The resulting structure should accommodate at least seven people inside or underneath the structure. The free span should be at least 12 ft (3.6 m). Develop a clear strategy about how your cast (the recording, the copy, the negative) is positioned toward the original (the real space, the formwork). Space is created by the specific relation between cast shell and original building part. **(3.5.8)**

Figure 3.5.8
A concrete *monocoque* being released from the wall surface against which it was cast

Figure 3.5.9
Certain surfaces will perform better than others to cast a *monocoque* and perform structurally; a corner (top) will lend more structural integrity than a flat wall (bottom)

Roam your studio spaces on a search for surface forms which seem to provide for both a specific spatial experience and structural performance. Certain forms will perform structurally better than others. **(3.5.9)** You will have to think spatially and structurally at the same time. Thin shells acquire their structural strength through deformation of their surface. The less "flat" a surface is, the more stiff it gets. Double curved surfaces and folds are especially effective. **(3.5.10)** While the surface of the formwork is "found," the surface facing you can be designed in a material-specific manner to enhance the structural performance of the shell. You are encouraged to manipulate the cast surface that is facing you to enhance the performance of the shell. The size and the shape of the perimeter of the shell are also critical.

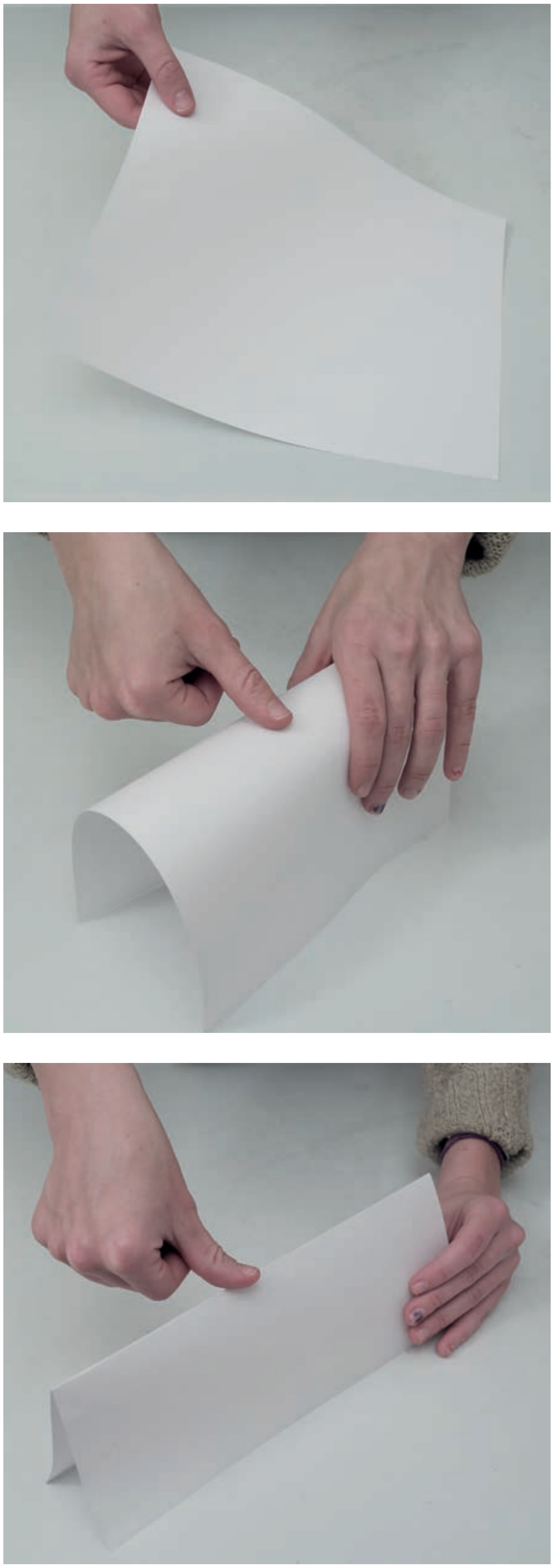


Figure 3.5.10
A flat sheet of paper showing how it begins to acquire compressive strength when curved or folded

Choose one of the following materials:

- hydrocal **(3.5.11a-k)**
- rope, twine or string **(3.5.12a-f)**
- paper pulp, twine pulp or paper strips **(3.5.13a-f)**
- concrete **(3.5.14a-m)**
- latex. **(3.5.15a-n)**

Each material listed has its own specific properties, behaviors, fabrication processes and appearance. Understanding these various aspects of your material is critical in this assignment.

Once you've chosen a specific material, start to work with it directly so that you can develop an understanding of its properties and behaviors. In the spirit of iterative modeling and empirical testing, make several test swatches to explore different ways of handling your material. Test swatches should be large enough so that they give you information about how your full-scale structure could work, but small enough so that you can make several of them quickly. Swatch areas of between 12 x 12 in. (30 x 30 cm) and 20 x 20 in. (50 x 50 cm) work well. **(3.5.16)**

Think about your material as a collaborator. Working with it directly is like having a conversation with it. It can show you what it can do and give you hints about how to exploit its physical capabilities to construct your *monocoque*. As you make your test swatches, ask yourself the following questions:

- How does material influence form, structural behavior and space?
- Do you need to add material to reinforce your casts?
- What can you learn from the other group with the same material as your group?

Before undertaking the construction of your span, make a diagram of your structural-spatial concept, indicating how the cast relates to the original surface, how the material will be applied and what the reinforcement strategy is.

Make construction drawings or "shop drawings" of the structure, including relevant details in a larger scale.

Document the fabrication process with a stop-motion film.

Notes

1 Heinrich Wolfflin, *Empathy, Form, and Space: Problems in German Aesthetics, 1873–1893* (Los Angeles, CA: The Getty Center for the History of Art, 1993), 157–158.

2 Frei Otto and Eda Schaur, *Form, Kraft, Masse = Form, Force, Mass* (Stuttgart: Institut für Leichte Flächentragwerke: Vertrieb, Freunde und Förderer der Leichtbauforschung, 1979), 5.

3 Otto and Schaur, *Form, Kraft, Masse*, 5.

Figure 3.5.11
Full-scale planar structure made using hydrocal:

(a) Test swatch to observe the behavior of fabric soaked in hydrocal

(b) Scale models and material samples to plan the assembly of the rigid fabric planes

(c) Fabrication of full-scale plane using fabric soaked in hydrocal, cast against a wall surface

(d–e) Moving rigid planes into final, enclosure assembly

(f–g) Hydrocal planar enclosure, exterior views

(h–j) Hydrocal planar enclosure, interior views

(k) Detail of the surface of the fabric soaked in hydrocal

Figure 3.5.12
Full-scale spaceframe structure made using rope, twine or string:

(a) Tying sisal twine to existing mechanical and structural elements in the studio space

(b) Sisal twine tied in-place, with additional, temporary string members used to locate the twine in specific positions

(c) Applying hydrocal to the twine

(d) Spaceframe twine structure, exterior view

(e–f) Spaceframe twine structure, interior views

Figure 3.5.13
Full-scale planar structure made using paper pulp, twine pulp or paper strips:

(a) Unraveled twine

(b) Test swatch of twine pulp (unraveled twine and diluted glue) cast against a window

(c) Process of casting a test swatch of twine pulp against a window

(d) Process of casting full-scale planes with twine pulp

(e) Finished full-scale twine pulp planes, cast with reinforcements in the pattern of the window muntin shadows, not yet released from the wall and floor

(f) Interior view of twine pulp structure

Figure 3.5.14
Full-scale planar structure made using concrete:

(a) Test swatch cast against a chair seat and flipped, to observe the behavior of reinforced hydrocal with a 2 ft. (61 cm) span

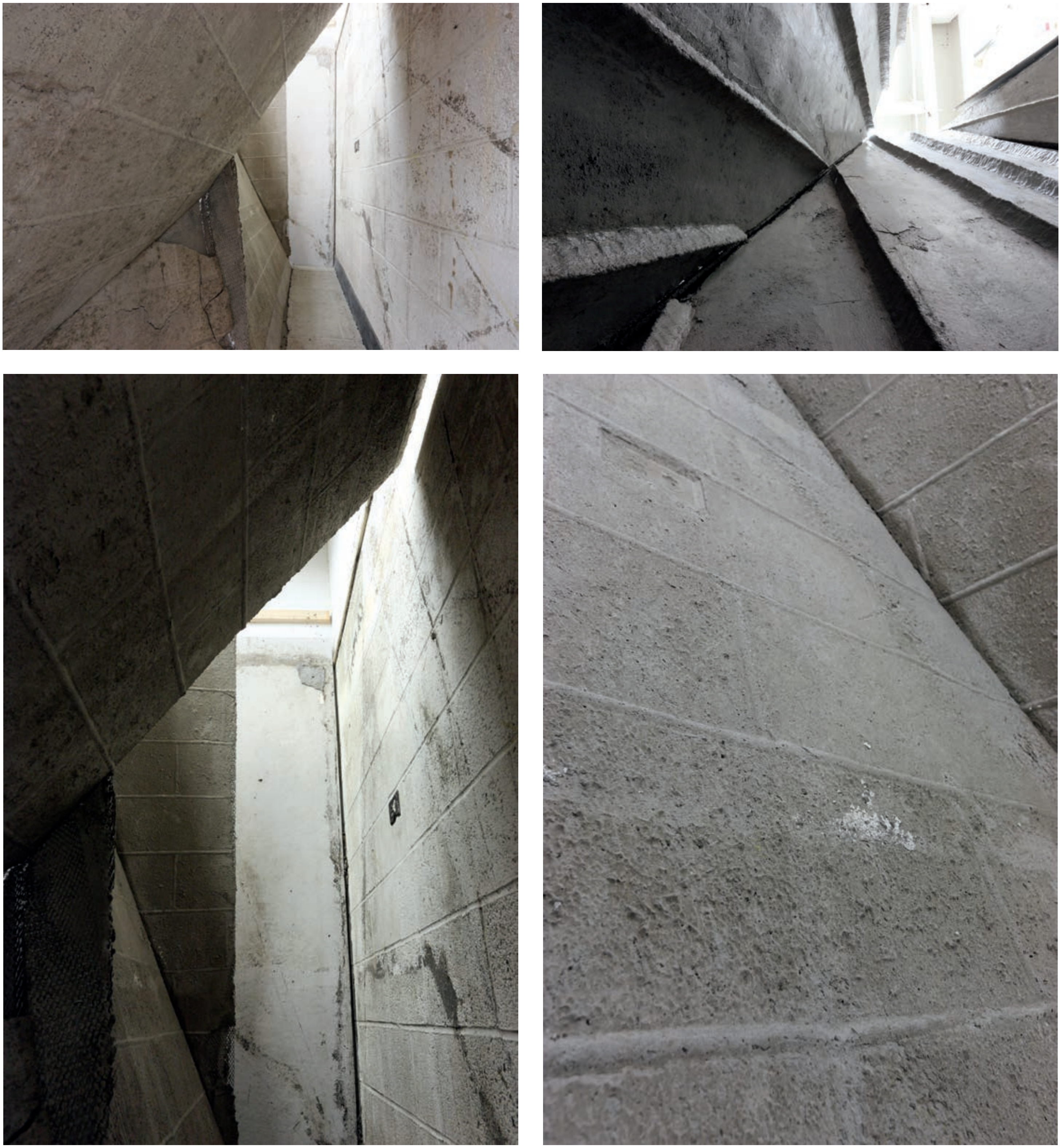
(b) Scale model of space used to work through various options for folding the cast plane into an enclosure

(c) Test swatch of reinforced concrete plane, 6 ft (1.8 m) tall, cast against a wall

(d) Fabrication of full-scale concrete plane

(e–g) Releasing the concrete plane from the wall

(h) Folded planar enclosure, exterior view

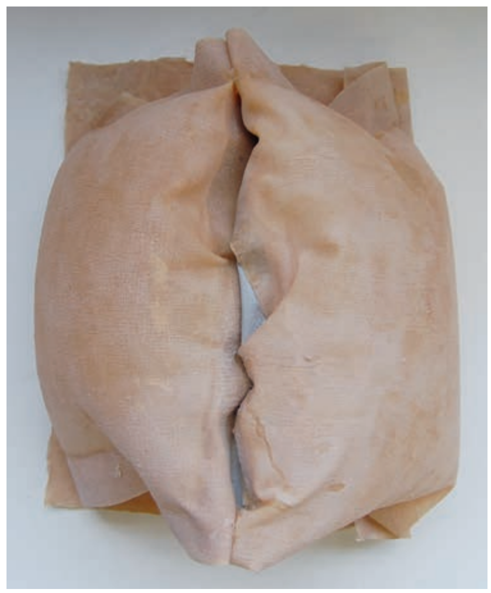


(i–l) Folded planar enclosure, interior views

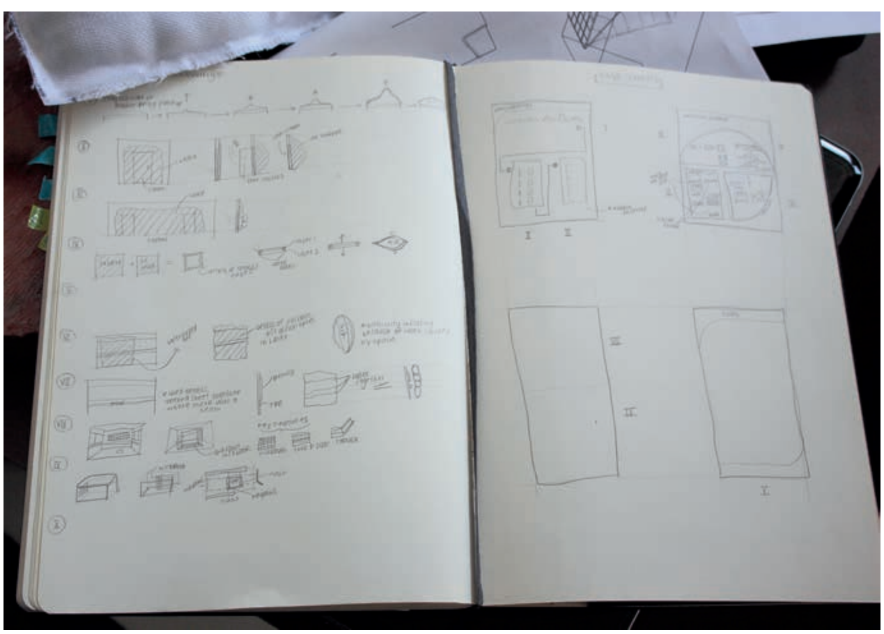
(m) Detail of the expanded metal reinforcement embedded in the thin concrete plane

Figure 3.5.15
Full-scale planar structure made using latex:

(a–c) Test models made from latex swatches exploring the structural potential of pneumatic, latex sacks



(d) Scale model of studio space to plan the installation of the latex structure



(e) Notes and sketches about installation planning

(f) Casting a latex skin against a wall

(g) Pneumatic latex structure

(h–j) Details of latex skin

(k) Detail of spigot cast into latex skin at various locations

(l) Detail of area of latex skin cast against electric outlet

(m) Detail of area of latex skin cast against a cutting surface, a tabletop

(n) Pneumatic latex structure deflating

Figure 3.5.16
Test swatch using concrete, to examine the effectiveness of a thin shell fabrication technique and the cast surface quality

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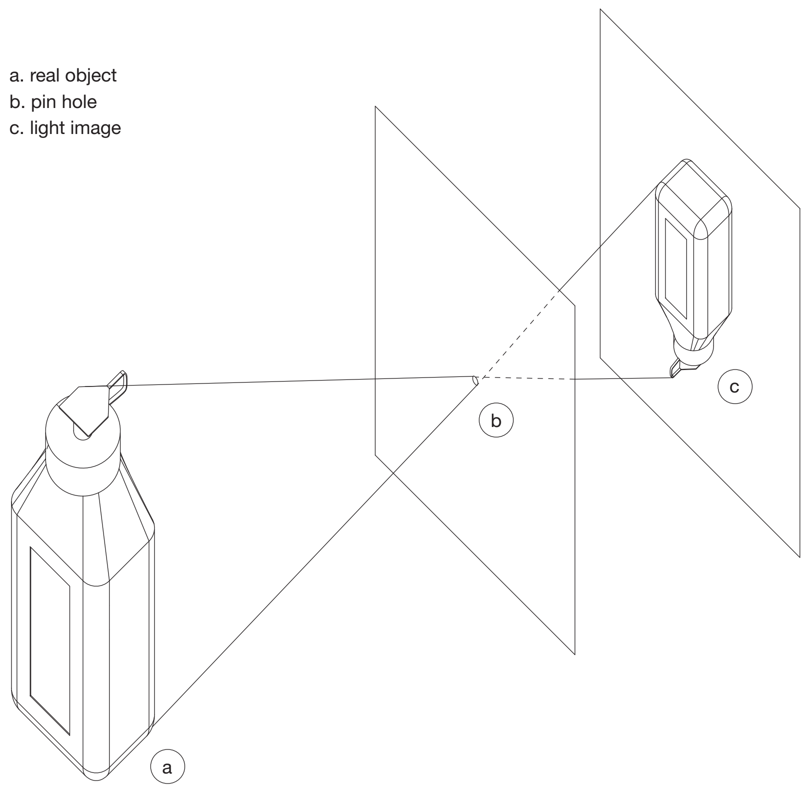
4 Manual of Techniques

4.1 TAKING PHOTOS OF SPACES

Photography is the recording of a light image produced by the camera principle (see "Glossary of Technical Terms and Materials"). **(4.1.1)** The image is either recorded chemically (on film) or digitally (via a sensor).

While photographs do resemble scenes as we see them with our eyes, they are not identical replicas of our view. The reason is that the anatomy of the camera and our eyes differ and so the resulting images do too. Some of these differences are particularly relevant to architectural photography:

a. real object
b. pin hole
c. light image



Light projects an image of an object through a pin hole (b) onto a picture plane (c). The projection lines converge and flip over at the pinhole, causing the light image to be a mirrored image of the actual object, in both vertical and horizontal planes.

Figure 4.1.1
The camera principle

- The human eye's picture plane (the retina) is spherical, while the camera sensor is flat. A spherical picture plane produces less perspectival distortion in comparison to photographs derived from a flat picture plane. When the angle of the cone of vision increases (see 4.6, "Perspectival Projection"), the discrepancy between the perspectival distortion of the human eye and the photograph increases.
- Our perception gives us a very wide-angle cone of vision because we move our eyes constantly; the result is an image with less perspectival distortion than the flat and "all at once" camera sensor view.
- We can see higher contrast between light and dark, known as the dynamic range (see "Glossary of Technical Terms and Materials") than a camera can record. For example, if we look at an interior wall with a bright window, we can see both the interior elevation and the exterior view at the same time. A camera cannot record the high discrepancy in brightness between the darker interior wall and the much brighter exterior view. This explains the common preference for photographers to photograph at dusk and dawn, when the exterior brightness is comparable to the amount of light emitted by artificial interior lighting.

It is important to familiarize yourself with the anatomy of a camera before beginning to photograph spaces. **(4.1.2)** To take photos of spaces, we will work with the following camera settings: shutter speed, aperture, focal length and exposure compensation.

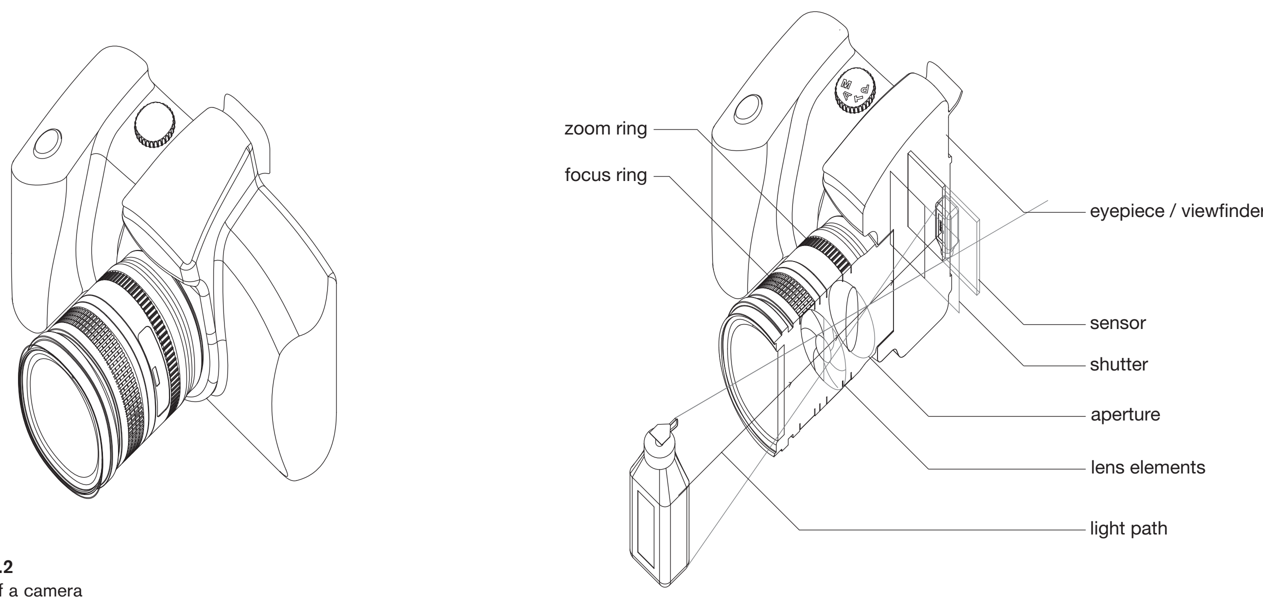


Figure 4.1.2
Anatomy of a camera

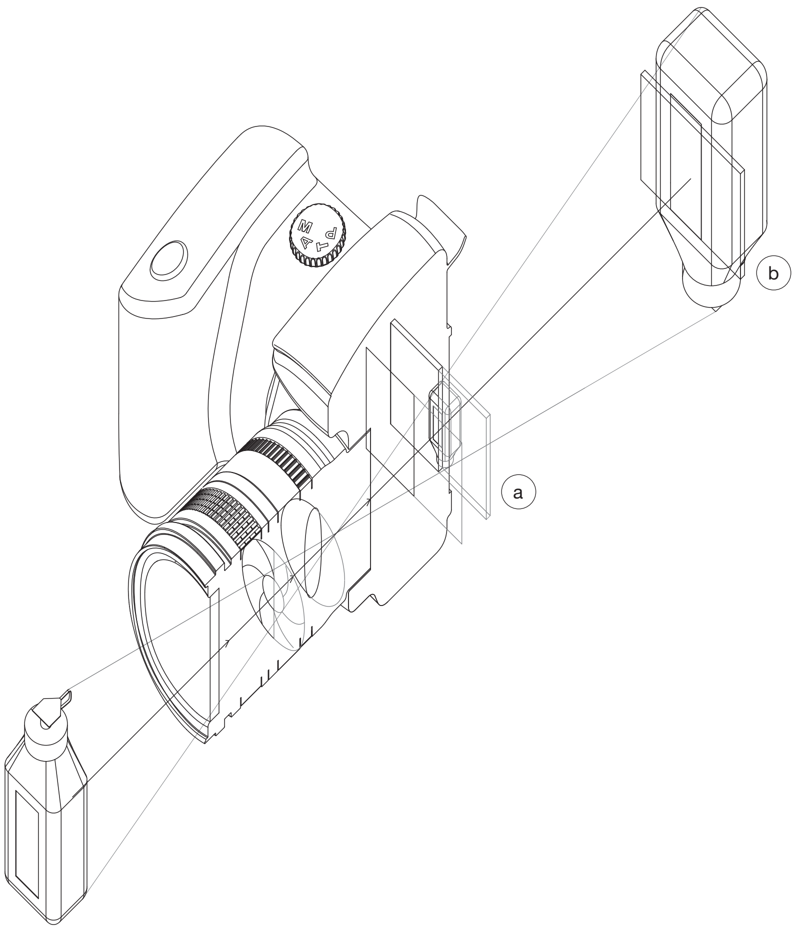
Figure 4.1.3
Examples of photos taken with (left) a short shutter speed and (right) a long shutter speed

Figure 4.1.4
Examples of photos taken with (left) a small aperture opening and (right) a large aperture opening

The *shutter speed* sets the time of how long the image sensor is exposed to the light image. Short shutter times can freeze motion, long shutter speeds show motion blur. **(4.1.3)**

The *aperture* controls the depth of field. The depth of field defines the range of distance that will appear sharp in your image. A small aperture opening (values of 8 and above) will have a large depth of field. With this setting, most of the elements in the image will be in focus. A large aperture opening (values of 4 and below) will have a shallow depth of field. With this setting, only surfaces that are close to the focusing plane will appear in focus. **(4.1.4)**

The *focal length* is used to set the angle of the cone of vision. Focal length, in the camera, is set in mm. A short focal length sets a large angle. **(4.1.5)** Large angles (60 degrees and larger) allow you to go very close to your object of interest. The closer you move toward your object, the more the wide-angle perspectival distortion



The focal length is measured from the point at which the light rays converge to the sensor. This illustration shows two focal length settings as examples' in (a), the focal length is shorter, and more is contained in the image in comparison to (b) where the focal length is longer.

Figure 4.1.5
Focal length settings as they relate to the angle of the cone of vision

becomes apparent. **(4.1.6)** Spatial depth appears unnaturally extended. A long focal length sets a small angle. Small angles (30 degrees or less) force you to stand far away from your subject to keep your subject in the picture frame. The further away you get from your subject, the more telephoto distortion you get (see "Glossary of Technical Terms and Materials"). Spatial depth appears unnaturally compressed.

With *exposure compensation* you can adjust the camera's evaluation of the brightness of your image. Setting the value in the minus range will darken the image. Likewise, setting it in the positive range will make the image brighter.

Experimenting with the settings is the best way to understand their impact. Beyond understanding the settings and the capabilities of the camera, there are a few key steps in taking photographs of spaces:

Figure 4.1.6
Examples of how perspectival distortion increases as photographer moves closer to the object and changes focal length setting: (top) focal length setting is 50mm equivalent; (middle) focal length setting is 28mm equivalent; (bottom) focal length setting is 17mm equivalent

1. *Use a Tripod*

In architectural photography it is important to carefully align edges and lines of your space within the frame of the image. You can do this in a precise manner only with the use of a tripod.

2. *Use a Wide-Angle Lens Setting*

You will most likely need to set a large angle for the cone of vision, or a short focal length, in order to capture a sufficient amount of your interior space in the photograph. Angles of 60 degrees or larger work best; these would be equivalent to focal lengths of 35 mm or less for 35 mm equivalent sensors.

3. *Choose the Light*

Photography is the recording of light. The quality of the light in your scene is the single most important aspect for your photograph. The site-specific light quality might also be an important feature of your chosen space. You should record your space photographically with its own inherent, undisturbed light quality. For the purpose of the exercise described in 3.1, don't use the built-in flash of your camera. There is also no need, technically, to use a flash when you are working with a tripod.

As discussed earlier, cameras have a limited dynamic range compared to human vision. A typical example of this limitation are photos of interior scenes with windows and exterior views. In these cases, the natural lighting of the exterior tends to be much brighter than the interior. Your camera will struggle to record this exaggerated difference in brightness. There are three simple ways to overcome this challenge, based on the composition that you want to achieve:

- If the exterior view is not relevant, increase the exposure compensation setting, so that the interior space is lit adequately and the window will appear as a white surface. **(4.1.7)**

Figure 4.1.7
Example of a photo of a window taken with an increased exposure compensation setting, so that the interior space is lit adequately

Figure 4.1.8
Example of the same photo taken with a decreased exposure compensation setting, so that the exterior space is visible

- If the exterior view is the most important aspect of your scene, reduce the exposure compensation setting so that the exterior view will be adequately lit and the interior space will appear dark. **(4.1.8)**

- If both the interior and exterior views are important to capture in the image, photograph around sunrise or sunset and use artificial lighting in your space. The idea here is to equalize the brightness of the exterior and the interior, so that both are shown in detail. This contact sheet shows a series of photos taken at dusk; the photos were taken approximately 20 minutes apart. At the beginning of the series, the exterior lighting is still more intense than the interior, artificial light, making the interior space appear dark; at the end of the series, the interior lighting is more intense than the exterior, natural light, which makes the scene through the window appear as a darker, bluish spot in the photographic composition. **(4.1.9)**

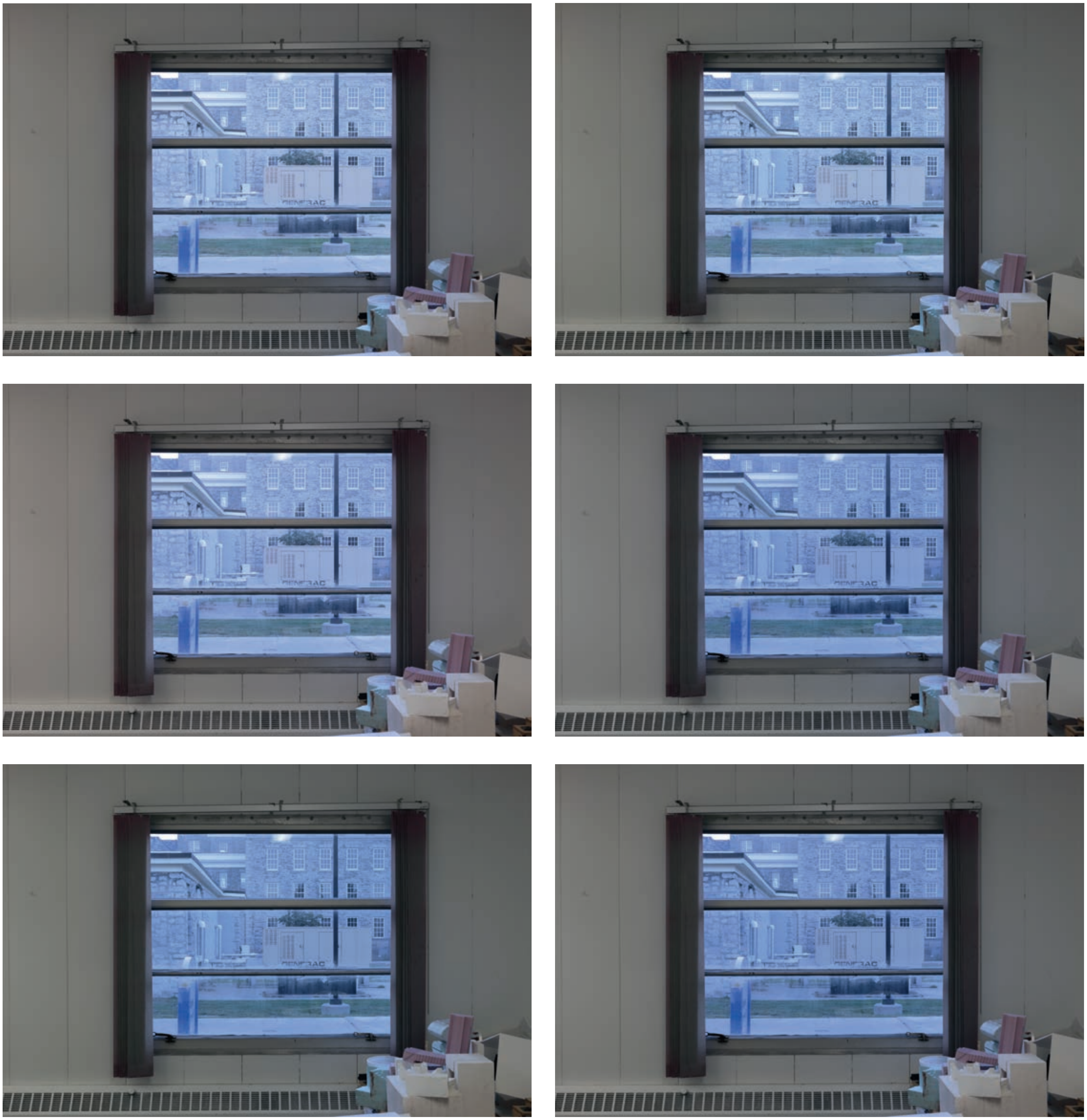


Figure 4.1.9
Photo series taken at dusk, a time of day when the interior artificial and exterior natural light intensity are comparable, and both interior and exterior space can be captured in a photograph

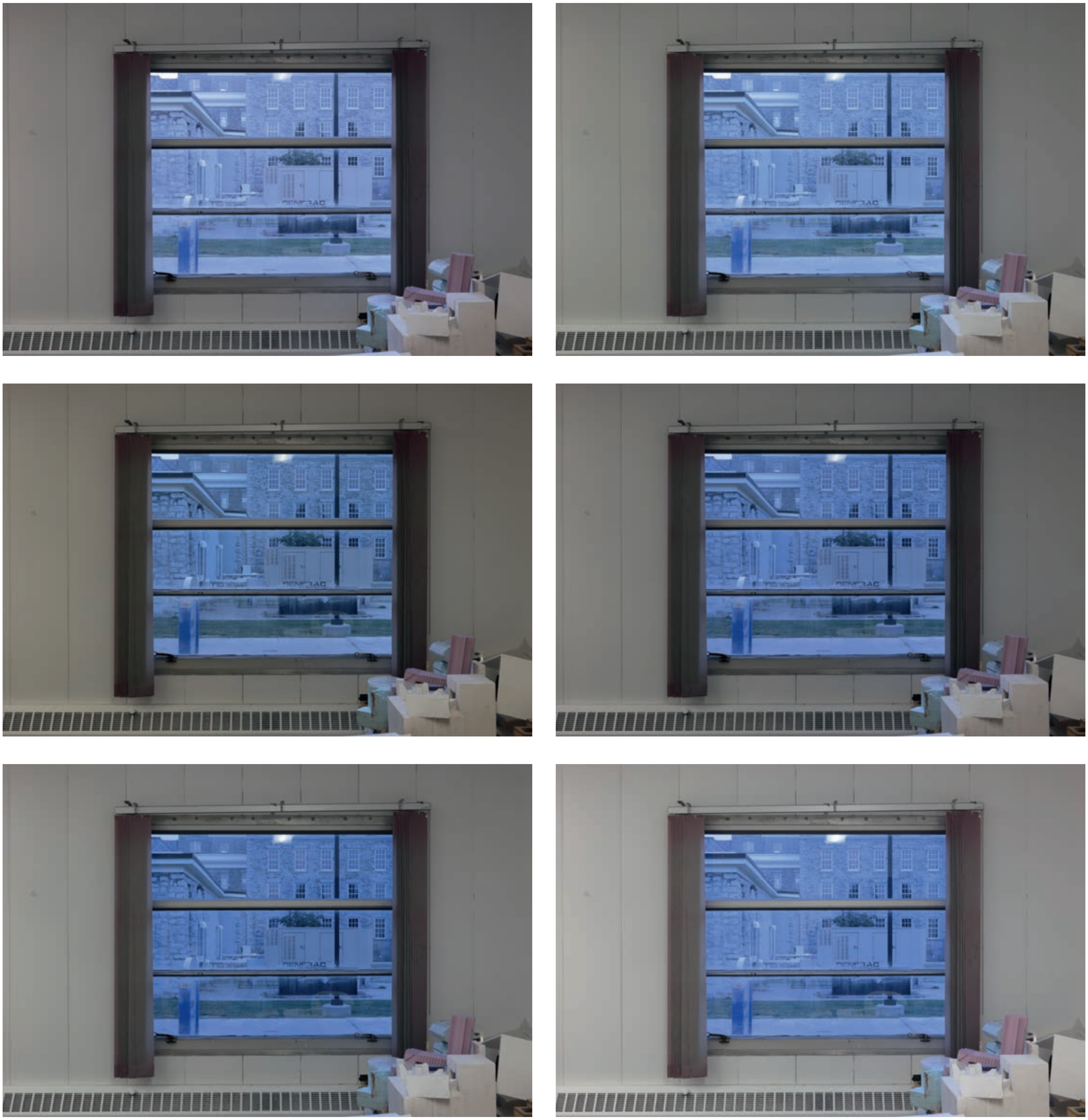


Figure 4.1.9
continued

4. *Set Up the Camera*

Choose a standpoint that captures your scene. Set the camera absolutely level, vertically and horizontally. Use a level. **(4.1.10)** If your camera is not absolutely vertical, the vertical lines of your space will not be parallel in your image, they will converge. This will make spaces and building look like they are leaning or falling. **(4.1.11)** If your camera is not absolutely level horizontally then horizontal lines will be tilted and the composition will look informal and unstable.

Figure 4.1.10
A hotshoe bubble level

Figure 4.1.11
Examples of a photograph taken with the camera levelled both vertically and horizontally (top), and tilted upward, no longer vertically level (bottom), creating a distorted, unstable photographic composition

5. *Define the Aperture Setting*

Set the camera to aperture priority (see "Glossary of Technical Terms and Materials"). You can set your desired aperture value and the camera will set the corresponding shutter speed accordingly. Decide upon the depth of field that you want in your image. Do you want to emphasize one detail and have the rest of the image out of focus? If this is the case, set the aperture setting to a low value (large aperture opening). Is it more effective in expressing your spatial quality to show the whole space in focus? If this is the case, set the aperture to a high setting (small aperture opening). Typically everything in an architectural photography scene should be in focus, which is achieved with an aperture around f/12–16.

6. *Define the Shutter Speed*

If the depth of field is not relevant for your image, you can experiment with the visual effects of the shutter speed. Set your camera to shutter priority (see "Glossary of Technical Terms and Materials"). You can set your desired shutter speed and the camera will set the corresponding aperture value accordingly. With slower shutter speeds, moving elements in the scene will be captured with a motion blur.

7. *Set the Camera to Manual Focus*

Set your camera/lens to manual focus. Focus to the main element in your scene.

Figure 4.1.12
Examples of post-processing: original photo (left) is too dark, and is post-processed using levels (middle); photo (right) illustrates the common tendency to increase contrast too much during post-processing, creating an image that looks explicitly doctored

8. *Assess the Need for Post-Processing*

In an ideal scenario, your photos would be well planned and constructed, and wouldn't need any "post-processing" or digital tweaking. But sometimes, particularly with light quality, photos benefit from a subtle amount of editing. Load your files onto your computer and open them with an image editor. Light quality can be adjusted with the contrast, brightness, saturation and tone curve functions in your image editing software. Experiment with the different settings that these editing tools have to optimize the light effects in your image. **(4.1.12)**

4.2 HOT WIRE FOAM CUTTING

Hot wire foam cutting allows quick production of scaled mass or volume models. This is very helpful in the design process, because many design options can be explored in model form in a short time.

Modeling in foam also allows you to evaluate a project according to its massing and suppresses other readings. It is therefore also an investigative and abstraction tool. It is also a very silent technique that enables you to work on your desk instead of the workshop, which means that you can quickly and effortlessly switch between drawing and modeling, to rapidly propel your design process forward.

1. *Set Up and Preparation*

Gather the following tools at your work area: hot wire foam cutter, utility knife with a long blade, steel ruler, triangle, pins, masking tape, white craft glue or wood glue, fine grit sandpaper. **(4.2.1)**

Before using the foam cutter, it needs to be aligned. Set the wire perpendicular to the foam cutter work surface in all directions using your right-angle triangle. **(4.2.2, 4.2.3)** Press down slightly on the metal overarm of the foam cutter while pulling the wire into tension from below, and turn the dial to clamp the wire in place. It is important to have the wire pulled taut, since it loosens a bit when heated. Make sure that the wire has no kinks in it, as they will show in the foam cuts as extrusions. As the hot wire melts the foam, the foam gives off gas vapors. These gases can be harmful to your health. Only use the foam cutter in a well-ventilated, supervised workspace. To minimize the production of foam off-gassing, it is important that the cutter is switched off after each cut. Alternatively, you can purchase pedal controls which are helpful in controlling the wire operation and minimize off-gassing.

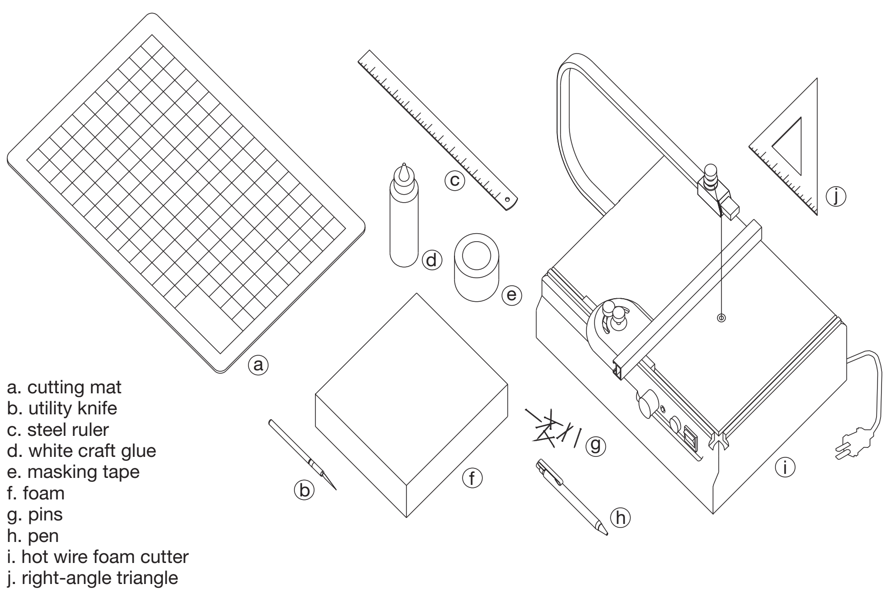
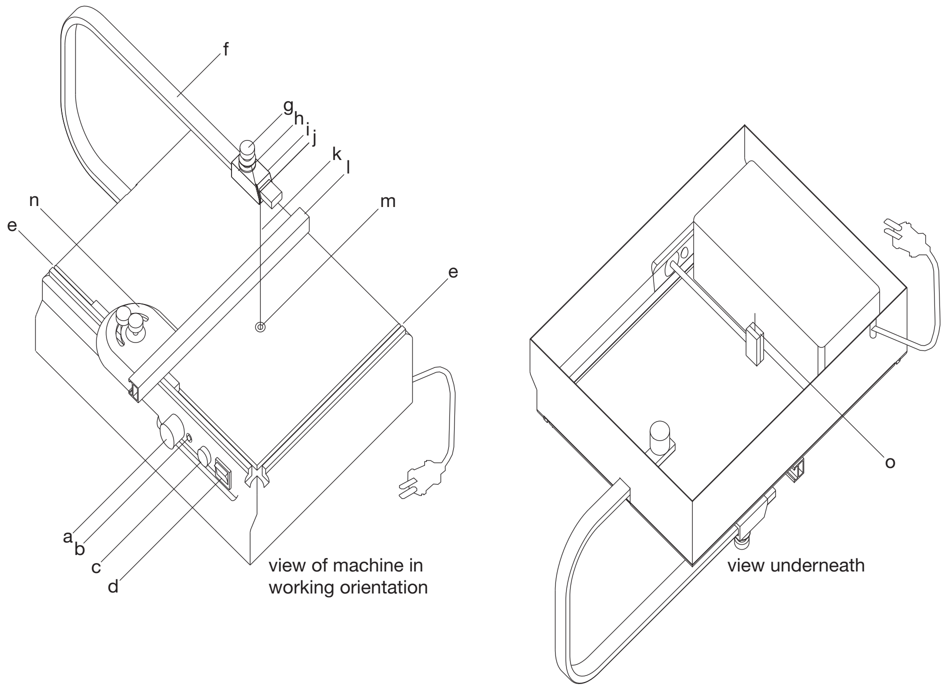


Figure 4.2.1
Tools and materials for hot wire foam cutting



a. knurled screw for clamping the cutting wire
b. standby led light
c. temperature adjustment knob
d. on/off switch
e. slot for angle stop
f. overarm
g. screw to adjust wire spool
h. wire spool
i. screw to adjust spool carrier
j. slot guide for wire
k. cutting wire
l. adjustable guide
m. bottom wire hole/guide
n. angle gauge
o. underneath wire fixation point

Figure 4.2.2
Anatomy of a hot wire foam cutter

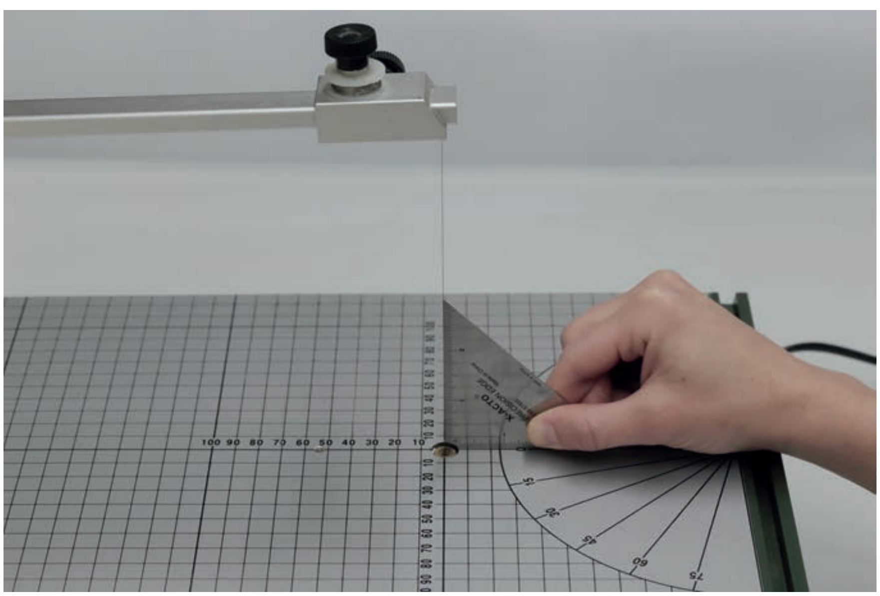


Figure 4.2.3
Use of a right-angle triangle to ensure that wire is set vertically

Make a test cut to evaluate the optimum temperature for the specific foam you want to cut. The temperature should be set so that you feel a slight resistance when you push the foam slowly through the machine. Lower temperatures yield higher precision. Higher temperatures melt more foam and can distort the cut surface. **(4.2.4)** As you cut, the wire should bow only slightly; if you apply too much force, the wire could break. In the case that the wire breaks, loosen the spool and re-thread the wire through the hole in the cutting surface.

2. *Gluing Foam*

Different types of foam can be used to make scaled, mass models, but the most common is extruded polystyrene foam, also known as XPS (see "Glossary of Technical Terms and Materials"). This closed-cell foam has a uniform foam structure. XPS can dissolve with solvents; use water-based glues, like generic white craft glue or wood

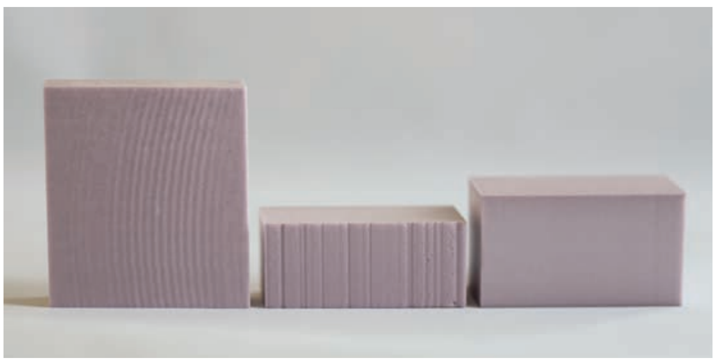


Figure 4.2.4
Comparison of foam surfaces resulting from forcing foam through the cutter too quickly (*left*), pushing foam through the cutter too slowly or having the temperature set too high (*center*), cutting at an optimal speed and temperature (*right*)

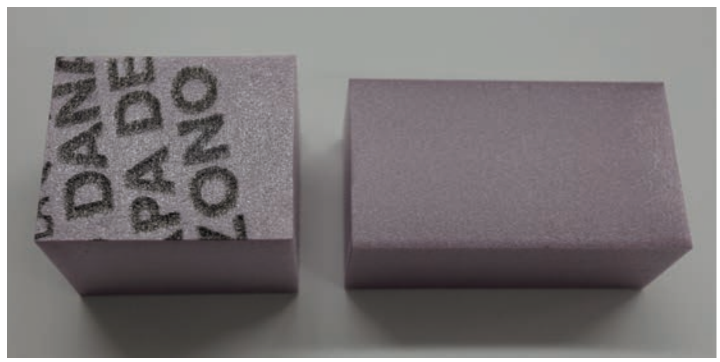


Figure 4.2.5
Comparison of factory cut foam surface (*left*) and surface cut with a hot wire cutter (*right*)

Figure 4.2.6
Application of glue to foam surface

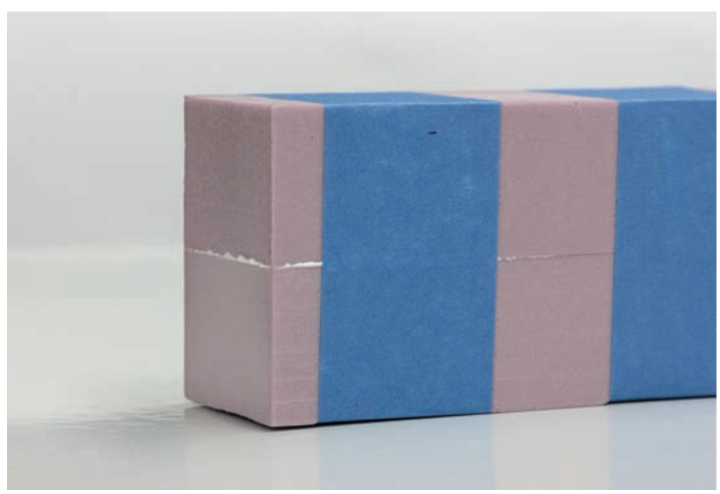


Figure 4.2.7
Foam pieces temporarily bound together with masking tape to secure adhesive bond

glue to create adhesive bonds between pieces of foam. These glues work well with porous materials such as XPS and can also be cut with the hot wire cutter, which is very important. It does take, however, a couple of hours for the glue to start bonding with the foam. The exact time required depends on the air humidity, ambient temperature, size of surface area glued and amount of glue used.

Make sure that all surfaces that receive glue are cut by you and are not the original factory surface. The factory surface is smooth and not porous enough for the glue to create a bond. **(4.2.5)**

Apply the glue in thin beads uniformly across the smaller surface of the two blocks that you want to glue together. Choose the smaller surface so that no traces of glue remain visible. Spread the glue as a very thin layer across the surface with a piece of thin cardboard or a small piece of foam. **(4.2.6)** Spread from the middle of the surface outward. The entire surface should be covered with a thin film of glue; remove all excess. If you leave too much glue on the surface, it will take too long to dry and will be harder to cut with the foam cutter. Press the two pieces to be bonded together and make small figure-eight shaped movements until a bit of glue is visible all along the joint line. Now lock the two pieces into position with masking tape. **(4.2.7)**

Wrap the masking tape around the pieces so that there is no gap visible all along the glue joint and let the glue set. **(4.2.8)**

3. *Evaluate Your Form: Inward-Facing Corners and Exterior Corners*

Carefully evaluate the form that you want to build. Although the appearance of your model will be of a continuous solid, paradoxically, foam models are often made in a combination of subtractive (cutting) and additive operations (gluing) to achieve the best craft.

You should always make complete cuts with the foam cutter, similar to how you would cut wood with a circular saw. It is not advisable to stop the cut in the middle of the foam block. The reason is that any change in the speed of pushing the foam will vary the width of the cut and will result in a wavy cut surface. **(4.2.9)** Identify

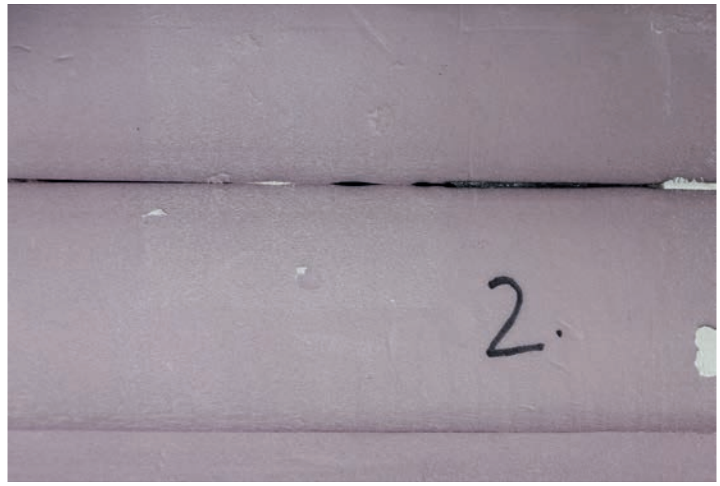


Figure 4.2.8
Ineffective adhesive bond between a factory cut foam surface and a surface cut with a hot wire cutter

Figure 4.2.9
Comparison of two methods used to build an inside corner out of foam: two separate pieces bonded with glue (*left*) and one piece cut with the hot wire (*right*)

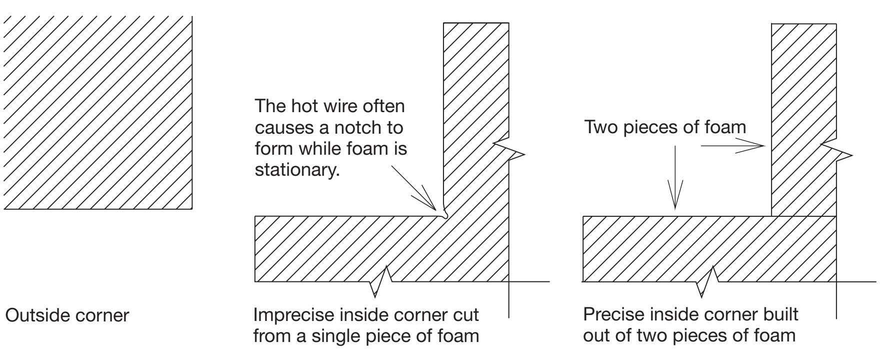


Figure 4.2.10
Diagram of outside and inside corners in foam

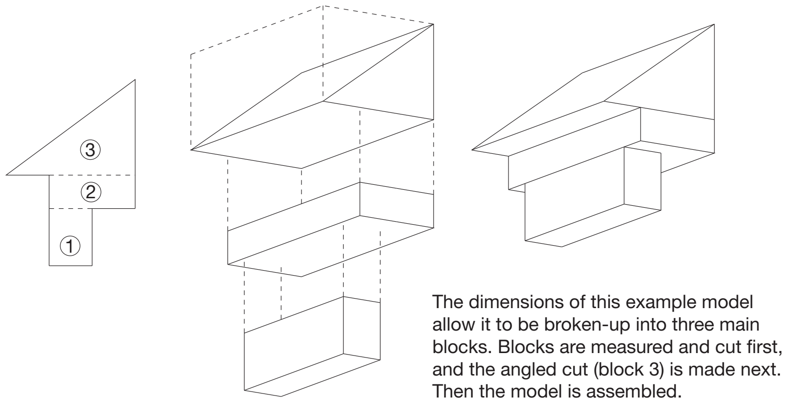


Figure 4.2.11
Breakdown of example model volume into foam pieces for clean assembly

Figure 4.2.12
Utility knife used to slice thin piece of foam

Figure 4.2.13
Plotted drawing used as cutting stencil

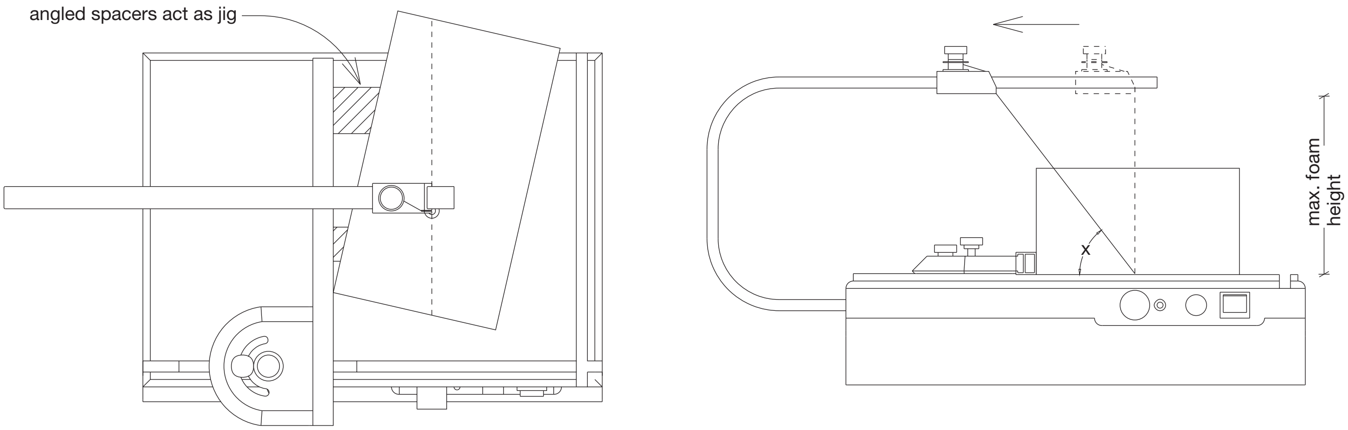
any inward-facing inside corners in your form. Inward-facing corners should be built in an additive fashion by cutting two rectangles and gluing them together. **(4.2.10)** Exterior corners, on the other hand, can be cut with the foam cutter out of a single piece. Using the logic about how to make inward-facing and exterior corners, you can break down the overall shape into smaller pieces to be cut with the foam cutter and then glued together. **(4.2.11)**

4. *Evaluate Your Form: Very Small Pieces*

Foam pieces which are very small or thin are best cut with a utility knife and a fresh sharp blade. Always use a steel ruler as a guide. **(4.2.12)** Depending on the complexity of the perimeter of the small and/or thin pieces, you can also use a drawing, plotted to the scale of the model, as a cutting template or stencil. **(4.2.13)** If you want to glue small pieces of foam and need to lock them into position until the glue is bonding, use pins.

5. *Evaluate Your Form: Angled Forms*

Depending on the cut, there are two ways to introduce a precise angle: by moving the adjustable spool carrier to the left or by introducing a jig to position the foam block at the desired angle against the guide. **(4.2.14)** To move the spool carrier is the more convenient and precise method for cutting an angle, but you are limited in size by the height of the foam cutter's overarm.



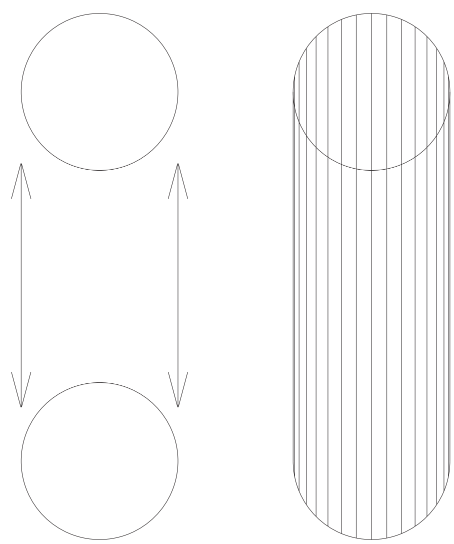
Option a: angled spacers act as a jig, positioning your foam at a deliberate angle for a cut.

Option b: adjustable spool carrier can be shifted and locked to position the wire at a deliberate angle. Unlike with option a, there is a height restriction for foam blocks being cut on an angle using this method.

Figure 4.2.14
Two methods used to make an angled cut in foam

6. *Evaluate Your Form: Extruded Surfaces*

Straight extrusions of irregular forms can be cut with the hot wire foam cutter by using adequate templates (see "Glossary of Technical Terms and Materials"). **(4.2.15)** Cut the shape to be extruded out of thin cardboard (0.5 mm). Attach the template onto your foam block with a minimum of three steel dressmaker pins or short lace pins. Use pins with tiny flat steel heads (instead of plastic ball heads). For the final cut, pin the template to the bottom of the foam block and set the block template-side down on the cutting surface. If placed at the top of the foam block, the template would bend the wire and it would be impossible to generate the intended form. Because the template isn't visible when placed on the bottom of the block, use a two-step process to ensure that the extrusion is accurate. First, orient the foam block with the template facing UP. Then make a freehand cut with the hot wire about $\frac{1}{4}$ in. (0.6 mm) offset out from the edge of the template, moving the block along the foam cutter surface. When the approximate form has been inscribed into the foam, flip the foam block so that the template faces DOWN, sitting on the foam cutter surface. Push the foam block



An extruded form has a fixed profile in section. In this example, a circle is extruded.

Figure 4.2.15
Extruded form

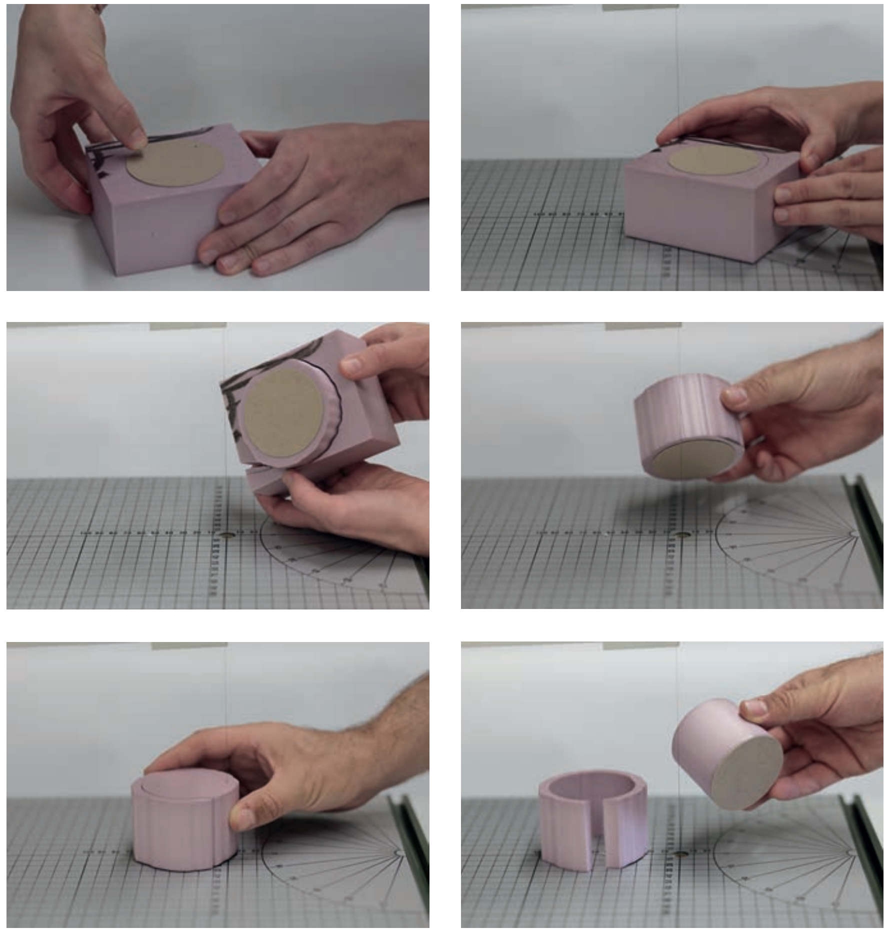


Figure 4.2.16
Two-step process to cut an extruded form out of foam using a cardboard template

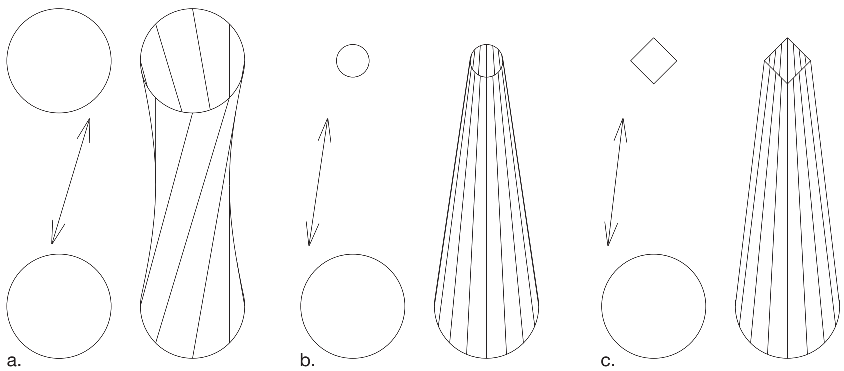
against the hot wire so that the edge of the template is touching the wire, and move the block so that the wire cuts the perimeter of your form, always touching the edge of the template. It is important that you move the foam block at a consistent speed; any change in the pace will result in an uneven and rippled cut surface. **(4.2.16)**

7. *Evaluate Your Form: Ruled Surfaces*

Ruled surfaces describe a volume in which, at every point of the surface, a straight line can be placed. **(4.2.17)** Because the hot wire is a straight line, ruled surfaces can be conveniently cut with your foam cutter using adequate templates. Extruded surfaces, as discussed in step 6, are ruled surfaces. But ruled surfaces do not need to be extrusions. For example you could use two templates, one at the bottom of your foam block and one at the top and make the hot wire touch BOTH at the same time. **(4.2.18)** The resulting curved ruled surfaces can be surprisingly complex.

Figure 4.2.17
Ruled surfaces

Ruled surfaces describe a volume in which, at every point of the surface, a straight line can be placed. Although straight, the lines which describe the surface are not horizontal or vertical



a) Two identical circles, connected with an angled, straight line; b) two circles of different sizes, connected with an angled, straight line; c) two different shapes, connected with an angled, straight line.

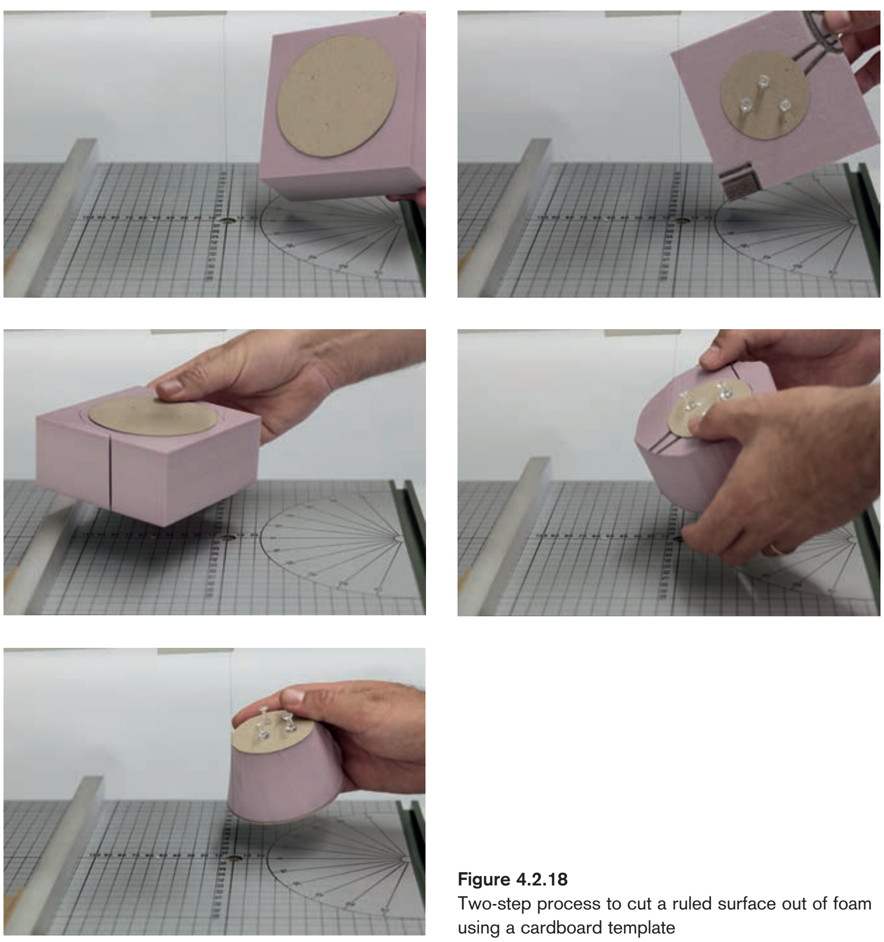


Figure 4.2.18
Two-step process to cut a ruled surface out of foam using a cardboard template

8. *Define a Sequence of Cuts*

After you evaluate your form, establish a sequence for cutting and gluing.

- First, cut the parts that will be glued together to form larger pieces with inside corners.
- Glue them together.
- Don't try to achieve flush surfaces when matching pieces together during gluing. Always make the finishing cut AFTER you glue volumes together to make a perfectly flush surface.
- In the case that your model has smaller pieces, add them to the larger blocks and secure the model with pins or tape so that the glue sets with the pieces joined tightly together.

Here is a detailed sequence for cutting and assembling an example form: **(4.2.19)**

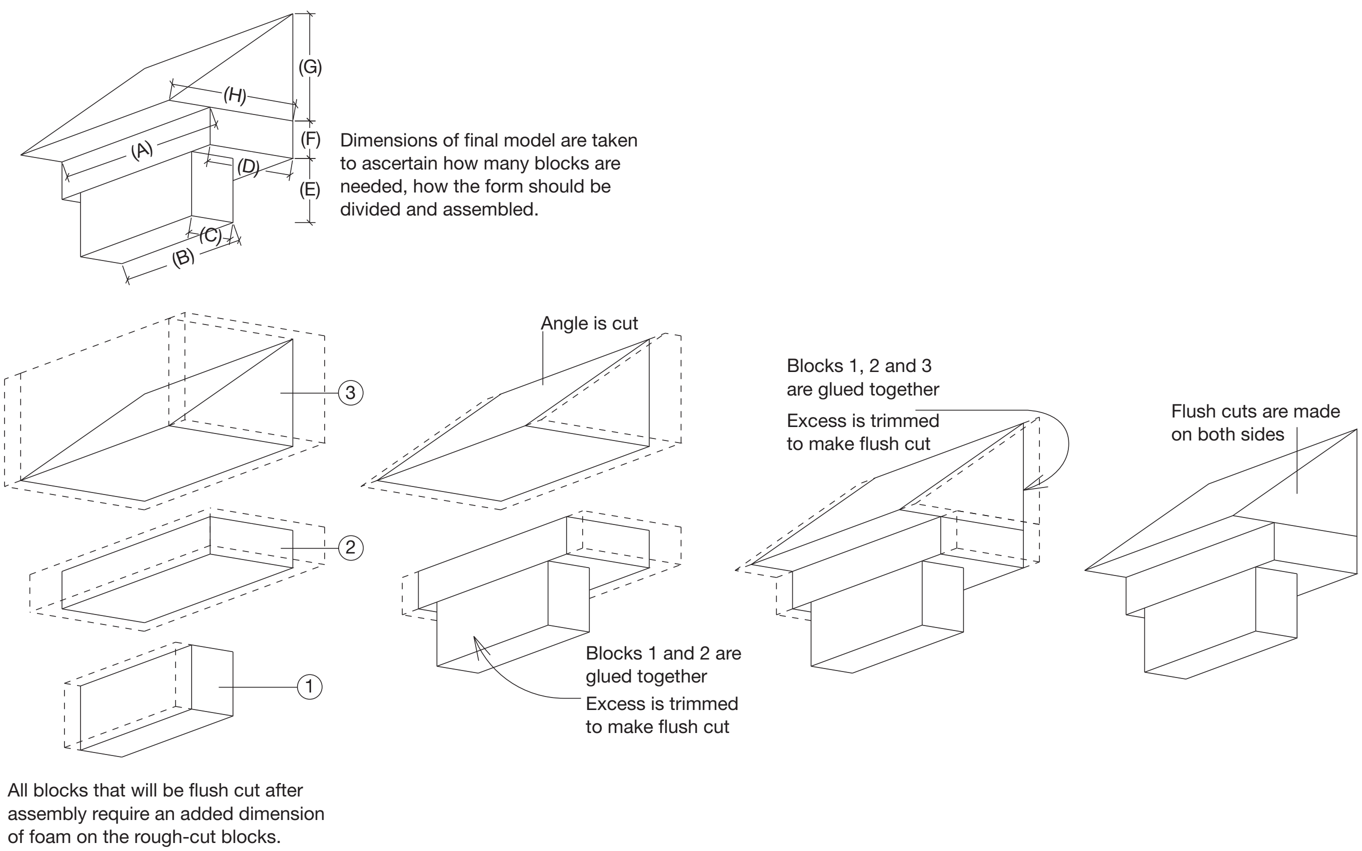
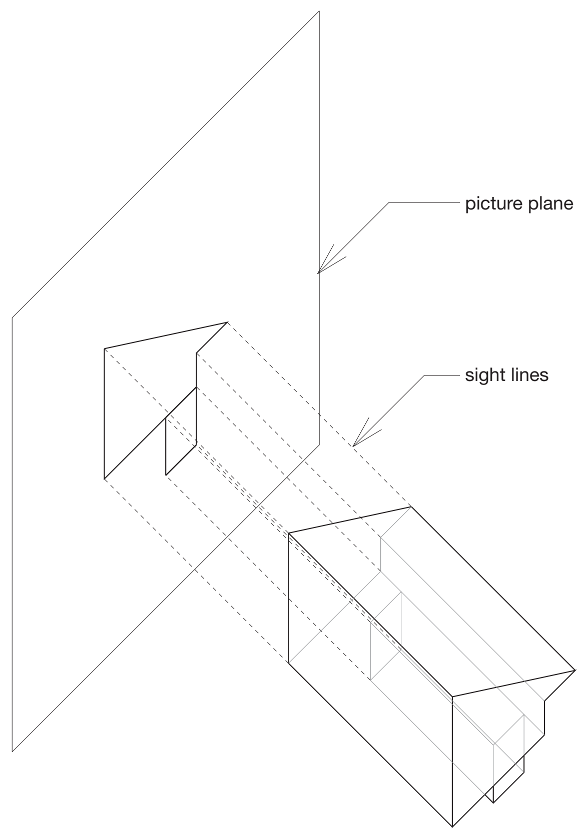


Figure 4.2.19
Detailed sequence for cutting and assembling an example form

- Cut block (1). Add $\frac{1}{2}$ in. (1.25 cm) to dimension (C) as you will have to flush-cut this block on one side.
- Cut block (2). Add 1 in. (2.5 cm) to dimension (D) and add 1 in. (2.5 cm) to length (A). You will need to flush-cut this block on both sides.
- Glue block (1) to block (2). Make sure to have $\frac{1}{2}$ in. (1.25 cm) excess length on both sides of block (2) for the flush cuts. Tape the assembly and let it dry for a couple of hours.
- While the adhesive bond between blocks (1) and (2) is setting, cut block (3). This is an angled surface. Its height is less than the height of the foam cutter arm, so you can angle the wire by adjusting the spool carrier and avoid making a jig. Add 1 in. (2.5 cm) to the overall length (A) and $\frac{1}{2}$ in. (1.25 cm) to the back of dimension (H) as shown in the illustration.
- Make the first flush side to the bonded blocks (1) and (2). Block (2) should still have a $\frac{1}{2}$ in. (1.25 cm) excess in the (D) dimension, opposite the flush side.
- Glue block (3) onto the other piece. Let the assembly dry for a couple of hours.
- Make the final three flush cuts, to the back and the two sides.

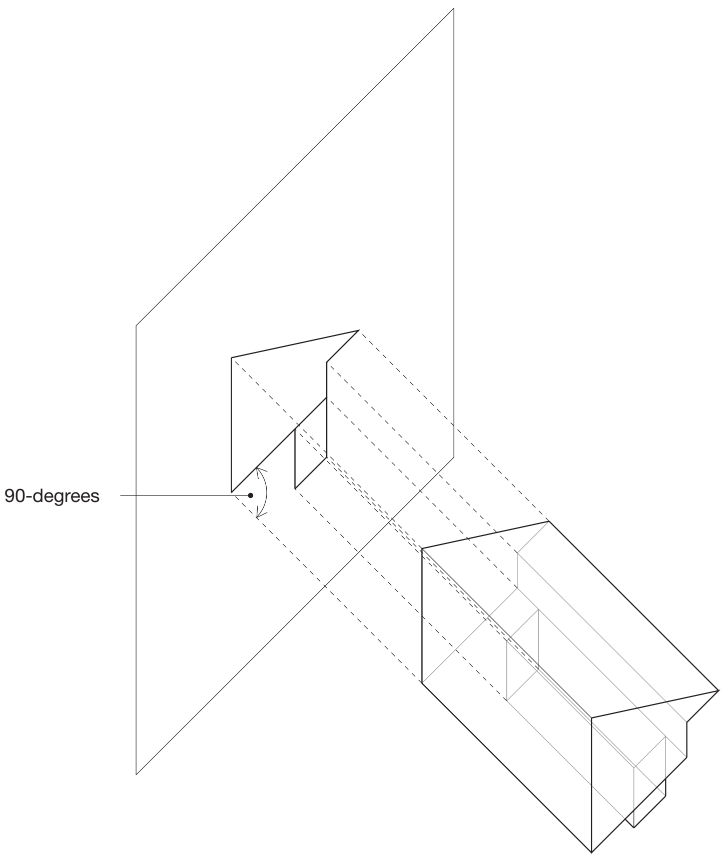
4.3 ORTHOGRAPHIC PROJECTION AND MULTIVIEW DRAWINGS

To generate architectural drawings, we are dependent on projection methods. Projection methods allow us to use lines of sight to project a three-dimensional object onto a two-dimensional picture plane, a sheet of paper (compare also with 4.1, "Taking Photos of Spaces," and 4.6, "Perspectival Projection"). Architects typically employ two main types of projection methods: perspectival projection and parallel projection to generate architectural drawings. In perspectival projection, lines of sight converge at the station point, representing the eye of the viewer (see 4.6, "Perspectival Projection"). In parallel projection, lines of sight remain parallel to one another; they don't converge. **(4.3.1)**



The face that is to be documented as an orthographic view is set parallel to the picture plane. Sight lines translate that face into a flat, two-dimensional projection on the picture plane using sight lines that all run parallel with one another.

Figure 4.3.1
Principle of parallel projection



In an parallel projection, sight lines converge with the picture plane at a 90-degree angle. This perpendicular relationship is what preserves the true dimension of the face of the object as it gets translated to a two-dimensional view.

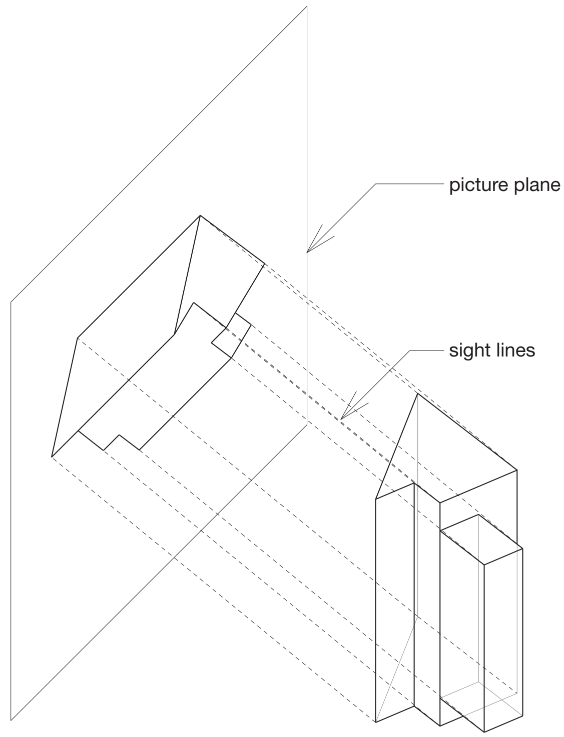
Figure 4.3.2
Lines of sight perpendicular to the picture plane in parallel projection

Orthographic projection is a type of parallel projection. With orthographic projection, the picture plane is oriented perpendicular to the lines of sight. **(4.3.2)** Orthographic projection can produce two types of drawings: pictorial drawings and multiview drawings.

A pictorial drawing shows all three dimensions of an object in a single view. We can create a pictorial drawing with the orthographic projection method, if no dominant surface of the object is parallel with the picture plane. An axonometric projection is an example of pictorial drawing. In an axonometric drawing, lines of sight are parallel with one another and perpendicular to the picture plane, but the picture plane is not parallel with a dominant plane of the object. **(4.3.3)**

Unlike a pictorial drawing, a multiview drawing appears flat because it is focused on a specific surface. To generate a single multiview drawing, the picture plane is oriented parallel to a specific surface of the depicted object. A surface that is parallel to the picture plane is represented in its true size and form. **(4.3.4)** While two

Figure 4.3.3
Principle of axonometric projection



In constructing an axonometric projection, the sight lines and the picture plane are perpendicular, and the sight lines are parallel with one another, but the object is not parallel with the picture plane.

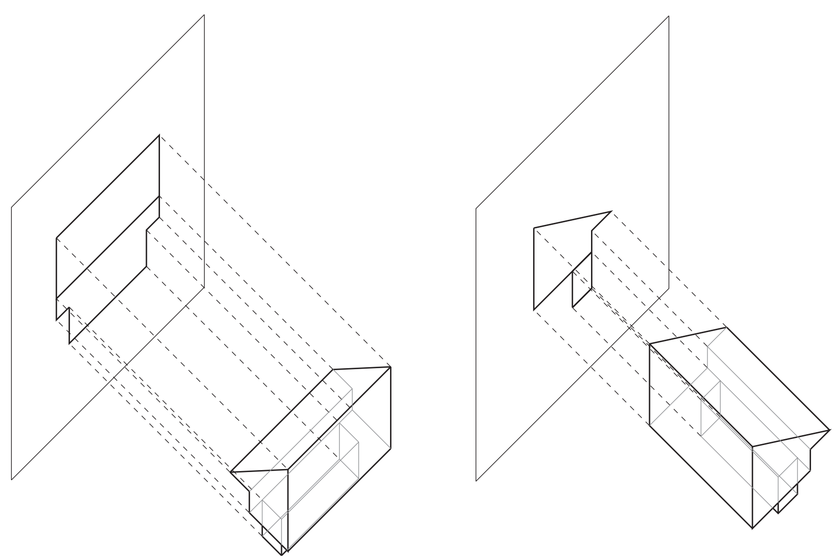


Figure 4.3.4
Multiview drawings

Multiview drawings are taken individually, flattening each face as a two-dimensional view.

dimensions are represented accurately in this method, the third dimension is hidden. Therefore, to describe all three dimensions of an object comprehensively with multiview orthographic projection, we need to generate several views, each view generated by reorienting the picture plane parallel with a specific surface of the depicted object. In architecture we use three main views which correspond to three principal orientations of the picture plane:

1 plan view, which corresponds with the horizontal plane;
2 longitudinal section and frontal elevation, which correspond with the frontal plane;
3 cross sections or side elevations, which correspond with the profile plane.

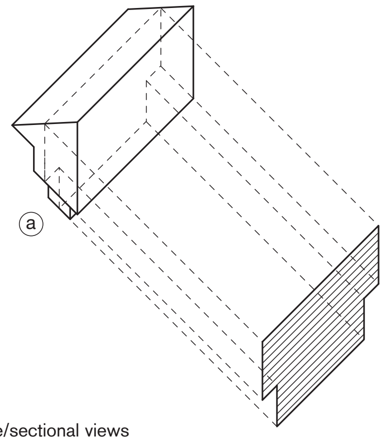
These three orientations of the picture plane are useful for architecture because buildings tend to be organized relative to gravity: vertical wall surfaces are parallel to gravity and flat, horizontal floor surfaces are perpendicular to gravity. Therefore, most architectural surfaces will be parallel to one of the three principal planes and will be depicted to true size and shape in multiview drawing. Before generating your own multiview drawing, it is important to have a firm understanding about the main views used in architectural drawings.

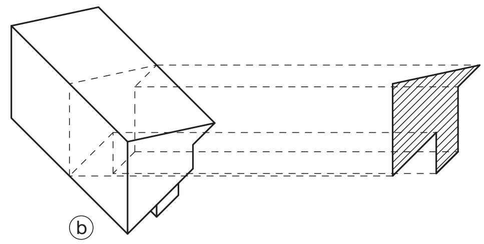
A *plan* is an orthographic projection representing a horizontal cut through a building or object with the picture plane (the *horizontal plane*) parallel to the floor plane of the building. The plan view is a horizontal section. The height at which the plan cut is made can be determined by the author of the drawing; typically for spaces, it is taken at about 4 ft (120 cm) above the respective floor plane in order to cut all windows, openings and doors in the walls. **(4.3.5)**

A *section* is an orthographic projection representing a vertical cut through a building with the picture plane perpendicular to the floor plane (parallel with the *frontal plane* or the *profile plane*) of the building. The cut plane is taken typically through important spaces, spatial arrangements and stairs. Avoid placing your cut through areas that misrepresent the space that you're drawing. **(4.3.6)**

An *elevation* is an orthographic projection representing a frontal view of a building with the picture plane (again the *frontal plane* or the *profile plane*) parallel to a dominant façade of the building. **(4.3.7)**

Figure 4.3.5
Horizontal plane/plan view

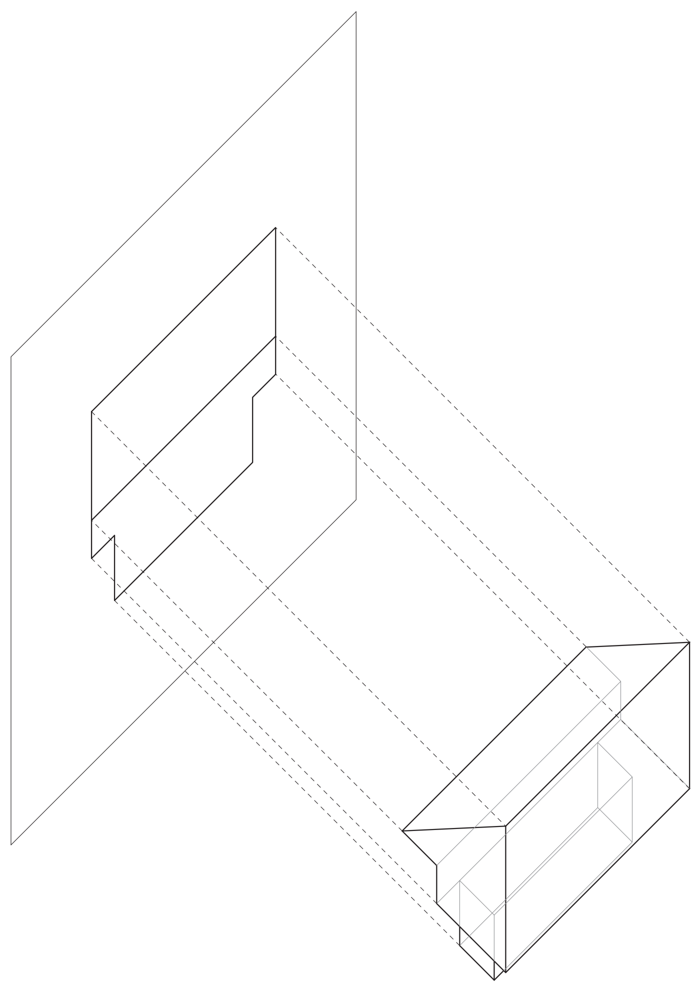




In this case, the frontal plane (a) yields a vertical section that might otherwise be referred to as a longitudinal section. The profile plane yields a section (b) that might otherwise be referred to as a lateral section.

Figure 4.3.6
Frontal plane and profile plane/sectional views

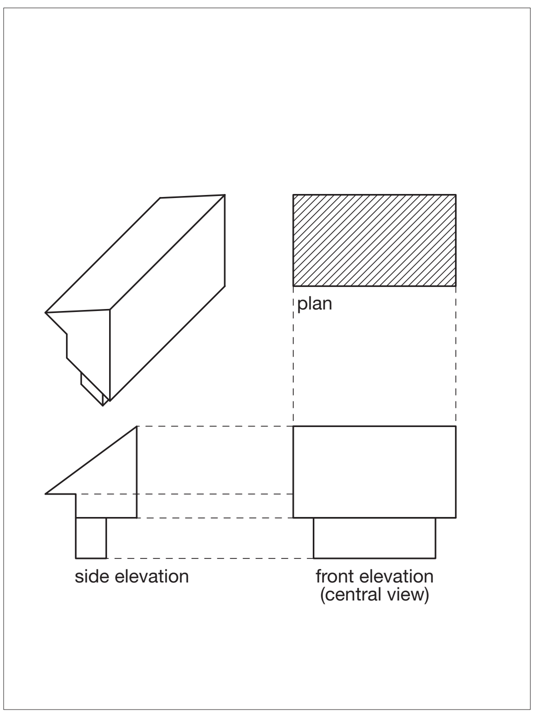
Figure 4.3.7
Elevation view



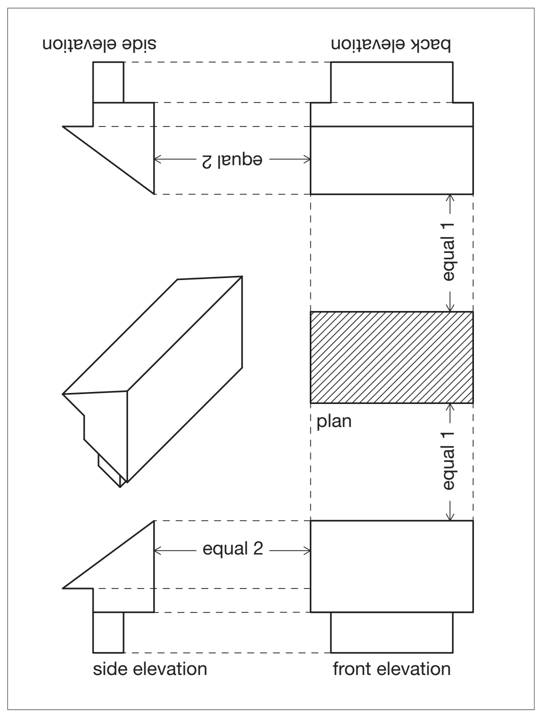
An *interior elevation* is an orthographic projection representing a frontal view of an interior wall surface. The picture plane is located directly in front of the surface and is parallel to it. No sectional information is shown on an interior elevation (refer to example in 3.2, "Survey of Space, Media 2: Orthographic Drawings").

A *reflected ceiling plan* is not constructed like a conventional internal elevation. Rather, it adopts the same view orientation as the plan to allow us to immediately compare the location of elements on the ground and on the ceiling. Reflected ceiling plans are constructed by taking the base geometry from the plan, with elements from the lower level like furniture omitted, and adding all elements at the ceiling level, as if the ceiling plan is transparent.

We can describe the geometry of a building with a comprehensive multiview drawing set. As you can see, you always need more than a single drawing to describe a building. These drawings share dimensions with each other and work together to explain an object, space or building. How the individual views are composed in relation to one another on a sheet impacts their legibility as a whole. Drawings that are placed next to each other in such a way that the dimensions they share are aligned are called *adjacent views*. Drawings that are adjacent to the same view are called *related views*. A *central view* is a view that is adjacent to more than one other drawing. **(4.3.8)**



Example layout with three main views.



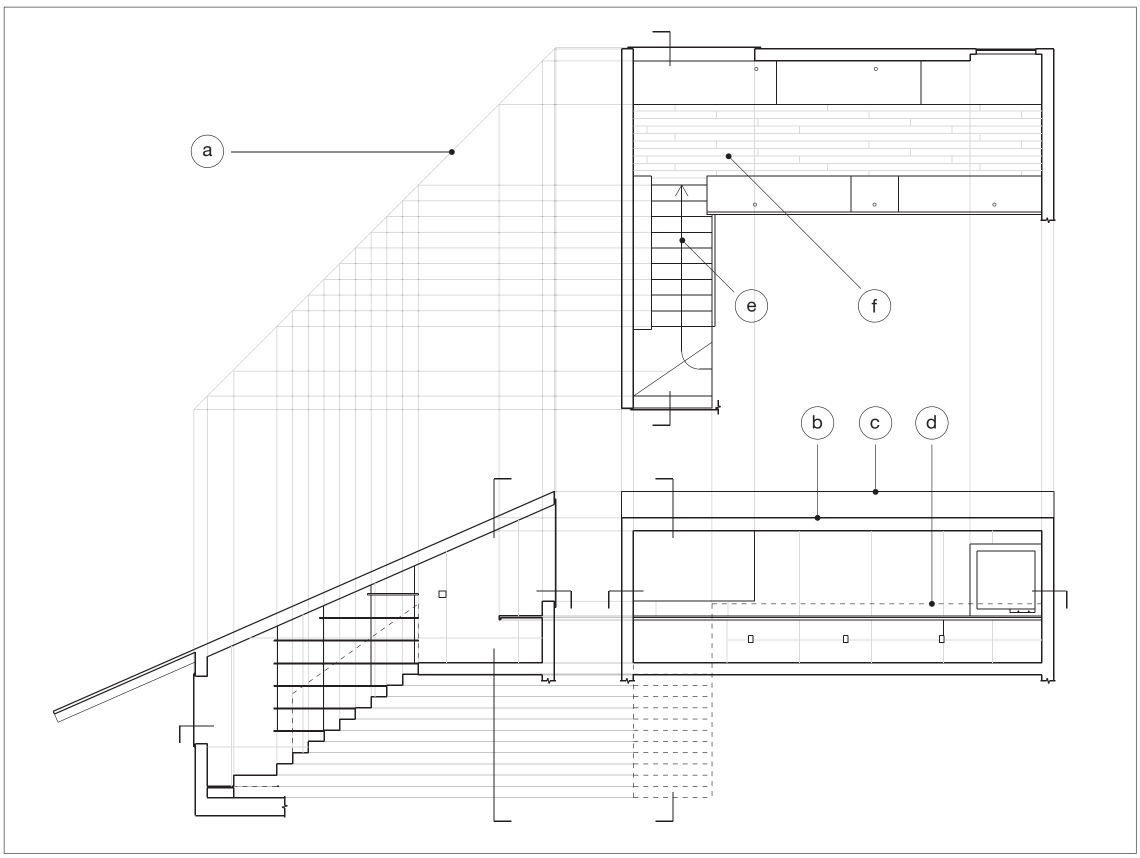
Example "unfolded" layout with five views. Any elevation, in this case, could be swapped-out for a section. Sections could also be added, with vertical extensions of the construction lines, either above or below the plan view. In general, formats should always be defined by the specific set of views that best describes the space.

Figure 4.3.8
Multiview drawings

1. *Organize a Layer System for Your Drawing*

Before beginning to draft, set up layers for the following line types and other elements in your CAD system:

- construction lines
- cut lines
- elevation lines
- dashed lines (lines in front of or above the cut section plane and covered invisible lines)
- annotation and text
- invisible lines.
  (4.3.9)



a. construction lines
b. cut lines
c. elevation lines
d. dashed lines
e. annotation
f. invisible lines

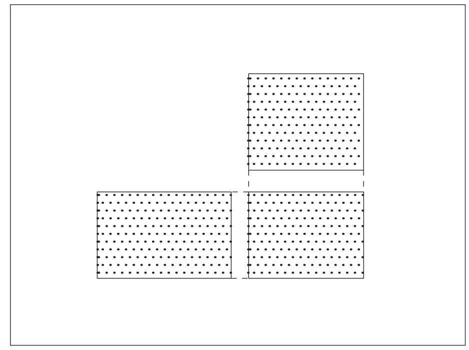
Figure 4.3.9
Line type reference

2. *Block-Out a Composition*

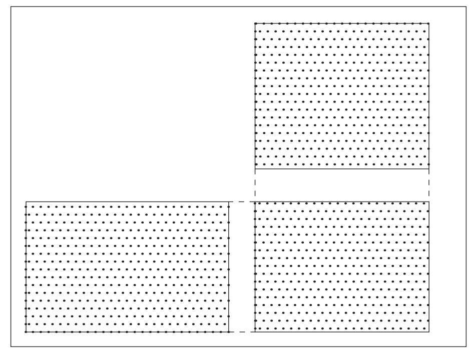
To establish your multiview drawing in your layout, first choose a central view. In architectural multiview drawings, the plan is often the central view; it is the surface which is perpendicular to gravity, and the largest flat surface containing circulation, the position of furniture and most other program-related elements. Block-out your layout by drawing the simplified, outer perimeters of all views on your invisible layer, in your Arch C (or A2) layout. Use your measurements to draw the outer perimeters, don’t estimate the sizes. Blocking out a layout before views are individually detailed is a technique carried over from hand drafting. It is a way of building up your drawing as an entire composition from a skeletal framework to an information-rich, detailed drawing. It is also a way of defining the composition of your page from the onset. As part of the blocking-out process, test several scales until you reach a composition that fills the page with drawing information while still allowing enough white space between views so that they don’t visually merge. **(4.3.10)**

3. *Draw Your Plan View*

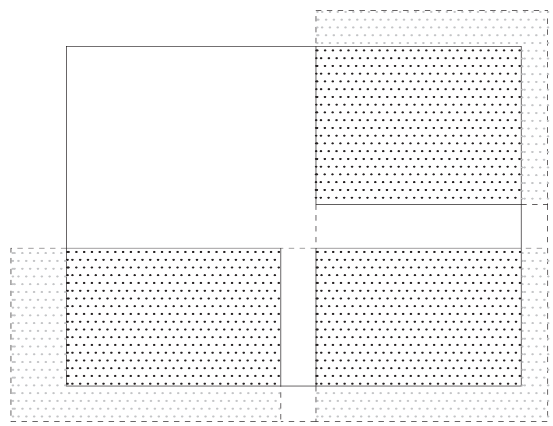
Within the area that you blocked out for your plan view, draw it based on your survey measurements. Even if your plan is not your central view, it is an intuitive starting point for a multiview drawing set. **(4.3.11)** For the particular exercise given in 3.2, you are asked to draft the single, interior space that you chose. Because your single space is probably one of many housed in a larger building, you will have to crop your plan, so that your drawing is depicting only your chosen, single space. To crop your plan, employ the crop marks shown in the illustration. You will also probably have to make inferences about wall thickness, which are shown in plan view. For any wall thickness, interior or exterior, that isn’t immediately visible, you can measure the wall assembly at a point where you have access from the interior and exterior, at an opening, to make an inference about the base thickness of the wall.



An Arch C or A2 layout with three views at $\frac{1}{4}$”=1’ or 1:48

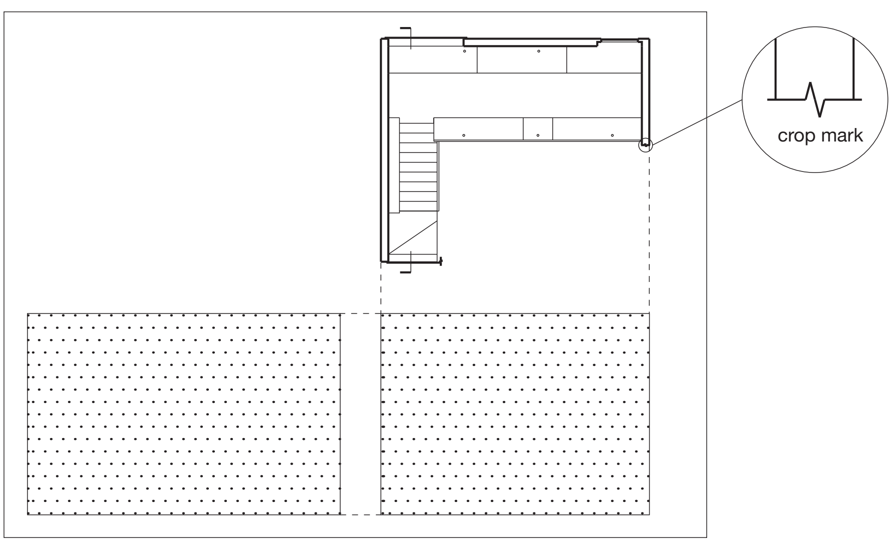


An Arch C or A2 layout with three views at $\frac{3}{8}$”=1’ or 1:32



An Arch C or A2 layout with three views at $\frac{1}{2}$”=1’ or 1:24

Figure 4.3.10
Blocking-out process, testing scales



Once the layout has been blocked, drafting the views is a “fill-in-the-blocks” process. Beginning with the plan view, whether or not it is the central view in your layout, is an intuitive starting point. This example plan is shows one space which belongs to a larger building. To focus on this single space, crop marks are used.

Figure 4.3.11
Establishing the plan in your layout

4. *Decide upon the Level of Detail for Your Drawing*

At this point in the drawing process, as you're working on your first view, the plan view, decide upon how much detail to include in your drawing. The scale that you have chosen for your plot will determine, to a large extent, the level of detail that the drawing can accommodate. If a drawing is plotted at a very small scale, and it includes a high degree of detail, lines will tend to merge together. This will render detailed areas illegible, and they will be more graphically prominent than they are intended to be. **(4.3.12)** It is drafting convention to adjust the amount of detail to the chosen plot scale; for example, a window opening shown at $\frac{1}{8}$″ = 1′ (or 1:100) would be drawn in more simplified manner than a window opening shown at 1″ = 1′ (or 1:10). **(4.3.13) (4.3.14)**

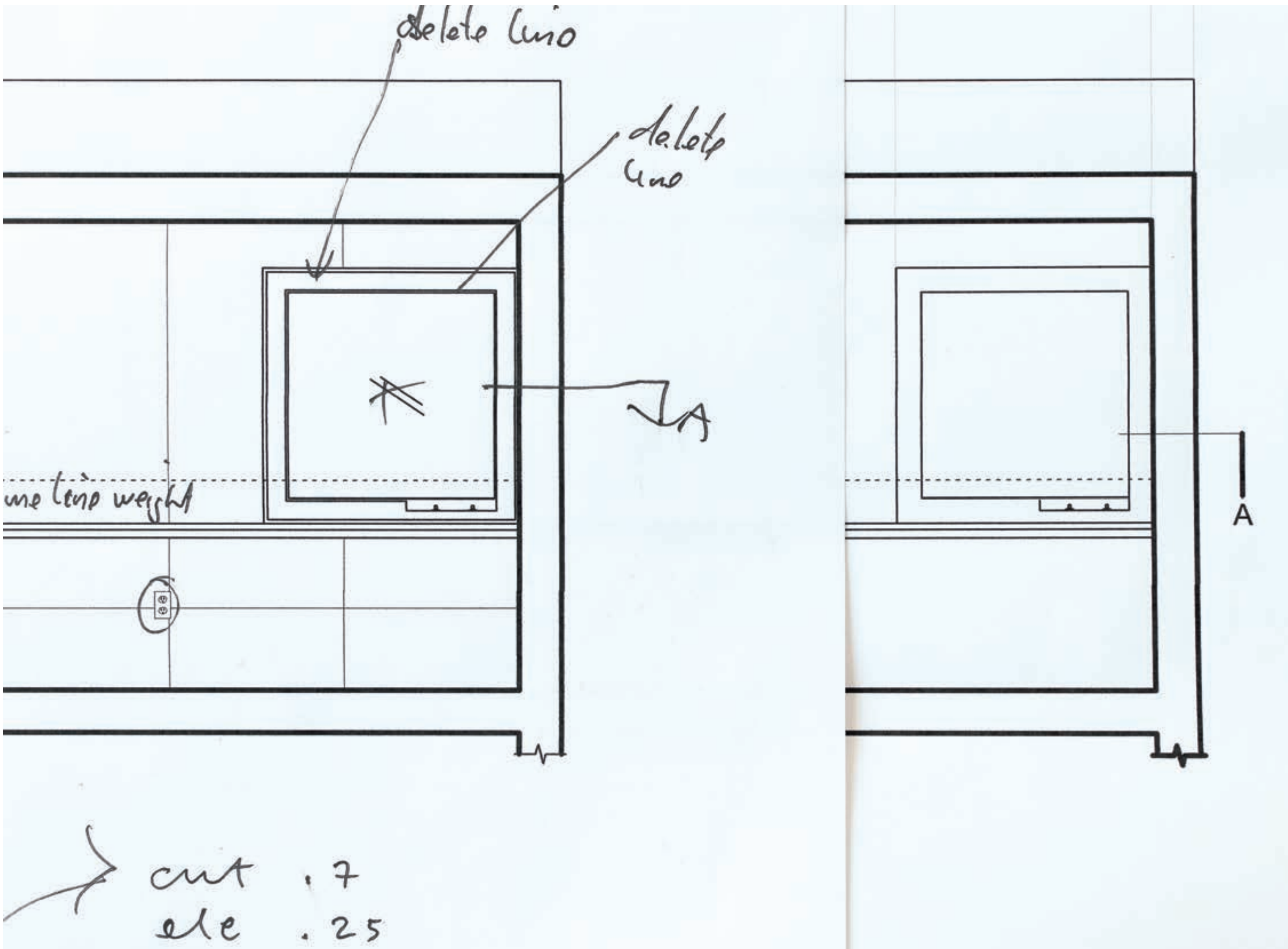


Figure 4.3.12
Close-up view of two plots, one (*left*) with too much line density in the elevation of a window and the other (*right*) edited to increase legibility of the elevation line of the window

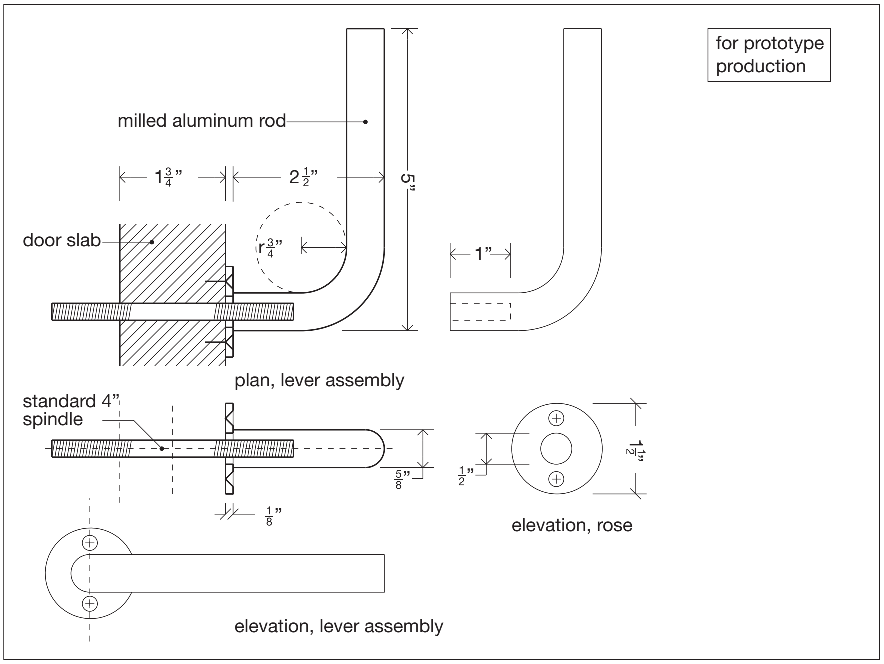
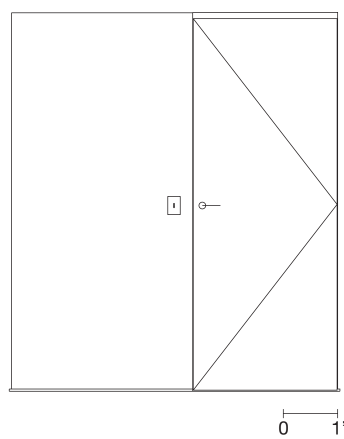


Figure 4.3.13
Levels of information contained in differently scaled drawings, in this example, a door and its respective lever mechanism

In this example layout, the design for a door lever is shown with dimensions. This drawing is intended for a fabricator. Regardless of the size of the print, the drawing contains the basic information for the fabricator to bid on the lever and make a prototype.

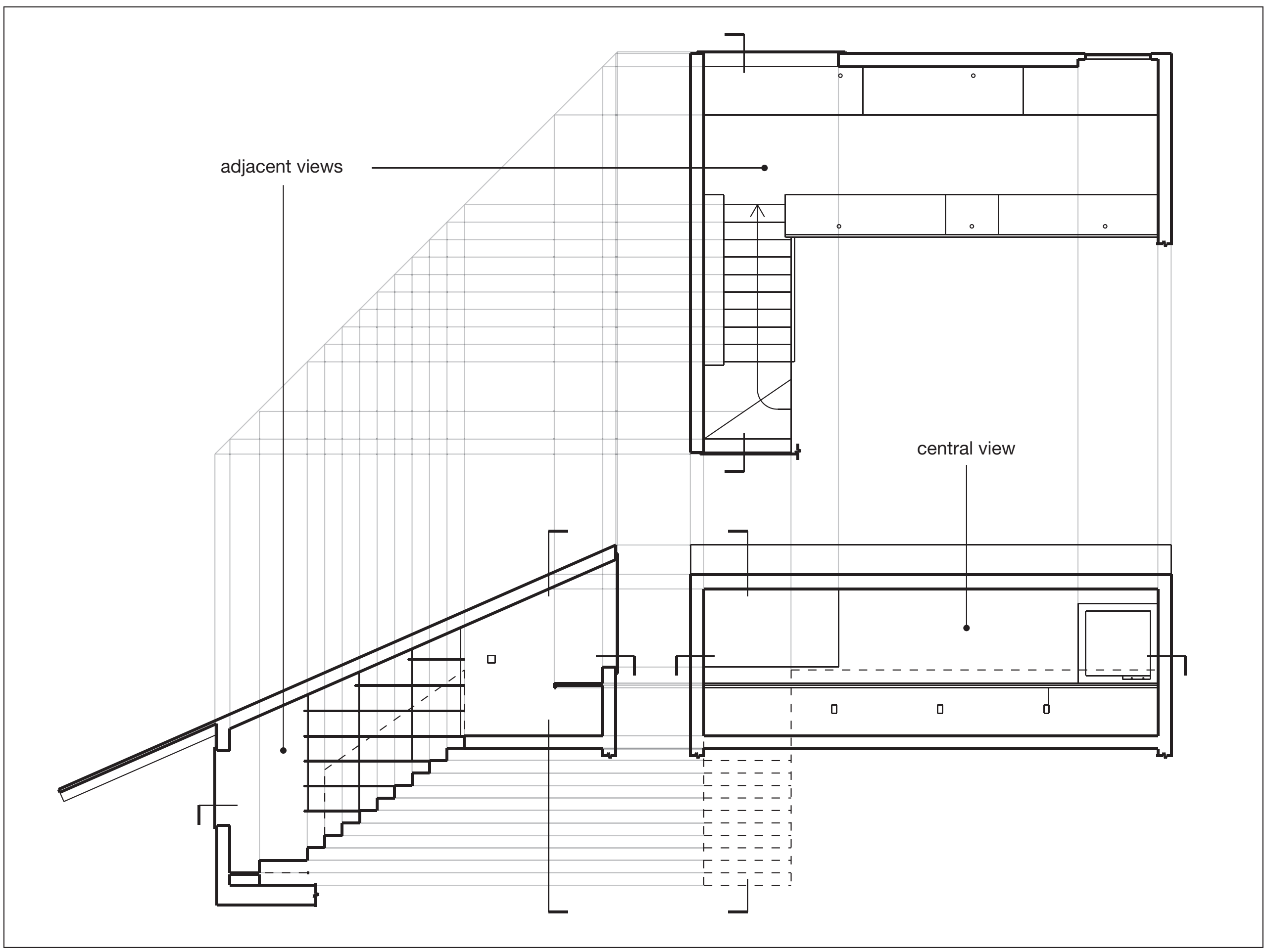


The lever is simplified when shown in the context of elevation drawings, plotted at $\frac{1}{4}$”=1’ (1:50)

Figure 4.3.14
Lever installed

5. *Construct Your Adjacent and/or Relative Views*

Enter each dimension from your survey notes and sketches only *once* into CAD. If the dimension appears in other views, then transfer the dimension with construction lines to that corresponding view. Using construction lines in this manner will allow you to test that adjacent views share the exact same measurements. Construction lines also assist in generating orthographic projections more time efficiently and, most importantly, link all views to each other graphically, assisting in the legibility of the drawing set as a whole. For the layout described in 3.2, "Survey of Space, Media 2: Orthographic Drawings," you should have two views adjacent to your central view. **(4.3.15)**



In this example layout, the plan view and the cross section are adjacent to the central view, the longitudinal section. Construction lines tie all three views together.

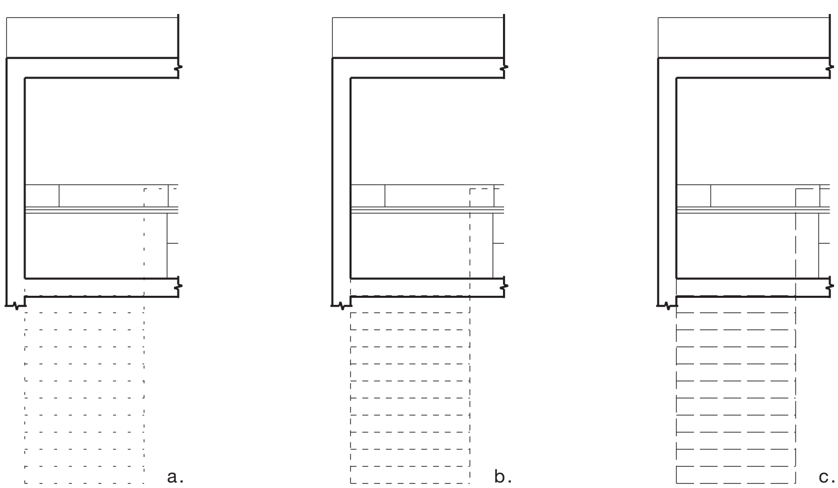
Figure 4.3.15
Constructing adjacent views in your layout

6. *Clean Up Your Layers*

Make sure that all lines are set to their respective layer so that they plot with the correct line weight, line type and color.

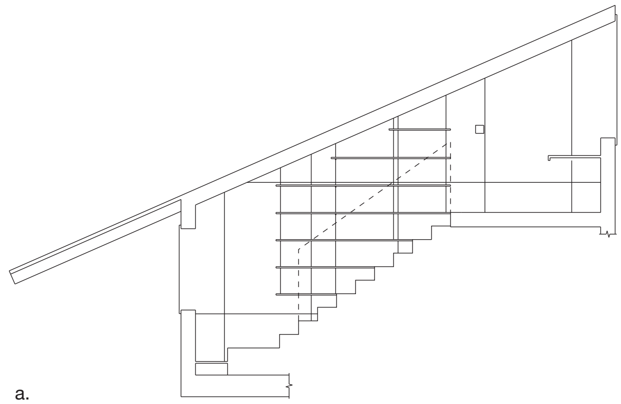
7. *Define Your Line Weights*

Assign line weights to each line type (see step 1). As described in the drawing exercise in 3.2, "Survey of Space, Media 2: Orthographic Drawings," a single, correct way of handling line types and line weights doesn't exist. Rather, it is up to you to know some general rules of thumb about drawing convention, and then test various options for your lines to see what kind of graphic character best suits the purpose of the drawing. A conventional way of handling line weights is to assign clearly different line weights to each line type. With this approach, the cut line, for example, should be clearly thicker than the elevation line weight, about twice as thick. Likewise, the elevation line should be clearly thicker than the construction line weight. The dashed line adopts the elevation line weight, but is dashed using a density of dashes (referred to in some CAD programs as "linetype scale") that suits the scale of the drawing. **(4.3.16)** In some cases where wall thickness is of particular importance to the drawing, *poché* could be used instead of thick lines to describe the cut plane (see "Glossary of Technical Terms and Materials"). The opposite approach to using *poché*, which makes the difference between line types very distinct, is the single-line-weight approach, seen in drawings by Valerio Olgiati and Enric Miralles. This approach erases all distinction between line types and gives a drawing a distinct graphic character in which there is no particular graphic hierarchy; the drawing appears more like a pattern. **(4.3.17)**

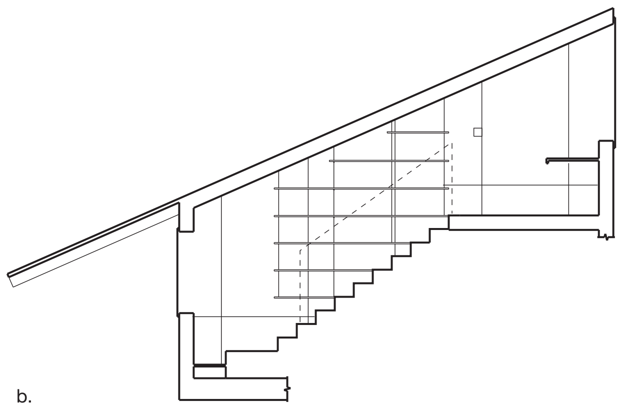


Dashes are just one of many line types in a drawing, but an improperly scaled dashed line can make an otherwise legible line drawing hard to read. If dashes are very short, with wide spacing, the lines become broken-up and hard to follow (a). Similarly, dashes that are very long for a small-scale drawing appear unbalanced within the graphic composition of the whole drawing. Experiment with the scale of your dashed lines.

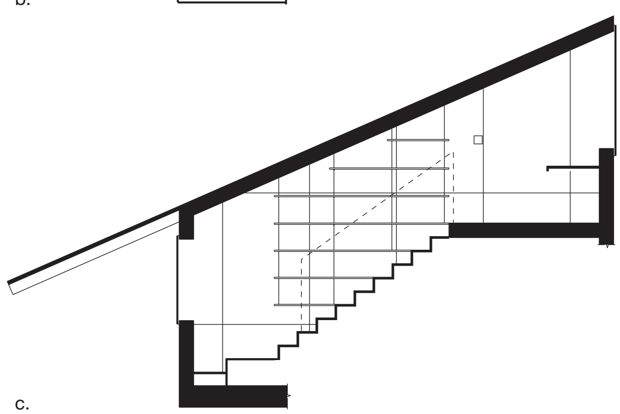
Figure 4.3.16
Line scales



a.



b.



c.

These example sections compare the graphic character that emerges from use of a single lineweight (a), a conventional range of differentiated lineweights (b), and the use of poche or a solid-fill hatch (c).

Figure 4.3.17
Graphic character

8. *Annotate Your Drawing*

Annotation in drawings, or text that serves to point out elements that might not be immediately evident graphically, should be used to further highlight the particular purpose of the drawing. For your multiview drawing set, annotate the following:

- section cuts located precisely in the various views, annotated with flags (see "Glossary of Technical Terms and Materials");
- individual titles for each view;
- a general title referring to the space;
- the scale in which the drawing is plotted. **(4.3.18)**

9. *Make a Series of Test Plots*

Refer to the exercise in 3.2, "Survey of Space, Media 2: Orthographic Drawings," to see a sample sequence of test plots. Test plots are essential to assess the graphic legibility of a drawing set.

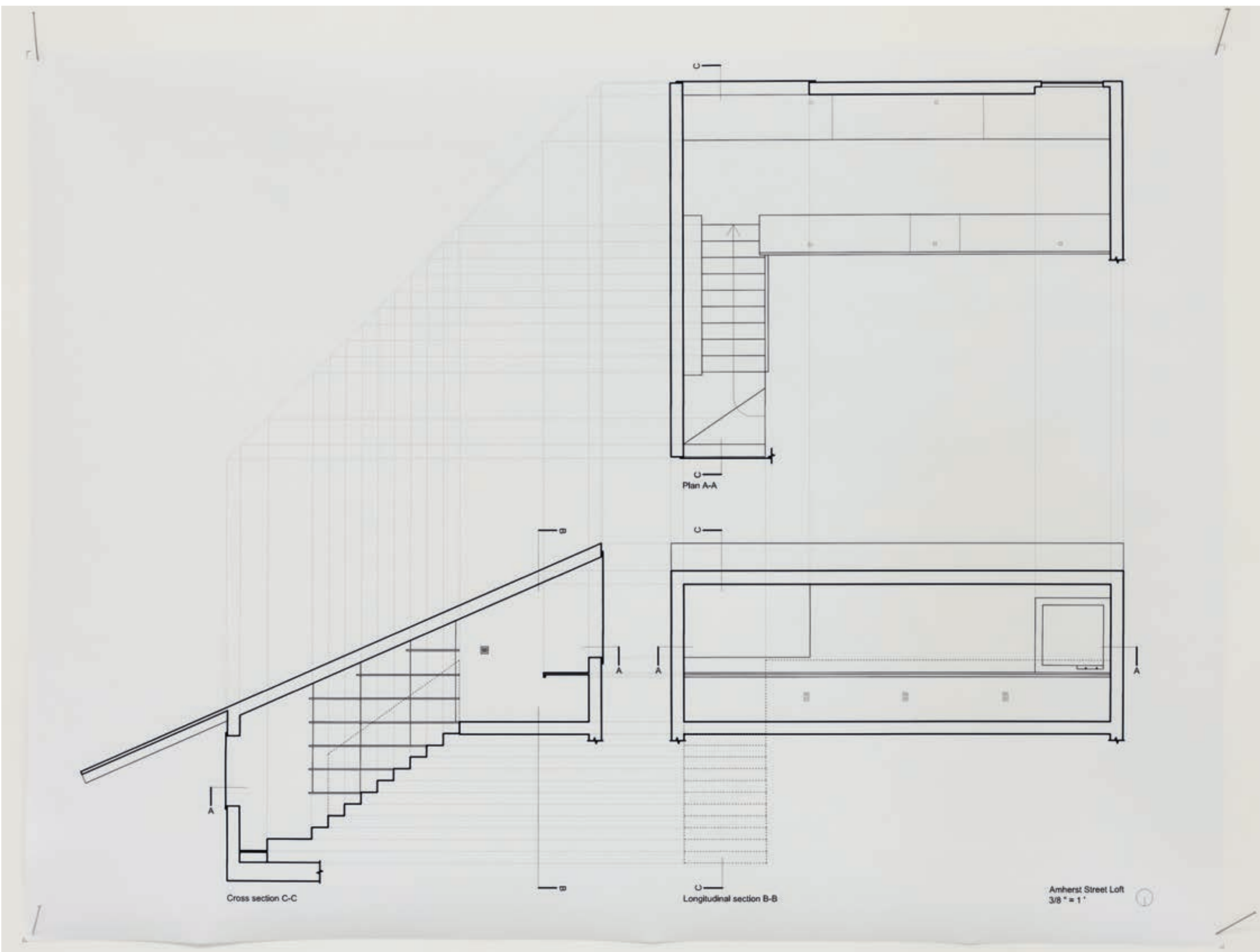


Figure 4.3.18
Annotated, plotted multiview drawing

4.4 MULTI-PART RIGID MOLD MAKING

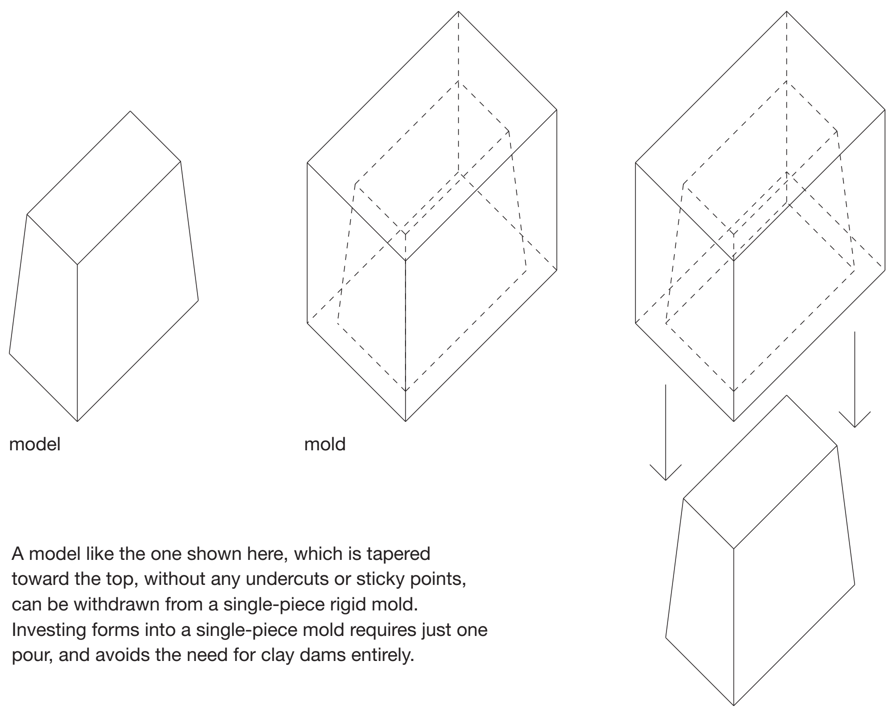
Molds enable multiple copies of a model to be reproduced through casting.

The first step in designing a multi-piece mold is to look very closely at the object to be invested. How should it be oriented on the baseplate? Where should the mold be divided to avoid undercuts? What is the most effective way to withdraw the mold pieces?

A simple object can be invested in a single-piece mold. If a volume is rounded or tapered at the top, and cast in a material that doesn't expand, it should release naturally from the mold. **(4.4.1)**

Multi-part molds allow more complex volumes to be invested and withdrawn without breaking either the mold or the model. **(4.4.2)** Using a rigid material such as plaster, rather than a flexible mold-making material such as silicone, forces the mold maker to really study the volume and design the mold so that it releases the cast form easily.

Safety note: work under the close supervision of your instructor and, as with the handling of all materials, follow the safety precautions outlined on the material packaging.



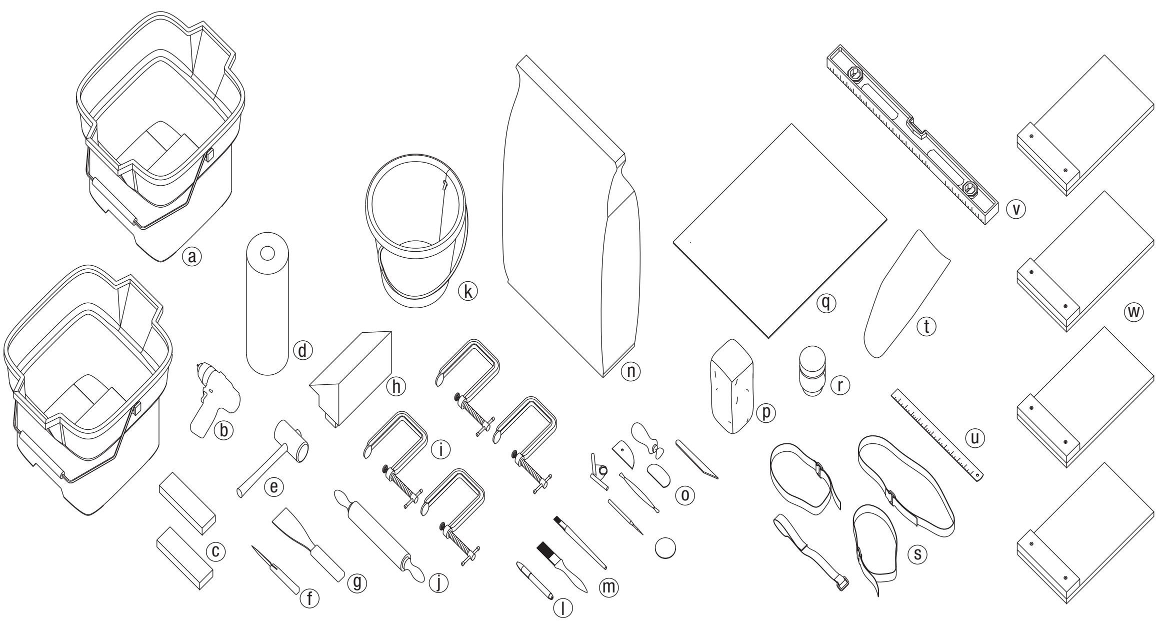
A model like the one shown here, which is tapered toward the top, without any undercuts or sticky points, can be withdrawn from a single-piece rigid mold. Investing forms into a single-piece mold requires just one pour, and avoids the need for clay dams entirely.

Figure 4.4.1
Example of a form that can be extracted from a rigid, single piece mold

Figure 4.4.2
Multiple casts from a mold

1. *Cottle Board Construction and General Preparation*

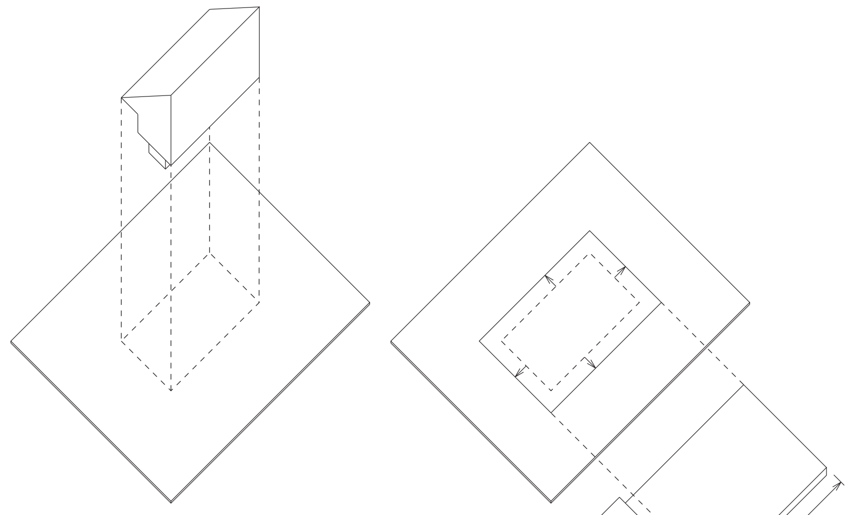
Assembling the necessary tools for multi-piece mold making is the first step in the process. **(4.4.3)** Cottle boards, the rigid exterior formwork for the mold, are simple to make. To size your cottle boards, measure the footprint of your model, taking its

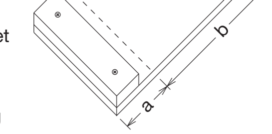


a. utility buckets (2)
b. power drill
c. wooden spacers, 2 identical
d. paper towels
e. rubber mallet
f. utility knife
g. scraper or palette knife
h. foam model
i. appropriately sized c-clamps
j. wooden rolling pin
k. flexible bucket
l. permanent marker
m. paint brushes
n. plaster
o. clay tools (set)
p. clay
q. plywood baseplate
r. release agent (petroleum jelly)
s. cinch straps
t. funnel
u. ruler
v. level
w. cottle boards

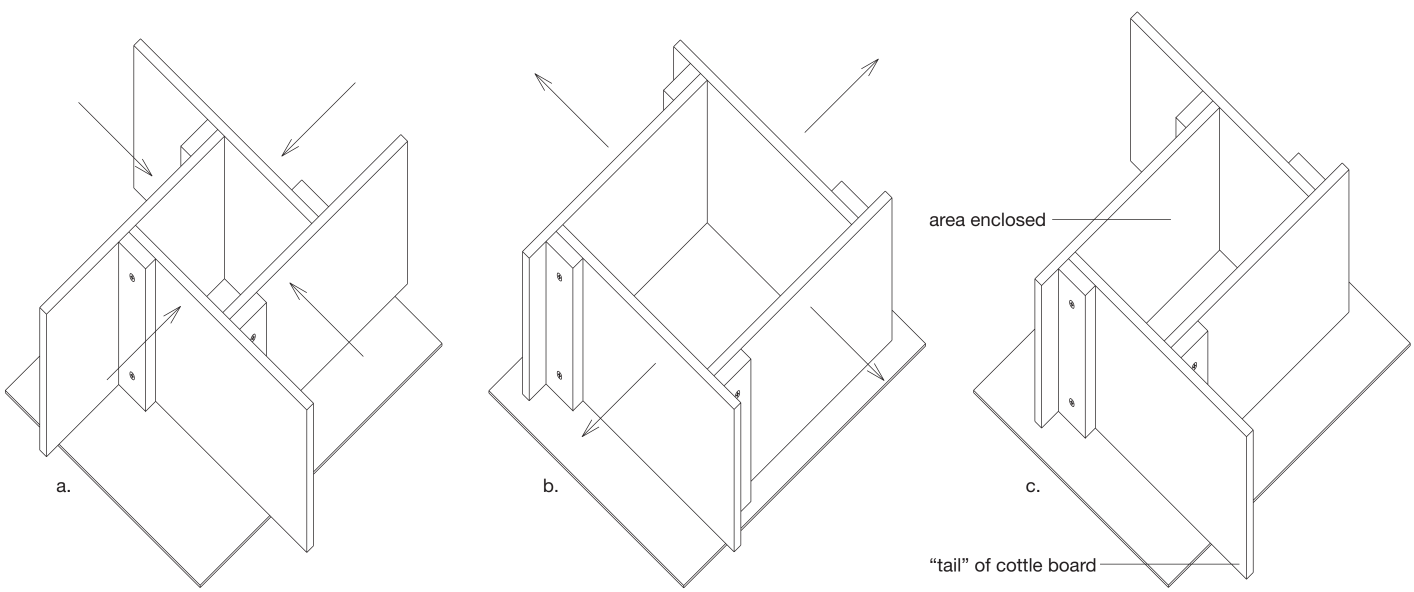
Figure 4.4.3
Tools and materials for mold making

Figure 4.4.4
Sizing your cottle boards





Draw a rectangle defined by the furthest extents of your model. Offset the rectangle outward 1 to 1½ in (2.5 to 4 cm). Add enough length (a) to attach a grip to your cottle board, and to give your cottle board assembly some flexibility in size. Make all of your cottle boards using the longest side (b) as your base dimension.



A set of cottle boards doesn’t have a fixed position. The same set can slide inward to frame a small object (a), adjust outward to use the full length of the boards (b), or frame a rectangular shape (c). As long as the area enclosed is situated squarely on the baseplate, it doesn’t matter if the tails of the cottle boards extend beyond the edges of the baseplate.

Figure 4.4.5
Adjustability of cottle boards

furthest extents and drawing them down into a generalized rectangle. **(4.4.4)** Offset outward 1 to $1\frac{1}{2}$ in. (2.5–4 cm) to get the exterior dimension of your mold volume. This is the volume that you should plan to securely contain within your cottle boards. Use the long side of your rectangle as your base dimension. Add between 2 and 4 in. (5–10 cm) to your measured length, giving your cottle board a generous tail, so that it can be clamped to the abutting cottle board securely, and so that you have some flexibility in the size of your overall volume. **(4.4.5)** To determine the height of your cottle boards, measure your model at its highest point, and add 1 to $1\frac{1}{2}$ in. (2.5–4 cm); this measurement will be the cottle board height. Each cottle board needs a grip, aligned perfectly on one side of the board. The grips should be thick enough to be clamped securely—1 in. (2.5 cm) minimum—and should be mechanically fastened to the bottle board using screws of an appropriate length. **(4.4.6)** Using mechanical connections rather than adhesive bonds to assemble the cottle boards is essential; when exposed to liquid plaster, adhesive bonds can be weakened and dissolve (see "Glossary of Technical Terms and Materials"). The precision with which the cottle boards are made has a direct impact on the mold. When grips are cut even slightly too long, a gap is created between the cottle boards and the baseplate, and plaster can leak out of the edges of the cottle board assembly. **(4.4.7)** Take time to make sure that all cuts are square and measured precisely when fabricating your cottle boards.

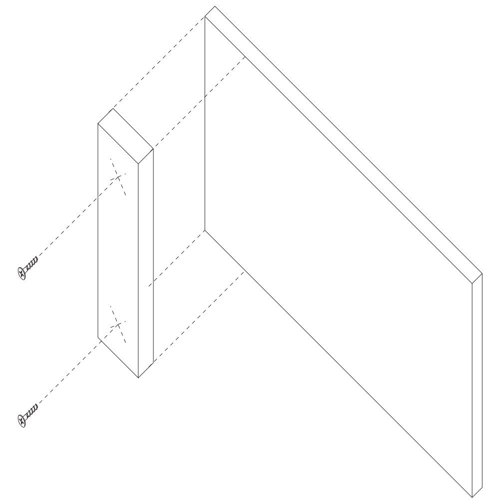
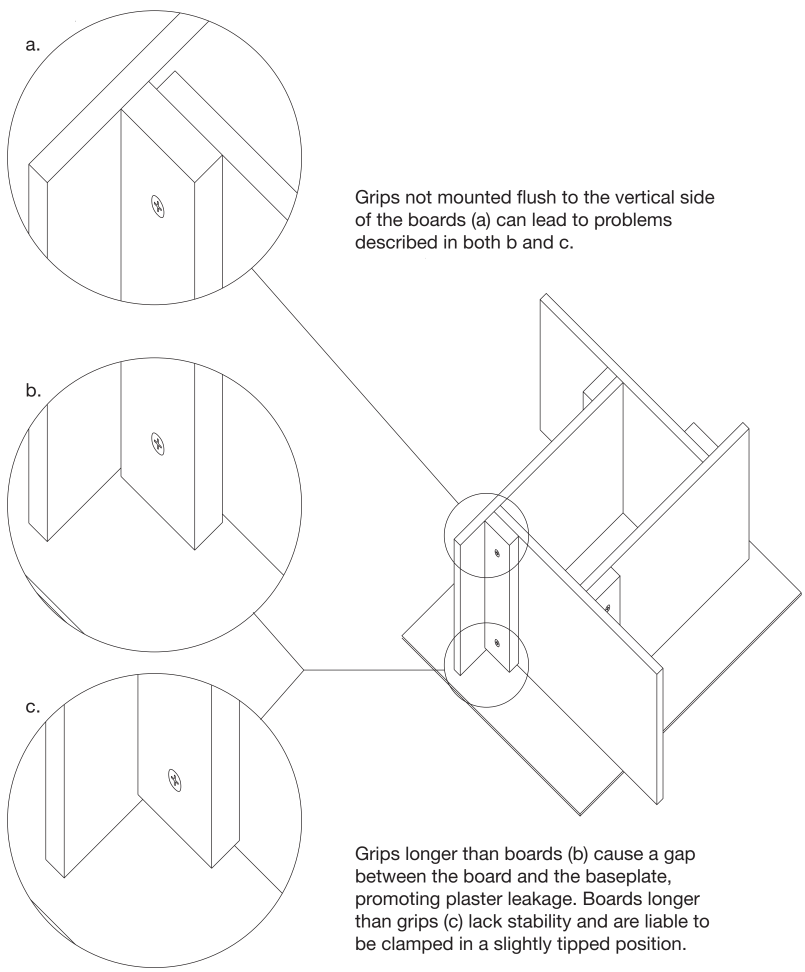


Illustration showing how wood screws can be placed to secure a grip mechanically to a cottle board.

Figure 4.4.6
Mechanically fastening grips to cottle boardst

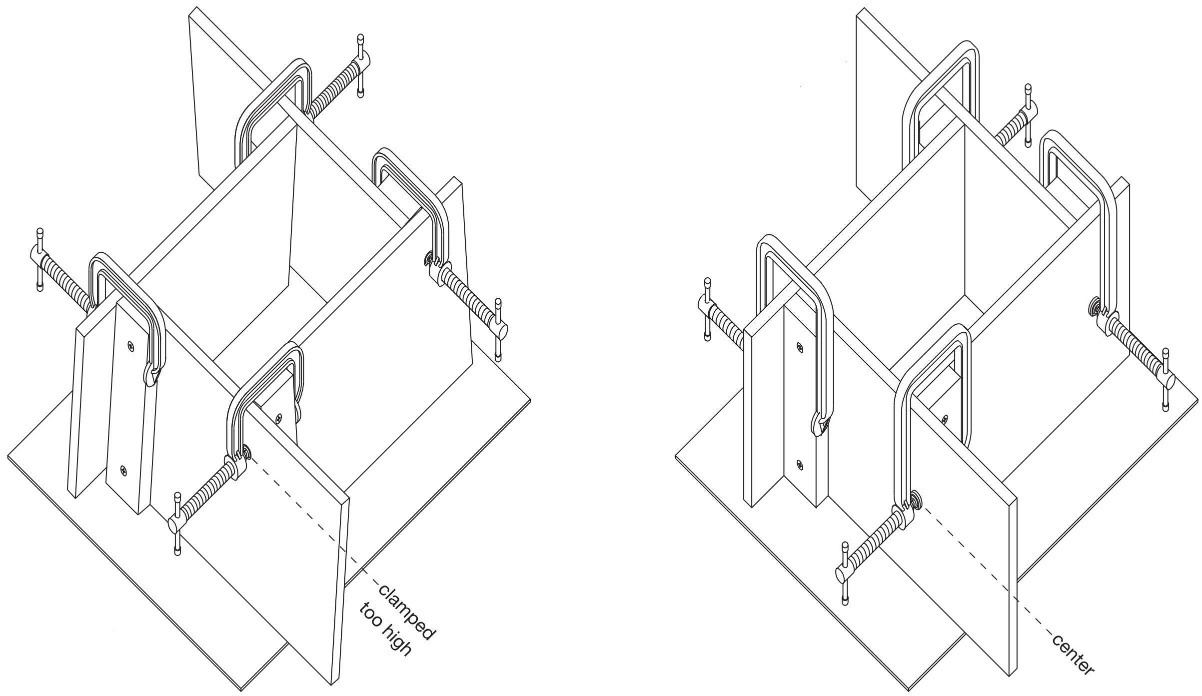


Grips not mounted flush to the vertical side of the boards (a) can lead to problems described in both b and c.

Grips longer than boards (b) cause a gap between the board and the baseplate, promoting plaster leakage. Boards longer than grips (c) lack stability and are liable to be clamped in a slightly tipped position.

Figure 4.4.7
Square assembly of boards and grips

The correct type and dimension of clamp is a key part of any successful cottle board assembly. Deep throat clamps are needed to pinch in the center of the cottle board height. Aim to have a clamp with a throat depth that is approximately one half of your cottle board height. Standard c-clamps without a sufficiently deep throat will pinch cottle boards together at the top, leaving the bottom of the assembly vulnerable to leakage when plaster is poured. **(4.4.8)** Make sure that your work surface is flat and level. **(4.4.9)**



Cottle boards bound with standard c-clamps

Cottle boards bound with deep throated c-clamps

Cottle boards that are clamped too high are prone to splaying and breaking apart when plaster, especially in large amounts, is poured in.

Figure 4.4.8
Choosing appropriate clamps for your cottle board assembly

Figure 4.4.9
Checking the level of a work surface

2. *Plan the Mold Parts and Casting Sequence*

Before beginning the investment process, sketch out various possible ways that you can create your mold. **(4.4.10)** Make a thorough formal assessment of your model to identify any undercuts or sticky points, that could cause the model to be locked into the mold. **(4.4.11)**

Start to plan your mold pieces, with the parting lines, or breaks between mold pieces, located so that undercuts and sticky points are accommodated. The angle of withdrawal, or the angle that you use to pull a mold piece away from the model, should be a consideration when subdividing the mold pieces. **(4.4.12)**

There is no single way of designing a multi-piece mold. The design of the mold can be a response to different criteria. You might be trying to invest a model with as few mold pieces as possible, or you might make more pieces than necessary, just to avoid all potential sticky points.

For the exercise described in 3.3, “Solid-Void Inversion of Space,” the criteria informing the design of your mold are to create a multi-piece mold which releases your model using a minimum of four pieces. Once you are confident that the way in which you’ve planned your mold pieces will avoid undercuts and will release the model easily, draw the parting lines directly on your foam model and number the faces/areas that you’ll invest in a specific sequence. **(4.4.13)**

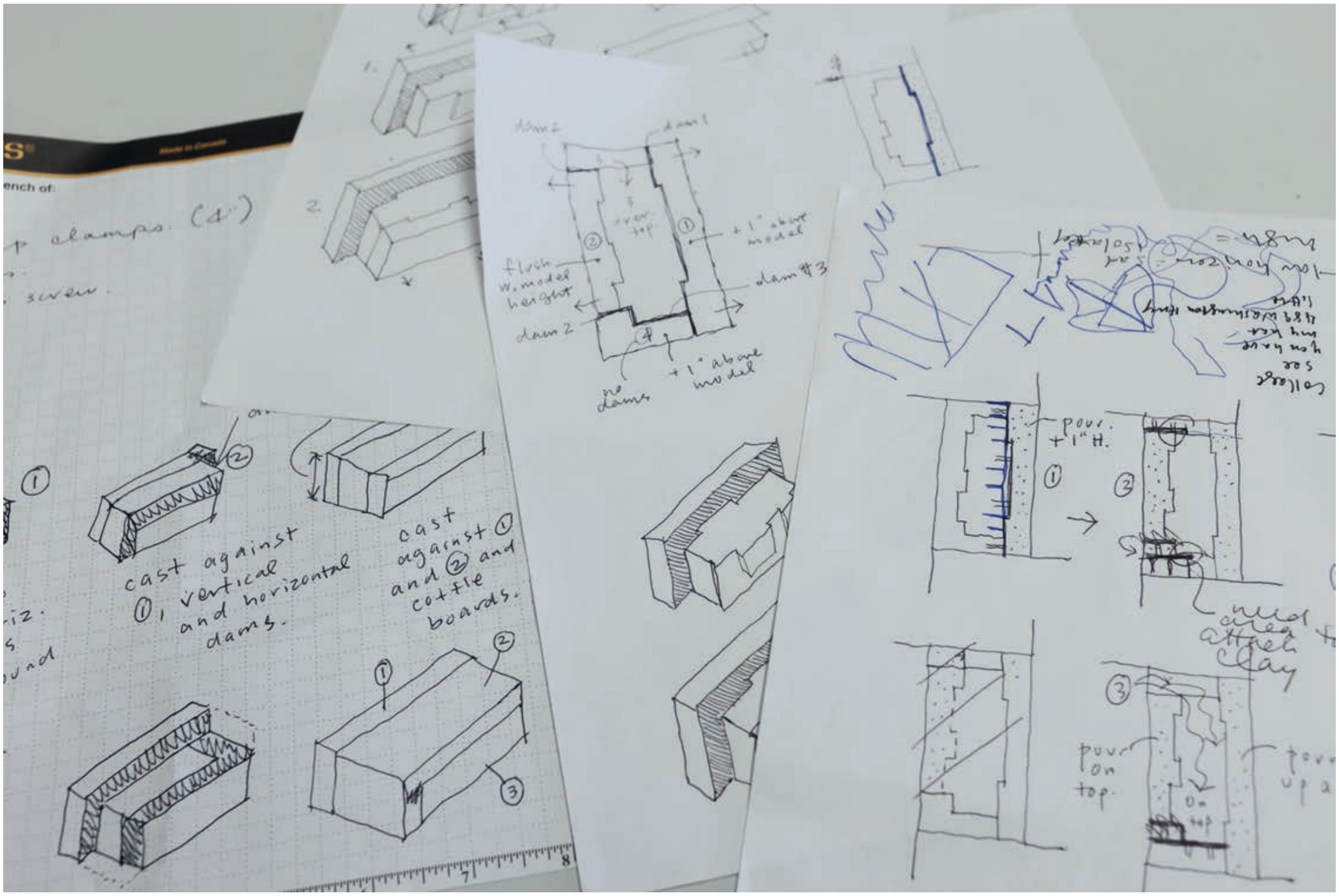


Figure 4.4.10
Sketches planning out mold pieces and pour sequence

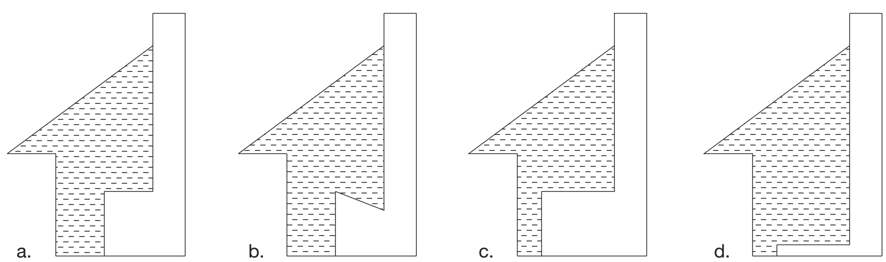


Figure 4.4.11
Undercuts

Accommodate a 90-degree undercut (form a), with a parting line that enables a horizontal angle of withdrawal. To release the model from a mold piece with a true undercut (form b), remove the model before the mold piece. A deeper undercut (form c) will often cause a slip cast skin to snag and tear when the mold piece is withdrawn. Remove the model before the mold piece. When undercuts are deep AND thin (form d), tip the model when it is partially released from the mold, to shift its weight and help it release from the stickiest mold piece(s).

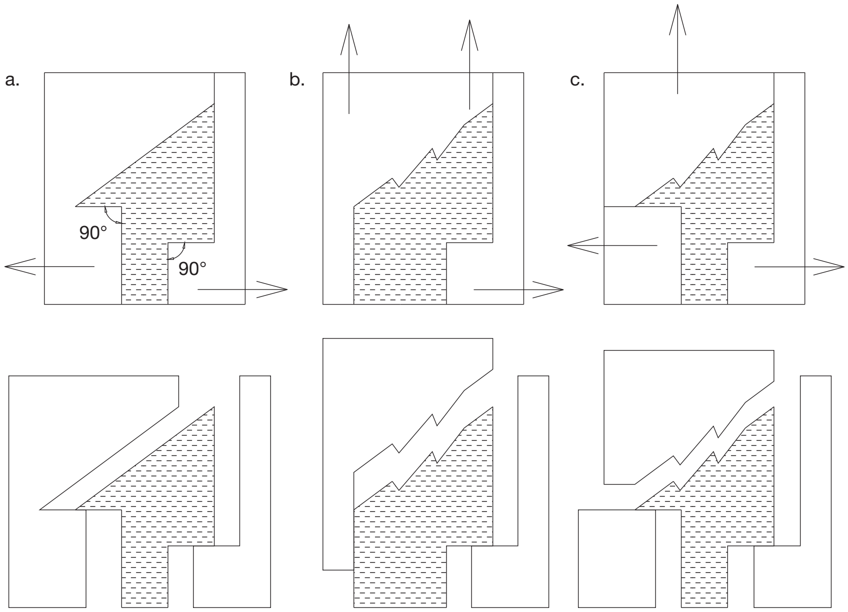


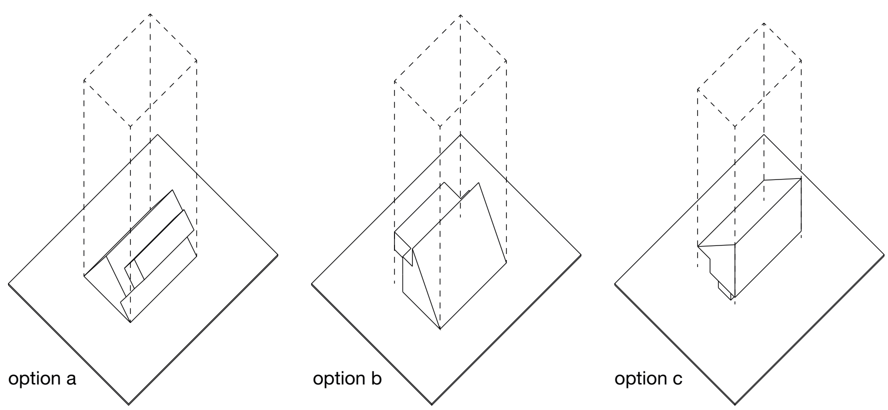
Figure 4.4.12
Parting lines and angles of withdrawal

Form a, with two 90-degree undercuts, allows two mold pieces to be withdrawn outward horizontally. The angles of withdrawal of the two pieces determine that the parting line should be at the apex of the form, so that neither piece encases the tip. The relief detail along angled top in form b determines the angle of withdrawal for the piece, which can still be poured as a single piece because the base of the form on the left-hand side is solid, free of undercuts. Variation c, with both relief detail and two undercuts, requires two parting lines and three mold pieces, the form of the relief detail and the undercuts determining the angles of withdrawal.

Figure 4.4.13
Parting lines drawn on foam models

3. *Orient and Fix the Model*

Before investing a model in plaster, particularly a lightweight model made out of foam, it needs to be connected mechanically to a baseplate. A mechanical fastener such as a screw is able to keep the model positioned securely on the baseplate when plaster is poured, whereas adhesive bonds are prone to breaking when exposed to liquid plaster. Rotate your model to look at the varying ways that it could sit on your baseplate. Ideally, your model should be stable when it's sitting on the baseplate. If it's prone to tipping, it will signal vulnerability to the weight of plaster pushing it over during the investment process. The surface facing downward, connected to the baseplate, should be perfectly flat, and as large a surface area as your model offers. **(4.4.14)** With your model in its chosen orientation, center it on your baseplate, and screw it from underneath at two points. **(4.4.15)** Make sure to countersink the screw heads so that they are either flush with, or recessed into, the bottom surface of your baseplate.



The example model was rotated to sit in three orientations on the baseplate. The option c orientation is chosen because the model is sufficiently stable in this orientation, and the footprint is the smallest, making the mold smaller and more manageable to handle.

Figure 4.4.14
Orienting your model on a baseplate

Identify two fixation points to secure your model to the your baseplate. Countersink screws and insert them from the bottom side of your baseplate.

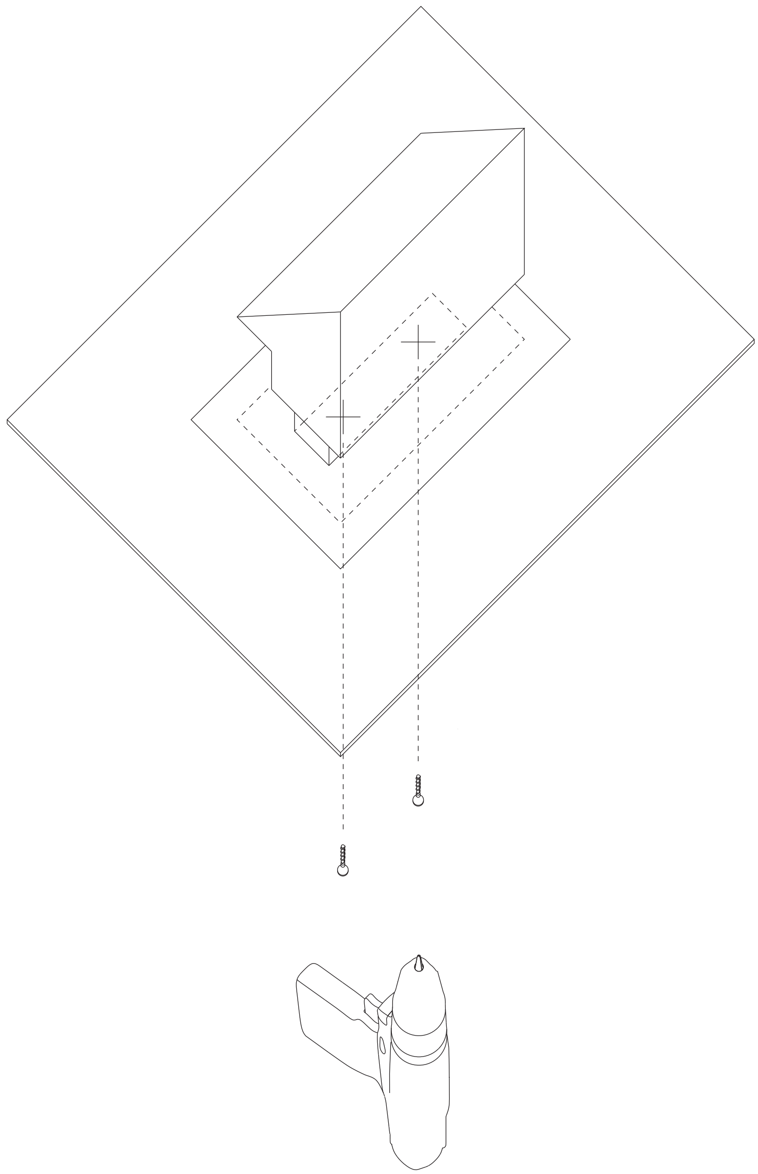


Figure 4.4.15
Securing the model to a baseplate

4. *Apply Release Agent to All Surfaces*

When working with plaster, it is crucial to use a release agent, also known as mold release. Mold release prevents all of the individual mold parts from bonding together into a single mold. It also prevents plaster from bonding to the wood cottle boards and to the model itself. Because plaster has a hydrophilic, or "water-loving," molecular make-up, it seeks out water and is able to create physical bonds with other porous, hydrophilic materials. This is most evident when a plaster mold is exposed directly to water, as in a slip-casting process (see 4.5, "Slip Casting"). Release agents, in working with plaster, are most commonly hydrophobic, or "water-repellant." Greasy, oily substances work effectively as release agents. Petroleum jelly, or even butter, can be applied in a thin film over your baseplate, model and cottle board interiors. Use your hands to apply the release agent, so that you are able to feel the greasy film. **(4.4.16)** If you can see a pattern, like finger marks, or a visible build-up of release agent, you have applied too much. The barrier should be palpable, but not visible. To be safe, and to ease your clean-up between pours, apply release agent also in areas where you imagine that plaster might drip or pool outside your cottle board assembly. Coat all surfaces that will come in contact with plaster.

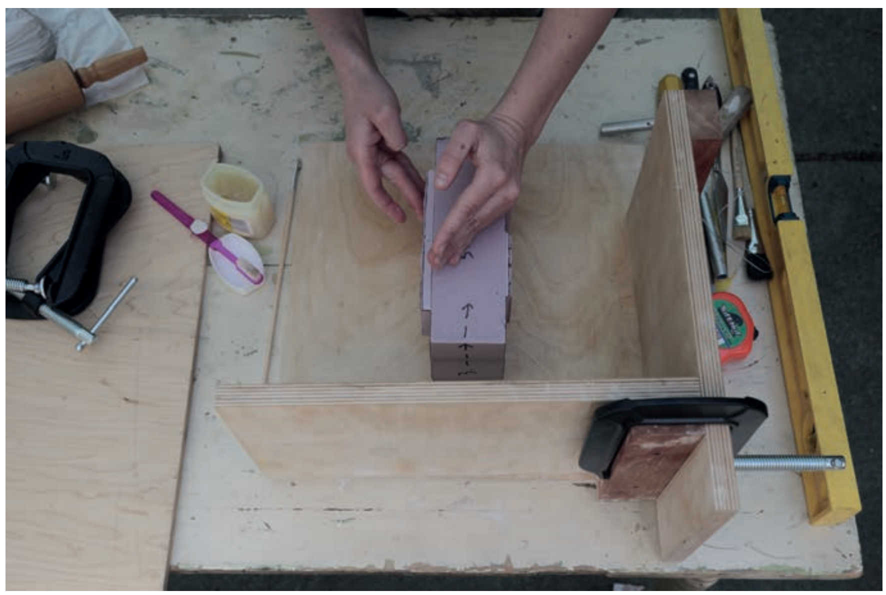
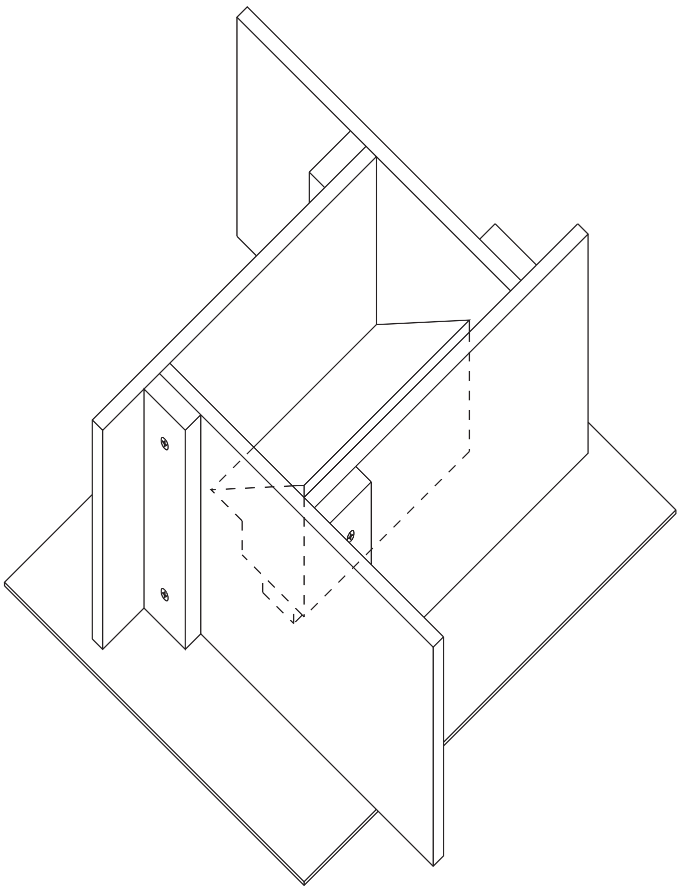


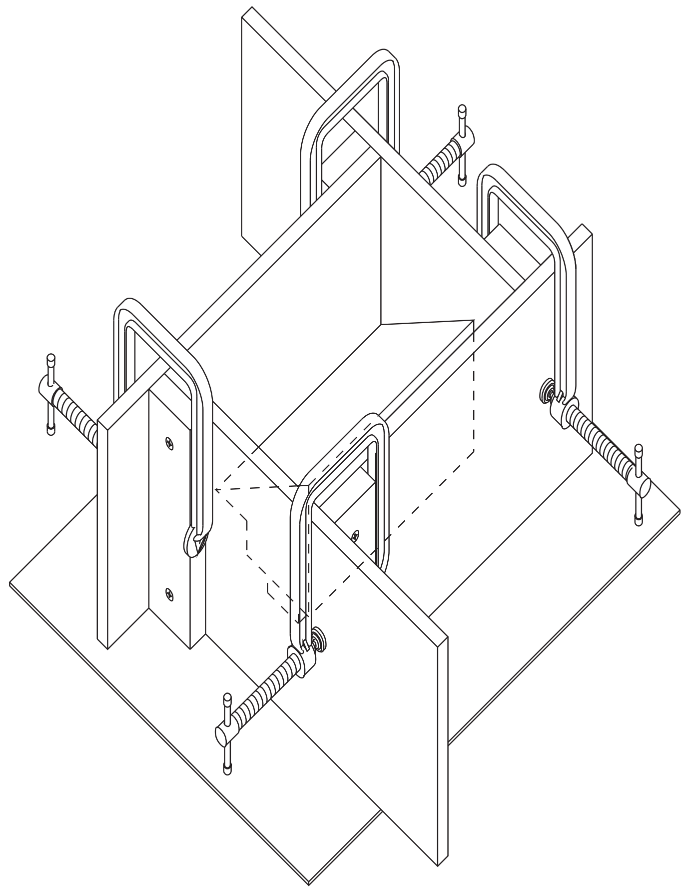
Figure 4.4.16
Application of release agent to mold and cottle boards

5. *Position the Cottle Boards*

Set your cottle boards up with the 1 to $1\frac{1}{2}$ in. (2.5–4 cm) space around the model that you planned when dimensioning your cottle boards. Clamp your cottle boards securely in place. **(4.4.17)**



Cottle boards placed 1 to $1\frac{1}{2}$ in (2.5 to 4cm) beyond the furthest extents of the model.



Cottle boards clamped in place with appropriately sized clamps. The weight of the assembly prevents uplift when plaster is poured in.

Figure 4.4.17
Clamp cottle boards in place

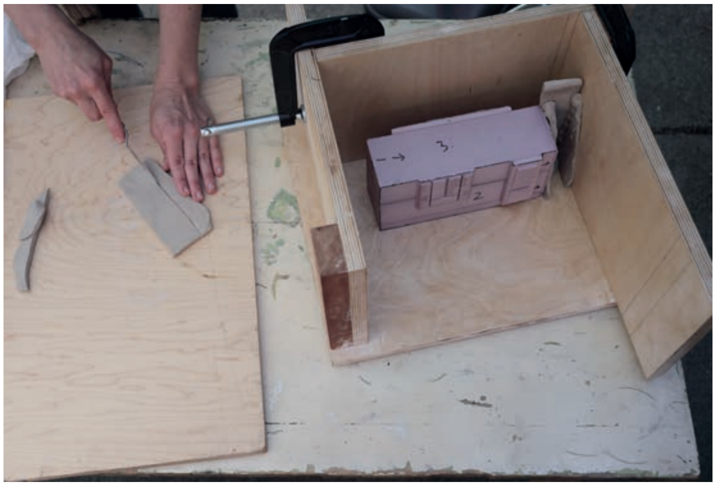
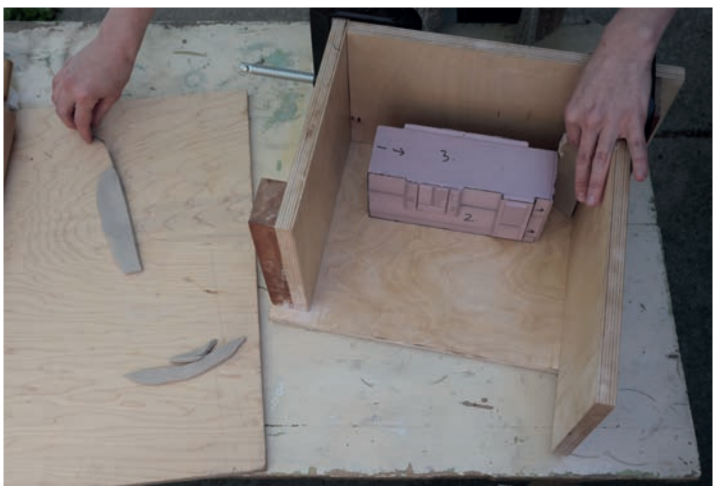


Figure 4.4.18
Cutting clay strips

6. *Subdivide the Space around the Model*

Casting the first piece of a multi-piece mold is always challenging because it is the first chunk of negative space to be quarantined and inverted into a solid mass. To subdivide the space within the formwork, you will need to build temporary dams and buttresses out of clay. Roll out a slab of clay with a thickness of approximately $\frac{5}{8}$ in. (1.5 cm). Work on a porous surface with your clay to prevent sticking; a piece of unfinished, dry plywood works well. Measure the distances between your model and the interior of the cottle boards and slice clay strips with these dimensions. **(4.4.18)** Lower the clay slices into your formwork and, using your clay tools, begin fixing them to the cottle boards and model, exploiting the inherent stickiness of the clay. **(4.4.19)** While the clay will stick in place quite easily, the dams need to be reinforced with additional supports from the back, referred to as buttresses, in order to withstand the weight and pressure of the liquid plaster. Slice right-angle triangles long enough to support the full height of your dams. **(4.4.20)** Attach these supports to the backs of the dams, and make as many as necessary to make the dams rigid. Using your clay tools, clean the connections between the clay and cottle board or model surfaces, making sure that they are water tight. Smooth the interior surface of the clay dams so that undercuts or sticky points don't unintentionally occur where your mold pieces connect. **(4.4.21)**



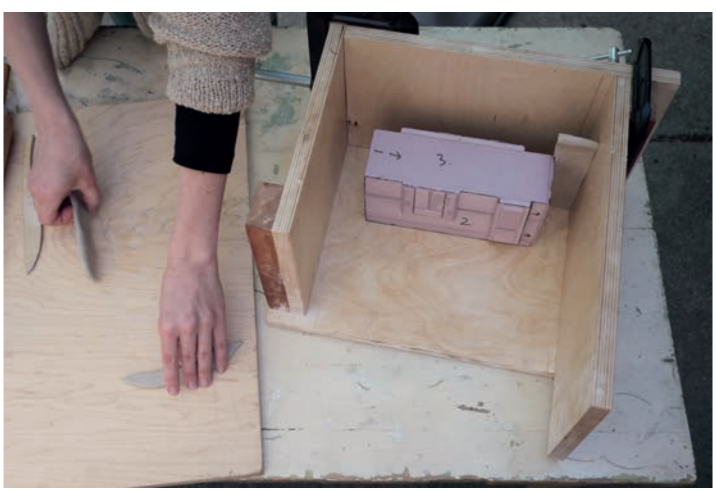


Figure 4.4.19
First clay dam placed

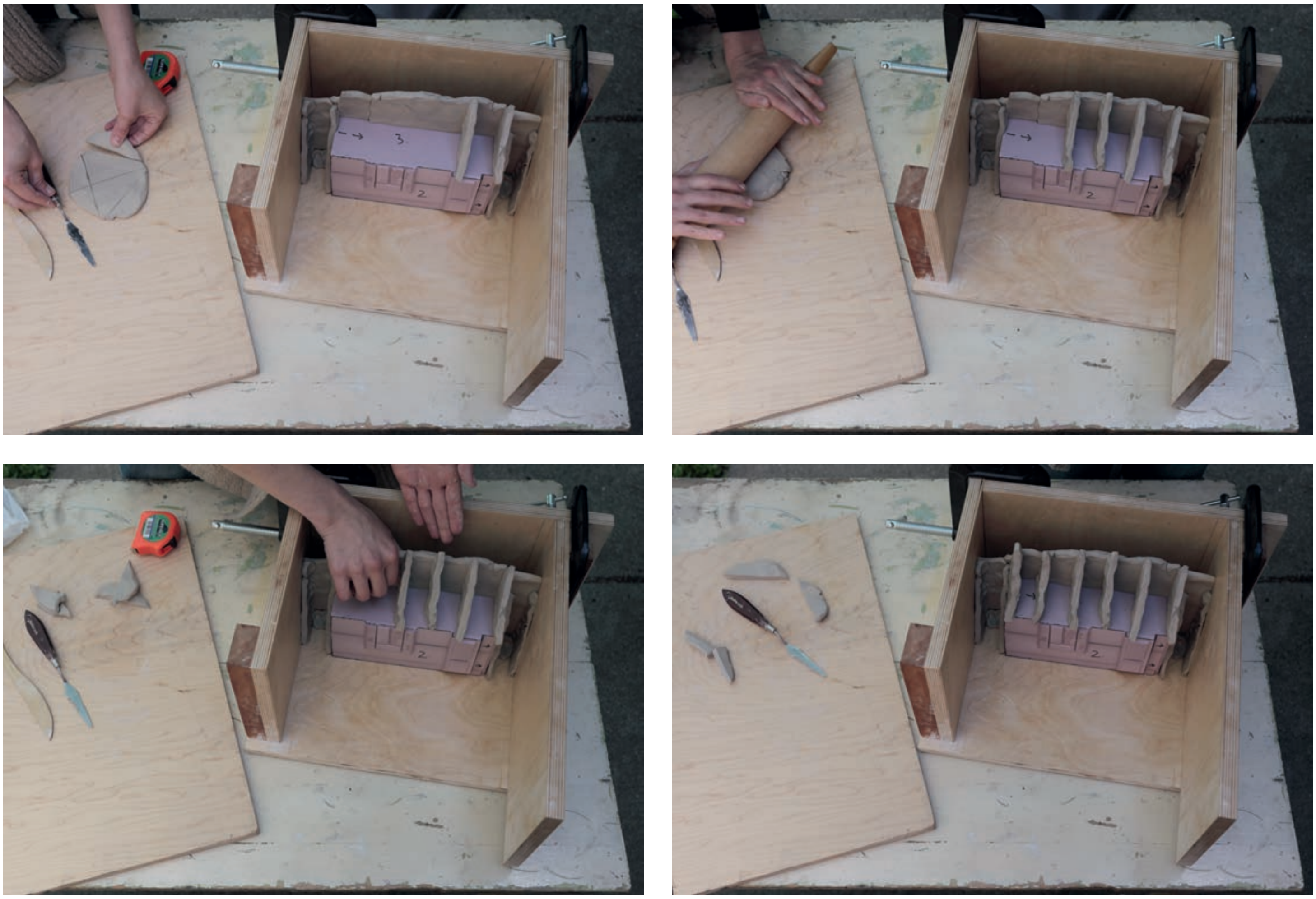


Figure 4.4.20
Buttressing

Figure 4.4.21
Smooth interior of clay dam, detail view

7. *Seal the Exterior of the Cottle Board Assembly*

Liquid plaster will find any crevice or crack, which might not be evident to the naked eye, to leak through. Having a leak inside or outside your formwork is not just a mess, but can also leave you with too little plaster to fill the space for the mold piece that you planned and defined in step 6. **(4.4.22)** Roll out several clay "worms" with diameters of approximately 1 in. Lay these worms along the exterior of your cottle board assembly, at each seam where plaster could potentially leak. **(4.4.23)** Use your thumb to press the clay into the seams; the inherent stickiness of the moist clay will make it an effective sealant. **(4.4.24)**

Figure 4.4.22
Distorted plaster surface as a result of a leak, detail view

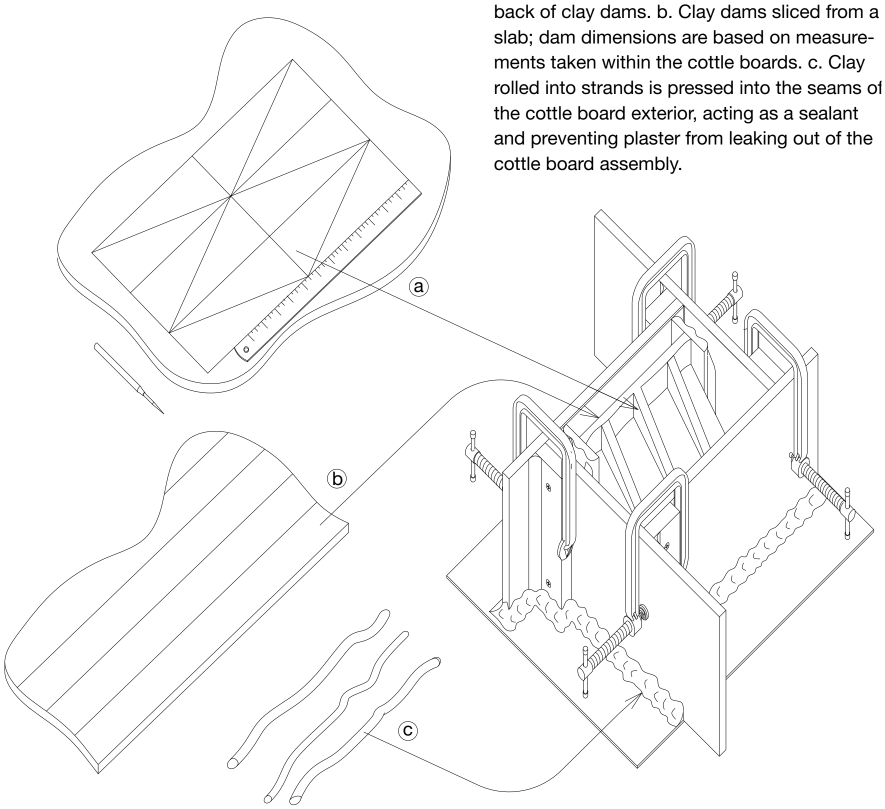


Figure 4.4.23
Using clay to seal the outside of the cottle board assembly, and to subdivide areas for pours

Figure 4.4.24
Sealing outside of cottle board assembly

Figure 4.4.25
Compromised plaster mixture, detail view

8. *Mix and Pour Plaster*

Once your individual mold part has been subdivided and defined with well-supported, watertight dams, and a sealed exterior, you are ready to invest that part of your model in plaster. There are several methods used in mixing plaster (see "Glossary of Technical Terms and Materials"). Regardless of the specific method used, having the proper ratio of plaster to water in the mixing process is essential; if the ratio is off, with either too much plaster or too much water in the mixture, the substance will not set to its maximum strength, and often has a weak and chalky consistency. **(4.4.25)** The "island method" of mixing plaster requires some trial-and-error at first, and relies, in part, on developing a physical sense of how the material behaves through its different states. Using a clean, flexible bucket with a sufficient capacity, put enough clean, potable water, at a temperature between 70 and 100 degrees Farenheit (20 and 37 degrees Celsius) (see "Glossary of Technical Terms and Materials"), in the bucket to fill approximately $1\frac{1}{2}$ times the volume that you plan to fill with plaster. With a clean cup, begin gently adding plaster to the water. Keep adding at a consistent rate until you begin to see a peak or small island accumulating. **(4.4.26)** Once that island remains visible above the water line, you will have reached your ideal water-to-plaster ratio. Let the mixture soak for one to two minutes,

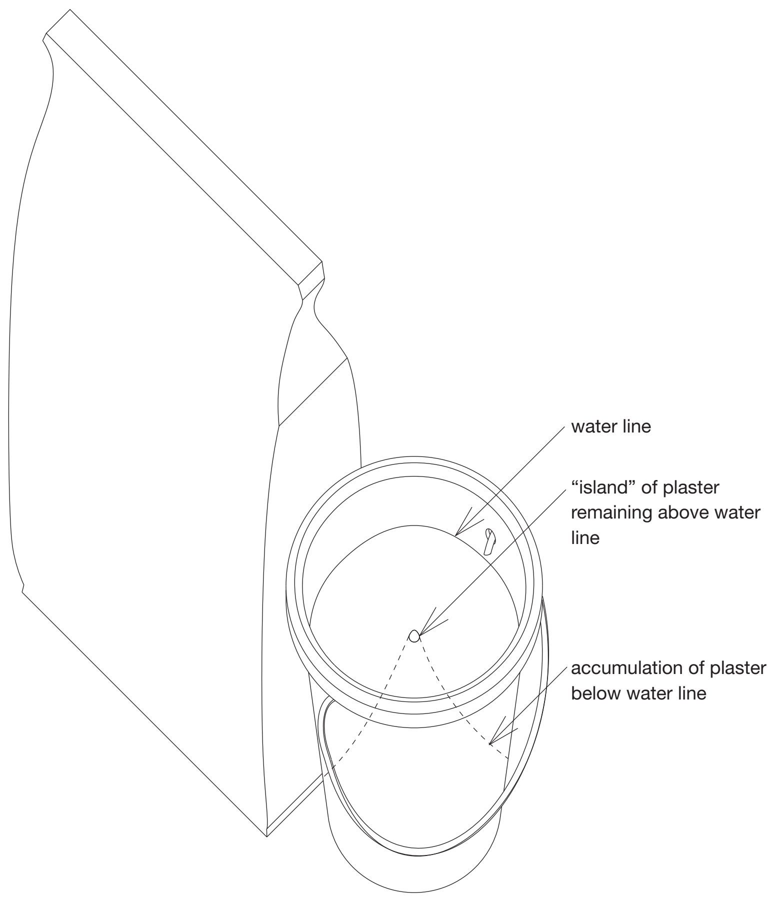
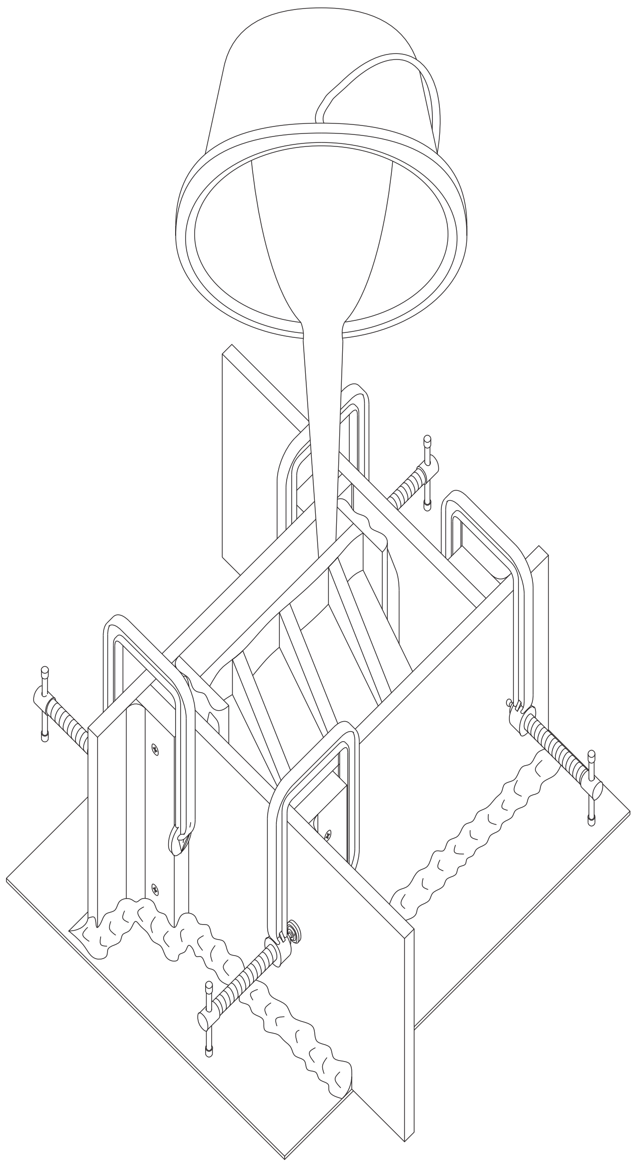


Figure 4.4.26
Mixing plaster

allowing all of the plaster to make contact with water. After the soaking period, begin to gently stir the mixture with your hand. Immerse your hand with your fingers straight and together, like a paddle. Avoid grabbing clumps of plaster at the bottom of the bucket. In a figure-eight pattern, stir the mixture for five to ten minutes, or until you feel the consistency of the plaster start thickening slightly, from watery to a thick cream. If you wait until the plaster begins to warm up, you have stirred for too long. Gently pour some plaster into your dammed space, until it reaches a height of about 1 in. (2.5 cm). **(4.4.27)** Stop pouring, and check for leaks. If there are leaks at this

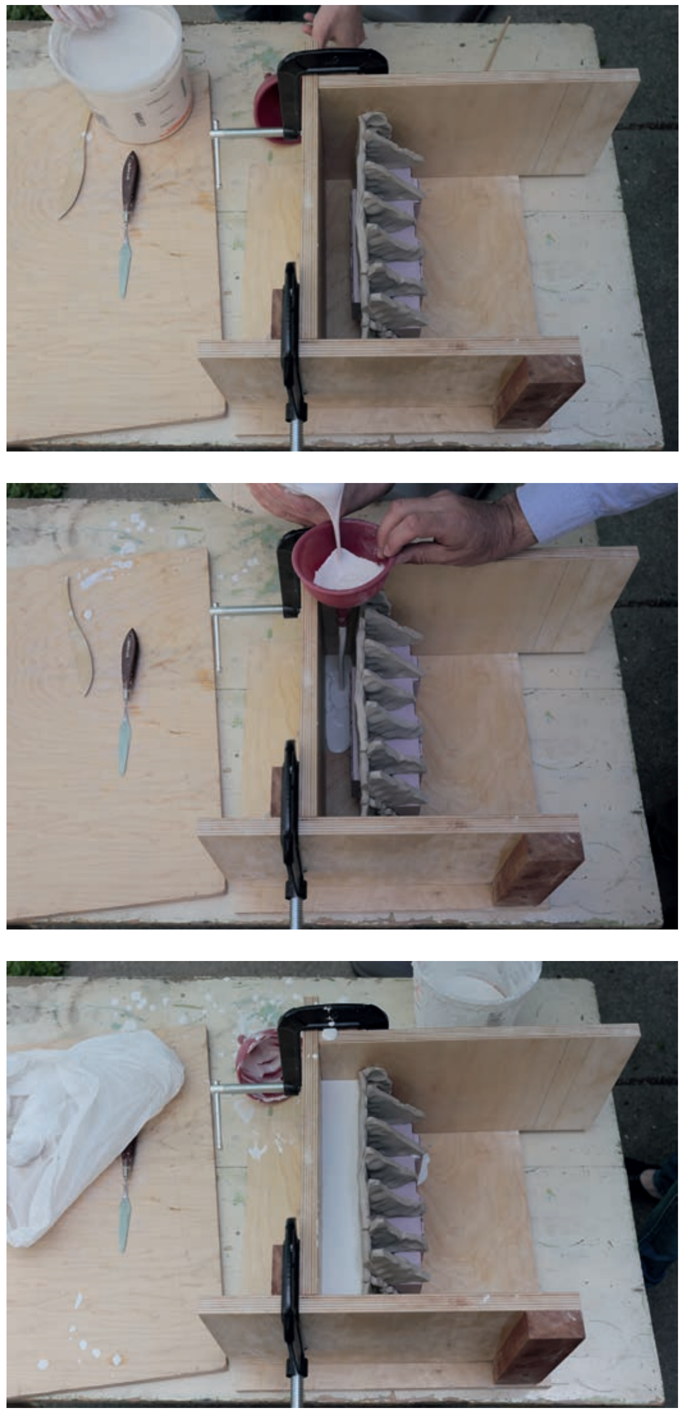


By making an initial 1-inch pour (2.5 cm), you can check your cottle boards and dams for leaks without having the volume and pressure of the full amount of plaster. Have clay ready at your fingertips to fortify dams if needed, or to plug leaks.

Figure 4.4.27
The 1-in. (2.5-cm) initial pour

point, it is easier to remedy than when the entire volume is full of plaster. Use clay to plug any leaks, and then proceed to fill the dammed space with plaster, pouring, ideally, against a cottle board surface. If the space that you've dammed is small, you might need to use a flexible funnel to direct the plaster against the cottle board and into the space. **(4.4.28)** Once the dammed space has been filled to a level even with the top of your cottle board assembly, use a rubber mallet to gently tap the tabletop surface. This action will help any trapped air bubbles in the plaster rise to the top.

Figure 4.4.28
Using a flexible funnel to pour into a small area



9. *Remove Dams and Prepare for Next Pour*

Different types of plaster have different setting times (see "Glossary of Technical Terms and Materials"); the setting time that corresponds with the plaster that you choose to use should be written directly on the bag or on an accompanying data sheet. For the pottery plaster used in these examples, the setting time is 14–24 minutes for a machine-mixed batch, and longer for a hand-mixed batch (see "Glossary of Technical Terms and Materials"). Once the plaster appears matte, it has changed phase from liquid to solid. You can monitor the setting process of your plaster by touching it now and then. The chemical reaction that occurs when plaster is mixed with water is exothermic, which means that it releases heat energy as it sets. Once it has heated up and then started to cool, between 45 minutes to one hour, it will be stable enough to remove the clay sealant and dams. **(4.4.29)** Ideally, the cottle boards will remain clamped in place. After having set for about one hour, the plaster will be rigid enough to retain its cast form, but still soft enough to make registration marks (also referred to as keys) in the sides of the freshly poured mold piece. The registration marks will ultimately help lock the mold pieces in place, and ensure that the mold is properly assembled. To make a registration mark in recently set plaster, use a small coin and dig it gently into the face of the plaster, rotating it

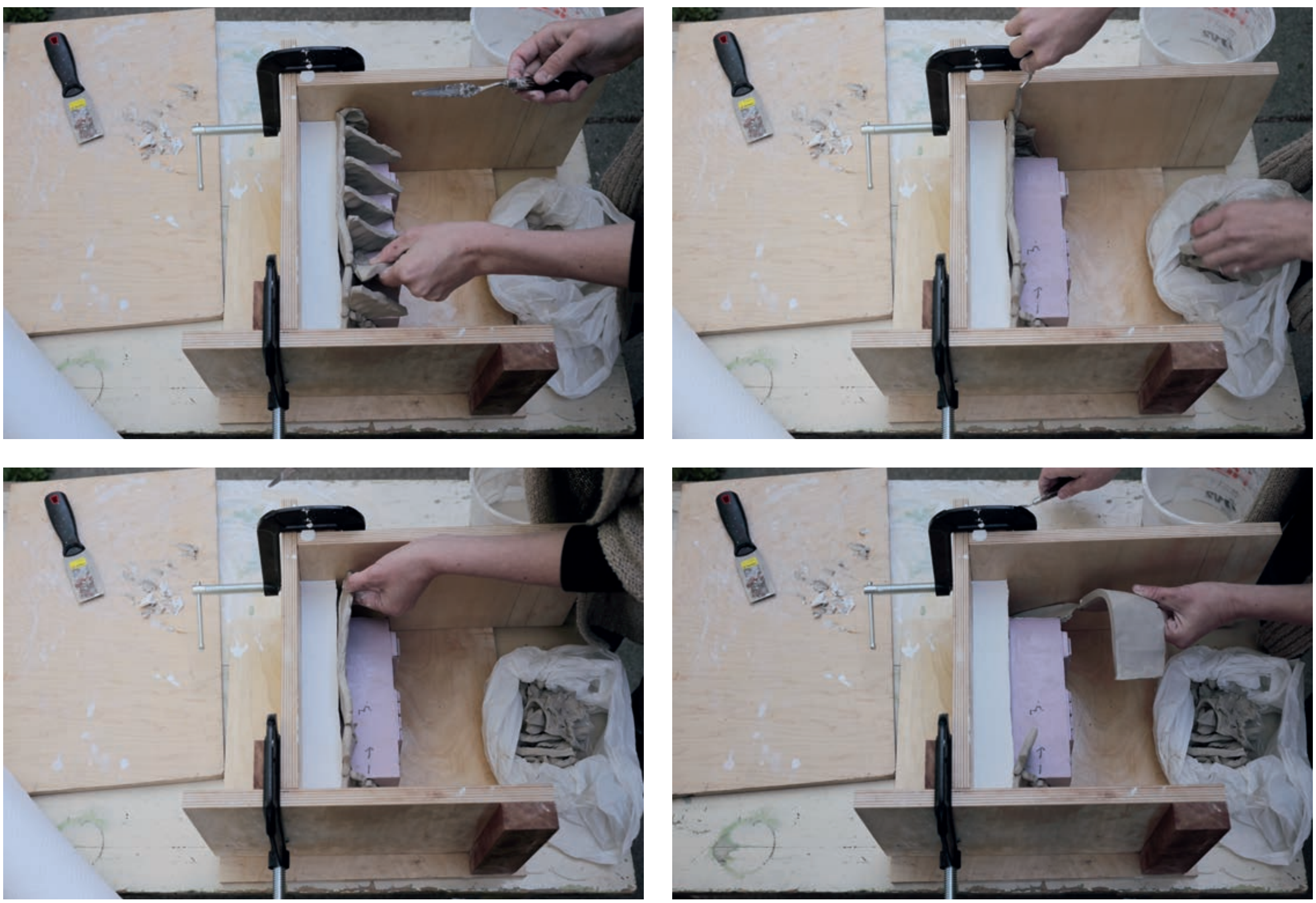


Figure 4.4.29
Removal of clay dams

around fully. **(4.4.30)** Be conservative about how deeply you insert the coin (or other tool) to make the registration mark. Registration marks that are chiseled too deeply into the plaster may act as undercuts or simply break off. **(4.4.31)** Apply release agent to the recently poured plaster and follow steps 6 through 9 to cast each mold piece and fully invest the model. **(4.4.32)**

Figure 4.4.30
Registration marks

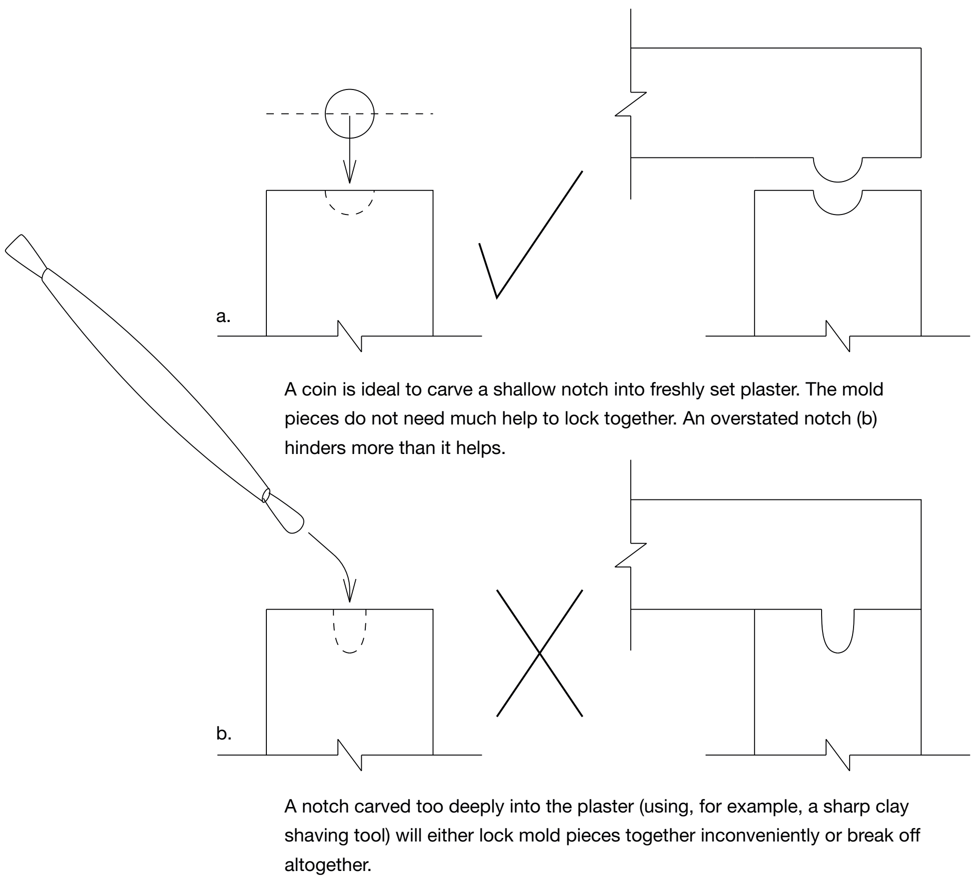


Figure 4.4.31
Registration marks

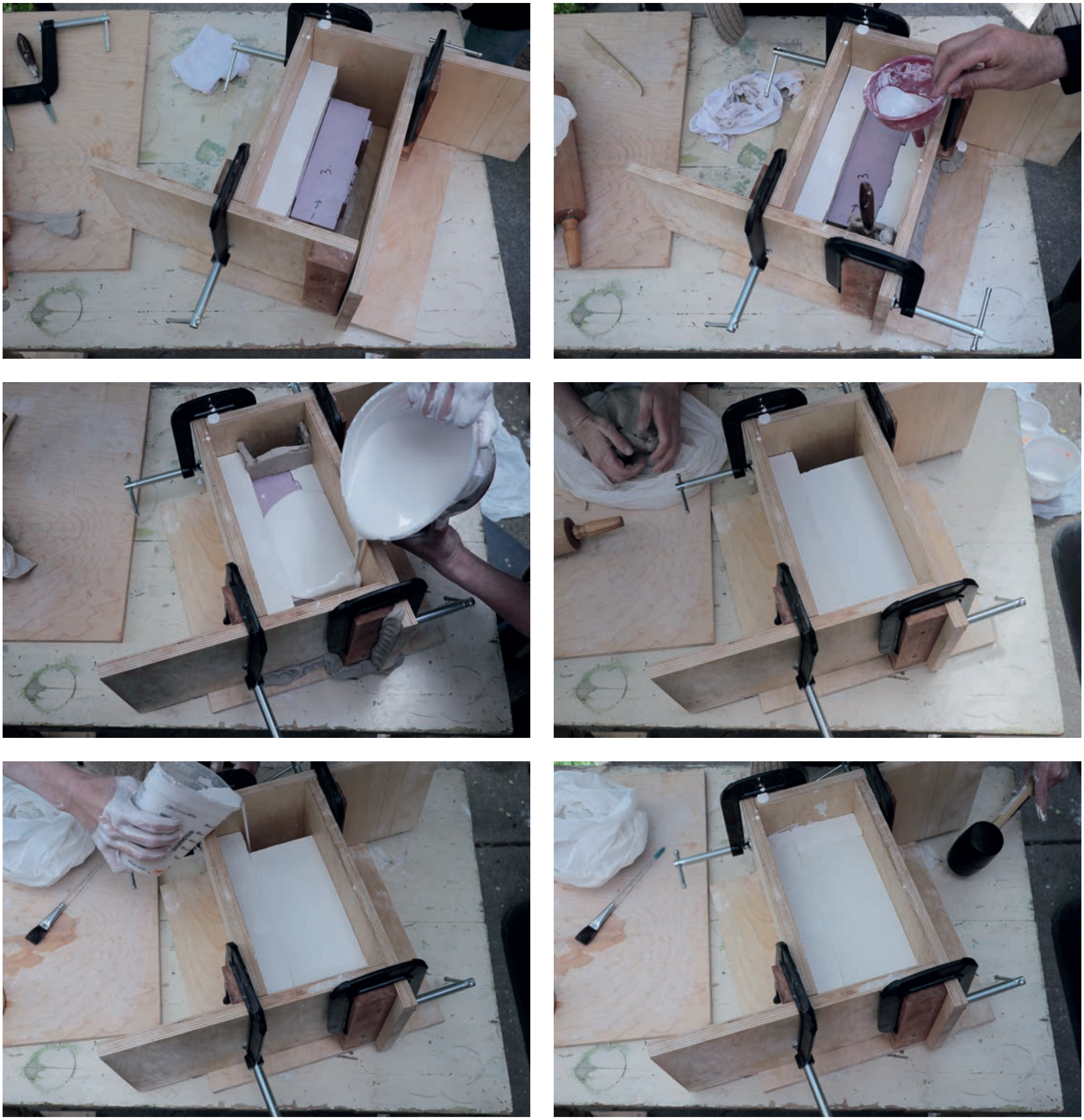


Figure 4.4.32
Subsequent piece pours

10. *Crack the Mold*

Once the entire model has been invested in plaster, and set for 45 minutes to one hour, loosen the clamps and remove the cottle boards. **(4.4.33)** Leaving the mold clamped within the cottle boards for more than an hour is unnecessary and prevents the plaster from releasing its moisture. For the same reason, a model should not be left within a mold for longer than necessary. Within a few hours of the last mold piece setting, the mold can be cracked or broken apart into its various pieces, releasing the model and allowing the mold to begin to dry from both the inside and outside. Cracking the mold is always nerve-wracking, even for a seasoned mold maker. Plaster sometimes finds sticky points or subtle undercuts which our eyes fail to see during the formal assessment of the model and design of the mold pieces. This can make the mold pieces hug the model, or neighboring pieces, in unexpected ways. Patience is essential in cracking a mold. Remember that the plaster reaches its full strength after a few hours; although it may seem robust and massive, it is liable to crack or chip if handled aggressively. Locate your parting lines. If your parting lines have been covered by plaster, you can use a surform rasp or shaver to scrape away excess plaster and reveal the joints. **(4.4.34)** Gently wedge a paint scraper or palette knife into the joint at several spots, pushing the blade of the knife no more than $\frac{1}{2}$ in. (1.25 cm). The objective here is to begin to introduce air into the greased joint.

Figure 4.4.33
Releasing mold from cottle assembly

Although the release agent acts as a barrier for the plaster to bond to itself, it also is very sticky, and acts as a kind of glue, especially in a vacuum, with no air. Once air is allowed into the greased crevice, it should break apart quite easily. Wedge your paint scraper gently into the joints all around your mold, picking the mold up and rotating it. Often, just the movement of handing the mold and rotating it in your arms will help dislodge the mold pieces and help loosen it apart. Once a first piece is dislodged and successfully removed, try to grip a second piece and gently wiggle it out. Remember the angles of withdrawal that you planned in step 2 and try to remove the mold pieces in the reverse sequence that you poured them. **(4.4.35)** When your mold is cracked, immediately reassemble it, bind it together snugly using an adjustable cinch strap, and set it on spacers so that air can circulate in and through the interior. Let it dry. **(4.4.36) (4.4.37)**

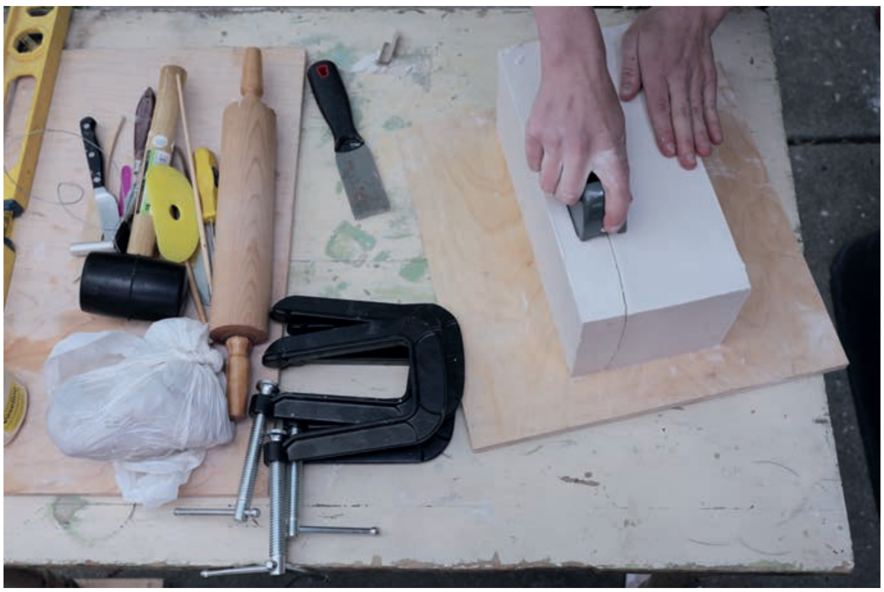


Figure 4.4.34
Parting lines being revealed with surform shaver

Figure 4.4.35
Cracking the mold

Figure 4.4.36
Reassembling your mold and setting it on spacers to dry

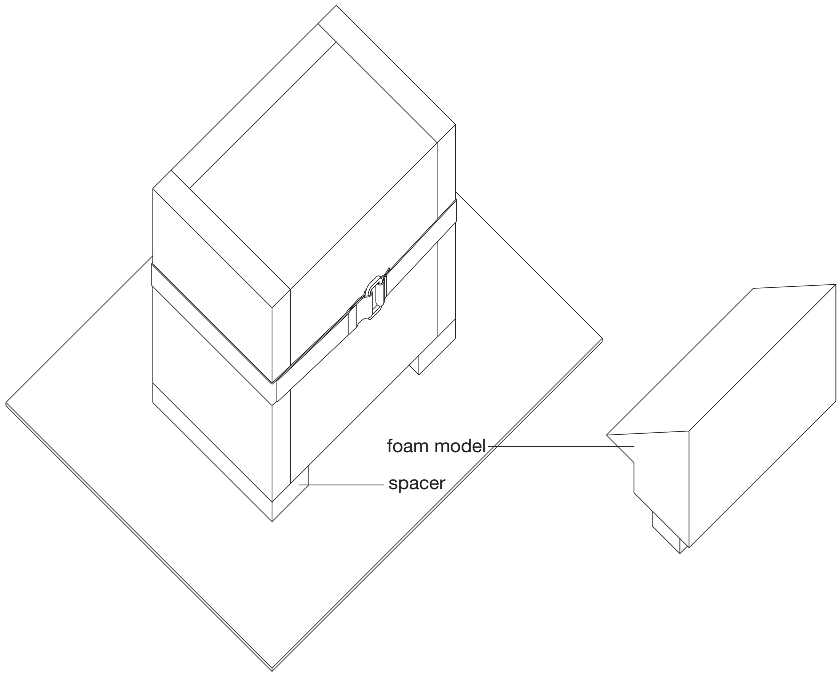


Figure 4.4.37
Binding your mold and letting it air dry

4.5 SLIP CASTING

Slip casting is an ancient fabrication process. Artifacts found in Italy evidence the use of molds for the mass-production of clay vessels tracing back to the second century BCE.[1] The process of slip casting is based on the relationship between two materials—clay slip and plaster. Both materials are hydrophilic and disperse in water. When dry plaster comes in contact with slip, or liquid clay, they have a moisture exchange: the dry, porous plaster immediately begins to absorb the water from the fluid, viscous clay. The result, based solely on the material properties of plaster and slip, is that the moisture content of the plaster increases as the moisture of the clay slip decreases. The surface where clay slip makes direct contact with plaster changes in consistency as it loses water moisture; it turns into a soft, muddy skin. This skin, when the excess slip is poured out of the mold, becomes more physically stable as it passes through various stages of drying. Eventually, it can be released from the mold altogether, then fully dried and fired. At that point, it's a completed reproduction of the model that was originally invested in the mold—an inversion of negative to positive space—in the form of a shell with a high degree of surface detail. **(4.5.1)** Many identical slip casts can be pulled from a single mold. **(4.5.2)** Compared to multi-part mold making, slip casting is a relatively straightforward process requiring fewer tools. **(4.5.3)**

Safety note: work under the close supervision of your instructor and, as with the handling of all materials, follow the safety precautions outlined on the material packaging.

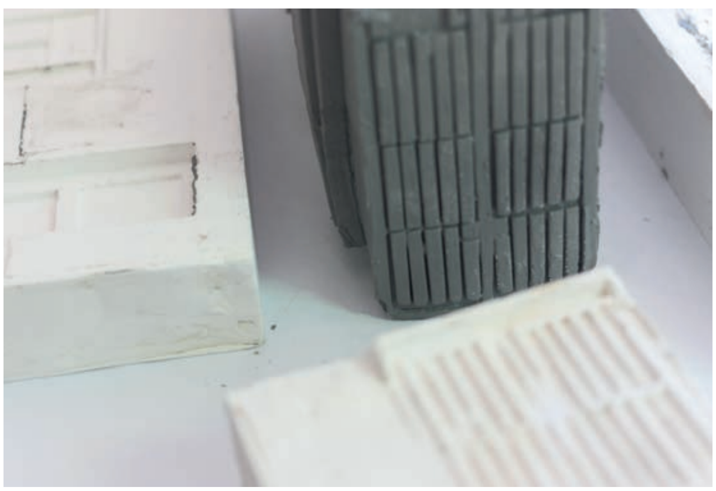


Figure 4.5.1
Relief detail on slip-cast model

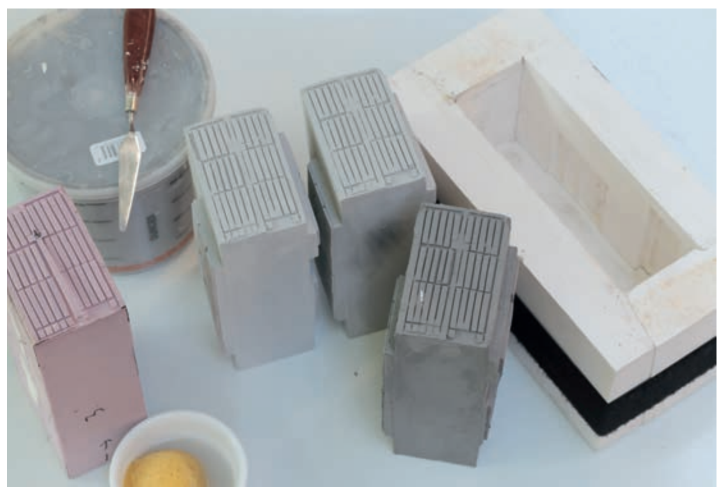
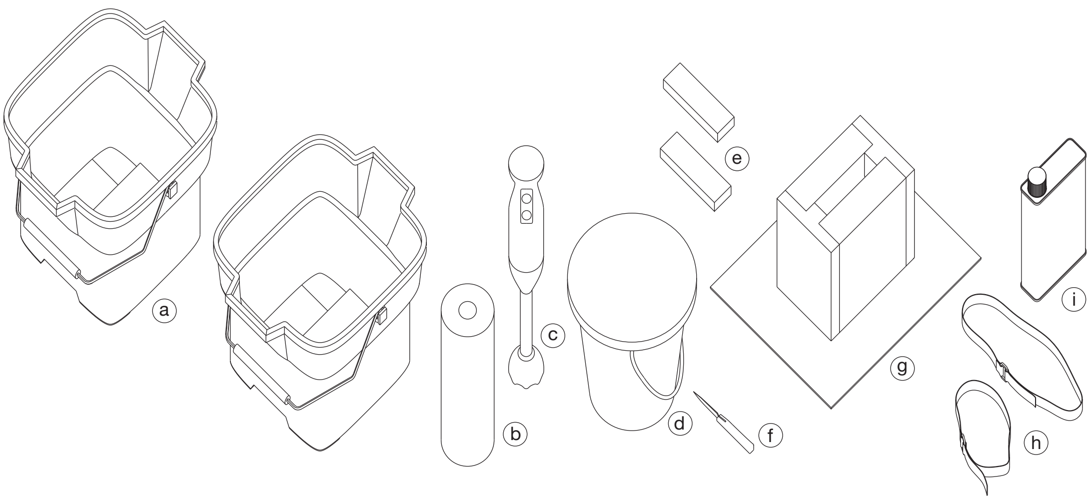


Figure 4.5.2
Multiple casts from mold



a. utility buckets (2)
b. paper towels
c. immersion blender
d. clay slip in sealed container
e. wooden spacers
f. utility knife
g. plaster mold, baseplate
h. cinch straps
i. solvent

Figure 4.5.3
Tools and materials for slip casting

1. *Make Sure That Your Plaster Mold Is Dry*

Plaster molds need to be dry to work effectively. Maximum dryness is crucial to facilitate the mold's capacity to absorb moisture and create the clay skin. To determine whether your mold is dry enough to begin the slip casting process, touch it. **(4.5.4)** If it feels cold and clammy, it needs longer to dry. If it feels cool, it has an intermediary moisture content and, depending on the atmospheric moisture level, it may or may not perform well. When the mold no longer feels cool to the touch,

Figure 4.5.4
Feeling the mold to assess moisture content

it is ready to be used for slip casting. Depending on the time of year, and atmospheric conditions, the process of drying a mold might be very lengthy. If you are working in a facility that has a drying cabinet, equipped with a heat source, dehumidifier and a fan, place your mold on spacers in the cabinet to facilitate the drying process. In lieu of a cabinet, you might choose to let your mold dry outside, if conditions are warm and sunny, or inside near a heat source. Ideal drying conditions for plaster molds are dry with circulating air.

Figure 4.5.5
Cleaning the mold with solvent

2. *Clean the Mold*

Any trace of release agent on the interior of the mold will work as a barrier against the slip casting process, preventing the plaster from absorbing water out of the clay slip. Because the release agent won't necessarily be detectible, it is best to clean the interior of the mold as a precaution. Using a rag dampened with a solvent (see "Glossary of Technical Terms and Materials") gently wipe the interior of the mold thoroughly. **(4.5.5)** Before handling solvents and other materials, always read the labels on the packaging outlining safety precautions.

3. *Mix Your Clay Slip*

Clay slip is liquid clay, with high water content (see "Glossary of Technical Terms and Materials"). When left sitting even for a short time, the slip composition will tend to separate, with heavier sediment settling to the bottom of the mixture, and lighter, muddy water rising to the top. Mixing the slip thoroughly is essential in slip casting, to ensure the consistency is even throughout the mixture. If inadequately mixed, the resulting shell will likely be weak in spots, and also uneven in thickness. Although there are mixers specially designed for slip, for small projects and small batches of slip, a standard, handheld immersion blender works very effectively. Make sure that your slip has been transferred from a bag into a re-sealable container. A glass or plastic container with a spout and a lid is ideal. Immerse the hand blender and mix the slip thoroughly, until you can no longer detect clumps of sediment, and until the mixture appears to be a uniform color. **(4.5.6)** Concentrate most on mixing the material at the bottom of the container and, after that has been thoroughly agitated, move the blender up and down so that the light sediment is mixed with the heavier material. Do not take the blender out of the slip mixture at all during this process, as air bubbles will be introduced into the slip. Depending on the slip and the size of the batch being mixed, the mixing process could take ten minutes.

Figure 4.5.6
Immersion blending of slip

4. *Secure Cinch Straps and Fill Your Mold*

Secure your cinch straps around your mold before pouring the slip in. Make sure that the mold pieces are locked into their proper position, and that the cinch strap is snug. Pour the thoroughly mixed slip into the mold, up to the very top, until you see a convex meniscus curve at the top surface of the liquid (see "Glossary of Technical Terms and Materials"). **(4.5.7)** Seal the excess slip in its container with the lid, and observe the slip closely. **(4.5.8)** If the mold was sufficiently dry, you should see the level of the slip lower immediately, in response to water content of the slip being drawn into the dry and porous plaster mold. Keep adding more slip to the mold as the level lowers, so that the skin at the visible edges of the shell retains a thickness that is indicative of the overall shell thickness. **(4.5.9)**

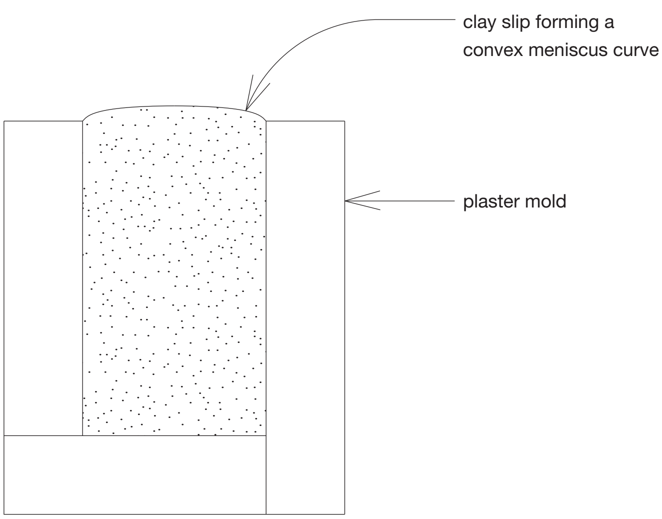


Figure 4.5.7
Convex meniscus

Liquid slip should fill the plaster mold to the point where it forms a convex meniscus. As water is absorbed from the slip into the plaster and the slip level lowers, more should be added to maintain the curve.

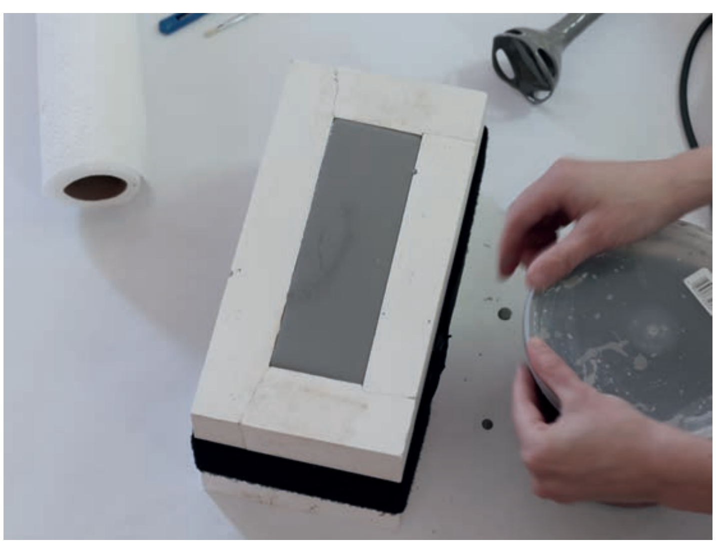
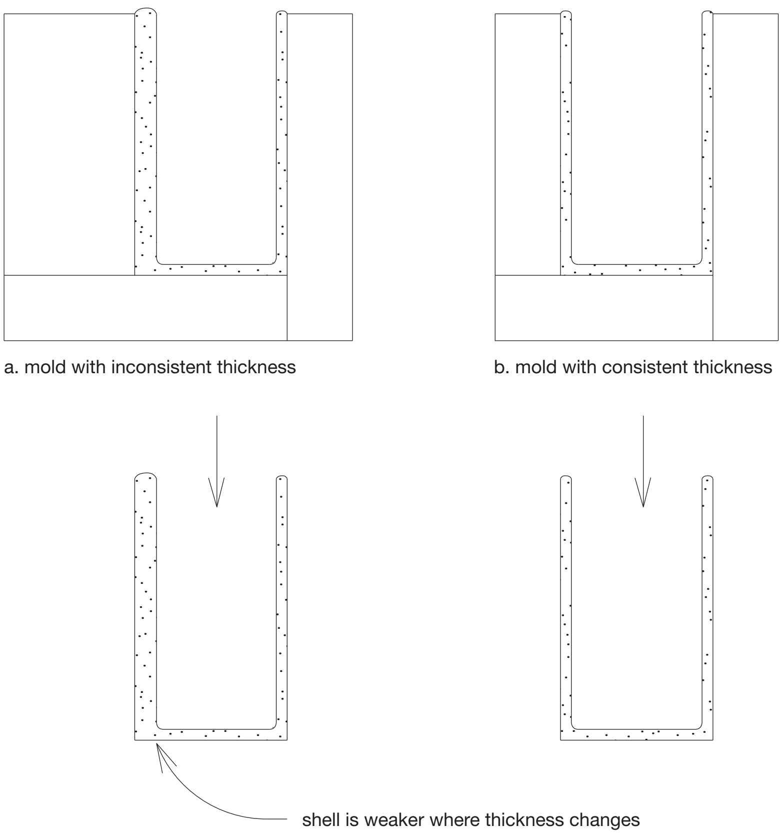


Figure 4.5.8
Mold filled with slip

Figure 4.5.9
Slip level being topped up

5. *Assess the Thickness of Your Clay Skin*

There is no single reference for how long slip should remain in a plaster mold in order to achieve certain shell thicknesses. Many variables impact the rate at which the skin accumulates: moisture content of the mold, consistency of the slip, ambient temperature and humidity, thickness of the mold, among others. Molds can be very idiosyncratic and can have unexpected behaviors. **(4.5.10)** To get a general idea of how much clay has accumulated on the inside of your mold, you can do a "blow test." A "blow test" involves blowing along the inside edge of your mold, causing liquid slip to separate away from the thickened clay skin. **(4.5.11)** This is a way of seeing an approximate thickness and judging whether or not the mold should be emptied. Depending on the form and scale of the object being slip cast, shell thicknesses can vary from around $\frac{1}{8}$ in. (3 mm) to being completely solid.



Molds with inconsistent wall thicknesses (a) are more liable, through the slip casting process, to produce clay shells with an inconsistent wall thickness.

Figure 4.5.10
Potential impact of a mold with variable thickness on a slip-cast shell

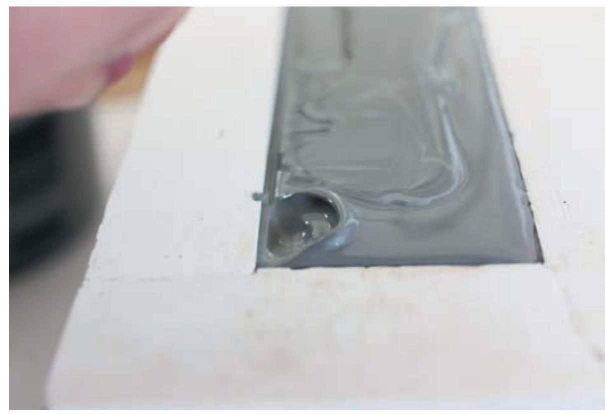


Figure 4.5.11
Blow test

6. *Drain the Mold*

When the clay skin has reached your desired thickness, gently pick your mold up and tip the excess slip out, back into its storage container. **(4.5.12)** Be careful to not pour the liquid slip out too quickly, since the force of the liquid pouring out can suck the clay skin with it. When it appears as if all the slip has been emptied from the mold, turn the mold upside down and place it on spacers so that it can drain completely. Spacers are essential when the mold is placed upside-down; placing the mold directly on a work surface will prevent air from circulating into the mold. Leave the mold in this position for a few hours to allow the clay skin to dry and gain rigidity. **(4.5.13)**

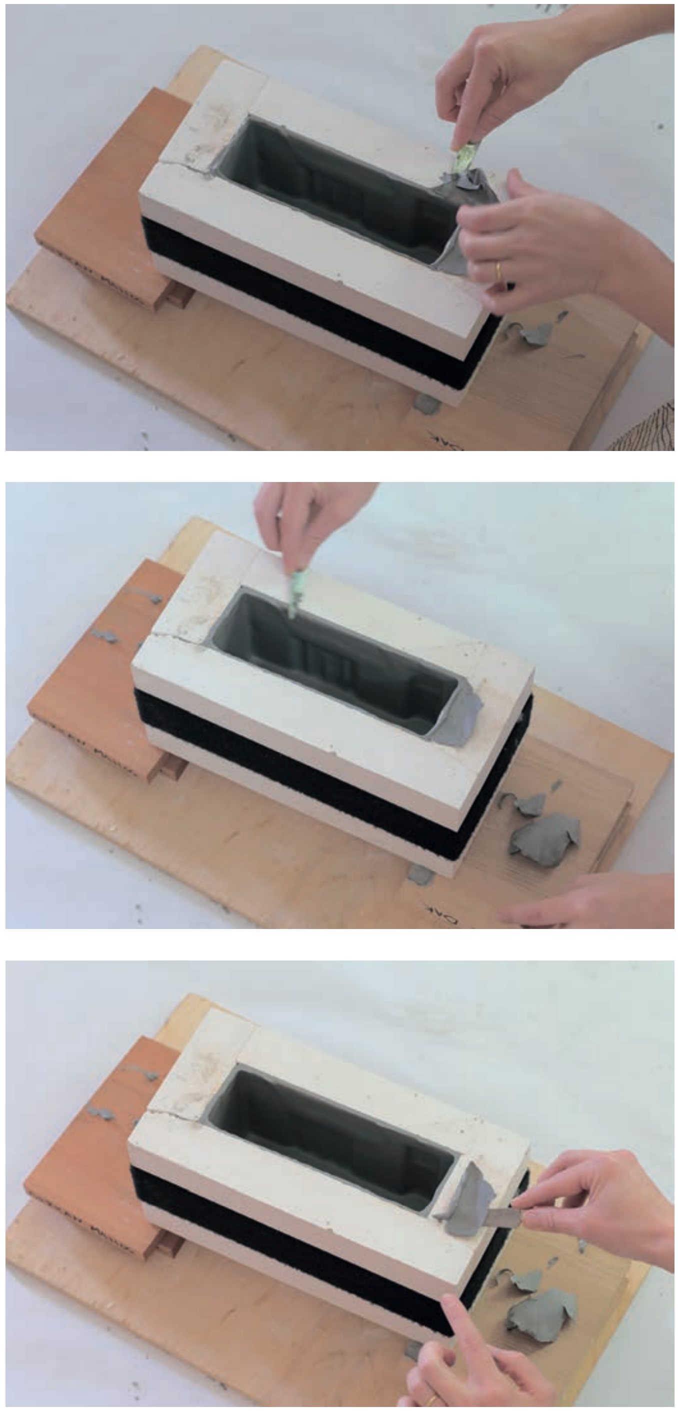
Figure 4.5.12
Draining the mold

Figure 4.5.13
Leaving the mold to drip and harden to a leather state

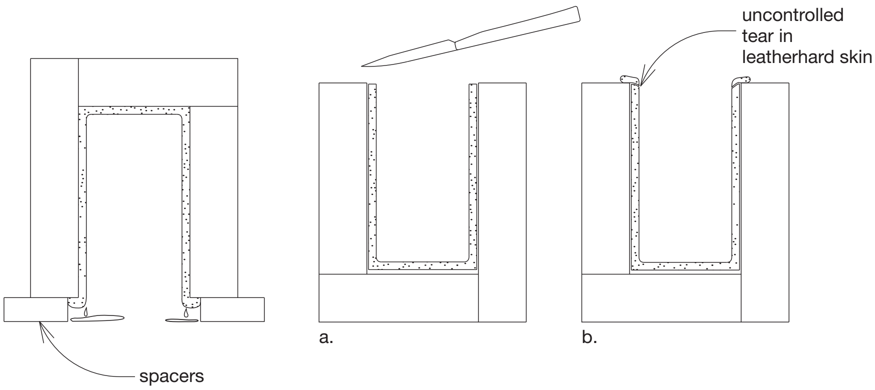
7. *Release the Slip-Cast Shell from the Mold*

After a couple of hours have passed, rotate your mold to observe the clay skin. You will notice the skin pull inward, away from the mold surface. Clay shrinks when it is drying and during firing. The amount of shrinkage depends on the particular clay body and on its moisture content.[2] When the clay skin in your mold has air dried enough that it pulls away from the plaster mold surface, make sure to free the entire lip of the shell by trimming it with a knife. **(4.5.14)** Left untrimmed, the lip, at the

Figure 4.5.14
Trimming the lip



points where the slip has splashed or drained over the edge of the mold, will cause the shell to tear in irregular ways. **(4.5.15)** Loosen the cinch straps around your mold and gently jiggle the mold pieces apart using the planned angles of withdrawal. **(4.5.16)** If the shell is sticking to the mold at one or more points, it is often best to leave the unbound mold upside-down to allow gravity to assist the skin to release away from the mold. **(4.5.17)**



The lip of the slip cast shell should be trimmed with a knife once the clay has reached a leatherhard state. Trimming will allow the shell to shrink away from the mold while drying (a) and avoid tearing at the rim (b).

Figure 4.5.15
Trimming the lip of the slip-cast shell

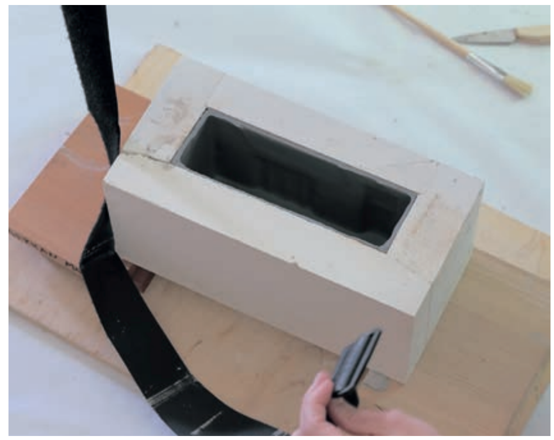


Figure 4.5.16
Releasing cinch strap

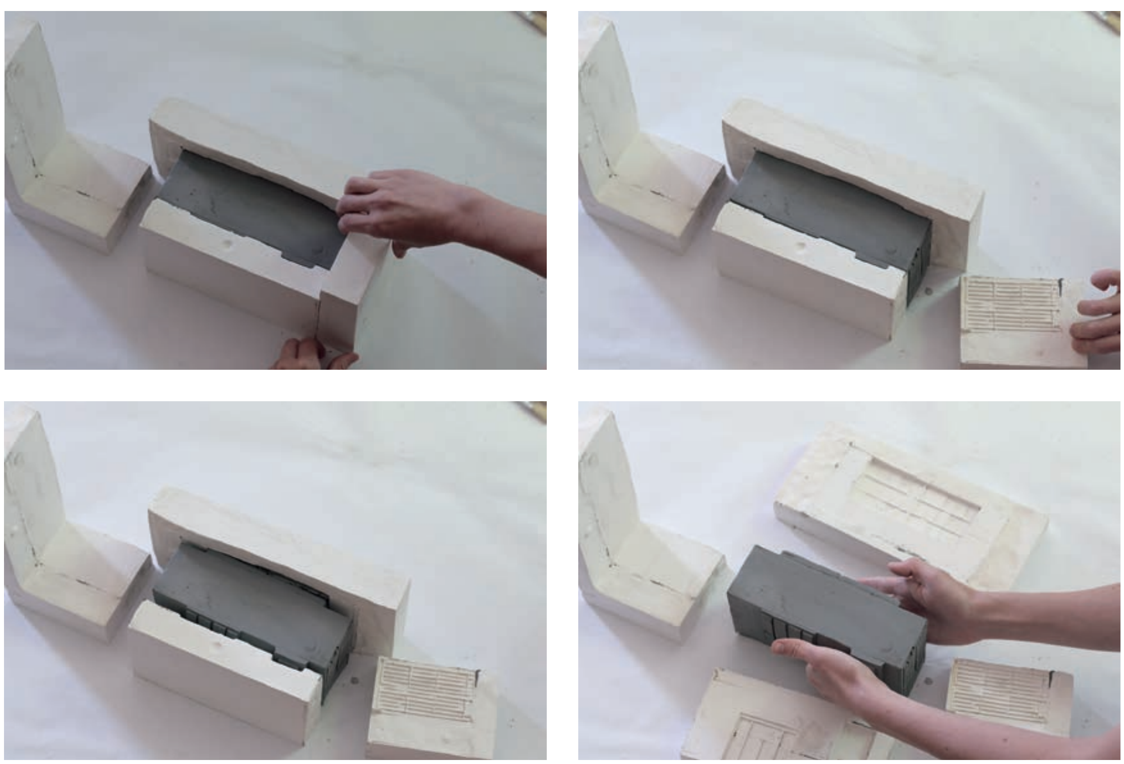


Figure 4.5.17
Releasing the leather-hard form from the mold

Figure 4.5.18
Packing the leather-hard shell with paper to resist collapse

8. *Stabilizing the Leather-Hard Shell*

Depending on the scale, form and dryness of your clay shell, it may or may not need some stabilization during its leather-hard phase. Certain forms, like boxes or other forms with flat planes, can be challenging to keep from distorting during the leather-hard phase (see 4.11, "Planar Structures"). To help the flat planes resist collapsing inward, you can use scrunched up paper towel or newspaper to gently pack the mold and help it retain its form until it is completely dry and rigid. **(4.5.18)** Once the leather-hard shell has been stabilized, it is ideally oriented on its rim and placed on a plaster slab or other dry, porous surface to dry.

9. *Greenware and Bisqueware*

Once the slip-cast shell has air dried completely and is no longer cool to the touch (refer back to step 1), it is ready to fire. Unfired slip-cast shells are referred to as greenware, whereas clay which has been fired once, physically transformed into ceramic, is called bisqueware (see "Glossary of Technical Terms and Materials"). **(4.5.19)** Different clay bodies, also referred to as clay mixtures and ceramic pastes, fire at different temperatures, ranging from around 1760 degrees Farenheit (960 degrees Celsius) for some earthenware mixtures, to over 2912 degrees Farenheit (1600 degrees Celsius) for some refractory clays.[3] Greenware is extremely fragile, and sensitive to moisture. Greenware forms can be easily smoothed or altered before firing by gently using a moist sponge, or fine-grit sandpaper.

Figure 4.5.19
Bisqueware (*left*) and greenware (*right*)

10. *Letting the Mold Rest between Slip Casts*

Water from clay slip is sucked into the capillaries of the porous plaster mold during the slip casting process (see "Glossary of Technical Terms and Materials"). With each slip cast, the moisture level of your mold will increase. As it becomes more water-saturated, it will become less effective, absorbing water more slowly from the clay slip. Letting molds rest between slip casts, ideally in a warm and dry environment with well-circulating air, will give them a chance to release some of that moisture into the air through evaporation (see "Glossary of Technical Terms and Materials"). Refer to step 1, Making sure that your plaster mold is dry, to determine when your mold is ready to continue slip casting.

Notes

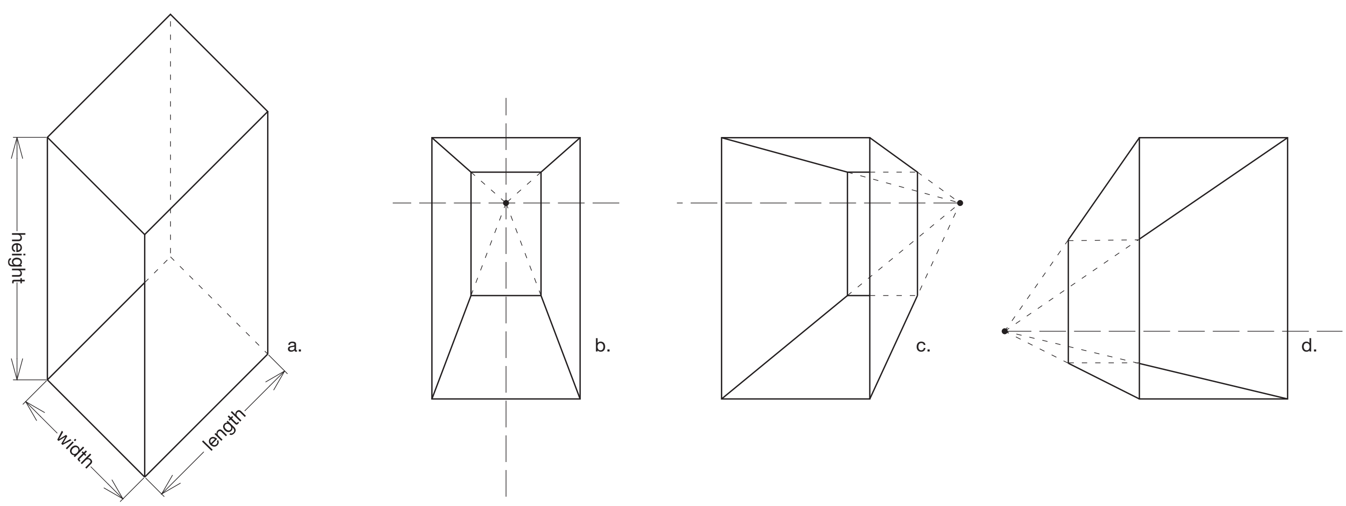
1 Joaquim Chavarria, *The Big Book of Ceramics* (New York: Watson-Guptill Publications, 1994), 15.
2 Chavarria, *The Big Book of Ceramics*, 27.
3 Chavarria, *The Big Book of Ceramics*, 30.

4.6 PERSPECTIVAL PROJECTION—ONE-POINT PERSPECTIVE DRAWING

Linear perspective projections are drawings that resemble the view seen while standing in an actual three-dimensional space. Douglas Cooper, in *Drawing and Perceiving*, explains that linear perspective drawings are "[b]ased on the apparent convergence of parallel lines to common vanishing points with increasing distance from the observer."[1] One-point perspective is confined to a single vanishing point. Spatial depth is created through the foreshortening of lines which are not parallel to the picture plane (see "Glossary of Technical Terms and Materials"). Lines or planes in the actual object converge to a single point in the drawing, creating the illusion of pictorial depth.

Perspectival projection was a dominant form of representation in the Renaissance. The importance of the Renaissance to the history of art and architecture in Western culture has, according to Massimo Scolari, led to a "hegemony of perspective [which] has prevented consideration of other equally important methods of representation."[2] Parallel projection, addressed in 4.3, is a fundamentally different way of both viewing and representing objects in space, and comes with different cultural and historic associations. As Scolari asserts: "[p]arallel projection appeared in Western culture as early as the fourth century BC and has remained the predominant form of presentation in China."[3]

Let's take a rectangular box as a case study to illustrate one-point perspective. The size of the box is defined by its height, width and length. If the width and height lines (edges of the box) of the box are parallel to the edges of the picture plane, then only the length lines are foreshortened and all lines parallel to the length lines converge to a single vanishing point. These perspectives, when the center of vision is placed through the middle of the object in plan view, tend to have a documentary, matter-of-factly character with pictorial compositions that are distinct, static and formal. **(4.6.1)**



We can describe a rectangular box with three dimensions: height, width and length (a). In a one-point perspective, only one of these dimensions is drawn toward the vanishing point. In these examples, the length lines converge at the vanishing point. The same object appears very different based on the placement of the center of vision. When the center of vision is positioned symmetrically, the perspective appears formal and static (b); centers of vision that are offset on either side of the object offer less formal side views (c and d).

Figure 4.6.1
Dimensions of a one-point perspective

If only the height lines are parallel to the picture plane, then the width lines and the length lines converge at two respective vanishing points. This projection is called a two-point perspective. The two-point perspective has a more dynamic character and emphasizes, as the example in **(4.6.2)** illustrates, the sharp corner of the box instead of the flat elevation surface.

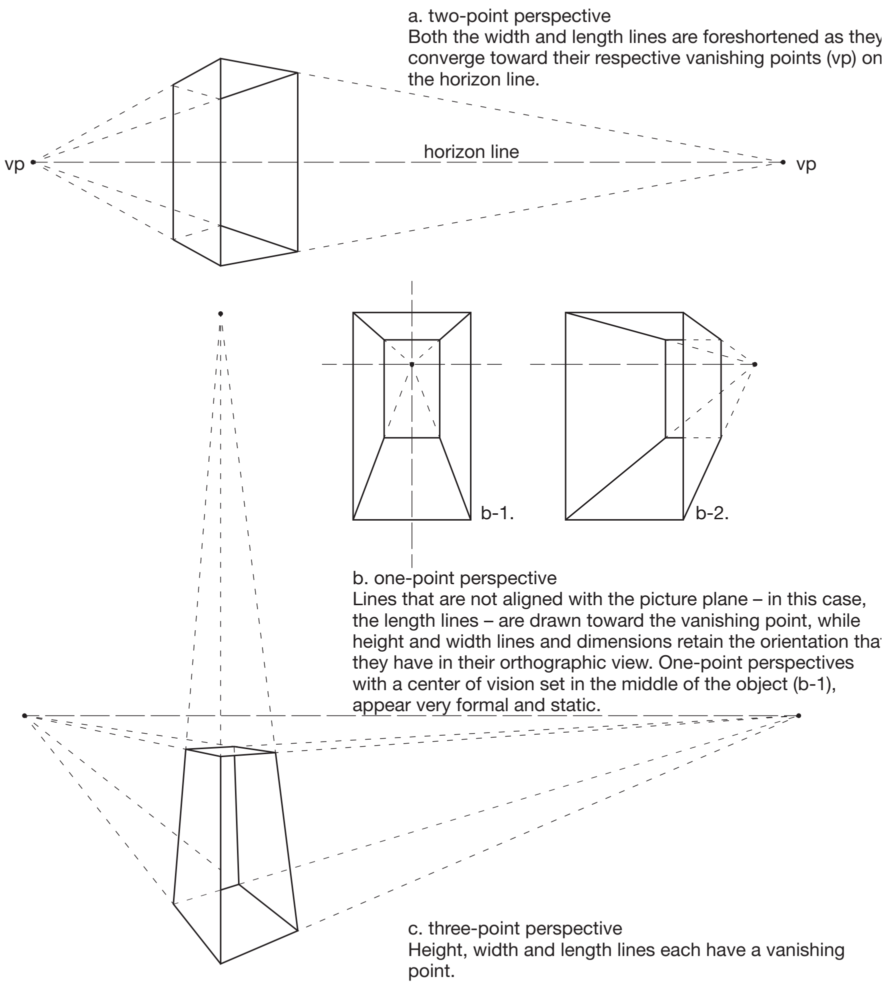


Figure 4.6.2
One-, two- and three-point perspective projections

If the height lines, width lines and length lines are not parallel to the picture plane, then each of these lines converge at a respective vanishing point. This projection is called a three-point perspective. Converging height lines give an impression of instability; in the example, the box appears as if it is falling over. This perspective is the most dynamic and restless.

For the purpose of the exercise in 3.3, "Solid-Void Inversion of Space, Media 3: One-Point Perspective," we will work with the one-point perspective. A one-point perspective drawing is constructed using a plan and an elevation of the mold pieces that you want to project, each with a respective center of vision, station point, picture plane and sight lines, which ultimately define a vanishing point and a horizon line (see "Glossary of Technical Terms and Materials"). **(4.6.3)**

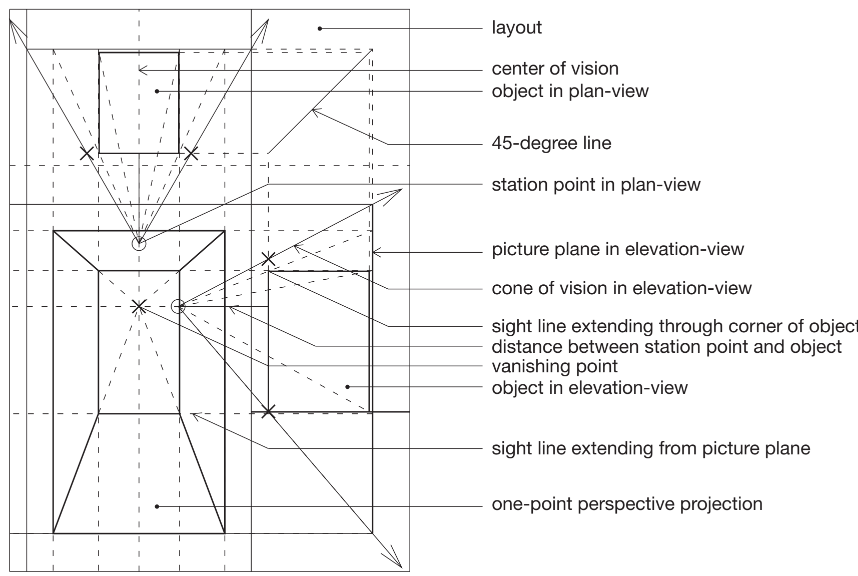
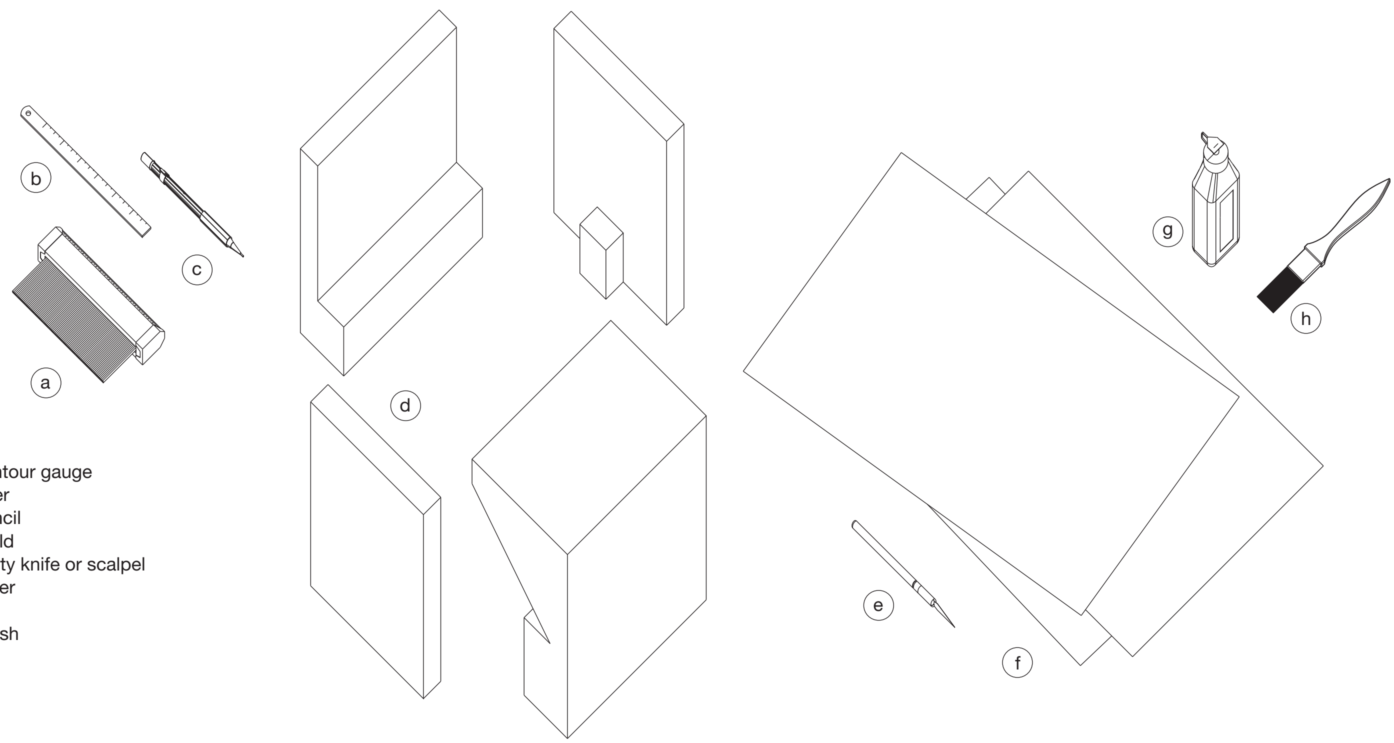


Figure 4.6.3
Anatomy of a one-point perspective drawing

1. *Make an Orthographic Drawing Set of Your Mold Pieces*

Before executing the task described in 3.3, "Solid-Void Inversion of Space," and making one-point perspective projections of your mold pieces, you'll need to make accurate orthographic drawings of the forms (see "Glossary of Technical Terms and Materials"). **(4.6.4)** To manually record the complex geometries of the mold pieces in two dimensions, use a contour gauge (see "Glossary of Technical Terms and Materials"). Using pencil, make grid marks on your mold piece. The intervals of the grid should suit the particular scale and geometry of your mold piece. For simple volumes, you may not even need to record profiles using the contour gauge; simple measurement may suffice. Following the pencil marks, take the contours of your mold piece and transfer them by tracing to a piece of paper. **(4.6.5)** These traces are the manually derived cross sections that you can scan or photograph, then import, trace and scale as needed in a CAD program. The final outcome should be one plan view and one vertical section of the mold piece orientation you chose. Once a mold piece has been surveyed manually and the drawings have been input into CAD, you'll be ready to set up your one-point perspective projection. **(4.6.6)**



a. contour gauge
b. ruler
c. pencil
d. mold
e. utility knife or scalpel
f. paper
g. ink
h. brush

Figure 4.6.4
Tools and materials for drawing from a mold

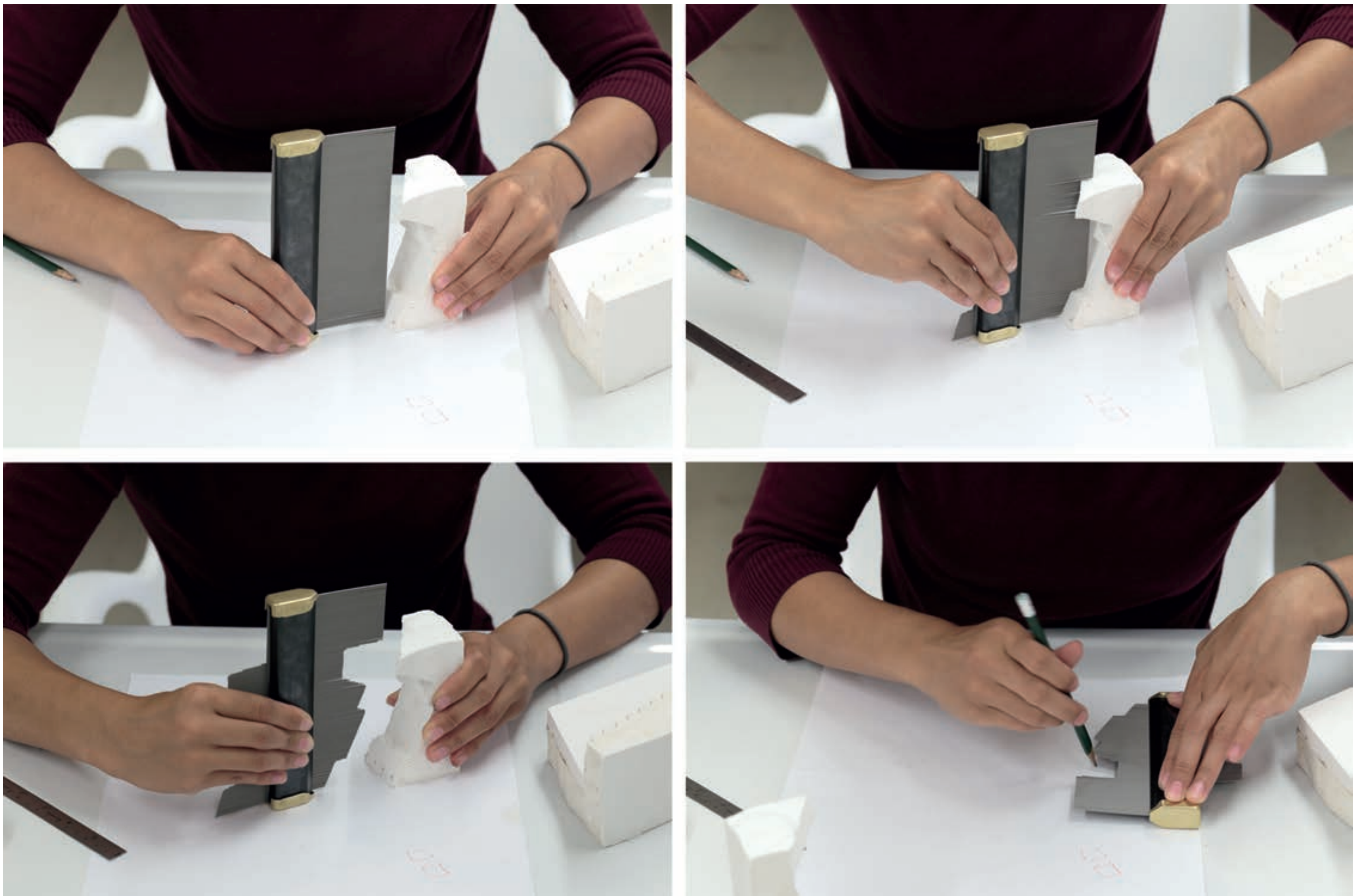


Figure 4.6.5
Using a contour gauge to register sections of a mold piece and transfer them to a drawing

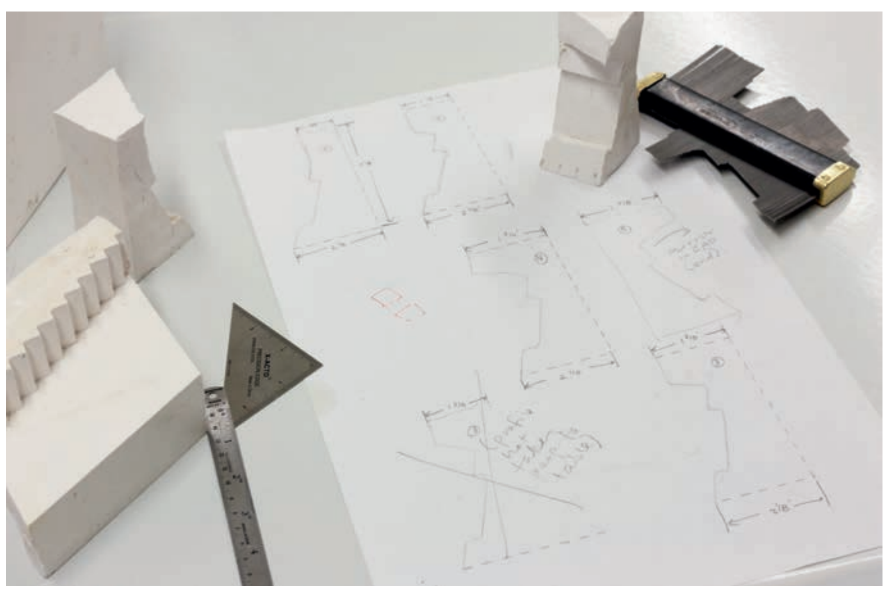
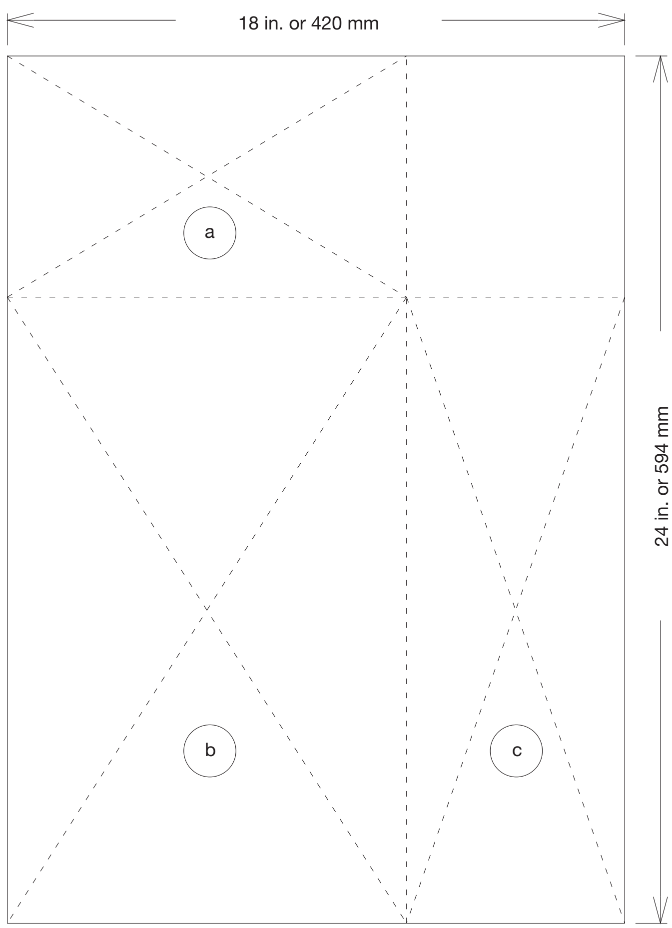


Figure 4.6.6
Traced sections of a mold piece, registered using a contour gauge

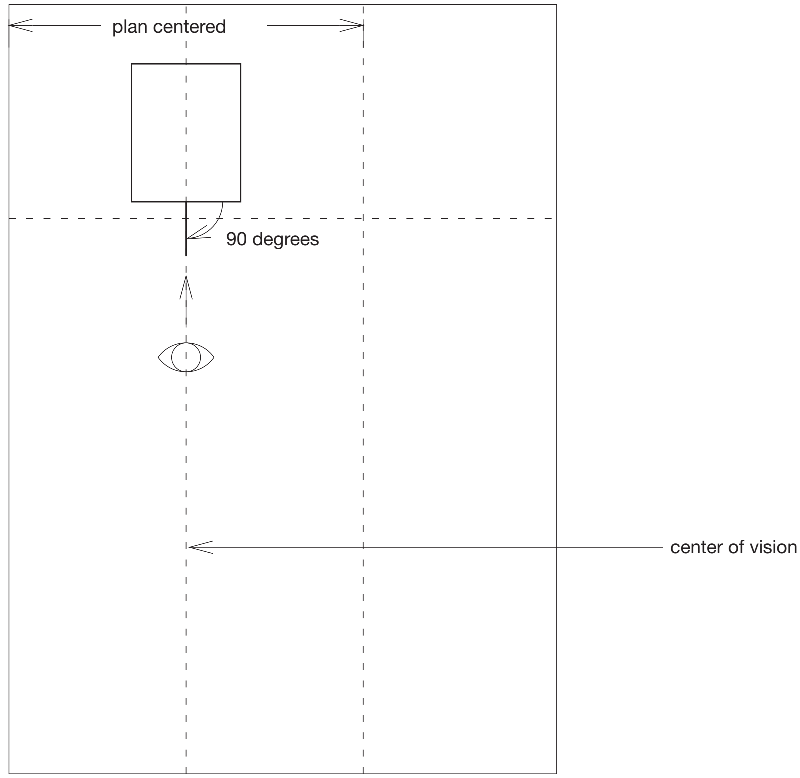
2. *Organize Your Layout and Locate the Center of Vision in Plan*

Using a crosshair, divide your layout into four uneven quadrants; as shown in the illustration, the largest quadrant, for the perspective view, should be located in the bottom left-hand corner, while the plan should be parked above, and the elevation to the right, of the perspective quadrant. **(4.6.7)** The orientation of your mold pieces should be established in 3.3, but to make your perspective projection, you need to decide how you are looking *into* the objects, one by one. At least one surface of each mold piece should be flat and vertical so that it translates easily into a one-point perspective. Orient the plan drawing of your mold piece so that you are looking into a flat surface, and your center of vision is a vertical line in the middle of the plan quadrant. **(4.6.8)**



The illlustrations in this chapter use an 18 x 24 in. portrait layout (closest layout in the ISO series is A2, 420 x 594 mm). Quadrants should be sized to accommodate the size of your orthographic views (a, plan view, and c, elevation view), and your desired perspective view (b).

Figure 4.6.7
Layout for a one-point perspective



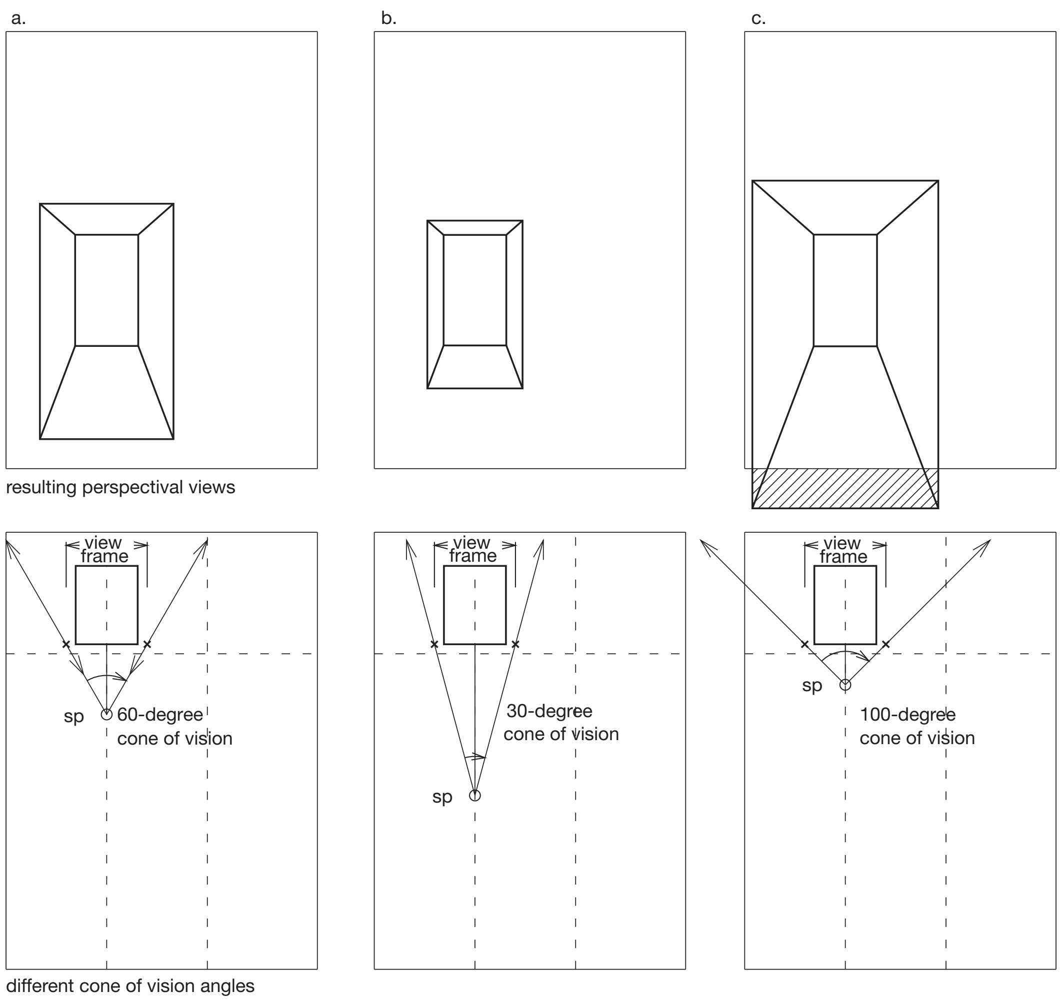
Center the plan within the plan quadrant of the layout, making sure that the front face is perpendicular to the center of vision. Locate the center of vision through the middle of the object in plan-view.

Figure 4.6.8
Positioning the object and center of vision in plan-view

3. *Establish the Cone of Vision*

To achieve a perspectival view that most closely resembles our first-hand perception of space, the angle of the cone of vision should be between 30 and 60 degrees.[4] You can purposefully choose to modify the cone below 30 degrees or above 60 degrees to achieve certain spatial effects (see “Glossary of Technical Terms and Materials”). With a cone below 30 degrees, the perspective drawing will look flattened, with less spatial depth. Spaces will appear smaller than they actually are. If there are objects in the space, the space will look unusually dense. If you want to focus on the objects in the space or want to create a sense of a densely packed space, you should consider experimenting with tight cones of vision, with angles below 30 degrees. The equivalent in photography would be telephoto photography (see 4.1, “Taking Photos of Spaces”). With a cone above 60 degrees, the depth of the projection will increase and become exaggerated. Your space will look larger in general. Objects which are far away look unusually small. Objects which are close to the station point appear unusually large. Perspectives drawn with very wide

cones of vision look generally more empty. If you have a small space that should appear larger, you should experiment with wider cones of vision. The equivalent in photography would be wide-angle photography (see 4.1, "Taking Photos of Spaces"). Decide how much of the object and its environment that you want to show by sliding the station point and the cone of vision up and down along the center of vision. **(4.6.9)** Figure 4.6.9 illustrates how dramatically a perspective view changes when the angle of the cone of vision is made smaller and larger, and the corresponding position of the station point shifts. Define the angle of your cone of vision based on the spatial effect and composition that you want.



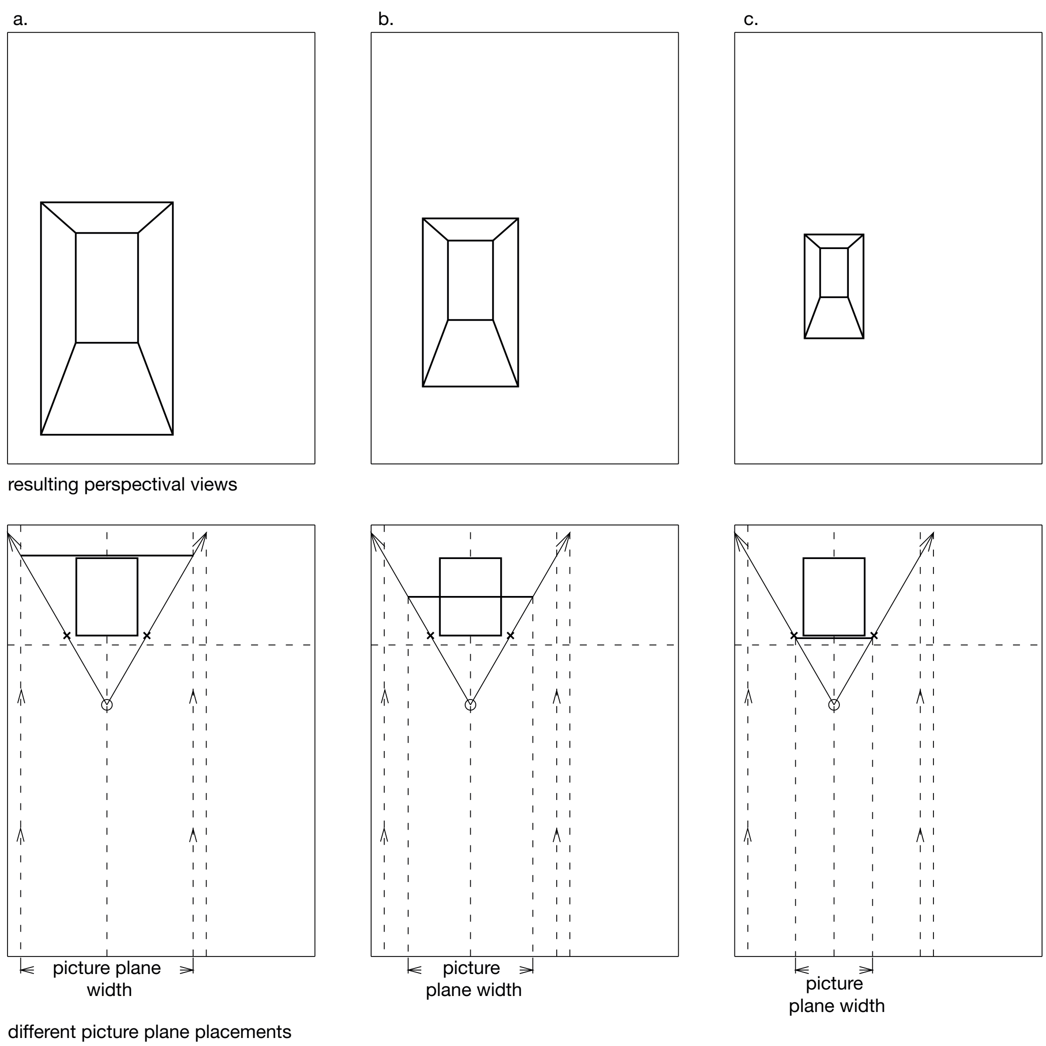
After defining your view frame, which determines how much of the object and its environment that you see in the perspective, you can decide upon the angle of your cone of vision. Illustration b shows how cones of vision with smaller angles result in more compressed perspectival space, whereas illustration c shows how deep and expansive cones of vision with wide angles can be. The angle of the cone of vision determines the location of the station point.

Figure 4.6.9
Establishing the angle of the cone of vision

4. *Place the Picture Plane in Plan View*

In constructing a perspective projection, the picture plane is "[t]he plane where we form the perspective image. It is always perpendicular to the viewer's direction of sight, but we can position it in front or behind the subject, depending upon the size of the perspective view we desire."[5] You can control how large the perspective drawing should be in your layout by establishing the picture plane. By moving the picture plane further away from the station point, the perspective drawing becomes larger in the layout. Likewise, by moving the picture plane closer to the station point, the perspective drawing becomes smaller in the layout. **(4.6.10)** Position your picture plane so that the distance between the intersection of the picture plane and the cone of vision has the desired width for your perspective drawing. Place the picture plane for your elevation drawing in the same location with respect to the station point.

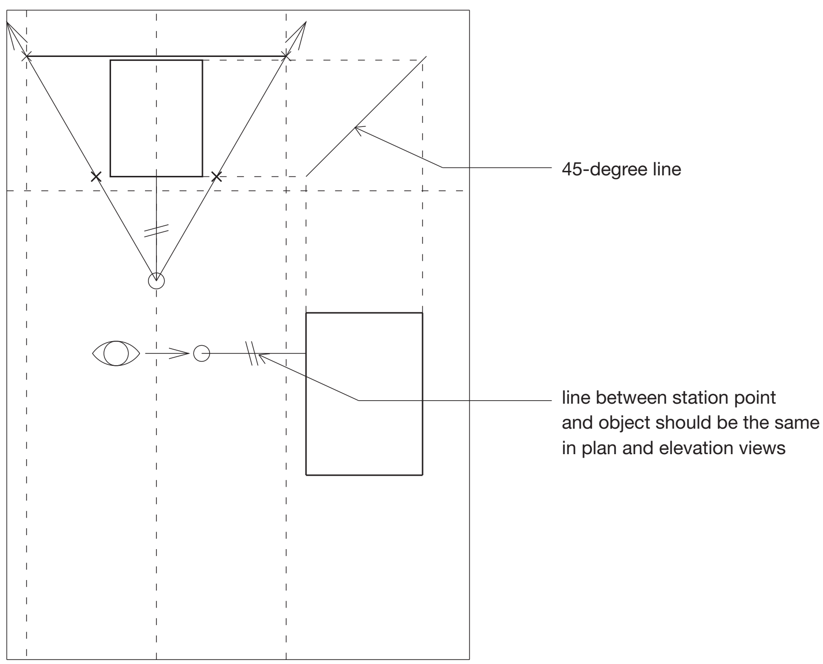
Figure 4.6.10
Placing the picture plane



These illustrations show how the placement of the picture plane impacts the perspective drawing. To determine where the picture plane should be placed inside the cone of vision, draw two lines within your perspective quadrant which mark your desired perspective drawing width. Extend those lines up until they intersect with your cone of vision. The horizontal line which connects these two intersection points will be your picture plane. These examples show how, generally, picture planes placed further away from the station point create larger perspectives (a), whereas picture planes placed close to the station point create smaller perspectives (c). Because the station point and angle of the cone of vision remains the same, these perspectives have the same proportions; they just differ in size.

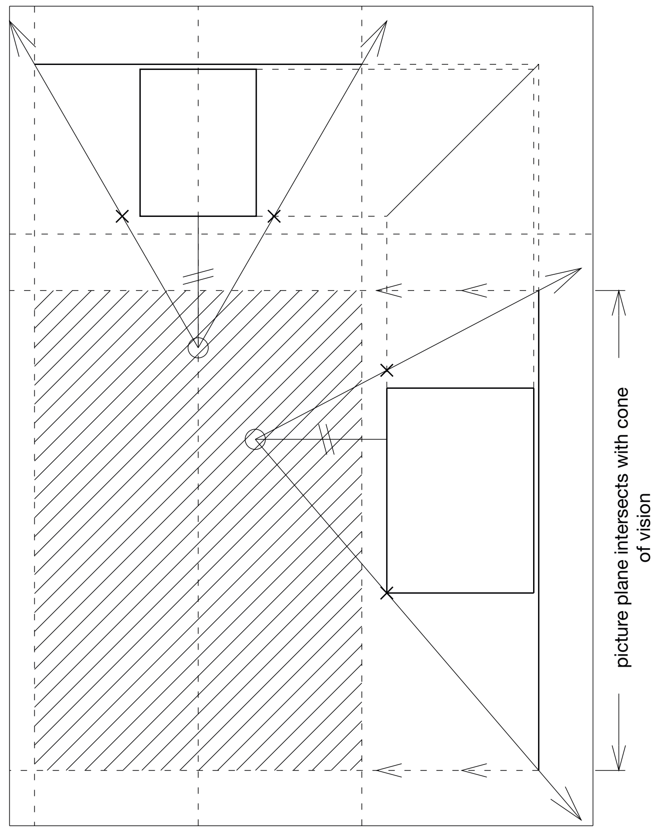
5. *Locate the Station Point in Elevation*

The station point and the cone of vision, in relation to your object in plan view, have been established. Now, establish the station point in your elevation drawing. In your layout, position the elevation of your object rotated over a 45-degree axis so that it corresponds to your plan view. **(4.6.11)** The distance of the station point to the object should correspond with your plan view. The height at which the station point is placed in elevation, however, is defined by you. For the purpose of this exercise, choose your own personal eye height. Before beginning to construct your perspective drawing, confirm that the perspective will sit in your desired spot in your layout by tracing the extents of your cone of vision in elevation-view into the perspective quadrant. Remember that the angle of the cone of vision, for the elevation-view, can be freely defined. **(4.6.12)**



Once the elevation view has been placed so that it corresponds to the plan-view over a 45-degree axis, the station point for the elevation can be defined. Here, the station point is placed at eye height.

Figure 4.6.11
Integrating the elevation into the format

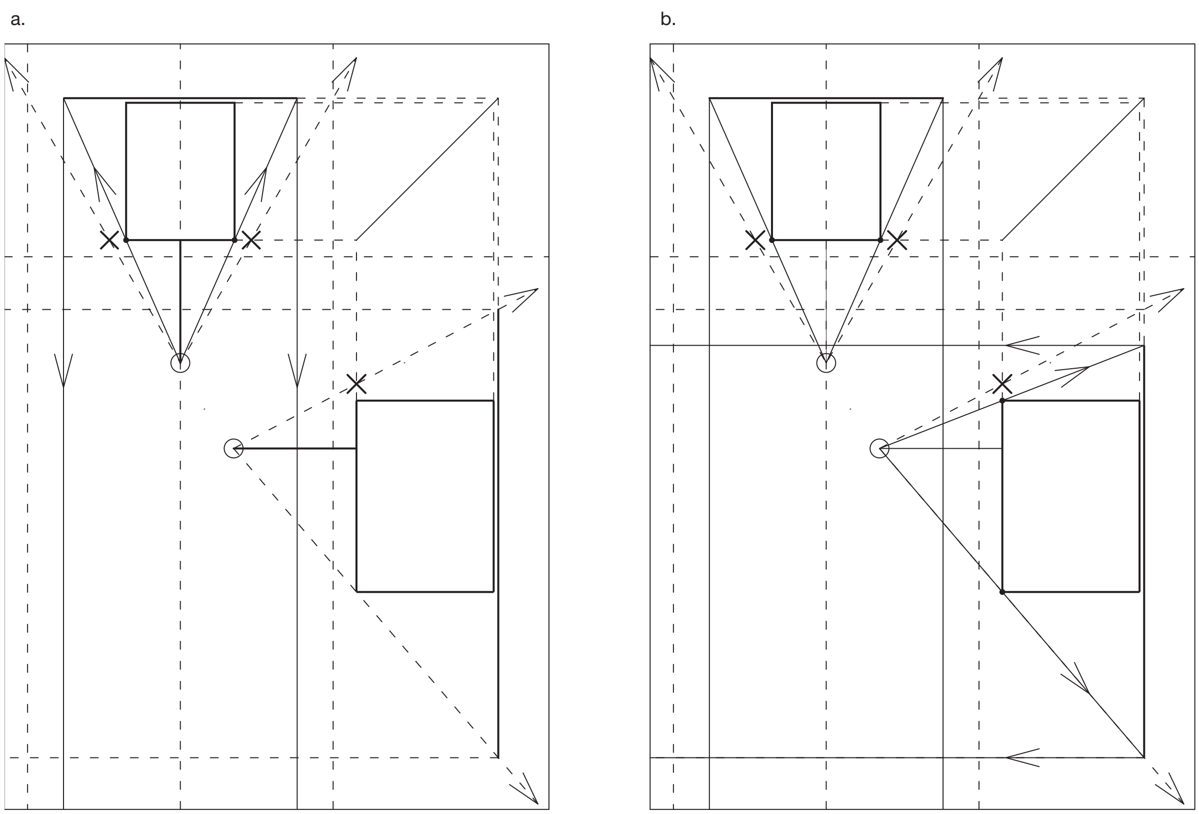


The elevation-view inherits the same location of the picture plane as defined in plan-view. The cone of vision, however, for the elevation view, can be defined independently; it is the last parameter to be defined to set the outer perimeter of the perspective view, shown here as a hatched area.

Figure 4.6.12
Defining the perimeter of the perspective view

6. *Construct the Perspective Drawing*

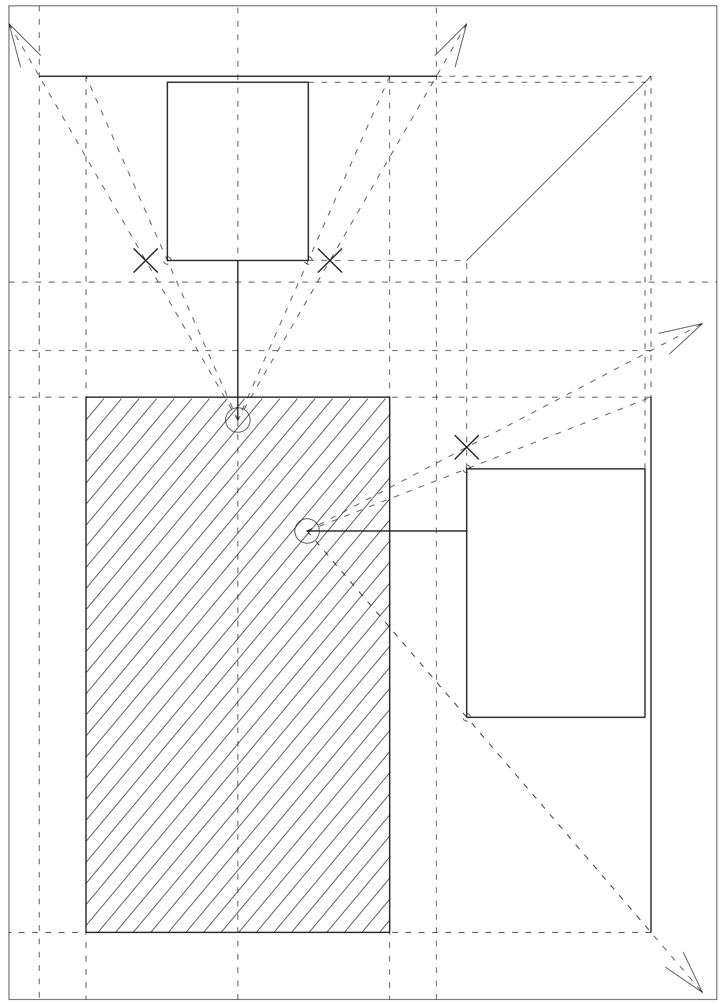
To draw your one-point perspective projection, you will construct a series of sight lines (see "Glossary of Technical Terms and Materials"). The sight lines, together with the picture plane and station point, will give you the framework for your perspective. Begin with the corners of the front face of your object in plan view; connecting the front corners with the station point. These connection lines are sight lines. Draw vertical lines downward from the intersection of your sight lines and your picture plane; just imagine that the sight lines bounce off of the picture plane and shoot directly downward. **(4.6.13)** The first two vertical lines mark the width of the object in your perspective drawing. Next, construct sight lines that connect the station point with the front top corner and your front bottom corner of your object in elevation-view. Draw horizontal extensions at the intersections of the new sight lines and the picture plane. This first set of horizontal and vertical extensions define the foreground



Sight lines are pulled from the station point in plan (a) so that they bypass the front corners of the object, hit the picture plane, and bounce directly down into the perspective quadrant. The same sight lines are then drawn for the elevation-view (b).

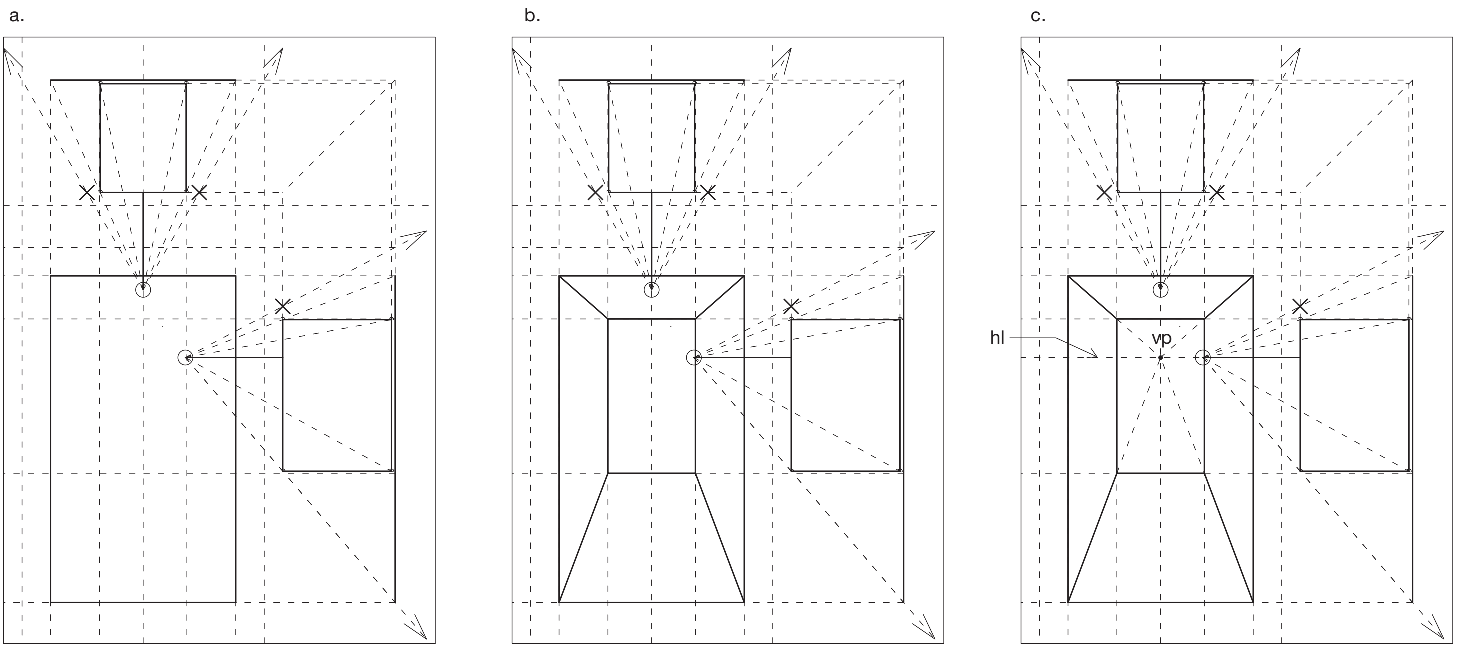
Figure 4.6.13
Drawing sight lines

frame of your object in one-point perspective view. **(4.6.14)** Repeat this process for the remaining corners of your object and connect the intersecting extensions to create the one-point perspective. **(4.6.15)** It may seem dizzying, but the method works for even the most complex shapes, rendering precise, perspectival views that bring you one step closer to experiencing the volumes as spaces.



The frame, in the perspective quadrant, resulting from the intersection of the first set of sight lines is the foreground frame of the perspectival view.

Figure 4.6.14
Defining the foreground frame



To complete the perspective, use sight lines to transpose all remaining points in both plan and elevation views to the picture plane, then into the perspective quadrant. In the resulting perspectival view, all foreshortened lines should converge at a single point: the vanishing point (vp). The vanishing point sits on the horizon line (hl).

Figure 4.6.15
Completing the perspective

Adding Atmosphere, Depth and Texture to the Perspectival Framework

There are many different graphic techniques that can be used to create depth in perspectival views, like stippling, and making tonal gradients with charcoal or ink (see "Glossary of Technical Terms and Materials"). Once your one-point perspective line drawings are constructed, you can experiment with different techniques to accentuate the graphic illusion of depth, and to evoke light, textural and atmospheric qualities. The following illustrated sequence of instructions describes a process in which ink washes are used to create tonal collages out of your perspective drawings.

7. *Print the Perspective Drawing and Make Notes*

Begin by printing your perspective line drawing out in a scale that makes sense for your planned format. In this example, the tonal perspective collage will be added to the layout which shows how the perspective was constructed. With the corresponding mold piece as a reference, make notes directly on the perspective drawing print that indicate light and dark areas. **(4.6.16)**

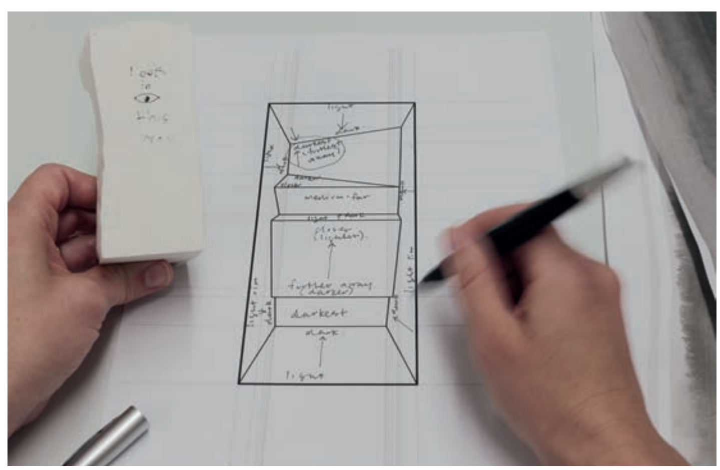


Figure 4.6.16
Print of perspective drawing with hand written annotation about desired gradient swatches

Figure 4.6.17
Making an ink wash

8. *Make Several Ink Washes*

Using a size of paper that will yield gradient areas large enough for your drawing, make several ink washes. Dampen your paper before applying the ink, so that the ink will spread and create gradients from very dense black, to light grey. The more washes you make and the more you alter your technique, the wider palette of gradients you'll have to choose from when you cut and assemble the collage. **(4.6.17)**

9. *Choose Tonal Areas and Use Your Drawing as a Stencil*

While your ink washes are drying, follow the lines to cut your perspective drawing into numbered pieces. These will be the tonal regions that you will define with ink washes. Following the notes that you made on your drawing in step 7, look through your ink washes for tonal regions that suit specific parts of your perspective. Use the pieces of your cut-up drawing as a stencil to cut the same shapes from your ink washes. **(4.6.18)**

Figure 4.6.18
Using a drawing as a stencil to find gradients of ink wash, tracing and cutting the areas out

10. *Assemble the Collage*

Assemble the cut-out in wash pieces into a tonal collage on your chosen format. **(4.6.19) (4.6.20)**

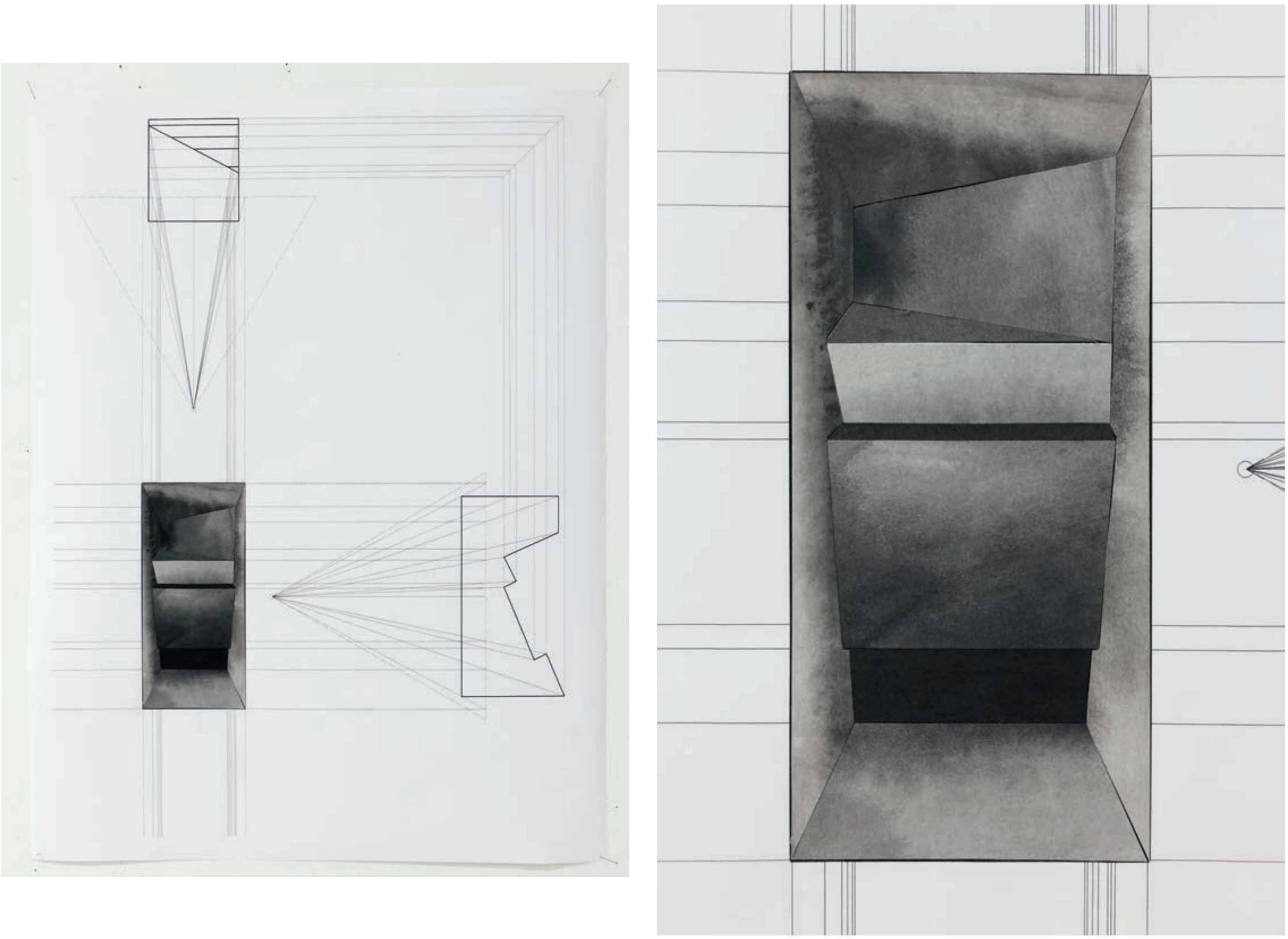


Figure 4.6.19
Finished ink wash gradient collage integrated into plot format

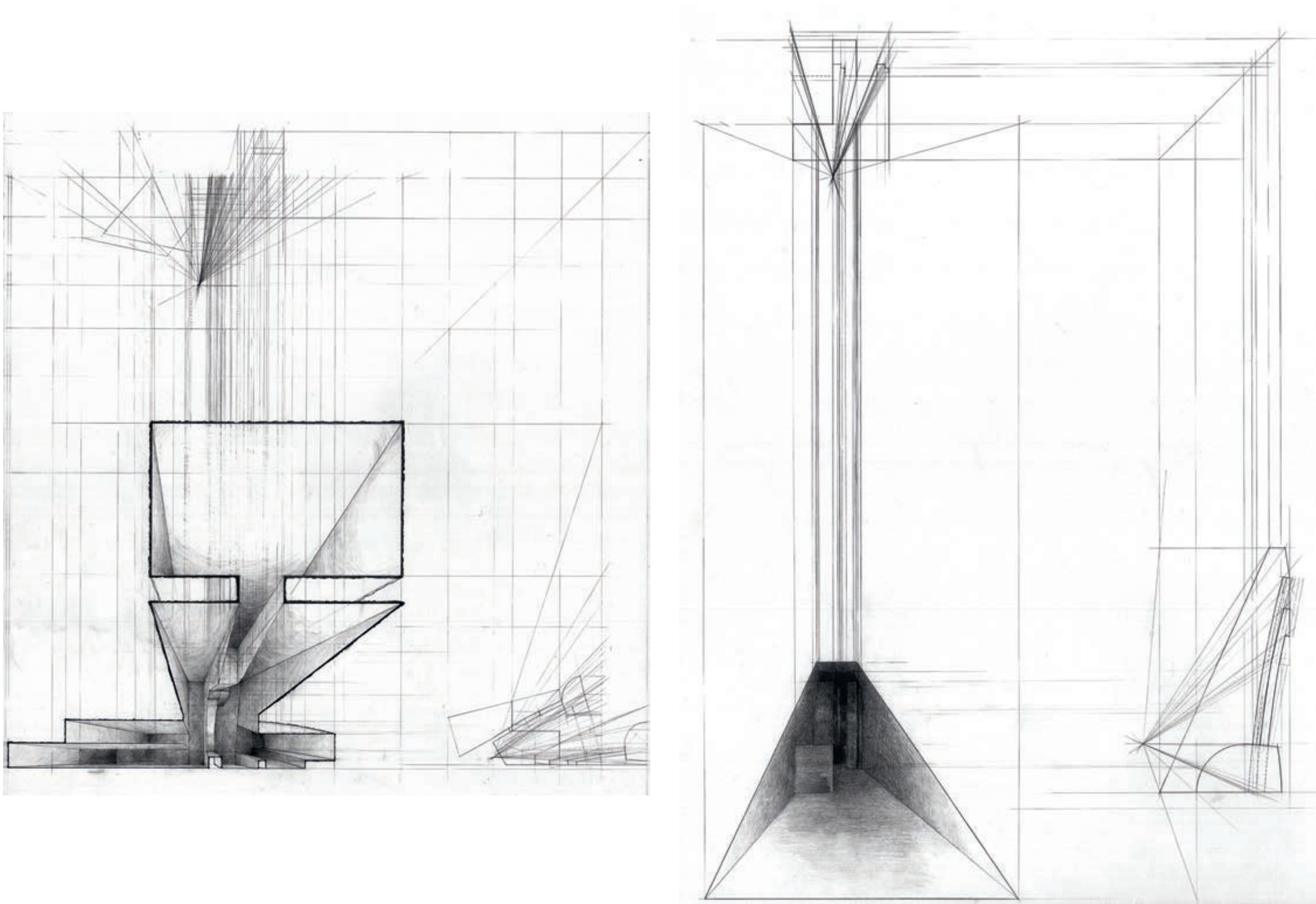


Figure 4.6.20
Examples of student drawings made using various techniques to achieve gradients

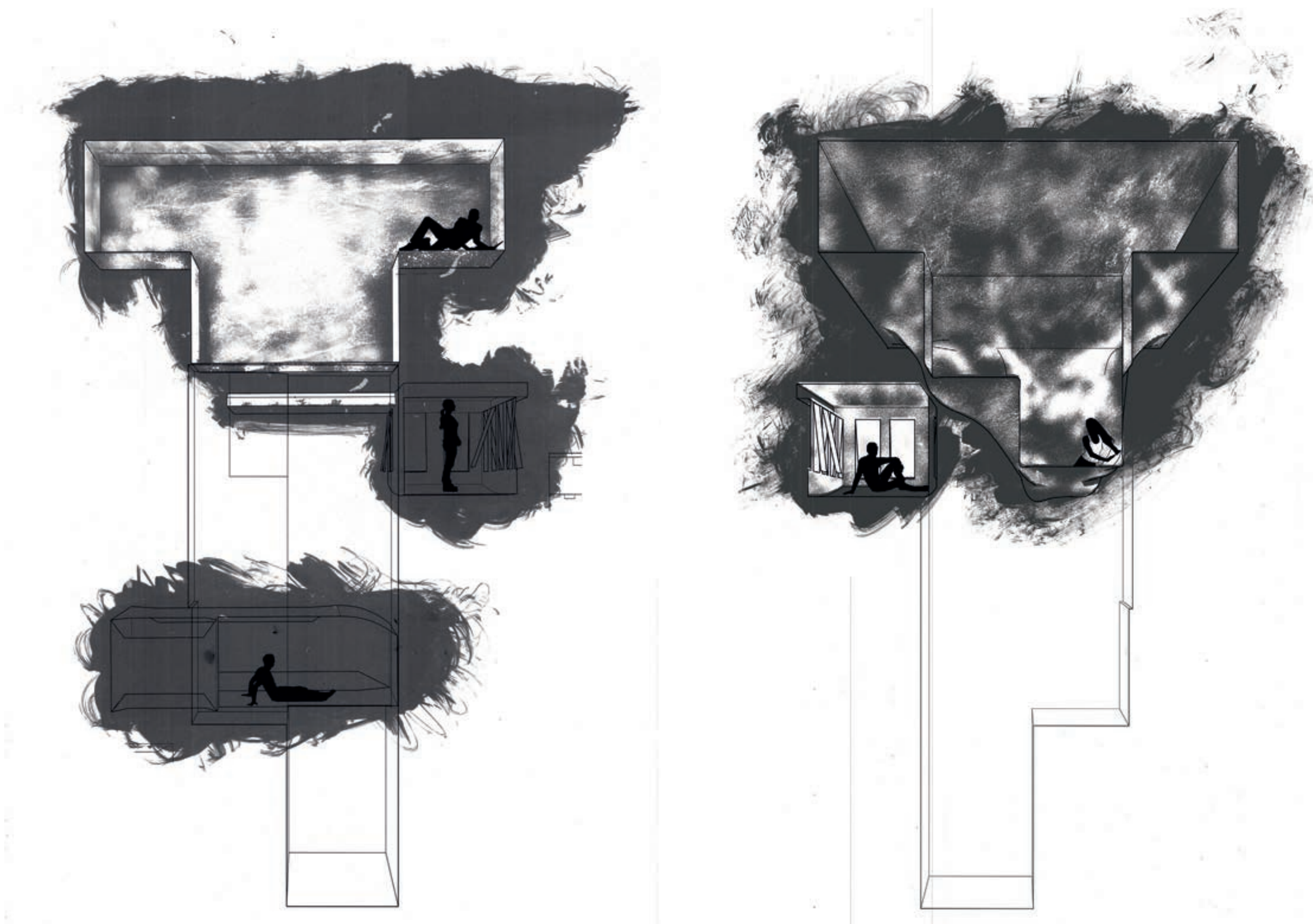


Figure 4.6.20 Continued

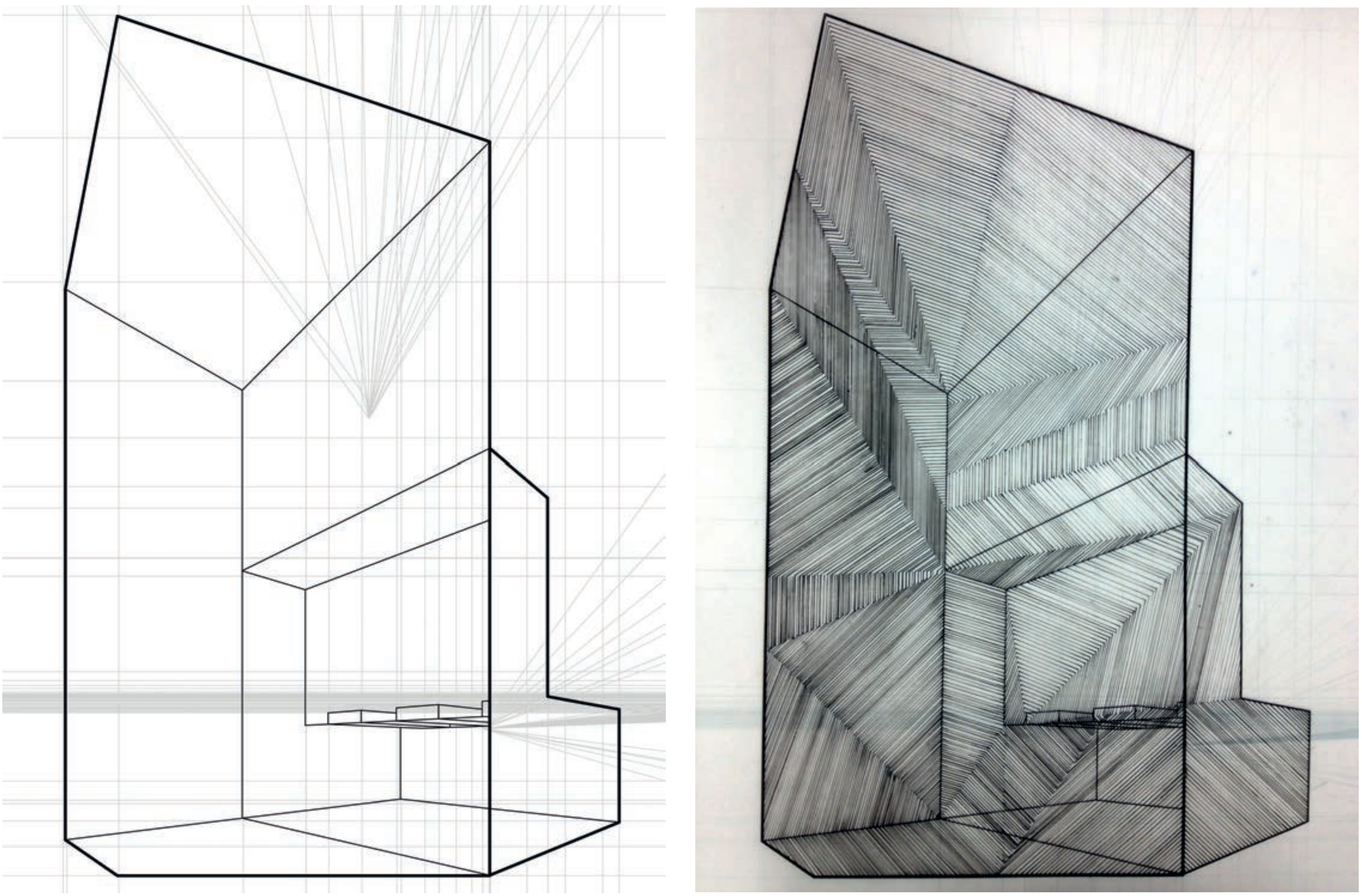


Figure 4.6.20 Continued

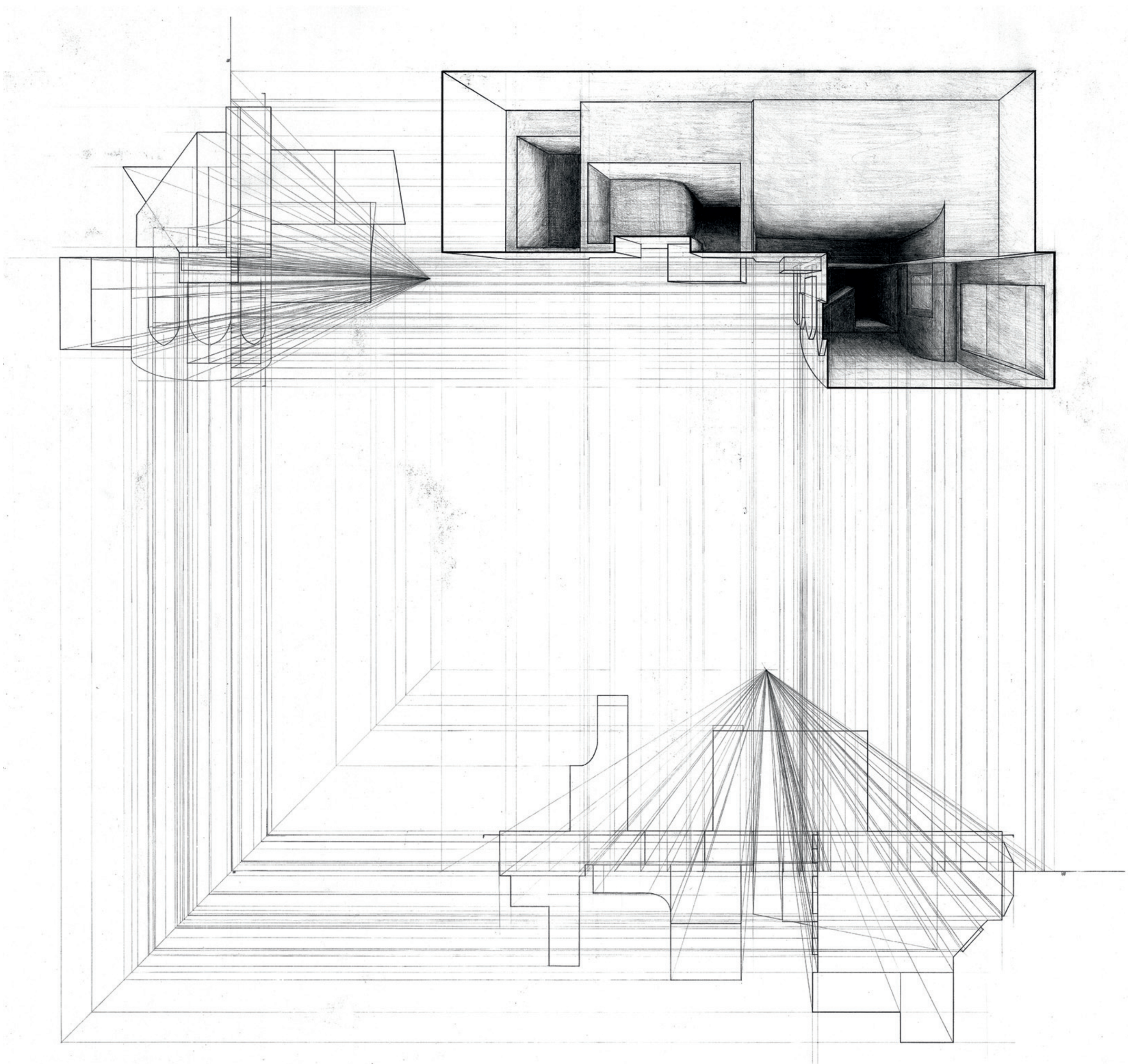


Figure 4.6.20 Continued

Notes

1 Douglas Cooper, *Drawing and Perceiving: Life Drawing for Students of Architecture and Design* (New York: John Wiley, 2001), 94.
2 Massimo Scolari, *Oblique Drawing: A History of Anti-Perspective* (Cambridge, MA: MIT Press, 2012), 1.
3 Scolari, *Oblique Drawing*, 1.
4 Cooper, *Drawing and Perceiving*, 156.
5 Cooper, *Drawing and Perceiving*, 154.

4.7 PAPER CASTING TO MAKE A *MONOCOQUE*

Paper casting involves piling up soaking wet fibers into a desired shape or form, using a mold or an armature, and keeping them there until dry.[1] The mass of wet fibers is called pulp, and can be made with wood fibers, or with non-wood fibers like flax or cotton. Pulp can be used to create a massive cast from a mold, or a thin cast, around or on top of a moisture-resistant armature. This series of instructions will detail how to make a self-supporting shell or *monocoque* using paper casting. For the pulp, we will use cotton linters and water, with wheat paste added to contribute added strength and flexibility to the shell. Cotton linters are the short, fuzz-like fibers that are harvested from around cotton seeds; they are generally between 1.5 and 6 mm long.[2] **(4.7.1)** In the paper industry, cotton linters are used alone and in pulps mixed with other fibers to make insulating paper, filter paper, non-woven fabrics and some fine art papers.[3] Mixing the linters with water and blending them makes the fibers pliable and sticky. During mixing and straining, the fibers overlap and interweave to create a coherent surface or mass. **(4.7.2)** Familiar, everyday objects like recyclable trays, egg cartons and packaging are examples of paper cast *monocoque*. **(4.7.3)**

Figure 4.7.1
Cotton linters

Figure 4.7.2
Image made with a scanning electron microscope of mold-made Arches cotton paper. Image at 100X, The Paper Project (paperproject.org), Arizona State University, Tempe, Arizona, USA.

Figure 4.7.3
An everyday example of a paper cast *monocoque*, an egg carton

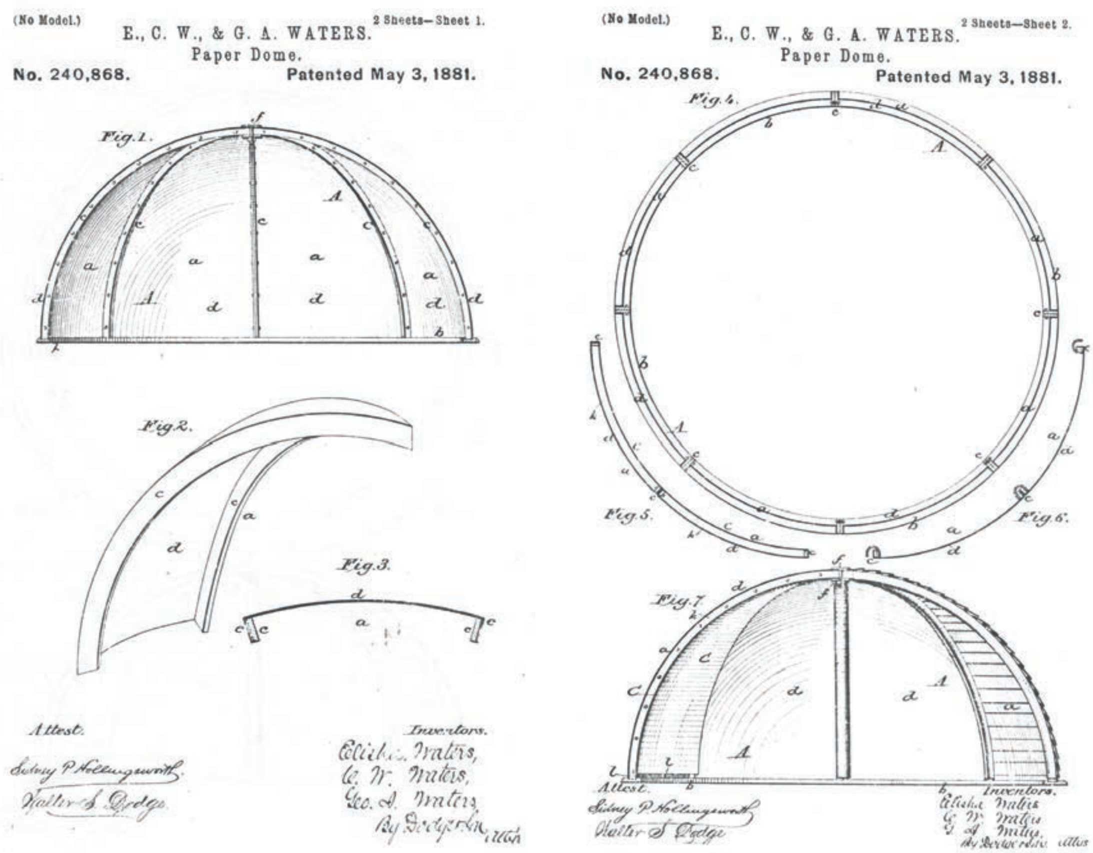


Figure 4.7.4
Illustrated pages from U.S. patent number 240,868, Paper Dome, Elisha Waters, Clarence W. Waters, and George A. Waters, Troy, New York, USA, 1881.

Paper casting might seem like an outlier in the context of architectural materials and construction techniques, but there are exciting precedents for paper-cast building envelopes. In 1878, E. Waters & Sons, a nineteenth-century company based in Troy, New York, credited with innovating an approach to manufacturing paper boats, fabricated the first of a series of paper observatory domes for a local observatory.[4] Waters went as far as obtaining a US patent for the paper observatory domes in 1881, and, the same year, constructed the largest one: **(4.7.4)**

> It was slightly over 30 feet in diameter and contained over 2,000 pounds of paper. The paper was from 3/8″ to $\frac{1}{2}$ inch thick and had the light wood framework similar to that shown in the Waters patent. The interior photograph of the dome also shows the basic wood-frame structure. According to the publication *Paper World* of 1881, "It weighs only $\frac{1}{10}$th as much as a copper dome of equal size. It is expected that the paper will act as a nonconductor of heat and electricity, will maintain a uniform temperature within the building, and will prevent any electrical disturbance from destroying the accuracy of the instruments."[5]

The large dome lasted over 40 years without major repairs. Surface treatment was done by adding more paper and shellac, to make it impermeable to the harsh New York state elements. It was dismantled in 1959.[6]

As an architectural model-making technique, the paper cast *monocoque* is attractive because it is easy to modify. It is just paper, and simple to cut and fold. It is also easy to reinforce some spots or areas with a thicker accumulation of pulp, and make other areas very thin and translucent. **(4.7.5)** It is also a fabrication process with potentially very little waste.

1. *Prepare Your Mold Pieces to Act as Your Paper Casting Armature*

In 4.5, "Slip Casting," the porous nature of the plaster mold is described as key to the slip casting process. In this case, when we use the plaster mold pieces as an armature for creating a paper cast shell, you will need to minimize the porosity of the plaster by applying a very thin film of release agent to the surface of the plaster (see "Glossary of Technical Terms and Materials"). Once you have decided upon the arrangement that you'd like to cast as a *monocoque*, arrange the mold pieces in your chosen configuration and apply mold release to all surfaces. The drier that your mold pieces are, the easier the paper casting process will be. **(4.7.6)**

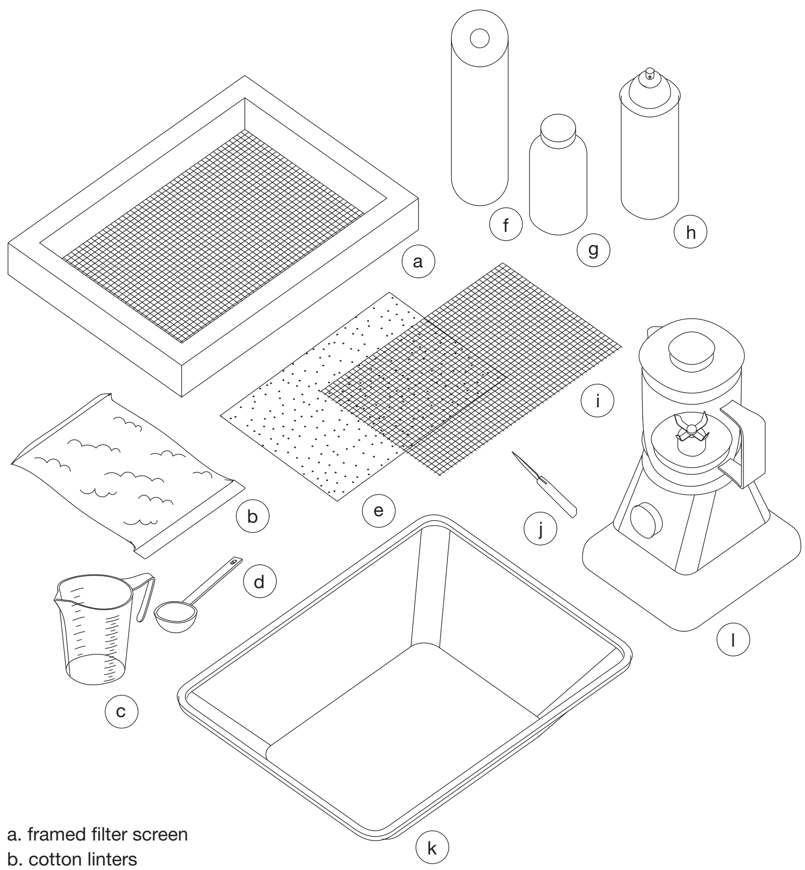
Figure 4.7.5
Paper cast skin with uneven translucency from varying densities of pulp

Figure 4.7.6
Applying a release agent—in this case cooking spray—to the mold parts

2. *Assemble Your Materials and Tools* **(4.7.7)**

Assemble the following materials and tools:

- cotton linters (one to three 8 oz bags, depending on the surface area to be cast)
- blender
- water
- wheat paste
- mold release
- a measuring cup for liquid (water)
- a measuring device for solids (wheat paste)
- a large strainer or a stretched screen
- a very fine mesh, paper casting screen
- medium density vinyl mesh screen
- a large bowl or washing tub
- paper towel
- paring knife.



a. framed filter screen
b. cotton linters
c. measuring device for liquids
d. measuring device for solids
e. unframed screen, fine density
f. paper towels
g. wheat paste
h. cooking oil spray
i. unframed screen, medium density
j. paring knife
k. bowl or washbin
l. blender

Figure 4.7.7
Tools and materials for paper casting

3. *Make Pulp*

Make your pulp in small, manageable batches. The ratio of cotton linters to water for your pulp should be roughly 1:8. An initial test batch could be $\frac{1}{4}$ cup (60 ml) loosely packed linters to 2 cups (500 ml) water, for example. Add about a tablespoon (15 ml) of wheat paste (see "Glossary of Technical Terms and Materials") to every two cups of water. Put the linters, water and wheat paste in a blender and mix for about one minute. **(4.7.8)**

Figure 4.7.8
Blending pulp

4. *Strain the Pulp*

Pouring the pulp over a sieve, strainer or stretched screen is a critical part of the casting process, since it is the point at which the pulp transforms from a liquid to a more dense paper skin. The fibers mesh instantly once excess water is strained out. Pour your initial test batch slowly over your straining medium, ideally a fine mesh specifically for paper casting, with a bucket or a pan positioned to catch the excess water. **(4.7.9) (4.7.10)** A screen is useful if you want to achieve large, thin areas, and a strainer is useful if you want larger, denser clumps. Keep the excess water for your next pulp mixture; it contains wheat paste and traces of linter, and doesn't lose its value in the paper making process as it is recycled. **(4.7.11)**

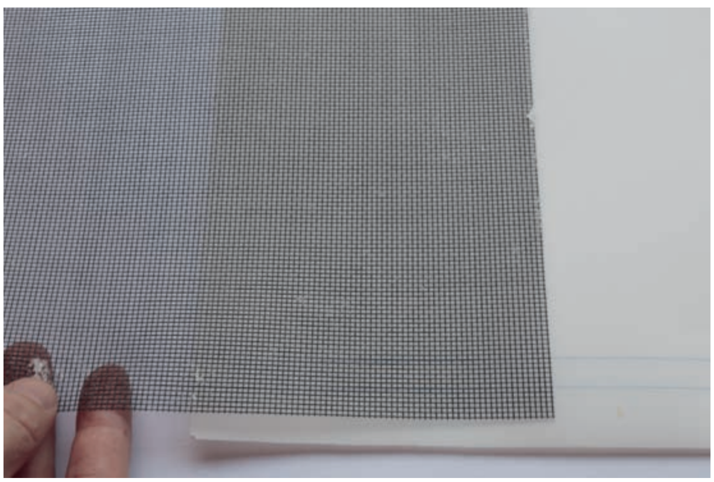


Figure 4.7.9
Two different densities of mesh screens to strain moisture from the pulp and help support fibers to make a sheet

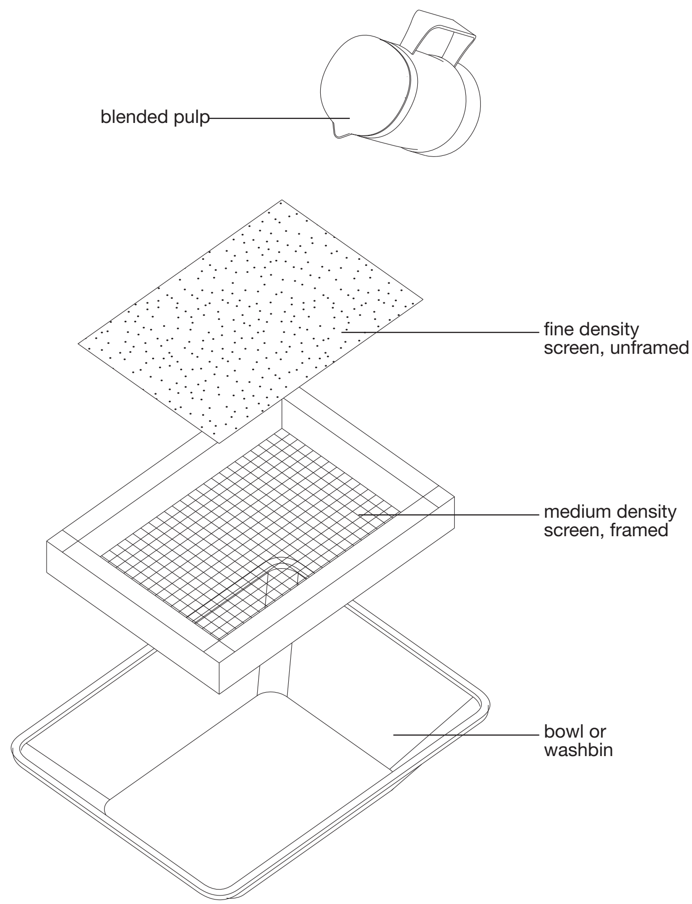


Figure 4.7.10
Straining pulp

5. *Pat the Pulp*

Using the vinyl mesh screen and a dry rag, small towel or paper towel, gently pat your strained paper pulp to press out remaining, excess water. Placing the vinyl mesh between the pulp and towel or paper towel will prevent the pulp from sticking to the absorptive material. **(4.7.12)**

Figure 4.7.11
Straining pulp

Figure 4.7.12
Removing excess water from the pulp

6. *Peel Up Pulp Strips and Cast Them over Your Armature*

After patting the pulp, you should be able to carefully peel up strips of paper pulp that remain intact. **(4.7.13)** Gently cast them over your plaster armature, until the entire surface that you want as a shell is covered with strips of pulp. **(4.7.14)**

Figure 4.7.13
Pulling strips of pulp from the mesh

Figure 4.7.14
Casting strips of pulp on the plaster armature

7. *Pat the Pulp Layer*

Again, using the vinyl mesh and a dry rag, small towel or paper towel, gently pat the wet layer of pulp to encourage strips to bind together, and to absorb as much excess moisture as possible. **(4.7.15)**

8. *Let the Paper Dry*

An ideal environment for air-drying a freshly cast paper object is very warm and dry, even sunny, with gently circulating air. If left for too long on top of the armature, in an environment that doesn't aid the drying process, the paper pulp and plaster will mold.

Figure 4.7.15
Removing excess water from the cast pulp

9. *Release the Dry* Monocoque *from the Armature*

How easily your dry *monocoque* releases from your plaster armature depends on the complexity of the forms. Textures and undercuts on your forms will, like in the slip casting process, tend to make the paper cling to the armature. With your new understanding of parting lines learned in 4.4, "Multi-Part Rigid Mold Making," make strategic cuts as necessary to release your plaster forms. **(4.7.16)** Be patient when prying the paper from the plaster. Insert a paring knife or utility knife between the paper shell and the plaster forms to release any fibers or still-moist areas that stick to the armature. **(4.7.17)**

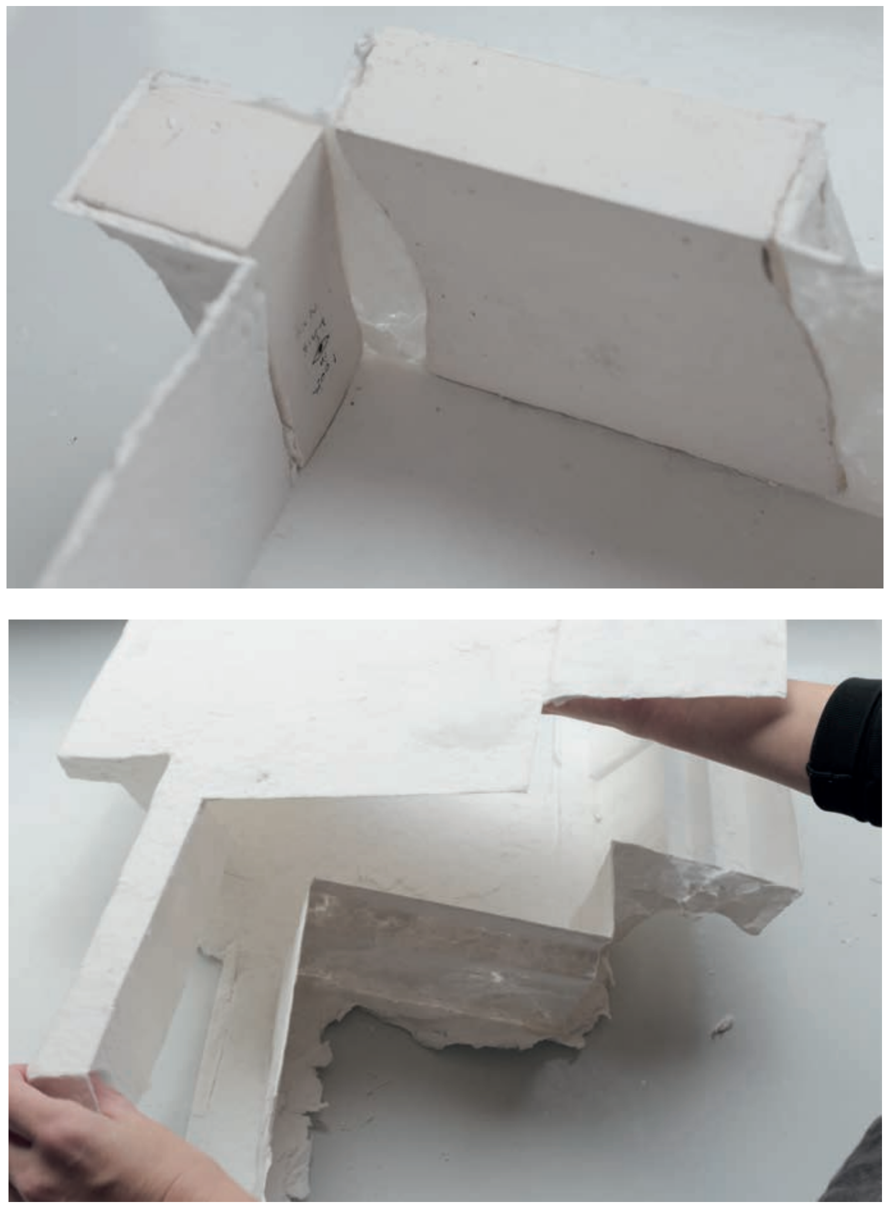


Figure 4.7.16
This example *monocoque* could be removed in two pieces

Figure 4.7.17
Releasing the *monocoque* from the armature

10. *Repair as Needed*

To repair or reassemble cut parts of your paper shell, or if your shell tore in certain spots when it was being removed from the armature, use white washi or masking tape. **(4.7.18)** If the layers of your cast de-laminate, it is a sign that you had too little wheat paste in your pulp mixture. **(4.7.19)**

Figure 4.7.18
White washi paper tape and masking tape

Figure 4.7.19
Paper pulp without enough wheat paste will result in a shell that flakes apart easily

Notes

1 Arnold Gummer, *Arnold Gummer's Complete Guide to Paper Casting* (Iola, WI: Krause Publications, 2002), 7.
2 "Cotton Linters: A Valuable Raw Material for Paper Industry," *Paper Mart: A Bi-monthly Magazine for Pulp, Paper & Converting Industries in India*, July 4, 2012, accessed September 12, 2015, http://papermart.in/2012/07/04/5622/.
3 "Cotton Linters."
4 Ken Cupery, "Paper Observatory Domes," accessed September 13, 2015, www.cupery.net/dome.html.
5 "Paper Observatory Domes."
6 "Paper Observatory Domes."

4.8 TAKING PHOTOS OF SCALE MODELS

Refer to 4.1, "Taking Photos of Spaces," for a general introduction to photography.

Model documentation translates your three-dimensional models and artifacts into two-dimensional images. You can integrate these images into your drawings or collage work. These images also allow you to show these objects in your portfolio. While physical models are important in your design process and for your reviews, a larger audience can see these objects only through images. Documenting your models photographically allows you to compile an archive, since you aren't able to keep everything that you build. Model documentation therefore fulfills several critical roles in your architectural work.

1. *Set Up a Studio Backdrop*

A simple way to achieve even, soft lighting for your model documentation is with natural light. Choose the largest window available to you. Any window orientation will work, you just need to choose the time of day when the lighting is most favorable. Avoid direct sunlight in your image. Direct sunlight will create too much contrast (remember the limited dynamic range of image sensors, see 4.1, "Taking Photos of Spaces"). Hard shadow lines will add random geometries to your model that will counteract the documentary, archival nature of these photographs. **(4.8.1)** Place a table perpendicular to the window so that your object is illuminated from the side and slightly from the front.

Do not use any additional artificial lighting. Artificial light has a different color spectrum than daylight and will tint surfaces that should appear white.

To visually isolate the object in your photograph, use an even, white, matte background. You can use a large white thin cardboard or thick plotter paper. Make a vertical stand at the back of your table; it could be a high stack of books. Place the white background on the table, so that half of it covers the table surface and the other half sweeps up vertically onto the vertical stand. The curve will not be visible in your photograph and will give the illusion of an endless white ground. **(4.8.2)**

Figure 4.8.1
Model photographed outdoors with dramatic sun and shadow effects

Figure 4.8.2
Photo of basic photo studio set-up

Document your object in its entirety with a minimum of views. A comprehensive set could be:

- four elevation views **(4.8.3)**
- two corner views **(4.8.4)**
- one top view **(4.8.5)**
- two “bird’s eye” corner perspectives from opposite ends. **(4.8.6)**

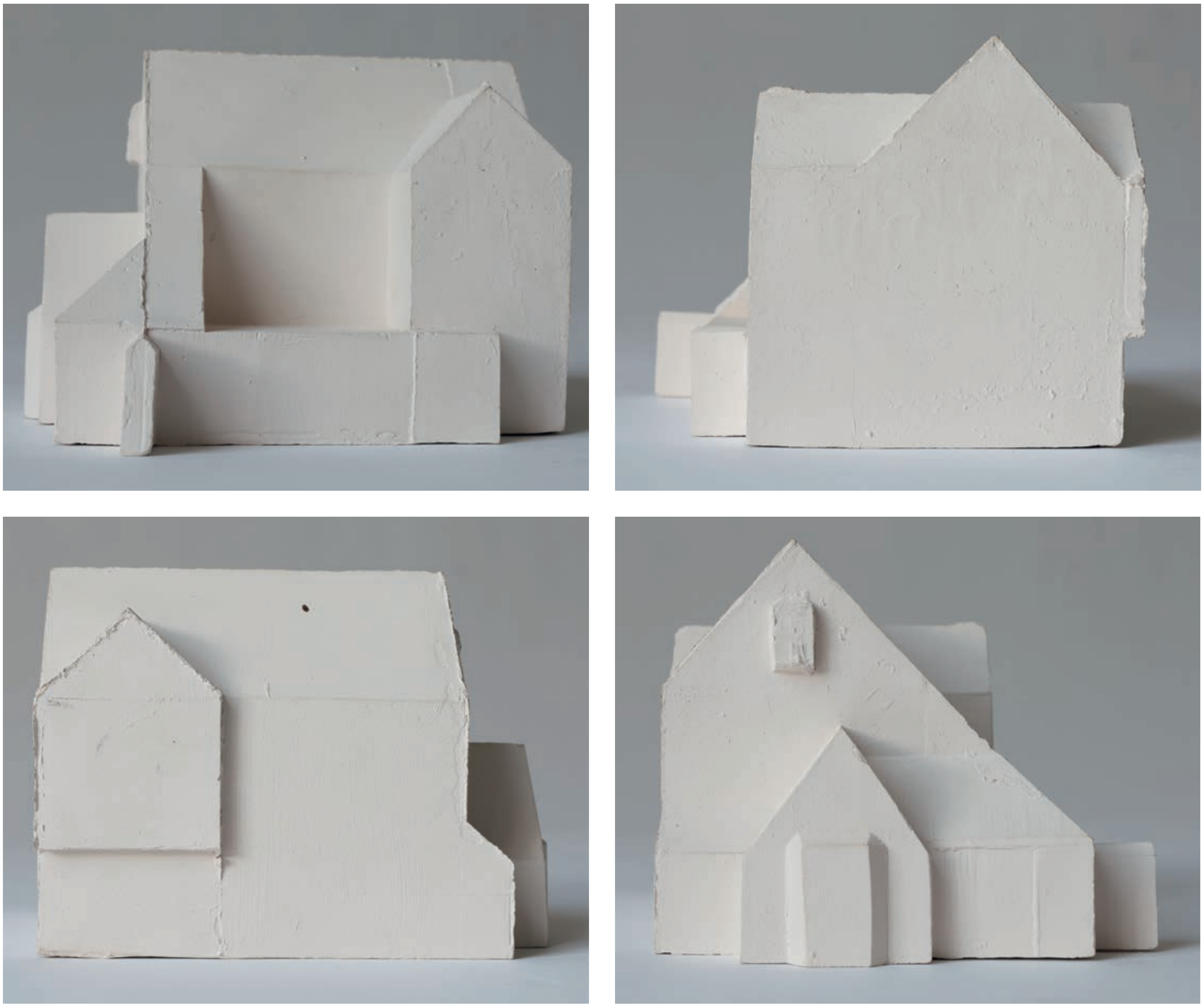


Figure 4.8.3
Four elevation views of a model

Figure 4.8.4
Two corner views of a model

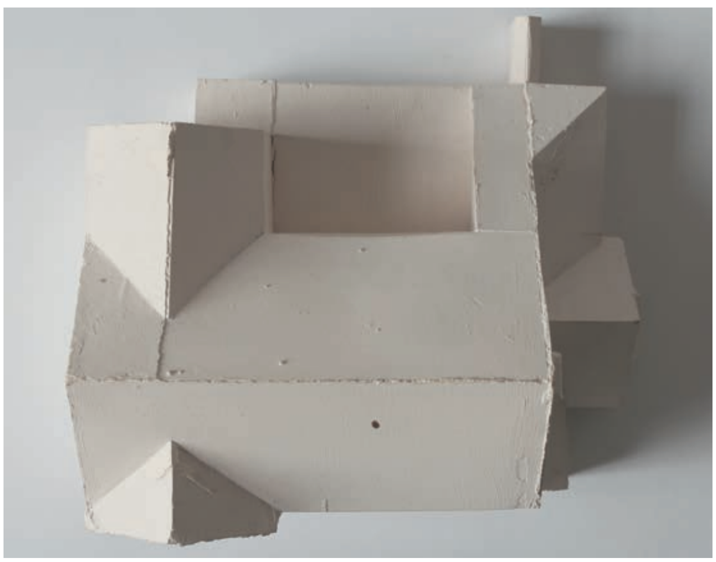
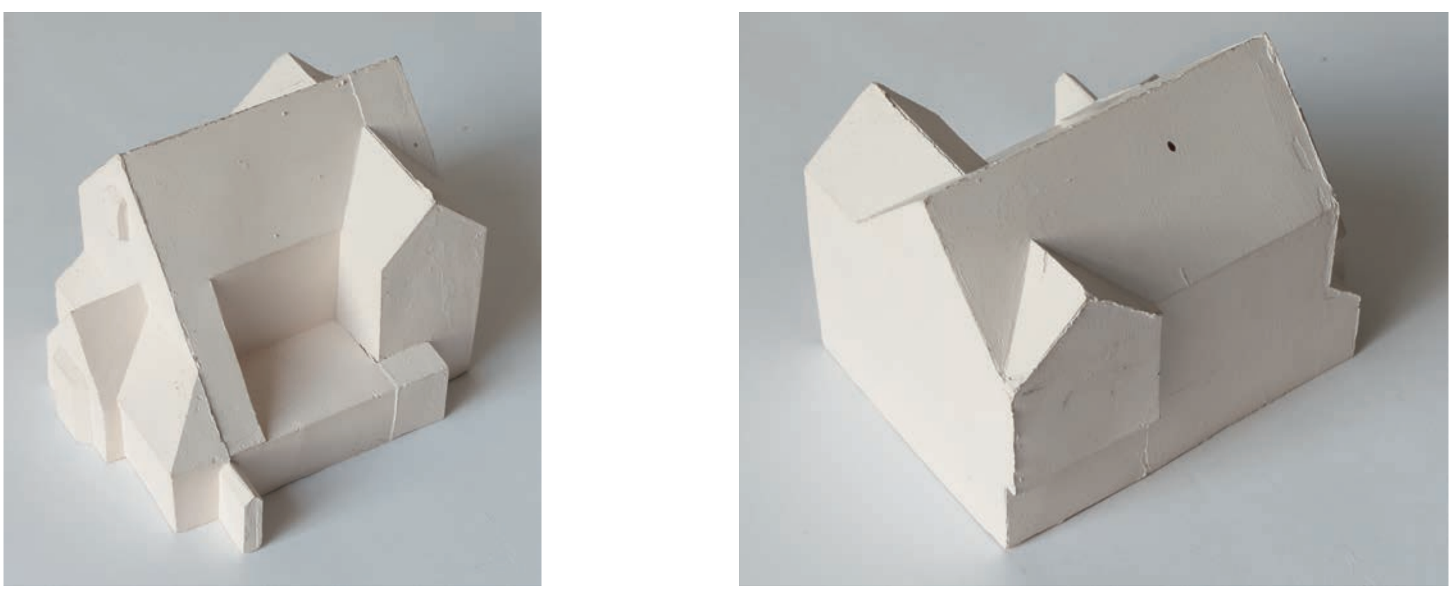


Figure 4.8.5
One top view of a model

Figure 4.8.6
Two “bird’s eye” corner perspective views of a model



2. *Define Your Camera Settings*

The best focal length (see 4.1, "Taking Photos of Spaces") for a documentary purpose is between 50 and 100 mm, because the perspectival distortion is at its lowest within this range, and because it allows for a comfortable working distance to the table.

For documentary purposes, you want the photographs to capture as much information about your model as possible. Therefore, your whole object should be

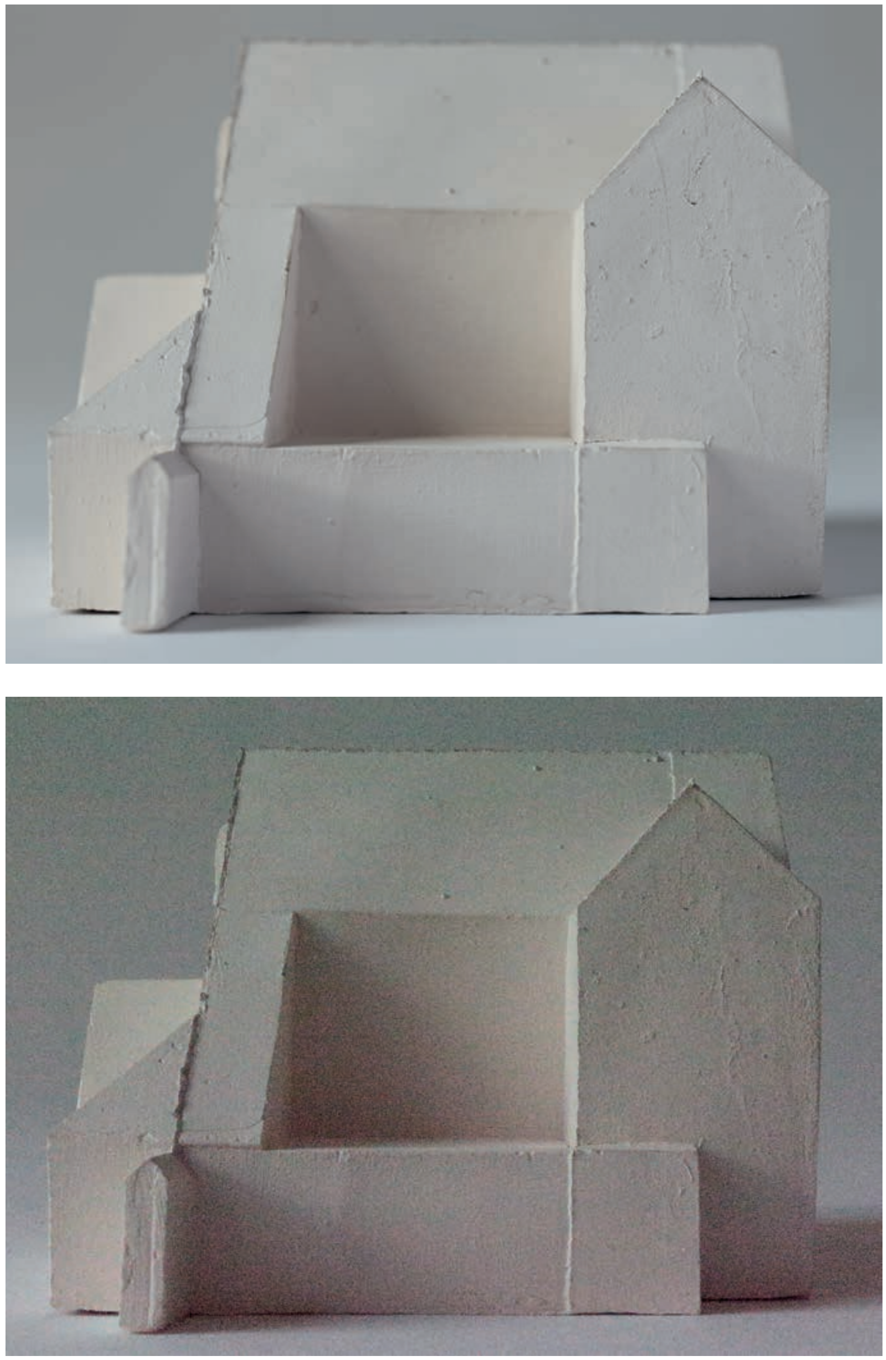


Figure 4.8.7
Example of two identical frames taken with different settings, one with photographic "noise," an undesirable attribute in documentary photos

in focus. Set your aperture between f/8 and f/16; a small aperture will give you a large depth of field (see 4.1, "Taking Photos of Spaces").

Because you are using a tripod, shutter speed settings do not matter. Set the ISO setting at 100 for most noise-free images (see "Glossary of Technical Terms and Materials"). **(4.8.7)**

3. *Take Your Photos*

Place your camera on a tripod, set it absolutely level, both vertically and horizontally. Place your model on your studio backdrop. Set the height of your camera so that the model is in the center of your image, comfortably filling the frame. Rotate your model so that the elevation is parallel to the camera. Take a photo and rotate the model to the next elevation.

For the top view, set your model on one of its sides.

Now set the camera higher and tilt it down so that it points back down to the model. Rotate the model so that the corner faces the camera, take a photo and rotate the model so that the opposite corner faces the camera and take the last photo.

4. *Post-Processing*

Refer to 4.1, "Taking Photos of Spaces," for instructions on post-processing; the same rules apply.

Taking Interior Model Photos (Macrophotography)

When photographing the interior spaces of architectural models, the camera should be positioned very close to the model. Photography with a close distance between the camera and the subject is called macrophotography. **(4.8.8)** Photographing

Figure 4.8.8
Setting up for interior model documentation

interior model spaces is a special type of macrophotography, as it carries over some requirements from architectural photography discussed in 4.1:

- Keep vertical lines parallel to your camera.
- Use a wide-angle lens to capture a whole space and not just a detail of your model interior. You need a wide-angle lens with a wide cone of vision.
- Establish a large depth of field to get as much in focus as possible. The closer you get to your subject, the shallower your depth of field gets. You therefore want to counteract that with very small apertures, the smallest available on your camera.

Equipment

The smaller the sensor of your camera, the closer you can focus without the need for specialty lenses. Smart phones and pocket cameras have smaller sensors than a DSLR camera (see "Glossary of Technical Terms and Materials"). For this type of macrophotography, a DSLR is not necessarily needed. If you use a DSLR, make sure that you can focus with a distance of 12 in. (30.5 cm) or less between the camera sensor and the back wall of your interior model. This can be achieved in three ways:

- through the use of a macro lens or general lens with a close focusing distance of not more than 12"
- extension tubes
- close-up filters.

1. *Stage Your Model*

Set up your model: furnish it, place scaled figures in it, plants printed on transparent paper, set printed scenery behind window openings. Everything that you want to see in the image should be in the model. Avoid digitally adding extra elements into the image. This disturbs the specific light situation in the model photo. **(4.8.9)**

Figure 4.8.9
Staging a model

2. *Set Up Lighting*

The aim is not to get a documentary, objective description of the space as in the exterior photos. The aim is to get an atmospheric impression of the spatial quality of your space. Set the lighting up so that you achieve the spatial effect you designed. Be aware that your camera is very close to your model, so it can easily change your lighting condition or cast a shadow into your image. **(4.8.10)**

Figure 4.8.10
Comparison of photos taken with different lighting conditions, with (top) the model is lit from the back, highlighting the translucency of the paper shell, and with (bottom) the model is lit from the front, causing the paper shell to appear opaque

3. *Focus*

If you have a DSLR, set it to the closest focusing distance and move toward your model until the back wall is in focus. Use a tripod and set your camera absolutely level to avoid falling lines (see 4.1, "Taking Photos of Spaces").

4. *Define Your Camera Settings*

Set the aperture as high as possible to achieve the largest depth of field. If you use a pocket camera, set it to macro mode; the rest is done automatically by the camera. **(4.8.11)**

Figure 4.8.11
Comparison of photos taken from the same standpoint, with (top) the camera is set with an f-stop at 32 (small aperture), everything is sharp, and with (bottom) the camera is set with an f-stop at 2.5 (large aperture), the face of the figure is in focus, while other elements are blurry

5. *Experiment with Settings*

Once you have achieved a basic interior shot that is technically resolved with adequate lighting, in focus, with a large depth of field, then you can experiment further with these parameters to see what different atmospheres can be created in the space of your model.

4.9 WORKING WITH CONCRETE

Concrete is a liquid mixture of water, cement and aggregate that hardens to a stone-like material. The most common cement is Portland cement.[1] The most common aggregates are sand, gravel and crushed stone (see "Glossary of Technical Terms and Materials").[2] To increase tensile strength, reinforcement is often cast in concrete structures. This is called reinforced concrete. Concrete alone has a very long lifespan which is often compromised by the steel reinforcement corroding and creating cracks in the concrete. **(4.9.1)**

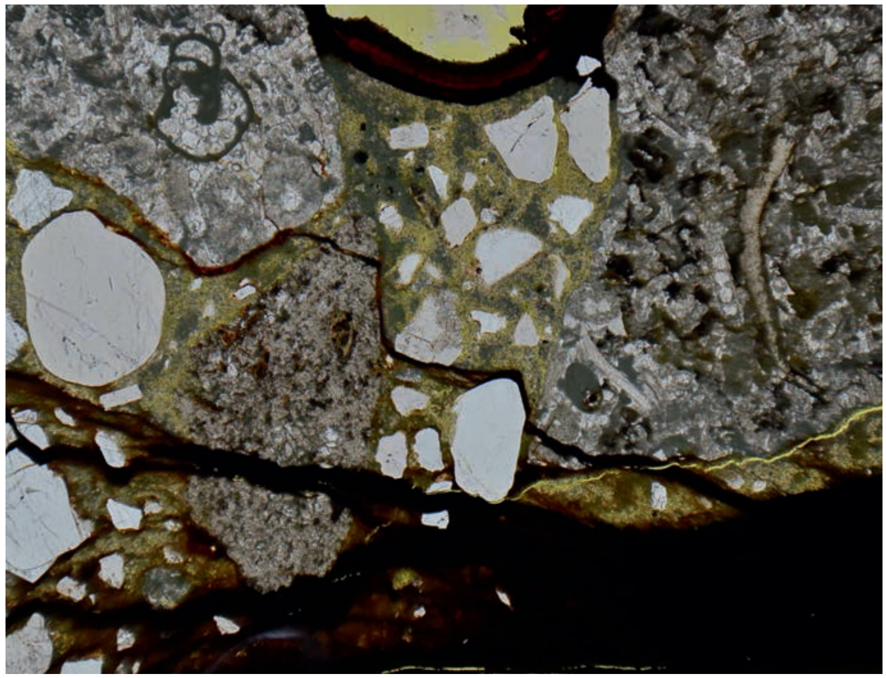


Figure 4.9.1
Petrographic scan showing reinforcement corrosion in concrete, Petrolab, "concrete reinforcement-corrosion-x4ppl," Cornwall, England

Figure 4.9.2
Comparison between a concrete mixture (*left*) and a cement mixture (*right*)

Figure 4.9.3
Piece of concrete cut sectionally showing the different sizes of the aggregate particles, Petrolab, "Large-Aggregate," Cornwall, England

Portland cement itself is brittle but the added aggregate gives concrete compressive strength. Portland cement is made from ground hydraulic lime. Limestone with impurities of clay is sintered in cement kilns to produce cement clinker. The cement clinker is ground to a fine powder. The finer the grind, the faster the cement will set.[3] **(4.9.2)**

Aggregates are grouped into two distinct categories: fine aggregate and coarse aggregate. Fine aggregates consist of sand and crushed stone that pass through a $\frac{3}{8}$-in. (0.95-cm) sieve. Coarse aggregates are particles that are between $\frac{3}{8}$ and $1\frac{1}{2}$ in. (0.95 and 3.8 cm) in diameter. **(4.9.3)**

The composition of aggregate and cement has a direct impact on the strength of the concrete. Because the aggregate provides the compressive strength and the cement acts mainly as a binder, a dense and uniform distribution of aggregate is important in making concrete that performs well and with consistency. The term "grading" within the context of concrete refers to the distribution of different aggregate particle sizes in concrete. Roughly textured, angular aggregate particles require more water and cement than rounded and compact particles, because of the larger void content in between the particles. **(4.9.4)** Well-graded aggregate has various sizes to achieve maximum material density and minimal void content in between the particles.[4]

Water is an essential ingredient in concrete, but too much water has an adverse effect on the strength of the mixture. It has been proven mathematically that a lower water-to-cement ratio results in a higher strength of concrete, provided that the mix is workable.[5]

Concrete, once poured, takes time to cure and achieve its maximum strength. Ordinary grade concrete, without accelerators, takes 28 days to cure.[6]

For your application, in the fabrication of very thin concrete shells, you will need to use fine aggregates. You could use premixed concrete and, if you want to decrease the size of the aggregates in the premixed concrete, you could simply sieve it. **(4.9.5)**

Safety note: concrete is very heavy and accrues weight rapidly with increased size. Work under the close supervision of your instructor and, as with the handling of all materials, follow the safety precautions outlined on the material packaging.

Grading

Roughly textured, angular aggregate particles have a larger void content in between the particles.

Rounded particles are able to nestle together more densely than angular particles.

A well graded aggregate mixture is composed of particles of various sizes, and has a high aggregate-to-cement ratio.

Figure 4.9.4
Grading

Figure 4.9.5
Sieving large aggregates out of premixed concrete mix

1. *Assemble Your Materials and Tools* **(4.9.6)**

Have the following materials and tools available:

- gloves
- safety glasses
- rubber mixing tub or wheelbarrow
- hoe
- shovel
- measuring pail
- concrete (quantity and mixture depends on the scale and nature of your project).

a. concrete
b. gloves
c. safety goggles
d. pail
e. shovel
f. hoe
g. wheelbarrow

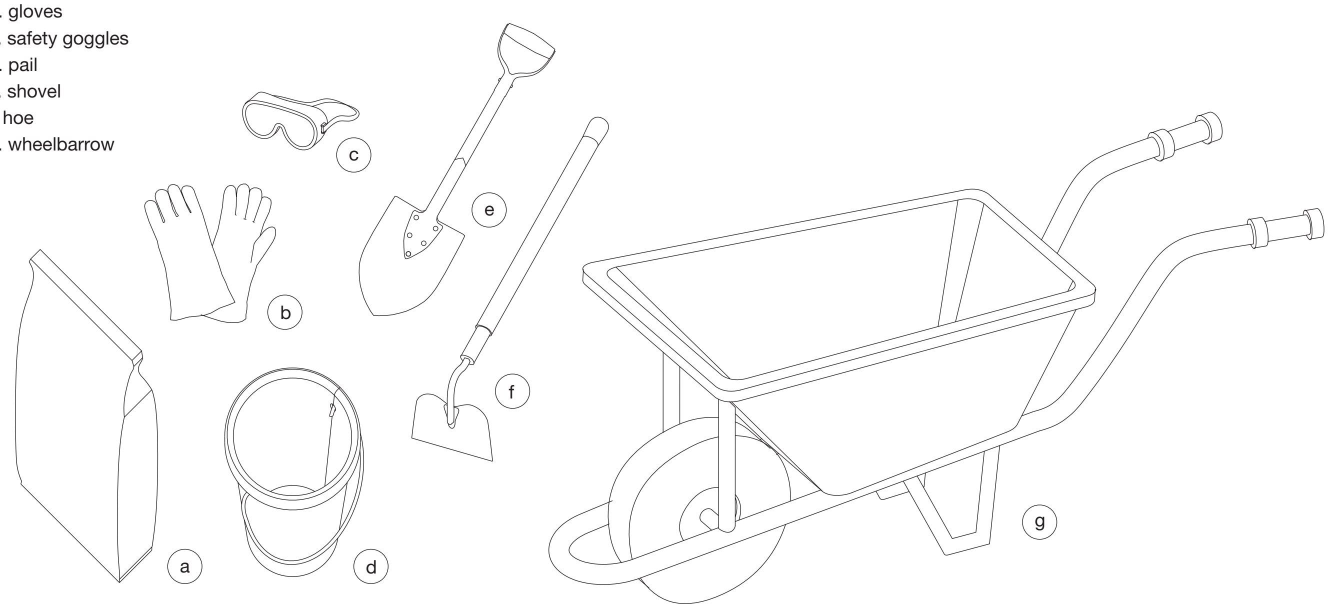


Figure 4.9.6
Tools and materials for working with concrete

2. *Pour Dry Concrete Mixture into a Mixing Container*

Make a test swatch before mixing concrete for your full-scale application. Empty a small amount of the concrete mixture into a mortar tub or wheelbarrow. Form a depression in the middle of the mix. **(4.9.7)**

Figure 4.9.7
In a mortar tub, a depression is made in a test batch of sieved concrete in preparation for water

3. ***Add Water***

Measure the recommended water amount for your particular concrete composition and add two-thirds of it to the mixture, pouring it into the depression that you made in step 2 (each 80-pound bag of concrete mix will require about 3 quarts of water). **(4.9.8)**

4. ***Mix***

Work the mix with a hoe, gradually adding the remaining water, until the mixture reaches a uniform, workable consistency. **(4.9.9)** Properly mixed concrete should look like thick oatmeal and should hold its shape when it is squeezed in a gloved hand. **(4.9.10)** Too much water weakens the concrete; adding one quart (0.9 l) more than the recommended amount of water per 80 lb (36 kg) bag can reduce the strength of the concrete by up to 40%.[7]

5. *Apply the Mixture in Your Chosen Manner*

Figure 4.9.8
Water is added to the concrete

Figure 4.9.9
Mixing

Figure 4.9.10
Typical consistency of construction grade concrete; concrete with more and larger aggregate is typically thicker, while finer mixtures are thinner and less viscous

Notes

1 Andrea Deplazes, ed., *Constructing Architecture: Materials, Processes, Structures: A Handbook*, second edition (Basel: Birkhäuser, 2008), 60.
2 Deplazes, *Constructing Architecture*, 60.
3 Deplazes, *Constructing Architecture*, 60.
4 C.C. Furnas, "Grading Aggregates," *Industrial and Engineering Chemistry*, vol. 23, no. 9 (Washington, DC: American Chemical Society Publications, September 1931), 1052.
5 P.C. Varghese, *Building Materials* (PHI Learning Private Limited, Delhi, 2012), Kindle edition, chap. 11.
6 Varghese, *Building Materials*, chap. 11.
7 "How-To Videos, Mixing Concrete—Hand Mixing," *Quikrete Cement & Concrete Products*, accessed October 17, 2015, www.quikrete.com/AtHome/Video-Mixing-Concrete-Hand.asp.

4.10 WORKING WITH LATEX

Natural latex rubber is typically used to make flexible molds that can record the slightest surface texture and detail.[1] **(4.10.1)** Depending on the material thickness, set latex rubber can stretch multiple times its original length without tearing. Liquid latex rubber can be brushed onto surfaces in thin layers and is especially suited for the exercise in 3.5, "Structure and Space."

Natural latex is a stable dispersion of polymer micro particles in water solution.[2] Latex is found in plants as a protection against plant-eating insects.[3] The stickiness of latex seals wounds in plants caused by, among other things, insects. Latex rubber is harvested from rubber trees. Freshly harvested latex, called field latex, contains 25–40% rubber.[4] To prevent it from coagulating, ammonia is added.[5]

Once latex is applied to a surface and exposed the ammonia and water content dissipate and cured natural rubber remains.[6] Porous materials help absorb water and ammonia and encourage the setting of latex rubber.

Figure 4.10.1
Test swatch of a latex skin, showing the side that registered the surface detail of the surface against which the material was cast

Safety note: as latex contains ammonia, you will need to work in a well-ventilated workspace. Work under the close supervision of your instructor and, as with the handling of all materials, follow the safety precautions outlined on the material packaging. Wear an apron or old clothes; rubber can't be removed from textiles.

1. *Assemble Your Materials and Tools* **(4.10.2)**

Have the following materials and tools available:

- liquid latex
- enough wide, soft-bristle brushes or rollers for your group to use
- release agent (if necessary)
- masking tape
- aluminum foil pan
- distilled water.

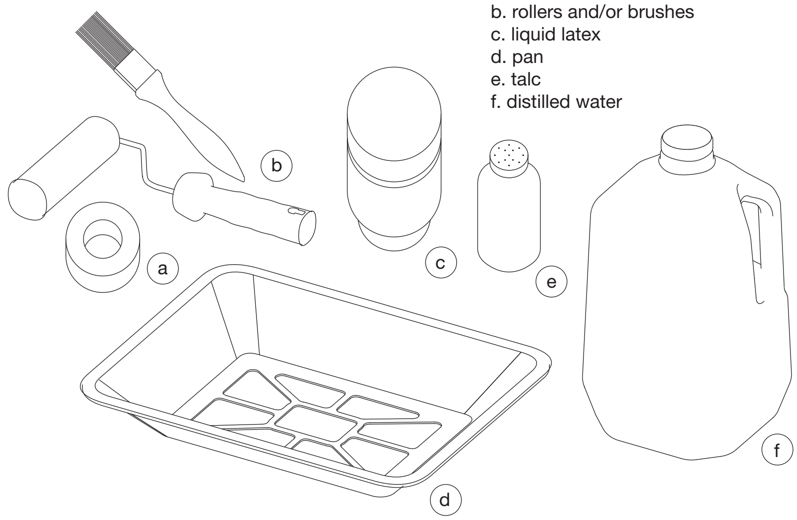


Figure 4.10.2
Tools and materials for working with latex

2. *Make a Test Swatch*

Use the application method that you've chosen for the project to make a small test swatch. The purpose of this swatch, beyond introducing you to the material, is to find out whether or not you need a release agent on the surface to which you're applying the latex. If you do need a release agent, use talc powder, wax paste or silicone spray. Do not use petroleum-based substances like cooking spray or Vaseline; these materials weaken latex rubber.

3. *Tape the Area to Cast*

Define the perimeter of the area that you plan to cast with masking tape. **(4.10.3)**

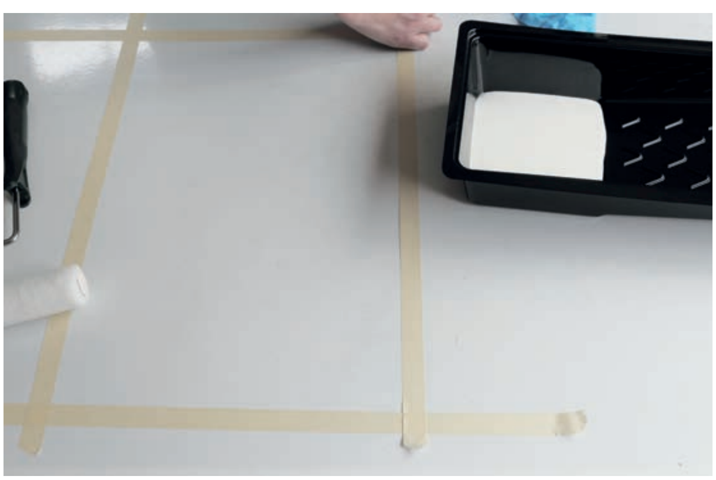


Figure 4.10.3
Tape the perimeter to be cast with latex

4. *Check the Consistency of the Liquid Latex*

Pour the liquid latex into a foil baking pan. For brushing or rolling, the consistency of the liquid latex should be similar to motor oil. If the latex is too thick, it can be diluted with a small amount of distilled water. **(4.10.4)**

Figure 4.10.4
Pour latex into pan to check consistency

5. *Apply the First Layer of Latex*

Apply the first coat of latex gently and lightly to avoid air bubbles. Make sure to cover any undercuts that might not be immediately visible. As the first layer dries, you'll notice it change from a milky-white to transparent. **(4.10.5)** Depending on temperature, humidity and ventilation, the first layer could cure and become transparent in between five to ten minutes.

6. *Apply More Layers*

After the first coat has cured completely, apply the next coat. Do not wait too long in between coats, otherwise the layers could separate. **(4.10.6)** If you want to embed inlays of reinforcement, place them on top of the first layers and brush or roll over them. Inlays could include grommets, strings, wires, cheese cloth or other fabric. **(4.10.7)** Embedded in the translucent, thin and stretchy skin, reinforcements impact both how the skin behaves (more rigid, less stretchy) and look. **(4.10.8)**

Figure 4.10.5
First coat of latex being applied

Figure 4.10.6
Additional coats of latex are applied

Figure 4.10.7
A strip of cotton is embedded in the test swatch as reinforcement

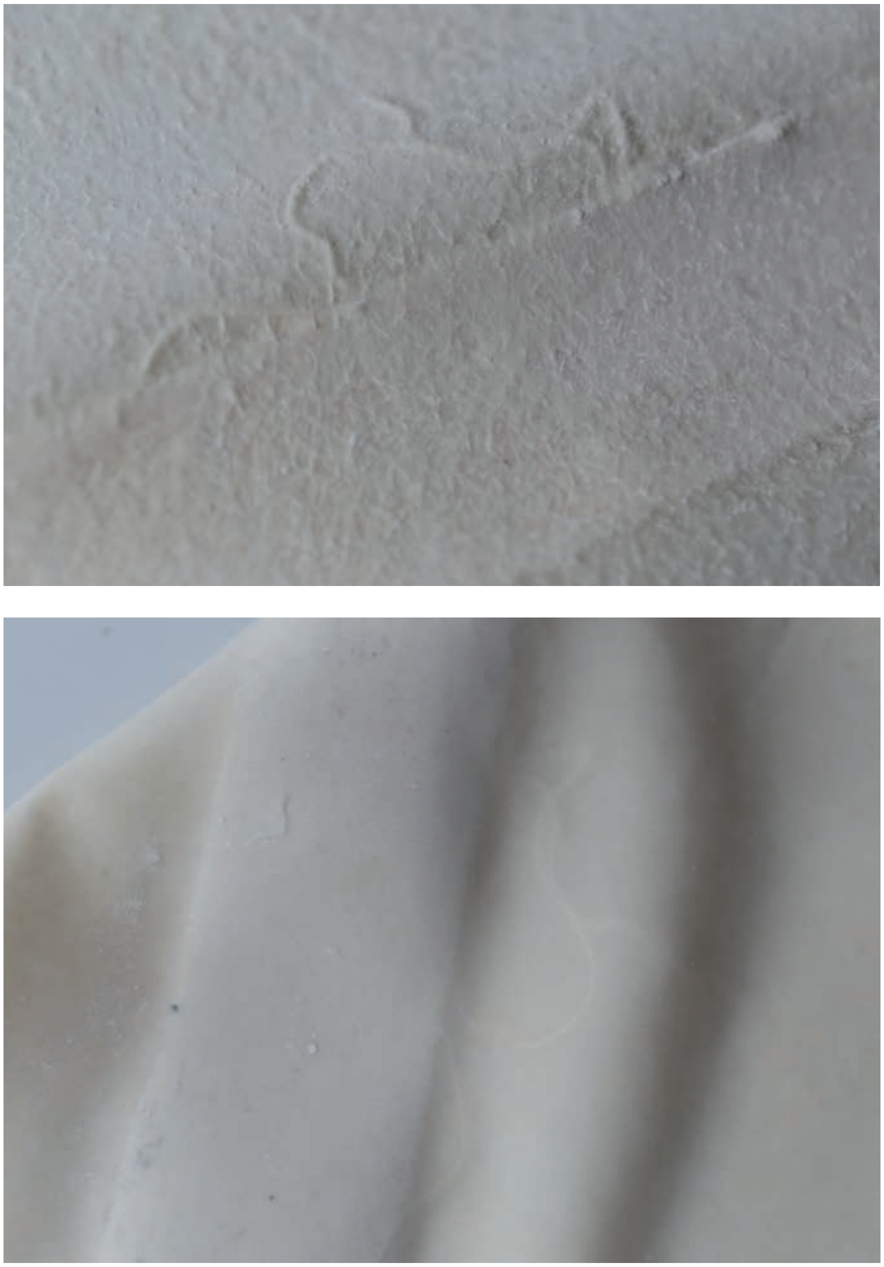


Figure 4.10.8
Macro views of cotton reinforcement embedded in a latex skin: the (top) surface retains the texture of the roller while the (bottom) surface is as smooth as the metal table against which it was cast

7. *Talc the Finished Surface*

After you have applied the desired number of layers and the surface is no longer tacky to the touch, dust talc powder over the latex surface and edges to avoid having the cast sheet stick to itself. **(4.10.9)**

Figure 4.10.9
Talc finished surface

8. *Trim the Cast*

Cut along the masking tape with an exacto knife to get a clean edge for your latex cast. **(4.10.10)**

Figure 4.10.10
Trim the edge along the masking tape

9. *Release the Cast*

Release the latex sheet from the surface against which it was cast by lifting the edges gently and working your way toward the center. **(4.10.11)** Apply talc to the newly exposed side to avoid self-adhesion. **(4.10.12)**

To increase the lifespan of your cast latex sheet, avoid exposing it to direct sun and rub it with castor oil from time to time to refresh the rubber.

Figure 4.10.11
Release the cast sheet

Figure 4.10.12
Latex surface without talc applied

Notes

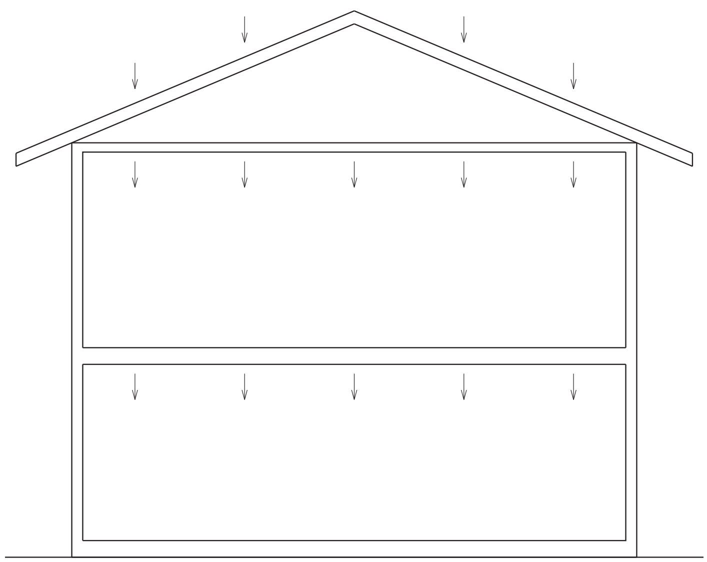
1 Thurston James, *The Prop Builder's Molding & Casting Handbook* (Cincinnati, OH: Betterway Books, 1989), 93.
2 Stanislaw Slomkowski et al., "Terminology of Polymers and Polymerization Processes in Dispersed Systems," *Pure and Applied Chemistry*, vol. 83, no. 12 (2011): 2229.
3 Anurag A. Agrawal and Kotaro Konno, "Latex: A Model for Understanding Mechanisms, Ecology, and Evolution of Plant Defense against Herbivory," *Annual Review of Ecology, Evolution, and Systematics*, vol. 40 (2009): 311.
4 Márcia M. Rippel, Lay-Theng Lee, Carlos A.P. Leite, and Fernando Galembeck, "Skim and Cream Natural Rubber Particles: Colloidal Properties, Coalescence and Film Formation," *Journal of Colloid and Interface Science*, 268 (2003): 330.
5 Sirinapa Santipanusopon and Sa-Ad Riyajan, "Effect of Field Natural Rubber Latex with Different Ammonia Contents and Storage Period on Physical Properties of Latex Concentrate, Stability of Skim Latex and Dipped Film," *Physics Procedia*, 2 (2009): 127.
6 Thurston James, *The Prop Builder's Molding & Casting Handbook*, 51.

4.11 PLANAR STRUCTURES

All physical objects, including the artifacts that you produce through the exercises in *Processes of Creating Space,* are able to transmit forces. In architecture, we harness the ability of physical objects to transmit forces to create motionless and stable structures that hold up buildings. There are three main types of forces that act upon a building:

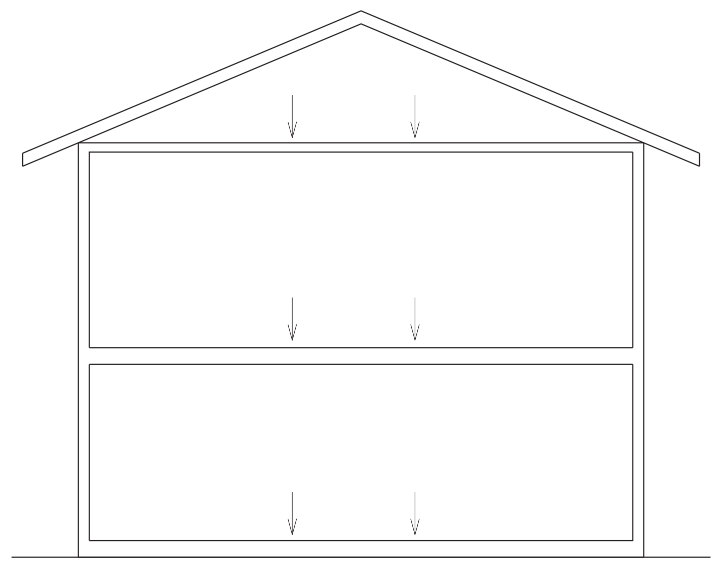
- Dead loads (relatively stable loads like the weight of the building itself). **(4.11.1)**
- Live loads (changing loads like occupants, vehicles, furniture, goods, etc.). **(4.11.2)**
- Environmental loads (wind, snow, rain, earthquakes. etc.). **(4.11.3)**

These forces cause stress in building structures, and the task of structural analysis is to makes sure that the resulting stresses are smaller than the structural capacity of the structure in all critical parts.



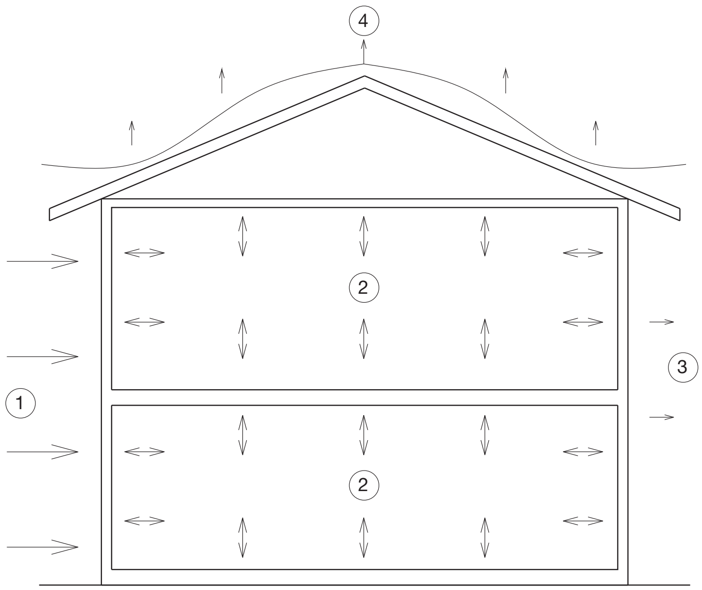
Dead loads are constant loads. For example, the weight of the intrinsic parts of a building are a dead load.

Figure 4.11.1
Dead loads



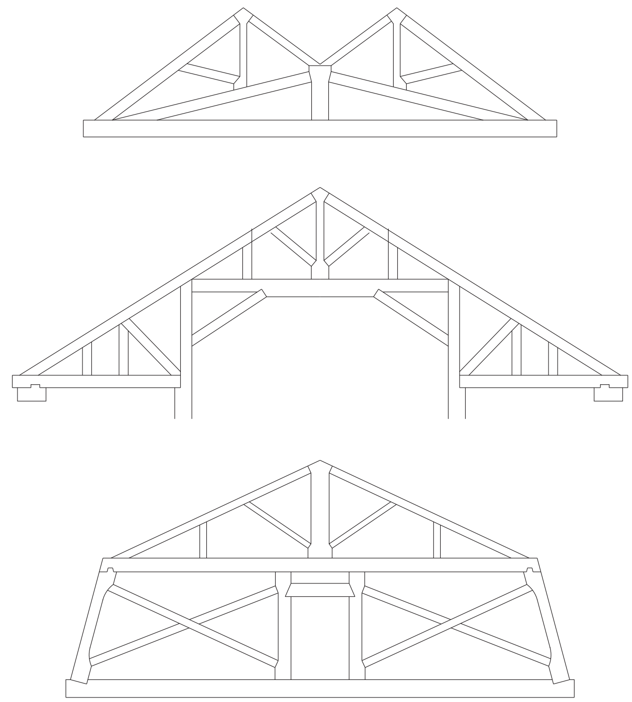
Live loads in a structure are ever-changing; people and furniture are examples of live loads.

Figure 4.11.2
Live loads



Environmental loads are forces that originate in the environment, like wind and snow. Like live loads, environmental loads are ever-changing. Forces from wind loads (1) can translate to internal pressure in a building (2) and suction (3) and uplift forces (4).

Figure 4.11.3
Environmental loads

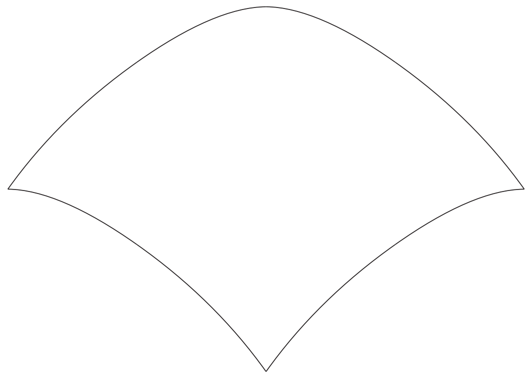


These historic roof trusses are examples of linear structures. The trusses achieve stability through the specific orientation of the linear members, the dimensions of the linear members, as well as the connections.

Figure 4.11.4
Linear structure, example

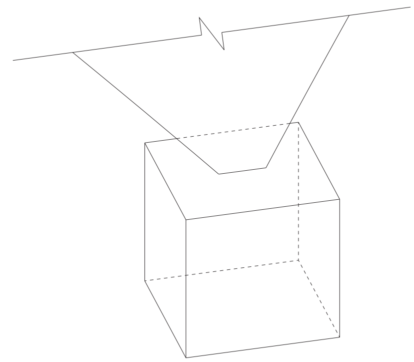
There are different methods for classifying structures. One way is to distinguish them according to their geometry. A geometric system of classification for structures has three main categories and determines the structural model used to calculate the behavior of the structure:

1. *Linear Structures*: these structures are made up of elements with a single dominant dimension. The remaining two other dimensions are comparatively small. Post-and-beam construction and trusses are made up of linear structural elements. **(4.11.4)**
2. *Planar Structures*: these structures have two dominant dimensions and one comparatively small dimension. The paper casts and the artifacts from the exercises in chapters 3.4 and 3.5 fall into this category. Walls, domes, shells and vaults are all examples of planar structures. **(4.11.5)**
3. *Volumetric Structures*: these structures are characterized by three dominant dimensions. The plaster mold pieces or the foam model from the exercises in 3.3 fall into this category. In conventional construction, a cast footing for a point-load like a column can be considered a volumetric structure (see "Glossary of Technical Terms and Materials"). **(4.11.6) (4.11.7)**



A shell is an example of a planar structure.

Figure 4.11.5
Planar structure, example



A solid footing is an example of a volumetric structure.

Figure 4.11.6
Volumetric structure, example

Figure 4.11.7
An example of a volumetric structure in a renovation context: massive concrete footings cast in excavated pockets in an existing masonry foundation distribute the point load of the steel columns

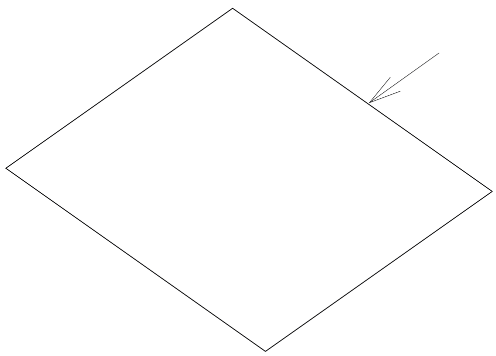


Figure 4.11.8
Shear plate

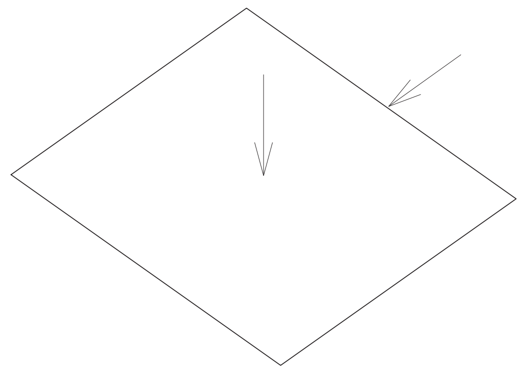


Figure 4.11.9
Plate

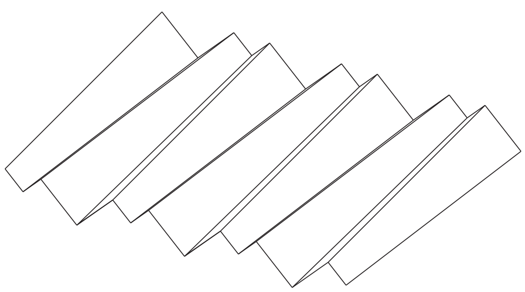


Figure 4.11.10
Folded plate

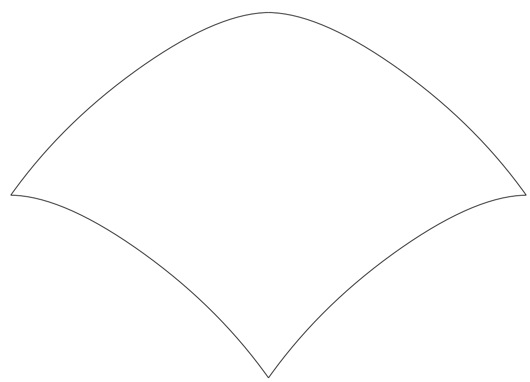


Figure 4.11.11
Shell

Planar structures, like the full-scale structures produced as part of the exercise in 3.5, can be classified further into four subcategories:

1. *Shear Plates*: these structures are flat planes with all forces parallel to the plate surface, causing stretching or compressing. Forces perpendicular to the plate surface, known as shearing forces, are negligible (see "Glossary of Technical Terms and Materials"). **(4.11.8)**
2. *Plates*: these structures are flat planes with forces parallel to the plate surface, causing stretching or compressing, and perpendicular to the plate surface, causing bending and shearing. **(4.11.9)**

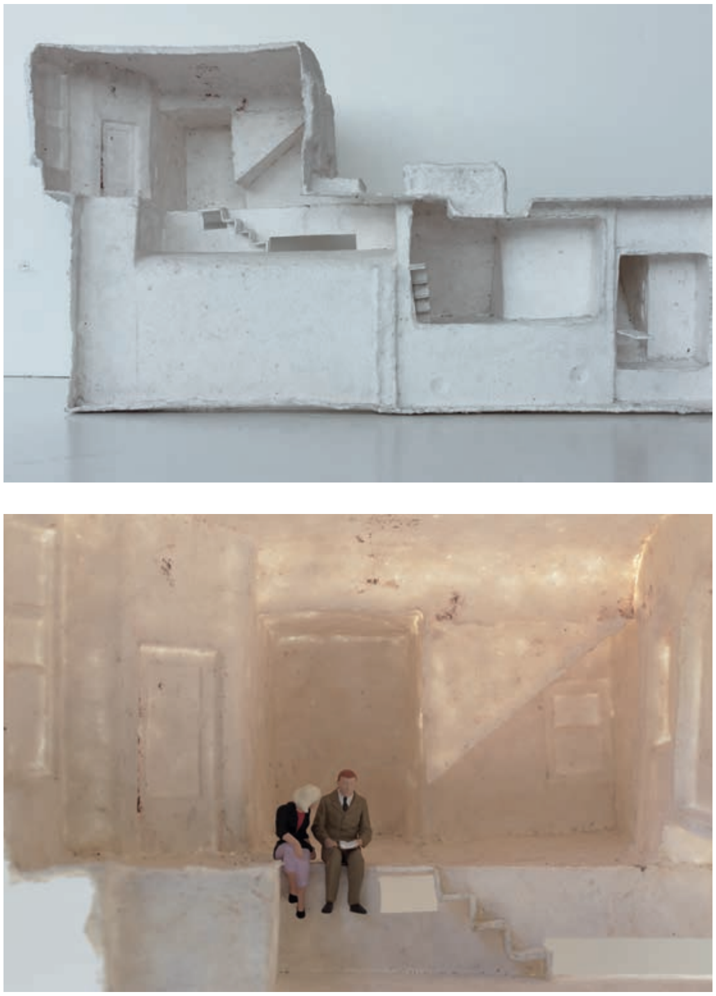


Figure 4.11.12
Scale model paper *monocoque* from the exterior, and interior view with scaled figure

3. *Folded Plates*: these structures channel forces along shearing-resistant folds and direct them as forces that run parallel to adjoining plates. **(4.11.10)**
4. *Shells*: these surfaces gain structural rigidity through continuous curvature. Shells cannot be deformed (e.g. flattened) without stretching their surface. Applied forces are redirected into stresses that run parallel to the shell surface. **(4.11.11)**

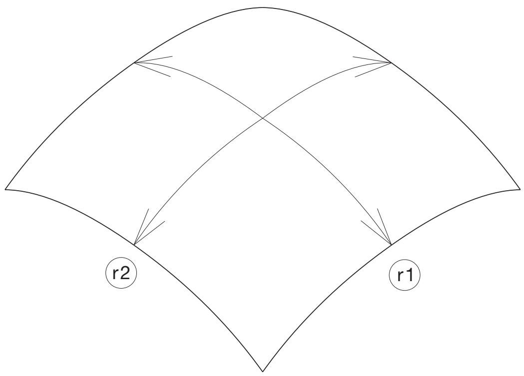
The surfaces that we are working with in exercise 3.4 and 3.5 fall into the third and fourth categories, folded plates and shells. These structures form surfaces that are not flat; they are inherently spatial. **(4.11.12)** These structures are especially relevant for our purposes because structural and spatial qualities have to be thought about in an integrated manner.

The curvature of shells is an important parameter of their structural performance. Specific types of shell curvatures can be divided into three categories:

1. Shells with two curving radii r1 and r2 oriented toward the same side. The resulting surface is double curved, not ruled and not developable (see "Glossary of Technical Terms and Materials"). This form cannot be changed without stretching the surface. Normal forces are predominant, while bending moments and shear forces are comparatively small (see "Glossary of Technical Terms and Materials"). This is the most rigid shell type. **(4.11.13)**
2. Shells with two curving radii r1 and r2 oriented toward different sides of the surface. The resulting surface is ruled but, like the previous curvature type, is non-developable (see "Glossary of Technical Terms and Materials"). The inherent lines in the surface can be bent without stretching the surface, where some bending moments or shear forces occur. This is therefore a less rigid shell type than the double curved shell. **(4.11.14)**
3. Shells with a single curving radius r1. This type of surface is ruled and developable. The cross section can be bent without stretching the surface. This shell type is subject to normal forces and bending/shear forces. It is the least rigid shell type. **(4.11.15)**

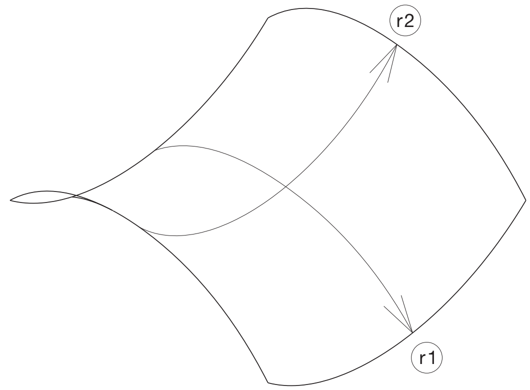
Structural principles are easiest to understand in real-world situations. Develop a habit of looking at your environment through the lens of structure; try to first identify the basic geometry of a structure —is it linear, planar or volumetric? Old structures sometimes show stress fractures which illustrate very clearly how forces are being transmitted; take note of these signs as you zoom out and look at the structure as a whole. Try to imagine the animate forces flowing down through the building into the ground.

For the purpose of the exercise in 3.5, roam your workspace, looking at the interior surfaces through the specific lens of folded plates and shells. Are there certain spots with areas and geometries that you could exploit to generate a spatial structure? **(4.11.16)**



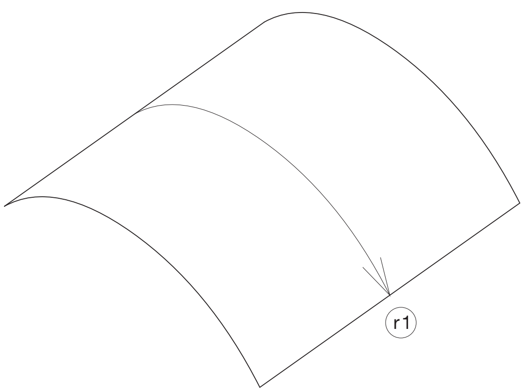
This is an example of a shell with a curvature consisting of two radii that are both oriented in the same direction.

Figure 4.11.13
Shell with two curving radii r1 and r2 oriented toward the same side



This is an example of a shell with a curvature consisting of two radii that are oriented in opposite directions.

Figure 4.11.14
Shell with two curving radii r1 and r2 oriented toward different sides



This is an example of a shell with a curvature consisting of a single radius.

Figure 4.11.15
Shell with a single curving radius r1

Figure 4.11.16
A potential site, in a student studio space interior, to support the casting of a *monocoque*

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Glossary of Technical Terms and Materials

Additive process:
In model making, an additive process involves building up a form in a piece-by-piece manner, where smaller elements ultimately make up a larger whole. It is the opposite of a subtractive process.

Adhesive bond:
Adhesive bonds between two or more materials are achieved with the use of glue, epoxy, cement or any other bonding agent.

Adjacent views:
Adjacent views are two orthographic views that are placed next to each other in such a way that the dimensions they share are aligned.

Aggregate:
In the making of concrete, aggregates are the "natural sands, gravels, and crushed stone used for mixing with cementing material."[1]

Ambient temperature:
The ambient temperature refers to the temperature of one's surroundings.

Aperture priority:
In the aperture priority mode, you set the aperture manually, and the camera sets the appropriate shutter speed accordingly.

Aqueous solution:
An aqueous solution refers to water-based liquid compositions, where water acts as the solvent in the solution.

Armature:
A framework to support the building up of a form. An armature might be temporary, and removed once the form has been defined around or on top of it, or might remain as a structural core to a form.

Axonometric projection:
An axonometric projection is constructed with lines of sight parallel to each other and perpendicular to the picture plane, where the picture plane is not parallel to any dominant plane of the object.

Bisqueware:
Bisqueware refers to objects made of clay or clay slip that have been fired one time. Bisqueware is porous, and only achieves an impermeable surface after glazing.

Buttress:
In mold making, a buttress supports a wall of a dam. In architecture, it is typically an "exterior mass of masonry set at an angle to or bonded into a wall which it strengthens or supports; buttresses often absorb lateral thrusts from roof vaults."[2]

Camera principle:
If light shines through a small hole into a dark box or space, the image of the scene in the lit environment is flipped and projected onto the surface opposite the small hole. This is the shared principle of the *camera obscura* (room sized) and the pinhole camera (object sized).

Capillaries:
Capillaries, in porous materials, are responsible for absorbing moisture: "[t]he polar water molecule 'magnet' is attracted to many materials in both the vapor and liquid state. For example, water drops will cling to your skin and to the mirror after a shower. Liquid water is actually sucked into the very small tubes (termed capillaries) present in porous materials: the smaller the tube the greater this capillary suction."[3]

Central view:
In orthographic drawing, the central view is the single view from which adjacent views are aligned.

Cinch straps:
In mold making and slip casting, adjustable cinch straps are commonly used to bind a multi-piece mold together. Wide cinch straps (around 2 in. or 5 cm) that are secured with velcro are especially suited for binding plaster molds, as they can be tightened without digging grooves in the corners of the mold.

Circulation:
In architecture, circulation refers to the ways in which people move through a space or sequence of spaces.

Clay:
Clay bodies vary widely, from high-fire porcelain to low-fire earthenware. Used as a material to make temporary dams in a mold, clay is not fired, so the clay body is not relevant. The clay used in mold making should, however, be organic clay, and not a type of synthetic modeling clay. It should be kept moist and soft, for easy handling, stored in a plastic bag or airtight container.

Clay slip:
Clay slip is liquid clay, with a higher water content than solid clay.

Contour gauge:
A contour gauge is a tool used to precisely register a profile. Contour gauges, also known as profile gauges, are often made with metal or plastic pins that can be pressed against a surface to record the profile in two dimensions.

Cottle boards:
Cottle boards, in mold making, provide an adjustable, reusable, rigid, exterior formwork.

Cotton linters:
Cotton linters are short fibers or fuzz located around cotton seeds. These fibers are separated from cotton seeds using a special machine, called a linter machine or a delinting machine. Not all species of cotton give linters; the *Gossypium Hirsutum Latifolium* yields most of the world cotton fiber production.[4]

Dam:
A dam, in multi-part mold making, is a temporary wall built inside the cottle boards, which serves to contain an area of plaster. Dams are traditionally constructed using clay, and work in concert with the cottle boards to subdivide areas of negative space around the model.

Dead loads:
Dead loads are constant loads. For example, the weight of the intrinsic parts of a building are a dead load.

Developable surface:
A developable surface can be flattened into a two-dimensional plane without stretching.[5]

DSLR:
A "digital single reflex camera" (DSLR) is a digital camera that has a mirror that reflects the image from the lens to a viewfinder. When a picture is taken, the mirror flips away and lets the image project onto a digital sensor.

Dynamic range:
Dynamic range describes the amount of contrast between bright and dark areas of an image that a camera is able to record.

Elevation:
An elevation is an orthographic view created by projecting a building façade to a picture plane that is parallel to the respective façade.

Environmental loads:
Environmental loads are forces that originate in the environment, like wind and snow. Like live loads, environmental loads are ever-changing.

Evaporation:
Evaporation is one of the phase change processes of water, and is the opposite of condensation. Water that evaporates from a porous material like plaster changes from a liquid, saturating the material, to an air-borne gas.[6]

Exothermic reactions:
An exothermic reaction is a physical or chemical reaction that emits heat. Both plaster and concrete emit heat as they cure.

Extruded polystyrene foam (XPS):
Extruded polystyrene foam (XPS) is a closed-cell foam used mainly as building insulation. It is a good model-making material to fabricate mass models, using a hot wire foam cutter.

Extrusion:
The process of extrusion creates objects with a fixed profile in section.

Flags:
In architectural drafting, flags refer to the graphic symbols used to locate specific cut views. Two flags typically show either side of a cut section, and the direction in which they point, with an arrow or just a line, indicates the direction in which we are looking in the object or space/building.

Foreshortening:
Foreshortening is the apparent shortening of elements that are not parallel to the picture plane.[7]

Formwork:
Formwork, in architecture, can be either temporary or permanent. Formwork provides a rigid container into which a liquid material like concrete can be poured.

Frontal plane:
The frontal plane is the picture plane (or plane of projection) that is parallel to the front view of the depicted object. The resulting orthographic projection is the front elevation of the depicted object.[8]

Greenware:
Greenware refers to a piece of molded clay that has not been fired. Greenware is essentially dry mud, and is extremely absorptive and fragile.

Horizontal plane:
The horizontal plane is the picture plane (or plane of projection) that is parallel to the top view of the depicted object. The resulting orthographic projection is a plan drawing.[9]

Hot wire foam cutter:
A hot wire foam cutter is a tool to cut polystyrene foam (Styrofoam and similar products) with a heated taut metal wire.

Hydrophilic substances:
Hydrophilic or “water loving” substances absorb water and are soluble in water.

Hydrophobic substances:
Hydrophobic or “water repellant” substances do not absorb water and are not soluble in water.

Interior elevation:
An interior elevation shows the elevation view of interior wall surfaces. It is an orthographic view created by projecting the wall surface to a picture plane parallel to the respective wall surface. Interior elevations show only elevational information without any cut elements, in contrast to sections.

Investment:
In mold making, investing refers to the process of embedding a model in a mass, which becomes a mold.

ISO:
The ISO setting defines light sensitivity in a camera. The base ISO setting, 100, has the lowest light sensitivity and the highest noise free resolution characteristic. As you increase ISO you increase light sensitivity (good for low light situations without a tripod) but decrease the overall image quality.[10]

Live loads:
Live loads in a structure are ever-changing; people and furniture are examples of live loads.

Mechanical connection:
A mechanical connection, unlike an adhesive connection, refers to the fastening together of two or more elements using mechanical fasteners like screws or nails.

Meniscus curve:
A meniscus is the curved surface at the top of a cylinder of liquid.

Moment:
A moment is created when a force acts perpendicular to an object without an equal and directly opposite force and makes the object twist. A typical example is a cantilever with the tendency to twist downwards.

Monocoque:
A French term referring to structural shells.

Multiview drawing set:
A multiview drawing set refers to a collection of essential views or an object, space or building, constructed using orthographic projection, formatted on a single layout. A multiview set usually consists of a plan and sections and/or elevations.

Noise (photographic):
The camera sensor translates light into an electric signal which gets subsequently amplified. This amplification process creates noise which appears as randomly placed colored dots on the digital photo.

Normal forces:
A normal force is the reaction to a force exerted onto an object. The normal force is always perpendicular to the surface upon which force is exerted.

Orthographic projection:
Orthographic projection is a type of parallel projection, in which the plane of projection is perpendicular to the parallel lines of sight. The orthographic projection technique can produce pictorial drawings that show all three dimensions or multiview orthographic drawings that show only two dimensions of an object in a single view.

Parallel projection:
Parallel projection refers to a drawing method where a view is constructed using lines of sight which are parallel to one other.

Perspectival projection:
Perspectival projection refers to a drawing method where a view is constructed using lines of sight which converge at a station point, representing the eye of the viewer.

Plan:
A plan is an orthographic projection representing a horizontal cut through a building with the picture plane parallel to the floor plane of the building. The cut plane is taken typically at about 4 ft (1.2 m) above the respective floor plane in order to cut window openings and doors in the walls.

Plaster (USG No.1 pottery plaster):
Plaster is made of calcium sulfate that is ground and heated after mining. USG (United States Gypsum Corporation) No.1 pottery plaster is optimized for a high degree of water absorption, making it well suited for mold making and slip casting.[11]

Plywood (marine grade):
In multi-part mold making, cottle boards and baseplates are exposed to a considerable amount of moisture. When left untreated, standard plywood can delaminate and develop mold if exposed to moisture often. Using marine grade plywood, a type of plywood with a more moisture-resistant face and core veneers, will give your cottle boards a longer life.

Poché
The French term, with an acute accent on the e, is sometimes anglicized and referred to as poche. Both terms reference the graphic style in drawing where the thickness of a cut wall, for example, is shown as solid black.

Point load:
"A load concentrated over a tiny area."[12]

Profile plane:
The profile plane is the picture plane (or plane of projection) that is parallel to the side view of the depicted object. The resulting orthographic projection is the side elevation of the depicted object.[13]

Registration mark:
In multi-part mold making, a registration mark, also known as a key, is a notch shared by two pieces, one with a negative notch and the other with a positive notch that enables the mold to be assembled tightly and precisely.

Related views:
In orthographic drawing, related views are two views that are adjacent to a shared, central view.

Release agent:
In multi-part mold making, a release agent, also known as mold release, is a hydrophobic substance that prevents one plaster mold piece from bonding to another. It is applied to all surfaces that should ultimately "release" away from the plaster. Petroleum jelly is a commonly used release agent.

Ruled surface:
Ruled surfaces describe a volume in which, at every point of the surface, a straight line can be placed. Although straight, the lines which describe the surface are not horizontal or vertical.

Scale:
Scale in the context of architectural drawings refers to "[a] drawing of an object or structure showing all parts in the same proportion of their true size."[14]

Section:
A section is an orthographic projection representing a vertical cut through a building with the picture plane being perpendicular to the floor plane of the building. The cut plane is taken typically through important spaces, spatial arrangements and stairs. Avoid to cut through elevator shafts, as they will appear as solid vertical barriers in your section drawing.

Shear force:
Shear forces are created when forces push on opposite sides onto an object and are not aligned.

Shutter priority:
In the shutter priority mode you set the shutter speed manually, and the camera sets the appropriate aperture value accordingly.[15]

Subtractive process:
In model making, a subtractive process involves starting with an oversized mass and cutting away parts of the mass until the desired form is achieved. It is the opposite of an additive process.

Telephoto perspective distortion:
Telephoto distortion is a perspective distortion that occurs if you use long focal length lenses. The distance between objects and space in general appears unnaturally compressed.

Undercut:
"An undercut is an indentation in a side facet of a pattern (or mold) that allows a casting material to get a locking grip on its surface. Undercuts prevent easy removal of the casting and are usually avoided at all costs."[16]

Wheat paste:
Wheat paste is a gel or paste made from mixing wheat flour with water.

Wide-angle perspective distortion:
Wide-angle distortion is a perspective distortion that occurs if you use short focal length lenses. The distance between objects and space in general appears unnaturally enlarged.

Notes

1 *McGraw-Hill Dictionary of Scientific and Technical Terms*, sixth edition, s.v. "aggregate."
2 Cyril M. Harris, ed., *Dictionary of Architecture and Construction,* fourth edition (New York: McGraw-Hill, 2006), 158.
3 John Straube, "Moisture and Materials," *Building Science Digest,* 138 (October 2006): 3, http://buildingscience.com/documents/digests/bsd-138-moisture-and-materials.
4 "Cotton Linters: A Valuable Raw Material for Paper Industry," *Paper Mart: A Bi-monthly Magazine for Pulp, Paper & Converting Industries in India*, July 4, 2012, accessed September 12, 2015, http://papermart.in/2012/07/04/5622/.
5 David Hilbert *and Stephan* Cohn-Vossen, *Geometry and the Imagination*, second edition (New York: Chelsea Publishing, 1952), 341–342.
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7 Douglas Cooper, *Drawing and Perceiving* (New York: John Wiley, 2001), 202.
8 Gary R. Bertoline, Eric N. Wiebe, Craig L. Miller and James L. Mohler, *Technical Graphics Communications*, second edition (Boston, MA: McGraw Hill, 1997), 379.
9 Bertoline et al., *Technical Graphics Communications*, 381.
10 Adrian Schulz, *Architectural Photography* (Santa Barbara, CA: Rocky Nook, 2012), 113.
11 Jonathan Kaplan, "Know Your Plaster," *Ceramic Arts Daily*, accessed October 31, 2015, http://ceramicartsdaily.org/wp-content/uploads/2010/06/knowyourplaster.pdf.
12 Harris, *Dictionary of Architecture and Construction*, 746.
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14 *McGraw-Hill Dictionary of Scientific and Technical Terms*, sixth edition, s.v. "scale drawing."
15 Schulz, *Architectural Photography*, 110.
16 Thurston James, *The Prop Builder's Molding & Casting Handbook* (Cincinnati, OH: Betterway Books, 1989), 27.

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