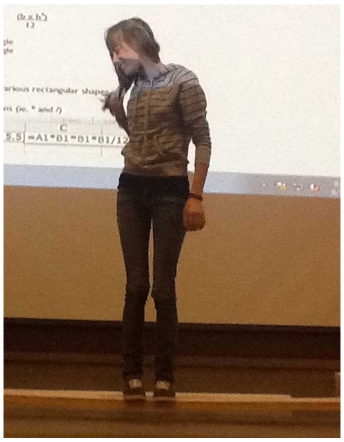
Building relationships:

Introducing construction and structural logic through detailed Building Information Modeling

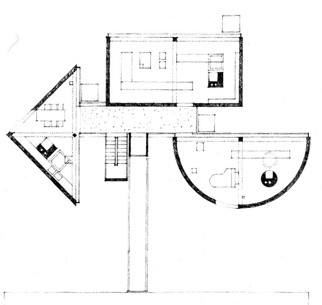


The recalibration of practice in the era of Building Information Modeling represents a unique opportunity in architectural education to bridge an age-old chasm between compositional design and construction reality. To an inexperienced designer, design tends to follow a process that moves from abstract ideas to details as a one-way operation. Our curriculum is centered around the idea that discovery at the detail level can re-inform an early gesture, and lays a foundation that prepares students to engage with the art of making a building at every scale.

The "team" in this project consists of 120 sophomore students in a semester-long conversation with their instructor and graduate assistants around the virtual construction of a simple building.

The pedagogical approach presented introduces beginning students to the concepts of Building Information Modeling and parametric design with an eye to the eventual completion of a three-dimensional building model that would lend itself to direct digital fabrication processes.

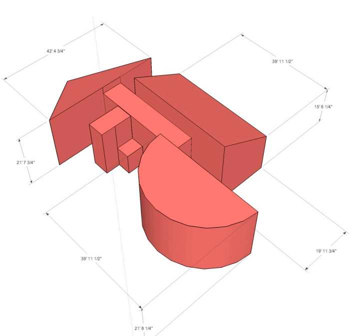
Our approach assumes that BIM, practiced at the level of modeling individual components of construction, will soon be commonplace and that we should prepare our students for a practice in which the complete, virtual model of a building and all of its components will be an expectation instead of a unrealistic goal.



The strategy articulates a practical methodology to move students with little to no construction or parametric modeling background to thinking about relationships and first principles of structure and construction, preparing them for advanced level coursework and the future BIM-to-digital-fabrication practice reality.

There are many examples of strong academic efforts to integrate Building Information Modeling with most of the well-documented cases occurring in upper levels of the curriculum. There are few examples of foundation or introductory levels of BIM integration in curricula.

Consequently, this effort focuses on an introductory Design Science course for sophomore students who have never heard the terms parametric modeling or BIM and have no experience in 3-D computer modeling or the art of integrating building systems and construction detailing into design.



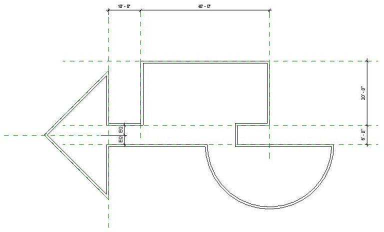
PEDAGOGICAL FRAMEWORK

Providing a large sophomore class of 120 students with a tailored learning experience led to the selection of the Half House by John Hejduk as the instrument for developing a parametric BIM construction experience. The three separate geometries of the Half House lend themselves to independent modeling of three different construction types based on three different structural systems and the creation of several variables that give each student a unique building experience. Each student inherits a set of variables based on their ID and includes alternative slopes for the site, differing sizes of geometry, varying the construction type, etc.

The overarching goal of the course is to continually reinforce the concept of modeling relationships rather than simply modeling components of construction as static elements. Classes typically include a lecture component and an in-class "lab" where students follow the construction modeling process on their own laptops.

This relationship-building exposes students to the power and potential of parametric modeling with the expectation that construction and structural logic will inform design logic in the studio.

COURSE CONCEPTS



Regulating Lines and Levels

Given the simplicity of the form, major regulating lines, driven by the individual student's dimensions, are produced directly as part of the project in both plan and elevation. Students do not often immediately grasp why they are asked to begin their model this way. But it becomes abundantly clear as soon as they need to adjust a major aspect of their construction.

Material Distribution

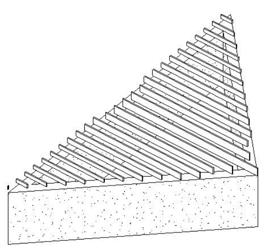
The first content area covered in the class is simple wood frame construction, which provides a relatively straightforward introduction to the complexity of structure and construction. On the first day of entering the class, students are asked to "walk the plank"—a 12' long 2" x 8" supported at either end with wood blocks This experience launches the discussion about the designer's responsibility for the distribution of material and the patterns of that distribution. After a brief foray into calculating the Moment of Inertia for simple rectangular beams the focus shifts to modeling this behavior parametrically as a simple element that grows in depth proportionally to the length of the span.

SOUTHERN PINE SPAN TABLES

Maximum spans given in feet and inches
Inside to inside of bearings

TABLE 3 FLOOR JOISTS – 50 PSF LIVE LOAD, 10 PSF DEAD LOAD, 360 DEFLECTION

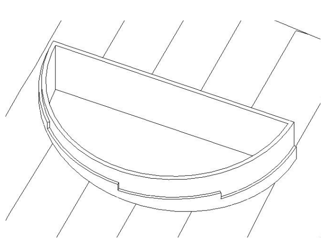
Size inches	Spacing inches on center	Grade									
		Visually Graded				Machine Stress Rated (MSR)			Machine Evaluated Lumber (MEL)		
		SS	No.1	No.2	No.3	2400f - 2.0E	2250f - 1.9E	1950f - 1.7E	M-23	M-14	M-12
2x6	12.0	10-4	10-2	9-11	8-6	10-9	10-6	10-2	10-4	10-2	9-11
	16.0	9-5	9-3	9 -1	7-4	9-9	9-7	9-3	9-5	9-3	9-1
	19.2	8-10	8-8	8-6	6-9	9-2	9-0	8-8	8-10	8-8	8-6
	24.0	8-3	8-1	7-9	6-0	8-6	8-4	8-1	8-3	8-1	7-11
2x8	12.0	13-8	13-5	13-1	10-10	14-2	13-11	13-5	13-8	13-5	13-1
	16.0	12-5	12-2	11 - 11	9-5	12-10	12-7	12-2	12-5	12-2	11-11
	19.2	11-8	11-5	11-3	8-7	12-1	11-11	11-5	11-8	11-5	11-3
	24.0	10-10	10-8	10-0	7-8	11-3	11-0	10-8	10-10	10-8	10-5
2x10	12.0	17-5	17-1	16-9	12-10	18-0	17-9	17-1	17-5	17-1	16-9
	16.0	15-10	15-6	14 - 8	11-1	16-5	16-1	15-6	15-10	15-6	15-2
	19.2	14-11	14-7	13-5	10-1	15-5	15-2	14-7	14-11	14-7	14-4
	24.0	13-10	13-4	12-0	9-1	14-4	14-1	13-7	13-10	13-7	13-3
2x12	12.0	21-2	20-9	19-10	15-3	21-11	21-7	20-9	21-2	20-9	20-4
	16.0	19-3	18-10	17 - 2	13-2	19-11	19-7	18-10	19-3	18-10	18-6
	19.2	18-1	17-9	15-8	12-1	18-9	18-5	17-9	18-1	17-9	17-5
	24.0	16-10	15-11	14-0	10-9	17-5	17-1	16-6	16-10	16-6	16-2

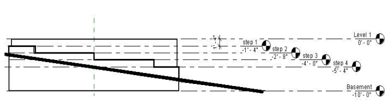


At a more detailed level, we consider and model a typical 16" on-center deployment of joists and discuss how the different spacing and grades of lumber in the Southern Pine Span Table affect the joist's ability to span. Students then create their first if-then statement that drives the depth of their parametric element based on the length utilizing values extracted from the Southern Pine table.

By experimenting with the dynamically adjusting joist, the students learn that the design must somehow address material distribution according to the principles of physics.

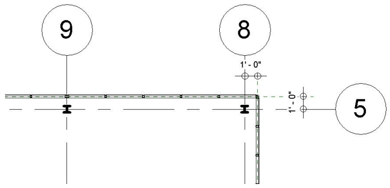
This experimentation provides students with a graphic, diagrammatic, intuitive understanding of a fundamental principle of beam theory and its relationship to material choices and design.

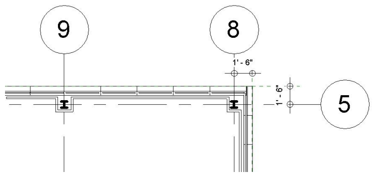




References and Relationships

Emphasis is continually placed on defining relationships rather than modeling static elements. The clear advantage of this approach is that if change is necessary (which it often is with inexperienced designers) it would not require complete remodeling or starting over. As an example of this approach, consider the relationship between a brick ledge and a sloping site. Since each student models their own slope it is unlikely that two slopes will be identical. Consequently, the focus shifts to defining the logic using reference planes to drive the configuration. As students follow along and

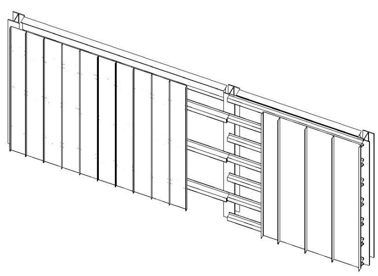


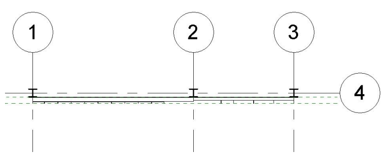


model this logic, it is trivial then to "tune" their model according to their specific conditions and dimensions. Once the logic is clear, students use their references in order to associate a brick ledge appropriately in their model.

Another example of the use of references used to articulate relationships is the distance between the exterior reference line that defines the form and the line of a structural bay. This relationship can vary greatly based on the specifics of the envelope, the size of the columns, or the depth of the girts to name a few.

By modeling relationships as variable, students can quickly adjust their models to accommodate the specifics of their design choices.





Everything is Structural

All construction obeys the laws of physics and as such, the logic of structure applies, whether it is a series of joists resisting gravity loads or a series of girts that withstand wind load. While it may seem unintuitive to model girts using the same strategy for a system of joists, the first principles and rules for distributing material apply to both. As the thickness of the final layer increases, its Moment of Inertia and capacity to span increases, which in turn allows the spacing of the girts, furring strips or stringers to increase. Students quickly develop intuitive understanding of the inverse relationship between the size of members and the necessary number of members. They also see that this choice has a visual affect that may or may not be consistent with design aspirations.

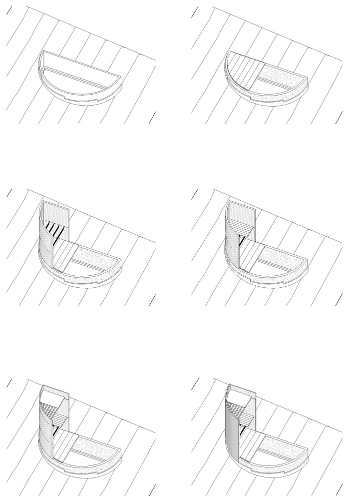
Girts in this case are simple sections that dynamically adjust their depth based on span. As the spacing between columns changes the girts grow in depth accordingly. Since the line of the exterior envelope has already been related to the grid line that controls the position of the columns, adjusting the distance between them to accommodate the combined thicknesses of envelope and girt is an easy task.

Modeling the Layers of Construction.

While architects customarily think of a wall assembly as a final unit, the reality of construction is that the layers in a typical wall section are assembled in a very particular order. There are several advantages to this approach; none the least of which is the ability to match the evolving model to photographs of construction as well as providing the ability to incrementally model aspects of construction as they are learned. Consequently, we model structure first, then outside envelope then interior lining.

As a teaching tool, this approach lends itself well to discussing the sequence of construction and introducing concepts of construction incrementally.

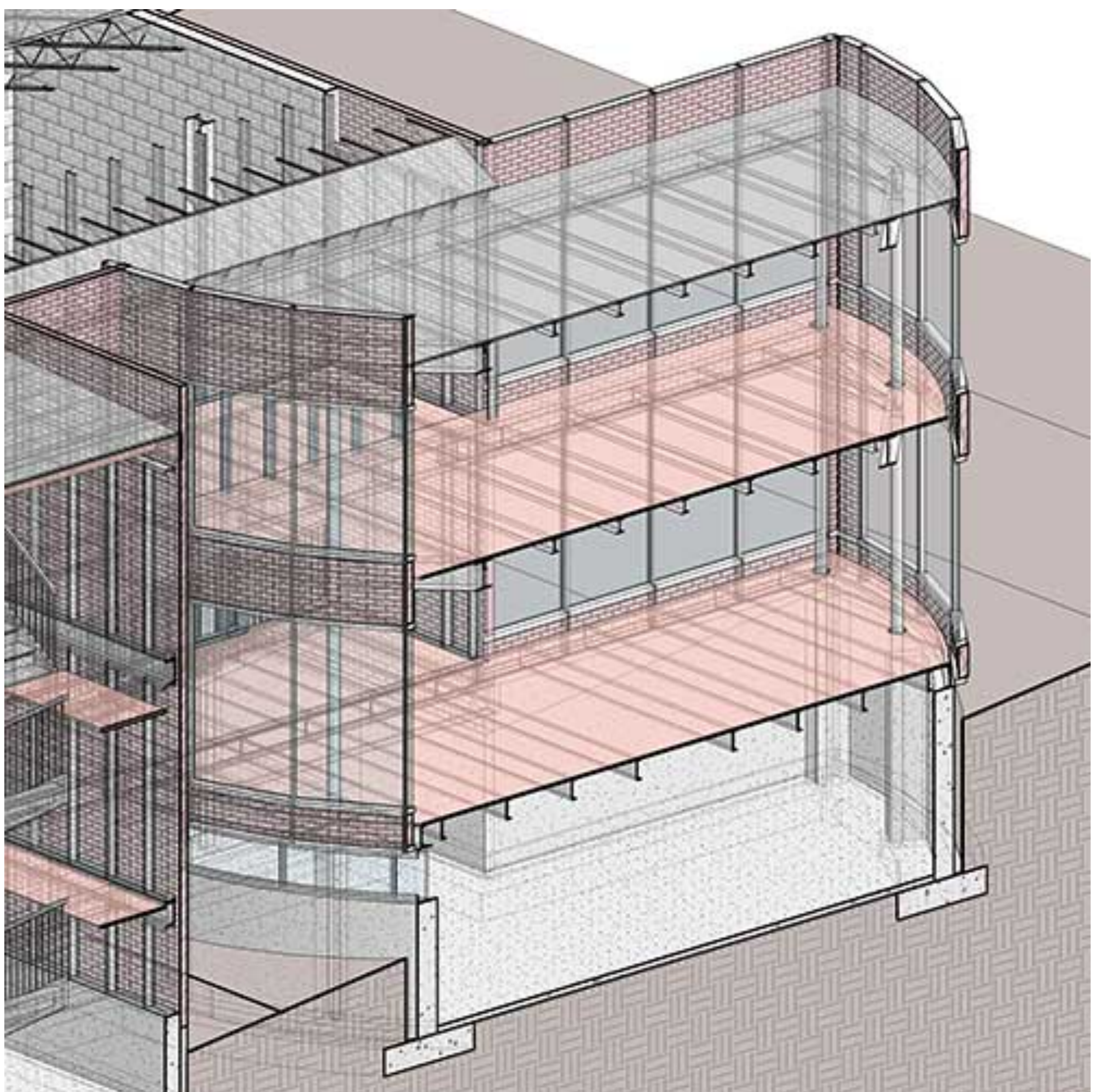
Another advantage of this method is the ability to define the relationship between the exterior skin, the structural wall, and the interior lining by tying them to reference lines as well. This separate modeling strategy forces a more conscious act of design than a single broad-brush stroke of a

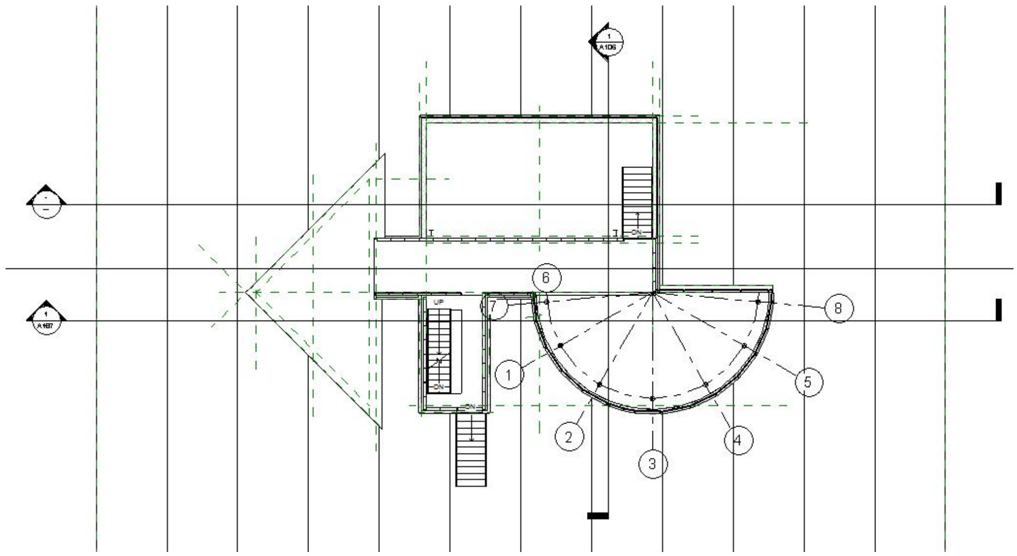


single wall. Furthermore, with all the layers separately built, it is a rather trivial task to adjust one layer of construction without remodeling or redefining the assembly. In this way, students are able to explore various envelope materials, bearing wall thicknesses or interior linings as separate assemblies instead of modifying the composition of the entire assembly each time.

END NOTE

As an introductory construction and BIM course the focus was more on building the skills and understanding of the potential of a parametrically built, detailed model. The data exchanges occurred throughout the term as a feedback loop between the students and the instructor/graduate assistants. The images that follow are a single student's project completed during an academic term.

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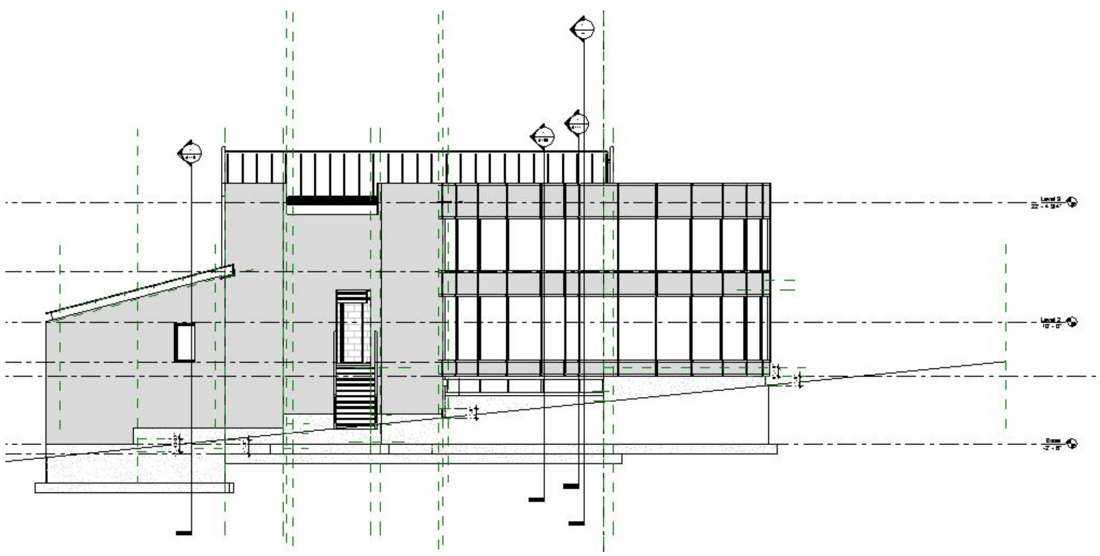


2nd floor
15' - 2 1/2"
1st floor
5' - 10 3/4"
basement hallway
-3' - 6 1/2"