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Architectural Tectonics and Structural Systems

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Abstract

This paper examines, through lectures and tutorial assignments, architectural tectonics and structural systems, to provide undergraduate architecture students with a comprehensive understanding of how structural principles interact with architectural design or spatial quality.

The lectures guide students in analyzing case studies in Japanese architecture and engaging in hands-on exercises. Thus, the students develop critical thinking skills and creative problem-solving abilities in basic structural design and engineering. The tutorial assignments guide students through the iterative design process: from initial space study to basic structural systems and the ideas for integrating them. A structure rulebook, which is the original material provided, assists in effective communication between architectural and engineering disciplines.

In summary, through architectural tectonics, this paper studies the spatial qualities in both architectural design and structural design. Accordingly, even a subpar proposed space can be improved based on the choice of the structural system alone. Through this teaching approach, this paper highlights that undergraduate students studying architectural design can gain broad general knowledge of the fundamentals of architectural tectonics in the structural field.

Keywords: architectural tectonics, special quality, architectural student, archi-(tec)tonics, structural design, undergraduate.

1. Introduction

This teaching approach consists of lectures and tutorial assignments. Undergraduate students will be taught a new design theory called "architectural tectonics." It is not yet precisely defined, but it is generally recognized as a term related to structural analysis, construction methods, and local context details. This trend is reflected in the theory of tectonic culture, as suggested by Kenneth Frampton. (1) Moreover, this paper examines the meaning of tectonics further as it applies to structural or constructive approaches to design, including esthetic considerations. Clarifying the thought process behind a structural system can help them to understand the techniques in architectural tectonics. Furthermore, if the definition of architectural tectonics or technological inspiration is not limited to designing structural objects, students would be able to learn the important qualitative and quantitative aspects of tectonics, which would allow them to deeply explore sustainable design as well.

2. Description of study scheme

This paper introduces the basic principles of tectonics in architecture by presenting basic structural systems and their relationship to construction details and techniques. This work will guide undergraduate architecture students on the structural properties of materials and their impacts, structural systems, and building components, which all contribute to an integrated architectural design. This paper discusses tectonics as an expressive quality of architecture and structures from the perspective of materials, construction, construction details, and the integration of building components. This study also explores sustainability by incorporating both qualitative and quantitative thinking in lecture series and tutorial assignments.

2.1. The values of this approach

The primary objective is to enable the broad acquisition of general knowledge regarding one of the basic structural rules in architecture and fundamental insights into tectonics in the structural field by undergraduate students of architectural design rather than engineering. This study aims to expand the thinking on how tectonics affects the designed space. Structural knowledge would benefit architecture students. We expect them to show higher spatial quality in their structural proposals such that the architecture can qualify as archi-(tec)tonics. In other words, architectural tectonics goes beyond structural design, engineering, or construction and teaches more than merely structural design or engineering.

2.2. Learning outcomes

- Understand sustainability and construction.
- Understand the integrated and inter-related nature of building components.
- Understand the fundamental principles of materials and construction.
- Demonstrate the integration of building components to achieve the architectural design.
- Understand the integrative relationship of architecture, structure, and construction in achieving tectonic quality.
- Understand structural design.

2.3. Assessment strategies and student's evaluation

- Attendance status and communication skills as a group (10% formative)
  Assess students' outcomes every week for their design proposals, and their ability to articulate their ideas clearly and effectively with tutors in structural principles terms.

- Project-based portfolio assessment as a group (20% formative, 50% summative)
  Assess students as a group (maximum four people) and compile a portfolio showcasing their design process, project narrative, and reflections throughout all outcomes. This provides a comprehensive overview of their progress and allows for the assessment of their development over time. The portfolio document provides some formats (fixed page layout) to get a sense of students' awareness of structural constraints, and hence students are expected to present their originality.
  All tutors will jointly check all projects of the portfolio and discuss grades. Assignment projects will be designed to assess students' understanding of architectural tectonics and their ability to integrate structural principles into architectural design or spatial quality.

  Note that a tutor will not decide grades as independently, and portfolio documents that do not follow the formats will be flagged and penalized.

- Project based on a cross-sectional perspective as an independent (20% summative)
  Asses a cross-sectional perspective with basic information filled in black and white (not in color). The most important consideration is to refer to the structure rulebook and correctly present the size of the designed structural dimensions, such as columns, beams and slabs. In addition, users and furniture are expected to be presented, including how a designed space can be used. Originality involving varying the thickness of the lines to create depth in the 2D drawings is expected.

3. Lecture series and flow

This lecture series delves into how structural aspects are influenced by Japanese architects influence structural aspects.

3.1. Lecture series

The lectures focus on structurally distinctive architecture and different structural types; the cases elucidate these structural systems and explain how they were constructed, including Sendai Mediatheque (steel rigid), 21st Century Museum of Contemporary Art Kanazawa and Rolex Learning Center (steel brace), Musashino Art University Museum & Library (exceptional steel rigid), Gunma Museum of Modern Art (reinforced concrete (RC) rigid), and Teshima Museum (RC shell). The Sannomarusquare (timber) and the 4 episodes (seismic renovation using timber, steel, and RC) are exceptional cases. Students learn the relationship between architectural design and structural design from this experience; structural design is not only the design of the frame but also an important element that influences the form of a space. This is the first step in developing student interest in structural design.

At the beginning of the lecture, students watch a video on architecture without explanations being offered, and the aspects of the architecture that they focused on are noted. Then, after explaining both architectural design and structural design, they watch the same video again. This process will involve discussions based on their notes so that they can notice new aspects of the architectural features to draw comparisons between what they focused on initially and later, and tutors and students discuss the integration of tectonics into the designed space. Notably, because they already shared their comments through notes, questions or opinions need not be invited. Rather, this dialogue aims to automatically create an active learning opportunity, as students will not be afraid to engage in this discussion.

3.2. Lecture flow

- Week 01: Introduction/Tectonics in architecture
- Week 02: Archetypes and Structural systems
- Week 03 + 04 + 05: Steel structure 01, 02, 03
  The Sendai Mediatheque (steel rigid), the 21st Century Museum of Contemporary Art Kanazawa, the Rolex Learning Center (steel brace), and the Musashino Art University Museum & Library (exceptional steel rigid).
- Week 06 + 07 + 08: Concrete structure 01, 02, 03
  Gunma Museum of Modern Art (RC rigid), En Park Shiojiri-City Community Center (RC wall), and Teshima Museum (RC shell).
- Week 09: Interim
- Week 10 + 11: Exceptional cases
  Sannomarusquare (timber), 4 episodes (seismic renovation using timber, steel, and RC)
- Week 12: No Lecture (production week)
- Week 13: Presentation

4. Tutorial flow and Assignments

The tutorial project involves proposing a four-story building as a public gallery, and the building width, depth, and height are each 18 m. other spaces, such as toilets, an office or reception, are needed, they can be freely added.

4.1. Tutorial flow

The assignment flows from P1 to P4 are as follows.

- Week 01 + 02: P1/proposal of a first space study in a 1/100 physical model
- Week 03 +04 + 05: P2a/proposal of a structure studies in a 1/100 physical model
- Week 06 + 07 + 08: P2b/proposal of a structure studies in a 1/100 physical model

- Week 09: Interim
- Week 10: P3/proposal of an integration idea in a 1/100 physical model
- Week 11: P4/a section perspective drawing in 1/50
- Week 12: No Tutorial (production week)
- Week 13: Presentation

Students can change the design of P1 proposal while they design for the development idea or structural issues afterward. However, P3 and P4 proposals should align with P2a and P2b.

4.2. Structure rulebook

During P2a and P2b works, structure rulebook 1 (a total number of pages: 16) is provided, which is an original guidebook for structural systems that is used for the assignment project. Students experience thinking in terms of architectural design from an engineering perspective. To learn this, the approach of sharing structural engineer's common sense (manner) is used. This book aims to teach architecture students the essence of the common sense to assist in future collaborative work with structural engineers.

4.2.1. How to apply the structure rulebook

The structure rulebook introduces two structural systems: a steel frame structure and a RC frame structure. The steel frame structure consists of a rigid structure and a brace structure system, whereas the RC frame structure consists of a rigid structure and wall structure.

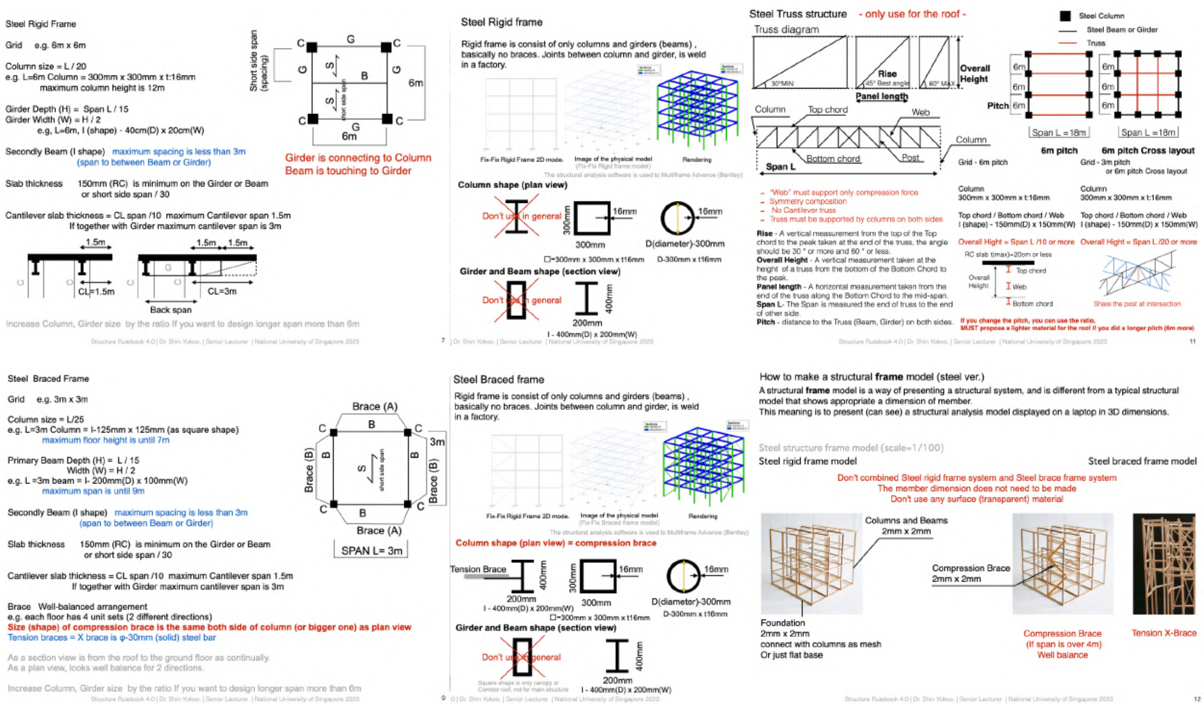

Figure1: A part of the structure rulebook 1 (For P2a: steel structure part)

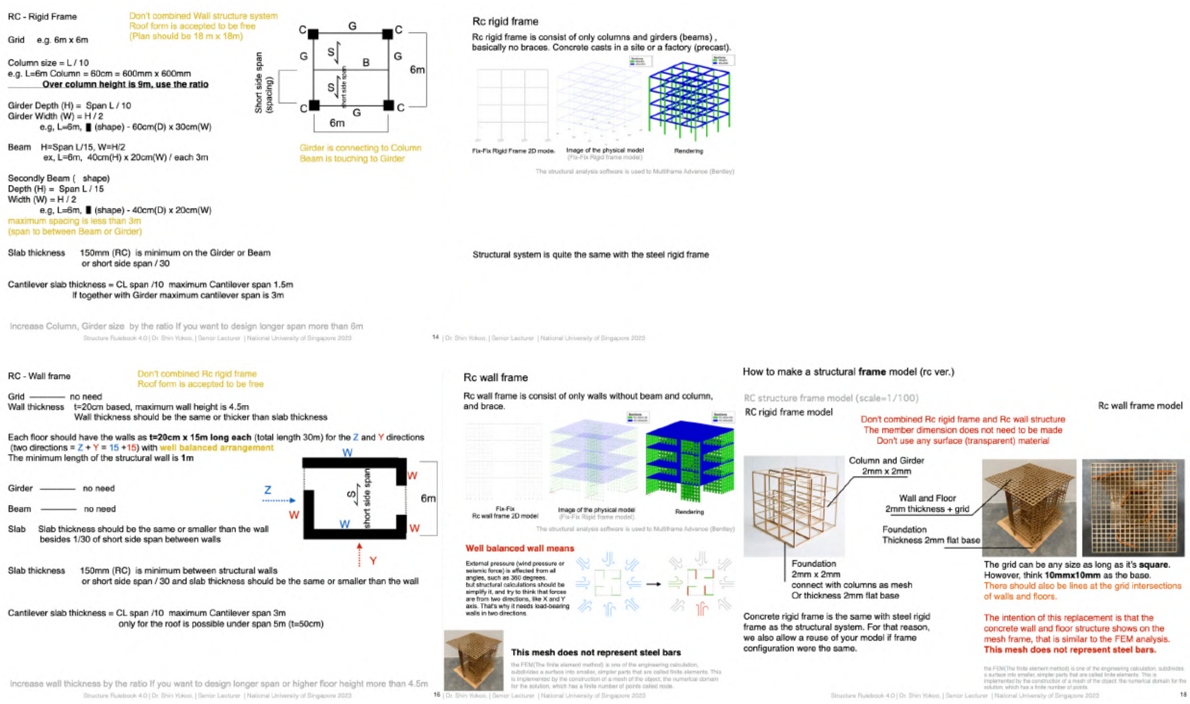

Figure 2: A part of the structure rulebook 1 (For P2b: RC structure part)

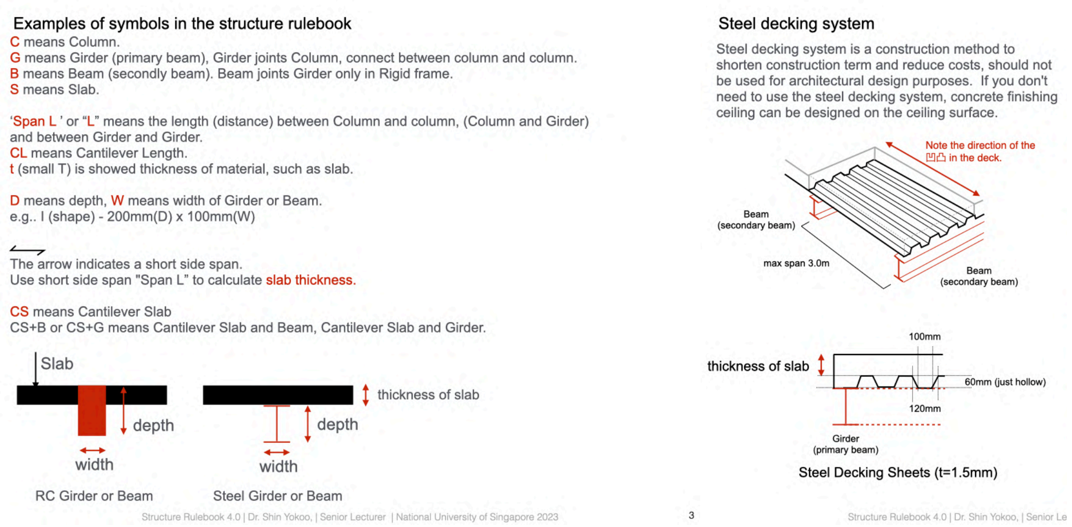

Figure 3: A part of the structure rulebook 1

4.3. Tutorial Assignments: project information

The project site is located in an urban area surrounded by office buildings of similar height. However, a park is situated next to the site, and only one of the four facades faces the park. This project challenges students to propose the following three points.

- Propose an open space for creating a connection to a park and between the upper and lower floors, such as an atrium or skip floors.

- Provide two different evacuation “stair routes” from the top floor to the street in accordance with a general building standard law. Proposing a space structure in which the flow line does not follow a one-stroke path from the entrance to the exit would be better.
- Students cannot change the shape of the building (18 m width, 18 m depth, and 18 m height), and a small roof design is unacceptable. The roof outline should be 18m × 18m.

4.4. P1/proposal of the first space study as 1/100 physical model

This proposal is not for the design studio, and there is less emphasis on proposing an interesting space (shape) and building program. The first space study would be acceptable, as it seems to be a rough model. Here, the quality of the physical model is not focal. However, the three points mentioned above should be featured.

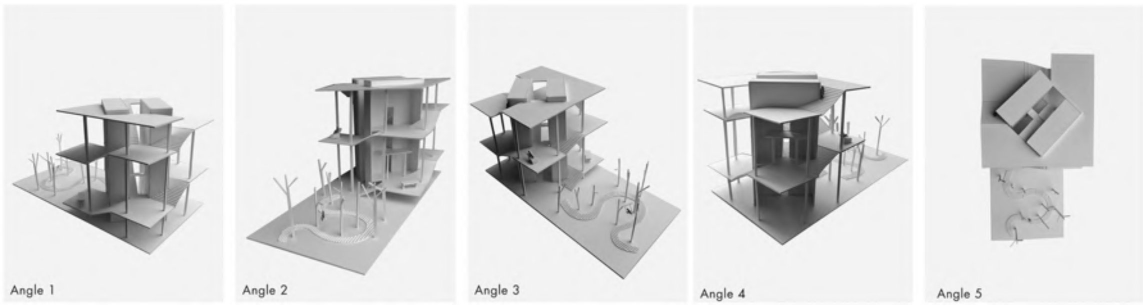

Figure 4: A first space study as a 1/100 physical model
(project by: Dominic Chia, Darien Too, Seah Jia Jun, Abdul Muqsith)

4.5. P2a and P2b/proposal of structure studies in a 1/100 physical model

After designing a space study model, students propose a steel structure (P2a) and RC structure (P2b), referring to the structure rulebook, through a physical frame model in a 1/100 scale. Moreover, some variations in the digital or physical model are expected until the end of the term.

4.5.1. P2a: proposal of a steel structure study in a 1/100 physical model

The steel structure physical model is created with a 2 mm square (wooden) member, and slabs are not required except in important cases. However, if they are included, beams should also be added. The same is applied to a steel rigid frame or steel brace frame. If X-braces are required, they should be 1 mm.

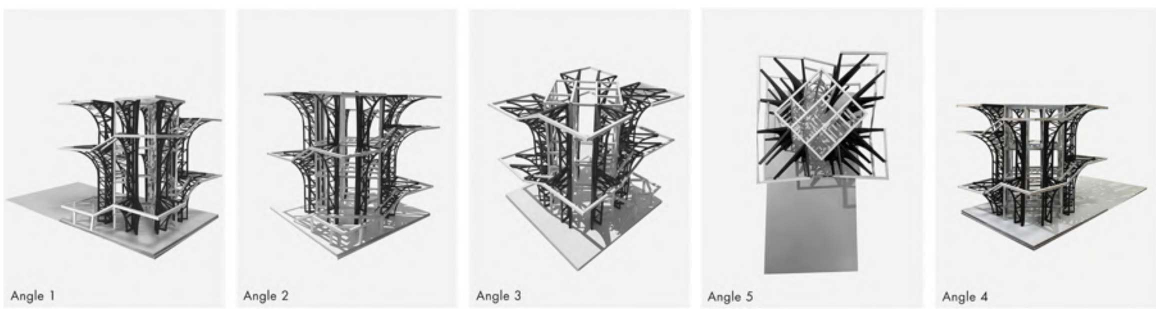

Figure 5: Proposal of a structure study as a 1/100 physical model (steel frame structure - brace type)
(project by: Dominic Chia, Darien Too, Seah Jia Jun, Abdul Muqsith)

4.5.2. P2b/proposal of a reinforced concrete structure study in a 1/100 physical model

The RC structure is manufactured with 2 mm square (wooden) members, and only the RC wall structure has a slab. Instead of beams, the slab is a square mesh with as many meshes as possible, similar to the wall.

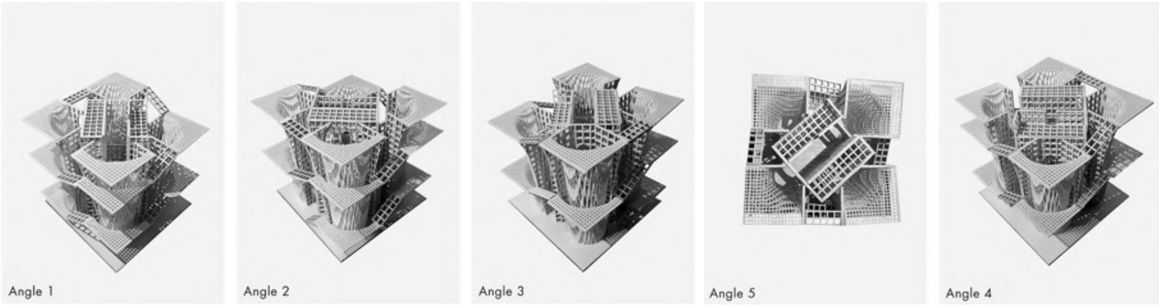

Figure 6: Proposal of a structure study as a 1/100 physical model (RC frame structure - wall type)

(project by: Dominic Chia, Darien Too, Seah Jia Jun, Abdul Muqsith)

4.5.3. P3/proposal of an integration idea in a 1/100 physical model

The final space model to demonstrate the influence of structure studies on the proposed spaces must reflect the thickness of walls and floors or expose beams and columns. Students can choose to develop two structural proposals (steel and RC) or only one (steel or RC). However, the present work recommends that students make both final space models even if one is physical and the other digital, as this would influence the quality of individual drawings later.

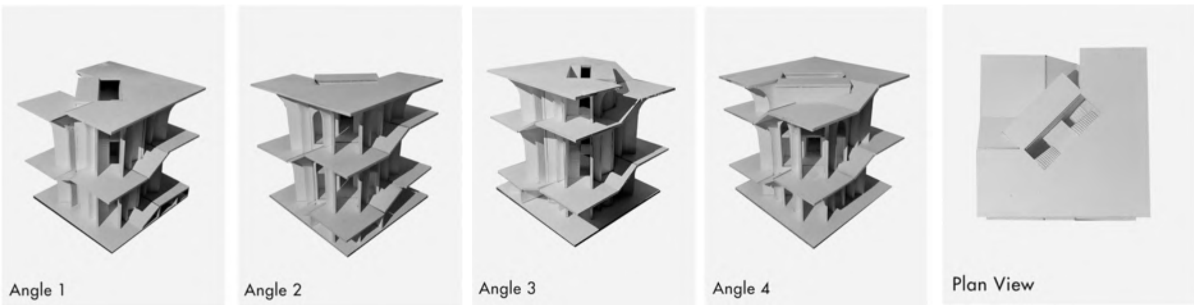

Figure 7: A final space study as a 1/100 physical model (based on P2b proposal)
(project by: Dominic Chia, Darien Too, Seah Jia Jun, Abdul Muqsith)

4.5.4. P4/a section perspective drawing in 1/50

The drawings should only be in black and white (no color use). The point is to show depth in 2D drawings using different line thicknesses. Furthermore, basic information, such as finishing materials from a floor to ceiling and a wall from outside to inside, as well as rooftop details (waterproof and parapet or drains) should be written. (2) (3) Primarily, structural material and member dimensions, such as columns, beams, and slabs, should be expressed based on the structure rulebook. Moreover, it is better to represent users and furniture, including how the designed space is used if possible. In this case, students need not share the same material, such as users, facade design, and finishing materials. In this phase, it is expected that students will share the same project data; however, if two drawings sharing structure systems were to resemble, it may result in a penalty. Originality is a priority even if the spaces and structure systems are the same.

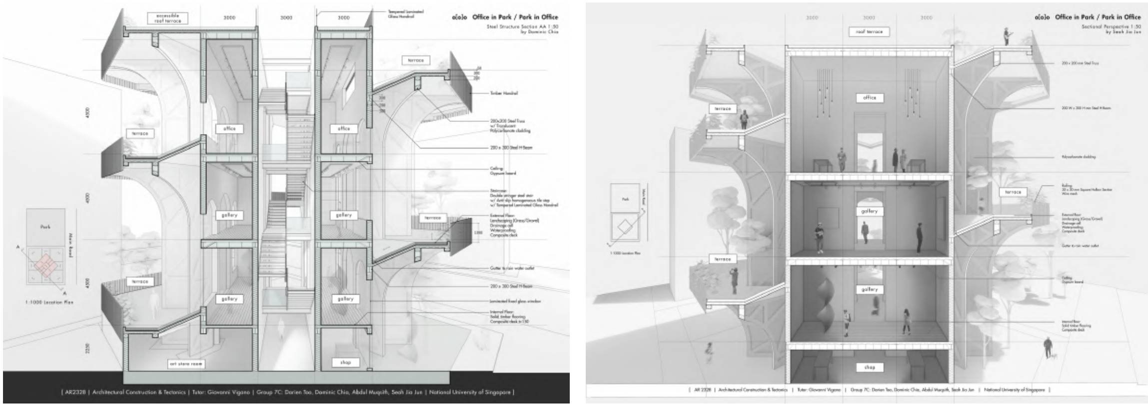

Figure 8: Section perspective drawings as 1/50 (steel frame structure - brace type)
(drawn by Dominic Chia, Seah Jia Jun)

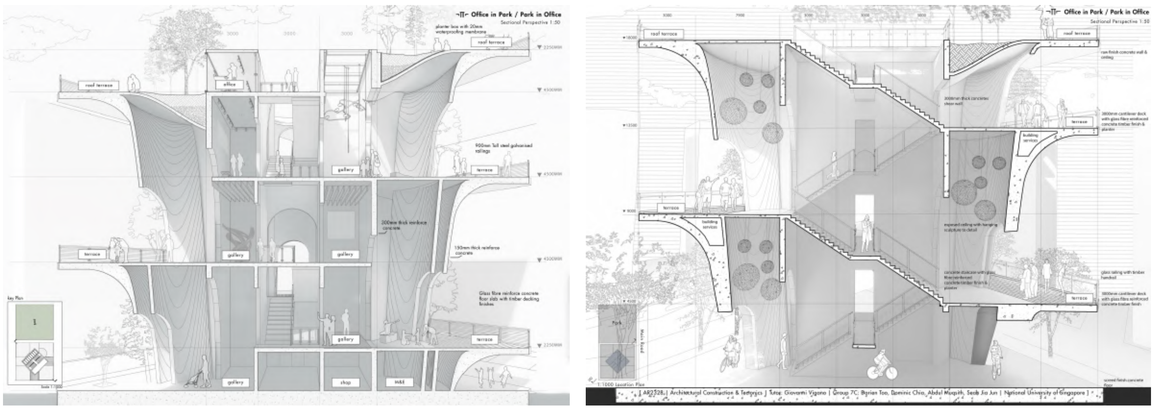

Figure 9: Section perspective drawings as 1/50 (RC frame structure - wall type)
(drawn by Darien Too, Abdul Muqsith)

5. Other cases

5.1 If students focused on the differences in structural systems

If students notice in advance that the spatial quality of the space will differ depending on the type of structure or material used, they can propose a hybrid structural system. An example is when an expansion joint is installed. Meanwhile, this type of work focuses on ensuring students realize that these structural proposals are interesting as a spatial experience and whether they designed an interesting circulation.

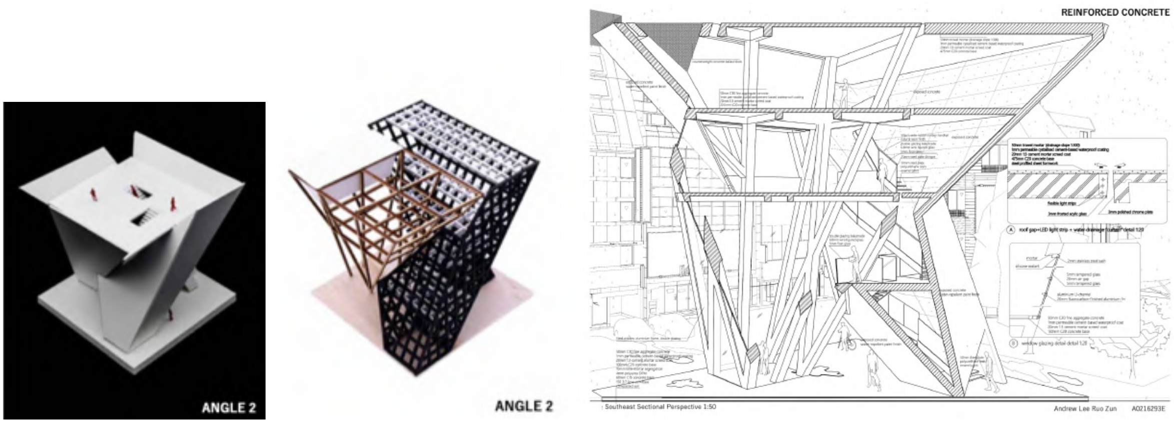

Figure 10: Iteration from a first space study to structure study (RC hybrid type) as 1/100 physical models and Section perspective drawings as 1/50
(Project by Mitch Teh De Xiang, Wang Liang En, Andrew Lee Ruo Zun, Chee Meng Chan)

5.2 If students proposed the rigid frame for both P2a and P2b

Understanding the essence of the structural system is crucial. For instance, the steel rigid and the RC rigid have largely similar structural systems. Unsurprisingly, the calculations employed, cross-section dimensions for columns and beams, and materials used, are expected to differ. However, architectural students tend to choose structural system based on their knowledge (experience).

In the students' proposals, it is expressed in a space with sharply contrasting spatial qualities depends on a structural system. Accordingly, it would be acceptable even if rigid frames were proposed for both P2a and P2b, as they will understand these differences in spatial quality through section perspective drawings.

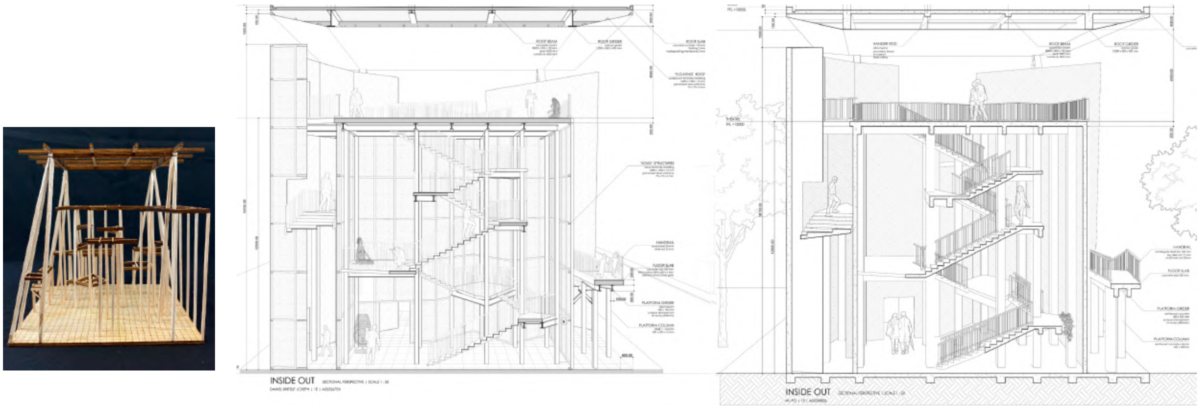

Figure 11: Section perspective drawings in 1/50 (P4: steel rigid and RC rigid)
(Project by Daniel Britelit Joseph, Goh Ee En Matz, Hu Po, Lim Shu Juan Laura)

5.3: If students focused on long span structure

Architectural students generally dislike placing columns in their architecture. In this case, it is also possible to design a long-span structure by using big columns and large beams. The standard span listed in the structure rulebook is 6 m, but if they want to design as 18 m, this can be achieved by adjusting the ratio. Designated dimensions in the rulebook for all materials are calculated thrice as big (from 6 m to 18 m). For some students who prefer not to use materials with such dimensions, an economical truss structure may be an option.

If students realize that big columns and large beams have become too characteristic of design, they can begin to think positively about designing columns and beams. Through iteration, spatial quality that exceeds expectations can be proposed from a first space study.

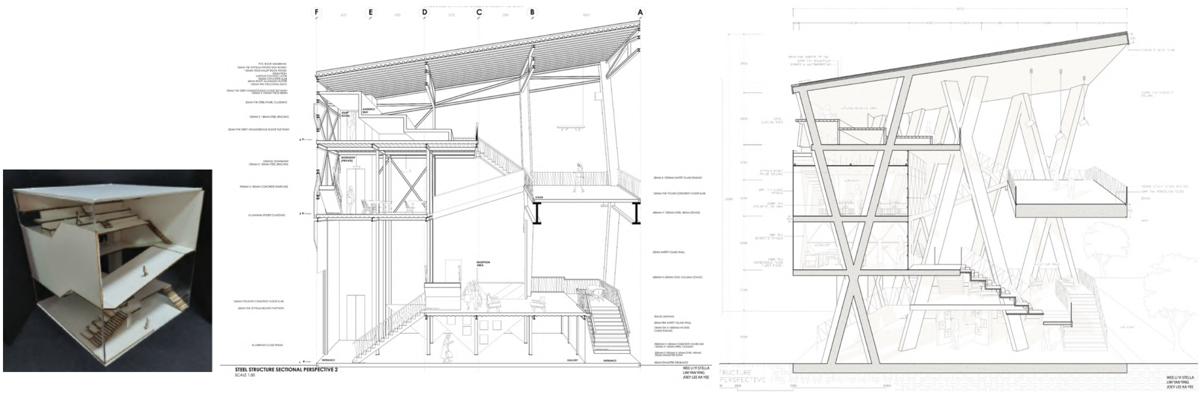

Figure 12: Section perspective drawings in 1/50 (steel structure and RC structure)
(Project by Wee Li Yi Stella, Lim Yan Ying, Joey Lee Ka Yee)

6. Conclusion

The study revealed that the architectural tectonics, which combines architectural and structural design, can improve a proposed space by only altering the type of structural system, regardless of the design quality. Through this teaching approach, this paper reveals that undergraduate students who study architectural design gain broad knowledge of the fundamentals of tectonics in the structural field.

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