Course Title:

Present-Future Infrastructure
Design Non-conventional Architectural Structures

Spring 2018,
ARCH 704-209
Mondays, Wednesdays (Fridays) 2:00 – 6:00 pm

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1 Studio brief

In the most recent assessment examining current infrastructure conditions of the US, needs, capacity, and safety, American Society of Civil Engineers (ASCE) graded the overall quality of the US infrastructures as D+, rated from A to D where A is exceptional and fit for future and D is poor and at risk. Most of the infrastructural projects in the US were built in the 50s and 60s and were aimed to serve almost 50 years. Those projects need to be replaced immediately including half of the existing bridges in the country (The Economist, June 17th, 2014 Eco).

The ASCE grade for the aviation infrastructure is D. Although aviation industry uses technologically advanced aircrafts, their receiving airport infrastructures heavily suffer from the lack of the equivalent facilities and organization systems to handle large passenger traffics. The most recent major airport in the US was built almost 20 years ago in Denver and stays in the 28th place in the annual ranking of the top 100 airports in the world together with Boston Logan airport in 89th place according to Skytrax. Crumbling infrastructures will limit the US ability to contribute to the ever-growing global economy of the future. Thus, reconstructing/replacing the deteriorating infrastructures is unavoidable.

1.1 Problem statement and Objectives

Indeed, architects should play a significant role in designing and rethinking the future of infrastructures. In response, this studio aims to research the formal and organizational configuration of the next generation of infrastructures specifically airports.

The architecture of the future will be positively affected by technology: the technological advances in the transportation industries such as drone taxis and Hyperloop will change our perception of commuting, transitional space, and the so-called terminals. The terminals will be the interstitial spaces occur at the intersection of multiple transportation modes, and therefore pose an interesting architectural question for us: what is the terminal of the future?

Designing such architectural spaces requires utilizing specific structures. In fact, the studio will concentrate on the development of non-conventional architectural structures that can respond to the needs of such spaces and programs more succinct than the conventional solutions.

Therefore, the main research objectives of the studio can be summarized as follows:

- formal structural explorations of the efficient structural typologies suitable for infrastructural design;
- material computing research including tectonic studies on the design of structural forms using various construction materials and prefabrication techniques including as wood, stone, brick, concrete, steel, carbon fiber, etc;
- programmatic studies of the future airport terminals including the integration of high-speed ground transportation station with drone port; and,
- and finally the architectural design of the space to manifest the research.

2 Design research approach

The studio will be divided into multiple modules to design a structure for a terminal in Philadelphia airport. The following sections will expand on the approach of the studio.

Workshop on parametric 3D Graphic statics The studio will include an intense 3D graphic statics workshop introducing constrained 2D graphic statics to lay the foundation for describing geometrically constrained structural forms and their force diagrams in 3D. The workshop will present the equivalent methods in 3D and students will develop constrained spatial structures with compression and tension combined systems. Relevant readings will be suggested from Akbarzadeh et al. (2014, 2015a,b); Akbarzadeh (2016); Schumacher (2016); Harris and Li (2012).

Structural module development The students will develop parametric structural modules as building components and explore variety of equilibrium states by manipulating the force diagram. The parametric studies will be translated into physical scale models to test the space-making potential of the studies. Relevant readings will be suggested from Engel and Rapson (2007); da Sousa Cruz (2016); Moussavi (2018).

Material computation The structural forms developed in the previous step will be translated into construction materials. Algorithms will be developed to populate the structural forms with discrete/continuous elements. Innovative construction systems such as prefabrication and smart assembly of the parts will be developed and tested in smaller scales to manifest the research. Following references will be introduced to students including Block et al. (2017); Gramazio et al. (2014); da Sousa Cruz (2016); Meijs and Knaack (2009); Hauschild and Karzel (2011); Tichelmann and Pfau (2008).

Programmatic studies of future terminals In the next exercise, students will research the programmatic relationships among various transportation systems intersecting at an airport terminal involving Hyperloop, drones, and airplanes and derive their needs and necessities to efficiently lead passengers within the space.

Developing massing strategies based on structural module The programmatic studies from previous exercise will be used to develop a massing strategy for the terminal incorporating the programmatic studies. This massing strategy will also follow the geometry of the structural modules that were developed earlier.

Developing sectional strategies Student should specifically address the sectional design of the terminal to receive and circulate passengers in multiple levels from Hyperloop, drones, and airplanes. Necessary geometric and construction details should be developed to reflect various structural and architectural properties of the project. The relevant readings will be introduced including (Kerez et al., 2009; Morgan and Sobek, 2004; Conzett and Mostafavi, 2006)

3 Studio schedule

Table 1 represents the schedule including the titles of the lectures and their related exercises.

Course Sessions			*Titles*
Part I: Developing a structural module			
	Jan 10	w1	Intense workshop on 2D/3D Graphic Statics and relevant assignments
	Jan 24	w2	workshop on and relevant assignments
	Jan 22	w3	Form finding exercises
	Jan 29	w4	Form finding exercises
	Feb 5	w5	Material computation
	Feb 12	w6	Material computation
	Feb 19	w7	fabrication and physical prototyping
	Feb 26	w8	Roof design
Part II: Designing an airport terminal			
	Mar 12	w9	Programmatic research
	Mar 19	w10	Massing studies/figure ground
	Mar 26	w11	Structural module development
	Apr 2	w12	sectional development
	Apr 9	w13	concept development
	Apr 16	w14	concept development
	Apr 23	w15	Model/detail production
	Apr 30	w16	documentation

Table 1: Studio schedule with the outline for various sections and exercises

4 Studio Requisites

The students are obliged to attend the Spring Lecture Series at the department, specially the lecture by Prof. Block from Block Research Group, ETH Zurich.

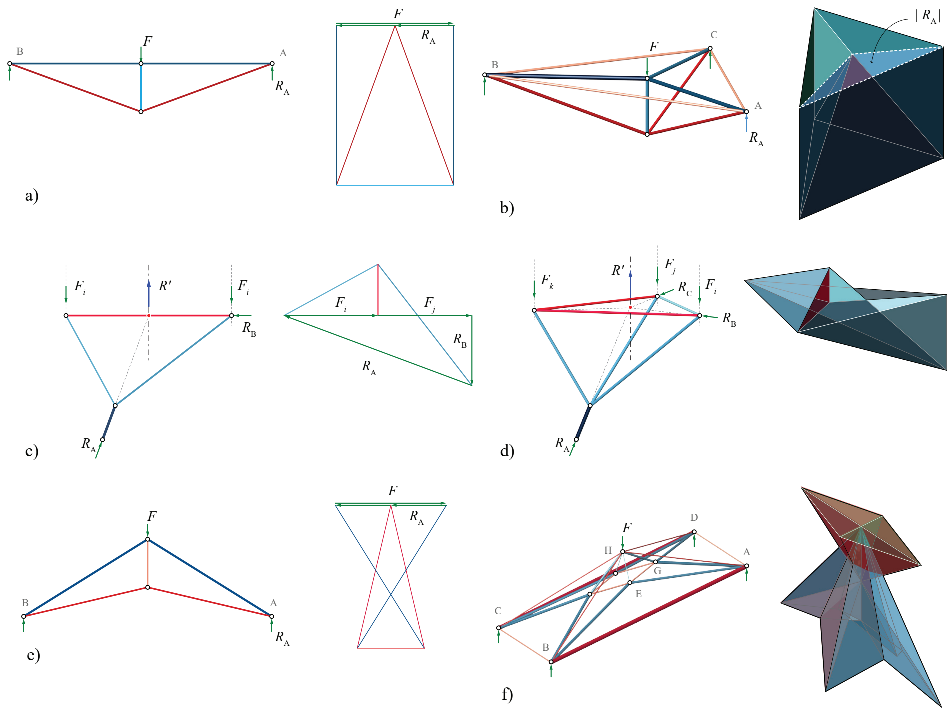

Figure 1: a) 2D form and force diagram generated using 2DGS; b) similar structural system and its polyhedral force diagram in 3D; c) 2D branching system and its force equilibrium; d) similar branching system in 3D and its force equilibrium; e) a 2D truss system and its force diagram; and f) a similar 3D truss and its polyhedral force diagram.

5 Assignment 1

The first assignment is aimed to develop a better understanding of the relationship between form and the force diagrams in three dimensions: it will emphasize the geometric articulation of the structural configurations by designing their topological force diagram. This research should result in a variety of different spatial structural forms that can be used as the basis for architectural spaces of the airport terminal.

The first assignment is to find spatial funicular structural modules using subdivision/aggregation of polyhedral cells. For this exercise, each person in each group is responsible for generating ten (10) various compression-only spatial structural forms that clearly describe:

- the opening features in plan;
- uni-directional opening features in elevation;
- multi-directional opening features in elevation: combination of opening features in plane and elevation.

5.1 Deliverable

The following items are due Wed January 17th at 2:00 pm.

Drawings The form and force diagrams and their clear drawings should be presented on letter-sized papers in a format of a pamphlet in each session. The format of the pamphlet will be provided for you by the TA as an InDesign files. Each person, in each group, is responsible for his/her chapter of the pamphlet. The format of the drawings, line weights, naming and coloring convention will be explained by your teaching assistant.

Model The structural configurations should be printed (preferably in black filament) and presented in a $4'' \times 4'' \times 4''$ transparent box made of $1/16$" acrylic sheets. Please be meticulous about the way you make your models and the boxes.

6 Assignment 2

The primary objective of this assignment is to articulate your structural modules and develop a better understanding of the parameters that can control certain geometric features on each module. Moreover, we need to explore the space-making potential of each module by aggregating multiple modules and combination of them. The following exercises are necessary to achieve the objectives:

Controlling the global force polyhedron You need to reduce the number of faces of the Global Force Polyhedron (GFP). Note that the majority of the applied forces to your systems are gravitational forces. Therefore, the majority of the faces of your global force polyhedron should be parallel to the ground.

Smoothing the structural Module: You should work with your modules and try to identify the surface qualities of your system. Apply subdivision procedures to accentuate those qualities. Simply put, you should smooth your geometry by subdividing the force diagram.

Controlling the geometry of the module: You need to manipulate the existing force diagram of your module to derive various geometries with different architectural qualities. Emphasize on the architectural quality of your modules. For instance, a module might provide exciting quality in section, or it can be used as a transition from one space to the next, etc. This exercise requires you not to change the number of faces or elements of your force diagram, instead, you should play with the direction of faces and generate a family of solutions to be used in your design.

Aggregation of structural modules: The primary objective for developing a structural module is that it can work as a capable system in providing various solutions for different architectural needs. The modules should be aggregated to create a structural system that can reflect the massing strategy of the whole project. The modules should also be able to geometrically adapt within a system to increase the flexibility of the system.

6.1 Deliverable

The following items are due Mon January 22th at 2:00 pm. Each person is responsible for the development of two of the chosen units in the previous exercise. Note that the chosen units should be improved by smoothing (subdividing techniques). The smooth unit should be manipulated using its force diagram to generate asymmetrical units with a variety of architectural qualities. Note that, in this exercise, the topology does not change (number of nodes, edges, and cells stay intact), but the geometric typology of the structure might change to emphasise the architectural design of the module. The modules should be aggregated to represent a system reflecting the potential of the scheme to serve as an airport terminal.

Drawings: Please follow the instructions for the previous assignment and use the format of the pamphlet for your drawings and presentation. Please include the photo shots of your best models in the booklet.

Models: Each person should develop three models for only one of the chosen unit representing the geometric change and architectural potential of the module. The same bounding box of the previous assignment can be used for these models. In addition to the single modules, each person is responsible for two aggregation modules ($6'' \times 6'' \times 3''$) to show the variety of spaces that can be created by aggregating a single structural unit or combination of two. Therefore, in total, each person should present five models in total for this exercise.

7 Assignment 3

This assignment is designed to investigate the existing program of Terminal E of Philadelphia International Airport to understand the existing programs, circulations, different modes of transportation and their connections, and functional mechanism of the terminal including the passenger control, luggage transfer, etc. Moreover, each person in the studio is responsible for the analysis of an existing and important airport terminal in the world to better understand the reason of their success/failure to fulfill the ultimate objectives of course to which is design a better airport for future.

Programmatic requirements Prior to design a terminal, we need to conduct a comprehensive study to realize the existing programs and identify the current architectural problems of the Philadelphia's terminal. Each team is responsible for an axonometric drawing of the existing programs of the terminal with their approximate square footage/meter. Moreover, each person is responsible for presenting a research related to the precedent airports.

Structure In addition to the program analysis, we need to increase our understanding of the structures designed to cover the analyzed airports. The typology of the structures, materials, detailing, joints, architectural qualities, etc. For instance, you can visit DETAIL magazine to find good drawings of the airport structures/long-span systems.

Circulations The analysis of the airports should be supported by clear drawings of the circulation in their buildings. I understand that the circulation in some of these airports are quite sophisticated, so try to understand a clear concept of the circulation in complex airports and presented by axon drawings. The circulation in the airports will include all the possible routes that a passenger can take from curb to his seat on the airplane.

Other modes of transportation Almost all airports are connected with various means of transportation such as train, car to transfer passengers to/from the airport. Some airports have their own systems of transportation such as trains and buses.

Proposed programs The results of these studies should inspire you with certain ideas for circulation and additional programs that you think would make your airport a better place to spend time.

7.1 Deliverable

Drawings: Please prepare the following drawings:

- axonometric drawings that clearly describes the programs and circulation of Terminal E of Philadelphia International Airport (per group). You might need to separate the drawings to emphasize program, transportation, access, circulation, etc.
- an axonometric drawing of the circulation within different programs of an analyzed airport (per person: this would be fair for everyone in the studio regardless of the number of people in each group)

Presentation Each person is responsible for presenting his/her analyzed airport, so please prepare your images/slides/drawings related to the airports and presented them on the screen to convey your ideas clearly.

8 Assignment 4

The primary objective of this assignment is to start with some programmatic definition of the space to give our structural explorations an architectural function. Note that the primary intention of this studio is to push the existing conventional structural systems and come up with systems that have additional architectural values. Do not forget that your programmatic proposition is not going to solve the problem of the existing airports in the world and the result of the studio might not apply to many cases and this is not the studio for research in programmatic problems of the airport terminals. What you should concentrate is to develop various structural systems that can potentially be used for future airports rather than the conventional structural systems.

8.1 Deliverable

- A diagrammatic drawing of the layout of your airport. Please give some ideas how you need to have essential programs of the airport by learning from your precedents and explain how you would like to distribute this in plan or section to create an exciting space for your design.
- You might get the idea of your layout from your modules, or you might find modules that can fulfil your diagrammatic ideas. I would like to see the diagrammatic figure-ground of your project. This does not require lots of details. You are designers and you should communicate with me through your diagrammatic drawings.
- If you think that some of the modules that you develop can generate the program for you, please show it with simple diagrammatic section/plan drawings.

9 Assignment 5

We need to have a coherent concept explaining the main idea of the terminal and its program flow and structure. Therefore, we need to pick up the pace in the development of the modules and relate them to the program of the terminal. For the next assignment, you need to have a clear programmatic layout of your terminal. The modules should be developed such that they represent the sectional and plan ideas of your program.

9.1 Deliverable

The following items are necessary for the next session (Due Friday Feb, 12th):

- the semi-final layout of your terminal for the mid-review;
- various modules that represent each part of the terminal as you put them side by side it can coherently describe the program of your terminal;
- develop each module with scaled people in the section and elevation to describe the section and the quality of the space provided by the module;

- refined modules and transitional techniques to connect various modules with each other to create a system that works uniformly.

Note that scale and proportions are critical in both diagrams and modules.

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