LEARNING PORTFOLIO

Imma Güdstudnt

arch 331 | fall 20[redacted]

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CONTENTS

I'm going to be frank. When I first started this class I was not interested in it. Not one bit.

I didn't particularly care what held my buildings up, how much they would cost, or honestly whether they would stay up or not. Those were concerns for civil engineers who would check my work and I was just taking this class because it was required. It wasn't because I was particularly bad at math or physics (although when I'm tired I do tend to put the wrong numbers in my calculator!) I just simply didn't care for them.

And while I can't honestly say that I am extremely excited to find the sizing and spacing of rebar in concrete even now, I at least understand the importance of know how to do it. I can now look at my buildings and be sure that they can be built, and if not, I can find ways to rework them instead of an engineer doing the changes and interrupting my design aesthetic.

Over the course of the semester, there were an overwhelming number of concepts introduced, each building on one another, so if you got lost or behind, it kinda snowballed.

concepts

We started with the basic requirements of structures to resist forces, stay in equilibrium, resist stresses and structural actions like lateral forces. We looked at the types of resisting systems for lateral and vertical load resistance. In assignment 1, which was simple enough, we were introduced us to the types of charts we could be using to help size or plan structural systems and how to start reading them. It also helped us brush up on the basic mathematical skills we would need to complete the course.

The next topics of forces, moments, and equilibrium of points were familiar coming off a semester of physics. We were asked in assignment 2 to set up free body diagrams and transfer and add forces using the rules of trigonometry to find components and summing moments using the forces with their perpendicular distances. This assignment was a great refresher for me after a summer of little mathematical work (or work at all for that matter). To me, however, the most important and exciting aspect of this assignment was at the end when we started to apply the same ideas to forces in truss members that act in the direction of the geometry and must be in equilibrium at a joint. This, at last, was architecture, not the theoretical "when am I going to use this?!" type of physics problems I'd been doing for a semester. For me, these problems helped bridge the gap, showing a clear example of how the two were interrelated. I also was introduced to Multiframe, a software tool that will surely only become more valuable the further I progress in architecture and the more complex my designs and the structural systems supporting them become. I also learned something through the Multiframe assignment that I had never known. -I had always assumed that connections in buildings were supposed to be fixed. It seemed strange to me that I would ever want a joint between truss members to be able to move around.

After equilibrium of points, we followed up with rotational equilibrium for bodies and mechanics of materials which relates stresses and strains by type of material. I discovered that steel could be elastic and plastic! In assignment 3 things started to get more complex and more related to buildings and structures in a very concrete way. We started getting into the specifics of calculating moments and setting up the equations of equilibrium for various systems. Most fundamental, of course, was the topic of beams. This assignment started with them and also required me to calculate support reactions, a concept that at first seemed strange, but made more sense the more I thought about it. I also had to cut a section of a truss and rely on the uncut geometry to find perpendicular distances for all the moments of the force components. The other problems challenged me to find areas or solve for them if I knew the forces and limit stresses defined by P/A that we used for the maximums. This was our introduction to Allowable Stress Design. It was interesting to find a length change due to temperature to see how it could cause a stress as a result of the system being unable to move and forcing "back".

After this topic, we looked at beams in detail with the internal forces and moment. Shear and bending moment diagrams are plots of the values over the beam length, and we practiced making them in assignment 4 in order to find the maximums for design. We discovered how the moments and the shear stresses in beam are interrelated, and how the moment is the integral of the shear plot. It was also another chance to practice with Multiframe to produce the diagrams (in a fraction of the time it took by hand).

Once we had covered shear and bending moment diagrams we looked at the geometric wonders of a cross section. We defined the centroid (area center) and a moment of inertia (area "spun" around squared) because it was central to finding beam bending and shear stresses. Finding cross sections and first area moment (Q) involved lots of tedious math and assignment 5 was not my favorite. I was not able to read data off the charts associated with the problems in the correct fashion, and was feeling overwhelmed as we added things such as design of a beam using materials, section modulus, allowable stresses, economy (based on weight), etc. to find the section size required or area or pitch spacing of nails... All in all though, I leaned several important things from doing this assignment, such as how to tackle those same charts and deal with important things like materiality, as well as how to find a centroid in a beam with complex geometry (by simply splitting it up into different basic shapes and comparing them) and the moment of inertia. Looking back on the assignment, it wasn't that it was difficult; I only had a hard time with it as I let the intimidating aspects of the assignment get the best of me. Unfortunately, while cleaning out my various notebooks after my midterm, this assignment found its way into the trash by accident and I am thus unable to find it to correct the mistakes I made.

We next talked about the type of structural systems that could be pinned or rigid. It involved drawing more free body diagrams for a problem than we had been used to. Then we practiced drawing more shear and bending moment diagrams. So assignment 6 was rather easy by comparison to assignment 5. We analyzed a compound beam joined with a pin, which it turns out is not that different from a simple beam. To set up the free body diagrams for these, one needs to set up a different FBD for each part of the beam, making sure to account for the forces that meet at the connection, which are equal and opposite.

Pinned and rigid frames could be conquered rather easily by being split into their basic components with matching forces at the corners and separate FBDs. Shear and moment diagrams for these were especially interesting as you could start to work out the deflected shape from the sense (+/-) in the moment diagram. The tricky part was remembering that a load on a comer of a frame was only applied to one of the FBDs.

Columns and "impending doom" were our next subject, where we no longer had to worry about moments but buckling instead, and had to start finding slenderness ratios (the effective length divided by the width of the column on that axis. We also discussed he concept of a weak and strong axis, an Idea which I somehow got backwards (this will be discussed further in my reworking of quiz 4 in the section titled Illustrative Documents). The critical load (smallest) turned out to come from the biggest slenderness ratio.

When we were covering where the minimum design loads and weight of materials come from, load tracing to find beam and column loads, and being introduced to ASD and LRFD design requirements, the mounting pressures of studio was too strenuous for the week and I elected to take my late pass for assignment 7 (a decision I came to regret recently around the due date of my final project). Nevertheless, by the time I did complete this assignment, I had learned the last steps to put everything together, as well as a bit about design and loads on retaining walls. This assignment was critical to my overall success in the class and also introduced me to several important charts that I would be using over and over again, as well as the magic factors for live and dead load (1.6 and 1.2 respectively) that I don't believe I'll ever be able to forget.

The rest of the semester we were focused on structural *design.* This was where it got real and everything was finally coming together as we started to design beams, columns, connections, etc. for wood, steel, and concrete, and finally, foundations. Each was, for the most part, the same, with their own little quirks. Beams were designed so that stress wasn't exceeded (ASD) or the material limit was "nominally" reached if it was braced or unbraced (LRFD) and that elastic deflections weren't exceeded or slabs had a minimum thickness. The columns couldn't exceed stress or capacity based on slenderness ratios, and there had to be enough nails, welds, or bolts to transfer loads in connections. Foundations had to transfer loads using ASD, but we design the concrete using LRFD. We also returned to look at steel trusses with open web joists and had to load trace each joint load. There were tension member in trusses and we had to remember that bolt holes causes more stress.

Reinforced concrete was the weirdest to design because you couldn't find an S or Z or use helpful charts. The only design aid (with R_n) helped me pick a reinforcement ratio that could be used to find area of steel if you knew the area of the concrete (which we didn't once). We did get practice finding the moment capacity knowing the compressive strength and the lever arm to the steel centroid. And who knew about stirrups?! I've seen cracks in concrete beams, but having to put in loops to keep the beam from shearing was something I'd never imagined.

In every one of the last Assignments (8, 9, 10, 11 and 12), we were asked to find the most economical section possible for beams, an idea I had a surprising amount of trouble with.

This, along with the idea of superpositioning forces tripped me up for a while, until I went back and finally worked it out for myself. Because of this difficulty that spanned through several assignments, I had decided to fix the mistakes I made in economic beam choice in my reworked quiz 4, which can be found in the Illustrative Documents section of the portfolio.

Before this semester I had no idea how many different things must be accounted for in a building. I assumed that there was a force, and if you applied too much of it, something would break. I had no idea that a force applied to a beam could cause either a shear force or bending moment, or if applied to a column it could cause buckling, which was in effect very different from either shear or bending. I also, in a way, had assumed that structural analysis was a quagmire or "what ifs" and "maybes"--an inscrutable mess of different ways that one force had to be calculated. To me, structures couldn't have just been solved with linear algebra and the tables - it had to be solved with magic. After this semester, however, I feel confident that I could figure out the loads on a simple house or orthogonal structure and be sure that it would stand up, that my columns and beams were the right material and size, and that, yes, some had to be supported by pinned and roller type supports. Although I still feel a Frank Gehry building is beyond my grasp to analyze, a Richard Meier or a Mies van der Rohe doesn't seem too terrifying. I can visualize load tracing, and know where to avoid placing those loads to prevent things such as bending failures.

skills

Skills are "execution of learned task" by Websters dictionary. The three biggest ones for structures are free body diagrams for equilibrium, using charts and design aids, and making the right decisions to evaluate the design criteria. Free body drawing required an understanding of supports and how to draw reactions and of "exposed" forces and whether to draw them "away" (assuming tension). We had to show the unknowns and put them in equilibrium equations saying that the sum of component forces and all moments were zero. (Solving with algebra and using trig were skills you assumed we had.) Drawing shear and bending moment diagrams were just showing equilibrium graphically relying on (more) previous knowledge of finding areas from shapes. We also got the loads for our structural sketches from tracing volume loads to area loads to distributed loads to point loads.

The design charts and tables we used included preliminary depths for spans, areas and section data for timber and steel shapes, beam diagrams and formulas, economical steel sections, column data by slenderness ratio, beam data by unbraced length, bolt and weld strengths, truss and precast loads by span length, reinforcement areas and ratios, and design shear and moments for continuous beams, and one and two way slabs.

The decisions we had to make were if areas or sections were large enough so that stresses weren't bigger than allowed (or V or M was not bigger than the limits), we had to change what we chose if it was too big and we had to do the same for beam deflections. We had to choose load factors from the combinations of load types for LRFD. We had to find all the different maximum loads for connections or columns and pick the governing (smallest) one.

We had to choose areas of steel reinforcing and know if our concrete was over-reinforced (not allowed) or if a minimum area had to be used. We had to make certain the bars fit (with cover and stirrups) in our beam width. We had to find spacing for shear stirrup depending on how much shear the concrete had in it.

problem solving abilities

I found very quickly in this class that the main obstacle to doing structures problems was the feeling of being overwhelmed because I felt confident with my math ability at the start of the semester. When I looked at the entire problem at once it seemed daunting and I couldn't tell where to start. It was only when I started to break the problem down into steps that it seemed to unmuddle itself and become manageable. In hindsight, this strategy should haw been obvious. Not only have I been doing it for studio projects and such for as long as I can remember, but you told us to do so several times yourself. Once I was finally able to make myself sit and think before doing a problem instead of brashly rushing at it head on the class became quite a bit easier.

learning abilities

The main thing that I encountered this semester was that this class demanded as much time as studio and systems and my other class! In order to make time to learn and do structures, I couldn't pull ridiculous three day spans where I simply did studio work and ignored everything else anymore because this homework had a due date which wasn't at the end of the semester. I had to carefully balance the amount of time I could spend on each class each week, and, it ended being much less stressful than I know it would have been otherwise. I found that re-working the problems we did in class after I'd looked at a homework problem helped me find the similar steps, but I also learned the power of collaboration with more heads that could remember the steps! Until now I have always preferred working alone, as I always felt I could accomplish things faster and on my own schedule. This class finally forced me to ask others for help on things I just didn't understand for whatever reason and made me keep up by being accountable to my study group when we met. (I also was really good at drawing diagrams for my group to reference and sometimes laugh at!) I found that reading the note set and textbook was boring, but even if it didn't all make sense at the time, I was learning the lingo.

Illustrative Documentation

In the following section I will present a quiz I did poorly on. I have provided a detailed narrative of what I was thinking (not just which numbers I wrote down wrong, but how I ended up writing them down) and misconceptions I had with misapplications I made. I will follow up with an annotated and corrected version and describe how I knew what to do and why.

Quiz 4 | Problem A

This was a beam design problem which required me to satisfy the strength criteria while selecting a beam that didn't cost too much (figure 1). I calculated the maximum shear and bending moment using the self weight provided using the beam diagrams and formulas for the [redacted] load case and the [redacted] load case. Because the maximum values for shear were at the end, I could add them using superpositioning. I also found that the location of the maximum bending moment was at the same place, so I could add the moments directly as well. I was able to use the design relationships that require the bending stress not to exceed the allowable bending stress and the shear stress not to exceed the allowable shear stress to find the section modulus required and the area required.

With the timber section table provided, I found the closest value to the section modulus that had the second number in the name which was the smallest and chose that one –Done! On to the next part of the quiz, which was column analysis and I was really confident with that from my practice and the sketches I could make of buckling columns – and I was starting to run out of time....

(fIgure 1)

POOR QUIZ AS GRADED

After reviewing my quiz and my study group's quizzes, I saw that they had chosen based on the smallest area to satisfy $A_{req'd}$ (figure 2). For some reason in the course of the class, I came to the impression that the last number in the nominal value's name of a member indicated weight, and knew that weight was the true deciding factor in the cost of the beam. I now know that this is only for standard steel sections, like a W shape that has a name of W 12 x 48 where the 48 mean pounds/foot. This doesn't apply to 2 x 4's or to concrete beams!!! Thus, this time I picked a lumber size off the chart that was the closest (but above) the area required while making certain that the section met the size requirement for section modulus. I also noticed that moxt of the 6 x's and all of the 8, 10 and 12 x's could have worked, but were just too costly (and frivolous for you).

(figure 2)

POOR QUIZ REWORKED
with annotations
(arrows and text)

Quiz 4 | Problem B

This was a column analysis problem which required me to determine the load capacity and compare it to the load that it was supposed to hold and make a decision if it was "adequate", which really means will it crush or buckle (figure 3)? (You should really add this word to the Structural Glossary notes....) I had drawn my pretty little buckling figures, compared the slenderness ratio of L_e/d for the strong axis and the weak axis, plugged the biggest of these into the F_{cE} formula to find the stress that I needed to divide by the F^*_c value so I could look up the column adjustment factor. Then I had to say if the column load was smaller than the allowable load (allowable stress times area).

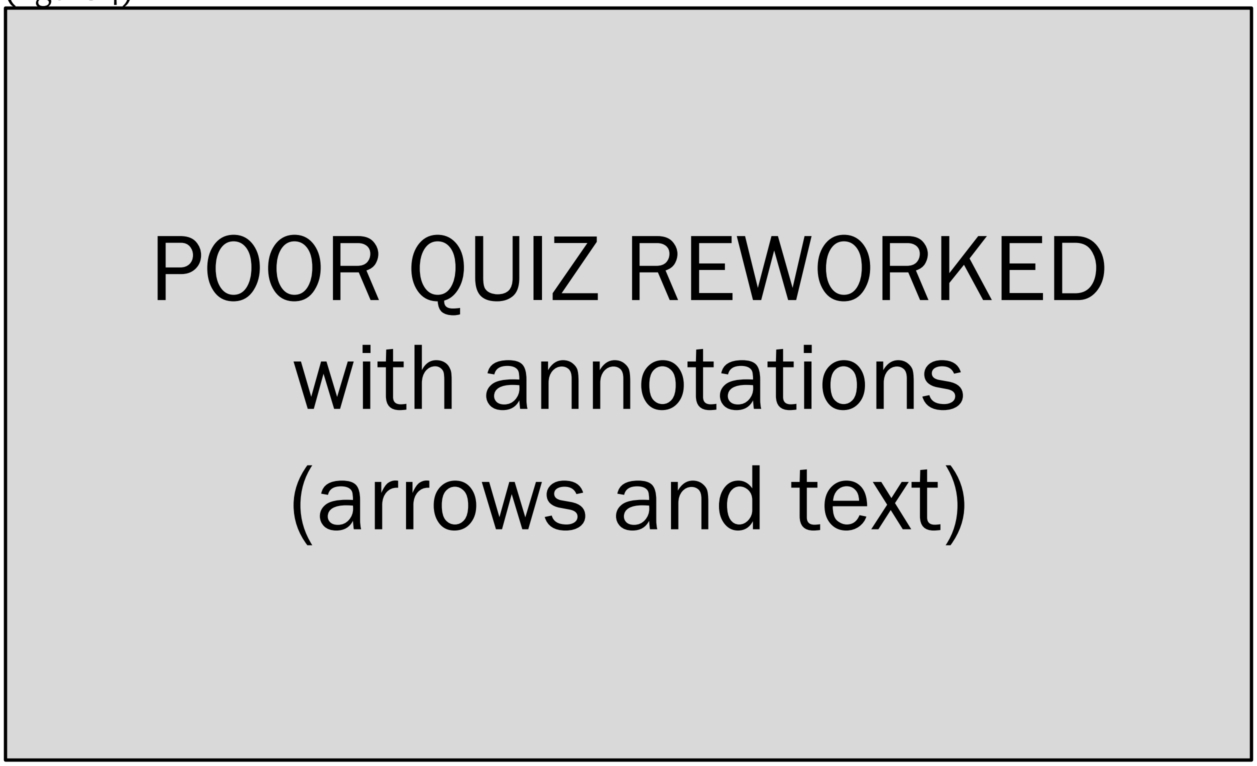
(FIgure 3)

POOR QUIZ AS GRADED

After reviewing my quiz and my study group's quizzes, I saw that I had gotten tripped up on deciding which of the column measurements to go with the effective length of each axis (figure 4)! It's a pretty simple question when the column widths in my sketch are drawn to a better scale. And I know that the results of getting it wrong are that your slenderness ratios are all off, causing the entire result to be wrong. Also factor in a slight error in the formula for F_{cE} (the bottom quantity is always squared), and forgetting to convert $P_{allowable}$ at the end and you have a very wrong problem.

Changing those two values changes everything accordingly, and it's very interesting to note that it changes which axis governs (from the strong axis to the weak one). The reason the values go with the axis they do is that the numeric values of wood columns are given in the standard x, y format (for width and depth). I did not realize this simple fact (see misconception with the numbers mentioned above) and simply guessed based on the figure given with the problem.

(figure 4)



CONCLUSIONS

This semester has certainly been the most challenging of my college career, and no small part of it is due to this class. Overall though, I feel like I've learned a lot, both about structures, and how to handle high levels of work and stress in general, and I will definitely be using what I have learned in my career and beyond, especialty when I am asked, as I think I will be again, how on earth my design is going to stand up?! And, most importantly to me, I have completed my personal goal for every class and everything I do: I understand the world around me a little bit more, and am overall a more knowledgable person.