Construction Design

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Home Sweet Home

Prity Rungta

Courtesy of Prity Rungta

Constructing a building that people will live in can take months—sometimes years—of planning and execution. The task may require teams of engineers, designers, and skilled tradespeople. It involves coordinating the purchase, delivery, and use of a long list of materials and tools. And the whole process must happen within a given time frame and budget. That's why every construction project needs a manager.

My name is Prity Rungta, and I am a construction project manager for a building company in Toronto, Canada, called Bolt Developments. My company specializes in residential and commercial projects in the Toronto area. These projects can take a year or longer to complete and must be completed on time and on budget. It's my job to make sure that happens.

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I got into construction when I was studying engineering in college. I took a course in construction management and loved it. Construction project managers are problem solvers. Unlike some engineers, we don't use the design process to create new technologies. Instead, we use it to determine the best possible way to complete a construction project given the key constraints of time and money.

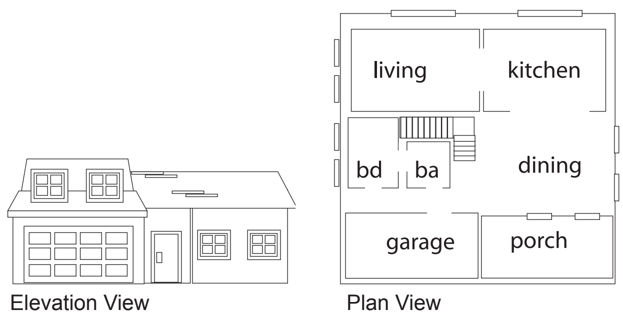
Breaking into the construction industry was a challenge for me. I don't fit the typical mold of what most people in my position are like. People often assume that I work in this industry because I come from a family in construction and grew up around construction. That could not be further from the truth. The truth is that, aside from a course in construction management, my first exposure to the industry wasn't until my first job out of college.

I was a project coordinator of the construction of a very large house. I knew I had a lot to learn, so I asked tons of questions to the subcontractors—the plumbers, the roofers, the electricians, and many other skilled tradespeople—who were working on the project. They were always more than happy to explain their work to me. I think they appreciated the fact that I recognized their expertise even though I was part of the management team. That really helped keep communications strong. Now that I have a lot of knowledge about all aspects of building a home, I try to remember that there is something to learn from every new project.

From Start to Finish

When my company takes on a new construction project, I first review plans with the architect. In order to communicate the design to me, the architect creates elevation and plan drawings of the structure. An ***elevation view*** is a scale drawing of the front view of the above-ground portion of a structure.

A ***plan view*** is drawn as though the ceiling and roof are removed so you can look down at how the floor is divided into rooms and different sections. The plan drawing communicates the floor plan of the structure to me.



The architect also usually includes a plan view of the foundation, which is the below-ground portion of the structure, as well as cross-sectional drawings, which are essentially elevation drawings of the home's interior. I can gain a lot of useful information from these drawings, including information about materials and dimensions. They are always drawn to scale, usually ¼ inch = 1 foot. Although the drawings are always to scale, all significant dimensions are marked by the architect. The scale of the drawings is used more for rough calculations.

When I understand what needs to be built, I develop a week-by-week plan for the project, detailing what will get done and when. Buildings are constructed in a series of steps, and most projects follow the steps in a similar order. However, the details of the project such as the materials, construction techniques, equipment needs, and expenses vary greatly from project to project. After I have a sense of the timeline, I begin to form a budget by pricing out materials and determining how much I'll need to pay subcontractors. When I've determined a realistic schedule and budget, I present it to my supervisors and to the clients.

Getting Down to Work

When the plans are finalized and the budget is set, I can start ordering materials and hiring the subcontractors. After we get started, I'm on the job site every day, making sure everything gets done according to plan. This requires constant troubleshooting. Sometimes people are ill and miss work, and I have to scramble to find substitutes. Sometimes everyone is on site and ready to work, then a snowstorm hits and makes it impossible to complete the day's required tasks. Sometimes materials don't arrive on time, or equipment malfunctions. Every day, it seems, I have to design a new strategy to figure out how to make up lost time and get a house built by the deadline—all while staying within the budget.

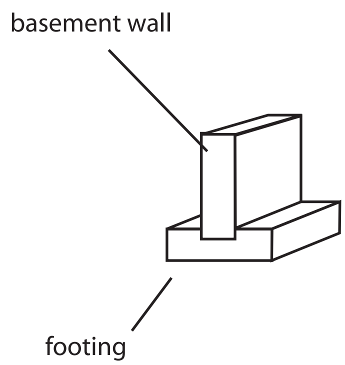

Courtesy of Prity Rungta

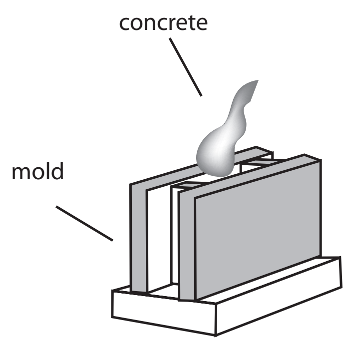
Laying the Foundation

The first group of contractors to arrive at the job site prepares it for construction by removing any topsoil and trees that may be in the way. This team generally brings a back-hoe or bulldozer to do the job. After the land is prepped, the team will dig a large, deep hole that is the size of the footprint of the home. A ***footprint*** refers to the area contained within the perimeter of the building. The foundation and part of the basement of the home will be constructed in the hole.

A ***foundation*** transmits loads from the structure to the ground. In most buildings, foundations extend underground. There are many different types of foundations, and when selecting the right type, architects and builders consider the size of the structure, its location, the quality of the soil on which it is being constructed, and many other variables. In all cases, a strong foundation is what anchors a structure to the ground and keeps it there. It also provides a strong base on which the above-ground part of the house will be built. A home with a weak foundation can have major structural weaknesses and even failures. So it's important that we get the foundation done right.

To form the foundation of the house we're currently working on, we constructed massive concrete footings that are 4 feet wide by 18 inches tall. These are dug into the soil around the perimeter of the hole. The basement walls are also made of poured concrete that is 22 inches thick, and they sit directly on top of the footings. These footings and foundations are about twice the size normally used on houses. When building with concrete, we first construct a wooden mold, lay reinforcing steel bars (commonly known as re-bar) inside, and then pour the liquid concrete into it. We cast the concrete in place and remove the mold, leaving the concrete part. The concrete is allowed to set for a period of days before we remove the wooden mold.

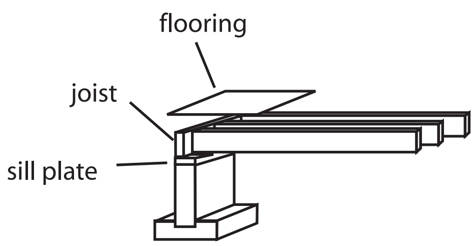




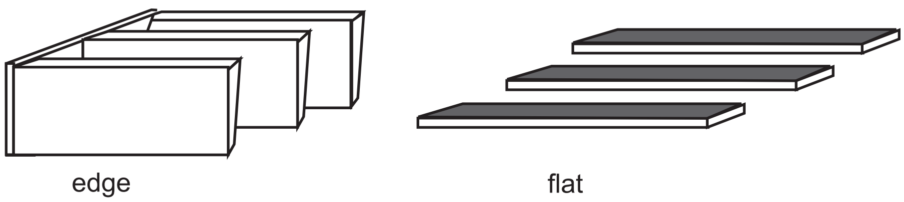
Framing the House

After the foundation and basement are complete, a crew comes to the site and begins to build the ground floor of the house on top of the basement. A floor must be very stable because its job is to support the loads in the living space above it. Remember, the dead load is the load associated with the structure itself. The live load is load not associated with the structure, such as people and furniture.

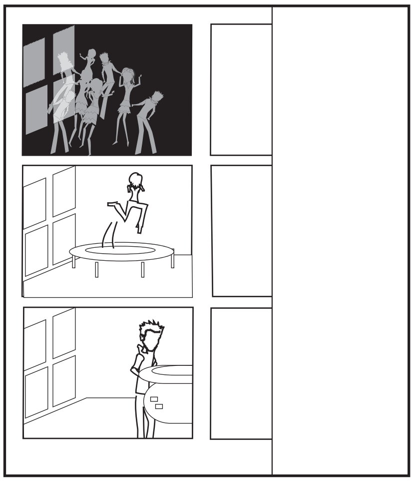
The floor is constructed of wooden joists. A ***joist*** is a horizontal beam, traditionally a 2-by-8-inch piece of lumber set on its edge. The joists are spaced approximately 16 inches apart, and their ends are fixed to a wooden sill plate that sits on top of the basement walls.



When set on its edge, a joist is more resistant to bending forces and can support higher loads than if it were laid flat. This is because when a load is placed perpendicular to the beam, the wider section of material distributes the load.



These days, it's more common to use engineered wood joists that are made of composite wood and designed to move less and provide squeak-free floors. A thin sheet of ply board goes directly on top of the joist system, and the chosen flooring material will lie on top of that. That flooring material may be hard wood, ceramic tile, slate tile, or sometimes carpeting. We won't actually put in the flooring material until we have the exterior walls of the home and the roof complete. These materials aren't designed to withstand the elements.



Every floor must be designed to support a live load. But it's not easy to predict what the live loads in a structure will be. The occupants of a house may move heavy furniture in the living room, throw dance parties for hundreds of guests, install a larger bathtub in the bathroom, or buy a small trampoline for indoor exercise. How can architects, engineers, and builders make sure that the structures they are building are strong enough to support a huge variety of live loads?

Building codes are laws that specify how buildings are to be constructed. Codes regulate the structural, electrical, and plumbing systems of a building as well as fire safety design.

Building codes provide guidelines for professionals in the construction industry. They refer to these guidelines when determining how to design their structure so that it will be safe for its occupants. ***Building codes*** are community ordinances that govern how a home can be constructed or modified. Codes regulate the structural, electrical, and plumbing systems of a building as well as fire safety design.

Every community building code lists the minimum live load that a building must be designed to support. The code is usually listed as a load per unit area, which is a ***stress.*** The structural requirements dictated by the building code are different for structures with different uses, and they vary depending on the type of room.

The Massachusetts Building Code states that the minimum live load requirement for the floor of a living room in a residential building is 40 pounds for every square foot of area. The floor of a school classroom, however, must be designed to support 50 pounds per square foot.

Massachusetts Building Code

Living room:

Live load of 40 lbs/ft^2

40 lbs ↓ 1 ft^2

Classroom:

Live load of 50 lbs/ft^2

50 lbs ↓ 1 ft^2

The value in the code is calculated by estimating the highest likely live load for a particular dwelling space, then multiplying it by a safety factor. For example, the highest likely live load for a residential living room with an area the size of 400 square feet might be 4,000 pounds. This includes all furniture, people, pets, television sets, tables, and chairs, and anything else that may be in the room. Therefore, the stress, or load per unit area, that the floor of the room must be able to withstand can be calculated with the following equation:

$$\sigma = \frac{F}{A}$$

$\sigma = Stress$

$F = Force\ of\ Load$

$A = Unit\ Area$

$$\sigma = \frac{F}{A}$$

$$\sigma = \frac{4000\ lb.}{400\ ft.^2}$$

$$\sigma = 10\frac{lb.}{ft.^2}$$

Ten pounds per square foot is quite a bit lower than the 40-pounds-per-square-foot minimum stated in the building code. That's because the building code minimum includes a safety factor. A ***safety factor*** is a factor by which a maximum likely stress is multiplied in order to ensure the safety of a structure. Safety factors are necessary because the occupants may use the space in unexpected ways.

$$S_F = \frac{\sigma_{designed}}{\sigma_{experienced}} \qquad S_F\ \sigma_{experienced} = \sigma_{designed}$$

$\sigma_{designed} =$ *minimum stress a structure is designed to withstand*

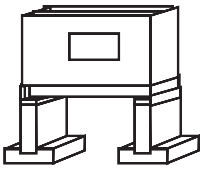
$\sigma_{experienced} =$ *maximum stress a structure is likely to experience*

$$S_F = \frac{\sigma_{designed}}{\sigma_{experienced}}$$

$$S_F = \frac{40\ \frac{lb.}{ft.^2}}{10\ \frac{lb}{ft.^2}}$$

$$S_F = 4$$

Before starting construction of a new structure of any kind—or renovating an older structure—architects and engineers who want to build something must present their designs and load calculations to city officials. These officials check that the structure is designed with materials and structural geometry that will meet the minimum loading requirements in the code. If a design is not up to code, it's back to the drawing board!



Building the Walls

Most of the interior walls in the house I'm building now will be framed in wood. But some of the interior walls will be as high as 15 feet. In those cases, regular wood won't work for our purposes. Instead, we will use an engineered material that is made of wood strands but is much stronger. The interior wall frame will be covered with drywall, or plaster sheeting, which can be painted or finished.

The exterior walls of many houses are also constructed from wood. But in this house, our client really wanted thick and solid walls with deep window wells, so the architect designed the home with very thick concrete walls. I was happy to build the home with concrete walls but, because of our timeline, we had to construct the above-ground walls in the middle of winter. This posed a significant challenge. Concrete must be kept warm and dry in order for it to harden quickly. In Toronto, where winters can be very cold and snowy, this meant tenting the structure with tarps and using portable heaters to keep the concrete warm for weeks. This would get very expensive.

As project manager, it's my job to find the best way for the job to get done. After researching some options, we decided to use a technique for raising concrete walls using Insulated Concrete Forms (ICF). This technique involves using thick Styrofoam molds instead of wooden ones. The concrete is mixed with chemicals that heat up, and then the concrete is poured between the Styrofoam molds. The chemicals in the concrete heat the concrete as it sets, and the Styrofoam molds help keep the concrete warm much like a Styrofoam cup helps to keep hot coffee warm. Doesn't that sound like a great solution?

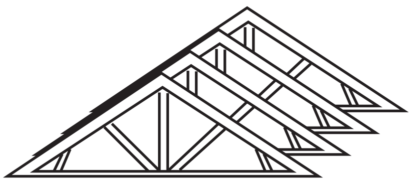
Courtesy of Prity Rungta

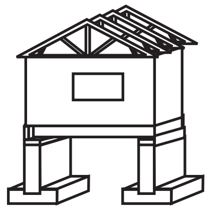
Using ICF to raise concrete walls

Raising the Roof

With the walls standing, we can now put a roof on top of the house. A roof adds tremendous stability to the structure. Of course, it also protects the interior of the structure from weather.

There are many different ways to build a roof. A common way is to erect trusses underneath the roof to hold it up. The triangulated members of the truss bring extra stability. Below is a diagram of a standard roof truss.





Trusses stabilize a roof considerably, but they also limit how high the ceiling can be inside the structure. While trusses can be designed to accommodate some high ceilings, they also have some limitations. Many of our homes have very high ceilings. For this reason, we often use a "hand-cut" roof that is framed in lumber, using 2-by-8-inch boards like those in the floor. Though hand-cut roofs are more labor-intensive, they allow us to maximize our ceiling heights for dramatic effects on the interior of the home.

The truss or hand-cut roof frame is covered with layers of ply board and, finally, a roofing material. The house I'm working on now will have a slate shingle roof. Slate is a type of rock that breaks easily into thin sheets. It makes a good-looking shingle, and it's quite durable. But slate shingles are heavy—quite a bit heavier than the cedar wood or asphalt shingles that are commonly used on houses. The structural engineer had to take the high load of the slate roof into account when designing the roof and the thickness of the exterior walls of the house.

All Systems a Go

With the walls in place and a roof over our heads, our structure is ready for the elements. But we still have *a lot* of work to do. Electricians will wire the home for electrical power. Plumbers will install the intricate systems of pipes that will bring fresh water to the home and carry wastewater away. Heating and cooling systems technicians will install climate-control systems to keep the home cozy all year round. Carpenters will construct cabinetry, build banisters in stairwells, and install flooring. Many other types of subcontractors will leave their mark before the home is move-in ready.

So, as you can see, building a house requires a tremendous amount of planning and teamwork, as well as ongoing troubleshooting. It also requires keeping up with new technologies like the Insulated Concrete Forms that help us do our jobs better. My favorite part of the construction process comes at the very end, when I take a step back and look at the beautiful home we just made. It's a feeling of accomplishment like no other. More often than not, we've built someone's dream home—and we did it on time and on budget.


Courtesy of Prity Rungta

Your apartment normally experiences around 5,000 pounds of force from live loads. If the building is required by law to have a safety factor of 4, how much stress must it be able to withstand? The building is 500 square feet.

1 Define the Problem

What is the problem asking for?

The problem is asking for the maximum amount of stress the building should be designed to withstand.

We have learned that this type of stress is a particular type of stress value, called $\sigma_{designed}$.

So, the problem wants you to find $\sigma_{designed}$.

2 Research the Problem

What information do you have?
What information do you need?

You are given values for the live load the building experiences, the square footage of the building, and the safety factor (S_F).

$S_F = 4$
$A = 500$ ft.^{2}
$F = 5{,}000$ lbs.

3 Develop Solutions and Select the Best Solution

Which equations do you use?
What do you solve for?

It's not always easy to know what formulas you should use, and you can often use different formulas to solve for the same thing, but as you get more familiar with your areas of study, it will get easier!

Looking at the list of values you have, you can say useful formulas would be formulas dealing with safety factor and stress.

1 $$S_F = \frac{\sigma_{designed}}{\sigma_{experienced}}$$

2 $$\sigma = \frac{F}{A}$$

4 Solve the Problem

Because, you want to find $\sigma_{designed}$, you can rearrange the first equation to be

3 $$\sigma_{designed} = S_F(\sigma_{experienced})$$

$$\sigma_{designed} = 4(\sigma_{experienced})$$

You don't have the value for $\sigma_{experienced}$, but with the information you have, you can use

2 $$\sigma_{experienced} = \frac{F}{A}$$

$$\sigma_{experienced} = \frac{5000\ lb.}{500\ ft.^2}$$

$$\sigma_{experienced} = 10\frac{lb.}{ft.^2}$$

Now you have all the values you need. Going back to equation 3,

$$\sigma_{designed} = 4(\sigma_{\text{experienced}})$$

$$\sigma_{designed} = 4(10\ \tfrac{lb.}{ft.^2})$$

$$\sigma_{designed} = 40\ \tfrac{lb.}{ft.^2}$$

5 Test and Evaluate

What does it all mean?

Does it make sense that $\sigma_{designed}$ = 40 lb./ft.^{2}?

Well, if $\sigma_{experienced}$ is 10 lb./ft.^{2} and $\sigma_{designed}$ is 40 lb./ft.^{2}, that means the building typically experiences 10 pounds of load per square feet, but it can withstand 40 pounds of load per square foot. So the safety factor is 4, meaning the designed stress is 4 times the amount of stress that is typically experienced. That makes a building pretty safe.

What's the Story?

1. Prity does not design structures, but she says she does use the engineering design process. How?
2. What is the primary way that the architect communicates his or her building plans to Prity's team?
3. Prity describes two new construction technologies that help her team deliver a higher-quality product for the money. What are they?

Designing with Math and Science

4. You are an structural engineer working for a design firm, and you have been given the task of designing a scaffold that can support a load of 300 pounds. The scaffold must have a safety factor of 2. How many pounds must your design be able to support?

Connecting the Dots

5. Sketch a plan view and elevation view of your school's lunchroom or library. The drawings should not include furnishings, but they should include architectural features such as windows, doors, pillars, or skylights.

What Do You Think?

6. Prity explains that she learned a lot about the construction industry by asking questions of the people she was working with. Describe a time when you've had to ask a lot of questions to learn what you needed to know in order to do a job or an assignment well.