Design Scenario: Supported Platform

Design III, Week 14

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supervised by
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"I pledge my honor that I have abided by the Stevens Honor System."

1 Introduction

1.1 Objective

The group was tasked with designing a column support for a single story platform. The platform would be similar to that used in a parking garage and may be used as a garage, storage platform, balcony, etc. In order to create the most optimal 10 foot by 10 foot platform, the group looked at the values of price and strength across multiple different rods and tubing possibilities.

1.2 Requirements and Given Equations

To speed up the process of testing and calibration, the group was asked to create a robust and flexible model of the scenario to be able to come up with a valid design. This way, any change in inputs would cause the model to give new pieces of data for those values and the group would be able to compare the values.

In order to do this, the group was given multiple equations that when put together would strengthen the validity of a design and help choose between different designs of similar structure. The group was given equations for Euler's Critical Buckling, Moment of Inertia for four different shapes of rod cross sections, a slenderness equation, and an equation for the total cost of material. By using each of these equations and allowing the values to change dynamically, the group could easily see which of two models would buckle under the load earlier, which design would be stronger, and which designs would be most cost effective.

2 Model Design

In order to develop a working model for the supported platform, the group decided to create a dynamic calculator through google sheets to input a select few variable that would alter the values of other parameters that were measured. By creating this dynamic calculator, the group was able to speed up the process of optimizing and iterating through designs until the strongest, while still least expensive one could be found.

2.1 Construction of the Model

Initially, the group began by creating a rough estimate for the total weight that would be supported by the platform. The group did this by finding the rough weight of cars, as well as snow that may lie on top of the platform after being built. Furthermore, a factor of safety was considered in order to make sure the expected weight we believe would exist on top of the platform to not accidentally exceed the amount.

After setting up the total load, the only other inputs put in by the group were for the inside and outside diameters of the tubes and rods. By adjusting these variables, every other variable in our table dynamically altered its value to make sure that it passed certain tests of viability as well as stayed strong enough to support the load with the factor of safety. Most of the table was filled with formulas that adjusted due to the change in cross section of the tube/rod.

2.2 Pass and Fail Logic

Since a lot of the dynamic calculator was expected to change in tandem with a change of the cross section, the group decided to implement logic into the Google sheets calculator to allow for inequalities to be solved in a visual manner. In this case, there were two tests that needed to pass, one being the minimum wall thickness value, and the other being the slenderness ratio test. By using the logic implemented in Google sheets, changing the inputs out of range of the values allowed would very notably change the green Pass cell into a red Fail cell. After these logical inequalities were set, each of the inputs could be very quickly judged for feasibility and optimized by the group.

3 Design Choice

The final design choice of the group was to use circular tubing to support the platform. The tubing would have an outside diameter of 3.33 in., and an inside diameter of 3.1635 in., resulting in a wall thickness of 0.1665 in., which is also the calculated minimum wall thickness for the circular tubing using the outside diameter size. The cross-sectional area of the planned tubing is 0.85 square inches which allowed for the lowest amount of material used, reducing costs for construction.

As shown in the figure below, testing was done using the dynamic calculator in order to achieve the most efficient measurements for each type of support. All four of the given support types were given measurements that passed the slenderness ratio test, and all of their slenderness ratios were calculated. The slenderness ratio was directly correlated with the cost of the support, and by using the formula given the group was able to assess that the tubes were more cost efficient than the solid supports. By testing different measurements, the group also found that the circular tube had the lowest slenderness ratio, and in turn had the lowest cost to create, which is crucial in the group's decision to use circular tubing over any other type of support.

Figure 1: Measurement Values

Wall Thickness (outside-inside/2)				0.15	in	0.08325	in				
Max Width/Diamter	36	in									
Radius of Gyration (r = sqrt(I/A)				0.9124509119		1.148276759		0.5513695071		0.545	
Slenderness Ratio Calculation				138.0896203		109.729644		228.5218867		231.1926606	
Slenderness Ration Test (75 <= r_s <= 400)				Pass		Pass		Pass		Pass	
Height of Column (above and below ground)	204	in									
Cost = $0.77 / lb * lbs * (6-5(SR/400))				$254.71		$175.06		$510.80		$517.07	
Cost = $0.75 / lb * lbs * (6-5(SR/400))	Hypothetical			$248.10		$170.51		$497.53		$503.64	

As shown above, the cost was minimized by using the circular tubing, with a price of $175.06 for a total of 49.12 lbs. of material. The total material used was considerably lower than that of any other type of support, but there was no drop-off in the critical buckling load of circular tubing against any other type. The total estimated load was 10579 lbs., and resulted in a total of 18513 lbs. after multiplying by the factor of safety. The circular tubing was extremely similar to the other types of support, as shown in the figure below, exhibiting that the drop off in material needed and cross-sectional area are not in direct correlation with the critical buckling.

Figure 2: Calculated Equations

Young's Modulus (E)	27,000,000	psi									
Moment Of Interia (I)				1.114	in^4	1.120	in^4	1.109052801	in^4	1.109	in^4
Critical Buckling Load	Hypothetical	2% Reduced Strength		18324	lbs	18417	lbs	18243	lbs	18237	lbs
Critical Buckling Load	Hypothetical	1% Reduced Strength		18141	lbs	18233	lbs	18061	lbs	18054	lbs
Critical Buckling Load	Hypothetical	12% Reduced Strength		15964	lbs	16045	lbs	15893	lbs	15888	lbs
P(cr) - Critical Buckling Load				18698	lbs	18793	lbs	18615	lbs	18609	lbs
Cubic in of Column = Area (in2) * Total Length (in)				273	in^3	173	in^3	744.2124	in^3	761	in^3
Cubic Feet Column				0.158	ft^3	0.100	ft^3	0.431	ft^3	0.441	ft^3
Material Needed:	490	lb / ft^3		77.39958333	lbs	49.12080476	lbs	211.0324514	lbs	215.9162744	lbs

4 Considerations

The first thing that the team noticed was an assumption made in the model outline that is practical. The model should be based on a hollow design. It was discovered that the hollow design held about as much load as the solid design did, however it is significantly cheaper for a hollow design due to the overall amount of material that would be used.

Although the team came up with optimal design when comparing strength of the design with the cost, there are several assumptions that can be made when implementing this design in the real world. In the real world, this design would be much too thin although it was the optimal size when designing it electronically. It would be worth making the design slightly thicker in the real world compared to how thin it is theoretically because of the wear and tear of material. The program does not account for weathering and by being thin, there is a higher chance that it becomes brittle when it is affected by weathering. Another reason that it would be smart to make the design thicker is because if someone were to hit into it, for example with a car, it can easily become unstable. By making the design thicker, there will be a stronger stability to the overall design, so then if it were to be hit, it would be much harder to ruin the beam. Therefore, by making it a little thicker, it may cost a little more, however it will still be significantly cheaper than a solid rod would be and it would become more stable when it comes to wear and tear and the stability of the rod.

5 Full Design

Figure 3: Excel Design Calculator

				Square Tube		Circular Tube		Solid Square		Solid Rod	
Known Variables:		*Units:*									
Platform Length and Width (10 feet)	120	in									
Platform Height	3	in									
Platform Mass	5,000	lbs									
Car Mass	0	lbs	Hypothetical								
Snow Mass	0	lbs									
Weather	0	lbs	Hypothetical								
Pallets	0	lbs	Hypothetical								
Rave Party/People	20000	lbs									
Total Load	25,000	lbs									
Factor of Safety (1,1.5,2,3,4)	1.75										
Total Load w Factor of Safety	43750	lbs									
Height (15 feet)	180	in									
Below Ground (2 feet)	24	in									
Fixed (Bottom) - Hinged (Top) - Kt	0.7										
Effective Length (Kt * 180in)	126	in									
Outside Length/diameter				2.38	in			1.91	in		
Inside Length/diameter				2.08	in						
Cross Sectional Area				1.34	in.²			3.6481	in.²		
Minimum Wall Thickness				0.3	in			0.0955	in		
Test Wall Thickness				Pass				Pass			
Outside Diameter						3.33	in			2.18	in
Inside Diameter						3.1635	in				
Cross Sectional Area						0.85	in.²			3.73	in.²
Minimum Wall Thicknesss						0.1665	in			0.109	in
Test Wall Thickness						Pass				Pass	
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