# Designing an Executive Stone Topped Desk Using Ansys APDL

## FEA Analysis for the optimization of Table Design

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**ABSTRACT**

. The purpose of this project was to design the dimensions and materials of an executive stone topped desk to withstand specified load parameters, using ANSYS APDL to ensure the deformation and stresses experienced by each component do not fail under the load and meet the design constraints. The loading conditions provided were those expected to be experienced during the tables regular usage. The material and cross section of the table legs and crossbeams were iterated to withstand the loading conditions with a buckling factor of safety of 4 and a stress factor of safety of 1.75, as were the material and thickness of the support plate.

The final design of the stone tabletop used Stainless Steel 304 square beams with an 0.08m x 0.08m cross section as the legs and crossbeams, and an Aluminum 6061 support plate with a thickness of 0.03m underneath the 18mm granite tabletop. These choices gave a stress factor of safety of 14, and a buckling FOS of 4.85, sufficiently meeting the design constraints.
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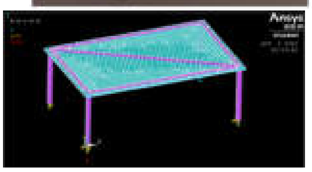
## 1. Introduction

The goal of this project is to design an executive stone topped desk, comprising of a granite stone top plate with a thickness of 18mm, a top support plate underneath that will support the stone top, a perimeter framing to support the edges and hold up the support plate and stone top, and 4 legs to hold up the structure. In the model, the support plate and stone top were given an overhang of 100mm from the frame. The support plate was chosen to be made of aluminum 6061, while the table supportive beams were made of 304 stainless steel.



The design constraints of the table are:

- The table must be able to withstand its own weight.
- The table must be able to withstand a point load of 1112N anywhere on the table surface.
- he table must avoid stress failure by a factor of safety of 1.75
- The table must avoid buckling failure by a factor of safety of 4.

The approach that will be taken in designing this will be very iterative. The dimensions of the supportive beams and the support plate affect the weight and loading of the table, while the loading affects the dimensions of the table. The recursive nature of the design makes it easier to begin with arbitrary, realistic dimensions for the beams and plates and then converging on the design constraints after consecutive analyses.

## 2. Given Constraints & Chosen Dimensions

For this desk, the support legs will be made of Stainless steel AISI 304. Below are all the design constraints and dimensions. The standard of units used throughout will be the SI units.

Measurements

| Material properties | Granite | Stainless Steel 304 | Aluminum |
|---|---|---|---|
| Density (kg/m^3) | 2550 | 7.86*10^3 | 2.71*10^3 |
| Young's Modulus (GPa) | 70 | 193 | 73.1 |
| Poisson's ratio | 0.3 | 0.27 | 0.35 |
| Yield stress (MPa) | N/A | 515 | 241 |

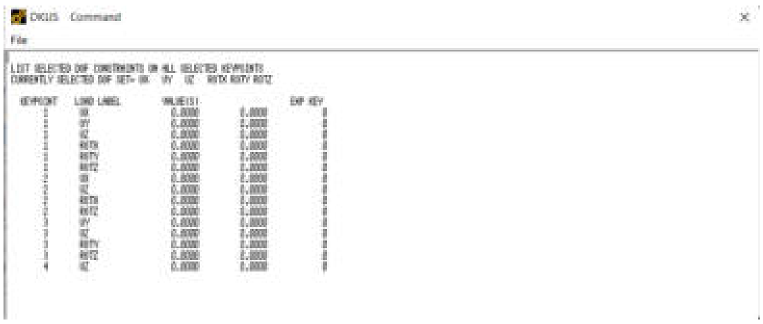


**Fig. 1:** The imposed constraints on the legs of the table using the 'corner of the room' concept to get the correct behaviour.

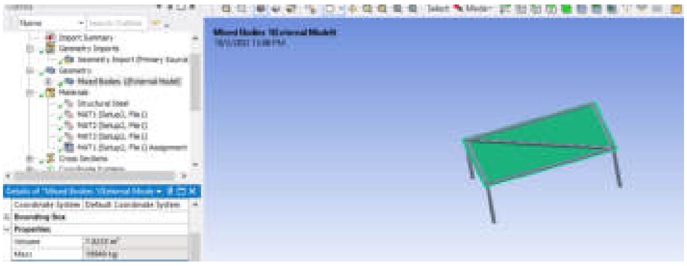


**Fig. 2:** The dead load of the table, displayed as kg because of units from APDL, actually in grams! Dead load of table is 195.7N

## 3. Hand Calculations

### 3.1. Reaction forces at legs

A check that can be used is to determine the reaction forces of each leg, which would be an indeterminate case.This approach will give us an insight on the magnitude and orders that we should expect to see through the legs and understand whether the applied load is being distributed correctly. In this given model, the concern is whether nodes of different bodies, being the plates and the table frame, are interacting correctly. To simplify the calculations for this approach, the legs will be taken as rigid - not reflective of the real world or our constraints posed in APDL, however it will provide us with a ballpark of magnitudes and orders to expect. A more rigorous method where the legs are modeled as elastic is Surya N.Patnaik's work for NASA, "Compatibility Conditions of Structural Mechanics". Using the simplified assumptions of "Reactions on Rigid Legs of Rectangular Tables" that has an uncertainty of around 1N per reaction between experimental and theoretical, the equations obtained are:

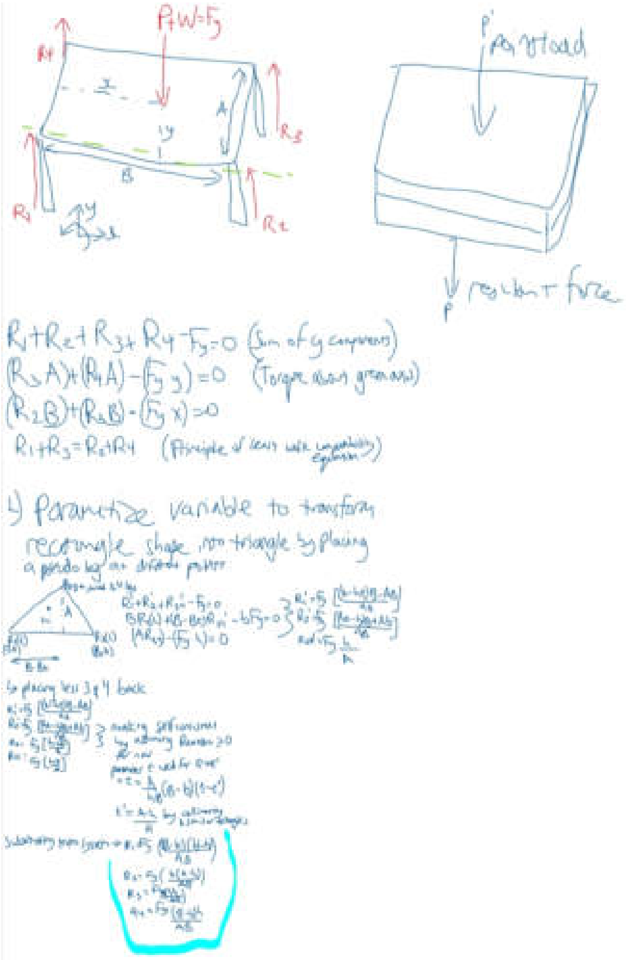



**Fig. 3:** The approach that can be taken from here is to either model the support and top plate as a single plate made of a composite material which would mean Fy is simply applied load and weight, and not the resultant force; or modelling it as two separate plates deflecting together but not constrained to each other as if they were glued.

### 3.2. Weight calculation

To find the weight of the stone top: $\rho V g = 2550 \frac{kg}{m^3} * (18 \cdot 10^{-3} * 2m \times 3m) = \boxed{2701N}$

## 4. Simulations

To model the table using ANSYS, a few simplifications were made. Firstly, the deflection of the table is forced to act across the diagonal of the table surface by constraining the base of each leg as if the table were in the corner of a room. This is necessary as the FEA software would otherwise yield singularities or truncation errors in the solution. This causes the deflection in the free leg to be greater than every other leg as it is the least stiff, while the fully constrained leg would experience a greater stress than real life as it is stiffer. This is a valid assumption as this represents the worst case loading scenario for the table, meaning a table able to withstand these forces should be able to withstand the lesser loads of real life.Secondly, the table legs and perimeter framing (support beams) are modeled as 1D beams with a square cross section and further attributes. This improves the efficiency of our work given that less computational resources and

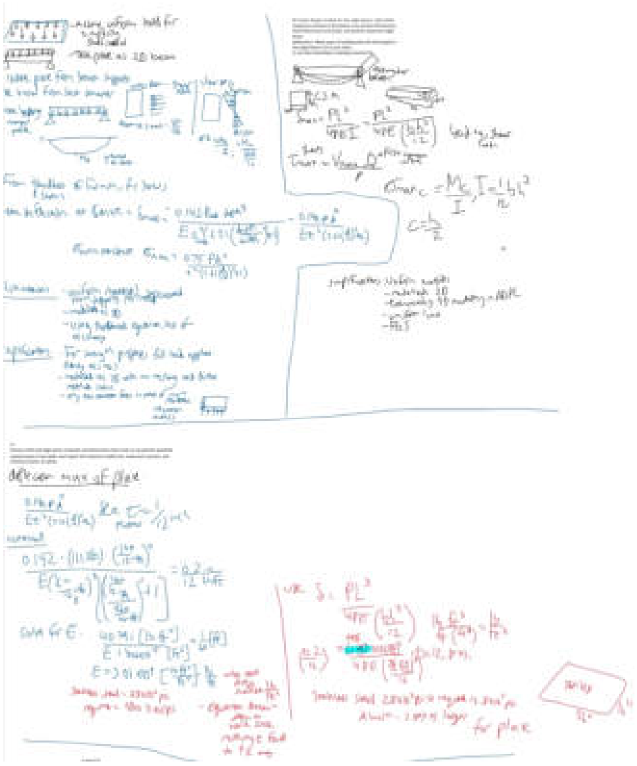


**Fig. 4:** Background hand calculations for material choice, deflection and stresses with dummy cross sections.

time need to be spent on running the simulation for an answer. Lastly, the table top and support plate are assumed to be glued together and are thus modeled as a 2D shell comprising of two layers - the aluminum support plate and the granite stone top. This top surface is then assumed to be glued to the 4 perimeter beams as well at the diagonal cross beam. Such an assumption is reasonable as construction of such a table would not involve welding, but would either utilize screws or an adhesive method.

### *4.1. Iteration 1*

**Initial Component Dimensions:**
Table beam Cross-section: 0.08m x 0.08m
Support plate height: 0.03m
**Mesh:**
Beam element length: 0.1m
Shell element length: 0.1m (smallest length before mesh can't generate)
Shell cross section: 0.018 m thickness, material ID 2, Integration parts 3; 0.005 m thickness material ID 3, 3 integration parts as well.
**Boundary conditions used:**The constraints on the legs are listed in Figure 1.
**PHysics Model:** The densities of every material used is applied to the materials in the simulation. The acceleration due to gravity is applied in the Z direction to simulate the dead loads of each component. (define loads>structural>inertia>gravity> Z direction +1).

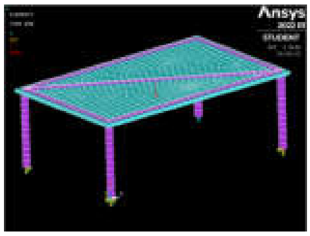



**Fig. 5:** The tabletop area is divided into 3 areas by the perimeter lines and the diagonal crossbeam before the mesh is generated.

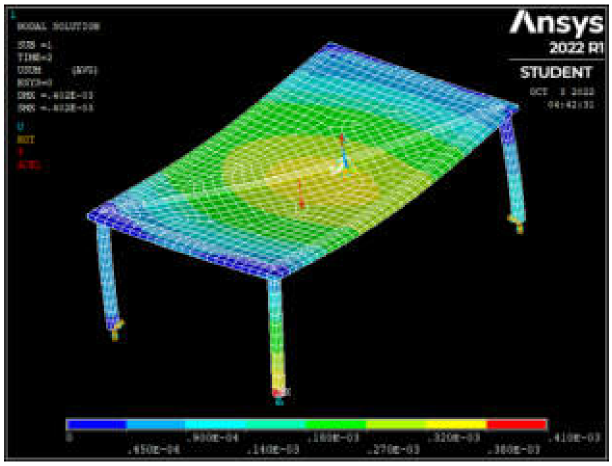



**Fig. 6:** Deflection of the table.The maximum deflection experience by the table is 0.402mm at the base of the free table leg since it is the least stiff component, the table surface deflects by a maximum of 0.313mm.

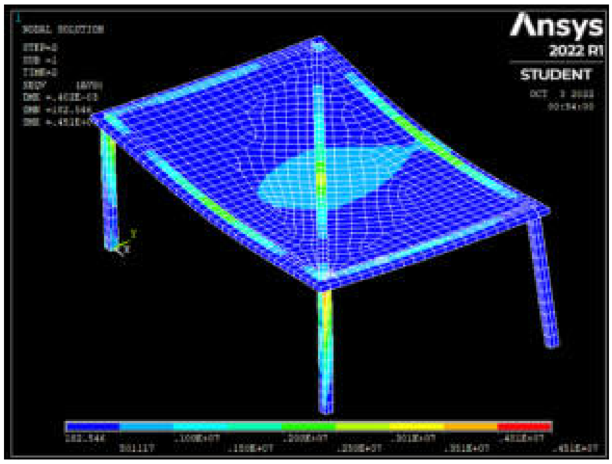
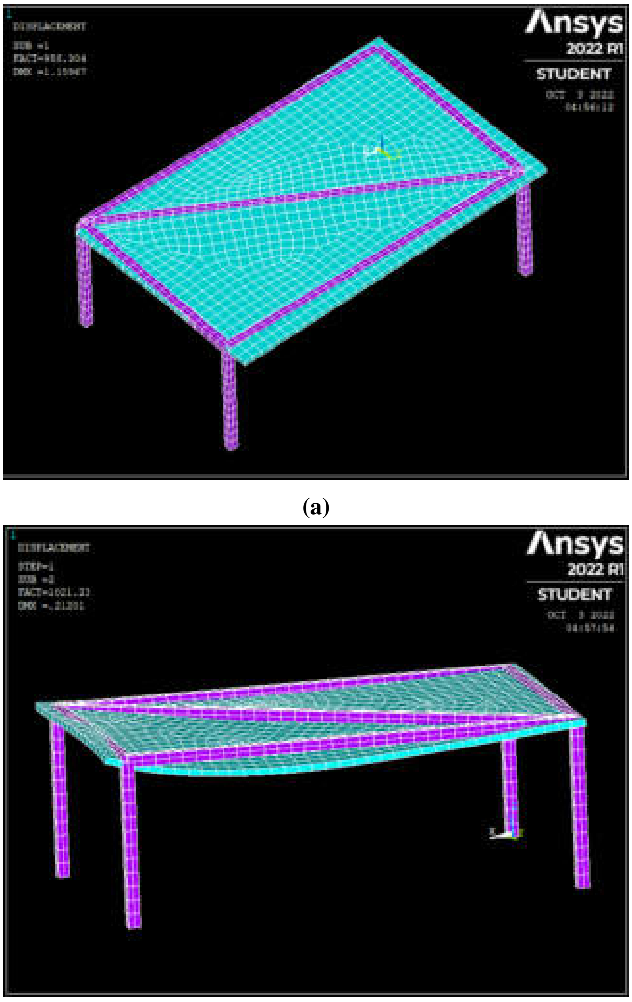



**Fig. 7:** The maximum stress experienced by the support beam is 4.57MPa, representing a FOS of 114.19, calculated by $\frac{\sigma_{yield}}{\sigma_{max}}$ . It is clear that the beams are greatly over-dimensioned




**(a)**

**(b)**

**Fig. 8:** (a) Mode 1 (b) Mode 2

Given that the smallest buckling factor of safety is 958 for the first modal shape of the top plate, it is clear that the 3cm support plate is also greatly over dimensioned. The two parts can both be shrunk.

### *4.2. Iteration 2*

**Component Dimensions:**
Table beam Cross-section: 0.01m x 0.01m
Support plate height: 0.005m
**Mesh:**
Beam element length: 0.1m
Shell element length: 0.1m (smallest length before mesh can't generate)
Shell cross section: 0.018 m thickness, material ID 2, Integration parts 3; 0.005 m thickness material ID 3, 3 integration parts as well.

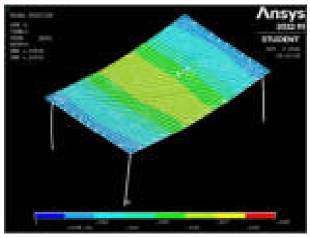



**Fig. 9:** Dead load deflection in the beams is 8.39mm, max deflection in the plate is 6.53mm. Max stress in the support beams is 22MPA, representing a factor of safety of 23.4. Max stress in the plate is 8.25MPa

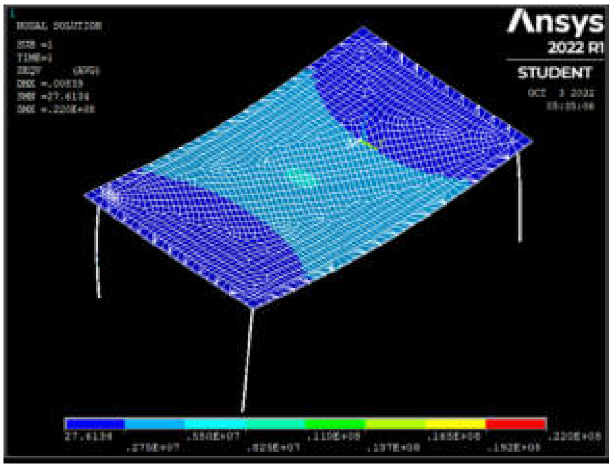



**Fig. 10:** Overall Von-Mises Stress

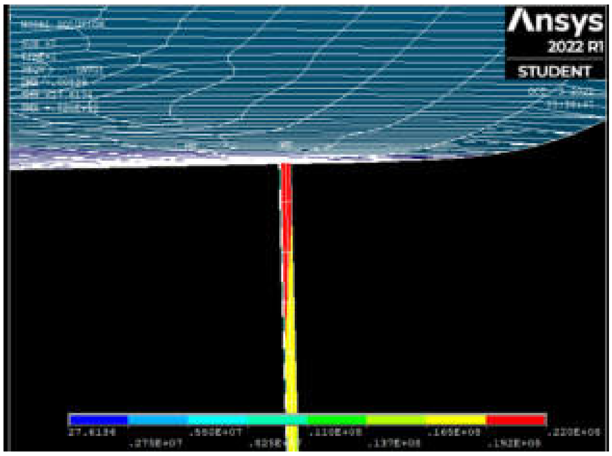



**Fig. 11:** Max Von-Mises Stress

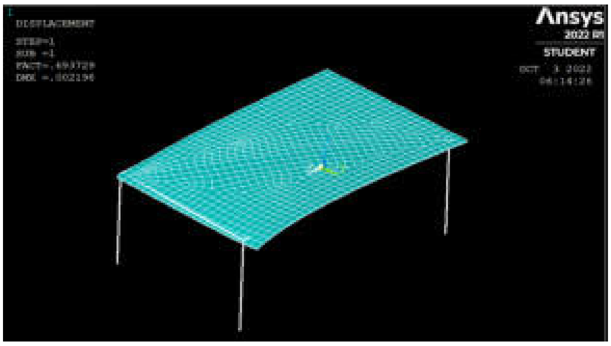



**Fig. 12:** First modal eigenvalue solution of Case 2.The factor of is solution is 0.694, which is lower than 4. The plate is either too thin, or the crossbeams are too thin and allow for buckling under the load. We will try increasing the beam width to increase the FOS of the buckling.

### *4.3. Iteration 3*

**Component Dimensions:**
Table beam Cross-section: 0.03m x 0.03m
Support plate height: 0.005m
**Mesh:**
Beam element length: 0.1m
Shell element length: 0.1m (smallest length before mesh can't generate)
Shell cross section: 0.018 m thickness, material ID 2, Integration parts 3; 0.005 m thickness material ID 3, 3 integration parts as well.

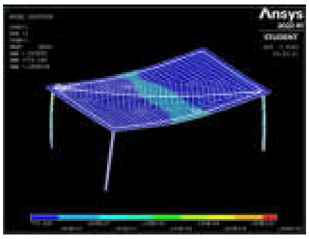



**Fig. 13:** The Von Mises Stress of the system under the 1112N point load at the center. The maximum stress seen was $0.3E08N/m^2$ or 28.8MPa, with a FOS of 17.88.

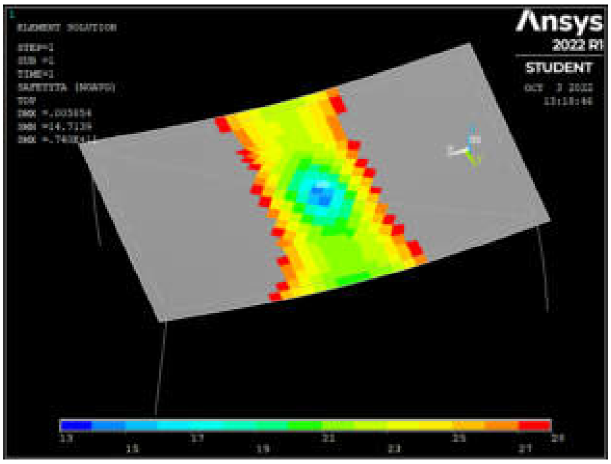



**Fig. 14:** A FOS plot, indicating that the minimum FOS on te table is 14 when loaded near the centre. This is well within design constraints

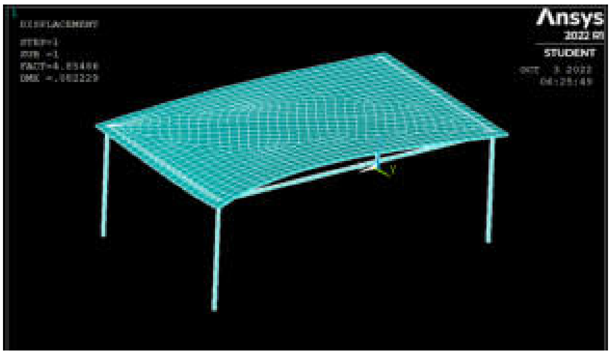



**Fig. 15:** As can be seen by the eigenvalue solution, the table has a buckling safety factor of 4.85 which is sufficient for the design constraints. We now consider the stresses on the components to see if the table can withstand the loading stress.

## 5. Conclusion

After several iterations and exploring various features of APDL, we were able to meet the delicate balance between structural strength and buckling FOS. Initially the table designed would heavily deflect under its own weight, and after a couple of hours of troubleshoot,the order of the density was off.The final design of the stone tabletop used Stainless Steel 304 square beams with an 0.08m x 0.08m cross section as the legs and crossbeams, and an Aluminum 6061 support plate with a thickness of 0.03m underneath the 18mm granite tabletop. These choices gave a stress factor of safety of 14, and a buckling FOS of 4.85, sufficiently meeting the design constraints.
Closed loop transfer equation:

## 6. References

Material properties were found at:

- https://www.matweb.com/search/datasheet.aspx?matguid=3d4056a86
- https://material-properties.org/what-is-strength-of-stainless-steels-yield-uts-definition/
- https://www.aluminum-products.com/yield-strength-of-6061.html