Engineering Senior Design Reports

Engineering Science Department

11-22-2010

Platform Project - Senior Design Group

S. Brady

R. Gamboa

D. Megalo

U. Pastran

T. Pursell

Repository Citation

Brady, S.; Gamboa, R.; Megalo, D.; Pastran, U.; and Pursell, T., "Platform Project - Senior Design Group" (2010). *Engineering Senior Design Reports*. 86.
https://digitalcommons.trinity.edu/engine_designreports/86

TRINITY UNIVERSITY

Platform Design Report

ENGR-4381

11/22/2010

Platform Project – Senior Design Group

S. Brady, R. Gamboa, D. Megalo, U. Pastrán, T, Pursell.
Dr. Glawe, Advisor

Darren Megalo Ulises Pastrán

After extensive research and analysis, the final design solution for a durable, transportable, strong, and cost-effective water bladder platform has been selected. The platform will be constructed modularly and each module will be comprised of four separate subsystems. The top will consist of a frame that connects rods assembled in a grid pattern. These tops will rest on pedestal supports that keep the grid-tops in place. Hollow square legs will attach the pedestal supports to leveling mount feet that are adjustable for uneven terrain. With the selection of this optimized design, the team will move forward with the construction and testing phase towards the final project objectives of designing a functional prototype that meets all design constraints and providing detailed manufacturing and use instructions for a full-scale model.

Executive Summary

Trinity University students are working with Medair to develop a water bladder platform. These platforms will be used by Medair in their emergency disaster relief efforts in remote areas of Southern Sudan. The water bladders that are supported by these platforms are used to deliver fresh and clean water to isolated communities, which use the water for cleaning, personal hygiene, and drinking. The platform must be at least 1m tall to provide enough water pressure at the end of the fluid transport system. The top surface of the platform must be at least 4m x 5m in order to hold the entire bladder. The platform must be easy to transport and should not exceed 250kg. It must be a durable design due to the varied and extreme African climate conditions and must be produced for a total cost of less than $3000.

The final design will be drafted in Pro-Engineer and tested using Pro-Mechanica in order to ensure the solution can hold the weight of the bladder with a safety factor of four.
The final design is modular and comprised of four main components: the platform surface, support pedestals, legs, and feet. The top surface is a grid design that uses aluminum rods. These rods are connected to a frame made from hollow rectangular aluminum tubes. The pedestal support includes four pegs that will secure one corner from each of the four tops supported at the joint. This pedastal support sits on a square hollow aluminum tube that will serve as the leg and will hold the top at just over one meter. The feet are leveling mounts that will be screwed onto the bottom of each leg. The production of the entire platform is not feasible with the current resources, so four prototype modules will be constructed and tested. After obtaining data from the prototype modules, analysis will be performed to ensure the structural integrity of the full scale model and success in meeting stated constraints.

Table of Contents

Table of Figures

Table of Tables

1 Introduction

Engineering design students from Trinity University are designing a platform to support a water bladder for Medair International, a non-governmental organization (NGO). Their primary objective is to "seek out and serve the most vulnerable people affected by crises, particularly the forgotten men, women, and children who live in difficult-to-access regions in Africa, the Middle East, and Asia" (Medair) by providing relief and rehabilitation services such as healthcare, water, sanitation, and shelter. When providing drinking water for communities, Medair uses 2,642 gallon (10m^3) water bladders which must be positioned at least 1m off the ground to provide adequate water pressure. In the past, Medair has used local materials, such as 55 gallon drums covered with plywood or locally made bricks to construct platforms for these water bladders. The ultimate design will replace the use of these more rudimentary platforms in relief efforts and diminish the need for new platforms to be created at each new relief location, providing increased mobility, reduced amount of labor, and reduced set-up time. Additionally, a mobile platform will eliminate the need to consume local supplies in regions already depleted of resources. This will allow Medair to more efficiently and more effectively respond to areas in need of emergency relief. The project team is working under the guidance of Brady Davis—a Medair employee and 2005 Trinity graduate—to complete a feasible design. After a design is chosen, the platform will be constructed, tested, and evaluated, and manufacturing and use plans will be provided to Medair.

1.1 Applicable Constraints

The design of the new platform is constrained by necessity in the areas of dimensions, cost, ease of transport/assembly, durability, and manufacturability. The top surface of the platform must have dimensions of 4m by 5m in order to hold the water bladder. Additionally, the height of the platform must be at least 1m in order to provide sufficient water pressure at the end of the piping network. The overall cost of the platform must not exceed $3,000.

In order to transport the platform to areas in need, it must not exceed a mass of 250kg and must be designed to fit onto a Cessna 208B aircraft. The door of the aircraft is 49in by 50in while the hub of the aircraft in which the platform must fit is approximately 42in wide, 46in tall, and 144in long (with necessary considerations for seating space). In addition, the assembly or disassembly of the platform should take two untrained persons less than six hours to complete. The assembly does not include either unloading the water bladder from the aircraft or filling the bladder with water.The platform must be able to withstand a harsh environment, which includes heavy rain, intense sun, and temperatures of up to 45°C. The ground in areas of platform application is also typically uneven or unstable, so the design must account for this as well.

While an emphasis will be put on the ease of manufacturability of each part of the design, it is not expected that the product will be mass produced. Thus, it will be assumed that it is reasonable for the end product to be manufactured and assembled by hand rather than by an automated process.

1.2 Project Objectives (SMART)

The first primary objective is to design a platform and test the proposed design using Pro-Mechanica. This test will indicate whether the platform can hold the necessary 10 metric tons of water (10m^3) with a safety factor of four. Secondly, a module or portion of the platform will be constructed. This prototype will be tested for success in lab conditions similar to those present in the area of use. The lab conditions for this testing will include both a concrete surface as well as deep sand. The success of this prototype will be based on a proportionate weight for the given sections of the platform tested. Finally, the prototype and the results from its testing will be used to propose detailed manufacturing and use plans.

2 Design Overview

A platform prototype, which will consist of four subsystems, has been selected for construction and testing. The first system is a modular grid-top that consists of an aluminum frame that holds eight aluminum rods running across the frame in a square grid pattern (four rods along each axis). These modules will be assembled together with "pedestal supports," each of which will support the adjacent corners of four module grid-tops. A total of thirty hollow square aluminum legs will be attached to the base of these pedestal supports and provide the link between the pedestals and the feet. The feet attached to the legs must adjust to the type of topography and ground conditions. Therefore, leveling mounts with threaded screws on one end and a ball joint and plate on the other end were selected to enable self-adjustment.

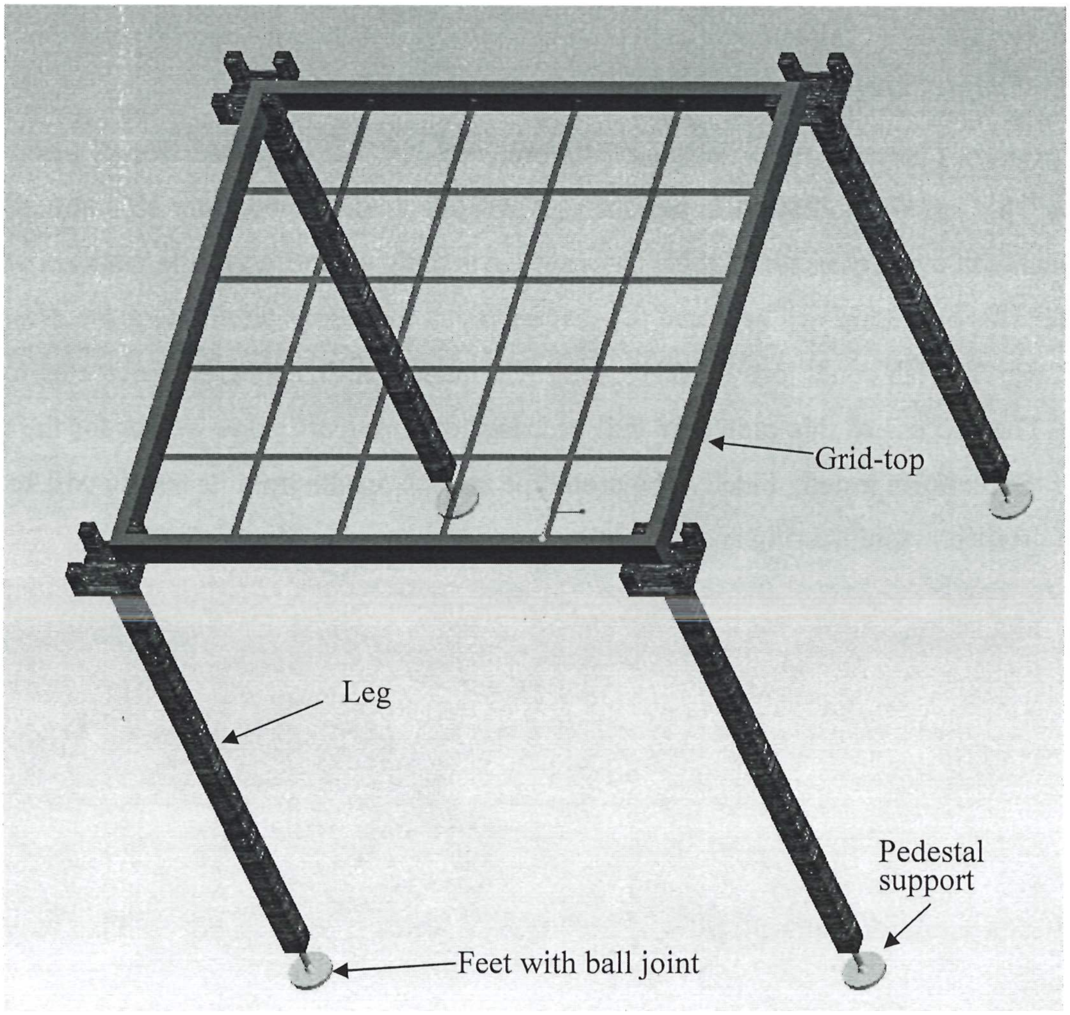

Figure 1: Platform module measuring $1m^2$.

3 Subsystems Design

3.1 Grid-Top Surface

The grid-top surface of each module will consist of a 6063-T52 aluminum frame utilizing 1 in by 2 in. by 0.125 in. rectangular tubing connected at the corners with L-brackets and oriented such that the 2 in. dimension of the tubing is vertical. The inside of each member of the frame will have four evenly spaced ½ in. diameter holes that extend through the inside wall of the frame. These holes will secure ½ in. diameter aluminum rods running across the frame (four in each direction), forming a grid. All the rods running in each direction will be on the same plane as dictated by the holes in the frame. A schematic of the surface modules can be seen in Fig. 5., with each module measuring 1m by 1m.

3.2 Pedestal Support

The grid-top modules will be assembled together through the use of pedestal-like supports mounted on top of the legs. The pedestal supports will consist of a 4.5 in. by 4.5 in. steel plate with pegs in each corner. The schematic of this design can be seen in Fig. 2. The corners of four modules will be placed onto the pedestal so one pedestal and leg assembly will support one-fourth of four modules weight or the equivalent weight of one module. The modules will be assembled in the fashion displayed in Fig. 4.

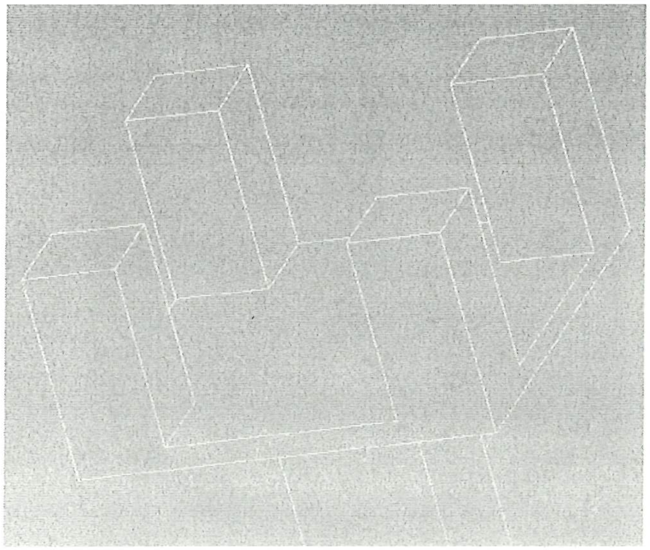

Figure 2: Pro-E model of the pedestal support in wireframe view.

3.3 Legs

The support subsystem will consist of hollow square legs. Aluminum was chosen from an analysis of different materials for its strength to weight ratio. Buckling will be the first mode of failure so the analysis of the legs was exhaustive to ensure no buckling would occur. Tubular legs were selected because they have a higher buckling strength for the same amount of material when compared to solid rods. The square geometry was chosen because it can have the same buckling strength but requires less material than a circular geometry. The size of leg selected was 1.5 in. by 1.5 in. with a wall thickness of 0.125 in. and a height of 1 m. The design will require 30 legs total.

3.4 Feet

Feet are required to support the legs and the rest of the structure. Crucial to the feet design is the ability to adapt to various topography and conditions of the ground. Leveling mounts were found to be the best option with threaded screws on one end and a ball joint with a plate on the other end. A model of this design is displayed in Fig 2.

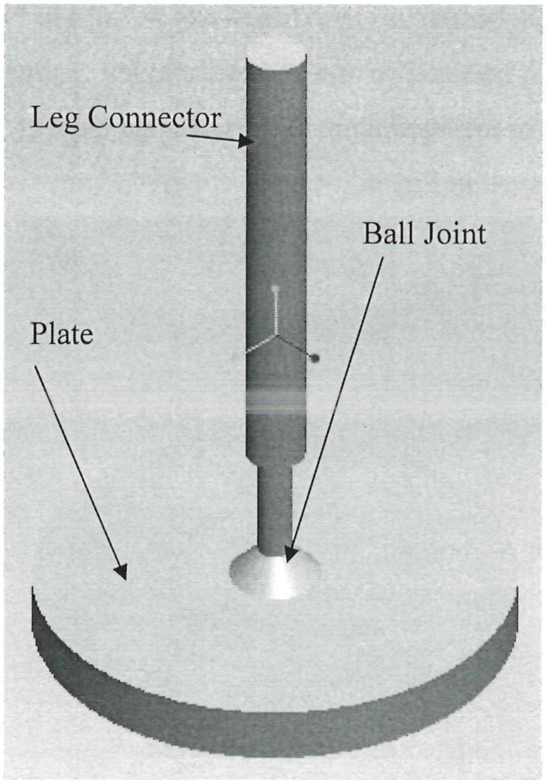

Figure 3: Pro-E model of leveling mount (foot).

The threads will screw up into the tubular legs. The base plate of the leveling mount may be augmented with a larger plate to prevent sinking into the ground. The ball joint will adjust to the uneven conditions of the ground.

4 Conclusion and Future Work

With the complete specification of parts and design, the next few months of the design process will be entirely focused on building and testing the prototype. In the immediate future, all necessary parts for the build will be ordered from the locations listed in Table 1. Since no off-the-shelf products are used for any of the final subsystem designs, with the exception of the feet, assembly and connection of the components will be a major challenge in the next phase of the project. Since both aluminum and steel (which cannot be welded to each other) components are utilized, the method of attaching the steel plate to the aluminum leg remains an open issue. Although the plan is to use a sleeve attachment with a stud to connect the legs to the feet, some machine shop work will be required to perfect the implementation of this connection.

Early in the second phase of the project, each individual subsystem will be machined and assembled. A large amount of time will be budgeted for this portion of the project since it is expected that several unforeseen issues will arise during the build. For the grid-top subsystem, the magnitude of the maximum displacement on the aluminum rods remains somewhat of an open issue as all forms of deflection analysis have taken into account considerable assumptions. Though all analysis suggests that the rods will be significantly stronger than what is necessary, there is still some concern about the rod integrity due to the assumptions made during the analysis process. Therefore, once the modules are assembled, extensive testing will be performed to assure integrity of all components as well as acceptable performance on the project constraints of strength, disassembled size, and assembly time. Designing a feasible experimental procedure to test the strength of the modules will be a project challenge since a large amount of weight will be required. However, once structural integrity is confirmed, the remainder of the time will be devoted to auxiliary tasks such as clearly documenting manufacturing and use details and working on a method of transportation for the platform.

5 Bibliography (MLA)

Aluminum. 2010. 3 November 2010 <http://www.onlinemetals.com/merchant.cfm?id=60&step=2&top_cat=60>.

Aluminum Platforms. 2010. 4 October 2010 <http://www.folding-tables-chairs.com/aluminum-platforms-staging.html>.

Fun Spot Trampolines. "Trampoline Fabric." 2010. Funspot.com. 12 October 2010 <http://www.funspot.com/trampoline_fabric.php?source=Google_trampoline_fabric&gclid=COTEseHP0KQCFYXs7Qod8S-TCg>.

IntelliStage Portable Stage Risers. 28 September 2010 <http://www.stagedrop.com/products/risers.html>.

Leveling Mounts - Monroe PMP. 17 November 2010 <http://www.monroeengineering.com/levelingmounts/page397.htm>.

Medair. Medair International - Emergency relief and rehabilitation. September 2010. 06 September 2010 <http://www.medair.org/en/who-we-are/>.

Occupational Safety and Health Administration. OSHA - Safety Requirements for Scaffolding. 2010. 25 September 2010 <http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9720>.

Portable Stages. 2010. 4 October 2010 <http://www.folding-tables-chairs.com/portable-stages.html?tab=2#pt>.

stylemexican.com. Authentic Mayan Hammocks & Mexican Hammocks. 2010. 28 September 2010 <http://www.stylemexican.com/super_king_hammocks.html>.

Ten Cate Nicolon. "Baycor® 24109/24119 PERMATRON TRAMPOLINE FABRIC." Hurricane Glass Shield, Inc. 4 October 2010 <http://www.hurricaneglassshield.com/pdfs/PERMATRON.pdf>.

Tesner, John. Structural Engineer Sonia Brady. 28 September 2010.

A Figures

Pro-Engineer generated figures of the complete design as well as of each modular component used to create the platform.

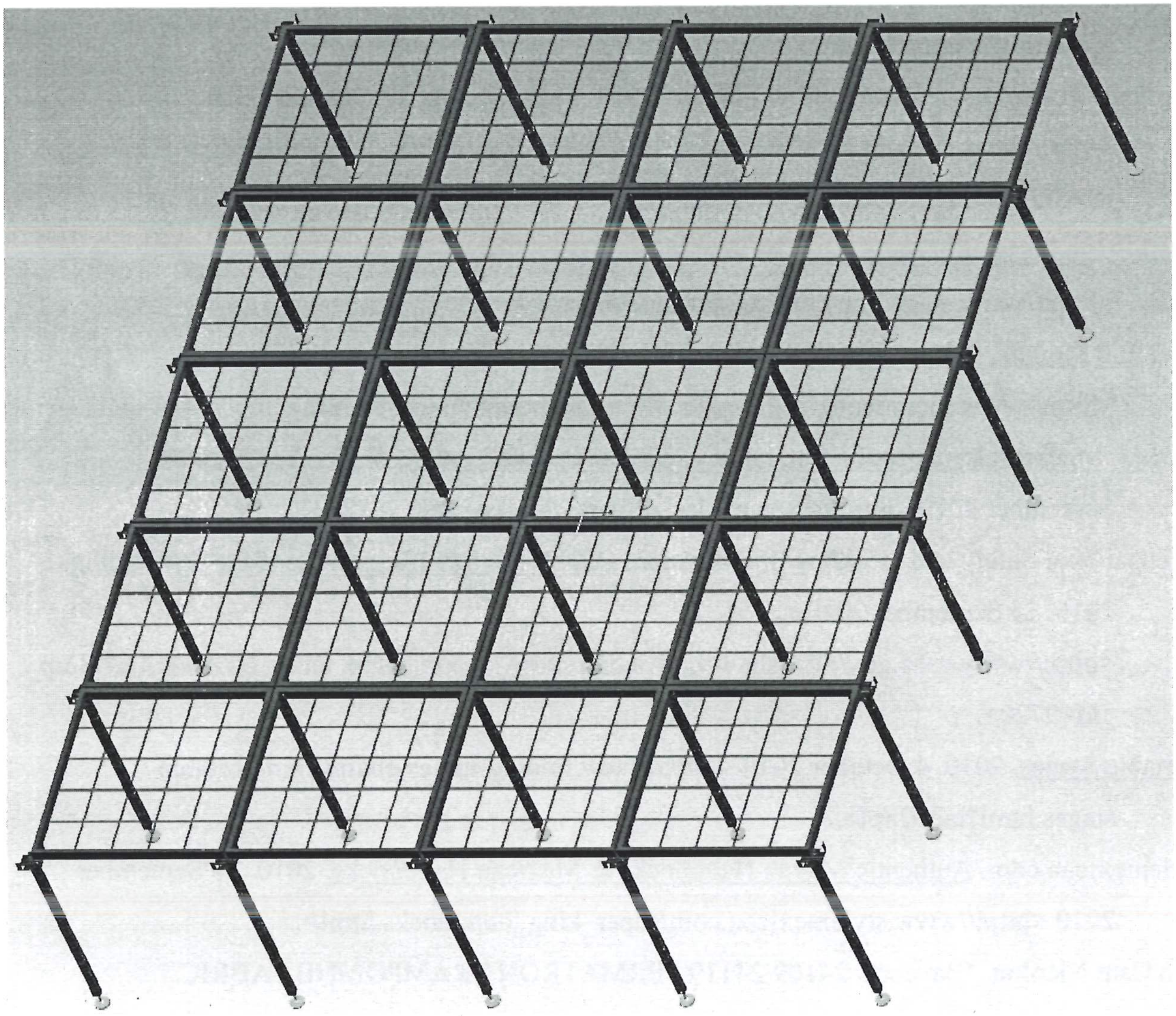

Figure 4:Pro-E Rendering of the 4m x 5m platform.

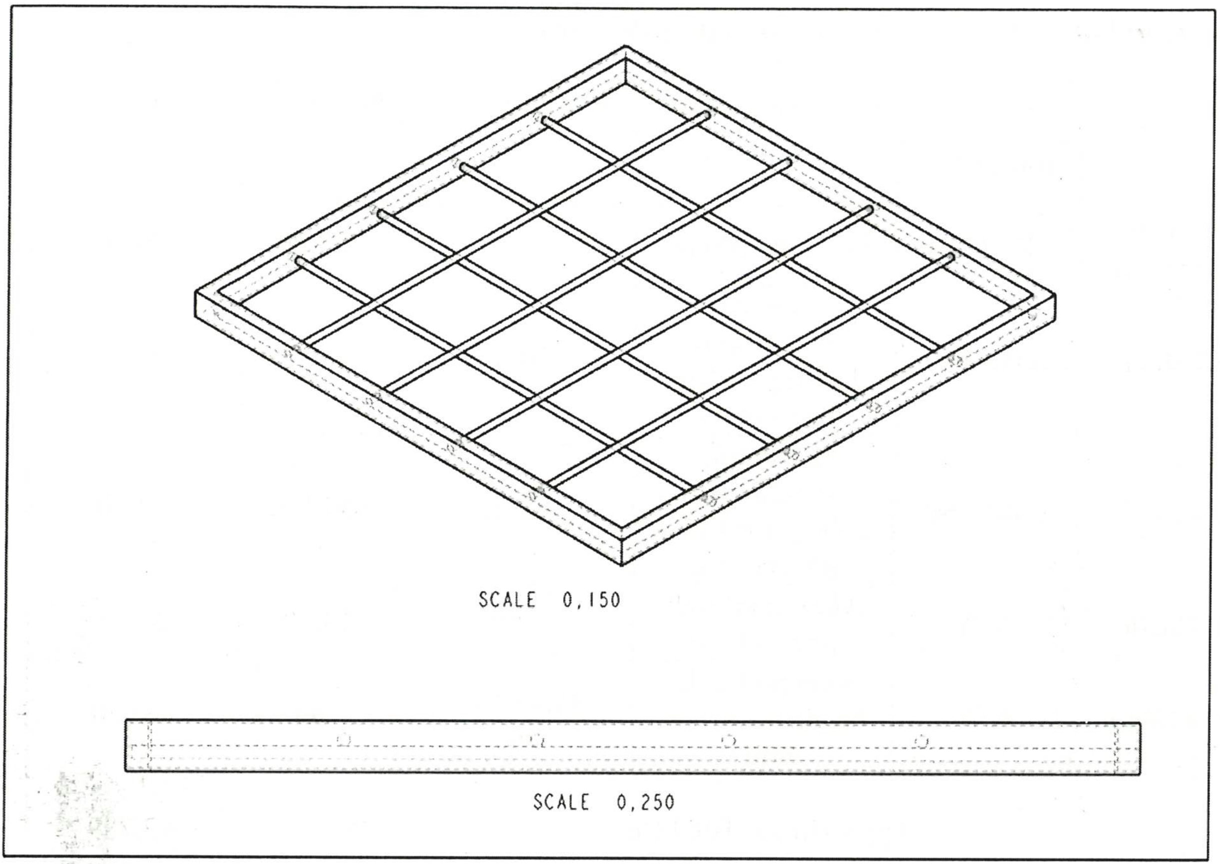

Figure 5: Engineering sketch of the top module

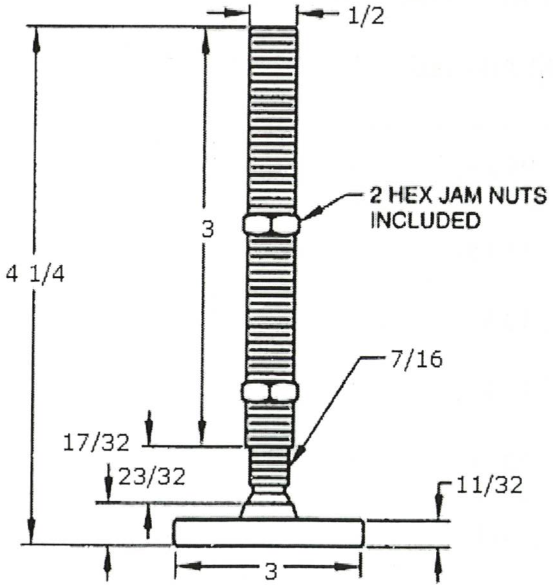

Figure 6: Schematic of Leveling Mount (Leveling Mounts - Monroe PMP)

Table 1: Bill of Materials and Cost for Entire Platform

Vendor	Part Number	Item Description	Quantity	Price/Ea	Actual Amount
Monroe Engineering	LPS-1230	Leveling Mount	30	$23.00	$690
SSS-Steel	6063-T52	Square Aluminum Tubing for legs plus cut fee	30 m	~$11/m	~$330
SSS-Steel	6063-T52	Rectangular Aluminum Tubing for frame plus cut fee	80 m	~$14/m	~$1120
TAP Plastics	N/A	Aluminum rods plus cut fee	160	$3.30	$529
Home Depot	N/A	Steel plates, L-brackets, nuts & bolts	30 pedestals total	~$4	~$120
Approximate Total Cost					$2,789

Table 2: Weight Budget for Entire Platform

Major Component	Weight Allotted
Frame	95 kg.
Rods within frame	55 kg.
Legs	40 kg.
Feet	30 kg.
Other/Miscellaneous	20 kg.
Total Weight	240 kg.

B EES

This appendices includes the EES Code, solution window and additional information from EES concerning the analysis of the surface and legs.

B.1 Bar Grid Surface

B.1.1 EES Code to determine required dimensions of bars for grid-top.

```
"Bar Grid Design Analysis"

"Procedure function for deflection"
Procedure defl(Lx,n_x,n_y,f_y,q,E,I,z:defl_SF)
"Note - this is true for the deflection for the first half of the bar. Due to symmetry, the same is true for the
other half starting from the opposite end"
b1 = Lx - Lx/(n_y+1)
b2 = Lx/(n_y+1)
b3 = Lx - 2*Lx/(n_y+1)
b4 = 2*Lx/(n_y+1)
a1 = Lx-b1
a2 = Lx-b2

"Note - these equations are technically only valid from 0<z<=a1, but are used as approximations for the
0<z<=L/2 with the deflection being the same for the second half of the bar as well"
if ((n_x=3) and (n_y=3)) then
    defl_SF = -q*z/(24*E*I)*(Lx^3-2*Lx*z^2+z^3)+ f_y*b1*z/(6*Lx*E*I)*(Lx^2-b1^2-
z^2)+f_y*z/(48*E*I)*(3*Lx^2-4*z^2)+f_y*b2*z/(6*Lx*E*I)*(Lx^2-b2^2-z^2)
else
    if ((n_x=4) and (n_y=4)) then
        defl_SF = -q*z/(24*E*I)*(Lx^3-2*Lx*z^2+z^3)+ f_y*b1*z/(6*Lx*E*I)*(Lx^2-b1^2-
z^2)+f_y*b3*z/(6*Lx*E*I)*(Lx^2-b3^2-z^2)+f_y*b4*z/(6*Lx*E*I)*(Lx^2-b4^2-
z^2)+f_y*b2*z/(6*Lx*E*I)*(Lx^2-b2^2-z^2)
    else
        if ((n_x=5) and (n_y=5)) then
            defl_SF = -q*z/(24*E*I)*(Lx^3-2*Lx*z^2+z^3)+ f_y*b1*z/(6*Lx*E*I)*(Lx^2-b1^2-
z^2)+f_y*b3*z/(6*Lx*E*I)*(Lx^2-b3^2-z^2)+f_y*b4*z/(6*Lx*E*I)*(Lx^2-b4^2-
z^2)+f_y*b2*z/(6*Lx*E*I)*(Lx^2-b2^2-z^2) +f_y*z/(48*E*I)*(3*Lx^2-4*z^2)
         else
        endif
    endif
endif
end

"Given"
x=5       "x dimension of full platform"
y=4       "y dimension of full platform"

$ifnot parametric table
```

```
a=5        "# of modules in the x-direction [5m side]"
b=4        "# of modules in the y-direction [4m side]"
n_x=4      "# of bars in the x-direction (top)"
n_y=4      "# of bars in the y-direction (bottom)"
E= 4.68*(10^10)            "modulus of elasticity"
d= .5       "diameter of the rod"
rho=2020  "density"
z=.5        "position along a bar, from left to right (used in defl eqn)"
$endif

"Simple Relationships"
I=pi*(d*Convert(in,m))^4/64          "2nd moment of inertia - circular cross-section"
Ac=.25*pi*(d*Convert(in,m))^2      "Circular Cross-sectional area of the rod"
m=40000                              "mass of bladder w/ a S.F. of 4"
F_module=m*g#/(a*b)                "weight force experienced by one module - w/ safety factor"
Lx=x/a "length of module in the x-direction"
Ly=y/b "length of module in the y-direction"

"X-bars (bars on top)"
F_beamx =F_module/n_x "weight force experienced by each beam in the x-direction"
q=F_beamx/Lx              "uniformly distributed force on a beam in the x-direction - w/safety factor"
F_beamx=(n_y+2)*f_y     "sum of forces equation"


"Y-bars (bars on bottom)"
f_x=f_y
Ra_y= .5*(n_x+2)*f_x

"Shear stress - x-bars"
V=f_y
sigma=V/Ac

"Deflection equations - x-bars"
Call defl(Lx,n_x,n_y,f_y,q,E,I,z:defl_SF)

defl_noSF = .25*defl_SF

"Platform Weight"
W_module=(n_x*Ac*Lx+n_y*Ac*Ly)*rho
W_platform=W_module*a*b
```

B.1.2 EES Solutions Window – Bar Grid

a=5
Ac=0.0001267 [m^2]
b=4
d=0.5 [in]
defl_noSF=-0.4593 [m]
defl_SF=-1.837 [m]
E=6.895E+09 [Pa]
F_beamx=4904 [N]
F_module=19614 [N]
f_x=817.3 [N]
f_y=817.3 [N]I=1.277E-09 [m^4]
Lx=1 [m]
Ly=1 [m]
m=40000 [kg]
n_x=4
n_y=4
q=4904 [N/m]
Ra_y=2452 [N]
rho=2712 [kg/m^3]
sigma=6.451E+06 [N/m^2]
V=817.3 [N]
W_module=2.748 [kg]
W_platform=54.97 [kg]
x=5 [m]
y=4 [m]
z=0.5 [m]

B.1.3 EES Plots – Bar Grid

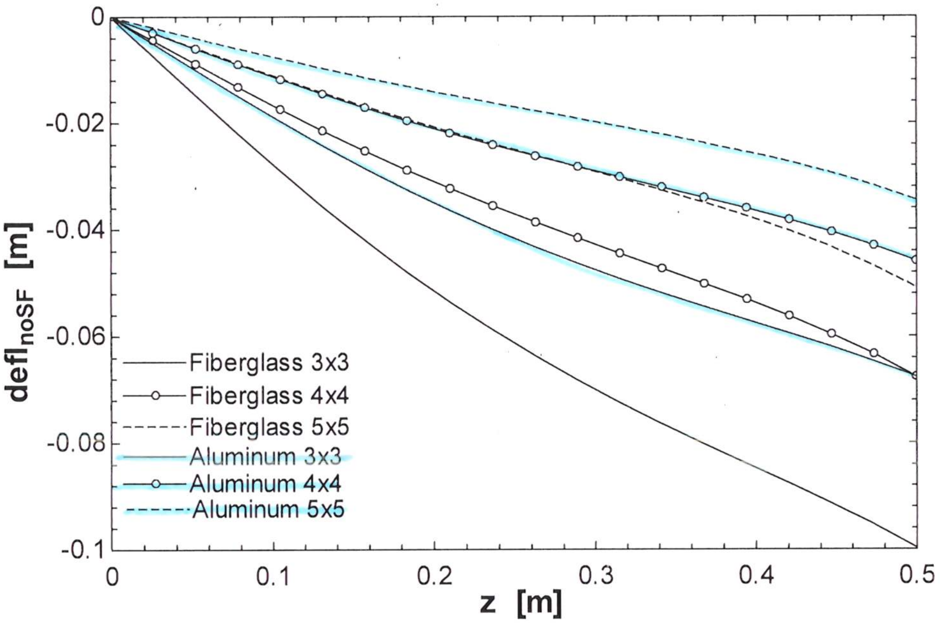

Figure 7 – Deflection of the bars from the end to the middle at z=.5m using fiberglass and aluminum bars for 3x3, 4x4, and 5x5 grid formations

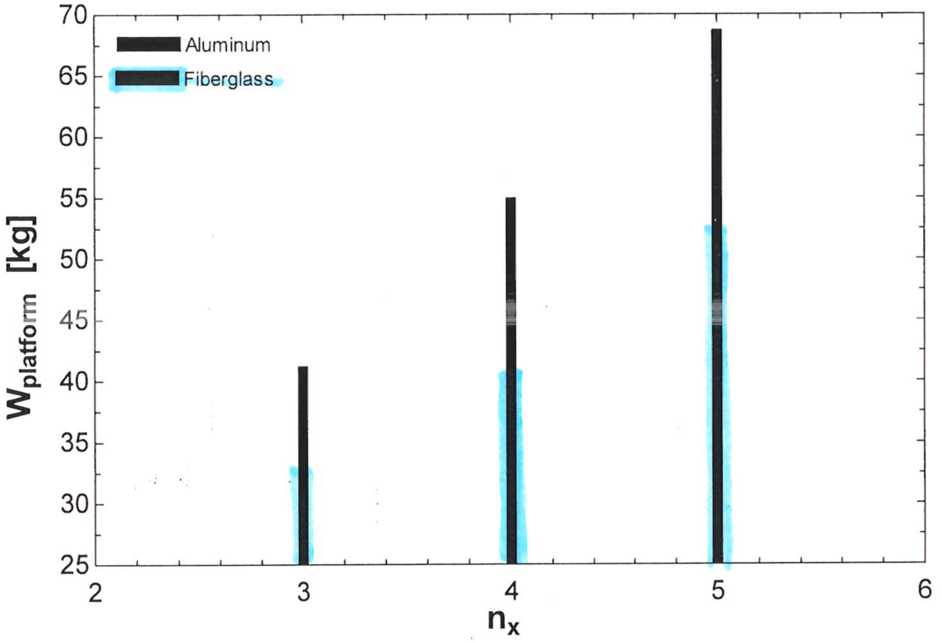

Figure 8 – Weight of the bars for the entire platform using aluminum and fiberglass for 3x3, 4x4, and 5x5 grid formations

B.2 Leg Analysis & Solution

Leg Analysis

Given values

$F = 88000 \quad [lb_m]$

$L = 1 \quad [m]$

$SF = 4$

$n = 30$

$E = E_{al}$

$\rho = \rho_{al}$

$g = 32.2 \quad [ft/sec^2]$

$\rho_{al} = 0.101$

$E_{al} = 1 \times 10^7 \quad [lb_f/in\text{-}in]$

rho=
E=

Calculating Moment of Inertia

$$I = F \cdot g \cdot \left| 12 \cdot \frac{in}{ft} \right| \cdot SF \cdot \frac{L^2 \cdot \left| 1550.0031 \cdot \frac{in^2}{m^2} \right|}{\pi^2 \cdot E \cdot \left| 12 \cdot \frac{in}{ft} \right| \cdot n^2}$$

Hollow Circle

$$I_{circle} = \frac{\pi \cdot d^3 \cdot t}{8}$$

$d = 2 \quad [in]$

$t = 0.065 \quad [in]$

$$A_{circle} = \pi \cdot \left[\left(\frac{d}{2} \right)^2 - \left(\frac{d - 2 \cdot t}{2} \right)^2 \right]$$

$$V_{circle} = A_{circle} \cdot L \cdot \left| 39.37 \cdot \frac{in}{m} \right|$$

$$W_{circle} = \rho_{al} \cdot V_{circle}$$

Hollow Square

$$I_{square} = \frac{a^4 - b^4}{12}$$

$a = 1.5$ [in]

$b = 1.25$ [in]

$$A_{square} = a^2 - b^2$$

$$V_{square} = A_{square} \cdot L \cdot \left| 39.37 \cdot \frac{in}{m} \right|$$

$$W_{square} = \rho_{al} \cdot V_{square}$$

SOLUTION

Unit Settings: SI C kPa kJ mass deg

$a = 1.5$ [in]

$A_{circle} = 0.3951$ [in^2]

$A_{square} = 0.6875$ [in^2]

$b = 1.25$ [in]

$d = 2$ [in]

$E = 1.000E+07$ [lb$_f$/in^2]

$E_{al} = 1.000E+07$ [lb$_f$/in-in]

$F = 88000$ [lb$_m$]

$g = 32.2$ [ft/sec^2]

$I = 0.1978$ [in^4]

$I_{circle} = 0.2042$ [in^4]

$I_{square} = 0.2184$ [in^4]

$L = 1$ [m]

$n = 30$ [-]

$\rho = 0.101$ [lb$_f$/in^3]

$\rho_{al} = 0.101$ [lb$_f$/in^3]

$SF = 4$ [-]

$t = 0.065$ [in]

$V_{circle} = 15.56$ [in^3]

$V_{square} = 27.07$ [in^3]

$W_{circle} = 1.571$ [lb$_f$]

$W_{square} = 2.734$ [lb$_f$]

No unit problems were detected.