Resolution of Forces on Parallelogramic Tables

By

Rabindranath M. Polito

A dissertation submitted in partial fulfillment of the requirements for the degree of

Masters in Science

(Mathematics)

at the

CALIFORNIA STATE UNIVERSITY - CHANNEL ISLANDS

2010

APPROVED FOR THE MATHEMATICS PROGRAM

Nov 23/2010

Dr. Jorge Garcia, Advisor Date

12/16/2010

Dr. Ivona Grzegorzyck Date

Dec 16/2010

Dr. Gregory Wood Date

APPROVED FOR THE UNIVERSITY

Dr. Gary Berg Date

To my precious daughter Adelaine and her baby, Raelynn for the inspirations that both of you gave me, to my fellow candidates for the Master's program in Mathematics, most especially Cindy, Bobby, Dave and Bekka, to my mentors, Dr. Ivona Grzegorczyk, Dr. Sittinger, Dr. Roybal, Dr. Wyels, and most especially to my advisor, Dr. Jorge Garcia who believed in me, thank you very much. I could have not done this without all of your support, mental, emotional and technical. I am forever in debt to you!

Acknowledgements

This was done with the aid and help of Dr. Ivona Grzegorczyk, Dr. Gregory Wood and Dr. Jorge Garcia from California State University Channel Islands.

Camarillo, California

December 15, 2010

Abstract

There are many things in life that we take for granted. Take for example, the mystery of a folding sunshade. What forces cause the sunshade to fold into a smaller circle and lock? There is actually a mathematical model for that process. Or consider a table that is used in everyday life. What are the forces that act on the legs of the table? In this paper, we will analyze these forces and will try to compute their vectors. We will start with studying forces acting on a beam. Then we will work with triangular table and finally with parallelogramic table. We will show physical models that govern forces in those cases. We will describe some specific solutions.

Contents

Chapter 1

Introduction

We say that a system of particles is in static equilibrium when all the particles of the system are at rest and the total force acting on each particle is permanently zero. This is a strict definition but often the term "static equilibrium" is substituted by a broader term of "mechanical equilibrium" which assumes only that the net force acting upon the particle is zero.

This means that static equilibrium is a special case of mechanical equilibrium of a stationary object. For example, a paperweight standing on a desk is in static equilibrium. An object in space moving at a constant speed is in mechanical equilibrium, but not in static equilibrium.

For another example of static equilibrium, consider a person trying to press a spring. The person can push it up to a point after which the spring reaches a state where the compressing force and the resistive force are equal. The moment the person can no longer press it any further makes the system to be in static equilibrium. When the pressing force is removed the spring attains its original state.

We will consider three equations that govern the relationships of the forces which are in static equilibrium. We call these Systems Of Equations(SOE^1). These equations give us the solution for the reactive forces in our models that are in state of equilibrium. However, we have conditions that *will not* allow us to solve for the reactive forces even if they are in state of equilibrium. Our models include:

1. Solvable Conditions - Default Case
   (a) Single Beam Loading
   (b) Triangular Table Loading
2. Unsolvable Conditions - Indeterminate Case
   (a) Rectangular Table Loading
   (b) Parallelogramic Table Loading

These following equations which we call Systems Of Equations(SOE^1) are:

$$\sum M_{x-axis} = 0, \qquad \text{Equation 1.01}$$

$$\sum M_{y-axis} = 0, \qquad \text{Equation 1.02}$$

$$\sum F_{forces} = 0, \qquad \text{Equation 1.03}$$

M which stands for **Moment** in a given point or axis is equal to the perpindicular $Force$ multiplied by the $Distance$ of the arm where the force is acting. In equation form

$$M = Force\ *\ Distance\ *\ sin\ \theta$$

the $sin\ \theta$ is inserted if the Force is not perpindicular to the arm of the Distance.

From The Fundamental Theorem of Algebra we know that a solution to a system of equations always exist if the number of unknowns is larger or equal to the number of equations relating those unknowns. Navier[2], a French engineer and physicist, who formulated the $Theory\ of\ Elasticity$ in early part of the 18^{th} century tried to solve the reactions of four forces acting on legs of a rectangular table knowing fully well that he had only three (3) fundamental equations describing forces in equilibrium state. His attempts were not successful. Later in 1999, three (3) NASA engineers wrote a book on the very same issue of solving the reactions of the four legs of an ordinary table. They utilized Navier's Theory of Elasticity. Their solution however appeared to be lacking in proof when exposed to the real world.

In this thesis we consider similar question. So far, all our laboratory works and computer simulations confirmed our suggested solution. Even though the work is not complete by any means, it contributes significantly to the progress of the problems.

Our human minds should not stop at what is the obvious. We should be brave and exploratory enough to delve into the unknown, to boldly go where no one has gone before(Star Trek - The Next Generation).

Current state of Physics considers a string theory together with quantum physics (which says that a particle could be at different places at the same time!) This is beyond our comprehension and yet, we do this theory in order to understand the deeper meaning of what is going around us in sub-atomic levels.

It is the hope of the author of this thesis that this very endeavor would motivate and inspire others to do something beyond from that of our comfort zone.

Chapter 2

Single Beam Loading Model

Consider a single beam loading with two (2) supports and one concentrated load in between those supports, we have

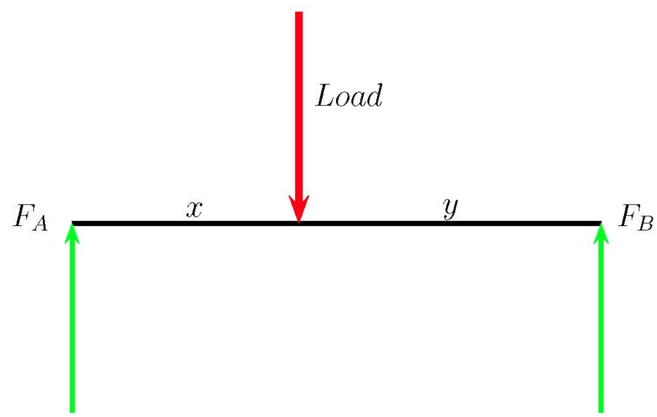


Figure 1. Forces Acting on a Beam.

To describe this model we use SOE[1] and we get the sum of moment around the point where F_B acts and set it to zero as

$$F_A \cdot (x + y) - Load \cdot y = 0$$

and the sum of moments around the point where F_A acts and set it to zero as

$$F_B \cdot (x + y) - Load \cdot x = 0$$

which, after simplifying, give the final equations as

$$F_A = Load \cdot \frac{y}{x+y}$$
$$F_B = Load \cdot \frac{x}{x+y}$$

which are *ratios* of distances of the load and the supports. In other words, to get the reaction of the supports in a beam, all you have to do is to determine the location of the load. When the location is established, the distances where the load is from the supports help to determine the ratio of those distances. For example: if you have a 10-foot beam and a load of 100 Newtons (N) is 4 feet from the left, then the reaction on the left support would simply be using our simplified ratio equations as

$$\begin{aligned} F_A &= 100 \cdot \frac{6}{10} \\ &= 60\ N \\ F_B &= 100 \cdot \frac{4}{10} \\ &= 40\ N \end{aligned}$$

Note that writing these equations of ratios would make the solutions look simpler. Throughout this thesis, we are going to focus on and emphasize *ratios* as they will turn out to be the governing factor in deriving reactions of supports on indeterminate loadings.

Chapter 3

Triangular Table Loading Model

With a given triangular table and a load inside the table, we can easily calculate the reactive force on one of its legs just using the first two(2) equations of our Systems of Equations.

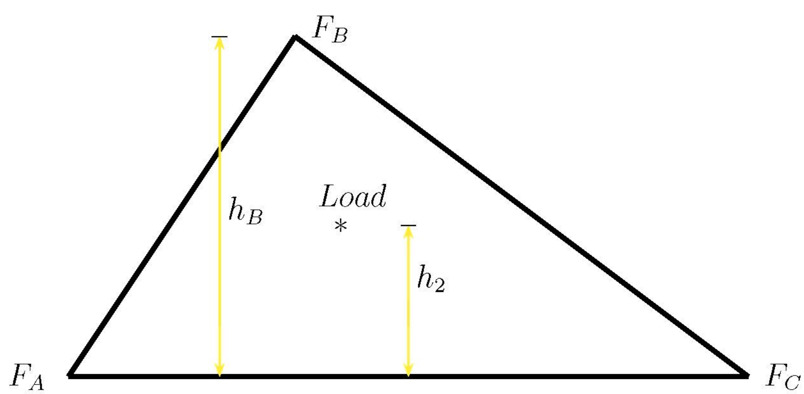


Figure 2. Forces Acting on a Triangular Table.

If we let $h_A,\ h_B\ and\ h_C$ as the perpendicular distances of the supports $F_A,\ F_B\ and\ F_C$ to their respective opposite bases of the triangle, and let

$h_1,\ h_2\ and\ h_3$ as the perpendicular distances of the load to their corresponding opposite bases of the triangle, then our SOE becomes

$$F_A \cdot h_A - Load \cdot h_1 = 0$$

$$F_B \cdot h_B - Load \cdot h_2 = 0$$

$$F_C \cdot h_C - Load \cdot h_3 = 0$$

and simplifying, we have

$$F_A \cdot h_A = Load \cdot h_1$$

$$F_B \cdot h_B = Load \cdot h_2$$

$$F_C \cdot h_C = Load \cdot h_3$$

which when we simplify further, we have

$$F_A = Load \cdot \frac{h_1}{h_A}$$

$$F_B = Load \cdot \frac{h_2}{h_B}$$

$$F_C = Load \cdot \frac{h_3}{h_C}$$

Taking F_B as an example, if we multiply the equation by $1/2 * AC$, we will actually have

$$F_B = Load \cdot \frac{h_2}{h_B} \cdot \frac{1/2 * AC}{1/2 * AC}$$

which turns out to a ratio of certain areas. That is:

$$F_B = Load \cdot \frac{Opposite\ Area\ (blue\ triangle)}{Total\ Area\ (black\ triangle)}$$

where Opposite Are is the area of the blue triangle and and the Total Area is the black triangle.

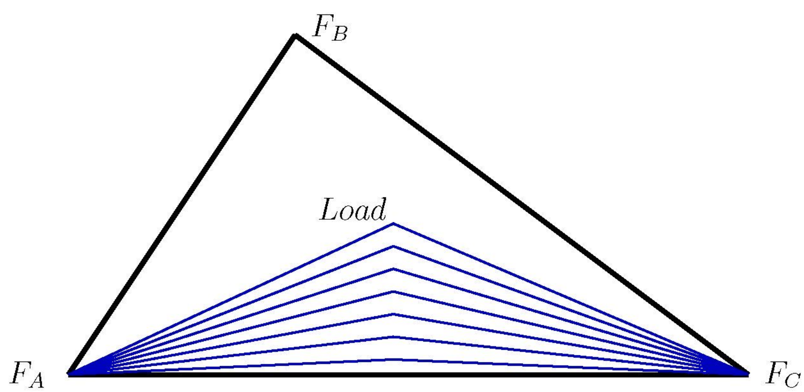


Figure 3. Forces Acting on a Triangular Table.

Therefore the model for a triangular table is a generalization of the model for a beam.

Chapter 4

Rectangular Table Problem

4.1 Unsolvable Condition - Indeterminate Case

Consider a rectangular table. It may be noted that there are four (4) reactive forces (from the four(4) legs). Hence, we have four unknowns and we only have three equations to rely on. There is therefore no unique solution i.e the case is indeterminate.

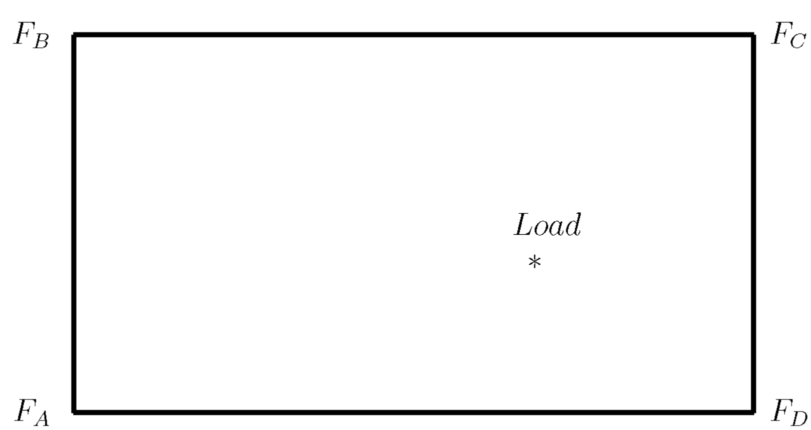


Figure 4. Forces Acting on a Rectangular Table.

Therefore we investigated this problem using laboratory experimentation to formulate a hypothesis on the possible solution for the forces on the table. But before we do that, we will give an interesting historical background for this problem.

4.2 History and Our Model

In the early 18th century, a self-proclaimed scientist name Navier (1785-1836) recognized the structural indeterminacy of the table problem. He proposed using **Strength of Materials** equations to provide a fourth equation in order to produce a unique solution. He also assumed that the table actually had a plane deflection due to the action of forces supporting the load. Even though his results are quoted through literature, we could not find a publication of his results. Later in the 1990's [3], three NASA engineers proposed a fourth equation following the suggestion of Navier; that is describing the Strength of Materials principles. The suggested equation is:

$$R_1\frac{l}{AE_1} - R_2\frac{l}{AE_2} + R_3\frac{l}{AE_3} - R_4\frac{l}{AE_4} = 0$$

where l is the length of the legs of the table, A is the cross-sectional area of the legs and E is the Modulos of Elasticity of the materials used in the legs. Assuming that if the legs are all uniform, i.e. they are of the same cross-sectional areas, of the same type of material and of the same length, we can actually factor out the expression $\frac{l}{AE}$ and the resulting equation becomes

$$R_1 + R_3 = R_2 + R_4$$

However, it is easy to show that this equation is incorrect for the considered table problem. We can show that by putting the load very near the bottom right of the table and by performing simple geometric analysis, we can tell that $R_1 + R_3 \neq R_2 + R_4$. Note that in this situation, R_3 will get almost all the load.

We in this paper propose the following additional equation describing forces acting on the table with the assumption that there is no deflection due to the load.

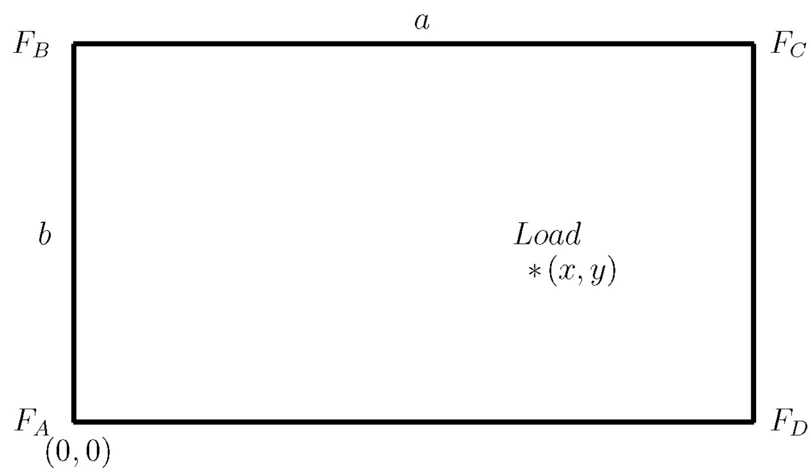


Figure 5. Forces Acting on a Rectangular Table.

Suggested Equation:

$$\frac{F_B}{x*y} - \frac{F_D}{(b-y)(a-x)} = 0$$

Below is the geometric representation of the above equation for F_B.

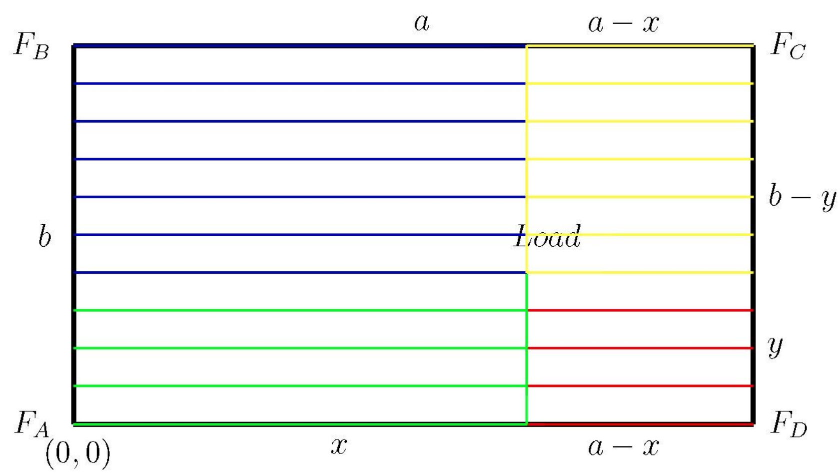


Figure 6. Forces Acting on a Rectangular Table.

Using vertical line passing through the load as y-coordinate, we have the following equation:

$$F_{BC} = Load * \frac{y}{b}$$

Using the horizontal line passing through supports B and C as x-coordinate:

$$F_B = F_{BC} * \frac{(a-x)}{a}$$

Now substituting F_{BC} back to the equation we obtain:

$$F_B = Load * \frac{(a-x)*y}{a*b}$$

which is a ratio of Opposite Area of the support divided by Total Area of the table! The equation is hereby presented.

$$F_{support} = Load \cdot \frac{Opposite\ Area}{Total\ Area}$$

In similar manner we obtain the equations for F_B, F_C, and F_D. We have

$$F_C = Load * \frac{x * y}{a * b}$$

$$F_D = Load * \frac{x * (b - y)}{a * b}$$

$$F_A = Load * \frac{(a - x) * (b - y)}{a * b}$$

Therefore the area model that we used for triangular tables, generalizes to rectangular tables.

Chapter 5

Parallelogramic Table Loading

5.1 Another Unsolvable Situation

We consider now a parallelogramic table. This table has four (4) supports and the model has only three (3) equations, SOE.

Figure 7. Forces Acting on a Parallelogramic Table.

Following the experiments similar to modeling the rectangular table, we performed laboratory experimentation in order to determine appropriate equations that would describe our situation. To start, we put a concentrated load right on the geometric center of the table.

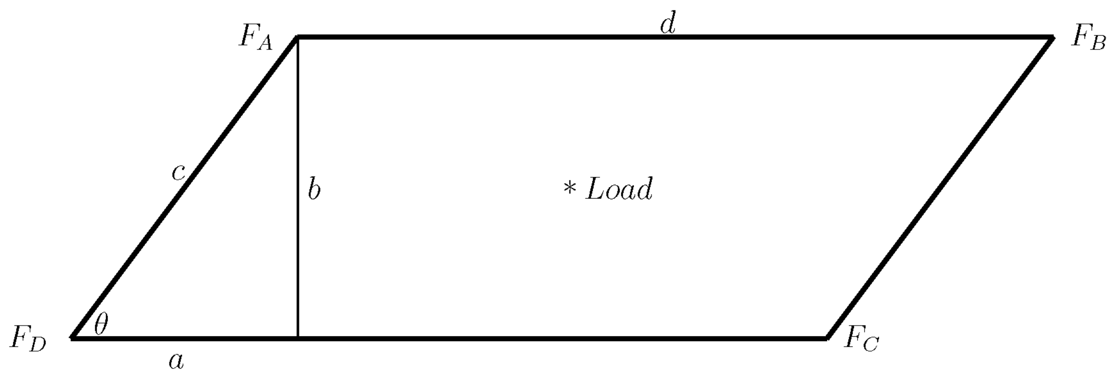


Figure 8. Forces Acting on a Parallelogramic Table.

Performed experiments suggest the following equation to resolve the F_A force:

$$F_A = \left(\frac{Load}{4}\right) \cdot (1 \ + \ cos \ \theta)$$

Hypothesis 5.1.1. *Given a parallelogramic table with a concentrated load at its geometric center, the reactive force experienced by the vertex nearest to the load is equal to the* $\left(\frac{Load}{4}\right) \cdot \ (1 \ + \ cos \ \theta)$. *By symmetry* $F_A = F_C$ *and* $F_B = F_D$.

5.2 Area Computations

With the load at the geometric center of the parallelogramic table, we would like to define the area that will represent the reactive force on F_A. We can actually derive it in this case using the model described in the figure below.

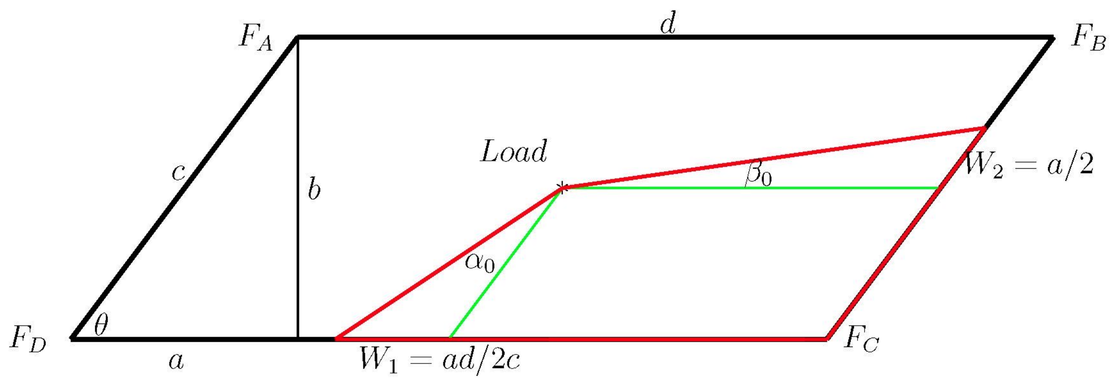


Figure 9. Forces Acting on a Parallelogramic Table.

We claim that the reactive force F_A is equal to the Load multiplied by the area bounded by the *red* color divided by the total area.

$$F_A = Load * \frac{Red\ Area}{Total\ Area}$$

Note that as the angle θ decreases, the lengths of W_1 and W_2 get shorter and approach zero and the smaller W_1 and W_2 are related by the following equation

$$W_2 = W_1 \cdot \frac{c}{d} \ .$$

On the other hand the lenght W_1 is described by

$$W_1 = \frac{ad}{2c} \ .$$

Therefore, we can calculate the length of W_2 as

$$W_2 = a/2 \ .$$

Now, we will show that our experimental equation for F_A is also equal to the Load multiplied by the ratio of the areas shown in Figure 9, hence the area model extends to the parallelogramic tables. We will show that:

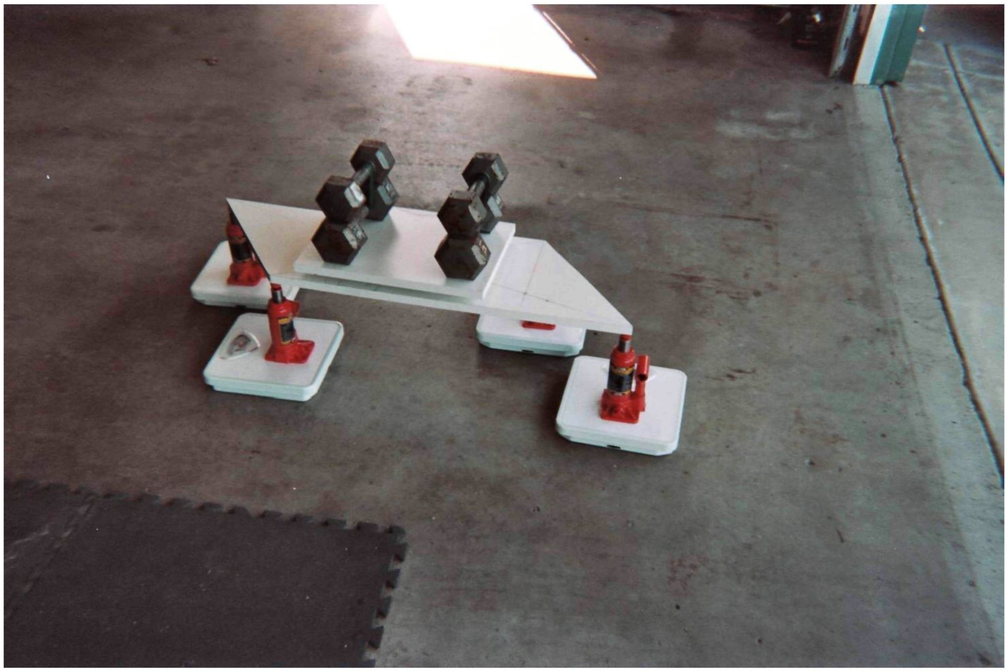
$$\begin{aligned} F_A &= Load * \frac{Red\ Area}{Total\ Area} \\ &= \frac{Load}{4} * (1\ +\ cos\ \theta) \end{aligned}$$

We start with our experimental formula, we have:

$$\begin{aligned} \frac{Load}{4} * (1\ +\ cos\ \theta) &= \frac{Load}{4} * (1\ +\ a/c) \\ &= \frac{Load}{4} * (1\ +\ a/2c\ + a/2c) \quad \text{multiplying by 4bd/4bd we have} \\ &= \frac{Load}{bd} * [bd/4 + abd/8c + abd/8c] \\ &= \frac{Load}{bd} * [b/2 * d/2 + 1/2 * b/2 * ad/2c + 1/2 * d/2 * ab/2c] \\ &= \frac{Load}{bd} * [b/2 * d/2 + 1/2 * (b/2)(ad/2c) + 1/2 * (d/2)(ab/2c)] \\ &= Load * \frac{Red\ Area}{Total\ Area} \end{aligned}$$

Therefore our experimental formula for parallelograms extends the area models for triangles and rectangles.

5.3 Laboratory Experiments



We did some laboratory works on this with the following values:

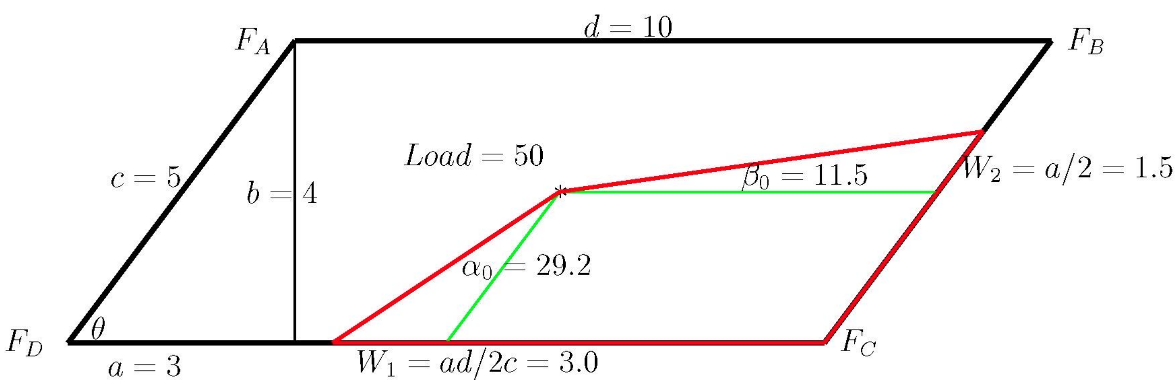


Figure 10. Forces Acting on a Parallelogramic Table.

We verify our formula by computing the values of W_1, W_2 ,α_0, and β_0.

Calculating the length W_1 we have

$$W_1 = (a * d)/(2 * c)$$

$$= (3 * 10)(2 * 5)$$

$$= 3.0$$

Computing W_2 we obtain:

$$W_2 = a/2$$

$$= 3/2$$

$$= 1.5$$

Our laboratory results produced an average value for $F_A = 20$ after 16 trials. Using our equation, the value of F_A is

$$F_A = \frac{Load}{4} * (1 \ + \ cos\ \theta)$$

$$= \frac{50}{4} * (1 \ + \ 3/5)$$

$$= 20$$

Therefore the formula is confirmed by our experiments.

At the end of this section, we calculate formulas for α_0 and β_0. We need specific values for α_0 and β_0 as in Figure 10.

$$\alpha_0 = cos^{-1}(a/c) - tan^{-1}[(b/2)/tan^{-1}(W_1 + (b/2)/tan(cos^{-1}a/c))]$$

$$= cos^{-1}(3/5) - tan^{-1}[(4/2)/tan^{-1}(3.0 + 2/tan(cos^{-1}3/5))]$$

$$= 53.130 \ - \ 23.962$$

$$= 29.1676$$

And finally, computing for β_0 we have

$$\beta_0 = tan^{-1}[W_2 * sin(cos^{-1}(a/c))/(d/2 + W_2 * cos(cos^{-1}(a/c)))]$$

$$= tan^{-1}[1.5 * sin(cos^{-1}(3/5))/(10/2 + 1.5 * cos(cos^{-1}(3/5)))]$$

$$= tan^{-1}[1.5 * .8/(5 + 1.5 * .6)]$$

$$= tan^{-1}[1.2/5.9]$$

$$= 11.4965$$

Chapter 6

Parallelogramic Table

6.1 Off-Center Loading

Now we will consider a parallelogramic table with the load placed away from its geometric center. To derive the theory for this kind of loading, we will use the results from the previous chapter on the geometric center loading .i.e center loading where calculations were based on the values of W_1 and W_2. We have the following picture

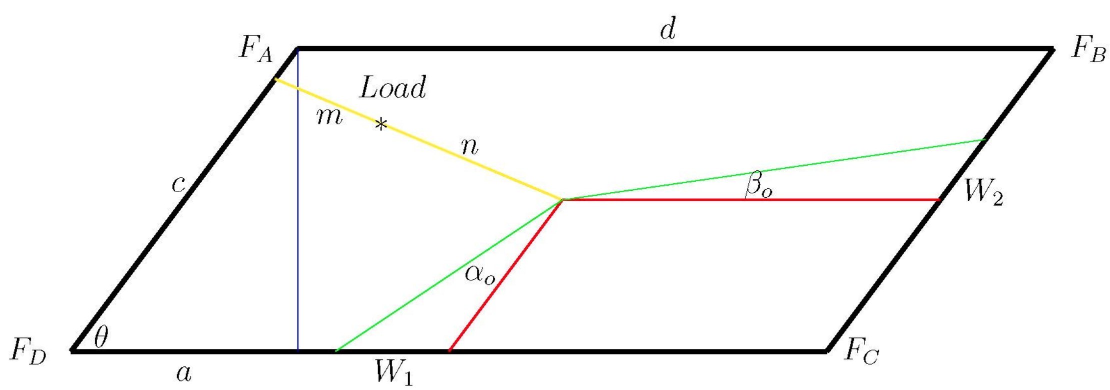


Figure 11. Forces Acting on a Parallelogramic Table.

where the smaller parallelogram has a vertex in the geometric center of the table. Note that the angle α_0 and angle β_0 will play important role in our model. We introduce two new variables where n is the distance from the load to the geometric center and m is the length of the segment as shown in Figure 11.

In previous chapter, we were able to calculate the lengths of W_1 and W_2 and measures of angles α_0 and β_0. Our model for the off-center loading depends on the values of n and m. Figure 12 describes our current setup. From the geometric center of the parallelogramic table, we draw the line passing through the *Load* and intersecting the *edge* of the table. The lengths of n and m can be measured. We calculate the angles α_1 and β_1 and then project the lengths of W_3 and W_4.

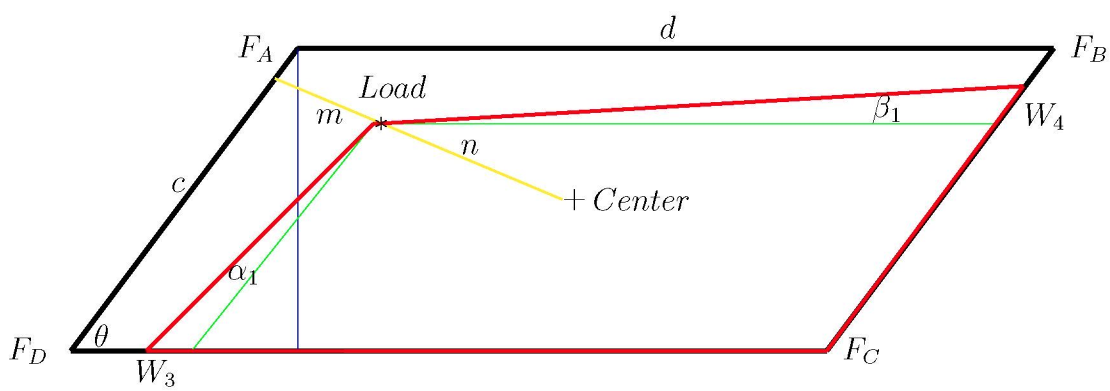


Figure 12. Forces Acting on a Parallelogramic Table.

$$F_A = Load * \frac{Red\ Area}{Total\ Area}$$

For W_1 and W_2 from the previous chapter we have

$$W_1 = \frac{a \cdot d}{2 \cdot c}$$
$$W_2 = W_1 \cdot \frac{c}{d}$$

which will give us

$$W_2 = a/2$$

Now the angles

$$\alpha_0 = \mathit{Angle\ subtended\ by}\ W_1$$

$$\beta_0 = \mathit{Angle\ subtended\ by}\ W_2$$

can be calculated as in Chapter 5. Now we can choose segments W_3 and W_4 and angles α_1 and β_1 as follows

$$\mathit{Angle\ subtended\ by}\ W_3 = \alpha_0 \cdot \frac{n}{n+m} = \alpha_1$$
$$\mathit{Angle\ subtended\ by}\ W_4 = \beta_0 \cdot \frac{n}{n+m} = \beta_1$$

Now we will calculate the Red Area using simple geometric formulas. In the figure above if we use b_1 as the new height of the green parallelogram and if we use d_1 as the new base of the green parallelogram (that we actually measure these values just as we measure the values of n and m) and knowing the measures of α_0 and β_0 from the geometric center loading, we can calculate the measure of angles α_1 and β_1. Then we calculate the lengths W_3 and W_4. Therefore the Red Area is equal to

$$Read\ Area = 1/2 * (d_1 + W_3 + d_1) * b_1 \ + \ 1/2 * (d_1) * (W_4 * sin\ \theta)$$

and obtain the value of the reaction at F_A as

$$F_A = Load\ * \ \frac{1/2 * (d_1 + W_3 + d_1) * b_1 \ + \ 1/2 * (d_1) * (W_4 * sin\ \theta)}{b * d}$$

Note that again this model is an extension of the previously discussed area models.

6.2 Laboratory Experiments

In our laboratory experiments with off-center loading on parallelogramic table, we were able to get the average value of 37 pounds for F_A (16 trials) with a given Load of **52** pounds. To confirm our model we will perform theoretical calculations using the diagram in the figure below that corresponds to our experimental setup.

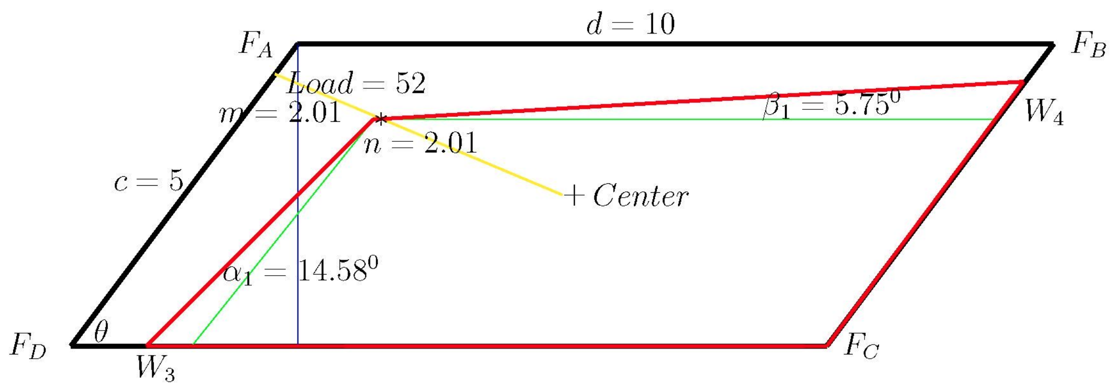


Figure 13. Forces Acting on a Parallelogramic Table.

From the previous chapter the values we use the values of α_0 and β_0. We will compute the values of α_1 and β_1. In this laboratory experiment we have the value of $n = 2.01$ and the value of $n + m = 4.0311$. Since we showed that the angles of α_1 and β_1 are dependent to the values of n and $n + m$, we can calculate both angles.

$$\alpha_1 = 29.17 * (2.01/4.0311)$$

$$= 14.58^0$$

And for the value of the other angle, we have

$$\beta_1 = 11.496 * (2.01/4.0311)$$
$$= 5.748^0$$

Now, we can calculate W_3

$$W_3 = 3.0 * tan^{-1}(\alpha_1 + cos^{-1}(3/5) - 3.0 * tan^{-1}(cos^{-1}(3/5)$$
$$= 0.7797$$

and W_4 as

$$W_4 = sin\beta_1 * 7.5/(sin(180 - \beta_1 - (180 - cos^{-1}(3/5))$$
$$= 1.467$$

Now, we will calculate the areas. We start first with the area of the *trapezoid* formed by the green parallelogram and W_3 and then we find the area of the *triangle* with the base W_4. The first area is given by:

$$Area_{one} = 1/2 * (7.5 + 7.5 + .7797) * 3.0$$
$$= 23.669$$

and the area of the triangle is given by

$$Area_{two} = 1/2 * (7.5) * (1.467 * .8)$$
$$= 4.401$$

The total Red Area is therefore

$$ReadArea = 23.669 + 4.401$$
$$= 28.07$$

Our theoretical reaction at F_A with a given load of 52 pounds is therefore equal to

$$F_A = 52 * 28.07/40$$
$$= 36.49$$

We compare this with the lab results

$$Lab\,Value \;=\; 37\,pounds \qquad Theoretical\,Value \;=\; 36.49\,pounds$$

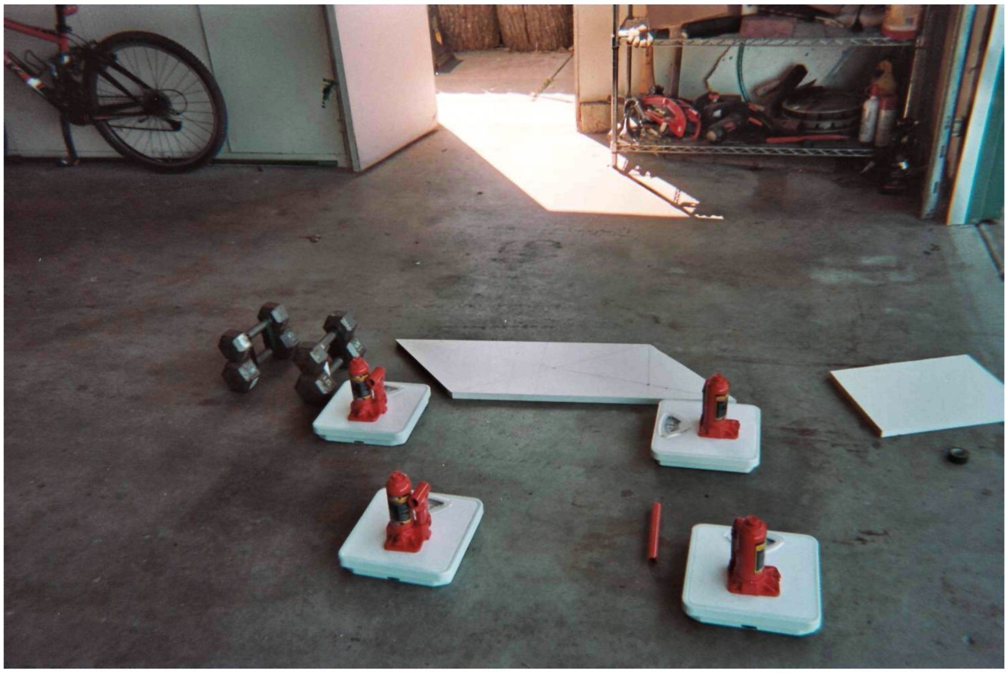
and conclude that the results are very close to each other.We note that our weigh scale has an accuracy of one(1) pound per graduation, hence the error is less than the accuracy of the scale. This shows that our model predicted well the experimental results.

Chapter 7

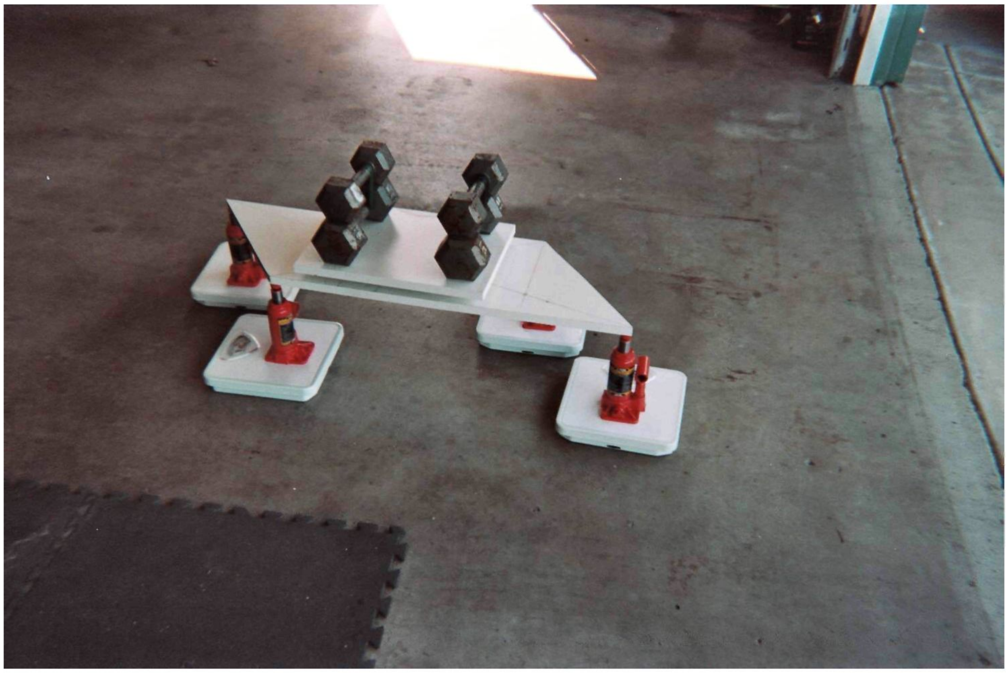
Laboratory

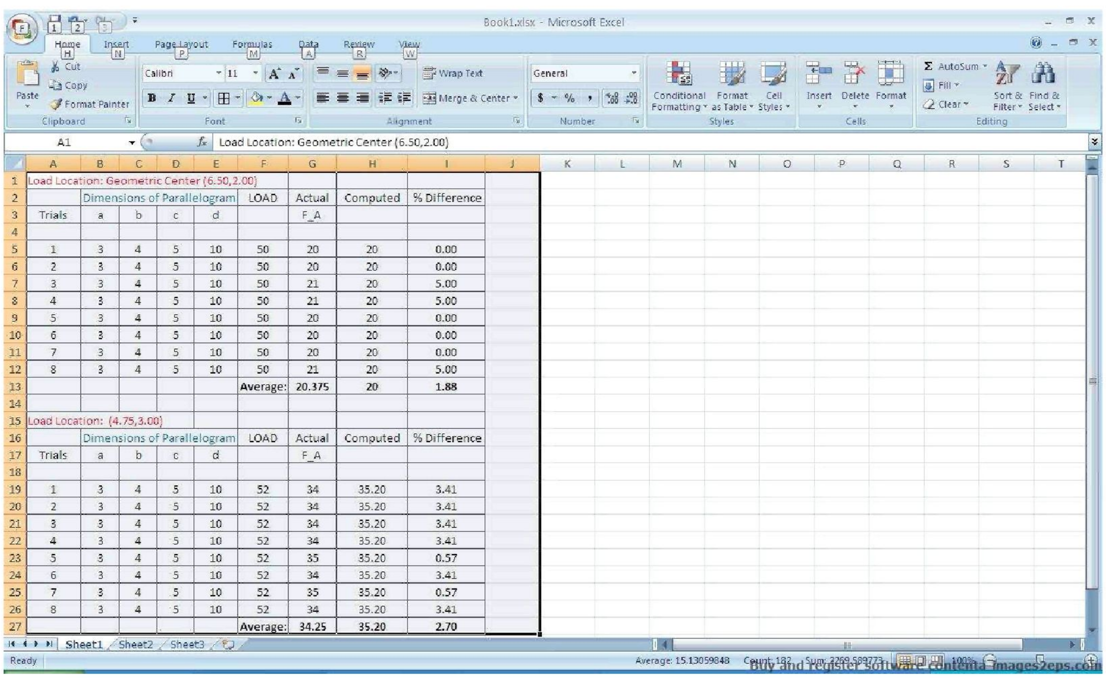
7.1 Lab Works, Pictures and Tabulated Data

These lab experiments were done in my garage!




5XCU947



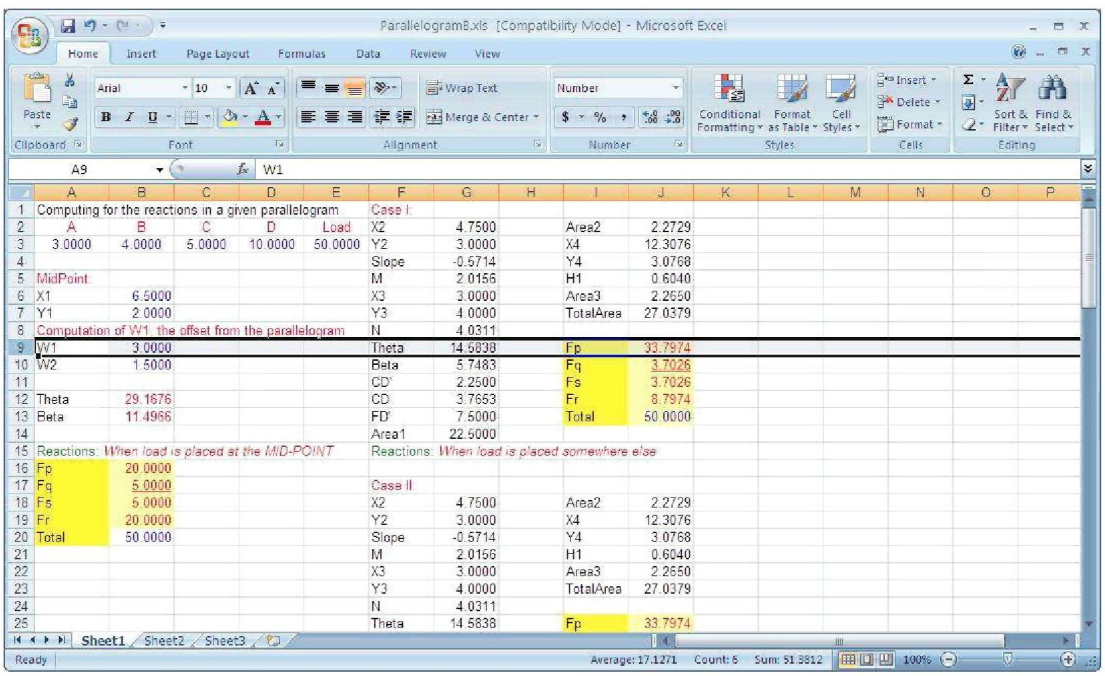


Load Location: Geometric Center (6.50,2.00)

Trials	a	b	c	d	LOAD	Actual F_A	Computed	% Difference
	Dimensions of Parallelogram							
1	3	4	5	10	50	20	20	0.00
2	3	4	5	10	50	20	20	0.00
3	3	4	5	10	50	21	20	5.00
4	3	4	5	10	50	21	20	5.00
5	3	4	5	10	50	20	20	0.00
6	3	4	5	10	50	20	20	0.00
7	3	4	5	10	50	20	20	0.00
8	3	4	5	10	50	21	20	5.00
					Average:	20.375	20	1.88

Load Location: (4.75,3.00)

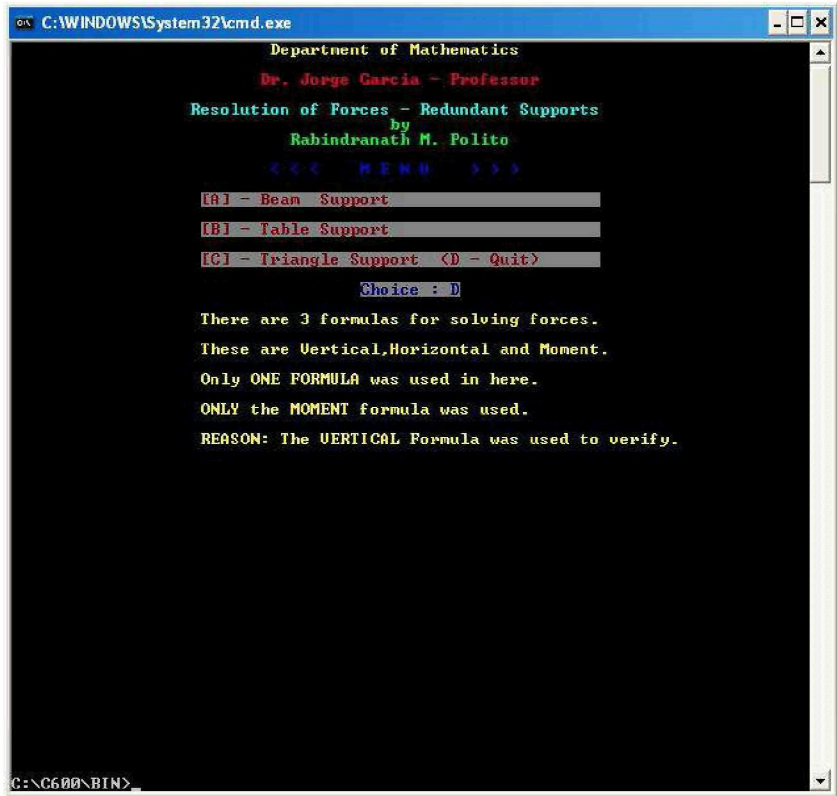
Trials	a	b	c	d	LOAD	Actual F_A	Computed	% Difference
	Dimensions of Parallelogram							
1	3	4	5	10	52	34	35.20	3.41
2	3	4	5	10	52	34	35.20	3.41
3	3	4	5	10	52	34	35.20	3.41
4	3	4	5	10	52	34	35.20	3.41
5	3	4	5	10	52	35	35.20	0.57
6	3	4	5	10	52	34	35.20	3.41
7	3	4	5	10	52	35	35.20	0.57
8	3	4	5	10	52	34	35.20	3.41
					Average:	34.25	35.20	2.70

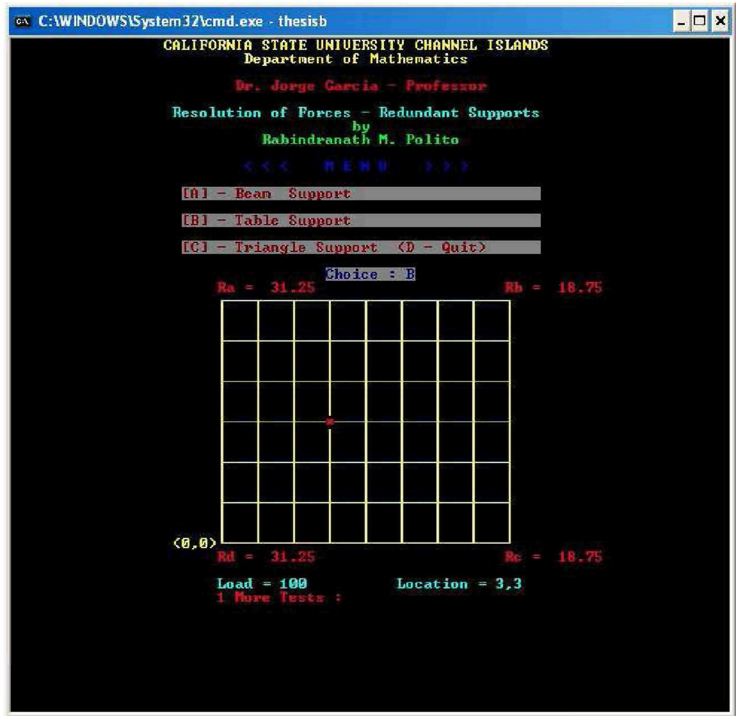


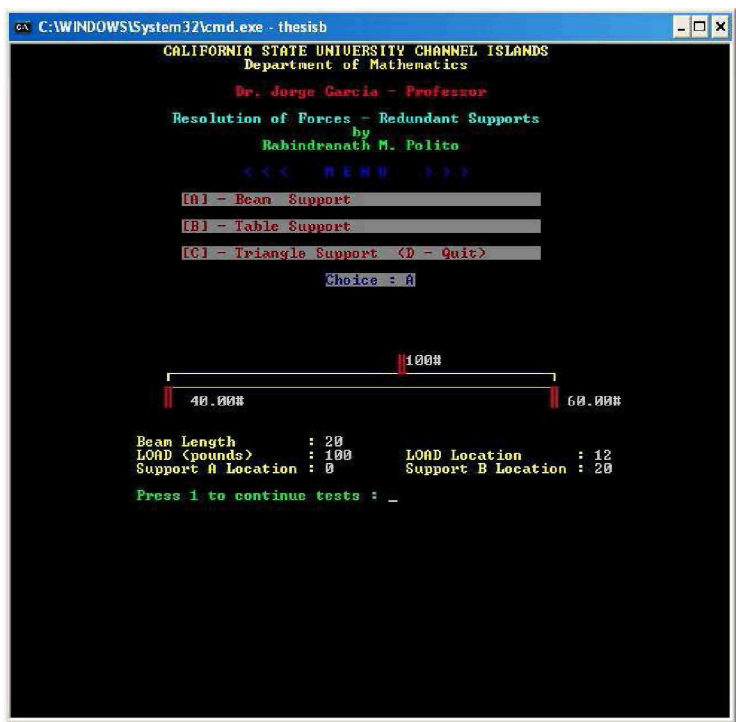
ParallelogramB.xls [Compatibility Mode] - Microsoft Excel

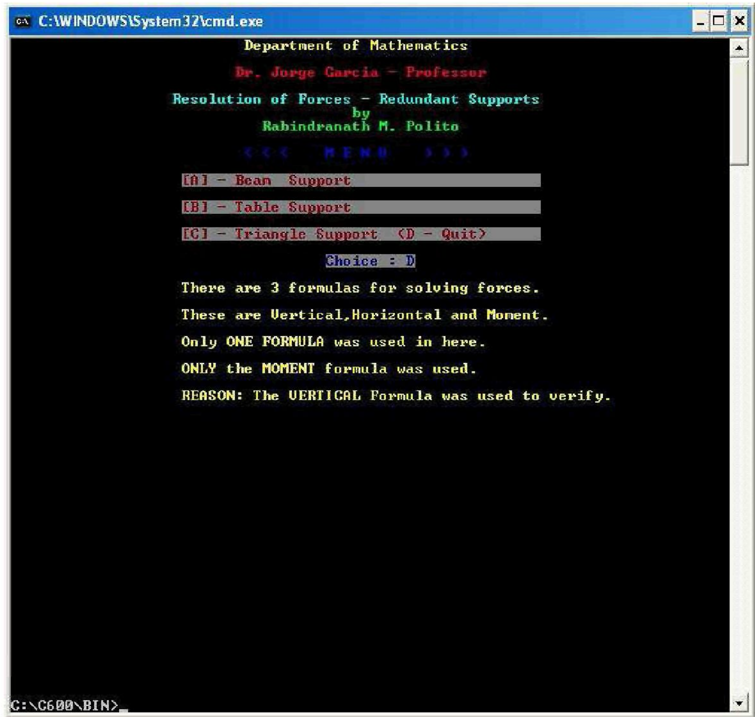
	A	B	C	D	E	F	G	H	I	J
1	Computing for the reactions in a given parallelogram					Case I:				
2	A	B	C	D	Load	X2	4.7500		Area2	2.2729
3	3.0000	4.0000	5.0000	10.0000	50.0000	Y2	3.0000		X4	12.3076
4						Slope	-0.5714		Y4	3.0768
5	MidPoint					M	2.0156		H1	0.6040
6	X1	6.5000				X3	3.0000		Area3	2.2650
7	Y1	2.0000				Y3	4.0000		TotalArea	27.0379
8	Computation of W1, the offset from the parallelogram					N	4.0311			
9	W1	3.0000				Theta	14.5838		Fp	33.7974
10	W2	1.5000				Beta	5.7483		Fq	3.7026
11						CD'	2.2500		Fs	3.7026
12	Theta	29.1676				CD	3.7653		Fr	8.7974
13	Beta	11.4966				FD'	7.5000		Total	50.0000
14						Area1	22.5000			
15	Reactions: *When load is placed at the MID-POINT*					Reactions: *When load is placed somewhere else*				
16	Fp	20.0000								
17	Fq	5.0000				Case II				
18	Fs	5.0000				X2	4.7500		Area2	2.2729
19	Fr	20.0000				Y2	3.0000		X4	12.3076
20	Total	50.0000				Slope	-0.5714		Y4	3.0768
21						M	2.0156		H1	0.6040
22						X3	3.0000		Area3	2.2650
23						Y3	4.0000		TotalArea	27.0379
24						N	4.0311			
25						Theta	14.5838		Fp	33.7974

Computer Simulations!


C:\WINDOWS\System32\cmd.exe
Department of Mathematics
Dr. Jorge Garcia - Professor
Resolution of Forces - Redundant Supports
by
Rabindranath M. Polito
<<< MENU >>>
[A] - Beam Support
[B] - Table Support
[C] - Triangle Support (D - Quit)
Choice : D
There are 3 formulas for solving forces.
These are Vertical,Horizontal and Moment.
Only ONE FORMULA was used in here.
ONLY the MOMENT formula was used.
REASON: The VERTICAL Formula was used to verify.
C:\C600\BIN>


C:\WINDOWS\System32\cmd.exe - thesisb
CALIFORNIA STATE UNIVERSITY CHANNEL ISLANDS
Department of Mathematics
Dr. Jorge Garcia - Professor
Resolution of Forces - Redundant Supports
by
Rabindranath M. Polito
< < < M E N U > > >
[A] - Beam Support
[B] - Table Support
[C] - Triangle Support (D - Quit)
Choice : B
Ra = 31.25
Rb = 18.75
(0,0)
Rd = 31.25
Rc = 18.75
Load = 100
Location = 3,3
1 More Tests :


C:\WINDOWS\System32\cmd.exe - thesisb
CALIFORNIA STATE UNIVERSITY CHANNEL ISLANDS
Department of Mathematics
Dr. Jorge Garcia - Professor
Resolution of Forces - Redundant Supports
by
Rabindranath M. Polito
< < < M E N U > > >
[A] - Beam Support
[B] - Table Support
[C] - Triangle Support (D - Quit)
Choice : A
100#
40.00#
60.00#
Beam Length : 20
LOAD (pounds) : 100
LOAD Location : 12
Support A Location : 0
Support B Location : 20
Press 1 to continue tests : _


C:\WINDOWS\System32\cmd.exe
Department of Mathematics
Dr. Jorge Garcia - Professor
Resolution of Forces - Redundant Supports
by
Rabindranath M. Polito
<<< M E N U >>>
[A] - Beam Support
[B] - Table Support
[C] - Triangle Support (D - Quit)
Choice : D
There are 3 formulas for solving forces.
These are Vertical,Horizontal and Moment.
Only ONE FORMULA was used in here.
ONLY the MOMENT formula was used.
REASON: The VERTICAL Formula was used to verify.
C:\C600\BIN>_

Chapter 8

Computer Simulation

8.1 Source Codes of C-Programs

Part of the Laboratory works performed was the design of C programs in order to facilitate the computed values versus the actual laboratory values. Here is the code for the beam loading and rectangular table loading for computer simulations.

```
//::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::://
//  Professor Name :  Rabin Polito        Programming Fundamentals //
//  Program Name   :  Forces              CS V11                   //
//  June 24, 2009                         Ventura College          //
//  Comments:  Resolution of Forces Program                        //
//::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::://
#include <graph.h>     // _outtext, _settextcolor, _settextposition
```

```
#include <string.h>    // strlen

#include <stdio.h>     // sprintf

#include <stdlib.h>    // srand, rand, toupper

#include <time.h>

#include <math.h>

void ClearTheScreen();

void CenterText(char *TheText,int Row, int Color);

void Heading();

void LineText(char *TheText,int Row, int Col, int Color);

void ChoiceA();

void ChoiceB();

void ChoiceC();

void ChoiceD();

void SingleBox(int A,int B);

void SingleBoxA(int A,int B);

void ClearBox();

void main()

{

   char Choice,Chose[2];

   int Flag;
```

```
Chose[1] = '\0';
Flag = 1;
while(Flag)
{
    Heading();
   _settextposition(18,45);
    scanf("%c",&Choice);
    Chose[0] = toupper(Choice);
   _settextposition(18,45);
   _outtext(Chose);
   if ( Choice == 'a' || Choice == 'A')
   {
        ChoiceA();
   }
   if ( Choice == 'b' || Choice == 'B')
   {
        ChoiceB();
   }
   if ( Choice == 'c' || Choice == 'C')
   {
```

```
            ChoiceC();
        }
        if ( Choice == 'd' || Choice == 'D')
        {
            ChoiceD();
            Flag = 0;
        }
      }
        _settextposition(50,1);
}
{
     ClearTheScreen();
     CenterText("CALIFORNIA STATE UNIVERSITY CHANNEL ISLANDS",1,14);
     CenterText("Department of Mathematics",2,14);
     CenterText("Dr. Jorge Garcia - Professor",4,12);
     CenterText("Resolution of Forces - Redundant Supports",6,11);
     CenterText("by",7,10);
     CenterText("Rabindranath M. Polito",8,10);
     CenterText("< < <    M E N U    > > >",10,9);
     LineText("[A] - Beam  Support                     ",12,20,20);
```

```
     LineText("[B] - Table Support                         ",14,20,20);
     LineText("[C] - Triangle Support  (D - Quit)          ",16,20,20);
     LineText("Choice : ",18,36,17);
}
void ClearBox()
{
    int k,m;
    char Space[2];
    Space[0] = 32;
    Space[1] = '\0';
    for (k=0;k<18;k++)
    {
        for(m=0;m<55;m++)
        {
            _settextposition(24+k,14+m);
            _outtext(Space);
        }
    }
}
void ChoiceA()
```

```
{
    char LowerLeft[2],LowerRight[2],UpperLeft[2],UpperRight[2];
    char Horizontal[2],La[2],Ra[2],Vert[2];
    char Text[80],Answer;
    int k,Load,Location,BL,FA,FB,Flog,Fc,FC;
    double Fa,Fb;
    UpperLeft[0]  = 218;
    UpperRight[0] = 191;
    LowerLeft[0]  = 192;
    LowerRight[0] = 217;
    Horizontal[0] = 196;
    Ra[0]         = 210;
    La[0]         = 208;
    Vert[0]       = 186;
    UpperLeft[1]  = '\0';
    UpperRight[1] = '\0';
    LowerLeft[1]  = '\0';
    LowerRight[1] = '\0';
    Horizontal[1] = '\0';
    Ra[1]         = '\0';
```

```
    La[1]          = '\0';

    Vert[1]        = '\0';

    Flog = 1;

}
```

Chapter 9

Further Work

What we have done here is just a tip of an iceberg. We limited ourselves to a regular-type of polygon. What happens when tables have different shapes? For example

1. Irregular Quadrilaterals

2. n-side Regular Polygon

3. n-side Irregular Polygon

It is the hope of this author that someday, models for all of the polygons will be derived and the problem of determining forces acting on the table with a given shape will be easy to calculate.

Chapter 10

Bibliography

[1] - Engineering Mechanics, Boresi and Schmidt, Brooks Publishing, 2001

[2] - Navier and Suspension Bridges in France, Picon, Cambridge University Press, 1988

[3] - Compatibility Conditions of Structural Mechanics, Patnaik, Coroneos and Hopkins NASA/TM, Coroneos Publishing, 1999