Angry Boards

New Mexico
Supercomputing Challenge
Final Report
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Team #75
Sarracino Middle School

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Executive Summary

Buildings are strong and make up the modern world, but do we really know how strong the building materials are? Our project is researching that question by using a code to determine the weaknesses of building materials. One of the reasons we chose this project is because it relates to the game Angry Birds. In this game, you launch (throw) the birds at structures to break them. We saw this as an opportunity to turn the game Angry Birds into science research. We took this game's concept and made a code to show how fast you have to throw a skateboard to make various materials break. We wanted to find weaknesses in each of the building materials. The goal of our code was to have it simulate a skateboard being thrown at different walls made of various materials and show the minimum velocity needed to break the wall. We used Python to create a program that will test different building materials to find their weaknesses. We simulated a skateboard being thrown at the building materials in order to test how the materials hold up at different speeds. This concept is a way to incorporate a fun game (Angry Birds) into our scientific research. Our research showed that the weakest material was glass and the strongest was graphene rubber.

Problem Statement

Since buildings are being built continuously and are pushing the boundaries of the materials being used, it is important to know the limits of many materials. If we don’t know this, masses of money will be wasted. We wanted to create a code/program that tested the structural integrity of any building material and where the limits of each material are. We want to know what materials would be the best for building structures in the future as well as possibly giving the ability to test future building materials. Since the most common materials used in most buildings today are metal, glass, plywood, and concrete. We also tested ceramic and rubber and these were materials we decided to test. We also decided to test ceramic and rubber so that we had another material that is on the stronger side and one that is on the weaker end of the scale.

Prediction

We did a lot of research before we wrote the code to be sure that we had plausible materials and correct strengths for each one. Based on this information, we thought that the glass would be the weakest. We also thought that the metal would be the strongest (appendix A).

Research

In order to write the code, we needed to research properties of the materials we were using and properties of the projectiles (skateboards). The first things we had to know were what made up the materials (on a molecular scale) and how that relates to the toughness of the materials. Using this, we found that glass had a maximum toughness of 8 joules per meters squared, ceramic had a maximum toughness of 200 joules per meters squared, wood had a maximum toughness of 3,400 joules per meters squared, the composite (concrete) had a maximum toughness of 60,000 joules per meters squared, metal had a maximum toughness of 145,000 joules per meters squared, and rubber had a maximum toughness of 200,000 joules per meters squared (appendix A).

Once we knew the toughness of the materials, we needed to get some information on the skateboard projectile. We based the dimensions of the skateboard on a basic skateboard. Our weights were based off of four other other skateboards of similar dimensions (appendix C). Our four masses were 0.0907 kilograms, 0.136 kilograms, 0.1814 kilograms, 0.2267 kilograms. These weights include the wheels even though the dimensions don’t since the wheels aren’t actually hitting the materials. Even though this is true, the wheels still add weight to the skateboard.

Our dimensions were 0.2032 meters wide, 0.7874 meters long, 0.01 meters high (appendix B). The last key part to our code is the formula. We based our formula off of the kinetic energy formula. The kinetic energy formula is ½*mass*velocity^2. We added toughness term and an area term to the equation since they are both crucial to finding minimum speeds for breakage. In the end, our equation was √(2*toughness*area/mass) to equal the minimum velocity needed for damage. To make this equation, we added impact area and toughness, then solved for velocity in the rest of the equation.

Method

For this problem, we used the scientific method so that the main parts of the process are creating a description, make a hypothesis, plan, research, create a code (most important), gather results, and draw conclusions.

We learned Netlogo at the kickoff and Python while we worked on the project. We used many websites including a coding interface called IDLE (python 32-bit 3.7.0) and a online website called: Online GDB, which is a programing website we used to learn python.

Code

Our code is as follows:

```
import pylab as pl
from math import sqrt
Mt={}
Mt['glass']={}
Mt['glass']['T']=8
Mt['ceramic']={}
Mt['ceramic']['T']=200
Mt['wood']={}
Mt['wood']['T']=3400
Mt['metal']={}
Mt['metal']['T']=145000
Mt['composite']={}
Mt['composite']['T']=60000
Mt['rubber']={}
Mt['rubber']['T']=200000

print("Calculating for Min. Velocity",list(Mt.keys()))
print()

Masses=[0.0907,0.1360,0.1814,0.2267]
Areas=[0.15999968,0.002032,0.007874]

pl.interactive(True)

iplt=0
for mat in Mt.keys():
    T=Mt[mat]['T']
    Mt[mat]['Vmin']=[]
    print(" Material=",mat," Toughness=",T,":")
    for    Area in    Areas:
        print("  Area=",Area)
        Vmines=[]
        for Mass in Masses:
            Vmin=sqrt(2*Area*T/Mass)
            Mt[mat]['Vmin'].append(Vmin)
            Vmines.append(Vmin)
            print(" Mass=",Mass," Min. Velocity=",Vmin)
        print(Masses)
```

```
        print(Mt[mat]['Vmin'])
        pl.subplot(2,3,iplt+1)
        #pl.plot(Masses,Mt[mat]['Vmax'],'ko')
        #pl.plot(Masses,Mt[mat]['Vmax'])
        pl.plot(Masses,Vmines,'ko')
        pl.plot(Masses,Vmines)
    pl.xlabel('Mass(kg)')
    pl.ylabel('Min Velocity m/s')
    pl.title(mat)
    iplt+=1

print(Mt)

input("Type A and return to finish")
```

Results

Our final results are based on the strongest type of each of six materials: glass, ceramic, wood, composites, metal, and rubber (materials are listed from weakest to strongest). We used the strongest materials because we wanted to find the very outer limits of each material.

In the beginning we thought it would take a less speed than it actually did take to break the materials. With the Graphene concrete we thought it would take around 50 meters per second but actually took about 100 meters per second. Plywood was also misestimated. We thought it would take 15 meters per second but actually took about 30 meters per second.

We know that alkali-aluminosilicate glass is the weakest, but we want to know the speed that it could withstand. It held up to around 3.5 meters per second. We believe it only held up to that speed because its modulus of rupture (which is how much energy a material can support) is very low (around 8 J). The second material, Zirconia ceramic, we know is also not that strong, but did do better than glass. It survived around 10 meters per second. It’s modulus of rupture is 200 J.

Since the riding surface hit took a higher speed to break each of the materials, we can infer that the force was spread out over a larger surface making it harder to damage the wall. The head on hit took the least speed because the same amount of force was more concentrated therefor needing less force to break the wall.

Key for Graphs:

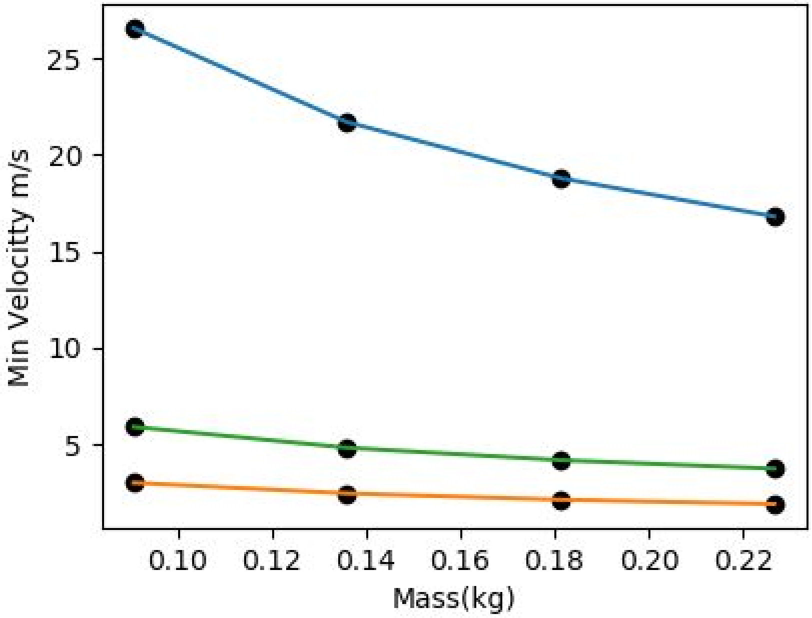
Blue= Top side hit

Green=Side hit

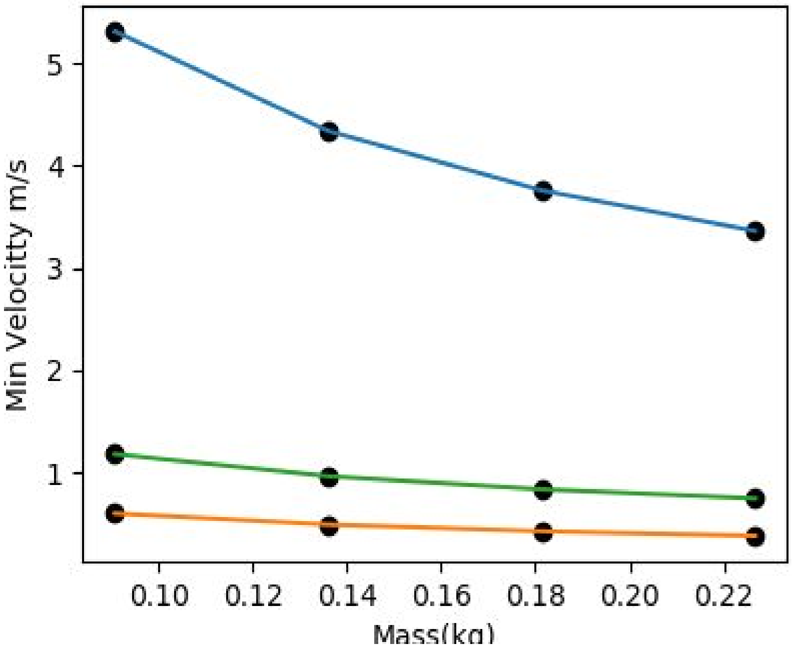
Orange=Head on hit

X axis= Mass of skateboard

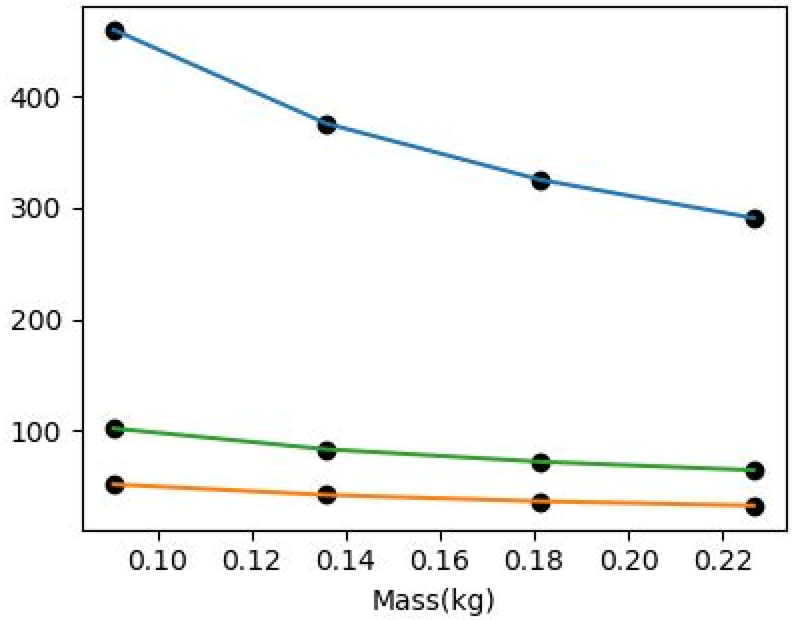
Y axis= Minimum velocity in meters per second



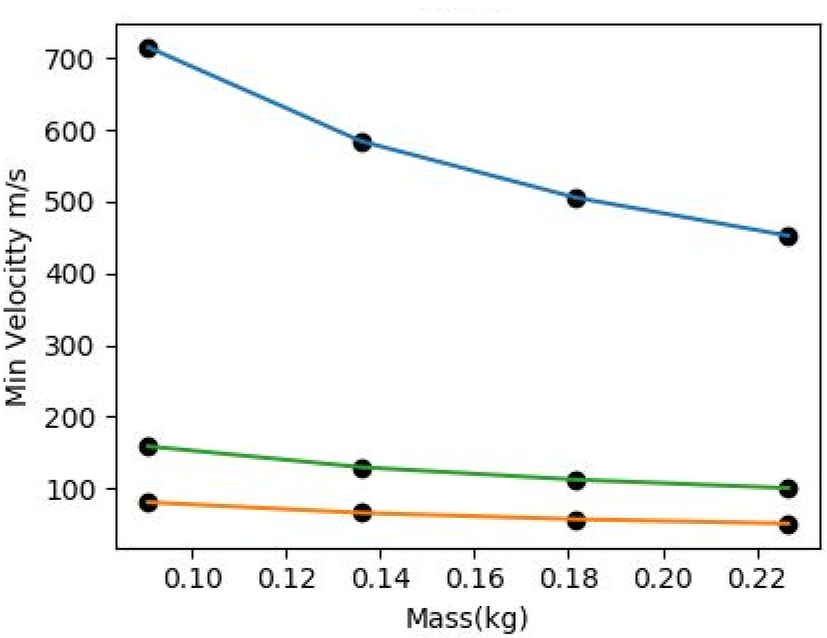
This graph displays the results for zirconia ceramic with each of the skateboard surfaces. Since the riding surface hit took a higher speed to break the material, we can infer that the force was spread out over a larger surface making it harder to damage the wall. The head on hit took the least speed because the same amount of force was more concentrated therefor needing less force to break the wall. Each point represents a different skateboard mass. The lower the point is on the graph, the less force it took for that particular weight to break the material.



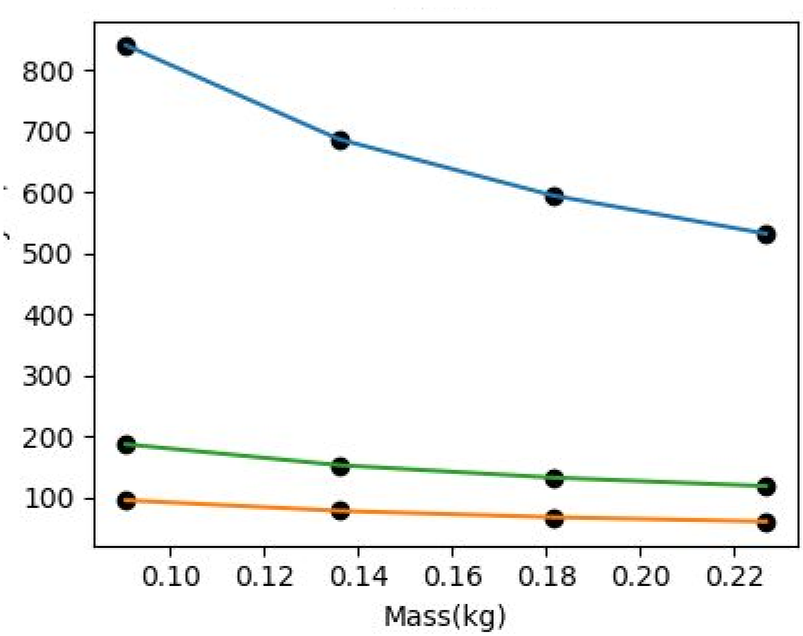
For the alkali-aluminosilicate glass, we found that it took less speed than it took for the ceramic to break. Glass required the least amount of force to break out of all of our materials. At the least speed, the heaviest skateboard with the head on impact, it took less than 0.5 m/s to break the material.



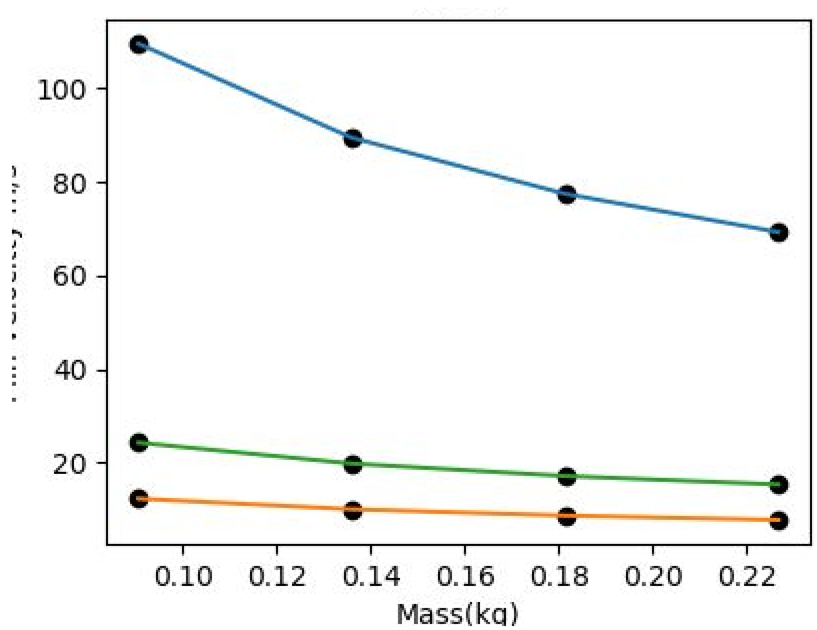
This is the graphene-concrete composite graph. At the most, the riding surface impact of the lightest skateboard took 450+ m/s to break. At the least, the head on impact of the heaviest skateboard, it took less than 50 m/s to break it.



This is the titanium graph. The fastest speed was also the riding surface of the lightest skateboard. This speed is over 700. The slowest speed was less than 50 m/s (see previous for skateboard weight and configuration).



This is the graph for the strongest material we had: graphene rubber. The slowest speed needed was the heaviest skateboard and a head on impact. This speed was about 50 m/s.The highest speed was the lightest skateboards riding surface impact. This speed was over 850 m/s.



This is the graph is for plywood. The slowest speed needed was the heaviest skateboard and a head on impact.this speed was less than 10 m/s. The highest speed was the lightest skateboards riding surface impact. This speed is over 100 m/s.

Conclusion

In conclusion, we learned that most of the brittle materials, such as glass and ceramic, failed at a low speed of impact since they are easier to break. The more elastic materials, such as rubber, were very strong and took a skateboard speed of about two hundred mph to be ruptured. Materials like metal were also very strong.

For us personally, the most significant achievement was learning how to code and graph in python. We also created a formula for calculating the maximum velocity you have to throw an object to break a material. The equation is Vmin=sqrt (2*Area*Toughness/Mass) where Area is the impact area, the toughness is the toughness of the material, and Mass is the mass of the projectile. We learned what we wanted to know with our code.

Limits

The main limits of our work are the knowledge of certain variables such as wall thickness that cannot be changed or varied in the code. The wall thickness is something that is not accounted for in the code since it is designed to measure speed needed to damage a material, not to burst completely through a wall of it. Another thing that cannot be changed in the code is the impact angle of the skateboards. Different sides of the skateboards can be accounted for (head-on hit, standing surface hit, and side hit) when being thrown but there is no control over changing the angle of hit. The skateboards are coming at an angle of 90° to the wall of material.

Time Constraints

The time constraints did end up affecting the work that we have gotten done by only giving us enough time to write the code, test the code multiple times, write the report, and prepare the board. We were not sure about what exactly we needed so we did what we were sure we needed to do (like coding). We did not have enough time to figure out how to make a real-time demo using NetLogo and Python together. Something we would extend on if we had more time, would be using more skateboard designs and weights. We might also investigate more building materials such as solid woods rather than plywood or more ordinary materials like steel rather than titanium and incorporate them in the code. This would require adding the new material to the python dictionary. We could also look into editing the code and the equation to calculate how much force it would take to break clean through something rather than just damage it. This would require adding thickness of material as a variable. We could also research what weathering of materials over time would do to the materials. This could be useful in working out how fragile ancient artifacts are and how likely they are to break (throwing something smaller than skateboards).

Recommendations and Result Accuracy

We believe that the results are accurate because during trial and error it took awhile before we made a good program. In our first code we inferred that the area was the area of the wall and not the impact area. We also added the extra variable of modulus of elasticity, which shows how much a material can stretch before it breaks, when we didn’t actually need it for the computer to do the calculations. This is because the code is designed to calculate the velocity needed for the material to be damaged, not stretched. We also verified the units multiple times to insure they were consistent.

We are confident that our results are correct based off of qualitative observations and common sense from everyday life. We knew that glass should be weaker than metal and composites based on everyday experiences. For example, if you drop glass onto concrete (composite), you know that the glass will break and not the concrete since concrete is generally stronger than glass.

In the beginning we thought it would take a less speed than it actually did take to break the materials. With the Graphene concrete we thought it would take around 50 meters per second but actually took about 100 meters per second. Plywood was also underestimated. We thought it would take 15 meters per second but actually took about 30 meters per second.

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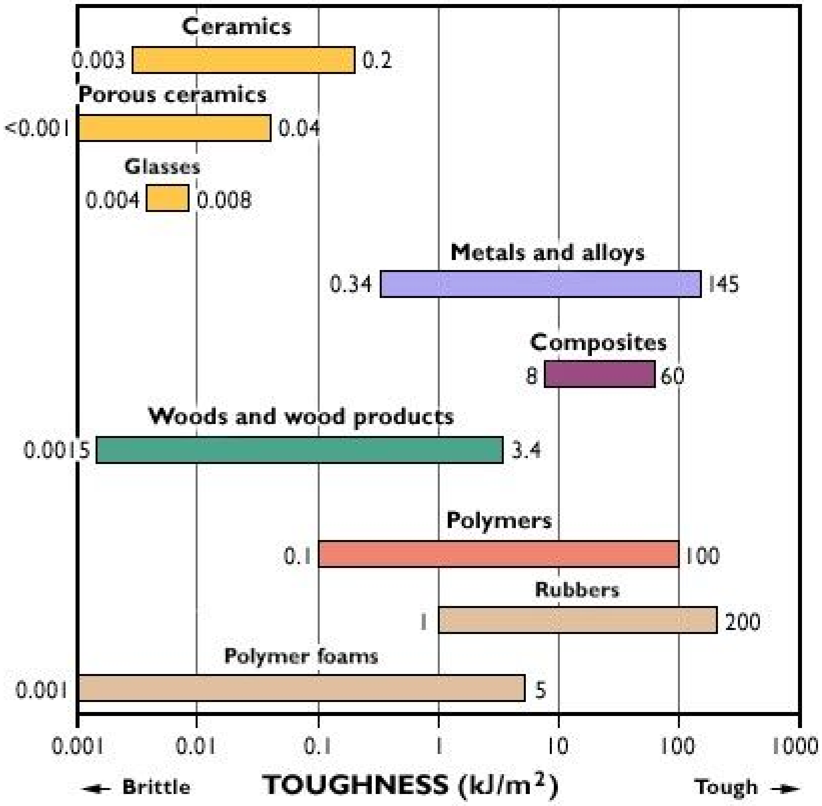
OutReach Skateboarding, “Average Skateboard Deck Weight (Does It Matter?) ” https://outreachskateboarding.com/average-skateboard-deck-weight-does-it-matter/

Appendix A

Graph of toughness:



Appendix B

Hikole skateboard
Specification:

- Material: Maple Wood, PU Wheels, Alloy Bearing
- Wheel Diameter: 85A,5.5cm/2.1inch
- Net Weight: approx. 2.1KG
- Capacity: 100KG(220LBS)
- Deck size: 78.5 x 19.5 x 9.5cm/30.6 x 7.6 x 3.7inch(L X W X H)
- Package size: 81 x 22 x 13cm/31.6 x 8.6 x 5.1inch(L X W X H)
- Trucks: high performance wheel trucks
- Bushings: super soft PU bushings
- Bearings: ABEC-7 bearing

Appendix C

Skateboard masses are:
0.907 Kg 1.36 Kg 1.814 Kg 2.267 Kg

Weighing My Skateboard Parts

Skateboard Part	Weight (Grams)
Deck (Shop Deck)	1148g
(56mm)Wheel With Bearing	74g
Bones Reds (1 Bearing)	21g
Krux (No Wheels Or Bearings)	329g
Krux (With Wheels/Bearings)	484g