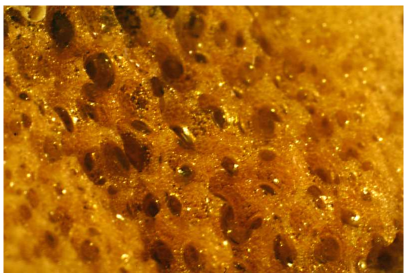
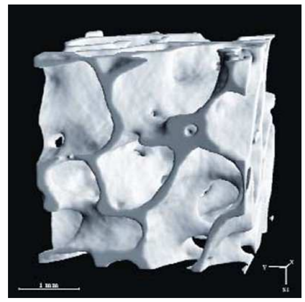
Is Crunchie a suitable bone structure?

Many people will need bones replaced during their lifetime, most of the spare parts are made from polymers and now artificial bone has been developed and is being used. As you can see below both, the Crunchie and the human bone have a similar honeycomb like structure.
I am going to test the breaking stress that a Crunchie chocolate bar has. We are going to use this data and compare it to the breaking stress that an ankle bone has to see if it is a suitable replacement. Materials such as Titanium and coral are used, they are chosen because of their tensile strength and how well blood vessels can be threaded through. These two properties may be found in a Crunchie chocolate bar as the honeycomb structure is likely to give room for the blood vessels but also give strength.





Equipment

Crunchie chocolate bars – *I have decided to leave the outer layer of chocolate on the Crunchie bar as this will give a similar affect as the hard outer layer on the bone, and will give me an answer which will be more accurate.*

Vice – *This will be used to hold the Crunchie bar and scales in place, it will also be tightened at an even rate to see what the breaking stress of the crunchie is.*

Scales – *I will use this to work out how much mass the Crunchie bar can take, that number will then be converted to Newtons (N) by multiplying it by 9.81*ms^{-2} *to show how much force it can take.*

Cutting board – *I will use this to cut the Crunchies in to separate pieces which are 0.027m long.*

Knife – *I will use this to cut the Crunchie into pieces which are all the same size.*

Micrometer – *As this is much more accurate than a ruler I will use this to measure the length and height of the Crunchies so a cross sectional area can be calculated, using this means I will get much more reliable results. The micrometer is very accurate; it measures to the nearest 100*th *of a mm.*

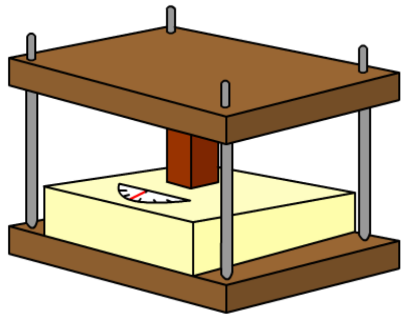
Goggles – *I will be wearing these for safety reasons because when the Crunchie finally breaks it will shatter and pieces may go flying.*

Rubber Gloves – *I will use these to make my results more accurate, as when cutting the Crunchies my hands may melt the chocolate which will affect the results.*

Method

1. Cut the Crunchie into pieces as stated above, I need to make sure all the crunchie pieces have the same cross sectional area.
2. I will then put the Crunchie into the vice and scales set up like shown in the picture below.
3. I will then tighten the vice.
4. I will keep doing this until the Crunchie breaks.
5. I will record the Kg on the scale at the point the Crunchie broke, and convert it into newtons (N).
6. I will repeat all of the above steps 8 times, and make sure I have 8 results at the end of the experiment. I am doing this 8 times as the more I do it the more accurate my results will be as I will be able to spot anomalous results easier and will get a more accurate average.

7. I will then work out the stress the Crunchie can take, and draw a graph to show this.



To keep my results as accurate as possible I will make sure I keep every single piec e of Crunchie the same size and shape I will do this as if I don't it will give me an anomalous results which will affect my overall result. I will also make sure that when I take the reading off the scales I will stand directly in front of the scales so I can get the most accurate reading possible. Another way to keep my results as accurate as possible is to tighten each screw equally when increasing the pressure on the Crunchie to make sure that the force is equally spread all over the Crunchie.

Crunchie	Mass in Kg	Converted to N
1	30.0	294.3
2	28.0	274.7
3	22.0	215.9
4	27.0	264.9
5	32.0	313.9
6	23.0	225.6
7	30.0	294.3
8	27.0	264.9
Average	27.4	268.6

Breaking Stress in the bone

Speed

I am calculating the speed you would hit the floor from 10m.

$v^2 = u^2 + 2as$
$v^2 = 2.000 \times 9.810 \times 10.00$
$v^2 = 196.2$
$v = \sqrt{196.2}$
$v = 14.00ms^{-2}$

Deceleration

$\frac{\Delta v \text{ (Change in velocity)}}{\Delta t \text{ (Change in time)}}$

$\frac{14.00}{0.100} = 140.0ms^{-2}$

Force on legs

$f = ma$
$f = 70.00 \times 140.0$
$f = 9.800 \times 10^3 N$

Cross sectional area of bone

$\pi \times \frac{0.072^2}{2.000} = 8.143\text{x}10^{-3}\text{m}$

Breaking stress of bone

$\sigma = \frac{f}{a}$

$\sigma = \frac{9.800\text{x}10^{3}\text{N}}{8.143\text{x}10^{-3}\text{m}}$

$\sigma = 1.203\text{x}10^{6}$ Pa

Pascal (Pa) is the S.I unit for the measurement of stress.

Breaking stress of a Crunchie

Using my results I obtained I can work out the breaking stress and then compare it to that of a bone.

$\sigma = \frac{f}{a}$

$\sigma = \frac{268.6\text{N}}{4.617\text{x}10^{-4}\text{m}}$

$\sigma = 5.820\text{x}10^{5}$ Pa

Using my results I will also work out the range of breaking stress using the highest and lowest values.

Highest:

$\sigma = \frac{f}{a}$

$\sigma = \frac{313.9\text{N}}{4.617\text{x}10^{-4}\text{m}}$

$\sigma = 6.800\text{x}10^{5}$ Pa

Lowest:

$\sigma = \frac{f}{a}$

$\sigma = \frac{215.9\text{N}}{4.617\text{x}10^{-4}\text{m}}$

$\sigma = 4.680\text{x}10^{5}$ Pa

As you can see the range of breaking stress of Crunchie I obtained from my results is from $4.680\text{x}10^{5}$Pa to $6.800\text{x}10^{5}$Pa.

Conclusion and Evaluation

The breaking stress of a bone is $1.200\text{x}10^{6}$ Nm^{-2}
The breaking stress of a Crunchie bar is $5.820\text{x}10^{5}$ Nm^{-2}

As you can see the difference between the two is at least the power of 10 and that is a massive difference. It would have severe affects on the patient if they had one of there bones replaced with a Crunchie. The Crunchie bar would get compressed, making the bone smaller, and therefore different to the other side, which would lead to walking crookedly and having a twisted spine. Crunchie is also not a suitable replacement for other reasons; one of the main ones is that its main ingredient is sugar, which makes it soluble. Also the actual structure is too simple; this is because bone is made up of many different layers of minerals, which makes the bone no where near as brittle as a Crunchie bar. The several layers act as shock absorbers and allow the bone to be a bit flexible.

There were certain limitations in this experiment; these were that we are only testing one type of stress, which was compressive. There are other types of stress we could have tested to make this experiment more accurate such as normal stress, shear stress and tensile stress. Also the fact that the Crunchie bar is a lot more brittle than bone will affect the similarity between the two, the Crunchie bar is much more like an older person's bone. This is because as a person gets older they may get a bone disease called osteoporosis and this is where the bone gets more and bigger holes inside it, which makes it a lot more brittle and easier to break, which is a lot more similar to a Crunchie bar. Another thing that could have affected results is the effect of pressure melting on the Crunchie bar. This is where the pressure being put on the Crunchie causes a melting affect.

To improve the experiment I would use a more accurate set of scales, maybe digital ones. I would also set up at video recorder to record the scales so I can play it back in slow motion to get the most accurate reading off of them when the Crunchie breaks. I could also use a set of scales which records the maximum pressure exerted on the Crunchie at the point where it breaks. I would also try and use a vice which is tightened up by just the one screw so I can keep pressure as even as possible, therefore giving me more accurate results.

Percentage Error

Scales:

I think that when I recorded the number off of the scales I could have been out by 1Kg either way as I was only using my eyes to watch the scales. I will work it out using 27.4Kg as this is the average out of my results.

$$\frac{1.00}{27.4} \times 100 = 3.65\%$$

Micrometer:

This is very accurate as it measure to the nearest 100th of a mm. As I only measured two lengths with the micrometer I will work out the percentage error for both lengths.

$$\frac{1.00\text{x}10^{-5}}{1.71\text{x}10^{-2}} \times 100 = 5.85\text{x}10^{-2}\%$$

$$\frac{1.00\text{x}10^{-5}}{2.70\text{x}10^{-2}} \times 100 = 3.70\text{x}10^{-2}\%$$

As you can see both lengths came out with very low percentage errors, which proves that this measuring was very accurate.