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How Strong is the Silk of a Colossal Monstrous Spider from Dungeons and Dragons?

Spider silk is known as a natural material with extremely high strength. Many sources even point to spider silk as stronger than steel and other commonly used real world substances. This strength is often exaggerated in media, especially when describing massive spiders that often appear in pop culture. In this paper we will examine the silk of the Colossal Monstrous Spider using the text of the Dungeons and Dragons Monster Manual (v. 3.5) and online sources to draw real world comparisons.

Source Text

In the Dungeons and Dragons Monster Manual the following text is used to describe the spider.

"The Spiders often wait in their webs or in trees than lower themselves silently on silk strands and leap onto prey passing beneath. A single strand is strong enough to support the spider and one creature of the same size."

This text gives an approximation of just how strong the spider's silk is, as long as we can figure how much a spider weighs. Once we find that weight, we can multiply by two because *"A single strand is strong enough to support the spider and one creature of the same size."* The spider is also described as being 40 feet long, which will be important to find proportional measurements.

Real World Parallels

To find the weight of the Colossal Monstrous Spider, we will assume that it would be proportional to real world spiders, and simply scaled up from their size. With that assumption, we can use laws of similar shapes to estimate the spider's mass.

The Goliath Birdeater *Theraphosa blondi* is one of the largest spiders in the world, so it will be used as a real world example so that we are as close as we can be to the Colossal Monstrous Spider. The Goliath Birdeater also has many measurements and statistics available online, making it easy to use for comparisons.

The Goliath Birdeater has an average leg span of 1 foot, and weighs an average of 170 grams. The Colossal Monstrous Spider is 40 times as long as the Goliath Birdeater, so using the principle of the square cube law, we can find the weight of the Colossal Giant Spider. As the Spider scales proportionally, we can assume that the two spiders have the same density, and therefore say that $M_2 = M_1(\frac{l_2}{l_1})^3$. Here, That would mean $M_{Colossal} = 170g * 40 = 10880kg$.

The Empire State Building

Our next goal will be to find how many strands of spider silk would be required to lift the Empire State Building. To do this, we can find how much weight a single strand can hold, and scale that to the weight of the Empire State Building. We found the mass of the Empire State Building to be 331122430kg according to the Empire State Building website.

We can find the strength of the silk with the equation $s * A = F \rightarrow sn\pi r^2 = mg$. Here we see that s, π, r^2, and g are constants, leaving n and m on either side, showing that the number of strands and the mass lifted are directly proportional.

To scale between the scenario of a spider supporting itself and another *"creature of the same size"* to lifting the Empire State Building, we can find that the number of strands will be proportional to the mass lifted, i.e. $\frac{n_2}{n_1} = \frac{m_2}{m_1}$ where variables with subscript 1 refer to lifting the spider and another creature while variables subscripted with 2 refer to supporting the Empire State Building. This yields $\frac{n_2}{1} = \frac{331122430kg}{21760kg}$, or $n_2 = 15217.023$. The question asks how many strands would be necessary to support it, so we need to apply a ceiling function to this number, $\lceil 15217.023 \rceil = 15218$.

Therefore, it would require 15218 strands of Colossal Monstrous Spider silk to lift the Empire State Building.

If we wanted to find the radius of a strand that would be able to lift the Empire State Building on its own, we could use $s\pi r^2 = mg$. We have all of the values, except for s and r. Therefore to find r, we first need to find s. We will use the strength of real spider silk as a parallel. We will be using the value of 1.3 Gigapascals found online. then we can plug everything in to our equation to get

$$1.3 * 10^9 * \pi * r^2 = 331122430 * 9.80 \rightarrow r = \sqrt{\frac{331122430*9.8}{1.3*10^9*\pi}} = 0.89m.$$

Therefore, we would need a strand with a radius of 0.89 meters to support the weight of the Empire State Building.

Weaknesses of the Model

While this model does yield some interesting results, it has some glaring issues that make it purely theoretical. Firstly, The idea that the mass of a spider would scale proportionally with its size using square cube law from a spider 1 foot long to 40 feet long is ridiculous. The structure of a spider would have to be completely different at this scale, or else it would simply collapse under its own weight. If we were able to find numbers for several spiders of different sizes and run an empirical model comparing their size to weight, then we could possibly find a trend and come up with a more reasonable estimate for the weight of a spider.

Strengths of the Model

We opted to use the largest spider with measurements readily available, which should make our numbers more accurate than models that use smaller spiders, in which small calculation differences can make a massive change in the overall results as they scale up massively.