The Tensile and Compression Strengths of Triangles in Truss Bridges

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Trees manage to withstand immense wind speeds and other weather causing them to frantically move to and fro. Why do they not just snap under the pressure? Simple, the tensile and compression strengths of trees are truly magnificent. In around 2000 BC, the Greeks noticed this and saw that the ability of the chords (sides) of a triangle could also support such stress but from above not from the sides. Thus dawned the truss design. They first used it for their roofs making them out of wood and much later bridges were made from this surprisingly simple yet strong design (The editors of, 2014). The Warren truss is one of the simplest designs of the truss today and it is a great example to study.

Background Information

A bridge is a structure that carries a road or path over an obstacle (Bridge, 2019). This obstacle can be just about anything, a gorge; canyon; or body of water of sorts. Truss bridges are different from, for example, a suspension bridge because a truss bridge is much simpler, just using triangles while the suspension bridge uses vertical uprights and cables to suspend the road in the air. Although the suspension (and just about every bridge design in the word) bridge use(s) compression and tension, the truss uses much less material than most other bridges and can hold a substantial amount of weight on it. The reason for triangles is because of all the shapes in nature, the triangle is the only one that will not distort under pressure (Truss Bridge, 2019). This means that it can hold extreme amounts of weight and will not break. This is cool, and the Greeks thought so too so they gifted the world with the truss design (The editors of, 2014).

Terms & Definitions

The great strength of this bridge design is due to two things, tensile strength and compression strength (The editors of, 2014). These may sound like terms only an engineer could understand but they are quite simple concepts. Tension is “a force that acts to expand or lengthen the thing it is acting on” (*Clark*, 2017). In essence, this means how much force is exerted on an object when it is being pulled. A great example of this is a coil spring. The thicker the spring, the more force is needed to stretch it out. Once the spring has been pulled to its limit and it is construed to be pulled, the technical term for it is snapping which is simple since the spring has snapped (*Clark*, 2017). Now compression is the opposite of tension. Compression is “a force that acts to compress or shorten the thing it is acting on” (*Clark*, 2017). This means that when we take our spring and press on its sides instead of pulling them, the spring becomes shorter, and the thicker the spring, the more force is needed to shorten it. When the spring can no longer support more force in this way, it will buckle (*Clark*, 2017). In a triangle, these qualities are present and when a series of them are put together to make a bridge, the triangles have two ways to deal with tension and compression. These ways are dissipation and transfer (*Clark*, 2017). When the forces are dissipated, they are spread out so that no single spot is marked responsible for bearing all the load (*Clark*, 2017). As we all know, an object that distributes the weight of the forces is less likely to be penetrated. When the forces are transferred, they are transferred from weaker areas to areas where more weight is supported (*Clark*, 2017). These are two abilities that bridges should have in order to be effective and truss bridges are good examples because they possess these properties and because of their simplicity in design.

A common truss design, the Warren truss was designed by James Warren, an English engineer. Although its exact origin is unknown, James Warren patented it in 1848 and it is now called the Warren truss. This truss uses equilateral triangles spreading load throughout the bridge. The Neville truss, a different truss, uses isosceles triangles for its design. Since it uses equilateral triangles, the Warren truss is an easy bridge to replicate as a model and in real life (Boon, 2016).

Problem

Plastic bottles like Coke bottles are made from polyethylene terephthalate plastic. This plastic is quite common today and is used to make most containers. For short, it is called PET plastic. In 1973, PET was patented and was starting to be used in bottles. On average, 3.1 million tons of PET plastic are produced in North America yearly. In a perfect world, all this plastic would be used and then recycled to become something else. However, it is not. Although in 2012 850,000 tons of it were recycled, this is still not enough to do something with all the PET in the world (*Cho*, 2018). There are still always plastic bottles polluting cities and not everyone is doing something about it. This is a pandemic problem, since plastic is just about everywhere, and it does not look pretty, at least not just laying around. This affects not only the world, but communities. If communities came together to do something with all the plastic bottles, the world would be a much prettier place. All it takes is someone with the desire to make a difference. Something that was done by a school in 2020 was a couple of students took plastic bags made of PET and made sticks out of them by an arduous process and used them to make truss bridges. After reading their abstract, this process seemed to be quite tedious. However, their idea still made an impact on their school, involving the school community in science and helping the environment, they made it quite far with their idea. This is the kind of mindset needed to make an impact. Another project recently introduced was that of a group of kids taking bottles made from PET and creating structures that were able to hold great amounts of weight, entire humans, in fact. One of these structures was a scale truss bridge capable of withstanding people walking on it (Hcihpi, 2017).

Science of the Problem

The project that used plastic bottles may at first thought seem foolish since many may find it hard to believe that the Coke bottle you drank today can hold your weight. Well although the bottle itself cannot hold your own weight, a series of those bottles could. All it takes is for them to be organized into the correct shape. As we learned, the triangle is just about the strongest shape in nature (Truss Bridge, 2019). So, if these bottles are arranged in triangles, they could hold your weight. Although this sounds cool, there is science behind it that should be explained. This simply goes back to tension and compression. We also learned that triangles are a great and rather simple way to demonstrate this since they possess strengths against both forces. Equilateral triangles are the best at this because since they are equiangular (all the angles are 90º), the weight can be equally distributed between all the parts of the triangle making it better for holding weight on the truss bridge (Let's Talk, 2020). The properties of the equilateral triangle are also helpful in limiting all forces acting on the truss bridge to just the ones that pull and push on the members (compression and tension). As can be deduced easily, the middle of the bridge is usually the weakest portion of the bridge since it is always going to be farthest away from a support under it, such as the ground of concrete support. So, when a car is in the middle of the Warren bridge, the forces all seem to multiply. This is so because the bridge in the middle already must hold itself in place and when a car is right in the middle of it, the force is greater since more stress is put on the bridge (Boon, 2016). This can be explained with a very long PVC pole. If we support the pole with two chairs at each end, it will remain straight on its own. Once we tie a 10kg ball in the middle of the pole, it will dip severely. This is because although it is only 10kg, the force is multiplied on the pole because it is put on its weakest point. It is also because the pole does not have adequate tensile or compression strength but that is not the main point, the point is that on the weakest member, 10kg can feel like 10Mg. What is great about the equilateral triangle is that thanks to its ability to dissipate force among its members, it can withstand great weight even in the center. Now where we see the most amount of weight supported by the Warren truss is when there are cars dispersed throughout the bridge. This is where we see the dissipation of the forces by the triangles. If we go back to the pole and instead of putting the ball right in the middle, we place five increments of two kilograms along the pole, it will not dip as it did when 10kg was put right in the middle (Boon, 2016). When we do this to our bridge but with cars or other great amounts of weight, we see that some trusses like the Quebec bridge can hold millions of pounds (Quebec, 2020). This is so because the bridge can take the forces of tension and compression acting on its members and dissipate them to the whole bridge so that instead of only one holding a great amount of weight, all the members can hold small parts of the greater object or objects. It is important that the bridge can dissipate and transfer forces because if it cannot, it will either buckle or snap; sometimes both. A rather devastating accident occurred in 1917 when a multi-million-dollar enormous Warren Cantilever truss bridge was built but collapsed twice, first because one of the members supporting the bridge buckled and could not hold the compression of the weight on it and the second when the middle was simply not strong enough for its own weight and so it fell into the river it was suspended over. Lives were lost in both incidents and the bridge has been repaired a third time since then and is still around today (Quebec, 2020). This goes to show how important it is that all factors of tension and compression are found and assessed.

Limitations

Although the idea of using all the bottles in the world to make aesthetically pleasing structures sounds like a fantastic idea, it cannot be done with all the plastic in the world and there are things that would prevent us from carrying out this idea. In a perfect world, we could take all the plastic bottles and make bridges out of them (or other structures), however, not all bottles are the same so they would have to be assorted which is not a huge setback but could still be a problem if one structure requires one type of plastic while another needs another and both run out somehow. Another setback is that PET plastic is a thin airy material, not a solid one capable of enduring extreme heat since it will warp and eventually melt. This would make these bridges not great for the outside in places with much sunlight. Another thing that could set back this idea is the way of connecting the bottles together to make the triangles to make the bridges since it is a brand-new idea, there is not much research on what the best way to do so. The introducers of this project used 3D printing to make joints for the bottles and this may be the best way to go with this part of the project (Hcihpi, 2017). This could also present a problem since not everyone has access to a 3D printer. 3D printing has been making its own name in the engineering industry. If you look around at new inventions or even things that were once manufactured, are now produced by a 3D printer. If the scientists are trusting these printers to make things for everyday use, then it might be the way to go. Even though not everyone has one right now, soon almost everyone will have a 3D printer or at least have access to one. This, then, makes the idea of using bottles to make bridges to clean up the environment more feasible and perhaps easier thanks to the abundance of materials we have.

Conclusion

Truss bridges have been around for quite some time. They have served by providing a simple build design able to hold great amounts of weight when the correct science is carried out. Warren trusses are a common bridge and thanks to their simplicity in design, using equilateral triangles to hold much weight, they are a great example of bridge to study. What makes the equilateral triangle so special is that thanks to its equal angles all around, it can dissipate the forces acting on it to other areas and so it can hold a lot of weight but only experience little to almost no stress. However, when science is ignored, the bridge will not work, and the result could be fatal. A way we can incorporate helping the environment and science is by taking as many PET plastic bottles as we can and building structures to place in the community such as bridges or other aesthetically pleasing objects. Especially now, when recycling is crucial, plastic bottles can now have a rather easy and great way of being used to help the community.

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Warren bridges are a design of truss bridge that uses equilateral triangles to dissipate and transfer the forces of compression and tension among the triangle itself and the other members of the bridge. This information is useful because the bridges I will be building will be Warren trusses.

Bridge | Definition of Bridge by Lexico. Lexico Dictionaries | English, 2019, www.lexico.com/en/definition/bridge

A bridge is a structure that carries a road or path over obstacles. The text speaks on what a bridge basically is. It gives me the definition mentioned. Since it gives me a definition of half of what my project is, I can use the website and its contents when I do my research

Bridgehunter.Com | K-Truss. Bridgehunter.Com, 2013. bridgehunter.com/category/tag/k-truss

In the early nineteenth century, Phelps Johnson designed the K truss. This is a dominant design of the truss bridge today, so it gives me a version of the bridge design I am studying so it is good that I include this source in my research.

Cho, Renee. *State of the Planet.* State of the Planet, 18 June 2018, blogs.ei.columbia.edu/2012/01/31/what-happens-to-all-that-plastic/

Plastic is found everywhere. In all forms too, mainly, bags and bottles. Now I already used bags in last year's project, so the next thing is going to be bottles. This article gives me a general idea of just how much plastic there is in the world. A lot. Thus, this information makes it good for my research.

Clark Bridge: Alton, IL building bridges: The basics – mesa. Mesa.ucop.edu/wp-content/uploads/2017/11/2.6-Bridge-Building-Bridges-The-Basics.pdf.

Truss bridges use equilateral triangles to hold great amounts of weight while maintaining a simple, not too expensive design. This is great and is owed to the way the triangle deals with tension and compression, through dissipation and transfer. This is relevant because my project is all about triangle bridges.

Encyclopedia Britannica, inc. *Truss.* Encyclopedia Britannica. www.britannica.com/technology/bridge-engineering/Truss.

A truss bridge gets its ability to hold weight by tensile and compression strengths. This is useful because it gives me another source that tells me how the bridge works.

Hcihpi, & Instructables. (2017, November 28). *Connect PET bottles, make TRUSSFAB structures*. Instructables. www.instructables.com/How-to-Connect-PET-Bottles-for-TrussFab-Structures/

Plastic bottles are everywhere. A group of kids in Germany thought it smart to use them to build structures. It was a great idea. The bridges that were created proved to be strong enough to allow humans to walk on them and not break with so much load. This is where half of my project this year comes from. my bottles. Since the article gives me another design of the bridge, it is good for research.

Humphrey, Alen. Personal Interview.

In my community we have truss bridges, and their main use is to carry railroad tracks across our big river, and as smaller ones, simply for crossing small obstacles. Since Mr. Humphrey works for the city, he gave me a look into what kind of bridges are in my community.

Let's Talk Science, & amp; 17, A. (2020, August 17). *Why is a triangle a strong shape?* Let's Talk Science. letstalkscience.ca/educational-resources/backgrounders/why-a-triangle-a-strong-shape.

The equilateral triangle is just about the strongest shape in nature. Its equal angles allow for it to hold great amounts of weight through tension and compression. This is useful since my project deals with triangles.

Truss Bridge - Facts and Types of Truss Bridges. Historyofbridges.Com, 2019, www.historyofbridges.com/facts-about-bridges/truss-bridge/

The three main types of truss bridges are the Warren, Howe, and Pratt. A truss bridge uses triangles to be able to withstand substantial amounts of load making the truss bridge one of the greatest engineering feats ever. This article gives me information on the truss bridge, so it is useful in my research.

Zuniga, Irene. Personal Interview.

Like Mr. Humphrey, Ms. Irene also works for my city and was able to tell me that in my community the truss bridge is used for train tracks and in smaller more aesthetic places, small obstacles. Since she gave me this information, she is credible and gives me a scope of the personal and community side of my project.