CHAPTER 10

Applications of mathematics and physics for the construction of a stress bridge in high school

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ABSTRACT
Through the knowledge acquired by students in mathematics and physics classes with regard to the contents of plane geometry, spatial geometry, force and moment, a proposal was given to build a truss bridge with barbecue sticks in which the system should support a load many times greater than its own weight. Students, even in high school, should research the balance, efforts and construction conditions for a truss system based on literature from the basic disciplines of architecture and engineering courses. The students who developed the project and presented it at a math fair at a local university are part of an applied physics research group. This group is made up of three-year high school students.

Keywords: Knowledge, Mathematics, Physical, Trellis Bridge, High school.

1 INTRODUCTION

According to Neves (2014), the triangle is a geometric figure that from the moment the measures of the sides are fixed, consequently, the measures of the angles do not change. The triangle, when subjected to tensile and compression tests, manages to maintain its properties. Due to this unique characteristic, the triangle has been used since antiquity for the simplest construction systems to the most complex ones, such as the construction of bridges, in which truss systems are used.

According to Nirschi (2019), when it comes to a particular construction system, structures are characterized by being fundamental and resistant throughout the construction process. They are mainly responsible for the efforts, whether they are absorption or transmission when the system is requested, thus bringing all the resistance and security that the building needs. Of the elements studied to compose the structure of a bridge, the trusses proved to be very advantageous, as they are elements made up of bars joined by means of knots and play an efficient role in receiving and transmitting tensile and compressive forces.

According to BNCC, in High School Mathematics, the focus is to build an integrated and applied vision of Mathematics in a real way for the most different contexts. In a way, with reference to reality, we need to consider the intellectual baggage of the daily experiences of high school students, as they are directly impacted by the advancement of technology and by all the demands that the job market needs. In a current context, the importance of digital resources and the use of technologies is perceived, but for this project, in addition to being necessary for computational research, we want our students to put into practice the construction of a lattice system, challenging their motor skills and his creativity to compose, in addition to a resistant project, but also artistic.

Still according to the BNCC, for students to present their purposes they must be able to have skills related to research processes, model building and problem solving. For this to happen successfully, they must present a way of reasoning, representing, communicating, arguing and learning concepts and developing increasingly sophisticated representations and procedures.

According to Krause et al. (2021), students cannot understand certain contents in the teaching-learning process because they do not associate them with any practical application. And in this work developed for the construction of a trellis system, it was verified that the fact that the students are building in a more participative way, their learning became more effective. Including better understanding the applications of mathematics and physics with regard to geometry and statics.

We had as objectives for the development of this work to apply the basic knowledge of Geometry of Mathematics and Mechanics of Physics to understand the problems that are applied in Engineering and Architecture, it was also proposed to design a simple structural system, in addition, of course, to communicate and justify the project orally and in writing.

2 THE PROPOSED REPORT

2.1 TRUSSES

According to Magalhães (1996), we can use truss systems in the most diverse areas of civil construction, with regard to Engineering and Architecture, as they are structures considered, in a way, simple and with a certain financial advantage. The trusses can also be presented in the most diverse forms and be built with the most different materials, and can be seen in buildings, sheds and in the construction of bridges, which was the purpose of this work.

The trusses, as we can see in figure 01, are junctions of several triangles, it supports large loads precisely because it is made in a triangular shape. A truss system has high strength and safety, and is often used in civil construction works, such as bridges, power towers, buildings and other larger constructions. As they are triangles, the lattice system is based on three interconnected rods, forming the geometric figure, the choice of this shape is based on its resistance and difficult deformation, this is because the vertices of the triangles define a single plane, giving stability to these figures flat, normally with an angle of 45° to each interconnection of these rods, which provides more strength and resistance to impacts. These interconnections are usually made through pins, welds, rivets, glues and screws, which aim to form a rigid structure. Because they are built with cheap materials such as steel and wood, trusses become more practical and lower the cost of works.

Figure 01: Truss system used in the construction of large bridges and viaducts.

Source: Simbratec (2020)

3 METHODOLOGY

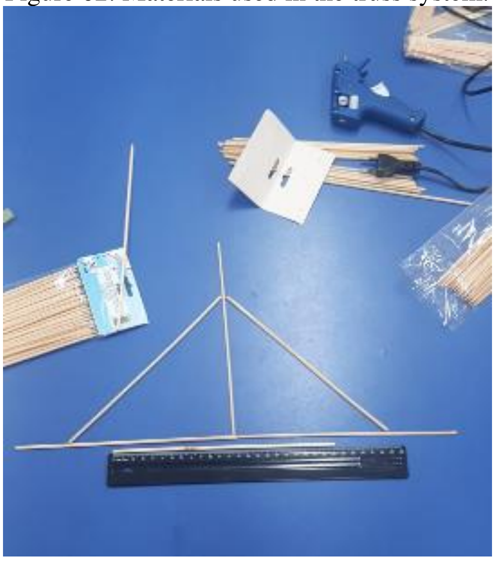
The team will present an indivisible truss bridge. The bridge must be built using only wooden sticks (barbecue type) and putty type epoxy glue (Loctite Durepoxi). Hot glue gun was used to join the bars at the nodes. In the weight of the bridge, the following were considered: the mass of the sticks, the glues used, the support mechanism of the ends. The bridge spanned a free span of at least 40 cm, being freely supported at its ends, with such free span. The use of vertical faces as bridge support points is not allowed. So that there was no collapse before the execution of the project, only a test load of 10 kg was placed on the truss bridge. Each end of the bridge was extended 20 cm in length beyond the free span.

The methodology used in the construction of the bridge came from the Warren model, being a rectilinear structure (not curved), which uses shapes of right triangles with angles of 45 and 90 degrees. The project relies on a trussed bridge, which can withstand 100 times its own weight, which is 0.5 kg. The bridge was built with barbecue sticks (bamboo type), as shown in figure 02, and for the joints (which we call knots) Loctite Durepoxi (Durepoxi) was used. Before the final process, which would be gluing the sticks with the epoxy putty, we used a hot glue gun for the initial joint, which served to help fix the sticks so that they would not leave the angle they were placed, with the purpose of not compromising the structure of the bridge. After the whole process, we did tests with weights, and then, right after fixing what had broken or broken in this process, we finished everything with a layer of varnish.

As a result, it was possible, based on its methodology, to ensure that:

- The bridge supported a hundred times its own weight on a flat surface;
- There was resistance of thirty-two times its own weight in a span of approximately 74 cm;
- The triangle is the strongest shape we can have for the best force distribution.

Figure 02: Materials used in the truss system.

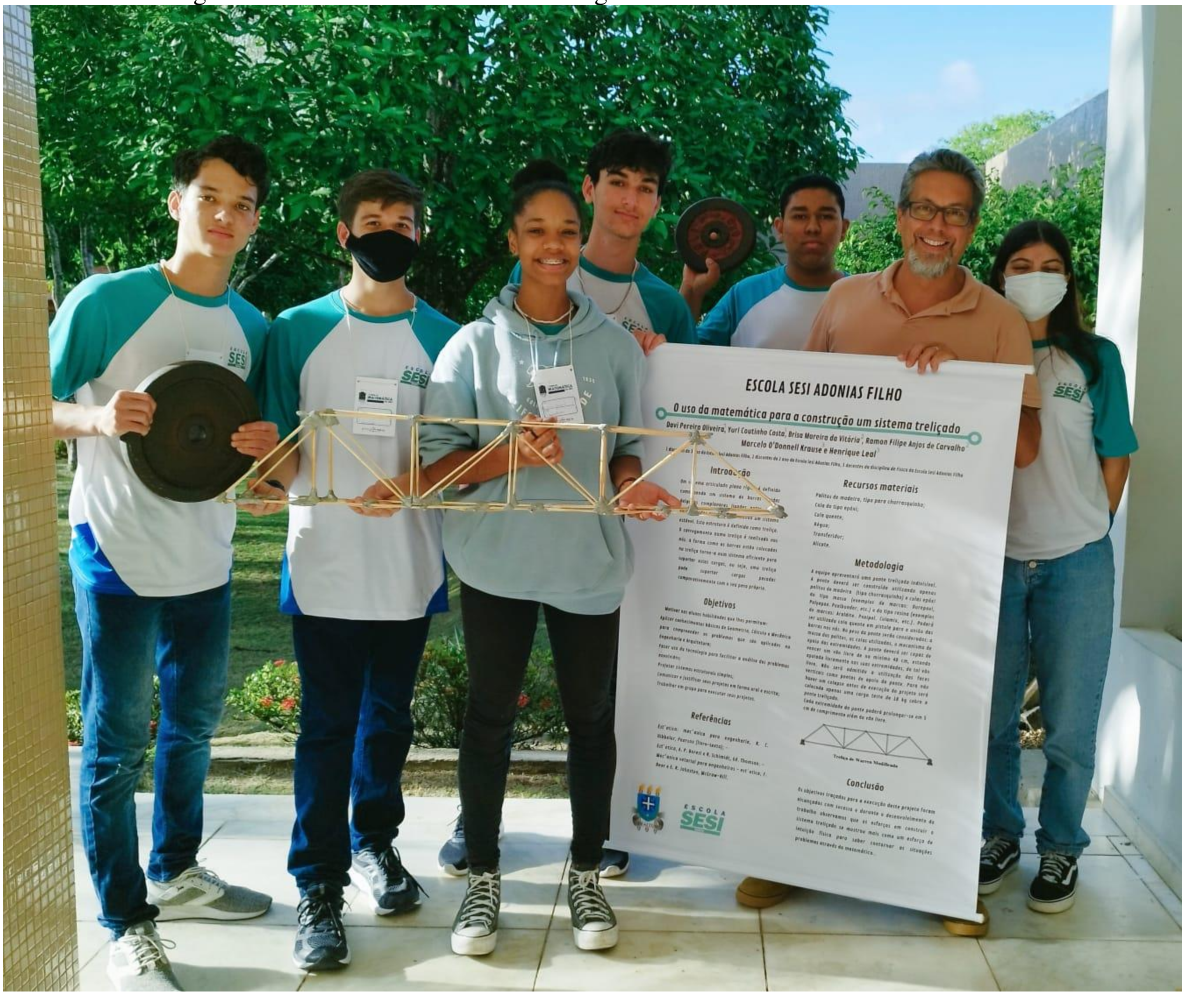


Source: Project data, 2022.

4 RESULTS AND DISCUSSION

Through the studies carried out, we realized that the truss bridge, made with barbecue sticks, supported loads much higher than its own weight. As in the aforementioned tests, such as at Ciranda na Praça and at the V Mathematics Fair carried out by UESC (figure 03), we have that in the first event cited the bridge supported 35 kg, while at UESC it supported, during the presentation of the work, 16 kg (a smaller mass was used in order to present the project without risks) and later the project was able to support a load equivalent to 50 kg, of a university student, on a flat surface. The truss system proved to be efficient and resistant, capable of supporting up to 100 times its own weight and not only in model form, but also in full-size form, as we can see in several construction systems across the planet.

Figure 03: Presentation of the truss bridge at the V Mathematics Fair of UESC.



Source: Project data, 2022.

5 CONCLUSION

According to Silva et al. (2021), there is, in this type of work, an advantage in understanding certain concepts applied in Engineering and Architecture courses and students can have the opportunity to verify and justify why wood is a structure used over many years in constructive systems, mainly in bridges.

Finally, we conclude that the project proved to be efficient and resistant, not only in the form of a model, but also in the form of a real size as we can see in several places on the planet, noting several engineering works with the same construction methodology as the Golden Gate Bridge, the Cantilever Bridge and the Sky Gate Bridge R. With this, we notice a perspective on the study of bridges within engineering, since we live in a modern society in which the format used is considered old, but widely used as observed in the research carried out.

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