‘UNIVERSIDADE DO VALE DO ITAJAÍ’
CENTER FOR APPLIED SOCIAL SCIENCES
DEPARTMENT OF ARCHITECTURE AND URBANISM
CLASS: INTRODUCTION TO STRUCTURAL AND TECHNOLOGICAL SYSTEMS
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SPAGHETTI BRIDGE

REPORT

Florianopolis, July of 2016.

PRESENTATION

Introduction to Structural and Technological Systems of the Undergraduate Course in Architecture and Urbanism, on 'Universidade do Vale do Itajaí - UNIVALI', Brazil.
Students: Asaph Coimbra, Franciane Lisboa, Francine Lisboa and Stephanie Katcipis.
Guidance of: Prof. MS. Anna P. de Souza Pimenta.

PROJECT GOALS

This is a project of construction and destructive testing of a spaghetti bridge, using the structural technique of trusses made from spaghetti dry pasta number 7, of the brand Barilla, and glue.
To reach the objective, the participating teams should research several possible forms of bridges to reach the objective of supporting the greatest possible weight, obeying the competition rules specified previously by the teacher.

COMPETITION RULES

1. The bridge must be indivisible, such that moving or dockable parts will not be accepted.

2. The cross-sections described below must have at most:
• Upper Banzo - 15 noodles fillets
• Lower Banzo - 15 noodles fillets
• Diagonals - 10 pasta fillets
• Amounts - 10 noodles fillets

3. The bridge must be built using only spaghetti type pasta number 7, epoxy mass type glues (examples of brands: Durepoxi, Polyepox, Poxibonder, etc.), and resin type (examples of brands: Araldite, Poxipol, Colamix, etc.). White glue is not recommended. The use of hot glue in a pistol will also be allowed to join the bars in the knots. Other types of glue may be accepted if submitted in advance for consideration by the professor.

4. The weight of the bridge (considering the spaghetti pasta and the glues used) cannot exceed 950 g.

5. The bridge must be able to overcome a free span of 0.50m, being supported freely at its ends, and being able to fix only one of the ends if the students think it should.

6. Each end of the bridge may extend up to 5.0 cm in length beyond the vertical face of each support block, that is, the bridge will have a total of 0.60 m.

7. The maximum height of the bridge, measured vertically from its lowest point to its highest point, must not exceed 50 cm.

8. The bridge must have a minimum width of 5 cm and a maximum of 15 cm, along its entire length.

9. In the presentation of the models, the following criteria of assessment will be considered:

- Finishing of fillets and joints
- Texture (plaster glue, spackle, acrylic putty, etc.)
- Resistance
- Rules for carrying out load tests:
    - The initial load to be applied will be 2 kg. If, after 10 seconds of applying the load, the bridge does not show structural damage, it will be considered to have passed the minimum load test, being able to participate in the collapse load test.
    - If the bridge passes the minimum load test, subsequent loads will be applied in increments defined by the teacher. A minimum of 10 seconds will be required between each load increment application.
    - The bridge will be considered to have collapsed if it presents severe structural damage less than 10 seconds after the application of the load increase. The bridge's official collapse load will be the last load the bridge has been able to withstand for 10 seconds, without severe structural damage.
    - If, when applying a load increment, the load application point is destroyed, the bridge will be considered to have collapsed, due to the impossibility of applying further load increments (even if the rest of the bridge remains without major structural damage).
    - After the collapse of each bridge, the remains of the tested bridge can be examined by the teacher, to verify that only the permitted materials were used in its construction. If the use of disallowed materials is found, the bridge will be disqualified.
    - In the case of a tie of two or more bridges with the same collapse load, the smallest weight will be used as a tiebreaker. If the tie persists, it will be considered the bridge with the best design.

- Any problem, doubt, or occurrence not covered in this regulation must be analyzed by the teacher, and the teacher will make the final decision on the matter in question.
- The highest grade will be the bridge that supports the greatest weight.

PROJECT DEVELOPMENT

The construction was preceded by the analysis of some options of types of bridges, according to basic principles of Structures learned during the semester and the analysis of the history of previous competitions.

The bridges that suffered less specific effort in each component were those that had the upper chord in the form of an arc, formed by several straight segments. The diagonals of the formed trusses joined in the center of the lower chord. Thus, the load is divided between all diagonals, consequently requiring less effort of each one. In addition, the type of effort required for diagonals is traction, precisely the one that the material best supports.

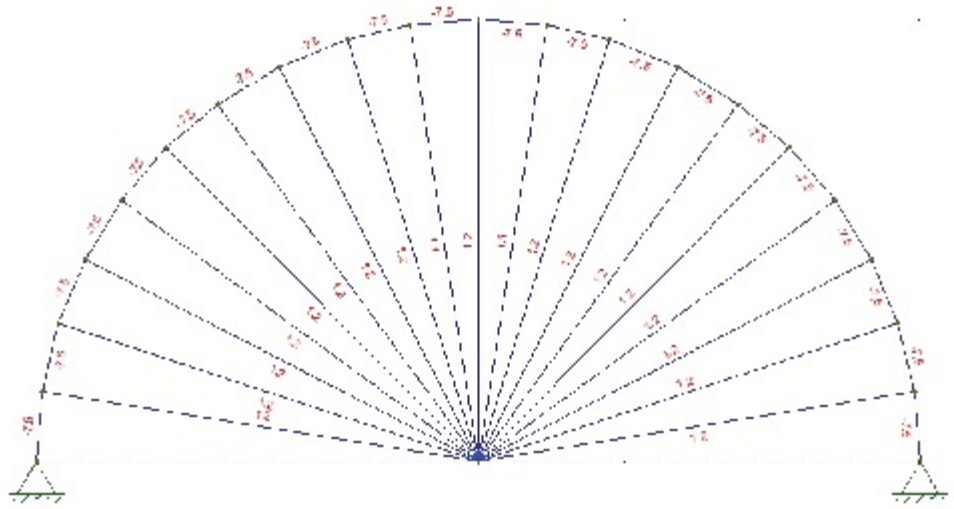
With these characteristics, the arch model seemed to present better resistance to the requested efforts, a determining factor for the choice of shape.

Table with the characteristics of the spaghetti mass Barilla no7 used to develop the project and make the simulation on the *Ftool* Software:

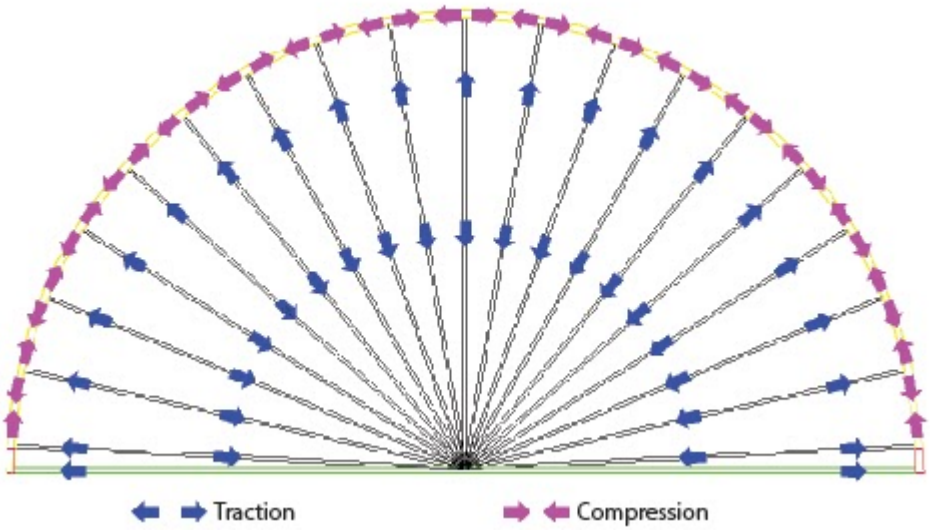
Description	**Measurements**
Number of Spaghetti fillets on the package	500 unities
Average diameter	1.8 mm
Average radius	0.9 mm
Cross-sectional area	2.545 x 10-2 cm2
Section momentum of inertia	5.153 x 10-5 cm4
Average length of each fillet	25.4 cm
Average weight of each fillet	1.011 gr
Linear weight	3.937 x 10-2 g/cm

Longitudinal modulus of elasticity	36000 kgf/cm2 (3600MPa)

After choosing the shape of the bridge, we performed the analysis of the most requested points through simulation made on the Ftool software and found out that the upper chord and the diagonals would be the most overloaded parts (increasingly, n this order) when we submitted the bridge to the effort proposed, as shown in the following figure:



Simulation of efforts obtained through the Ftool Software



After checking which segments would be most demanded, the thickness of each component was decided. For the upper chord, which would be the most requested, a thickness of 14 fillets was adopted, arranged as indicated in the table below. For the lower chord, where the eventual break would occur, it was decided to use 12 thick fillets. In the diagonals, 3 thick

fillets were used, as they are the elements least requested individually and will be submitted to traction.
Then it was calculated the number of spaghetti strips that would be used, and with that, it could be concluded that the maximum permitted weight would not be exceeded. The next step was execution.

EXECUTION

The drawing of the bridge was made in 1:1 scale in AutoCAD to use as a template in the assembly of the two arches and the truss that would join these at the top
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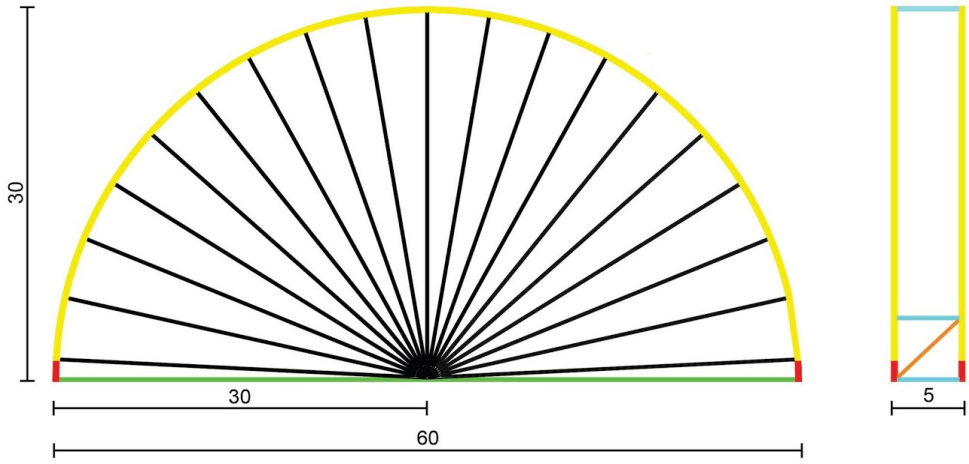


Name	Identification	Quant.	Act. forces	Value of force	Length (cm)	Fillets amount	Organization
Bottom chord		4	Traction	-	30	12	
Top chord		4	Compression	-7.5	1,7	14	
Top chord		36	Compression	-7.5	5	14	
Diagonal		38	Traction	1.2	30	3	
Side king post		38	Compression	-	5	2	
Side diagonal		36	Traction	-	6,7	2	

After that, the team managed to do some tests to chose the gluing materials that would be used, aiming at the strength of the final bridge. Besides Spaghetti nº7 from the Barilla, the chosen glue to unite the fillets one another was the Araldite brand, due to its adhesion power

and its composition that does not dry out the spaghetti. It was chosen epoxy resin from the Durepoxi brand to connect the elements for its resistance, easy handling, and quick drying. For the component where the load would be applied, it was chosen a ¾” PVC pipe mainly due to its lightness.

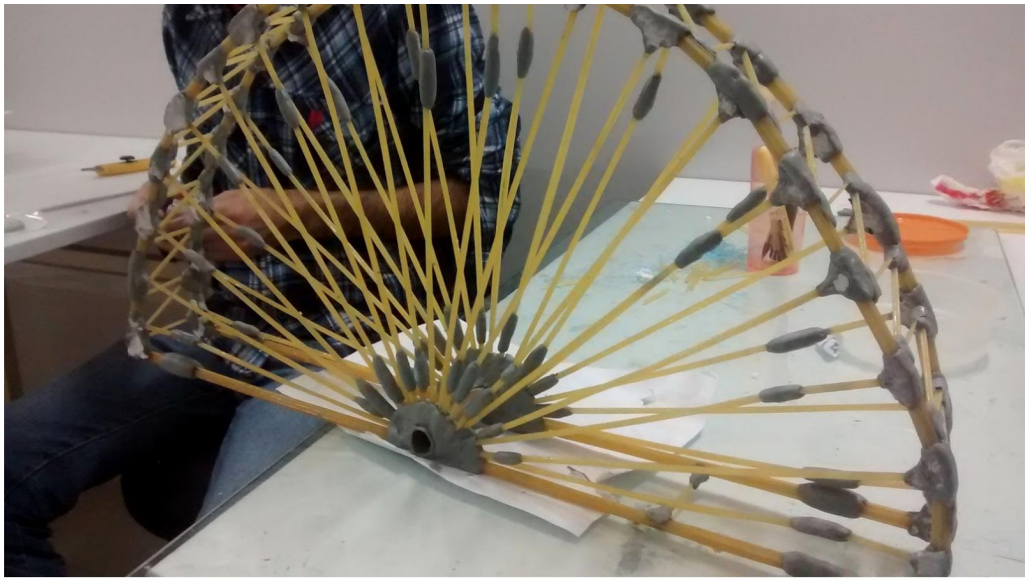
Amount of materials used on the construction of the Model:

- 350g Spaghetti n°7 from the Barilla brand
- 69g Araldite Glue
- 500g Durepoxy Resin
- 11g of ¾” PVC pipe (for load support).

Costs: R$179.00.
Project time: 4 hours.
Execution time: 18 hours.

Construction process.

Construction process.



Construction Completed.

After the bridge was completed, it had a total weight of 930g and resisted the minimum weight of 2kg, moving on to the second stage, the competition itself.

DESTRUCTIVE TEST

On the destructive test, the bridge withstood the additions of loads up to the limit of **33.829kg**, adding up to a total of 8 minutes of testing. Surprisingly all the weights were used and the bridge did not collapse, having no more weight to load, the weights were then being removed and after removing a few kilos the bridge collapse.

Diagonals collapsing.

Total collapse.

CONCLUSION

We conclude with this experiment that the arched shape adopted in the upper chord, the reinforcement given to the most stressed areas of the structure, the excellent distribution of forces performed by the 38 diagonals, and the adoption of a truss joining the arches enabled the excellent performance of the bridge, **supporting the weight of 33,829 kg and winning the proposed competition with a difference of 22,829 kg for the second place**.
It was noticed that the bridge collapse was due to an execution failure at the junction of one of the diagonals marked with the number 1 in the diagonals collapsing image. When joining the aforementioned diagonal to the lower flange, we do not add the catalyst that provides the correct drying. Due to this failure, the region was weakened, which triggered the collapse, which could have supported a few extra kilos.