# PET BOTTLE STRUCTURES DEVELOPMENT IN COLLABORATIVE DESIGN STUDIO. A COLLABORATIVE SEMINAR FOCUSED ON ARCHITECTS' STRATEGIES IN SUSTAINABLE DESIGN THINKING

Kateřina NOVÁKOVÁ
*FA ČVUT Prague, Thákurova 9, Praha 6, bruhokat@fa.cvut.cz*

Henri ACHTEN
*FA ČVUT Prague, Thákurova 9, Praha 6, achtent@fa.cvut.cz*

## Summary

In the experimental design studio we lead students to accept the problem of sustainability in architecture through awareness of garbage problem of the world also caused by the building industry. In particular, we focus on perceiving garbage as a resource. Through analyses of the garbage topic, discussions, designing and manufacturing prototypes we are trying to broaden students' knowledge of this problem. [1] Furthermore, we believe the physical contact with unusual building material is essential as well as visualization methods used in modeling architecture from garbage. The building potential of waste is large and we are trying to make students develop innovative strategies in the domain of architecture.

As a case study we will present results of a collaborative studio partly held in cooperation with ETH Zürich. The task was to visualize daily consumption of PET bottles of the city of Zürich in an architectural way. Two groups of students in Prague and Zürich were experimenting with material as well as computer modeling to deliver a solution in the form of a PET bottle tower. We will describe problems of using PET material as a building material as well as results of this still on-going project.

**Keywords:** pedagogy; garbage architecture, collaborative seminar, parametric design

## 1 Hypothesis

By offering an experimental design studio project with a large impact of reality we are bringing students closer to the topic of sustainability and recycling. Being aware of total broadness of this problem we are focusing only on plastic waste reuse symbolized by PET bottle. When combining architectural design seminar with a reality project we anticipate bigger interest of students in this topic and greater impact on their further work. In this paper we would like to present the results of several physical tests on PET bottles followed by construction strategies.

### 1.1 Precedents

The experimental design studio is inspired by several preliminary projects in which PET bottles are used. PET bottles are a ubiquitous material which after normal consumption may be used in various other ways. Several different attitudes towards reusing PET bottles exist. Many buildings constructed from PET bottles directly combined with concrete arose around the world, generating in principle unrecyclable housings [2]. In the United Bottle project, led by prof. Dirk Hebel, a specific new shape of bottle was designed which later can be used as a construction element [3]. For the so-called EcoARK project highly specific new bottles were created in the form of Polli-Bricks, made out of recycled PET bottles [4]. We also looked at student projects, where PET bottles were used as connecting material [5] or the PET bottle boat race, where construction ideas were innovative and inspiring [6]. In education, we are only aware of the work by Daniel Baerlacken, who also ran design studios concerned with PET bottles on Georgia Institute of Technology [7].

## 2 Case study

The original task of the experimental design studio was to visualize the daily consumption of PET bottles in Zürich (150000 PET bottles). We decided to do this in the form of a tower: "PETtower," which is 20m tall. The whole structure should be displayed as a show at the Zürifäscht event. During this event which lasts three days, it must be built, displayed, and later demolished. The structure must be self-standing, and recyclable.

In the first semester the design studio ran as a collaborative design studio between two countries (ETH Switzerland and CVUT Czech Republic). In the second semester the project was further elaborated at CVUT only, while remaining in contact with parties in Zürich.

### 2.1 First semester

At the start of the first semester two groups of students tried to get an understanding of the amount of PET bottles. 150000 PET bottles cover the same area as the whole Zürich main train station. One student printed the bottles in scale of 1:100 in 2D, while others visualized the amount in 3D.

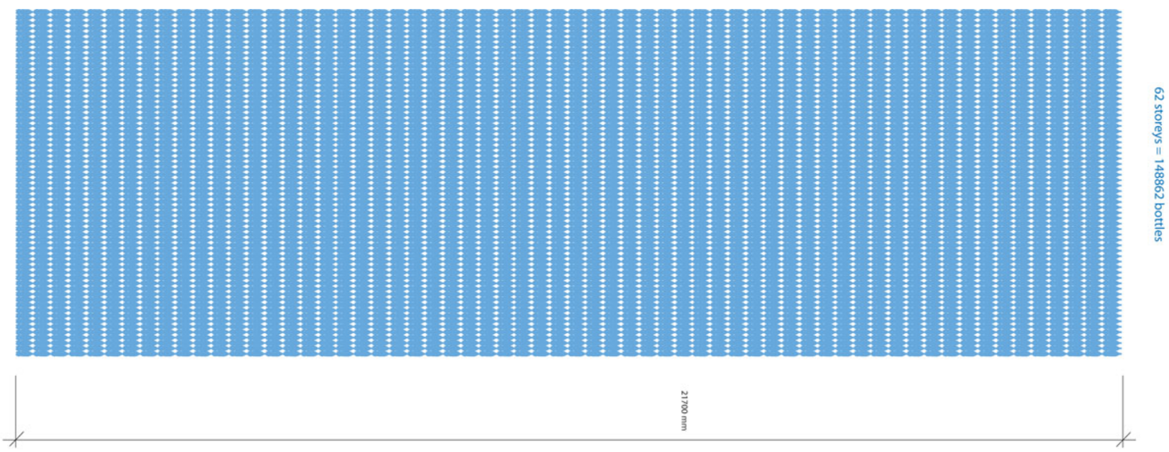


***Fig. 1*** *Ondřej Soukup: 150 000 PET bottles*

Because material and design task were completely new to us, we did not succeed to create a convincing complete design for the tower. This was because we used conventional tower ideas that were realizable with PET bottles but missed the design potential of the material. Three projects were presented in the end of the semester using this approach. (Fig. 2)


***Fig. 2*** *Three solutions from the first semester*

The second aspect was lack of rigorous material testing. Some informal tests were done with combined PET bottles, but they did not give us sufficient information. Thirdly, the connection between PET bottles was by means of wrapping them with PET food foil and tie wraps, which resulted in rather weak connections (Fig. 4) .

***Fig. 3*** *system of connection by wrapping the food-foil around*

***Fig. 4*** *connection with PET stripes and naïve load test*

No sophisticated CAD visualization tools were used. Students were inclined to hand-sketch their ideas without further application of advanced CAD tools, and stayed with a basic calculation. From the first semester we learned that the material has potential, but we also saw that more advanced tests were necessary.

## 2.2 Second semester

With the knowledge we gained in the first semester it was obvious some sophisticated lab tests must be done. We also decided to organize a workshop and divided it into two parts: In the first 3 days Grasshopper lectures took place, where students parametrically visualized their initial sketches. We chose a visual programming system – Rhino Grasshopper – mainly to gain control over the large number of elements. In the second part (also 3 days) of the workshop students finished visualization of designs and facilitated a prototype of a detail of connection in scale 1:1. Throughout the workshop students went back to paper sketches in order to quickly solve basic numerical calculations or create layout pattern of PET bottles in the structure.

Nevertheless, students of the second “PETower” semester based their design strategy on the experience from the first semester, which gave them a headstart. Compared to the previous semester we also intensified our hands-on work in the lab and tried to switch with “sitting at computer” mode as following: design – experiments – design – excursion – design – analyses and laboratory – design – sophisticated design tools – design – prototyping.

### 2.3 Design evolution (described pictures)

We collected all sketches, made screenshots of the developing projects and made documentation of the 1:1 models. (Fig. 5) We observed that students not only sketched in the initial phases of designing, but all the time of project development even when sitting by the screen. With the students, who were using the parametric design tools, we could see enthusiastic reaction when seeing their own project flexible and still controlled in terms of numerical variations. In the phase of moving towards construction we could see simple drawings of connection details or patterns of assembled units. As we observed, teams of 2 or 3 people were able to deliver results which fulfilled all conditions of the project, while individuals remained by trial and error. All students found interesting how much the parametrical design tool was connected to reality.

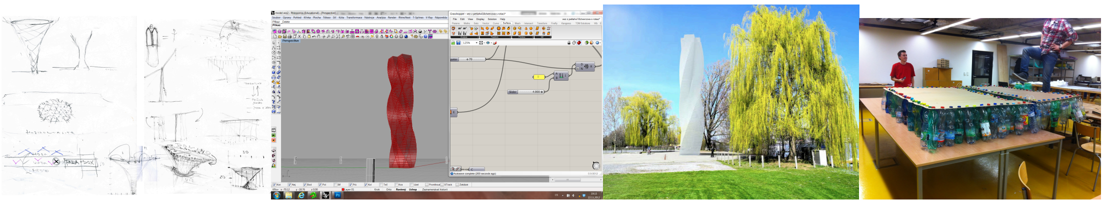

***Fig. 5*** *From sketch to a calculated visualization and 1:1 prototype of element.*

## 3 Results from experiments

We found that as long as the bottle is closed, it can take large amount of pressure. Their load – bearing is highest when horizontally (lying down). First of all we started to examine the PET material and the PET bottle itself (Tab. 2). We also experimented with the cap and screw of the bottle (Tab. 3). This part of the bottle is very strong indeed.

***Tab. 1*** *Measurements from the laboratory: horizontal versus vertical position*

| Bottle | Brand | Position | Loading type | Number of bottles | Max load with stable shape (kN) |
|---|---|---|---|---|---|
| 1 | Rajec | vertical | on cap | 1 | 5 to 8 |
| 2 | Rajec | horizontal | on bottle | 1 | no valid measurement |
| 3 | Mattoni | horizontal | on plate | 1 | 47 |
| 4 | Mattoni | vertical | on plate | 1 | |
| 5 | Rajec | horizontal | on plate | 1 | |
| 6 | Bonny | horizontal | on plate | 1 | |
| 7 | 4 Rajec, Dobra Voda, 2 Mattoni | vertical | on plate | 7 | 8 |

***Tab. 2*** *Results of testing the screw of the bottle in the laboratory*

| Test | Material | Loading type | Maximum load (kN) |
|---|---|---|---|
| 1 | cap | pull from bottle screw | 0.7 |
| 2 | cap | pull from bottle screw | 0.4 |
| 3 | cap | pull from bottle screw | 0.825 |
| 4 | cap | pull from bottle screw | 1.2 |
| 5 | cap | pull from bottle screw | 1.1 |
| 6 | cap in 2 sheets | vertical load on sheets | 3 |
| 7 | cap in 2 sheets | vertical load on sheets | 3 |
| 8 | cap in 2 sheets | vertical load on sheets | no measurement |
| 9 | one sheet | vertical load on single sheet | 1.6 |

The polyethylene tereftalate material is extraordinarily unsuitable material for assembling due to its natural features. Without penetrating the bottle itself its almost impossible to connect with glue, which would be nature friendly and recyclable. We found out, that the bottles' strength and stability is highest when in best condition, unpunctuated and full with air. The cap must be closed.

Our students came with three possible connections of PET bottles. Type A (Fig. 6) used PET bottles, PET ropes and PET food foil. 2,5 meter long tubes showed stability only when wrapped in a pattern of 6 in PET food foil.

***Fig. 6*** *type B*

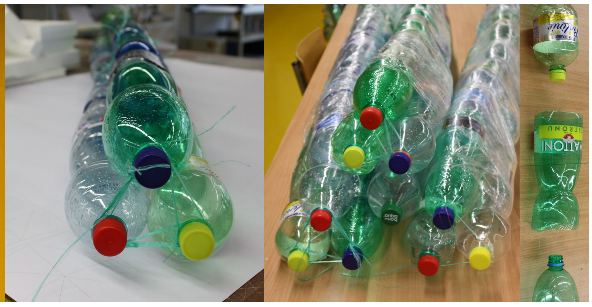

***Fig. 7*** *type A*

The type B construction (Fig.7) used PET foil of 1,5 mm (desks) with drilled holes as a connection material. This solution rely on forces of vertical pressure generated by pressing the bottles against each other. The bottles were layered horizontally, where major strength was manifested as shown in table 2. Cylindrical structural elements performed stability and strength in pressure.

Type C of connection also used PET foil of 1,5 mm with a different pattern of holes (Fig. 8).

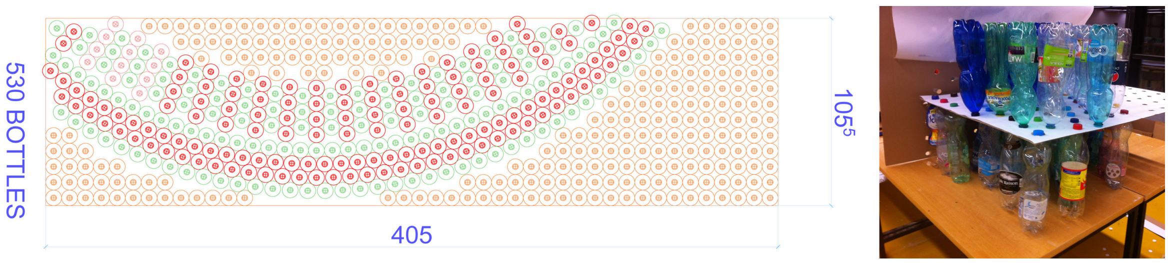


***Fig. 8*** *sheet module with holes for drilling (in mm), prototype of the module 1:1*

In this system, bottles remain in vertical position, in which they remain stable in form until 30 kg of load. A sophisticated system of rotation of panels was invented by the students, which allowed elegant design by implementing only one type of the module. The prototype showed the use of this system (Fig. 8).

## 4 Conclusion

With the combined use of sophisticated design tools combined with lab tests and prototyping we showed students the possibility of use of PET material in architecture. We accepted the PET dump material as a building material. Using the traditional method of designing we started by sketching and continued with parametric modeling, visualization and online presentation of the project to a client (Fig. 9). We finished our seminar [8] with prototyping of a building block in scale 1:1. In the end one of the project was convincing enough for the client to pass it forward to other parties, and is in the process of obtaining sponsorship so that it may be realized. In projects which are connected to reality we can see biggest potential. We believe that this approach has raised student's awareness of sustainability.

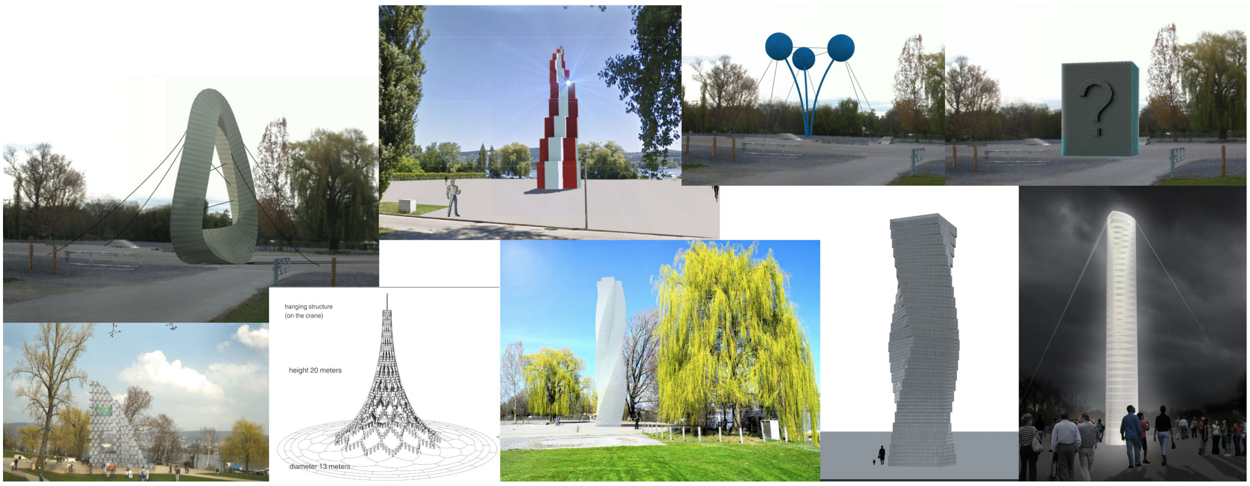


***Fig. 9*** *Finished projects in 2$^{nd}$ semester*

## Acknowledgements

*We kindly thank the students of both seminars and the workshop and all external consultants: Dr. Kotnik, Prof. Hebel and others. We also thank the chair of iA Zürich for help with remote communication. We would also like to thank mr. Litoš of LAB of the Faculty of Civil Engineering of CVUT in Prague for the strength tests of the bottle.*

## References

[1] K. Nováková, H. Achten, D. Matějovská, *A Design Studio Pedagogy for Experiments in Collaborative Design*, Proceedings of the 28th eCAADe 2010 Conference, Zürich, Switzerland.

[2] [2<http://inspirationgreen.com/plastic-bottle-homes.html>.

[3] <http://www.united-bottle.org>.

[4] <http://www.miniwiz.com/miniwiz/projects/ecoark>.

[5] VOREL, KUNAROVA, LUKES: PET-BAG project, GAU:DI competition 2011.

[6] <http://www.theplastici.com>.

[7] Baerlecken D., Reitz J. Duncan D. *Junk: reuse of waste material*, Proceedings of eCAADe 2012 Prague.

[8] http://www.facebook.com/groups/285845308192762/