

FULL SCALE PROTOTYPE LABORATORY FOR ARCHITECTURE STUDENTS

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Abstract

Innovation in prefabrication with new technologies in product development of building components together with the important role materialization is playing in the education of architectural engineers and building technology designers are the main motifs for full scale material prototyping in the Master track of Architectural Engineer and the Master track Building Technology at the Technical University Delft faculty of Architecture.

The chair 'Product Development (and design of Components)' headed by professor Mick Eekhout from the very beginning in 1992 acknowledged the importance of material prototyping in the education of technical oriented architectural designers. For professor Mick Eekhout, director of Octatube of Delft, a design & build company specialized in innovative façades and roofs in architecture, is essential in any innovative product development of building components.

Started in 1995 with a small group of students, a provisional staff and workshop, 15 years of full-scale material prototyping provided more than 750 graduates with this very valuable experience of design and build innovation. The knowledge of and the hands-on experience in getting any technical design into reality controlling the material properties and available production techniques equipped these graduates eminently as technical and innovative designers in the realm of architecture.

In education of this type of engineers it is no use to design and prototype the usual, the familiar. Instead the innovation with all the risk of failure is far more instructive. To get the stronger effect in the desired education the students in small groups are prototyping their own design ideas. The development of the education in our Master tracks is showing smaller groups of students prototyping more innovative designs in a shorter span of time.

It goes without saying that the costs of these material educational exercises are often a multitude of normal design and engineering courses. In the more than 15 years of its existence there was a continuous battle to get faculty funding. Originally the Chair had ample means, but after a rigorous slandering of its size due to unforeseen and ad hoc management games, the extra over funds came from the department. To keep such a facility going means commitment from the department and the faculty, which had to be forced in 1995, but later was never actually doubted.

Most of our alumni have stated that the experience with this design and build process opened their mind for an innovative way of thinking that is such an important element in the toolbox of the architectural and technical engineer. For this type of architectural engineer the aesthetics of a building or a building component is in a reciprocal relation to the materialization.

1. INTRODUCTION

Prototyping building components, if at all, is a rare phenomenon in the building industry as every building traditionally is viewed itself as a full-scale prototype. Innovative industrially prefabricated important building components like façades, however, inevitably demand design and build processes to prevent failure and by that prevent complicated claims.

In the scope of this type of design & build of new innovative building components the necessity of full-scale prototyping is an essential element. The complexity of bringing new technologies in the process of product development cannot do without the trial and error character of full-scale prototyping.



Fig. 1 Woven facade with penetrating material samples

The prevention of failure in the design, engineering, production & assembly process is a motif for introducing prototyping into the design and build product development of building components. But there are also the benefits for the speed of the process as a whole. The trial and error character of material prototyping shows possibilities and impossibilities much faster than a process that is based on sketching and drawing exclusively. Every technical designer has experienced the reciprocal relation between hand and mind. Sometimes the handling of material shows new possibilities to the open mind just as the mind brings the hand to new ways to handle material.

Clearly prefabrication and innovation necessitates prototyping as an important part of the curriculum in the education of architectural engineers. The importance of knowledge of and experience in full-scale material prototyping cannot be overestimated.

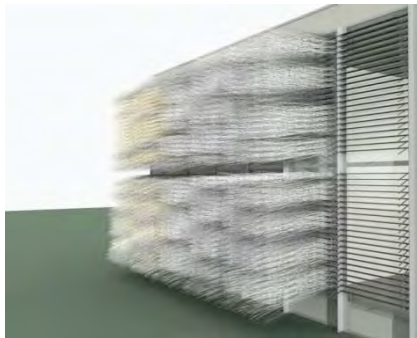


Fig.2 Facade with furry louvers

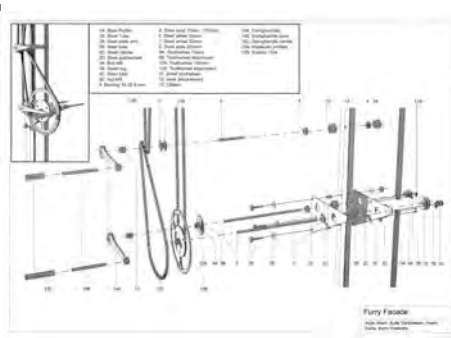


Fig. 3 Exploded view of furry louvers mechanism

However important this knowledge and experience is, any graduate of the Delft Master track Architectural Engineering or the Master track Building Technology, has to experience at least once in his education the 'hell of materialization'. The confrontation between the esthetics of technical design with the brutal world of material, tolerances and of production techniques properties is a must have experience for any technical designer. Graduates should at least once have experienced this: what looks so beautiful and easy in any drawing could be very difficult to materialize. In a way, a drawing is like a "Fata Morgana", it looks so beautiful but this destiny is never to be reached without sweat.

2. A NEW CHAIR, A NEW BEGINNING

The chair of Product Development (and Design of Components) was inaugurated in January 1992 in the department of Building Technology, which became a new graduation track at the same time. The chair focused on design and development of special lightweight building components designed by architects and also, but less, on the development of systems and standard products for the (secondary rated) suppliers in the building industry. The chair also focused on the (fundamental) methodology of design, development and research of building components, building products and systems.



Fig.4 Triangular umbrella sun shading

The Chair was established at the end of the High-Tech period in architecture, started with the Pompidou Centre, Paris, designed by Piano & Rogers in 1976 and culminating in the Kansai Airport hall, Osaka, designed by Renzo Piano in 1995. In 1996 the Guggenheim Museum would be built, designed by Frank O'Gehry, opening the free-form period in architecture for which technology and dealing with 3D-tolerances would become even more important although architectural designers hardly seem to be aware and to acknowledge this shift.



Fig. 5 & 6 Vertical axis rotating element of small Pavilion

Professor Mick Eekhout, introduced immediately the full-scale prototyping into the curriculum based on the before mentioned observations. Every out-of-the-box thinking technical designer needs this experience in his/her education, innovation in the design of complex building components is speeded up by prototyping and any mature technical industry cannot do without full-scale prototyping.



Fig. 7 Exploded view of aluminium curved louver

The Chair however needed three difficult years to convince the Board of the faculty of the necessity to incorporate the materialization into the curriculum and to provide for the extra over costs of the expensive type of education. Thanks to the perseverance and zeal of professor Mick Eekhout the Delft faculty of Architecture is at this moment one of the very few faculties in the world having an extensive prototype laboratory for her students in the Master of Science track of Architectural Engineering and Building Technology.

As the owner and director of Octatube of Delft, specialized in designing, developing, engineering, producing and realizing new and innovative structures for roofs and facades, Mick Eekhout is well aware of the importance of material prototyping in any innovation in the building industry. To equip and to staff such a laboratory is however a very expensive exercise apart from the money needed to

maintain such a facility and to provide the students with the material needed for the prototyping. This financial means for the laboratory is much higher than the money that is usually spent on studies with paper and pencil.

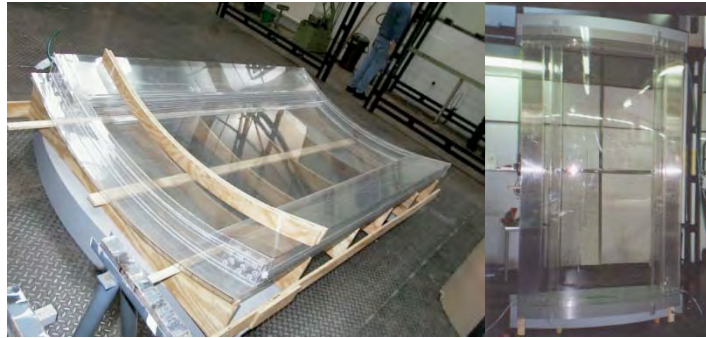


Fig.8 & 9 Full extruded transparent polymer façade component

The Prototype Lab is pretty much geared to be a reflection of professor Eekhouds innovative experiences of the past 40 years, in this case not for production of building projects but for the education of young students. Technical innovation lights the inspiration by properties of materials, technical inventions get developed during materialization and for students to get accustomed with the different tolerances between various different elements and components of a construction or structure and working together in a play of roles are the four major ingredients that students learn in our Master track.

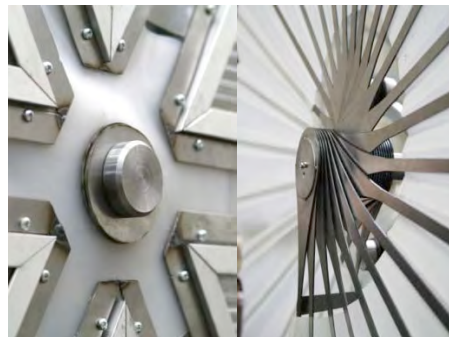


Fig.10 Detail of joint in hinged second skin wind façade

Fig.11 Detail of "Chinese fan" sun shading façade

Many students claim that during their study that: "they saw the light in this course", as they were amazed by the meaning and the potential of high technology in architecture, technology that they could steer themselves by designing, developing, understanding and production of a full-scale prototype. They are not any more afraid of the materialization phase as other students are.

3. THE PRODUCT DEVELOPMENT LABORATORY

The Product Development Laboratory at the start in 1995 was a provisional staffed and rented facility in which a small group of 12 students for the first time in their education got the opportunity to build a façade component. After this small but successful start the laboratory in 1998 settled in an former machine hall at the Leeghwaterstraat in Delft with a permanent staff.

From then on the prototype laboratory has been the main educational focus of the Chair. Right from the beginning Peter van Swieten, the part-time assistant-professor of the Chair, with his education in Industrial Design Engineering at TU Delft and practicing in his Leiden architectural firm, has been responsible for the educational content of the Prototype course. The students are just enough acquainted with machining, welding and sheet metal handling to build, of course with some help of the staff, their own prototype. A crash course in these production techniques in our prototype Lab used to be managed by Henk Rijgersberg and nowadays Cees Baardolf is responsible for this crash course and later on for the guiding of students in the building of the prototype.

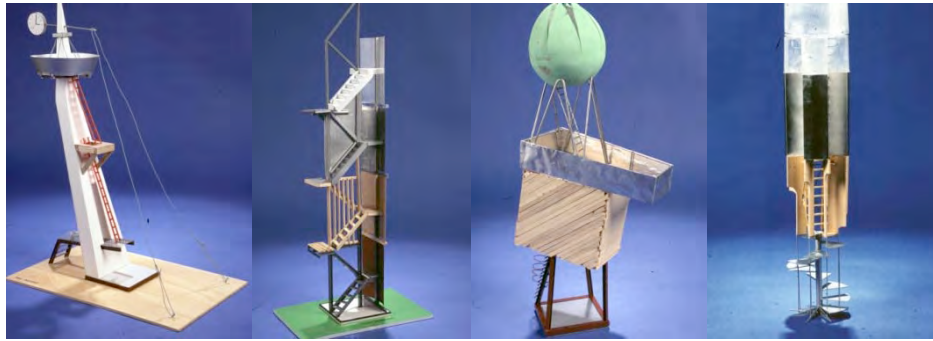


Fig.12 Models segmented towers with stairs

The Laboratory had to move from this location in 1998 due to the fact that University decided to demolish this building. With this move the laboratory at the same time lost two exceptional results of the design and build effort of the students. The first one was a small office of the instructor Henk Rijgersberg in the machine hall itself. The second one was an elevated colloquium room that seated about 50 people also designed and built by students. This memorable loss, however, was compensated by the fact that the new facility was in-house at the faculty of Architecture itself. For the first time in the existence of the laboratory all the students and the staff were confronted with the impressive results of the prototype exercise. This leads to a more extensive use of the laboratory by every student who wanted "to make architecture".



Fig.13 Full-scale prototype 10 m towers

May 13th 2008 the Great Fire of Architecture happened, the traumatic burning down of the famous faculty of Architecture building, designed in 1966 by professor Jaap Bakema. It did scatter all of the faculty staff and students over the seven other faculties of TU Delft for a few months, after which a renovation plan was realized of the former headquarters of the TU Delft. Alas, although the designer of the two new Glass Houses in the new faculty was professor Mick Eekhout himself, the prototype laboratory was not to be housed in the Architecture faculty, but instead was installed in the Stevin II Hall of Civil Engineering



Fig.14 Each tower segment with different material

However, plans are again being developed to house the prototype laboratory for the second time within the premises of the faculty of Architecture. Hopefully this laboratory will soon be back in the faculty of Architecture in a new set-up with a shift from the heavy metal workshop into the modern world of computer aided manufacturing and rapid prototyping which is the future in architectural design. However, the hands-on experience with material properties and production methods will be kept as the most valuable part in the education of our students.

Education and Research are both important but separate elements in any University as it is at the Technical University Delft. Scientific technological research is mostly very complicated and should not be mixed with education in material prototyping. One of the research activities of the chair Product Development (and Design of Components) was set up by dr. Fred Veer on the instigation of professor

Mick Eekhout. This research focused on the realisation of a transparent material with the combined properties of aluminium for strength and glass for transparency. With the start of this project this omnipotent material filled in the illustrious name of 'Zappi' Prof.Eekhout had announced in 1992.

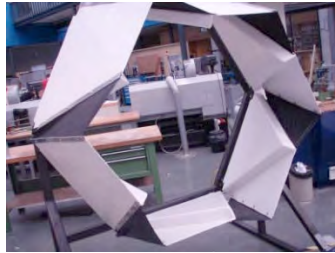


Fig.15 "Cracker"box top sun shading component

Dr. Veers research was incorporated into the prototype laboratory during the first 10 year. Graduation students were doing research for dr. Veer: 'Research by Education'. The research in this period developed from a search for a fundamentally new material into a research of the possibilities of a laminate of glass and transparent plastic. For this reason this research migrated from the chair of professor Eekhout to the chair of professor Jan Rots at the faculty of Civil Engineering. Sophisticated research laboratories located at faculties Civil Engineering or Aerospace Engineering are far better equipped for this type of technical research.

4. THE PROTOTYPE CURRICULUM

In the curriculum of the Master Track Architectural Engineering and the Master track Building Technology students start with the design of a building component, usually the design of a façade. A building façade is selected as the focus for its significance in architecture as well as for its technical complexity. In a short period of three weeks students in this Master track are provided with all essential knowledge in façade design. With this knowledge students design a concept for a new innovative façade, what is called in the curriculum their own'façade scenario'.



Fig.16 Façade with motorized horizontal opening windows

These scenario's are designed by each student individually in two weeks of the semester. Several examples of these scenario's express a specific form in relation to a specific function as is shown in the pictures. After a presentation of the scenario's by the students the best half is selected to be developed to shop drawings for a full scale material prototype. In the next three weeks groups of two students are working together on the shop drawings of a material prototype. In the same period the students get an introduction in production techniques. The instructions are being organised in the Lab and do contain several types of welding, machining, milling and sheet metal forming.

The shop drawings of the material prototype are required to be according to European standards, to be clear and to contain all information to manufacture the desired prototype in elements and components. A list of materials is included in the presentation of the shop drawings. The budget for a prototype is usually € 250,00 including VAT. Overcosts had to be compensated by students raising external funding. In a second selection the best of these shop drawings are selected to be built as a

prototype. The prototypes are segments mostly at full scale but due to savings on the budget for material prototypes just the most intriguing part of the total façade is built as a prototype.

5. PRODUCTS AND PROTOTYPES

Every year from the start in 1995 onwards a number of ten to twenty full-scale prototypes have been built by students in our Prototype Laboratory. Such a production during so many years is of course not without any development and conclusions to be made. In retrospect several important observations can be made as to the role prototyping is playing in the education of our graduates.

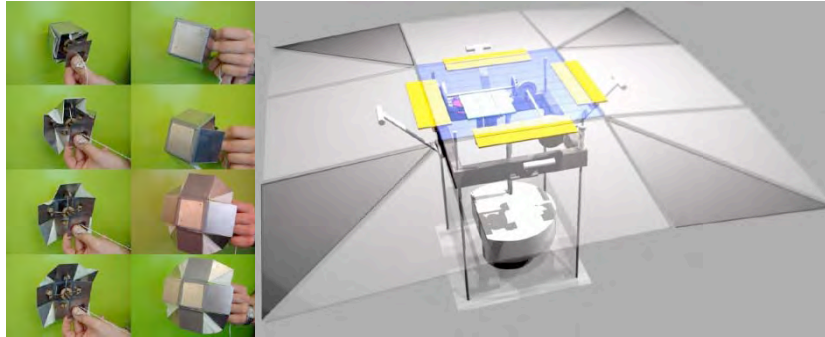


Fig.17 PV cell driven sun shading mini cubes
Fig.18 Detail of open mini cube with mechanism

The education at the faculty of Architecture was from 1992 onwards organized in a problem-oriented set up in which knowledge is presented to students followed by exercises in which this knowledge can be applied. For this reason the full-scale prototyping is part of a semester in the Master track that combines a design cycle from innovative idea to a final design with knowledge of the design methodology of product development, applied mechanics, material science and computer aided design technology.



Fig.19 Rendered façade with mini cube sun shading

The development in the prototype laboratory is of course to integrate even more all this knowledge, to exercise and to obtain insight and overview over production and assembly of technical architecture. Results from the exercises in applied mechanics get immediately use in the search for the appropriate material in for example a CES databases. The introduction and use of the computer combined with the possibilities of the Internet both in all exercises speed the development of the process up in any way that was unconceivable in 1995. This is one of the reasons that the prototyping started in 1995 with teams of six to eight students and at this moment students are able to develop even more complex prototypes in teams of two students.



Fig.20 Double curved interactive 3D façade structure

Students are able to test design ideas with more speed than in 1995, produce necessary shop drawings of more complex prototypes from the 3D modelling exercise almost immediately and for example acquire information about materials and production techniques on the internet within minutes. So without doubt smaller teams are able at this moment to build more sophisticated prototypes within a shorter period than the students did in 1995.

The growing complexity of the student prototypes during the lifetime of the laboratory is a second observation. From absolutely static facades with the start in 1995 the prototypes of today often incorporate complex mechanisms for sun shading, multimedia features, energy producing equipment, folding glass second skin and even more idiosyncratic features.



Fig.21 Prototype of façade with full glass louvers

With few exceptions the design and build character of this part of the education of our graduates is always focussed on the design of facades of office building. The few exceptions are worth mentioning as the concerned the design and build of complete, although small buildings. The first exceptional buildings were two ten meter towers each in four sections of four different materials, from top to bottom respectively in plastic, aluminium, wood and steel. The base of the towers was limited to four m2 and a staircase was to be incorporated in the tower. Two groups of fifteen students designed and built these two towers.

During the lifetime of the prototype laboratory also two times an office for the instructors was designed and built by students, the first one in the former Leeghwaterstraat location and more recently the new office at laboratory at the faculty of Civil Engineering. This last one has a structural frameless glass door with the exceptional dimensions of 3 by 3,5 meter, an elevated floor with a rubber coating and a curved sectioned plastic wall. A team of 26 students was responsible for design, ordering and sponsoring of the materials, assembly and mounting and building of this office.

The most spectacular design and build object that was set up with students focussed on the realisation of a whole new elevated colloquium room in the former laboratory. This was to seat 50 people elevated to the first floor of the adjacent office space and provided with a beautiful curved roof of corrugated aluminium on external curved aluminium tube hangers. This colloquium room however was very short lived due that the TU Delft board decided to house the Laboratory at the former faculty building. But the result was there and the main goal to get students acquainted with the design and build process that is in our opinion the essential of the modern product development of building components.

The last exceptional object that was partly designed and build by students worth mentioning concerns the 6 meter all-glass dome that students built together with Jan Wurm. In this very instructive process students guided by Jan Wurm students got to the very limit in the connection joints between the separate glass panes. Pictures of this dome, which regrettably was destroyed in the burning down of the faculty, show an exceptional elegant dome. Dr. Wurm is now an established specialist at Arup's for glass and facades.



Fig.22 Elegant 3D façade structure system

6. MATERIAL VERSUS VIRTUAL PROTOTYPING

With the increasing power of personal computers virtual 3D modelling is becoming a very useful tool in the design process of building components as it is in every field of design. Nowadays walking in and around a new building design in virtual reality is quite possible and is even used for the smallest contracts. This development could raise some doubt about the necessity of using full scale material prototypes in the design process.

As the four main reasons for material prototyping were identified:

1. The formal and functional research of the design;
2. The speeding up of the design process;
3. The use of a material prototype as a marketing tool;
4. The use of a prototype for performance testing.

Next to this material prototyping serves a different goal in Master Course of Building Technology. A technical designer has to have a feeling for material and production methods. The best way to develop this feeling is gain experience by working with material and production methods. So in our opinion material prototyping should always be a part of the education of graduates of the Master Course of Building Technology.

However, it is not quite sure at this moment in which way virtual prototyping will in the future render material prototyping completely obsolete. The wide spread use of computer aided modelling is bringing designer close to the end product of their efforts and can often be used to get very convincing marketing pictures. So, for what reason all the effort and the expenses in the production a material prototype is put, is an inevitable question.

The first reason is of course inevitability to materialise the design at the end of the product development process. We are in the business of developing building components of real buildings. The brief usually does not contain the word virtual, the product specifications have to be met in reality and not in virtual reality. So somewhere in the process of design and developing of building components a material try-out makes sense.

As helpful as 3D modelling really is, it is quite impossible to get a grip on every material aspect of the design with this tool. Assembly, for example, of all the elements of a building component into the final product can be much more complicated in reality than it appeared to be on a computer screen. Building and testing a material prototype will usually reveal all kind problems, which have to be solved before production can start. The way these problems are solved is always influential on the design of a building component. And a designer should very much care about this aspect of the product

development. In other words, material prototyping is still an unavoidable step in the process of product development within the control of a designer.

The elaborate use of 3D modelling in the process of product development however will push the use of a material prototype more to the end of the process. In 3D modelling the strength, the acoustic and thermal isolation characteristics and even the assembly of the design can be researched in detail. This means that a designer nowadays will get relatively more certain about the characteristics of his design than he or she could get in earlier days.

With all the possibilities of eloquent virtual 3D modelling, like assembly testing, testing of applied mechanics etc one is likely for solely depending on the virtual tool. It seems every aspect of the design can be developed sitting at a computer screen without getting dirty hands at all. But fooling yourself with all the beautiful pictures and virtual analyses is at same time a real danger to every designer. Material prototype leaves a designer no room for fooling himself or his client for that matter. So in our opinion a material model of every design is as necessary as ever despite all the use of virtual 3D modelling.

In our opinion the virtual and material prototyping are complementary to each other and should be part of a design process at the same time. Researching every aspect of a conceptual design will be very useful for the design process and will as a consequence speed up the process.



Fig.23 Full scale prototype of vertical roll blinds

7. CONCLUSIONS

The Prototype Laboratory is an expensive tool but with exceptional results in the educational progress of students in the Master tracks Architectural Engineering and Building Technology.

The 'Design & Build' process in the prototype laboratory inspires and motivates students in technical innovation. Technical knowledge of materials, production techniques, applied mechanics and product development in itself is not enough to get the extensive effect design and build of a material full-scale prototype. Learning the existence of material tolerances, without its compensation no technical building would mature.

Most of our alumni have stated that the experience with this design and build process opened their mind for an innovative way of thinking that is so important element in the toolbox of the architectural and technical engineer. Focus of any architectural engineer is of course on the aesthetics of a building or a building component but such an engineer is in an equivalent way focussed on the technology that brings these aesthetics into life.

REFERENCES

Photo references: The illustrations relate to the projects of Building Technology students. The illustrations are not directly related to the text.