Multi-criteria experimentation and conception of building components and materials.

Nadia Hoyet, architect
Professor at *L' Ecole d'architecture de Versailles*. France.

PhD candidate at *INPL* (Nancy, France), with laboratory *MAP CRAI*/ Research Center in Architecture and Engineering.

5 avenue de Sceaux. 78000 Versailles. France
nadia.hoyet@wanadoo.fr

Abstract
In the field of building design, this paper try and demonstrate that architects may bring useful innovation in components and materials design, and furthermore supposes that experimentation is one of the good way to reach it. This idea is found on an observation of several trends and evolutions in the building industry that shows the links between architectural design and industrial materials production.
In the first part of the development, different ways of designing components are presented, one depends of industrial supply, and the other of architect's demand. Then cases studies illustrate how innovations are elaborated. In the second part of the paper, the different manners and meanings of experimentation are studied.
As a conclusion, different ways of experimentation are studied, using multi-criteria method, including physicochemical measures of the behaviour of materials and qualities relative to human perception. The difficulties of this multi-criteria process are in the resolution of the conflict between the two types of tests. It requires methods able to model all the criteria as it is done in project management. It needs a hierarchy scheme to classify the criteria and it also needs to introduce variable parameters for adapting the scheme to different cultures, because human perception is relative to its culture field.

Key words
evolution of building process
architecture
design of building components
dry building site
experimental prototype
testing methods
multi-criteria evaluation

« Multi-Criteria Experimentation and Conception of Building Components and Materials »

I will develop one aspect of building design, which makes a link between architectural design and industrial materials and components production.
I think that architects may be usefully associated with components design, by imagining original uses of technological advances. However it requires specific working methods to realize effective relationships.

1. Building and Architecture Evolutions.

This idea is founded on an observation of several trends and evolutions in the building industry.
The first trend that I have identified concerns the reality of the building site.
The « value added » of the materials moves from the building site to factories. Building trades are changing in a profound manner. Labor-intensive work is disappearing from the building site. Construction workers become people who assemble complex components, which are produced in factories. These complex components require design. Architects are able to design these products with engineers, because they are an integral part of the architectural design. However, architects are not specifically trained to do this.
Second trend.
Base material notions are enhanced through the association between different materials. This phenomenon occurred by introducing applied sciences into the fabrication at the beginning of the industrial era and it is becoming more pervasive. For example, research on physicochemical properties of polymers have deeply transformed the nature of major traditional building materials:
- laminated glass would not exist without butyral
- new high performance concrete would not exist without admixtures (adjuvants)
- laminated wood or OSB panels would not exist without glue.

and so on…
This infinite variety of products requires the definition of expected performances for the building construction. We must know the specific functions of a material in a building before fabricating it. It is like the definition of a program for architecture. It is an integral step of the design.
Third trend.
Computers allow the management of an increasing number of parameters in the process. Fabrication tools are now connected to computers and movements are made by machines, which are managed by central units. So limited fabrication on a scale of one building is possible today, without increasing costs. The architect can henceforth aspire to a limited fabrication, according to the scale of one single building.
Fourth trend
New trends in architectural design are created with surface materials. For example, the skin of a building becomes a major element of the architectural composition. The building’s form no longer expresses its structure as it did during the sixties and seventies. De-constructivism has broken right angles. New software modeling programs have liberated the boundaries of forms to various non-standard conceptions. This recurrent, but marginal design trend has increased today because new generations are interested in it and computer tools allow them to be built. The Guggenheim museum designed by Franck O. Ghery in Bilbao is an emblematic example.

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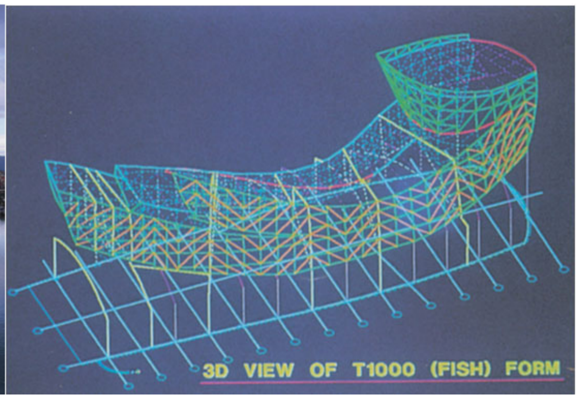

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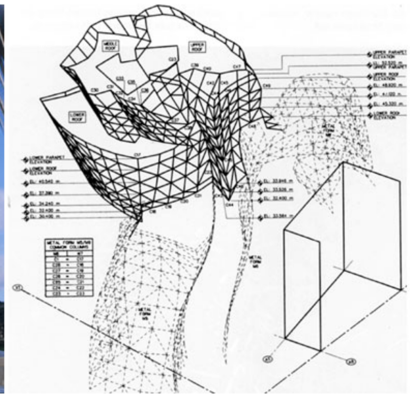

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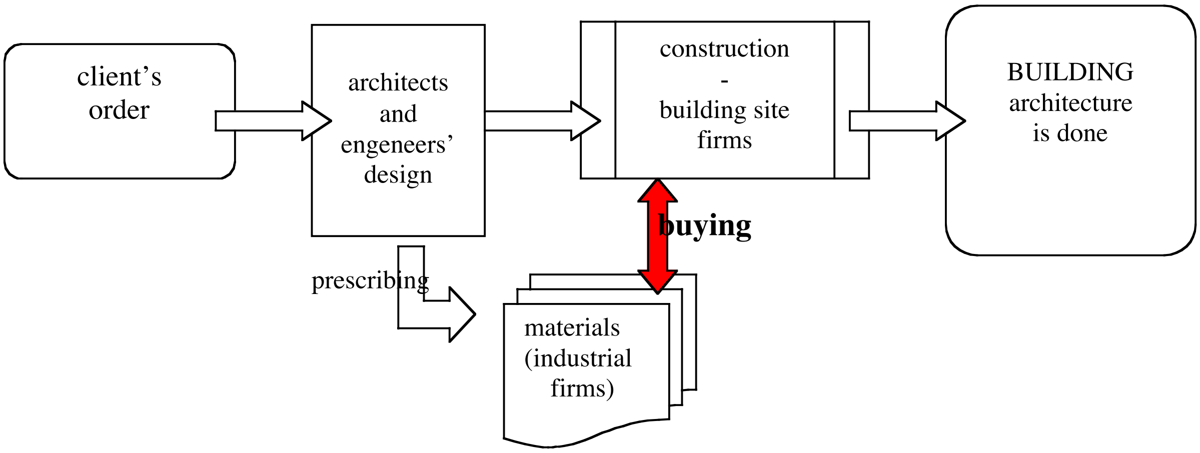
Guggheineim Museum. Bilbao. Spain. Arch : Franck O. Ghery
1. general view of the Museum in front of the river 2. model of the main hall “fish form”
3. detail of the top of the entry “the flour”. 4. model of the flour : first step of the steel structure design.
This project have been designed as an envelope which products space. The major order of the building is its skin.

This method of design results from a process, which takes shape through the skin or the envelope’s expression. This attention focused on the envelope of the building means that all the aspects related to the material’s perception, as texture, brilliance, transparency, but also absorption, etc. are directly linked to sensitivity and sensuality. So that, for example, acoustic characteristics of a material is as important as visual properties. The perception register is extended to all the senses. The interest that architects give to ambient design is located in a same type of consideration and represents new ways for design where materials are more important than before. This formal evolution is also technical because architectural design is concerned with a material’s conception.
Fifth and last trend
In certain cases, the client, or the contracting authority, makes decisions about material choices, their life cycle and their upkeep. They may even elaborate technical systems, which determine these requirements at the first stages of concept development of a building.

These five points of evolution, observed from factory to building site, show the necessity of materials design. It has become a foundation element of architectural design. It is an integral part of the design process if architects want to control the realization of their building.

2. BUILDING COMPONENTS’ DESIGN

Today, two methods exist for component’s design: one way from industrial supply, and the other way from architects’ demand. In the first case, industrial supply is engaged with the great market of building activities. Products are elaborated with the own particular manufacturing process of the industrial firm, directly related with its own way of thinking and meaning. According to this scheme, the more frequent scheme, the direct client of the industrial firm is the building site firm.



Thereby, the design of new products conceived in the research department of the industrial firm, integrates a part of building site operating, in the aim of facilitating them, for example, reducing building site hard tasks, or minimizing time working, etc… We can observe that this process induces more and more unskilled workers on the building site that requires more and more complex components, ready for use. In another case, the engineers of industrial firm's research departments are working with the same thoughts and opinions as the engineers of building site firms. Frequently they come from the same schools. The exchanges are direct, with similar references but conception is limited to shared opinions. To integrate other parameters from other meanings, to convey other needs, it is necessary to associate other designers, such as architects. This case naturally occurs when the second scheme is working.

In this second case, architectural demand is expressed in the design of a product, which is conceived during a project. The architect imagines use of materials according to his whole architectural design: there are two principal reasons:

- Technology of the project requires components from fabrics, as dry building sites. Wood, steel or prefabricated concrete buildings are realized in such a manner. The parts of the building are made in fabrics and assembled on building site. These components are made with the characteristics of the project: dimensions, physical strength, and so on. It corresponds to an exact transfer of operating, from building site to industrial firm, and nothing else.

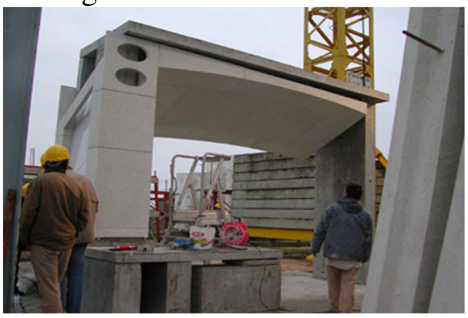

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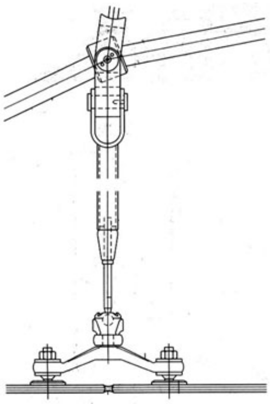
photo 1 : prefabricated concrete components for "Meteor", new subway of Paris.
Photo 2 : Delivery of the wood walls of a house building site.
Dry building sites :
The parts of the building are made in fabrics and assembled on building site. The components are specifics for one single project.

- The architect and the whole design team of the project, design a new component with the industrial firm. This kind of process occurs with important realizations, which are able to make profit with the investment spent on design and conception of the new component. And, frequently, when building is achieved, the component may be sold by the industrial firm that produced it. It becomes a new product in the firm's catalogue.
The cases of *Les Grands Projets* in Paris, in the 80's provide good examples. In the *Cité des Sciences et de l'Industrie*, the architect Adrien Fainsilber designed three very large green houses in front of the main façade. He imagined glass walls providing as much transparency as possible. But the building was 30 meters high. At that time, the most transparent wall was realized with vertical beams made of glass, but this technology was not possible for a height of 30 meters. With the engineering team managed by the genius Peter Rice, and with the partnership of an industrial glass firm, they conceived the suspended glass curtain wall, which is now one of the most used solutions for the realization of transparent walls.



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Green house of Cité des Sciences et de l'Industrie in Paris.
photo n°1 : view of one green house on the main façade
photo n°2 : detail of the glass curtain wall
photo n°3 : drawing of the steel piece on which glass is suspended. This manner of assembling, conceived for this project, is now frequently used.

A similar process occurred when IM Pei, the architect of the *Grand Louvre* was looking for a glass, the least reflective as possible, for use at the entry to the pyramid. The aim was to make the pyramid as transparent as possible, to preserve the identity of the Napoleon courtyard. In this case, the glass firm conducted research to get rid of the green color of the flat glass panels, by working on the composition of the base materials. They obtained a very clear glass, as clear as crystal. This kind of glass is now integrated in the standard series of the firm's production.
These two examples show that evolutions in production design and innovative products may be the result of cross-disciplinary conception methods, represented by the design process of creative persons such as architects. In a sensitive way, these professionals are closer to the evolutions of social, artistic and even technological phenomena, where new trends appear.
As a matter of fact, an architect is a generalist and thus has knowledge related to a lot of different fields. So, the architect, who is involved in a creative process where material design is an important part of the design (they are not all like that), can help industrial manufacturers to improve their products. The tiny quantity of materials, which is fabricated for only one building, can be reported in the catalog of the industrial firm with its standard criteria and its specific characteristics as control qualities or economic performances.

3. Role of experimentation

In another connection, I would like to evoke the role of experimental procedures in the conception or design of new products, in order to apply scientific methods to the creative process. Indeed, essentially unexpected and immeasurable, the creative process possesses the power to produce originality and diversity. It thus offers new combinations, which have the potential for innovation. However, the corollary of this emergence of thought is that it is deprived of rigor and thus is unable to prove its relevance and validity.
The object of my research consists of investigating the ways and methods in which creation and scientific methods could coalesce. I chose the ground of experimentation to reach that point.

When a new product or a new component belongs to the market, it has to be tested to prove it has correct physical and chemical properties. In France, the *DTU, Documents Techniques Unifiés* (technical and unified documents) gives the rules about all the building site tasks. The *CSTB , Centre Technique et Scientifique du Bâtiment* (scientific and technical building organization) is in charge of elaborating these documents. In another way, specific technological organizations study and test the physicochemical performances of the materials and their behavior such as, the *Centre Technique du Bois et de l'Ameublement (CTBA)* for wood and secondary wood products, the *Centre d'Etudes et de recherche pour les Industries du Béton (CERIB)* for industrial concrete products, and so on. These organizations give exact information about the products, which is useful for specifying them in a project. The kind of experiments they realize is a normal step in the industrial production process and it provides guarantees for building safety and for insurance as well. When a product or a material is conceived during an architectural project, which is huge enough, it is possible to use short processes of control that can be integrated at the time of the realization. They are referred to as ' experimental technical advice '; the CSTB delivers this advice and describes the way the component is tested for verifying its behavior in extreme situations, such as fire or storms, etc. In Paris, the Great Library curtain was tested in this way.


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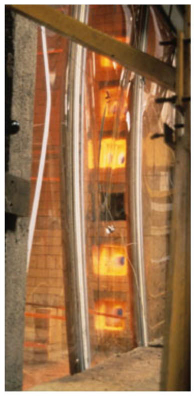
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Photo n°1 : the Great Library in Paris. Photo n°2 : experimental prototype in CSTB laboratory for testing the curtain wall's behaviour of the Great Librairy, in case of fire. Photo n°3 : Fire testing. Photo n°4 : After fire.
In France, in case of huge projects, the CSTB delivers ' experimental technical advice ' after testing components.

Sometimes, the architect designs with experiments. For example, on each architectural project of which he is in charge, Renzo Piano, designs the details of his architecture as industrial components. His workshop designs a piece of work, makes a model and then a prototype, often with industrial firm's research offices, and tests its qualities with certified organizations. For example, they have designed a brick façade component, which is now in

the industrial catalog. The design began twenty years ago for a building located near George Pompidou center, and was perfected during the construction of the *Cité Internationale* in Lyon.
On this building site, which is immense, the Renzo Piano Building Workshop made prototypes of the main pieces of work. Thus, everyone on the building site could appreciate and experiment with these components. It is interesting for building workers too, because they can imagine the best way to assemble.
Testing products becomes a material improvement of virtual conception. It is one of the best ways to increase the qualities of a building. From performances tests, the experimental process becomes a real tool of design, exactly like experiments in scientific research.



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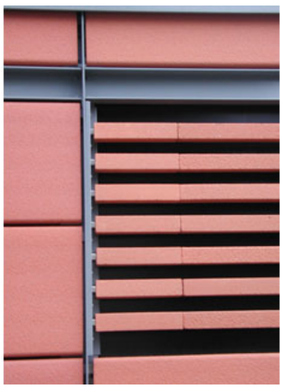
Evolution of the design of a brick façade component, dry assembled.
Photo n°1 : IRCAM building by Renzo Piano, near Centre Georges Pompidou, in Paris : the first form of the component. Photo n°2 : Guiraud Frères catalog : standard commercialisation of the component which was designed with Renzo Piano Building Workshop. Photo n°3 : last form of the component used for the façade of the Cité internationale in Lyon. France.





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Building site of the Cité internationale in Lyon and experimental prototypes. Photo N° 3 : variations of the brick component.

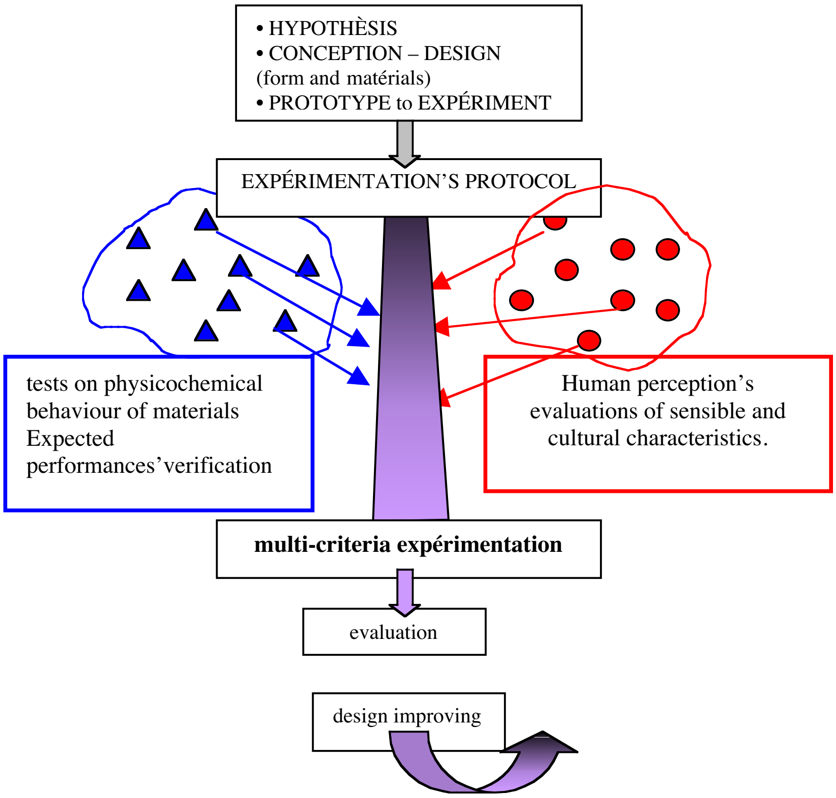
4. Experimenting differently.

The Renzo Piano Building Workshop's case shows that all the steps of architectural component design, from conception to realization, is a main part of the whole architectural process. In addition, we can imagine that experimental research in the architectural materials field is able to innovate industrial production.
Experimental processes have two meanings. On one hand, experimenting is carried out like a single test, measuring performances as certification does. On the other hand, based on experiences, experimenting is looking for discovery. It is a heuristic process, which in a certain part, is similar to the design process.

Such a research process, founded on architectural components experiments and able to integrate complex criteria, requires specific tools where space characteristics can be evaluated at the same time as the objective characteristics. Huge platforms where multi-materials can be tested are necessary like the *Grands Ateliers*, near Lyon in France.

The main hall of the "*Grands Ateliers*"

In this pedagogic and research center, we can build parts of housing both indoors or outdoors and experiment with pieces of a façade and test them. The architectural qualities' evaluation requires the possibility of evaluation of all the dimensions of the object located in its space, with human perception, through the senses. Exact measuring must be placed alongside sensitive evaluation, according to the following scheme.



The experiment of an architectural piece of work depends on two types of tests:
- One for measuring physicochemical properties of materials and their behavior.
-The other to evaluate qualities relative to human perception; these belong to human sciences.

The research protocol will be elaborated with these two types, in response to the aim of the design program. The Hypotheses are validated with the resulting evaluation experiences, but the experiences allow one to discover some unexpected properties, which are able to improve the design.

The difficulties of this multi-criteria process are in the resolution of the conflict between the two types of tests. It requires methods able to model all the criteria as it is done in project management. It needs a hierarchy scheme to classify the criteria and it also needs to introduce variable parameters for adapting the scheme to different cultures, because human perception is relative to its culture field. One way of the method consists of modeling the parameters to manage them within a specific objective; the other way consists in partnership between the different trades. In that case the method elaborated through a cooperative conception process must be applied.

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