What went wrong?! Teaching about failures in building design and construction

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ABSTRACT: The field of architecture is so divers and the need to accumulate information from a very large spectrum of professions is so high, that teaching architecture implies variation of approaches, means, methods.
From sociology to geography and from philosophy to the theory of colours, the laws of physics, biology or chemistry apply wherever a building is designed and build. While some topics are fascinating, due to the history of culture and art that supports them, the field of technology is less romantic and seems rather arid. However, it is this side of the profession that is responsible with the transfer from the idea of the artist to the physical element that is the building itself. The fair approach is the logical scheme. Everything is based on the Laws of Nature and therefore has to be subordinated to them. Construction deals with logic. Teaching construction is teaching about materials, principles examples.
This paper does not deal with faults of the architectural design or dis-functionalities of the building caused by the general architectural concept, but analyses some of the causes that lead to failures of the building subassemblies, focusing on deficiencies that appeared after the interventions on the envelope of the building.

Keywords: education, architectural design, construction, maintenance, failure

1. INTRODUCTION

Teaching about sustainable design is teaching about how to design for a long life cycle, how to increase the life of a component or a subassembly so that the building itself should have a longer life, for the benefit of the end-users. It is also about how to preserve a building in time and how to intervene without damaging or destroying the inner and outer environment and / or the building itself.

Teaching constructions is about seeing, touching and understanding materials, products, components, buildings.

There are two ways of teaching constructions (and in fact this applies to everything): learning the right way, the "how to do things right", and learning from… mistakes, preferably from somebody else's.

There are three main "actors" (three categories of humans) that determine the behaviour of the building: the designer (the architect and the specialized engineers), the builder and the user.

Therefore, any of the three human factors involved in a building (designer – constructor – end user) is liable to cause damages to a building and, in consequence, to the occupants.

2. WHAT CAUSES THE MISTAKES

This specific course does not focus on structural failures. The idea is not to present to the students spectacular failures, but the ones that repeat themselves. The building is considered to be the result of human actions. In this particular approach the cultural context is overlooked as it represents a background of the philosophical concepts and technological evolution, with specific local features resulting from the conditionings imposed by the natural and built environment. Where buildings are concerned, mistakes are caused by human action. Buildings don't make mistakes. Humans do.

The human mistakes have repercussions on buildings, and take the form of deficiencies and failures.A building is – or should be - the result of cooperation and work between lots of people. From the drawing on the board or computer to the everyday use, from the high qualified professionals to the unqualified personnel from the client to the floor sweeper there is a long line of individuals who can make mistakes.

When there are so many people involved, with such different qualifications, with different background (including cultural, financial, educational), somebody is bound to make a mistake, sooner or later.

In general the causes of deficiencies can be separated in three main categories: Ignorance, Haste and Indifference. Some mistakes are repeating: different buildings, the same causes. Therefore, the mechanisms that lead to one or more of these situations appear to be more or less identical and thus can be predicted.

2.1 Ignorance:

Designers' ignorance can be caused by lack of information of the material or system as well as by a poor degree of general knowledge. Sometimes the two combine. Throughout history some of these mistakes lead to the improvement of the building systems. This is the case of improving the performances of building components, most of them used on the envelope of the building: facade systems, window systems, roof systems.

Designing is assuming hypothesis and verifying them. Testing materials and systems *in situ* in real time and not on mock-ups are the only authentical guarantees that can be given to building systems and technologies, because there will always appear unexpected chemical, physical, biological or mechanical factors that act on the buildings.

The way a building behaves in the given environment can be taken as an example for other similar situations. The deficiencies experimented by a building or by building components can be avoided if similar cases are studied and known.

A „classical" situation is the one of materials and systems (paints, cladding systems, windows, for instance) that belong from a geographical space and are used on the envelope of the building in an altogether different climatic environment.

Either the inappropriate finishing material (marble in Figure 1), the supporting system or a combination of both can lead to failures on the facades.

a b

Figure 1: Deteriorated (broken or detached) marble panels: a) mechanical fixing b) „wet" fixing

When the supporting system keeps the cladding material from behaving appropriately (a very rigid fixing system that doesn't accommodate the expansion movements and a weak stone on a western oriented facade) the result is an unimaginable bowing marble panel that eventually collapses (Figure 2).

Figure 2: Bowing marble panel at a church, in Bucharest

Cardinal orientation has to be taken into consideration as well as the characteristics of the cladding material and of the system that attaches it to the wall or bearing elements (Figure 2 and 3).

Figure 3: Detached ceramic tiles on West oriented facades.

While some categories of mistakes lead to research and technological progress (the development of some facade systems for instance is based on experiencing and improving; the current window systems with ventilation devices is based on generations of airtight PVC and metallic windows) that cause a difficult pathology; in most cases there is a simple matter of ignorance at one – or more – of the „actors" presented above.

Designers' ignorance

The designer makes a mistake when, for the sake of the aspect, omits the performance of a system or a product. The designer makes a mistake when, instead of studying the specifications, is „carried away" by the commercial presentation of a product or system.

The poor detailing - when it exists – is another cause for building deficiencies. Architects love forms and space and often leave the details for the constructor to deal with. The designer makes a mistake assuming that other persons involved (constructor, commerciant) should know how to do some things and that there is no need of detailing some of the elements. The argument for this is that the constructor knows what he can do best and what technology he is familiarized with and therefore he should take the task of detailing altogether.

In most cases the cooperation with a good or responsible constructor or technologist (specialist in a restricted field: joinery, paints, tiles, wood, metal, etc), leads to avoiding or correcting mistakes in the first stages of design or on site.

If the partner does not see or *ignores* the problem (haste? Indifference?), the failure is bound to appear either immediately (easier to repair, if the building is still under construction) or within months or years (more difficult to repair; sometimes more expensive than building it again).

To illustrate this principle, Figure 3 presents the case of envelope(s) where the thermal insulation is properly placed on the outer side of the exterior wall, as a blanket, but where it is protected against weathering by an aluminium sheet that acts like a vapour barrier set on the wrong side.

The dealer of mineral wool is convinced of the necessity of this protection against the pouring rain

that can pass through the vertical slits between two adjacent cladding panels.


Figure 3: Aluminium vapour barrier provided on the wrong side of the thermal insulation

Unfortunately, in this case(s), the constructor respected the design.

Ignorance can be decreased by studying, „reading" (specialized literature, technical specifications) and by ... seeing.

Respecting technical regulations, specifications of materials or systems, conditions of putting in work, field of use is one compulsory condition for a practician, designer or constructor.

„Seeing" is dependent on a theoretical base: one can „see" only what one can understand and therefore knows what to look for (and here we go back to "reading"...)

A subcategory of ignorance is naivety: „I had no idea that this can happen..." It is just as dangerous for the building and its users.

Constructors' ignorance.

The problem should have no object, considering that the constructor has all the design project, details included, with the specifications on materials, systems, tools and that he respects them. In some cases he can correct inappropriate details, if he sees the mistake and is willing to take responsibility.

Still, in many cases the builder is responsible for the deficiencies; in these situations there is a problem of *haste* or *indifference* (or even worse, disconsideration) to what the result may be.

End-users' ignorance.

When the end-user changes elements, assemblies, parts of buildings without requesting specialized assistance, the equilibrium of the building may be put in question – mainly in regard to the buildings' response to the natural and / or artificial environmental agents: changing the hygro-thermal balance of the interior space, changing the structural balance of the building, etc.

The individual interventions over an existing building in most cases accelerate the failures. The end-user is price-oriented. Not knowing the implications, he chooses a product according to the budget and, in some cases, according to the colour.

In many situations well preserved buildings have been deteriorated by an apparently simple and inoffnsive intervention: the change of windows.

In many cases the original windows were valuable, with sculpted massive wooden frames and they could have been repaired or improved. They were replaced with cheap, white, PVC or aluminium frame windows, with high air tightness that led to a change of the inner hygro-thermal environment, as all the pollutants and the CO_2 remained captive inside the room.

The next consequence is that adjacent to the window, permanent humidity leads to mould and fungi, as shown in Figure 4.


Figure 4: Airtight window produced mold on the adjacent wall

2.2 Haste

Any of the three human factors involved can be responsible for failures due to haste. In most cases, all of them are...

The designer.

The designer should allow himself the time for detailing more or less everything. Any part that has been left unexplained can and will become a source of problems. It will be resolved on site, with the first solution that comes at hand, with the left over materials and with a minimum of concern. If the designer is lucky a good constructor will compensate the designer's haste.

A current mistake is made in the relation with the end – user, by accepting suggestions from the latter without taking into consideration all (the predictable „all") implications of a change.

Changes practically lead to another project, due to the implications over the whole assembly. The client (owner, end-user) wants the change to be made without changing the deadline of finalizing the work and of course without raising the costs.

For instance, changing the glazing proportion of a facade may also lead to changes of the structure of the glazing and / or of the walls, in order to maintain the overall thermal characteristics. Large, glazed surfaces need alternative measures (systems, technologies) to ensure thermal savings that imply higher costs of the building but lower costs in its exploitation.

Haste leads sometimes to adopting solutions used in other projects, in other countries (and here we return to „Ignorance"). What is right for a situation may be wrong in another context, especially when dealing with natural, environmental agents.

The designer should take notice of the traditional building systems and forms, as they resulted from centuries of improvement.

The designer can make hasty assumptions, that lead to missfunction. Hasty details can be corrected on the way, considering that there is a good cooperation between the specialists (architect, structural engineer, HVAC engineers, constructor). The costs of repairing such a mistake are proportional with the moment of the discovery of the mistake (if the mistake is observed after the materials have been bought or supplied, changing their destination and buying new materials increases the costs).

A poor coordination between specialities can lead to misunderstandings. Sometimes it is caused by haste.

The combination of ignorance and haste can be taken in consideration as a cause for many failures.

The constructor

The most frequent failures due to *haste* are coming from the constructor: either he wants to finish and go to another site, or he is pushed by the owner (end – user) who wants to see the work finished and therefore he (the constructor) does not respect the specifications.

Another reason of failures due to the constructors' haste is changing the materials or the solutions on site („I couldn't find this, but I got that"), without being fully aware of the implications. The responsibility for this action is normally shared with the designer... But sometimes the materials come from the client ("I found this material that looks well and costs half of the other one; put this instead")

As a consequence, quantities may differ from the first evaluation and the problem of transportation, manipulation and storing of the materials may be solved inappropriately, leading to the changing of performances and ultimately to the deterioration of the materials.

Haste may conduct to unrealistic schedules of the work on site, that lead to a chain of dysfunctions and deterioration, from the inappropriate manipulation and storing of the materials to the display of labor hand, that often has an adverse effect, of entangling the different teams and trades. This may conduct to the deterioration of the work accomplished in a previous phase, by another team.

On the edge - at the limit of mistake and compromise - the drying of different layers imposes *time*. The more time there is to dry, the less problems are expected to occur. But a constructor never has enough time to wait.

The owner (end – user)

This character is in a haste anyway. However, he should not put pressure on either the designer or the constructor. In many cases he tends to take over the role of designer and constructor himself.

2.3 Indifference

The designer.

Normally this person is not indifferent to what comes out of his mind. There may be parts of the building that the designer considers he is not interested in and (or) that it is not his business and lets go off them.

The architect should be the one who combines the form, the function and the overall comfort performances.

In many situations the form and the function prevail and the hygro-thermal and acoustic exigencies are left for someone else to deal with.

The constructor.

Probably more than 90 % of the failures during the building process are due to indifference are caused either by a poor schedule of categories of work or by the dis-respect of teams of workers in regard with things done by other teams.

„I don't care, it is not my house" or „I am paid to do my job, I don't care about the others" can be heard in many languages, in many countries, on the site when a team comes and... scratches the paint off from a wall or stains the glass with paint. It is not the constructor as category who is indifferent but here are the most individuals, with a very large range of qualifications (from none to academic). In this case it is a matter of management (who comes after whom, how is the work checked, if the project is respected etc), but also a matter of education of the workers.

The owner (end – user).

The persons who cause deficiencies because of indifference, once the building is finished, are normally not the owners as much as the tenants, who do not care about what is happening to the building, in terms of *maintenance*. These deficiencies are mainly caused by the defect installation systems (plumbs, pipes, ducts) that are not repaired in time.

Many buildings are being slowly destroyed by a deficient maintenance. In some cases accessories are missing (for instance grids that prevent leaves from entering in water pipes or other roof accessories) in other cases the owners are too poor to finance work of repairing, not to mention rehabilitation. In this case the cause is not indifference, but helplessness (Figure 5).

Figure 5: Poor maintenance helps vegetation grow on the gutter

In many cases the replacement of elements is made only on the basis of the best price so low quality products are installed, sometimes replacing more valuable ones.

So what is to be done? Without considering this list exhaustive, each of the "actors" presented above should at least respect the following:

Table 1: Who should do what

"actor"	**requests**
The Designer (architect, engineers) should:	elaborate a complex "script' of what is going to happen in the designed space: activities, links, relations
	have basic knowledge of the principles of Building Physics
	have basic knowledge of Natural Sciences
	have basic knowledge of technical regulations
	have basic knowledge of technical specifications
	carefully elaborate (all) details
	carefully consider the implications of changes,
	avoid hasty decisions
The architect manages and coordinates specialists	
The Constructor should:	have basic knowledge of the principles of Building Physics
	have basic knowledge of Natural Sciences
	have knowledge of materials systems and technologies
	have basic knowledge of technical regulations
	respect the technical specifications of systems
	respect the solutions provided in the project (if they are)
	respect the timings of the processes
	elaborate a realistic schedule of work
	ensure training of the personnel
The constructor manages and coordinates specialists on the site	
The owner (end-user) should:	decide what he wants
	complete the architecture theme
	avoid interfering with the designer and constructor
	accept the technological times
	avoid individual interventions
	ask for authorized advice
	respect the programme of periodical check of the building components
	maintain the building with care
The end-user is responsible for the well preservation of a building	

There are cases when everybody involved in a building contributes, from all facets, to the decay of a building.

No building escapes, but while new buildings are subject to a coherent scenario, interventions on existing buildings are an adventure anyway, as one never knows exactly what is hidden behind the finishing. The stock of existing buildings has to be refurbished, as it does not correspond to the needs of today. We cannot demolish them, so we have to improve them.

The original building system should be object of an expertise, followed by general repairing. In a logical approach, one should not jump over phases: an out-dated building should be brought to its original state before improving it. We start by improving (changing) and then wonder what went wrong, when humid surfaces appear and stains and mould. Interventions on the existing buildings are both challenging and risky. The whole set of possibilities of failures is at hand, because the designer, constructor and owner (end-user) had had all their share of interventions and led to the current state of the building. The need of a complex up-grade (structural, functional, energetic) joins the three "actors" once again, in the attempt to improve the performances of the building. However, the improvement sometimes destroys the building.

3. CONCLUSIONS

The aim of this paper is not to discourage the building activity but to draw attention on some of its aspects, mainly on the most common ones.

Mistakes will always be made: there are too many factors involved, too many heads and hands that contribute for accomplishing a building, a space. It is not possible to avoid altogether the mistakes: the art is to make the minimum compromise, or to ensure that the failures are minimum.

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