Functional analysis as a method to design new building components

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Abstract
The paper presents a method to develop a functional analysis as a tool for designing new building components well balanced with respect to the different aspects of the technological quality: performances of a component at the beginning of service life, during service life and maintainability.
The analysis begins from a set of hypothesis of functional models which foresees different organisations of the distributions of functions through the structure of the component. These are the functions which the component must be able to develop in order to assure the technological performance goals, i.e. the functions strictly linked with the performances.
This analysis goes on through a set of actual models; every actual model comes from one of the previously set out functional models and foresees different choices of functional elements of the-component; every functional element will have defined values of the functional characteristics, i.e. the characteristics linked to performances, that must be held by the materials chosen to form the component (see paper "Methodology and experimental programme to evaluate building components and service life", Politecnico di Milano, DISET).
In this way it is possible to achieve the goals of a design of innovative building components within a policy of sustainable construction approach, which implies a balanced use of materials and natural resources without compromising the ability of future generations to satisfy their needs.
Keywords: Building components, durability, functional analysis, maintainability, performances, service life, sustainable construction.

1 Introduction

The paper's subject takes place in the general theme of the Symposium "Material and technologies for sustainable construction" and, in particular, in the main theme "Performance, durability and service life".

The problem's solution of the sustainable development in building sector passes through the individuation of the priorities in the choice of the materials to be used in the design and the production of building components. The choice of these materials must take into account their compatibility with the global equilibrium of use of natural resources. Therefore only the materials of which this compatibility is recognised should be taken into account for an environmental conscious building process.That is to say materials which minimise the intrinsic energetic waste of the involved raw materials, the energetic waste due to the transformation into building materials, the waste implied by an eventual recycling to reduce the environmental impact.

Within some years at DISET, Politecnico di Milano, it has been developped researches, coordinated by prof. P.N. Maggi, about setting up of evaluation methods for the three components of building components technological quality: zero time quality (characteristic quality) quality during service life (durability) and maintenance quality (maintainability).

This paper, related with other papers titled: "Methodology and experimental programme to evaluate building components service life" and "Experimental programme to evaluate building components service life: an application", reports about the functional analysis (see Figure 1 and Figure 2), as a building components design method; it allows to operate a choice in the following terms:

- at the beginning the materials selection and/or building components is based on a service life optimisation. In this design phase are calculated the real dimensions which avoid materials over-usage. The innovation which this paper, related with the two others, is proposing is the goal of a full rationalisation of the entire process, from the conception and design until the service life and the maintenance;
- in a second step will be operated, if necessary, a further reduction of the choices, considering only those materials recognised as compatible with a sustainable construction.

2 Building component functional analysis method

The functional analysis method allows to define during conception and design phase a building component belonging to a given class. In this way it is possible to define also its performances parameters values (characteristic quality, durability, maintenance quality and executive quality).

In the conception phase the design process can be controlled following the iter here indicated.

Given, for a specific list of building components classes, a fundamental functions package, individuated as those functions which generate the building components technological requirements, can be built the working model of the building component.

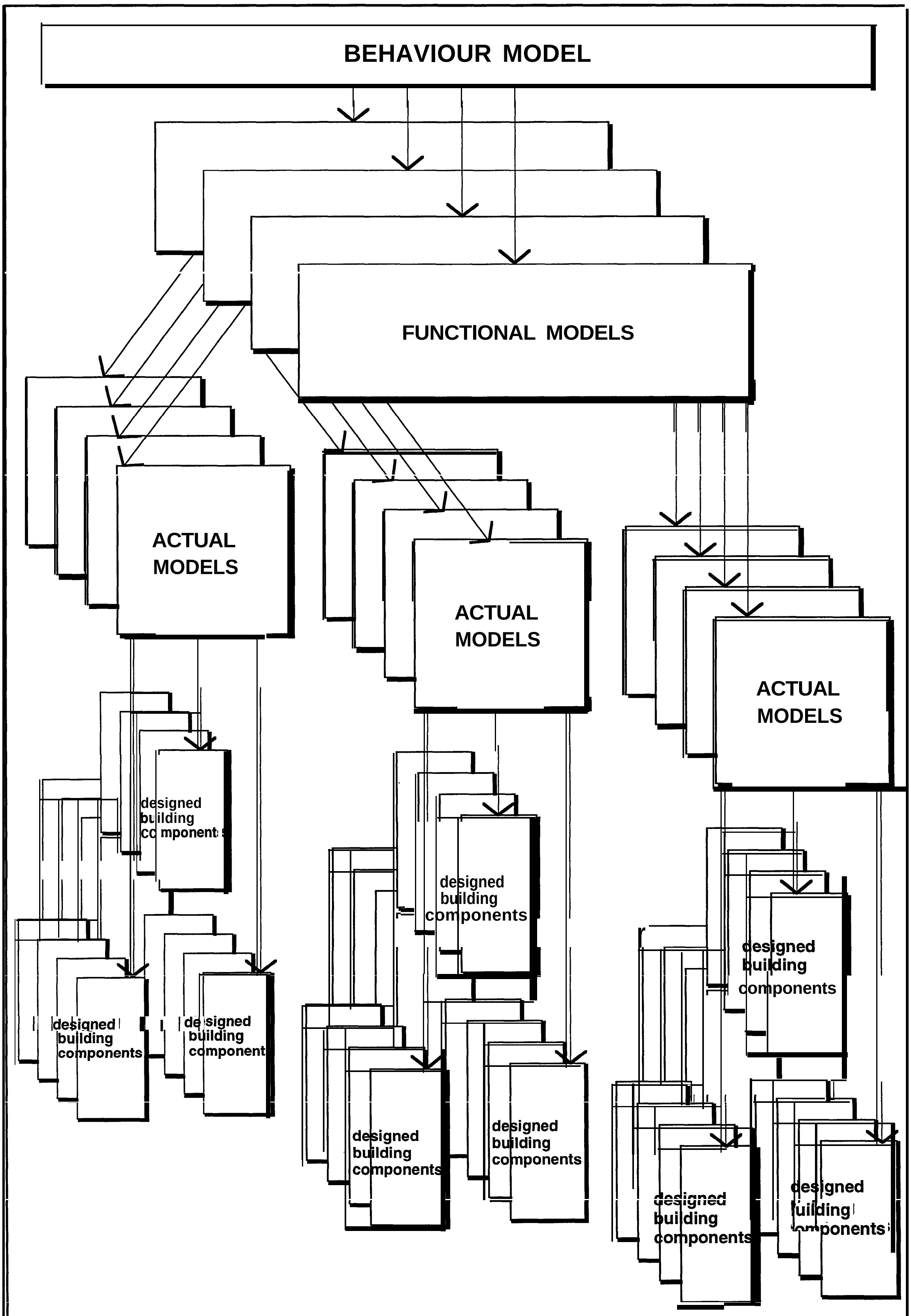

Figure 1: Steps in building components designing

BEHAVIOUR MODEL

technologicals requirements
- interstitial condensation control
- superficial condensation control
- thermal inertia control in hot season
- thermal inertia control in cold season
- acoustic insulation
- thermal insulation
- suspended loads mechanical resistance
- watertight

FUNDAMENTAL FUNCTIONS

F1- to control interstitial condensation
F1- to control superficial condensation
F3- to control thermal inertia in hot season
F4- to control thermal inertia in cold season
F5- to control acoustic insulation
F6- to control thermal insulation
F7- to control suspended loads mechanical resistance
F8- to control watertight

WORKING MODEL

FUNCTIONAL MODEL

E	I	II	III	IV	V	I
	f h.1	fh.1	fc.1			
		fc'.2	fc.2	fc'.2	ff.2	
		fc'.3	fc.3	fd.3		
		fc'.4	fc.4	fd'.4		
	fp.5	fm.5	fo.5	fm'.5		
		fc'.6	fc.6	fc'.6		
				fr.7	fr.7	
	ft'.8	ft'.8				

ACTUAL MODEL

E	1	2	3	S	4	5	6	7	I
F 1	fh.1	fh.1	fh.1		fc.1				
F 2			fc'.2		fc.2	fc'.2	ff.2		
F 3			fc'.3		fc.3	fd.3			
F 4			fc'.4		fc.4	fd'.4			
F 5	fp.5	fp.5	fm.5		fc.5	fm'.5			
F 6			fc'.6		fc.6	fc'.6			
F 7						fr.7	fr.7		
F 8	ft'.8	ft'.8	ft'.8						

BUILDING COMPONENT

	FUNCTIONAL ELEMENTS	THICKNESS (cm)
1	plastic covering with continuous application with an acrylic base	0.2
2	rustic plaster	1.3
3	semi-hollow brick and laying mortar	12.0
A	glue with a syntetic-cement base	0,5
4	resin panel of fibregass	4.0
5	perforated bricks and laying mortar	8.0
6	skim-coat	1.5
7	wash-painting with acrylic base	...
	total thickness	27,5

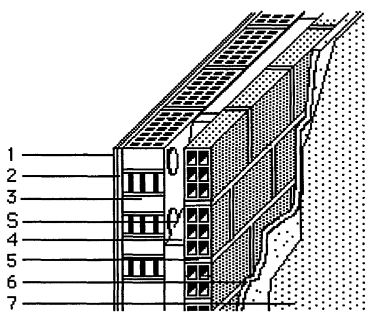

Figure 2: Building component design process

This model (functional model + actual model) individuates where are applied the specific functions which characterise the building component.

The fundamental functions of the functional model come from the technological requirements of the specific building components class and each of them consists in several analytical functions (see figure 3). The building component technological requirements compose the building component behaviour model.

To be noted that one behaviour model can generate several functional models which even if alternatives one to each other, are all coherent with the generator model.

The successive phase consists in an elaboration of alternatives of actual models all coherent with a given functional model.

For the elaboration of the alternatives of the actual models, starting from the spots of the corresponding functional model, these spots are transformed in a functional elements structure.

To each functional element are assigned the analytical functions groups to be accomplished and then the corresponding functional characteristics and the value ranges which these characteristics must show.

To be noted that for each functional model can be individuated several actual models, but coherent.

The successive phase consists in the design of a building component which for each actual model, previously identified, implies, for each functional element of the model, the choice of the materials which must meet the functional characteristics coherent with those admitted by the corresponding actual model.

To be noted that each actual model can generate several designs of building component (see Figure 1).

At this point of the functional analysis, the methodology allows to optimise the choice of the design of the building component either for durability or for maintainability.

For the durability optimisation will be chosen those materials which show the smaller functional obsolescence of their functional characteristics.

As far as the maintainability optimisation is concerned will be chosen those materials and the configuration of the building component which make easier the maintenance interventions, i.e. which maximise the value of the availability to maintainability and then minimise the average time of repairing.

FUNDAMENTAL FUNCTIONS, ANALYTICAL FUNCTIONS FOR EXTERNAL NON-BEARING WALLS

	F1 TO CONTROL INTERSTITIAL CONDENSATION	F2 TO CONTROL SUPERFICIAL CONDENSATION	F3 TO CONTROL THERMAL INERTIA IN HOT SEASON	F4 TO CONTROL THERMAL INERTIA IN COLD SEASON	F5 TO CONTROL ACOUSTIC INSULATION	F6 TO CONTROL THERMAL INSULATION	F7 TO RESIST TO HANGING LOADS	F8 TO CONTROL WATER INFILTRATION
fa to resist to radiative heat flows		●	●	●		●		
fb to resist to convective heat flows		●	●	●		●		
fc to resist to conductive heat flows	●	●	●	●		●		
fd to provide heat storage			●	●				
fe to foster convective heat flows			●					
ff to foster water re-evaporation	●	●						●
fg to resist to water vapour permeation	●							
fh to provide water vapour permeation	●							
fi to provide constant resistance to water vapour permeation	●							
fl to provide constant resistance to heat transmission	●							
fm to hinder by mass the transmission of sound waves					●			
fn to interrupt the transmission of sound waves in solids					●			
to provide r-elastic dampening in solid mean					●			
to provide air tightness					●			
fq to provide acoustic absorption					●			
fr to provide compressive strength.							●	
fs to provide bending strength							●	
ft to provide resistance to water flow								●
fu to provide opposition to capillary water permeation								●

Figure 3: Division of fundamental functions into analytical functions for external non-bearing walls

3 Conclusions

Applying the functional analysis methodology to the design phase of a building component it is possible, through successive approximations, to rationalise and optimise the process, obtaining a correct dimensioning of the single materials responding to the individuated functions, and which compose the building component functional elements.

The design development following the exposed criteria, if from one side allows to obtain a saving in terms of material resources, from the other side can become an instrument finalised to the design of innovative products in the respect of the sustainable construction.

It is actually possible, following the individuated design process, to orient the choice to innovative products already present on the market or to promote the conception and design of other ones, compatible with the functional models and with the durability and maintainability objectives established.

The conception and design of innovative products above prefigured, compatible with the global equilibrium of use of natural resources, can be operated by organisations coherent accordingly to ISO14001.

4 References

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